Battery Electric Bus Familiarization

Module 1:

Battery Electric Bus Overview:

Fundamentals

Overview

- Overview
- BEBs vs. ICE vs. Hybrid Buses
- Details of BEB Systems and Components
- BEB High Voltage ID & Risks, System Cooling and Data Communication
- Battery Management & Cooling
- Preventive Maintenance
- Summary

Learning Outcomes

- COMPARE AND CONTRAST DIFFERENCES AND SIMILARITIES BETWEEN BEBS AND OTHER CURRENT BUS TYPES
- EXPLAIN THE GENERAL ADVANTAGES AND DISADVANTAGES OF EACH PROPULSION TYPE
- DESCRIBE THE PROCESS OF POWER FLOW ON A BEB
- IDENTIFY THE COMPONENTS AND SUBSYSTEMS THAT MAKE UP A STANDARD BEB
- DESCRIBE THE PRIMARY FUNCTION(S) OF EACH SUBSYSTEM AND COMPONENT IN THE OVERALL PROCESS OF BEB OPERATION
- IDENTIFY THE AREAS OF HIGH VOLTAGE RISK ASSOCIATED WITH EACH SUBSYSTEM OF A BEB
- LIST THE BEB SUBSYSTEMS THAT UTILIZE A COOLANT LOOP
- EXPLAIN WHY VARIOUS SYSTEMS UTILIZE A COOLANT LOOP

Learning Outcomes

- DESCRIBE THE COMMUNICATION PROTOCOLS ON A BEB
- DESCRIBE ESS/BATTERY MAKEUP AND HOW TO IDENTIFY THEM
- LIST THE BATTERY SAFETY SYSTEMS AND DEVICES
- DESCRIBE THE PURPOSE AND OPERATION OF BATTERY THERMAL MANAGEMENT SYSTEMS [BTMS]
- IDENTIFY THE PURPOSE OF PREVENTIVE MAINTENANCE
- LIST TYPICAL TASKS AND MAINTENANCE INTERVALS FOR BEBS
- DIFFERENTIATE BETWEEN MAINTENANCE TASKS ON BEBS VS. TRADITIONAL BUSES
- IDENTIFY TYPICAL DIAGNOSTIC EQUIPMENT

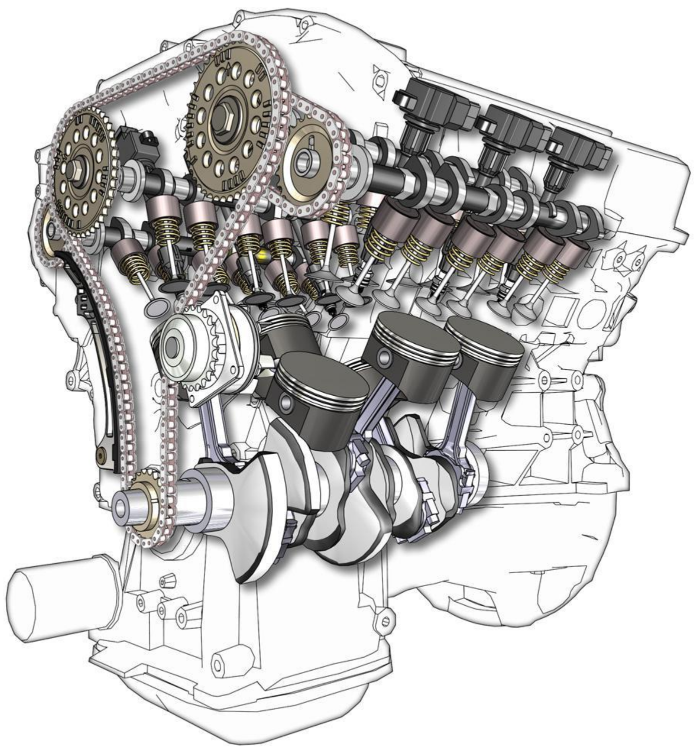
Overview (3)

A quick note to participants: Not every agency will have the same bus manufacturer or model as demonstrated in this course. Please consult your manufacturer's manual and agency's specific guidelines when it comes to working with a BEB. Each agency may have a variation of names for a specific tool and can vary from agency to agency.

Overview – Terminology (3)

ABS – Anti-Lock Braking System	AC- Alternating Current	BEB- Battery Electric Bus
BMS- Battery Management System	CAN- Controller Area Network	DC-Direct Current
ECU- Electronic Control Unit	EMI- Electromagnetic Interference	ESS- Energy Storage System
HV- High Voltage	HVIL- High Voltage Interlock Loop	HVJB- High Voltage Junction Box
IGBT-Insulated Gate Bipolar Transistor	LOTO- Lock-out/Tag-out	LV- Low Voltage
MSD- Manual Service Disconnect	MUX- Multiplex	TM- Traction Motor

Overview – A Brief History (4)



Practical electric vehicles [EV] have actually been around for quite a while, dating back to nearly the 1890s

Limiting factors such as range and durability, high costs, lower overall speed led to a general dismissal of EVs in favor of vehicles with the more appealing **internal combustion engine** (ICE)

ICE vehicles dominated the worldwide market up until the turn of the 21st century

Challenges such as rising oil prices and increasing interest in environmental concerns (global warming and alternative fuel sources) provided a stronger platform a comeback

Overview – What is a Battery Electric Bus? (4)

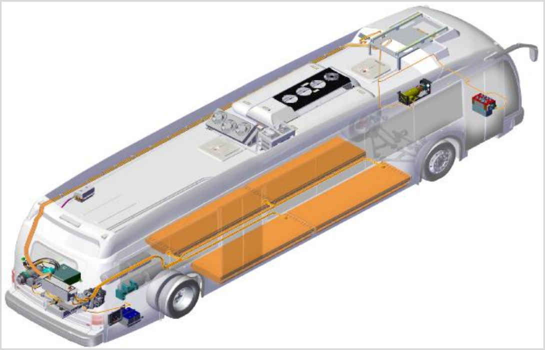
BEB = A bus driven by one or more electric motors that utilize energy from the onboard high voltage batteries

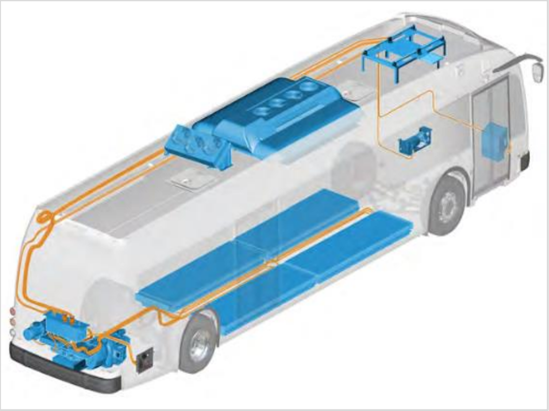
Design stems from response of a need to reduce greenhouse gases, utilize renewable energy, increase fuel economy and offer quiet operations

Design of BEB systems and components is pretty similar to current bus designs

With BEBs, High Voltage [HV] is considered anything 50 volts or more

Common BEB voltages run between 400 and 800 volts





Section 1-2: BEBs vs. ICE vs. Hybrid Buses

Vehicle Characteristics & Operations (5-6)

Similarities

- Low voltage 12/24VDC system
- Air system and power steering
- Multiplex [MUX] and I/O systems
- Grounding
- Suspension
- CAN principles
- Brakes
- Doors & ADA equipment

Vehicle Characteristics & Operations (5-6)

Powertrain

HV Batteries & battery management systems; ESS

Fueling vs. charging methods

Differences

Vehicle Characteristics & Operations (6-7)

SAE J1772 –
Standard for plug in chargers (most common depot application for North America

SAE J3068 –

More to do with AC charging;

Not as applicable

SAE J3105 –

Covers Overhead charging, applies to conductive or pantograph charging

SAE J2954-2 –

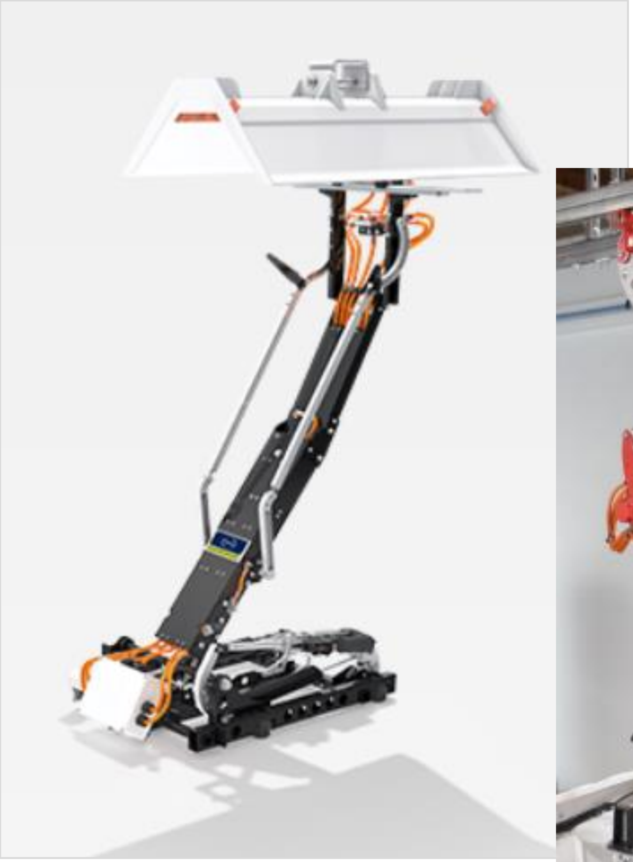
Covers inductive charging (contactless)

Charging (7)

Plug-In Charging

- Infrastructure includes a physical charging station and charger plug unit
  - The plug needs to be manually connected or inserted into the vehicle charge receptacle
- Includes safety features to ensure safe handling and operation

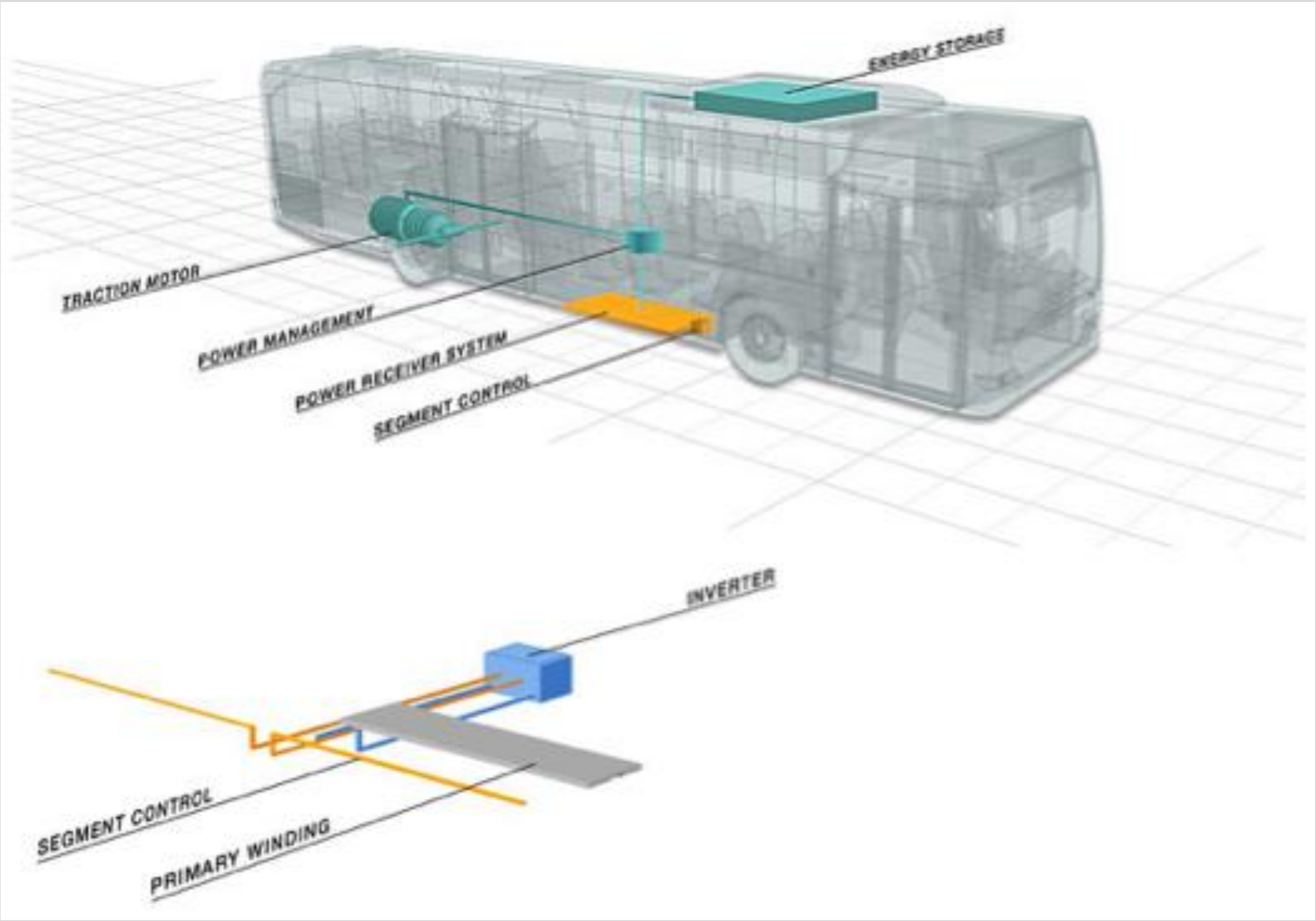
Charging (7-8)



Overhead Charging

- Currently most common method for BEB charging
- Infrastructure includes charger and charge post/dispenser:
    - Roof-mounted pantograph charging ("bus up" [left])
    - Inverted pantograph charging ("bus down" [right])
- HV not present until "handshake" between charger and vehicle is complete

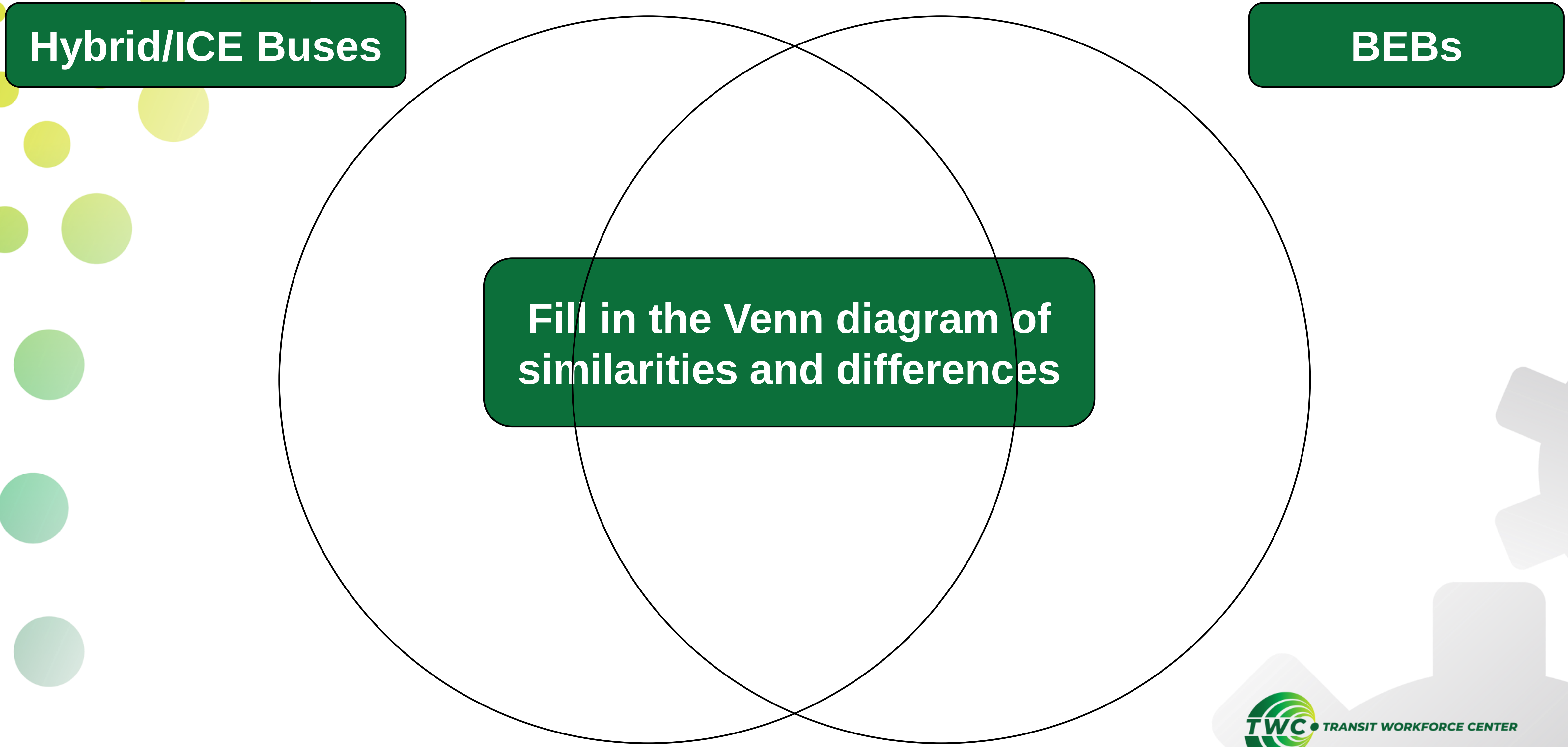
Charging (8)



Inductive Charging

- Method for both on-route and depot charging options
- Receiver under bus floor will convert EMF into viable energy to supply charge to ESS or HV Batteries
- Windings are built into road(s) which then generate electromagnetic fields
- Similar to modern cell phone charging

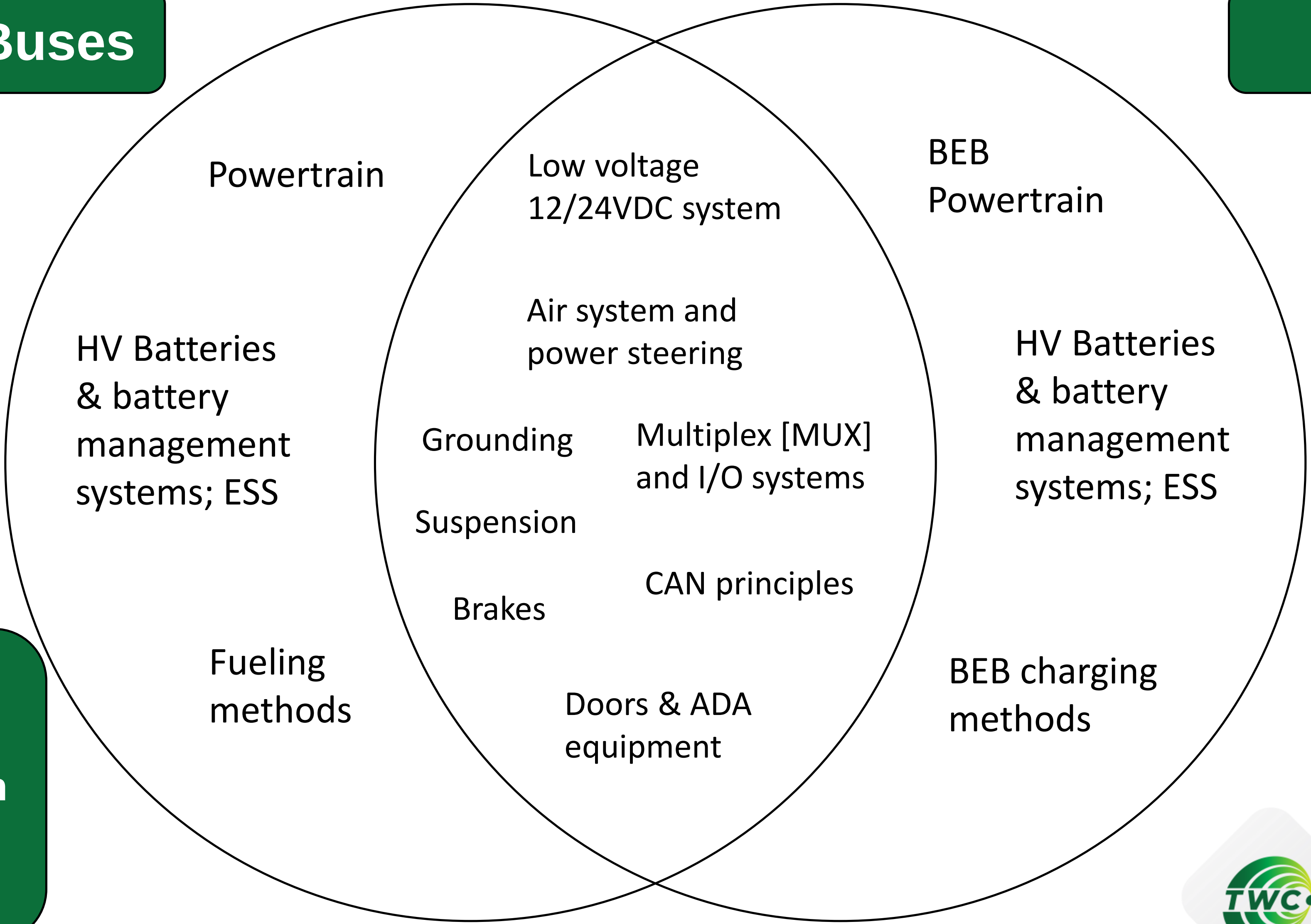
Learning Application 1A



Learning Application 1A - Answers

Hybrid/ICE Buses

BEBs



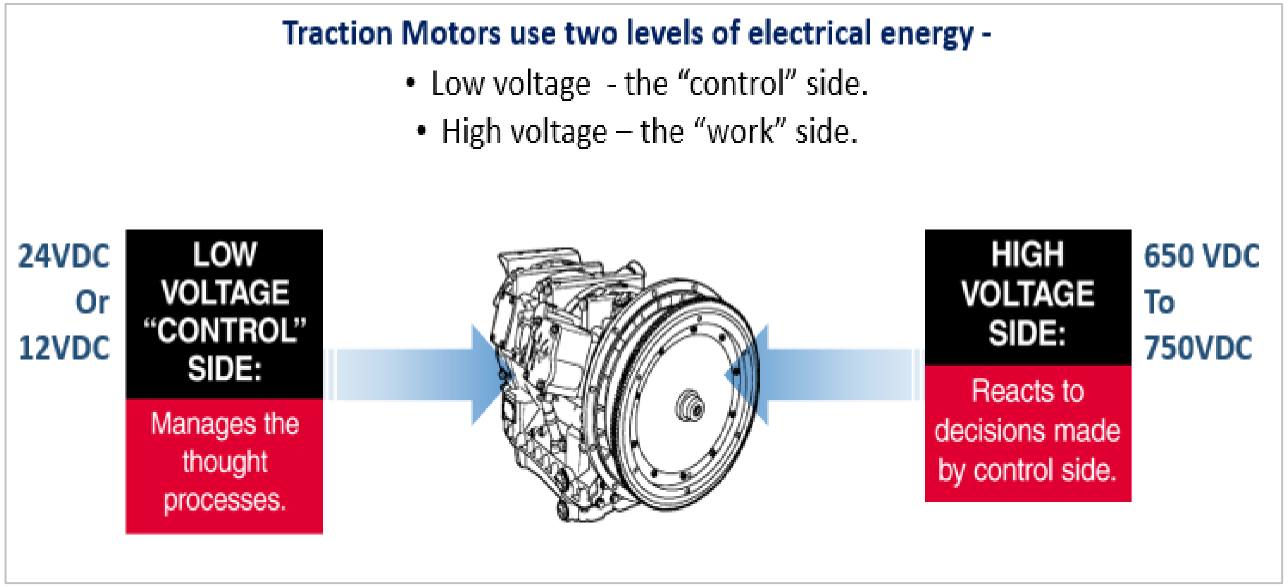
Note: The cooling systems and transmissions can be the same across bus types

Section 1-3: Details of BEB Systems and Components

Vehicle-Specific Electrical Systems (9-10)

Traction motors in BEBs

- Traction motors use two levels of electrical energy:
  - Low voltage - **Control**
  - High voltage - **Movement**
- Two separate systems work together
- Low voltage on transit vehicles is generally 12/24VDC
- High voltage side generally 650-750 VDC range

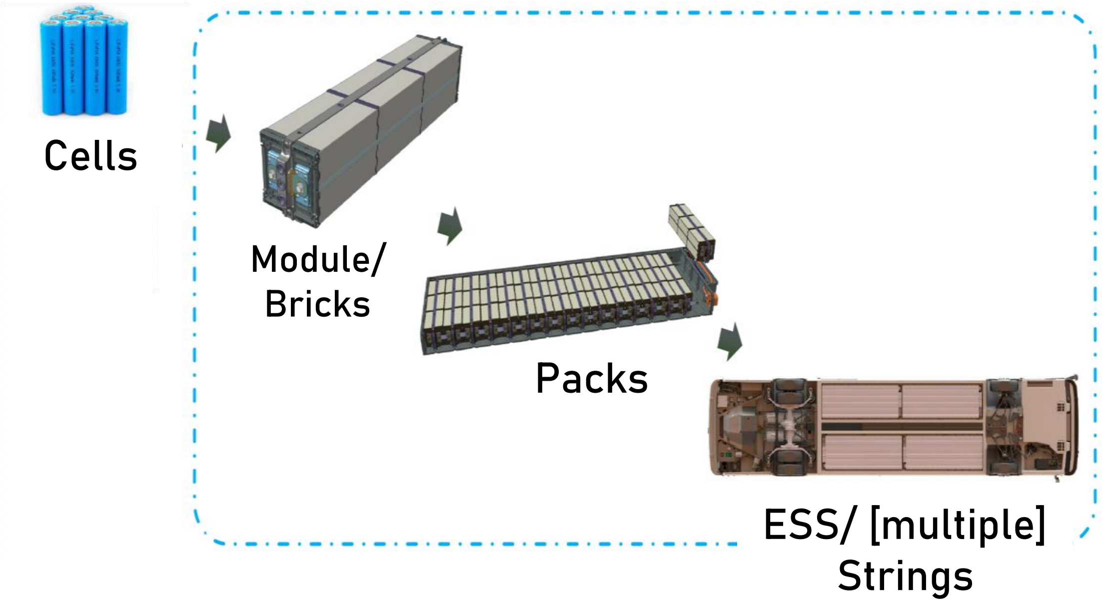


Major Components (11)

Manual (External) Charge Port - used to connect the depot's installed charging equipment to the bus

- Allows for Controller area network [CAN] communication b/w vehicle charge controller and charging equipment

Major Components (11)



Energy Storage Systems [ESS] – component comprised of HV batteries and various controllers

- In an ESS, cells populate bricks, which populate packs connected together to create strings. Multiple strings make up the ESS.

Major Components (12)

High Voltage Junction Box [HVJB]

Used to safely distribute HV from ESS to various HV components & subsystems on the bus

Inverters

Components used to change the DC voltage stored in HV batteries to 3-phase alternating current [AC]

- The AC voltage is supplied to an electric motor to generate movement

Major Components (13)

DC-DC Converter

Used to change HV DC to low voltage DC

Charges the LV batteries and supplies LV power when HV system is enabled

Electronic Controller

Used to monitor an control the HV and LV power, ensuring safe operation of all bus subsystems

Electrical Switching Device

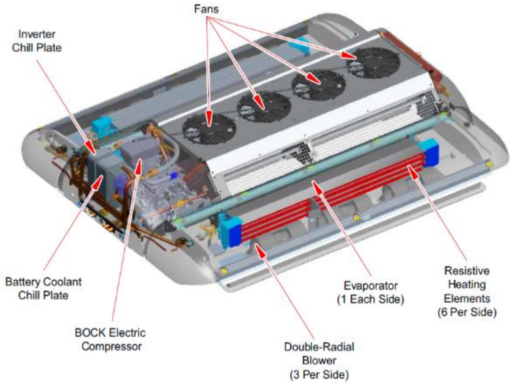
An electrically controlled switch used to switch electrical power in a circuit (usually higher voltages and amperages than typical switches and relays can handle)

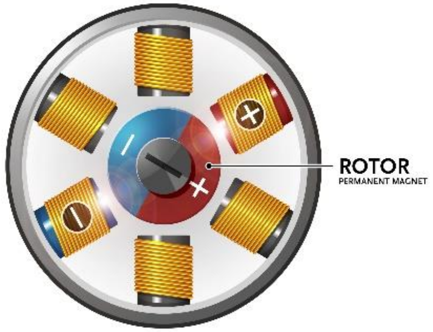
Major Components (13-14)

High Voltage Cables– thick orange cables used to convey the locations and flow of HV energy from ESS to various HV subsystems on the bus

Electric drive accessories/subsystems- within auxiliary subsystems that utilize HV energy from the HV batteries

- Includes power steering, air compressors and HVAC





Traction Motor– uses AC voltage from inverter to generate torque to turn the wheels, replacing a traditional diesel engine

Knowledge Check [MC]

Choose the correct answer(s). Which of the following are components that are *similar* in both traditional and battery electric buses?

A) Air system & power steering

B) Axles

C) Low voltage 12V and 24V systems

D) Grounding Process

E) Multiplexing and I/O systems

F) Cooling systems

G) CAN systems and principles

H) Doors and ADA equipment

I) All are similar between bus types

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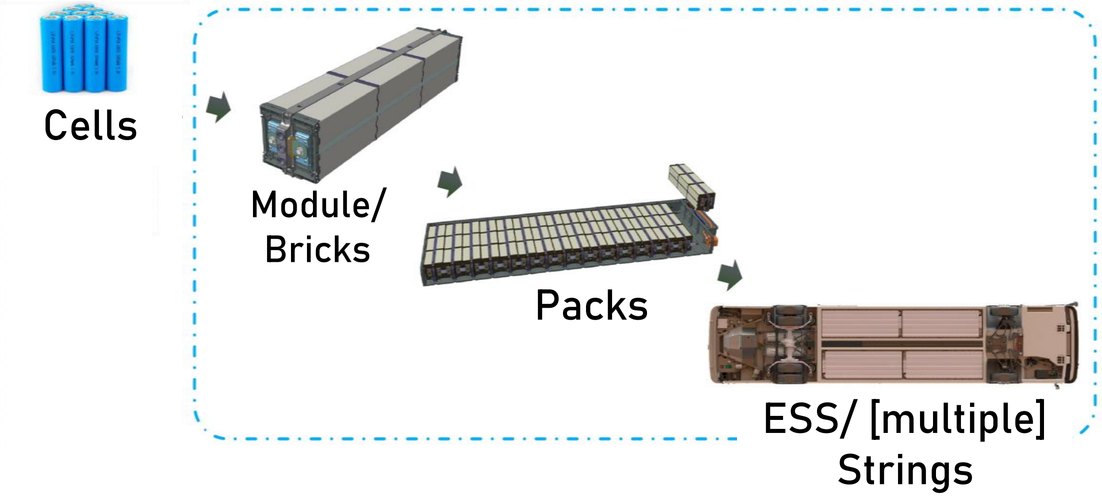
Learning Application 1B



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AT-BUS DEMONSTRATION – Components, Power Flow, Regenerative Braking and High Voltage Awareness

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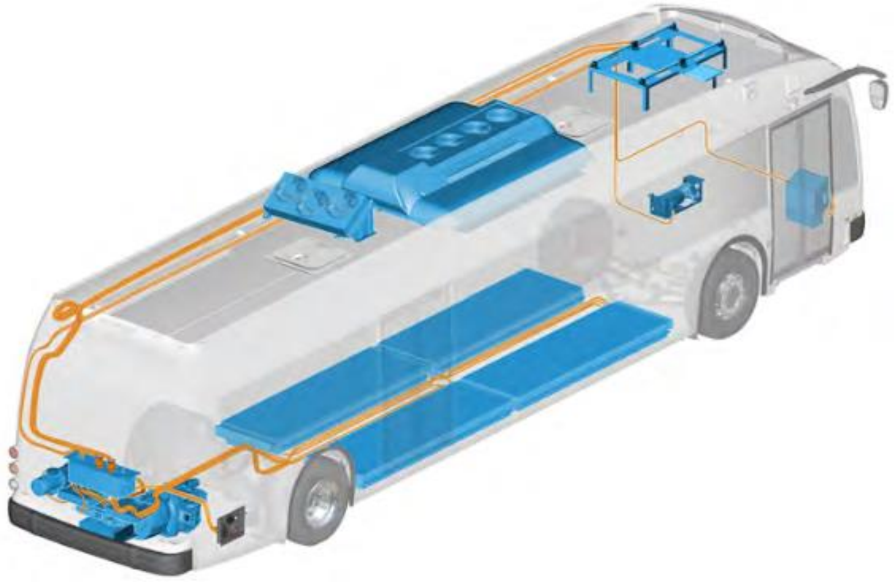
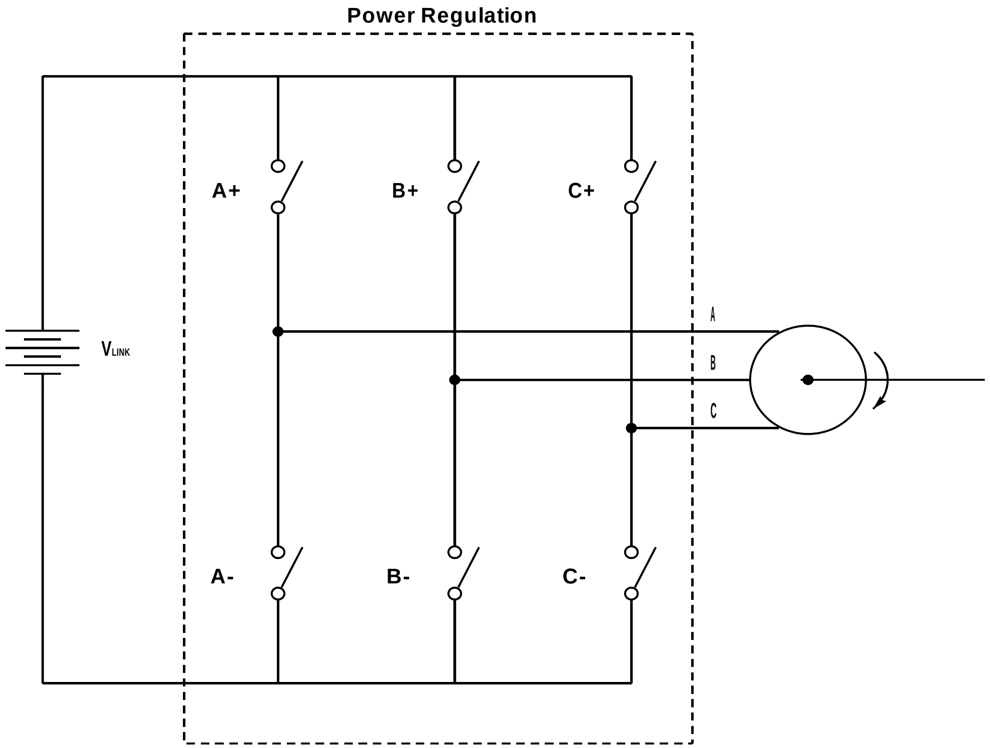
Theory of Operation (16)

- Diesel engines have power generated from engine
  - Energy is transferred to axle through torque
  - From there it goes to the transmission and last to the wheels
- BEBs will use stored energy in the **ESS** to power traction motor, connected to the drive axle
- In subsystem where driven by accessory belt on diesel, an appropriate sized **electric motor** will be used on BEB



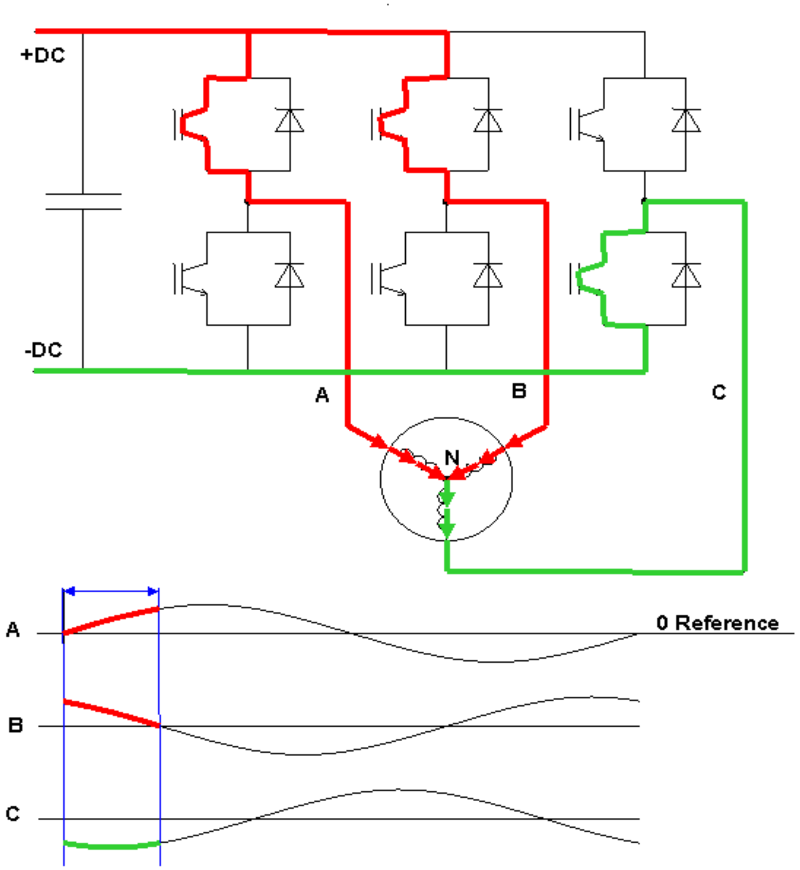
Theory of Operation: Inverters and Motors (16)

SIMPLIFIED AC MOTOR CIRCUIT



- Insulated Gate Bipolar Transistors [IGBT] can be represented as switches
- 3-phase inverters switch high voltage DC energy on and off to create an **AC waveform**

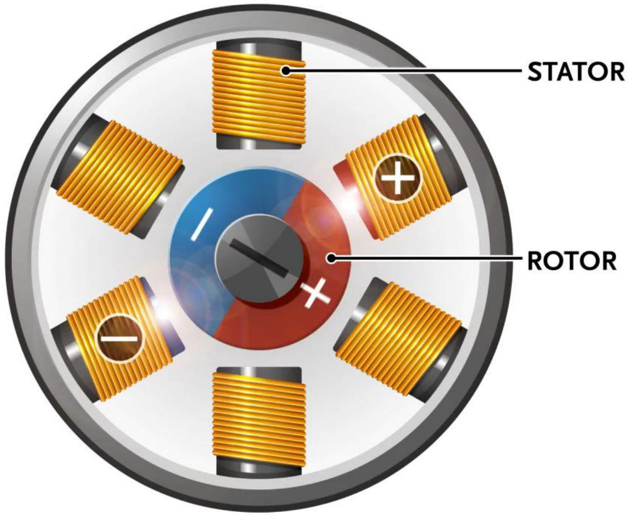
Theory of Operation: Inverters and Motors (17)



- Switching on two phases (two positive or two negatives)
  - **Positives and negatives must not be switched on at the same time**
- To continue rotation and power traction motor, the pattern needs to **alternate**

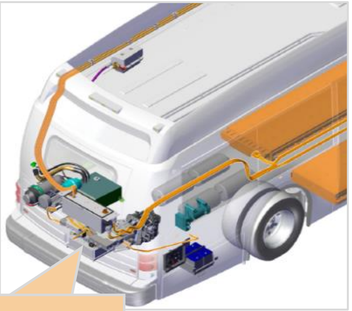
Theory of Operation: Inverters and Motors (18)

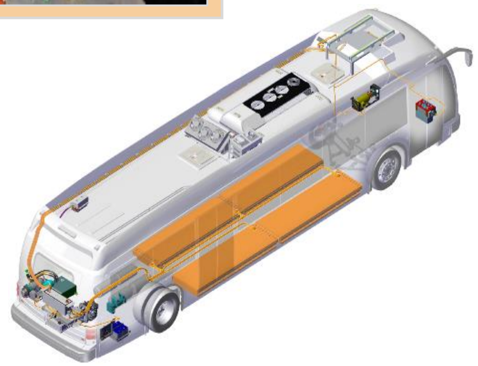
- To turn a traction motor, need power supply from coils to generate **magnetic field** in each
- To continue the rotation, pattern needs to **alternate**
- Rotor will follow the rotating field and stator windings due to the **magnetic attraction**
- Rotor will turn at a slower speed than the alternating magnetic field of the stator, known as "slip"
  - No "slip" means no current, and no torque



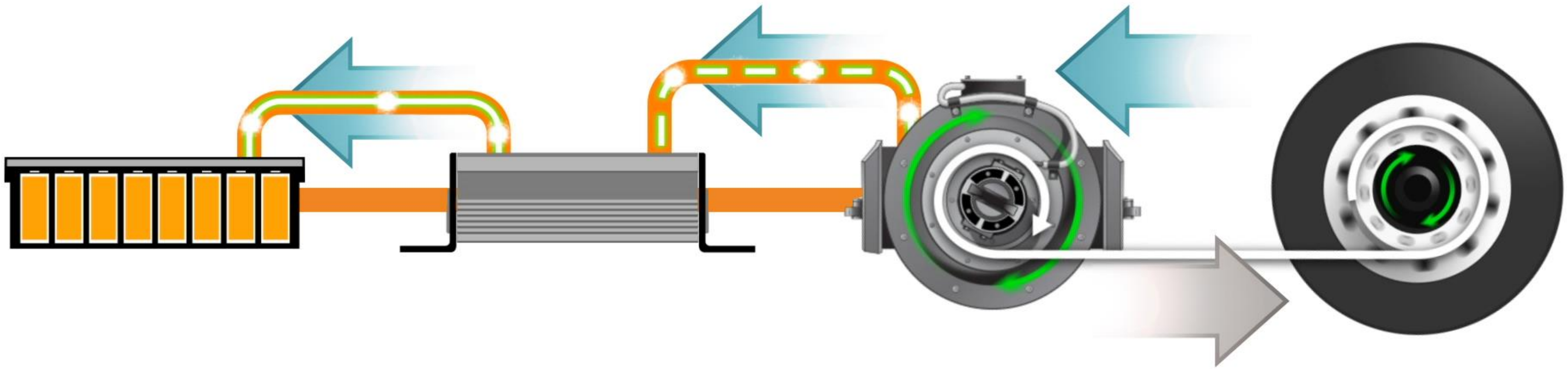
Theory of Operation: Power Flow (18)

- After initial safety checks are performed by **controllers**
  - Contactors inside high voltage batteries are commanded closed to supply power to HV system
  - HV power sent from ESS to the **high voltage junction box [HVJB]** for distribution among HV subsystems
    - Includes power steering, HVAC, air compressor, battery management system, heater and chiller
- The HVJB contains fuses, contactors and sensors
- Considered your first point of HV energy after batteries





Regenerative Braking (19)



- BEBs during normal drive conditions the HV batteries to provide energy to traction motor which supplies torque to turn wheels
- With regenerative braking, the flow of energy is **reversed**
  - Traction motor becomes a generator, with the motion of wheels on drive axle turning the transmission & traction motor, which charges the HV batteries and extends drive time

Regenerative Braking (20)

This process begins anytime the operator reduces acceleration, which starts the reverse process to recover energy

KEEP IN MIND

- It is not perpetual motion
- There is no alternative source to charge batteries

Regen-braking depends on battery state of charge. The following will limit regen-braking:
• High battery temperatures • Low battery temperatures • High battery state of charge • Towing

Learning Application 1C

1. BEBs however, will use the energy stored in the _______, which is connected to the drive axle.

2. In any instance where a subsystem was driven by an accessory belt on a diesel bus, an appropriately-sized electric motor is used to drive that accessory; The 3-phase inverters switches high voltage DC energy on and off to create an ___ ____________.

3. Essentially, you are switching on—whether it be two positive phases, or two negative phases—but ____.

4. In order to turn the rotor inside the traction motor, power is supplied to the coils to generate a magnetic field in each. To continue the rotation of the rotor, the pattern needs to ________

Word Bank: traction motor, ESS, never a positive and negative together, alternate, contactors, AC waveform, High Voltage Junction Box [HVJB], magnetic attraction

Learning Application 1C

5. An AC motor works by applying alternating current to stator windings, which produce a rotating magnetic field in the rotor. The rotor will then start to follow the rotating field and stator windings due to the _______________

6. Starting off, after initial safety checks are performed by the controllers, the _________ inside the high voltage batteries are commanded closed to supply power to the high voltage system

7. High voltage power from the ESS is sent first to the____________________for distribution amongst the high voltage subsystems

8. From the HVJB, high voltage power is supplied to the ______________and inverted to provide acceleration to move the bus bottom

Word Bank: traction motor, ESS, never a positive and negative together, alternate, contactors, AC waveform, High Voltage Junction Box [HVJB], magnetic attraction

Learning Application 1C - Answers

1. BEBs however, will use the energy stored in the **ESS** to power a traction motor, which is connected to the drive axle.

2. In any instance where a subsystem was driven by an accessory belt on a diesel bus, an appropriately-sized electric motor is used to drive that accessory. The 3-phase inverters switches high voltage DC energy on and off to create an **AC waveform**.

4. Essentially, you are switching on—whether it be two positive phases, or two negative phases—but **never a positive and negative of the same phase at the same time**.

5. In order to turn the rotor inside the traction motor, power is supplied to the coils to generate a magnetic field in each. To continue the rotation of the rotor, the pattern needs to **alternate**.

6. An AC motor works by applying alternating current to stator windings, which produce a rotating magnetic field in the rotor. The rotor will then start to follow the rotating field and stator windings due to the **magnetic attraction**.

7. Starting off, after initial safety checks are performed by the controllers, the **contactors** inside the high voltage batteries are commanded closed to supply power to the high voltage system

8. High voltage power from the ESS is sent first to the **high voltage junction box [HVJB]** for distribution amongst the high voltage subsystems

9. From the HVJB, high voltage power is supplied to the **traction motor** and inverted to provide acceleration to move the bus bottom

Knowledge Check [MC]

Choose the correct answer(s). Which of the following are components that are *different* in both traditional and battery electric buses?

A) Power train

B) HV batteries and HV battery management systems

C) Charging methods and equipment

D) All of these are different between bus types

E) None of these are different between bus types

Section 1-4: BEB High Voltage Identification & Risks, System Cooling and Data Communications

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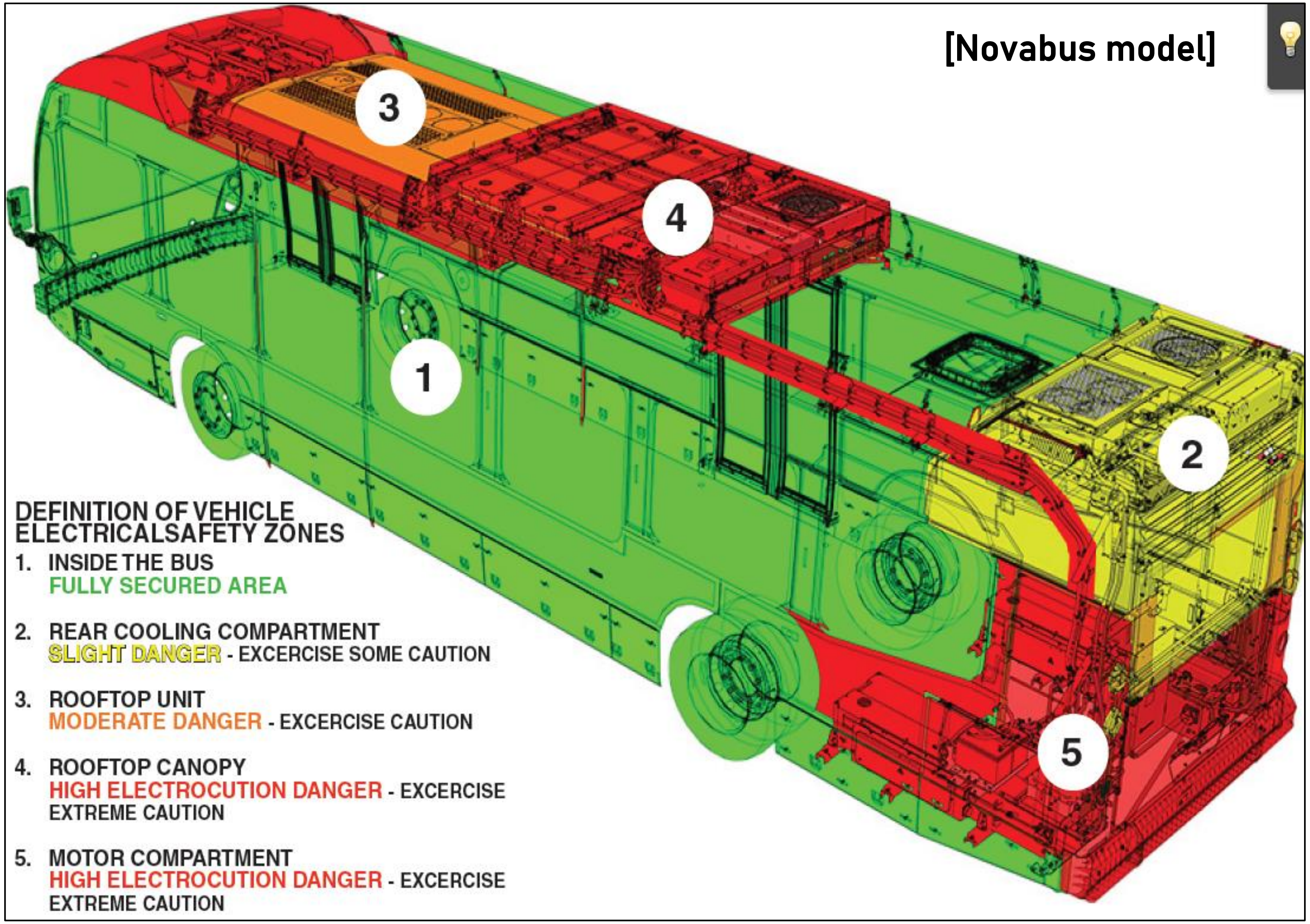
High Voltage Awareness & Identification (22)



HV is present in:

- Charger
- Battery Pack
- Inverter
- Electric Traction Motor
- DC-DC Converter
- Power Distribution node
- Compressor
- Electric AC accessories

High Voltage Awareness & Identification (22-23)

High Risk [red]:

- Batteries, between 1 and 4 of them. Located in engine bay and/or roof top or built-into the floor.
- Junction Boxes. Bringing batteries together with devices like the inverter or an Accessories converter.
- Pantograph rails (front of the bus). The area would be at full 750-volt DC potential

Moderate Risk [orange]:

- Air compressor
- HVAC
- Steering

Slight Risk [yellow]:

- Rear cooling compartment

Low to No Risk [green]:

- Low voltage 12/24 VDC systems
- Passenger area
- Driver area
- Front axle/rear axle
- Brake job or grease axle w/out HV concerns

High Voltage Awareness & Identification (23-24)

HV Cables within the bus can be identified by orange sheathing

Cables are well protected, with layers of a middle conductor, protective sheathing, stainless steel braiding and an external protective layer

HV is NEVER grounded through the chassis.

Each component will have Positive (+) and Negative (-) HV cable

- Return path of any component is through an orange HV cable
- Refer to vendor specific materials as designations and labels can vary

HV System and a vehicle 12/24V system are separate

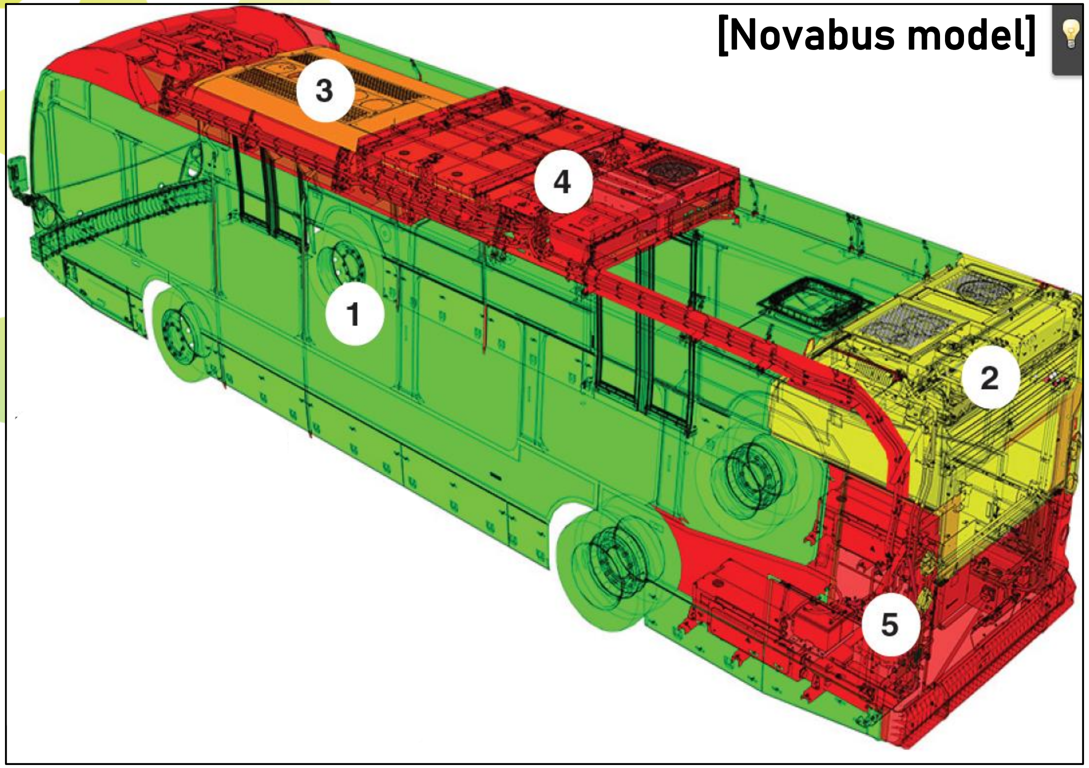
Isolation between HV and chassis ground is ALWAYS monitored by ECMs

- If there is loss of isolation between, all ESS are immediately shut down
- **HV is like a loaded gun, treat it like it's always loaded**

High Voltage Awareness & Identification (24-25)

- **Familiarize yourself with OEM manuals and procedures**
- Check for any orange cables in the areas you are working on to check them for voltage
- Point out and identify warning labels (be on guard)
- Follow Lockout/Tagout procedures
    - “Live-dead-live”; insulated tools, setting up barriers
- Use the one-handed method to probe a circuit (one hand not touching bus or other area to prevent completing a circuit)
- **ALWAYS assume HV is present**

Learning Application 1D



1. Which areas of the bus are indicated with high risk levels of HV? How were they identified?

2. Discuss how you would identify and assess any risk factor(s) of a BEB in:

- Low to No areas
- Moderate/Medium areas
- High Risk areas

3. In medium and high risk areas, what components have high voltage?

4. Discuss what actions would you need to take to protect yourself in HV areas.

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Temperature/Cooling Systems and Management (26)

Since BEBs use many electrical systems, **avoid excess heat or overheating and potential for thermal runaway**

- However, the same is true for heating components where locations experience cold/freezing temperatures

BEBs can utilize two independent cooling loops to cool HV batteries and power electronics

Overall Cooling System Flow

The diagram below shows the two individual coolant loops on a Proterra Catalyst E2M H-DP bus:

- The GREEN lines indicate High-Voltage Battery coolant flow
- The YELLOW lines indicate Power Electronics coolant flow

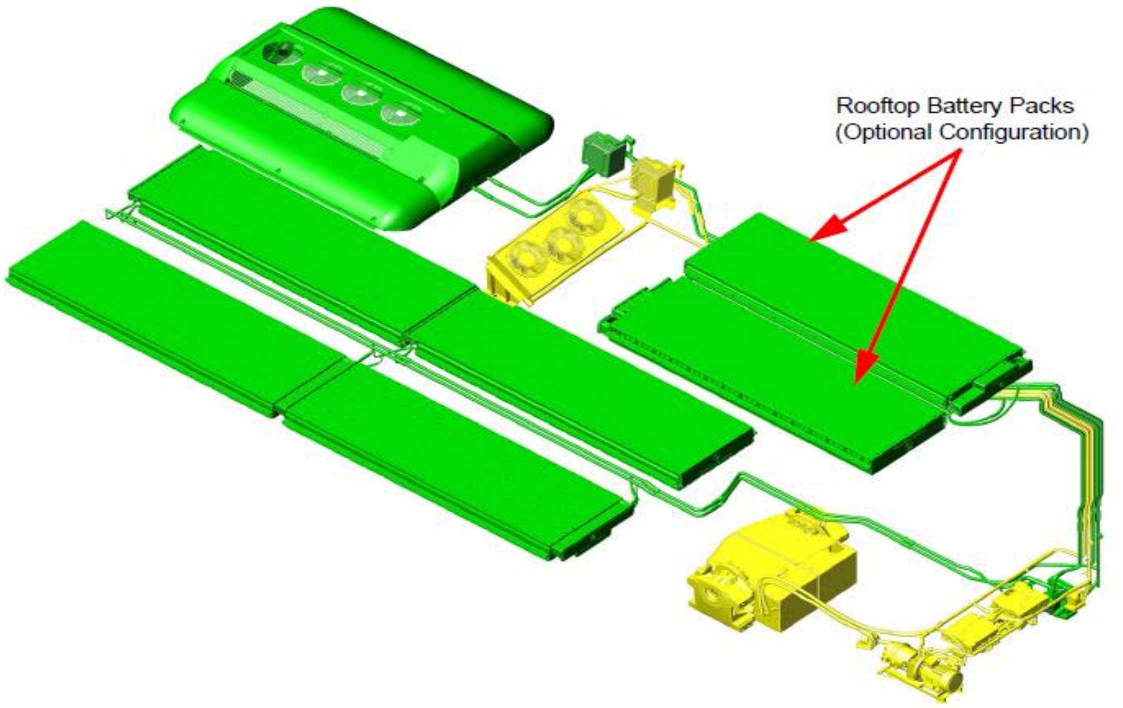
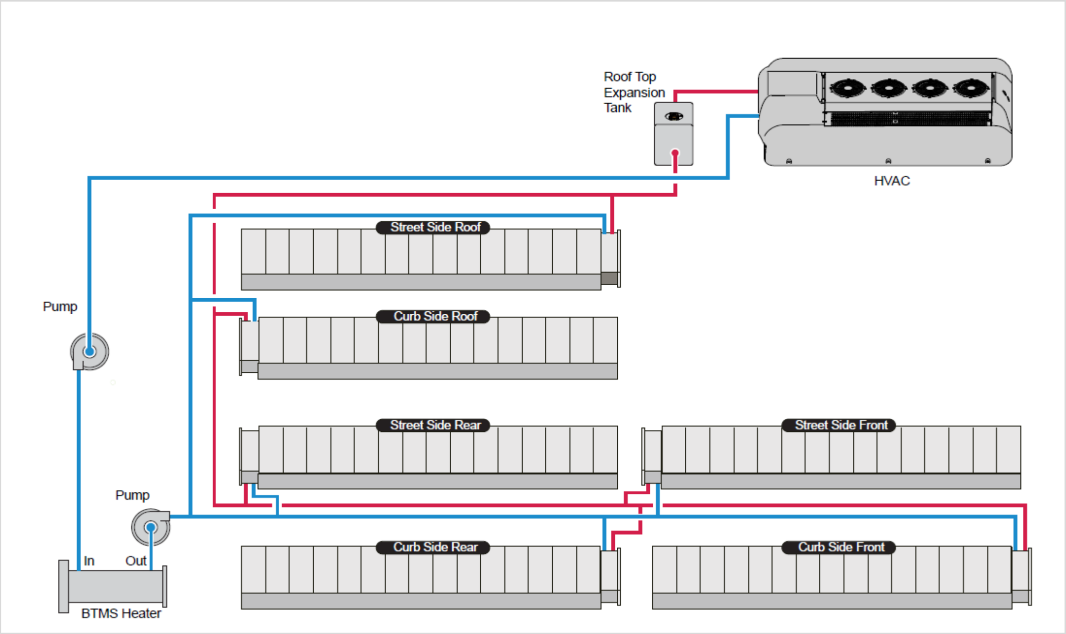


Figure 13-2. Coolant Loop Flow Diagrams

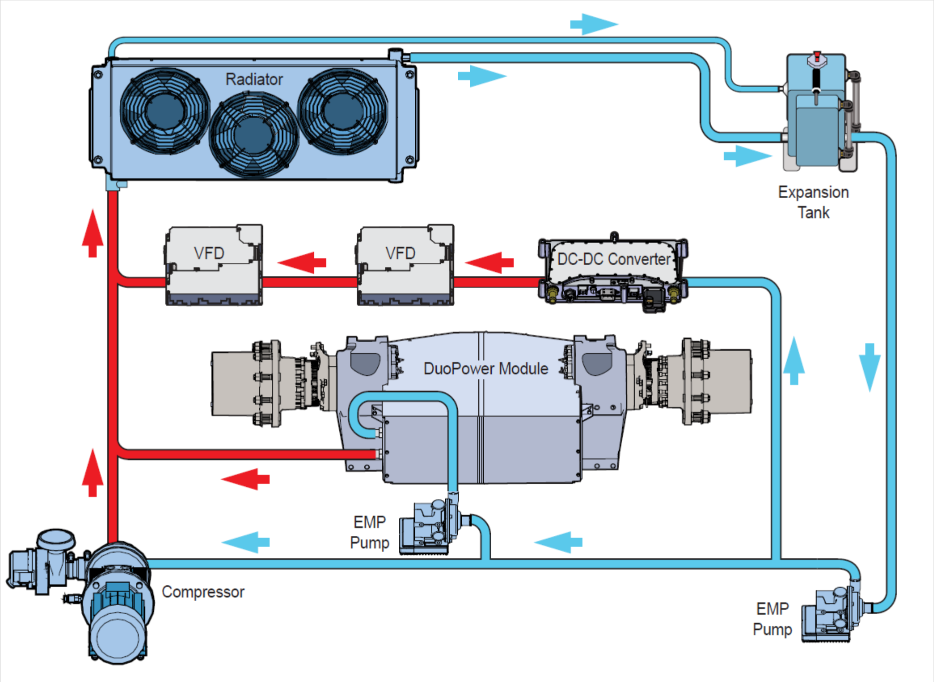
Temperature/Cooling Systems and Management (27)

Battery Coolant Loop

- The battery coolant loop will provide heat or cooling for all battery packs based on ambient temperature
- Independent loop used running into and through the batteries
  - Ideal operating temps for Lithium ion (Li-ion) batteries is 65-85 degrees
  - Ratio for makeup is 50:50 ethylene glycol and water



Temperature/Cooling Systems and Management (28)



Power Electronics Coolant Loop –

Used to cool the following:

- Traction motor
- Inverter(s)
- DC-DC converter
- Additional HV components (outside the batteries)

Does not heat components

Radiator fans can start and stop automatically. Keep your hands clear of the rotating fan blades to avoid injury

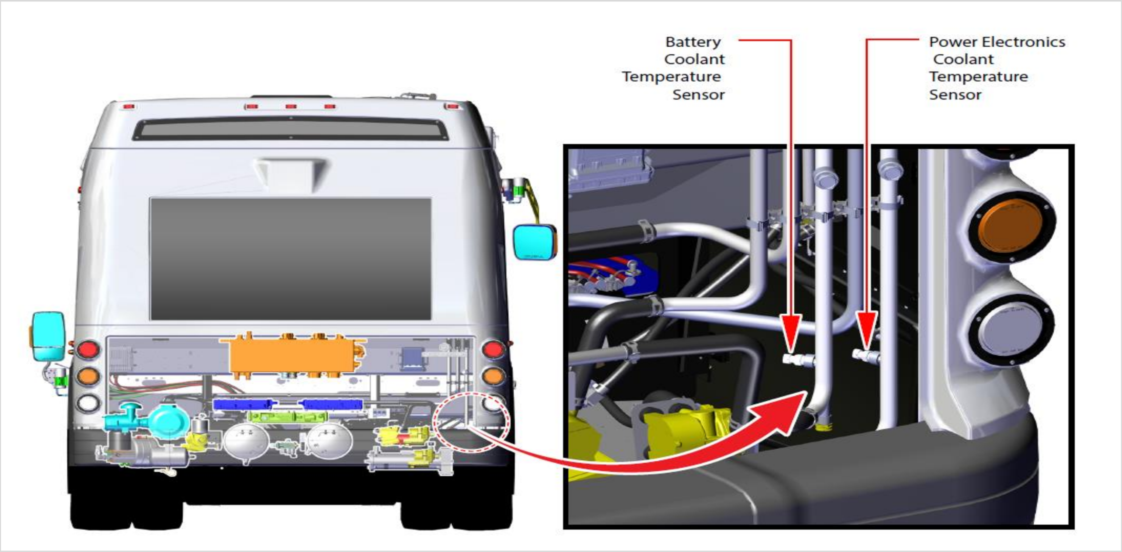
Temperature/Cooling Systems and Management (29)

Expansion Tanks

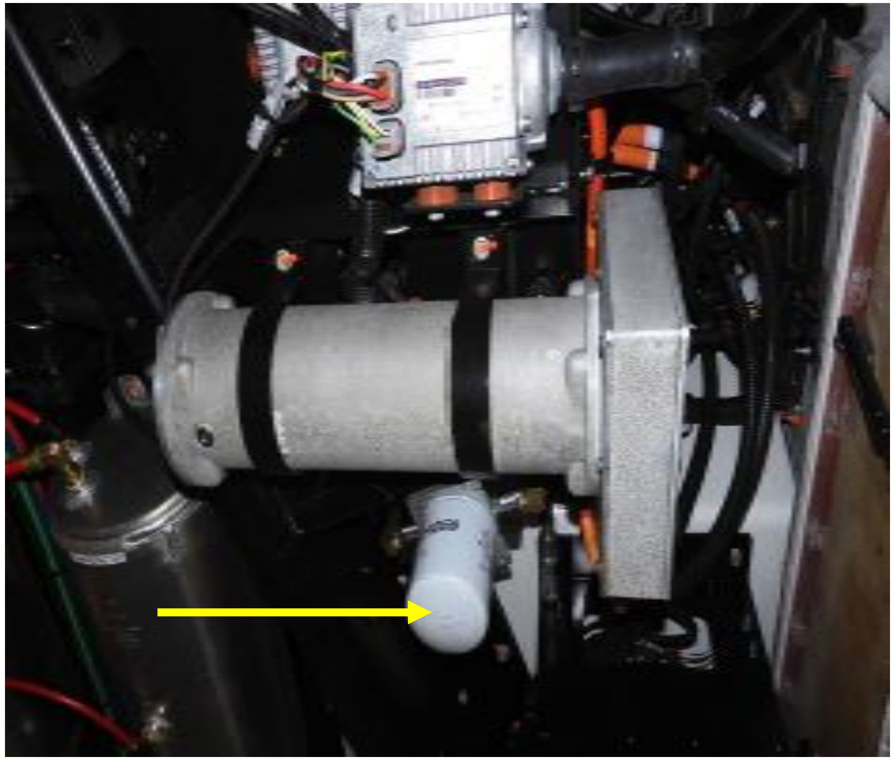
- On each closed loop system and is equipped with level sensors to indicate fill status
- Can open/close to fill with coolant or purge air as needed
- At least one tank for each loop

Coolant Temp Sensors

- Sensors for monitoring temp of coolant in that specific loop
- At least one coolant temp sensor is used for each loop



Temperature/Cooling Systems and Management (29)



Coolant Loop Filters

- Filters used to clean and remove dirt/debris from the coolant
- At least one filter will be used for each isolated loop

Knowledge Check [MC]

Choose the correct answer(s). Which of the following is a component of a BEB that does not have coolant running through it?

A) DC/DC Converter

B) Battery coolant loop

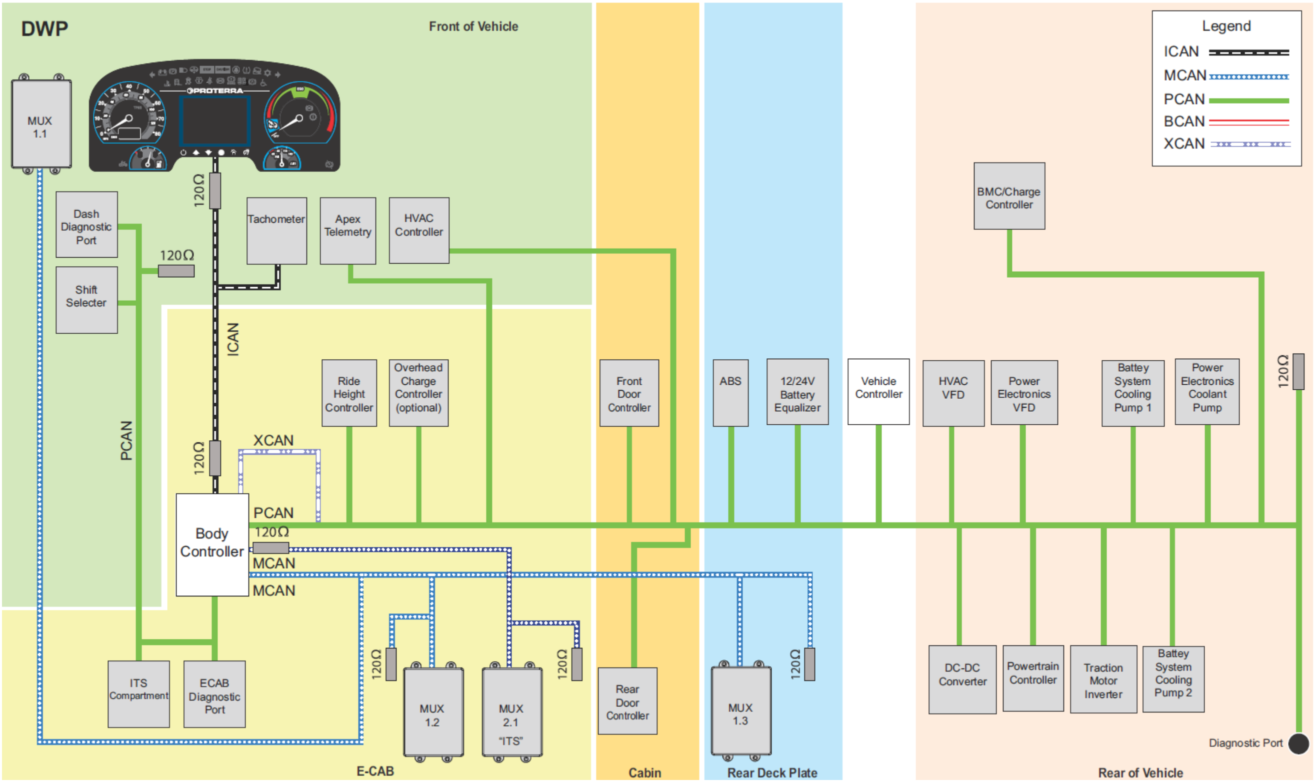
C) Power electronics coolant loop

D) Coolant temperature sensors

E) Coolant loop filters

F) All are components that utilize coolant loops/cooling management

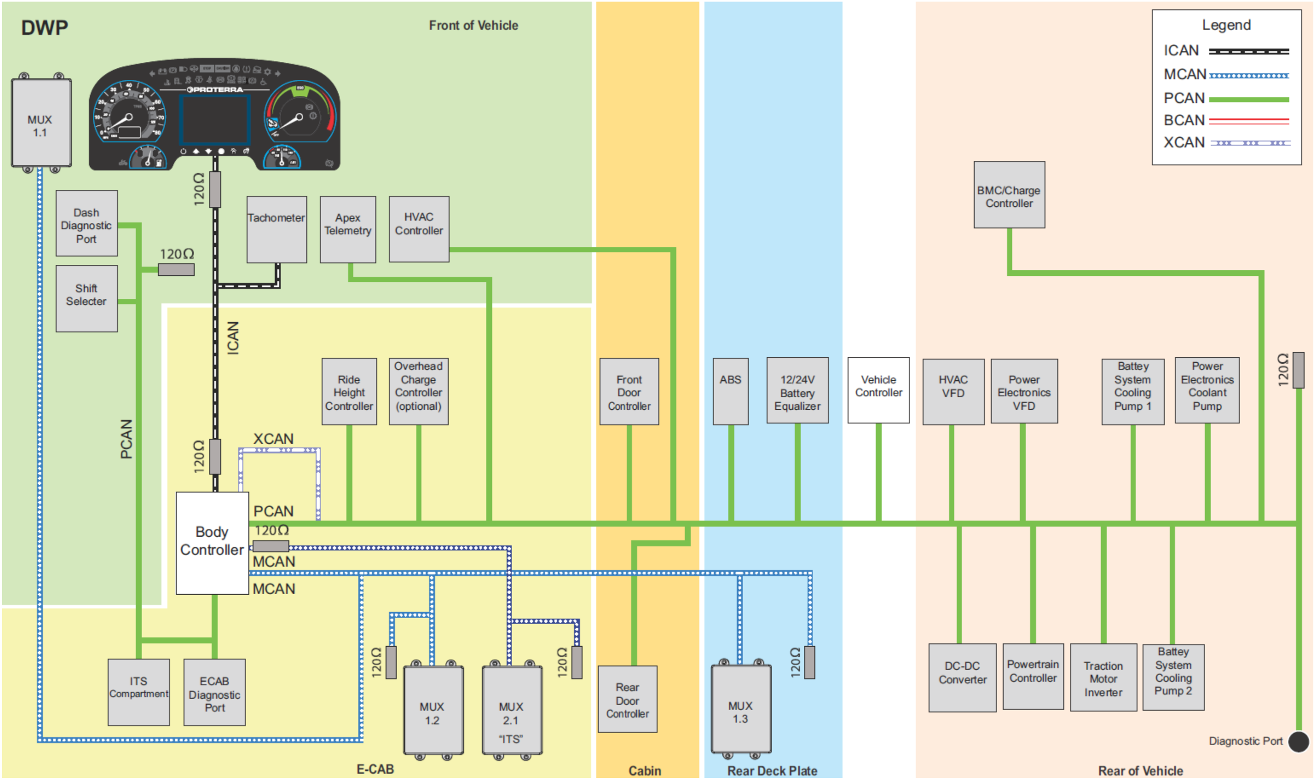
Data Communications Systems Basics (30)



Controller area network (CAN)

- A serial communications protocol that allows electronic units to communicate and share essential vehicle control data
- Currently very similar or identical to other systems in BEBs (though the number increases with more interacting electrical components)

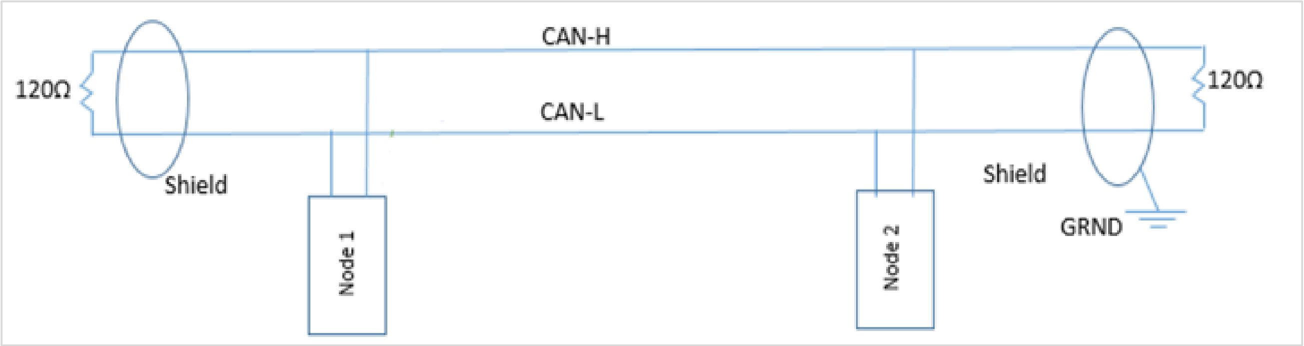
Data Communications Systems Basics (30-31)



Controller area network (CAN)

- Simple CAN messages allows reduction of transmissions necessary
- All devices can receive every message transmitted, but may ignore in a certain device if not relevant
- Sends and receives messages by changing voltage between two lines, either pulling one line to higher voltage or pulling the other low

Data Communications Systems Basics (31)



Controller area network (CAN)

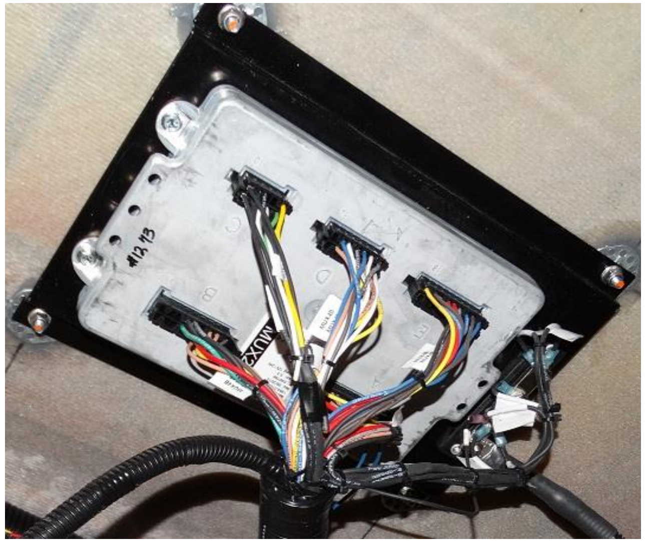
- CAN devices work by changing the voltage between two lines, pulling one to higher voltage (CAN HI) and pulling the other low (CAN LO)
- CAN devices rely on accurate voltage measurements, so having solid wiring and clean connections is crucial
  - Also need proper resistance at each end of the network

Data Communications Systems Basics (32)

Multiplexing System (known as MUX)

A system comprised of one Main and any multitude of Secondary controllers.

Provides intelligent programmed interaction between components instead of standard mechanical



With MUX, multiple component signals are simultaneously transmitted along a common data bus and controlled/monitored by a digital microprocessor

Simplifies system by replacing multiple mechanical relays and switches, and provides significant advantages over mechanical wiring and components as a centralized troubleshooting tool

Data Communications Systems Basics (32)

MUX Theory of Operation

1. An **input** is received by a module (from a switch, sensor, etc.).
2. The input acts as a **signal** (of voltage or ground from a switch, sensor, etc.).
3. That module will then send a signal over the communication network to the **other modules**.
4. The other modules are programmed to **act** when they receive a particular command.
5. An **output** is sent as a signal (voltage or ground) from a module to a load or another device.
6. The process continues constantly; every module is constantly in communication with the **other modules.**

Knowledge Check [True/False]

Simple CAN messages allow for the reduction of transmissions necessary.

TRUE

FALSE

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Section 1-5: Battery Management & Cooling

Basics on the High Voltage Battery (ESS) Construction (33)

Energy Store System [ESS]

Also called a high voltage battery

- AKA battery strings, cells, packs

- Battery packs do have CAN

For troubleshooting, CAN identifies which battery

General rule - packs will contain multiple cells; producing about 2 volts per cell (may be more/less)

Cells tied in series like a traditional 12-V battery to achieve 400-800V within the packs

Basics on the High Voltage Battery (ESS) Construction (34)

Configuration

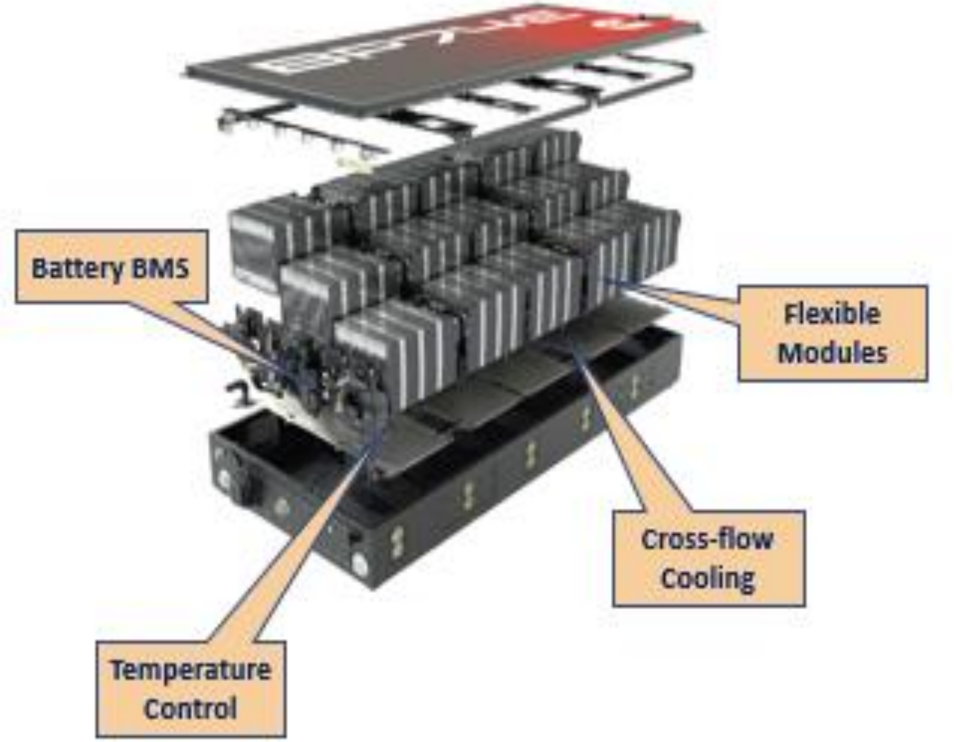
Inside are multiple LV controllers to monitor the battery

One controller will talk to another controller (the battery master controller or BMC)

An external controller monitors all batteries

Controllers are designed to operate at 12 or 24 volts (by OEM)

Typical for 24V system; may not function as intended in 12V systems



Basics on the High Voltage Battery (ESS) Construction (34)

Sample Battery	
Nominal voltage	400-800 V
Battery chemistry (electrolyte)	Lithium ion
Cooling	Water and Ethylene glycol (50:50)
Capacity	74 kWh

Basics on the High Voltage Battery (ESS) Construction (34)

Handling HV Batteries

Need HV to flow out into the system to accomplish propulsion

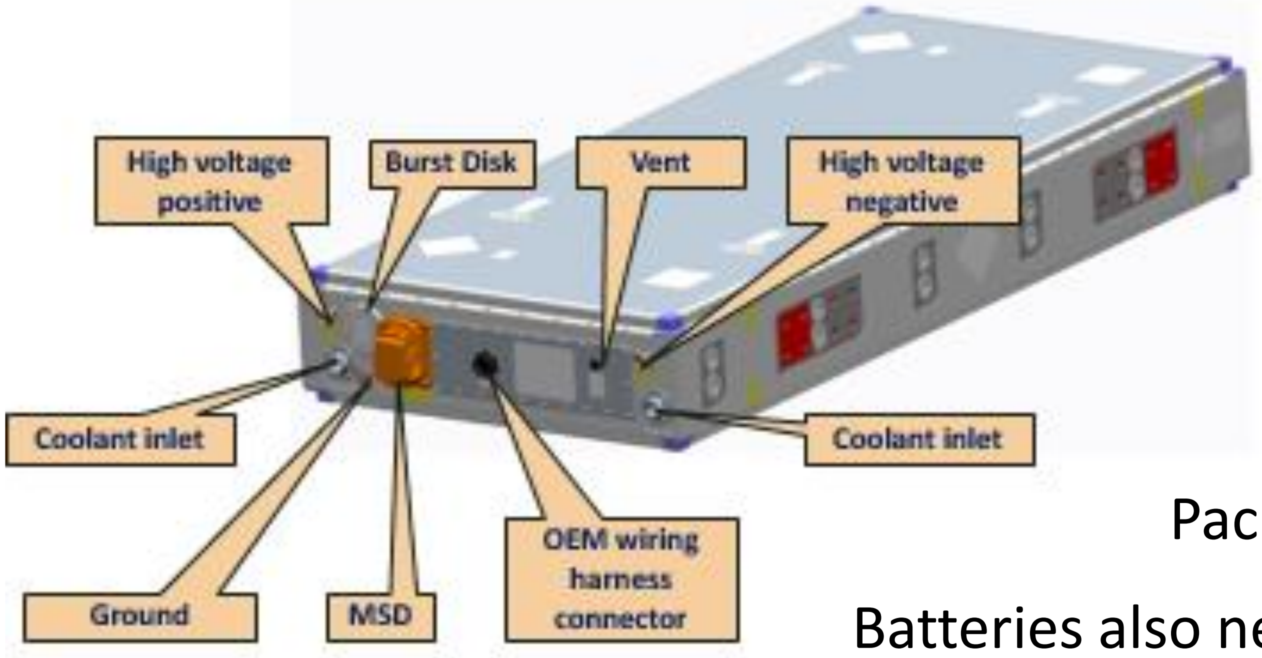
At least 2 contactors in a pack:

- HV contactor (negative side)
- HV contactor (positive side)

Contactors need to be turned on (closed) to allow current to flow from battery out; these are controlled by LV

Once the manual service disconnect [MSD] is disconnected, connections (terminals) should be isolated

Basics on the High Voltage Battery (ESS) Construction (35)



Handling HV Batteries

May be connected differently by OEM

Can be mounted in another location

Can be single or multiple packs

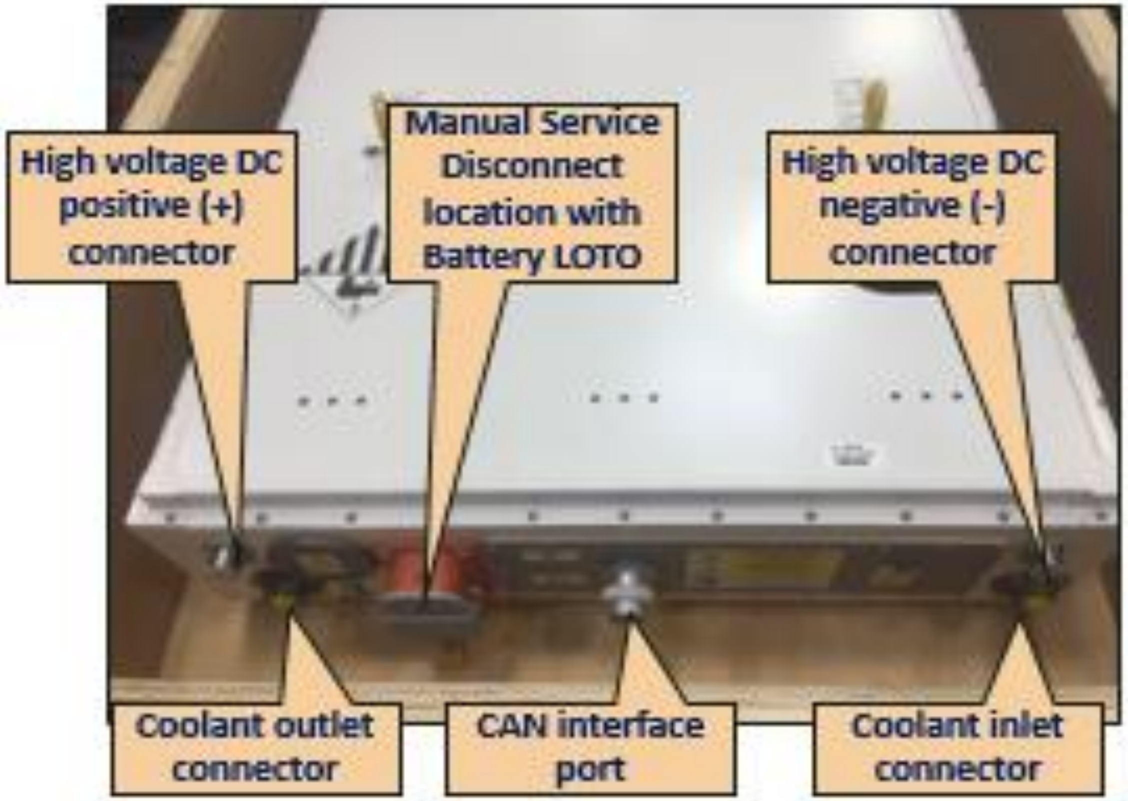
Packs store chemical energy to power HV devices

Batteries also need to supply power to run MUX systems, etc.

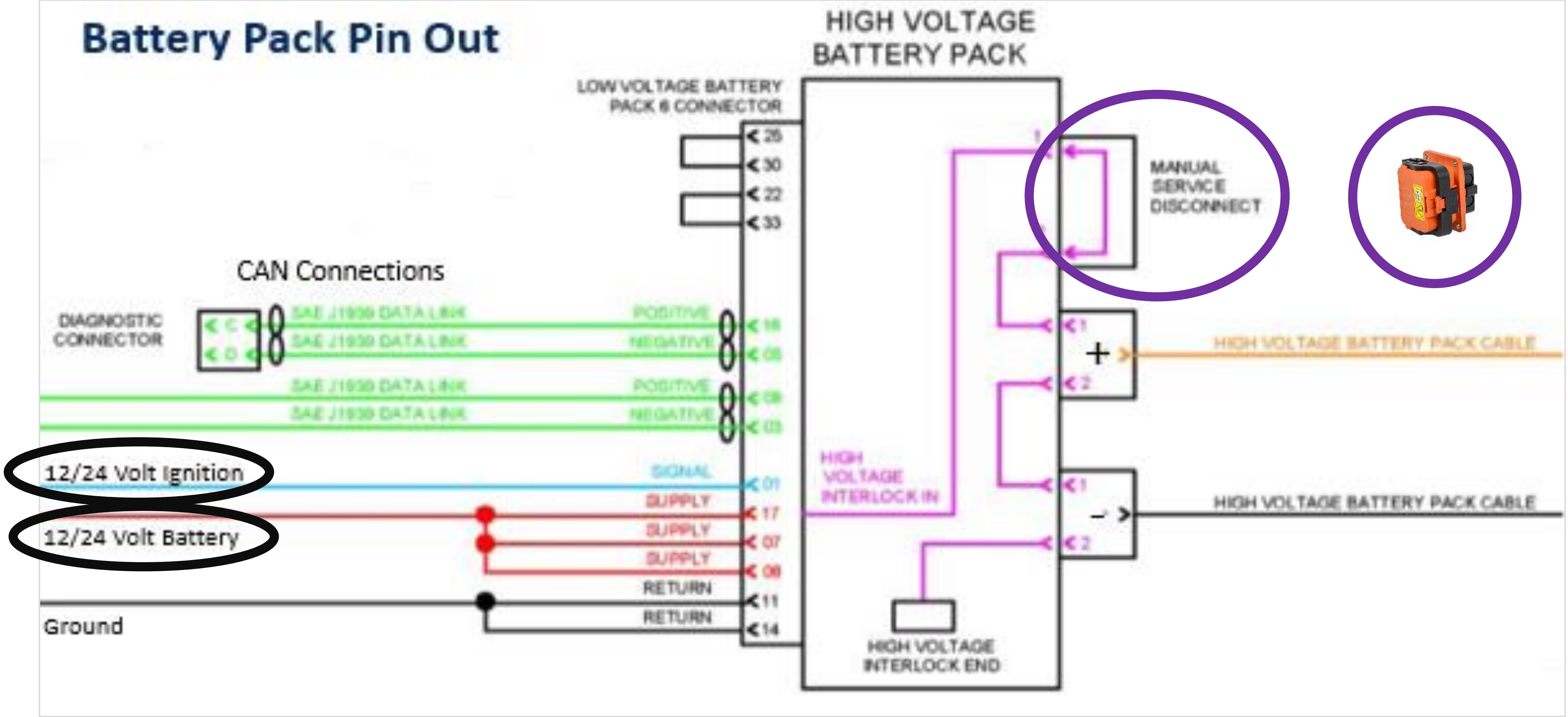
Basics on the High Voltage Battery (ESS) Construction (35)

Typical connects on a battery include:

- A high voltage connection (positive & negative)
- Coolant inlet and outlets (to run coolant through)
- Low voltage connection to battery packs; Low voltage harness
- Manual service disconnect [MSD]
- Battery Lockout/Tagout device [BLOTO]



Basics on the High Voltage Battery (ESS) Construction (36)



ESS Data Network Communication (37)

Battery Management Controller [BMC]

Runs and monitors the whole battery

Receives information from controllers inside the packs

Then shares that data with the main system controller to allow us to read data for troubleshooting

Some are serviceable, some are not but will have fuses, relays and some form of control board if so

Learning Application 1E

1. An _____ is received by a module (from a switch, sensor, etc.)
2. The input acts as a _______ (of voltage or ground from a switch, sensor, etc.)
3. That module will then send a signal over the communication network to the _____________.

4. The other modules are programmed to _____ when they receive a particular command.

5. An ________ is sent as a signal (voltage or ground) from a module to a load or another device

6. The process continues constantly; every module is constantly in communication with the ______________________.

Word Bank: Input, signal, other modules, act, output, other modules

Learning Application 1E

1. An input is received by a module (from a switch, sensor, etc.)
2. The input acts as a signal (of voltage or ground from a switch, sensor, etc.)
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6. The process continues constantly; every module is constantly in communication with the other modules.

Word Bank: Signal, output, act, other modules, input, other modules

ESS and Batteries (38)

1. NMC – Lithium Nickel Manganese Cobalt Oxide
   a. Benefits?
   b. Negatives?
2. LFP – Lithium Iron Phosphate
   a. Benefits?
   b. Negatives?
3. Others: LTO (Lithium Titanite Oxide) and more

ESS and Battery Safety (38)

ESS and battery packs have some great security features to prevent incidents. For example, the battery management system (BMS) has:

- The ability to disable and re-enable packs if there is an internal issue.
- A feature called *overcurrent protection* to prevent thermal run away.

Emerging technologies- such as Passive Propagation Resistance – are adding additional levels of safety

- Safety feature of encompassing individual cells in a specialized foam that serves as an isolator between cells

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ESS and Battery Safety (38)

Isometer: looks for severe fault(s) that can occur in a high voltage system due to a breakdown in isolation. These can include:

- A coolant leak in the battery pack (or traction motor)
- Damaged cables
- Cell leakage
- If the vehicle is in an accident and tries to initialize HV
- Can be installed anywhere in a HV circuit

Helps prevent exposure to high voltage in the event of one of these conditions;
If a problem is found it will attempt to open the positive & negative contactors in the pack and isolate voltage and amperage.

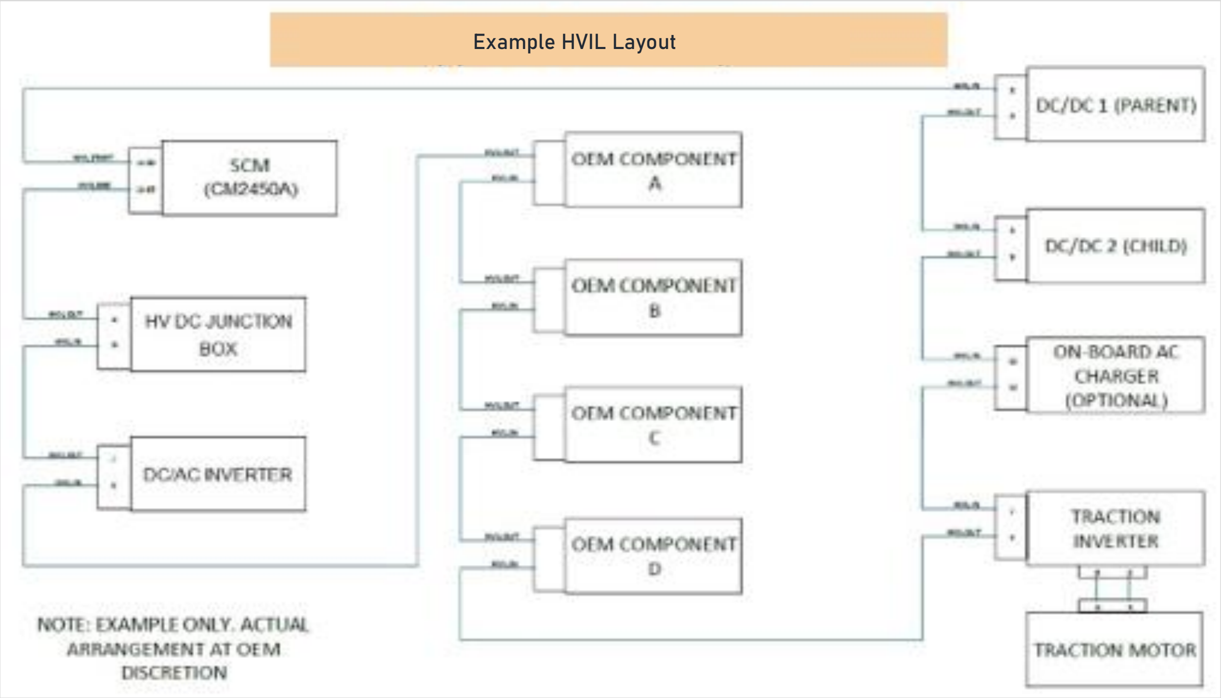
ESS and Battery Safety (39)

If we see an isolation fault the device will measure resistance but calculate a voltage drop b/w HV positive and HV negative in chassis. Then it compares the two figures for any leaking HV into the LV or chassis parts

Figures will vary by manufacturer

- Normal isolation measurement ranges are between **250 KΩ** and **50 MΩ**

ESS and Battery Safety (39)



High Voltage Interlock Loop [HVIL]

- A low voltage control function; will be a low voltage controller somewhere in the system (may be multiple based on OEM)
- The LV controller will send a LV signal through a wire and it goes out to every part through a connection point (HVJB)
- If you forget to remove a cable from the HVJB and your shutdown sequence, the HVIL would open; LV controller would see an open circuit and disable HV by opening the contactors

ESS and Battery Safety (40)

HVIL & Driver Display

- Would get an indicator/warning light in the instrument panel of exposure or HVIL issue (i.e. "HVIL Fault")
- Check the HVIL low voltage circuit for troubleshooting
  - Instinct is to assume high voltage issue
- These features are built in and there to protect you – **THEY CAN STILL FAIL**
- Check your OEM manuals to understand what to look for when a HVIL fault occurs

Knowledge Check [MC]

Choose the correct answer(s). Which of the following is the purpose of a battery thermal management system [BTMS]?

A) A low voltage control safety feature

C) Maintain the internal temperatures of the battery packs to prolong lifespan

B) A device to prevent us from getting exposed to high voltage in the event of leakage in the batteries

D) A serial communication network that allows electronic units to share essential vehicle data

ESS Thermal Management (40)

To keep systems in check, typically a J1939 signal is sent to the **Battery Thermal Management System [BTMS or BTM]**

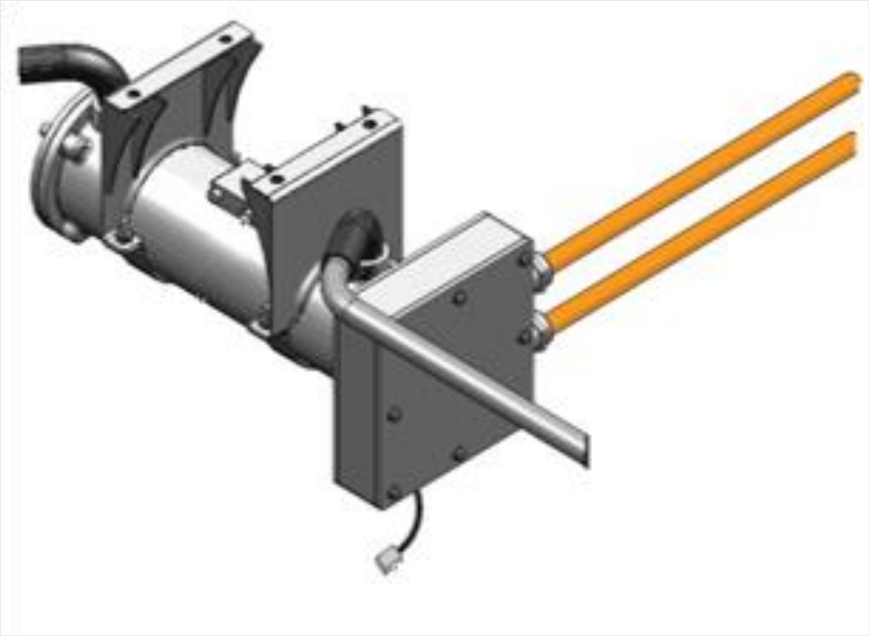
Some OEMs use a liquid cooling system, some use a fan-cooled approach

Whenever we charge/discharge a battery it will generate heat, thus we want to manage HV battery systems so they are heated, cooled and subcooled within the optimal ranges

Target Temp = 20 C / 68 F	
Winter	**Heating** request ON: 8 C / 46.4 F **Heating** request OFF: 10 C / 50 F
Summer	**Cooling** request ON: 20 C / 68 F **Cooling** request OFF: 18 C / 64.4 F

We need to control the temperature anytime the vehicle is "awake", including stationary charging, regenerative braking, etc.

ESS Thermal Management (41)



Designed to maintain the internal temperature of battery packs to prolong lifespan

Consists of:

- A form of refrigeration loop
- A form of coolant heater
- A radiator
- A pump to move the fluid

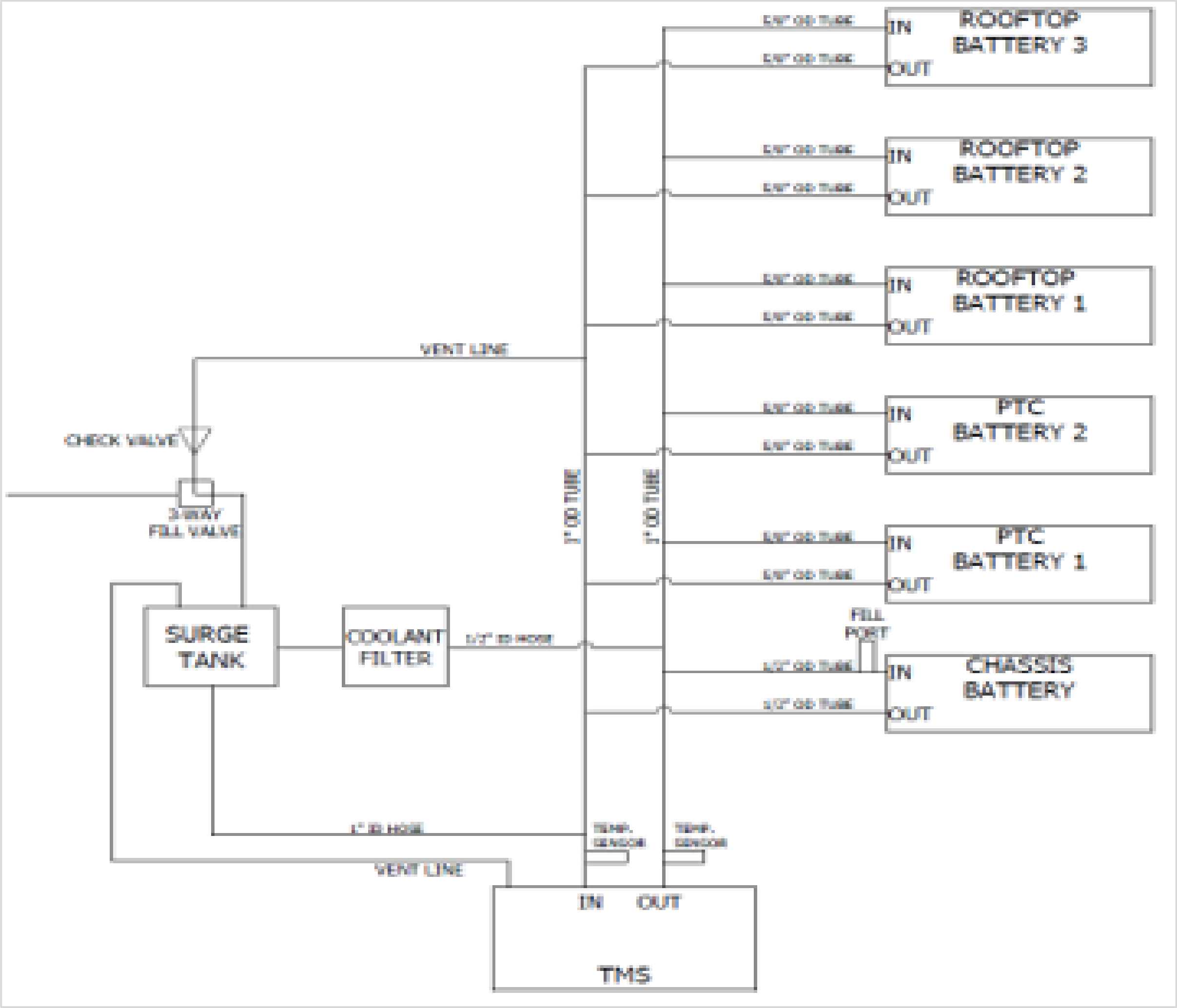
Compressor for cooling and heater for cooling the batteries will be a HV part; LV is used to activate the pump and turn fans to move coolant or warm coolant to get to the batteries

ESS Thermal Management (41)

Coolant will start in a reservoir, move through the battery packs and return to reservoir through a surge tank and a radiator or fan system

Battery life can be affected by:

- Distance or range
- Amount needed to heat/cool the batteries
- Charger



Section 1-6: Preventive Maintenance

Preventive Maintenance (42)

PM Item	Focus	Initial	Weekly	Monthly	Quarterly	Semi-Annual	Annual
Traction Motor	Lube	x		x			
Electric HVAC	Cycle		x				
Battery Pack Voltage	Measure			x			
Battery Charging and Balance	Measure			x			
Traction Motor	Inspect			x			
ESS Battery Chiller	Inspect				x		
High Voltage Cable Inspection	Inspect				x		
LV (25 VDC) Electrical Wiring	Inspect				x		
Rear Battery Strings Inspection	Inspect				x		
Roof Top Battery Strings Inspection	Inspect				x		
DC-DC Converter Inspection	Inspect				x		
Roof Top Electronics Enclosure	Inspect				x		
Traction Motor Inverter Inspection	Inspect				x		
ESS Battery Cooler Condenser Inspection	Inspect				x		
HV Accessory Cable Inspection	Inspect				x		
Power Steering	Inspect				x		
Air compressor	Inspect				x		
Charging Cable Receptacle	Inspect				x		
HVAC System	Inspect					x	
Coolant Fluid	Inspect					x	
Low Voltage Distribution Box	Inspect						x
High Voltage Distribution Box	Inspect						x
Auxiliary Power Distribution Box	Inspect						x
Insulation Monitoring Device	Inspect						x
Battery Pack Inspection	Inspect						x
Battery Thermal Management System	Inspect				x		

Intervals

1. Initial PM
2. Weekly
3. Monthly
4. Quarterly
5. 6-month period
6. Annual

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Preventive Maintenance (43)

	Component	Preventative Maintenance Item	Description	Maintenance Interval (Miles unless noted by time)	Applicability to Battery-Electric Bus
1	Alternator	Bearings	Replacement	2-Years	Not required
2	Engine	Air Filter	Restriction Inspection	3,000	Not required
3	Engine	Fluid and Filter	Drain and Refill	6,000	Not required
4	Engine	Primary Fuel Filter	Replacement	6,000	Not required
5	Engine	Secondary Fuel Filter	Replacement	15,000	Not required
6	Engine	Turbocharger	Inspection	30,000	Not required
7	Engine	Vibration Damper	Inspection	30,000	Not required
8	Engine	Spark Plugs	Inspection / Replacement	45,000	Not required
9	Engine	Ignitiion Coil	Inspection and Test	45,000	Not required
10	Engine	Valves	Adjust	60,000	Not required
11	Engine	Oil-Water Seperator	Filter	2-Years	Not required
12	Engine	CNG Tank Vent Caps	Inspection	6-Months	Not required
13	Engine	Oil-Water Seperator	Inspection	6-Months	Not required
14	Engine	Air Filter	Replacement	As needed	Not required
15	Engine	Fluid	Check dipstick level	Daily	Not required
16	Engine	Crankcase Breather Tube	Inspect	Daily	Not required
17	Engine	CNG Fuel Filter	Drain and Inspection	Daily	Not required
18	Engine	Muffler	Inspection	Daily	Not required
19	Engine	Air Intake Piping	Inspection	Daily	Not required
20	Engine	Gas Leak Detectors	Inspection	Monthly	Not required
21	Engine	CNG Fuel Tanks	Inspection	Yearly	Not required
22	Transmission	Various conditions	Inspect Breather, Mounting, bolts, oil leaks	6,000	Not required
23	Transmission	Fluid	Drain and Refill	75,000	Not required
24	Transmission	Filter	Change	75,000	Not required
25	Transmission	Fluid	Check dipstick level	Daily	Not required

Preventive Maintenance (43)

New Flyer Traction Motor

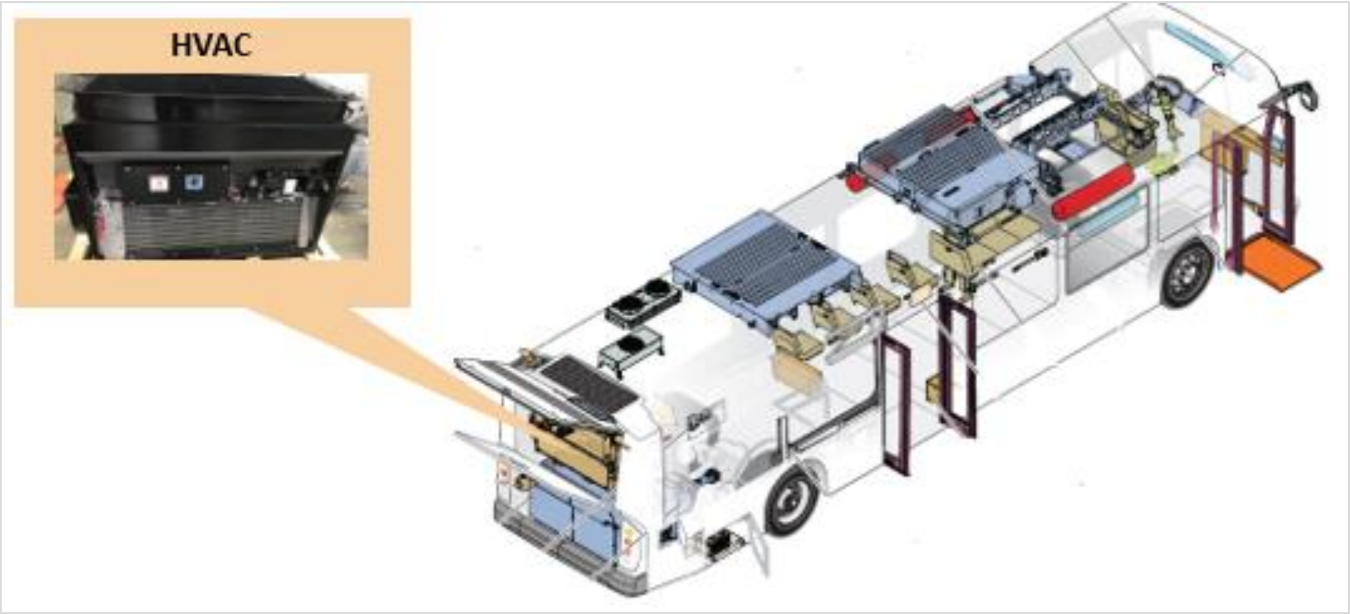
Grease Fittings

- Lubrication of all appropriate joints
- Inspection of all coolant lines
- Inspection of HV/LV terminals
- Retorqueing any loose fasteners

Intervals

1. **Initial PM** ←
2. **Weekly**
3. **Monthly**
4. **Quarterly**
5. **6-month period**
6. **Annual**

Preventive Maintenance (44)

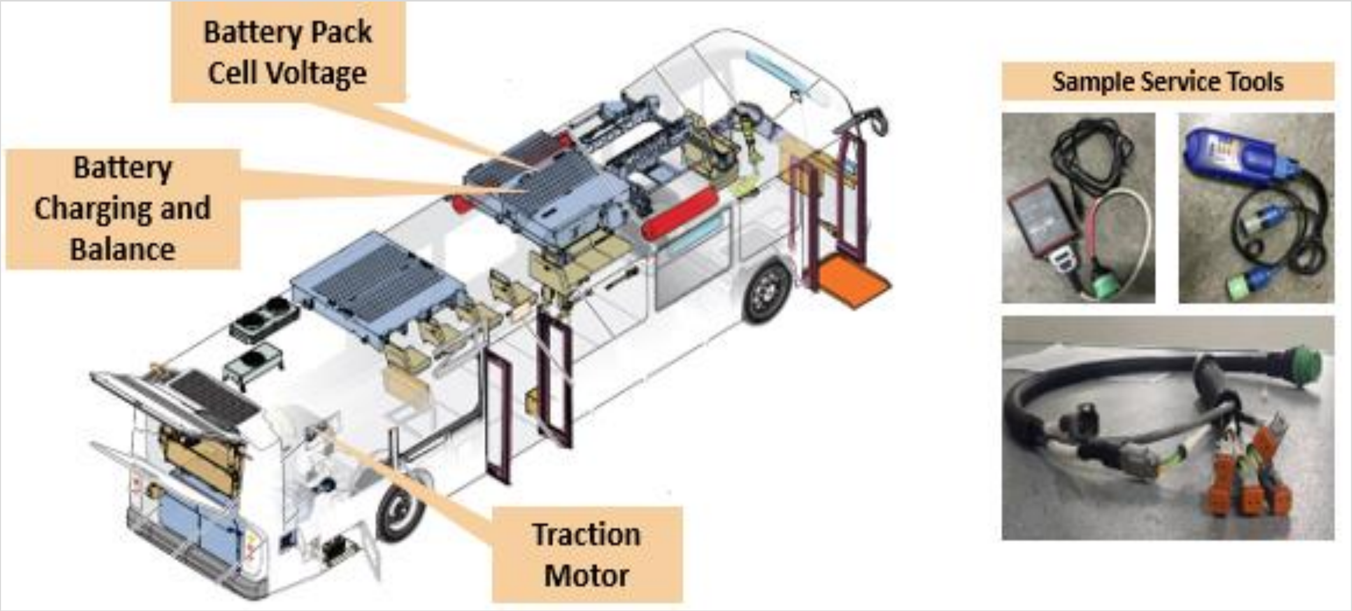


- Inspection of diagnostics to check that there are no failure icons present on the dash
- Inspection of the lights, body, wheels and tires (no different from other buses)
- HVAC inspection

Intervals

1. Initial PM
2. Weekly
3. Monthly
4. Quarterly
5. 6-month period
6. Annual

Preventive Maintenance (44)



Intervals

1. Initial PM
2. Weekly
3. Monthly
4. Quarterly
5. 6-month period
6. Annual

- Routine tests and measurements with diagnostic tools to verify the actual battery/ESS is functioning at right levels.
- Inspection of the air filters on the pneumatic system
- Lift the bus and perform routine inspection of the underbody and suspension
- Inspect ramp and door systems for proper operation and adjustment

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Knowledge Check [True/False]

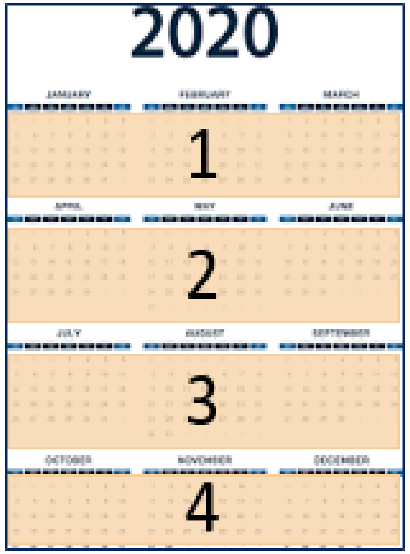
BEB battery packs will be well-encased and included locked/non conductive covers, venting and are moisture proof

TRUE

FALSE

Preventive Maintenance (45)

- Inspect BTMS
- High voltage cables
- Low voltage 12/24 VDC electrical wiring
- ESS inspection (inspection of batteries)
- DC-DC Converter inspection
- Rooftop equipment
- Power steering
- Air compressor
- Charging cable receptacle

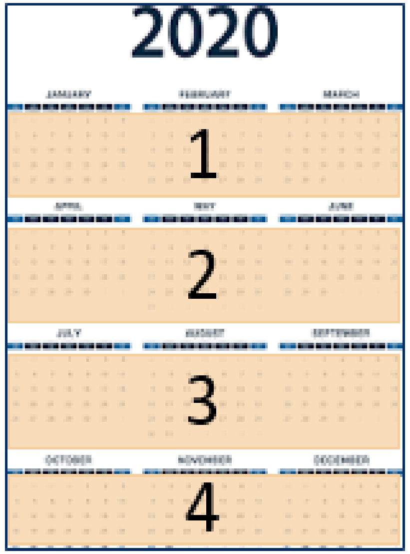


Intervals

1. **Initial PM**
2. **Weekly**
3. **Monthly**
4. **Quarterly**
5. **6-month period**
6. **Annual**

Preventive Maintenance (45)

- Generally repeats many Quarterly inspections
- Coolant may need to be assessed with a refractometer when applicable



Intervals

1. **Initial PM**
2. **Weekly**
3. **Monthly**
4. **Quarterly**
5. **6-month period**
6. **Annual**

Preventive Maintenance (46)

- Low Voltage Distribution Box – more in depth, varies from manufacturer to manufacturer High Voltage Distribution Box
- Auxiliary Power Distribution Box
- Insulation Monitoring Device
- Battery Pack (ESS or battery strings) inspection

Intervals

1. **Initial PM**
2. **Weekly**
3. **Monthly**
4. **Quarterly**
5. **6-month period**
6. **Annual** ⬅

Preventive Maintenance (46)

Diagnostic Troubleshooting

Many PM tasks will result in a need for inspection & maintenance

BEBs are electric - can’t troubleshoot through mechanical means

- Must run diagnostics through OEM software to accurately gauge and identify areas for inspection

Will need at least the following:

- Powertrain Diagnostic Software
- Battery Diagnostic Software
- Typical Fault & Troubleshooting
- Data Logging Software

Preventive Maintenance (47)

Diagnostic Tools

- Tests are run through diagnostic software on HV components and areas to perform quality checks for safe operation, particularly assessing effectiveness of any insulation
- To correctly assess and measure diagnostics you need tools to supplement OEM software to control, record and read measurements and data.
- Tools include:
  - J1939 Connector (powertrain dongle)
  - NEXIQ interface tool
  - Laptop

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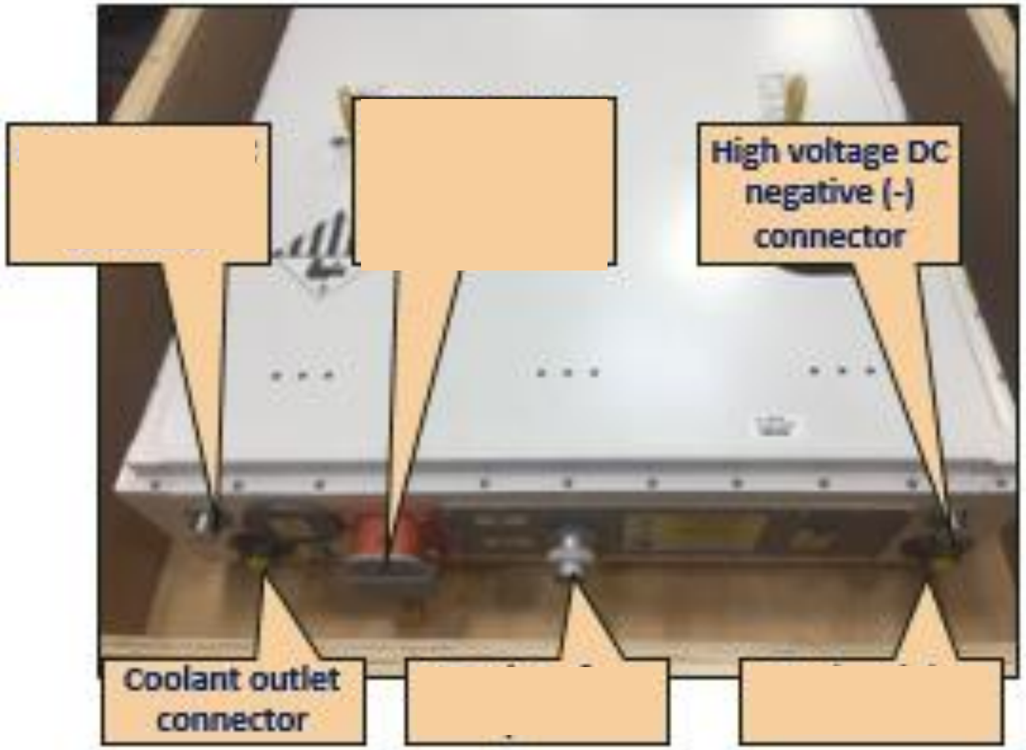
Learning Application 1F



Word Bank: High Voltage DC Positive (+), Coolant inlet connector, CAN interface port, Manual Service Disconnect location with Battery LOTO

Knowledge Check [True/False]

Preventive maintenance is the act of performing a series of maintenance tasks/activities within a regularly scheduled period to prevent possible outcomes or vehicle failures

TRUE

FALSE

Summary (48)

1. Looked at the differences and similarities between the BEB and traditional bus types
2. Review of the major components that are featured on a BEB, high voltage risks associated with BEB
3. Discussed integral BEB safety features and functions
4. A review of preventive maintenance intervals and tasks that should be performed for a BEB.
5. While these should be a good cover-all, make sure that you refer to your agency guidelines, standard operating procedures and instructor’s experiences before making any actions or doing anything out in the field.