Contents

Section 4

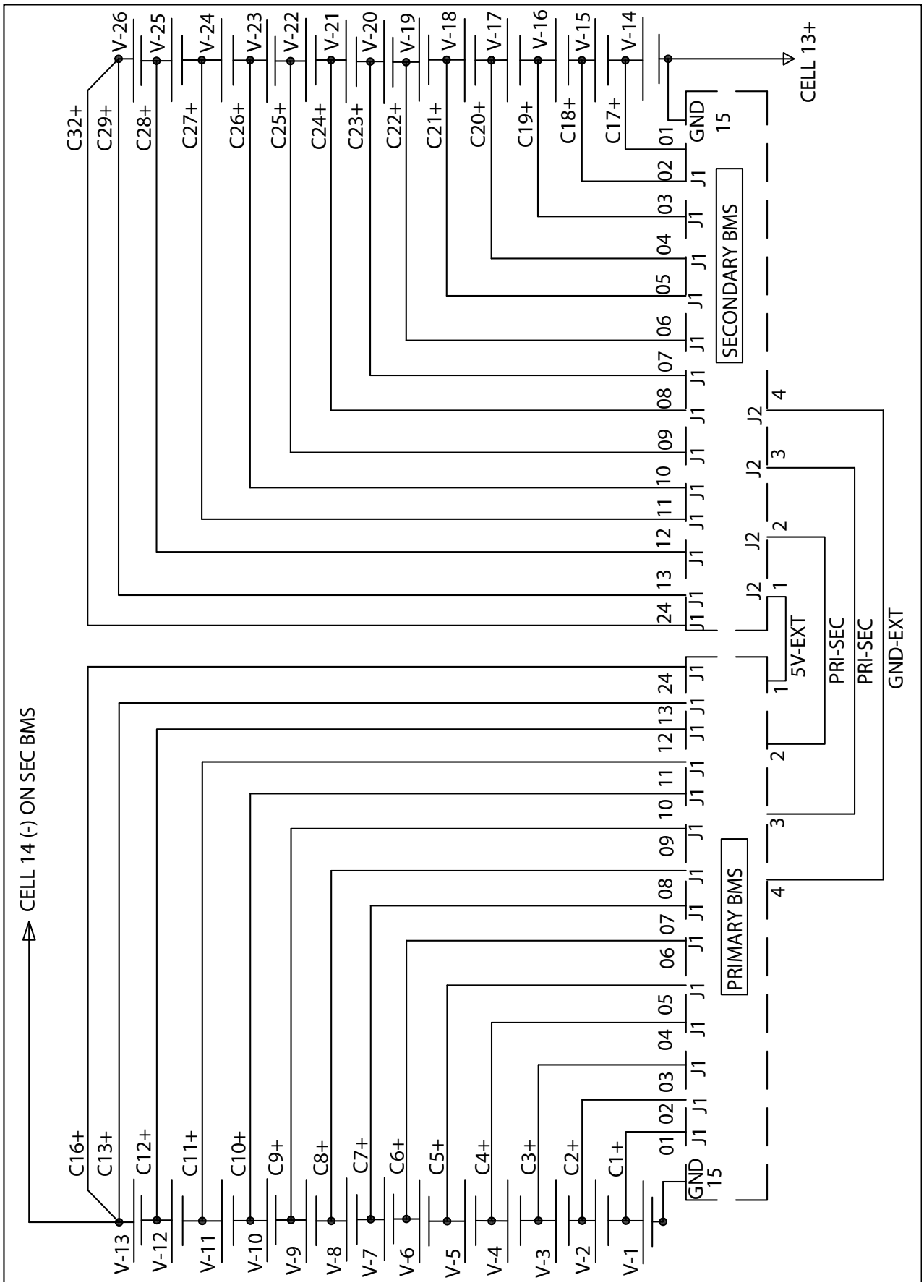
Battery Pack System Diagnosis

This section will be used to perform diagnostic procedures on the battery pack system/device. The section describes system circuits and diagnostic tables used to diagnose circuits. It will be used to correct diagnostic trouble codes (DTCs) by following the tables for either non-scan or scan tool use. This section contains the On-Board Diagnostic System Check that is the first step to perform before any further diagnostics or repairs are made to the system. The assumption is made that on all diagnostic tables, the battery pack is equipped with an INDUSTRIAL BMS and is equipped with the standard set of sensors and sensing leads. The wiring schematics and circuit identification are for a battery pack equipped with the Industrial BMS.
The diagnostic tables and voltages shown are prepared with the requirement that the system functioned correctly at the time of assembly and that there are not multiple failures.

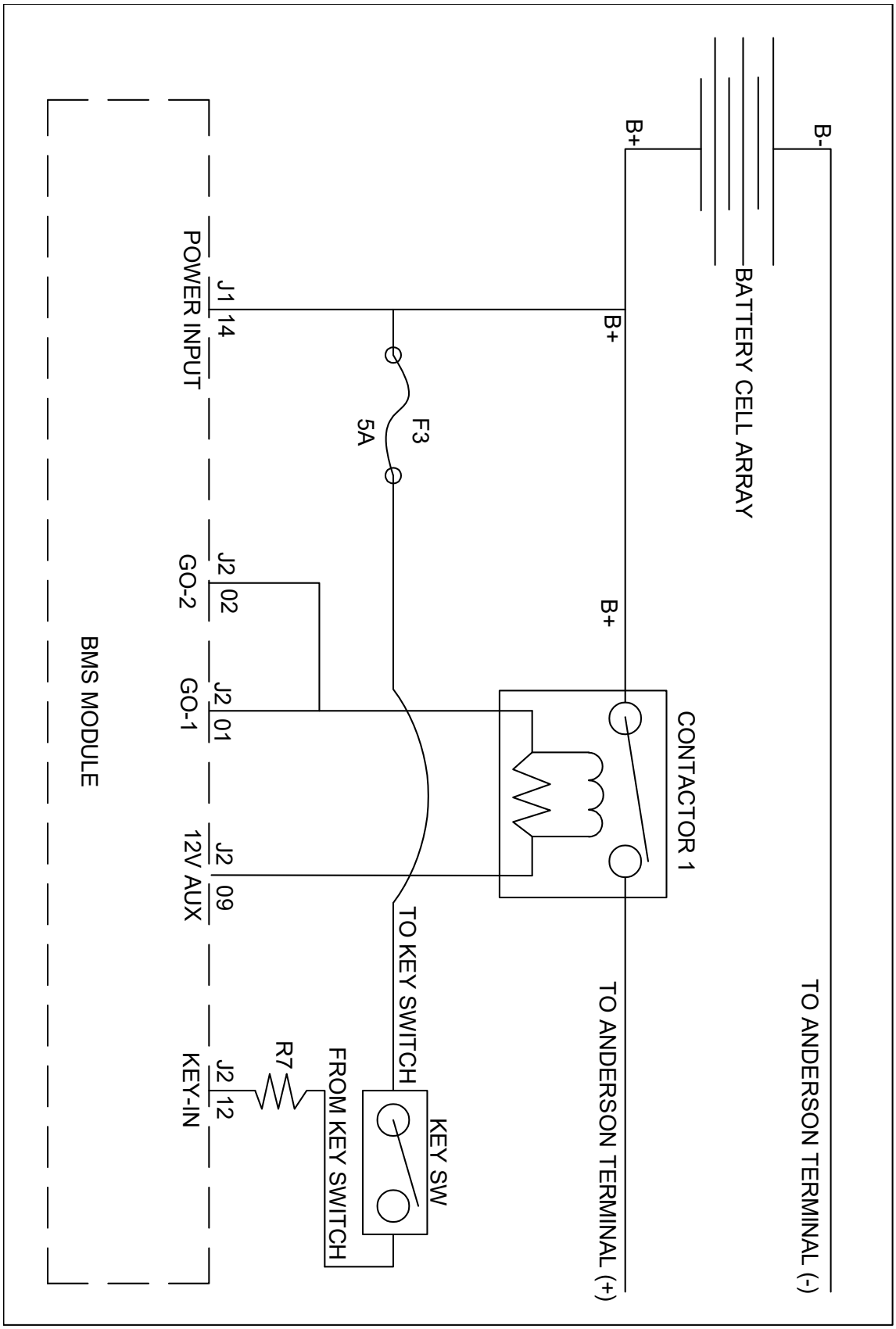
Section 4 Battery Pack System Diagnostics

.

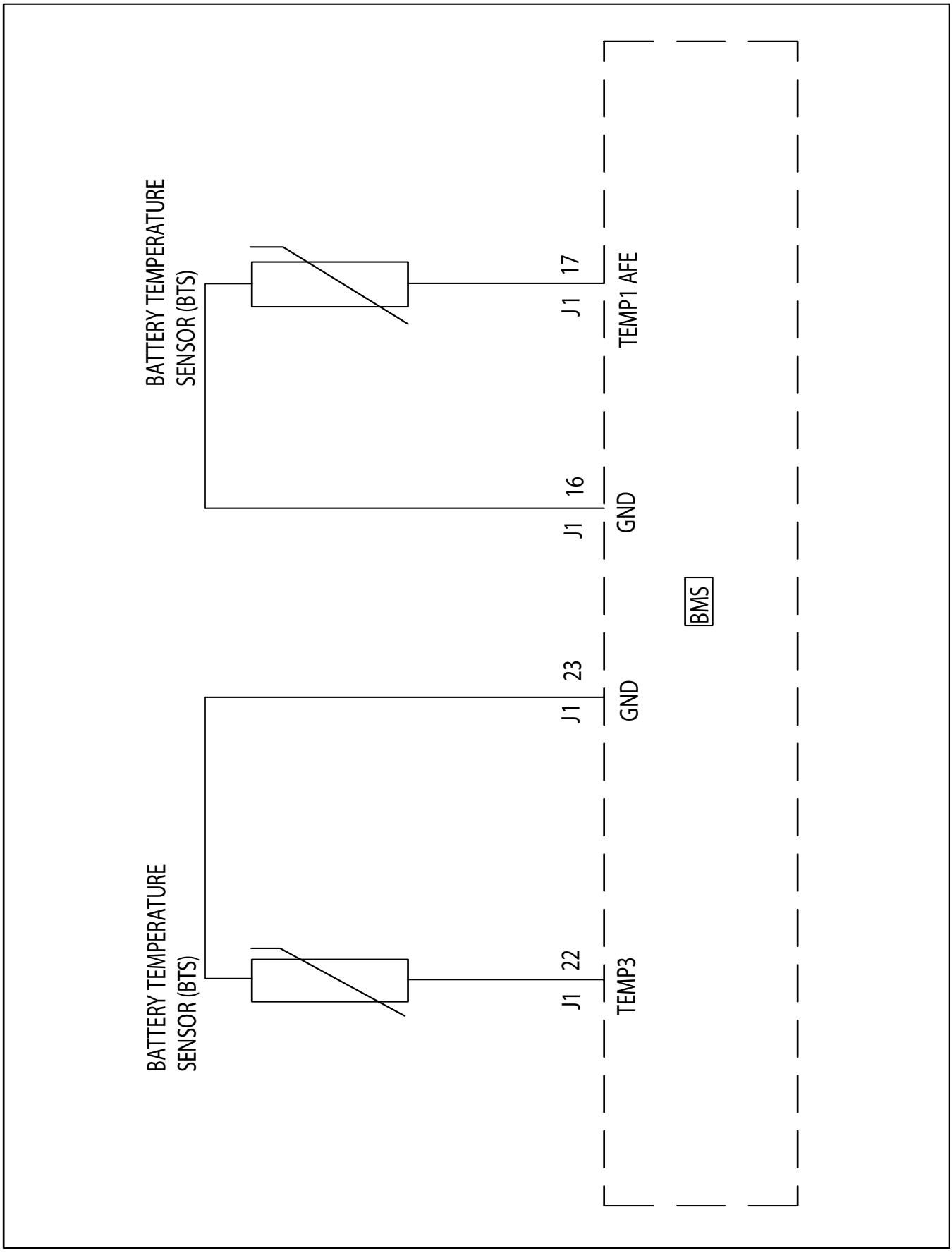
BMS Wiring (1 of 7) 80 Volt



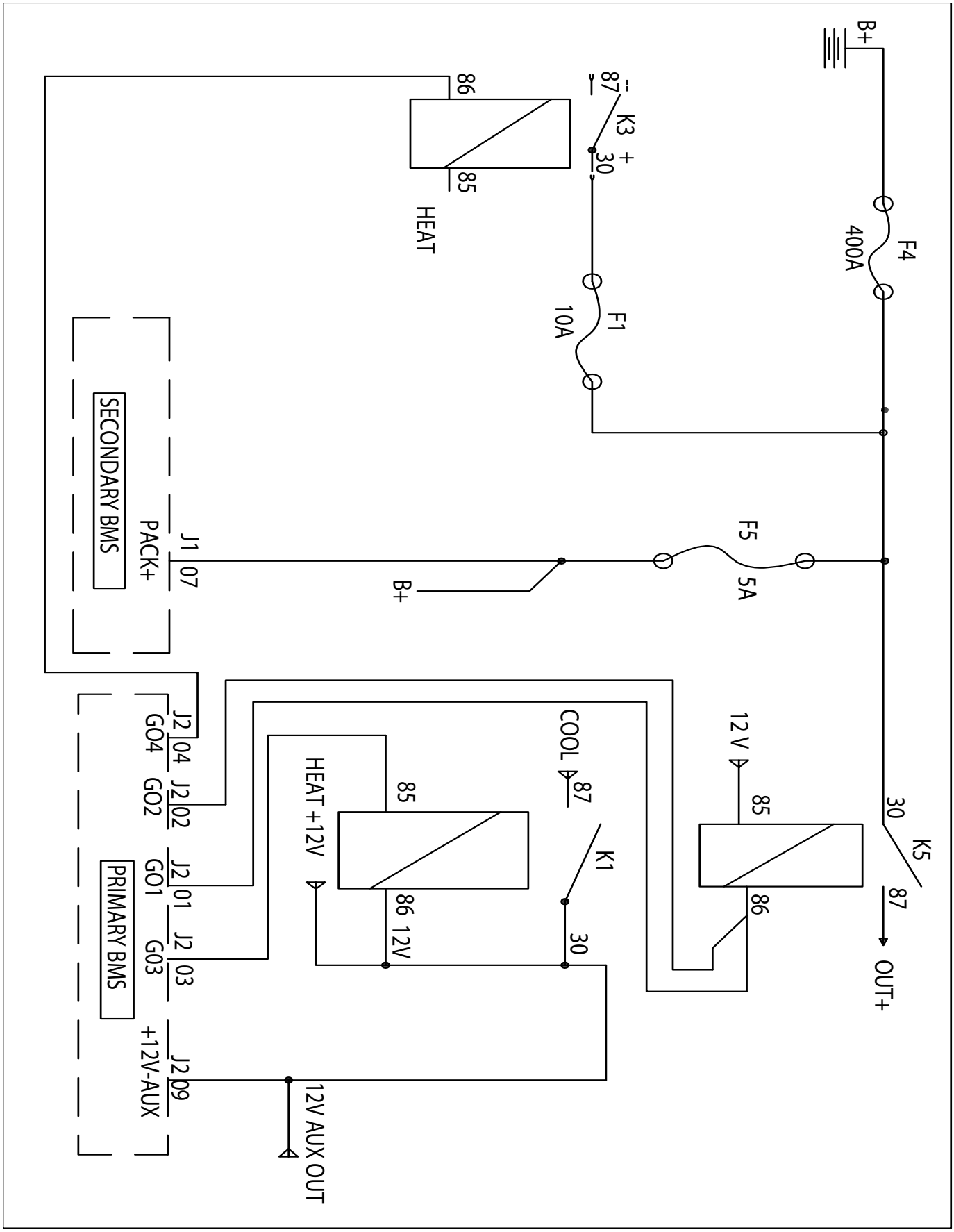
BMS Wiring (2 of 7) 80 Volt



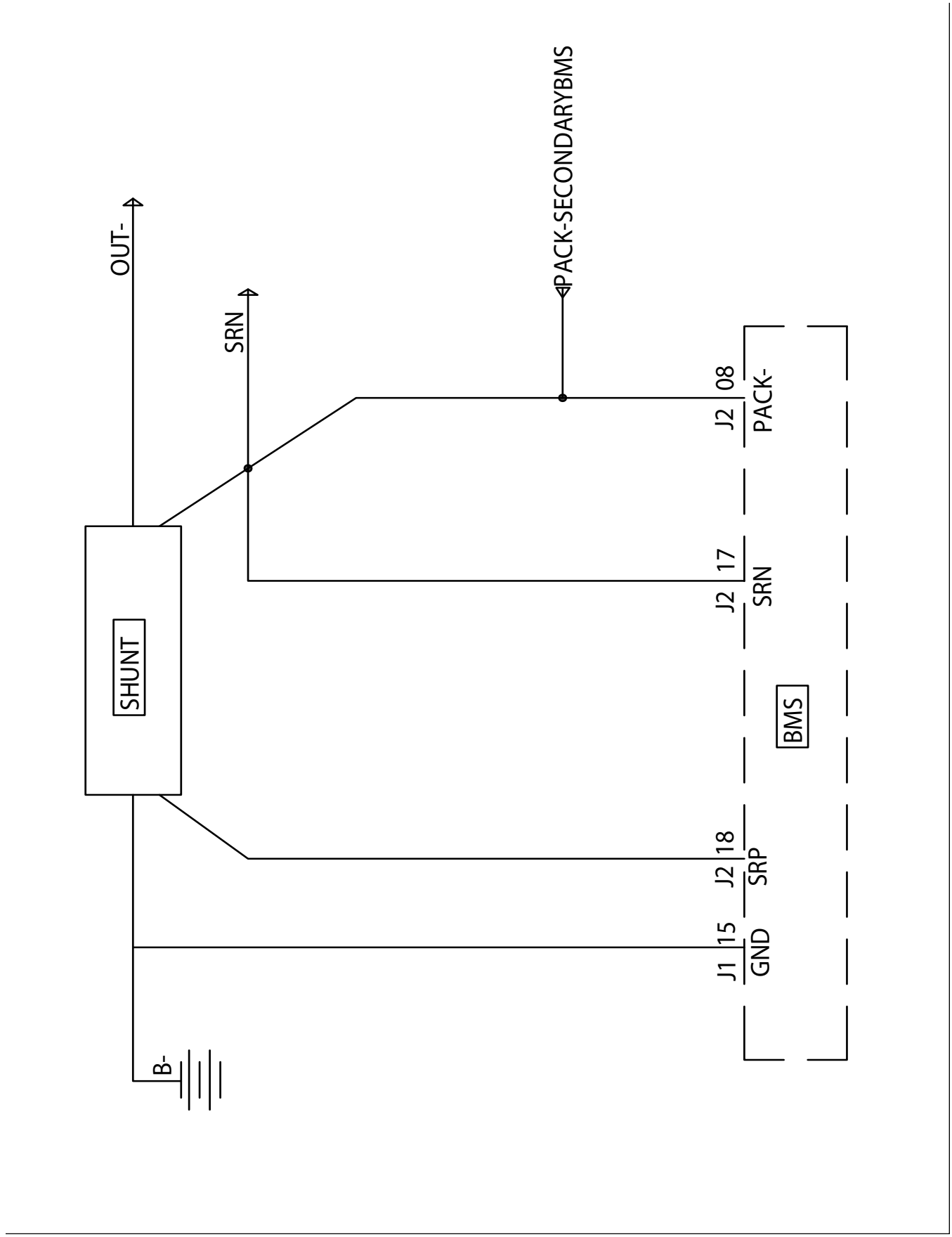
BMS Wiring (3 of 7) 80 Volt



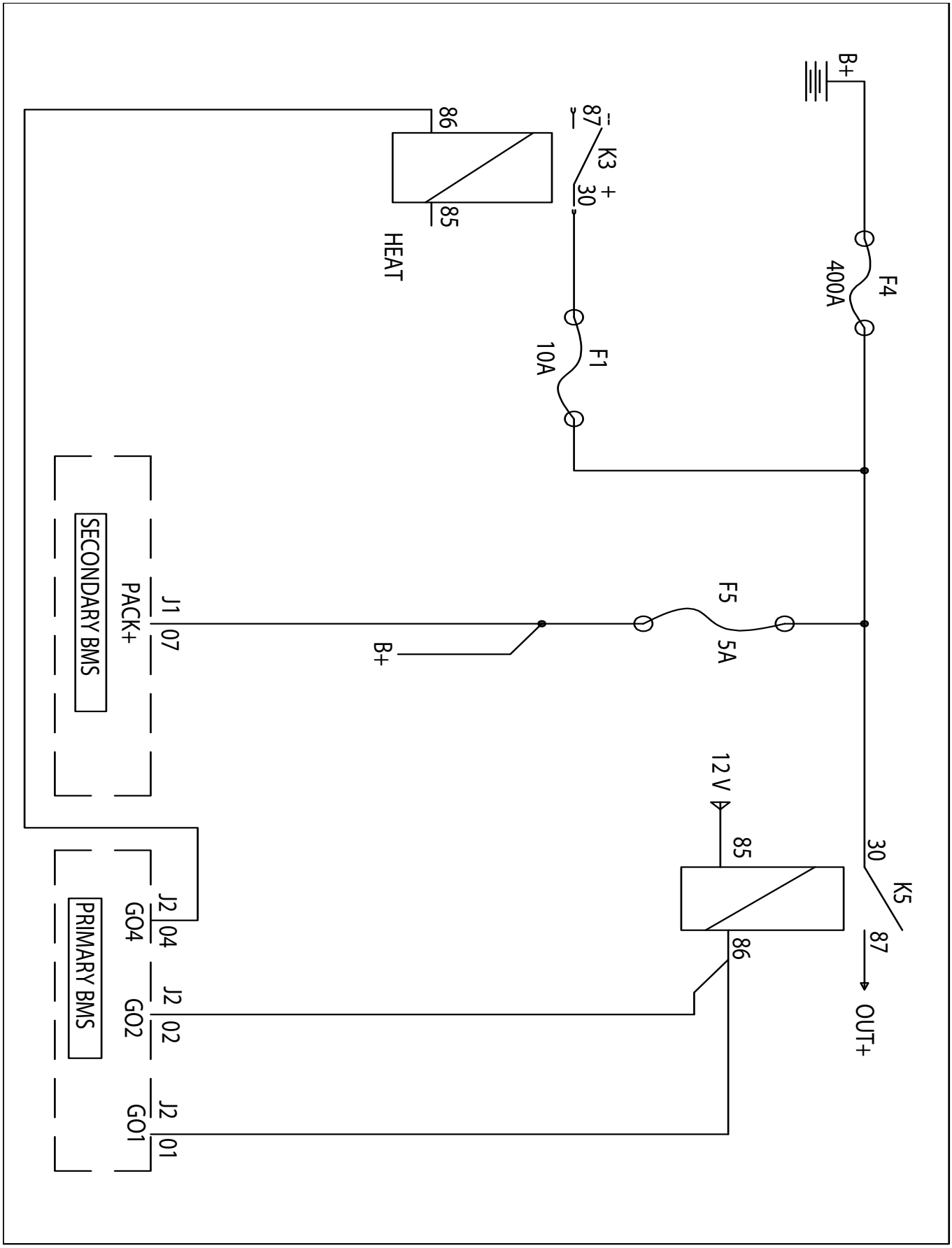
BMS Wiring (4 of 7) 80 Volt



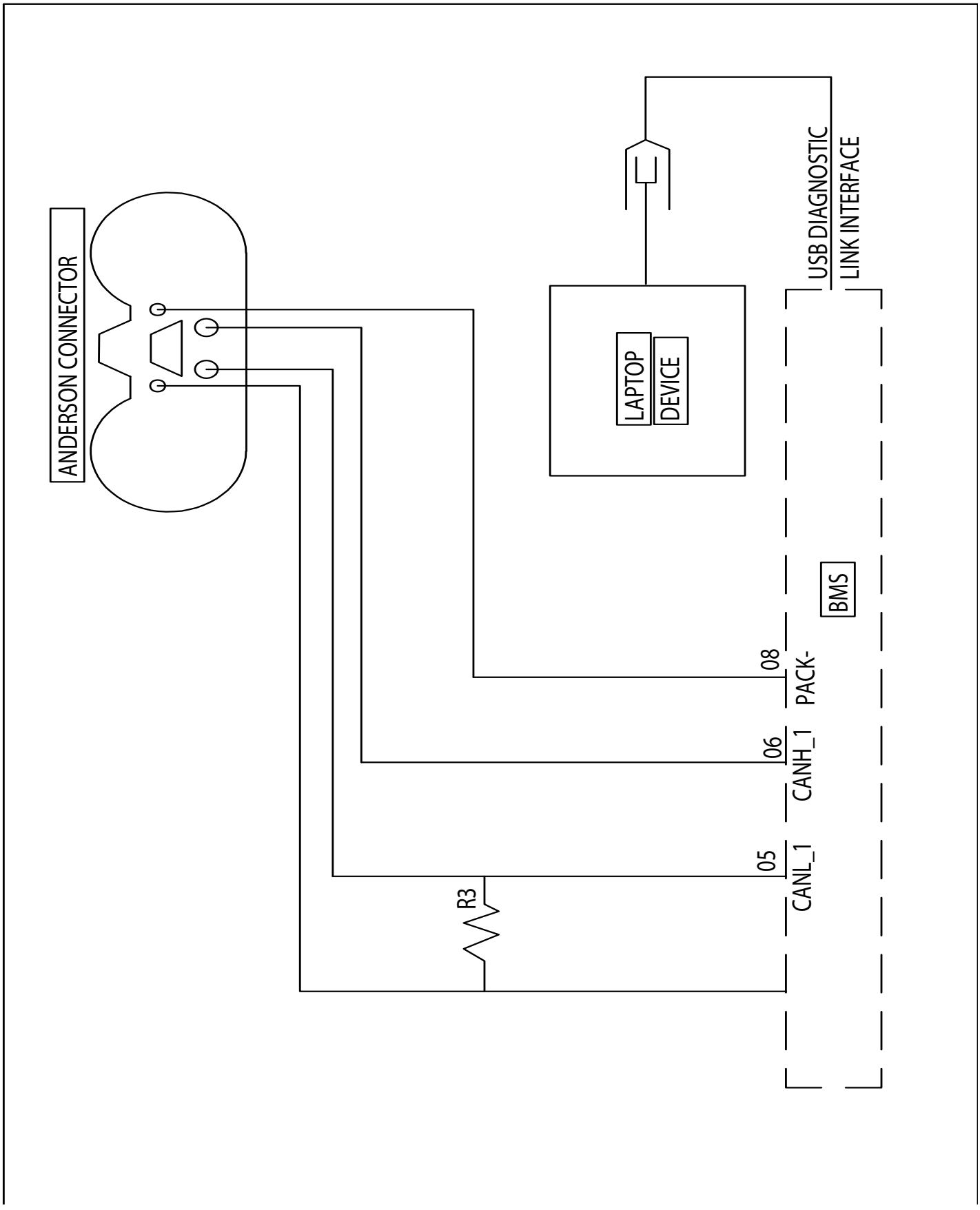
BMS Wiring (5 of 7) 80 Volt



BMS Wiring (6 of 7) 80 Volt

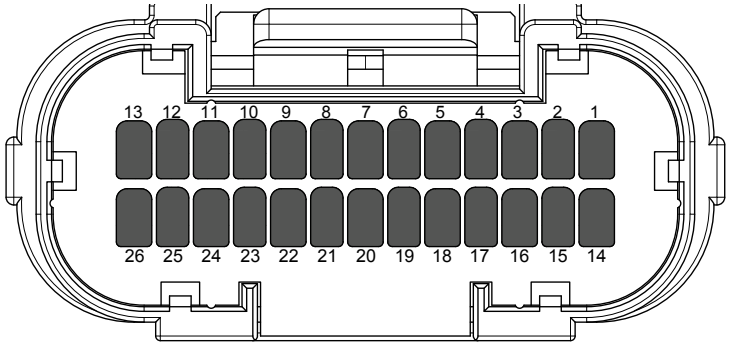


BMS Wiring (7 of 7) 80 Volt



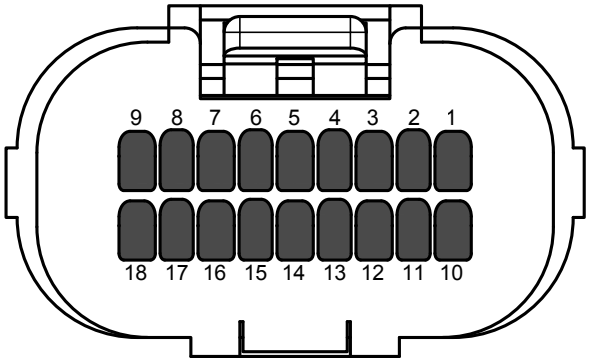
This page left intentionally blank

BMS Connector Identification (1 of 2) Primary



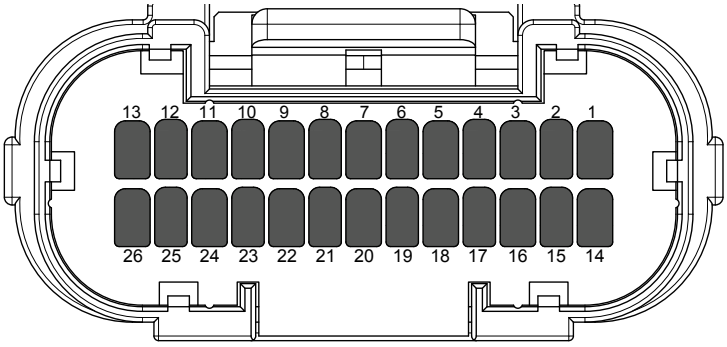
BMS Pin Number J1 (J100)	Circuit type	Wire Color	Circuit Description
J1-1	C1+	WHT	Cell 1 Monitor input
J1-2	C2+	WHT	Cell 2 Monitor input
J1-3	C3+	WHT	Cell 3 Monitor input
J1-4	C4+	WHT	Cell 4 Monitor input
J1-5	C5+	WHT	Cell 5 Monitor input
J1-6	C6+	WHT	Cell 6 Monitor input
J1-7	C7+	WHT	Cell 7 Monitor input
J1-8	C8+	WHT	Cell 8 Monitor input
J1-9	C9+	WHT	Cell 9 Monitor input
J1-10	C10+	WHT	Cell 10 Monitor input
J1-11	C11+	WHT	Cell 11 Monitor input
J1-12	C12+	WHT	Cell 12 Monitor input
J1-13	C13+	WHT	Cell 13 Monitor input
J1-14	PWR-IN	WHT	Power Input
J1-15	PWR-GND	WHT	Power Ground
J1-16	BTS 1-RTN	WHT	Battery Temperature Sensor Return (Ground)
J1-17	BTS 1- FEED	WHT	Battery Temperature Sensor 1 (BTS1) Signal
J1-18			Battery Temperature Sensor 2 (BTS 2) Signal
J1-19			Battery Temperature Sensor 4 (BTS 4) Signal
J1-20			Battery Temperature Sensor 5 (BTS 5) Signal
J1-21			Battery Temperature Sensor 6 (BTS 6) Signal
J1-22	BTS 3 (2)-FEED	WHT	Battery Temperature Sensor 3 (BTS 3) Signal
J1-23	BTS 3 (2) RTN	WHT	Battery Temperature Sensor Return (Ground)
J1-24	C16+	WHT	Cell 16 Monitor input
J1-25	C15+	WHT	Cell 15 Monitor input
J1-26	C14+	WHT	Cell 14 Monitor input

BMS Connector Identification (2 of 2) Primary



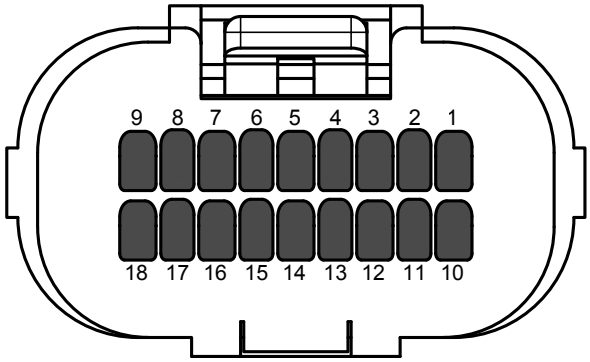
BMS Pin Number J2-(J101)	Circuit type	Wire Color	Circuit Description
J2-1	GO 1	WHT	Contactor 1 enable
J2-2	GO 2	WHT	Contactor 2 enable
J2-3	GO 3	WHT	Cooling relay enable (if equipped)
J2-4	GO 4	WHT	Heating relay enable (if equipped)
J2-5	CAN 1 LO	WHT	CAN 1 Low
J2-6	CAN 1 HI	WHT	CAN 1 High
J2-7	EXT-RESET	WHT	External Reset
J2-8	PACK NEG (-)	WHT	Battery Pack Ground (NEG) (-)
J2-9	+12V AUX	WHT	+ 12 Volt Auxiliary
J2-10	GO 5		
J2-11	GO 6		
J2-12	KEY IN	WHT	Key Switch Voltage In (Wake Up)
J2-13	CHGR DET	WHT	Charger Detect Input
J2-14	SPARE IN	WHT	Cooling Feed +
J2-15	CAN 2 HI	WHT	CAN 2 High
J2-16	CAN 2 LO	WHT	CAN 2 Low
J2-17	SRN	WHT	Shunt Return
J2-18	SRP	WHT	Shunt Feed

BMS Connector Identification (1 of 2) Secondary



BMS Pin Number J1 (J100)	Circuit type	Wire Color	Circuit Description
J1-1	C17+	WHT	Cell 17 Monitor input
J1-2	C18+	WHT	Cell 18 Monitor input
J1-3	C19+	WHT	Cell 19 Monitor input
J1-4	C20+	WHT	Cell 20 Monitor input
J1-5	C21+	WHT	Cell 21 Monitor input
J1-6	C22+	WHT	Cell 22 Monitor input
J1-7	C23+	WHT	Cell 23 Monitor input
J1-8	C24+	WHT	Cell 24 Monitor input
J1-9	C25+	WHT	Cell 25 Monitor input
J1-10	C26+	WHT	Cell 26 Monitor input
J1-11	C27+	WHT	Cell 27 Monitor input
J1-12	C28+	WHT	Cell 28 Monitor input
J1-13	PACK VOLT IN +	WHT	Volt in +
J1-14	PWR-IN	WHT	Power Input
J1-15	PWR-GND	WHT	Power Ground
J1-16	BTS 7 & 8- RTN	WHT	Battery Temperature Sensor Return (Ground)
J1-17	BTS 7- FEED	WHT	Battery Temperature Sensor 1 (BTS3) Signal
J1-18	BTS 8- FEED		Battery Temperature Sensor 2 (BTS 4) Signal
J1-19			
J1-20			
J1-21			
J1-22			
J1-23			
J1-24	PACK VOLT IN +	WHT	Volt in POS (+)
J1-25			
J1-26			

BMS Connector Identification (2 of 2) Secondary



BMS Pin Number J2-(J101)	Circuit type	Wire Color	Circuit Description
J2-1	GND- From BMS Pri	WHT	Ground from BMS Pri interface
J2-2	AY from BMS Pri	WHT	Communication line from BMS Pri
J2-3	BZ from BMS PRI	WHT	Communication line from BMS Pri
J2-4	5V REF from BMS PRI	WHT	5V In from BMS Pri
J2-5			
J2-6			
J2-7	PACK POS)+)	WHT	Battery Pack Positive (POS) (+)
J2-8	PACK NEG (-)	WHT	Battery Pack Ground (NEG) (-)
J2-9	+12V AUX	WHT	+ 12 Volt Auxiliary
J2-10			
J2-11			
J2-12			
J2-13			
J2-14			
J2-15			
J2-16			
J2-17			
J2-18			

NOTE: J2-1 thru J2-4 are communication interface between BMS Primary and BMS Secondary This lead set exits BMS Primary as a flying lead (No connector on BMS Pri)

BMS Diagnostic Trouble Codes

The Malfunction Indicator Lamp (MIL) will be “ON” if a malfunction exists under the conditions listed below. If the malfunction clears the lamp will go out and the diagnostic trouble code will be stored in the BMS fault history log section. You will notice there are both short term logs and long term logs for your review.
Many of the DTC tables will include a functional check of the system that may pinpoint a problem. However, it is important to remember that the DTC tables are designed for use only when a DTC is set. Therefore, a thorough understanding of the normal operation of the system being diagnosed is necessary, and the use of tables for this purpose is at the discretion of the technician.
NOTICE: Most of our DTC’s are not considered latching codes. In other words, if the system fault clears during operation, the BMS will not keep the MIL illuminated. Once a fault clears, the MIL will immediately go out. Codes in this system do NOT need to be cleared.

Diagnostic Trouble Code (DTC) Table

DTC	Description
DTC 1	Discharge FET over-temp Error
DTC 2	Charge FET over-temp error
DTC 3	SPI communication error
DTC 4	BQ 12C general communication error
DTC 5	Battery over-voltage error
DTC 6	Battery under-voltage error
DTC 7	Cell over-voltage error
DTC 8	Cell under-voltage error
DTC 9	Charge over-current error
DTC 10	Discharge over-current error
DTC 11	Charge over-temp error
DTC 12	Discharge over-temp error
DTC 13	EEPROM 12C communication
DTC 14	SD card error
DTC 15	BQ 12C secondary BMS address error
DTC 16	Charge under-temp error
DTC 17	Discharge under-temp error
DTC 18	Invalid configuration file

Warnings

Cell under voltage
Cell over voltage
Battery under temperature
Battery over temperature
Battery Over current

BMS Diagnostic Trouble Codes in LOG file

Locating errors through the use of log file diagnostics

Using log files for diagnostics can be a very helpful tool for the service technician. The log file is a type of event recording that can display small variances in voltage or a circuit by showing an event over time. While voltmeters are handy for taking measurements, they typically don't display an event over time. Additionally, they don't allow for a convenient way to manipulate data.
The log file feature in the BMS tool will not only allow you to view a series of events over time, it will also allow you to see a triggered event such as a fault code or fault warning. Since the fault codes used in the logging software displays different code numbers than the BMS code table- we have devised a code chart for your refence. Please note this code chart is specific to the log file system.

WARNING 1	WARNING/ERROR
ERROR 32	CELL OVER VOLTAGE
ERROR 40	CELL OVER VOLTAGE & BATTERY OVER VOLTAGE
ERROR 64	CELL UNDER VOLTAGE

WARNING 2	WARNING/ERROR
ERROR 1	DISCHARGE OVER CURRENT
ERROR 2	CHARGE OVER TEMP
ERROR 7	DISCHARGE OVER TEMP & DISCHARGE OVER CURRENT & CHARGE OVER TEMP
ERROR 32	BQ I2C COMMUNICATION GENERAL
ERROR 132	EEPROMM I2C COMMUNICATION

WARNING 3	WARNING/ERROR
ERROR 6	LCD I2C COMMUNICATION & INVALID CONFIGURATION FILE
ERROR 8	INTERBMS I2C COMMUNICATION
ERROR 32	GO2 FET OVER TEMP
ERROR 132	GO4 FET OVER TEMP & LCD I2C COMMUNICATION

During normal operation the BMS continually monitors all the battery pack functions. Three of the main parameters monitored are temperature, cell voltage and pack voltage. When the pack voltage or the cell voltage gets too high, the BMS shuts down the pack. Then the pack voltage gets too low, the BMS sends a low voltage warning. About ~10 minutes after sending the low voltage warning the BMS will shut down the pack. Below you will find a chart with the thresholds used to instigate or remove alert and shut down actions. Keep in mind that we make dozens of different packs and that the figures shown here are for comparative purposes only. Your particular battery pack may have slightly different thresholds or actions.
In order for the BMS to be absolutely certain about a voltage or temperature event, we delay each action for a few seconds to allow the BMS to ensure that the measurement causing a particular action was a verified measurement.

Alert/Shut down Chart (80V pack)

Cause	ACTION Alert or Shutdown	Instigate Action	Remove Action
Charge over-temp	Alert	57 C / 134.6 F	55 C / 131 F
Charge under-temp	Alert	-7C / 19.4 F	-5C / 23 F
Discharge over-temp	Alert	57C /134.6 F	55C
Discharge under-temp	Alert	-22 C / -7.6 F	-20 C / -4 F
Pack Over voltage	Alert	94.9 V	89.7 V
Pack under voltage	Alert	72.8 V	75.4 V
Cell over voltage	Alert	3650 mV	3450mV
Cell under voltage	Alert	2800 mV	2900 mV
Pack over-temp	Shutdown	65 C / 149 F	
Cell under-voltage	Shutdown	2550 mV	
Cell over voltage	Shutdown	3700 Mv	

This page left intentionally blank

Diagnostic Information and Procedures

A Diagnostic Starting Point- System Controls

Begin your diagnostic system check with some basic tests. Insure that some facet of the vehicle controls are not limiting the device or vehicle operation. Items such as “parking brake not set” or “vehicle angle excessive” may cause a “vehicle won’t operate” problem. Then insure that you

- Have your BMS tool communication cable appropriately connected between the battery pack and your PC.
- Have identified any stored Diagnostic Trouble Codes (DTCs) or Logged Warnings

Diagnostic System Check- BMS Controls

The diagnostic system check is an organized approach to identifying a condition that is created by a malfunction in the BMS control system.

The Diagnostic System Check should be the starting point for any operational concerns. The Diagnostic Service Check directs the technician/diagnostician to the next logical step in order to diagnose the concern. Understanding and correctly using the diagnostic table reduces diagnostic time and frequently prevents the replacement of good parts.

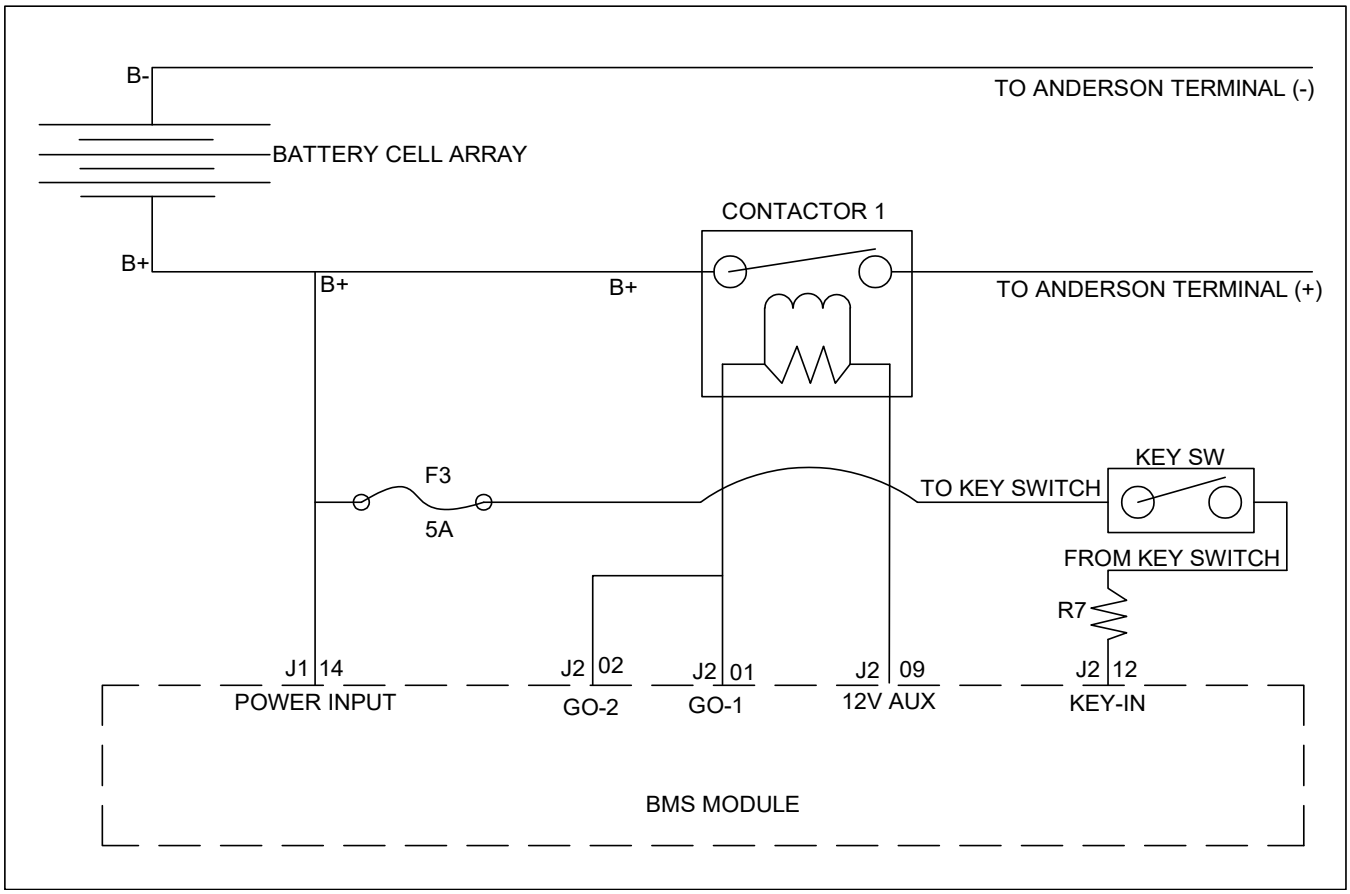
Test Description

Consider the following items when performing your diagnostic procedures.

1. The MIL light should be “ON” or have been recently on (if the condition is intermittent).
2. Be sure to check your serial data connection (Diagnostic interface USB cable) and insure that your BMS tool is reading data.
3. If the device will not operate or the vehicle will not move, be sure to consider checking the “NO (or) LOW Voltage at Output Connector) diagnostic fault tree.
4. A scan tool parameter which is not within the typical range may also help you isolate the area which is causing the problem.

On-Board Diagnostic System Check- Scan

Step	Action	Value	Yes	No
1	**Important:** • Do not perform this diagnostic if there is not an operational concern, unless another procedure directs you to this diagnostic. • Before you proceed with diagnosis, search for applicable service advisories and service bulletins. • If there is an operational issue with the vehicle or device, address that problem first. • Ensure the battery has a full charge • Ensure the main cables are clean and tight • Ensure the BMS grounds are clean and tight • Install your BMS tool • Does the Scan tool connect with the BMS?	–	Go to step 2	Go to Data Link connector diagnosis.
2	Attempt to “key-up” the pack. Do you get battery voltage at the output connector?	>65 volts	Go to step 3	Go to No voltage at output connector
3	1. Review the following symptoms 2. Refer to applicable symptom diagnostic table. • No voltage at output connector • Low voltage condition • Over temperature/under temperature • Cell voltage too high • Under temp condition Did you find and correct the condition?	–	System OK	Go to intermittent conditions



No voltage at Output Connector

Circuit Description

When the key switch is ON, the BMS activates the contactor. This action allows current from the battery pack to flow through the secondary output cables. The contactor remains closed as long as the key switch remains in the ON position.

Conditions which may cause the contactor to NOT close may include:

- Fuse is blown
- Fuse is faulty
- Over temp
- Under temp
- Over charge
- Under charge
- Wiring fault- short or open
- Under minimum cell voltage

Diagnostic Aids

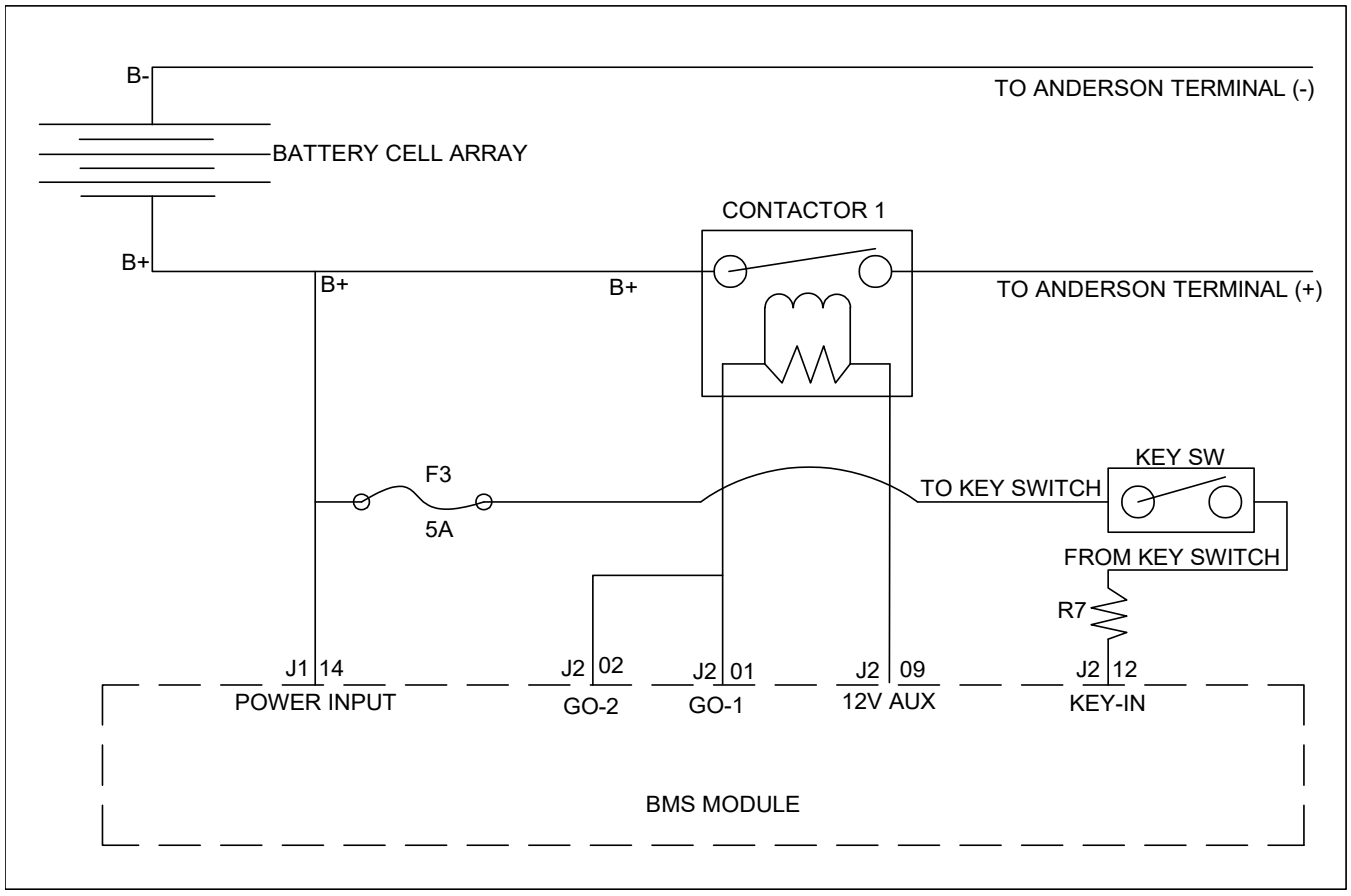
The battery pack system is protected by a number of input parameters that the BMS continually monitors. If the key switch is ON the contactor should close after a typical 5 seconds or less delay. If the contactor fails to close, refer to the diagnostic system checks further outlined in this section.

No Voltage at Output Connector

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	Key ON, Measure voltage at the connector Is voltage greater than 0 but less than 65 V	0 to<65 volts	Go to step 3	Go to step 5
3	Charge battery at 10 Amps max until battery voltage is greater than 65V	>65 volts	Go to step 4	Verify 10 amp charge
4	If over 65V- Action is complete- Continue to full charge	>89.7 volts	System OK	Go to step 5
5	Check battery temp via BMS Battery temp it should be over -5C / 23 F	> -5C / 23 F	Go to step 7	Go to step 6
6	Warm battery to above -5C / 23 F	> -5C / 23 F	Temp OK	Go to step 7
7	Check Harness connections to cells	loose	Go to step 8	Go to step 9
8	Tighten connections to recommended torque and re-test. Ensure battery is charging	tight & charging	System OK	Go to step 9
9	Inspect harness connector to charger for damage	damaged	Go to step 10	Go To step 11
10	Repair harness and re-test-		System OK	Go to step 11
11	Inspect 18 pin BMS connector terminals and connector seating continuity	damaged	Go to step 12	System OK
12	Repair damaged terminals/wires does this correct problem?		Go to step 13	Go to step 14
13	Re-test to validate system is charging		System OK	Go to step 14
14	Re seat BMS J1 and J2 connectors does that restore system function?			

Alert/Shut Down Chart

Cause	ACTION Alert or Shutdown	Instigate Action	Remove Action
Charge over-temp	Alert	57 C / 134.6 F	55 C / 131 F
Charge under-temp	Alert	-7C / 19.4 F	-5C / 23 F
Discharge over-temp	Alert	57C /134.6 F	55C
Discharge under-temp	Alert	-22 C / -7.6 F	-20 C / -4 F
Pack over-voltage	Alert	94.9 V	89.7 V
Pack under-voltage	Alert	72.8 V	75.4 V
Cell over-voltage	Alert	3650 mV /	3450mV
Cell under-voltage	Alert	2800 mV	2900 mV
Pack over-temp	Shutdown	65 C / 149 F	
Cell under-voltage	Shutdown	2550 mV / 2.5 V	
Cell over voltage	Shutdown	3700 Mv / 3.7 V	



Output Connector Voltage LOW

Circuit Description

When the key switch in ON, the BMS activates the contactor. This connects the output connector to the battery cell array. If the output voltage measured at the output connector is low (Meaning above 0V but less than 73 V) the battery has entered a discharge state that is below normal charging parameters. If this condition occurs, the battery must be recovered or "slow charged" past the threshold "overly discharged" condition. That is- brought back to a pack voltage of over 73 volts. Once the pack reached 73 volts, the traditional charging event can commence.

In order to facilitate this "slow charge" event. You must remove the battery lid and connect a slow charger (less than 10A charge rate) to the battery pack main terminals.

Diagnostic Aids

Voltage parameters for all battery packs is a critical consideration.

3. If the pack voltage is below 65 volts it must be "slow charged" until the voltage reaches 65 volts. After 65 volts- a regular fast charger can be used.

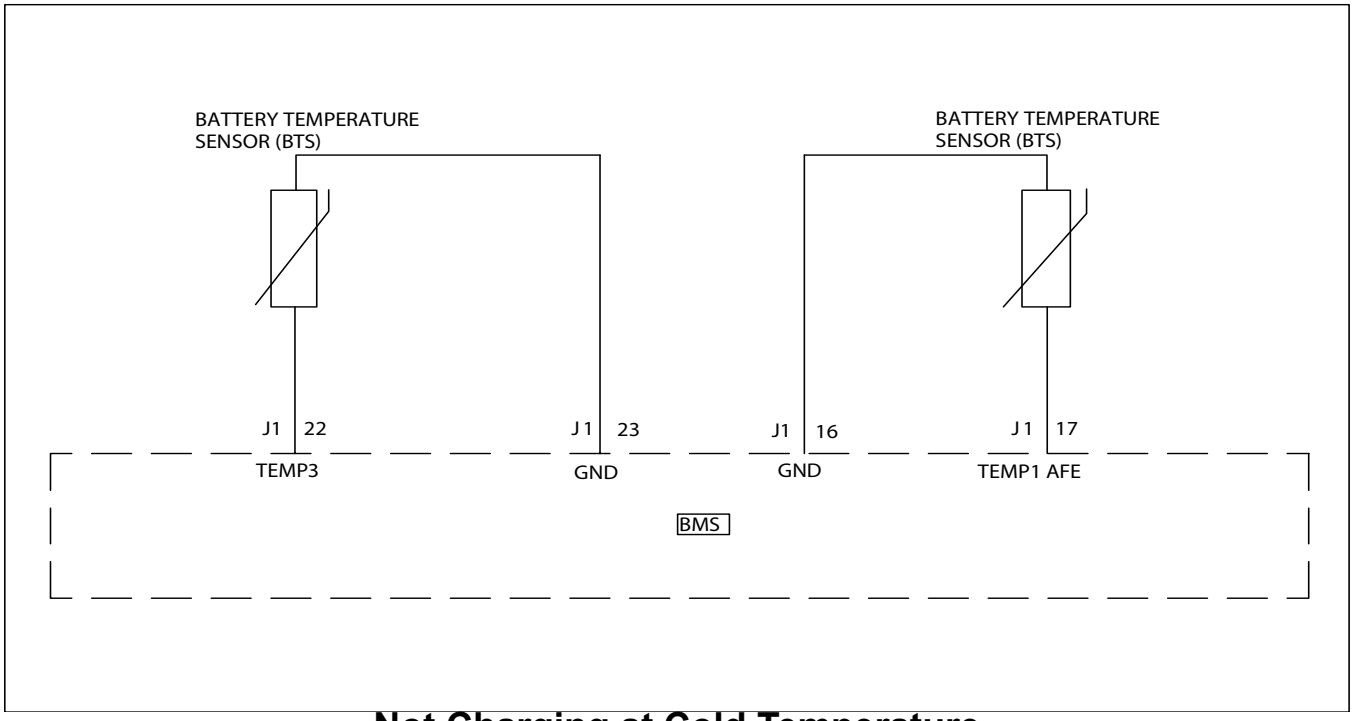
5. Cell voltages must be between 2.5 and 3.6 volts. If the battery voltage was allowed to drop below 65 volts, it might be prudent to check all cell voltages and restore them to specification.

- Be careful not to overlook standard mechanical issues such as backed-out terminals, loose terminals, corroded terminals, and other mechanical issues.
- Incorrect or incomplete charge caused by a faulty charging device or charging cables are also a possible cause for an undercharged battery

Output Connector Voltage LOW

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	Key ON, Measure voltage at the connector Is voltage greater than 0 but less than 65 V	0 to<65 volts	Go to step 3	Go to step 5
3	Charge battery at 10 Amps max until battery voltage is greater than 65V	>65 volts	Go to step 4	Verify 10 amp charge rate & continue charging
4	Check individual cell voltages. Cells must be between 2.5 and 3.6 volts.	less than 2.5V	Go to step 5	Go to step 6
5	Charge individual cells to between 2.5 and 3.6 volts	2.5 to 3.6V	Go to step 6	Continue cell charging or replace faulty cells
6	If over 65V- Action is complete- Continue to full charge with regular charger.	_	System OK	_

This page left intentionally blank



Not Charging at Cold Temperature

Circuit Description

The battery system includes a heater system that will allow battery charging to occur during lower temperature. To maintain appropriate conditions under which the battery may operate, the BMS continually monitors the temperature of the battery pack. If the battery pack temperature falls below a specified value (typically -5C / 23 F), the BMS will not allow the battery to charge if not equipped with heaters. On some large battery packs, there is a heating device that serves to maintain the battery temperature during cold charging. However, the heating device is not typically used to warm up an already cold battery because it uses battery energy to operate the heater.

If the battery voltage is below a specified value and below a specified temperature, the pack must be heated by some external source. The following diagnostic trouble table will walk the technician through the overly cold temperature diagnostic. Once the battery pack has been warmed past the low temperature threshold, the battery may be charged at normal rates. As long as a charger is detected by the BMS and is operational, the heating units will operate.

Diagnostic Aids

- Poor connection at the BMS Inspect harness connectors for improper mating or backed-out terminals.
- Damaged Harness. The temperature sensors are equipped with very small wire leads and connectors. Carefully inspect leads and connectors. Additionally look for damaged sections on other parts of the harness.
- In some packs, BTS sensors share a common ground. If two sensors are displaying open circuit issues, inspect the ground part of the circuit.
- You can verify approximate BTS sensor temperatures using the ohm chart in the BMS and sensors section (section 2).
- **Sleep Mode** If the battery is inactive with the key switched to the “ON” position for a period of 72 hours, the battery will enter the “sleep mode” To exit the “sleep mode” Cycle the key off/on.
- Bad / Dammaged heating pads.

•

Test Description

1. An important first step here is to verity that the BMS is functional through the OBD system check. While performing this check verify the temperature being displayed by the BMS.

7. The “thermistor” (temperature measuring) part of the BTS can occasionally cause this system to fail. However, wiring system open circuits are much more prevalent than component (sensor) failures in this circuit. An open BTS circuit will cause the pack to shut down.

NOTE:

The BMS will only allow the heaters to function during a cold battery charge IF the battery is connected to a charger and the charger is operational.

CAUTION:

Use only chargers that are designed for charging Lithium-Ion batteries. Using a charger designed for a standard lead-acid type battery may result in overcharging or other charging related problems.

Temperature vs Resistance
Approximate Comparative Values

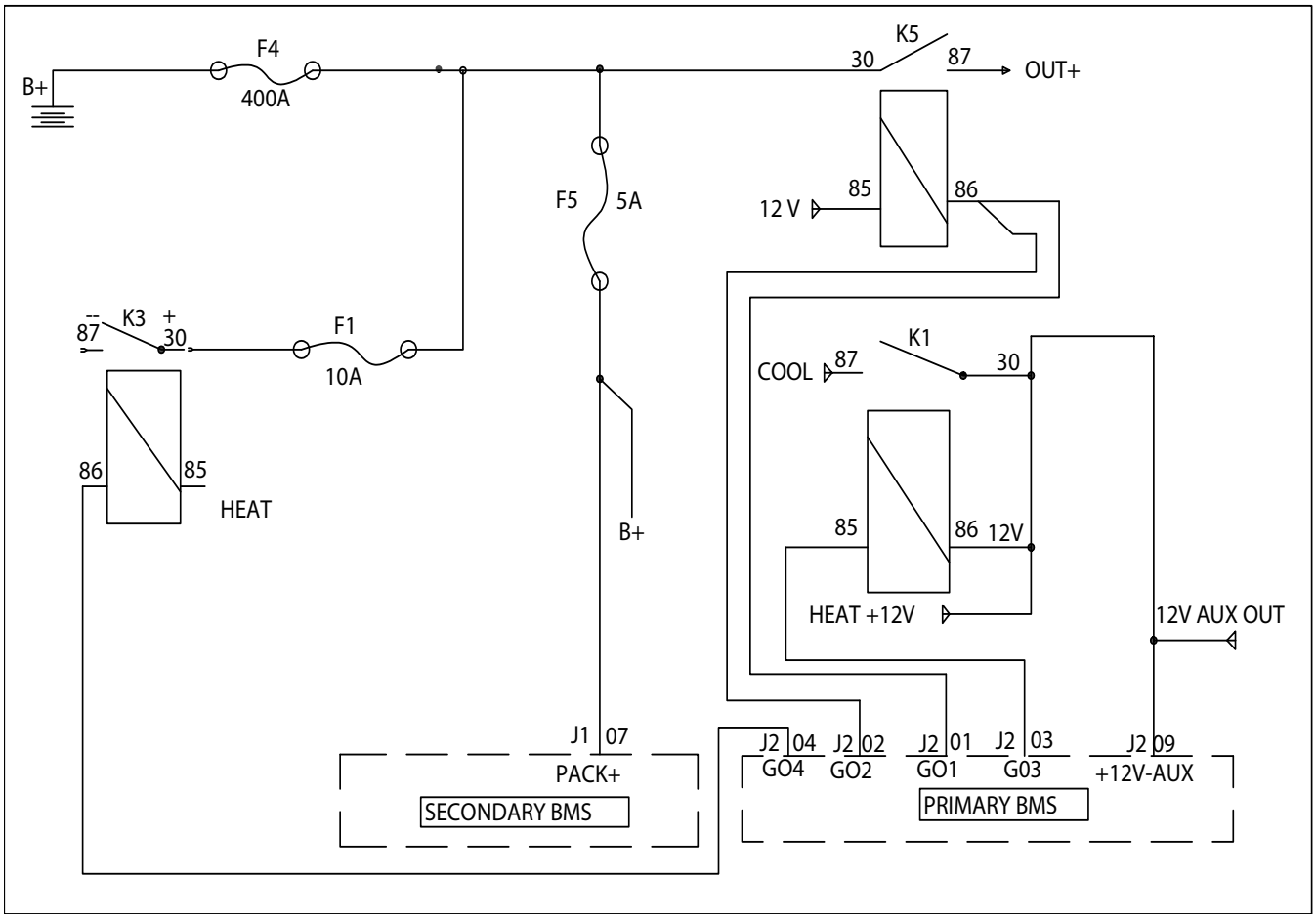
°°F	°°C	Ohms
Temperature vs Resistance Values (Approximate)		
-35	-37.22	279880
-31	-35.00	242427
-25	-31.67	196227
-19	-28.33	159488
-15	-26.11	139316
-9	-22.78	114165
-5	-20.56	100218
1	-17.22	82670
5	-15.00	72911
11	-11.67	60592
15	-9.44	53647
21	-6.11	44874
25	-3.89	39921
31	-0.56	33599
35	1.67	29996
41	5.00	25395
45	7.22	22770
51	10.56	19376
55	12.78	17437
61	16.11	14925
65	18.33	13478
71	21.67	11590
75	23.89	10501
81	27.22	9078
85	29.44	8251
91	32.78	7163
95	35.00	6530
101	38.33	5697
105	40.56	5207
111	43.89	4561
115	46.11	4182
121	49.44	3679
125	51.67	3380
131	55.00	2985
135	57.22	2751
141	60.56	2438

Not Charging in Cold Temperature

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	Key ON, Check BMS measured battery temperature. Greater than -5C / 23 F?	> -5C / 23 F	Go to step 3	Go to step 5
3	“NO Charging” issue is not cold temperature related		System OK	Go to step 4
4	See Check Harness connections to cells diagnostic chart: Section 4-2	_	Go to step 5	_
5	Warm battery to above -5C / 23 F	> -5C / 23 F	Temp OK	Go to step 6
6	Verify temperature sensors are connected to harness	loose or open circuit	Go to step 7	Go to step 8
7	Re-connect or repair harness connections	-	System OK	Go to step 8
8	With key still on- verify 5V signal at BMS pins J1-17 and J1-22 on Primary BMS and J1-17 and J1-18 on secondary BMS	5V	Go to step 9	Go to step 10
9	System functional, Test is complete	_	System OK	_
10	Verify Key ON- BMS functional.			

Charge Range Specification Table

Maximum continuous discharge current	320 A
Maximum peak current	<20 sec @ 720 A
Maximum charge current	320A
Fused Main Circuit Protection	400A



Auxiliary Heater or Cooler Circuit Diagnosis

Circuit Description

The BMS is able to control auxiliary battery pack heating and cooling systems through the use of a simple relay. The relays are controlled by the BMS based on temperatures that the BMS can read from the Battery Temperature Sensor (BTS) inputs.

The BMS will not allow either relay to function if the battery pack voltage is under a specified value.

Either relay could be non-operative because of the following symptoms:

- The BMS is not programmed to operate the device
- The BMS pack voltage is below the specified threshold
- The operating wire lead is not connected or is broken or open
- The relay is faulty
- The threshold temp has not been met

Diagnostic Aids

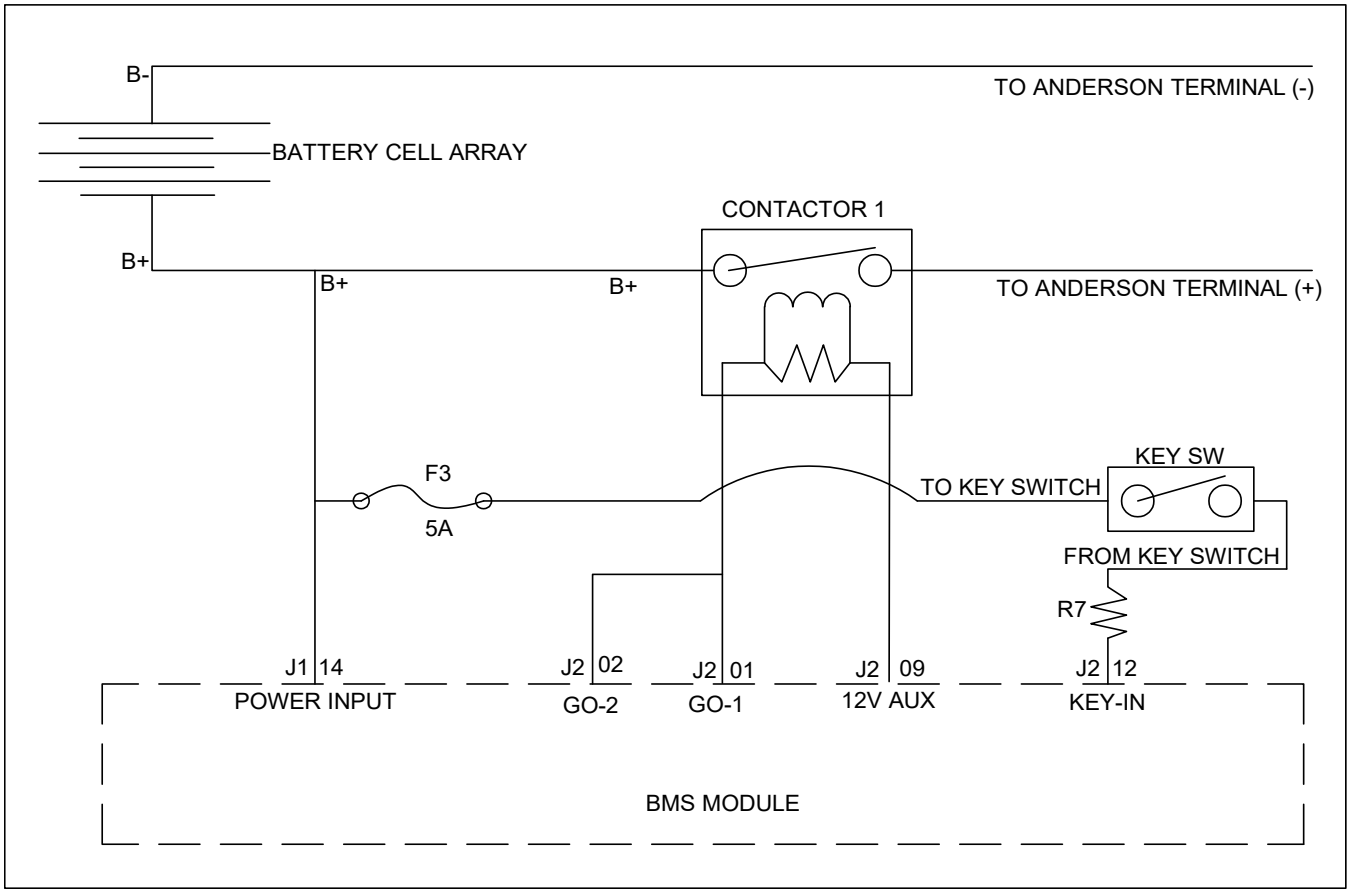
This typical relay has 4 terminals that are used. The switching side of the relay will typically have 12V applied to terminal 85. Terminal 86 will be switched by the BMS by applying a low side signal or a ground. Terminal 30 will be connected with supply voltage and terminal 87 will supply voltage to the heater or cooling fan.

Consider the following as you perform your diagnosis:

- Teminals 30 and 85 must be supplied voltage when Key “ON”
- The BMS control strategy is to apply ground to terminal 86 to act as the activating “switch”

Auxiliary Heater or Cooler Circuit Diagnosis

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	Key ON, Verify system (pack) voltage at relay terminal 30	>73 volts	Go to step 4	Go to step 3
3	Charge battery & re-test	>73 volts	Go to step 4	Continue charging
4	Is the contactor operational? Check voltage at contactor secondary stud output terminal to insure pack is on. NOTE: Output terminal is the one with the lead that goes to the output (Anderson) connector	>73 volts	Go To step 5	Perform “No voltage at contactor” diagnostic
5	KEY ON Verify 12V input at relay terminal 85	> 11 volts	Go to step 6	Verify ~12 V at corresponding BMS terminal- check for lead open circuit
6	When heater or cooling are called for as related to temperature, verify ground input from BMS on relay terminal 86	ground is applied	Go to step 7	Go to step 8
7	If ground from BMS is applied to 86, do you see voltage on relay pin 87?	> 73 volts	go to step 10	Replace faulty relay
8	Check for open circuit on BMS to terminal J2-04- heater or J2-03 cooling (primary BMS)	< 1 volt	Repair open	Go to step 9
9	Verify temperature sensors are connected to harness and that BMS is displaying a temperature that would call for heat or cooling	loose or open circuit	Go to step 10	Repair BTS sensors or leads
10	Verify functionality of heating or cooling physical device	-	System OK	_



System Relay (Contactor) Diagnosis

Circuit Description
The system relay (Contactor) is the main connective device for the battery pack. The BMS controls the system relay when the key switch is cycled to the “ON” position.

Important NOTE:
There are a number of threshold voltage and temperature conditions that will cause the BMS to “shut down the battery pack” .Refer to the Alert/Shut down Chart to insure that a non-operating contactor is not a result of a shut-down action.

Diagnostic Aids
The following may cause an intermittent:

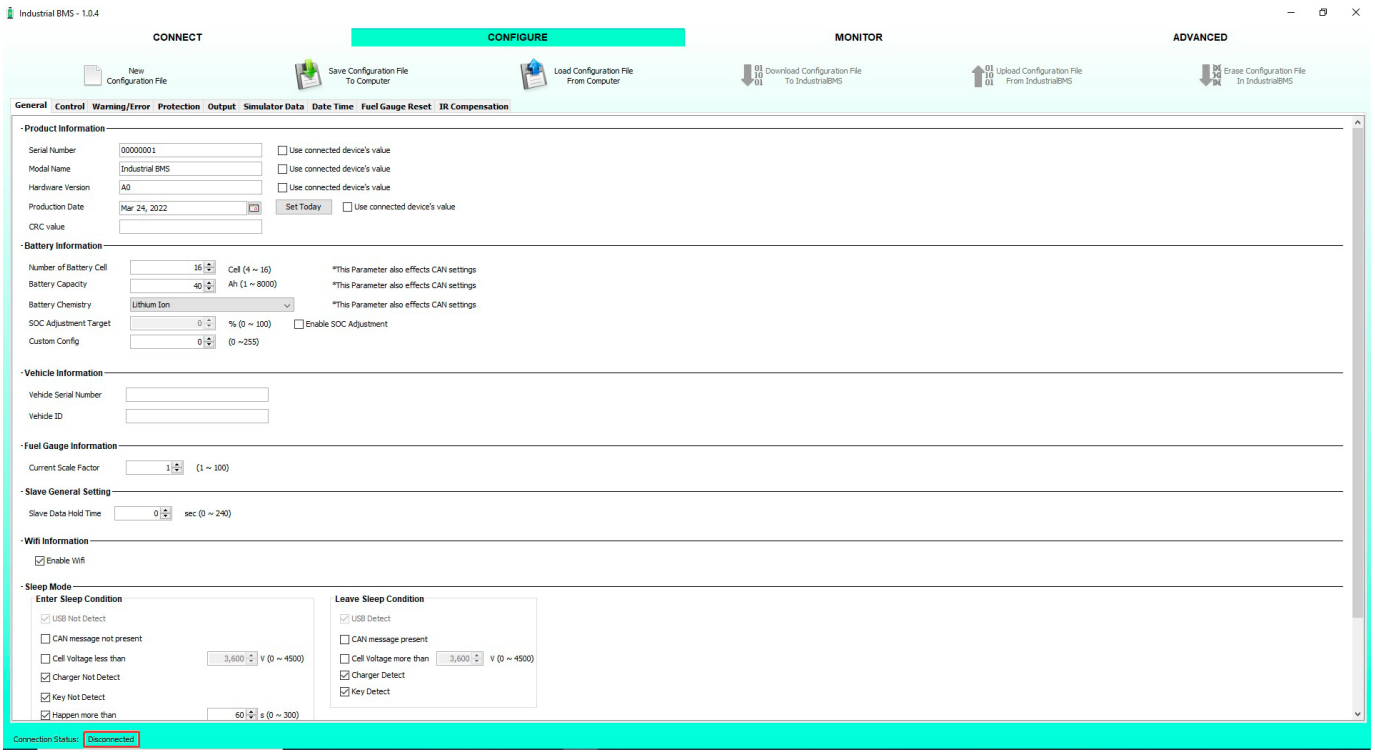
- Poor connections- check for adequate terminal tension/torque.
- Corrosion
- Mis-routed harness
- Rubbed through wire insulation
- Broken wire inside insulation

System Relay (Contactor) Diagnosis

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	Key ON and check voltage between the primary (smaller) gage leads.	>11 volts	Go to step 4	Go to step 3
3	Check fuse in Contactor circuit	has continu-ity-	Go to step 4	replace fuse
4	Check for pack voltage at both secondary leads to system ground	pack volt-age- typically > 73V	Contactor OK	go to step 5
5	Replace Contactor	_	System OK	_

Alert/Shut Down Chart

Cause	ACTION Alert or Shutdown	Instigate Action	Remove Action
Charge over-temp	Alert	57 C / 134.6 F	55 C / 131 F
Charge under-temp	Alert	-7C / 19.4 F	-5C / 23 F
Discharge over-temp	Alert	57C /134.6 F	55C
Discharge under-temp	Alert	-22 C / -7.6 F	-20 C / -4 F
Pack over-voltage	Alert	94.9 V	89.7 V
Pack under-voltage	Alert	72.8 V	75.4 V
Cell over-voltage	Alert	3650 mV	3450mV
Cell under-voltage	Alert	2800 mV	2900 mV
Pack over-temp	Shutdown	65 C / 149 F	
Cell under-voltage	Shutdown	2550 mV	
Cell over-voltage	Shutdown	3700 Mv	



Group DTCs Directly Related to the BMS (Device)
DTCs: 1, 2, 3, 4, 13, 14 & 15

BMS DTCs Overview

Diagnostic Trouble Codes (DTCs) are formulated to assist the service technician in diagnosing problems related to the battery pack. There are a number of DTCs associated with the battery packs that relate directly to the BMS. The service technician must verify some basic operational characteristics of the BMS- basically that the BMS has power and ground and communication. If these conditions are met, an acceptable service procedure might be to replace the BMS.

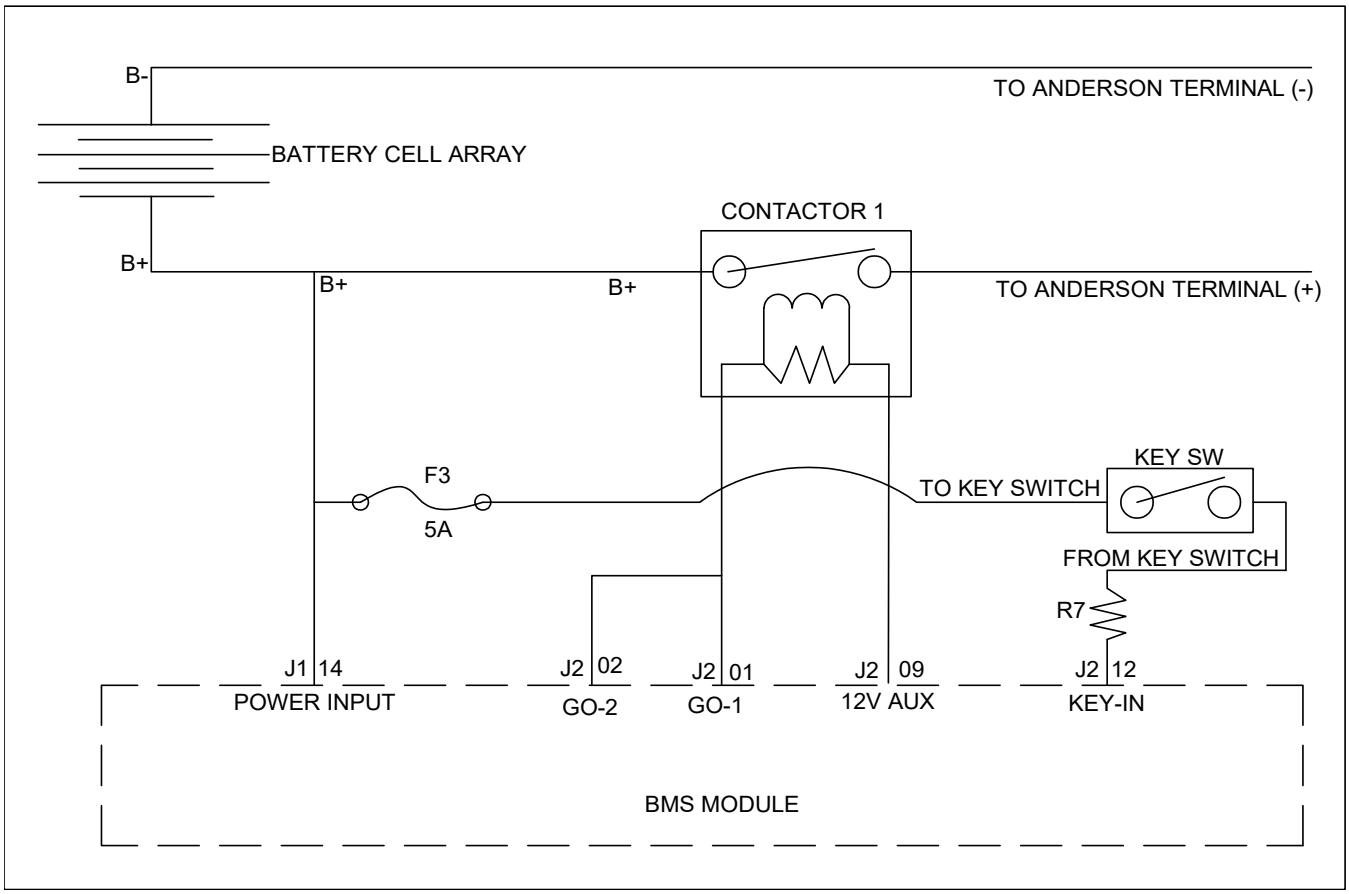
Diagnostic Aids

Check for the following conditions:

- Poor connections at the BMS. Inspect harness connectors for backed out terminals, improper mating, broken locks, improperly formed or damaged terminals, and poor terminal to wire connections.
- Damaged harness. Perform a careful visual inspection of the harness. If it appears to be OK, observe the display on your BMS tool while moving wires that connect to the BMS. A change in the display may indicate a lead that may be loose or damaged and may indicate the location of the fault.
- Look for discoloration. Discoloration in the wire insulation. This often suggests that the lead may have been hot and internal sections of the lead may be damaged.
- Loose connections. It is important to note that loose connections associated with the main feed of the battery pack can cause voltage surges that may damage the BMS. Additionally loose connections, especially loose grounds, can cause erratic readings on items within the pack.
- Grounds. Ground circuits are essential to the BMS and all components associated with battery pack operation. Verify grounds to insure proper connections and continuity.

BMS Device related System Faults DTC's 1, 2, 3, 4, 13, 14, 15

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	–	Go to step 2	Go to OBD system check
2	During OBD system check cick on "control details" Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered "safety disconnect"	Parameter	-	-
4	Key ON, Do you have rated output voltage on the output connector?	> 73 Volts	System Functional	Go to step 5
5	BMS is operational, some internal fault may exist	fault	Go to step 6	Go to step 7
6	Verify that correct and up to date calibration program is loaded in BMS		System OK	Load updated program and proceed to step 7
7	Re-test BMS with BMS tool. Is fault corrected?	–	System OK	Go to step 8
8	Replace BMS and insure correct software load version.	–	System Restored- NO faults	–



DTC 5 Battery Overvoltage Error

Circuit Description

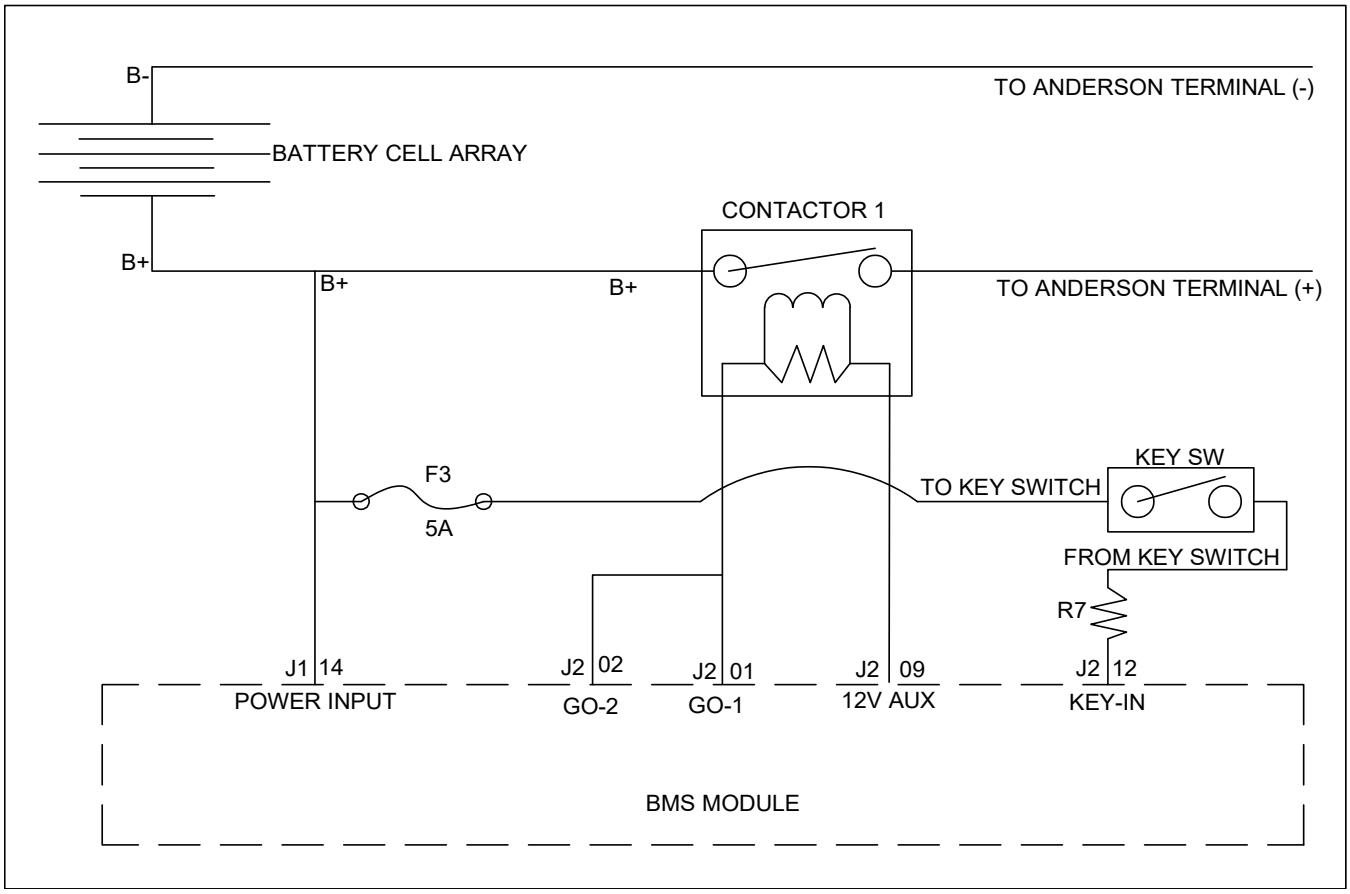
The BMS constantly monitors voltages of both the individual cells and of the entire pack. If any of the cells become over charged or if all of the cells become overcharged. The BMS will log an Overvoltage Error. This error could be caused by an imbalance that resulted in a single cell becoming overcharged or it could be the result of a BMS control issue or a charger issue that caused the entire pack to become overcharged.

Diagnostic Aids

- Always check for correct torque on main connection lugs and cables.
- Use the BMS tool to verify individual cell voltages. If one is out of range- verify voltage with your DVOM
- Verify that CAN lines associated with the charge port connector are properly connected and fully functional.
- Check voltages at the main connector lugs during the charging event to verify charger is regulating to an acceptable voltage.

DTC 5 Battery Over voltage Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	–	Go to step 2	Go to OBD system check
2	During OBD system check, click on “control details”Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read the voltage for the entire pack at the output connector.	> 94.9 volts	Go to step 3	System OK
5	Discharge battery pack to acceptable voltage	<94.9volts	System OK-Check Charger Step	Go to step 4
6	Continue discharge	< 94.9 volts	System OK	Continue discharge
7	Check battery charger settings and output	~90 volts	Charger OK	Go to Step 6
8	Discharge battery pack to acceptable voltage	< 94.9 volts	System OK	Go to step 5
9	Continue discharge	< 94.9 volts	System OK	Go to step 6
10	Repair charger input specifications or charger assembly	~ 3.3 V	System OK	Replace charger



DTC 6 Battery Under voltage Error

Circuit

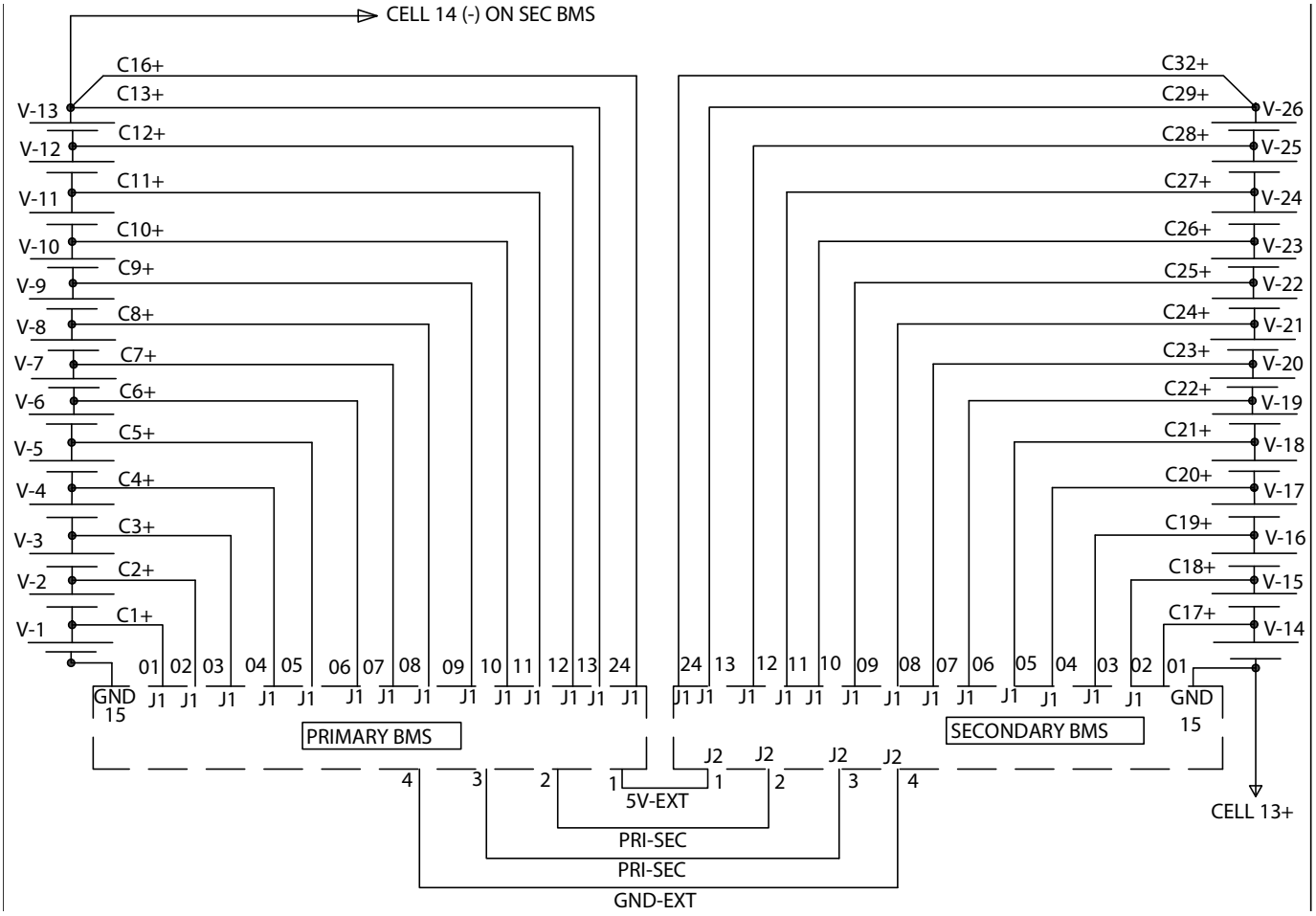
The BMS constantly monitors voltages of both the individual cells and the entire battery pack. If the entire battery pack becomes under charged the BMS will log an Undercharge Error. This error could be caused by an imbalance that resulted in a single cell becoming undercharged or the entire pack becomes undercharged or it could be the result of a BMS control issue or a charger issue that caused the entire pack to become undercharged.

Diagnostic Aids

- Check for loose or severed wires in the pack that might prevent the charging event.
- Check their main battery charging connector for opens.
- Perform a visual inspection of the charger connector plug.
- Insure that the BMS to charger leads (typically 4) are connected and properly routed
- Verigy that there is voltage at the connector when the charging is selected at the charger.

DTC 6 Battery Under voltage Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	During OBD systemk check, click on “control details” is safety disconnect ON?	ON	Go to step 3	Go to Step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read cell voltages for the entire pack assembly on your BMS tool.	< 72.8	Battery is under-charged Charge battery	Attempt to charge battery
5	Connect to charger and charge battery	> 72.8	Continue charging	Go to step 6
6	Verify charger output at charger connectiion	~ 87 volts	Charger output is OK	Go to step 7
7	Continue charging	>72.8 volts	System OK	Go to step 8
8	Replace battery cell pack		System OK	-



DTC 7- Cell overvoltage Error

Circuit Description

Each cell or cell group in the battery pack is equipped with a wire lead that allows the BMS to monitor the voltage on the associated cell or cell group. If the cell voltage for any one cell or cell group is above the threshold specification, the BMS will log a “Cell Overvoltage Error”.

Some items to consider if this error is logged:

- Cell is damaged or degraded
- Sensing lead is loose or damaged
- Cell buss bar is loose
- BMS is reading erroneously
- Charger or charge regulation error has occurred

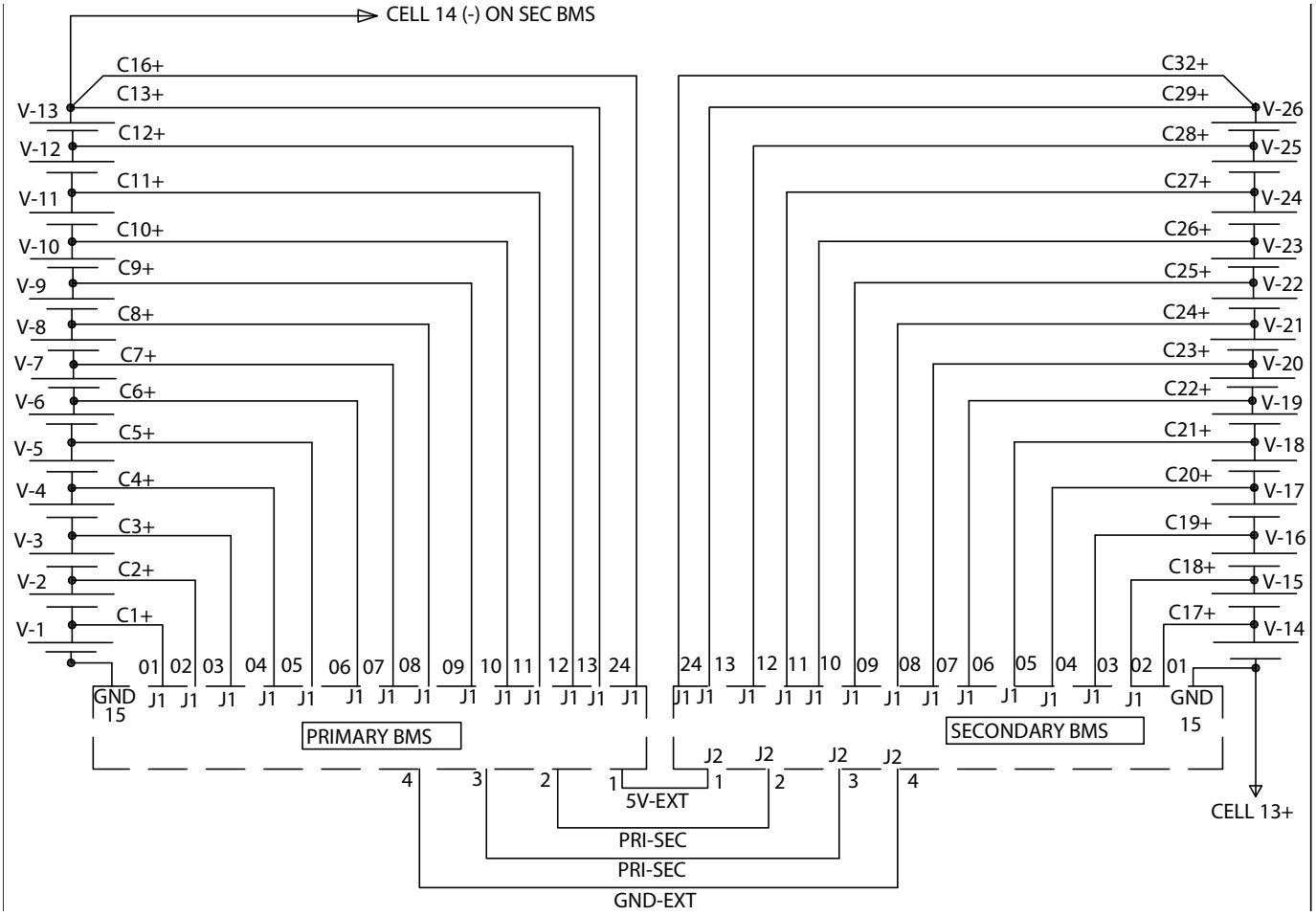
Diagnostic Aids

Wiring issues are a common cause of erroneous readings and pack problems. One of the first items to consider as one works through a diagnostic procedure is a visual inspection and physical tightness check of cell leads and bus bars as well as pack main cable leads. Loose connections can cause excessive amperage and intermittent voltage issues.

- If a cell sensing wire is open, the BMS tool will display BOTH a Cell Overvoltage and a Cell Undervoltage error.

DTC 7- Cell Overvoltage Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	During OBD system check, click on “control details” S SAFETY DISCONNECT ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read cell voltages for all of the cells in the pack on your BMS tool.	> 3.3 volts	Go to step 5	Note erroneous cells. Go to step 3
5	Locate cells that display over voltage	> 3.6 volts	Go to step 6	System OK
6	Discharge cell to threshold voltage	<3.4 volts	System OK	Go to step 7
7	Continue discharge	<3.4 volts	System OK	Go to step 8
8	Replace battery cell pack	~ 3.3 V	System OK	-



DTC 8- Cell Undervoltage Error

Circuit Description

Each cell or cell group in the battery pack is equipped with a wire lead that allows the BMS to monitor the voltage on the associated cell or cell group. If the cell voltage for any one cell or cell group is below the threshold specification, the BMS will log a “Cell Undervoltage Error”.
Some items to consider if this error is logged:

- Cell is damaged or degraded
- Sensing lead is loose or damaged
- Cell buss bar is loose
- BMS is reading erroneously

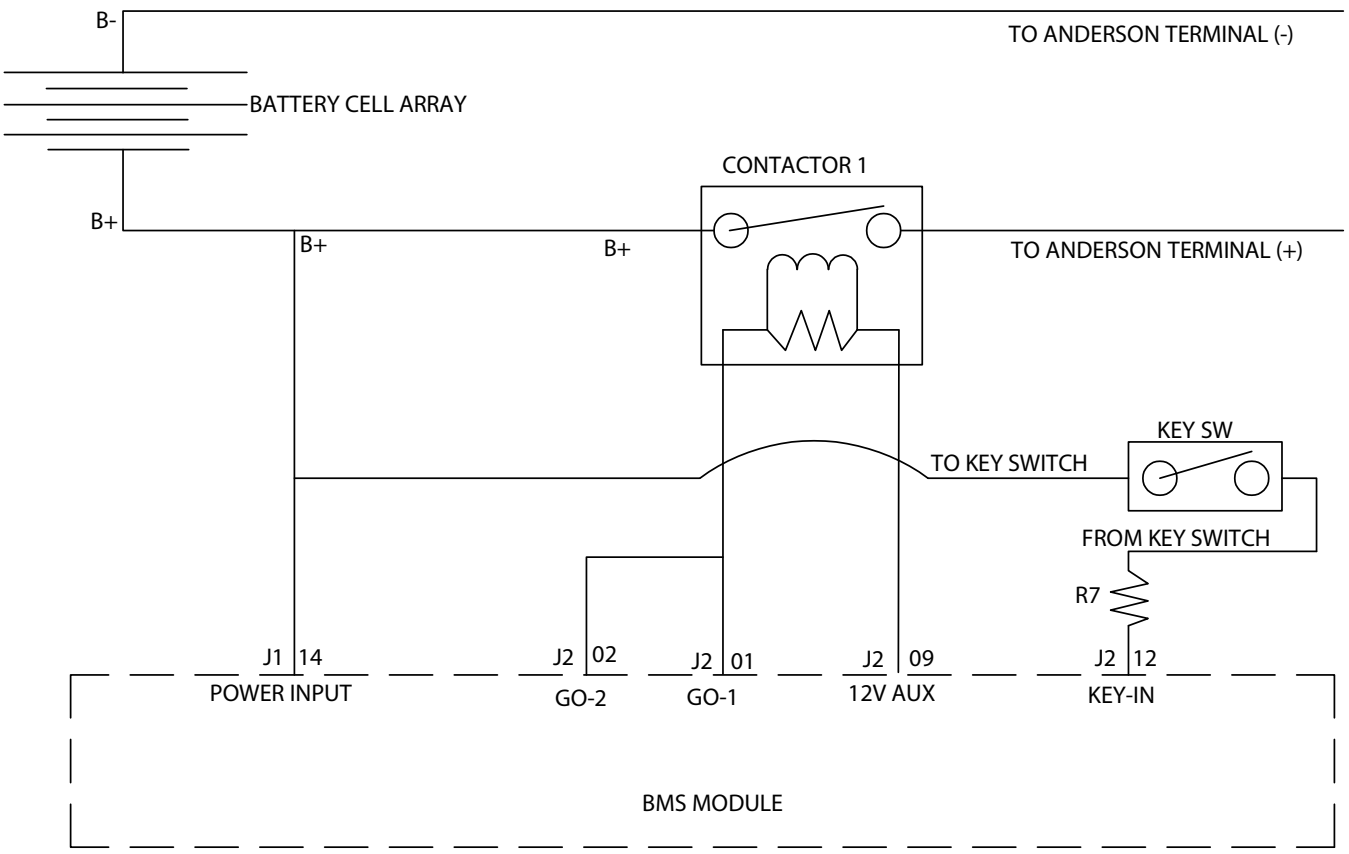
Diagnostic Aids

Wiring issues are a common cause of erroneous readings and pack problems. One of the first items to consider as one works through a diagnostic procedure is a visual inspection and physical tightness check of cell leads and bus bars as well as pack main cable leads. Loose connections can cause excessive amperage and intermittent voltage issues.
If you experience a cell undervoltage error and the cell will not charge to an acceptable voltage, the cell should be replaced. If the battery had significant age, it is possible that more cells may need replacement.

- NOTE: If a cell sensing line is open, the BMS will display BOTH a Cell Overvoltage and a Cell Undervoltage error.

DTC 8- Cell Undervoltage Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	–	Go to step 2	Go to OBD system check
2	During OBD system check, click on “control details” Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read cell voltages for all of the cells in the pack on your BMS tool.	< 2.9 volts	Go to step 5	Note erroneous cells
5	Locate cells that display under voltage	< 2.9 volts	Go to step 6	System OK
6	Slow-charge cell to specified voltage	<3.2 volts	System OK	Go to step 7
7	Continue slow charge	<3.2 volts	System OK	Go to step 8
8	Replace battery cell pack	~ 3.3 V	System OK	-



DTC 9- Charge Overcurrent Error

Circuit Description

The battery pack has a connection across the shunt to measure battery charge current. If the battery overcurrent error is logged, the BMS is aware that the battery is being charged too quickly or to a voltage greater than the acceptable threshold.

Diagnostic Aids

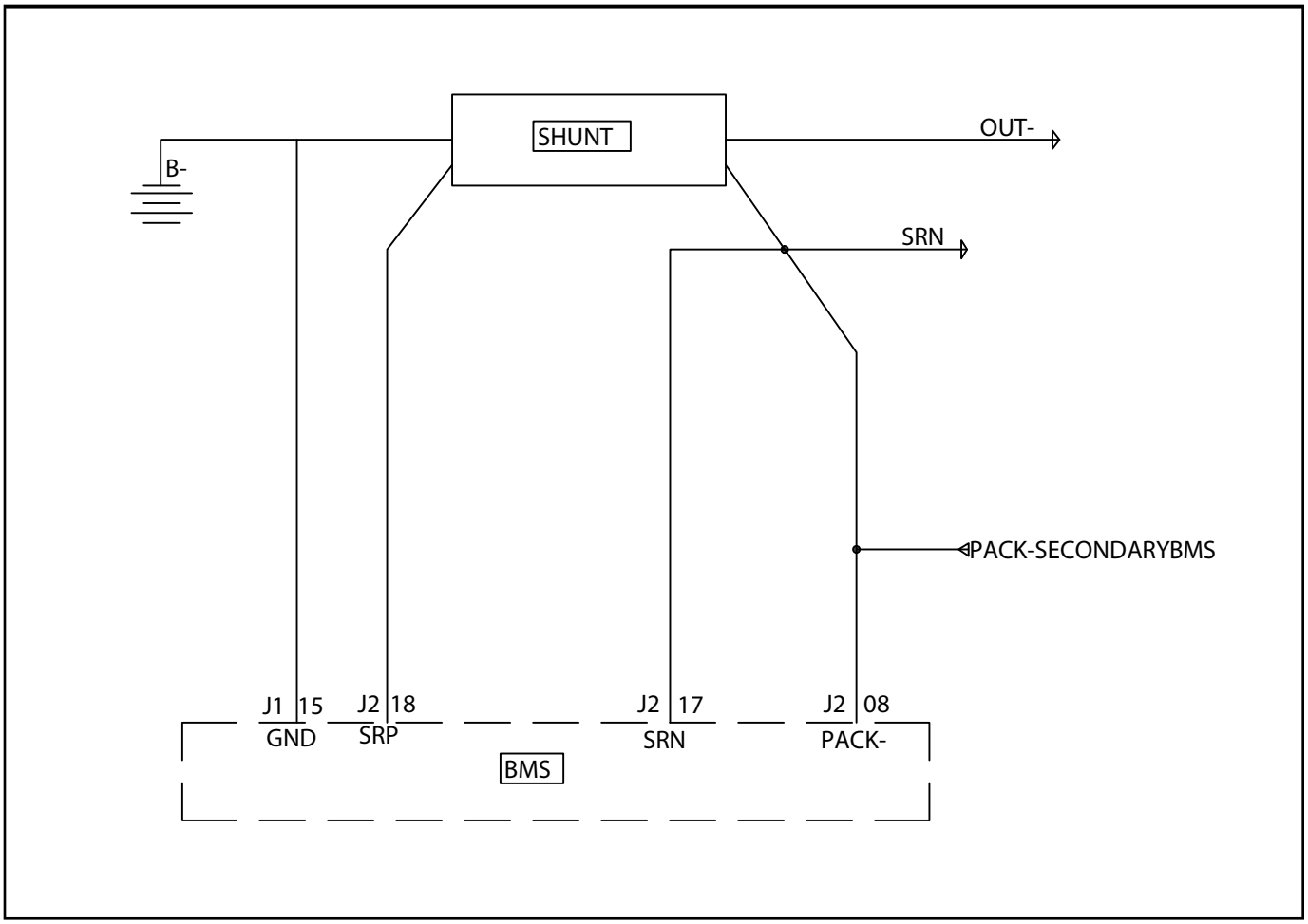
Although it is possible that wiring leads or main cable connections can contribute to this problem, do not overlook possible problems associated with either the vehicle or with the charging device.

Overcharge conditions could be caused by several problems but most of the issues are likely wiring related.

- Loose wiring leads on the main input or output cables
- Faulty battery charger connection
- Loose sensing leads at the shunt connection
- Faulty shunt
- Open or damaged leads on the charge connection CAN circuit
- Faulty connections or leads on the “charge detect” line going to the BMS

DTC 9- Charge Overcurrent Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	–	Go to step 2	Go to OBD system check
2	Durng OBD system ckeck, click on “control details” Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	VALUE	-	-
4	Key ON, determine that you can read cell voltages for all of the cells in the pack on your BMS tool.	< 2.9 volts	Go to step 5	Note erroneous cells
5	Locate cells that display under voltage	< 2.9 volts	Go to step 6	Voltage is acceptable
6	Slow-charge cell to specified voltage	<3.2 volts	System OK	Go to step 7
7	Continue slow charge	<3.2 volts	System OK	Go to step 8
8	Replace battery cell pack	~ 3.3 V	System OK	-



DTC 10- Discharge Overtemperature Error

Circuit Description

The battery pack has a connection across the shunt to measure battery discharge overcurrent. If the battery discharge overcurrent error is logged, the BMS is aware that the battery is being discharged too quickly or to a voltage greater than the acceptable threshold. Overcurrent discharge can cause the battery to experience elevated temperatures which is detremental to the cells in the pack.

Diagnostic Aids

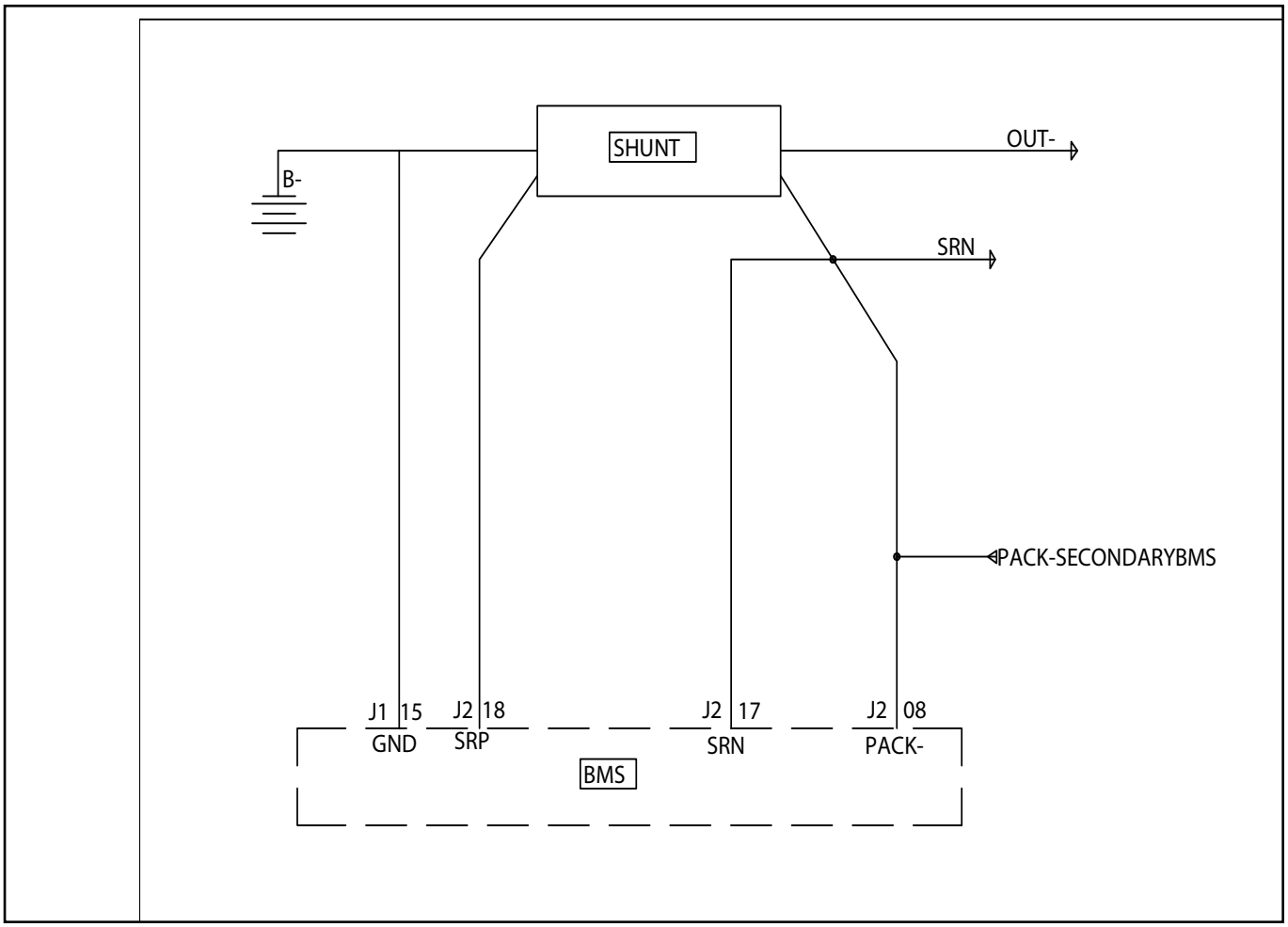
Although it is possible that wiring leads or main cable connections can contribute to this problem, do not overlook possible problems associated with the vehicle.

- Poor connections to the motor
- Dragging motor or worn motor end bearings
- Excessive drag due to hydraulic issues
- Stuck or frozen braking components
- Applied parking brake

Additional pack related issues might include:

- Loose connections at the main cable lugs
- Improper or loose connections at the shunt
- BMS related error

DTC 10- Discharge Overtemperature Error



DTC 11- Charge Overcurrent Error

Circuit Description

During the charge event, energy is being applied to the cell packs. Due to the nature of the chemistry associated with charging, there is a level of heat built up in the cells. If the charging event is proceeding too fast or if there are loose wiring connections, the heat build up can become excessive. In an effort to protect the cells from an overheated condition, the BMS will either taper or shut down the charge rate.

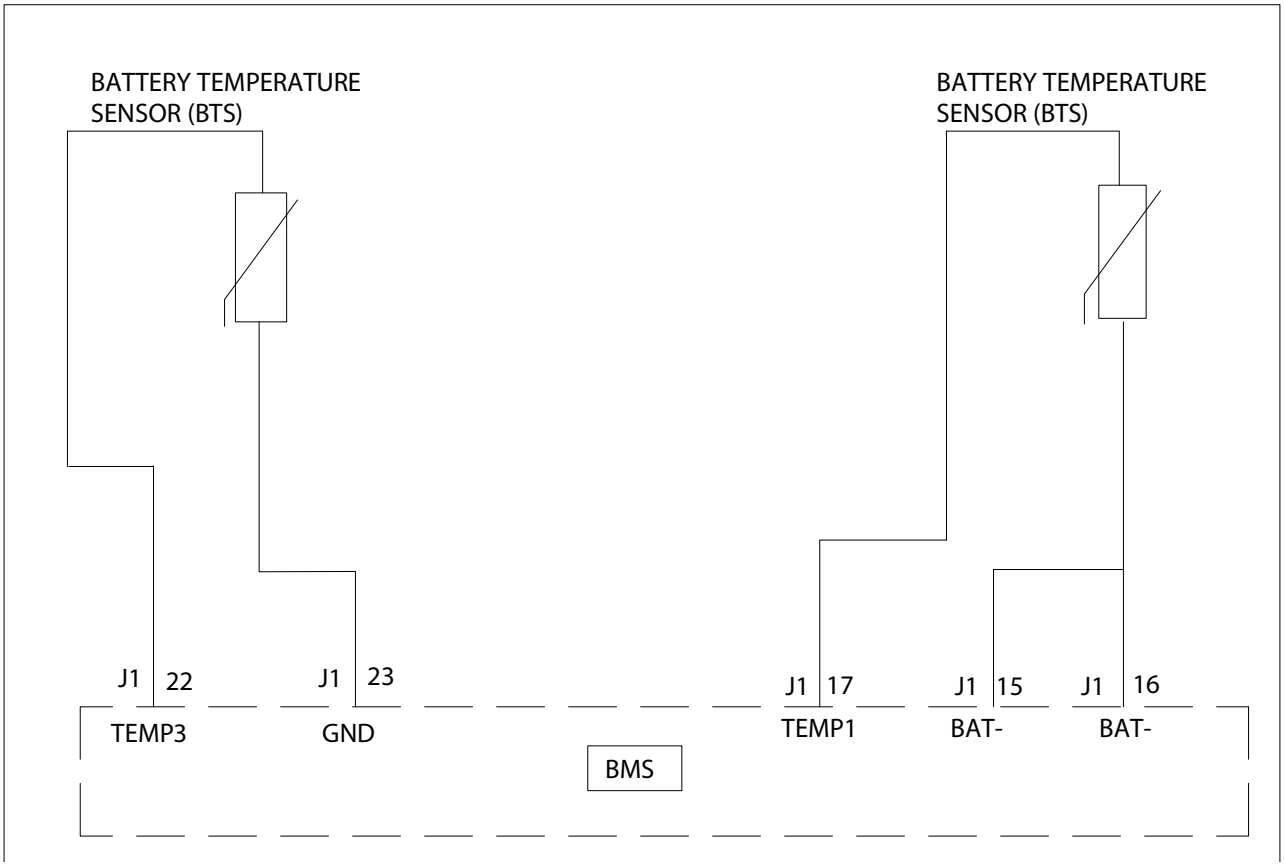
Diagnostic Aids

Although it is possible that wiring leads or main cable connections can contribute to this problem, cell pack over use issues can contribute as well.

- Check for loose connections. Tighten connections to their recommended torque
- Check for visual damage to cells
- Check for case warpage
- Check for discolored terminals
- Check for discolored wire sheathing.
- Check for warped or melted connections- indicating loose connections
- Once the battery temperature reaches its threshold temperature, thee is a 10 second delay before the overtemp warning/error is set

DTC 11- Charge Overtemp Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	–	Go to step 2	Go to OBD system check
2	During OBD system check, click on “control details” Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that the BMS is reading an overcurrent error	>320 Amps	Go to step 5	Check for intermittent loose connections
5	Tighten all main-lug cable connections	<320 Amps	Go to step 6	Amperage draw is acceptable
6	Check vehicle related items- Brake drag or faulty motor issues	<320 Amps	Repair vehicle issues	System OK



DTC 12- Discharge Overtemp Error

Circuit Description

The cell pack is equipped with two or more Battery Temperature Sensors (BTSs) that monitor temperature in the cell pack.

If the cells are discharged too rapidly, the temperature will elevate. If the temperature elevation exceeds the safe threshold, the BMS will shut down the battery pack.

The BMS institutes a 20 second delay after the temperature threshold is reached before the pack is shut diown.

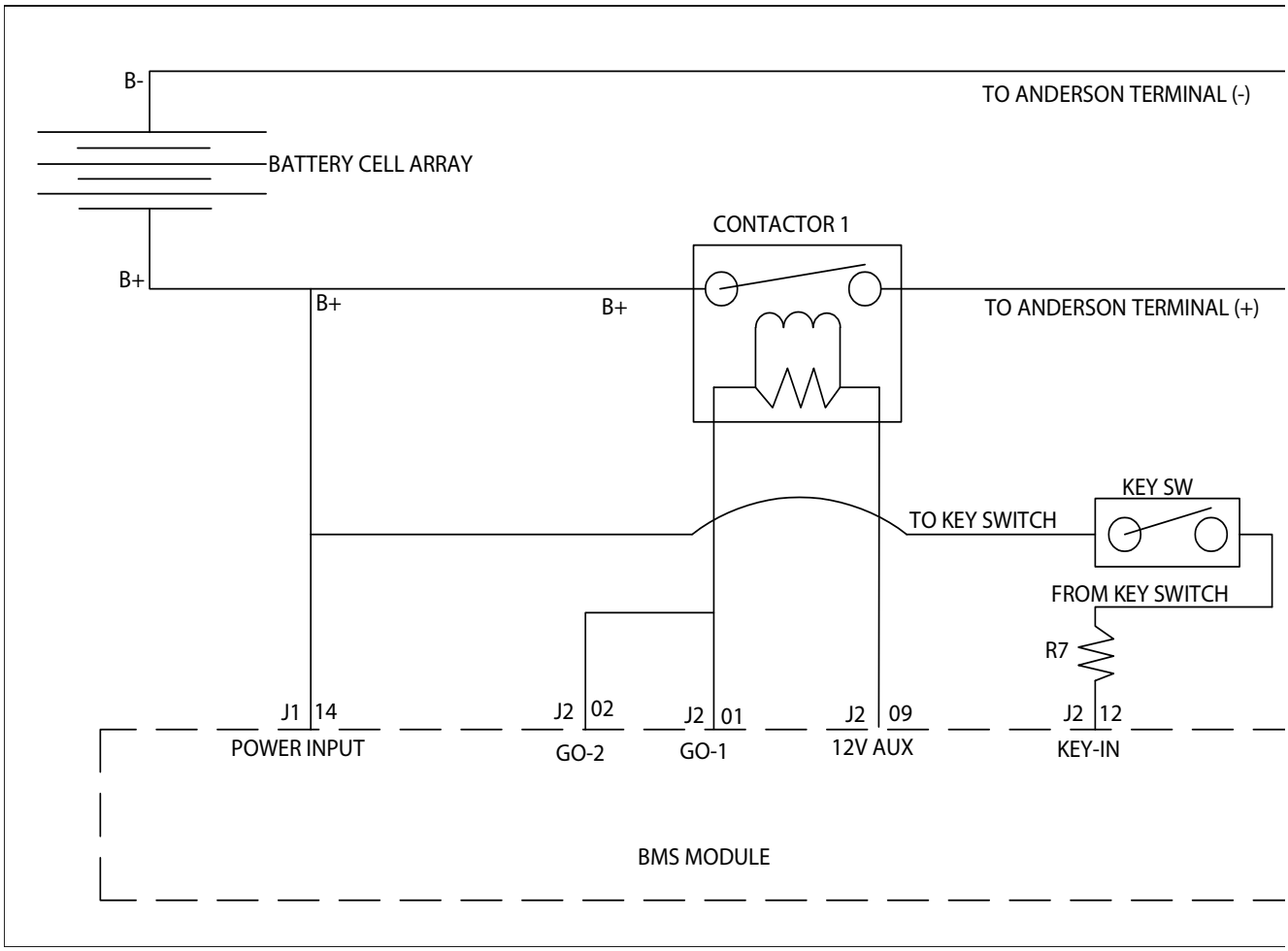
Diagnostic Aids

Wiring issues are a common cause of erroneous readings and pack problems. One of the first items to consider as one works through a diagnostic procedure is a visual inspection and physical tightness check of cell leads and bus bars as well as pack main cable leads. Loose connections can cause excessive amperage and intermittent voltage issues as well as overheating issues.

- Check BTS leads for pinched or severed leads
- You may want to check the actual temperature with an Infrared Temperature test gun to verify that the cell temperature is actually too high
- check all connections for proper torque tightness
- Look for discolored wires as an indication of overheating.

DTC 12- Discharge Overtemp Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	During OBD System check, click on “control details” Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read the BTS temperature and that it is over the specified temperature	> 57C/134F	Go to step 5	Test with infrared test gun
5	Check continuity of BTS to BMS terminal	< 1 ohm	Continuity OK	Go to step 6
6	Determine cause of high resistance- wire lead open	< 1 ohm	Repair/replace lead	Test BTS Go to step 7
7	Test BCS for approx temp using Ohm-Temp chart in section 2	Ohm reading commensurate with ambient temp.	System OK	Go to step 8
8	Replace battery cell pack	~ 3.3 V	System OK	-
9				



DTC 16 Charge under-temp error

Circuit Description

The BMS constantly monitors temperatures of the pack between selected cells with BTS (Battewry Temperature Sensors) . If the temperature of the cells being measured become two cold during a charging event, the BMS will shut down the charging event. At this point, the battery will need to be warmed to a pre-set temperature.

Diagnostic Aids

- Always check for correct torque on main connection lugs and cables.
- Use the BMS tool to verify individual cell voltages. If one is out of range- verigy voltage with your DVOM
- Verify that CAN lines associated with the charge port connector are properly connected and fully functional.
- Check voltages at the main connector lugs during the charging event to verify charger is regulating to an acceptable voltage.

DTC 16 Charge Under-temp Error

Step	Action	Value	Yes	No
1	Did you perform On board diagnostic OBD system check?	_	Go to step 2	Go to OBD system check
2	During OBD system check, click on “control details” Is safety disconnect ON?	ON	Go to step 3	Go to step 4
3	Determine parameter that triggered “safety disconnect”	Value	-	-
4	Key ON, determine that you can read the BTS temperature and that it is over the specified temperature	> 57C/134F	Go to step 5	Test with infrared test gun
5	Check continuity of BTS to BMS terminal	< 1 ohm	Continuity OK	Go to step 6
6	Determine cause of high resistance- wire lead open	< 1 ohm	Repair/replace lead	Test BTS Go to step 7
7	Test BCS for approx temp using Ohm-Temp chart in section 2	Ohm reading commensurate with ambient temp.	System OK	Replace BTS