CATALYST® : 35 FOOT BUS

PERFORMANCE SPECIFICATIONS

PROTERRA

	Description	XR	E2
CATALYST VEHICLE WITH DUOPOWER™ DRIVETRAIN			
Total Energy	kWh	220	440
Operating Efficiency*	kWh/mile	1.5-2.0	1.6-2.3
	MPGe	18.8-25.1	16.4-23.5
Operating Range*	Miles; Usable energy/Operating efficiency	95-125	172-240
Top Speed (Proterra-governed)	mph (**per tire rating**)	65	65
Acceleration (at SLW, seconds)	0 to 20 mph	5.6	5.7
	20 to 50 mph	14.7	12.3
Gradability (top speed at % grade, at SLW, mph)	5%	56	65
	10%	38	50
	15%	27	32
Max Grade (at SLW)		33%	29.5%
Horsepower	Peak	338	550
	Continuous	170	338
Motor	Dual independent 205 kW motors	•	•
Gearbox	Proterra 2-speed auto-shift EV gearbox	•	•
Curb Weight	lbs	26,358	29,658
Max Gross Vehicle Weight Rating	lbs	42,000	42,000
CATALYST VEHICLE WITH PRODRIVE DRIVETRAIN			
Total Energy	kWh	220	440
Operating Efficiency*	kWh/mile	1.6-2.0	1.7-2.4
	MPGe	18.8-23.5	15.7-22.2
Operating Range*	Miles; Usable energy/Operating efficiency	94-124	164-227
Top Speed (Proterra-governed)	mph (**per tire rating**)	65	65
Acceleration (at SLW, seconds)	0 to 20 mph	5.9	6.1
	20 to 50 mph	20.9	23.1
Gradability (top speed at % grade, at SLW, mph)	5%	48	44
	10%	29	28.5
	15%	24	21.5
Max Grade (at SLW)		26%	23.5%
Horsepower	Peak	335	335
	Continuous	170	240
Motor	Single 250kW permanent magnet drive motor	•	•
Gearbox	Proterra 2-speed auto-shift EV gearbox	•	•
Curb Weight	lbs	26,558	29,858
Max Gross Vehicle Weight Rating	lbs	42,000	42,000
CHARGING			
Max Plug-in Charge Rate at 200A	kW	73	132
Max Overhead Charge Rate	kW	165	330
Overhead Charging	Miles replenished per 10 minutes **	17	32
	Est. time Empty to Full***	2.8 hrs.	2.8 hrs.
Plug-in Charging	Est. time Empty to Full***	2.9 hrs.	3.4 hrs.

*Operating range and efficiencies approximated from simulations based on Altoona testing results at SLW, and will vary with route conditions, weather, vehicle configuration and driver behavior.
** ProDrive powertrain efficiencies | *** Charge time will vary depending on charger type. Estimated charge time empty to full based on 0-97%

CATALYST® : 35 FOOT BUS

PLATFORM SPECIFICATIONS

PROTERRA

	Description
VEHICLE DIMENSIONS	
Length	443″
Height	128″
Width (without mirrors)	102.7″
Width (with mirrors)	118.8″
Wheelbase	243″
Approach Angle	9.3°
Breakover Angle	7.8°
Departure Angle	9.3°
Turning Radius	432″
INTERIOR	
Seating Capacity	29
Door Width	Front 43.2″, Rear 49.1″
Lighting	LED interior lighting system
Handles	Stainless-steel stanchion system
Stop Request	ADA pull cord or touch tape stop request
Doors	Senstive edges on both front and rear door
Wipers	Electric wipers and washers
HVAC	Overhead integrated system
EXTERIOR	
Bus Body	Carbon-fiber-reinforced composite material
Tires	Standard: Michelin 315/80R22.5
Exterior Lights	LED
BRAKES & SUSPENSION	
Braking System	Regenerative braking; front & rear air disk brakes
Traction	4-wheel ABS with optional traction control
Suspension	Multi-Link Air Ride rear suspension
ELECTRICAL SYSTEM	
Battery System	Integrated battery management system
Low Voltage	Two, Group 31 700 CCA 12v batteries
Charge Ports	J1772 CCS: One port standard at curb-side rear, 2nd port optional at street-side rear or curb-side front
Overhead Charging	Optional
Plug-in Charging	Universal standard J1772-CCS
Overhead Charging	Universal standard J3105
ADA	
	Two ADA locations, one on each side of the aisle directly behind the front wheel
	ADA securement system
	Front ADA power wheelchair ramp (4:1, 6:1 slope)
	Rear door modesty panels
	Aisle width between front wheel wells: 35.7″
WARRANTY	
Vehicle	Complete Bus - 1 year or 50,000 miles Extended warranties and service contracts available upon request
Batteries	12 years / unlimited miles, materials and workmanship

CATALYST® : 40 FOOT BUS

PERFORMANCE SPECIFICATIONS

PROTERRA

	Description	XR	E2	E2 max
CATALYST VEHICLE WITH DUOPOWER™ DRIVETRAIN				
Total Energy	kWh	220	440	660
Operating Efficiency*	kWh/mile	1.6-2.1	1.7-2.4	1.8-2.7
	MPGe	17.9-23.5	15.7-22.2	13.9-20.9
Operating Range*	Miles; Usable energy/Operating efficiency	92-120	163-232	221-329
Top Speed (Proterra-governed)	mph (**per tire rating**)	65	65	65
Acceleration (at SLW, seconds)	0 to 20 mph	5.7	5.7	5.8
	20 to 50 mph	15.4	12.8	13.6
Gradability (top speed at % grade, at SLW, mph)	5%	54	65	65
	10%	36	48	33
	15%	25.5	31.5	31
Max Grade (at SLW)		30.5%	27.5%	25%
Horsepower	Peak	338	550	550
	Continuous	170	338	338
Motor	Dual independent 205 kW motors	•	•	•
Gearbox	2-speed auto-shift EV gearbox	•	•	•
Curb Weight	lbs	26,649	29,849	33,149
Max Gross Vehicle Weight Rating	lbs	43,650	43,650	43,650
CATALYST VEHICLE WITH PRODRIVE DRIVETRAIN				
Total Energy	kWh	220	440	660
Operating Efficiency*	kWh/mile	1.7-2.2	1.8-2.5	1.9-2.8
	MPGe	17.1-22.2	15.1-20.9	13.5-19.8
Operating Range*	Miles; Usable energy/Operating efficiency	91-117	154-216	205-297
Top Speed (Proterra-governed)	mph (**per tire rating**)	65	65	65
Acceleration (at SLW, seconds)	0 to 20 mph	6	6.2	6.4
	20 to 50 mph	22.2	24.5	26.9
Gradability (top speed at % grade, at SLW, mph)	5%	45	41	30
	10%	28	28	27
	15%	22.5	20	18
Max Grade (at SLW)		24.5%	22%	20%
Horsepower	Peak	335	335	335
	Continuous	170	240	240
Motor	Single 250kW permanent magnet drive motor	•	•	•
Gearbox	2-speed auto-shift EV gearbox	•	•	•
Curb Weight	lbs	26,850	30,050	33,350
Max Gross Vehicle Weight Rating	lbs	43,650	43,650	43,650
CHARGING				
Max Plug-in Charge Rate at 200A	kW	73	132	132
Max Overhead Charge Rate	kW	165	330	330
Overhead Charging	Miles replenished per 10 min**	17	32	30
	Est. time Empty to Full***	2.8 hrs.	2.8 hrs.	2.9 hrs.
Plug-in Charging	Est. time Empty to Full***	2.9 hrs.	3.4 hrs.	4.7 hrs.

*Operating range and efficiencies approximated from simulations based on Altoona testing results at SLW, and will vary with route conditions, weather, vehicle configuration and driver behavior.
** ProDrive powertrain efficiencies | *** Charge time will vary depending on charger type. Estimated charge time empty to full based on 0-97%

CATALYST® : 40 FOOT BUS

PLATFORM SPECIFICATIONS

PROTERRA

	Description
VEHICLE DIMENSIONS	
Length	510″
Height	128″
Width (without mirrors)	102.7″
Width (with mirrors)	118.8″
Wheelbase	296″
Approach Angle	9.3°
Breakover Angle	7.8°
Departure Angle	9.3°
Turning Radius	503″
INTERIOR	
Seating Capacity	40
Door Width	Front 43.2″, Rear 49.1″
Lighting	LED interior lighting system
Handles	Stainless-steel stanchion system
Stop Request	ADA pull cord or touch tape stop request
Doors	Sensitive edges on both front and rear door
Wipers	Electric wipers and washers
HVAC	Overhead integrated system
EXTERIOR	
Bus Body	Carbon-fiber-reinforced composite material
Tires	Standard: Michelin 315/80R22.5
Exterior Lights	LED
BRAKES & SUSPENSION	
Braking System	Regenerative braking; front & rear air disk brakes
Traction	4-wheel ABS with optional traction control
Suspension	Multi-Link Air Ride rear suspension
ELECTRICAL SYSTEM	
Battery System	Integrated battery management system
Low Voltage	Two, Group 31 700 CCA 12v batteries
Charge Ports	J1772 CCS: One port standard at curb-side rear, 2nd port optional at street-side rear or curb-side front
Overhead Charging	Optional
Plug-in Charging	Universal standard J1772-CCS
Overhead Charging	Universal standard J3105
ADA	
	Two ADA locations, one on each side of the aisle directly behind the front wheel
	ADA securement system
	Front ADA power wheelchair ramp (4:1, 6:1 slope)
	Rear door modesty panels
	Aisle width between front wheel wells: 35.7″
WARRANTY	
Vehicle	Complete Bus - 1 year or 50,000 miles Extended warranties and service contracts available upon request
Batteries	12 years / unlimited miles, materials and workmanship

PROTERRA

BASE BUS CONFIGURATION (35' AND 40' BUS)

Proterra Tech Spec	Category	Customer Selection	Option
TS 9	Electric Drivetrain	x	Base - 250kW ProDrive (Motor, Invertor, & 2-speed Transmission)
TBD	Overhead Charging Interface	x	Base - None
TS 9	Charge Ports	x	Base - One (1) Standard J1772-CCS Charge Port: Curbside Rear
TS 32.1	Wheels	x	Base - Clean Buff Aluminum, ALCOA PN 896517
	Wheel & Tire Accessories	x	Base - Torque Indicators, Green (Wheel Check WLCH-B)
TS 32.2	Tires	x	Base - Michelin X InCity Energy Z LR L- 315/80R22.5
TS 46.3	Visors / Sun Shades	x	Base - One Shade on Front Window 30" (Mesh)
TS 46.6	Driver Foot Controls	x	Base - Non-Adjustable Pedals
TS 49.8	Mirrors (Exterior)	x	Base - Low Mount SS Exterior Mirror / High-Mount CS Ext. Mirror
TS 71.1	Appearance (Exterior Graphics)	x	Base - Base bus gel coat in white (high-gloss finish)
TS 75.8	Floor Covering	x	Base - Altro Meta 2.7 (Color = XXXX)
TS 49	Driver's Seat	x	Base - Recaro Ergo Metro P/N 8H0.01.591.VV11 (Proterra P/N 045151) 1. Head Rest (Vinyl) 2. No Armrests 3. No Alarms 4. 240 mm (9.25") Tracks 5. Right Hand Controls 6. Right Hand 2-PT Belt, Black Webbing 7. 12 Degree Recline 8. Powder Coated Black CRS (Cold Rolled Steel) Riser 9. Vinyl Inserts and Bolster (Recaro Lettering Stitching)
TS 78	Passenger Seating	x	Base - USSC Gemini, 40 Passenger, 2 VPRO II (4-pt) ADA Securement Systems **(40 FOOT BUS ONLY)**
		x	Base - USSC Gemini, 29 Passenger, 2 VPRO II (4-point) ADA Securement Systems **(35 FOOT BUS ONLY)**
TS 81.5	Wheelchair Accomodations	x	Base -2 ADA Positions with 4-point ADA securement system (Q'Straint)
TS 79	Passenger Assists (Stanchions)	x	Base - Stainless steel except exit stanchions (yellow), 2 modesty panels without polycarbonate screens
TS 79.5	Overhead	x	Base - 6 Grey Nylon Prima Grab Straps w/ Plastic Knuckle
TS 80	Passenger Doors	x	Base - Ventura Pneumatic, Rear door is In-Swinging
TS 80	Rear Door Operation	x	BASE - Driver Controlled Rear Door
TS 80	Door Safety	x	Base - Dual Redundant System (Sensitive Edge + Motor Feedback)
TS 81.1	Loading Systems for Low-Floor Bus (ADA Ramp)	x	Base - Ricon 4:1
TS 70.2	Bike Rack	x	Base - No Bike Rack
TS 70.2	Bike Rack Sensor	x	Base - No Sensor Installed
TS 66	Front License Plate Holder	x	Base - None
TS 85	Passenger Stop Request / Exit Signal	**x**	Base - Touch Tape
TS 85	Stop Request, Misc	x	Base - Single Switch on Stanchion Forward of Rear Door
TS 85.1	ADA Stop Request Signal Type	x	Palm Button
TS 83	Destination Signs	x	Base - Hanover, Amber Front - 160x17, Curb Side - 112x15, Rear - 48x15
TS 86.4.4	Emergency Alarm	x	Base - Covert switch to Destination sign only
TS 85.1	Stop Requested-Next Stop Sign	x	Base - Backlit "Stop Requested" sign, Transign #SRD300
TS 86.3	Standalone Automatic Passenger	x	Base - None
	WiFi	x	Base - None
	Winter Weather Package	x	Base - Heated Front Doorway

Proterra Tech Spec	Category	Customer Selection	Option
TS 62	Hatches	x	Base - 2 x Opaque Manually Operated **(40 FOOT BUS ONLY)**
		x	Base - 1 x Opaque Manually Operated **(35 FOOT BUS ONLY)**
TS 75.1	Operator's Barrier	x	Base - None
TS 72.1	Passenger Information System	x	Base - None
TS 53.4	Passenger Windows	x	Base - Single-Piece, Flush Mounted, 50% Grey, 5mm Tempered Glass
TS 53.2	Emergency Exit (Egress) Configuration	x	Base - 4 Egress Windows (3 SS & 1 CS) **(40 FOOT BUS ONLY)**
		x	Base - 2 Egress Windows (2 SS) **(35 FOOT BUS ONLY)**
TS 69.2	Access Door Latch/Locks	x	Base - Square Key for Exterior Access Panels (Except the Access Panel for the Master Battery Disconnect Switch which remains unlocked)
TS 75.9	Interior Lighting	x	Base - Overhead LED Interior Lighting - White
TS 53	Airflow	x	Base - Interior overhead panels airflow
TS 76	Fare Collection	x	Base - None
TS 86.1	Camera Surveillance System	x	Base - None
	Passive Collision Avoidance System	x	Base - None
TS 86.4	ITS	x	Base - None
TS 86.2	Public Address System	x	Base - REI PA Only w/ Gooseneck mic (foot switch operated). 8 interior speakers and 1 exterior speaker
TS 86.4	Voice/CB (2-way) Radio System	x	Base - None
TS 25	Towing	x	Base - Capable of front tow, no rear tow, no rear ditch extraction
	Tow Connections	x	Base - Single Male Industrial fitting @ bumper and Rear SS access panel
TS 5.10	Fire Detection / Suppression	x	Base - Sophisticated Fire Detection in HV Batteries (as part of the BMS) & Fire Extinguisher
	Switch Panels	x	Base - Standard Proterra Layout
	Steering Wheel	x	Base - Standard Proterra Layout (Leather 18")
	Pedals	x	Base - Standard Proterra Layout
	Dash Fans	x	Base - No Dash Fans
	Driver Coat Hook	x	Base - None

TECHNICAL SPECIFICATIONS

35’ Catalyst™ E2

Table of Contents

GENERAL

TS 1. Scope

Technical specifications define requirements for heavy-duty transit buses, which, by the selection of specifically identified alternative configurations, may be used for both suburban express service and general service on urban arterial streets. Buses have a minimum expected life of twelve (12) years or 500,000 miles, whichever comes first, and are intended for the widest possible spectrum of passengers, including children, adults, the elderly and people with disabilities.

TS 2. Definitions

Alternative: An alternative specification condition to the default bus configuration. The Agency may define alternatives to the default configuration to satisfy local operating requirements. Alternatives for the default configuration will be clearly identified.

Ambient Temperature: The temperature of the surrounding air. For testing purposes, ambient temperature must be between 16°C (50°F) and 38°C (100°F).

Analog Signals: A continuously variable signal that is solely dependent upon magnitude to express information content.

> **NOTE:** Analog signals are used to represent the state of variable devices such as rheostats, potentiometers, temperature probes, etc.

Audible Discrete Frequency: An audible discrete frequency is determined to exist if the sound power level in any 1/3-octave band exceeds the average of the sound power levels of the two adjacent 1/3-octave bands by 4 decibels (dB) or more.

Battery Compartment: Low-voltage energy storage, i.e. 12/24 VDC batteries.

Battery Management System (BMS): Monitors energy, as well as temperature, cell or module voltages, and total pack voltage. The BMS adjusts the control strategy algorithms to maintain the batteries at uniform state of charge and optimal temperatures.

Braking Resistor: Device that converts electrical energy into heat, typically used as a retarder to supplement or replace the regenerative braking.

Burst Pressure: The highest pressure reached in a container during a burst test.

Capacity (fuel container): The water volume of a container in gallons (liters).

Cells: Individual components (i.e., battery or capacitor cells).

Code: A legal requirement.

Combination Gas Relief Device: A relief device that is activated by a combination of high pressures or high temperatures, acting either independently or together.

Composite Container for CNG: A container fabricated of two or more materials that interact to facilitate the container design criteria.

Compressed Natural Gas (CNG): Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form that has been compressed for use as a vehicular fuel.

Container: A pressure vessel, cylinder or cylinders permanently manifolded together, used to store CNG.

Container Appurtenances: Devices connected to container openings for safety, control or operating purposes.

Container Valve: A valve connected directly to a container outlet.

Curb Weight: Weight of vehicle, including maximum fuel, oil and coolant; and all equipment required for operation and required by this Specification, but without passengers or driver.

dBA: Decibels with reference to 0.0002 microbar as measured on the “A” scale.

DC to DC Converter: A module that converts a source of direct current from one voltage level to another.

Default Configuration Bus: The bus described if no alternatives are selected. Signing, colors, the destination sign reading list and other information must be provided by the Agency.

Defueling: The process of removing fuel from a tank.

Defueling Port: Device that allows for vehicle defueling, or the point at which this occurs.

Destroyed: Physically made permanently unusable.

Discrete Signal: A signal that can take only pre-defined values, usually of a binary 0 or 1 nature, where 0 is battery ground potential and 1 is a defined battery positive potential.

DPF: Diesel particulate filter.

Driver’s Eye Range: The 95th-percentile ellipse defined in SAE Recommended Practice J941, except that the height of the ellipse shall be determined from the seat at its reference height.

Energy Density: The relationship between the weight of an energy storage device and its power output in units of watt-hours per kilogram (Wh/kg).

Energy Storage System (ESS):A component or system of components that stores energy and for which its supply of energy is rechargeable by the on-vehicle system(engine/regenerative braking/ generator)or an off-vehicle energy source.

Fill Pressure for CNG: The pressure attained at the actual time of filling. Fill pressure varies according to the gas temperatures in the container, which are dependent on the charging parameters and the ambient conditions. The maximum dispensed pressure shall not exceed 125 percent of service pressure.

Flow Capacity: For natural gas flow, this is the capacity in volume per unit time (normal cubic meters/minute or standard cubic feet per minute) discharged at the required flow rating pressure.

Fuel Line: The pipe, tubing or hose on a vehicle, including all related fittings, through which natural gas passes.

Fusible Material: A metal, alloy or other material capable of being melted by heat.

Fire Resistant: Materials that have a flame spread index less than 150 as measured in a radiant panel flame test per ASTM-E 162-90.

Fireproof: Materials that will not burn or melt at temperatures less than 2000°F.

Free Floor Space: Floor area available to standees, excluding the area under seats, area occupied by feet of seated passengers, the vestibule area forward of the standee line, and any floor space indicated by manufacturer as non-standee areas, such as the floor space “swept” by passenger doors during operation. Floor area of 1.5 sqft shall be allocated for the feet of each seated passenger protruding into the standee area.

Fuel Management System: Natural gas fuel system components that control or contribute to engine air fuel mixing and metering, and the ignition and combustion of a given air-fuel mixture. The fuel management system would include, but is not limited to, reducer/regulator valves, fuel metering equipment (e.g. carburetor, injectors), sensors (e.g., main throttle, wastegate).

GAWR (Gross Axle Weight Rated): The maximum total weight as determined by the axle manufacturer, at which the axle can be safely and reliably operated for its intended purpose.

Gross Load: 150lbs for every designed passenger seating position, for the driver, and for each 1.5 sqft of free floor space.

GVW (Gross Vehicle Weight): Curb weight plus gross load.

GVWR (Gross Vehicle Weight Rated): The maximum total weight as determined by the vehicle manufacturer, at which the vehicle can be safely and reliably operated for its intended purpose.

High Pressure: Those portions of the CNG fuel system that see full container or cylinder pressure.

High Voltage (HV): Greater than 50 V(AC and DC).

Hose: Flexible line.

Hybrid: A vehicle that uses two or more distinct power sources to propel the vehicle.

Hybrid System Controller (HSC): Regulates energy flow throughout hybrid system components in order to provide motive performance and accessory loads, as applicable, while maintaining critical system parameters (voltages, currents, temperatures, etc.) within specified operating ranges.

Hybrid Drive System (HDS): The mechanical and/or electromechanical components, including the engine, traction motors and energy storage system, which comprise the traction drive portion of the hybrid propulsion system.

Intermediate Pressure: The portion of a CNG system after the first pressure regulator, but before the engine pressure regulator. Intermediate pressure on a CNG vehicle is generally from 3.5 to 0.5 MPa (510 to 70 psi).

Inverter: A module that converts DC to and from AC.

Labeled: Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization, which is acceptable to the authority having jurisdiction and concerned with product evaluation, which maintains periodic inspection of production labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Leakage: Release of contents through a Defect or a crack. See *Rupture*.

Line: All tubes, flexible and hard, that carry fluids.

Liner: Inner gas-tight container or gas container to which the overwrap is applied.

Local Regulations: Regulations below the state level.

Low-Floor Bus: A bus that, between at least the front (entrance) and rear (exit) doors, has a floor sufficiently low and level so as to remove the need for steps in the aisle between the doors and in the vicinity of these doors.

Low Voltage (LV):50 V or less (AC and DC).

Lower Explosive Limit: The lowest concentration of gas where, given an ignition source, combustion is possible.

Maximum Service Temperature: The maximum temperature to which a container/cylinder will be subjected in normal service.

Metallic Hose: A hose whose strength depends primarily on the strength of its metallic parts; it can have metallic liners or covers, or both.

Metering Valve: A valve intended to control the rate of flow of natural gas.

Module: An assembly of individual components

Motor (Electric): A device that converts electrical energy into mechanical energy.

Motor (Traction): An electric motor used to power the driving wheels of the bus.

Operating Pressure: The varying pressure developed in a container during service.

Physical Layer: The first layer of the seven-layer International Standards Organization (ISO) Open Systems Interconnect (OSI) reference model. This provides the mechanical, electrical, functional and procedural characteristics required to gain access to the transmission medium (e.g., cable) and is responsible for transporting binary information between computerized systems.

Pipe: Nonflexible line.

Pressure Relief Device (PRD): A pressure and/or temperature activated device used to vent the container/cylinder contents and thereby prevent rupture of an NGV fuel container/cylinder, when subjected to a standard fire test as required by fuel container/cylinder standards.

> **NOTE:** Since this is a pressure-activated device, it may not protect against rupture of the container when the application of heat weakens the container to the point where its rupture pressure is less than the rated burst pressure of the relief device, particularly if the container is partially full.

Power: Work or energy divided by time

Power Density: Power divided by mass, volume or area.

Propulsion System: System that provides propulsion for the vehicle proportional to operator commands. Includes, as applicable, engine, transmission, traction motors, the hybrid drive system,(HDS), energy storage system (ESS), and system controllers including all wiring and converter/inverter.

Real-Time Clock (RTC): Computer clock that keeps track of the current time.

Regenerative Braking : Deceleration of the bus by switching motors to act as generators, which return vehicle kinetic energy to the energy storage system.

Rejectable Damage: In terms of NGV fuel containers/cylinders, this is damage as outlined in CGA C-6.4, “Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations,” and in agreement with the manufacturer’s recommendations.

Retarder: Device used to augment or replace some of the functions of primary friction based braking systems of the bus.

Rupture: Sudden and unstable damage propagation in the structural components of the container resulting in a loss of contents. See *Leakage*.

Seated Load: 150lbs for every designed passenger seating position and for the driver.

SLW (Seated Load Weight): Curb weight plus seated load.

Serial Data Signals: A current loop based representation of ASCII or alphanumeric data used for transferring information between devices by transmitting a sequence of individual bits in a prearranged order of significance.

Service Pressure: The settled pressure at a uniform gas temperature of 21°C (70°F) and full gas content. It is the pressure for which the equipment has been constructed, under normal conditions. Also referred to as the nominal service pressure or working pressure.

Settled Pressure: The gas pressure when a given settled temperature, usually 21°C (70°F), is reached.

Settled Temperature: The uniform gas temperature after any change in temperature caused by filling has dissipated.

Solid State Alternator: A module that converts high-voltage DC to low-voltage DC (typically 12/24 V systems).

Sources of Ignition: Devices or equipment that because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable compressed natural gas-air mixtures when introduced into such a mixture, or when such a mixture comes into contact with them.

Special Tools: Tools not normally stocked by the Agency.

Specification: A particular or detailed statement, account or listing of the various elements, materials, dimensions, etc. involved in the manufacturing and construction of a product.

Standard: A firm guideline from a consensus group. Standards referenced in “Section 6: Technical Specifications” are the latest revisions unless otherwise stated.

Standee Line: A line marked across the bus aisle to designate the forward area that passengers may not occupy when the bus is moving.

State of Charge (SOC): Quantity of electric energy remaining in the battery relative to the maximum rated amp-hour (Ah) capacity of the battery expressed in a percentage. This is a dynamic measurement used for the energy storage system. A full SOC indicates that the energy storage system cannot accept further charging from the engine-driven generator or the regenerative braking system.

Stress Loops: The “pigtails” commonly used to absorb flexing in piping.

Structure: The basic body, including floor deck material and installation, load-bearing external panels, structural components, axle mounting provisions and suspension beams and attachment points.

Thermally Activated Gas Relief Device: A relief device that is activated by high temperatures and generally contains a fusible material.

> **NOTE:** Since this is a thermally activated device, it does not protect against over-pressure from improper charging practices.

Wheelchair: A mobility aid belonging to any class of three- or four-wheeled devices, usable indoors, designed for and used by individuals with mobility impairments, whether operated manually or powered. A “common wheelchair” is such a device that does not exceed 30 in. in width and 48 in. in length measured 2 in. above the ground, and does not weigh more than 600 lbs when occupied.

TS 3. Referenced Publications

The documents or portions thereof referenced within this specification will be considered part of the requirements of the specification. The edition indicated for each referenced document is the current edition, as of the date of the issuance of this specification.

TS 4. Legal Requirements

Proterra will comply with all applicable federal, state and local regulations. These will include but not be limited to ADA, as well as state and local accessibility, safety and security requirements. Local regulations are defined as those below the state level.

Buses will meet all applicable FMVSS regulations and will accommodate all applicable FMCSR regulations in effect at the location of the Agency and the date of manufacture.

In the event of any conflict between the requirements of these specifications and any applicable legal requirement, the legal requirement will prevail. Technical requirements that exceed the legal requirements are not considered to conflict.

TS 5. Overall Requirements

Proterra will ensure that the application and installation of major bus subcomponents and systems are compliant with all such subcomponent vendors’ requirements and recommendations. Proterra and Agency will identify subcomponent vendors that will submit installation/application approval documents with the completion of a pilot or lead bus. Components used in the vehicle will be of heavy-duty design and proven in transit service.

TS 5.1 Weight

The design goal at Proterra is for each bus to remain as light in weight as possible without degrading safety, appearance, comfort, traction or performance.

Buses at a capacity load will not exceed the tire factor limits, brake test criteria or structural design criteria.

TS 5.2 Capacity

The vehicle is designed to carry the gross vehicle weight, which will not exceed the bus GVWR. The vehicle does not exceed the individual gross axle weight rating (GAWR) at curb weight plus gross load.

TS 5.3 Service Life

The minimum useful design life of the bus in transit service is at least twelve (12) years or 500,000 miles. It is capable of operating at least 40,000 miles per year, including the 12th year.

TS 5.4 Maintenance and Inspection

Scheduled maintenance tasks will be related and in accordance with Proterra's recommended preventative maintenance schedule (along with routine daily service performed during the fueling operations).

Test ports, as required, will be provided for commonly checked functions on the bus, such as air intake, exhaust, hydraulic, pneumatic, charge-air and motor cooling systems.

Proterra will give prime consideration to the routine problems of maintaining the vehicle. All coach components and systems, both mechanical and electrical, which will require periodic physical work or inspection processes are installed so that a minimum of time is consumed in gaining access to the critical repair areas. It will not be necessary to disassemble portions of the coach structure and/or equipment such as seats and flooring under seats in order to gain access to these areas. Each coach will be designed to facilitate the disassembly, reassembly, servicing or maintenance, using tools and equipment that are normally available as standard commercial items. Requirements for the use of unique specialized tools will be minimized.

The body and structure of the coach is made of a monocoque composite material and will be designed for ease of maintenance and repair. Sections of a monocoque composite body that may be damaged in normal service are easily repairable with common composite repair techniques. Ease of repair will be related to the vulnerability of the item to damage in service.

Proterra will provide a list of all special tools and pricing required for maintaining this equipment. Said list will be submitted as a supplement to the Pricing Schedule.

TS 5.5 Interchangeability

Unless otherwise agreed, all units and components procured under a contract, whether provided by suppliers or manufactured by Proterra, are duplicates in design, manufacture and installation to ensure interchangeability among buses in each order group of a procurement. This interchangeability extends to the individual components as well as to their locations in the buses. These components include, but are not limited to, passenger window hardware, interior trim, lamps, lamp lenses and seat assemblies. Components with non-identical functions will not be, or appear to be, interchangeable.

Any one component or unit used in the construction of Proterra buses will be an exact duplicate in design, manufacture and assembly for each bus in each order group of a Contract. Proterra will identify and secure approval for any changes in components or unit construction provided within a contract.

In the event that the Proterra is unable to comply with the interchangeability requirement, the contractor will notify the Agency and obtain the Agency's prior written approval, including any changes in pricing.

Agency will review proposed product changes on a case-by-case basis and has the right to require extended warranties to ensure that product changes perform at least as well as the originally supplied products.

TS 5.6 Training

Proterra will have at least one qualified instructor who will be available at the Agency's property at a time and for a duration mutually agreed to by both parties. Instructor(s) will conduct schools and advise the personnel of the Agency on the proper operation and maintenance of the equipment. Proterra also will provide visual and other teaching aids (such as manuals, slide presentations and literature) for use by the Agency's own training staff, which become the property of the Agency.

The following training is included with the purchase of the bus and charger.

- Operator Training
  - 40 hours of operator training
  - Utilizes a "train-the-trainer" approach to enable customers to provide as much training as required for their operators
  - 50/50 split between classroom and seat-time for the operators
- Bus Maintenance Training
  - 36 hours of vehicle maintenance training.
  - Classroom and hands-on training
- Bus Introduction Training
  - 16 hours of general bus introduction training
  - Meant for supervisors, managers, procurement
- Charger Maintenance Training
  - 24 hours of charger maintenance training
  - Classroom and hands-on training

Additional training options and curriculum can be provided upon request.

TS 5.6.1 Technical/Service Representatives

Proterra will, at its own expense, have one or more competent technical service representatives available on request to assist the Agency in the solution of engineering or design problems within the scope of the specifications that may arise during the warranty period. This does not relieve the Proterra of responsibilities under the provisions of "Section 7: Warranty Requirements."

TS 5.7 Operating Environment

The bus achieves normal operation in ambient temperature ranges of 10 ºF to 115 ºF, at relative humidity between 5 percent and 100 percent, and at altitudes up to 3000 ft above sea level. Degradation of performance due to atmospheric conditions is minimized at temperatures below 10 °F, above 115 °F or at altitudes above 3000 ft. Speed, gradeability and acceleration performance requirements are met at, or corrected to, 77 °F, 29.31 in. Hg, dry air per SAEJ1995.

TS 5.8 Noise

TS 5.8.1 Interior Noise

The composite body structure provides sufficient sound insulation so that a sound source with a level of 80 dBA measured at the outside skin of the bus has a sound level of 65 dBA or less at any point inside the bus. These conditions prevail with all openings, including doors and windows, closed and with the motor and accessories switched off.

The bus-generated noise level experienced by any rider at any seat location in the bus does not exceed 80 dBA, on average. Sound will be measured during a zero to 35 mph acceleration event, on a smooth level surface. All windows and doors will be closed during test. Pending testing, measurements of interior noise levels will be taken in accordance with Altoona 7-1 Interior Noise Test Procedure.

TS 5.8.2 Exterior Noise

Airborne noise generated by the bus and measured from either side does not exceed 80dBA under full power acceleration when operated at 0 to 35 mph at curb weight. The maximum noise level generated by the bus pulling away from a stop at full power does not exceed 83 dBA. The bus-generated noise at curb idle does not exceed 65dBA. If the noise contained an audible discrete frequency, a penalty of 5 dBA was added to the sound level measured. Proterra will comply with the exterior noise requirements defined in local laws and ordinances identified by the Agency and SAEJ366.

TS 5.9 Fire Safety

The bus is designed and manufactured in accordance with all applicable fire safety and smoke emission regulations. These provisions include the use of fire-retardant/low-smoke materials, fire detection systems, bulkheads and facilitation of passenger evacuation.

TS 5.9.1 Materials

All materials used in the construction of the passenger compartment of the bus are in accordance with the Recommended Fire Safety Practices defined in FMVSS 302. An option is available to meet the requirement for FTA Docket 90-A.

TS 5.10 Fire Suppression

Proterra's Battery Management System (BMS) provides a constant mechanism for fire detection in the Energy Storage System (ESS). In addition, operating electric propulsions systems does not generate the heat like an internal combustion engine; with the maximum temperature in the rear

ProDrive area typically measuring at 10 degrees F warmer than the ambient temperature. As such, the standard configuration is for no fire suppression system. However, options for fire suppression are available if the agency has a strong preference for it.

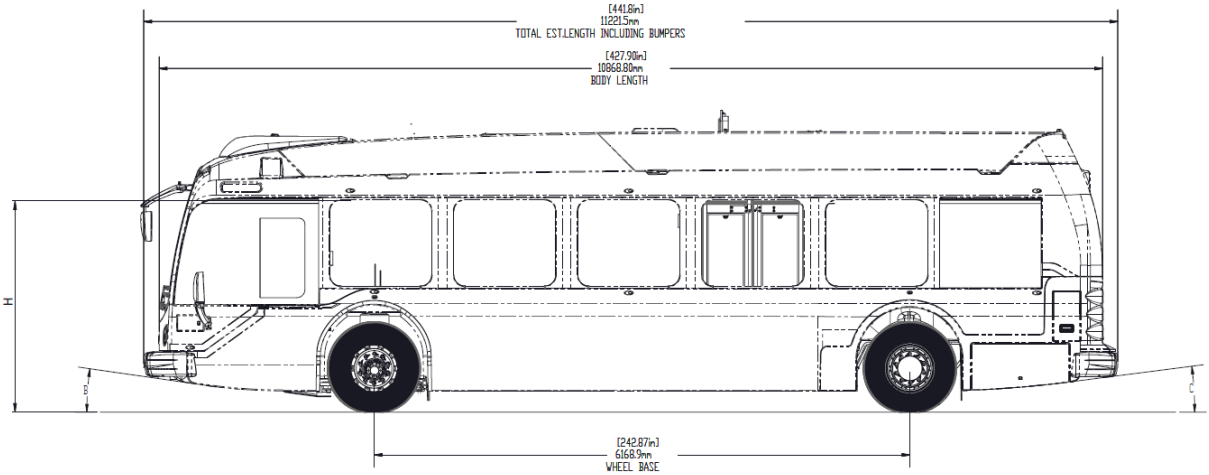
TS 5.11 Respect for the Environment

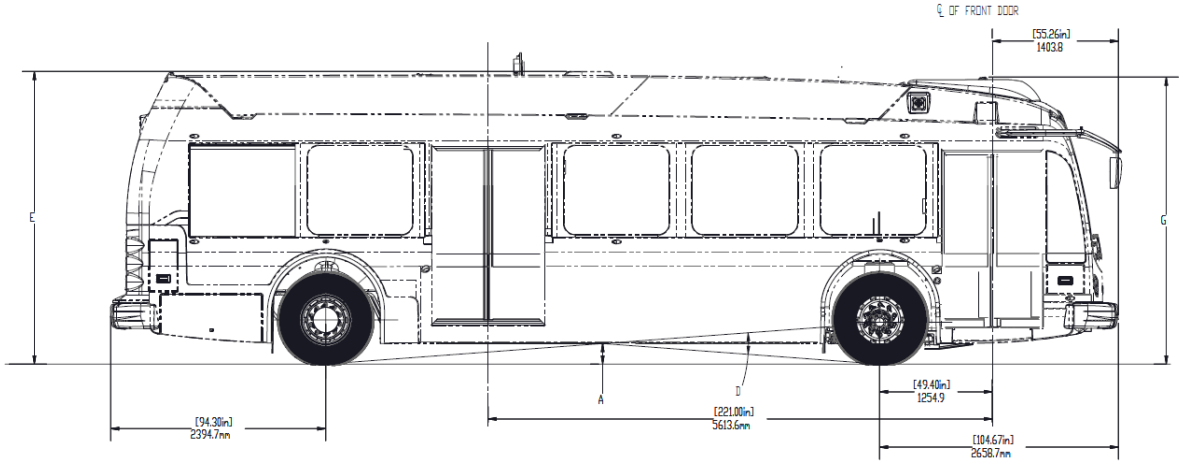
In the design and manufacture of the bus, Proterra has made every effort to reduce the amount of potentially hazardous waste. In accordance with Section 6002 of the Resource Conservation and Recovery Act, Proterra uses, whenever possible and allowed by the specifications, recycled materials in the manufacture of the bus.

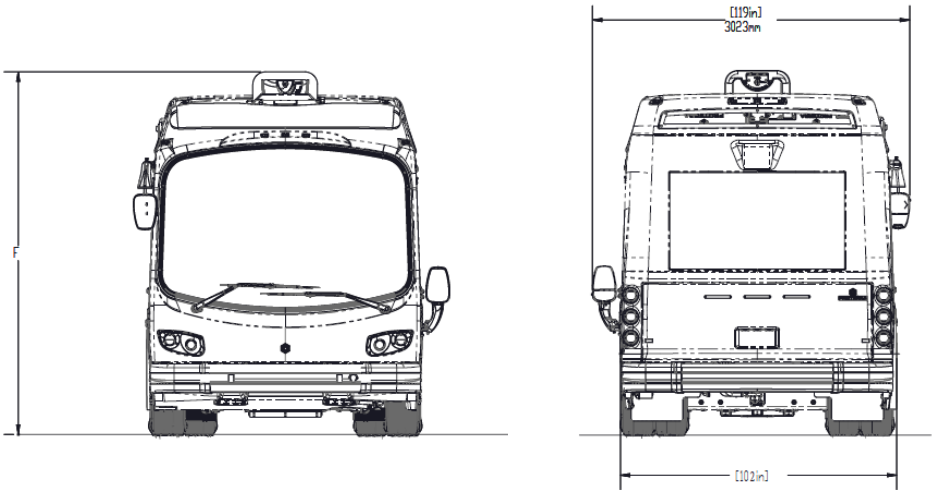
DIMENSIONS

TS 6. Physical Size

With exceptions such as exterior mirrors, marker and signal lights, bumpers, fender skirts, washers, wipers, ad frames, cameras, object detection systems, bicycle racks, feelers and rubrails, the bus has the following overall dimensions at static conditions and design height.







RIDING CONDITIONS	RIDE HEIGHT (in) A	APPROACH (deg) B	DEPARTURE (deg) C	BREAKOVER (deg) D	HIGHEST POINT (in) E	ESCAPE HATCH IN OPEN POSITION (in) F	HEIGHT OF CHARGE RAIL (in) G	MAIN ROOF HEIGHT(in) H
NORMAL	9	8.1	7.3	8.5	128	136.2	125.5	96.1
DRIVING	10	9.3	9.3	7.8	129	137.2	127.9	97.1
OVER RISE	11.5	10.1	10	8.9	130.5	138.7	129.4	98.6

Figure 1- Transit Bus Exterior Dimensions

TS 6.1 Bus Length

The 35’ Catalyst E2 is 36 ft., 11 in. measured from bumper to bumper.

TS 6.2 Bus Width

The 35’ Catalyst E2 meets the specification of 102 in. wide exclusive of the mirrors and wheel skirts.

TS 6.3 Bus Height

The 35’ Catalyst E2 is 128 in. high, including all rigid roof-mounted items.

TS 6.4 Step Height

The step height does not exceed 16.5 in. at the front doorway without kneeling and does not exceed 15.5 in. at the step.

The rear step height does not exceed 17 in. The bus comes standard with an automatic ride height feature which provides an automatic ¾ inch change in ride height as the doors are opened and closed. Kneeling is driver controlled and can be adjusted up to 3 inches. The raised aisle floor in the rear of the bus is designed with two steps.

TS 6.5 Underbody Clearance

The bus maintains the minimum clearance dimensions as defined and shown in Figure 2 of SAE Standard J689, regardless of load up to the gross vehicle weight rating. This is accomplished by the use of ride height sensors on all four corners of the vehicle.

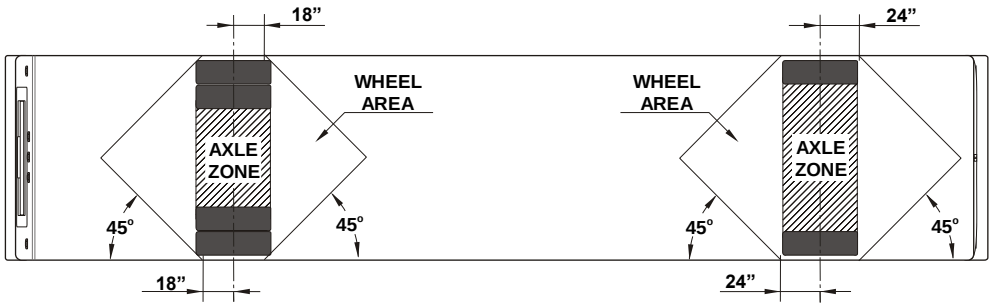


Figure 2-Transit Bus Minimum Road Clearance

TS 6.6 Ramp Clearances

The approach angle is the angle measured between a line tangent to the front tire static loaded radius arc and the initial point of structural interference forward of the front tire to the ground.

The departure angle is the angle measured between a line tangent to the rear tire static loaded radius arc and the initial point of structural interference rearward of the rear tire to the ground.

The breakover angle is the angle measured between two lines tangent to the front and rear tire static loaded radius and intersecting at a point on the underside of the vehicle that defines the largest ramp over which the vehicle can roll. See Figure 3.

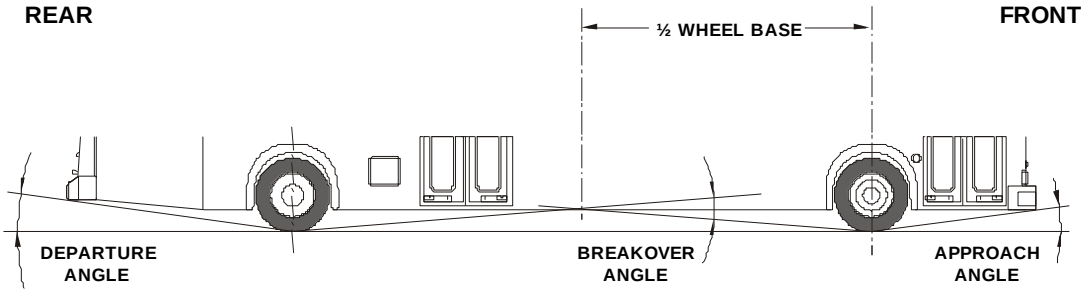


Figure 3-Ramp Clearance

The 35’ Catalyst E2 provides a 7 degrees front breakover angle. This breakover angle is the result of placing the high voltage battery packs under the floor, between the axles (much like leading EV automobile designs, e.g. Tesla, Chevrolet Bolt, BMW i3, etc.). See Table 1 for Proterra angles.

	APTA Spec	35’ Catalyst E2
Angle	**30 to 45 ft Bus**	**35 ft Bus**
Approach	8.6° (min.)	9.3°
Front breakover	7.5° (min.)	7.8°
Departure	7.5° (min.)	9.3°

Table 1- Alternative Breakover Angle

TS 6.7 Ground Clearance

The 35’ Catalyst E2 meets all APTA requirements at Dynamic Ride Height. When the vehicle is stopped and the doors are opened the vehicle is static and is closer to the ground by ¾ in. With the doors closed, the vehicle is dynamic and meets the following ground clearances.

Ground Clearance: Ground clearance is no less than 9 inches (8 inches at jacking pad), except within the axle zone and wheel area.

Axle Clearance: Axle zone clearance, which is the projected area between tires and wheels on the same axial centerline, is 6”.

Wheel Area Clearance: Wheel area clearance, is 7.85” for parts fixed to the bus body and 6” for parts that move vertically with the axles. Wheel area items are protected by a skid plate.

The jacking pad clearance is 8.5” with 1/4” plate and 1/4" bond gap. Ride height sensor are provided on each corner of the bus to keep the bus at the same ride height no matter the weight or capacity of the bus.

TS 6.8 Floor Height

Height of the step above the street is no more than 16 in. measured at the centerline of the front doorway. The height of the step above the street is no more than 17in. measured at the centerline of the rear doorway. All floor measurements are with the bus at the design running height and on a level surface and with the standard installed tires. Two steps are designed to accommodate a raised aisle floor in the rear of the bus. The floor is inclined along the longitudinal axis of the bus, and the incline will be less than 3 1/2 degrees off the horizontal except locally at the doors where a maximum 5 degrees slope toward the door is allowed. The floor height is dictated by the placement of the battery packs under the floor and between the wheels which provides the following major benefits:

- Lower center of gravity, better handling
- Increased safety
- No HV batteries inside the passenger compartment

• Batteries are lower than the side impact height for automobiles

Proterra buses are capable of full kneeling functionality.

TS 6.9 Interior Headroom

Headroom above the aisle and at the centerline of the aisle seats is not less than 78 in. in the forward half of the bus tapering to no less than 74 in. forward of the rear settee. At the centerline of the window seats, headroom is not lower than 65 in. Headroom at the back of the rear bench seat may be reduced to a minimum of 56 in, but it will increase to the ceiling height at the front of the seat cushion. In any area of the bus directly over the head of a seated passenger and positioned where a passenger entering or leaving the seat is prone to strike his/her head, padding will be provided on the overhead paneling.

TS 6.10 Aisle Width

The minimum clear aisle width between pairs of transverse seats with all attached hardware is at least 22 in.

The aisle width between the front wheelhouses is at least 35.5 in., and the entire area between the front wheelhouses is available for passengers and mobility aid devices.

VEHICLE PERFORMANCE

TS 7. Power Requirements

The propulsion system is sized to provide sufficient power to enable the bus to meet the defined acceleration, top speed and gradeability requirements, and operate all propulsion-driven accessories using actual road test results and computerized vehicle performance data.

> **Note**: The performance results below are representative of a 35’ Catalyst E2 bus with a ProDrive propulsion system. Proterra offers several different battery configuration and propulsion systems options which will have different performance results from what is stated below. The results below summarize the minimum performance capability of a Catalyst 35’ E2 bus.

TS 7.1 Top Speed

35’ Catalyst E2 is capable of achieving a top speed of 65 mph on a straight, level road at GVWR with all accessories operating. The bus is capable of safely maintaining the vehicle speed according to the recommendations by the tire manufacturer.

TS 7.2 Gradeability

The ProDrive propulsion system enables the bus to achieve a speed of 40 mph on a 2½ percent ascending grade and 15 mph on a 10 percent ascending grade. As an exception, under some circumstances the vehicle speed may be reduced to 28 MPH on a 2.5% grade and to 12 MPH on a 10% grade to thermally protect drivetrain components. The two contributing factors are ambient

temperature and time spent ascending the grade. Gradeability requirements are met on grades with a dry commercial asphalt or concrete pavement at GVWR with all accessories operating.

TS 7.3 Acceleration

The acceleration of the 35' Catalyst E2 meet the requirements in Table 2 below and is sufficiently gradual and smooth to prevent throwing standing passengers off-balance. Acceleration measurement commence when the accelerator is depressed. The acceleration produces a maximum jerk rate of 0.3 g's/sec.

Speed (mph)	Maximum time (seconds)
10	5
20	10
30	18
40	30
50	60
Top speed	

Table 2-Maximum Start Acceleration Times on a Level Surface[1]

1. Vehicle weight = GVWR

TS 7.4 Operating Range

Proterra offers a modular, technology-centric approach to vehicle configuration. Customers can choose from two vehicle sizes and can select their energy level, as well as charging solutions to meet the needs of their specific routes. Catalyst buses can be upgraded to meet changing needs throughout the vehicles' life. The 35' Catalyst platform allows for a variety of different battery configurations and charging options to meet customer requirements.

TS 8. Fuel Economy (Design Operating Profile)

Proterra utilizes proprietary route simulation tools to predict real world range and fuel economy for customer routes. Please work with Proterra representatives to determine the most appropriate solution to meet route requirements.

TS 9. Propulsion System Description

TS 9.1 ProDrive

The Proterra 35’ Catalyst E2 is a 100% battery electric powered transit bus. Proterra's high-performance ProDrive™ drivetrain maximizes performance and efficiency to meet the challenges of most routes.

It consists of three major components; the permanent magnet synchronous traction motor, the power inverter, and the two-speed automated manual transmission where the traction motor and the transmission are the only moving parts.

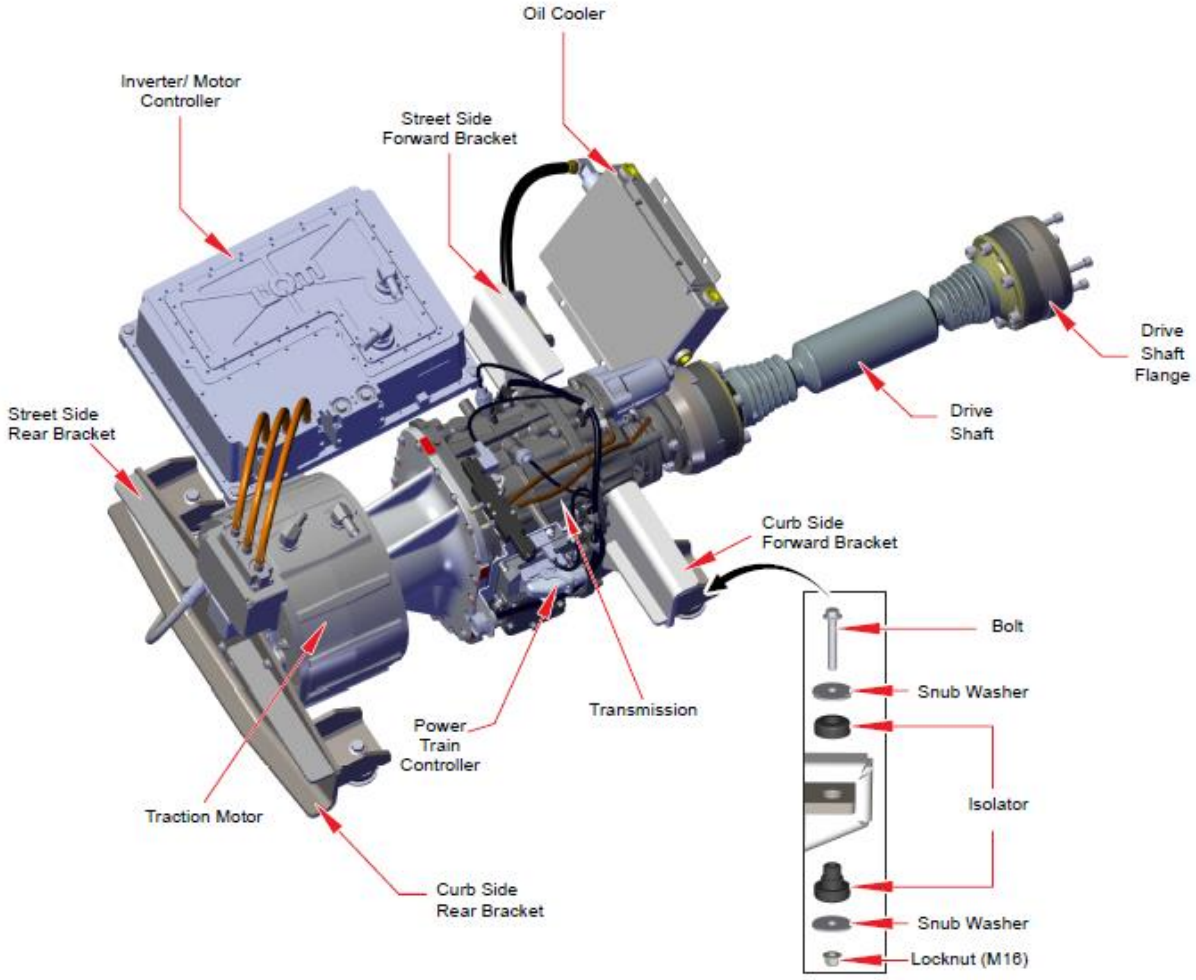


Figure 4-Catalyst ProDrive Propulsion System

The traction motor is capable of 250kW peak power and the traction motor is controlled via an inverter which receives direct current from the high voltage battery system. Both the motor and inverter are liquid cooled.

Parameter	Specification
Peak Power	250 kW
Continuous Power	180 kW
Peak Torque	900 Nm
Continuous Torque	550 Nm
Full Power	600 V DC and up
Max Speed (full performance)	5500 RPM

Table 3-Traction Motor Technical Specifications

The unique Proterra two-speed transmission contains a planetary gear set with a pneumatically driven shift mechanism. The transmission is oil-cooled and contains an additional oil cooler to ensure that the transmission remain at ideal temperatures under the most difficult driving cycles. The output of the transmission supplies power to the ZF drop center rear axle.

All actuators and sensors for the transmission are connected to the Proterra powertrain controller which controls both the torque/speed commands of the traction motor as well as the transmission shift actuation. These controls have been optimized for transit bus service for best drivability and maximized efficiency. They are designed and calibrated using real world data from customer vehicles, engineering tests utilizing proprietary drive cycles and standard FTA drive cycles (CBD, Arterial, Commuter), and using our high-fidelity simulation tool similar to the model used for fuel economy analysis.

With the two-speed transmission Proterra can utilize a smaller, lighter traction motor to meet the needed performance requirements while still offering excellent efficiency. This transmission also allows the powertrain system the flexibility to provide the needed torque while also operating at more efficient traction motor operating points.

The combination of the traction motor, the power inverter, and the transmission are a primary reason why the Catalyst broke the Altoona records for acceleration, efficiency, and gradeability.

TS 9.2 DuoPower

The new “DuoPower” Proterra Catalyst drivetrain system employs state-of-the-art electric vehicle technology that is conveniently integrated into the rear axle of the bus. Proterra uses two permanent magnet synchronous motors, each directly coupled to a multi-speed gearbox that independently drives its respective wheel. The system is capable of up to 475 peak horsepower and is

controlled via an inverter which receives direct current from the high voltage battery system. The drivetrain system uses a liquid cooling circuit to reject heat through the bus heat exchanger.

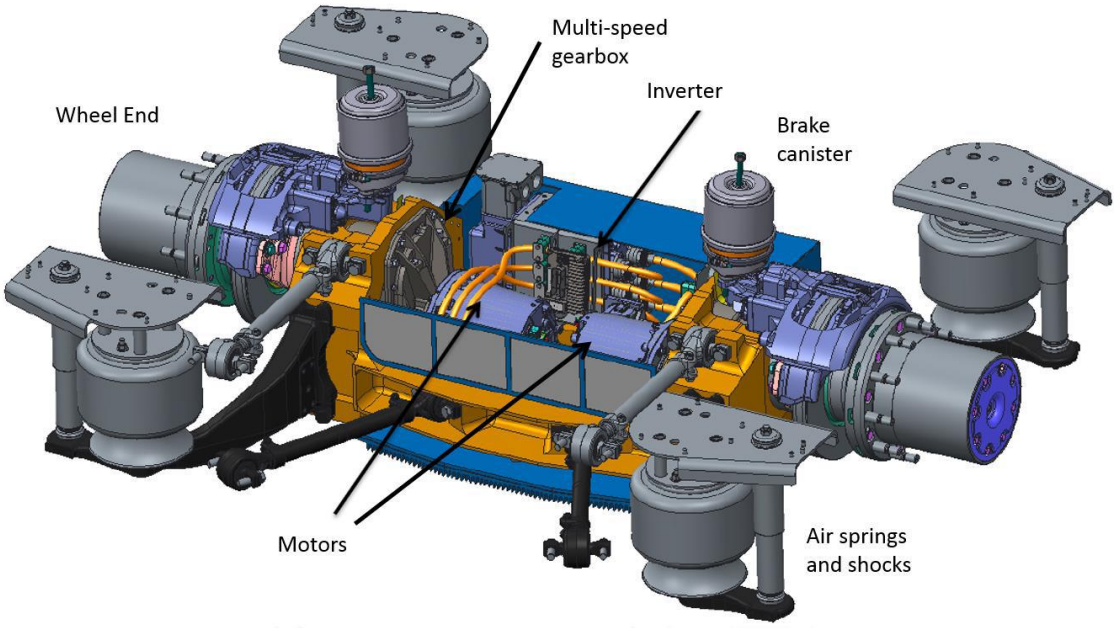


Figure 5-Catalyst DuoPower Drivetrain

The Proterra multi-speed gearbox is purpose designed and built for heavy duty electric vehicle operation. The gear ratios were selected to maximize fuel economy for transit bus operation while ensuring best in class performance. The gearbox contains a pneumatically actuated shift mechanism to seamless shift

between low and high gear. An external electric pump is used to circulate oil for lubrication and heat rejection. The output of the gearbox is coupled to a planetary gear reduction unit housed within the wheel hub.

All actuators and sensors for the gearbox are connected to the Proterra powertrain controller which is responsible shift actuation and motor torque commands. The controls have been optimized for transit bus service for best drivability and maximized efficiency. These controls are designed and calibrated using real world data from customer vehicles, engineering tests utilizing proprietary drive cycles and standard FTA drive cycles (CBD, Arterial, Commuter), and using our high-fidelity simulation tool similar to the model used for this fuel economy analysis.

With the multi-speed gearboxes Proterra can utilize smaller, lighter weight traction motors to achieve best in class acceleration and gradeability performance. The gearboxes also allow the drivetrain system the flexibility to operating at more efficient motor operating points, thus improving overall vehicle efficiency.

The combination of the traction motors, inverter, and the gearboxes integrated into a compact and lightweight package are a primary reason why the Catalyst continues to provided best in class acceleration, efficiency, and gradeability for customers.

Drivetrain System Specifications:

Parameter	Specification
Peak Power	356 kW
Continuous Power	192 kW
Peak Wheel Torque	21,000 Nm
Continuous Wheel Torque	13,500 Nm
Max Vehicle Speed	65 MPH

The Proterra Catalyst drivetrain system is a new product that takes learnings from our first powertrain system to improve performance and efficiency. The original version of the Proterra powertrain has accumulated over 3.7 million miles of in revenue service.

The data and customer feedback from this time in service has been essential in developing the new drivetrain system. The design life of the drivetrain system is 500,000 miles of heavy-duty transit bus use.

Advantages

- Best in class low speed torque, can achieve grades up to 20%
- Multi-speed gearbox enables this drivetrain to achieve the highest bus efficiency compared to other transit buses
- Very high efficiency = >95% motor efficiency
- High power = 475 HP
- Lightweight and compact => all components located between rear wheels
- Long life = > Designed for full life of vehicle (500,000 mi)
- Few moving parts = Traction motor has ~3 moving parts and the inverter has zero
- Use of industry standard motor and inverter components means better reliability and uptime

TS 9.3 Propulsion Control System

The propulsion control system is capable of transmitting and receiving electronic inputs and data from drivetrain components, and broadcasting that data to other vehicle systems. Communication between electronic drivetrain components and other vehicle systems is made using the communications networks.

The vehicle system has onboard diagnostic capabilities able to monitor vital motor functions, store and time stamp parameter conditions in memory, and communicate faults and vital conditions to service personnel. Diagnostic reader device connector ports, suitably protected against dirt and moisture, is provided in the operator's area. The onboard diagnostic system

informs the operator via visual and/or audible alarms when out of parameter conditions exist for vital engine functions. The on-board diagnostic system has capabilities for storing hard and soft codes and processing data and provide detailed information/reports on various aspects of fleet usage. The information is retrievable via cabling or wireless transmission to a laptop.

The motor drive protects the drive system against progressive damage. The system monitors conditions critical for safe operation and automatically de-rate power and/or speed and initiate motor shutdown as needed. The on-board diagnostic system triggers a visual and audible alarm to the operator when the motor control unit detects a malfunction and the engine protection system is activated.

The propulsion control system is designed with redundancy in mind. For certain failure conditions, a “limp home mode” driving condition is available which enables limited vehicle operation to reduce the need for towing. It is Proterra’s design principle to allow for some level of safe operation if the failure allows.

A control is available to the operator to allow a 30-second override, which, when depressed, will allow the operator to delay the drive system shutdown but not the activation and alarm system.

TS 9.4 Propulsion System Service

The propulsion motor is designed to operate for not less than 300,000 miles without major failure or significant deterioration. Components of the control system are designed to operate for not less than 150,000 miles without replacement or major service.

The propulsion system is arranged so that accessibility for all routine maintenance is assured. No special tools, other than dollies and hoists, are required to remove the propulsion system or any subsystems. However, the Agency shall recognize that properly rated test equipment and safe electrical work practices are essential when servicing high voltage components. Proterra will provide all specialty tools and diagnostic equipment required for maintaining the Propulsion System in accordance with Special Tools List.

TS 10. Energy Storage System

The Energy Storage System (ESS) is an integrated system that was designed with safety as top priority. The ESS will be described by the five main sections to this system:

10.1) the battery chemistry, 10.2) the mechanical design, 10.3) the electrical design, 10.4) the control system interacting with the battery system, and 10.5) Energy storage system safety.

TS 10.1 Battery Chemistry

The Catalyst E2 vehicles utilize a proprietary high-energy density battery chemistry that falls into the broader category of lithium-ion batteries. The high-energy density allows for more on-board energy storage without the need to add battery packs to the passenger cabin or on the roof. The battery cells are provided from a top tier, global EV battery manufacturer that currently supports major automotive and heavy-duty vehicle OEMs. These cells are proven EV batteries that have been extensively tested to validate battery safety, both by the cell manufacturer and by Proterra's world-class battery engineering team.

TS 10.2 Mechanical Design

The mechanical design starts with the battery packs themselves and the carbon-fiber reinforced body structure, then continues through to the structure encasing the battery modules and the actual module designs. The bus body incorporates four primary composite stringers that run the length of the body, surrounding the underbody-mounted battery packs between the front and rear axles. Each of these four stringers incorporates full-length, pultruded carbon fiber stringers that maximize strength to weight ratio and add stiffness and rigidity to the battery box surround. It should also be noted that the body serves as a natural electric insulator due to its composite construction vs. a metal chassis normally associated with a transit bus. The vertical location of the battery boxes behind these beams is also located below bumper height of most vehicles which provides additional protection from a direct side impact. This location also provides for an extremely low center of gravity as well as an ideal weight distribution.

Each pack is contained in an aluminum enclosure that is reinforced with 3mm of a heavy-duty polyurethane spray-on covering that lends individual protection to its sub-components. The pack is designed to be sealed to IP66/7 and ANSI/ISE 60529-2004 standards. The pack also fully contains any electrolyte should a cell leak (pursuant to SAE J1766) and meets the 1,000 hours salt spray per ASTM B 117 testing. The packs are designed to handle 5g half-sine peak shock accelerations. The modules within the battery packs are actively cooled to keep the batteries in the ideal temperature range to maximize battery life and comply with the requirements from the battery manufacturer. The battery cooling system includes a chiller integrated with the HVAC system that runs if the ambient environment is too warm for the module manufacturer's desired system set-points. The battery management system monitors cell voltage, temperature and current to ensure safe performance. Should the cooling system fail, the controls monitor and limit operation as a function of temperature, so that the vehicle will function and de-rate performance safely while indicating a fault to the operator. In this way, a cooling system failure will not result in a hard or immediate stop in operation.

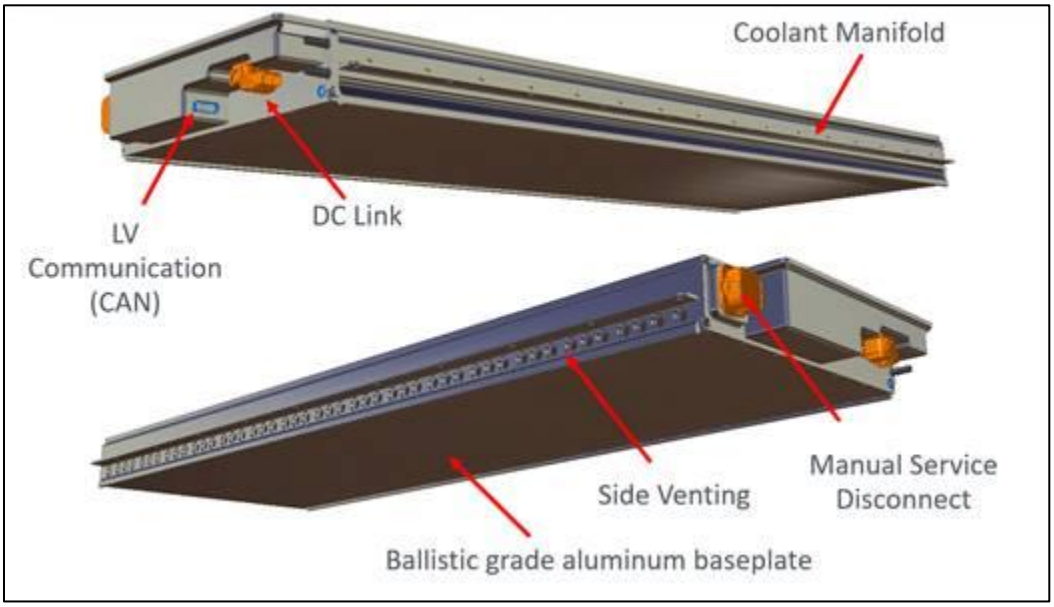


Figure 6-Battery Mechanical Design

TS 10.3 Battery Thermal Management

Battery thermal management is powered whenever the battery contactors are closed. Therefore, the bus in charging mode or on would have all battery thermal functions monitored. Diagnostics monitor the performance of the Battery Thermal Management System, pumps, fan and chiller and will set faults in the event a problem is detected. The batteries will automatically derate (reduce their power output) if they become too hot so that cooling system failures will not damage the batteries. Thermal management has appropriate safety interlocks installed to react to adverse conditions as stated in SAE J1772.

Battery temperatures never exceeds the Proterra's recommended range during operation in the design operating profile and specified ambient conditions. Battery cooling is sufficient to prevent the temperature from exceeding the Proterra's recommended maximum temperature when the ambient temperature is above 105 degrees F for a period of 16 hours.

TS 10.4 Electrical Design

The wiring from each pack is insulated and shielded to industry standards and passes into the center cavity formed between the stringers under the vehicle, referred to as "Broadway". Broadway provides a protected route the length of the bus back to the high voltage junction box in the rear compartment of the vehicle. This is where the individual batteries are bussed together to provide for one high voltage electrical system. The high voltage interlock circuit and control wires for the battery system run along this route with the high voltage cables for maximum safety.

Each battery pack is internally fused and contains a set of contactors. The contactors are located near the pack outputs. Each pack also contains an individual pack controller which serves as a central hub to gather and report information specific to that pack. Each battery module has a monitoring board that measures voltage of each cell and performs cell balancing. This information is communicated to the pack controller via serial communication.

TS 10.5 Battery Management System

The battery management system (BMS) performs the following functions:

A. The BMS system is capable of monitoring the voltage level of cells within each battery pack. The BMS reads and stores individual battery or block voltages at a frequency of 1 data point per block every 15 seconds. The system also monitors battery pack temperatures using no fewer than 2 thermocouples placed in and around each battery pack sampled at the same 4 samples per minute frequency.

B. The BMS system is capable of communicating when a battery fault (as defined by Proterra) has occurred and is able to identify and communicate the faulty battery in order to perform maintenance.

C. The BMS system is capable of engaging prudent safety interlocks when an unsafe battery condition has been detected.

D. The BMS system is able to monitor the battery state-of charge and update a gauge viewed by the operator at least once every 15 seconds.

E. The BMS system is able to communicate all data to the bus level information system for storage and communication.

TS 10.6 Control System

The battery control system is a hierarchical control with the energy storage module (ESM) acting as the interface and lead controller to the rest of the battery system. This module communicates on the main vehicle CAN bus to interface with the cooling, powertrain, charge and other systems. This module can also communicate on the separate battery CAN bus with all of the individual packs. The main controller exchanges information about battery input and output capability as well as cooling needs and diagnostic information.

The pack controllers control the contactors internal to the pack. They also gather the current information as well as pack voltage, cell voltage, and temperature information. Pertinent data is provided back to the master controller which uses this information to compute system limits, determine overall health status, and apply system-wide boundaries on use. The system uses algorithms and feedback to know the position of all contactors. The temperature measurements in the pack are redundant. There are also additional sensors that perform miscellaneous items like moisture detection in each pack. The battery system algorithms coordinate all activities related to the safety and performance of the system.

The battery control system provides system discharge limits to ensure that the lowest cell never goes below its minimum and that the highest cell never goes above its maximum allowable state. The system is also designed to monitor current imbalances between the packs, temperatures throughout all the packs, moisture, and isolation detection. Should loss of communication occur with a pack or module, the system will gracefully handle this with independent fault actions.

TS 10.7 Energy Storage Safety

The energy storage system (ESS) is designed and constructed such that occupants will not be exposed to hazardous electrical current during normal operation or in the event of an accident as defined by ECE80 and APTA TS 23.2 (Crashworthiness).

Under normal conditions, the ESS is designed to protect against electric shock per ISO 6469-3. The protection is composed of:

- Basic protection measures against direct contact with live parts.
- All high voltage circuits are rated to IPXXB for direct contact.
- Measures for protection under single fault conditions.
- The isolation resistance is continuously monitored to ensure adequate isolation.
- If the isolation resistance value is less than 500 Ohm/V, a diagnostic event is triggered.
- If the isolation resistance value is less than 100 Ohm/V, a diagnostic event is triggered and an indicator light is displayed on the dashboard.
- Each high voltage battery pack utilizes a set of two contactors, independently capable of providing galvanic isolation between Class A and Class B circuits.
- The contactors are implemented in a manner to comply with SAE J2929, Section 4.13.1 Protection Against High Voltage Exposure, Automatic Disconnects.
- Each high voltage battery pack utilizes a manual service disconnect (MSD).
- The MSD is implemented in a manner to comply with SAE J2929, Section 4.13.2 Protection Against High Voltage Exposure, Manual Disconnects.

TS 10.7.1 ESS SAFETY STANDARDS AND REFERENCES

STANDARD	DESCRIPTION
UN 38.3	Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria
ECE R100	Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train
ISO 6469-1	Electrically propelled road vehicles — Safety specifications — Part 1: On-board rechargeable energy storage system (RESS)
ISO 6469-3	Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock
ISO 12405-3	Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 3: Safety performance requirements
SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells
SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
ISO 26262	Road vehicles -- Functional safety -- Part 1: Vocabulary
NFPA 70E, Edition 15	Standard for Electrical Safety in the Workplace
SAE J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
IEC 60664-1	Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests

TS 10.7.2 ESS DURABILITY STANDARDS AND REFERENCES

STANDARD	DESCRIPTION
SAE J1455	Recommended Environmental Practices for Electronic Equipment Design in Heavy Duty Vehicle Applications
IEC 60068-2-1	Low Temperature Operating Environment
ISO 12405-2	Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 2: High-energy applications
ISO 20653	Road vehicles -- Degrees of protection (IP code) -- Protection of electrical equipment against foreign objects, water and access
SAE J2380	Vibration Testing of Electric Vehicle Batteries
DIN EN 55025	Radio Disturbance Characteristics For The Protection Of Receivers Used On Board Vehicles, Boats, And On Devices - Limits And Methods Of Measurement
ISO 7637-1	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 1: Definitions and general considerations
ISO 7637-2	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 2: Electrical transient conduction along supply lines only
ISO 11452-4	Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 4: Harness excitation methods
ISO 10605	Road vehicles -- Test methods for electrical disturbances from electrostatic discharge
ISO 16750-2	Road vehicles -- Environmental conditions and testing for electrical and electronic equipment -- Part 2: Electrical loads

TS 11. Charging the Catalyst

The 35' Catalyst E2 comes standard with a single manual charging port located at the rear curb-side of the bus that meets the SAE J1772 CCS Type 1 North American standard for plug-in charging. Additional options are available for dual charge ports located either on each rear side of the bus.

The port(s) is capable of charging at 350A continuously. That is the equivalent of 140kW per port assuming a nominal system voltage of 400 VDC. The charge port is capable of supporting charging with a peak voltage of 500 VDC.

TS 12. Cooling Systems

This vehicle utilizes two independent cooling loops to cool the high-voltage batteries and the power electronics on the vehicle.

TS 12.1 Battery Coolant Loop

The battery coolant loop has two dedicated coolant pumps that circulate coolant through a battery coolant heater, the battery packs, into the HVAC integrated chiller plate, and back through an inline coolant filter before returning to the coolant pumps. The coolant heater and chiller plate provide heating and cooling, independently, as required to maintain battery temperatures.

TS 12.2 Power Electronics Loop

The power electronics loop also has a dedicated coolant pump that circulates coolant through the power electronic units that require cooling, through a three fan radiator and then through a strainer to repeat the loop. The transmission is equipped with a standalone oil-to-air cooler mounted next to the transmission.

The cooling systems is of sufficient size to maintain the motor, electronics and batteries at a safe, continuous operating temperatures during the most severe operations possible and in accordance with the manufacturers' cooling system requirements. System temperatures are monitored and the cooling system controlled to ensure equipment temperature is maintained in a safe range. The fan control system is designed with a fail-safe mode of "fan on." The cooling system meets the requirements stated in the operating environment. The coolant system consists of the following components:

Heat Exchanger (Radiator)

- Roof mounted (center)
- Heat rejection – 20kW
    - Fluid temp from 140°F to 120°F @ 30 LPM (109°F ambient)
- Core size 39" x 17" x 1.6"
- Overall size including shroud and fins 48" x 18" x 16"
- Variable speed air transfer fans

- Integral side tanks

Overflow tank

- Accommodates fluid expansion
- Incorporates de-aeration feature

Coolant transfer pump

- Constant speed fluid transfer pump

Coolant transfer lines

- Rigid coolant tubes – mild steel powder coated (exceeds salt spray corrosion test parameters)

TS 12.2.1 Radiator Screen

The 35' Catalyst E2 design does not require a radiator screen. The power electronics loop is equipped with 1 radiator. This radiator, is located on the roof and is effectively screened from large debris which eliminating the need for a radiator screen. It is designed to withstand thermal fatigue and vibration associated with the installed configuration. The radiator cores are easily cleaned with standard pressure-washing equipment.

TS 12.2.2 Coolant

The 35' Catalyst E2 is equipped with coolant filtration. The water filter is sized properly with an in-line element and does not contain supplemental coolant additives.

TS 12.2.3 Drive Design

The 35' Catalyst E2 is equipped with an electric fan drive bus cooling system. A screen guard is installed on electric motor fans per SAE J1308.

TS 12.2.4 Mounting

The 35' Catalyst E2 is equipped with a roof mounted radiator.

TS 12.3 Transmission Cooling

The transmission is cooled by a dedicated heat exchanger sized to maintain operating fluid within the transmission manufacturer's recommended parameters of flow, pressure and temperature. The transmission cooling system is separate from the motor cooling system. The transmission cooling system is a standalone system designed to circulate oil through a small radiator next to the transmission (See figure 5).

TS 13. Transmission

The Proterra Catalyst ProDrive and DuoPower drivetrains use electronically-controlled pneumatically shifted 2-speed gear boxes (transmission). A torque converter and retarder are not needed. The transmission rated torque, power and speed limits are compatible with the motor capabilities. The transmission is designed to operate for not less than 300,000 miles on a transit bus operating profile without replacement or major service. The transmission is easily replaceable without removing the motor and accessible for service from the underside of vehicle.

The controls system is capable of transmitting and receiving electronic inputs and data from other vehicle components through the vehicle CAN network. The control system is powered by the vehicle 24 V distribution system. The control system is responsible for shift execution of the transmission which is done by monitoring powertrain component and driver inputs to select the most appropriate gear. At a minimum, drivetrain components consisting of the motor, transmission and anti-lock braking systems are powered to ensure data communication among components exists when the vehicle ignition is switched to the “on” position.

A moderate brake pedal application is required by the driver to engage forward or reverse range from the neutral position to prevent sudden acceleration of the bus from a parked position.

The electronically controlled powertrain and vehicle controller has on-board diagnostic capabilities, is able to monitor functions, store and time-stamp out-of-parameter conditions in memory, and communicate faults and vital conditions to service personnel, in coordination with the body controls/diagnostic tool. The transmission contains built-in protection software to guard against severe damage. The on-board diagnostic system triggers a visual alarm to the driver when the electronic control unit detects a malfunction.

Although the 2-speed transmission is an automatically shifted unit, it has a manual transmission architecture, i.e. gears, shafts and shift collars but with no clutches, or torque converter, therefore there is not a need to monitor the fluid on an ongoing basis. The fluid will remain at a constant level between specified fluid change intervals. The oil change frequency recommended for Proterra’s transmission is 100,000 miles. In automotive applications, manual transmissions never require an oil change and thus level indications are not required.

The transmission shifts to neutral immediately when the park brake is applied. However, when the parking brake or door brake interlock is active the traction motor is prohibited from applying torque for functional safety requirements. The driver is required to apply the service brake to re-engage forward or reverse gear selection. The door interlock system inhibits vehicle motion by applying the rear brakes until the doors close again. In fact, what happens at zero speed highlights the major difference between Proterra’s EV powertrain and a conventional diesel bus. In a Proterra bus, zero speed means the motor is not spinning. For a diesel bus, the engine still spins at idle so that powertrain requires the torque converter to decouple the engine from the transmission.

Proterra’s transmission also does not shift to neutral while the hill hold feature is active. It stays in gear, but the motor is not spinning. When this feature is activated the brake system will lock allowing the vehicle to stay stationary.

Because the all-electric powertrain is consuming very little power at a complete stop and has no rotation, there is no reason to automatically select neutral when the parking brake or door brake interlock is applied.

TS 14. Regenerative Braking

The Proterra bus utilizes two main systems to slow down or decelerate the vehicle, a standard pneumatic friction brake system and regenerative braking. Regenerative braking uses the main traction

motor to generate electricity which is then captured and used to charge the main High Voltage (HV) battery. The ability to capture energy while braking, results in a large improvement in energy efficiency of the vehicle. On a traditional vehicle the energy created during braking is lost to heat through either the friction brake or the retarder.

When the driver lifts off the accelerators pedal (zero pedal) ~70% of available regenerative braking torque is automatically applied. The remaining 30% of available regenerative braking is then applied linearly when the driver begins to press on the brake pedal. The pneumatic brakes begin to work linearly with increased brake pedal travel. The feel of the regenerative braking system is similar to a traditional retarder.

Regenerative braking is reduced below 3mph to make low speed bus movement smoother. In the event of an ABS or Traction Control event, regenerative braking is automatically disabled until the vehicle comes to a complete stop. At that point it is automatically re-enabled. This is done to ensure vehicle stability in slippery conditions.

An efficient driver will be able to drive nearly completely with limited use of the brake pedal and very limited use of the friction brakes. Drivers should anticipate stops and allow regenerative braking to slow the vehicle for maximum energy recapture.

TS 15. Mounting

All powerplant mounting is mechanically isolated to minimize transfer of vibration to the body structure and provide a minimum clearance of 0.75 in. Mounts control the movement of the powerplant so as not to cause strain in piping and wiring connections to the powerplant.

TS 15.1 Service

The propulsion system is arranged for ease of access and maintenance. The only special mechanical tool needed for service is a hydraulic lift table for the transmission, motor and battery removal. The air compressor, radiator, all accessories and any other component requiring service or replacement is easily removable and independent of the motor and transmission removal. Since the 35' Catalyst E2 is equipped with an electric traction motor, there is no exhaust, oil or air intake systems to service.

TS 16. Hydraulic Systems

Hydraulic system service tasks are minimized and scheduled no more frequently than those of other major coach systems. All elements of the hydraulic system are easily accessible for service or unit replacement. Critical points in the hydraulic system are fitted with service ports so that portable diagnostic equipment may be connected or sensors for an off-board diagnostic system permanently attached to monitor system operation when applicable.

Proterra's standard system has a hydraulic pump which does not include cleanable strainers. The pump is operated by an electric motor, which is controlled by the Motor Controller (Variable Frequency Drive). The pump and motor are non-serviceable assemblies and must be replaced when failed. The only device powered by the hydraulic system is the power steering system. The hydraulic system operates within the allowable temperature range as specified by the lubricant manufacturer. The hydraulic system is mounted approximately under the driver and is accessible from the outside of the

vehicle. The modular system can be removed with four bolts. The supply tank is also mounted external of the vehicle and has a magnet drain plug for ease of service and enables maximum heat dispersion.

Our vehicle offers no gauges in the motor compartment. The diagnostic ports on the interior of the vehicle and the diagnostics on the dash allow you to access all systems in order to troubleshoot any issues that are occurring. In addition, we meet the following specs also:

- Mean time between repairs >50,000 miles
- Max oil temp does not exceed 200°F
- Max system working pressure = 2,000 psi
- Hoses comply w/ SAE 100R2 / SAE 100R9 / SAE J517
- Hose installation complies w/ SAE J1273
- High pressure hose fittings comply w/ SAE J516 w/ 37° flare
- Suction line fluid velocity is under 4 ft/sec
- Discharge line fluid velocity is under 25 ft/sec

TS 16.1 Fluid Lines

All lines are rigidly supported to prevent chafing damage, fatigue failures, degradation and tension strain. Lines are sufficiently flexible to minimize mechanical loads on the components. Lines passing through a panel, frame or bulkhead are protected by grommets (or similar devices) that fit snugly to both the line and the perimeter of the hole that the line passes through to prevent chafing and wear. Pipes and fluid hoses are not bundled with or used to support electrical wire harnesses.

Lines are as short as practicable and are routed or shielded so that failure of a line will not allow the contents to spray or drain onto any component operable above the auto-ignition temperature of the fluid.

All hoses, pipes, lines and fittings are specified and installed per the manufacturer's recommendations. The 35' Catalyst E2 comes standard with EPDM hoses for better securement and reliability. Cooler temperatures provided in an electric bus do not require the use of the more expensive, less reliable silicon hoses. Proterra's coolant system is regulated to only 13 psi which allows the use ¼" to 1" coolant hose that meet SAE J20R3 and 1.5" coolant hoses that meet SAE J20R1. In addition, SAE J2044 Quick Connects and hose barb fittings are use across the system.

TS 16.2 Fittings and Clamps

All clamps maintain a constant tension at all times, expanding and contracting with the line in response to temperature changes and aging of the line material. These clamps are manufactured from magni coated carbon spring steel and rated at 1000 hours of salt spray according to ASTM B117.The lines are designed for use in the environment where they are installed.

Compression fittings are standardized to prevent the intermixing of components. Compression fitting components from more than one manufacturer are not mixed, even if the components are known to be interchangeable.

TS 16.3 Charge Air Piping

The lack of an engine precludes the use of a turbocharger is in the 35' Catalyst E2.

TS 17. Radiator Piping

The 35' Catalyst E2 radiator piping is powder-coated steel rated at 1000 hours of salt spray according to ASTM B117. Where practical, hoses are kept to a minimum. Necessary hoses are impervious to all bus fluids. All hoses are secured with constant tension clamps manufactured from magni coated carbon spring steel and rated at 1000 hours of salt spray according to ASTM B117, that provide a complete 360° seal. The clamps maintain a constant tension at all times, expanding and contracting with the hose in response to temperature changes and aging of the hose material. The radiator will be accessible for cleaning and will be easily removable from the bus.

TS 18. Oil and Hydraulic Lines

Oil and hydraulic lines are compatible with the substances they carry. The lines are designed and intended for use in the environment where they are installed. Lines within the motor compartment are composed of steel tubing where practical, except in locations where flexible lines are required.

Hydraulic lines of the same size and with the same fittings as those on other piping systems of the bus, but not interchangeable, are tagged or marked for use on the hydraulic system only.

TS 19. Emissions and Exhaust

TS 19.1 Exhaust Emissions

The 35' Catalyst E2 is a zero emission vehicle and therefore meets all applicable emission standards.

STRUCTURE

TS 20. General

TS 20.1 Design

The structure of the bus is designed to withstand the transit service conditions typical of an urban or intercity duty cycle throughout its service life. The vehicle structural frame is designed to operate with minimal maintenance well beyond the FTA mandated 12-year design operating profile.

The 35' Catalyst E2 has an all-composite, corrosion-proof monocoque body manufactured from high strength materials such as carbon fiber and molded fiberglass with a balsa wood core. The benefits of using the composite body include: a lighter total vehicle weight (reducing the impact to local roads / infrastructure), improved vehicle efficiency and fuel economy, improved thermal and noise reducing properties, exceptional torsional stiffness (resulting in an excellent ride and handling), increased durability, corrosion resistance, and best-in-class safety.

TS 21. Validation Testing (Including Altoona)

Federal Transit Bus Test report number LTI-BT-R1406 documents the performance of the 40-foot Proterra Catalyst BE40 vehicle during its 12 Year / 500,000 miles service-life testing at Altoona. The testing completed in April of 2015 and the final report was published in May 2015.

Proterra anticipated excellent performance results for its second-generation 40-foot Catalyst vehicle based on the lessons learned from deploying the 35 foot BE35 EcoRide and given the considerable amount of design engineering that went into the vehicle. For instance, Proterra's vehicle design team was able to reduce the vehicle weight by over 1,000lbs on a vehicle that is six (6) feet longer than its predecessor.

The Catalyst vehicle didn't disappoint, breaking Altoona records for efficiency, gradeability, weight and acceleration. While conventional diesel buses average 3.86 MPG, the Proterra Catalyst achieved the best efficiency rating ever for a 40-foot transit bus at 1.7kW/mi (or 22 MPGe). Nearly six times more efficient than a diesel or CNG bus, the Catalyst is also more energy efficient per mile than other electric buses that have been through the same tests. The end result is that operating Proterra buses translates to a lower lifetime energy consumption.

Gradeability has been a historic obstacle for electric buses, which until now, weighed more and had less power, making steep inclines difficult if not impossible to climb. The Catalyst conquered a 15.5% grade, unprecedented in this test by an electric bus. Also, due to the composite nature of the bus body, Proterra's curb weight was measured at only 27,370lbs, meaning that the Proterra Catalyst is not only lighter than any other electric bus (leading to greater efficiency), but also more durable than buses made of aluminum or steel and less prone to corrosion. As proof of the vehicle's superior power-to-weight ratio, the Proterra 40′ Catalyst also achieved 0-20 acceleration in just 6.7 seconds.

TS 21.1 Post-Altoona Upgrades

Since the testing at Altoona, Proterra has used the test results as they are intended, to improve the design and reliability of our 40-foot Catalyst vehicle. Most items noted in the Altoona report have since received a design update in order to improve the areas that failed. While the sole Class 2 failure is explained in greater detail below, we stand ready to review any and all details
from the report if the agency so desires.

The 40-foot Catalyst bus experienced a class 2 failure of the vertical wall where the rear suspension bracket, which mounts the four-bar suspension, is attached. The vertical wall failed in the area where it was molded to the bottom surface of the body. The extended downtime noted in the Altoona report is attributed to the time it took to complete the root cause analysis, which involved physical inspections of the failure, independent reviews by a third-party engineering firm, and failure reviews by the body supplier relative to their initial Finite Element Analysis (FEA). The result of the root cause investigation was that the composite structure in this area was incorrectly manufactured by Proterra's body supplier.

The composition of the composite body (referred to as the "laminate schedule") design for the body structure was improved based on results of the root cause analysis. An updated laminate schedule was developed, validated via physical testing, and then retrofitted to the Altoona test bus in the failure

area in order to sustain the applied loads. As a result, the Altoona test bus was returned to the test track and successfully completed the remaining Altoona testing with no further composite body issues. After the successful completion of the Altoona test, Proterra's body supplier retrofitted the bodies which had been previously delivered and updated the laminate schedule for all future production buses. To stand by the performance of the Proterra Catalyst design, Proterra includes a standard warranty for 12 years or 500,000 miles against defects pertaining to the composite body structure.

TS 21.2 Altoona Testing for the 35' Catalyst E2

Prior to acceptance of first bus, the vehicle will have completed any FTA-required Altoona testing. Any items that required repeated repairs or replacement will undergo the corrective action with supporting test and analysis. A report clearly describing and explaining the failures and corrective actions taken to ensure that any and all such failures will not occur will submitted to the Agency.

TS 21.3 Structural Validation

Prior to acceptance of first bus, the vehicle will have completed any FTA-required Altoona testing. Any items that required repeated repairs or replacement will undergo corrective action with supporting test and analysis. A report clearly describing and explaining the failures and corrective actions taken to ensure that any and all such failures will not occur will be submitted to the Agency. The Altoona Test Report will be provided at the request of the Agency.

TS 21.4 Post Testing

In 2016, a Proterra Catalyst vehicle completed 4-Post Durability Testing at Exova Defiance in Michigan. The purpose of the test was to validate the vehicle design over a simulated 750,000 miles. The testing is broken up into six segments, each representing 125,000 miles of service and taking approximately 25 days to complete. Overall the bus spent 8 months completing the 4-post testing. While we learned a great deal about the durability of components attached to the body structure (e.g. air bags, etc.), the composite body did not disappoint, with no structural or body issues noted during the simulated 18-year testing (no Class 2 failures and the handful of Class 3 failures remedied at the beginning of the test). In general, all our major manufacturing processes and engineering designs were validated to 50% past the FTA mandated service life of vehicle.

The full report is available upon request.

Figure 7-Catalyst 4-Post Durability Test

TS 22. Distortion

The bus, loaded to GVWR and under static conditions, did not exhibit deflection or deformation that impairs the operation of the steering mechanism, doors, windows, passenger escape mechanisms or service doors. Static conditions include the vehicle at rest with any one wheel or dual set of wheels on a 6 in. curb or in a 6 in. deep hole.

TS 23. Resonance and Vibration

All structure, body and panel-bending mode frequencies, including vertical, lateral and torsional modes, are sufficiently removed from all primary excitation frequencies to minimize audible, visible or sensible resonant vibrations during normal service.

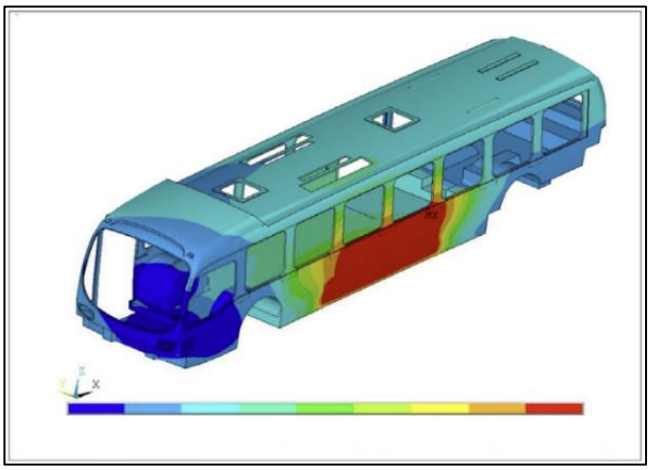
TS 23.1 Motor Compartment Bulkheads

The passenger and motor compartment are separated by fire-resistant bulkheads. This bulkhead shall preclude or retard propagation of an motor compartment fire into the passenger compartment and is in accordance with the Recommended Fire Safety Practices defined in FTA FMVSS 302. There is no access panel from inside of the bus that allows for anyone to reach the ProDriver. Harnesses have connectors at the bulkhead and we don't have engine access panels.

Only necessary openings are allowed in the bulkhead, and these are fire-resistant. Climate controlled air does not pass through the motor compartment. Wiring passing through the bulkhead use connectors or other means to prevent or retard fire propagation through the bulkhead.

TS 23.2 Crashworthiness

Regarding the body's best-in-class safety and structural rigidity, a Finite Element Analysis (FEA) was completed in order to ensure the bus body and roof structure will withstand a static load equal to 150 percent of the curb weight evenly distributed on the roof with no more than a 6 in. reduction in any interior dimension. Windows will remain in place and will not open under such a load. These requirements are met without the roof-mounted equipment installed.



The finite element analysis shows the bus will withstand a 25 mph impact by a 4000lb automobile at any side, excluding doorways, along either side of the bus with no more than 3 in. of permanent structural deformation at seated passenger hip height. This impact will not result in sharp edges or protrusions in the bus interior.

The finite element analysis shows the body below 35 in. from ground level will withstand a static load of 2000 lbs applied perpendicular to the bus by a pad no larger than 5 sq in. This load will not result in deformation that prevents repair of the body to the original appearance of the bus. Reports are available upon request.

TS 24. Corrosion

The bus flooring, sides, roof, understructure and axle suspension components are designed to resist corrosion or deterioration from atmospheric conditions and de-icing materials for a period of 12 years or 500,000 miles, whichever comes first. It will maintain structural integrity and nearly maintain original appearance throughout its service life, with the Agency's use of proper cleaning and neutralizing agents.

All materials that are not inherently corrosion resistant are protected with corrosion-resistant coatings. All joints and connections of dissimilar metals are corrosion resistant and are protected from galvanic corrosion. The metallic structural components under the bus body (ProDrive, Axles) are first electro-coated (e-coated), then powder-coated to ensure maximum corrosion protection to meet the 1,000 hour ASTM B117 requirement with no red rust or weight loss. This provides a superior corrosion protection when compared to zinc chromate or zinc phosphate prime paints. There are no roll cage under the bus, but any tubes under body are e-coated then powder coated so inner surface is protected.

Representative samples of all materials and connections withstand a two-week (336-hour) salt spray test in accordance with ASTM Procedure B-117 with no structural detrimental effects to normally visible surfaces and no weight loss of over 1 percent.

The 35' Catalyst E2 body is manufactured from a composite material consisting of high strength fiberglass, carbon fiber in high stress areas that is infused with resin. Sub frames for the front and

rear suspension are manufactured from high-strength low-alloy (HSLA) steel that is E-coated and powder-coated. The combination of composite body and treated sub frames yields an entire vehicle which is corrosion resistant.

TS 25. Towing

Each towing device withstands, without permanent deformation, tension loads up to 1.2 times the curb weight of the bus within 20° of the longitudinal axis of the bus. The rear towing device(s) will not provide a toehold for unauthorized riders. The method of attaching the towing device will not require the removal, or disconnection, of front suspension or steering components.

Shop industrial type air connectors are provided at the front and rear street side of the bus and are capable of supplying all pneumatic systems of the bus with externally sourced compressed air. The location of these shop air connectors facilitate towing operations.

A plug connector permanently mounted at the front of the bus provides for bus tail lamp, marker, stop and turn signal lamp operation as controlled from the towing vehicle. The connector includes a spring-loaded dust- and water-resistant cap.

The front towing devices allow attachment of adapters for a rigid tow bar and permit the lifting and towing of the bus, at curb weight, while the front wheels are clear off the ground. These devices also permit common flat towing.

Two rear recovery devices/tie downs do not permit the lifting of the bus to the extent where the rear wheels are lifted off the ground. The method of attaching the tow bar or adapter requires the specific approval of the Agency. Any tow bar or adapter exceeding 50 lbs will have means to maneuver or allow for ease of use and application. Each towing device accommodates a crane hook with a 1 in. throat.

Upon request, the 35’ Catalyst E2 vehicle can be manufactured with additional support permitting the lifting and towing of the bus for a short distance, such as in cases of an emergency, to allow access to provisions for front towing of bus.

TS 26. Jacking

It is possible to safely jack up the bus, at curb weight, with a common 10-ton floor jack with or without special adapter, when a tire or dual set is completely flat and the bus is on a level, hard surface, without crawling under any portion of the bus. Jacking from a single point permits raising the bus sufficiently high to remove and reinstall a wheel and tire assembly. Jacking pads located on the axle or suspension near the wheels permits easy and safe jacking with the flat tire or dual set on a 6 in. high run-up block not wider than a single tire. The bus withstands such jacking at any one or any combination of wheel locations without permanent deformation or damage.

Jacking pads are painted safety yellow and decals are applied to identify locations. The locations shown below are the Proterra recommended jacking locations:

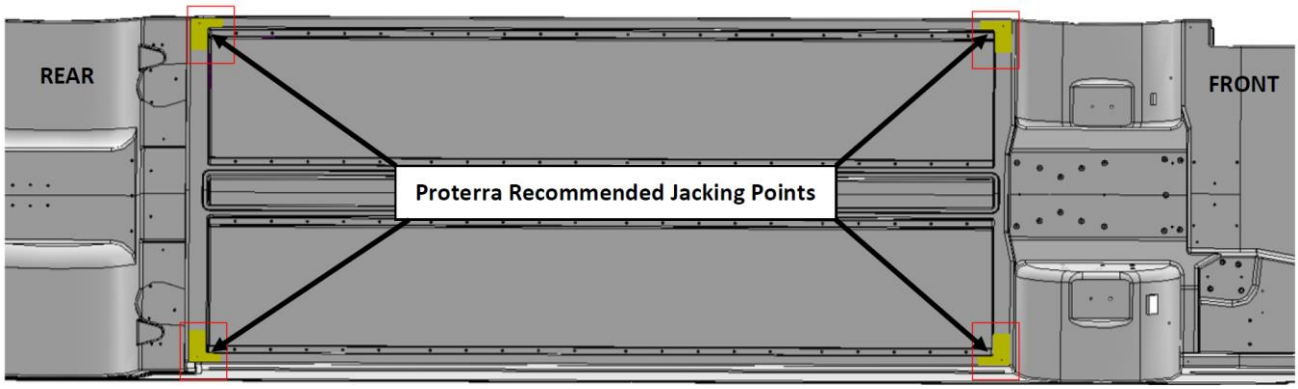


Figure 8-Proterra Recommended Jacking Points

TS 27. Hoisting

The bus axles or jacking plates accommodate the lifting pads of a two-post hoist system. Jacking plates, if used as hoisting pads, are designed to prevent the bus from falling off the hoist. Other pads or the bus structure supports the bus on jack stands independent of the hoist.

The vehicle is capable of being lifting by the wheels.

The locations shown below are the Proterra recommended hoisting locations:
The bus may be picked up by the following locations, but MUST have a surface area of no less than 5 square inches per mounting pad that contacts the bus body. The zones shown below are acceptable lifting areas:

Figure 9-Proterra Recommended Lifting Zones

TS 28. Floor

TS 28.1 Design

The floor is essentially a continuous plane, except at the wheel housings and platforms. Where the floor meets the walls of the bus, as well as other vertical surfaces such as platform risers, the surface edges are blended with a circular section of radius not less than ¼ in. or installed in a fully sealed butt joint. Similarly, a molding or cover prevents debris accumulation between the floor and wheel

housings. The vehicle floor in the area of the entrance and exit doors has a lateral slope not exceeding 2° to allow for drainage.

The floor design consists of two levels (bi-level construction). Aft of the rear door extending to the rear settee riser, the floor height is not raised to a height more than 21 in. above the lower level, with equally spaced steps. An increase slope does not to exceed 3.5° off the horizontal.

TS 28.2 Strength

The floor deck is integral with the basic structure and designed to last the life of the bus. Sheet metal screws are not used to retain the floor, and all floor fasteners are serviceable from one side only. Any adhesives, bolts or screws used to secure the floor to the structure will last and remain effective throughout the life of the coach. All floor fasteners are secured and protected from corrosion for the service life of the bus.

The floor deck is reinforced as needed to support passenger loads. At GVWR, the floor will have an elastic deflection of no more than 0.60 in. from the normal plane. The floor withstands the application of 2.5 times gross load weight without permanent detrimental deformation. The floor, with coverings applied, withstands a static load of at least 150 lbs applied through the flat end of a ½ in. diameter rod, with 1/32 in. radius, without permanent visible deformation.

TS 28.3 Construction

Proterra's 35' Catalyst™ E2 composite floor is integral with the basic structure and consists of the subfloor and the floor covering that will last the life of the bus. The floor as assembled, including the sealer, attachments and covering, is waterproof, non-hygroscopic and resistant to mold growth. The subfloor is resistant to the effects of moisture, including decay (dry rot). It is impervious to wood-destroying insects such as termites.

TS 29. Platforms

TS 29.1 Driver's Area

The covering of platform surfaces and risers, except where otherwise indicated, are the same material as specified for floor covering. Trim is provided along top edges of platforms unless integral nosing is provided.

TS 29.2 Driver's Platform

The driver's platform is of a height such that, in a seated position, the driver can see an object located at an elevation of 42 in. above the road surface, 24 in. from the leading edge of the bumper. Notwithstanding this requirement, the platform height does not position the driver such that the driver's vertical upward view is less than 15 deg. A warning decal or sign is provided to alert the driver to the change in floor level. Figure 10 illustrates the means by which this requirement was determined.

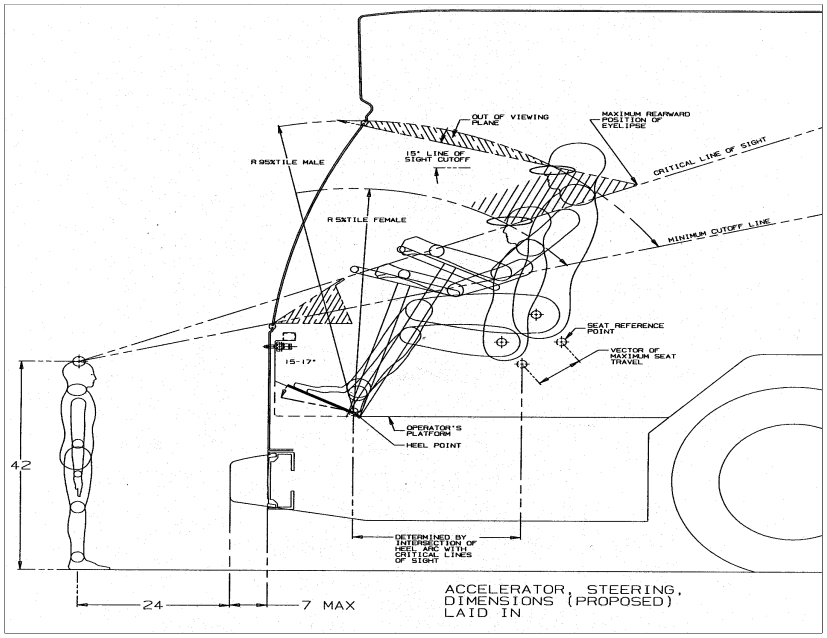


Figure 10-Determining Platform Height

TS 29.3 Farebox

Farebox placement minimizes impact to passenger access interference with the driver's line of sight. If required by the Agency, the farebox will be mounted on a platform of suitable height to provide accessibility for the driver without compromising passengers' access. Stanchions are located around the farebox.

TS 29.4 Rear Step Area to Rear Area

The vehicle is a bi-level floor design. A rear step area is provided along the center aisle of the bus to facilitate passenger traffic between the upper and lower floor levels. This step area is cut into the rear platform and is approximately the aisle width, a minimum 12 in. deep and approximately half the height of the upper level relative to the lower level. The horizontal surface of this platform is covered with skid-resistant material with a visually contrasting nosing and is sloped slightly for drainage. A warning decal or sign is provided at the immediate platform area to alert passengers to the change in floor level.

TS 30. Wheel Housing

TS 30.1 Design and Construction

Sufficient clearance and air circulation is provided around the tires, wheels and brakes to preclude overheating when the bus is operating on the design operating profile. Wheel housings are constructed of corrosion-resistant and fire-resistant material.

Wheel housings, as installed and trimmed, withstand impacts of a 2in. steel ball with at least 200 ft-lbs of energy without penetration.

Interference between the tires and any portion of the bus is not possible in maneuvers up to the limit of tire adhesion with weights from curb weight to GVWR. Wheel housings are adequately reinforced where seat pedestals are installed. Wheel housings have sufficient sound insulation to minimize tire and road noise and meet all noise requirements of this specification.

Design and construction of front street side wheel housings allows for the installation of a radio or electronic equipment storage compartment on the interior top surface. Design and construction of front curb side wheel housings allows its use as a luggage rack.

The finish of the front wheel housings is scratch-resistant and complement interior finishes of the bus to minimize the visual impact of the wheel housing. The wheel housings are color-impregnated to match interior finishes. The lower portion extending to approximately 10 to 12 in. above the floor is equipped with scuff-resistant coating or stainless steel trim.

Wheel housings not equipped with seats or equipment enclosure have a horizontal assist mounted on the top portion of the housing no more than 4 in. higher than the wheel well housing.

The wheel housing are designed to have the ability to chain buses.

CHASSIS

TS 31. Suspension

TS 31.1 General Requirements

The front and rear suspensions are pneumatic type, with a heavy-duty ZF Independent Front Suspension (IFS). It has a smaller turning radius them typical transmissions, better ride quality, improved vehicle handling, higher roll stiffness, and less load on road surface by reducing unsprung masses. The basic suspension system will last the service life of the bus without major overhaul or replacement. Adjustment points are minimized and will not be subject to a loss of adjustment in service. Routine adjustments are easily accomplished by limiting the removal or disconnecting the components.

TS 31.2 Alignment

All axles are properly aligned so the vehicle tracks accurately within its size and geometry of the.

TS 31.3 Springs and Shock Absorbers

TS 31.3.1 Suspension Travel

The suspension system permits a minimum wheel travel of 2.75 in. jounce-upward travel of a wheel when the bus hits a bump (higher than street surface), and 2.75 in. rebound-downward travel when the bus comes off a bump and the wheels fall relative to the body. Elastomeric bumpers are provided at the limit of jounce travel. Rebound travel is limited by elastomeric bumpers or hydraulically within the shock absorbers. The suspensions incorporates Smart Air Management Systems (SAMS) for automatic height control so that regardless of load the bus height relative to the centerline of the wheels does not change more than ½ in. at any point from the height required. The safe operation of a bus will not be impacted by ride height up to 1 in. from design normal ride height. The SAMS system is able to raise and lower the chassis while moving at slow speeds, can automatically control

the ride height of vehicle during normal road use resulting in a smoother ride and has built-in diagnostics

TS 31.3.2 Damping

Vertical damping of the suspension system is accomplished by hydraulic shock absorbers mounted to the suspension arms or axles and attached to an appropriate location on the chassis. Damping is sufficient to control coach motion to three cycles or less after hitting road perturbations. The shock absorber bushing is made of elastomeric material that will last the life of the shock absorber. The damper incorporates a secondary hydraulic rebound stop.

TS 31.3.3 Lubrication

All elements of steering, suspension and drive systems requiring scheduled lubrication will be provided with grease fittings conforming to SAE Standard J534. These fittings are located for ease of inspection and are accessible with a standard grease gun from a pit or with the bus on a hoist. Each element requiring lubrication has its own grease fitting with a relief path. The lubricant specified shall be standard for all elements on the bus serviced by standard fittings and is required no less than every 6000 miles.

TS 31.3.4 Kneeling

A kneeling system lowers the entrance(s) of the bus a minimum of 2.5 in. during loading or unloading operations regardless of load up to GVWR, measured at the longitudinal centerline of the entrance door(s) by the driver. The kneeling control provides the following functions:

- Downward control must be held to allow downward kneeling movement.
- Release of the control during downward movement will completely stop the lowering motion and hold the height of the bus at that position.
- Upward control actuation allows the bus to return to normal floor height without the driver having to hold the control.

Kneeling of the bus shall only be enable if the speed of the bus is below 2 mph. The brake and speed control interlock prevents movement when the bus is kneeled. The kneeling control is disabled when the bus is in motion. The bus kneels at a maximum rate of 1.25 in. per second at essentially a constant rate. After kneeling, the bus will rise within 4 seconds to a height permitting the bus to resume service and will rise to the correct operating height within 7 seconds regardless of load up to GVWR. The bus is capable of kneeling with the front door in the open or close position.

An indicator visible to the driver is illuminated until the bus is raised to a height adequate for safe street travel. An audible warning alarm will sound simultaneously with the operation of the kneeler to alert passengers and bystanders. A warning light mounted near the curbside of the front door with minimum 1.75 in. diameter amber lens, is provided that will blink when the kneel feature is activated. Kneeling will not be operational while the wheelchair ramp is deployed or in operation.

TS 32. Wheels and Tires

TS 32.1 Wheels

All wheels are interchangeable. Standard configuration wheels are compatible with standard configuration tires in size and load-carrying capacity. Front wheels and tires are balanced as an assembly per SAE J1986.

The standard configuration includes brushed-aluminum finish ALCOA 22.5 in. x 9 in. Wheels. Additional finishes are available upon request.

TS 32.2 Tires

Tires are suitable for the conditions of transit service and sustained operation at the maximum speed capability of the bus. Load on any tire at GVWR will not exceed the tire supplier's rating.

Sufficient space is not provided to allow the Agency to carry a spare tire.

The tire size for the Catalyst E2 buses is 315/80R22.5. If the tires will be provided by the customer, please coordinate tire selection in order to provide ample weight ratings for the front axle at full standing and seating capacity.

TS 33. Steering

Hydraulically assisted steering is provided. The steering gear is an integral type with the number and length of flexible lines minimized or eliminated. Power steering hydraulic pump is electrically driven.

TS 33.1 Steering Axle

The ZF front axle is an independent suspension design, non-driving, with a load rating sufficient for the bus loaded to GVWR and is equipped with grease type front wheel bearings and seals (figure 11).

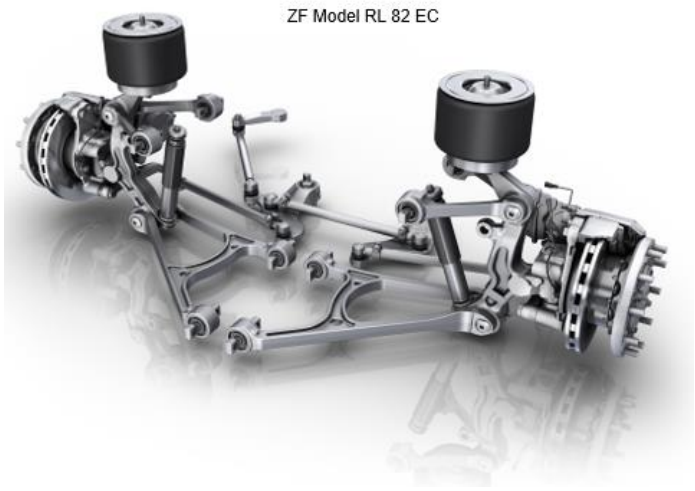


Figure 11-Proterra ZF front axle

All friction points on the front axle are equipped with replaceable bushings or inserts and, if needed, lubrication fittings easily accessible from a pit or hoist.

The steering geometry of the outside (frontlock) wheel is within 2° of true Ackerman up to 50 percent lock measured at the inside (backlock) wheel. The steering geometry is within 3.5° of true Ackerman for the remaining 100 percent lock measured at the inside (backlock) wheel.

TS 33.2 Steering Wheel

TS 33.2.1 Turning Effort

Steering effort is measured with the bus at GVWR, stopped with the brakes released on clean, dry, level, commercial asphalt pavement and the tires inflated to recommended pressure.

Under these conditions, the torque required to turn the steering wheel 10° is no less than 5 ft-lbs and no more than 10 ft-lbs. Steering torque may increase to 70 ft-lbs when the wheels are approaching the steering stops, as the relief valve activates.

Power steering failure will not result in loss of steering control. With the bus in operation, the steering effort will not exceed 55 lbs at the steering wheel rim, and perceived free play in the steering system will not materially increase as a result of power assist failure. Gearing will require no more than seven turns of the steering wheel lock-to-lock.

Caster angle will be selected to provide a tendency for the return of the front wheels to the straight position with minimal assistance from the driver.

TS 33.2.2 Steering Wheel, General

The steering wheel diameter is available in either 18 in or 20 in.; the rim diameter is ⅞ to 1¼ in. and shaped for firm grip with comfort for long periods of time.

Steering wheel spokes and wheel thickness ensures visibility of the dashboard so that vital instrumentation is clearly visible at center neutral position (within the range of a 95th-percentile male, as described in SAE 1050a, Sections 4.2.2 and 4.2.3). Placement of steering column is as far forward as possible, and in line with the instrument cluster.

TS 33.2.3 Steering Column Tilt

The steering column has full tilt capability with an adjustment range of no less than 40° from the vertical. It is easily adjustable by the driver and accessible by a 5th percentile female and 95th percentile male.

TS 33.2.4 Steering Wheel Telescopic Adjustment

The steering wheel has full telescoping capability and has a minimum telescopic range of 1.91 in. and a minimum low-end adjustment of 29 in., measured from the top of the steering wheel rim in the horizontal position to the cab floor at the heel point.

TS 34. Drive Axle

The bus is driven by a ZF heavy-duty axle (Figure 12) with a load rating sufficient for the bus loaded to GVWR. The drive axle has a design life to operate for not less than 300,000 miles on the design operating profile without replacement or major repairs. The lubricant drain plug is magnetic type. The oil level in the planetary gears is easily checked through the plug or sight gauge. The axle and driveshaft components are rated for both propulsion and retardation modes with respect to duty cycle.

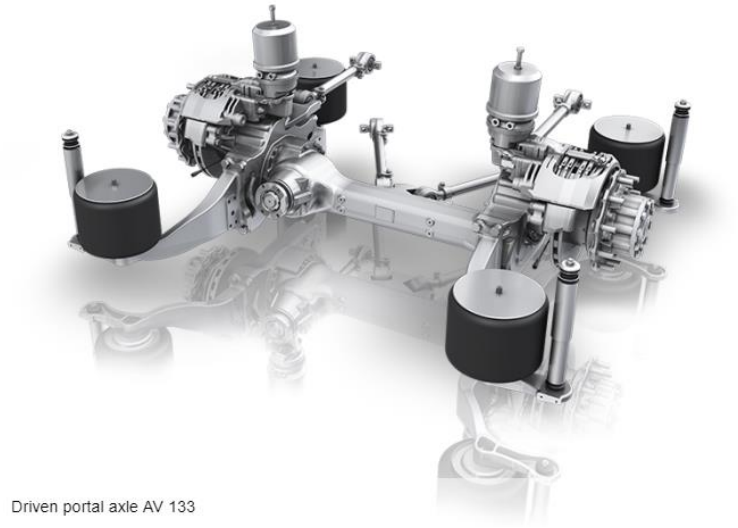


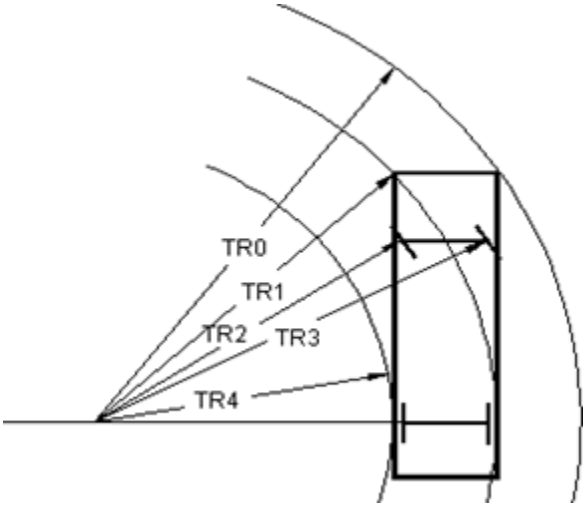
Figure 12-Proterra rear axle

The drive shaft is guarded to prevent hitting any critical systems, including brake lines, coach floor or the ground, in the event of a tube or universal joint failure.

TS 35. Turning Radius

Bus Length (approximate)	Maximum Turning Radius (see Figure 13)	35’ Catalyst E2
35 ft	39 ft (TR0)	36 ft (TR0)

Table 1-Proterra’s 35’ Catalyst™ E2 to APTA’s guidelines



Horizontal turning envelope (see diagram below)

Outside body turning radius, TR0 (including bumper)	36	ft	0	in.
Front inner corner radius, TR1	TBD	ft		in.
Front wheel inner turning radius, TR2	TBD	ft		in.
Front wheel outer turning radius, TR3	32	ft	8.4	in.
Inside Body Turning Radius innermost point, TR4 (including bumper)	17	ft	6	in.

Figure 13-Proterra's 35' Catalyst™ E2 Horizontal turning envelope

TS 36. Brakes

TS 36.1 Service Brake

Proterra's 35' Catalyst™ E2 is equipped with self-adjusting disc brakes on the four wheel ends manufactured by Knorr-Bremse. The brakes are equipped with a rubber bush with axial ribbing (see figure 14 arrow H). The pads/disc wear can be visually determined without removing the wheel, by noting the position of the wear marker point see arrow G, the change-over point from the ribbed to the smooth surface (see Figure 14).

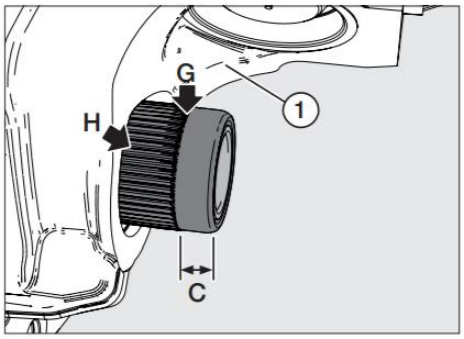


Figure 14-Dimension C with new disc and brake pads

If dimension C is less than 1 mm, the brake pad thickness and brake disc must be checked with the wheel removed (see Figure 15).

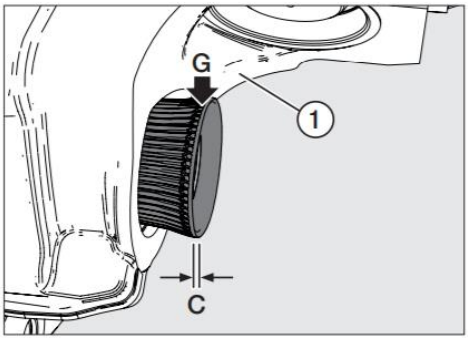


Figure 15-Dimension C with worn disc/brake pads

If any minimal tolerance limits have been reached the pads and/or disc must be changed.

TS 36.2 Actuation

Service brakes are controlled and actuated by a compressed air system. Force to activate the brake pedal control is an essentially linear function of the bus deceleration rate and will not exceed 75 lbs at a point 7 in. above the heel point of the pedal to achieve maximum braking. The heel point is the location of the driver's heel when his or her foot is rested flat on the pedal and the heel is touching the floor or heel pad of the pedal. The ECU for the ABS system is protected, yet in an accessible location to allow for ease of service.

Microprocessor controlled automatic traction control (ATC) is provided.

TS 36.3 Friction Material

The brake linings are made of non-asbestos material. In order to aid maintenance personnel in determining extent of wear, brakes are equipped with a rubber bush with axial ribbing as specified at TS 36.1 indicating the thickness C (see figure 15) at which replacement becomes necessary is provided on each brake lining.

TS 36.4 Hubs and Drums/Discs

Replaceable wheel bearing seals are run on replaceable wear surfaces or are of an integral wear surface sealed design. Wheel bearing and hub seals and unitized hub assemblies will not leak or weep lubricant when operating on the design operating profile for the duration of the initial manufacturer's warranty.

The bus is equipped with disc brakes on all axles, and the brake discs allow machining of each side of the disc to obtain smooth surfaces per manufacturer's specifications.

The brake system material and design was selected to absorb and dissipate heat quickly so that the heat generated during braking operation does not glaze the brake linings.

TS 36.5 Parking/Emergency Brake

The parking brake is a spring-operated system, actuated by a valve that exhausts compressed air to apply the brakes. The parking brake may be manually enabled when the air pressure is at the operating level per FMVSS 121. The parking brake valve button will pop out when air pressure drops below requirements of FMVSS 121.

An emergency brake release is provided to release the brakes in the event of automatic emergency brake application. The driver can manually depress and hold down the emergency brake release valve to release the brakes and maneuver the bus to safety. Once the driver releases the emergency brake release valve, the brakes engage to hold the bus in place. Air to the emergency brake release system is provided by a dedicated emergency air tank.

TS 37. Interlocks

TS 37.1 Passenger Door Interlocks

To prevent opening rear passenger doors while the bus is in motion, a speed sensor is integrated with the door controls to prevent the rear door from being enabled or opened unless the bus speed is less than 2 mph.

To preclude movement of the bus, an accelerator interlock locks the accelerator in the closed position, and a brake interlock engages the service brake system to stop movement of the bus when the driver's door control is moved to an open position, or the rear door panel is opened more than 3 in. from the fully closed position (as measured at the leading edge of the door panel). The interlock engagement brings the bus to a smooth stop and will be capable of holding a fully loaded bus on a 6 percent grade, until the interlocks are released. These interlock functions are active whenever the vehicle master run switch is in any run position.

All door systems employing brake and accelerator interlocks are supplied with supporting failure mode effects analysis (FEMA) documentation, which demonstrates that failure modes are of a failsafe type, thereby never allowing the possibility of release of interlock while an interlocked door is in an unsecured condition, unless the door master switch has been actuated to intentionally release the interlocks.

The brake interlock regulator is non-adjustable.

As an option, an accelerator interlock locks the accelerator in the closed position, and a brake interlock engages the service brake system to stop movement of the bus whenever front doors are open.

TS 38. Pneumatic System

TS 38.1 General

The bus air system operates the air-powered accessories and the braking system with reserve capacity. New buses will not leak down more than 5psi over a 15-minute period of time as indicated on the dash gauge.

Provision are available to apply shop air to the bus air systems. A quick disconnect fitting is easily accessible and located in the motor compartment and near the front bumper area for towing. Retained caps are installed to protect fitting against dirt and moisture when not in use. Air for the compressor is filtered. The air system is protected per FMVSS 121.

TS 38.2 Air Compressor

The electrically driven, vane-style air compressor is sized to charge the air system from 40psi to the governor cut-off pressure in less than 4 minutes. See figure 16 for compressor specification.

Parameter	Specification
Compressor Type	Hydrovane Transit 0009-0010 Water-Cooled Air End Compressor
Frame Foot and Flange Mount Type	LSMV 100L
Nominal Power	3kW
Rated Power	3.2kW @ 3200 RPM
Nominal Supply Voltage	230VAC 3-Phase, D Connection
Air Delivery	285 Nl/m (10 CFM) @ 9 Bar (130 PSI), 3200 RPM
Rated Speed	1000 to 3200 RPM, stepped speed operation
Max Operating Pressure	10.3 Bar (150 PSI)
Motor	Winding Squirrel Cage Induction Motor
Lubrication	VAFFHPO2000-4
Protection	IP 55 (IP 65 Terminal Box)
Water Cooling	20 l/min / 55°C Max Inlet Temperature
Coolant Connections	15L (M22 x 1.5)
Duty	S1 in 40°C Ambient, External Air Cooling
Weight	27 kg (60 lb), Aluminum Frame
Other	- Transit Inlet Adapter and End Cap - Compressor/Motor sub-assembly fully supported on AV Mounts - Internal thermostatic valve to oil cooler - Dual Over Temperature Switch fitted (110°C and 120°C) - Coolant to have suitable antifreeze and corrosion inhibitor Motor

Figure 16-Air Compressor specification

TS 38.3 Air Lines and Fittings

Air lines, except necessary flexible lines, conform to the installation and material requirements of SAE Standard J1149 for copper tubing with standard, brass, flared or ball sleeve fittings, or SAE Standard J844 for nylon tubing if not subject to temperatures over 200 °F. The air on the delivery side of the compressor where it enters nylon housing is not above the maximum limits as stated in SAE J844. Nylon tubing is installed in accordance with the following color-coding standards:

- **Green:** Indicates primary brakes and supply.
- **Red:** Indicates secondary brakes.
- **Brown:** Indicates parking brake.
- **Yellow:** Indicates transmission and ride height controller feed (we don't have governor air lines).
- **Black:** Indicates accessories & doors.
- **Blue:** Indicates curb side air bags.
- **Orange:** Indicates street side air bags

Line supports prevent movement, flexing, tension, strain and vibration. No copper or rigid lines are used in the pneumatic system of the Proterra bus. Nylon lines may be grouped and are supported at 30 in. intervals or less.

The compressor discharge line between power plant and body-mounted equipment is a flexible Teflon hose with a braided stainless steel jacket. Other lines necessary to maintain system reliability are flexible Teflon hose with a braided stainless steel jacketed fittings. They use standard SAE or JIC brass or steel, flanged, swivel-type fittings. Braided flexible hoses are as short as practicable and individually supported. They will not touch one another or any part of the bus except for the supporting grommets. Flexible lines are supported at 2ft intervals or less.

Air lines are clean before installation and are installed to minimize air leaks. All air lines are routed to prevent water traps to the extent possible. Grommets or insulated clamps protect the air lines at all points where they pass through understructure components.

TS 38.4 Air Reservoirs

All air reservoirs meet the requirements of FMVSS Standard 121 and SAE Standard J10 and are equipped with drain plugs and guarded or flush type drain valves. Major structural members protect these valves and any manual moisture ejector valves from road hazards. Reservoirs are sloped toward the drain valve. All air reservoirs have drain valves that discharge below floor level with lines routed to eliminate the possibility of water traps and/or freezing in the drain line. The Proterra Catalyst uses a single analog needle to display the lowest air pressure in both the primary and secondary reservoirs instead.

The single air pressure gauge displays the lowest pressure of the two systems. Our system does not use pressure regulators (except for pneumatic doors). Our controls regulate our pressure and all 3 pressures (primary, secondary, & aux) can be read at the dash.

TS 38.5 Air System Dryer

An air dryer prevents accumulation of moisture and oil in the air system. The air dryer system includes one or more replaceable desiccant cartridges. The 35' Catalyst E2 comes standard with a Bendix AD-IS air dryer.

A provision for an additional oil separator is not provided.

ELECTRICAL, ELECTRONIC AND DATA COMMUNICATION SYSTEMS

TS 39. Overview

The vehicle control system is based around a vehicle controller from Continental VDO with KIBES-32 firmware developed for heavy duty vehicles.

The Continental VDO vehicle control system is based around several hardware components. The ZR-32A is the master controller and contains all the functionality software that controls the main vehicle components. The multiplexing units distribute the master controller's needed discreet and analog inputs and outputs to convenient locations around the vehicle. The fully integrated driver's instrument cluster contains all needed gauge dials and tell tales. Additionally the instrument cluster includes a high performance digital display that is used to inform the driver of various system states including additional driver tell-tale indications, overhead charging instructions and diagnostic information.

The ZR-32A controller is based on two, 32-bit RISC processors with internal 1024kB flash for program memory and SRAM for data parameter storage. It can run 5 independent data networks, at speeds up to 500kB/s based on the CAN J1939 architecture. The CAN (Controller Area Network) is a high-integrity serial data communications bus for real-time applications governed by ISO 11898 and has safety-agency approval for passenger vehicle control.

The MUX-2B units run on an 8-bit processor, having internal programming memory and are equipped with 24 quasi-analog status inputs, 6 dedicated analog inputs, and 32 digital outputs with internal fault detection and protection. The digital outputs are organized in sub groups to be able to run sets of independent systems (i.e., 12V loads as well as 24V loads including outputs that have current capacity up to 10 amps).

The utilized networks are:

- PCAN: Used for high-performance systems like the Traction Motor, cooling System, battery management and ABS.
- MCAN: Used for the multiplexing units that distribute the master controller's needed discrete and analog inputs and outputs to convenient locations around the vehicle.

- ICAN: Used for interfacing with the driver's instrument cluster including the digital display screen. This network includes communicating the discreet input/outputs available from the instrument cluster as well as controlling the clusters dial gauges, tell-tales and what is displayed on the digital display.

TS 39.1 Modular Design

Design of the electrical, electronic and data communication systems are modular so that each electronic device, apparatus panel, or wiring bundle is easily separable from its interconnect by means of connectors.

Power plant wiring is an independent wiring harness. Replacement of the ProDrive compartment wiring harnesses does not require pulling wires through any bulk head or removing any terminals from the wires. As an exception, there is a multicore cable that runs from the ProDrive to the power steering motor at the front of the vehicle. This cable passes through 2 bulkheads and is part of a ProDrive harness.

TS 40. Environmental and Mounting Requirements

The electrical system and its electronic components are capable of operating in the area of the vehicle in which they will be installed, as recommended in SAE J1455.

Electrical and electronic equipment are not located in an environment that will reduce the performance or shorten the life of the component or electrical system when operating within the design operating profile. No vehicle component generates, or is affected by, electromagnetic interference or radio-frequency interference (EMI/RFI) that can disturb the performance of electrical/electronic equipment as defined in SAE J1113 and UNECE Council Directive 95/54 (R10).

TS 40.1 Hardware Mounting

The mounting of the hardware is not used to provide the sole source ground, and all hardware is isolated from potential EMI/RFI, as referenced in SAE J1113.

All electrical/electronic hardware mounted in the interior of the vehicle is inaccessible to passengers and hidden from view unless intended to be viewed. The hardware is mounted in such a manner as to protect it from splash or spray.

All electrical/electronic hardware mounted on the exterior of the vehicle that is not designed to be installed in an exposed environment is mounted in a sealed enclosure.

All electrical/electronic hardware and its mounting complies with the shock and vibration requirements of SAE J1455.

TS 41. General Electrical Requirements

TS 41.1 Batteries

TS 41.1.1 Low-Voltage Batteries (24V)

The 35' Catalyst E2 includes two (2) Group 31, deep cycle, maintenance free batteries. This is sufficient to ensure reliable vehicle startup. These batteries can be "jumped" in the same manner as standard buses and an Anderson connector is provided for this in the event the batteries lose their charge. Low voltage battery state-of-charge warnings are displayed on the drivers screen.

TS 41.1.2 Battery Cables

The battery terminal ends and cable ends are color-coded with red for primary positive, black for negative and green for the intermediate voltage (12 volts). Positive and negative battery cables do not cross each other, are flexible and are sufficiently long to reach the batteries. The cables do not lie directly on top of the batteries. Battery cables are continuous except for the connection to the master battery switch and are bolted terminals meeting SAE Standard J1127-Type SGX. Battery cables are sized at 2/0 and are more than sufficient to "start" the bus.

TS 41.1.3 JumpStart

Proterra provides a red (24V) Anderson-style connector in the motor compartment (ProDrive), equipped with dust cap and adequately protected from moisture, dirt and debris. Alternate connectors are available as an option.

TS 41.1.4 Battery Compartment

The battery compartment prevents accumulation of snow, ice and debris on the top of the batteries and is vented and self-draining. It is only accessible from the outside of the vehicle. All components within the battery compartment, and the compartment itself, is protected from damage or corrosion from the electrolyte. The inside surface of the battery compartment's access door is electrically insulated. The battery compartment temperature does not exceed manufacturer's specification.

The vehicle is equipped with a 12VDC and 24VDC quick disconnect switch. The battery quick disconnect access door is identified with a decal. The battery hold-down bracket is constructed of non-conductive and corrosion-resistant material.

The access door is designed to require a square key lock. The access doors are flush-fitting and incorporate a spring tensioner to retain the door in a closed position when not in use.

The batteries are securely mounted on a powder-coated steel tray which accommodates the size and weight of the batteries. The battery tray pulls out easily and properly supports the batteries while they are being serviced. A locking device retains the battery tray in the stowed position. No sparking devices are located within the battery box.

TS 41.1.5 Auxiliary Electronic Power Supply

The standard vehicle does not utilize any gel-packs or sealed non-vented batteries for auxiliary power. If gel-packs or sealed non-vented batteries are installed, Proterra will comply with this paragraph and install them in a labeled, vented compartment accessible only to maintenance personnel.

TS 41.1.6 Master Battery Switch

The location of the master battery switch is clearly identified on the exterior access panel, is accessible in less than 10 seconds. The installation prevents corrosion from fumes and battery acid when the batteries are washed off or in normal service.

Turning the master switch off with the power plant operating, during an emergency, shuts off the motor and does not damage any component of the electrical system. The master switch is capable of carrying and interrupting the total circuit load.

The standard configuration is equipped with a single switch for disconnecting 12V and 24V power. The access panel is locked with a standard square key.

TS 41.1.7 Low-Voltage Generation and Distribution

The low-voltage generating system maintains the charge on fully charged batteries. The low-voltage batteries are maintained through a DC/DC converter by the high-voltage batteries. There is no generator.

Voltage monitoring and over-voltage output protection is provided.

Dedicated power and ground are provided as specified by the component or system manufacturer. Cabling to the equipment is sized to supply the current requirements of heavy-duty systems with no greater than a 5 percent voltage drop across the length of the cable.

TS 41.1.8 Circuit Protection

All branch circuits are protected by current-limiting devices such as circuit breakers, fuses or solid state devices sized to the requirements of the circuit. The circuit breakers or fuses are easily accessible for authorized personnel. Fuse holders are constructed to be rugged and waterproof. All in-line fuses are shown in the final schematic drawings. Manually resettable circuit breakers provide a visible indication of open circuits.

Circuit breakers or fuses are sized to a minimum of 15 percent larger than the total circuit load. The current rating for the wire used for each circuit exceeds the size of the circuit protection being used.

TS 41.2 Grounds

The batteries are grounded to the chassis in a single location, as close to the batteries as possible. Ground bars are provided throughout the bus, evenly distributed to prevent ground loops. No more than five ground ring/spade terminal connections are made per ground stud with spacing between

studs ensuring conductivity and serviceability. Electronic equipment and systems requiring an isolated ground to the battery is not grounded through the chassis.

TS 41.3 Low Voltage/Low Current Wiring and Terminals

Power and ground wiring conforms to specification requirements of SAE Recommended Practice J1127, J1128 and J1292 for type GXL and SXL wiring. Double insulation is maintained as close to the junction box, electrical compartment or terminals as possible.

Wiring is grouped, labeled and color-coded. Wiring harnesses do not contain wires of different voltage classes unless all wires within the harness are insulated for the highest voltage present in the harness. Kinking, grounding at multiple points, stretching, and exceeding minimum bend radius are prevented.

Strain-relief fittings are provided at all points where wiring enters electrical compartments. Grommets or other protective material is installed at points where wiring penetrates metal structures outside of electrical enclosures. Wiring supports are protective and non-conductive at areas of wire contact and will not be damaged by heat, water, solvents or chafing.

To the extent practicable, wiring is not located in environmentally exposed locations under the vehicle. Wiring and electrical equipment necessarily located under the vehicle is insulated from water, heat, corrosion and mechanical damage. Where feasible, front-to-rear electrical harnesses are installed above the window line of the vehicle.

All wiring harnesses over 5 ft. long and containing at least five wires include 10 percent (minimum one wire) excess wires for spares. Wiring harness length allow end terminals to be replaced twice without pulling, stretching or replacing the wire. Terminals are crimped to the wiring according to the connector or manufacturer's recommendations for techniques and tools.

Cable connectors are locking type, keyed and sealed, unless enclosed in watertight cabinets or the vehicle interior. Pins are removable, crimp contact type, of the correct size and rating for the wire being terminated. Unused pin positions are sealed with sealing plugs. Adjacent connectors use different inserts or different insert orientations to prevent incorrect connections.

Terminals are crimped, corrosion-resistant and full ring type or interlocking lugs with insulating ferrules. When using pressure type screw terminal strips, only stranded wire is used. Insulation clearance ensures that wires have a minimum of "visible clearance" and a maximum of two ties the conductor diameter or 1/16 in., whichever is less. When using shielded or coaxial cable, upon stripping of the insulated, the metallic braid is free from frayed strands.

Ultra-sonic and T-splices may be used with 8 awg or smaller wire. When T-splice is used, it meets these additional requirements:

- It includes a mechanical clamp.

- The wire supports no mechanical load in the area of the splice.
- The wire is supported to prevent flexing.

All splicing is staggered in the harness. Wiring located in the motor compartment (Pro Drive) is routed away from high-heat sources or is shielded and/or insulated from temperatures exceeding the wiring and connector operating requirements.

The instrument panel and wiring are accessible for service from the driver's seat or top of the panel. The instrument panel is separately removable and replaceable without damaging the instrument panel or gauges. Wiring is of sufficient length and routed to permit service without stretching or chafing the wires.

As standard we use HellermanTyton heavy-duty cable management system (which includes plastic tie wraps) which is the standard mechanism for securing wires in our vehicle.

TS 41.4 Electrical Components

All electrical components, including switches, relays, flashers and circuit breakers, are heavy-duty designs with either a successful history of application in heavy-duty vehicles or design specifications for an equivalent environment.

All electric motors are heavy-duty brushless type where practical, and have a continuous duty rating of no less than 40,000 hours, except washer pumps and wiper motors.

All electric motors are easily accessible for servicing.

TS 41.5 Electrical Compartments

Relays, controllers, flashers, circuit breakers and other electrical components are mounted in easily accessible electrical compartments. Compartments exposed to the outside environment are corrosion-resistant and sealed. The components and their functions in each electrical compartment are identified and their location recorded on a schematic drawing permanently attached to the inside of the access panel or door. The drawing is protected from oil, grease, fuel and abrasion. The front compartment is completely serviceable from the driver's seat.

"Rear start and run" controls are not required as the electric drive motor does not idle like a diesel or CNG engine. Alternatively, a "run disable" switch is located in the motor compartment (ProDrive). It will disable the drive system and gear selection without requiring the vehicle to be turned off. The switch is protected and rated for the environment it is installed in. Also, 12/24V disable switch and High Voltage Disconnect is also available in the motor compartment. Both of these switches can be locked in the off position with a lockout-tagout system. The bus has two diagnostic ports in the front and rear interior and a diagnostic tool for accessing vehicle information which can communicate wirelessly or via bluetooth.

TS 42. General Electronic Requirements

If an electronic component has an internal real-time clock, it will provide its own battery backup to monitor time when battery power is disconnected, and/or it may be updated by a network component. If an electronic component has an hour meter, it will record accumulated service time without relying on battery backup.

Proterra will ensure that their electronic equipment is self-protecting in the event of shorts in the cabling, and also in over-voltage and reverse polarity conditions. If an electronic component is required to interface with other components, it will not require external pull-up and/or pull-down resistors. Where this is not possible, the use of pull-up or pull-down resistor is limited as much as possible and is easily accessible and labeled.

TS 42.1 Wiring and Terminals

Kinking, grounding at multiple points, stretching and reducing the bend radius below the manufacturer's recommended minimum is not permitted except at our overhead charge cable installation which does result in certain areas where the bend radius is below the minimum recommended radius. However, these cables have been tested by the manufacturer and Proterra expects the design as installed to last the life of the vehicle.

The Proterra Catalyst vehicles have protective coverings over the high voltage wiring from the battery packs and for wiring to the ProDrive area where the traction motor, transmission, and air system are located.

TS 42.1.1 Discrete I/O (Inputs/Outputs)

Wiring to I/O devices, either at the harness level or individual wire level, are labeled, stamped or color-coded in a fashion that allows unique identification at a spacing not exceeding 4 in. Wiring for each I/O device is bundled together. Where I/O terminals are the same voltages, jumpers may be used to connect the common nodes of each I/O terminal.

TS 42.1.2 Shielding

Wiring that requires shielding meets the following minimum requirements. A shield will be generated by connecting to a ground, which is sourced from a power distribution bus bar or chassis. To extent possible the shield will be connected to one side only. However, some shields are grounded at both ends per the component manufactures installation instructions (i.e. power cables between the motor and Inverter).

When using shielded or coaxial cable, upon stripping of the insulation, the metallic braid is free from frayed strands, which can penetrate the insulation of the inner wires. To prevent the introduction of noise, the shield will not be connected to the common side of a logic circuit.

TS 42.1.3 Communications

The data network cabling is installed according to the selected protocol requirements. The physical layer of all network communication systems is not used for any purpose other than communication between the system components, unless provided for in the network specifications.

Communications networks that use power line carriers (e.g., data modulated on a 24V power line) meet the most stringent applicable wiring and terminal specifications.

TS 42.1.4 Radio Frequency (RF)

Coaxial cable is used to carry the signal for all RF components such as radios, video devices, cameras, global positioning systems, etc. Connectors are minimized, since each connector and crimp has a loss that will attribute to attenuation of the signal. Cabling allows for the removal of antennas or attached electronics without removing the installed cable between them. The corresponding component vendors will be consulted for proper application of equipment, including installation of cables.

TS 42.1.5 Audio

Cabling used for microphone level and line level signals is 22 AWG minimum with shielded twisted pair. Cabling used for amplifier level signals is 18 AWG minimum.

TS 43. Multiplexing

TS 43.1 General

The primary purpose of the multiplexing system is control of components necessary to operate the vehicle. This is accomplished by processing information from input devices and controlling output devices through the use of an internal logic program.

Versatility and future expansion is provided for by an expandable system architecture. The multiplex system is capable of accepting new inputs and outputs through the addition of new modules and/or the utilization of existing spare inputs and outputs. All like components in the multiplex system are modular and interchangeable with self-diagnostic capabilities. The modules are easily accessible for troubleshooting electrical failures and performing system maintenance. Multiplex input/output modules use solid-state devices to provide extended service life and individual circuit protection.

Ten percent of the total number of inputs and outputs, or at least one each for each voltage type utilized (12V, 24V) at each module location is designated as spares.

The Multiplex system has a number of different outputs that are individually rated to 1A, 3A, 5A or 10A max. The CAN wiring is SAE J1939 approved. Module power is GXL wiring which is SAE 1128 approved.

TS 43.2 System Configuration

Proterra's 35' Catalyst™ E2 multiplexing is centralized. The system consist of several modules connected to form a control network. It utilizes a Continental VDO multiplex system. This system is

managed by a master vehicle controller, ZR-32A. It provides the configurability and the control required to integrate all systems on the bus.

TS 43.2.1 I/O Signals

The input/output for the multiplex system contains three types of electrical signals: discrete, modulating and analog.

Discrete signals reflect the on/off status of switches, levers, limit switches, lights, etc. Analog signals reflect numerical data as represented by a voltage signal (for example 0–5V) or resistance signal (for example NTC thermistor). Both types of analog signals represent the status of variable devices such as rheostats, op-amps, potentiometers, temperature probes, etc.

TS 44. Data Communications

TS 44.1 General

All data communication networks are in accordance with a nationally recognized interface standard, such as those published by SAE, IEEE or ISO.

Any electronic vehicle components used on a network are conformance tested to the corresponding network standard.

The vehicle is designed with a fully integrated diagnostic system were the master vehicle controller, ZR-32A, monitors and records the fault status from all systems on the main PCAN network as well as fault status from the multiplex devices. This includes subsystems such as the powertrain controller, cooling system, ABS system, HVAC system, battery management system and other power devices. This diagnostic system also includes the detection of loss of communication of all individual devises on the PCAN and MCAN network.

All faults are recorded, time stamped, odometer stamped and assigned a priority level based on the severity of the fault. These priority levels are broken into 10 groups ranging from the most severe fault requiring an immediate vehicle shutdown to the least severe fault requiring attention at the next service interval. Some minor faults are only recorded to help the technician troubleshoot issues and are not indicated to the driver. Various indicators communicate to the driver the severity and priority of the fault. These indicators include a general red or amber LED tell-tale, fault specific LED tell-tales, fault specific driver's screen displayed tell-tales and/or an audible buzzer.

Many faults have the ability to automatically reset if a fault is no longer active. All faults that are active or previously active are accessed using the Proterra service tool or the maintenance menus accessible from the driver's instrument cluster. The Proterra service tool has a troubleshooting guide to aid in quick resolution of individual faults. The following information is displayed when using the instrument cluster and Proterra service tool:

- Fault status (active or previously recorded and inactive)
- Identifying number (SPN and FMI according to J1939)
- General description of part faulted (SPN description)
- Type of fault (FMI description; i.e. value to high, to low, data erratic, loss of communication)

- Mux input or output pin where fault was detected or system where fault was originated
- Time, date and odometer reading at time of fault

A vehicle data logger is provided to monitor J1939 communications System. It provides:

- Continuous monitoring and recording of the PCAN J1939 data bus.
- Software that can generate structured reports using the gathered data.
- Software to create tools for incident definition, data import/export, analysis and presentation.
- Software for recording of user selected J1939 fault codes.

TS 44.2 Drivetrain Level

Drivetrain components, consisting of the drive motor inverters, regenerative braking system, anti-lock braking system and all other related components, are integrated and communicate fully with respect to vehicle operation with data using SAE Recommended Communications Protocols J1939. Drivetrain components are powered by a supply voltage to ensure data communication among components exists when the vehicle ignition is switched to the “on” position.

TS 44.2.1 Diagnostics, Fault Detection and Data Access

Drive train performance, maintenance and diagnostic data, and other electronic messages are formatted and transmitted on the communication network.

The drivetrain level has the ability to record abnormal events in memory and provide diagnostic codes and other information to service personnel. These codes can be read from the driver’s digital display or the Proterra service tool. The communication ports are located at the front and rear interior of the vehicle.

TS 44.2.2 Programmability (Software)

The drivetrain level components are programmable by the Agency with limitations as specified by the subsystem Supplier. The Proterra powertrain controller is programmable using the Proterra service tool laptop via the vehicle OBD port located in the rear of the vehicle. Reprogramming these controllers is access controlled via multiple user levels with different passwords. Revision control tracking is electronic and communicated on the J1939 PCAN bus.

TS 44.3 Multiplex Level

TS 44.3.1 Data Access

Information is available via a communication port at the front and rear of the vehicle. The location of the communication ports are easily accessible. The preferred way to review this information is via the instrument cluster’s digital display. Maintenance screens, available only to technicians, provide visual feedback of each individual MUX input and output state (i.e. on, off, or faulted). Standard bus uses J1708 interface with the Asynchronous Transfer Mode Switching (ATMS) wireless communications system for transmittal of diagnostic fault codes.

Other interfaces such as J1939 are not available on the bus.

TS 44.3.2 Diagnostics and Fault Detection

The multiplex system has a proven method of determining its status (system health and input/output status) and detecting either active (online) or inactive (offline) faults through the use of on-board visual/audible indicators.

In addition to the indicators, the system employs an advanced diagnostic and fault detection system, which is accessible via the Proterra service tool laptop. The service tool has the ability to check logic function.

As an option, a mock-up board can be provided.

TS 44.3.3 Programmability (Software)

The vehicle master controller is programmable using the Proterra service tool laptop via the vehicle OBD port located in the front of the vehicle. Reprogramming these controllers is access controlled via multiple user levels with different passwords. Revision control tracking is electronic and communicated on the J1939 PCAN bus as well as displayed on the driver's display screen. Programming of the multiplex devices is an automatic process that is completed by the vehicle ZR-32A master controller upon startup.

TS 44.4 Electronic Noise Control

Third party testing per CISPR 12, 36 and ISO 11451 has been conducted to ensure that electrical and electronic subsystems and components on all buses do not emit electromagnetic radiation that will interfere with on-board systems, components or equipment, telephone service, radio or TV reception, or violate regulations of the Federal Communications Commission.

Electrical and electronic subsystems on the coaches are not affected by external sources of RFI/EMI. This includes, but is not limited to, radio and TV transmission, portable electronic devices including computers in the vicinity of or onboard the buses, AC or DC power lines and RFI/EMI emissions from other vehicles.

DRIVER PROVISIONS, CONTROLS AND INSTRUMENTATION

TS 45. Driver's Area Controls

TS 45.1 General

In general, when designing the driver's area, SAE J833, "Human Physical Dimensions," was used. Switches and controls are divided into basic groups and assigned to specific areas, in conformance with SAE Recommended Practice J680, Revised 1988, "Location and Operation of Instruments and Controls in Motor Truck Cabs," and are essentially within the hand reach envelope described in SAE Recommended Practice J287, "Driver Hand Control Reach."

TS 45.2 Glare

The driver's work area is designed to minimize glare to the greatest extent possible. Objects within and adjacent to this area are matte black or dark gray in color wherever possible to reduce the

reflection of light onto the windshield. The use of polished metal and light-colored surfaces within and adjacent to the driver's area was avoided.

TS 45.3 Visors/Sun Shades

An adjustable roller type sunscreen is provided over the driver's windshield. The sunscreen is capable of being lowered to the midpoint of the driver's window. When deployed, the screen is secure, stable, and will not rattle, sway or intrude into the driver's field of view due to the motion of the coach or as a result of air movement. Once lowered, the screen remains in the lowered position until returned to the stowed position by the driver. Sunscreen is shaped to minimize light leakage between the visor and windshield pillars to the extent possible.

An option to include an additional driver's side window sunscreen is also available.

TS 45.4 Driver's Controls

Frequently used controls are in easily accessible locations. These include the door control, kneel control, windshield wiper/washer controls, ramp, and lift and run switch. Any switches and controls necessary for the safe operation of the bus are conveniently located and provide ease of operation. They are identifiable by shape, touch and permanent markings. Controls also are located so that passengers may not easily tamper with control settings.

All panel-mounted switches and controls are marked with easily read identifiers. Graphic symbols conform to SAE Recommended Practice J2402, "Road Vehicles – Symbols For Controls, Indicators, and Tell Tales," where available and applicable. Color of switches and controls are dark with contrasting typography or symbols.

Mechanical switches and controls are replaceable, and the wiring at these controls are serviceable from a convenient location. Switches, controls and instruments are dust- and water-resistant.

All switches/controls in the driver's controls area, if required, can be mounted in an angled panel steep enough to discourage drivers from using it as a personal storage area for items like food, drinks, cell phones, etc.

TS 45.5 Normal Bus Operation Instrumentation and Controls

The following list identifies bus controls used to operate the bus. These controls are either frequently used or critical to the operation of the bus. They are located within easy reach of the operator. The operator will not be required to stand or turn to view or actuate these controls unless specified otherwise.

Systems or components monitored by onboard diagnostics system are displayed in clear view of the operator and provide visual and/or audible indicators. The intensity of indicators permits easy determination of on/off status in bright sunlight but not cause a distraction or visibility problem at night. All indicators are illuminated using backlighting.

The indicator panel is located in the instrument cluster mounted in the center of the driver's dash, within easy view of the operator instrument panel. All indicators have a method of momentarily testing

their operation. The audible alarm is tamper-resistant and has an outlet level between 80 and 83 dBA when measured at the location of the operator's ear.

On-board displays visible to the operator are limited to indicating the status of those functions described herein that are necessary for the operation of the bus. All other indicators needed for diagnostics and their related interface hardware is concealed and protected from unauthorized access. **Table 6** represents Proterra's standard instruments and alarms. Additional options are available upon request. The intent of the overall physical layout of the indicators is in a logical grouping of systems and severity nature of the fault.

Consideration was provided for future additions of spare indicators as the capability of onboard diagnostic systems improves.

Device	Description	Location	Function	Visual/ Audible
Master run switch	Rotary, four-position detent	Right Dash	Master control for bus, off, day run, night run and clearance ID lights	
Vehicle start	Approved momentary switch	Right Dash	Activates the High Voltage System	
Drive selector	Three illuminated push buttons	Side Switch Panel	Provides selection of propulsion: Drive, Neutral, Reverse	Gear selection
HVAC	Switch or switches to control HVAC	Overhead panel	Permits selection of passenger ventilation: off, cool, heat, low fan, high fan or full auto with on/off only	
Driver's ventilation	Rotary, four-position detent	Dash left panel	Permits supplemental ventilation: fan off, low, medium, or high	
Defroster fan	Rotary, four-position detent	Dash left panel	Permits defroster: fan off, low, medium or high	
Defroster temperature	Rotary, four-position detent	Dash left panel	Adjusts defroster temperature	
Windshield wiper	One-variable rotary position operating both wipers	Side Switch Panel	Variable speed control of left and right windshield wipers	
Windshield washer	Push button	Side Switch Panel	Activates windshield washers	
Dash panel lights	Push button	Main display	Provides adjustment for light intensity in night run and day run position	

Device	Description	Location	Function	Visual/ Audible
Interior lights	Three-position switch	Right dash panel	Selects mode of passenger compartment lighting: bright, OFF, dim.	
Front door ramp enable	Two-position switch	Right dash panel	Permits ramp activation from front door area	
Front door ramp	Three-position momentary switch	Right dash panel	Permits deploy and stow of front ramp	Amber light; exterior alarm
Front kneel	Three-position momentary switch	Right dash panel	Permits kneeling activation and raise and normal at front door remote location	Amber dash indicator; exterior alarm
Left remote mirror	Joystick type	Left dash panel	Permits two-axis adjustment of left exterior mirror	
Right remote mirror	Joystick type	Left dash panel	Permits two-axis adjustment of right exterior mirror	
Mirror heater	Switch activated	Side console	Permits heating of outside mirrors when required	
Passenger door control	Two momentary push buttons	Side console	Permits open/close control of front and rear passenger doors	Red light on push button indicating door open, amber light in instrument cluster indicating door open
shutdown override	Momentary switch with operation protection	Lower Switch Panel	Permits driver to activate the override of a vehicle fault condition or a vehicle shutdown condition	Continuous buzzer
Hazard flashers	Two-position switch	Side Switch Panel	Activates emergency flashers	Two green left/right indicator lights
Farebox interface	Farebox coach operator interface panel	Near farebox	Facilitates driver interaction with farebox system	LCD display
Destination sign interface	Destination sign interface panel	Over head	Facilitates driver interaction with destination sign system, manual entry	LCD display

Device	Description	Location	Function	Visual/ Audible
Turn signals	Momentary push button (two required) raised from other switches	Left foot panel	Activates left and right turn signals	Two green left/right indicators and audible indicator
PA manual	Momentary push button	Side console and left foot panel	Permits driver to manually activate public address microphone	
High beam	Detented push button	Left foot panel	Permits driver to toggle between low and high beam	Blue light
Parking brake	Pneumatic PPV	Lower Switch Panel	Permits driver to apply and release parking brake	Red light
Interlock Override	Two-position switch	Rear Switch Panel	Permits driver override to disable door and brake/throttle interlock	Red light and continuous buzzer
Stop Reset	Push button momentary	Side Switch Panel	Permits driver to clear a passenger stop request	
Speedometer	Speedometer, odometer, and diagnostic capability	Dash center panel	Visual indication of speed and distance traveled, accumulated vehicle mileage, fault condition display	Analog dial
Door obstruction	Sensing of door obstruction	Dash center	Indication of rear door sensitive edge activation	Red symbol always flashing and buzzer
Door opened	Door not fully closed	Dash center	Indication of rear door not properly closed	Amber light
Low system air pressure	Sensing low primary and secondary air tank pressure	Dash center	Indication of low air system pressure	Amber light, always constant
ABS indicator	Detects system status	Dash center	Displays system failure	Amber light
HVAC indicator	Detects system status	Dash center	Displays system failure	Amber light
Charging system indicator (12/24 V)	Detect charging system status	Dash center	Detects no charge condition and detects battery high, low, imbalance and no charge condition	Red or yellow light based on condition

Device	Description	Location	Function	Visual/ Audible
Bike rack deployed indicator	Detects bike rack position	Dash center	Indication of bike rack not being in fully stowed position	Amber light
High Voltage battery system state of charge	Analog gauge and digital display	Dash center	Indication of high voltage battery system state of charge	Analog dial and digital bar
Active charge/regeneration and power draw	Analog gauge and digital display	Dash center	Indication of electric regeneration, charging and power draw	Analog dial and digital bar

Table 2-Proterra Bus Instruments and Alarms

TS 45.6 Driver Foot Controls

Accelerator and brake pedals are designed for ankle motion. Foot surfaces of the pedals are faced with wear-resistant, nonskid, replaceable material.

TS 45.6.1 Pedal Angle

The vertical angle of the accelerator and brake pedals are determined from a horizontal plane regardless of the slope of the cab floor. The standard configuration for the 35' Catalyst E2 accelerator pedal is an angle of 45° at initiation and 25° at full throttle. The angles for the brake pedal are 45° at initiation and 25° at full brake.

TS 45.6.2 Pedal Dimensions and Position

The floor-mounted accelerator pedal is 10 to 12 in. long and 3 to 4 in. wide. Clearance around the pedal allows for no interference precluding operation.

The accelerator and brake pedals are positioned such that the spacing between them, measured at the heel of the pedals, is between 1 and 2 in. Both pedals are located on the same plane coincident to the surface of the pedals.

TS 45.7 Brake and Accelerator Pedals

The brake and accelerator pedals are not adjustable. Optionally, adjustable brake and accelerator pedals are available. This option provide pedals that are adjustable forward and rearward a minimum of 3 in. The adjustment is made by use of a dash-mounted rocker switch. The switch is clearly labeled to identify it as pedal adjustment and is within easy reach of the driver. Pedal adjustment are enabled only when the bus is stationary and the parking brake engaged.

TS 45.8 Driver Foot Switches

The control switches for the turn signals are mounted on an inclined, floor-mounted inclined metal plate mounted to the driver's platform, located to the left of the steering column. The location and design of this plate is such that foot room for the operator is not impeded. The inclined mounting

surface is skid-resistant. All other signals, including high beam and public address system, are in approved locations.

The angle of the turn signal platform is determined from a horizontal plane, regardless of the slope of the cab floor. The turn signal platform is angled at a minimum of 10° and a maximum of 37°. It is located no closer to the seat front than the heel point of the accelerator pedal.
The platform is not adjustable.

The foot switches are UL-listed, heavy-duty type, of a rugged, corrosion-resistant metal construction. The foot switches for the turn signals and PA system are momentary type, while the high beam is latching type. The spacing of the switches are such that inadvertent simultaneous deflection of switches is prevented.

TS 46. Driver's Amenities

TS 46.1 Coat Hanger

The standard configuration is for no coat hanger. Optionally a coat hanger can be provided.

TS 46.2 Drink Holder

The standard configuration is for no drink holder. Optionally a drink holder can be provided. It will securely hold the driver's drink container, which may vary widely in diameter. It will be mounted within easy reach of the driver and has sufficient vertical clearance for easy removal of the container. When the container is in the device, the driver's view of the road will not obstructed, and leakage from the container will not fall on any switches, gauges or controls.

TS 46.3 Storage Box

An enclosed driver storage area on the curbside wheel well is provided with a positive latching door and/or lock. The minimum size is 2750 in^3.

TS 47. Windshield Wipers and Washers

TS 47.1 Windshield Wipers

The bus is equipped with a windshield wiper for each half of the single-piece windshield. At 60 mph, no more than 10 percent of the wiped area is lost due to windshield wiper lift. The wipers park along the bottom edge of the windshield in an overlapping position. Windshield wiper motors and mechanisms are easily accessible for repairs or service from the inside of the bus. The fasteners that secure the wiper arms to the drive mechanism are corrosion-resistant. The wipers are single-control, with an electric two-speed intermittent system.

TS 47.2 Windshield Washers

The windshield washer system, when used with the wipers, deposits washing fluid evenly and completely wets the entire wiped area.

The windshield washer system has 4.5-gallon reservoir that is easily refilled from outside of the bus. The tank has two levels sensor (high and low). One triggers a message on the dash when the tank is

empty. The other will turn on a light on the fill pocket to alert to stop filling. Reservoir pump, lines and fittings are corrosion-resistant and include a means to determine fluid level.

TS 48. Driver's Seat

TS 48.1 Dimensions

The driver's seat is comfortable and adjustable so that people ranging in size from a 95th-percentile male to a 5th-percentile female may operate the bus.

TS 48.1.1 Seat Pan Cushion Length

Measurement is from the front edge of the seat pan to the rear at its intersection with the seat back. The adjustment of the seat pan length is no less than 16.5 in. at its minimum length and no more than 20.5 in. at its maximum length.

TS 48.1.2 Seat Pan Cushion Height

Measurement is from the cab floor to the top of the level seat at its center midpoint. The seat adjusts in height from a minimum of 14 in., with a minimum 6 in. vertical range of adjustment.

TS 48.1.3 Seat Pan Cushion Slope

Measurement is the slope of the plane created by connecting the two high points of the seat, one at the rear of the seat at its intersection with the seat back and the other at the front of the seat just before it waterfalls downward at the edge. The slope can be measured using an inclinometer and will be stated in degrees of incline relative to the horizontal plane (0 degrees). The seat pan adjusts in its slope from no less than plus 12 degrees (rearward "bucket seat" incline), to no less than minus 5 degrees (forward slope).

TS 48.1.4 Seat Base Fore/Aft Adjustment

Measurement is the horizontal distance from the heel point to the front edge of the seat. The minimum and maximum distances are measured from the front edge of the seat when it is adjusted to its minimum seat pan depth (approximately 15 in.). On all low-floor buses, the seat-base shall travel horizontally a minimum of 9 in. It adjusts no closer to the heel point than 6 in. On all high-floor buses, the seat base travels a minimum of 9 in. and adjusts no closer to the heel-point than 6 in.

TS 48.1.5 Seat Pan Cushion Width

Measurement is the horizontal distance across the seat cushion. The seat pan cushion is 17 to 21 in. across at the front edge of the seat cushion and 20 to 23 in. across at the side bolsters.

TS 48.2 Seat Suspension

The driver's seat is appropriately dampened to support a minimum weight of 380 lbs. The suspension is capable of dampening adjustment in both directions.

Rubber snubbers are provided to prevent metal-to-metal contact.

TS 48.2.1 Seat Back

The width measurement is the distance between the outermost points of the front of the seat back, at or near its midpoint in height. The seat back width is no less than 19 in. Seat back will include dual recliner gears on both sides of the seat. The standard height is the normal height seat back.

TS 48.2.2 Headrests

Standard configuration comes with adjustable headrest.

TS 48.2.3 Seat Back Lumbar Support

Measurement is from the bottom of the seat back at its intersection with the seat pan to the top of the lumbar cushioning. The seat back provides adjustable depth lumbar back support with three individual operating lumbar cells within a minimum range of 7 to 11 in.

TS 48.2.4 Seat Back Angle Adjustment

The seat back angle is measured relative to a level seat pan, where 90 degrees is the upright position and 90 degrees-plus represents the amount of recline.

The seat back adjusts in angle from a minimum of no more than 90 degrees (upright) to at least 105 degrees (reclined), with infinite adjustment in between.

TS 48.3 Seat Belt

The Proterra 35’ Catalyst E2 standard configuration comes with 2 Point, black color belts. The seat belts are stored in auto-locking retractors (ALR). The belts are mounted to the seat frame so that the driver may adjust the seat without resetting the seat belt. Standard the lap belt assembly is a minimum of 72 in. in length.

The seat and seat belt assemblies as installed in the bus withstands static horizontal forces as required in FMVSS 207 and 210.

TS 48.4 Adjustable Armrest

The standard configuration is for no armrests. Optionally armrests can be provided.

TS 48.5 Seat Control Locations

While seated, the driver is able to make seat adjustments by hand without complexity, excessive effort or being pinched. Adjustment mechanisms shall hold the adjustments and shall not be subject

to inadvertent changes. Seat controls standard location are on the right hand side of the driver's seat clear of any obstruction.

TS 48.6 Seat Structure and Materials

TS 48.6.1 Cushions

Cushions shall be fully padded with at least 3 in. of materials in the seating areas at the bottom and back.

TS 48.6.2 Cushion Materials

The standard configuration is for closed-cell polyurethane that is FMVSS 302 compliant. Optionally Docket 90A compliant material is available.

TS 48.6.3 Pedestal

The standard configuration is for powder-coated steel pedestal.

TS 48.6.4 Seat Options

Some options may or may not be available depending on the model of seat selected.

TS 49. Mirrors

TS 49.1 Exterior Mirrors

The bus is equipped with corrosion-resistant, outside rearview mirrors mounted with stable supports to minimize vibration. Mirrors are firmly attached to the bus to minimize vibration and to prevent loss of adjustment with a breakaway mounting system. Mirrors permit the driver to view the roadway along the sides of the bus, including the rear wheels. Mirrors are positioned to prevent blind spots.

Mirrors manually retract or fold sufficiently to allow bus washing operations but avoid contact with the windshield.

The curbside rearview mirror is mounted so that its lower edge is no less than 80 in. above the street surface with a standard 9x13 in head. The street side rearview mirror standard configuration is low mounted and it is also a standard 9x13 in head. An option for high mount is also available.

The driver is able to adjust either mirror remotely while seated in the driving position. Mirror heat is active by turning on the mirror heat switch. LED turn signals are integrated into the mirrors.

TS 49.2 Interior Mirrors

Mirrors are provided for the driver to observe passengers throughout the bus without leaving the seat and without shoulder movement. The standard configuration is for 3 interior mirrors that allow the driver to observe passengers in the front/entrance and rear/exit areas, anywhere in the aisle, and in the rear seats.

WINDOWS

TS 50. General

The windows on the 35’ Catalyst E2 exceed the specified minimum window area of 8,000 square inches for a 35’ bus.

TS 51. Windshield

The single-piece windshield permits an operator’s field of view as referenced in SAE Recommended Practice J1050. The vertically upward view is a minimum of 14°, measured above the horizontal and excluding any shaded band. The vertically downward view permits detection of an object 3½ft high no more than 2 ft in front of the bus. The horizontal view is a minimum of 82° above the line of sight, not 90°. Windshield pillars do not exceed 10° of binocular obscuration. The windshield is designed and installed to minimize external glare as well as reflections from inside the bus.

The windshield is easily replaceable by removing zip-locks from the windshield retaining moldings.

TS 51.1 Glazing

The 35’ Catalyst E2 single-piece windshield glazing has the following characteristics:

-Material: 6.76mm 73% L.T.
-Laminated glass.
-Conforms to SAE J673, J674, ANSI/SAE Z26.1-1996 and APTA Standard Bus Procurement Guidelines.

The vehicle is equipped with a single-piece windshield and does not have a shaded band in the upper portion of the glazing, as this area serves as the destination sign compartment glazing.

TS 52. Driver’s Side Window

The driver’s side window is the sliding type, it is sufficient to permit the seated operator to easily adjust the street-side outside rearview mirror. When in an open position, the window will not rattle or close during braking. This window section slides in tracks or channels designed to last the service life of the bus. The operator’s side window is not bonded in place and is easily replaceable. The glazing material has a single-density tint.

The driver’s view, perpendicular through operator’s side window glazing, extends a minimum of 33 in. (840 mm) to the rear of the heel point on the accelerator, and in any case accommodates a 95th percentile male operator. The view through the glazing at the front of the assembly begins not more than 27.2 in. above the operator’s floor. Driver’s window construction maximizes ability for full opening of the window.

The driver’s side window glazing material has a ¼ in. nominal thickness tempered safety glass conforming to the requirements of ANSI Z26.1-1996 Test Grouping AS-2 and the recommended practices defined in SAE J673.

The design prevents sections from freezing closed in the winter. Light transmittance is 75 percent on the glass area below 53 in. from the operator platform floor. On the top-fixed-over-bottom-slider configuration, the top fixed area above 53 in. may have a maximum 5 percent light transmittance.

The driver's side window is only available as a hidden frame (Flush "Euro-Look") top fixed over bottom slider, non-egress with tempered glass.

TS 53. Side Windows

TS 53.1 Configuration

Side windows are not bonded in place and are easily replaceable without disturbing adjacent windows. They are mounted so that flexing or vibration from operation or normal road excitation is not apparent. All aluminum and steel material is treated to prevent corrosion.

The quarter window in front of the entrance door is bonded in place.

TS 53.2 Emergency Exit (Egress) Configuration

Passenger windows meet the requirements of FMVSS 217 for emergency egress. The standard configuration is 2 street-side egress windows. The addition of extra egress windows is optional.

TS 53.3 Configuration

Side windows are fixed in position, except as necessary to meet the emergency escape requirements.

TS 53.4 Materials

Window glazing will be 5mm tempered safety glass. Windows will meet the requirements of ANSI Z26.1-1996 Test Grouping 2 and the Recommended Practices defined in SAE J673.

Windows will be tinted 50% gray. Window glazing will have 50% light transmittance as measured by ASTM D-1003 and 45% solar transmittance as measured by ASTM E-424. The window at the destination/location sign will not be tinted in the vicinity of the sign.

TS 53.5 Rear Window

The 35' Catalyst E2 is not equipped with a rear window as standard configuration.

HEATING, VENTILATING AND AIR CONDITIONING

TS 54. Capacity and Performance

Please see below for current system design and planned performance.

The HVAC climate control system is capable of controlling the temperature and maintaining the humidity levels of the interior of the bus as defined in the following paragraphs.

The 35' Catalyst E2 is equipped with a roof-mounted HVAC. It provides cabin heating and air-conditioning. It is an all-electric system using both high and low voltage systems.

With the bus running at the design operating profile with corresponding door opening cycle, and carrying a number of passengers equal to 150 percent of the seated load, the HVAC system will control the average passenger compartment temperature within a range between 65 and 80 °F, while maintaining the relative humidity to a value of 50 percent or less. The system will maintain these conditions while subjected to any outside ambient temperatures within a range of 10 to 95 °F and at any ambient relative humidity levels between 5 and 50 percent.

When the bus is operated in outside ambient temperatures of 95 to 115 °F, the interior temperature of the bus is permitted to rise 0.5°F for each degree of exterior temperature in excess of 95 °F. When the bus is operated in outside ambient temperatures in the range of -10 to 10 °F, the interior temperature of the bus will not fall below 55 °F while the bus is running on the design operating profile after stabilization with doors closed or a permitted door cycling.

System capacity testing, including pull-down/warm-up, stabilization and profile, shall be conducted in accordance to APTA's Recommended Practice "Transit Bus HVAC System Instrumentation and Performance Testing."

The air-conditioning portion of the HVAC system will be capable of reducing the passenger compartment temperature from 115 to 95 °F in less than 30 minutes after vehicle start-up. During the cool-down period, the refrigerant pressure will not exceed safe high-side pressures, and the condenser discharge air temperature, measured 6 in. from the surface of the coil, will be within the manufacturer's acceptable air temperature rise. There will be no passengers on board, and the doors and windows will be closed.

The pull-up requirements for the heating system will be in accordance with Section 11.1 of APTA's Recommended Practice" Transit Bus HVAC System Instrumentation and Performance Testing." With ambient temperature at -0 °F, and vehicle cold soaked at that temperature, the bus heating system will warm the interior passenger compartment to an average temperature of 70 °F ±2 °F within 70 minutes.

The air conditioning system meets these performance requirements using R134a.

TS 55. Controls and Temperature Uniformity

Please see below for current system design and planned performance.

The HVAC system, excluding the driver's heater/defroster, is centrally controlled with an advanced electronic/diagnostic control system with provisions for extracting/reading data. The system is compliant with J1939 Communication Protocol for receiving and broadcasting of data.

The 35' Catalyst E2 is an all-electric vehicle and does not have hot engine coolant. Therefore, hot engine coolant water cannot be delivered to the HVAC system driver's defroster/heater. The driver's defroster/heater is an all-electric system.

After manual selection and/or activation of climate control system operation mode, all interior climate control system requirements for the selected mode will be attained automatically to within ±2 °F of specified temperature control set point.

The driver has full control over the defroster and driver's heater. The driver is able to adjust the temperature in the driver's area through air distribution and fans. The interior climate control system switches automatically to the ventilating mode if the refrigerant compressor or condenser fan fails.

Interior temperature distribution is uniform to the extent practicable to prevent hot and/or cold spots. After stabilization with doors closed, the temperatures between any two points in the passenger compartment in the same vertical plane, and 6 to 72 in. above the floor, will not vary by more than 15 °F with doors closed while the HVAC is actively providing heat to the cabin. Any measured interior temperature will not vary more than ±10 °F from the average temperature determined in accordance with APTA's "Recommended Instrumentation and Performance Testing for Transit Bus Air Conditioning System" while the HVAC is actively providing heat to the cabin.

TS 55.1 Auxiliary Heater

The standard configuration is for no auxiliary heater. However, Proterra offers an optional auxiliary heater for cold-weather environments. Additional information can be provided upon request.

TS 56. Air Flow

TS 56.1 Passenger Area

Please see below for current system design and planned performance.

The cooling mode of the interior climate control system introduces air into the bus at or near the ceiling height at a minimum rate of 25 cubic ft per minute (cfm) per passenger based on the standard configuration bus carrying a number of passengers equal to 150 percent of the seated load. Airflow is evenly distributed throughout the bus, with air velocity not exceeding 100 ft per minute on any passenger, however some passengers can see more or less depending on where they are seated. The ventilating mode provides air at a minimum flow rate of 20 cfm per passenger.

Airflow may be reduced to 15 cfm per passenger (150 percent of seated load) when operating in the heating mode. The fans will not will activate as soon as the HVAC is turn on. The heating air outlet temperature will not exceed 125 °F under any normal operating conditions.

The climate control blower motors and fan are designed such that their operation complies with the interior noise level requirements.

The climate control system provides operating modes with and without "fresh air".

TS 56.2 Driver's Area

Please see below for current system design and planned performance.

The bus interior climate control system delivers at least 100 cfm of air to the driver's area when operating in the ventilating and cooling modes. Adjustable nozzles permit variable distribution or shutdown of the airflow. Airflow in the heating mode is reduced proportionally to the reduction of airflow into the passenger area. There is no provisions to provide fresh-air (exterior air) to the driver's area, except through ventilated air from the HVAC.

Pending testing, the windshield defroster unit will meet the requirements of SAE Recommended Practice J382, “Windshield Defrosting Systems Performance Requirements,” and has the capability of diverting heated air to the driver’s feet and legs. The defroster or interior climate control system maintains visibility through the driver’s side window.

TS 56.3 Controls for the Climate Control System (CCS)

The controls for the driver’s compartment for heating, ventilation and cooling systems are integrated and meet the following requirements:

1) The heat/defrost system fan is controlled by a separate switch that has an “off” position and at least two positions for speed control. All switches and controls preclude the possibility of clothing becoming entangled. An “on/off” switch is located near the main defroster switch.

2) The system does not required the use of a manually operated control valve as the heater is electrical and does not use heated water.

TS 56.4 Driver’s Compartment Requirements

Please see below for current system design and planned performance.

A separate heating, ventilation and defroster system for the driver’s area is provided and is controlled by the driver. Heating provided by the defroster does not have an option for fresh air. Heating provided by the HVAC does have the option to pull in fresh air. The system meets the following requirements:

- The heater and defroster system provides heating for the driver and heated air to completely defrost and defog the windshield. There are no designed components for the driver’s side window, and the front door glass. Fan(s) are able to draw air from the bus body interior and pass it through the defroster system and over the driver’s feet. Pending testing, a minimum capacity of 100 cfm is provided. The driver has complete control of the heat for the driver’s area.

- The defroster supply outlets are located at the lower edge of the windshield. These outlets are durable and are free of sharp edges that can catch clothes during normal daily cleaning. The system is such that foreign objects such as coins or tickets cannot fall into the defroster air outlets. There are no adjustable ball vents or louvers provided at the left of the driver’s position to allow direction of air onto the side windows.

A ventilation system is provided to ensure driver comfort and is capable of providing fresh air in both the foot and head areas via HVAC ventilation. Vents are controllable by the driver from the normal driving position. Decals are provided, indicating “operating instructions” and “open” and “closed” positions. When closed, vents are sealed to prevent the migration of water or air into the bus.

TS 56.5 Driver's Cooling

There is no dedicated evaporator for drivers cooling. A booster blower for the driver are standard and it pulls the air from the street side AC duct and provides air conditioner to the driver.

TS 57. Air Filtration

Air is filtered before entering the AC system and being discharged into the passenger compartment. The filter meets the ANSI/ASHRAE 52.1 requirement for 5 percent or better atmospheric dust spot efficiency, 50 percent weight arrestance, and a minimum dust holding capacity of 120 g per 1000 cfm cell. Air filters are easily removable for service and cleanable.

TS 58. Roof Ventilators

The 35' Catalyst E2 is equipped with one roof ventilator in the roof of the bus, located approximately in the middle of the roof. The standard roof ventilators is opaque although options are available for clear roof ventilators. The ventilator is easily opened and closed manually. When open with the bus in motion, this ventilator provides fresh air inside the bus. The ventilator covers an opening area of no less than 425 sq. in. and is capable of being positioned with all four edges raised simultaneously to a height of no less than 3½ in. An escape hatch is incorporated into the roof ventilator. The roof ventilator is sealed to prevent entry of water when closed.

TS 59. Maintainability

Manually controlled shut-off valves in the refrigerant lines allow isolation of the compressor and dehydrator filter for service. To the extent practicable, self-sealing couplings utilizing O-ring seals are used to break and seal the refrigerant lines during removal of major components, such as the refrigerant compressor. Shut-off valves are provided in lieu of self-sealing couplings. The condenser is located to efficiently transfer heat to the atmosphere and will not ingest air warmed above the ambient temperature by the bus mechanical equipment, or to discharge air into any other system of the bus. The location of the condenser precludes its obstruction by wheel splash, road dirt or debris. HVAC components located within 6 in. of floor level are constructed to resist damage and corrosion.

High and low refrigerant pressure gauges are not available in the return air area.

TS 60. Entrance/Exit Area Heating

The standard configuration for the 35' Catalyst E2 has no provisions for entrance/exit area heating. Options for entrance/exit heating are available.

TS 61. Floor-Level Heating

The standard configuration is for no floor-level heating to be installed.

EXTERIOR PANELS, FINISHES AND EXTERIOR LIGHTING

TS 62. Design

The bus has a clean, smooth, simple design, primarily derived from bus performance requirements and passenger service criteria. The exterior and body features, including grilles and louvers, are

shaped to facilitate cleaning by automatic bus washers without snagging washer brushes. Water and dirt will not be retained in or on anybody feature to freeze or bleed out onto the bus after leaving the washer. The body and windows are sealed to prevent leaking of air, dust or water under normal operating conditions and during cleaning in automatic bus washers for the service life of the bus.

Exterior panels are sufficiently stiff to minimize vibration, drumming or flexing while the bus is in service. When panels are lapped, the upper and forward panels will act as a watershed. The windows, hatches and doors are able to be sealed. Accumulation of spray and splash generated by the bus's wheels is minimized on windows and mirrors.

TS 62.1 Materials

Body materials were selected and the body fabricated to reduce maintenance, extend durability and provide consistency of appearance throughout the service life of the bus. Detailing was kept simple, and add-on devices and trim are minimized and integrated into the basic design.

The use of composite materials provides a much stronger, more durable and longer lasting body than provided with conventional steel or aluminum "stick built" construction. Finite Element Analysis indicates the body should easily endure sixteen years of transit service.

TS 62.2 Roof-Mounted Equipment

A non-skid, clearly marked walkway or steps was incorporated on the roof to provide access to equipment without damaging any system or bus paneling.

TS 63. Pedestrian Safety

Exterior protrusions along the side and front of the bus greater than ½ in. and within 80 in. of the ground have a radius no less than the amount of the protrusion. The exterior rearview mirrors, cameras and required lights and reflectors are exempt from the protrusion requirement. Advertising frames protrude no more than ⅞ in. from the body surface. Grilles, doors, bumpers and other features on the sides and rear of the bus are designed to minimize toeholds or handholds.

Exterior protrusions do not cause a line-of-sight blockage for the driver.

TS 64. Repair and Replacement

TS 64.1 Side Body Panels

The 35' Catalyst E2 has an all-composite body. Composite body buses do not have exterior paneling. The outer skin is integral to the body structure. When damage occurs to the exterior of the vehicle, the repair is contained to just the damaged area. The side body from floor to window is repairable with common composite repair techniques. The body is also covered with a gel coat that resists chips and cracks.

TS 64.2 Composite Body Repair

Composite bus bodies are pretty resistant to impact, however sections of a monocoque composite body or other equipment that may be damaged in normal service are easily repairable with common

composite repair techniques. If requested by the by the agency Proterra will send our regional service representative to review the bus after the accident. The service rep will take pictures of the issue and assess the damage, then will communicate with the customer and Proterra Service.

There are 3 options to perform the repair:

1) For relatively minor issues that have just affected the skin layer of the bus body or an access door, our field service representatives can handle the repair or can assist the agency's maintenance group to complete. Proterra keeps spare parts of access doors if it is the preference of the agency to have these replaced instead.
2) Proterra offers optional composite repair training to all customers. If the agency has its own body shop or a body shop of preference, it can opt to complete this training and then complete any repairs internally. Proterra will provide a recommended materials list and can support with instructions as needed.
3) Proterra has partnered with a third party composite repair company who can come to the agency and complete the repair. Proterra has already completed several projects with them, although none were related to accident repairs.

TS 65. Rain Gutters

Rain gutters are integral to the design of the composite body. Our vehicles employ a uniquely designed roof profile that channels water away from passenger entrance and exit areas. This provides similar functionality via the body design and roof profile.

TS 66. License Plate Provisions

Provisions have been made to mount standard-size U.S./Canada license plates per SAE J686 on the rear of bus. These provisions direct-mount the license plates so that they can be cleaned by automatic bus-washing equipment without being caught by the brushes. The rear license plate provision is illuminated per SAE J587. An option for a front license plate is available.

TS 66.1 Rub rails

The standard configuration is for no rub rails installed. Our fender flares act as a rub rail and our composite body is more robust then the thin aluminum paneling of most buses.

TS 67. Fender Skirts

Fender skirts are installed to minimize water spray from the bus in wet conditions. They do not extend beyond the body width.

TS 68. Wheel Covers

The standard configuration is for no wheel covers.

TS 68.1 Splash Aprons

The standard configuration is for no splash aprons.

TS 69. Service Compartments and Access Doors

TS 69.1 Access Doors

Conventional or pantograph hinged doors are used for the motor compartment and for all auxiliary equipment compartments. Access openings are sized for easy performance of tasks within the compartment, including tool operating space. Access doors are of rugged construction and maintain mechanical integrity and function under normal operations throughout the service life of the bus. They close flush with the body surface. All doors are hinged at the top or on the forward edge and are prevented from coming loose or opening during transit service or in bus washing operations. All access doors are retained in the open position by gas-filled springs with safety props and are easily operable by one person. Springs and hinges are corrosion resistant. Latch handles are flush with, or recessed behind, the body contour and are sized to provide an adequate grip for opening.

The lower side access doors for the motor compartment, when opened, will restrict access to the upper side access doors. All other access doors, when opened, do not restrict access for servicing other components or systems.

TS 69.2 Access Door Latch/Locks

Access doors larger than 100 sq in. are equipped with corrosion-resistant flush-mounted latches or locks. All such access doors that require a tool to open are standardized throughout the vehicle and will require a nominal 5/16 in. square male tool to open or lock.

TS 70. Bumpers

TS 70.1 Location

Bumpers provide impact protection for the front and rear of the bus with the top of the bumper being 27 in., ±2 in., above the ground. Bumper height is such that when one bus is parked behind another, a portion of the bumper faces will contact each other.

TS 70.2 Front Bumper

No part of the bus, including the bumper, will be damaged as a result of a 5mph impact of the bus at curb weight with a fixed, flat barrier perpendicular to the bus's longitudinal centerline. The bumper will return to its pre-impact shape within 10 minutes of the impact. The bumper protects the bus from damage as a result of 6.5 mph impacts at any point by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000lbs parallel to the longitudinal centerline of the bus. It protects the bus from damage as a result of 5.5mph impacts into the corners at a 30° angle to the longitudinal centerline of the bus. The energy absorption system of the bumper is independent of every power system of the bus and will not require service or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in.

The 35' Catalyst E2 can be configured with or without a bike rack. The bumpers are a three piece design.

TS 70.3 Rear Bumper

No part of the bus, including the bumper, will be damaged as a result of a 2mph impact with a fixed, flat barrier perpendicular to the longitudinal centerline of the bus. The bumper will return to its pre-impact shape within 10 minutes of the impact. When using a yard tug with a smooth, flat plate bumper 2 ft wide contacting the horizontal centerline of the rear bumper, the bumper provides protection at speeds up to 5 mph, over pavement discontinuities up to 1 in. high, and at accelerations up to 2 mph/sec. The rear bumper protects the bus when impacted anywhere along its width by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000 lbs, at 4 mph parallel to or up to a 30° angle to the longitudinal centerline of the bus. The rear bumper is shaped to preclude unauthorized riders standing on the bumper. The bumper will not require service or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in. The bumpers are a three piece design.

TS 70.4 Bumper Material

Bumper material is corrosion-resistant and will withstand repeated impacts of the specified loads without sustaining damage. Bumpers are made of aluminum and the outer shell is solid elastomer. These bumper qualities will be sustained throughout the service life of the bus.

TS 71. Finish and Color

TS 71.1 Appearance

All exterior surfaces are smooth and free of wrinkles and dents. The 35' Catalyst E2 is a composite body. It has a gel-coated exterior finish in white with Proterra logos on the front & rear.

Options for paint or full-body decal / wrap are available.

TS 72. Decals, Numbering and Signing

Monograms, numbers and other special signing will be applied to the inside and outside of the bus as required. Signs are durable and fade, chip and peel-resistant. All decals are installed per the decal supplier recommendations. Signs are provided in compliance with the ADA requirements defined in 49 CFR Part 38, Subpart B, 38.27. The standard configuration is for an English decal package.

TS 72.1 Passenger Information

ADA priority seating signs as required and defined by 49 CFR are provided to identify the seats designated for passengers with disabilities.

Requirements for a public information system in accordance with 49 CFR are not standard but can be provided as an option.

TS 73. Exterior Lighting

All exterior lights are designed to prevent entry and accumulation of moisture or dust. Lamps, lenses and fixtures are interchangeable to the extent practicable. Hazard lamps at the rear of the bus are not enabled when the motor service door is opened. Light lenses are designed and located to prevent damage when running the vehicle through an automatic bus washer.

Commercially available LED-type lamps are utilized at all exterior lamp locations including the head lamps.

TS 73.1 Backup Light/Alarm

Visible and audible warnings inform following vehicles or pedestrians of reverse operation. Visible reverse operation warning conforms to SAE Standard J593. Audible reverse operation warning conforms to SAE Recommended Practice J994 Type C or D.

TS 73.2 Doorway Lighting

Lamps at the front and rear passenger doorways comply with ADA requirements and activate only when the doors open. These lamps illuminate the street surface to a level of no less than 1 foot-candle for a distance of 3 ft outward from the outboard edge of the door threshold. The lights are positioned below the lower daylight opening of the windows and are shielded to protect passengers' eyes from glare.

TS 73.3 Turn Signals

Turn-signal lights are provided on the front, rear, curb and street sides of the bus in accordance with federal regulations.

TS 73.4 Headlights

Headlamps are designed for ease of replacement. Standard OEM headlight installation will be provided in accordance with federal regulations.

The headlamps can be configured for daytime running. The standard configuration is currently for LED headlamps. The design life of the headlamps can be provided.

TS 73.5 Brake Lights

Brake lights are provided in accordance with FMVSS 108 and Part 393, Subpart B of the FMCSA as applicable. An addition brake strip light center mounted is provided.

TS 73.6 Service Area Lighting (Interior and Exterior)

LED lamps are provided in the motor and all other compartments where service may be required to generally illuminate the area for night emergency repairs or adjustments. These service areas include, the motor compartment and the communication box. The passenger door operator compartments and junction/apparatus panels do not have service lights. Lighting is adequate to light the space of the service areas to levels needed to complete typical emergency repairs and adjustments. The service area lamps are suitable for the environment in which they are mounted.

Motor compartment lamps are controlled by a switch mounted in the motor compartment. All other service area lamps are controlled by switches mounted on or convenient to the lamp assemblies. Power to the service area lighting is programmable. Power latches on with activation of the switch and is automatically discontinued (timed out) after 30 minutes to prevent damage caused by inadvertently leaving the service area lighting switch in the "on" position after repairs are made.

INTERIOR PANELS AND FINISHES

TS 74. General Requirements

Materials were selected on the basis of maintenance, durability, appearance, safety, flammability and tactile qualities. Materials are strong enough to resist everyday abuse and be vandalism and corrosion resistant. Trim and attachment details are kept simple and unobtrusive. Interior trim is secured to avoid resonant vibrations under normal operational conditions.

Interior surfaces more than 10 in. below the lower edge of the side windows or windshield are shaped so that objects placed on them fall to the floor when the coach is parked on a level surface. Any components and other electrical components within close proximity to these surfaces are also resistant to this cleaning method.

The standard configuration does not have any additional anti-graffiti/vandalism surface treatments.

TS 75. Interior Panels

Panels are easily replaceable and tamper resistant. They are reinforced, as necessary, to resist vandalism and other rigors of transit bus service. Individual trim panels and parts are interchangeable to the extent practicable.

Interior panels meet FMVSS 302. An option is available to install alternate interior panels that meet FTA Docket 90-A.

TS 75.1 Driver Area Barrier

A barrier or bulkhead between the driver and the street-side front passenger seat is provided. The barrier minimizes glare and reflections in the windshield directly in front of the barrier from interior lighting during night operation. Location and shape permits full seat travel and reclining possibilities that can accommodate the shoulders of a 95th-percentile male. The partition has a side return and stanchion to prevent passengers from reaching the driver by standing behind the driver's seat. The lower area between the seat and panel is accessible to the driver. The partition is strong enough in conjunction with the entire partition assembly for mounting of such equipment as flare kits, fire extinguishers (1.2kg), microcomputer, public address amplifier, etc. The panel is properly attached to minimize noise and rattles.

The driver's barrier extends continually from the floor area to the ceiling and from the bus wall to the first stanchion immediately behind the driver to provide security to the driver and to limit passenger conversation.

Options for full or partial driver barriers that provide a barrier between entering passengers are available.

TS 75.2 Modesty Panels

Sturdy divider panels constructed of durable, unpainted, corrosion-resistant material complementing the interior are provided to act as both a physical and visual barrier for seated passengers.

Design and installation of modesty panels located in front of forward-facing seats include a handhold or grab handle along its top edge. These dividers are mounted on the sidewall and project toward the aisle no farther than passenger knee projection in longitudinal seats or the aisle side of the transverse seats. Modesty panels extend from at least the window opening of the side windows, and those forward of transverse seats extend downward to 1 and 1½ in. above the floor. Panels forward of longitudinal seats extend to below the level of the seat cushion. Dividers positioned at the doorways, where applicable, provide no less than a 2½ in. clearance between the modesty panel and a fully open, inward opening door, or the path of a deploying flip-out ramp to protect passengers from being pinched. Modesty panels installed at doorways are equipped with grab rails if passenger assists are not provided by other means.

The modesty panel and its mounting withstand a static force of 250 lbs applied to a 4 × 4 in. area in the center of the panel without permanent visible deformation.

TS 75.3 Front End

The entire front end of the bus is sealed to prevent debris accumulation behind the dash and to prevent the driver's feet from kicking or fouling wiring and other equipment. The front end is free of protrusions that are hazardous to passengers standing at the front of the standee line area of the bus during rapid decelerations. Paneling across the front of the bus and any trim around the driver's compartment is formed metal or thermo-formed plastic material. Composite dash panels are reinforced as necessary, vandal-resistant and replaceable. All colored, painted and plated parts forward of the driver's barrier are finished with a surface that reduces glare. Any mounted equipment has provision to support the weight of equipment.

TS 75.4 Rear Bulkhead

Proterra's standard seating for the 35' Catalyst E2 bulkhead does not provide access to the motor compartment area (ProDrive). Any equipment installed at the rear of the bus can be accessed by the removal of fastened panels. The rear bulkhead and rear interior surfaces are material suitable for exterior skin; painted and finished to exterior quality.

The rear bulkhead paneling is contoured to fit the ceiling, side walls and seat backs so that any litter or trash will tend to fall to the floor or seating surface when the bus is on a level surface. Any air vents in this area are louvered to reduce airflow noise and to reduce the probability of trash or liter being thrown or drawn through the grille. Additionally, the rear bulkhead area is predominately taken up by the rear window.

TS 75.5 Headlining

Ceiling panels are made of durable, corrosion resistant, easily cleanable material. Headlining is supported to prevent buckling, drumming or flexing and is secured without loose edges. Headlining materials are treated or insulated to prevent marks due to condensation where panels are in contact with metal members. Moldings and trim strips, as required to make the edges tamperproof, are stainless steel, aluminum or plastic, colored to complement the ceiling material. Headlining panels covering operational equipment that is mounted above the ceiling is on hinges for ease of service but retained to prevent inadvertent opening.

TS 75.6 Fastening

Interior panels are attached so that there are no exposed unfinished or rough edges or rough surfaces. Fasteners are corrosion resistant. Panels and fasteners are not easily removable by passengers. Exposed interior fasteners are minimized, and where required are tamper resistant.

TS 75.7 Insulation

The Proterra Catalyst insulation meets the requirement of FMVSS 302. It has a composite body that provides even better insulation performance than adding insulation to a metal body bus. Composite body offers better U-factor / insulating properties. Insulation properties are unimpaired during the service life of the bus. Any insulation material used inside the motor compartment will not absorb or retain oils or water and are designed to prevent casual damage that may occur during maintenance operations.

The bus body is thoroughly sealed so that the driver or passengers cannot feel drafts during normal operations with the passenger doors closed.

TS 75.8 Floor Covering

The floor covering has a non-skid walking surface that remains effective in all weather conditions. The floor covering, as well as transitions of flooring material to the main floor and to the entrance and exit area, is smooth and present no tripping hazards. Seams are sealed/welded per manufacturer's specifications. The standee line is approximately 2 in. wide and extends across the bus aisle. The color and pattern is consistent throughout the floor covering.

Any areas on the floor that are not intended for standees, such as areas "swept" during passenger door operation, are clearly and permanently marked.

The floor is easily cleaned and arranged to minimize debris accumulation.

A one-piece center strip extends from the vertical wall of the rear settee between the aisle sides of transverse seats to the standee line. The floor is of a bi-level construction and the center strip is one piece at each level. The covering between the center strip and the wheel housings may be separate pieces. At the rear door, a separate strip as wide as the door extends from the center strip to the outboard edge of the rear/exit area.

The floor under the seats is covered with smooth surface flooring material. The floor covering shall closely fit the sidewall in a fully sealed butt joint or extend to the top of the cove.

TS 75.9 Interior Lighting

The light source is located to minimize windshield glare, with distribution of the light focused primarily on the passengers' reading plane while casting sufficient light onto the advertising display. The lighting system is designed to form part of or the entire air distribution duct.

The lens material is translucent polycarbonate. Lenses are designed to effectively "mask" the light source. Lenses are sealed to inhibit incursion of dust and insects yet be easily removable for service.

Access panels are provided to allow servicing of components located behind light panels. The entire light fixture is hinged.

TS 75.10 Passenger

The driver can select either dim, off or bright for interior lighting. When in “day run” mode, all interior lights will be as selected by the driver.

In “night run” mode, the front most lights on each side (behind the driver and the front door) are turned on only when either door is opened. With both doors closed, the front most lights will be off to minimize light reflection and glare on the windshield. The rear lights will be on in the setting selected by the driver (off, dim or bright).

Optionally, all of the lights can be configured to turn on to the dim or bright position when either door is opened.

All interior lighting is turned off whenever the transmission selector is in reverse.

The interior lights are LED.

TS 75.11 Driver’s Area

The driver’s area has a light to provide general illumination, and it illuminates the half of the steering wheel nearest the driver to a level of 5 to 10 foot-candles.

TS 75.12 Seating Areas

Seating lights were optimized to reduce glare on the driver’s area. With the front door closed and cabin lighting on (full and half, bright and dim) the light provided on a 1 sq. ft. plane at an angle of 45 degrees from horizontal, centered 33 in. above the floor and 24 in. in front of the seat back at each seat position. Average light level for the rear bench seats is above 7 foot-candles.

TS 75.13 Vestibules/Doors

Floor surface in the aisles is a minimum of 10 foot-candles, and the vestibule area a minimum of 4 foot-candles with the front doors open and a minimum of 2 foot-candles with the front doors closed. The front entrance area and curb lights illuminate when the front door is open. Rear exit area and curb lights illuminate when the rear door is opened.

Proterra and our customers have evaluated the light levels and found this to be the optimum design for passenger safety and reduced glare.

TS 75.14 Step Lighting

Step lighting for the intermediate steps between lower and upper floor levels is a minimum of 4 foot-candles and illuminates at all times in “night run” position and when doors are open in “day run” position. The step lighting is low profile to minimize tripping and snagging hazards for passengers and is shielded as necessary to protect passengers’ eyes from glare.

TS 75.15 Ramp Lighting

Exterior and interior ramp lighting comply with federal regulations.

TS 75.16 Farebox Lighting

A light fixture is mounted in the ceiling above the farebox location. The fixture is capable of projecting a concentrated beam of light on the farebox. This light will automatically come on whenever the front doors are opened and the run switch is in the “night run” position. Additionally the driver can command the fare box lighting on when the front door is open with a switch in the driver’s workplace.

TS 76. Fare Collection

Space and structural provisions are made for installation of currently available fare collection devices, which is as far forward as practicable. Location of the fare collection device does not restrict traffic in the vestibule, including wheelchairs if a front door loading device is used, and allows the driver to easily reach the farebox controls and to view the fare register. The farebox does not restrict access to the driver’s area, does not restrict operation of driver’s controls and does not—either by itself or in combination with stanchions, transfer mounting, cutting and punching equipment, or route destination signs—restrict the driver’s field of view per SAE Recommended Practice J1050. The location and mounting of the fare collection device allows use, without restriction, by passengers. The farebox location permits accessibility to the vault for easy manual removal or attachment of suction devices. Meters and counters on the farebox are readable on a daily basis. The floor under the farebox is reinforced as necessary to provide a sturdy mounting platform and to prevent shaking of the farebox.

Transfer mounting, cutting and punching equipment will be located in a position convenient to the driver.

TS 77. Interior Access Panels and Doors

Access for maintenance and replacement of equipment is provided by panels and doors that appear to be an integral part of the interior. Access doors are hinged with gas props or over-center springs, where practical, to hold the doors out of the mechanic’s way. Panels prevent entry of mechanism lubricant into the bus interior.

Some access doors are secured with hand screws or latches. All fasteners that retain access panels are, whenever practical, captive in the cover. Other access doors are secured with locks. The locks are standardized so that only one tool is required to open access doors on the bus.

TS 77.1 Floor Panels

There are no access openings in the floor.

PASSENGER ACCOMMODATIONS

TS 78. Passenger Seating

TS 78.1 Arrangements and Seat Style

The standard passenger seating arrangement in the bus is such that seating capacity is maximized. Passenger seats are arranged in a transverse, forward-facing configuration, except at the wheel housings where aisle-facing seats may be arranged as appropriate with due regard for passenger access and comfort. Other areas where aisle-facing seats may be provided are at wheelchair securement areas and platforms. Proterra's standard seating for the 35' Catalyst E2 vehicle is a 29-passenger, USSC Gemini seats. Optional seating arrangements are available.

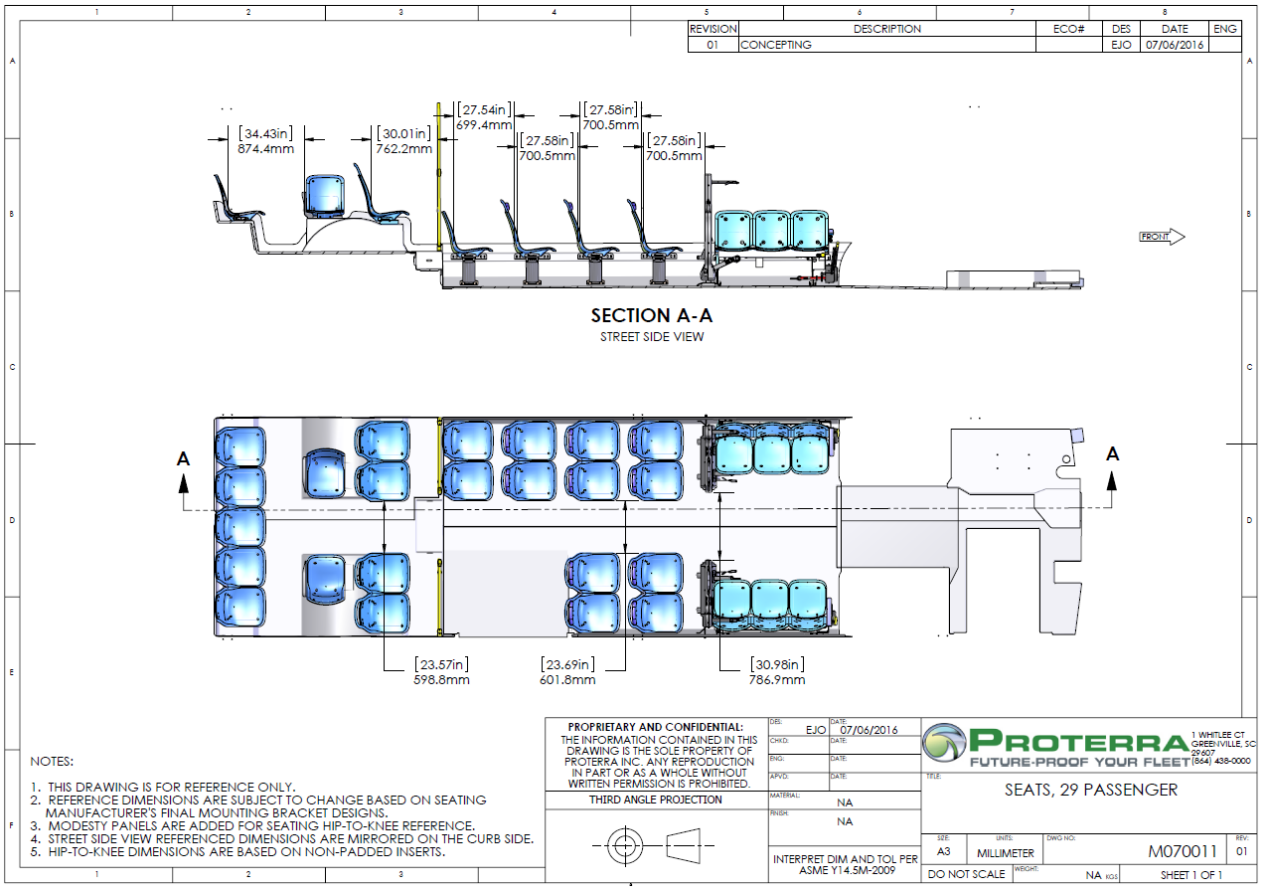


Figure 17- 35' Catalyst Seating Layout

TS 78.2 Rearward Facing Seats

Rearward facing seats are not installed.

TS 78.3 Padded Inserts/Cushioned Seats

In the standard configuration, the seats are equipped with upholstered vandal resistant inserts throughout the bus. Options are available.

TS 78.4 Seat back fitness

In the standard configuration, the seat back insert thickness does not exceed 1in. in the knee room area. Options are available.

TS 78.5 Drain Hole in Seats

The standard configuration is for no drain hole provision in the seat inserts. Options are available.

TS 78.6 Hip-to-Knee Room

Hip-to-knee room measured from the center of the seating position, from the front of one seat back horizontally across the highest part of the seat to a vertical surface immediately in front, is a minimum of 26 in. At all seating positions in paired transverse seats immediately behind other seating positions, hip-to-knee room is no less than 27 in.

TS 78.7 Foot Room

Foot room, measured at the floor forward from a point vertically below the front of the seat cushion, is no less than 14 in. Seats immediately behind the wheel housings and modesty panels may have foot room reduced.

TS 78.8 Aisles

The aisle between the seats is no less than 20 in. wide at seated passenger hip height. Seat backs are shaped to increase this dimension to no less than 24 in. at 32 in. above the floor (standing passenger hip height).

TS 78.9 Dimensions

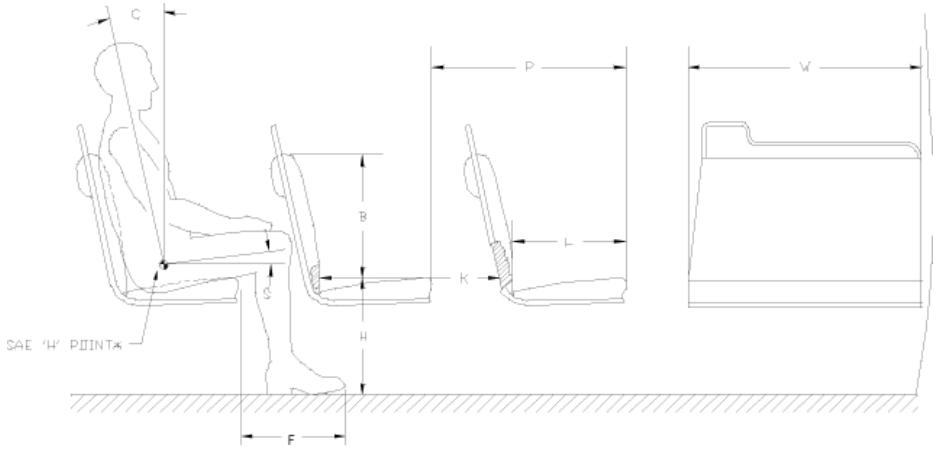


Figure 18- Seating Dimensions and Standard Configuration

Proterra complies with this paragraph. Seat dimensions for the various seating arrangements have the following dimensions (refer to Figure 18):

- The width, W, of the two-passenger transverse seat is a minimum 35 in.
- The length, L, is 17 in., ±1 in.
- The seat back height, B, is a minimum of 15 in.
- The seat height, H, is 17 in., ± 1 in. For the rear lounge (or settee) and longitudinal seats, and seats located above raised areas for storage of under-floor components, a cushion height of up to 18 in., ±2 in., will be allowed.
- Foot room = F.
- The seat cushion slope, S, is between 5 and 11 deg.
- The seat back slope, C, is between 8 and 17 deg.
- Hip to knee room = K.
- The pitch, P, is shown as reference only.

TS 78.10 Structure and Design

The passenger seat frame and its supporting structure is constructed and mounted so that space under the seat is maximized and is completely free of obstructions to facilitate cleaning.

Seats, structures and restraints around the securement area do not infringe into the mobility device envelope or maneuverability.

The transverse seat structure is fully cantilevered from the sidewall with sufficient strength for the intended service. The lowest part of the seat assembly that is within 12 in. of the aisle is at least 10 in. above the floor.

In locations at which cantilevered installation is precluded by design and/or structure, other seat mounting may be used.

All transverse objects—including seat backs, modesty panels, and longitudinal seats—in front of forward-facing seats do not impart a compressive load in excess of 1000lbs onto the femur of passengers ranging in size from a 5th-percentile female to a 95th-percentile male during a 10g deceleration of the bus. This deceleration peaks at 0.05 to 0.015 seconds from initiation. Permanent deformation of the seat resulting from two 95th-percentile males striking the seat back during this 10g deceleration does not exceed 2 in., measured at the aisle side of the seat frame at height H. The seat back does not deflect more than 14 in., measured at the top of the seat back, in a controlled manner to minimize passenger injury. Structural failure of any part of the seat or sidewall does not introduce a laceration hazard.

The seat assembly withstands static vertical forces of 500 lbs applied to the top of the seat cushion in each seating position with less than ¼ in. permanent deformation in the seat or its mountings. The seat assembly withstands static horizontal forces of 500 lbs evenly distributed along the top of the seat back with less than ¼in. permanent deformation in the seat or its mountings. The seat backs at the aisle position and at the window position withstands repeated impacts of two 40-lb sandbags without visible deterioration.

The back of each transverse seat incorporates a handhold no less than ⅞ in. in diameter for standees and seat access/egress. The handhold will not be a safety hazard during severe decelerations. The handhold extends above the seat back near the aisle so that standees shall have a convenient vertical assist, no less than 4 in. long that may be grasped with the full hand. This handhold does not cause a standee using this assist to interfere with a seated 50th-percentile male passenger. The handhold is also usable by a 5th-percentile female, as well as by larger passengers, to assist with seat access/egress for either transverse seating position. The upper rear portion of the seat back and the seat back handhold immediately forward of transverse seats are padded and/or constructed of energy-absorbing materials. During a 10g deceleration of the bus, the HIC number (as defined by SAE Standard J211a) does not exceed 400 for passengers ranging in size from a 5th percentile female through a 95th percentile male.

The seat back handhold may be deleted from seats that do not have another transverse seat directly behind and where a vertical assist is provided.

Longitudinal seats are the same general design as transverse seats but without seat back handholds. Longitudinal seats may be mounted on the wheelhouses. Armrests are included on the ends of each set of longitudinal seats except on the forward end of a seat set that is immediately to the rear of a transverse seat, the driver's barrier, or a modesty panel, when these fixtures perform the function of restraining passengers from sliding forward off the seat. Armrests are not required on longitudinal seats located in the wheelchair parking area that fold up when the armrest on the adjacent fixed longitudinal seat is within 3½ in. of the end of the seat cushion. Armrests are located from 7 to 9 in. above the seat cushion surface. The area between the armrest and the seat cushion is closed by a barrier or panel. The top and sides of the armrests has a minimum width of 1 in. and is free from sharp protrusions that form a safety hazard.

Seat back handhold and armrests withstand static horizontal and vertical forces of 250 lbs. applied anywhere along their length with less than ¼ in. permanent deformation. Seat back handhold and armrests withstands 25,000 impacts in each direction of a horizontal force of 125 lbs. with less than ¼in. permanent deformation and without visible deterioration.

TS 78.11 Construction and Materials

Selected materials minimize damage from vandalism and reduce cleaning time. The seats are attached to the frame with hex bolts rather than tamper-resistant fasteners. Coloring is consistent throughout the seat material, with no visually exposed portion painted. Any exposed metal touching the sides or the floor of the bus is stainless steel. The seat, pads and cushions are contoured for individuality, lateral support and maximum comfort and fit the framework to reduce exposed edges.

The minimum radius of any part of the seat back, handhold or modesty panel in the head or chest impact zone is a nominal ¼in. The seat back and seat back handhold immediately forward of transverse seats are constructed of energy-absorbing materials to provide passenger protection and, in a severe crash, to allow the passenger to deform the seating materials in the impact areas. Complete seat assemblies are interchangeable to the extent practicable.

TS 79. Passenger Assists

Passenger assists in the form of full grip, vertical stanchions or handholds are provided for the safety of standees and for ingress/egress. Passenger assists are convenient in location, shape and size for both the 95th-percentile male and the 5th-percentile female standee. Starting from the entrance door and moving anywhere in the bus and out the exit door, a vertical assist is provided either as the vertical portion of the seat back assist or as a separate item so that a 5th-percentile female passenger may easily move from one assist to another using one hand and the other without losing support. All handholds and stanchions at the front doorway, around the farebox, and at interior steps for bi-level designs are powder-coated in a high-contrast yellow color. The forward-most vertical stanchions on either side of the aisle immediately behind the driver's area are a stainless steel finish.

TS 79.1 Assists

Excluding those mounted on the seats and doors, the assists have a cross-sectional diameter between 1¼ and 1½ in. or provide an equivalent gripping surface with no corner radii less than ¼ in. All passenger assists permit a full hand grip with no less than 1½ in. of knuckle clearance around the assist. Passenger assists are designed to minimize catching or snagging of clothes or personal items and are capable of passing the NHTSA Drawstring Test.

Any joints in the assist structure is underneath supporting brackets and securely clamped to prevent passengers from moving or twisting the assists. Seat handholds may be of the same construction and finish as the seat frame. Door-mounted passenger assists are powder-coated metal. Connecting tees and angles are powder-coated metal castings. Assists will withstand a force of 300 lbs. applied over a 12in. lineal dimension in any direction normal to the assist without permanent visible deformation. All passenger assist components, including brackets, clamps, screw heads and other fasteners used on the passenger assists are designed to eliminate pinching, snagging and cutting hazards and are free from burrs or rough edges.

TS 79.2 Front Doorway

Front doors, or the entry area, are fitted with ADA-compliant assists. Assists are as far outward as practicable, but located no farther inboard than 6 in. from the outside edge of the entrance step and is easily grasped by a 5th-percentile female boarding from street level. Door assists are functionally continuous with the horizontal front passenger assist and the vertical assist and the assists on the wheel housing or on the front modesty panel.

TS 79.3 Vestibule

The aisle side of the driver's barrier, the wheel housings and when applicable the modesty panels is fitted with vertical passenger assists that are functionally continuous with the overhead assist and that extend to within 36 in. of the floor. These assists have sufficient clearance from the barrier to prevent inadvertent wedging of a passenger's arm.

A horizontal passenger assist is located across the front of the bus and prevents passengers from sustaining injuries on the fare collection device or windshield in the event of a sudden deceleration. Without restricting the vestibule space, the assist provides support for a boarding passenger from the front door through the fare collection procedure. The assist is no less than 36 in. above the floor. The assists at the front of the bus is arranged to permit a 5th-percentile female passenger to easily reach from the door assist, to the front assist, to vertical assists on the driver's barrier, wheel housings or front modesty panel.

TS 79.4 Rear Doorway(s)

Vertical assists that are functionally continuous with the overhead assist are provided at the aisle side of the transverse seat immediately forward of the rear door and on the aisle side of the rear door modesty panel(s). Passenger assists are provided on modesty panels that are functionally continuous with the rear door assists. The exit area is fitted with assists having a cross-sectional diameter between 1¼ and 1½ in. or providing an equivalent gripping surface with no corner radii less than ¼ in., and provides at least 1½ in. of knuckle clearance between the assists and their mounting. The assists are designed to permit a 5th-percentile female to easily move from one assist to another during the entire exiting process. The assists are located no farther inboard than 6 in. from the outside edge of the rear doorway step.

TS 79.5 Overhead

Except forward of the standee line and at the rear door, a continuous, full-grip, overhead assist is provided. This assist is located over the center of the aisle seating position of the transverse seats. The assist is no less than 70 in. above the floor. Optional configurations for grab straps are available.

Overhead assists will simultaneously support 150 lbs on any 12in. length. No more than 5 percent of the full grip feature will be lost due to assist supports.

TS 79.6 Longitudinal Seat Assists

Longitudinal seats have vertical assists located between every other designated seating position, except for seats that fold/flip up to accommodate wheelchair securement. Assists extend from near the leading edge of the seat and are functionally continuous with the overhead assist. Assists are staggered across the aisle from each other where practicable and are no more than 52 in. apart or functionally continuous for a 5th percentile female passenger.

TS 79.7 Wheel Housing Barriers/Assists

Passenger assists are mounted around the exposed sides of the wheel housings, which are designed to prevent passengers from sitting on wheel housings. Such passenger assists also effectively retain items, such as bags and luggage, placed on top of wheel housings.

TS 80. Passenger Doors

Passenger doors and doorways comply with ADA requirements.

The 35’ Catalyst E2 comes standard with pneumatic doors from Ventura Systems. All-electric doors are also available from Ventura Systems. Doorways are provided in the locations and styles as follows.

TS 80.1 Front door

The front door is forward of the front wheels and under direct observation of the driver.

TS 80.2 Rear Door

The curbside doorway centerline is located rearward of the point midway between the front door centerline and the rearmost seat back. The doors are pneumatic and operate per specification at air pressures between 90 and 130 psi.

TS 80.3 Materials and Construction

Structure of the doors, their attachments, inside and outside trim panels and any mechanism exposed to the elements are corrosion resistant. Door panel construction is of corrosion-resistant metal or reinforced non-metallic composite materials. When fully opened, the doors provide a firm support and will not be damaged if used as an assist by passengers during ingress or egress. Door edges are sealed to prevent infiltration of exterior moisture, noise, dirt and air elements from entering the passenger compartment, to the maximum extent possible based on door types.

The closing edge of each door panel has no less than 2 in. of soft weather stripping. The doors, when closed, will be effectively sealed, and the hard surfaces of the doors are at least 4 in. apart (not applicable to single doors). The combined weather seal and window glazing elements of the front door do not exceed 10° of binocular obstruction of the driver’s view through the closed door.

TS 80.4 Dimensions

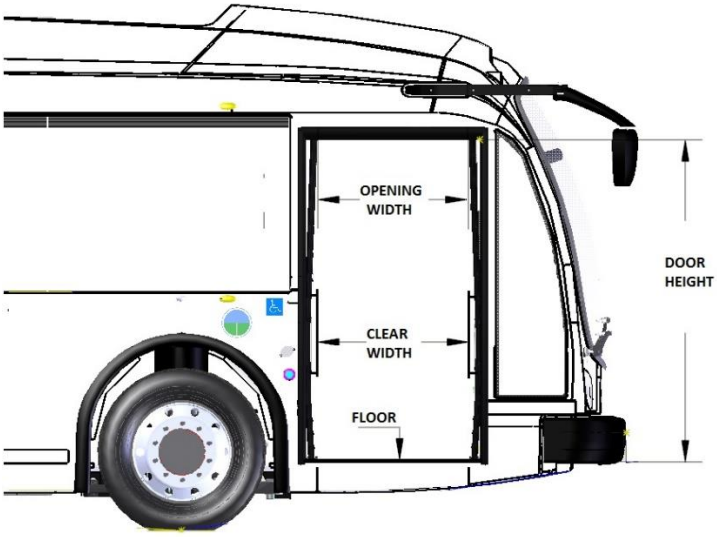


Figure 19-Transit Bus Minimum Door Opening

When open, the front door leave an opening no less than 74.9 in. in height. The front door clear width is 33.2” with the doors fully open. The rear door leaves an opening height of 75.75” and the clear width is 38.6” with the door fully open.

TS 80.5 Door Glazing

The doors on the 35’ Catalyst E2 are both fitted with full length glazing. Because the glazing is full length, it is bonded to the frame to maximize vision area and for aesthetic reasons. There is really no way due to current door construction to fit the glazing into a rubber frame. The manufacturer’s recommended repair procedure for replacing damaged glazing can be provided upon request.

TS 80.6 Door Projection

TS 80.6.1 Exterior

The exterior projection of the front doors beyond the side of the bus is minimized and does not block the line of sight of the rear exit door via the curb side mirror when the doors are fully open. The exterior projection of both doors is minimized and does not exceed 14 in. during the opening or closing cycles or when doors are fully opened

TS 80.6.2 Interior

Projection inside the bus does not cause an obstruction of the rear door mirror or cause a hazard for standees.

TS 80.7 Door Height Above Pavement

It is possible to open and close either passenger door when the bus loaded to gross vehicle weight rating is not knelt and parked with the tires touching an 8in. high curb on a street sloping toward the curb so that the street-side wheels are 5 in. higher than the right-side wheels.

TS 80.8 Closing Force

Closing door edge speed does not exceed 12 in. per second, and opening door speed does not exceed 19 in. per second. Power doors does not slam closed under any circumstance, even if the door is obstructed during the closing cycle. If a door is obstructed during the closing cycle, the pressure exerted on the obstruction does not increase once initial contact has been made.

Doors closed by a return spring or counterweight-type device are equipped with an obstruction-sensing device that, at a minimum, alerts the driver if an obstruction is detected between the closing doors. Doors closed by a return spring or counterweight type device, when unlocked, are capable of being pushed to the point where the door starts to open with a force not to exceed 25 lbs applied to the center edge of the forward door panel.

Whether or not the obstruction-sensing system is present or functional, it is possible to withdraw a 1½ in. diameter cylinder from between the center edges of a closed and locked door with an outward force not greater than 35 lbs.

TS 80.8.1 Rear Door Closing Force

Power-close rear doors are equipped with an obstruction-sensing system such that if an obstruction is within the path of the closing doors, the doors will stop and/or reverse direction. Our standard system will impart a force less than 10-lbs on a 1 sq. in. obstruction.

TS 80.9 Actuators

Doors open or close completely in not more than 3.5 seconds from the time of control actuation and are subject to the closing force requirements.

Door actuators are adjustable so that the door opening and closing speeds can be independently adjustable to satisfy the above requirements. Actuators and the complex door mechanism are concealed from passengers but are easily accessible for servicing. The door actuators are rebuildable. The standard doors are powered by compressed air. The exhaust from the door system is not routed below the floor of the bus. It exits through a muffler on the valve block of the actuator mechanism. The majority of oil in the air lines is separated out by an individual air filter for each door.

Door actuators and associated linkages will maximize door holding forces in the fully open and fully closed positions to provide firm, non-rattling, non-fluttering door panels while minimizing the force exerted by the doors on an obstruction midway between the fully open and closed positions.

The rear door actuator is under the complete control of the vehicle operator and will open and close in response to the driver's control.

Doors that employ a “swing” or pantograph geometry and/or are closed by a return spring or counterweight-type device will be equipped with a positive mechanical holding device that automatically engages and prevents the actuation mechanism from being back-driven from the fully closed position. The holding device is overcome only when the driver’s door control is moved to an “Exit Door Enable” position and the vehicle is moving at a speed of less than 2 mph, or in the event of actuation of the emergency door release.

Locked doors require a force of more than 300 lbs to open manually. When the locked doors are manually forced to open, damage is limited to the bending of minor door linkage with no resulting damage to the doors, actuators or complex mechanism.

TS 80.10 Emergency Operation

In the event of an emergency, it is possible to manually open doors designated as emergency exits from inside the bus using a force of no more than 25 lbs after actuating an unlocking device. The unlocking device is clearly marked as an emergency-only device and requires two distinct actions to actuate. The respective door emergency unlocking device is accessible from the doorway area. The unlocking device is easily reset by the operator without special tools or opening the door mechanism enclosure. Doors that are required to be classified as “emergency exits” meet the requirements of FMVSS 217.

TS 80.11 Door Control

The door control is located in the operator’s area within the hand reach envelope described in SAE Recommended Practice J287, “Driver Hand Control Reach”. The 35’ Catalyst E2 standard configuration is for two push button doors controls switches (front door and back door). The controls do not provide tactile feedback to indicate commanded door position, but resist inadvertent door actuation by providing visual feedback.

An additional exterior front door switch is located on the curbside headlight bezel. This exterior door switch opens the front door and illuminates the interior of the vehicle for 1 minute. The front door remains in the commanded position even if power is removed or lost.

TS 80.12 Door Controller

The doors are operated by push-button controls, conveniently located and operable within the driver’s reach. The push buttons are labeled. There is a separate set of push button controls for the front and rear door. These buttons operate as follows:

Push either the “front or rear door” button to open that door. While the door is opening or closing, a lamp in the button will flash on and off. When the door is fully opened, the button lamp illuminates steadily (does not flash). Push the button again to close the door.

Options for a five-position door controller are also available.

TS 80.13 Door Open/Close

Operation of, and power to, the passenger doors is completely controlled by the operator.

An exterior door control switch is provided and an air dump valve is accessible from the exterior of the bus.

TS 81. Accessibility Provisions

Space and body structural provisions are provided at the front door of the bus to accommodate a low-floor ramp system.

TS 81.1 Loading Systems

A low-floor ramp system is installed at the front door.

TS 81.2 Loading System for 30 to 60ft Low-Floor Bus

An automatically controlled, power-operated ramp system compliant to requirements defined in 49 CFR Part 38, Subpart B, §38.23c provides ingress and egress quickly, safely and comfortably, both in forward and rearward directions, for a passenger in a wheelchair from a level street or curb.

The standard wheelchair loading system is located at the front door, with the ramp being of a simple hinged, flip-out type design being capable of deploying to the ground at a maximum 4:1 slope.

The 35’ Catalyst E2 standard ADA ramp is a 1:4 slope ADA Ramp manufactured by Ricon and electrically operated. Options are available for alternative ADA ramps manufactured by Ricon and Lift-U.

TS 81.3 Wheelchair Accommodations

Two forward-facing locations, as close to the wheelchair loading system as practical, provide parking space and securement system compliant with ADA requirements for a passenger in a wheelchair.

TS 81.4 Interior Circulation

Maneuvering room inside the bus accommodates easy travel for a passenger in a wheelchair from the loading device and from the designated securement area. It is designed so that no portion of the wheelchair protrudes into the aisle of the bus when parked in the designated parking space(s). When the positions are fully utilized, an aisle space of no less than 20 in. is maintained. No width dimension is less than 34 in. Areas requiring 90° turns of wheelchairs have a clearance arc dimension no less than 45 in., and in the parking area where 180° turns are expected, space is clear in a full 60in. diameter circle. A vertical clearance of 12in. above the floor surface is provided on the outside of turning areas for wheelchair footrests.

TS 81.5 Roof Ventilation/Escape Hatches

One roof ventilators are provided and designed to perform as escape hatch. One ventilator/escape hatch is located approximately in the middle of the roof.

SIGNAGE AND COMMUNICATION

TS 82. Destination Signs

A destination sign system is furnished on the front, on the right side near the front door and at the rear of the vehicle. The standard bus is furnished with destination signs in the following configuration:

- Manufacturer: Hanover Displays
- Front Sign: LED, Amber
- Curb Side: LED, Amber
- Rear: LED, Amber
- Street Side: None
- Dash: None

Additional configurations for destination signs are available for selection.

All signs are controlled via a single human-machine interface (HMI). In the absence of a single mobile data terminal (MDT), the HMI is conveniently located within reach of the seated driver.

The destination sign compartments meet the following minimum requirements:

- Compartments are designed to prevent condensation and entry of moisture and dirt.
- Compartments are not designed with active defogging.
- Access is provided to allow cleaning of inside compartment window and unit glazing.
- The front window has an exterior display area of no less than 8.5 in. high by 56 in. wide.

TS 83. Passenger Information and Advertising

TS 83.1 Interior Displays

The standard configuration does not provide provisions on the rear of the driver's barrier or the equipment box located on the wheel well for a frame to retain information such as routes and schedules.

Advertising media 11 in. high and 0.09 in. thick which can be retained near the juncture of the bus ceiling and sidewall. The retainers are concave and support the media without adhesives. The media is illuminated by the interior lighting system.

TS 83.2 Exterior Displays

The standard configuration does not provide provisions to integrate advertising into the exterior design of the bus, i.e. the standard configuration will not include ad-frames. Many Proterra customers use the full vehicle for advertising via full body decals / wraps.

Optional configurations are available.

TS 84. Passenger Stop Request/Exit Signal

TS 84.1 Transit Coach

A passenger “stop requested” signal system that complies with applicable ADA requirements defined in 49 CFR, Part 38.37, is provided. The system consists of a touch tape, chime and interior sign message. The touch tape is accessible to all seated passengers, with provisions for standees. It is easily accessible to all passengers, seated or standing. Vertical touch tape is be provided at each window mullion and adjacent to each wheelchair parking position and priority seating positions.

Additional provisions are included at each wheelchair passenger position and at priority seating positions, to allow a passenger in a mobility aid to easily activate the “stop requested” signal.

An additional “stop request” button on the rear door stanchion is available.

Optional configurations are available.

TS 84.2 Signal Chime

A single “stop requested” chime sounds when the system is first activated. A double chime sounds anytime the system is activated from wheelchair passenger areas.

Exit signals located in the wheelchair passenger area are no higher than 4 ft. above the floor. Instructions are provided to clearly indicate function and operation of these signals.

TS 85. Communications

TS 85.1 Camera Surveillance System

The base vehicle is designed with minimal provisions for a customer requested surveillance system. Proterra can install additional provisions or a full surveillance system at the customer’s request.

TS 85.2 Public Address System

A public address system is provided on each bus for facilitating radio system and driver-originated announcements to passengers.

TS 85.2.1 Speakers

Eight (8) interior speakers and an exterior loudspeaker is provided, semi-flush mounted, on alternate sides of the bus passenger compartment, installed with proper phasing. Total impedance seen at the input connecting is 8 Ohms. Mounting is accomplished with riv-nuts and machine screws. One exterior loudspeaker is provided, mounted near the front door of the coach for announcement and arrival information.

TS 85.3 Automatic Passenger Counter (APC)

The base vehicle is designed with minimal provisions for an automatic passenger counter. At request, Proterra can install additional provisions or a full APC system.

TS 85.4 Radio Handset and Control System

TS 85.4.1 Drivers Speaker

Each bus has the option of a recessed speaker in the ceiling panel above the driver. This speaker is the same component used for the speakers in the passenger compartment. It has 8 Ohms of impedance.

TS 85.4.2 Handset

Each bus will be provided with a handset for driver use.

TS 85.4.3 Driver Display Unit (DDU)

The driver display unit is not included in our standard configuration, but if applicable, is installed as close to the driver's instrument panel as possible.

TS 85.4.4 Emergency Alarm

An emergency alarm is installed and is accessible to the driver but hidden from view.

TS 86. Event Data Recorders (EDR)

No EDR is installed in the standard configuration.

Revision History

Date	Rev.	Approver	Description of Change
09/18/2018	-	C. Prado	Initial Release
10/01/2018	01	C. Prado	Updated sections TS 32, 35, 54-57 & 85
08/10/2020	02	C. Prado	Updated several sections to align with latest technology.

TECHNICAL SPECIFICATIONS

40’ Catalyst™ E2

Table of Contents

GENERAL

TS 1. Scope

Technical specifications define requirements for heavy-duty transit buses, which, by the selection of specifically identified alternative configurations, may be used for both suburban express service and general service on urban arterial streets. Buses have a minimum expected life of twelve (12) years or 500,000 miles, whichever comes first, and are intended for the widest possible spectrum of passengers, including children, adults, the elderly and people with disabilities.

TS 2. Definitions

Alternative: An alternative specification condition to the default bus configuration. The Agency may define alternatives to the default configuration to satisfy local operating requirements. Alternatives for the default configuration will be clearly identified.

Ambient Temperature: The temperature of the surrounding air. For testing purposes, ambient temperature must be between 16°C (50°F) and 38°C (100°F).

Analog Signals: A continuously variable signal that is solely dependent upon magnitude to express information content.

> **NOTE:** Analog signals are used to represent the state of variable devices such as rheostats, potentiometers, temperature probes, etc.

Audible Discrete Frequency: An audible discrete frequency is determined to exist if the sound power level in any 1/3-octave band exceeds the average of the sound power levels of the two adjacent 1/3-octave bands by 4 decibels (dB) or more.

Battery Compartment: Low-voltage energy storage, i.e. 12/24 VDC batteries.

Battery Management System (BMS): Monitors energy, as well as temperature, cell or module voltages, and total pack voltage. The BMS adjusts the control strategy algorithms to maintain the batteries at uniform state of charge and optimal temperatures.

Braking Resistor: Device that converts electrical energy into heat, typically used as a retarder to supplement or replace the regenerative braking.

Burst Pressure: The highest pressure reached in a container during a burst test.

Capacity (fuel container): The water volume of a container in gallons (liters).

Cells: Individual components (i.e., battery or capacitor cells).

Code: A legal requirement.

Combination Gas Relief Device: A relief device that is activated by a combination of high pressures or high temperatures, acting either independently or together.

Composite Container for CNG: A container fabricated of two or more materials that interact to facilitate the container design criteria.

Compressed Natural Gas (CNG): Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form that has been compressed for use as a vehicular fuel.

Container: A pressure vessel, cylinder or cylinders permanently manifolded together, used to store CNG.

Container Appurtenances: Devices connected to container openings for safety, control or operating purposes.

Container Valve: A valve connected directly to a container outlet.

Curb Weight: Weight of vehicle, including maximum fuel, oil and coolant; and all equipment required for operation and required by this Specification, but without passengers or driver.

dBA: Decibels with reference to 0.0002 microbar as measured on the “A” scale.

DC to DC Converter: A module that converts a source of direct current from one voltage level to another.

Default Configuration Bus: The bus described if no alternatives are selected. Signing, colors, the destination sign reading list and other information must be provided by the Agency.

Defueling: The process of removing fuel from a tank.

Defueling Port: Device that allows for vehicle defueling, or the point at which this occurs.

Destroyed: Physically made permanently unusable.

Discrete Signal: A signal that can take only pre-defined values, usually of a binary 0 or 1 nature, where 0 is battery ground potential and 1 is a defined battery positive potential.

DPF: Diesel particulate filter.

Driver’s Eye Range: The 95th-percentile ellipse defined in SAE Recommended Practice J941, except that the height of the ellipse shall be determined from the seat at its reference height.

Energy Density: The relationship between the weight of an energy storage device and its power output in units of watt-hours per kilogram (Wh/kg).

Energy Storage System (ESS):A component or system of components that stores energy and for which its supply of energy is rechargeable by the on-vehicle system(engine/regenerative braking/ generator)or an off-vehicle energy source.

Fill Pressure for CNG: The pressure attained at the actual time of filling. Fill pressure varies according to the gas temperatures in the container, which are dependent on the charging parameters and the ambient conditions. The maximum dispensed pressure shall not exceed 125 percent of service pressure.

Flow Capacity: For natural gas flow, this is the capacity in volume per unit time (normal cubic meters/minute or standard cubic feet per minute) discharged at the required flow rating pressure.

Fuel Line: The pipe, tubing or hose on a vehicle, including all related fittings, through which natural gas passes.

Fusible Material: A metal, alloy or other material capable of being melted by heat.

Fire Resistant: Materials that have a flame spread index less than 150 as measured in a radiant panel flame test per ASTM-E 162-90.

Fireproof: Materials that will not burn or melt at temperatures less than 2000°F.

Free Floor Space: Floor area available to standees, excluding the area under seats, area occupied by feet of seated passengers, the vestibule area forward of the standee line, and any floor space indicated by manufacturer as non-standee areas, such as the floor space “swept” by passenger doors during operation. Floor area of 1.5 sqft shall be allocated for the feet of each seated passenger protruding into the standee area.

Fuel Management System: Natural gas fuel system components that control or contribute to engine air fuel mixing and metering, and the ignition and combustion of a given air-fuel mixture. The fuel management system would include, but is not limited to, reducer/regulator valves, fuel metering equipment (e.g. carburetor, injectors), sensors (e.g., main throttle, wastegate).

GAWR (Gross Axle Weight Rated): The maximum total weight as determined by the axle manufacturer, at which the axle can be safely and reliably operated for its intended purpose.

Gross Load: 150lbs for every designed passenger seating position, for the driver, and for each 1.5 sqft of free floor space.

GVW (Gross Vehicle Weight): Curb weight plus gross load.

GVWR (Gross Vehicle Weight Rated): The maximum total weight as determined by the vehicle manufacturer, at which the vehicle can be safely and reliably operated for its intended purpose.

High Pressure: Those portions of the CNG fuel system that see full container or cylinder pressure.

High Voltage (HV): Greater than 50 V(AC and DC).

Hose: Flexible line.

Hybrid: A vehicle that uses two or more distinct power sources to propel the vehicle.

Hybrid System Controller (HSC): Regulates energy flow throughout hybrid system components in order to provide motive performance and accessory loads, as applicable, while maintaining critical system parameters (voltages, currents, temperatures, etc.) within specified operating ranges.

Hybrid Drive System (HDS): The mechanical and/or electromechanical components, including the engine, traction motors and energy storage system, which comprise the traction drive portion of the hybrid propulsion system.

Intermediate Pressure: The portion of a CNG system after the first pressure regulator, but before the engine pressure regulator. Intermediate pressure on a CNG vehicle is generally from 3.5 to 0.5 MPa (510 to 70 psi).

Inverter: A module that converts DC to and from AC.

Labeled: Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization, which is acceptable to the authority having jurisdiction and concerned with product evaluation, which maintains periodic inspection of production labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Leakage: Release of contents through a Defect or a crack. See *Rupture*.

Line: All tubes, flexible and hard, that carry fluids.

Liner: Inner gas-tight container or gas container to which the overwrap is applied.

Local Regulations: Regulations below the state level.

Low-Floor Bus: A bus that, between at least the front (entrance) and rear (exit) doors, has a floor sufficiently low and level so as to remove the need for steps in the aisle between the doors and in the vicinity of these doors.

Low Voltage (LV):50 V or less (AC and DC).

Lower Explosive Limit: The lowest concentration of gas where, given an ignition source, combustion is possible.

Maximum Service Temperature: The maximum temperature to which a container/cylinder will be subjected in normal service.

Metallic Hose: A hose whose strength depends primarily on the strength of its metallic parts; it can have metallic liners or covers, or both.

Metering Valve: A valve intended to control the rate of flow of natural gas.

Module: An assembly of individual components

Motor (Electric): A device that converts electrical energy into mechanical energy.

Motor (Traction): An electric motor used to power the driving wheels of the bus.

Operating Pressure: The varying pressure developed in a container during service.

Physical Layer: The first layer of the seven-layer International Standards Organization (ISO) Open Systems Interconnect (OSI) reference model. This provides the mechanical, electrical, functional and procedural characteristics required to gain access to the transmission medium (e.g., cable) and is responsible for transporting binary information between computerized systems.

Pipe: Nonflexible line.

Pressure Relief Device (PRD): A pressure and/or temperature activated device used to vent the container/cylinder contents and thereby prevent rupture of an NGV fuel container/cylinder, when subjected to a standard fire test as required by fuel container/cylinder standards.

> **NOTE:** Since this is a pressure-activated device, it may not protect against rupture of the container when the application of heat weakens the container to the point where its rupture pressure is less than the rated burst pressure of the relief device, particularly if the container is partially full.

Power: Work or energy divided by time

Power Density: Power divided by mass, volume or area.

Propulsion System: System that provides propulsion for the vehicle proportional to operator commands. Includes, as applicable, engine, transmission, traction motors, the hybrid drive system,(HDS), energy storage system (ESS), and system controllers including all wiring and converter/inverter.

Real-Time Clock (RTC): Computer clock that keeps track of the current time.

Regenerative Braking : Deceleration of the bus by switching motors to act as generators, which return vehicle kinetic energy to the energy storage system.

Rejectable Damage: In terms of NGV fuel containers/cylinders, this is damage as outlined in CGA C-6.4, “Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations,” and in agreement with the manufacturer’s recommendations.

Retarder: Device used to augment or replace some of the functions of primary friction based braking systems of the bus.

Rupture: Sudden and unstable damage propagation in the structural components of the container resulting in a loss of contents. See *Leakage*.

Seated Load: 150lbs for every designed passenger seating position and for the driver.

SLW (Seated Load Weight): Curb weight plus seated load.

Serial Data Signals: A current loop based representation of ASCII or alphanumeric data used for transferring information between devices by transmitting a sequence of individual bits in a prearranged order of significance.

Service Pressure: The settled pressure at a uniform gas temperature of 21°C (70°F) and full gas content. It is the pressure for which the equipment has been constructed, under normal conditions. Also referred to as the nominal service pressure or working pressure.

Settled Pressure: The gas pressure when a given settled temperature, usually 21°C (70°F), is reached.

Settled Temperature: The uniform gas temperature after any change in temperature caused by filling has dissipated.

Solid State Alternator: A module that converts high-voltage DC to low-voltage DC (typically 12/24 V systems).

Sources of Ignition: Devices or equipment that because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable compressed natural gas-air mixtures when introduced into such a mixture, or when such a mixture comes into contact with them.

Special Tools: Tools not normally stocked by the Agency.

Specification: A particular or detailed statement, account or listing of the various elements, materials, dimensions, etc. involved in the manufacturing and construction of a product.

Standard: A firm guideline from a consensus group. Standards referenced in “Section 6: Technical Specifications” are the latest revisions unless otherwise stated.

Standee Line: A line marked across the bus aisle to designate the forward area that passengers may not occupy when the bus is moving.

State of Charge (SOC): Quantity of electric energy remaining in the battery relative to the maximum rated amp-hour (Ah) capacity of the battery expressed in a percentage. This is a dynamic measurement used for the energy storage system. A full SOC indicates that the energy storage

system cannot accept further charging from the engine-driven generator or the regenerative braking system.

Stress Loops: The “pigtails” commonly used to absorb flexing in piping.

Structure: The basic body, including floor deck material and installation, load-bearing external panels, structural components, axle mounting provisions and suspension beams and attachment points.

Thermally Activated Gas Relief Device: A relief device that is activated by high temperatures and generally contains a fusible material.

> **NOTE:** Since this is a thermally activated device, it does not protect against over-pressure from improper charging practices.

Wheelchair: A mobility aid belonging to any class of three- or four-wheeled devices, usable indoors, designed for and used by individuals with mobility impairments, whether operated manually or powered. A “common wheelchair” is such a device that does not exceed 30 in. in width and 48 in. in length measured 2 in. above the ground, and does not weigh more than 600 lbs when occupied.

TS 3. Referenced Publications

The documents or portions thereof referenced within this specification will be considered part of the requirements of the specification. The edition indicated for each referenced document is the current edition, as of the date of the issuance of this specification.

TS 4. Legal Requirements

Proterra will comply with all applicable federal, state and local regulations. These will include but not be limited to ADA, as well as state and local accessibility, safety and security requirements. Local regulations are defined as those below the state level.

Buses will meet all applicable FMVSS regulations and will accommodate all applicable FMCSR regulations in effect at the location of the Agency and the date of manufacture.

In the event of any conflict between the requirements of these specifications and any applicable legal requirement, the legal requirement will prevail. Technical requirements that exceed the legal requirements are not considered to conflict.

TS 5. Overall Requirements

Proterra will ensure that the application and installation of major bus subcomponents and systems are compliant with all such subcomponent vendors’ requirements and recommendations. Proterra and Agency will identify subcomponent vendors that will submit installation/application approval documents with the completion of a pilot or lead bus. Components used in the vehicle will be of heavy-duty design and proven in transit service.

TS 5.1 Weight

The design goal at Proterra is for each bus to remain as light in weight as possible without degrading safety, appearance, comfort, traction or performance.

Buses at a capacity load will not exceed the tire factor limits, brake test criteria or structural design criteria. See Table 1 for reference.

		Front axle			Rear axle			Total Bus
	No. of people	**Left**	**Right**	**Total**	**Left**	**Right**	**Total**	
Empty bus, full farebox	0			13,359			18,001	31,360
Fully seated, full farebox	41			15,979			21,531	37,510
Fully loaded standee and fully seated, full farebox	73			18,024			24,286	42,310
Crush load (1.5x fully loaded)	110			20,356			27,429	47,785
GVWR				18,078			25,572	43,650
GAWR				18,078			28,660	46,738

Table 1-Bus axle loads

TS 5.2 Capacity

The vehicle is designed to carry the gross vehicle weight, which will not exceed the bus GVWR. The vehicle does not exceed the individual gross axle weight rating (GAWR) at curb weight plus gross load.

TS 5.3 Service Life

The minimum useful design life of the bus in transit service is at least twelve (12) years or 500,000 miles. It is capable of operating at least 40,000 miles per year, including the 12th year.

TS 5.4 Maintenance and Inspection

Scheduled maintenance tasks will be related and in accordance with Proterra's recommended preventative maintenance schedule (along with routine daily service performed during the fueling operations).

Test ports, as required, will be provided for commonly checked functions on the bus, such as air intake, exhaust, hydraulic, pneumatic, charge-air and motor cooling systems.

Proterra will give prime consideration to the routine problems of maintaining the vehicle. All coach components and systems, both mechanical and electrical, which will require periodic physical work or inspection processes are installed so that a minimum of time is consumed in gaining access to the critical repair areas. It will not be necessary to disassemble portions of the coach structure and/or equipment such as seats and flooring under seats in order to gain access to these areas. Each coach will be designed to facilitate the disassembly, reassembly, servicing or maintenance, using tools and equipment that are normally available as standard commercial items. Requirements for the use of unique specialized tools will be minimized.

The body and structure of the coach is made of a monocoque composite material and will be designed for ease of maintenance and repair. Sections of a monocoque composite body that may be damaged in normal service are easily repairable with common composite repair techniques. Ease of repair will be related to the vulnerability of the item to damage in service.

Proterra will provide a list of all special tools and pricing required for maintaining this equipment. Said list will be submitted as a supplement to the Pricing Schedule.

TS 5.5 Interchangeability

Unless otherwise agreed, all units and components procured under a contract, whether provided by suppliers or manufactured by Proterra, are duplicates in design, manufacture and installation to ensure interchangeability among buses in each order group of a procurement. This interchangeability extends to the individual components as well as to their locations in the buses. These components include, but are not limited to, passenger window hardware, interior trim, lamps, lamp lenses and seat assemblies. Components with non-identical functions will not be, or appear to be, interchangeable.

Any one component or unit used in the construction of Proterra buses will be an exact duplicate in design, manufacture and assembly for each bus in each order group of a Contract. Proterra will identify and secure approval for any changes in components or unit construction provided within a contract.

In the event that the Proterra is unable to comply with the interchangeability requirement, the contractor will notify the Agency and obtain the Agency's prior written approval, including any changes in pricing.

Agency will review proposed product changes on a case-by-case basis and has the right to require extended warranties to ensure that product changes perform at least as well as the originally supplied products.

TS 5.6 Training

Proterra will have at least one qualified instructor who will be available at the Agency's property at a time and for a duration mutually agreed to by both parties. Instructor(s) will conduct schools and advise the personnel of the Agency on the proper operation and maintenance of the equipment. Proterra also will provide visual and other teaching aids (such as manuals, slide presentations and literature) for use by the Agency's own training staff, which become the property of the Agency.

The following training is included with the purchase of the bus and charger.

- Operator Training
  - 40 hours of operator training
  - Utilizes a “train-the-trainer” approach to enable customers to provide as much training as required for their operators
  - 50/50 split between classroom and seat-time for the operators
- Bus Maintenance Training
  - 36 hours of vehicle maintenance training.
  - Classroom and hands-on training
- Bus Introduction Training
  - 16 hours of general bus introduction training
  - Meant for supervisors, managers, procurement
- Charger Maintenance Training
  - 24 hours of charger maintenance training
  - Classroom and hands-on training

Additional training options and curriculum can be provided upon request.

TS 5.6.1 Technical/Service Representatives

Proterra will, at its own expense, have one or more competent technical service representatives available on request to assist the Agency in the solution of engineering or design problems within the scope of the specifications that may arise during the warranty period. This does not relieve the Proterra of responsibilities under the provisions of “Section 7: Warranty Requirements.”

TS 5.7 Operating Environment

The bus achieves normal operation in ambient temperature ranges of 10 ºF to 115 ºF, at relative humidity between 5 percent and 100 percent, and at altitudes up to 3000 ft above sea level. Degradation of performance due to atmospheric conditions is minimized at temperatures below 10 °F, above 115 °F or at altitudes above 3000 ft. Speed, gradeability and acceleration performance requirements are met at, or corrected to, 77 °F, 29.31 in. Hg, dry air per SAEJ1995.

TS 5.8 Noise

TS 5.8.1 Interior Noise

The composite body structure provides sufficient sound insulation so that a sound source with a level of 80 dBA measured at the outside skin of the bus has a sound level of 65 dBA or less at any point inside the bus. These conditions prevail with all openings, including doors and windows, closed and with the motor and accessories switched off.

The bus-generated noise level experienced by any rider at any seat location in the bus does not exceed 80 dBA, on average. Sound will be measured during a zero to 35 mph acceleration event, on a smooth level surface. All windows and doors will be closed during test. Pending testing,

measurements of interior noise levels will be taken in accordance with Altoona 7-1 Interior Noise Test Procedure.

TS 5.8.2 Exterior Noise

Airborne noise generated by the bus and measured from either side does not exceed 80dBA under full power acceleration when operated at 0 to 35 mph at curb weight. The maximum noise level generated by the bus pulling away from a stop at full power does not exceed 83 dBA. The bus-generated noise at curb idle does not exceed 65dBA. If the noise contained an audible discrete frequency, a penalty of 5 dBA was added to the sound level measured. Proterra will comply with the exterior noise requirements defined in local laws and ordinances identified by the Agency and SAEJ366.

TS 5.9 Fire Safety

The bus is designed and manufactured in accordance with all applicable fire safety and smoke emission regulations. These provisions include the use of fire-retardant/low-smoke materials, fire detection systems, bulkheads and facilitation of passenger evacuation.

TS 5.9.1 Materials

All materials used in the construction of the passenger compartment of the bus are in accordance with the Recommended Fire Safety Practices defined in FMVSS 302.

An option is available to meet the requirement for FTA Docket 90-A.

TS 5.10 Fire Suppression

Proterra's Battery Management System (BMS) provides a constant mechanism for fire detection in the Energy Storage System (ESS). In addition, operating electric propulsions systems does not generate the heat like an internal combustion engine; with the maximum temperature in the rear ProDrive area typically measuring at 10 degrees F warmer than the ambient temperature. As such, the standard configuration is for no fire suppression system.

Options for fire suppression systems are available if the agency has a strong preference for these systems.

TS 5.11 Respect for the Environment

In the design and manufacture of the bus, Proterra has made every effort to reduce the amount of potentially hazardous waste. In accordance with Section 6002 of the Resource Conservation and Recovery Act, Proterra uses, whenever possible and allowed by the specifications, recycled materials in the manufacture of the bus.

TS 6. Physical Size

With exceptions such as exterior mirrors, marker and signal lights, bumpers, fender skirts, washers, wipers, ad frames, cameras, object detection systems, bicycle racks, feelers and rubrails, the bus has the following overall dimensions at static conditions and design height.

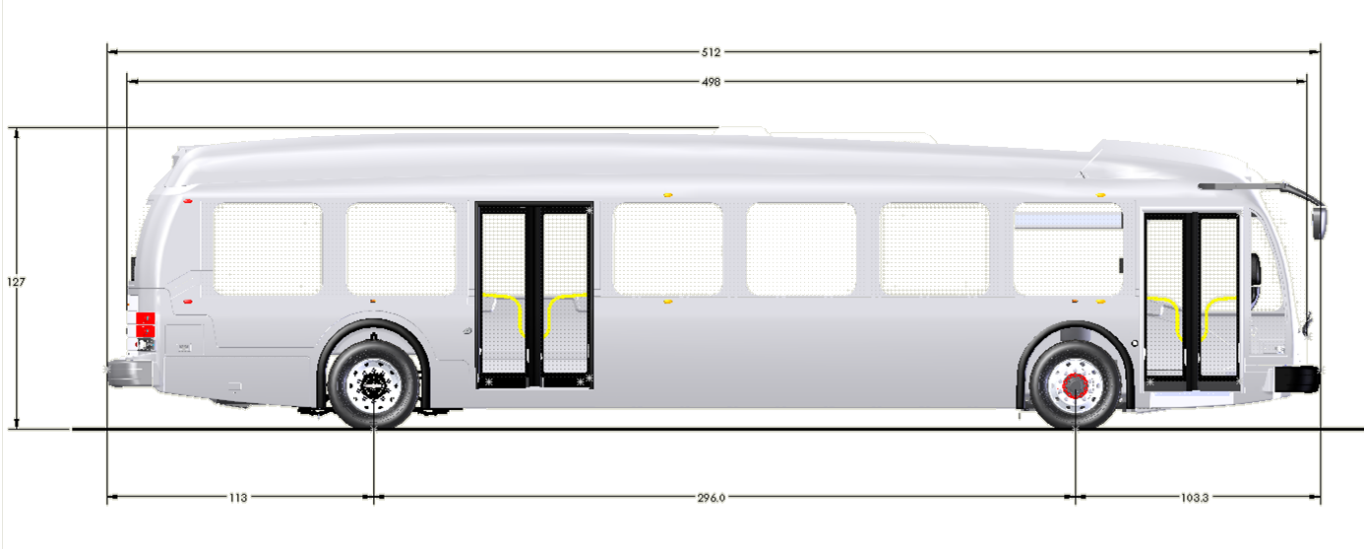


Figure 1- Transit Bus Exterior Dimensions

TS 6.1 Bus Length

The 40’ Catalyst E2 is 42 ft., 6 in. measured from bumper to bumper.

TS 6.2 Bus Width

The 40’ Catalyst E2 meets the specification of 102 in. wide exclusive of the mirrors and wheel skirts.

TS 6.3 Bus Height

The 40’ Catalyst E2 is 128 in. high, including all rigid roof-mounted items.

TS 6.4 Step Height

The step height does not exceed 16.5 in. at the front doorway without kneeling and does not exceed 15.5 in. at the step.

The rear step height does not exceed 17 in. The bus comes standard with an automatic ride height feature which provides an automatic ¾ inch change in ride height as the doors are opened and closed. Kneeling is driver controlled and can be adjusted up to 3 inches. The raised aisle floor in the rear of the bus is designed with two steps.

TS 6.5 Underbody Clearance

The bus maintains the minimum clearance dimensions as defined and shown in Figure 2 of SAE Standard J689, regardless of load up to the gross vehicle weight rating. This is accomplished by the use of ride height sensors on all four corners of the vehicle.

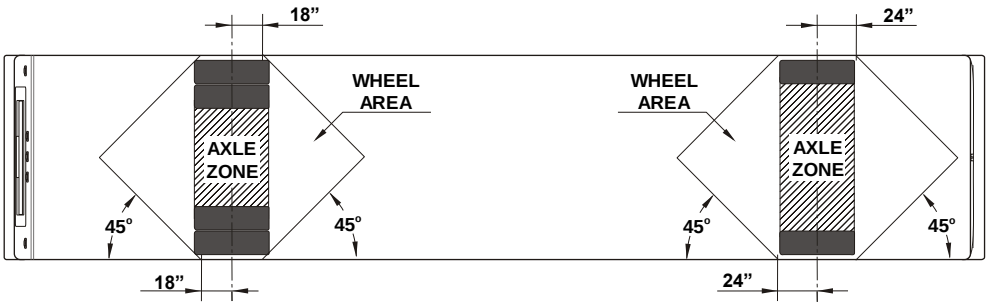


Figure 2-Transit Bus Minimum Road Clearance

TS 6.6 Ramp Clearances

The approach angle is the angle measured between a line tangent to the front tire static loaded radius arc and the initial point of structural interference forward of the front tire to the ground.

The departure angle is the angle measured between a line tangent to the rear tire static loaded radius arc and the initial point of structural interference rearward of the rear tire to the ground.

The breakover angle is the angle measured between two lines tangent to the front and rear tire static loaded radius and intersecting at a point on the underside of the vehicle that defines the largest ramp over which the vehicle can roll. See Figure 3.

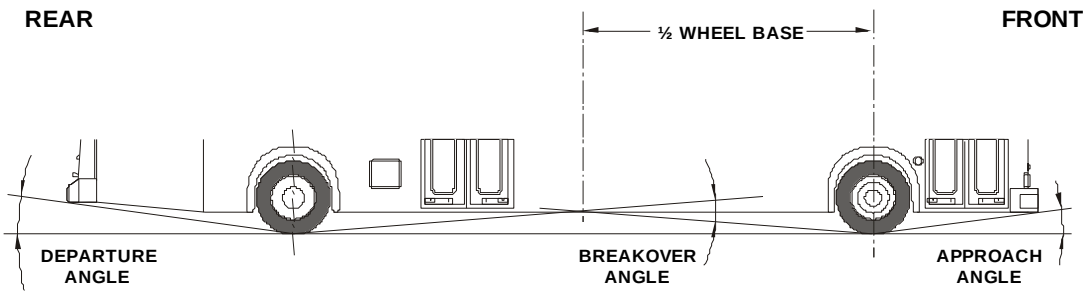


Figure 3-Ramp Clearance

The 40’ Catalyst E2 provides a 7 degrees front breakover angle. This breakover angle is the result of placing the high voltage battery packs under the floor, between the axles (much like leading EV automobile designs, e.g. Tesla, Chevrolet Bolt, BMW i3, etc.). See Table 2 for Proterra angles.

	APTA Spec	40’ Catalyst E2
Angle	**30 to 45 ft Bus**	**40 ft Bus**
Approach	8.6° (min.)	8.7°
Front breakover	7.5° (min.)	7.0°
Departure	7.5° (min.)	9.0°

Table 2- Alternative Breakover Angle

TS 6.7 Ground Clearance

The 40’ Catalyst E2 meets all APTA requirements at Dynamic Ride Height. When the vehicle is stopped and the doors are opened the vehicle is static and is closer to the ground by ¾ in. With the doors closed, the vehicle is dynamic and meets the following ground clearances.

Ground Clearance: Ground clearance is no less than 9 inches (8 inches at jacking pad), except within the axle zone and wheel area.

Axle Clearance: Axle zone clearance, which is the projected area between tires and wheels on the same axial centerline, is 6”.

Wheel Area Clearance: Wheel area clearance, is 7.85” for parts fixed to the bus body and 6” for parts that move vertically with the axles. Wheel area items are protected by a skid plate.

The jacking pad clearance is 8.5” with 1/4” plate and 1/4" bond gap. Ride height sensor are provided on each corner of the bus to keep the bus at the same ride height no matter the weight or capacity of the bus.

TS 6.8 Floor Height

Height of the step above the street is no more than 16 in. measured at the centerline of the front doorway. The height of the step above the street is no more than 17in. measured at the centerline of the rear doorway. All floor measurements are with the bus at the design running height and on a level surface and with the standard installed tires. Two steps are designed to accommodate a raised aisle floor in the rear of the bus. The floor is inclined along the longitudinal axis of the bus, and the incline will be less than 3 1/2 degrees off the horizontal except locally at the doors where a maximum 5 degrees slope toward the door is allowed. The floor height is dictated by the placement of the battery packs under the floor and between the wheels which provides the following major benefits:

- Lower center of gravity, better handling
- Increased safety
- No HV batteries inside the passenger compartment
- Batteries are lower than the side impact height for automobiles

Proterra buses are capable of full kneeling functionality.

TS 6.9 Interior Headroom

Headroom above the aisle and at the centerline of the aisle seats is not less than 78 in. in the forward half of the bus tapering to no less than 74 in. forward of the rear settee. At the centerline of the window seats, headroom is not lower than 65 in. Headroom at the back of the rear bench seat may be reduced to a minimum of 56 in, but it will increase to the ceiling height at the front of the seat cushion. In any area of the bus directly over the head of a seated passenger and positioned where a passenger entering or leaving the seat is prone to strike his/her head, padding will be provided on the overhead paneling.

TS 6.10 Aisle Width

The minimum clear aisle width between pairs of transverse seats with all attached hardware is at least 22 in.

The aisle width between the front wheelhouses is at least 35.5 in., and the entire area between the front wheelhouses is available for passengers and mobility aid devices.

VEHICLE PERFORMANCE

TS 7. Power Requirements

The propulsion system is sized to provide sufficient power to enable the bus to meet the defined acceleration, top speed and gradeability requirements, and operate all propulsion-driven accessories using actual road test results and computerized vehicle performance data.

> **Note**: The performance results below are representative of a 40’ Catalyst E2 bus with a ProDrive propulsion system. Proterra offers several different battery configuration and

propulsion systems options which will have different performance results from what is stated below. The results below summarize the minimum performance capability of a Catalyst 40' E2 bus.

TS 7.1 Top Speed

40' Catalyst E2 is capable of achieving a top speed of 65 mph on a straight, level road at GVWR with all accessories operating. The bus is capable of safely maintaining the vehicle speed according to the recommendations by the tire manufacturer.

TS 7.2 Gradeability

The ProDrive propulsion system enables the bus to achieve a speed of 40 mph on a 2½ percent ascending grade and 15 mph on a 10 percent ascending grade. As an exception, under some circumstances the vehicle speed may be reduced to 28 MPH on a 2.5% grade and to 12 MPH on a 10% grade to thermally protect drivetrain components. The two contributing factors are ambient temperature and time spent ascending the grade. Gradeability requirements are met on grades with a dry commercial asphalt or concrete pavement at GVWR with all accessories operating.

TS 7.3 Acceleration

The acceleration of the 40' Catalyst E2 meet the requirements in Table 3 below and is sufficiently gradual and smooth to prevent throwing standing passengers off-balance. Acceleration measurement commence when the accelerator is depressed. The acceleration produces a maximum jerk rate of 0.3 g's/sec.

Speed (mph)	Maximum time (seconds)
10	5
20	10
30	18
40	30
50	60
Top speed	

Table 3-Maximum Start Acceleration Times on a Level Surface[1]

1. Vehicle weight = GVWR

TS 7.4 Operating Range

Proterra offers a modular, technology-centric approach to vehicle configuration. Customers can choose from two vehicle sizes and can select their energy level, as well as charging solutions to meet the needs of their specific routes. Catalyst buses can be upgraded to meet changing needs throughout the vehicles' life. The 40' Catalyst platform allows for a variety of different battery configurations and charging options to meet customer requirements.

TS 8. Fuel Economy (Design Operating Profile)

Proterra utilizes proprietary route simulation tools to predict real world range and fuel economy for customer routes. Please work with Proterra representatives to determine the most appropriate solution to meet route requirements.

TS 9. Propulsion System Description

TS 9.1 ProDrive

The Proterra 40’ Catalyst E2 is a 100% battery electric powered transit bus. Proterra's high-performance ProDrive™ drivetrain maximizes performance and efficiency to meet the challenges of most routes.

It consists of three major components; the permanent magnet synchronous traction motor, the power inverter, and the two-speed automated manual transmission where the traction motor and the transmission are the only moving parts.

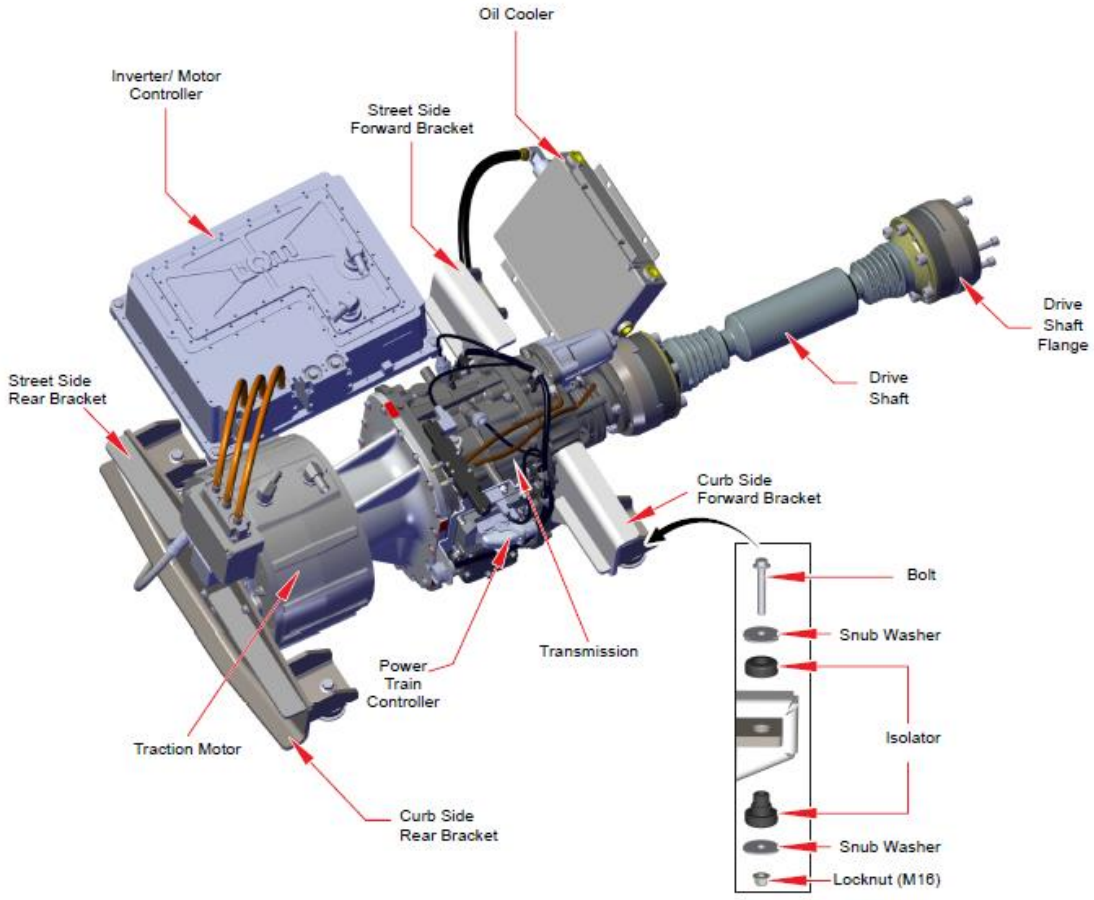


Figure 4-Catalyst ProDrive Propulsion System

The traction motor is capable of 250kW peak power and the traction motor is controlled via an inverter which receives direct current from the high voltage battery system. Both the motor and inverter are liquid cooled.

Parameter	Specification
Peak Power	250 kW
Continuous Power	180 kW
Peak Torque	900 Nm
Continuous Torque	550 Nm
Full Power	600 V DC and up
Max Speed (full performance)	5500 RPM

Table 4-Traction Motor Technical Specifications

The unique Proterra two-speed transmission contains a planetary gear set with a pneumatically driven shift mechanism. The transmission is oil-cooled and contains an additional oil cooler to ensure that the transmission remain at ideal temperatures under the most difficult driving cycles. The output of the transmission supplies power to the ZF drop center rear axle.

All actuators and sensors for the transmission are connected to the Proterra powertrain controller which controls both the torque/speed commands of the traction motor as well as the transmission shift actuation. These controls have been optimized for transit bus service for best drivability and maximized efficiency. They are designed and calibrated using real world data from customer vehicles, engineering tests utilizing proprietary drive cycles and standard FTA drive cycles (CBD, Arterial, Commuter), and using our high-fidelity simulation tool similar to the model used for fuel economy analysis.

With the two-speed transmission Proterra can utilize a smaller, lighter traction motor to meet the needed performance requirements while still offering excellent efficiency. This transmission also allows the powertrain system the flexibility to provide the needed torque while also operating at more efficient traction motor operating points.

The combination of the traction motor, the power inverter, and the transmission are a primary reason why the Catalyst broke the Altoona records for acceleration, efficiency, and gradeability

TS 9.2 DuoPower

The new “DuoPower” Proterra Catalyst drivetrain system employs state-of-the-art electric vehicle technology that is conveniently integrated into the rear axle of the bus. Proterra uses two permanent magnet synchronous motors, each directly coupled to a multi-speed gearbox that independently drives its respective wheel. The system is capable of up to 475 peak horsepower and is controlled via an inverter which receives direct current from the high voltage battery system. The drivetrain system uses a liquid cooling circuit to reject heat through the bus heat exchanger.

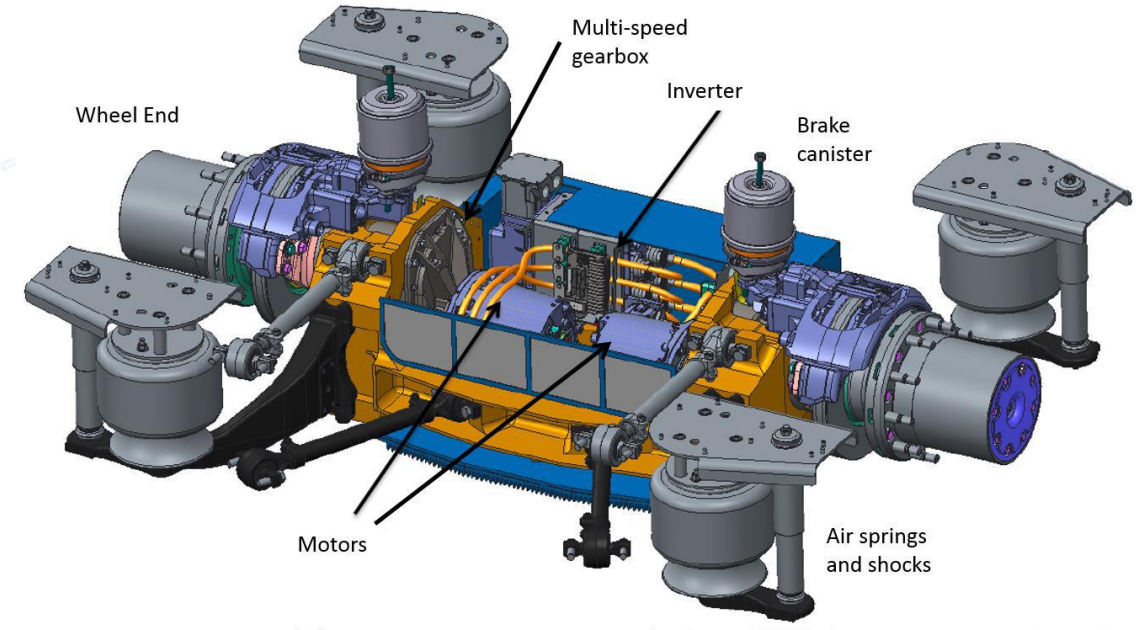


Figure 5-Catalyst DuoPower Drivetrain

The Proterra multi-speed gearbox is purpose designed and built for heavy duty electric vehicle operation. The gear ratios were selected to maximize fuel economy for transit bus operation while ensuring best in class performance. The gearbox contains a pneumatically actuated shift mechanism to seamless shift

between low and high gear. An external electric pump is used to circulate oil for lubrication and heat rejection. The output of the gearbox is coupled to a planetary gear reduction unit housed within the wheel hub.

All actuators and sensors for the gearbox are connected to the Proterra powertrain controller which is responsible shift actuation and motor torque commands. The controls have been optimized for transit bus service for best drivability and maximized efficiency. These controls are designed and calibrated using real world data from customer vehicles, engineering tests utilizing proprietary drive cycles and standard FTA drive cycles (CBD, Arterial, Commuter), and using our high-fidelity simulation tool similar to the model used for this fuel economy analysis.

With the multi-speed gearboxes Proterra can utilize smaller, lighter weight traction motors to achieve best in class acceleration and gradeability performance. The gearboxes also allow the drivetrain system the flexibility to operating at more efficient motor operating points, thus improving overall vehicle efficiency.

The combination of the traction motors, inverter, and the gearboxes integrated into a compact and lightweight package are a primary reason why the Catalyst continues to provided best in class acceleration, efficiency, and gradeability for customers.

Drivetrain System Specifications:

Parameter	Specification
Peak Power	356 kW
Continuous Power	192 kW
Peak Wheel Torque	21,000 Nm
Continuous Wheel Torque	13,500 Nm
Max Vehicle Speed	65 MPH

The Proterra Catalyst drivetrain system is a new product that takes learnings from our first power-train system to improve performance and efficiency. The original version of the Proterra powertrain has accumulated over 3.7 million miles of in revenue service.

The data and customer feedback from this time in service has been essential in developing the new drivetrain system. The design life of the drivetrain system is 500,000 miles of heavy-duty transit bus use.

Advantages

- Best in class low speed torque, can achieve grades up to 20%
- Multi-speed gearbox enables this drivetrain to achieve the highest bus efficiency compared to other transit buses
- Very high efficiency = >95% motor efficiency
- High power = 475 HP
- Lightweight and compact => all components located between rear wheels
- Long life = > Designed for full life of vehicle (500,000 mi)
- Few moving parts = Traction motor has ~3 moving parts and the inverter has zero
- Use of industry standard motor and inverter components means better reliability and uptime

TS 9.3 Propulsion Control System

The propulsion control system is capable of transmitting and receiving electronic inputs and data from drivetrain components, and broadcasting that data to other vehicle systems. Communication between electronic drivetrain components and other vehicle systems is made using the communications networks.

The vehicle system has onboard diagnostic capabilities able to monitor vital motor functions, store and time stamp parameter conditions in memory, and communicate faults and vital conditions to service personnel. Diagnostic reader device connector ports, suitably protected against dirt and moisture, is provided in the operator's area. The onboard diagnostic system informs the operator via visual and/or audible alarms when out of parameter conditions exist for vital engine functions. The on-board diagnostic system has capabilities for storing hard and soft codes and processing data and provide detailed information/reports on various aspects of fleet usage. The information is retrievable via cabling or wireless transmission to a laptop.

The motor drive protects the drive system against progressive damage. The system monitors conditions critical for safe operation and automatically de-rate power and/or speed and initiate motor shutdown as needed. The on-board diagnostic system triggers a visual and audible alarm to the operator when the motor control unit detects a malfunction and the engine protection system is activated.

The propulsion control system is designed with redundancy in mind. For certain failure conditions, a “limp home mode” driving condition is available which enables limited vehicle operation to reduce the need for towing. It is Proterra’s design principle to allow for some level of safe operation if the failure allows.

A control is available to the operator to allow a 30-second override, which, when depressed, will allow the operator to delay the drive system shutdown but not the activation and alarm system.

TS 9.4 Propulsion System Service

The propulsion motor is designed to operate for not less than 300,000 miles without major failure or significant deterioration. Components of the control system are designed to operate for not less than 150,000 miles without replacement or major service.

The propulsion system is arranged so that accessibility for all routine maintenance is assured. No special tools, other than dollies and hoists, are required to remove the propulsion system or any subsystems. However, the Agency shall recognize that properly rated test equipment and safe electrical work practices are essential when servicing high voltage components. Proterra will provide all specialty tools and diagnostic equipment required for maintaining the Propulsion System in accordance with Special Tools List.

TS 10. Energy Storage System

The Energy Storage System (ESS) is an integrated system that was designed with safety as top priority. The ESS will be described by the five main sections to this system:

10.1) the battery chemistry, 10.2) the mechanical design, 10.3) the electrical design, 10.4) the control system interacting with the battery system, and 10.5) Energy storage system safety.

TS 10.1 Battery Chemistry

The Catalyst E2 vehicles utilize a proprietary high-energy density battery chemistry that falls into the broader category of lithium-ion batteries. The high-energy density allows for more on-board energy storage without the need to add battery packs to the passenger cabin or on the roof. The battery cells are provided from a top tier, global EV battery manufacturer that currently supports major automotive and heavy-duty vehicle OEMs. These cells are proven EV batteries that have been extensively tested to validate battery safety, both by the cell manufacturer and by Proterra’s world-class battery engineering team.

TS 10.2 Mechanical Design

The mechanical design starts with the battery packs themselves and the carbon-fiber reinforced body structure, then continues through to the structure encasing the battery modules and the actual module designs. The bus body incorporates four primary composite stringers that run the length of the body, surrounding the underbody-mounted battery packs between the front and rear axles. Each of these four stringers incorporates full-length, pultruded carbon fiber stringers that maximize strength to weight ratio and add stiffness and rigidity to the battery box surround. It should also be noted that the body serves as a natural electric insulator due to its composite construction vs. a metal chassis normally associated with a transit bus. The vertical location of the battery boxes behind these beams is also located below bumper height of most vehicles which provides additional protection from a direct side impact. This location also provides for an extremely low center of gravity as well as an ideal weight distribution.

Each pack is contained in an aluminum enclosure that is reinforced with 3mm of a heavy-duty polyurethane spray-on covering that lends individual protection to its sub-components. The pack is designed to be sealed to IP66/7 and ANSI/ISE 60529-2004 standards. The pack also fully contains any electrolyte should a cell leak (pursuant to SAE J1766) and meets the 1,000 hours salt spray per ASTM B 117 testing. The packs are designed to handle 5g half-sine peak shock accelerations. The modules within the battery packs are actively cooled to keep the batteries in the ideal temperature range to maximize battery life and comply with the requirements from the battery manufacturer. The battery cooling system includes a chiller integrated with the HVAC system that runs if the ambient environment is too warm for the module manufacturer's desired system set-points. The battery management system monitors cell voltage, temperature and current to ensure safe performance. Should the cooling system fail, the controls monitor and limit operation as a function of temperature, so that the vehicle will function and de-rate performance safely while indicating a fault to the operator. In this way, a cooling system failure will not result in a hard or immediate stop in operation.

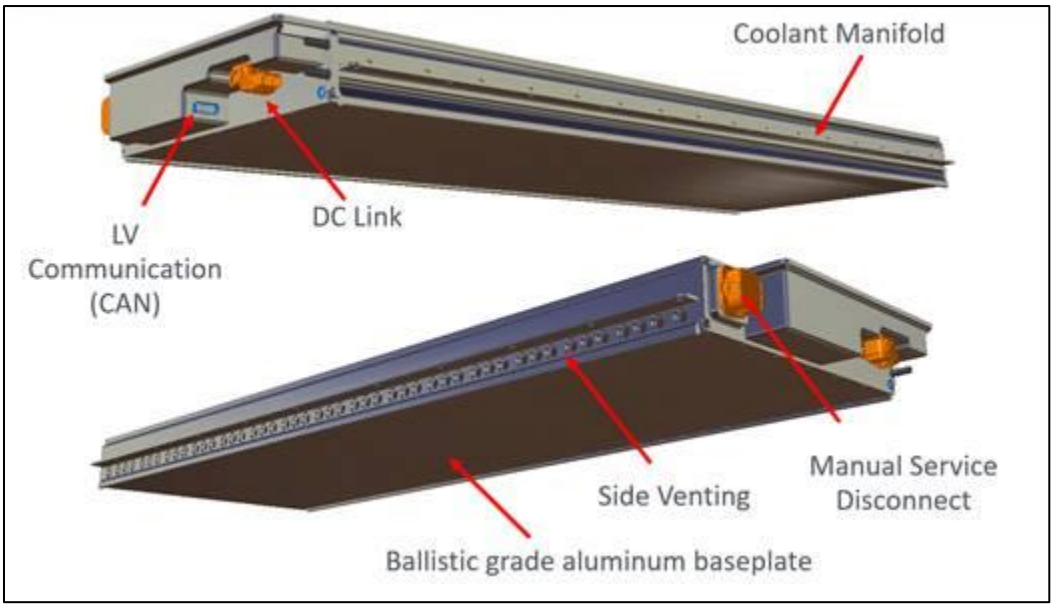


Figure 6-Battery Mechanical Design

TS 10.3 Battery Thermal Management

Battery thermal management is powered whenever the battery contactors are closed. Therefore, the bus in charging mode or on would have all battery thermal functions monitored. Diagnostics monitor the performance of the Battery Thermal Management System, pumps, fan and chiller and will set faults in the event a problem is detected. The batteries will automatically derate (reduce their power output) if they become too hot so that cooling system failures will not damage the batteries. Thermal management has appropriate safety interlocks installed to react to adverse conditions as stated in SAE J1772.

Battery temperatures never exceeds the Proterra's recommended range during operation in the design operating profile and specified ambient conditions. Battery cooling is sufficient to prevent the temperature from exceeding the Proterra's recommended maximum temperature when the ambient temperature is above 105 degrees F for a period of 16 hours.

TS 10.4 Electrical Design

The wiring from each pack is insulated and shielded to industry standards and passes into the center cavity formed between the stringers under the vehicle, referred to as "Broadway". Broadway provides a protected route the length of the bus back to the high voltage junction box in the rear compartment of the vehicle. This is where the individual batteries are bussed together to provide for one high voltage electrical system. The high voltage interlock circuit and control wires for the battery system run along this route with the high voltage cables for maximum safety.

Each battery pack is internally fused and contains a set of contactors. The contactors are located near the pack outputs. Each pack also contains an individual pack controller which serves as a central hub to gather and report information specific to that pack. Each battery module has a monitoring board that measures voltage of each cell and performs cell balancing. This information is communicated to the pack controller via serial communication.

TS 10.5 Battery Management System

The battery management system (BMS) performs the following functions:

A. The BMS system is capable of monitoring the voltage level of cells within each battery pack. The BMS reads and stores individual battery or block voltages at a frequency of 1 data point per block every 15 seconds. The system also monitors battery pack temperatures using no fewer than 2 thermocouples placed in and around each battery pack sampled at the same 4 samples per minute frequency.

B. The BMS system is capable of communicating when a battery fault (as defined by Proterra) has occurred and is able to identify and communicate the faulty battery in order to perform maintenance.

C. The BMS system is capable of engaging prudent safety interlocks when an unsafe battery condition has been detected.

D. The BMS system is able to monitor the battery state-of charge and update a gauge viewed by the operator at least once every 15 seconds.

E. The BMS system is able to communicate all data to the bus level information system for storage and communication.

TS 10.6 Control System

The battery control system is a hierarchical control with the energy storage module (ESM) acting as the interface and lead controller to the rest of the battery system. This module communicates on the main vehicle CAN bus to interface with the cooling, powertrain, charge and other systems. This module can also communicate on the separate battery CAN bus with all of the individual packs. The main controller exchanges information about battery input and output capability as well as cooling needs and diagnostic information.

The pack controllers control the contactors internal to the pack. They also gather the current information as well as pack voltage, cell voltage, and temperature information. Pertinent data is provided back to the master controller which uses this information to compute system limits, determine overall health status, and apply system-wide boundaries on use. The system uses algorithms and feedback to know the position of all contactors. The temperature measurements in the pack are redundant. There are also additional sensors that perform miscellaneous items like moisture detection in each pack. The battery system algorithms coordinate all activities related to the safety and performance of the system.

The battery control system provides system discharge limits to ensure that the lowest cell never goes below its minimum and that the highest cell never goes above its maximum allowable state. The system is also designed to monitor current imbalances between the packs, temperatures throughout all the packs, moisture, and isolation detection. Should loss of communication occur with a pack or module, the system will gracefully handle this with independent fault actions.

TS 10.7 Energy Storage Safety

The energy storage system (ESS) is designed and constructed such that occupants will not be exposed to hazardous electrical current during normal operation or in the event of an accident as defined by ECE80 and APTA TS 23.2 (Crashworthiness).

Under normal conditions, the ESS is designed to protect against electric shock per ISO 6469-3. The protection is composed of:

-Basic protection measures against direct contact with live parts

-All high voltage circuits are rated to IPXXB for direct contact.

-Measures for protection under single fault conditions.

-The isolation resistance is continuously monitored to ensure adequate isolation.

-If the isolation resistance value is less than 500 Ohm/V, a diagnostic event is triggered.

-If the isolation resistance value is less than 100 Ohm/V, a diagnostic event is triggered and an indicator light is displayed on the dashboard.

Each high voltage battery pack utilizes a set of two contactors, independently capable of providing galvanic isolation between Class A and Class B circuits.

-The contactors are implemented in a manner to comply with SAE J2929, Section 4.13.1 Protection Against High Voltage Exposure, Automatic Disconnects.

•Each high voltage battery pack utilizes a manual service disconnect (MSD).

-The MSD is implemented in a manner to comply with SAE J2929, Section 4.13.2 Protection Against High Voltage Exposure, Manual Disconnects.

TS 10.7.1 ESS SAFETY STANDARDS AND REFERENCES

STANDARD	DESCRIPTION
UN 38.3	Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria
ECE R100	Uniform Provisions Concerning the Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train
ISO 6469-1	Electrically propelled road vehicles — Safety specifications — Part 1: On-board rechargeable energy storage system (RESS)
ISO 6469-3	Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock
ISO 12405-3	Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 3: Safety performance requirements
SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells
SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
ISO 26262	Road vehicles -- Functional safety -- Part 1: Vocabulary
NFPA 70E, Edition 15	Standard for Electrical Safety in the Workplace
SAE J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
IEC 60664-1	Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests

TS 10.7.2 ESS DURABILITY STANDARDS AND REFERENCES

STANDARD	DESCRIPTION
SAE J1455	Recommended Environmental Practices for Electronic Equipment Design in Heavy Duty Vehicle Applications
IEC 60068-2-1	Low Temperature Operating Environment
ISO 12405-2	Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 2: High-energy applications
ISO 20653	Road vehicles -- Degrees of protection (IP code) -- Protection of electrical equipment against foreign objects, water and access
SAE J2380	Vibration Testing of Electric Vehicle Batteries
DIN EN 55025	Radio Disturbance Characteristics For The Protection Of Receivers Used On Board Vehicles, Boats, And On Devices - Limits And Methods Of Measurement
ISO 7637-1	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 1: Definitions and general considerations
ISO 7637-2	Road vehicles -- Electrical disturbances from conduction and coupling -- Part 2: Electrical transient conduction along supply lines only
ISO 11452-4	Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 4: Harness excitation methods
ISO 10605	Road vehicles -- Test methods for electrical disturbances from electrostatic discharge
ISO 16750-2	Road vehicles -- Environmental conditions and testing for electrical and electronic equipment -- Part 2: Electrical loads

TS 11. Charging the Catalyst

The 40’ Catalyst E2 comes standard with a single manual charging port located at the rear curb-side of the bus that meets the SAE J1772 CCS Type 1 North American standard for plug-in charging. Additional options are available for dual charge ports with additional charge ports available on the rear street side of the bus or the front curb side of the bus.

The port(s) is capable of charging at 350A continuously. That is the equivalent of 140kW per port assuming a nominal system voltage of 400 VDC. The charge port is capable of supporting charging with a peak voltage of 500 VDC.

TS 12. Cooling Systems

This vehicle utilizes two independent cooling loops to cool the high-voltage batteries and the power electronics on the vehicle.

TS 12.1 Battery Coolant Loop

The battery coolant loop has two dedicated coolant pumps that circulate coolant through a battery coolant heater, the battery packs, into the HVAC integrated chiller plate, and back through an inline coolant filter before returning to the coolant pumps. The coolant heater and chiller plate provide heating and cooling, independently, as required to maintain battery temperatures.

TS 12.2 Power Electronics Loop

The power electronics loop also has a dedicated coolant pump that circulates coolant through the power electronic units that require cooling, through a three fan radiator and then through a strainer to repeat the loop. The transmission is equipped with a standalone oil-to-air cooler mounted next to the transmission.

The cooling systems is of sufficient size to maintain the motor, electronics and batteries at a safe, continuous operating temperatures during the most severe operations possible and in accordance with the manufacturers' cooling system requirements. System temperatures are monitored and the cooling system controlled to ensure equipment temperature is maintained in a safe range. The fan control system is designed with a fail-safe mode of "fan on." The cooling system meets the requirements stated in the operating environment. The coolant system consists of the following components:

Heat Exchanger (Radiator)

- Roof mounted (center)
- Heat rejection – 20kW
    - Fluid temp from 140°F to 120°F @ 30 LPM (109°F ambient)
- Core size 39" x 17" x 1.6"
- Overall size including shroud and fins 48" x 18" x 16"
- Variable speed air transfer fans
- Integral side tanks

Overflow tank

- Accommodates fluid expansion
- Incorporates de-aeration feature

Coolant transfer pump

- Constant speed fluid transfer pump

Coolant transfer lines

- Rigid coolant tubes – mild steel powder coated (exceeds salt spray corrosion test parameters)

TS 12.2.1 Radiator Screen

The 40' Catalyst E2 design does not require a radiator screen. The power electronics loop is equipped with 1 radiator. This radiator, is located on the roof and is effectively screened from large debris which eliminating the need for a radiator screen. It is designed to withstand thermal fatigue and vibration associated with the installed configuration. The radiator cores are easily cleaned with standard pressure-washing equipment.

TS 12.2.2 Coolant

The 40' Catalyst E2 is equipped with coolant filtration. The water filter is sized properly with an in-line element and does not contain supplemental coolant additives.

TS 12.2.3 Drive Design

The 40’ Catalyst E2 is equipped with an electric fan drive bus cooling system. A screen guard is installed on electric motor fans per SAE J1308.

TS 12.2.4 Mounting

The 40’ Catalyst E2 is equipped with a roof mounted radiator.

TS 12.3 Transmission Cooling

The transmission is cooled by a dedicated heat exchanger sized to maintain operating fluid within the transmission manufacturer’s recommended parameters of flow, pressure and temperature. The transmission cooling system is separate from the motor cooling system. The transmission cooling system is a standalone system designed to circulate oil through a small radiator next to the transmission (See figure 5).

TS 13. Transmission

The Proterra Catalyst ProDrive and DuoPower drivetrains use electronically-controlled pneumatically shifted 2-speed gear boxes (transmission). A torque converter and retarder are not needed. The transmission rated torque, power and speed limits are compatible with the motor capabilities. The transmission is designed to operate for not less than 300,000 miles on a transit bus operating profile without replacement or major service. The transmission is easily replaceable without removing the motor and accessible for service from the underside of vehicle.

The controls system is capable of transmitting and receiving electronic inputs and data from other vehicle components through the vehicle CAN network. The control system is powered by the vehicle 24 V distribution system. The control system is responsible for shift execution of the transmission which is done by monitoring powertrain component and driver inputs to select the most appropriate gear. At a minimum, drivetrain components consisting of the motor, transmission and anti-lock braking systems are powered to ensure data communication among components exists when the vehicle ignition is switched to the “on” position.

A moderate brake pedal application is required by the driver to engage forward or reverse range from the neutral position to prevent sudden acceleration of the bus from a parked position.

The electronically controlled powertrain and vehicle controller has on-board diagnostic capabilities, is able to monitor functions, store and time-stamp out-of-parameter conditions in memory, and communicate faults and vital conditions to service personnel, in coordination with the body controls/diagnostic tool. The transmission contains built-in protection software to guard against severe damage. The on-board diagnostic system triggers a visual alarm to the driver when the electronic control unit detects a malfunction.

Although the 2-speed transmission is an automatically shifted unit, it has a manual transmission architecture, i.e. gears, shafts and shift collars but with no clutches, or torque converter, therefore there is not a need to monitor the fluid on an ongoing basis. The fluid will remain at a constant level between specified fluid change intervals. The oil change frequency recommended for Proterra’s

transmission is 100,000 miles. In automotive applications, manual transmissions never require an oil change and thus level indications are not required.

The transmission shifts to neutral immediately when the park brake is applied. However, when the parking brake or door brake interlock is active the traction motor is prohibited from applying torque for functional safety requirements. The driver is required to apply the service brake to re-engage forward or reverse gear selection. The door interlock system inhibits vehicle motion by applying the rear brakes until the doors close again. In fact, what happens at zero speed highlights the major difference between Proterra's EV powertrain and a conventional diesel bus. In a Proterra bus, zero speed means the motor is not spinning. For a diesel bus, the engine still spins at idle so that powertrain requires the torque converter to decouple the engine from the transmission.

Proterra's transmission also does not shift to neutral while the hill hold feature is active. It stays in gear, but the motor is not spinning. When this feature is activated the brake system will lock allowing the vehicle to stay stationary.

Because the all-electric powertrain is consuming very little power at a complete stop and has no rotation, there is no reason to automatically select neutral when the parking brake or door brake interlock is applied.

TS 14. Regenerative Braking

The Proterra bus utilizes two main systems to slow down or decelerate the vehicle, a standard pneumatic friction brake system and regenerative braking. Regenerative braking uses the main traction motor to generate electricity which is then captured and used to charge the main High Voltage (HV) battery. The ability to capture energy while braking, results in a large improvement in energy efficiency of the vehicle. On a traditional vehicle the energy created during braking is lost to heat through either the friction brake or the retarder.

When the driver lifts off the accelerators pedal (zero pedal) ~70% of available regenerative braking torque is automatically applied. The remaining 30% of available regenerative braking is then applied linearly when the driver begins to press on the brake pedal. The pneumatic brakes begin to work linearly with increased brake pedal travel. The feel of the regenerative braking system is similar to a traditional retarder.

Regenerative braking is reduced below 3mph to make low speed bus movement smoother. In the event of an ABS or Traction Control event, regenerative braking is automatically disabled until the vehicle comes to a complete stop. At that point it is automatically re-enabled. This is done to ensure vehicle stability in slippery conditions.

An efficient driver will be able to drive nearly completely with limited use of the brake pedal and very limited use of the friction brakes. Drivers should anticipate stops and allow regenerative braking to slow the vehicle for maximum energy recapture.

TS 15. Mounting

All powerplant mounting is mechanically isolated to minimize transfer of vibration to the body structure and provide a minimum clearance of 0.75 in. Mounts control the movement of the powerplant so as not to cause strain in piping and wiring connections to the powerplant.

TS 15.1 Service

The propulsion system is arranged for ease of access and maintenance. The only special mechanical tool needed for service is a hydraulic lift table for the transmission, motor and battery removal. The air compressor, radiator, all accessories and any other component requiring service or replacement is easily removable and independent of the motor and transmission removal. Since the 40’ Catalyst E2 is equipped with an electric traction motor, there is no exhaust, oil or air intake systems to service.

TS 16. Hydraulic Systems

Hydraulic system service tasks are minimized and scheduled no more frequently than those of other major coach systems. All elements of the hydraulic system are easily accessible for service or unit replacement. Critical points in the hydraulic system are fitted with service ports so that portable diagnostic equipment may be connected or sensors for an off-board diagnostic system permanently attached to monitor system operation when applicable.

Proterra’s standard system has a hydraulic pump which does not include cleanable strainers. The pump is operated by an electric motor, which is controlled by the Motor Controller (Variable Frequency Drive). The pump and motor are non-serviceable assemblies and must be replaced when failed. The only device powered by the hydraulic system is the power steering system. The hydraulic system operates within the allowable temperature range as specified by the lubricant manufacturer. The hydraulic system is mounted approximately under the driver and is accessible from the outside of the vehicle. The modular system can be removed with four bolts. The supply tank is also mounted external of the vehicle and has a magnet drain plug for ease of service and enables maximum heat dispersion.

Our vehicle offers no gauges in the motor compartment. The diagnostic ports on the interior of the vehicle and the diagnostics on the dash allow you to access all systems in order to troubleshoot any issues that are occurring. In addition, we meet the following specs also:

- Mean time between repairs >50,000 miles
- Max oil temp does not exceed 200°F
- Max system working pressure = 2,000 psi
- Hoses comply w/ SAE 100R2 / SAE 100R9 / SAE J517
- Hose installation complies w/ SAE J1273
- High pressure hose fittings comply w/ SAE J516 w/ 37° flare
- Suction line fluid velocity is under 4 ft/sec
- Discharge line fluid velocity is under 25 ft/sec

TS 16.1 Fluid Lines

All lines are rigidly supported to prevent chafing damage, fatigue failures, degradation and tension strain. Lines are sufficiently flexible to minimize mechanical loads on the components. Lines passing through a panel, frame or bulkhead are protected by grommets (or similar devices) that fit snugly to both the line and the perimeter of the hole that the line passes through to prevent chafing and wear. Pipes and fluid hoses are not bundled with or used to support electrical wire harnesses.

Lines are as short as practicable and are routed or shielded so that failure of a line will not allow the contents to spray or drain onto any component operable above the auto-ignition temperature of the fluid.

All hoses, pipes, lines and fittings are specified and installed per the manufacturer's recommendations. The 40' Catalyst E2 comes standard with EPDM hoses for better securement and reliability. Cooler temperatures provided in an electric bus do not require the use of the more expensive, less reliable silicon hoses. Proterra's coolant system is regulated to only 13 psi which allows the use ¼" to 1" coolant hose that meet SAE J20R3 and 1.5" coolant hoses that meet SAE J20R1. In addition, SAE J2044 Quick Connects and hose barb fittings are use across the system.

TS 16.2 Fittings and Clamps

All clamps maintain a constant tension at all times, expanding and contracting with the line in response to temperature changes and aging of the line material. These clamps are manufactured from magni coated carbon spring steel and rated at 1000 hours of salt spray according to ASTM B117. The lines are designed for use in the environment where they are installed.

Compression fittings are standardized to prevent the intermixing of components. Compression fitting components from more than one manufacturer are not mixed, even if the components are known to be interchangeable.

TS 16.3 Charge Air Piping

The lack of an engine precludes the use of a turbocharger is in the 40' Catalyst E2.

TS 17. Radiator Piping

The 40' Catalyst E2 radiator piping is powder-coated steel rated at 1000 hours of salt spray according to ASTM B117. Where practical, hoses are kept to a minimum. Necessary hoses are impervious to all bus fluids. All hoses are secured with constant tension clamps manufactured from magni coated carbon spring steel and rated at 1000 hours of salt spray according to ASTM B117, that provide a complete 360° seal. The clamps maintain a constant tension at all times, expanding and contracting with the hose in response to temperature changes and aging of the hose material. The radiator will be accessible for cleaning and will be easily removable from the bus.

TS 18. Oil and Hydraulic Lines

Oil and hydraulic lines are compatible with the substances they carry. The lines are designed and intended for use in the environment where they are installed. Lines within the motor compartment are composed of steel tubing where practical, except in locations where flexible lines are required.

Hydraulic lines of the same size and with the same fittings as those on other piping systems of the bus, but not interchangeable, are tagged or marked for use on the hydraulic system only.

TS 19. Emissions and Exhaust

TS 19.1 Exhaust Emissions

The 40’ Catalyst E2 is a zero emission vehicle and therefore meets all applicable emission standards.

STRUCTURE

TS 20. General

TS 20.1 Design

The structure of the bus is designed to withstand the transit service conditions typical of an urban or intercity duty cycle throughout its service life. The vehicle structural frame is designed to operate with minimal maintenance well beyond the FTA mandated 12-year design operating profile.

The 40’ Catalyst E2 has an all-composite, corrosion-proof monocoque body manufactured from high strength materials such as carbon fiber and molded fiberglass with a balsa wood core. The benefits of using the composite body include: a lighter total vehicle weight (reducing the impact to local roads / infrastructure), improved vehicle efficiency and fuel economy, improved thermal and noise reducing properties, exceptional torsional stiffness (resulting in an excellent ride and handling), increased durability, corrosion resistance, and best-in-class safety.

TS 21. Validation Testing (Including Altoona)

Prior to acceptance of first bus, the vehicle must have completed any FTA-required Altoona testing. Any items that required repeated repairs or replacement will undergo corrective action with supporting test and analysis. A report clearly describing and explaining the failures and corrective actions taken to ensure that any and all such failures will not occur will be submitted to the Agency. If available, the Altoona Test Report shall be provided to the Agency with the Proposal submittal. If not available, then the report shall be provided prior to first acceptance of bus.

The 40’ Catalyst E2 boasts the industry’s longest operating range documented at Altoona, 203.8 miles on a Heavy-Duty Urban Dynamometer Driving Schedule (HD-UDDS), besting prior Altoona-recorded ranges from competing electric buses of 87.01 miles and 128.6 miles.

TS 21.1 Structural Validation

Prior to acceptance of first bus, the vehicle will have completed any FTA-required Altoona testing. Any items that required repeated repairs or replacement will undergo corrective action with supporting test and analysis. A report clearly describing and explaining the failures and corrective actions taken to ensure that any and all such failures will not occur will be submitted to the Agency. The Altoona Test Report will be provided at the request of the Agency.

TS 21.2 Structural Durability Testing

Proterra has tested its 40' Catalyst vehicle in two separate 4-Post Durability Tests at Exova Defiance. The purpose of the tests were to validate the vehicle design over a simulated 750,000 miles. The tests are broken up into six segments, each representing 125,000 miles of service and taking approximately 25 days to complete. Overall the buses spent approximately 8 months completing the 4-post testing. While we learned a great deal about the durability of components attached to the body structure (e.g. air bags, etc.), the composite body did not disappoint, with no structural or body issues noted during the simulated 18-year testing (no Class 2 failures and the handful of Class 3 failures remedied at the beginning of the test). In general, all our major manufacturing processes and engineering designs were validated to 50% past the FTA mandated service life of vehicle.

Figure 7-Catalyst 4-Post Durability Test

TS 22. Distortion

The bus, loaded to GVWR and under static conditions, did not exhibit deflection or deformation that impairs the operation of the steering mechanism, doors, windows, passenger escape mechanisms or service doors. Static conditions include the vehicle at rest with any one wheel or dual set of wheels on a 6 in. curb or in a 6 in. deep hole.

TS 23. Resonance and Vibration

All structure, body and panel-bending mode frequencies, including vertical, lateral and torsional modes, are sufficiently removed from all primary excitation frequencies to minimize audible, visible or sensible resonant vibrations during normal service.

TS 23.1 Motor Compartment Bulkheads

The passenger and motor compartment are separated by fire-resistant bulkheads. This bulkhead shall preclude or retard propagation of an motor compartment fire into the passenger compartment and is in accordance with the Recommended Fire Safety Practices defined in FTA FMVSS 302. There is no access panel from inside of the bus that allows for anyone to reach the ProDriver. Harnesses have connectors at the bulkhead and we don't have engine access panels.

Only necessary openings are allowed in the bulkhead, and these are fire-resistant. Climate controlled air does not pass through the motor compartment. Wiring passing through the bulkhead use connectors or other means to prevent or retard fire propagation through the bulkhead.

TS 23.2 Crashworthiness

Regarding the body's best-in-class safety and structural rigidity, a Finite Element Analysis (FEA) was completed in order to ensure the bus body and roof structure will withstand a static load equal to 150 percent of the curb weight evenly distributed on the roof with no more than a 6 in. reduction in any interior dimension. Windows will remain in place and will not open under such a load. These requirements are met without the roof-mounted equipment installed.
The finite element analysis shows the bus will withstand a 25 mph impact by a 4000lb automobile at any side, excluding doorways, along either side of the bus with no more than 3 in. of permanent structural deformation at seated passenger hip height. This impact will not result in sharp edges or protrusions in the bus interior.

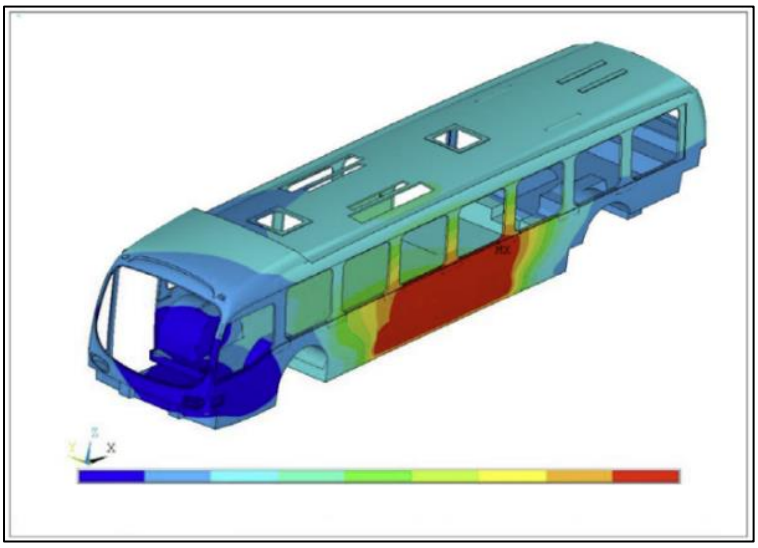


Figure 8 - FEA Side Impact

The finite element analysis shows the body below 35 in. from ground level will withstand a static load of 2000 lbs applied perpendicular to the bus by a pad no larger than 5 sq in. This load will not result in deformation that prevents repair of the body to the original appearance of the bus. Reports are available upon request.

TS 24. Corrosion

The 40' Catalyst E2 body is manufactured from a composite material consisting of high strength fiberglass, carbon fiber in high stress areas that is infused with resin. Sub frames for the front and rear suspension are manufactured from high-strength low-alloy **(**HSLA) steel that is E-coated and powder-coated. The combination of composite body and treated sub frames yields an entire vehicle which is corrosion resistant.

The bus flooring, sides, roof, understructure and axle suspension components are designed to resist corrosion or deterioration from atmospheric conditions and de-icing materials for a period of 12 years or 500,000 miles, whichever comes first. It will maintain structural integrity and nearly maintain original appearance throughout its service life, with the Agency's use of proper cleaning and neutralizing agents.

All materials that are not inherently corrosion resistant are protected with corrosion-resistant coatings. All joints and connections of dissimilar metals are corrosion resistant and are protected from galvanic corrosion. The metallic structural components under the bus body (ProDrive, Axles) are first electrocoated (e-coated), then powder-coated to ensure maximum corrosion protection to meet the 1,000 hour ASTM B117 requirement with no red rust or weight loss. This provides a superior corrosion protection when compared to zinc chromate or zinc phosphate prime paints. There are no roll cage under the bus, but any tubes under body are e-coated then powder coated so inner surface is protected.

Representative samples of all materials and connections withstand a two-week (336-hour) salt spray test in accordance with ASTM Procedure B-117 with no structural detrimental effects to normally visible surfaces and no weight loss of over 1 percent.

TS 25. Towing

Each towing device withstands, without permanent deformation, tension loads up to 1.2 times the curb weight of the bus within 20° of the longitudinal axis of the bus. The rear towing device(s) will not provide a toehold for unauthorized riders. The method of attaching the towing device will not require the removal, or disconnection, of front suspension or steering components.

Shop industrial type air connectors are provided at the front and rear street side of the bus and are capable of supplying all pneumatic systems of the bus with externally sourced compressed air. The location of these shop air connectors facilitate towing operations.

A plug connector permanently mounted at the front of the bus provides for bus tail lamp, marker, stop and turn signal lamp operation as controlled from the towing vehicle. The connector includes a spring-loaded dust- and water-resistant cap.

The front towing devices allow attachment of adapters for a rigid tow bar and permit the lifting and towing of the bus, at curb weight, while the front wheels are clear off the ground. These devices also permit common flat towing.

Two rear recovery devices/tie downs do not permit the lifting of the bus to the extent where the rear wheels are lifted off the ground. The method of attaching the tow bar or adapter requires the specific approval of the Agency. Any tow bar or adapter exceeding 50 lbs will have means to maneuver or allow for ease of use and application. Each towing device accommodates a crane hook with a 1 in. throat.

Upon request, the 40’ Catalyst E2 vehicle can be manufactured with additional support permitting the lifting and towing of the bus for a short distance, such as in cases of an emergency, to allow access to provisions for front towing of bus.

TS 26. Jacking

It is possible to safely jack up the bus, at curb weight, with a common 10-ton floor jack with or without special adapter, when a tire or dual set is completely flat and the bus is on a level, hard surface, without crawling under any portion of the bus. Jacking from a single point permits raising the bus sufficiently high to remove and reinstall a wheel and tire assembly. Jacking pads located on the axle or suspension near the wheels permits easy and safe jacking with the flat tire or dual set on a 6 in. high run-up block not wider than a single tire. The bus withstands such jacking at any one or any combination of wheel locations without permanent deformation or damage.

Jacking pads are painted safety yellow and decals are applied to identify locations. The locations shown below are the Proterra recommended jacking locations:

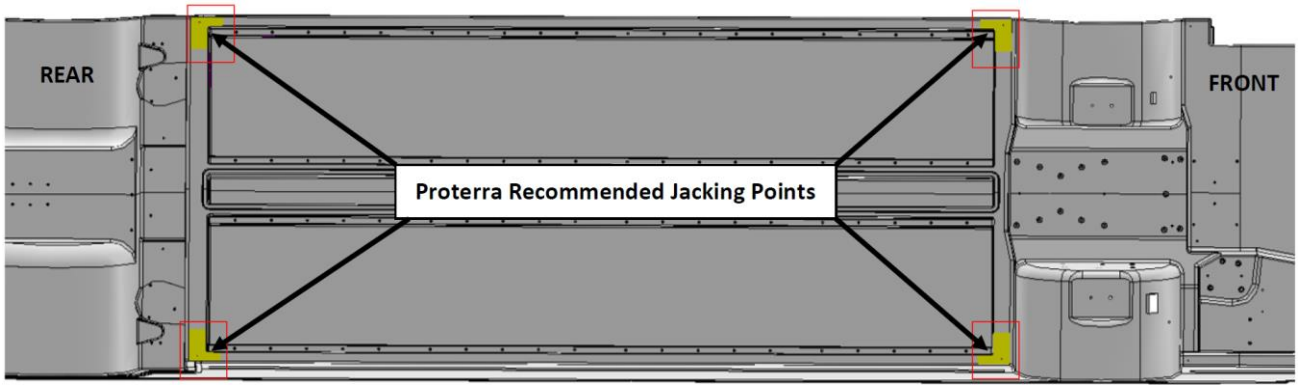


Figure 9-Proterra Recommended Jacking Points

TS 27. Hoisting

The bus axles or jacking plates accommodate the lifting pads of a two-post hoist system. Jacking plates, if used as hoisting pads, are designed to prevent the bus from falling off the hoist. Other pads or the bus structure supports the bus on jack stands independent of the hoist.

The vehicle is capable of being lifting by the wheels.

The locations shown below are the Proterra recommended hoisting locations:
The bus may be picked up by the following locations, but MUST have a surface area of no less than 5 square inches per mounting pad that contacts the bus body. The zones shown below are acceptable lifting areas:

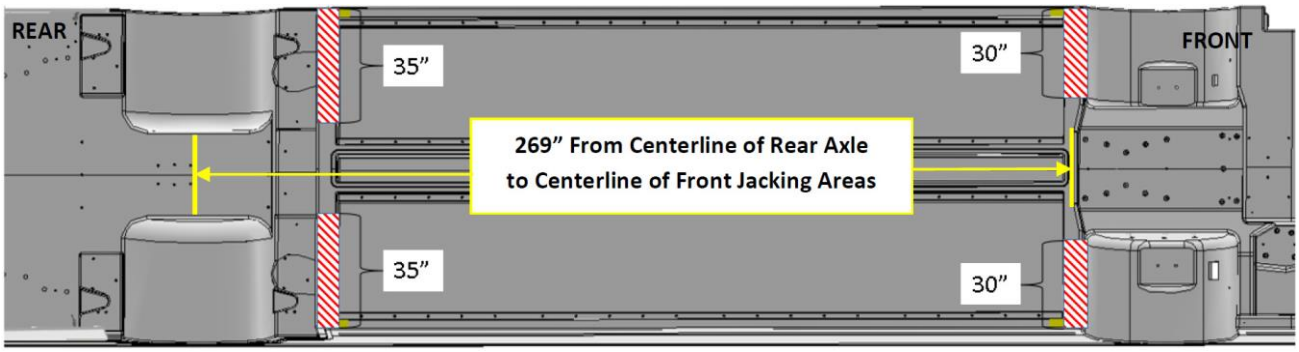


Figure 10-Proterra Recommended Lifting Zones

TS 28. Floor

TS 28.1 Design

The floor is essentially a continuous plane, except at the wheel housings and platforms. Where the floor meets the walls of the bus, as well as other vertical surfaces such as platform risers, the surface edges are blended with a circular section of radius not less than ¼ in. or installed in a fully sealed butt joint. Similarly, a molding or cover prevents debris accumulation between the floor and wheel housings. The vehicle floor in the area of the entrance and exit doors has a lateral slope not exceeding 2° to allow for drainage.

The floor design consists of two levels (bi-level construction). Aft of the rear door extending to the rear settee riser, the floor height is not raised to a height more than 21 in. above the lower level, with equally spaced steps. An increase slope does not to exceed 3.5° off the horizontal.

TS 28.2 Strength

The floor deck is integral with the basic structure and designed to last the life of the bus. Sheet metal screws are not used to retain the floor, and all floor fasteners are serviceable from one side only. Any adhesives, bolts or screws used to secure the floor to the structure will last and remain effective throughout the life of the coach. All floor fasteners are secured and protected from corrosion for the service life of the bus.

The floor deck is reinforced as needed to support passenger loads. At GVWR, the floor will have an elastic deflection of no more than 0.60 in. from the normal plane. The floor withstands the application of 2.5 times gross load weight without permanent detrimental deformation. The floor, with coverings applied, withstands a static load of at least 150 lbs applied through the flat end of a ½ in. diameter rod, with 1/32 in. radius, without permanent visible deformation.

TS 28.3 Construction

Proterra's 40' Catalyst™ E2 composite floor is integral with the basic structure and consists of the subfloor and the floor covering that will last the life of the bus. The floor as assembled, including the sealer, attachments and covering, is waterproof, non-hygroscopic and resistant to mold growth. The subfloor is resistant to the effects of moisture, including decay (dry rot). It is impervious to wood-destroying insects such as termites.

TS 29. Platforms

TS 29.1 Driver's Area

The covering of platform surfaces and risers, except where otherwise indicated, are the same material as specified for floor covering. Trim is provided along top edges of platforms unless integral nosing is provided.

TS 29.2 Driver's Platform

The APTA specification requires the driver's platform to be of a height such that, in a seated position, the driver can see an object located at an elevation of 42 in. above the road surface, 24 in. from the leading edge of the bumper. With a 5th percentile female at the lowest seated position, there is a section of the top of the dash that is 20 inches wide where the object could not be seen. The platform height does not position the driver such that the driver's vertical upward view is less than 15°. A warning decal is provided to alert the driver to the change in floor level. Figure 11 illustrates the means by which this requirement was determined.

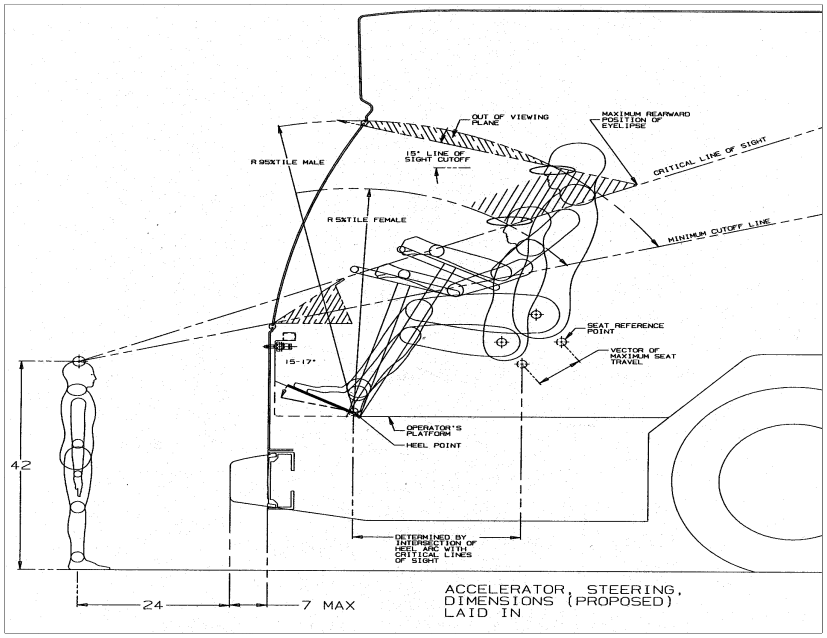


Figure 11-Determining Platform Height

TS 29.3 Farebox

Farebox placement minimizes impact to passenger access interference with the driver's line of sight. If required by the Agency, the farebox will be mounted on a platform of suitable height to provide accessibility for the driver without compromising passengers' access. Stanchions are located around the farebox.

TS 29.4 Rear Step Area to Rear Area

The vehicle is a bi-level floor design. A rear step area is provided along the center aisle of the bus to facilitate passenger traffic between the upper and lower floor levels. This step area is cut into the rear platform and is approximately the aisle width, a minimum 12 in. deep and approximately half the height of the upper level relative to the lower level. The horizontal surface of this platform is covered with skid-resistant material with a visually contrasting nosing and is sloped slightly for drainage. A warning decal or sign is provided at the immediate platform area to alert passengers to the change in floor level.

TS 30. Wheel Housing

TS 30.1 Design and Construction

Sufficient clearance and air circulation is provided around the tires, wheels and brakes to preclude overheating when the bus is operating on the design operating profile. Wheel housings are constructed of corrosion-resistant and fire-resistant material.

Wheel housings, as installed and trimmed, withstand impacts of a 2in. steel ball with at least 200 ft-lbs of energy without penetration.

Interference between the tires and any portion of the bus is not possible in maneuvers up to the limit of tire adhesion with weights from curb weight to GVWR. Wheel housings are adequately reinforced where seat pedestals are installed. Wheel housings have sufficient sound insulation to minimize tire and road noise and meet all noise requirements of this specification.

Design and construction of front street side wheel housings allows for the installation of a radio or electronic equipment storage compartment on the interior top surface. Design and construction of front curb side wheel housings allows its use as a luggage rack.

The finish of the front wheel housings is scratch-resistant and complement interior finishes of the bus to minimize the visual impact of the wheel housing. The wheel housings are color-impregnated to match interior finishes. The lower portion extending to approximately 10 to 12 in. above the floor is equipped with scuff-resistant coating or stainless steel trim.

Wheel housings not equipped with seats or equipment enclosure have a horizontal assist mounted on the top portion of the housing no more than 4 in. higher than the wheel well housing.

The wheel housing are designed to have the ability to chain buses.

CHASSIS

TS 31. Suspension

TS 31.1 General Requirements

The front and rear suspensions are pneumatic type, with a heavy-duty ZF Independent Front Suspension (IFS). It has a smaller turning radius them typical transmissions, better ride quality, improved vehicle handling, higher roll stiffness, and less load on road surface by reducing unsprung masses. The basic suspension system will last the service life of the bus without major overhaul or replacement. Adjustment points are minimized and will not be subject to a loss of adjustment in service. Routine adjustments are easily accomplished by limiting the removal or disconnecting the components.

TS 31.2 Alignment

All axles are properly aligned so the vehicle tracks accurately within its size and geometry of the.

TS 31.3 Springs and Shock Absorbers

TS 31.3.1 Suspension Travel

The suspension system permits a minimum wheel travel of 2.75 in. jounce-upward travel of a wheel when the bus hits a bump (higher than street surface), and 2.75 in. rebound-downward travel when the bus comes off a bump and the wheels fall relative to the body. Elastomeric bumpers are provided at the limit of jounce travel. Rebound travel is limited by elastomeric bumpers or hydraulically within the shock absorbers. The suspensions incorporates Smart Air Management Systems (SAMS) for automatic height control so that regardless of load the bus height relative to the centerline of the wheels does not change more than ½ in. at any point from the height required. The safe operation of a bus will not be impacted by ride height up to 1 in. from design normal ride height. The SAMS system is able to raise and lower the chassis while moving at slow speeds, can

automatically control the ride height of vehicle during normal road use resulting in a smoother ride and has built-in diagnostics

TS 31.3.2 Damping

Vertical damping of the suspension system is accomplished by hydraulic shock absorbers mounted to the suspension arms or axles and attached to an appropriate location on the chassis. Damping is sufficient to control coach motion to three cycles or less after hitting road perturbations. The shock absorber bushing is made of elastomeric material that will last the life of the shock absorber. The damper incorporates a secondary hydraulic rebound stop.

TS 31.3.3 Lubrication

All elements of steering, suspension and drive systems requiring scheduled lubrication will be provided with grease fittings conforming to SAE Standard J534. These fittings are located for ease of inspection and are accessible with a standard grease gun from a pit or with the bus on a hoist. Each element requiring lubrication has its own grease fitting with a relief path. The lubricant specified shall be standard for all elements on the bus serviced by standard fittings and is required no less than every 6000 miles.

TS 31.3.4 Kneeling

A kneeling system lowers the entrance(s) of the bus a minimum of 2.5 in. during loading or unloading operations regardless of load up to GVWR, measured at the longitudinal centerline of the entrance door(s) by the driver. The kneeling control provides the following functions:

- Downward control must be held to allow downward kneeling movement.
- Release of the control during downward movement will completely stop the lowering motion and hold the height of the bus at that position.
- Upward control actuation allows the bus to return to normal floor height without the driver having to hold the control.

The brake and throttle interlock prevents movement when the bus is kneeled. The kneeling control is disabled when the bus is in motion. The bus kneels at a maximum rate of 1.25 in. per second at essentially a constant rate. After kneeling, the bus will rise within 4 seconds to a height permitting the bus to resume service and will rise to the correct operating height within 7 seconds regardless of load up to GVWR. During the lowering and raising operation, the maximum vertical acceleration will not exceed 0.2g, and the jerk will not exceed 0.3g/second.

An indicator visible to the driver is illuminated until the bus is raised to a height adequate for safe street travel. An audible warning alarm will sound simultaneously with the operation of the kneeler to alert passengers and bystanders. A warning light mounted near the curbside of the front door with minimum 1.75 in. diameter amber lens, is provided that will blink when the kneel feature is activated. Kneeling will not be operational while the wheelchair ramp is deployed or in operation.

TS 32. Wheels and Tires

TS 32.1 Wheels

All wheels are interchangeable. Standard configuration wheels are compatible with standard configuration tires in size and load-carrying capacity. Front wheels and tires are balanced as an assembly per SAE J1986.

The standard configuration includes brushed-aluminum finish ALCOA 22.5 in. x 9 in. Wheels. Additional finishes are available upon request.

TS 32.2 Tires

Tires are suitable for the conditions of transit service and sustained operation at the maximum speed capability of the bus. Load on any tire at GVWR will not exceed the tire supplier's rating.

Sufficient space is not provided to allow the Agency to carry a spare tire.

The tire size for the Catalyst E2 buses is 315/80R22.5. If the tires will be provided by the customer, please coordinate tire selection in order to provide ample weight ratings for the front axle at full standing and seating capacity.

TS 33. Steering

Hydraulically assisted steering is provided. The steering gear is an integral type with the number and length of flexible lines minimized or eliminated. Power steering hydraulic pump is electrically driven.

TS 33.1 Steering Axle

The ZF front axle is an independent suspension design, non-driving, with a load rating sufficient for the bus loaded to GVWR and is equipped with grease type front wheel bearings and seals (Figure 12).

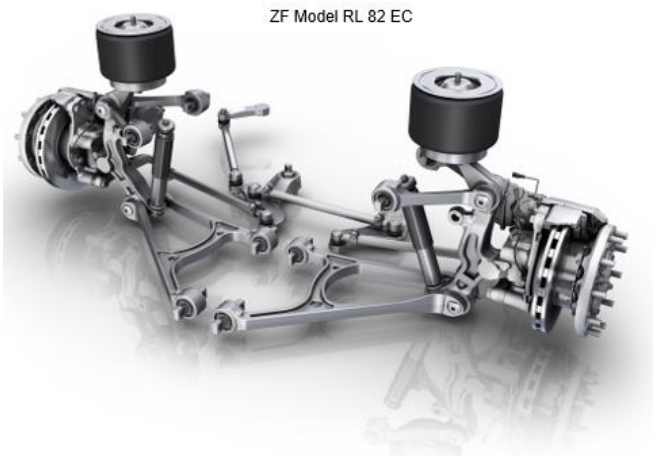


Figure 12 - Proterra ZF Model RL 82 Front Axle

All friction points on the front axle are equipped with replaceable bushings or inserts and, if needed, lubrication fittings easily accessible from a pit or hoist.

The steering geometry of the outside (frontlock) wheel is within 2° of true Ackerman up to 50 percent lock measured at the inside (backlock) wheel. The steering geometry is within 3.5° of true Ackerman for the remaining 100 percent lock measured at the inside (backlock) wheel.

TS 33.2 Steering Wheel

TS 33.2.1 Turning Effort

Steering effort is measured with the bus at GVWR, stopped with the brakes released on clean, dry, level, commercial asphalt pavement and the tires inflated to recommended pressure.

Under these conditions, the torque required to turn the steering wheel 10° is no less than 5 ft-lbs and no more than 10 ft-lbs. Steering torque may increase to 70 ft-lbs when the wheels are approaching the steering stops, as the relief valve activates.

Power steering failure will not result in loss of steering control. With the bus in operation, the steering effort will not exceed 55 lbs at the steering wheel rim, and perceived free play in the steering system will not materially increase as a result of power assist failure. Gearing will require no more than seven turns of the steering wheel lock-to-lock.

Caster angle will be selected to provide a tendency for the return of the front wheels to the straight position with minimal assistance from the driver.

TS 33.2.2 Steering Wheel, General

The steering wheel diameter is available in either 18 in or 20 in.; the rim diameter is ⅞ to 1¼ in. and shaped for firm grip with comfort for long periods of time.

Steering wheel spokes and wheel thickness ensures visibility of the dashboard so that vital instrumentation is clearly visible at center neutral position (within the range of a 95th-percentile male, as described in SAE 1050a, Sections 4.2.2 and 4.2.3). Placement of steering column is as far forward as possible, and in line with the instrument cluster.

TS 33.2.3 Steering Column Tilt

The steering column has full tilt capability with an adjustment range of no less than 40° from the vertical. It is easily adjustable by the driver and accessible by a 5th percentile female and 95th percentile male.

TS 33.2.4 Steering Wheel Telescopic Adjustment

The steering wheel has full telescoping capability and has a minimum telescopic range of 1.91 in. and a minimum low-end adjustment of 29 in., measured from the top of the steering wheel rim in the horizontal position to the cab floor at the heel point.

TS 34. Drive Axle

The bus is driven by a ZF heavy-duty axle (Figure 13) with a load rating sufficient for the bus loaded to GVWR. The drive axle has a design life to operate for not less than 300,000 miles on the design operating profile without replacement or major repairs. The lubricant drain plug is magnetic type. The oil level in the planetary gears is easily checked through the plug or sight gauge. The axle and driveshaft components are rated for both propulsion and retardation modes with respect to duty cycle.

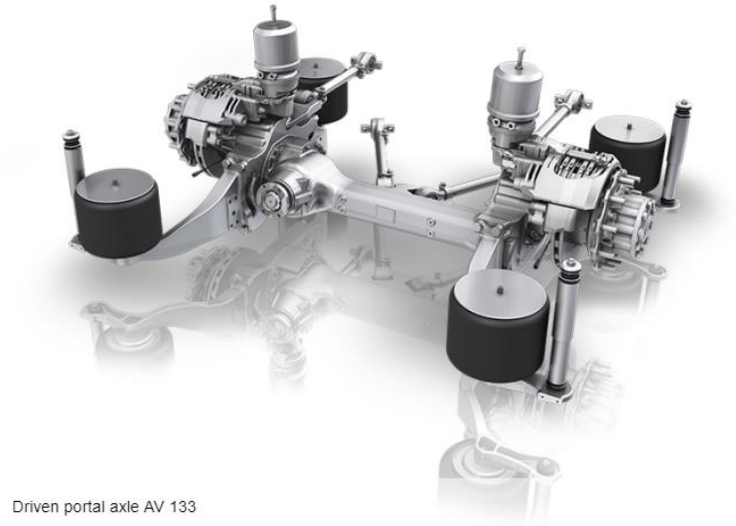
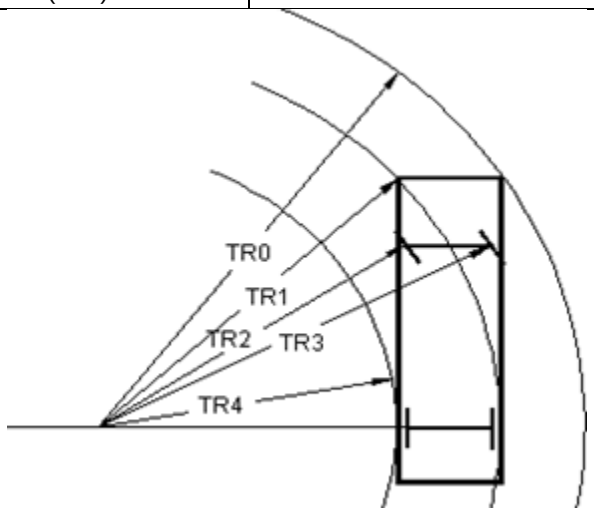


Figure 13-Proterra rear axle

The drive shaft is guarded to prevent hitting any critical systems, including brake lines, coach floor or the ground, in the event of a tube or universal joint failure.

TS 35. Turning Radius

Bus Length (approximate)	Maximum Turning Radius (see Figure 14)	40’ Catalyst E2
40 ft	44 ft (TR0)	41.9 ft (TR0)



Horizontal turning envelope (see diagram below)

Outside body turning radius, TR0 (including bumper)	41	ft	10.8	in.
Front inner corner radius, TR1	37	ft	6	in.
Front wheel inner turning radius, TR2	30	ft	1.2	in.
Front wheel outer turning radius, TR3	36	ft	1.2	in.
Inside Body Turning Radius innermost point, TR4 (including bumper)	17	ft	9.6	in.

Figure 14-Proterra’s 40’ Catalyst™ E2 Horizontal turning envelope

TS 36. Brakes

TS 36.1 Service Brake

Proterra’s 40’ Catalyst™ E2 is equipped with self-adjusting disc brakes on the four wheel ends manufactured by Knorr-Bremse. The brakes are equipped with a rubber bush with axial ribbing (see figure 14 arrow H). The pads/disc wear can be visually determined without removing the wheel, by noting the position of the wear marker point see arrow G, the change-over point from the ribbed to the smooth surface (see Figure 15).

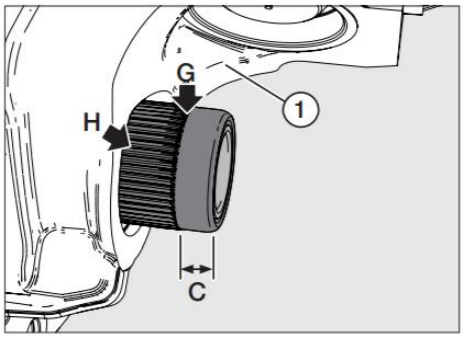


Figure 15-Dimension C with new disc and brake pads

If dimension C is less than 1 mm, the brake pad thickness and brake disc must be checked with the wheel removed (see Figure 16).

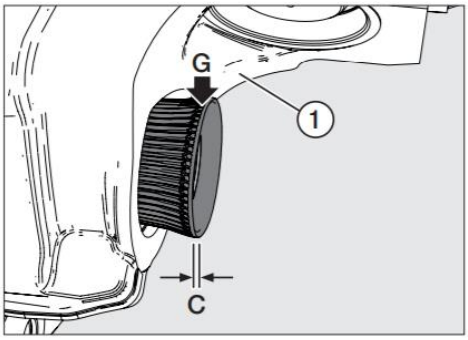


Figure 16-Dimension C with worn disc/brake pads

If any minimal tolerance limits have been reached the pads and/or disc must be changed.

TS 36.2 Actuation

Service brakes are controlled and actuated by a compressed air system. Force to activate the brake pedal control is an essentially linear function of the bus deceleration rate and will not exceed 75 lbs at a point 7 in. above the heel point of the pedal to achieve maximum braking. The heel point is the location of the driver's heel when his or her foot is rested flat on the pedal and the heel is touching the floor or heel pad of the pedal. The ECU for the ABS system is protected, yet in an accessible location to allow for ease of service.

Microprocessor controlled automatic traction control (ATC) is provided.

TS 36.3 Friction Material

The brake linings are made of non-asbestos material. In order to aid maintenance personnel in determining extent of wear, brakes are equipped with a rubber bush with axial ribbing as specified at TS 36.1 indicating the thickness C (see figure 16) at which replacement becomes necessary is provided on each brake lining.

TS 36.4 Hubs and Drums/Discs

Replaceable wheel bearing seals are run on replaceable wear surfaces or are of an integral wear surface sealed design. Wheel bearing and hub seals and unitized hub assemblies will not leak or weep lubricant when operating on the design operating profile for the duration of the initial manufacturer's warranty.

The bus is equipped with disc brakes on all axles, and the brake discs allow machining of each side of the disc to obtain smooth surfaces per manufacturer's specifications.

The brake system material and design was selected to absorb and dissipate heat quickly so that the heat generated during braking operation does not glaze the brake linings.

TS 36.5 Parking/Emergency Brake

The parking brake is a spring-operated system, actuated by a valve that exhausts compressed air to apply the brakes. The parking brake may be manually enabled when the air pressure is at the operating level per FMVSS 121. The parking brake valve button will pop out when air pressure drops below requirements of FMVSS 121.

An emergency brake release is provided to release the brakes in the event of automatic emergency brake application. The driver can manually depress and hold down the emergency brake release valve to release the brakes and maneuver the bus to safety. Once the driver releases the emergency brake release valve, the brakes engage to hold the bus in place. Air to the emergency brake release system is provided by a dedicated emergency air tank.

TS 37. Interlocks

TS 37.1 Passenger Door Interlocks

To prevent opening rear passenger doors while the bus is in motion, a speed sensor is integrated with the door controls to prevent the rear door from being enabled or opened unless the bus speed is less than 2 mph.

To preclude movement of the bus, an accelerator interlock locks the accelerator in the closed position, and a brake interlock engages the service brake system to stop movement of the bus when the driver's door control is moved to an open position, or the rear door panel is opened more than 3 in. from the fully closed position (as measured at the leading edge of the door panel). The interlock engagement brings the bus to a smooth stop and will be capable of holding a fully loaded bus on a 6 percent grade, until the interlocks are released. These interlock functions are active whenever the vehicle master run switch is in any run position.

All door systems employing brake and accelerator interlocks are supplied with supporting failure mode effects analysis (FEMA) documentation, which demonstrates that failure modes are of a failsafe type, thereby never allowing the possibility of release of interlock while an interlocked door is in an unsecured condition, unless the door master switch has been actuated to intentionally release the interlocks.

The brake interlock regulator is non-adjustable.

As an option, an accelerator interlock locks the accelerator in the closed position, and a brake interlock engages the service brake system to stop movement of the bus whenever front doors are open.

TS 38. Pneumatic System

TS 38.1 General

The bus air system operates the air-powered accessories and the braking system with reserve capacity. New buses will not leak down more than 5psi over a 15-minute period of time as indicated on the dash gauge.

Provision are available to apply shop air to the bus air systems. A quick disconnect fitting is easily accessible and located in the motor compartment and near the front bumper area for towing. Retained caps are installed to protect fitting against dirt and moisture when not in use. Air for the compressor is filtered. The air system is protected per FMVSS 121.

TS 38.2 Air Compressor

The electrically driven, vane-style air compressor is sized to charge the air system from 40psi to the governor cut-off pressure in less than 4 minutes. See Figure 17 for compressor specification.

Parameter	Specification
Compressor Type	Hydrovane Transit 0009-0010 Water-Cooled Air End Compressor
Frame Foot and Flange Mount Type	LSMV 100L
Nominal Power	3kW
Rated Power	3.2kW @ 3200 RPM
Nominal Supply Voltage	230VAC 3-Phase, D Connection
Air Delivery	285 Nl/m (10 CFM) @ 9 Bar (130 PSI), 3200 RPM
Rated Speed	1000 to 3200 RPM, stepped speed operation
Max Operating Pressure	10.3 Bar (150 PSI)
Motor	Winding Squirrel Cage Induction Motor
Lubrication	VAFFHPO2000-4
Protection	IP 55 (IP 65 Terminal Box)
Water Cooling	20 l/min / 55°C Max Inlet Temperature
Coolant Connections	15L (M22 x 1.5)
Duty	S1 in 40°C Ambient, External Air Cooling
Weight	27 kg (60 lb), Aluminum Frame
Other	- Transit Inlet Adapter and End Cap - Compressor/Motor sub-assembly fully supported on AV Mounts - Internal thermostatic valve to oil cooler - Dual Over Temperature Switch fitted (110°C and 120°C) - Coolant to have suitable antifreeze and corrosion inhibitor Motor

Figure 17 - Air Compressor Specification

TS 38.3 Air Lines and Fittings

Air lines, except necessary flexible lines, conform to the installation and material requirements of SAE Standard J1149 for copper tubing with standard, brass, flared or ball sleeve fittings, or SAE Standard J844 for nylon tubing if not subject to temperatures over 200 °F. The air on the delivery side of the compressor where it enters nylon housing is not above the maximum limits as stated in SAE J844. Nylon tubing is installed in accordance with the following color-coding standards:

- **Green:** Indicates primary brakes and supply.
- **Red:** Indicates secondary brakes.
- **Brown:** Indicates parking brake.
- **Yellow:** Indicates transmission and ride height controller feed (we don't have governor air lines).
- **Black:** Indicates accessories & doors.
- **Blue:** Indicates curb side air bags.
- **Orange:** Indicates street side air bags

Line supports prevent movement, flexing, tension, strain and vibration. No copper or rigid lines are used in the pneumatic system of the Proterra bus. Nylon lines may be grouped and are supported at 30 in. intervals or less.

The compressor discharge line between power plant and body-mounted equipment is a flexible Teflon hose with a braided stainless steel jacket. Other lines necessary to maintain system reliability are flexible Teflon hose with a braided stainless steel jacketed fittings. They use standard SAE or JIC brass or steel, flanged, swivel-type fittings. Braided flexible hoses are as short as practicable and individually supported. They will not touch one another or any part of the bus except for the supporting grommets. Flexible lines are supported at 2ft intervals or less.

Air lines are clean before installation and are installed to minimize air leaks. All air lines are routed to prevent water traps to the extent possible. Grommets or insulated clamps protect the air lines at all points where they pass through understructure components.

TS 38.4 Air Reservoirs

All air reservoirs meet the requirements of FMVSS Standard 121 and SAE Standard J10 and are equipped with drain plugs and guarded or flush type drain valves. Major structural members protect these valves and any manual moisture ejector valves from road hazards. Reservoirs are sloped toward the drain valve. All air reservoirs have drain valves that discharge below floor level with lines routed to eliminate the possibility of water traps and/or freezing in the drain line. The Proterra Catalyst uses a single analog needle to display the lowest air pressure in both the primary and secondary reservoirs instead.

The single air pressure gauge displays the lowest pressure of the two systems. Our system does not use pressure regulators (except for pneumatic doors). Our controls regulate our pressure and all 3 pressures (primary, secondary, & aux) can be read at the dash.

TS 38.5 Air System Dryer

An air dryer prevents accumulation of moisture and oil in the air system. The air dryer system includes one or more replaceable desiccant cartridges. The 40' Catalyst E2 comes standard with a Bendix AD-IS air dryer.

A provision for an additional oil separator is not provided.

ELECTRICAL, ELECTRONIC AND DATA COMMUNICATION SYSTEMS

TS 39. Overview

The vehicle control system is based around a vehicle controller from Continental VDO with KIBES-32 firmware developed for heavy duty vehicles.

The Continental VDO vehicle control system is based around several hardware components. The ZR-32A is the master controller and contains all the functionality software that controls the main vehicle components. The multiplexing units distribute the master controller's needed discreet and analog inputs and outputs to convenient locations around the vehicle. The fully integrated driver's instrument cluster contains all needed gauge dials and tell tales. Additionally the instrument cluster includes a high performance digital display that is used to inform the driver of various system states including additional driver tell-tale indications, overhead charging instructions and diagnostic information.

The ZR-32A controller is based on two, 32-bit RISC processors with internal 1024kB flash for program memory and SRAM for data parameter storage. It can run 5 independent data networks, at speeds up to 500kB/s based on the CAN J1939 architecture. The CAN (Controller Area Network) is a high-integrity serial data communications bus for real-time applications governed by ISO 11898 and has safety-agency approval for passenger vehicle control.

The MUX-2B units run on an 8-bit processor, having internal programming memory and are equipped with 24 quasi-analog status inputs, 6 dedicated analog inputs, and 32 digital outputs with internal fault detection and protection. The digital outputs are organized in sub groups to be able to run sets of independent systems (i.e., 12V loads as well as 24V loads including outputs that have current capacity up to 10 amps).

The utilized networks are:

- PCAN: Used for high-performance systems like the Traction Motor, cooling System, battery management and ABS.
- MCAN: Used for the multiplexing units that distribute the master controller's needed discrete and analog inputs and outputs to convenient locations around the vehicle.

- ICAN: Used for interfacing with the driver's instrument cluster including the digital display screen. This network includes communicating the discreet input/outputs available from the instrument cluster as well as controlling the clusters dial gauges, tell-tales and what is displayed on the digital display.

TS 39.1 Modular Design

Design of the electrical, electronic and data communication systems are modular so that each electronic device, apparatus panel, or wiring bundle is easily separable from its interconnect by means of connectors.

Power plant wiring is an independent wiring harness. Replacement of the ProDrive compartment wiring harnesses does not require pulling wires through any bulk head or removing any terminals from the wires. As an exception, there is a multicore cable that runs from the ProDrive to the power steering motor at the front of the vehicle. This cable passes through 2 bulkheads and is part of a ProDrive harness.

TS 40. Environmental and Mounting Requirements

The electrical system and its electronic components are capable of operating in the area of the vehicle in which they will be installed, as recommended in SAE J1455.

Electrical and electronic equipment are not located in an environment that will reduce the performance or shorten the life of the component or electrical system when operating within the design operating profile. No vehicle component generates, or is affected by, electromagnetic interference or radio-frequency interference (EMI/RFI) that can disturb the performance of electrical/electronic equipment as defined in SAE J1113 and UNECE Council Directive 95/54 (R10).

TS 40.1 Hardware Mounting

The mounting of the hardware is not used to provide the sole source ground, and all hardware is isolated from potential EMI/RFI, as referenced in SAE J1113.

All electrical/electronic hardware mounted in the interior of the vehicle is inaccessible to passengers and hidden from view unless intended to be viewed. The hardware is mounted in such a manner as to protect it from splash or spray.

All electrical/electronic hardware mounted on the exterior of the vehicle that is not designed to be installed in an exposed environment is mounted in a sealed enclosure.

All electrical/electronic hardware and its mounting complies with the shock and vibration requirements of SAE J1455.

TS 41. General Electrical Requirements

TS 41.1 Batteries

TS 41.1.1 Low-Voltage Batteries (24V)

The 40’ Catalyst E2 includes two (2) Group 31, deep cycle, maintenance free batteries. This is sufficient to ensure reliable vehicle startup. These batteries can be “jumped” in the same manner as standard buses and an Anderson connector is provided for this in the event the batteries lose their charge. Low voltage battery state-of-charge warnings are displayed on the drivers screen.

TS 41.1.2 Battery Cables

The battery terminal ends and cable ends are color-coded with red for primary positive, black for negative and green for the intermediate voltage (12 volts). Positive and negative battery cables do not cross each other, are flexible and are sufficiently long to reach the batteries. The cables do not lie directly on top of the batteries. Battery cables are continuous except for the connection to the master battery switch and are bolted terminals meeting SAE Standard J1127-Type SGX. Battery cables are sized at 2/0 and are more than sufficient to “start” the bus.

TS 41.1.3 JumpStart

Proterra provides a red (24V) Anderson-style connector in the motor compartment (ProDrive), equipped with dust cap and adequately protected from moisture, dirt and debris. Alternate connectors are available as an option.

TS 41.1.4 Battery Compartment

The battery compartment prevents accumulation of snow, ice and debris on the top of the batteries and is vented and self-draining. It is only accessible from the outside of the vehicle. All components within the battery compartment, and the compartment itself, is protected from damage or corrosion from the electrolyte. The inside surface of the battery compartment’s access door is electrically insulated. The battery compartment temperature does not exceed manufacturer’s specification.

The vehicle is equipped with a 12VDC and 24VDC quick disconnect switch. The battery quick disconnect access door is identified with a decal. The battery hold-down bracket is constructed of nonconductive and corrosion-resistant material.

The access door is designed to require a square key lock. The access doors are flush-fitting and incorporate a spring tensioner to retain the door in a closed position when not in use.

The batteries are securely mounted on a powder-coated steel tray which accommodates the size and weight of the batteries. The battery tray pulls out easily and properly supports the batteries while they are being serviced. A locking device retains the battery tray in the stowed position. No sparking devices are located within the battery box.

TS 41.1.5 Auxiliary Electronic Power Supply

The standard vehicle does not utilize any gel-packs or sealed non-vented batteries for auxiliary power. If gel-packs or sealed non-vented batteries are installed, Proterra will comply with this paragraph and install them in a labeled, vented compartment accessible only to maintenance personnel.

TS 41.1.6 Master Battery Switch

The location of the master battery switch is clearly identified on the exterior access panel, is accessible in less than 10 seconds. The installation prevents corrosion from fumes and battery acid when the batteries are washed off or in normal service.

Turning the master switch off with the power plant operating, during an emergency, shuts off the motor and does not damage any component of the electrical system. The master switch is capable of carrying and interrupting the total circuit load.

The standard configuration is equipped with a single switch for disconnecting 12V and 24V power. The access panel is locked with a standard square key.

TS 41.1.7 Low-Voltage Generation and Distribution

The low-voltage generating system maintains the charge on fully charged batteries. The low-voltage batteries are maintained through a DC/DC converter by the high-voltage batteries. There is no generator.

Voltage monitoring and over-voltage output protection is provided.

Dedicated power and ground are provided as specified by the component or system manufacturer. Cabling to the equipment is sized to supply the current requirements of heavy-duty systems with no greater than a 5 percent voltage drop across the length of the cable.

TS 41.1.8 Circuit Protection

All branch circuits are protected by current-limiting devices such as circuit breakers, fuses or solid state devices sized to the requirements of the circuit. The circuit breakers or fuses are easily accessible for authorized personnel. Fuse holders are constructed to be rugged and waterproof. All in-line fuses are shown in the final schematic drawings. Manually resettable circuit breakers provide a visible indication of open circuits.

Circuit breakers or fuses are sized to a minimum of 15 percent larger than the total circuit load. The current rating for the wire used for each circuit exceeds the size of the circuit protection being used.

TS 41.2 Grounds

The batteries are grounded to the chassis in a single location, as close to the batteries as possible. Ground bars are provided throughout the bus, evenly distributed to prevent ground loops. No more than five ground ring/spade terminal connections are made per ground stud with spacing between

studs ensuring conductivity and serviceability. Electronic equipment and systems requiring an isolated ground to the battery is not grounded through the chassis.

TS 41.3 Low Voltage/Low Current Wiring and Terminals

Power and ground wiring conforms to specification requirements of SAE Recommended Practice J1127, J1128 and J1292 for type GXL and SXL wiring. Double insulation is maintained as close to the junction box, electrical compartment or terminals as possible.

Wiring is grouped, labeled and color-coded. Wiring harnesses do not contain wires of different voltage classes unless all wires within the harness are insulated for the highest voltage present in the harness. Kinking, grounding at multiple points, stretching, and exceeding minimum bend radius are prevented.

Strain-relief fittings are provided at all points where wiring enters electrical compartments. Grommets or other protective material is installed at points where wiring penetrates metal structures outside of electrical enclosures. Wiring supports are protective and non-conductive at areas of wire contact and will not be damaged by heat, water, solvents or chafing.

To the extent practicable, wiring is not located in environmentally exposed locations under the vehicle. Wiring and electrical equipment necessarily located under the vehicle is insulated from water, heat, corrosion and mechanical damage. Where feasible, front-to-rear electrical harnesses are installed above the window line of the vehicle.

All wiring harnesses over 5 ft. long and containing at least five wires include 10 percent (minimum one wire) excess wires for spares. Wiring harness length allow end terminals to be replaced twice without pulling, stretching or replacing the wire. Terminals are crimped to the wiring according to the connector or manufacturer's recommendations for techniques and tools.

Cable connectors are locking type, keyed and sealed, unless enclosed in watertight cabinets or the vehicle interior. Pins are removable, crimp contact type, of the correct size and rating for the wire being terminated. Unused pin positions are sealed with sealing plugs. Adjacent connectors use different inserts or different insert orientations to prevent incorrect connections.

Terminals are crimped, corrosion-resistant and full ring type or interlocking lugs with insulating ferrules. When using pressure type screw terminal strips, only stranded wire is used. Insulation clearance ensures that wires have a minimum of "visible clearance" and a maximum of two ties the conductor diameter or 1/16 in., whichever is less. When using shielded or coaxial cable, upon stripping of the insulated, the metallic braid is free from frayed strands.

Ultra-sonic and T-splices may be used with 8 awg or smaller wire. When T-splice is used, it meets these additional requirements:

- It includes a mechanical clamp.

- The wire supports no mechanical load in the area of the splice.
- The wire is supported to prevent flexing.

All splicing is staggered in the harness. Wiring located in the motor compartment (Pro Drive) is routed away from high-heat sources or is shielded and/or insulated from temperatures exceeding the wiring and connector operating requirements.

The instrument panel and wiring are accessible for service from the driver's seat or top of the panel. The instrument panel is separately removable and replaceable without damaging the instrument panel or gauges. Wiring is of sufficient length and routed to permit service without stretching or chafing the wires.

As standard we use HellermanTyton heavy-duty cable management system (which includes plastic tie wraps) which is the standard mechanism for securing wires in our vehicle.

TS 41.4 Electrical Components

All electrical components, including switches, relays, flashers and circuit breakers, are heavy-duty designs with either a successful history of application in heavy-duty vehicles or design specifications for an equivalent environment.

All electric motors are heavy-duty brushless type where practical, and have a continuous duty rating of no less than 40,000 hours, except washer pumps and wiper motors.

All electric motors are easily accessible for servicing.

TS 41.5 Electrical Compartments

Relays, controllers, flashers, circuit breakers and other electrical components are mounted in easily accessible electrical compartments. Compartments exposed to the outside environment are corrosion-resistant and sealed. The components and their functions in each electrical compartment are identified and their location recorded on a schematic drawing permanently attached to the inside of the access panel or door. The drawing is protected from oil, grease, fuel and abrasion. The front compartment is completely serviceable from the driver's seat.

"Rear start and run" controls are not required as the electric drive motor does not idle like a diesel or CNG engine. Alternatively, a "run disable" switch is located in the motor compartment (Pro-Drive). It will disable the drive system and gear selection without requiring the vehicle to be turned off. The switch is protected and rated for the environment it is installed in. Also, 12/24V disable switch and High Voltage Disconnect is also available in the motor compartment. Both of these switches can be locked in the off position with a lockout-tagout system. The bus has two diagnostic ports in the front and rear interior and a diagnostic tool for accessing vehicle information which can communicate wirelessly or via bluetooth.

TS 42. General Electronic Requirements

If an electronic component has an internal real-time clock, it will provide its own battery backup to monitor time when battery power is disconnected, and/or it may be updated by a network component. If an electronic component has an hour meter, it will record accumulated service time without relying on battery backup.

Proterra will ensure that their electronic equipment is self-protecting in the event of shorts in the cabling, and also in over-voltage and reverse polarity conditions. If an electronic component is required to interface with other components, it will not require external pull-up and/or pull-down resistors. Where this is not possible, the use of pull-up or pull-down resistor is limited as much as possible and is easily accessible and labeled.

TS 42.1 Wiring and Terminals

Kinking, grounding at multiple points, stretching and reducing the bend radius below the manufacturer's recommended minimum is not permitted except at our overhead charge cable installation which does result in certain areas where the bend radius is below the minimum recommended radius. However, these cables have been tested by the manufacturer and Proterra expects the design as installed to last the life of the vehicle.

The Proterra Catalyst vehicles have protective coverings over the high voltage wiring from the battery packs and for wiring to the ProDrive area where the traction motor, transmission, and air system are located.

TS 42.1.1 Discrete I/O (Inputs/Outputs)

Wiring to I/O devices, either at the harness level or individual wire level, are labeled, stamped or color-coded in a fashion that allows unique identification at a spacing not exceeding 4 in. Wiring for each I/O device is bundled together. Where I/O terminals are the same voltages, jumpers may be used to connect the common nodes of each I/O terminal.

TS 42.1.2 Shielding

Wiring that requires shielding meets the following minimum requirements. A shield will be generated by connecting to a ground, which is sourced from a power distribution bus bar or chassis. To extent possible the shield will be connected to one side only. However, some shields are grounded at both ends per the component manufactures installation instructions (i.e. power cables between the motor and Inverter).

When using shielded or coaxial cable, upon stripping of the insulation, the metallic braid is free from frayed strands, which can penetrate the insulation of the inner wires. To prevent the introduction of noise, the shield will not be connected to the common side of a logic circuit.

TS 42.1.3 Communications

The data network cabling is installed according to the selected protocol requirements. The physical layer of all network communication systems is not used for any purpose other than communication between the system components, unless provided for in the network specifications.

Communications networks that use power line carriers (e.g., data modulated on a 24V power line) meet the most stringent applicable wiring and terminal specifications.

TS 42.1.4 Radio Frequency (RF)

Coaxial cable is used to carry the signal for all RF components such as radios, video devices, cameras, global positioning systems, etc. Connectors are minimized, since each connector and crimp has a loss that will attribute to attenuation of the signal. Cabling allows for the removal of antennas or attached electronics without removing the installed cable between them. The corresponding component vendors will be consulted for proper application of equipment, including installation of cables.

TS 42.1.5 Audio

Cabling used for microphone level and line level signals is 22 AWG minimum with shielded twisted pair. Cabling used for amplifier level signals is 18 AWG minimum.

TS 43. Multiplexing

TS 43.1 General

The primary purpose of the multiplexing system is control of components necessary to operate the vehicle. This is accomplished by processing information from input devices and controlling output devices through the use of an internal logic program.

Versatility and future expansion is provided for by an expandable system architecture. The multiplex system is capable of accepting new inputs and outputs through the addition of new modules and/or the utilization of existing spare inputs and outputs. All like components in the multiplex system are modular and interchangeable with self-diagnostic capabilities. The modules are easily accessible for troubleshooting electrical failures and performing system maintenance. Multiplex input/output modules use solid-state devices to provide extended service life and individual circuit protection.

Ten percent of the total number of inputs and outputs, or at least one each for each voltage type utilized (12V, 24V) at each module location is designated as spares.

The Multiplex system has a number of different outputs that are individually rated to 1A, 3A, 5A or 10A max. The CAN wiring is SAE J1939 approved. Module power is GXL wiring which is SAE 1128 approved.

TS 43.2 System Configuration

Proterra's 40' Catalyst™ E2 multiplexing is centralized. The system consist of several modules connected to form a control network. It utilizes a Continental VDO multiplex system. This system is

managed by a master vehicle controller, ZR-32A. It provides the configurability and the control required to integrate all systems on the bus.

TS 43.2.1 I/O Signals

The input/output for the multiplex system contains three types of electrical signals: discrete, modulating and analog.

Discrete signals reflect the on/off status of switches, levers, limit switches, lights, etc. Analog signals reflect numerical data as represented by a voltage signal (for example 0–5V) or resistance signal (for example NTC thermistor). Both types of analog signals represent the status of variable devices such as rheostats, op-amps, potentiometers, temperature probes, etc.

TS 44. Data Communications

TS 44.1 General

All data communication networks are in accordance with a nationally recognized interface standard, such as those published by SAE, IEEE or ISO.

Any electronic vehicle components used on a network are conformance tested to the corresponding network standard.

The vehicle is designed with a fully integrated diagnostic system were the master vehicle controller, ZR-32A, monitors and records the fault status from all systems on the main PCAN network as well as fault status from the multiplex devices. This includes subsystems such as the powertrain controller, cooling system, ABS system, HVAC system, battery management system and other power devices. This diagnostic system also includes the detection of loss of communication of all individual devises on the PCAN and MCAN network.

All faults are recorded, time stamped, odometer stamped and assigned a priority level based on the severity of the fault. These priority levels are broken into 10 groups ranging from the most severe fault requiring an immediate vehicle shutdown to the least severe fault requiring attention at the next service interval. Some minor faults are only recorded to help the technician troubleshoot issues and are not indicated to the driver. Various indicators communicate to the driver the severity and priority of the fault. These indicators include a general red or amber LED tell-tale, fault specific LED tell-tales, fault specific driver's screen displayed tell-tales and/or an audible buzzer.

Many faults have the ability to automatically reset if a fault is no longer active. All faults that are active or previously active are accessed using the Proterra service tool or the maintenance menus accessible from the driver's instrument cluster. The Proterra service tool has a troubleshooting guide to aid in quick resolution of individual faults. The following information is displayed when using the instrument cluster and Proterra service tool:

- Fault status (active or previously recorded and inactive)
- Identifying number (SPN and FMI according to J1939)
- General description of part faulted (SPN description)
- Type of fault (FMI description; i.e. value to high, to low, data erratic, loss of communication)

- Mux input or output pin where fault was detected or system where fault was originated
- Time, date and odometer reading at time of fault

A vehicle data logger is provided to monitor J1939 communications System. It provides:

- Continuous monitoring and recording of the PCAN J1939 data bus.
- Software that can generate structured reports using the gathered data.
- Software to create tools for incident definition, data import/export, analysis and presentation.
- Software for recording of user selected J1939 fault codes.

TS 44.2 Drivetrain Level

Drivetrain components, consisting of the drive motor inverters, regenerative braking system, anti-lock braking system and all other related components, are integrated and communicate fully with respect to vehicle operation with data using SAE Recommended Communications Protocols J1939. Drivetrain components are powered by a supply voltage to ensure data communication among components exists when the vehicle ignition is switched to the “on” position.

TS 44.2.1 Diagnostics, Fault Detection and Data Access

Drive train performance, maintenance and diagnostic data, and other electronic messages are formatted and transmitted on the communication network.

The drivetrain level has the ability to record abnormal events in memory and provide diagnostic codes and other information to service personnel. These codes can be read from the driver’s digital display or the Proterra service tool. The communication ports are located at the front and rear interior of the vehicle.

TS 44.2.2 Programmability (Software)

The drivetrain level components are programmable by the Agency with limitations as specified by the subsystem Supplier. The Proterra powertrain controller is programmable using the Proterra service tool laptop via the vehicle OBD port located in the rear of the vehicle. Reprogramming these controllers is access controlled via multiple user levels with different passwords. Revision control tracking is electronic and communicated on the J1939 PCAN bus.

TS 44.3 Multiplex Level

TS 44.3.1 Data Access

Information is available via a communication port at the front and rear of the vehicle. The location of the communication ports are easily accessible. The preferred way to review this information is via the instrument cluster’s digital display. Maintenance screens, available only to technicians, provide visual feedback of each individual MUX input and output state (i.e. on, off, or faulted). Standard bus uses J1708 interface with the Asynchronous Transfer Mode Switching (ATMS) wireless communications system for transmittal of diagnostic fault codes. (Other interfaces such as J1939 are not available on the bus)

TS 44.3.2 Diagnostics and Fault Detection

The multiplex system has a proven method of determining its status (system health and input/output status) and detecting either active (online) or inactive (offline) faults through the use of on-board visual/audible indicators.

In addition to the indicators, the system employs an advanced diagnostic and fault detection system, which is accessible via the Proterra service tool laptop. The service tool has the ability to check logic function.

As an option, a mock-up board can be provided.

TS 44.3.3 Programmability (Software)

The vehicle master controller is programmable using the Proterra service tool laptop via the vehicle OBD port located in the front of the vehicle. Reprogramming these controllers is access controlled via multiple user levels with different passwords. Revision control tracking is electronic and communicated on the J1939 PCAN bus as well as displayed on the driver's display screen. Programming of the multiplex devices is an automatic process that is completed by the vehicle ZR-32A master controller upon startup.

TS 44.4 Electronic Noise Control

Third party testing per CISPR 12, 36 and ISO 11451 has been conducted to ensure that electrical and electronic subsystems and components on all buses do not emit electromagnetic radiation that will interfere with on-board systems, components or equipment, telephone service, radio or TV reception, or violate regulations of the Federal Communications Commission.

Electrical and electronic subsystems on the coaches are not affected by external sources of RFI/EMI. This includes, but is not limited to, radio and TV transmission, portable electronic devices including computers in the vicinity of or onboard the buses, AC or DC power lines and RFI/EMI emissions from other vehicles.

DRIVER PROVISIONS, CONTROLS AND INSTRUMENTATION

TS 45. Driver's Area Controls

TS 45.1 General

In general, when designing the driver's area, SAE J833, "Human Physical Dimensions," was used. Switches and controls are divided into basic groups and assigned to specific areas, in conformance with SAE Recommended Practice J680, Revised 1988, "Location and Operation of Instruments and Controls in Motor Truck Cabs," and are essentially within the hand reach envelope described in SAE Recommended Practice J287, "Driver Hand Control Reach."

TS 45.2 Glare

The driver's work area is designed to minimize glare to the greatest extent possible. Objects within and adjacent to this area are matte black or dark gray in color wherever possible to reduce the

reflection of light onto the windshield. The use of polished metal and light-colored surfaces within and adjacent to the driver's area was avoided.

TS 45.3 Visors/Sun Shades

An adjustable roller type sunscreen is provided over the driver's windshield. The sunscreen is capable of being lowered to the midpoint of the driver's window. When deployed, the screen is secure, stable, and will not rattle, sway or intrude into the driver's field of view due to the motion of the coach or as a result of air movement. Once lowered, the screen remains in the lowered position until returned to the stowed position by the driver. Sunscreen is shaped to minimize light leakage between the visor and windshield pillars to the extent possible.

An option to include an additional driver's side window sunscreen is also available.

TS 45.4 Driver's Controls

Frequently used controls are in easily accessible locations. These include the door control, kneel control, windshield wiper/washer controls, ramp, and lift and run switch. Any switches and controls necessary for the safe operation of the bus are conveniently located and provide ease of operation. They are identifiable by shape, touch and permanent markings. Controls also are located so that passengers may not easily tamper with control settings.

All panel-mounted switches and controls are marked with easily read identifiers. Graphic symbols conform to SAE Recommended Practice J2402, "Road Vehicles – Symbols For Controls, Indicators, and Tell Tales," where available and applicable. Color of switches and controls are dark with contrasting typography or symbols.

Mechanical switches and controls are replaceable, and the wiring at these controls are serviceable from a convenient location. Switches, controls and instruments are dust- and water-resistant.

All switches/controls in the driver's controls area, if required, can be mounted in an angled panel steep enough to discourage drivers from using it as a personal storage area for items like food, drinks, cell phones, etc.

TS 45.5 Normal Bus Operation Instrumentation and Controls

The following list identifies bus controls used to operate the bus. These controls are either frequently used or critical to the operation of the bus. They are located within easy reach of the operator. The operator will not be required to stand or turn to view or actuate these controls unless specified otherwise.

Systems or components monitored by onboard diagnostics system are displayed in clear view of the operator and provide visual and/or audible indicators. The intensity of indicators permits easy determination of on/off status in bright sunlight but not cause a distraction or visibility problem at night. All indicators are illuminated using backlighting.

The indicator panel is located in the instrument cluster mounted in the center of the driver's dash, within easy view of the operator instrument panel. All indicators have a method of momentarily

testing their operation. The audible alarm is tamper-resistant and has an outlet level between 80 and 83 dBA when measured at the location of the operator's ear.

On-board displays visible to the operator are limited to indicating the status of those functions described herein that are necessary for the operation of the bus. All other indicators needed for diagnostics and their related interface hardware is concealed and protected from unauthorized access. **Table 6** represents Proterra's standard instruments and alarms. Additional options are available upon request. The intent of the overall physical layout of the indicators is in a logical grouping of systems and severity nature of the fault.

Consideration was provided for future additions of spare indicators as the capability of onboard diagnostic systems improves.

Device	Description	Location	Function	Visual/ Audible
Master run switch	Rotary, four-position detent	Right Dash	Master control for bus, off, day run, night run and clearance ID lights	
Vehicle start	Approved momentary switch	Right Dash	Activates the High Voltage System	
Drive selector	Three illuminated push buttons	Side Switch Panel	Provides selection of propulsion: Drive, Neutral, Reverse	Gear selection
HVAC	Switch or switches to control HVAC	Overhead panel	Permits selection of passenger ventilation: off, cool, heat, low fan, high fan or full auto with on/off only	
Driver's ventilation	Rotary, four-position detent	Dash left panel	Permits supplemental ventilation: fan off, low, medium, or high	
Defroster fan	Rotary, four-position detent	Dash left panel	Permits defroster: fan off, low, medium or high	
Defroster temperature	Rotary, four-position detent	Dash left panel	Adjusts defroster temperature	
Windshield wiper	One-variable rotary position operating both wipers	Side Switch Panel	Variable speed control of left and right windshield wipers	
Windshield washer	Push button	Side Switch Panel	Activates windshield washers	
Dash panel lights	Push button	Main display	Provides adjustment for light intensity in night run and day run position	

Device	Description	Location	Function	Visual/ Audible
Interior lights	Three-position switch	Side Switch Panel	Selects mode of passenger compartment lighting: bright, OFF, dim.	
Front door ramp enable	Two-position switch	Right dash panel	Permits ramp activation from front door area	
Front door ramp	Three-position momentary switch	Right dash panel	Permits deploy and stow of front ramp	Amber light; exterior alarm
Front kneel	Three-position momentary switch	Right dash panel	Permits kneeling activation and raise and normal at front door remote location	Amber dash indicator; exterior alarm
Left remote mirror	Joystick type	Side Switch Panel	Permits two-axis adjustment of left exterior mirror	
Right remote mirror	Joystick type	Side Switch Panel	Permits two-axis adjustment of right exterior mirror	
Mirror heater	Switch activated	Side console	Permits heating of outside mirrors when required	
Passenger door control	Two momentary push buttons	Side console	Permits open/close control of front and rear passenger doors	Red light on push button indicating door open, amber light in instrument cluster indicating door open
shutdown override	Momentary switch with operation protection	Lower Switch Panel	Permits driver to activate the override of a vehicle fault condition or a vehicle shutdown condition	Continuous buzzer
Hazard flashers	Two-position switch	Side Switch Panel	Activates emergency flashers	Two green left/right indicator lights
Farebox interface	Farebox coach operator interface panel	Near farebox	Facilitates driver interaction with farebox system	LCD display
Destination sign interface	Destination sign interface panel	Over head	Facilitates driver interaction with destination sign system, manual entry	LCD display

Device	Description	Location	Function	Visual/ Audible
Turn signals	Momentary push button (two required) raised from other switches	Left foot panel	Activates left and right turn signals	Two green left/right indicators and audible indicator
PA manual	Momentary push button	Side console and left foot panel	Permits driver to manually activate public address microphone	
High beam	Detented push button	Left foot panel	Permits driver to toggle between low and high beam	Blue light
Parking brake	Pneumatic PPV	Lower Switch Panel	Permits driver to apply and release parking brake	Red light
Interlock Override	Two-position switch	Rear Switch Panel	Permits driver override to disable door and brake/throttle interlock	Red light and continuous buzzer
Stop Reset	Push button momentary	Side Switch Panel	Permits driver to clear a passenger stop request	
Speedometer	Speedometer, odometer, and diagnostic capability	Dash center panel	Visual indication of speed and distance traveled, accumulated vehicle mileage, fault condition display	Analog dial
Door obstruction	Sensing of door obstruction	Dash center	Indication of rear door sensitive edge activation	Red symbol always flashing and buzzer
Door opened	Door not fully closed	Dash center	Indication of rear door not properly closed	Amber light
Low system air pressure	Sensing low primary and secondary air tank pressure	Dash center	Indication of low air system pressure	Amber light, always constant
ABS indicator	Detects system status	Dash center	Displays system failure	Amber light
HVAC indicator	Detects system status	Dash center	Displays system failure	Amber light
Charging system indicator (12/24 V)	Detect charging system status	Dash center	Detects no charge condition and detects battery high, low, imbalance and no charge condition	Red or yellow light based on condition

Device	Description	Location	Function	Visual/ Audible
Bike rack deployed indicator	Detects bike rack position	Dash center	Indication of bike rack not being in fully stowed position	Amber light
High Voltage battery system state of charge	Analog gauge and digital display	Dash center	Indication of high voltage battery system state of charge	Analog dial and digital bar
Active charge/regeneration and power draw	Analog gauge and digital display	Dash center	Indication of electric regeneration, charging and power draw	Analog dial and digital bar

Table 5-Proterra Bus Instruments and Alarms

TS 45.6 Driver Foot Controls

Accelerator and brake pedals are designed for ankle motion. Foot surfaces of the pedals are faced with wear-resistant, nonskid, replaceable material.

TS 45.6.1 Pedal Angle

The vertical angle of the accelerator and brake pedals are determined from a horizontal plane regardless of the slope of the cab floor. The standard configuration for the 40’ Catalyst E2 accelerator pedal is an angle of 36° at initiation and 15° at full throttle. The angles for the brake pedal are 35° at initiation and 8° at full brake.

TS 45.6.2 Pedal Dimensions and Position

The floor-mounted accelerator pedal is 10 to 12 in. long and 3 to 4 in. wide. Clearance around the pedal allows for no interference precluding operation.

The accelerator and brake pedals are positioned such that the spacing between them, measured at the heel of the pedals, is between 1 and 2 in. Both pedals are located on the same plane coincident to the surface of the pedals.

TS 45.7 Brake and Accelerator Pedals

The brake and accelerator pedals are not adjustable. Optionally, adjustable brake and accelerator pedals are available. This option provide pedals that are adjustable forward and rearward a minimum of 3 in. The adjustment is made by use of a dash-mounted rocker switch. The switch is clearly labeled to identify it as pedal adjustment and is within easy reach of the driver. Pedal adjustment are enabled only when the bus is stationary and the parking brake engaged.

TS 45.8 Driver Foot Switches

The control switches for the turn signals are mounted on an inclined, floor-mounted inclined metal plate mounted to the driver’s platform, located to the left of the steering column. The location and design of this plate is such that foot room for the operator is not impeded. The inclined mounting

surface is skid-resistant. All other signals, including high beam and public address system, are in approved locations.

The angle of the turn signal platform is determined from a horizontal plane, regardless of the slope of the cab floor. The turn signal platform is angled at a minimum of 10° and a maximum of 37°. It is located no closer to the seat front than the heel point of the accelerator pedal.
The platform is not adjustable.

The foot switches are UL-listed, heavy-duty type, of a rugged, corrosion-resistant metal construction. The foot switches for the turn signals and PA system are momentary type, while the high beam is latching type. The spacing of the switches are such that inadvertent simultaneous deflection of switches is prevented.

TS 46. Driver's Amenities

TS 46.1 Coat Hanger

The standard configuration is for no coat hanger. Optionally a coat hanger can be provided.

TS 46.2 Drink Holder

The standard configuration is for no drink holder. Optionally a drink holder can be provided. It will securely hold the driver's drink container, which may vary widely in diameter. It will be mounted within easy reach of the driver and has sufficient vertical clearance for easy removal of the container. When the container is in the device, the driver's view of the road will not obstructed, and leakage from the container will not fall on any switches, gauges or controls.

TS 46.3 Storage Box

An enclosed driver storage area on the curbside wheel well is provided with a positive latching door and/or lock. The minimum size is 2750 in^3.

TS 47. Windshield Wipers and Washers

TS 47.1 Windshield Wipers

The bus is equipped with a windshield wiper for each half of the single-piece windshield. At 60 mph, no more than 10 percent of the wiped area is lost due to windshield wiper lift. The wipers park along the bottom edge of the windshield in an overlapping position. Windshield wiper motors and mechanisms are easily accessible for repairs or service from the inside of the bus. The fasteners that secure the wiper arms to the drive mechanism are corrosion-resistant. The wipers are single-control, with an electric two-speed intermittent system.

TS 47.2 Windshield Washers

The windshield washer system, when used with the wipers, deposits washing fluid evenly and completely wets the entire wiped area.

The windshield washer system has 4.5-gallon reservoir that is easily refilled from outside of the bus. The tank has two levels sensor (high and low). One triggers a message on the dash when the tank

is empty. The other will turn on a light on the fill pocket to alert to stop filling. Reservoir pump, lines and fittings are corrosion-resistant and include a means to determine fluid level.

TS 48. Driver's Seat

TS 48.1 Dimensions

The driver's seat is comfortable and adjustable so that people ranging in size from a 95th-percentile male to a 5th-percentile female may operate the bus.

TS 48.1.1 Seat Pan Cushion Length

Measurement is from the front edge of the seat pan to the rear at its intersection with the seat back. The adjustment of the seat pan length is no less than 16.5 in. at its minimum length and no more than 20.5 in. at its maximum length.

TS 48.1.2 Seat Pan Cushion Height

Measurement is from the cab floor to the top of the level seat at its center midpoint. The seat adjusts in height from a minimum of 14 in., with a minimum 6 in. vertical range of adjustment.

TS 48.1.3 Seat Pan Cushion Slope

Measurement is the slope of the plane created by connecting the two high points of the seat, one at the rear of the seat at its intersection with the seat back and the other at the front of the seat just before it waterfalls downward at the edge. The slope can be measured using an inclinometer and will be stated in degrees of incline relative to the horizontal plane (0 degrees). The seat pan adjusts in its slope from no less than plus 12 degrees (rearward "bucket seat" incline), to no less than minus 5 degrees (forward slope).

TS 48.1.4 Seat Base Fore/Aft Adjustment

Measurement is the horizontal distance from the heel point to the front edge of the seat. The minimum and maximum distances are measured from the front edge of the seat when it is adjusted to its minimum seat pan depth (approximately 15 in.). On all low-floor buses, the seat-base shall travel horizontally a minimum of 9 in. It adjusts no closer to the heel point than 6 in. On all high-floor buses, the seat base travels a minimum of 9 in. and adjusts no closer to the heel-point than 6 in.

TS 48.1.5 Seat Pan Cushion Width

Measurement is the horizontal distance across the seat cushion. The seat pan cushion is 17 to 21 in. across at the front edge of the seat cushion and 20 to 23 in. across at the side bolsters.

TS 48.2 Seat Suspension

The driver's seat is appropriately dampened to support a minimum weight of 380 lbs. The suspension is capable of dampening adjustment in both directions.

Rubber snubbers are provided to prevent metal-to-metal contact.

TS 48.2.1 Seat Back

The width measurement is the distance between the outermost points of the front of the seat back, at or near its midpoint in height. The seat back width is no less than 19 in. Seat back will include dual recliner gears on both sides of the seat. The standard height is the normal height seat back.

TS 48.2.2 Headrests

Standard configuration comes with adjustable headrest.

TS 48.2.3 Seat Back Lumbar Support

Measurement is from the bottom of the seat back at its intersection with the seat pan to the top of the lumbar cushioning. The seat back provides adjustable depth lumbar back support with three individual operating lumbar cells within a minimum range of 7 to 11 in.

TS 48.2.4 Seat Back Angle Adjustment

The seat back angle is measured relative to a level seat pan, where 90 degrees is the upright position and 90 degrees-plus represents the amount of recline.

The seat back adjusts in angle from a minimum of no more than 90 degrees (upright) to at least 105 degrees (reclined), with infinite adjustment in between.

TS 48.3 Seat Belt

The Proterra 40’ Catalyst E2 standard configuration comes with 2 Point, black color belts. The seat belts are stored in auto-locking retractors (ALR). The belts are mounted to the seat frame so that the driver may adjust the seat without resetting the seat belt. Standard the lap belt assembly is a minimum of 72 in. in length.

The seat and seat belt assemblies as installed in the bus withstands static horizontal forces as required in FMVSS 207 and 210.

TS 48.4 Adjustable Armrest

The standard configuration is for no armrests. Optionally armrests can be provided.

TS 48.5 Seat Control Locations

While seated, the driver is able to make seat adjustments by hand without complexity, excessive effort or being pinched. Adjustment mechanisms shall hold the adjustments and shall not be subject

to inadvertent changes. Seat controls standard location are on the right hand side of the driver's seat clear of any obstruction.

TS 48.6 Seat Structure and Materials

TS 48.6.1 Cushions

Cushions shall be fully padded with at least 3 in. of materials in the seating areas at the bottom and back.

TS 48.6.2 Cushion Materials

The standard configuration is for closed-cell polyurethane that is FMVSS 302 compliant. Optionally Docket 90A compliant material is available.

TS 48.6.3 Pedestal

The standard configuration is for powder-coated steel pedestal.

TS 48.6.4 Seat Options

Some options may or may not be available depending on the model of seat selected.

TS 49. Mirrors

TS 49.1 Exterior Mirrors

The bus is equipped with corrosion-resistant, outside rearview mirrors mounted with stable supports to minimize vibration. Mirrors are firmly attached to the bus to minimize vibration and to prevent loss of adjustment with a breakaway mounting system. Mirrors permit the driver to view the roadway along the sides of the bus, including the rear wheels. Mirrors are positioned to prevent blind spots.

Mirrors manually retract or fold sufficiently to allow bus washing operations but avoid contact with the windshield.

The curbside rearview mirror is mounted so that its lower edge is no less than 80 in. above the street surface with a standard 9x13 in head. The street side rearview mirror is low mounted also a standard 9x13 in head.

The driver is able to adjust either mirror remotely while seated in the driving position. Mirror heat is active by turning on the mirror heat switch. LED turn signals are integrated into the mirrors.

TS 49.2 Interior Mirrors

Mirrors are provided for the driver to observe passengers throughout the bus without leaving the seat and without shoulder movement. The driver is able to observe passengers in the front/entrance and rear/exit areas, anywhere in the aisle, and in the rear seats.

WINDOWS

TS 50. General

The windows on the 40’ Catalyst E2 exceed the specified minimum window area of 10,000 square inches for a 40’ bus.

TS 51. Windshield

The single-piece windshield permits an operator’s field of view as referenced in SAE Recommended Practice J1050. The vertically upward view is a minimum of 14°, measured above the horizontal and excluding any shaded band. The vertically downward view permits detection of an object 3½ft high no more than 2 ft in front of the bus except in a section of the top of the dash that is 20 inches wide where the object could not be seen. The horizontal view is a minimum of 82° above the line of sight, not 90°. Windshield pillars do not exceed 10° of binocular obscuration. The windshield is designed and installed to minimize external glare as well as reflections from inside the bus.

The windshield is easily replaceable by removing zip-locks from the windshield retaining moldings.

TS 51.1 Glazing

The 40’ Catalyst E2 single-piece windshield glazing has the following characteristics:

-Material: 6.76mm 73% L.T.
-Laminated glass.
-Conforms to SAE J673, J674, ANSI/SAE Z26.1-1996 and APTA Standard Bus Procurement Guidelines.

The vehicle is equipped with a single-piece windshield and does not have a shaded band in the upper portion of the glazing, as this area serves as the destination sign compartment glazing.

TS 52. Driver’s Side Window

The driver’s side window is the sliding type, it is sufficient to permit the seated operator to easily adjust the street-side outside rearview mirror. When in an open position, the window will not rattle or close during braking. This window section slides in tracks or channels designed to last the service life of the bus. The operator’s side window is not bonded in place and is easily replaceable. The glazing material has a single-density tint.

The driver’s view, perpendicular through operator’s side window glazing, extends a minimum of 33 in. (840 mm) to the rear of the heel point on the accelerator, and in any case accommodates a 95th percentile male operator. The view through the glazing at the front of the assembly begins not more than 27.2 in. above the operator’s floor. Driver’s window construction maximizes ability for full opening of the window.

The driver’s side window glazing material has a ¼ in. nominal thickness tempered safety glass conforming to the requirements of ANSI Z26.1-1996 Test Grouping AS-2 and the recommended practices defined in SAE J673.

The design prevents sections from freezing closed in the winter. Light transmittance is 75 percent on the glass area below 53 in. from the operator platform floor. On the top-fixed-over-bottom-slider configuration, the top fixed area above 53 in. may have a maximum 5 percent light transmittance.

The driver's side window is only available as a hidden frame (Flush "Euro-Look") top fixed over bottom slider, non-egress with tempered glass.

TS 53. Side Windows

TS 53.1 Configuration

Side windows are not bonded in place and are easily replaceable without disturbing adjacent windows. They are mounted so that flexing or vibration from operation or normal road excitation is not apparent. All aluminum and steel material is treated to prevent corrosion.

The quarter window in front of the entrance door is bonded in place.

TS 53.2 Emergency Exit (Egress) Configuration

Passenger windows meet the requirements of FMVSS 217 for emergency egress. The standard configuration is 1 curbside egress window and 3 street-side egress windows. The addition of extra egress windows is optional.

TS 53.3 Configuration

Side windows are fixed in position, except as necessary to meet the emergency escape requirements.

TS 53.4 Materials

Window glazing will be 5mm tempered safety glass. Windows will meet the requirements of ANSI Z26.1-1996 Test Grouping 2 and the Recommended Practices defined in SAE J673.

Windows will be tinted 50% gray. Window glazing will have 50% light transmittance as measured by ASTM D-1003 and 45% solar transmittance as measured by ASTM E-424. The window at the destination/location sign will not be tinted in the vicinity of the sign.

TS 53.5 Rear Window

The 40' Catalyst E2 is equipped with a rear window as standard configuration.

HEATING, VENTILATING AND AIR CONDITIONING

TS 54. Capacity and Performance

Please see below for current system design and planned performance.

The HVAC climate control system is capable of controlling the temperature and maintaining the humidity levels of the interior of the bus as defined in the following paragraphs.

The 40’ Catalyst E2 is equipped with a roof-mounted HVAC. It provides cabin heating and air-conditioning. It is an all-electric system using both high and low voltage systems.

With the bus running at the design operating profile with corresponding door opening cycle, and carrying a number of passengers equal to 150 percent of the seated load, the HVAC system will control the average passenger compartment temperature within a range between 65 and 80 °F, while maintaining the relative humidity to a value of 50 percent or less. The system will maintain these conditions while subjected to any outside ambient temperatures within a range of 10 to 95 °F and at any ambient relative humidity levels between 5 and 50 percent.

When the bus is operated in outside ambient temperatures of 95 to 115 °F, the interior temperature of the bus is permitted to rise 0.5°F for each degree of exterior temperature in excess of 95 °F. When the bus is operated in outside ambient temperatures in the range of -10 to 10 °F, the interior temperature of the bus will not fall below 55 °F while the bus is running on the design operating profile after stabilization with doors closed or a permitted door cycling.

System capacity testing, including pull-down/warm-up, stabilization and profile, shall be conducted in accordance to APTA’s Recommended Practice “Transit Bus HVAC System Instrumentation and Performance Testing.”

The air-conditioning portion of the HVAC system will be capable of reducing the passenger compartment temperature from 115 to 95 °F in less than 30 minutes after vehicle start-up. During the cool-down period, the refrigerant pressure will not exceed safe high-side pressures, and the condenser discharge air temperature, measured 6 in. from the surface of the coil, will be within the manufacturer’s acceptable air temperature rise. There will be no passengers on board, and the doors and windows will be closed.

The pull-up requirements for the heating system will be in accordance with Section 11.1 of APTA’s Recommended Practice“ Transit Bus HVAC System Instrumentation and Performance Testing.” With ambient temperature at -0 °F, and vehicle cold soaked at that temperature, the bus heating system will warm the interior passenger compartment to an average temperature of 70 °F ±2 °F within 70 minutes.

The air conditioning system meets these performance requirements using R134a.

TS 55. Controls and Temperature Uniformity

Please see below for current system design and planned performance.

The HVAC system, excluding the driver’s heater/defroster, is centrally controlled with an advanced electronic/diagnostic control system with provisions for extracting/reading data. The system is compliant with J1939 Communication Protocol for receiving and broadcasting of data.

The 40’ Catalyst E2 is an all-electric vehicle and does not have hot engine coolant. Therefore, hot engine coolant water cannot be delivered to the HVAC system driver’s defroster/heater. The driver’s defroster/heater is an all-electric system.

The driver has full control over the defroster and driver's heater. The driver is able to adjust the temperature in the driver's area through air distribution and fans. The interior climate control system switches automatically to the ventilating mode if the refrigerant compressor or condenser fan fails.

Interior temperature distribution is uniform to the extent practicable to prevent hot and/or cold spots. After stabilization with doors closed, the temperatures between any two points in the passenger compartment in the same vertical plane, and 6 to 72 in. above the floor, will not vary by more than 15 °F with doors closed while the HVAC is actively providing heat to the cabin. Any measured interior temperature will not vary more than ±10 °F from the average temperature determined in accordance with APTA's "Recommended Instrumentation and Performance Testing for Transit Bus Air Conditioning System" while the HVAC is actively providing heat to the cabin.

TS 55.1 Auxiliary Heater

The standard configuration is for no auxiliary heater. However, Proterra offers an additional diesel-fired auxiliary heater for cold-weather environments. Additional information can be provided upon request.

TS 56. Air Flow

TS 56.1 Passenger Area

Please see below for current system design and planned performance.

The cooling mode of the interior climate control system introduces air into the bus at or near the ceiling height at a minimum rate of 25 cubic ft per minute (cfm) per passenger based on the standard configuration bus carrying a number of passengers equal to 150 percent of the seated load. Airflow is evenly distributed throughout the bus, with air velocity not exceeding 100 ft per minute on any passenger, however some passengers can see more or less depending on where they are seated. The ventilating mode provides air at a minimum flow rate of 20 cfm per passenger.

Airflow may be reduced to 15 cfm per passenger (150 percent of seated load) when operating in the heating mode. The fans will activate as soon as the HVAC is turn on. The heating air outlet temperature will not exceed 125 °F under any normal operating conditions.

The climate control blower motors and fan are designed such that their operation complies with the interior noise level requirements.

The climate control system provides operating modes with and without "fresh air".

TS 56.2 Driver's Area

Please see below for current system design and planned performance.

The bus interior climate control system delivers at least 100 cfm of air to the driver's area when operating in the ventilating and cooling modes. Adjustable nozzles permit variable distribution or shut-down of the airflow. Airflow in the heating mode is reduced proportionally to the reduction of airflow into the passenger area. There is no provisions to provide fresh-air (exterior air) to the driver's area, except through ventilated air from the HVAC.

Pending testing, the windshield defroster unit will meet the requirements of SAE Recommended Practice J382, “Windshield Defrosting Systems Performance Requirements,” and has the capability of diverting heated air to the driver’s feet and legs. The defroster or interior climate control system maintains visibility through the driver’s side window.

TS 56.3 Controls for the Climate Control System (CCS)

The controls for the driver’s compartment for heating, ventilation and cooling systems are integrated and meet the following requirements:

1) The heat/defrost system fan is controlled by a separate switch that has an “off” position and at least two positions for speed control. All switches and controls preclude the possibility of clothing becoming entangled. An “on/off” switch is located near the main defroster switch.

2) The system does not required the use of a manually operated control valve as the heater is electrical and does not use heated water.

TS 56.4 Driver’s Compartment Requirements

Please see below for current system design and planned performance.

A separate heating, ventilation and defroster system for the driver’s area is provided and is controlled by the driver. Heating provided by the defroster does not have an option for fresh air. Heating provided by the HVAC does have the option to pull in fresh air. The system meets the following requirements:

- The heater and defroster system provides heating for the driver and heated air to completely defrost and defog the windshield. There are no designed components for the driver’s side window, and the front door glass. Fan(s) are able to draw air from the bus body interior and pass it through the defroster system and over the driver’s feet. Pending testing, a minimum capacity of 100 cfm is provided. The driver has complete control of the heat for the driver’s area.

- The defroster supply outlets are located at the lower edge of the windshield. These outlets are durable and are free of sharp edges that can catch clothes during normal daily cleaning. The system is such that foreign objects such as coins or tickets cannot fall into the defroster air outlets. There are no adjustable ball vents or louvers provided at the left of the driver’s position to allow direction of air onto the side windows.

A ventilation system is provided to ensure driver comfort and is capable of providing fresh air in both the foot and head areas via HVAC ventilation. Vents are controllable by the driver from the normal driving position. Decals are provided, indicating “operating instructions” and “open” and “closed” positions. When closed, vents are sealed to prevent the migration of water or air into the bus.

TS 56.5 Driver's Cooling

There is no dedicated evaporator for drivers cooling. A booster blower for the driver are standard and it pulls the air from the street side AC duct and provides air conditioner to the driver.

TS 57. Air Filtration

Air is filtered before entering the AC system and being discharged into the passenger compartment. The filter meets the ANSI/ASHRAE 52.1 requirement for 5 percent or better atmospheric dust spot efficiency, 50 percent weight arrestance, and a minimum dust holding capacity of 120 g per 1000 cfm cell. Air filters are easily removable for service and cleanable.

TS 58. Roof Ventilators

The 40' Catalyst E2 is equipped with two roof ventilators in the roof of the bus, one approximately over the front axle and the other approximately over the rear axle. The standard roof ventilators are opaque although options are available for clear roof ventilators. Each ventilator is easily opened and closed manually. When open with the bus in motion, this ventilator provides fresh air inside the bus. Each ventilator covers an opening area of no less than 425 sq. in. and is capable of being positioned with all four edges raised simultaneously to a height of no less than 3½ in. An escape hatch is incorporated into the roof ventilator. Roof ventilator(s) are sealed to prevent entry of water when closed.

TS 59. Maintainability

Manually controlled shut-off valves in the refrigerant lines allow isolation of the compressor and dehydrator filter for service. To the extent practicable, self-sealing couplings utilizing O-ring seals are used to break and seal the refrigerant lines during removal of major components, such as the refrigerant compressor. Shut-off valves are provided in lieu of self-sealing couplings. The condenser is located to efficiently transfer heat to the atmosphere and will not ingest air warmed above the ambient temperature by the bus mechanical equipment, or to discharge air into any other system of the bus. The location of the condenser precludes its obstruction by wheel splash, road dirt or debris. HVAC components located within 6 in. of floor level are constructed to resist damage and corrosion.

High and low refrigerant pressure gauges are not available in the return air area.

TS 60. Entrance/Exit Area Heating

The standard configuration for the 40' Catalyst E2 has no provisions for entrance/exit area heating. Options for entrance/exit heating are available.

TS 61. Floor-Level Heating

The standard configuration is for no floor-level heating to be installed.

EXTERIOR PANELS, FINISHES AND EXTERIOR LIGHTING

TS 62. Design

The bus has a clean, smooth, simple design, primarily derived from bus performance requirements and passenger service criteria. The exterior and body features, including grilles and louvers, are shaped to facilitate cleaning by automatic bus washers without snagging washer brushes. Water and dirt will not be retained in or on anybody feature to freeze or bleed out onto the bus after leaving the washer. The body and windows are sealed to prevent leaking of air, dust or water under normal operating conditions and during cleaning in automatic bus washers for the service life of the bus.

Exterior panels are sufficiently stiff to minimize vibration, drumming or flexing while the bus is in service. When panels are lapped, the upper and forward panels will act as a watershed. The windows, hatches and doors are able to be sealed. Accumulation of spray and splash generated by the bus's wheels is minimized on windows and mirrors.

TS 62.1 Materials

Body materials were selected and the body fabricated to reduce maintenance, extend durability and provide consistency of appearance throughout the service life of the bus. Detailing was kept simple, and add-on devices and trim are minimized and integrated into the basic design.

The use of composite materials provides a much stronger, more durable and longer lasting body than provided with conventional steel or aluminum "stick built" construction. Finite Element Analysis indicates the body should easily endure sixteen years of transit service.

TS 62.2 Roof-Mounted Equipment

A non-skid, clearly marked walkway or steps was incorporated on the roof to provide access to equipment without damaging any system or bus paneling.

TS 63. Pedestrian Safety

Exterior protrusions along the side and front of the bus greater than ½ in. and within 80 in. of the ground have a radius no less than the amount of the protrusion. The exterior rearview mirrors, cameras and required lights and reflectors are exempt from the protrusion requirement. Advertising frames protrude no more than ⅞ in. from the body surface. Grilles, doors, bumpers and other features on the sides and rear of the bus are designed to minimize toeholds or handholds.

Exterior protrusions do not cause a line-of-sight blockage for the driver.

TS 64. Repair and Replacement

TS 64.1 Side Body Panels

The 40' Catalyst E2 has an all-composite body. Composite body buses do not have exterior paneling. The outer skin is integral to the body structure. When damage occurs to the exterior of the vehicle, the repair is contained to just the damaged area. The side body from floor to window is

repairable with common composite repair techniques. The body is also covered with a gel coat that resists chips and cracks.

TS 64.2 Composite Body Repair

Composite bus bodies are pretty resistant to impact, however sections of a monocoque composite body or other equipment that may be damaged in normal service are easily repairable with common composite repair techniques. If requested by the by the agency Proterra will send our regional service representative to review the bus after the accident. The service rep will take pictures of the issue and assess the damage, then will communicate with the customer and Proterra Service.

There are 3 options to perform the repair:

1) For relatively minor issues that have just affected the skin layer of the bus body or an access door, our field service representatives can handle the repair or can assist the agency's maintenance group to complete. Proterra keeps spare parts of access doors if it is the preference of the agency to have these replaced instead.
2) Proterra offers optional composite repair training to all customers. If the agency has its own body shop or a body shop of preference, it can opt to complete this training and then complete any repairs internally. Proterra will provide a recommended materials list and can support with instructions as needed.
3) Proterra has partnered with a third party composite repair company who can come to the agency and complete the repair. Proterra has already completed several projects with them, although none were related to accident repairs.

TS 65. Rain Gutters

Rain gutters are integral to the design of the composite body. Our vehicles employ a uniquely designed roof profile that channels water away from passenger entrance and exit areas. This provides similar functionality via the body design and roof profile.

TS 66. License Plate Provisions

Provisions have been made to mount standard-size U.S./Canada license plates per SAE J686 on the rear of bus. These provisions direct-mount the license plates so that they can be cleaned by automatic bus-washing equipment without being caught by the brushes. The rear license plate provision is illuminated per SAE J587. An option for a front license plate is available.

TS 66.1 Rub rails

The standard configuration is for no rub rails installed. Our fender flares act as a rub rail and our composite body is more robust then the thin aluminum paneling of most buses.

TS 67. Fender Skirts

Fender skirts are installed to minimize water spray from the bus in wet conditions. They do not extend beyond the body width.

TS 68. Wheel Covers

The standard configuration is for no wheel covers.

TS 68.1 Splash Aprons

The standard configuration is for no splash aprons.

TS 69. Service Compartments and Access Doors

TS 69.1 Access Doors

Conventional or pantograph hinged doors are used for the motor compartment and for all auxiliary equipment compartments. Access openings are sized for easy performance of tasks within the compartment, including tool operating space. Access doors are of rugged construction and maintain mechanical integrity and function under normal operations throughout the service life of the bus. They close flush with the body surface. All doors are hinged at the top or on the forward edge and are prevented from coming loose or opening during transit service or in bus washing operations. All access doors are retained in the open position by gas-filled springs with safety props and are easily operable by one person. Springs and hinges are corrosion resistant. Latch handles are flush with, or recessed behind, the body contour and are sized to provide an adequate grip for opening.

The lower side access doors for the motor compartment, when opened, will restrict access to the upper side access doors. All other access doors, when opened, do not restrict access for servicing other components or systems.

TS 69.2 Access Door Latch/Locks

Access doors larger than 100 sq in. are equipped with corrosion-resistant flush-mounted latches or locks. All such access doors that require a tool to open are standardized throughout the vehicle and will require a nominal 5/16 in. square male tool to open or lock.

TS 70. Bumpers

TS 70.1 Location

Bumpers provide impact protection for the front and rear of the bus with the top of the bumper being 27 in., ±2 in., above the ground. Bumper height is such that when one bus is parked behind another, a portion of the bumper faces will contact each other.

TS 70.2 Front Bumper

No part of the bus, including the bumper, will be damaged as a result of a 5mph impact of the bus at curb weight with a fixed, flat barrier perpendicular to the bus's longitudinal centerline. The bumper will return to its pre-impact shape within 10 minutes of the impact. The bumper protects the bus from damage as a result of 6.5 mph impacts at any point by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000lbs parallel to the longitudinal centerline of the bus. It protects the bus from damage as a result of 5.5mph impacts into the corners at a 30° angle to the longitudinal centerline of the bus. The energy absorption system of the bumper is independent of every power system of the bus and will not require service

or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in.

The 40’ Catalyst E2 can be configured with or without a bike rack. The bumpers are a three piece design.

TS 70.3 Rear Bumper

No part of the bus, including the bumper, will be damaged as a result of a 2mph impact with a fixed, flat barrier perpendicular to the longitudinal centerline of the bus. The bumper will return to its pre-impact shape within 10 minutes of the impact. When using a yard tug with a smooth, flat plate bumper 2 ft wide contacting the horizontal centerline of the rear bumper, the bumper provides protection at speeds up to 5 mph, over pavement discontinuities up to 1 in. high, and at accelerations up to 2 mph/sec. The rear bumper protects the bus when impacted anywhere along its width by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000 lbs, at 4 mph parallel to or up to a 30° angle to the longitudinal centerline of the bus. The rear bumper is shaped to preclude unauthorized riders standing on the bumper. The bumper will not require service or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in. The bumpers are a three piece design.

TS 70.4 Bumper Material

Bumper material is corrosion-resistant and will withstand repeated impacts of the specified loads without sustaining damage. Bumpers are made of aluminum and the outer shell is solid elastomer. These bumper qualities will be sustained throughout the service life of the bus.

TS 71. Finish and Color

TS 71.1 Appearance

All exterior surfaces are smooth and free of wrinkles and dents. The 40’ Catalyst E2 is a composite body. It has a gel-coated exterior finish in white with Proterra logos on the front & rear.

Options for paint or full-body decal / wrap are available.

TS 72. Decals, Numbering and Signing

Monograms, numbers and other special signing will be applied to the inside and outside of the bus as required. Signs are durable and fade, chip and peel-resistant. All decals are installed per the decal supplier recommendations. Signs are provided in compliance with the ADA requirements defined in 49 CFR Part 38, Subpart B, 38.27. The standard configuration is for an English decal package.

TS 72.1 Passenger Information

ADA priority seating signs as required and defined by 49 CFR are provided to identify the seats designated for passengers with disabilities.

Requirements for a public information system in accordance with 49 CFR are not standard but can be provided as an option.

TS 73. Exterior Lighting

All exterior lights are designed to prevent entry and accumulation of moisture or dust. Lamps, lenses and fixtures are interchangeable to the extent practicable. Hazard lamps at the rear of the bus are not enabled when the motor service door is opened. Light lenses are designed and located to prevent damage when running the vehicle through an automatic bus washer.

Commercially available LED-type lamps are utilized at all exterior lamp locations including the head lamps.

TS 73.1 Backup Light/Alarm

Visible and audible warnings inform following vehicles or pedestrians of reverse operation. Visible reverse operation warning conforms to SAE Standard J593. Audible reverse operation warning conforms to SAE Recommended Practice J994 Type C or D.

TS 73.2 Doorway Lighting

Lamps at the front and rear passenger doorways comply with ADA requirements and activate only when the doors open. These lamps illuminate the street surface to a level of no less than 1 foot-candle for a distance of 3 ft outward from the outboard edge of the door threshold. The lights are positioned below the lower daylight opening of the windows and are shielded to protect passengers' eyes from glare.

TS 73.3 Turn Signals

Turn-signal lights are provided on the front, rear, curb and street sides of the bus in accordance with federal regulations.

TS 73.4 Headlights

Headlamps are designed for ease of replacement. Standard OEM headlight installation will be provided in accordance with federal regulations.

The headlamps can be configured for daytime running. The standard configuration is currently for LED headlamps. The design life of the headlamps can be provided.

TS 73.5 Brake Lights

Brake lights are provided in accordance with FMVSS 108 and Part 393, Subpart B of the FMCSA as applicable. An addition brake strip light center mounted is provided.

TS 73.6 Service Area Lighting (Interior and Exterior)

LED lamps are provided in the motor and all other compartments where service may be required to generally illuminate the area for night emergency repairs or adjustments. These service areas include, the motor compartment and the communication box. The passenger door operator compartments and junction/apparatus panels do not have service lights. Lighting is adequate to

light the space of the service areas to levels needed to complete typical emergency repairs and adjustments. The service area lamps are suitable for the environment in which they are mounted.

Motor compartment lamps are controlled by a switch mounted in the motor compartment. All other service area lamps are controlled by switches mounted on or convenient to the lamp assemblies. Power to the service area lighting is programmable. Power latches on with activation of the switch and is automatically discontinued (timed out) after 30 minutes to prevent damage caused by inadvertently leaving the service area lighting switch in the “on” position after repairs are made.

INTERIOR PANELS AND FINISHES

TS 74. General Requirements

Materials were selected on the basis of maintenance, durability, appearance, safety, flammability and tactile qualities. Materials are strong enough to resist everyday abuse and be vandalism and corrosion resistant. Trim and attachment details are kept simple and unobtrusive. Interior trim is secured to avoid resonant vibrations under normal operational conditions.

Interior surfaces more than 10 in. below the lower edge of the side windows or windshield are shaped so that objects placed on them fall to the floor when the coach is parked on a level surface. Any components and other electrical components within close proximity to these surfaces are also resistant to this cleaning method.

The standard configuration does not have any additional anti-graffiti/vandalism surface treatments.

TS 75. Interior Panels

Panels are easily replaceable and tamper resistant. They are reinforced, as necessary, to resist vandalism and other rigors of transit bus service. Individual trim panels and parts are interchangeable to the extent practicable.

Interior panels meet FMVSS 302 *Flammability of Interior Materials*. An option is available to install alternate interior panels that meet FTA Docket 90-A.

TS 75.1 Driver Area Barrier

A barrier or bulkhead between the driver and the street-side front passenger seat is provided. The barrier minimizes glare and reflections in the windshield directly in front of the barrier from interior lighting during night operation. Location and shape permits full seat travel and reclining possibilities that can accommodate the shoulders of a 95th-percentile male. The partition has a side return and stanchion to prevent passengers from reaching the driver by standing behind the driver’s seat. The lower area between the seat and panel is accessible to the driver. The partition is strong enough in conjunction with the entire partition assembly for mounting of such equipment as flare kits, fire extinguishers (1.2kg), microcomputer, public address amplifier, etc. The panel is properly attached to minimize noise and rattles.

The driver’s barrier extends continually from the floor area to the ceiling and from the bus wall to the first stanchion immediately behind the driver to provide security to the driver and to limit passenger conversation.

Options for full or partial driver barriers that provide a barrier between entering passengers are available.

TS 75.2 Modesty Panels

Sturdy divider panels constructed of durable, unpainted, corrosion-resistant material complementing the interior are provided to act as both a physical and visual barrier for seated passengers.

Design and installation of modesty panels located in front of forward-facing seats include a handhold or grab handle along its top edge. These dividers are mounted on the sidewall and project toward the aisle no farther than passenger knee projection in longitudinal seats or the aisle side of the transverse seats. Modesty panels extend from at least the window opening of the side windows, and those forward of transverse seats extend downward to 1 and 1½ in. above the floor. Panels forward of longitudinal seats extend to below the level of the seat cushion. Dividers positioned at the doorways, where applicable, provide no less than a 2½ in. clearance between the modesty panel and a fully open, inward opening door, or the path of a deploying flip-out ramp to protect passengers from being pinched. Modesty panels installed at doorways are equipped with grab rails if passenger assists are not provided by other means.

The modesty panel and its mounting withstand a static force of 250 lbs applied to a 4 × 4 in. area in the center of the panel without permanent visible deformation.

TS 75.3 Front End

The entire front end of the bus is sealed to prevent debris accumulation behind the dash and to prevent the driver's feet from kicking or fouling wiring and other equipment. The front end is free of protrusions that are hazardous to passengers standing at the front of the standee line area of the bus during rapid decelerations. Paneling across the front of the bus and any trim around the driver's compartment is formed metal or thermo-formed plastic material. Composite dash panels are reinforced as necessary, vandal-resistant and replaceable. All colored, painted and plated parts forward of the driver's barrier are finished with a surface that reduces glare. Any mounted equipment has provision to support the weight of equipment.

TS 75.4 Rear Bulkhead

Proterra's standard seating for the 40' Catalyst E2 bulkhead does not provide access to the motor compartment area (ProDrive). Any equipment installed at the rear of the bus can be accessed by the removal of fastened panels. The rear bulkhead and rear interior surfaces are material suitable for exterior skin; painted and finished to exterior quality.

The rear bulkhead paneling is contoured to fit the ceiling, side walls and seat backs so that any litter or trash will tend to fall to the floor or seating surface when the bus is on a level surface. Any air vents in this area are louvered to reduce airflow noise and to reduce the probability of trash or liter being thrown or drawn through the grille. Additionally, the rear bulkhead area is predominately taken up by the rear window.

TS 75.5 Headlining

Ceiling panels are made of durable, corrosion resistant, easily cleanable material. Headlining is supported to prevent buckling, drumming or flexing and is secured without loose edges. Headlining materials are treated or insulated to prevent marks due to condensation where panels are in contact with metal members. Moldings and trim strips, as required to make the edges tamperproof, are stainless steel, aluminum or plastic, colored to complement the ceiling material. Headlining panels covering operational equipment that is mounted above the ceiling is on hinges for ease of service but retained to prevent inadvertent opening.

TS 75.6 Fastening

Interior panels are attached so that there are no exposed unfinished or rough edges or rough surfaces. Fasteners are corrosion resistant. Panels and fasteners are not easily removable by passengers. Exposed interior fasteners are minimized, and where required are tamper resistant.

TS 75.7 Insulation

The Proterra Catalyst insulation meets the requirement of FMVSS 302. It has a composite body that provides even better insulation performance than adding insulation to a metal body bus. Composite body offers better U-factor / insulating properties. Insulation properties are unimpaired during the service life of the bus. Any insulation material used inside the motor compartment will not absorb or retain oils or water and are designed to prevent casual damage that may occur during maintenance operations.

The bus body is thoroughly sealed so that the driver or passengers cannot feel drafts during normal operations with the passenger doors closed.

TS 75.8 Floor Covering

The floor covering has a non-skid walking surface that remains effective in all weather conditions. The floor covering, as well as transitions of flooring material to the main floor and to the entrance and exit area, is smooth and present no tripping hazards. Seams are sealed/welded per manufacturer's specifications. The standee line is approximately 2 in. wide and extends across the bus aisle. The color and pattern is consistent throughout the floor covering.

Any areas on the floor that are not intended for standees, such as areas "swept" during passenger door operation, are clearly and permanently marked.

The floor is easily cleaned and arranged to minimize debris accumulation.

A one-piece center strip extends from the vertical wall of the rear settee between the aisle sides of transverse seats to the standee line. The floor is of a bi-level construction and the center strip is one piece at each level. The covering between the center strip and the wheel housings may be separate pieces. At the rear door, a separate strip as wide as the door extends from the center strip to the outboard edge of the rear/exit area.

The floor under the seats is covered with smooth surface flooring material. The floor covering shall closely fit the sidewall in a fully sealed butt joint or extend to the top of the cove.

TS 75.9 Interior Lighting

The light source is located to minimize windshield glare, with distribution of the light focused primarily on the passengers' reading plane while casting sufficient light onto the advertising display. The lighting system is designed to form part of or the entire air distribution duct.

The lens material is translucent polycarbonate. Lenses are designed to effectively "mask" the light source. Lenses are sealed to inhibit incursion of dust and insects yet be easily removable for service. Access panels are provided to allow servicing of components located behind light panels. The entire light fixture is hinged.

TS 75.10 Passenger

The driver can select either dim, off or bright for interior lighting. When in "day run" mode, all interior lights will be as selected by the driver.

In "night run" mode, the front most lights on each side (behind the driver and the front door) are turned on only when either door is opened. With both doors closed, the front most lights will be off to minimize light reflection and glare on the windshield. The rear lights will be on in the setting selected by the driver (off, dim or bright).

Optionally, all of the lights can be configured to turn on to the dim or bright position when either door is opened.

All interior lighting is turned off whenever the transmission selector is in reverse.

The interior lights are LED.

TS 75.11 Driver's Area

The driver's area has a light to provide general illumination, and it illuminates the half of the steering wheel nearest the driver to a level of 5 to 10 foot-candles.

TS 75.12 Seating Areas

Seating lights were optimized to reduce glare on the driver's area. With the front door closed and cabin lighting on (full and half, bright and dim) the light provided on a 1 sq. ft. plane at an angle of 45 degrees from horizontal, centered 33 in. above the floor and 24 in. in front of the seat back at each seat position. Average light level for the rear bench seats is above 7 foot-candles.

TS 75.13 Vestibules/Doors

Floor surface in the aisles is a minimum of 10 foot-candles, and the vestibule area a minimum of 4 foot-candles with the front doors open and a minimum of 2 foot-candles with the front doors closed. The front entrance area and curb lights illuminate when the front door is open. Rear exit area and curb lights illuminate when the rear door is opened.

Proterra and our customers have evaluated the light levels and found this to be the optimum design for passenger safety and reduced glare.

TS 75.14 Step Lighting

Step lighting for the intermediate steps between lower and upper floor levels is a minimum of 4 foot-candles and illuminates at all times in “night run” position and when doors are open in “day run” position. The step lighting is low profile to minimize tripping and snagging hazards for passengers and is shielded as necessary to protect passengers’ eyes from glare.

TS 75.15 Ramp Lighting

Exterior and interior ramp lighting comply with federal regulations.

TS 75.16 Farebox Lighting

A light fixture is mounted in the ceiling above the farebox location. The fixture is capable of projecting a concentrated beam of light on the farebox. This light will automatically come on whenever the front doors are opened and the run switch is in the “night run” position. Additionally the driver can command the fare box lighting on when the front door is open with a switch in the driver’s workplace.

TS 76. Fare Collection

Space and structural provisions are made for installation of currently available fare collection devices, which is as far forward as practicable. Location of the fare collection device does not restrict traffic in the vestibule, including wheelchairs if a front door loading device is used, and allows the driver to easily reach the farebox controls and to view the fare register. The farebox does not restrict access to the driver’s area, does not restrict operation of driver’s controls and does not—either by itself or in combination with stanchions, transfer mounting, cutting and punching equipment, or route destination signs—restrict the driver’s field of view per SAE Recommended Practice J1050. The location and mounting of the fare collection device allows use, without restriction, by passengers. The farebox location permits accessibility to the vault for easy manual removal or attachment of suction devices. Meters and counters on the farebox are readable on a daily basis. The floor under the farebox is reinforced as necessary to provide a sturdy mounting platform and to prevent shaking of the farebox.

Transfer mounting, cutting and punching equipment will be located in a position convenient to the driver.

TS 77. Interior Access Panels and Doors

Access for maintenance and replacement of equipment is provided by panels and doors that appear to be an integral part of the interior. Access doors are hinged with gas props or over-center springs, where practical, to hold the doors out of the mechanic’s way. Panels prevent entry of mechanism lubricant into the bus interior.

Some access doors are secured with hand screws or latches. All fasteners that retain access panels are, whenever practical, captive in the cover. Other access doors are secured with locks. The locks are standardized so that only one tool is required to open access doors on the bus.

TS 77.1 Floor Panels

There are no access openings in the floor.

PASSENGER ACCOMMODATIONS

TS 78. Passenger Seating

TS 78.1 Arrangements and Seat Style

The standard passenger seating arrangement in the bus is such that seating capacity is maximized. Passenger seats are arranged in a transverse, forward-facing configuration, except at the wheel housings where aisle-facing seats may be arranged as appropriate with due regard for passenger access and comfort. Other areas where aisle-facing seats may be provided are at wheelchair securement areas and platforms. Proterra's standard seating for the 40' Catalyst E2 vehicle is a 40-passenger, USSC Gemini seats (Figure 19). Optional seating arrangements are available.

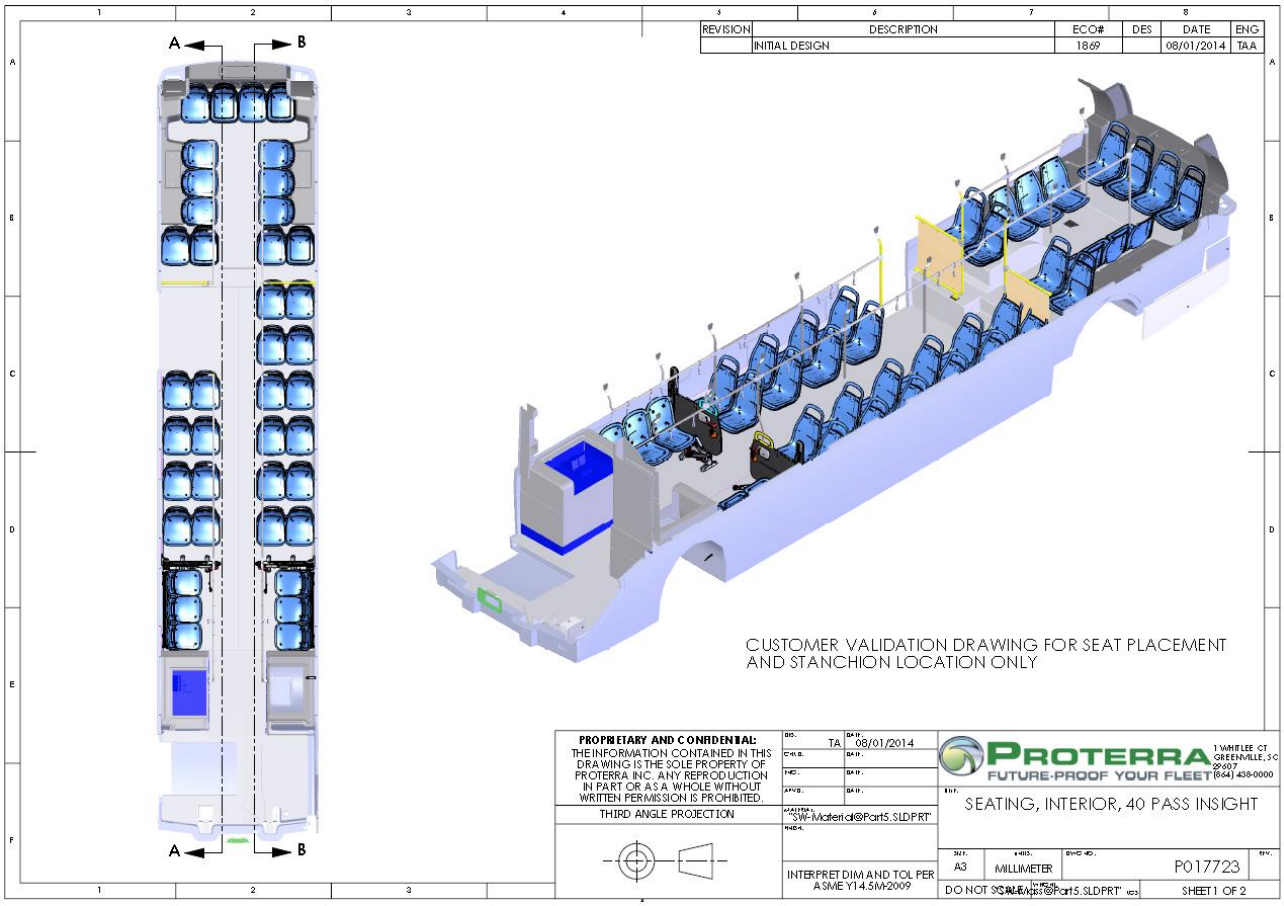


Figure 18- 40' Catalyst Seating Layout

TS 78.2 Rearward Facing Seats

Rearward facing seats are not installed.

TS 78.3 Padded Inserts/Cushioned Seats

In the standard configuration, the seats are equipped with upholstered vandal resistant inserts throughout the bus. Options are available.

TS 78.4 Seat back fitness

In the standard configuration, the seat back insert thickness does not exceed 1in. in the knee room area. Options are available.

TS 78.5 Drain Hole in Seats

The standard configuration is for no drain hole provision in the seat inserts. Options are available.

TS 78.6 Hip-to-Knee Room

Hip-to-knee room measured from the center of the seating position, from the front of one seat back horizontally across the highest part of the seat to a vertical surface immediately in front, is a minimum of 26 in. At all seating positions in paired transverse seats immediately behind other seating positions, hip-to-knee room is no less than 27 in.

TS 78.7 Foot Room

Foot room, measured at the floor forward from a point vertically below the front of the seat cushion, is no less than 14 in. Seats immediately behind the wheel housings and modesty panels may have foot room reduced.

TS 78.8 Aisles

The aisle between the seats is no less than 20 in. wide at seated passenger hip height. Seat backs are shaped to increase this dimension to no less than 24 in. at 32 in. above the floor (standing passenger hip height).

TS 78.9 Dimensions

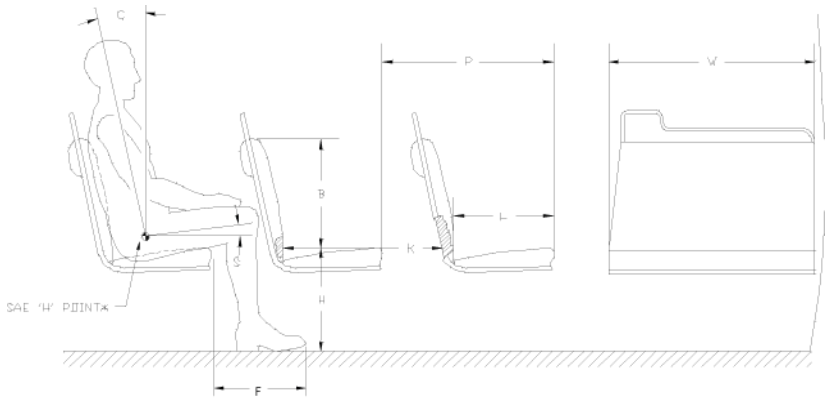


Figure 19- Seating Dimensions and Standard Configuration

Proterra complies with this paragraph. Seat dimensions for the various seating arrangements have the following dimensions (refer to Figure 20):

- The width, W, of the two-passenger transverse seat is a minimum 35 in.
- The length, L, is 17 in., ±1 in.
- The seat back height, B, is a minimum of 15 in.
- The seat height, H, is 17 in., ± 1 in. For the rear lounge (or settee) and longitudinal seats, and seats located above raised areas for storage of under-floor components, a cushion height of up to 18 in., ±2 in., will be allowed.
- Foot room = F.
- The seat cushion slope, S, is between 5 and 11 deg.
- The seat back slope, C, is between 8 and 17 deg.
- Hip to knee room = K.
- The pitch, P, is shown as reference only.

TS 78.10 Structure and Design

The passenger seat frame and its supporting structure is constructed and mounted so that space under the seat is maximized and is completely free of obstructions to facilitate cleaning.

Seats, structures and restraints around the securement area do not infringe into the mobility device envelope or maneuverability.

The transverse seat structure is fully cantilevered from the sidewall with sufficient strength for the intended service. The lowest part of the seat assembly that is within 12 in. of the aisle is at least 10 in. above the floor.

In locations at which cantilevered installation is precluded by design and/or structure, other seat mounting may be used.

All transverse objects—including seat backs, modesty panels, and longitudinal seats—in front of forward-facing seats do not impart a compressive load in excess of 1000lbs onto the femur of passengers ranging in size from a 5th-percentile female to a 95th-percentile male during a 10g deceleration of the bus. This deceleration peaks at 0.05 to 0.015 seconds from initiation. Permanent deformation of the seat resulting from two 95th-percentile males striking the seat back during this 10g deceleration does not exceed 2 in., measured at the aisle side of the seat frame at height H. The seat back does not deflect more than 14 in., measured at the top of the seat back, in a controlled manner to minimize passenger injury. Structural failure of any part of the seat or sidewall does not introduce a laceration hazard.

The seat assembly withstands static vertical forces of 500 lbs applied to the top of the seat cushion in each seating position with less than ¼ in. permanent deformation in the seat or its mountings. The seat assembly withstands static horizontal forces of 500 lbs evenly distributed along the top of the seat back with less than ¼in. permanent deformation in the seat or its mountings. The seat backs at the aisle position and at the window position withstands repeated impacts of two 40-lb sandbags without visible deterioration.

The back of each transverse seat incorporates a handhold no less than ⅞ in. in diameter for standees and seat access/egress. The handhold will not be a safety hazard during severe decelerations. The handhold extends above the seat back near the aisle so that standees shall have a convenient vertical assist, no less than 4 in. long that may be grasped with the full hand. This handhold does not cause a standee using this assist to interfere with a seated 50th-percentile male passenger. The handhold is also usable by a 5th-percentile female, as well as by larger passengers, to assist with seat access/egress for either transverse seating position. The upper rear portion of the seat back and the seat back handhold immediately forward of transverse seats are padded and/or constructed of energy-absorbing materials. During a 10g deceleration of the bus, the HIC number (as defined by SAE Standard J211a) does not exceed 400 for passengers ranging in size from a 5th percentile female through a 95th percentile male.

The seat back handhold may be deleted from seats that do not have another transverse seat directly behind and where a vertical assist is provided.

Longitudinal seats are the same general design as transverse seats but without seat back handholds. Longitudinal seats may be mounted on the wheelhouses. Armrests are included on the ends of each set of longitudinal seats except on the forward end of a seat set that is immediately to the rear of a transverse seat, the driver's barrier, or a modesty panel, when these fixtures perform the function of restraining passengers from sliding forward off the seat. Armrests are not required on longitudinal seats located in the wheelchair parking area that fold up when the armrest on the adjacent fixed longitudinal seat is within 3½ in. of the end of the seat cushion. Armrests are located from 7 to 9 in. above the seat cushion surface. The area between the armrest and the seat cushion

is closed by a barrier or panel. The top and sides of the armrests has a minimum width of 1 in. and is free from sharp protrusions that form a safety hazard.

Seat back handhold and armrests withstand static horizontal and vertical forces of 250 lbs. applied anywhere along their length with less than ¼ in. permanent deformation. Seat back handhold and armrests withstands 25,000 impacts in each direction of a horizontal force of 125 lbs. with less than ¼in. permanent deformation and without visible deterioration.

TS 78.11 Construction and Materials

Selected materials minimize damage from vandalism and reduce cleaning time. The seats are attached to the frame with hex bolts rather than tamper-resistant fasteners. Coloring is consistent throughout the seat material, with no visually exposed portion painted. Any exposed metal touching the sides or the floor of the bus is stainless steel. The seat, pads and cushions are contoured for individuality, lateral support and maximum comfort and fit the framework to reduce exposed edges.

The minimum radius of any part of the seat back, handhold or modesty panel in the head or chest impact zone is a nominal ¼in. The seat back and seat back handhold immediately forward of transverse seats are constructed of energy-absorbing materials to provide passenger protection and, in a severe crash, to allow the passenger to deform the seating materials in the impact areas. Complete seat assemblies are interchangeable to the extent practicable.

TS 79. Passenger Assists

Passenger assists in the form of full grip, vertical stanchions or handholds are provided for the safety of standees and for ingress/egress. Passenger assists are convenient in location, shape and size for both the 95th-percentile male and the 5th-percentile female standee. Starting from the entrance door and moving anywhere in the bus and out the exit door, a vertical assist is provided either as the vertical portion of the seat back assist or as a separate item so that a 5th-percentile female passenger may easily move from one assist to another using one hand and the other without losing support. All handholds and stanchions at the front doorway, around the farebox, and at interior steps for bi-level designs are powder-coated in a high-contrast yellow color. The forward-most vertical stanchions on either side of the aisle immediately behind the driver's area are a stainless steel finish.

TS 79.1 Assists

Excluding those mounted on the seats and doors, the assists have a cross-sectional diameter between 1¼ and 1½ in. or provide an equivalent gripping surface with no corner radii less than ¼ in. All passenger assists permit a full hand grip with no less than 1½ in. of knuckle clearance around the assist. Passenger assists are designed to minimize catching or snagging of clothes or personal items and are capable of passing the NHTSA Drawstring Test.

Any joints in the assist structure is underneath supporting brackets and securely clamped to prevent passengers from moving or twisting the assists. Seat handholds may be of the same construction and finish as the seat frame. Door-mounted passenger assists are powder-coated metal. Connecting tees and angles are powder-coated metal castings. Assists will withstand a force of 300 lbs. applied over a 12in. lineal dimension in any direction normal to the assist without permanent

visible deformation. All passenger assist components, including brackets, clamps, screw heads and other fasteners used on the passenger assists are designed to eliminate pinching, snagging and cutting hazards and are free from burrs or rough edges.

TS 79.2 Front Doorway

Front doors, or the entry area, are fitted with ADA-compliant assists. Assists are as far outward as practicable, but located no farther inboard than 6 in. from the outside edge of the entrance step and is easily grasped by a 5th-percentile female boarding from street level. Door assists are functionally continuous with the horizontal front passenger assist and the vertical assist and the assists on the wheel housing or on the front modesty panel.

TS 79.3 Vestibule

The aisle side of the driver's barrier, the wheel housings and when applicable the modesty panels is fitted with vertical passenger assists that are functionally continuous with the overhead assist and that extend to within 36 in. of the floor. These assists have sufficient clearance from the barrier to prevent inadvertent wedging of a passenger's arm.

A horizontal passenger assist is located across the front of the bus and prevents passengers from sustaining injuries on the fare collection device or windshield in the event of a sudden deceleration. Without restricting the vestibule space, the assist provides support for a boarding passenger from the front door through the fare collection procedure. The assist is no less than 36 in. above the floor. The assists at the front of the bus is arranged to permit a 5th-percentile female passenger to easily reach from the door assist, to the front assist, to vertical assists on the driver's barrier, wheel housings or front modesty panel.

TS 79.4 Rear Doorway(s)

Vertical assists that are functionally continuous with the overhead assist are provided at the aisle side of the transverse seat immediately forward of the rear door and on the aisle side of the rear door modesty panel(s). Passenger assists are provided on modesty panels that are functionally continuous with the rear door assists. The exit area is fitted with assists having a cross-sectional diameter between 1¼ and 1½ in. or providing an equivalent gripping surface with no corner radii less than ¼ in., and provides at least 1½ in. of knuckle clearance between the assists and their mounting. The assists are designed to permit a 5th-percentile female to easily move from one assist to another during the entire exiting process. The assists are located no farther inboard than 6 in. from the outside edge of the rear doorway step.

TS 79.5 Overhead

Except forward of the standee line and at the rear door, a continuous, full-grip, overhead assist is provided. This assist is located over the center of the aisle seating position of the transverse seats. The assist is no less than 70 in. above the floor. Optional configurations for grab straps are available.

Overhead assists will simultaneously support 150 lbs on any 12in. length. No more than 5 percent of the full grip feature will be lost due to assist supports.

TS 79.6 Longitudinal Seat Assists

Longitudinal seats have vertical assists located between every other designated seating position, except for seats that fold/flip up to accommodate wheelchair securement. Assists extend from near the leading edge of the seat and are functionally continuous with the overhead assist. Assists are staggered across the aisle from each other where practicable and are no more than 52 in. apart or functionally continuous for a 5th percentile female passenger.

TS 79.7 Wheel Housing Barriers/Assists

Passenger assists are mounted around the exposed sides of the wheel housings, which are designed to prevent passengers from sitting on wheel housings. Such passenger assists also effectively retain items, such as bags and luggage, placed on top of wheel housings.

TS 80. Passenger Doors

Passenger doors and doorways comply with ADA requirements.

The 40’ Catalyst E2 comes standard with electric doors from Ventura Systems. Doorways are provided in the locations and styles as follows.

TS 80.1 Front door

The front door is forward of the front wheels and under direct observation of the driver.

TS 80.2 Rear Door

The curbside doorway centerline is located rearward of the point midway between the front door centerline and the rearmost seat back. The doors are pneumatic and operate per specification at air pressures between 90 and 130 psi.

TS 80.3 Materials and Construction

Structure of the doors, their attachments, inside and outside trim panels and any mechanism exposed to the elements are corrosion resistant. Door panel construction is of corrosion-resistant metal or reinforced non-metallic composite materials. When fully opened, the doors provide a firm support and will not be damaged if used as an assist by passengers during ingress or egress. Door edges are sealed to prevent infiltration of exterior moisture, noise, dirt and air elements from entering the passenger compartment, to the maximum extent possible based on door types.

The closing edge of each door panel has no less than 2 in. of soft weather stripping. The doors, when closed, will be effectively sealed, and the hard surfaces of the doors are at least 4 in. apart (not applicable to single doors). The combined weather seal and window glazing elements of the front door do not exceed 10° of binocular obstruction of the driver’s view through the closed door.

TS 80.4 Dimensions

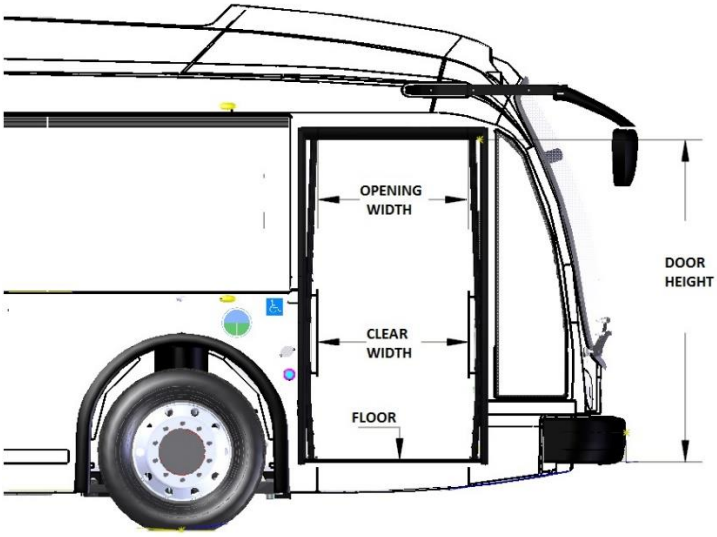


Figure 20-Transit Bus Minimum Door Opening

When open, the front door leave an opening no less than 74.9 in. in height. The front door clear width is 33.2” with the doors fully open. The rear door leaves an opening height of 75.75” and the clear width is 38.6” with the door fully open.

TS 80.5 Door Glazing

The doors on the 40’ Catalyst E2 are both fitted with full length glazing. Because the glazing is full length, it is bonded to the frame to maximize vision area and for aesthetic reasons. There is really no way due to current door construction to fit the glazing into a rubber frame. The manufacturer’s recommended repair procedure for replacing damaged glazing can be provided upon request.

TS 80.6 Door Projection

TS 80.6.1 Exterior

The exterior projection of the front doors beyond the side of the bus is minimized and does not block the line of sight of the rear exit door via the curb side mirror when the doors are fully open. The exterior projection of both doors is minimized and does not exceed 14 in. during the opening or closing cycles or when doors are fully opened

TS 80.6.2 Interior

Projection inside the bus does not cause an obstruction of the rear door mirror or cause a hazard for standees.

TS 80.7 Door Height Above Pavement

It is possible to open and close either passenger door when the bus loaded to gross vehicle weight rating is not knelt and parked with the tires touching an 8in. high curb on a street sloping toward the curb so that the street-side wheels are 5 in. higher than the right-side wheels.

TS 80.8 Closing Force

Closing door edge speed does not exceed 12 in. per second, and opening door speed does not exceed 19 in. per second. Power doors does not slam closed under any circumstance, even if the door is obstructed during the closing cycle. If a door is obstructed during the closing cycle, the pressure exerted on the obstruction does not increase once initial contact has been made.

Doors closed by a return spring or counterweight-type device are equipped with an obstruction-sensing device that, at a minimum, alerts the driver if an obstruction is detected between the closing doors. Doors closed by a return spring or counterweight type device, when unlocked, are capable of being pushed to the point where the door starts to open with a force not to exceed 25 lbs applied to the center edge of the forward door panel.

Whether or not the obstruction-sensing system is present or functional, it is possible to withdraw a 1½ in. diameter cylinder from between the center edges of a closed and locked door with an outward force not greater than 35 lbs.

TS 80.8.1 Rear Door Closing Force

Power-close rear doors are equipped with an obstruction-sensing system such that if an obstruction is within the path of the closing doors, the doors will stop and/or reverse direction. Our standard system will impart a force less than 10-lbs on a 1 sq. in. obstruction.

TS 80.9 Actuators

Doors open or close completely in not more than 3.5 seconds from the time of control actuation and are subject to the closing force requirements.

Door actuators are adjustable so that the door opening and closing speeds can be independently adjustable to satisfy the above requirements. Actuators and the complex door mechanism are concealed from passengers but are easily accessible for servicing. The door actuators are rebuildable. The standard doors are powered by compressed air. The exhaust from the door system is not routed below the floor of the bus. It exits through a muffler on the valve block of the actuator mechanism. The majority of oil in the air lines is separated out by an individual air filter for each door.

Door actuators and associated linkages will maximize door holding forces in the fully open and fully closed positions to provide firm, non-rattling, non-fluttering door panels while minimizing the force exerted by the doors on an obstruction midway between the fully open and closed positions.

The rear door actuator is under the complete control of the vehicle operator and will open and close in response to the driver's control.

Doors that employ a “swing” or pantograph geometry and/or are closed by a return spring or counterweight-type device will be equipped with a positive mechanical holding device that automatically engages and prevents the actuation mechanism from being back-driven from the fully closed position. The holding device is overcome only when the driver’s door control is moved to an “Exit Door Enable” position and the vehicle is moving at a speed of less than 2 mph, or in the event of actuation of the emergency door release.

Locked doors require a force of more than 300 lbs to open manually. When the locked doors are manually forced to open, damage is limited to the bending of minor door linkage with no resulting damage to the doors, actuators or complex mechanism.

TS 80.10 Emergency Operation

In the event of an emergency, it is possible to manually open doors designated as emergency exits from inside the bus using a force of no more than 25 lbs after actuating an unlocking device. The unlocking device is clearly marked as an emergency-only device and requires two distinct actions to actuate. The respective door emergency unlocking device is accessible from the doorway area. The unlocking device is easily reset by the operator without special tools or opening the door mechanism enclosure. Doors that are required to be classified as “emergency exits” meet the requirements of FMVSS 217.

TS 80.11 Door Control

The door control is located in the operator’s area within the hand reach envelope described in SAE Recommended Practice J287, “Driver Hand Control Reach”. The 40’ Catalyst E2 standard configuration is for two push button doors controls switches (front door and back door). The controls do not provide tactile feedback to indicate commanded door position, but resist inadvertent door actuation by providing visual feedback.

An additional exterior front door switch is located on the curbside headlight bezel. This exterior door switch opens the front door and illuminates the interior of the vehicle for 1 minute. The front door remains in the commanded position even if power is removed or lost.

TS 80.12 Door Controller

The doors are operated by push-button controls, conveniently located and operable within the driver’s reach. The push buttons are labeled. There is a separate set of push button controls for the front and rear door. These buttons operate as follows:

Push either the “front or rear door” button to open that door. While the door is opening or closing, a lamp in the button will flash on and off. When the door is fully opened, the button lamp illuminates steadily (does not flash). Push the button again to close the door.

Options for a five-position door controller are also available.

TS 80.13 Door Open/Close

Operation of, and power to, the passenger doors is completely controlled by the operator.

An exterior door control switch is provided and an air dump valve is accessible from the exterior of the bus.

TS 81. Accessibility Provisions

Space and body structural provisions are provided at the front door of the bus to accommodate a low-floor ramp system.

TS 81.1 Loading Systems

A low-floor ramp system is installed at the front door.

TS 81.2 Loading System for 30 to 60ft Low-Floor Bus

An automatically controlled, power-operated ramp system compliant to requirements defined in 49 CFR Part 38, Subpart B, §38.23c provides ingress and egress quickly, safely and comfortably, both in forward and rearward directions, for a passenger in a wheelchair from a level street or curb.

The standard wheelchair loading system is located at the front door, with the ramp being of a simple hinged, flip-out type design being capable of deploying to the ground at a maximum 4:1 slope.

The 40’ Catalyst E2 standard ADA ramp is a 1:4 slope ADA Ramp manufactured by Ricon and electrically operated. Options are available for alternative ADA ramps manufactured by Ricon and Lift-U.

TS 81.3 Wheelchair Accommodations

Two forward-facing locations, as close to the wheelchair loading system as practical, provide parking space and securement system compliant with ADA requirements for a passenger in a wheelchair.

TS 81.4 Interior Circulation

Maneuvering room inside the bus accommodates easy travel for a passenger in a wheelchair from the loading device and from the designated securement area. It is designed so that no portion of the wheelchair protrudes into the aisle of the bus when parked in the designated parking space(s). When the positions are fully utilized, an aisle space of no less than 20 in. is maintained. No width dimension is less than 34 in. Areas requiring 90° turns of wheelchairs have a clearance arc dimension no less than 45 in., and in the parking area where 180° turns are expected, space is clear in a full 60in. diameter circle. A vertical clearance of 12in. above the floor surface is provided on the outside of turning areas for wheelchair footrests.

TS 81.5 Roof Ventilation/Escape Hatches

Two roof ventilators are provided and designed to perform as escape hatches. One ventilator/escape hatch is located in the roof at the front of the coach, another in the roof at the rear of the coach.

SIGNAGE AND COMMUNICATION

TS 82. Destination Signs

A destination sign system is furnished on the front, on the right side near the front door and at the rear of the vehicle. The standard bus is furnished with destination signs in the following configuration:

- Manufacturer: Hanover Displays or Luminator
- Front Sign: LED, Amber
- Curb Side: LED, Amber
- Rear: LED, Amber
- Street Side: None
- Dash: None

Additional configurations for destination signs are available for selection.
All signs are controlled via a single human-machine interface (HMI). In the absence of a single mobile data terminal (MDT), the HMI is conveniently located within reach of the seated driver.

The destination sign compartments meet the following minimum requirements:

- Compartments are designed to prevent condensation and entry of moisture and dirt.
- Compartments are not designed with active defogging.
- Access is provided to allow cleaning of inside compartment window and unit glazing.
- The front window has an exterior display area of no less than 8.5 in. high by 56 in. wide.

TS 83. Passenger Information and Advertising

TS 83.1 Interior Displays

The standard configuration does not provide provisions on the rear of the driver's barrier or the equipment box located on the wheel well for a frame to retain information such as routes and schedules.

Advertising media 11 in. high and 0.09 in. thick which can be retained near the juncture of the bus ceiling and sidewall. The retainers are concave and support the media without adhesives. The media is illuminated by the interior lighting system.

TS 83.2 Exterior Displays

The standard configuration does not provide provisions to integrate advertising into the exterior design of the bus, i.e. the standard configuration will not include ad-frames. Many Proterra customers use the full vehicle for advertising via full body decals / wraps.

Optional configurations are available.

TS 84. Passenger Stop Request/Exit Signal

TS 84.1 Transit Coach

A passenger “stop requested” signal system that complies with applicable ADA requirements defined in 49 CFR, Part 38.37, is provided. The system consists of a touch tape, chime and interior sign message. The touch tape is accessible to all seated passengers, with provisions for standees. It is easily accessible to all passengers, seated or standing. Vertical touch tape is be provided at each window mullion and adjacent to each wheelchair parking position and priority seating positions.

Additional provisions are included at each wheelchair passenger position and at priority seating positions, to allow a passenger in a mobility aid to easily activate the “stop requested” signal.

An additional “stop request” button on the rear door stanchion is available.

Optional configurations are available.

TS 84.2 Signal Chime

A single “stop requested” chime sounds when the system is first activated. A double chime sounds anytime the system is activated from wheelchair passenger areas.

Exit signals located in the wheelchair passenger area are no higher than 4 ft. above the floor. Instructions are provided to clearly indicate function and operation of these signals.

TS 85. Communications

TS 85.1 Camera Surveillance System

The base vehicle is designed with minimal provisions for a customer requested surveillance system. Proterra can install additional provisions or a full surveillance system at the customer’s request.

TS 85.2 Public Address System

A public address system is provided on each bus for facilitating radio system and driver-originated announcements to passengers.

TS 85.2.1 Speakers

Eight (8) interior speakers and an exterior loudspeaker is provided, semi-flush mounted, on alternate sides of the bus passenger compartment, installed with proper phasing. Total impedance seen at the input connecting is 8 Ohms. Mounting is accomplished with riv-nuts and machine screws. One exterior loudspeaker is provided, mounted near the front door of the coach for announcement and arrival information.

TS 85.3 Automatic Passenger Counter (APC)

The base vehicle is designed with minimal provisions for an automatic passenger counter. At request, Proterra can install additional provisions or a full APC system.

TS 85.4 Radio Handset and Control System

TS 85.4.1 Drivers Speaker

Each bus has the option of a recessed speaker in the ceiling panel above the driver. This speaker is the same component used for the speakers in the passenger compartment. It has 8 Ohms of impedance.

TS 85.4.2 Handset

Each bus will be provided with a handset for driver use.

TS 85.4.3 Driver Display Unit (DDU)

The driver display unit is not included in our standard configuration, but if applicable, is installed as close to the driver's instrument panel as possible.

TS 85.4.4 Emergency Alarm

An emergency alarm is installed and is accessible to the driver but hidden from view.

TS 86. Event Data Recorders (EDR)

No EDR is installed in the standard configuration.

Revision History

Date	Rev.	Approver	Description of Change
11/14/2017	-	E. Carbaugh	Initial Release
08/08/2018	1	E. Carbaugh	Updates for 800V systems, front axle, E2 Performance measurements, passenger seating layout, and destination signs.
10/01/2018	2	C. Prado	• Updated sections TS 6-18, TS 21, TS 26, TS 27, TS 29, TS 31, TS 32, TS 35, TS 37, TS 39, TS 42, TS 43, TS 44, TS 45, TS 46, TS 48, TS 49, TS 51, TS 56, TS 58, TS 59, TS 66, TS 68, TS 70, TS 72, TS 75, TS 80, TS 81 & TS 84. • Created section TS85
7/23/2020	3	E. Carbaugh	Updated several sections to align with latest technology.

PROTERRA ENERGY™
FLEET SOLUTIONS

60kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

The Proterra® 60kW Charging System is a cost-effective solution for fleets with longer available charge times. Each 60kW Power Control System can be paired with up to 4 dispensers for automated, sequential charging.

The Proterra 60kW Charging System can recharge a Proterra Catalyst® E2 electric bus in approximately 6 hours. The Saf-T-Liner® C2 Jouley electric school bus powered by Proterra technology can charge in less than 3 hours with the Proterra 60kW Charging System, and with additional dispensers up to 4 electric school buses can be charged in automated sequence in less than 12 hours.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Multi-dispenser Capable**
- **Intelligent and Automated**

Open source communications protocol

V2G Bi-directional V2G capability

Smart grid ready

Telematics-enabled

PROTERRA

60 kW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™ FLEET SOLUTIONS

TECHNICAL SPECIFICATIONS

ELECTRICAL INPUT	
Nominal Power – Continuous	66 kVA
Input Voltage	480VAC, 5-Wire WYE (L1, L2, L3, Neutral, Ground)
Input Current	79A @ 480VAC, 60Hz
Input Frequency	60 Hz
Power Factor	>0.995
Maximum Efficiency	>91% @ 800 V (DC output voltage dependent)
THD - Full Power	<3%
ELECTRICAL OUTPUT	
Output Power Capability – Continuous	60 kW
Output Voltage	270 – 870 VDC
Output Current	± 200ADC
Charging Module	Remote dispenser with vehicle interface
Max Number of Dispensers	4 dispensers for automated, sequential charging
Max Distance - PCS to Dispenser	500 ft | 152 m
MECHANICAL	
Cooling	Air cooling
Weight	1400 lb | 635 kg
Dimensions (W x D x H)	31.5 in x 23.6 in x 70.8 in | 80 cm x 60 cm x 180 cm
Environmental Rating	NEMA 3R
Wall Clearance (Side, Back)	6 in, 1 in | 15.24 cm, 2.54 cm
Adjacent Unit Clearance (Side, Back)	1 in, 1 in | 2.54 cm, 2.54 cm
Door Clearance	Facing open space: 36 in | 91.4 cm
	Facing open door: 48 in | 121.9 cm
DISPENSER SPECIFICATIONS	
Dimensions - wall-mounted (W x D x H)	15.75 in x 8.5 in x 26.5 in | 40 cm x 21.6 cm x 67.3 cm
Dimensions - pedestal-mounted (W x D x H)	15.75 in x 8.5 in x 58 in | 40 cm x 21.6 cm x 147.3 cm
Weight (wall-mounted)	42 lb | 19 kg
Weight (pedestal-mounted)	112 lbs | 50.8 kg
Dispenser Installation	Wall or pedestal-mounted
Charging Cord Length	10 ft, 18 ft or 25 ft | 3 m, 5.5 m, or 7.6 m
Wall Clearance (Side, Back)	0 in, 0 in | 0 cm, 0 cm
Door Clearance (Facing open space, Facing another door)	36 in, 48 in | 91.44 cm, 121.92 cm
ENVIRONMENTAL	
Operational Temperature Range	-4°F to 113°F | -20°C to 45°C
Humidity	0% to 95%
Altitude	De-rates over 2000m above sea level
COMMUNICATIONS PROTOCOLS	
Remote Management	OCPP 1.6 via 4G Cellular
Compatible Charging Connections	J1772 CCS Type 1 universal plug-in, SAE J3105-1 pantograph system
CERTIFICATIONS	
UL	2202, 2231
Warranty	2 Years

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra charging systems are designed and manufactured in the USA, compliant with Federal DOT Buy America requirements.

proterra.com/energy-services

PROTERRA ENERGY™
FLEET SOLUTIONS

125kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

Fleets with high uptime requirements will benefit most from the Proterra® 125kW Charging System. The system allows for easy scalability as your electric fleet grows. Each 125kW Power Control System can be paired with up to four dispensers for automated, sequential charging.
A Proterra Catalyst® E2 vehicle can charge in approximately 3 hours using the Proterra 125kW Charging System.
With two dispensers, the 125kW system can charge two Proterra Catalyst vehicles in approximately 6 hours.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Multi-dispenser Capable**
- **Intelligent and Automated**

Open source communications protocol

V2G Bi-directional V2G capability

Smart grid ready

Telematics-enabled

PROTERRA

125kW | PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™ FLEET SOLUTIONS

TECHNICAL SPECIFICATIONS

ELECTRICAL INPUT		
Nominal Power – Continuous	138 kVA	
Input Voltage	480VAC, 5-Wire WYE (L1, L2, L3, Neutral, Ground)	
Input Current	166A @ 480VAC, 60Hz	
Input Frequency	60 Hz	
Power Factor	>0.995	
Maximum Efficiency	>94% @ 800 V (DC output voltage dependent)	
THD - Full Power	<3%	
ELECTRICAL OUTPUT		
Output Power Capability – Continuous	125 kW (@ ≥530VDC), 60kW (@ <530VDC)	
Output Voltage (Range automatically selected based on EV battery voltage)	530-920VDC	125kW
	270-529VDC	60kW
Output Current	± 200ADC	
Charging Module	Remote dispenser with vehicle interface	
Max number of dispensers	4 dispensers for automated, sequential charging	
Max distance - PCS to dispenser	500 ft | 152 m	
MECHANICAL		
Cooling	Liquid cooled – closed loop, exchanger integrated	
Weight	2500 lb | 1134 kg	
Dimensions (W x D x H)	39.5 in x 29.75 in x 115 in | 100.3 cm x 75.6 cm x 292.1 cm	
Environmental Rating	NEMA 3R	
Wall Clearance (Side, Back)	6 in, 1 in | 15.24 cm, 2.54 cm	
Adjacent Unit Clearance (Side, Back)	1 in, 1 in | 2.54 cm, 2.54 cm	
Door Clearance	Facing open space: 40 in | 101.6 cm	
	Facing another door: 48 in | 121.9 cm	
DISPENSER SPECIFICATIONS		
Dimensions - wall-mounted (W x D x H)	15.75 in x 8.5 in x 26.5 in | 40 cm x 21.6 cm x 67.3 cm	
Dimensions - pedestal-mounted (W x D x H)	15.75 in x 8.5 in x 58 in | 40 cm x 21.6 cm x 147.3 cm	
Weight (wall-mounted)	42 lb | 19 kg	
Weight (pedestal-mounted)	112 lbs | 50.8 kg	
Dispenser installation	Wall or pedestal-mounted	
Charging cord length	10 ft, 18 ft or 25 ft | 3 m, 5.5 m, or 7.6 m	
Wall Clearance (Side, Back)	0 in, 0 in | 0 cm, 0 cm	
Door Clearance (Facing open space, Facing another door)	36 in, 48 in | 91.44 cm, 121.92 cm	
ENVIRONMENTAL		
Operational Temperature Range	-4°F to 113°F | -20°C to 45°C	
Humidity	0% to 95%	
Altitude	De-rates over 2000m above sea level	
COMMUNICATIONS PROTOCOLS		
Remote management	OCPP 1.6 via 4G Cellular	
Compatible Charging Connections	J1772 CCS Type 1 universal plug-in, SAE J3105-1 pantograph system	
CERTIFICATIONS		
UL	2202, 2231	
Warranty	2 Years	

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

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