TN-13-44-003
June 26, 2013

Tesla Motors, Inc.
Tech Notes

Tech Note: HVIL Diagnostic Guide

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.

The High Voltage Interlock Loop (HVIL) routes through every high voltage (HV) component and HV connector in the vehicle. Figure 1 shows the HVIL circuit (in red), the HV components (in green), and some of the HV harness connectors.

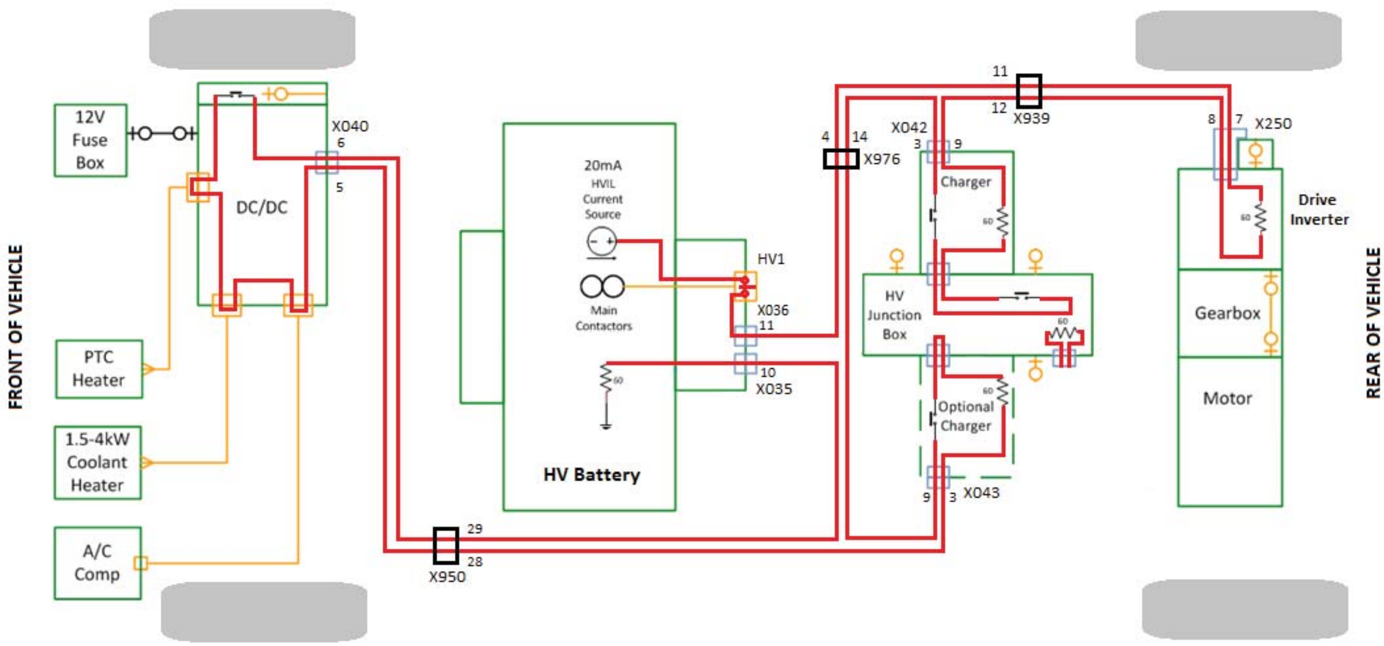


Figure 1

What the Technician Sees

The BMS produces a constant current and measures the voltage drop over 4 known resistance points in the loop (nominal: 0.02A x 240Ω = 4.8V). If the resistance changes, and the voltage drop is therefore higher or lower than the max thresholds, the BMS reports an HVIL failure.

- If the vehicle is in Standby, Support, or Charge mode, the failure is reported as a FAULT (example: BMS_f008_HW_HVIL). The vehicle opens contactors, or keeps them open.
- If the vehicle is in Drive, the failure is reported as a WARNING (example: BMS_w008_HW_HVIL), but does not open the contactors, to prevent loss of drive.

Potential causes for HVIL failures are:

- Increased resistance or intermittent connections (loose connectors and pins, intermittent shorts, intermittent open connections, bad crimps, out of spec parts, splayed-open terminals, etc.)
- Components with internal damage (non-functioning HVJB lid switch, improper resistance in any of the HV components, etc.)

If a technician sees an HVIL failure, several diagnostics can help to determine the problem:

- **Faulty DCDC HV Connector Test**
- **Loose Logic Connector Test**
- **HV Connector Continuity Check**
- **Crimp, Pin Drag, and Tension Check**

WARNING: Only Tesla Service technicians who have completed High Voltage training are allowed to service High Voltage components.

WARNING: These high voltage procedures are only overviews. Be sure to follow all warnings in the referenced procedures, and follow appropriate precautions for working with electricity safely (refer to Service Bulletin SB-13-92-003, "High Voltage Awareness Care Points"). Use HV gloves when handling the HVIL circuit.

Viewing HVIL Information in TDS

Tesla Diagnostic System, or TDS, has a panel for viewing HVIL information in TDS version 1.2.30 or newer. Follow these instructions to prepare for either of the faulty/loose connector tests in this document.

1. Launch the TDS tool on a Service laptop.
2. Connect to the car by changing Configuration settings to Ethernet.
3. In the TDS top menu bar, navigate to Views > HV Electronics > HVIL Diagnostic AF. If no data appears in the panel, check your connection to the car.
4. On the car's touchscreen, select CONTROLS > E-Brake & Power Off > POWER OFF. Confirm that you want to 'POWER OFF'. This turns off all rails.
5. Tap somewhere else on the touchscreen. Only the ACC and HVAC rails turn back on.
6. On the TDS panel, ensure that the drive rail is off, but the BMS contactors are closed (Figure 2).

While performing the wiggle checks in the following procedures, have another person watch the BMS HVIL Voltage readout carefully. If wiggling a connector causes an intermittent connection, the HVIL voltage drifts for the poor connection causing the HVIL alert. This is also indicated by the BMS_w008_HW_HVIL light turning red and the sound of the BMS contactors opening.

Some faults might not necessarily cause a high enough resistance to trigger a fault; however, the HVIL voltage still noticeably drifts when wiggling the affected connector.

Figure 2 (TDS HVIL panel view)

Faulty DCDC HV Connector Test

NOTE: Some vehicles are known to have HV connector pins that are too short for a reliable connection. Bulletin SB-13-44-003, “HVIL Connector Upgrade”, describes the affected VIN ranges and the replacement procedure for those connectors. Vehicles built after these VINs and dates already have the new longer pin (yellow dot) KET connectors:

- HVAC unit/ PTC heater: VIN P07354, 8-Apr-13
- Coolant heater: VIN P07590, 8-Apr-13
- Compressor harness: VIN P07354, 8-Apr-13

NOTE: Assembly marks connectors with a green or yellow line during factory testing, which might obscure the dot if overdrawn. The yellow dot from the manufacturer is different from the Assembly mark (Figure 3).

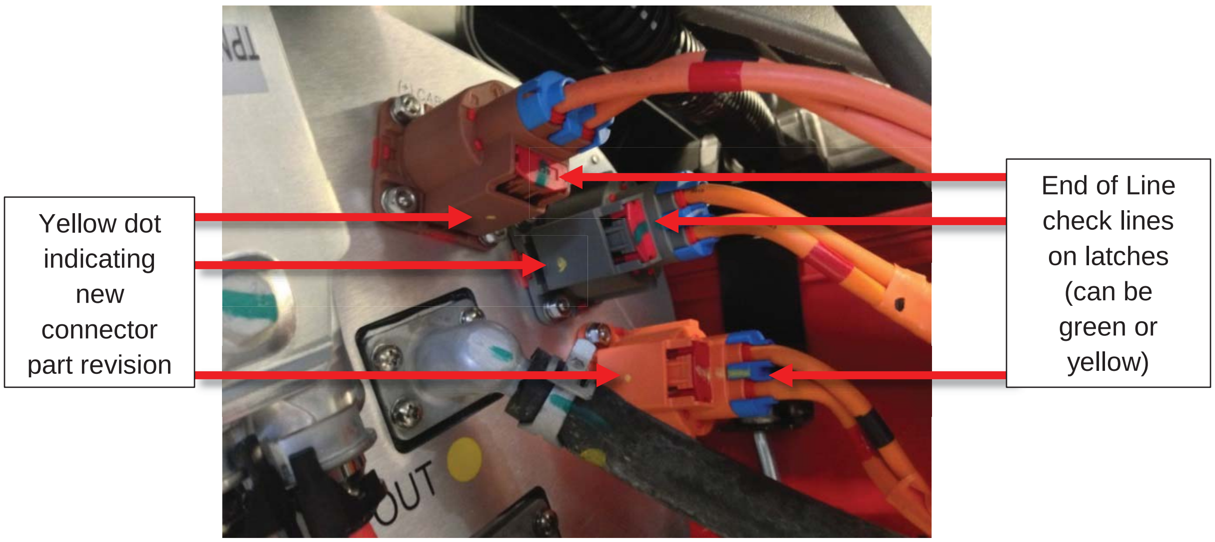


Figure 3 (New part revision of DCDC HVIL connectors)

1. Remove the front right wheel and wheel arch liner (refer to Service Manual procedures 34012301 and 12010902).

2. Verify on the TDS panel that the drive rail is OFF, the accessory rail and HVAC rails are ON, and the BMS contactors are CLOSED.

⚠ **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.

3. Check that all three connectors have yellow dots, regardless of VIN.

4. Check for a non-seated or non-latched HV connector (the red latch must be flush). For each of the 3 HV connectors, push and pull the connector completely in and out (Figure 4). Wiggle the connector in each direction while the connector is pushed in, and again while it is pulled out.

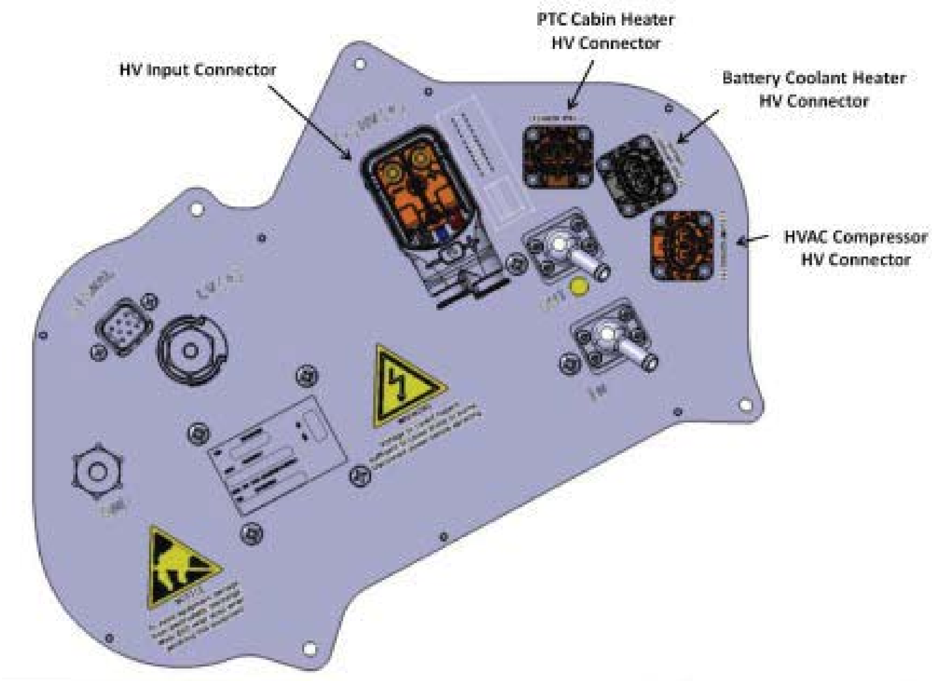


Figure 4 (DCDC connector face)

5. Listen to the alert tones and the sound of contactors opening to identify a loose connection during the previous step. Ideally, have a second person in the driver seat checking for alerts on the touchscreen. Figure 5 shows the DCDC HV connector circuit overview.

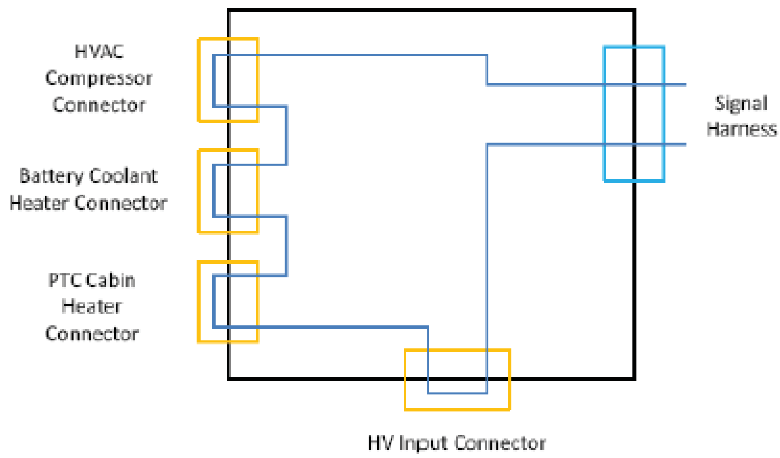


Figure 5

6. On any vehicle with HVIL failures, electrically isolate the vehicle and replace the DCDC KET HV connectors proactively, according to SB-13-44-003, “HVIL Connector Upgrade”.

Loose Logic Connector Test

1. Follow steps 1-2 from the previous procedure (wheel liner off, contactors closed, and drive rail off).

2. Check for a non-seated or non-latched logic connector. Check each logic connector visually, then push and pull the connector completely in and out. Wiggle the connector in each direction while the connector is pushed in, and again while it is pulled out. Do this for:
   - X040 on the DCDC (Figure 6)
   - X250 on the drive inverter (Figure 7)
   - X042 on the master charger (Figure 8)
   - X043 on the slave charger (if applicable) (Figure 8)
   - X976 behind the master charger (Figure 9)

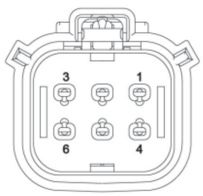


Figure 6 (X040, DCDC)

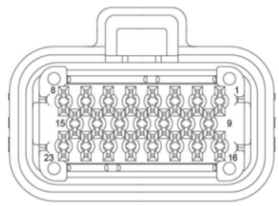


Figure 7 (X250, drive inverter)

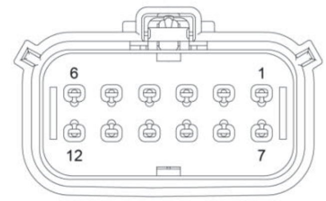


Figure 8 (X042, master charger and X043, slave charger)

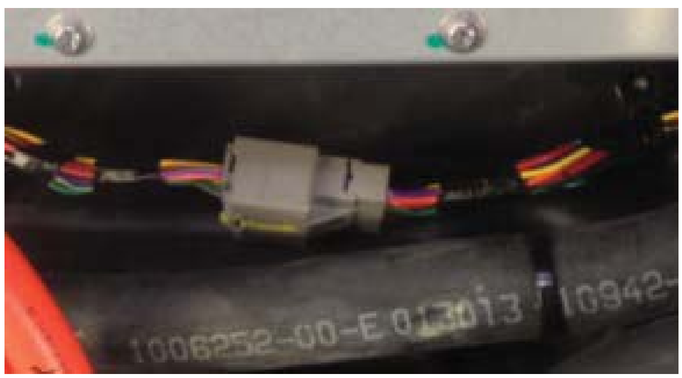


Figure 9 (X976, behind master charger)

3. Listen to the alert tones and the sound of contactors opening to identify a loose connection during the previous step. Ideally, have a second person in the driver seat checking for alerts on the touchscreen.

4. Check in the TDS panel that the HVIL currents are within specifications:
   - Master charger HVIL current should be ~20mA
   - Slave charger HVIL current should be ~20mA

5. If an internal failure is found in any HV component (charger, DI, DCDC, HV battery, etc.), open an ATTAC case to get confirmation before replacing the component.

HV Connector Continuity Check

⚠ **CAUTION:** Only use proper tools to check connectors. Improper handling of tools can damage pins and connectors.

1. Perform the electrical isolation procedure to open the contactors (refer to Service Manual procedure 17010000).

2. Measure resistance at the points listed in Table 1. Refer to the continuity check schematic (Figure 10) and expected connector measurements (Table 2).

3. Check the functionality of the HVJB lid reed switch. When the cover is removed, it should measure open loop (OL); with the cover installed, it should measure 0.1Ω – 0.6Ω. If the switch is faulty, order a new HVJB.

4. If an internal failure is found in any other HV component (charger, DI, DCDC, HV battery, etc.), open an ATTAC case to get confirmation before replacing the component.

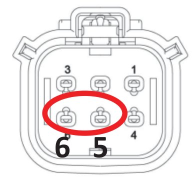
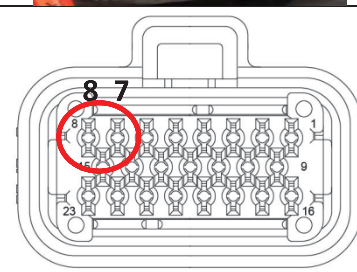
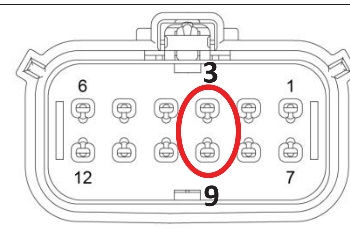
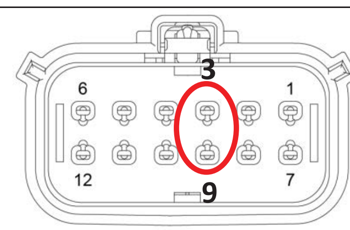
Location	Connector	Measurement	Enter Resistance	Pins
DCDC converter	**X040**	Connected: Back probe pin 6 to pin 5: check continuity for resistance < 1 Ohm		
		Connected: back probe pin 6 to GND		
Under rear seat (white connector behind master charger)	**X976**	Connected: Back probe pin 4 to GND		
Drive inverter	**X250**	Connected: back probe pin 7 to GND		
		Disconnected: pin 7 to pin 8 on DI side		
Master charger	**X042**	Connected: back probe pin 9 to GND		
		Disconnected: pin 9 to pin 3 on charger side		
	HVJB lid	Integrity of reed switch and lid switch connector: From inside JB, unplug lid switch. Measure resistance across terminals and check that the switch opens/closes with magnet.	*(Closed < 1 Ohm, open OL)*	
Slave charger	**X043**	Connected: back probe pin 9 to GND		
		Disconnected: pin 9 to pin 3 on charger side		

Table 1: Resistance measurement points

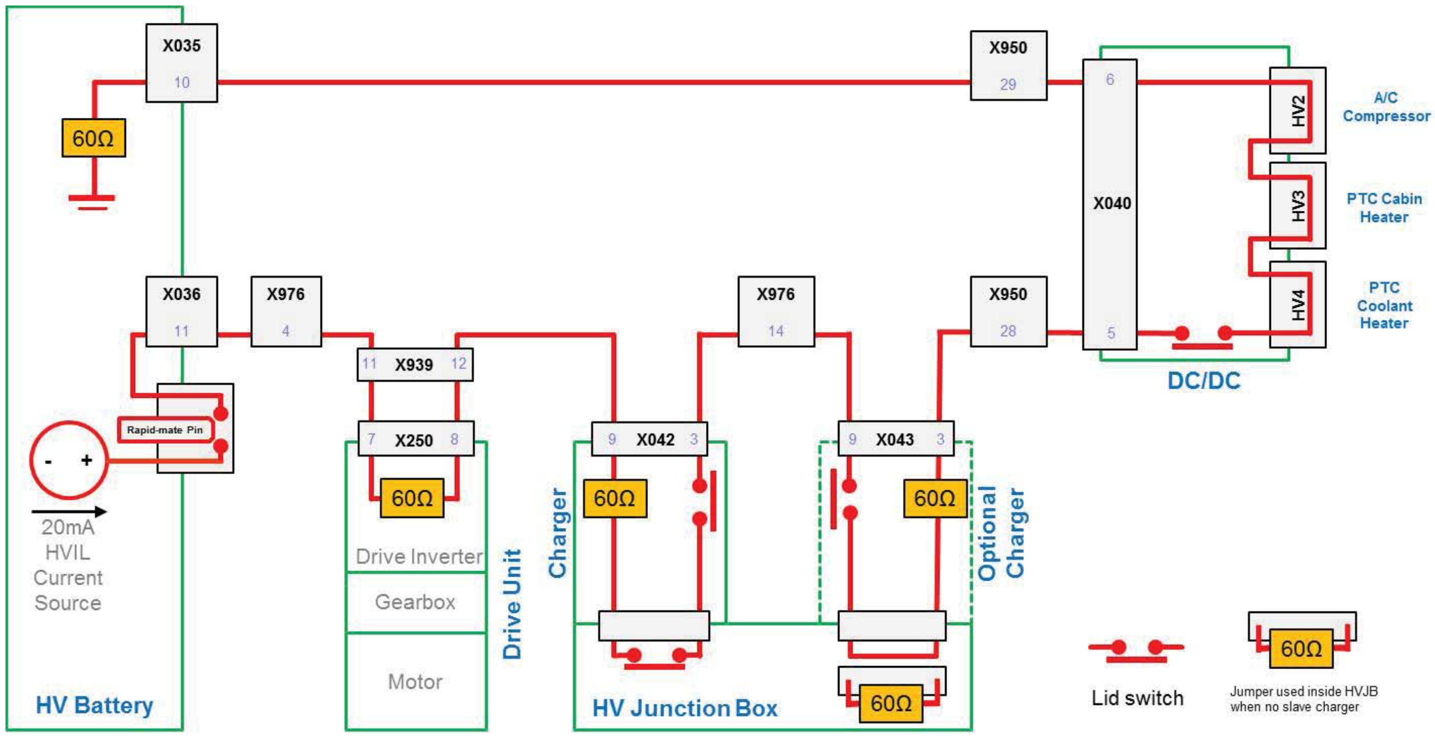


Figure 10

Connector	X036	X976	X939	X250	X250	X939	X042	X042	X976	X043	X043	X040	X040	X035	HV4	HV3	HV2
Pin	11	4	11	7	8	12	9	3	14	9	3	5	6	10	--	--	--
Expected Voltage (HVIL On)	4.8V	4.8V	4.8V	4.8V	3.6V	3.6V	3.6V	2.4V	2.4V	2.4V	1.2V	1.2V	1.2V	1.2V	--	--	--
Resistance to GND (HVIL Off)	240Ω	240Ω	240Ω	240Ω	180Ω	180Ω	180Ω	120Ω	120Ω	120Ω	60Ω	60Ω	60Ω	60Ω	60Ω	60Ω	60Ω

Table 2: Connector voltage and resistance

Crimp, Pin Drag, and Tension Check

If no root cause has been found in the three previous procedures:

1. Check the integrity of the crimps on all listed connectors.

2. Perform a pin drag test on all HVIL connectors and pins. Request an HVIL drag test kit through ATTAC if one is not available at your location.

Connector	Pins	Location	Pass/Fail
X250	7,8	Drive inverter side of drive unit	
X042	3,9	Master charger –under rear RH seat	
X043	3,9	Slave charger –under rear LH seat	
X040	5,6	DCDC converter –behind RH wheel well	
X976	4	Connector under RH rear seat behind master charger	
X950	28,29	RH lower A pillar (Figure 11)	
X939	11,12	Rear center undercarriage between drive unit and HV battery pack (Figure 12)	

Table 3: Crimp and pin drag check locations

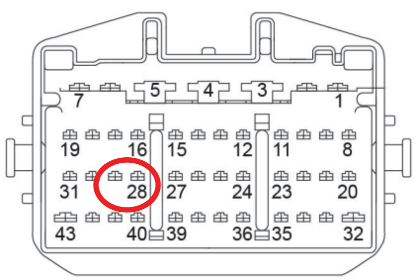


Figure 11 (X950)

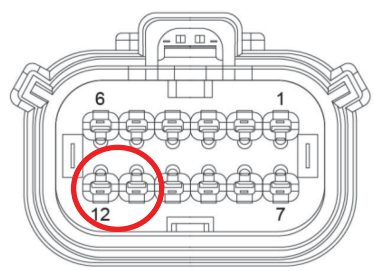


Figure 12 (X939)

HVIL Field Failure Examples (as of June 2013)

Highest Occurrence: 31 VINs in Service

- **Failure Type:** An intermittent or loose connection causes increased resistance and increased HVIL voltage.
- **Subsystem:** 3 DCDC HV connectors: PTC cabin heater, battery coolant heater, and AC compressor.
- **Issue:** Pins are too short. In the worst case, HVIL male and female pins do not touch. The supplier changed the plastic housing design without changing the pin length accordingly.
- **Diagnostic for Service:** Push and wiggle each connector and check resistance changes via HVIL voltage. If the voltage changes, replace the connectors using the instructions in Service Bulletin SB-13-44-003.
- **Corrective Actions:**
    - Assembly is implementing new design KET connectors with longer pins in new vehicles.
    - Service replaces any faulty connectors (Figure 3).

2nd Highest Occurrence: 10 VINs in Service

- **Failure Type:** A damaged reed switch causes increased resistance and increased HVIL voltage.
- **Subsystem:** High voltage junction box (Figure 13).
- **Issue:** The glass bulb protecting the reed switch is shattered inside the black plastic housing. The cause seems to be significant mechanical stress. Root cause is TBD.
- **Diagnostic for Service:** Check the resistance of the assembled HVJB. Check the switch function with a magnet. A closed switch should read < 1.0 Ohm. Also carefully check that the female pins of the reed switch are not splayed open.
- **Corrective Actions:** Replace the complete HVJB. An ATTAC case confirmation is needed to only replace the magnetic reed switch.

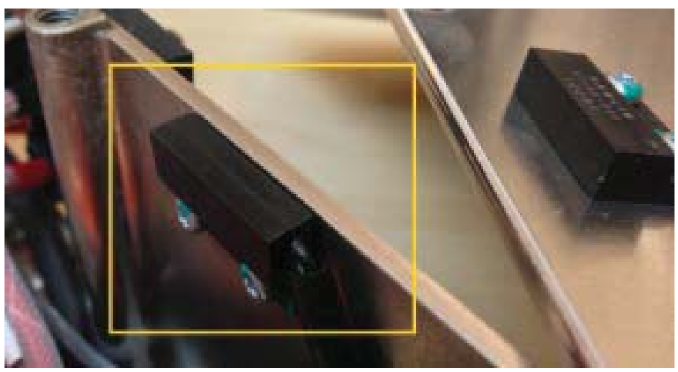


Figure 13

3rd Highest Occurrence: 7 VINs in Service

- **Failure Type:** A splayed-open female pin on the HVJB reed switch connector causes increased resistance and increased HVIL voltage.
- **Subsystem:** High voltage junction box reed switch connector into charger (Figure 14).
- **Issue:** One of the two female pins on this connector is splayed open, which causes poor connection with the male side. This is most likely a manufacturing defect, but root cause investigation is still ongoing.
- **Diagnostic for Service:** Unplug the connector from the charger and closely examine the female pins. If a pin is not completely round, it is bad (Figure 14). Affected connectors have currently been found on vehicles ranging from VIN P09968 to P11256.
- **Corrective Actions:** Replace the complete HVJB. An ATTAC case confirmation is needed to only replace the magnetic reed switch.

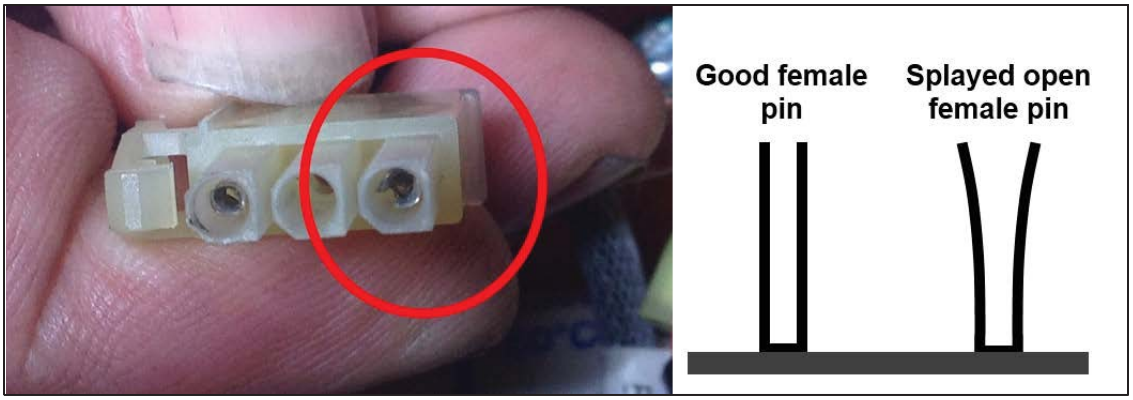


Figure 14

4th Highest Occurrence: 2 VINs in Service

- **Failure Type:** Component failure causes increased resistance at high temperatures and therefore causes HVIL failure.
- **Subsystem:** Charger (main control board, J3 connector).
- **Issue:** A poor solder connection on the J3 connector increases resistance above 90 Ω at high temperatures.
- **Diagnostic for Service:** Drive the vehicle for 20 minutes at freeway speeds and immediately charge it for at least 30 minutes. Disconnect the charge cable. Unplug logic connector X042 and measure the resistance of pins 9 and 3, probing into the hot charger.
- **Corrective Actions:** Log the results in an ATTAC case.

4th Highest Occurrence: 2 VINs in Service

- **Failure Type:** An intermittent or loose connection causes increased resistance and increased HVIL voltage.
- **Subsystem:** Connector X976 in the HVIL harness, under the rear seat (Figure 9).
- **Issues:** The connector can be partially seated but not fully locked together. In other cases, drag testing shows that the pin tension in the connector is loose.
- **Diagnostic for Service:** Check whether the connector is fully locked and strain is relieved. Perform a pin drag test to check for loose pins.
- **Corrective Actions:** Log the results in an ATTAC case.

4th Highest Occurrence: 2 VINs in Service

- **Failure Type:** An intermittent or loose connection causes increased resistance and increased HVIL voltage.
- **Subsystem:** Drive Inverter logic connector X250 (Figure 15).
- **Issue:** Four pins in the X250 connector are very loose (including 7 and 8 for HVIL).
- **Diagnostic for Service:** Check whether the connector is fully locked and assembled properly.
- **Corrective Actions:** Log the results in an ATTAC case.

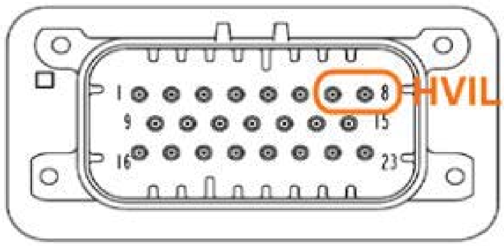


Figure 15

Occurrence: 1 VIN in Service

- **Failure Type:** The drive inverter leaks HVIL current to ground, causing HVIL failure.
- **Subsystem:** Drive inverter paddle board.
- **Issue:** A faulty component on the DI control board is leaking part of the HVIL current to ground.
- **Diagnostic for Service:**
  - On the TDS panel, check Master Charge HVIL current (should be 20 mA).
  - If contactors do not close, use a 60 Ω resistor to jump the HVIL lines at DI connector X250. This also requires the technician to jump the CANL and CANH lines. Consult with an FSE in ATTAC for this procedure.
- **Corrective Actions:** Log the results in an ATTAC case.

Occurrence: 1 VIN in Service

- **Failure Type:** Wire damage is causing an HVIL short to ground.
- **Subsystem:** The wire harness between connectors X950 and X043, near the driver side seatbelt pre-tensioner.
- **Issue:** The HVIL wire is squeezed and shorted to ground (Figure 16).
- **Diagnostic for Service:** Check wire for damage.
- **Corrective Actions:** Log the results in an ATTAC case.

Figure 16

Occurrence: 1 VIN in Service

- **Failure Type:** An intermittent or loose connection causes increased resistance and increased HVIL voltage.
- **Subsystem:** DCDC connector X040 (Figure 17).
- **Issue:** The connector is not properly holding its terminals.
- **Diagnostic for Service:** Check that the connector is fully locked and assembled properly.
- **Corrective Actions:** Log the results in an ATTAC case.

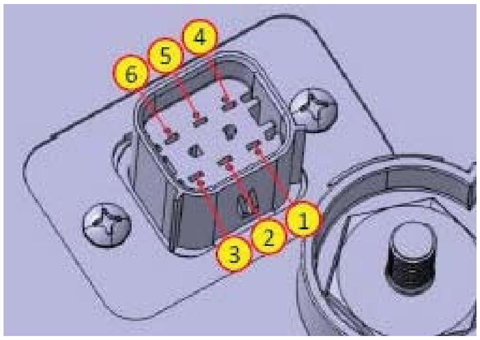


Figure 17