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Tesla Motors, Inc.
Tech Notes

Tech Note: Model S High Voltage Awareness

Tech Notes are internal-only, informal communications meant to help with communicating and tracking new information about Tesla service concerns. This is not an official bulletin and should not be used to book or bill labor for a customer. This does not replace the need for documenting issues in Service databases.

Background of the Model S High Voltage System

High Voltage Network

The Model S has an isolated high voltage network to supply the powertrain and HVAC components with energy (Figure 1). A high voltage battery acts as the source for this circuit. Isolation of this circuit from the rest of the vehicle means that there is no electrical connection between this high voltage circuit and the vehicle chassis. This isolation is constantly being monitored by sensors internal to the battery. When the contactors are open, this measurement only applies to the HV battery itself and not the rest of the DC bus. DC bus is commonly referred as DC Link + and DC Link –.

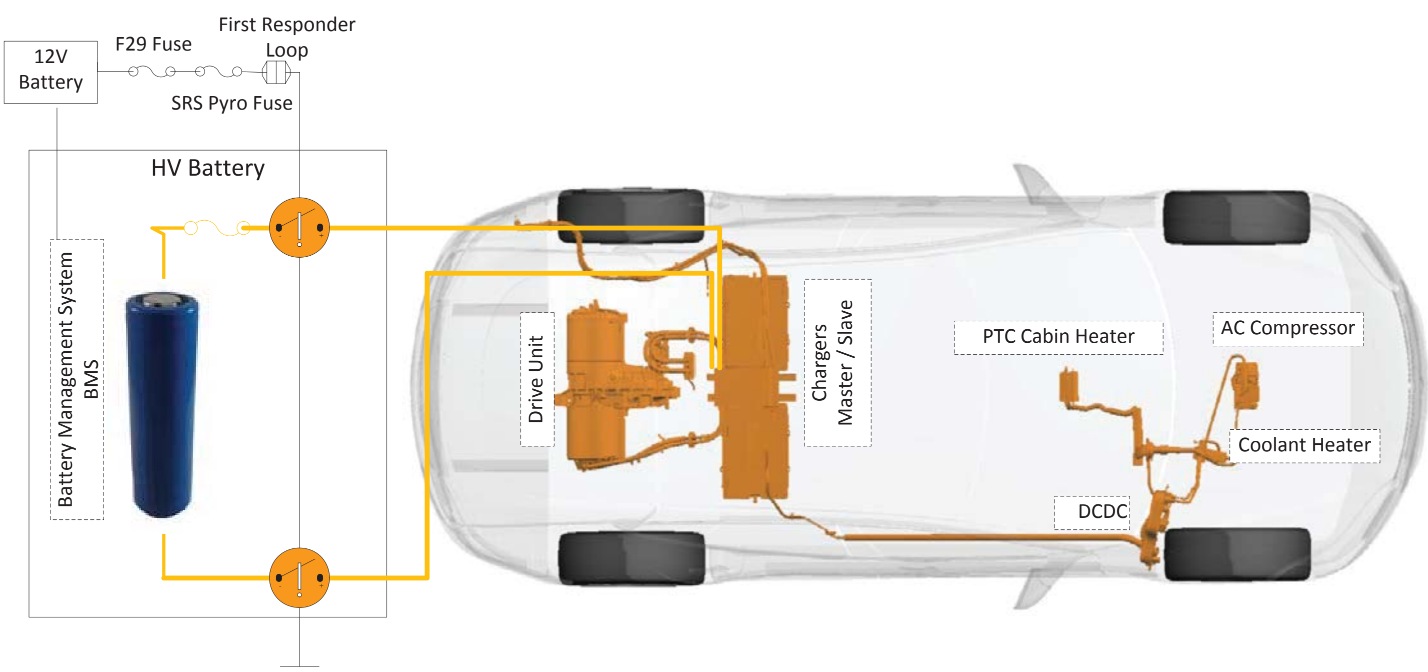

Figure 1

Three components in the Model S can provide high voltage into this isolated network: the high voltage battery, the drive inverter, and the chargers/supercharger.

WARNING: Never work on any powertrain component while the vehicle is charging or in drive.

The battery always has high voltage present internally. However, it can connect and disconnect itself from the rest of the vehicle with its contactors. These contactors are similar to relays, and are powered by a dedicated 12V line from the 12V system of the vehicle.

Other than driving and charging, several vehicle states can cause the battery to be connected to the rest of the powertrain. It is therefore essential to always verify that these contactors have opened and therefore disconnected the high voltage from the rest of the vehicle before working on any high voltage component.

⚠ **WARNING:** Always verify that there is no voltage at a high voltage component before beginning work on it.

Battery Management System (BMS)

The BMS reports the state of the contactors, which can be read by the Tesla Diagnostic System (TDS) (Table 1). A signal stating that the contactors are closed indicates that the BMS believes high voltage to be present on the bus. If the state reads open, the BMS believes that high voltage should be absent.

Contactor State	BMS State	High Voltage expected on Bus
Open	Standby	NO
Closed	Support	YES
Closed	Charge	YES
Closed	Drive	YES
Unknown	Fault	Depending on fault, the HV Battery might be connected or not isolated from the chassis.
Closed	Clear Fault	NO
Closed	Charger Voltage	YES
Closed	Fast Charge	YES

Table 2

Because there are multiple conditions that can cause the BMS to attempt to close the switches, the BMS might close contactors in the time it takes between observing the state on the TDS and starting work on any high voltage component. While it is the responsibility of the BMS to perform several safety tests before closing these contactors, the BMS should never be relied upon before working on the vehicle.

⚠ **WARNING:** The contactors make a very distinctive clicking sound when changing state. If the sound is observed while working on any high voltage component, immediately discontinue work and reassure absence of high voltage.

Energizing the Bus

Before the contactors can be closed, the other components need to be brought up to the battery voltage slowly as to not damage them. This process of pre-charging takes a few seconds and is accomplished by a separate circuit in the battery. This circuit is attached to the rest of the vehicle through a separate switching mechanism.

Just as the components require some time to reach operating voltage, it also takes several seconds for the voltage to decay when the contactors are opened.

⚠ **WARNING:** Always wait at least 30 seconds after disabling the vehicle before handling high voltage connections.

The 12V supply to both contactors is routed through the first responder connector in the frunk. Contactor power has a dedicated 12VDC wire routed through a 30 Amp fuse, a 10 Amp fuse, and the first responder loop (Figure 2). Disconnecting the first responder loop prevents the vehicle from actuating the contactors.

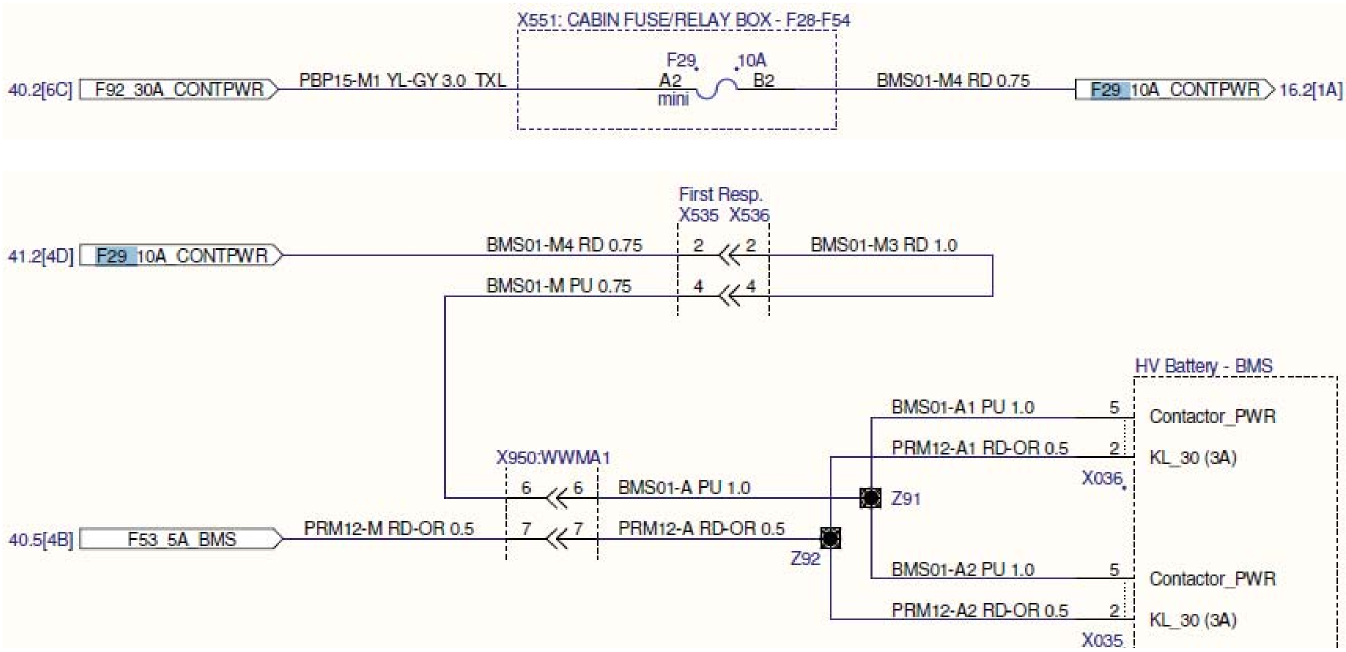

Figure 2

While removing the power supply from the contactors will prevent them from changing state, these components might have failed, causing them to become stuck in the closed position. Therefore, only disconnecting the first responder loop does not ensure that high voltage is removed from the vehicle.

⚠ **WARNING:** To ensure safe working conditions, the absence of high voltage should always be verified after removing the first responder loop by measuring the voltage on the HV bus with a digital multimeter (DMM) at the drive inverter. Refer to the high voltage lockout procedure in this document.

⚠ **WARNING:** Proper personal protective equipment (PPE) and insulating HV gloves with a minimum rating of class 00 (500V) must be worn any time a high voltage cable is handled. Refer to service bulletin SB–13-92-003, High Voltage Awareness Care Points for additional safety information.

⚠ **WARNING:** To prevent accidental exposure to high voltage, always cover the HV battery connector with the HV Rapid Mate cover (Tesla P/N 1016196-00-A) when the HV battery is removed from the vehicle.

To protect the high voltage components, several high amperage fuses exist in the circuit to provide a layer of safety against short circuits and elevated current draw. These fuses behave similarly to the fuses of the 12V system. The main fuse is located internal to the high voltage battery. Other high current fuses are located inside the high voltage junction box underneath the rear seats, and in the DCDC converter behind the right front wheel well liner (Figure 3).

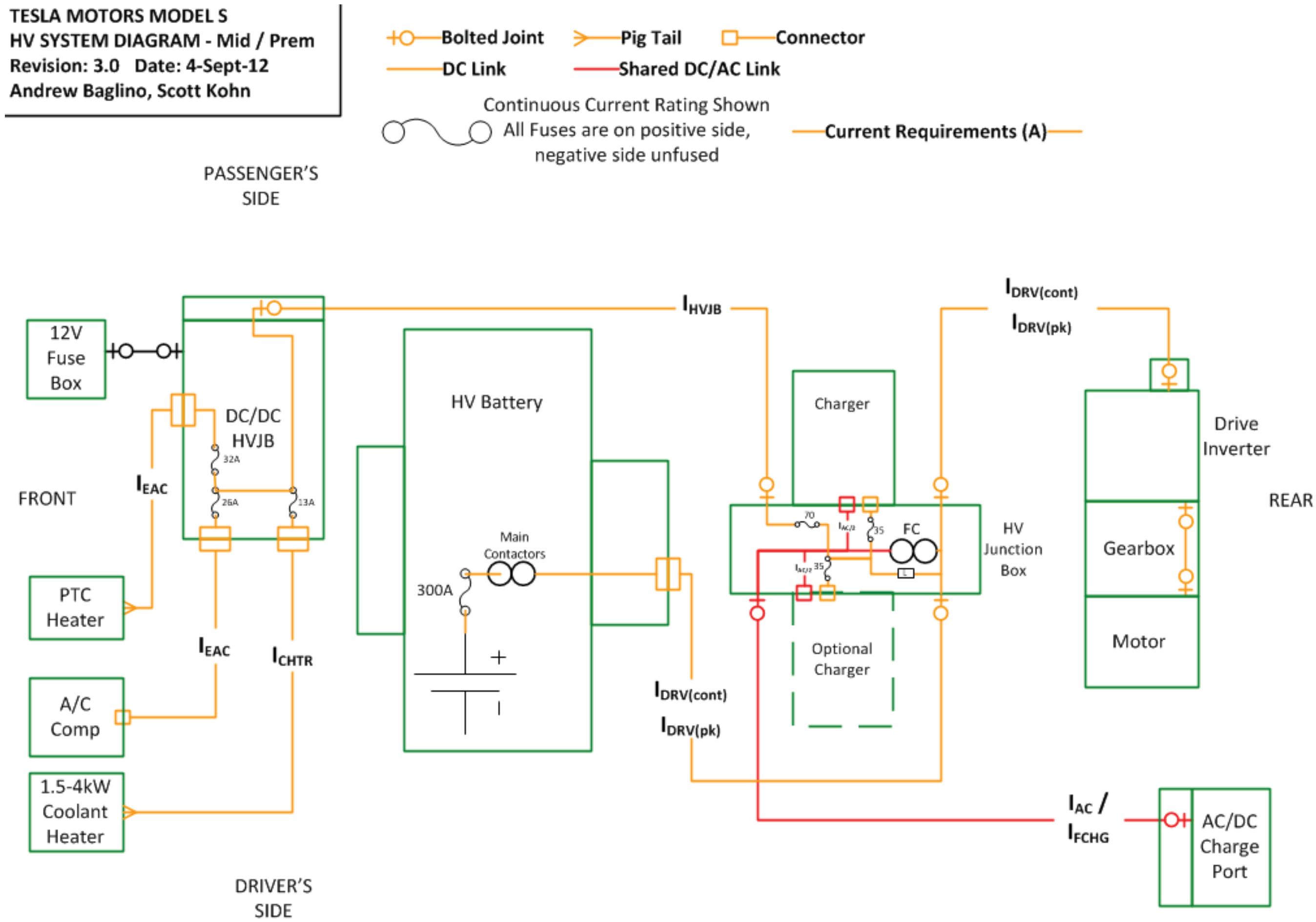

Figure 3

High Voltage Lockout Procedure

WARNING: Only technicians who have been trained in High Voltage Awareness are permitted to perform this procedure. Proper personal protective equipment (PPE) and insulating HV gloves with a minimum rating of class 00 (500V) must be worn any time a high voltage cable is handled. Refer to service bulletin SB–13-92-003, High Voltage Awareness Care Points for additional safety information.

WARNING: This procedure should be performed every time the High Voltage system is worked on, and should be performed immediately before beginning work on the High Voltage system. If work on the system is interrupted, re-check the system for high voltage before continuing.

Depending on the failure mode, the contactors might not open as expected. Therefore, it is essential to use this procedure to confirm that contactors are truly open.

1. Position the vehicle in preparation for raising it, but keep the vehicle at ground level at this time.

2. Close all doors.

3. Touch CONTROLS > DRIVING > JACK on the touchscreen to enable jack mode.

4. On the touchscreen, touch CONTROLS > E-BRAKE & POWER OFF > POWER OFF.

5. Connect a laptop running Tesla Diagnostic System (TDS) to the vehicle. Select Views > Battery > Battery Isolation. Monitor the following values:

Signal	Expected Value
BMS Isolation Resistance	> 3000 kΩ
BMS Contactor State	Open
Compressor Power	0 W
Cabin Heater PTC	0%
HVAC Rail	Off
ACC Rail	Off
Drive Rail	Off

NOTE: If TDS shows an isolation resistance reading below 3000 kOhm when contactors are shown open, the high voltage battery is faulty and needs to be replaced.

WARNING: Unless the first responder loop has been disconnected, the vehicle can go into support mode after being idle for a period of time. This can re-enable high voltage. Always disconnect the first responder loop after touching POWER OFF on the touchscreen. Failure to follow this instruction could result in serious injury or death due to exposure to high voltage.

6. Disconnect the First Responder Loop. This ensures that contactors stay open regardless of requests for 12V battery support.

NOTE: Do not remove the 12V battery negative cable.

7. Use a voltmeter to check that pin # 4 is 0 VDC with respect to chassis ground (Figure 4).

Figure 4

8. Wait at least 30 seconds to allow HV Bus Voltage to decay.

9. Raise and support the vehicle.

10. Remove the rear undershield panel (refer to Service Manual procedure 12030501).

WARNING: Proper personal protective equipment (PPE) and insulating HV gloves with a minimum rating of class 00 (500V) must be worn while performing this procedure.

11. Remove the orange drive inverter cover (Figure 5).

Figure 5

CAUTION: To prevent future water ingress, check the drive inverter cover O-rings for distortion or damage and replace as necessary. When reinstalling the drive inverter cover, insert the cover at an angle to prevent damage to the O-rings (Figure 6). Once the left (B+) O-ring is seated, rotate the cover into position.

Figure 6

12. Use the drive inverter case as a chassis ground. Measure the following voltages (Figure 7):
    - B+ to ground
    - B– to ground
    - B+ to B–

Figure 7

13. If any of the voltages are more than 10 V, the contactors are not fully opened. Refer to the stuck contactor guide to discharge the battery.

NOTE: Replace the high voltage battery if all voltages are zero and the vehicle has BMS internal isolation warnings or faults. There are failure modes (such as compromised isolation, blown fuse and damaged contactors) that could still result in 0 V DC Link Voltage.

NOTE: If possible, discharge the HV battery before removing it from the vehicle. Use the TDS Battery Shipping pane to check if the “Ok to ship by land” or “Ok to ship by air” indicators have turned green. If necessary, reduce the battery’s state of charge (SOC) by operating the cabin heater or driving the vehicle.

14. If possible, a second voltage measurement should be performed in the device you will be working on. For example, if replacing a DCDC converter, confirm that B+ to ground, B– to ground, and B+ to B– are all 0V. If any of them are greater than 10V, consult the stuck contactor guide.