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Supplement Manual

Models
X390AJ-X14J
X550AJ-X19J
X700AJ-X23J
X370AJ-X13JP
X430AJ-X15JP
X500AJ-X17JP
X600AJ-X20JP
X770AJ-X26JP
X1000AJ-X33JP

***See inside cover for serial break information**

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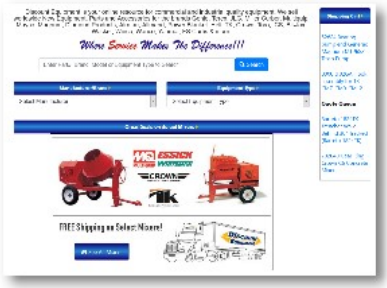

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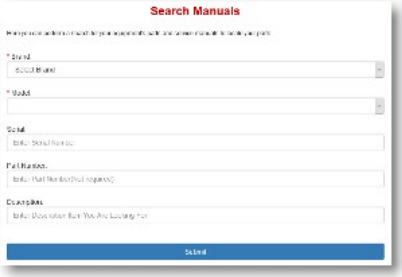

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Models	48V Gen1	48V Gen 2	72V Gen1	72V Gen 2
X390AJ-X14J	Prior to SN C170000323	SN 170000350 to Present		
X550AJ-X19J	Prior to SN C170000319	SN C170000332 to Present		
X700AJ-X23J			Prior to SN C170000340	SN C170000352 to Present
X370AJ-X13JP				
X430AJ-X15JP				
X500AJ-X17JP		All		
X600AJ-X20JP				All
X770AJ-X26JP				
X1000AJ-X33JP				

Models	83V Gen 2	38V Gen 3	76V/100Ah Gen 3	76V/150Ah Gen 3
X390AJ-X14J				
X550AJ-X19J				
X700AJ-X23J				
X370AJ-X13JP		All		
X430AJ-X15JP		All		
X500AJ-X17JP				
X600AJ-X20JP				
X770AJ-X26JP	Prior to SN C170001340		SN C170001340 to Present	
X1000AJ-X33JP				All

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SECTION A. INTRODUCTION - MAINTENANCE SAFETY PRECAUTIONS

GENERAL

These instructions include the technical information of the Lithium ION system, which is one of the power system configurations on JLG Compact Crawler Booms (CCB).

NOTICE

READ THESE INSTRUCTIONS AND OPERATION MAINTENANCE OF THE MACHINE CAREFULLY.

- IN CASE OF CELL FAILURE, DO NOT OPEN THE BATTERY COMPARTMENT.
- IF THE BATTERY COMPARTMENT TEMPERATURE IS HIGH, OPEN THE BATTERY COMPARTMENT CAREFULLY TO COOL THE CELLS. WAIT UNTIL THE COMPARTMENT IS COOLED DOWN TO AMBIENT TEMPERATURE.
- DO NOT OPEN THE BATTERY COMPARTMENT IF THE TEMPERATURE IN THE COMPARTMENT IS TOO HIGH. THERE IS A RISK OF EXPLOSION OR EXPOSURE TO HAZARDOUS SUBSTANCES.
- WEAR APPROPRIATE PROTECTIVE EQUIPMENT ON HANDS, FEET, EYES AND BODY WHILE WORKING ON BATTERIES MAINTENANCE AND BATTERY COMPARTMENT.

NOTICE

USE CLASS D FIRE EXTINGUISHER IN CASE OF FIRE HAZARD.

The CCB using Gasoline, Diesel or Lithium ION batteries have the same structure, functionality and the same hydraulic, electrical and electronic systems.

The CCB with dual power configuration, Gasoline/Diesel and electrical motor, are coupled with two tandem pumps, while those with the Lithium ION, have only one tandem pump, driven by an electrical motor which receives power through the Lithium ION battery pack.

The Lithium ION Battery pack integrates a system to control the RPM of the electrical motor, to supply sufficient amount of oil flow to the hydraulic system, to recharge the batteries, and to keep all components functional.

The Lithium ION Battery pack system is controlled by a device called Battery Management System (BMS). All component or functions are activated by the BMS. At the start of the machine, the 12 volts Lead-acid Battery switch ON the BMS through the ECM1-2. If there is no fault, the BMS gets supply from Lithium ION Battery pack.

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SECTION 1. SPECIFICATIONS

1.1 CAPACITIES

Table 1-1. Lithium Systems

Model	Battery Pack	Machine Arrangement
X390AJ-X14J	48V - 15 Cells	Refer inside cover for serial break information
X500AJ-X17JP		
X550AJ-X19J		
X700AJ-X23J	72V - 22 Cells	
X600AJ-X20JP	72V - 22 Cells	
X770AJ-X26JP	83V - 26 Cells	
X770AJ-X26JP	76V - 24 Cells Pair	
X370AJ-X13JP	38 V - 12 Cells Pair	
X430AJ-X15JP		
X1000AJ-X33JP	76V - 24 Cells, Trio	

Table 1-2. Cell Features

Lithium System Release	Lithium System 1	Lithium System 2	Lithium System 3
Cell Capacity	100 Ah	100 Ah	50 Ah/Pair 100 Ah/Trio 150 Ah
Battery Pack Total Voltage	48V/72V/83 V		38/76 V
Machine System Voltage	12 V		
DOD (Depth of Discharge)	80%		90%
Nominal Voltage	3.2 V		
Maximum Voltage	3.65 V		X26JP - X770AJ X33JP - X1000AJ
Minimum Voltage	2.5 Volt		
Maximum Discharge Current	150 A (<10s) 100 A (cont) 50 A (cont)		
No of Cycles	~2000		~3000
Cathode	Lithium Iron Phosphate (LiFePO4)		
Anode	Graphite		
Memory Effect	No		
*Reduced to 3.5 Volt due to the size of dual charge (120V-220V) 84.5V			

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1.2 BATTERY PACK CONFIGURATION LAYOUT

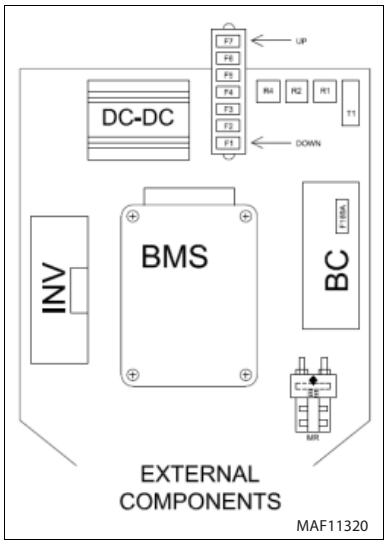

Figure 1-1. 48V Pack Upper Section (1st Generation)

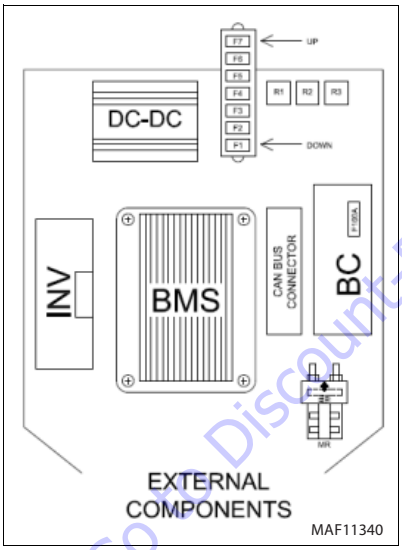

Figure 1-2. 48V Pack Upper Section (2nd Generation)

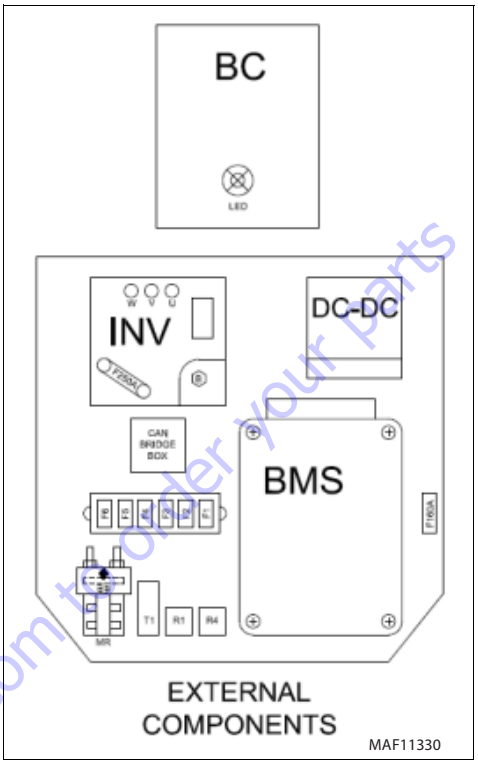

Figure 1-3. 72V Pack Upper Section (1st Generation)

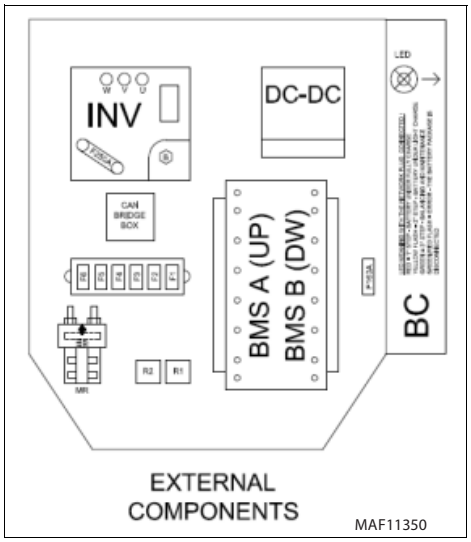

Figure 1-4. 72V/83V Pack Upper Section (2nd Generation)

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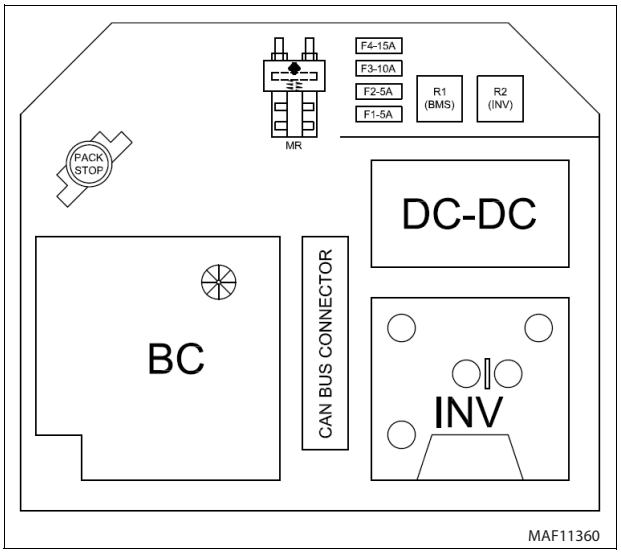

Figure 1-5. 38V Pack Upper Section (3rd Generation)

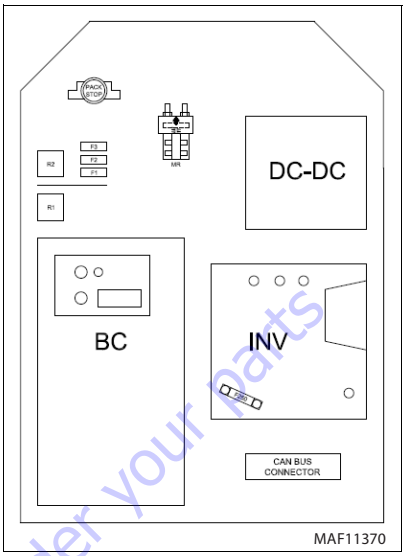

Figure 1-6. 76V Pack Upper Section (3rd Generation)

Table 1-3. Battery Pack Component Identification

BC	Battery Charger
BMS	Battery Management System
CAN Bridge Box	CAN BUS Lines Bridge (X23J - X700AJ only)
DC-DC	Electronic Current Transformer, from 38/48/72/76/83 Volt DC to 13.5 Volt
F No	Fuse Number Identification
INV	Inverter
Led	Battery Charger Lamp
MR	External Main Conductor
R No	Relay Number Identification
T1	Timer for Fans

Table 1-4. Battery Charger

Type	110V or 220V (±10%) - 50/60 Hz
Indicative Time to Recharge	2 to 4 hrs for 80% Recharge
Electric System	38/48/72/76/83V - Lithium Battery Pack 12V - Machine Systems
Electric Motor	• 38V - 3 Phase/2000 Watt • 48V - 3 Phase/2000 Watt • 72V - 3 Phase/2500 Watt • 76V - 3 Phase/2500 Watt • 83V - 3 Phase/3500 Watt

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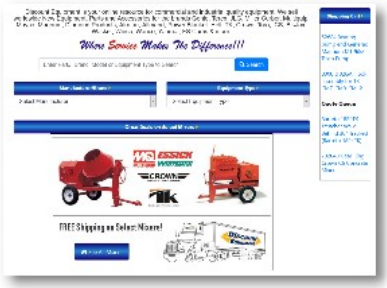

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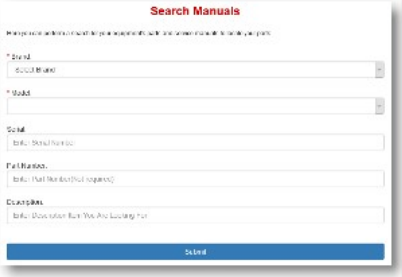

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SECTION 2. SERVICE PROCEDURE

2.1 12V DC POWER DISTRIBUTION

The 12V power distribution system provides the electrical power required to operate the machine's Electronic control modules (ECM), solenoid valves and lights. In Lithium ION 2nd Generation BMS powered machines, it also powers the battery management system (BMS) and Lithium ION system relays and contactors. In engine powered machines, the 12V power distribution system powers the glow plugs in diesel engines and the starter motor in diesel and gasoline engines. The 12V Power distribution system includes the following components:

- 12 Volt Lead-acid battery
- 12 Volt battery cutouts
- 12 Volt battery fuses
- Machine master controller (ECM1 and ECM2)
- Load Cell Board (ECM3)
- Reduced Stabilization Control Board (ECM4) X770AJ/X26JP only
- Battery management system (BMS)
- Start relay
- Starter
- Glow plug relay
- Glow plugs
- Generator

The 12V Lead-acid battery provides the power to the machine electronic control module (ECM) in the machine until the engine starts. Once the engine starts, the engine driven generator, provides 13.5V electrical power for the machine components and recharges the battery.

When the engine is not running, connect 120/230V AC power cord into a power receptacle to recharge the battery.

When the Battery Management System (BMS) is ON, the DC-DC converter also switches ON. When this occurs, the DC-DC converter powered by the Lithium ION battery, provides 12V electrical power for the machine components. It also recharges the battery.

When the machine's Lithium ION battery system is charging the DC-DC converter continues to recharge the 12V Lead-acid battery.

If the Lead-acid battery is completely discharged, the main controller and the BMS cannot be powered and machine cannot start. To avoid this situation, if the Lithium ION battery ON-OFF key switch is left on, and the voltage level of the Lithium ION battery pack is less than 20%, the master controller will turn off the system if no machine movements are performed for one hour.

Even if the operator leaves the Lithium ION battery ON-OFF key switch in ON position, the Lead-acid battery will be preserved from complete discharge.

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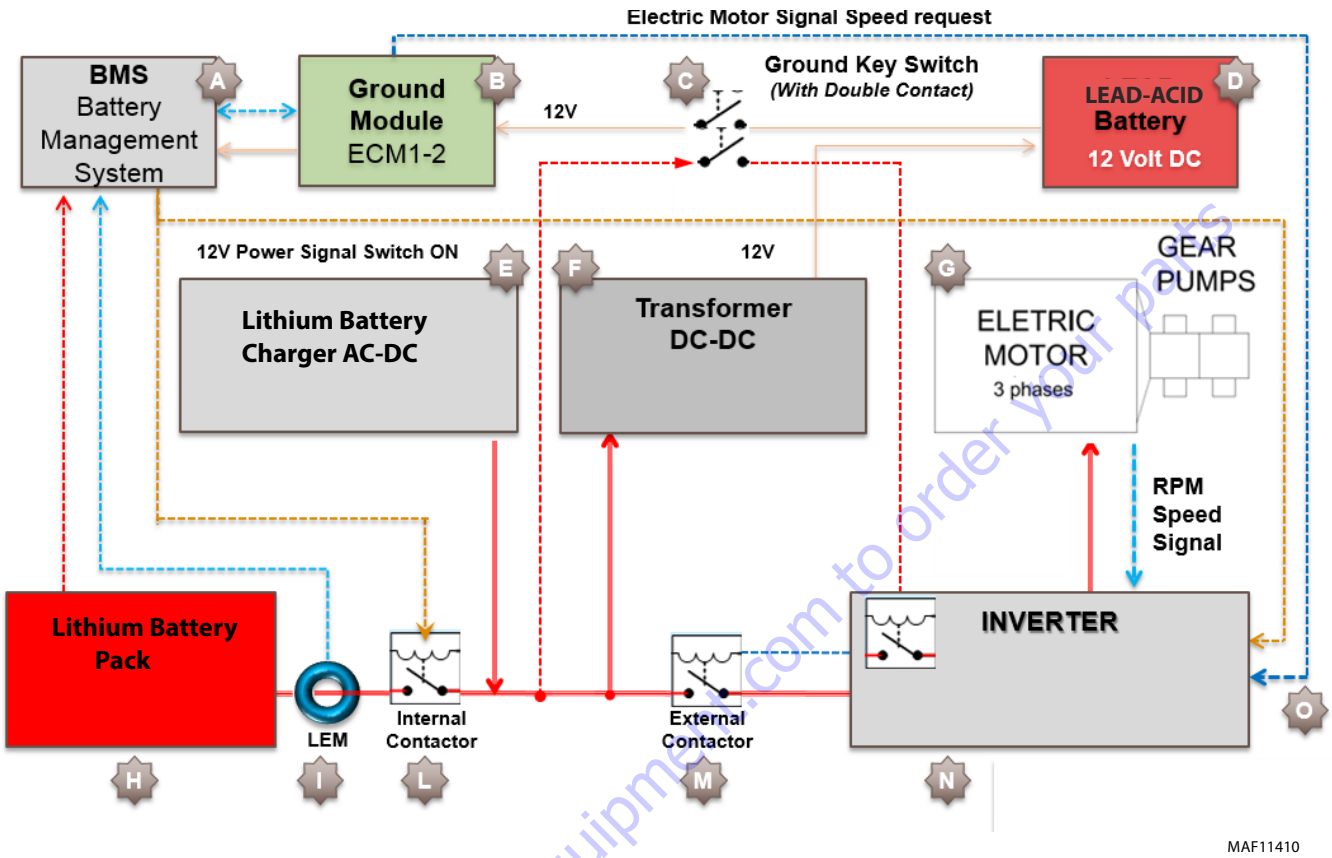
2.2 OPERATION OF THE POWER PACK COMPONENTS



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Theory of Operation

Switching ON the dual contact key switch (C) directs individual contact with the 12V power from the Lead-acid battery (D) to power-up the ground module ECM1-2 (B), while the other contact (38-48-72-76-83V) activates the inverter contactor (N). The ground module ECM1-2 (B) power-up the BMS (A) and the BMS (A) carries on the control of the power pack system.

The BMS (A) monitoring the cells, opens/closes the internal contactor (L), manages the charge of the Lead-acid battery (D) through the Transformer DC-DC (F) and switch ON the inverter (N). The Inverter will close the external contactor (M) when required to receive power to supply the electrical motor.

When the internal and external contactors (L & M) are closed, current from the Lithium battery pack is supplied to the Inverter (N). Current is supplied to the electric motor (G) according to the speed demand from the signal (O) from the ECM1-2 (B), and the reserve of existing battery power and is controlled by the BMS (A).

The BMS regulates the amount of current coming IN (recharge) and coming OUT (to electrical motor or the DC-DC transformer). The BMS measures the total current (IN – OUT) through the module LEM. (I).

If fault code occurs, the BMS keeps the internal contactor (L) open and power is not available for the system. If a fault is present, the Inverter (N) keeps the external contactor (M) open, so power is not available for the electrical motor.

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2.3 BATTERY MANAGEMENT SYSTEM (BMS)

The Battery Management System (BMS) is the electronic device which constantly monitors the state of the LiFePO4 cells and their best possible operation.

The main functions of the BMS are:

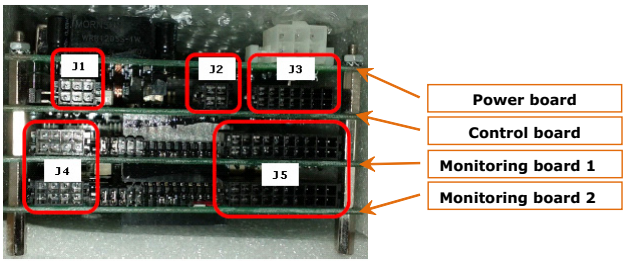
- Check the Voltage of every cell
- Check the Battery Pack Current in/out
- Check the Battery Pack temperature
- Manage the Battery charge
- Equalize the cell on final charge stage
- Control the cooling system in case of high temperature
- Manage the system in case of failure
- Protect the cells from overcharge, over discharge, over temperature, overvoltage, under voltage

48V/72V Systems with 1st Generation BMS

The 1st generation BMS is the same for 48V and 72V systems, but they are not interchangeable. The BMS is a device composed of electronic cards assembled together, in a box as the image below.

Monitoring boards can manage maximum 12 Lithium cells, so 2 of these boards are used on both batteries packs (48 or 72V). The electric cell connections are shown in the wiring diagrams.

MAF11420



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BMS Connectors (1st Generation BMS)

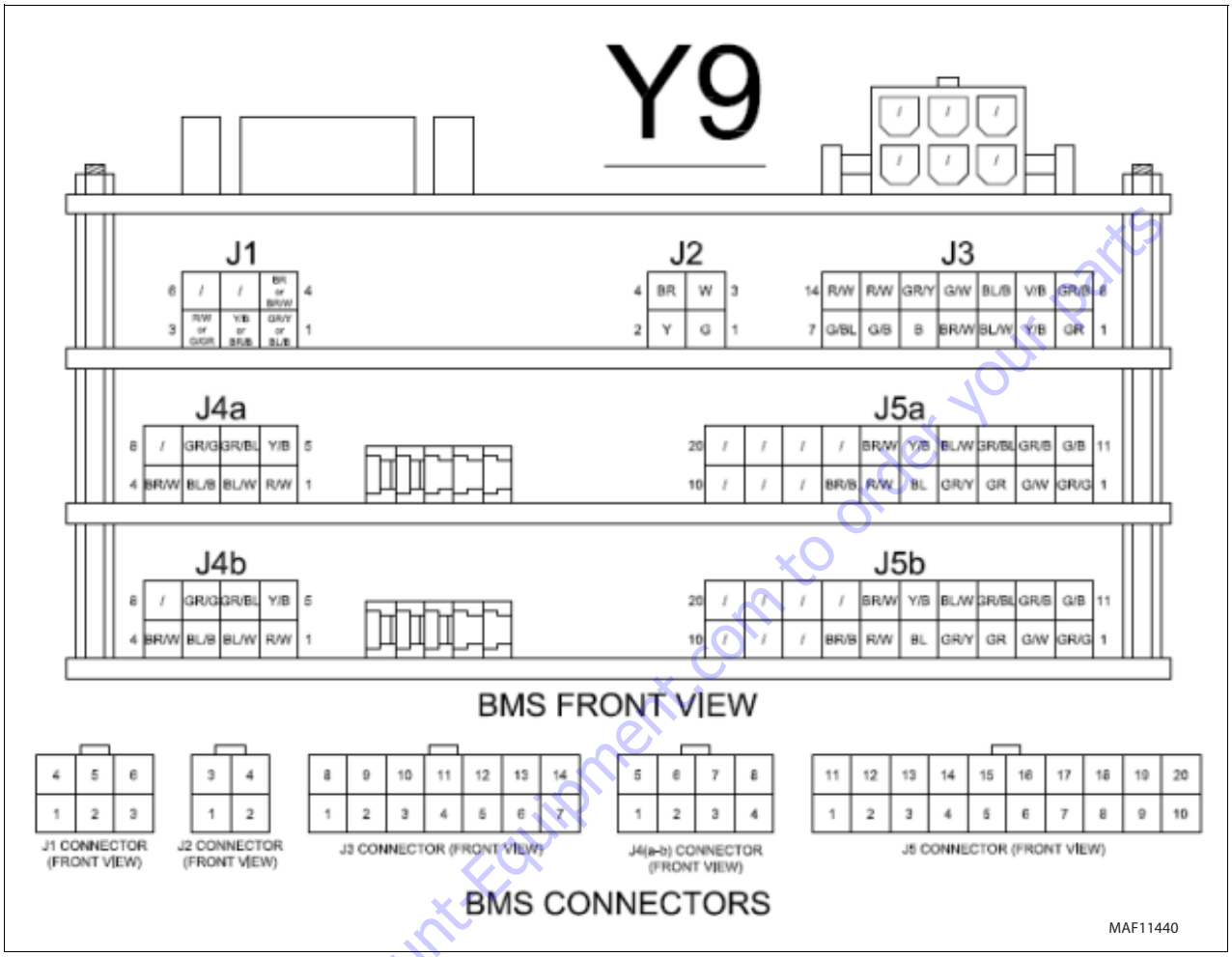

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Table 2-1. 1st Generation BMS Connectors

J1	CAN BUS Module Socket
J2	Current Sensor Socket (LEM)
J3	Power and Contactor Socket
J4	Temperature Sensor Socket
J5	Voltage Cells Measurements Socket Resistance to Discharge the Cells during the Equalization Phase

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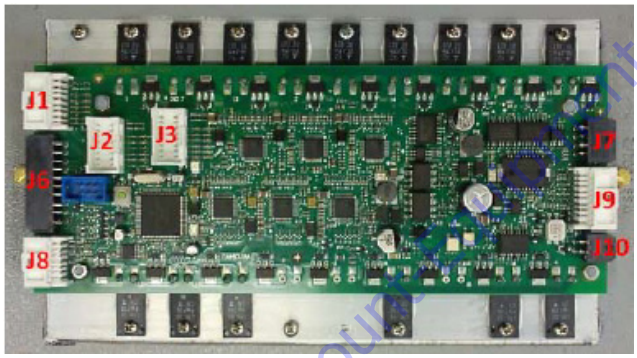
48V Systems with 2nd Generation BMS

The 2nd Generation BMS can be arranged with one or two electronic cards. The 48V 2nd Generation BMS manages all the functions as described in the 1st Generation BMS.

MAF11450

Figure 2-1. 48 Volt BMS



MAF11460

Figure 2-2. Single Electronic Card

Table 2-2. Internal Connector Identification on BMS module

J1	Temperature Input 1
J2	Temperature Input 2
J3	Temperature Input 3
J6	Voltage Input
J7	Internal Contactor and Fans
J8	LEM Sensor
J9	Power Supply
J10	CAN BUS

72V/83V with 2nd Generation BMS

The 72V and 83V BMS is composed of two electronic cards, positioned one above the other in the same case, BMS A on top and BMS B on bottom side. Each electronic card can manage maximum 16 cells. Both cards have the same functions but manage a defined group of cells. BMS Master and Slave are identified with letters M and S stamped on side case as shown below.

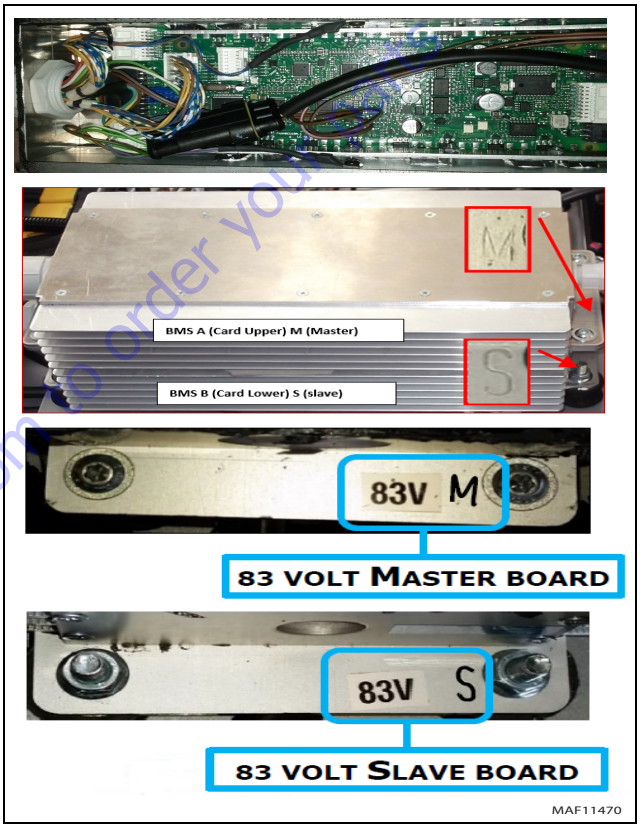


Figure 2-3. BMS A (Card Upper)

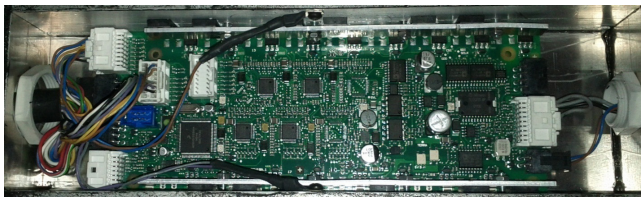


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Figure 2-4. BMS B (Card Lower)

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BMS Connectors (2nd Generation BMS)

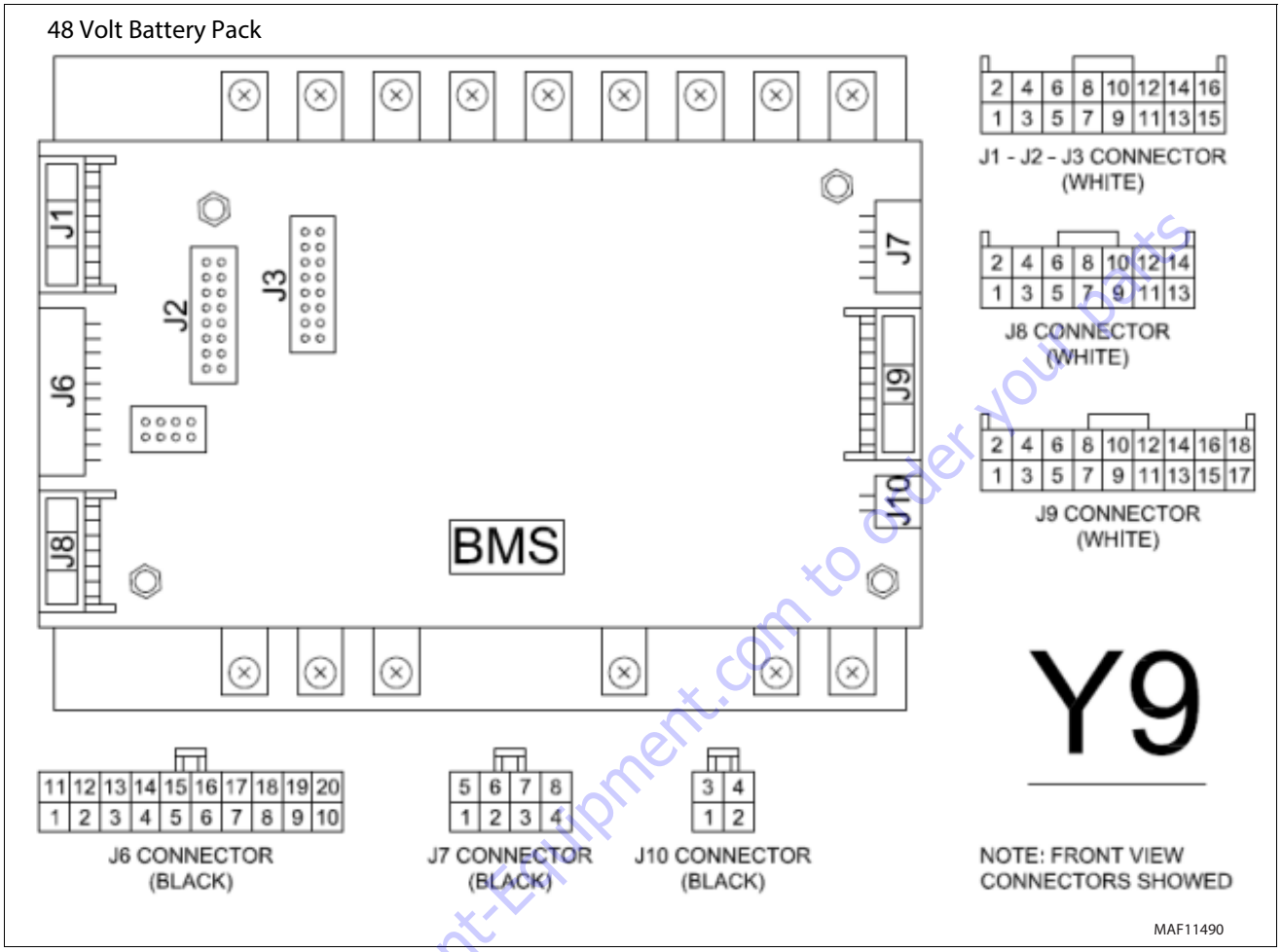

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Table 2-3. 2nd Generation BMS Connectors

J1, J2, J3	Temperature Sensor Sockets
J6	Voltage cells Measurements Socket Resistance to discharge the cells during the Equalization phase
J7	Internal contactor and fans
J8	Current sensor socket (LEM)
J9	BMS feed
J10	CAN BUS socket

On 2nd Generation BMS, the resistances to discharge the cells are located on the cage heating area, while 4 temperature sensors are placed on the same section to monitor the cage temperature. With temperatures above 70°C the BMS opens the internal battery contact to avoid overheating.

On the 1st Generation BMS the temperature sensors are located on the board cards, and the internal battery contact is opened when the temperature reaches 60°C.

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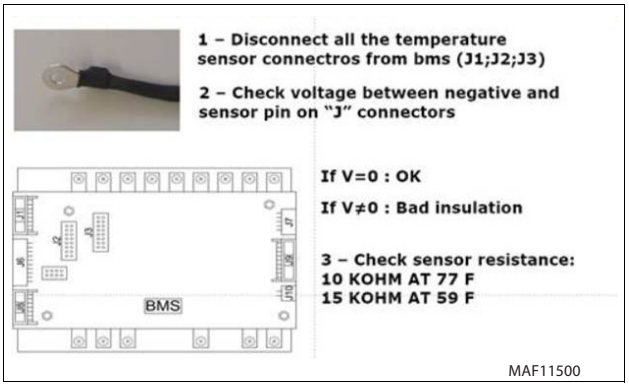
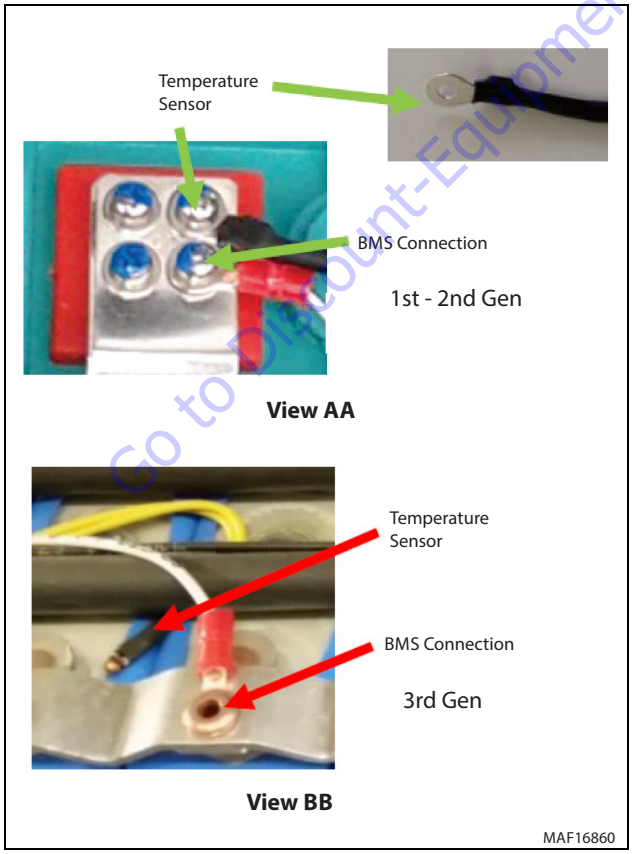
Temperature Sensor Test - 2nd Generation



1. Disconnect all temperature sensor connectors (J1, J2, J3) from the BMS.
2. Check voltage between negative terminal and sensor pin on connectors
   a. If V=0: OK
   b. If V≠0: Bad Insulation
3. Check sensor resistance values

   10000 Ohm at 77°F (25°C)

   15000 Ohm at 59°F (15°C)



38V/76V with 3rd Generation BMS

The 3rd Generation BMS can be arranged with one or two electronic cards. The 38V and 76V BMS for 3rd generation are interchangeable with software update. The 3rd Generation BMS manages all the functions as described in the 1st Generation BMS.

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Figure 2-5. 38 Volt BMS - 3rd Generation

MAF12860

Figure 2-6. 76 Volt BMS - 3rd Generation

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BMS Connectors (3rd Generation BMS)

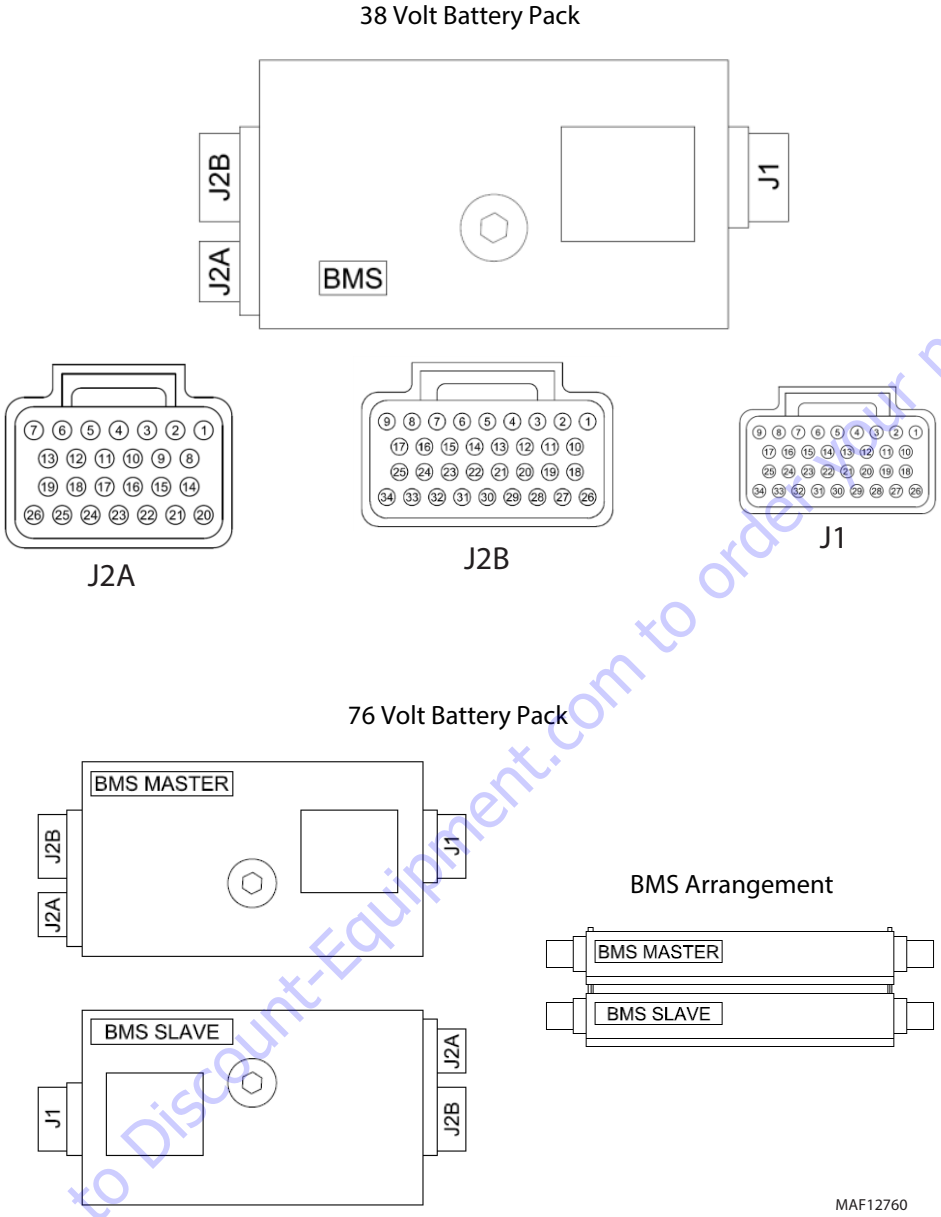

Figure 2-7. 3rd Generation BMS Connectors

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Table 2-4. 3rd Generation BMS Connectors

J1	Temperature Sensor
J2A	CAN BUS line Ignition
J2B	Feed to Devices (LEM Sensor, Fan, Heater, Internal Contactor)

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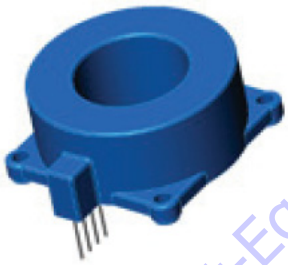
LEM Sensor and Internal Contactor

The BMS manages the battery pack through two devices:

1. LEM Sensor: LEM Sensor recognizes the amount of current passing through the batteries when charging or the current supply to the electrical motor. See below for LEM Sensors of different Generation BMS.

MAF11510

Figure 2-8. 1st Generation LEM Sensor



MAF11520

Figure 2-9. 2nd Generation LEM Sensor

MAF12770

Figure 2-10. 3rd Generation LEM Sensor

NOTE: *1st Generation, 2nd Generation and 3rd Generation LEM sensors are not interchangeable.*

NOTE: *The LEM sensor has a direction of installation. Carefully install the LEM sensor in correct direction.*

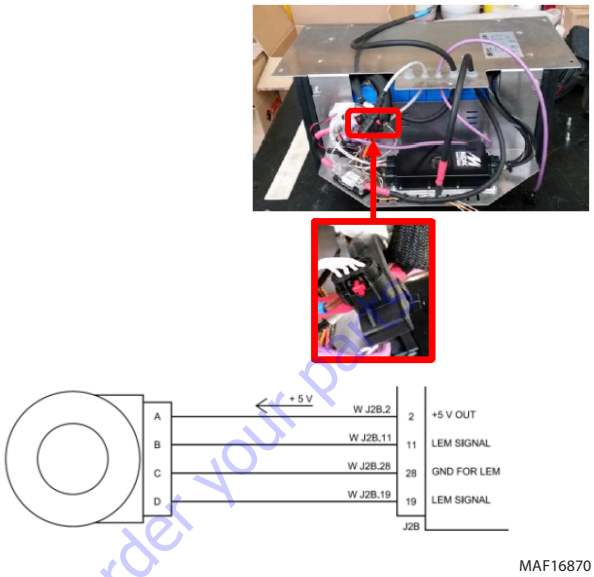


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Figure 2-11. LEM Sensor wires connections

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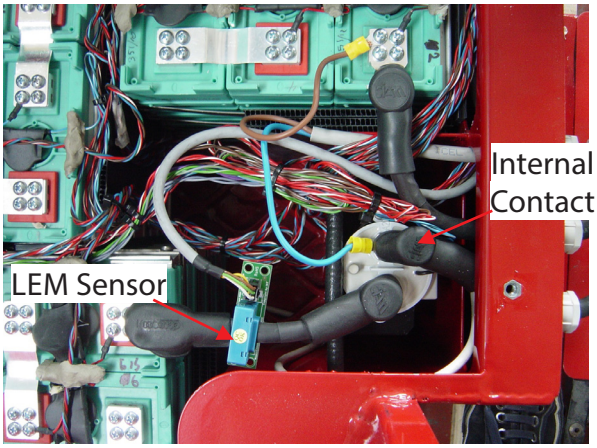
LEM sensors placed at the end of series cells connections are shown below.

1st and 2nd Generation



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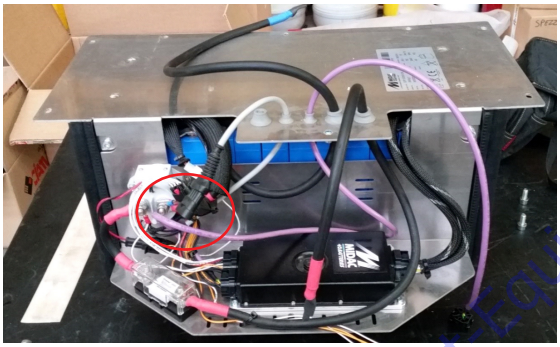
3rd Generation



MAF12780

1. Internal Contactor: A relay to disconnect the battery pack to the circuit of the machine. The Internal contactor is managed by the BMS by disconnecting the battery circuit to the machine in case of failure or incorrect electrical energy limit.

NOTE: *Make sure to connect the wire correctly to internal contactor for the system to function properly.*

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Figure 2-12. Internal Contactor

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2.4 LITHIUM BATTERY CELL

The battery pack is made up of cells as per required power storage. All the cells have the same characteristics and are connected in series by metal plates to get the necessary voltage level. The single cell has the same capacity as the entire battery pack.

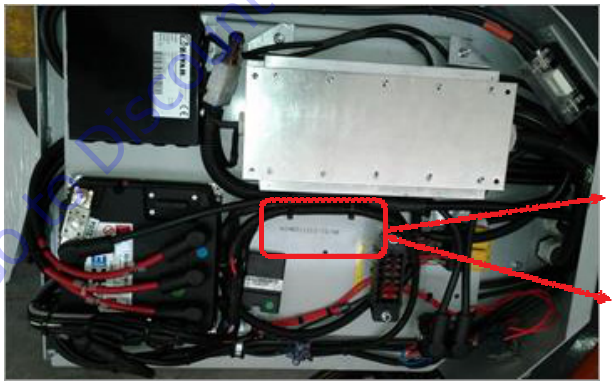
MAF11550

Cell Feature	
Rated Voltage of each Cell	3.2V
Maximum Cell Voltage	3.65V
Minimum Cell Voltage	2.5V
Cathode	Lithium Iron Phosphate (LiFePO4)
Anode	Graphite
Capacity	90/100/150 Ah

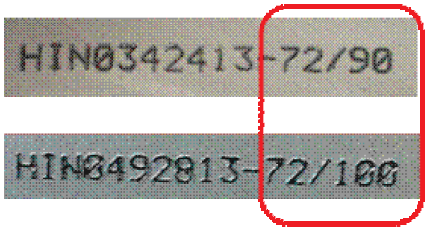
Power Pack Voltage V	-	48	72	-	83
Cell Capacity A/hr	50	90-100	90-100	100-150	100
No. of Cells in battery Pack	12	15	22	24	26

NOTE: *Cell Code, serial number and capacity are stamped on side of each cell.*

Valid on 1st and 2nd Gen only



NOTE: *Group Serial Number, voltage and capacity are stamped on top side plate case.*



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Valid on 1st and 2nd Gen only

NOTE: *The 90Ah, 100Ah and 150Ah Cells are the same size but are not interchangeable.*

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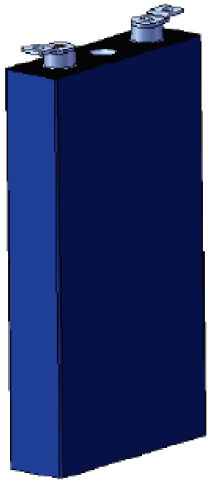

MAF16880

Cell Feature	
Nominal Cell Voltage	3.2 V
Maximum Cell Voltage	3.65 V
Minimum Cell Voltage	2.5 V
Cell Capacity	50 Ah
Pairs of Cells Capacity	100 Ah
Tris of Cells Capacity	150 Ah
Max Discharge Current	150 A (<10s) 100 A (Cont)
Max Charge Current	100 A (<10s) 50 A (Cont)
N° of Cycles	~3000

NOTE: *Cell Code, serial number and capacity are stamped on side of each cell.*

Valid on 3rd Gen only

MAF16890

Important Notes :

Recharge at least once per month
Do not store empty
Do not keep under the sun
Number of cycle = 3000, at 25°C, DOD 100% (standard reference)
Number of cycle = 2000, at 55°C, DOD 100% (standard reference)

Self Discharge : Calender life also depends on storage temperature
1%/ Month at 25°C
3%/ Month at 45°C

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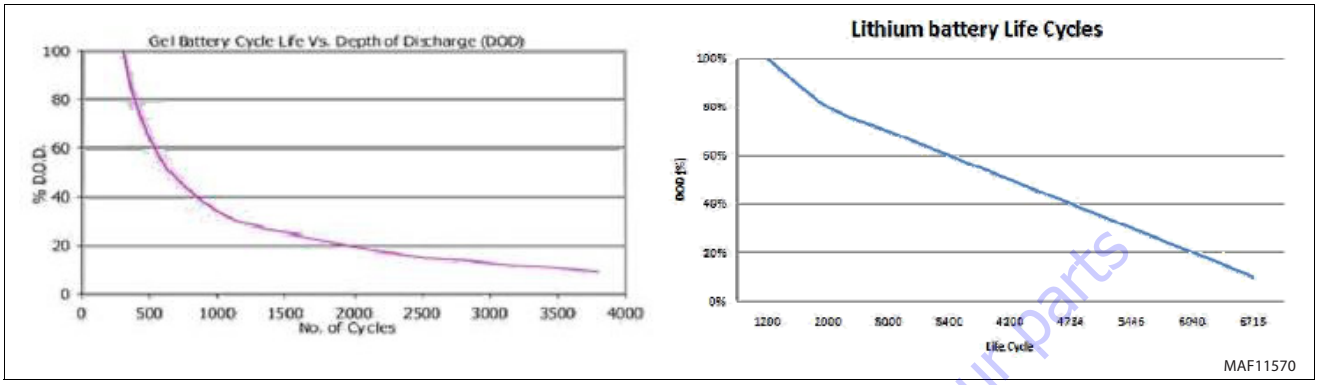
Characteristics of Lithium Batteries



The main characteristics of the lithium battery pack are:

1. Cells capacity are independent from discharge current (1C) and characteristic that is reflected in the final performance of the machine. According to the movement selected, machine will work with different current absorptions without affecting the battery pack performances.
2. Absence of memory effect: In Lithium Batteries, their cells capacity does not depend on the charge cycles. This results in the battery pack capacity to be charged with any charging principle used by the operator (small daily charges, charge only with machine completely flat, partial charges, etc). Refer to above diagrams.
3. Another important characteristic of the lithium batteries is the number of complete charge cycle before the charging capacity decreases. As shown in the diagram above, the cells may charge below 80% of its capacity only after 2000 complete charging cycles (100%) is valid for all three genrations and the cells may charge below 80% of its capacity only after 3000 complete charging cycles (100%) is valid for 3rd genration.
4. Time is not an important factor in cell deterioration. Thus if the machine is not used for a long time, the battery pack will not be damaged.

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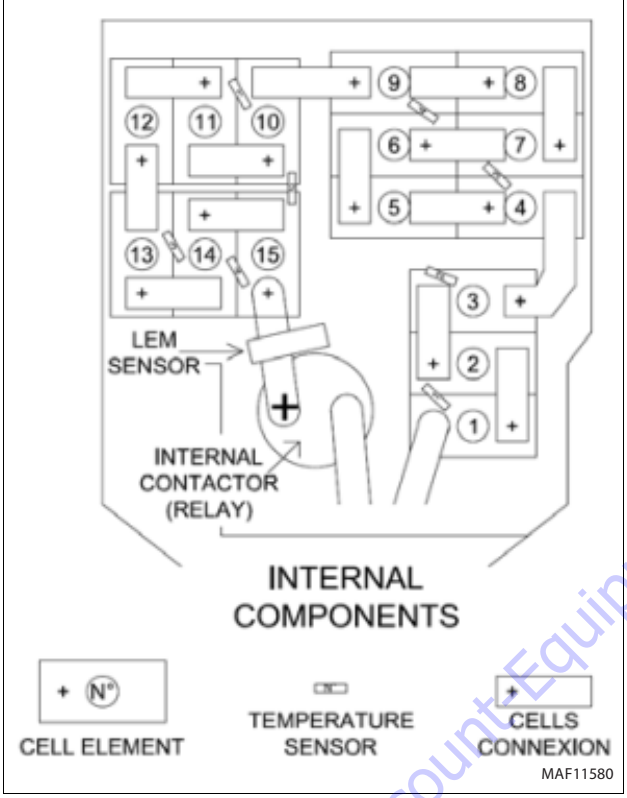
Cell Voltage Monitoring

Battery Management System (BMS) constantly monitors the voltage of every cell. The cells are identified in order so that the BMS can manage their charge and discharge. It is necessary to not interchange the wiring of the cells.

1st and 2nd Generation System for cells temperature sensor arrangement is shown below.

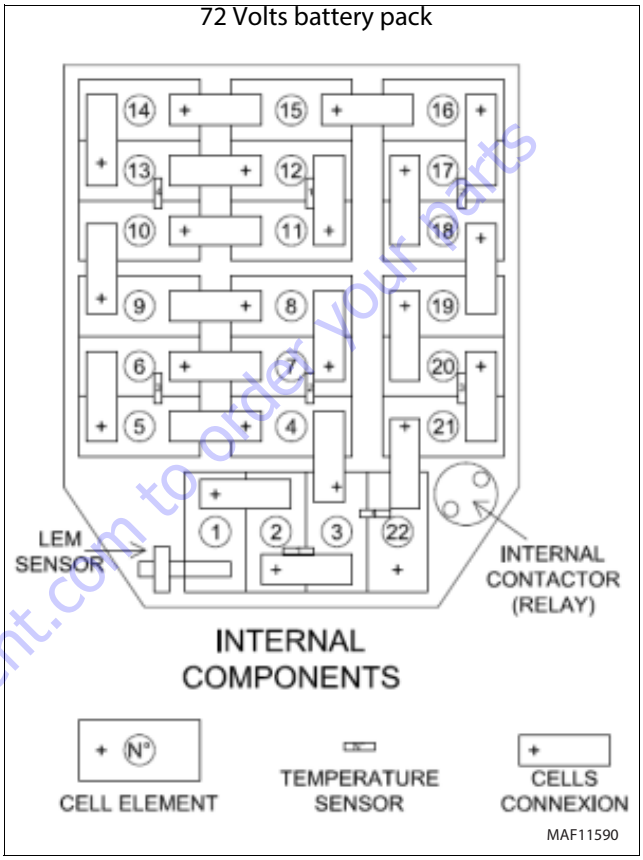
48 Volts battery pack



Eight temperature sensors are distributed in the battery pack near the cells to monitor the temperature.

The BMS activates two fans to cool down the temperature of the pack when the temperature inside the pack rises above limit.

72 Volts battery pack



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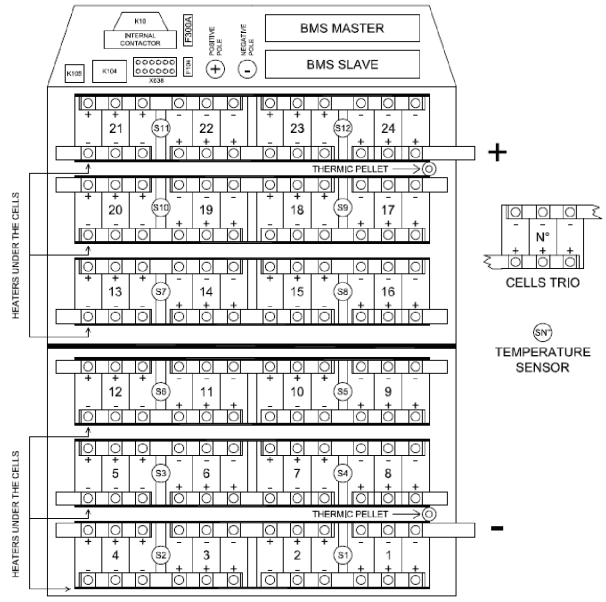
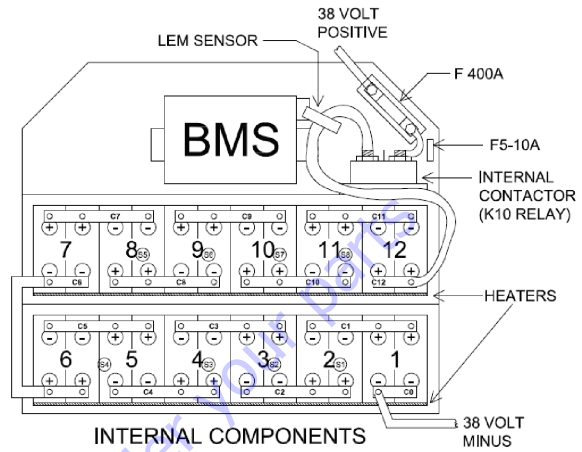
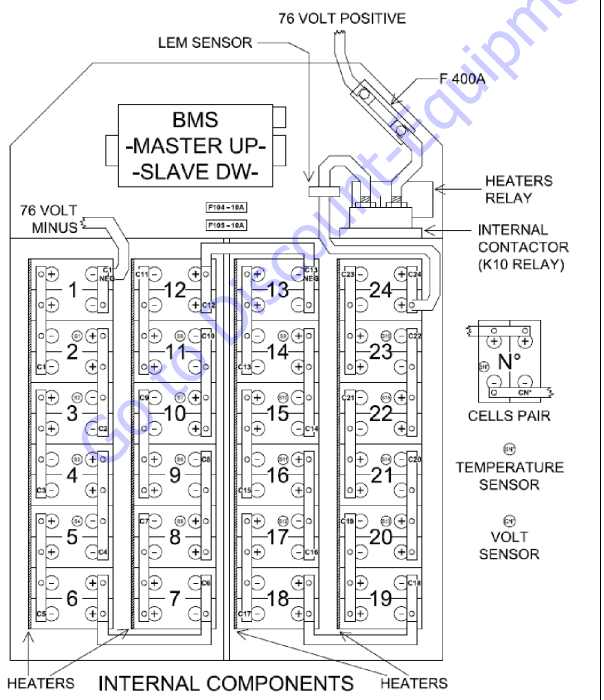
76 Volts 150 Ah battery pack



38 Volts 100 Ah battery pack



76 Volts 100 Ah battery pack



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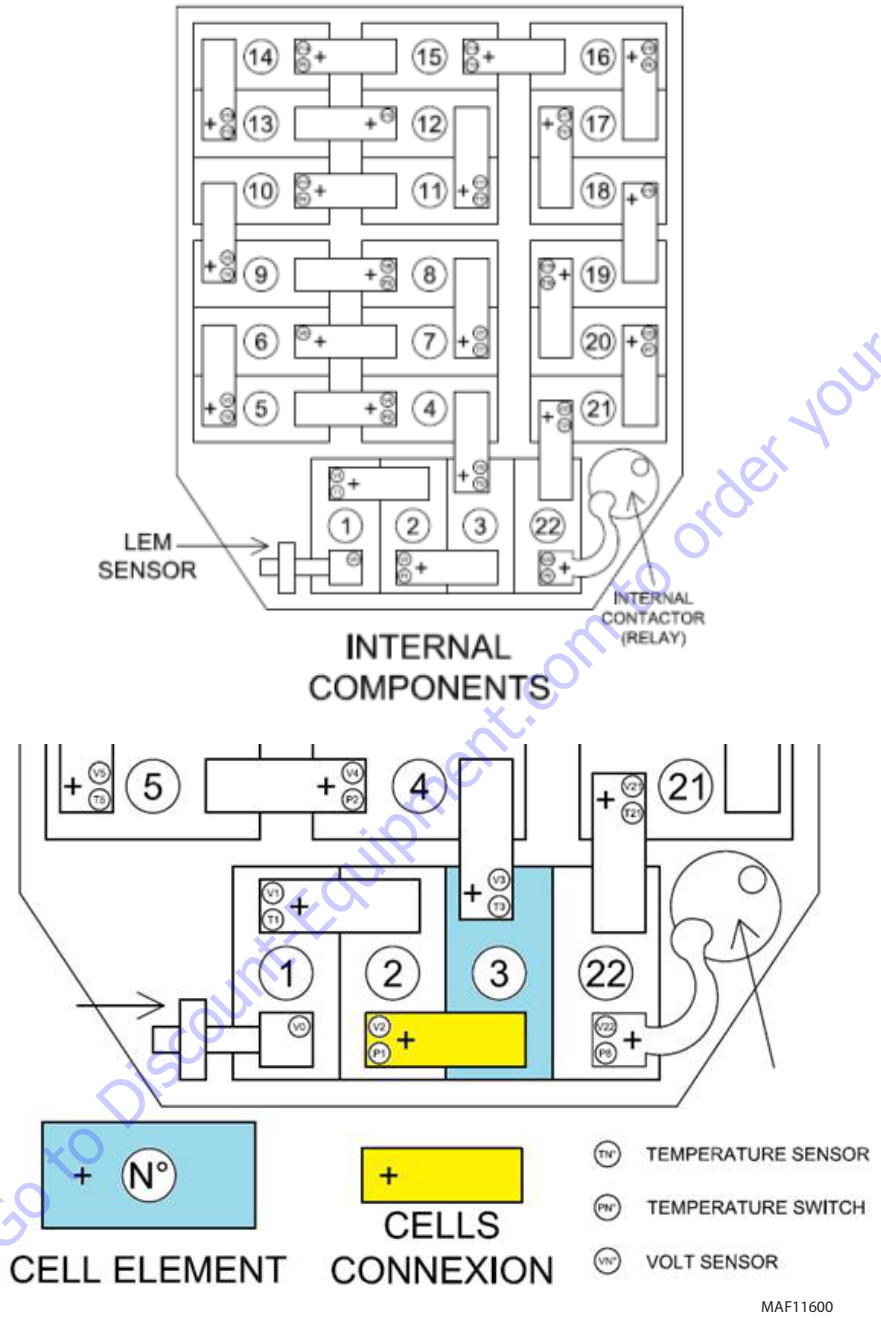
72 Volts battery pack (Valid for 2nd Gen only)



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There are 6 temperature sensors on 48V, 11 on 72V and 13 on 83V. The temperature sensors are put on the cells to monitor the temperature.

The temperature sensors are also supplied with internal switches that disable the sensor if any parameters are out of range. In such case the value shown will be “0”. If required, the BMS activates two fan to cool down the temperature inside the pack. Refer Section 1.

If everything is ok, the BMS feeds the coil of the internal contactor (relay), so the current can go outside the battery pack. In case of failure or incorrect parameters, the BMS keeps the internal contactor open and the current cannot reach the inverter.

2nd Generation system cells and temperature sensor arrangement are shown in above figure.

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Cell and Temperature Sensor Location

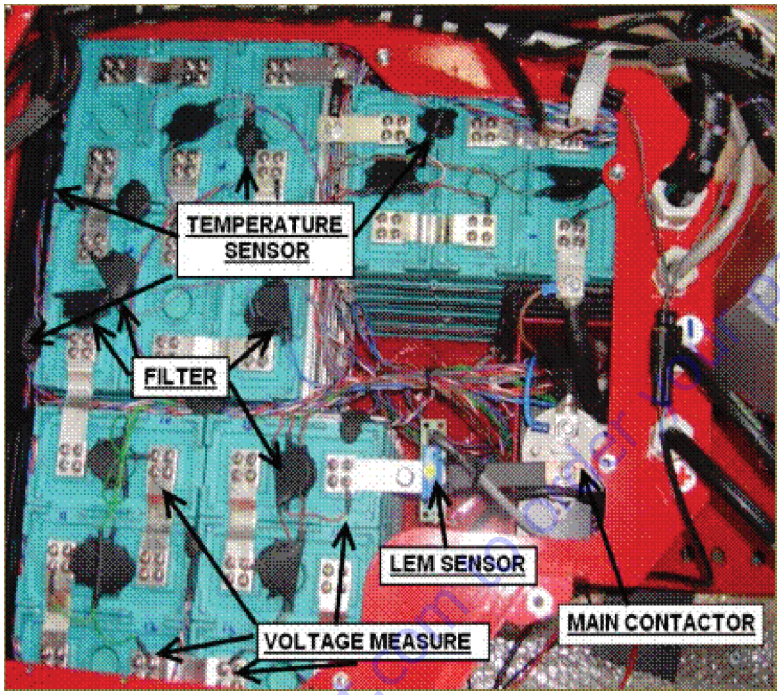

Figure 2-13. 48V Battery Pack - 1st Generation Only

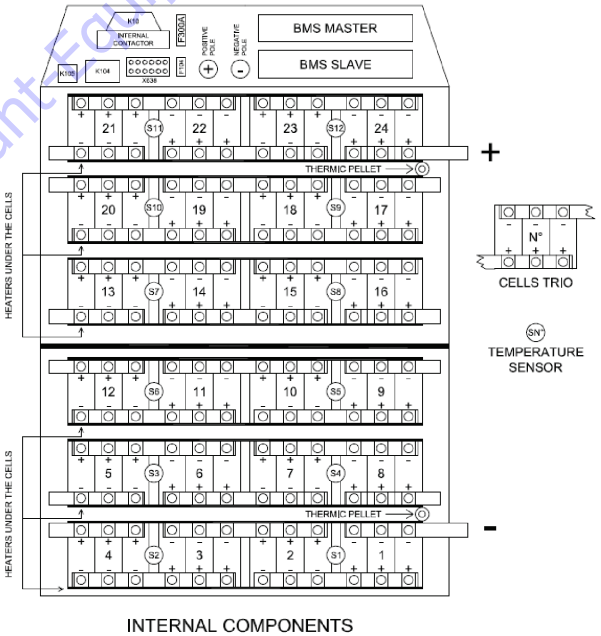

Figure 2-14. 76 Volt 150 Amp - 3rd Generation

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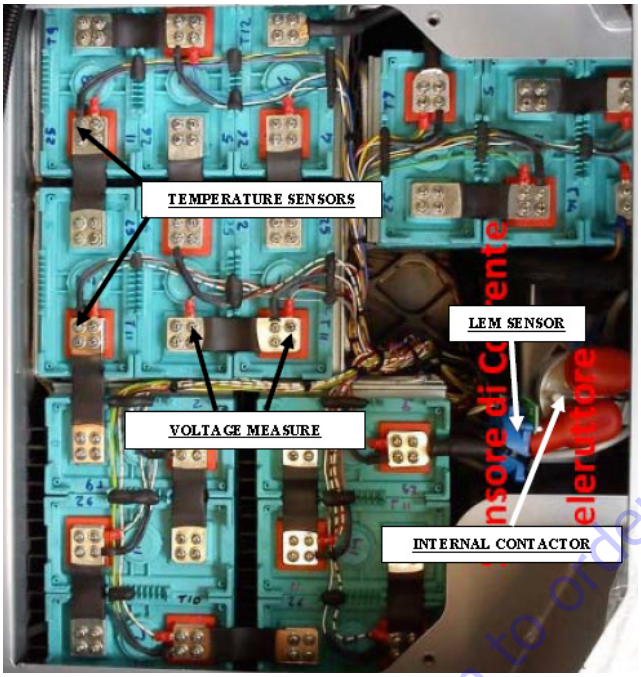

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Figure 2-15. 72V Battery Pack - 1st Generation Only

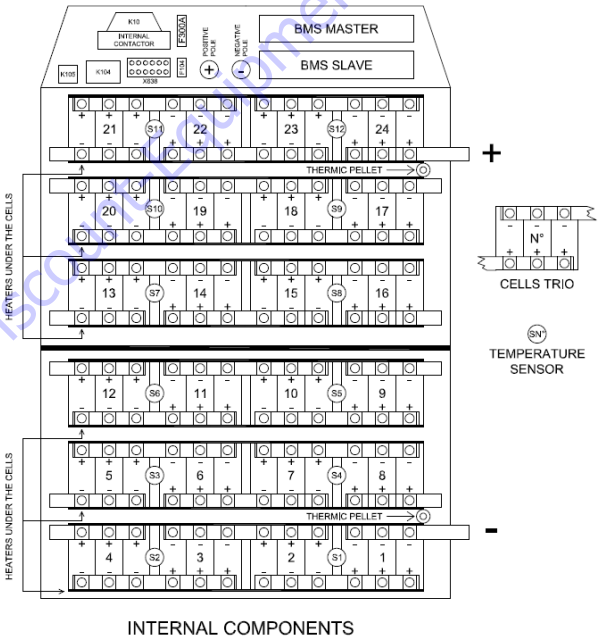

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Figure 2-16. X26JP - X770AJ before SN C170001340 83V 100Amp (Esagon Control)

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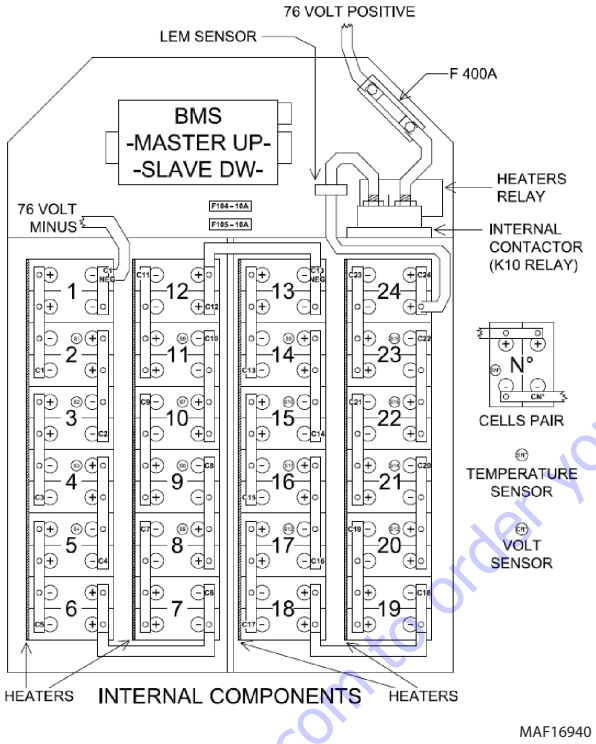

Figure 2-17. X26JP - X770AJ from SN C170001340 76V 100Amp (TTC Control)

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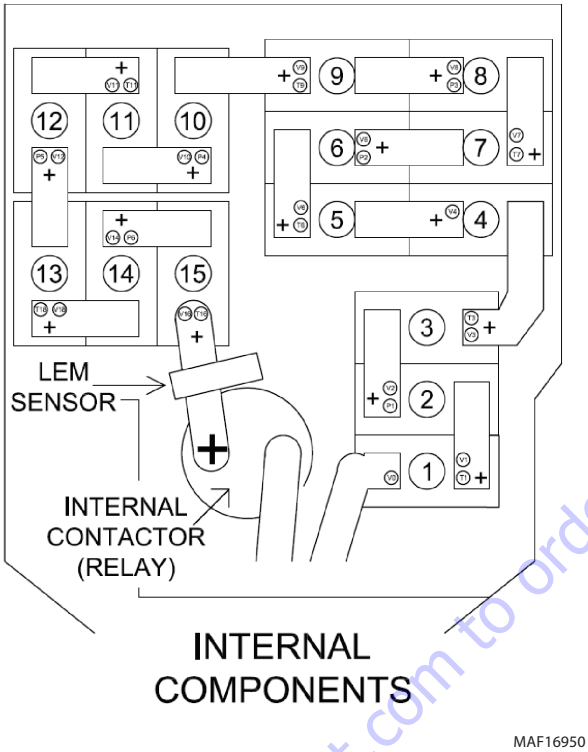

Figure 2-18. X17JP - X550AJ 48V

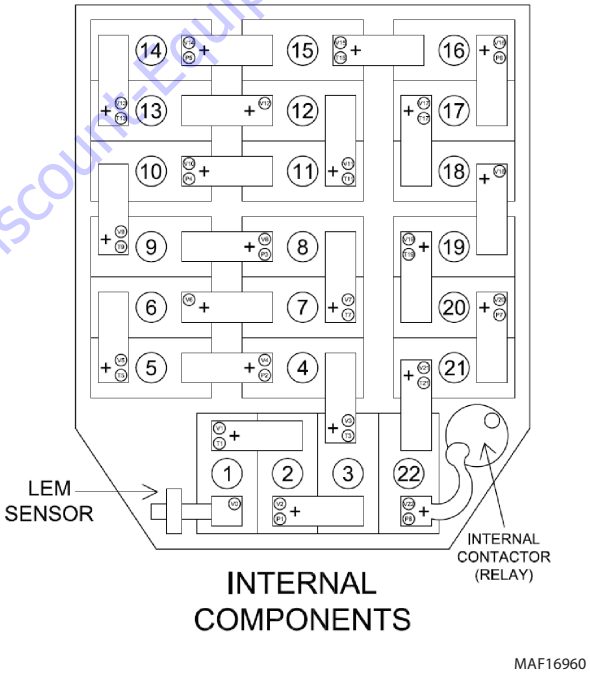

Figure 2-19. X20JP - X600AJ 72V

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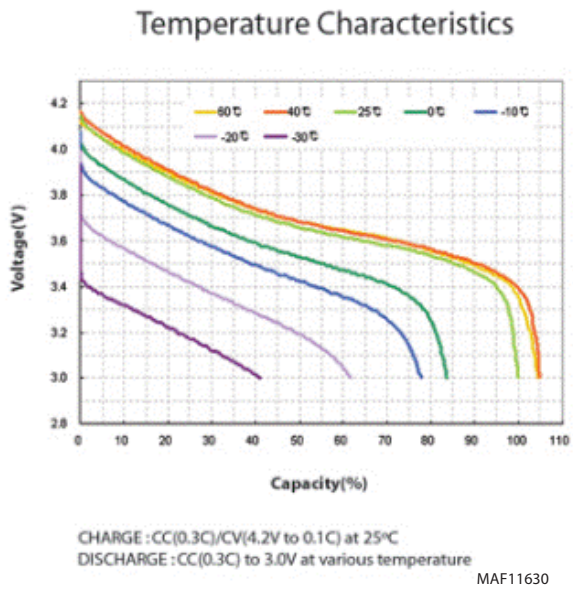
2.5 COOLING SYSTEM



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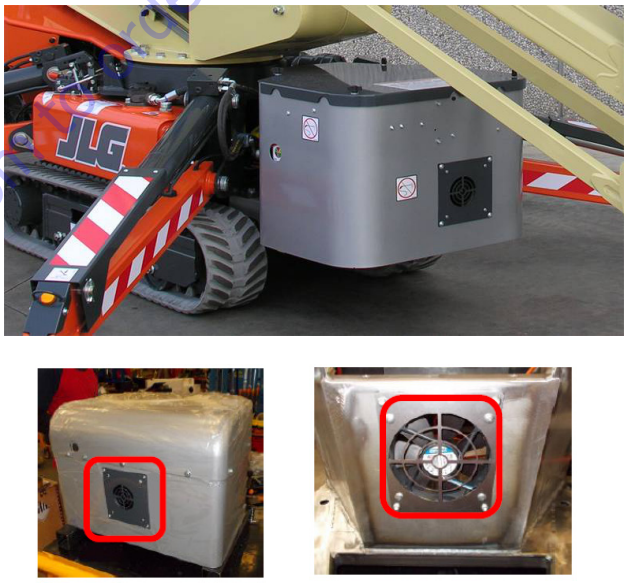
The cells performance is dependent on the temperature as indicated in the above image. The critical behaviors are recorded at low temperatures, At these temperatures the cells performance decreases. Park the machines with batteries charged.

NOTE: *Do not park the machine with flat batteries. The cells can lose a small quantity of charge capacity. This can lead to an increase in charging time during reignition and the charge level will be very low. In such condition, if external temperatures are below* 0°C, charging time of cells will increase as compared to the standard time with completely flat batteries and temperature above 0°C.

The optimal solution in cases of very low temperature is to use the platform for a few minutes before the charge to heat the battery pack and reduce the charging times or charge the machine after having completed work when the battery pack is still warm. It is important to store the machine with some charge remaining in the battery. There will not be any problems if the battery is completely discharged, but it will require longer time during charge cycle. There is a self cooling system in case of high temperature which is described later.

When temperature of any cell is below 0 °C (32 °F), the machine will recover in the low speed function; then the icon “Cold Battery” appears on the display.

Case Cooling Air Flow



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The case of the lithium battery pack has a cooling system (see figure above). The fan no. 1 pulls the fresh air and pushed through the bottom case. The fresh air flows through the cells from the lower side and then pulled though the fan no. 2.

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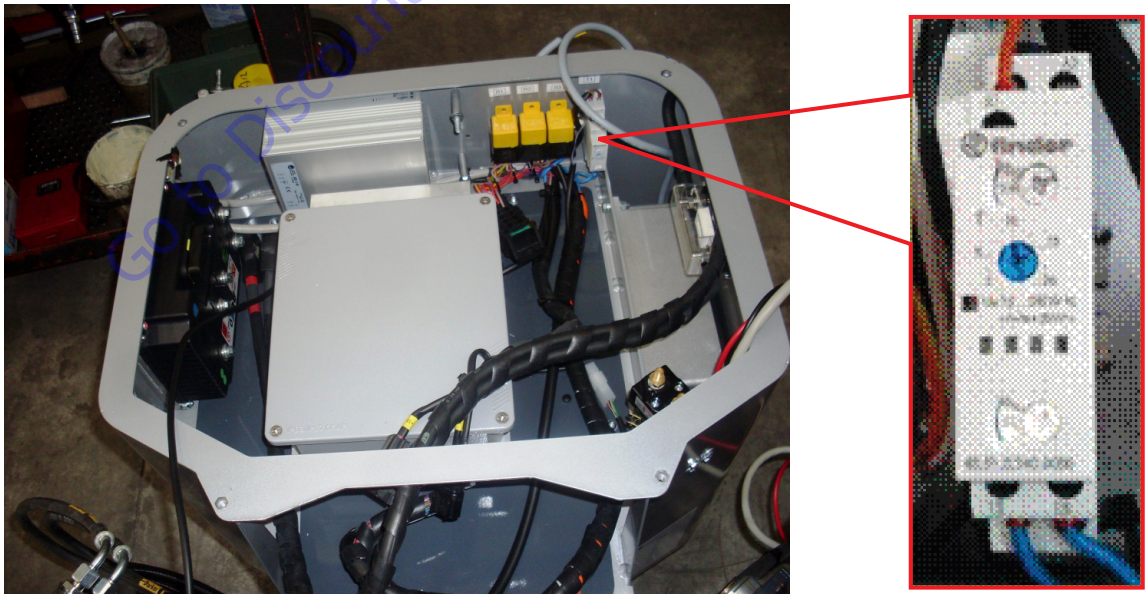
The two fans are activated at the same time when average temperature of the battery pack is more than 30°C. If the temperature of the battery pack is more than 50°C, the internal contactor opens. The power to the machine is then cut to allow cooling of the system.

In the 1st generation system, the fans are managed by a timer T1 (shown below) which is controlled by the BMS. When the internal temperature is high, the BMS sends signal to the timer coil that sends signal to the two fans for a set time. After this time, if temperature is still high, the timer is activated again.
In the 2nd and 3rd generation system, BMS controls the fans when necessary.



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Temperature, voltage of the single cells and the system power absorption controls are highlighted.

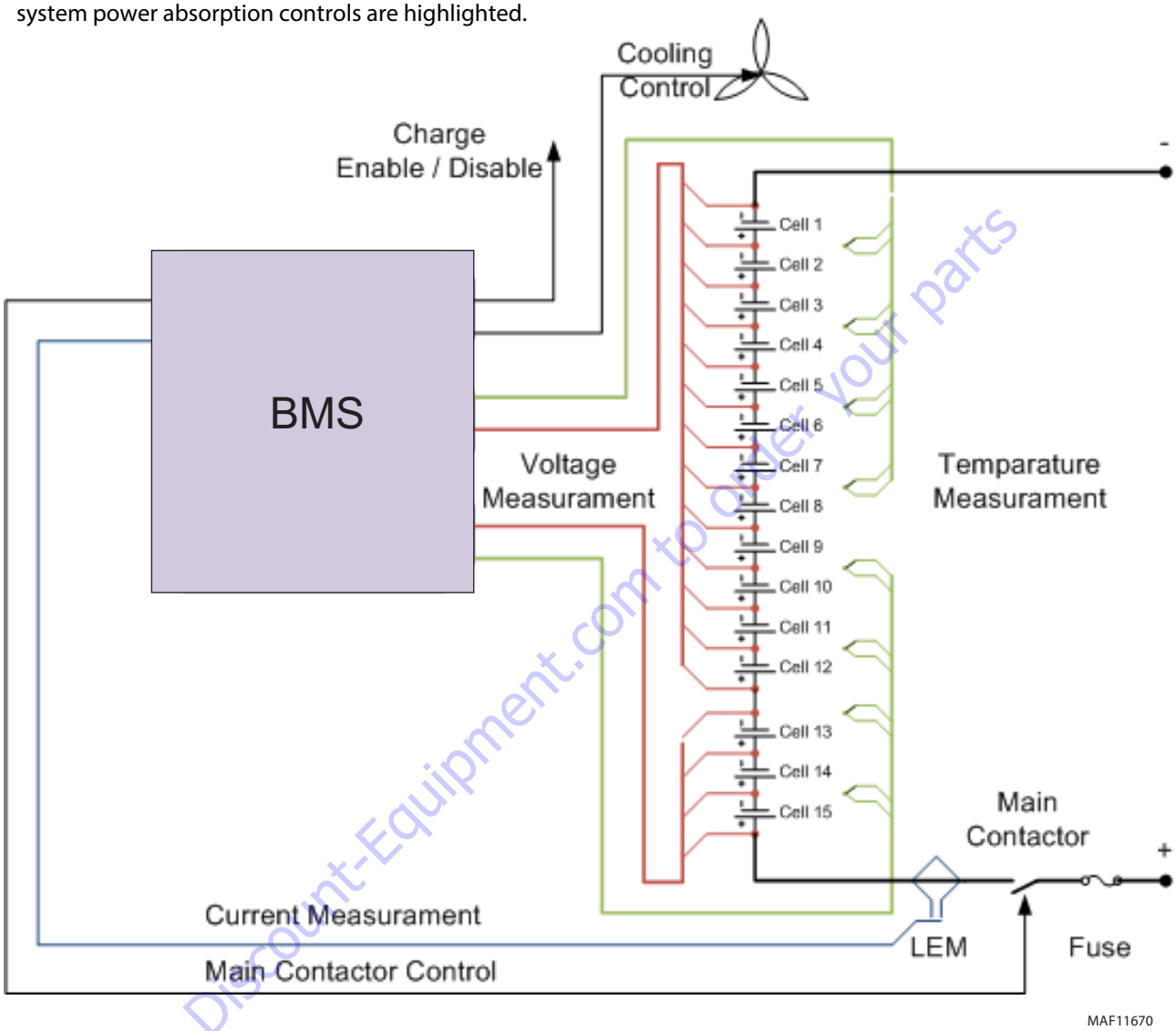

Figure 2-20. 1st Example of BMS Wiring Interface

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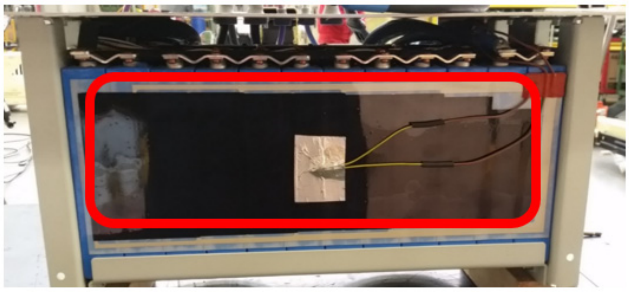
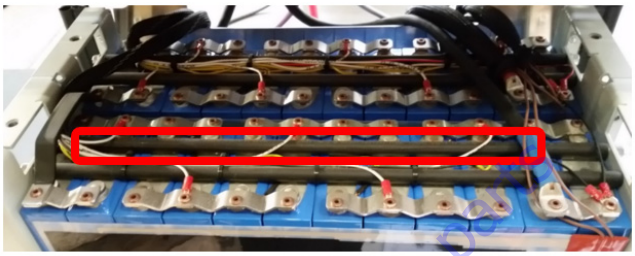
2.6 HEATER SYSTEM (3RD GENERATION)

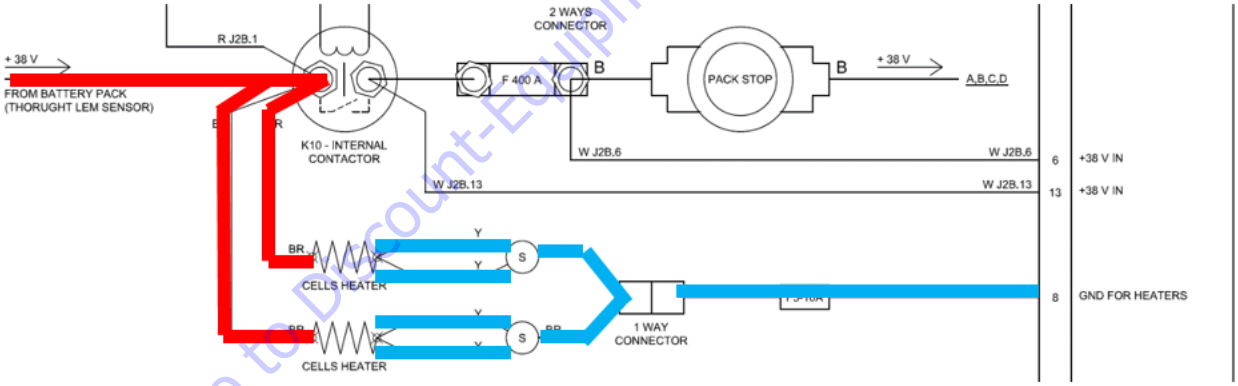
Heater - 38V





2 Heaters

60 W each one



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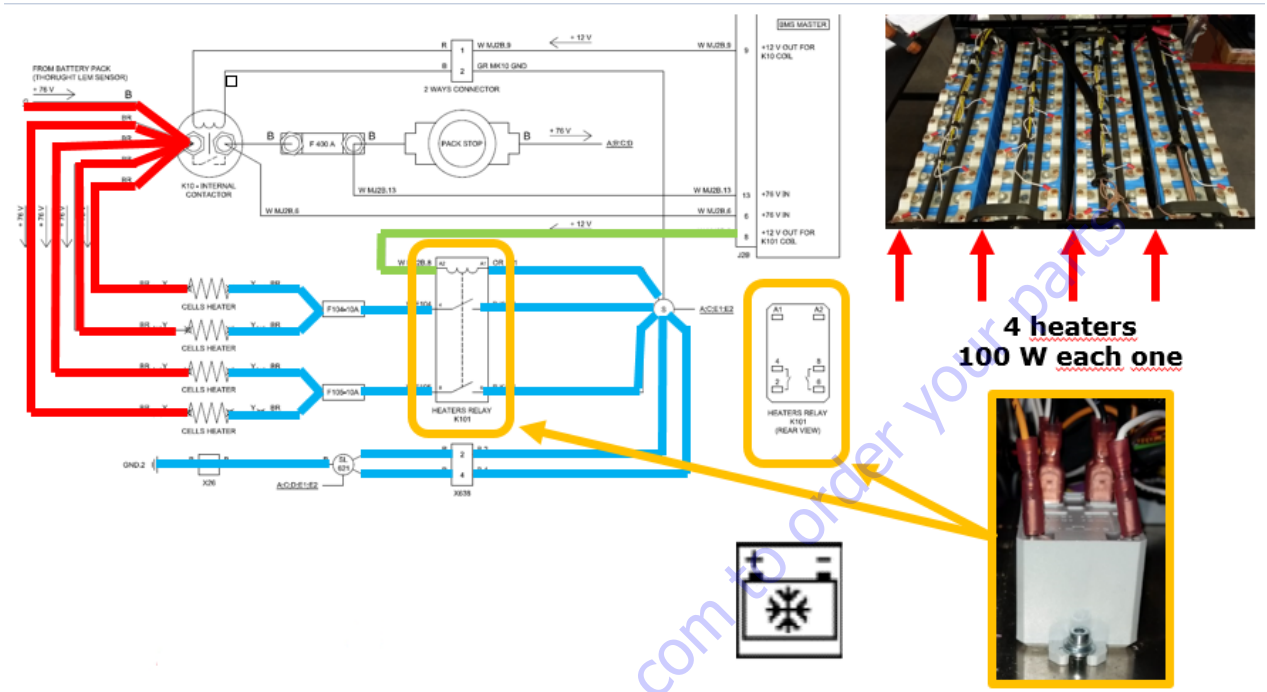
Heater - 76V/100AH



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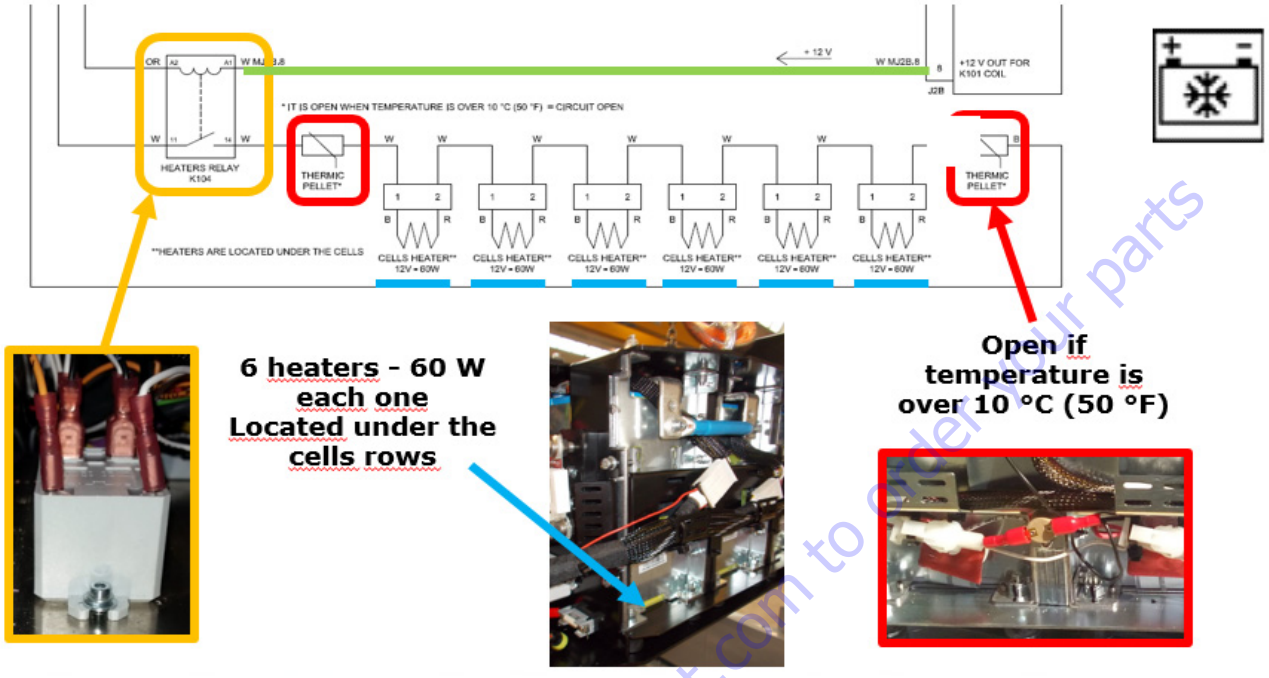
Heater - 76V/150AH



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Heater Function

- Start at -1°C (or lower); stop at +2°C
- Managed automatically by BMS
- From -20°C to + 2°C
- If SOC <1% they are in any case

NOTE: *If SOC < 1% heaters will work only if BC plug is connected.*

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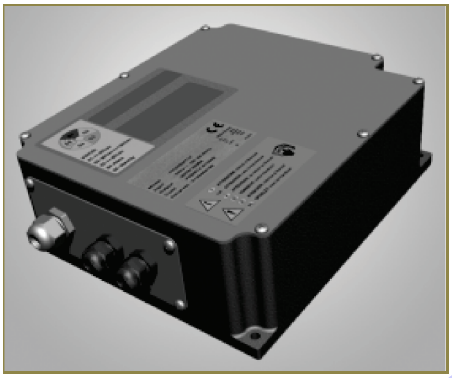
2.7 LITHIUM ION BATTERY PACK CHARGER

Battery charger changes the 110/230V, 50/60Hz current coming from the local network to 38/48/72/76/83V DC necessary to charge the cells.

The Inverter, the BMS and the battery charger are linked to the CAN BUS cable, The charger receives the required current to supply to the cells from the BMS through the CAN BUS cable.

In the initial phase of battery charging, the BMS controls the maximum current available from the charger, and afterward, the current will decrease according to the cells voltage level. The battery chargers have an LED with a flashing code which shows the state of charging process.



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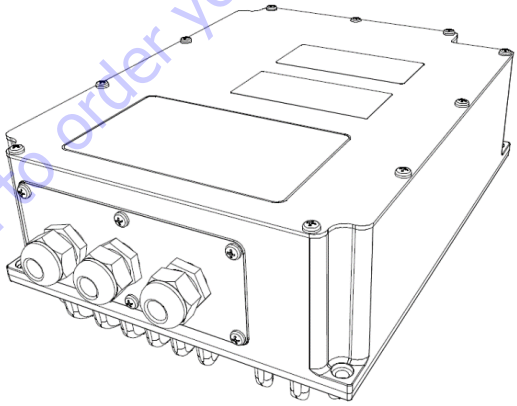
48 Volt Battery Pack Charger - 1st & 2nd Gen
38 Volt Battery Pack Charger - 3rd Gen

Figure 2-21. Battery Pack Charger

MAF11690

Figure 2-22. 83V Battery Pack Charger (2nd Generation)



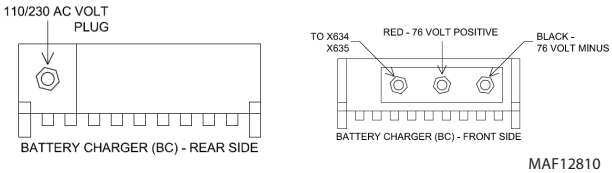


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Figure 2-23. 76V Battery Pack Charger (3rd Generation)

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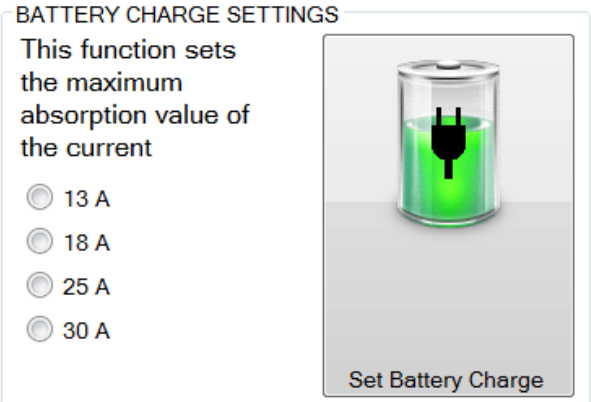
Lithium ION Battery Charger Setting (1st & 2st Gen)

Due to difference in the local power supply, the settings on battery charger can change the maximum current drawn from network from 18 A to 30 A. The difference on the setting is the time required for charge.



MAF11700

Configuration setting

ANSI US - 18Amp 48 volt - 13 Amp 72Volt

CE - 25 Amp 48Volt - 30 Amp 72Volt

Figure 2-24. Battery Charger Setting

On CE spec machines, the time required to completely charge a battery pack is approximately 4 hours, but after 2 hours the level will be at 80%. The BMS controls the battery charger to supply the maximum current for 2 hours (according the set-up mentioned above); sufficient time for at least one cell to reach 3630 mV. Then the BMS controls the battery charger to reduce the charging current.

The difference for the 72V and 83V battery pack is the current setting between CE and ANSI North America spec. This causes a difference in time necessary to reach the Equalization phase will be approximately 4 hours instead of 2 in case of ANSI North America spec machines. The equalization phase could be shorter as the cells level grows more consistent because the cells are supplied with lower current and as a result the cells will be almost equalized. The time required to charge a 72V battery pack on ANSI machine is 6-8 hours.

If a cell reaches an excessive voltage during the charging process, the BMS goes in emergency mode and it opens the internal contactor immediately.

It is possible to operate the machine when batteries are charging; in this condition if the current necessary for the movement is more than the maximum current available from the battery charger, the additional energy required by the system is utilized from the battery pack to run the electric motor.

Charge options :

1	Standard	2,2kW
2		1,2kW

MAF16970

Figure 2-25. Charger Set (3rd Gen)

Battery Charging and Discharging

Battery discharge condition

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Remote Control Display

All the cells will discharge together while machine is operating as they are connected in series. BMS constantly monitors the total voltage level and sends this value in the CAN BUS cable and the data is shown on the remote control display.

As soon as the voltage level drops to 20% or below, the remote control starts to beep to inform the operator that the battery pack level is low. If the voltage level drops to 10% or less, BMS reduces the current supply to the electrical motor to operate with the machine in a very slow speed. The operator to recharge the batteries before the complete discharge.

Battery level below 10% = Extra Low Speed

Complete battery discharge is not 100%. Even if the operator uses the machine until it stops, the cells cannot get damaged due to excessive low voltage. If one cell goes below a specific voltage level, the BMS decreases the speed or stops the machine by interlock of the internal contactor.

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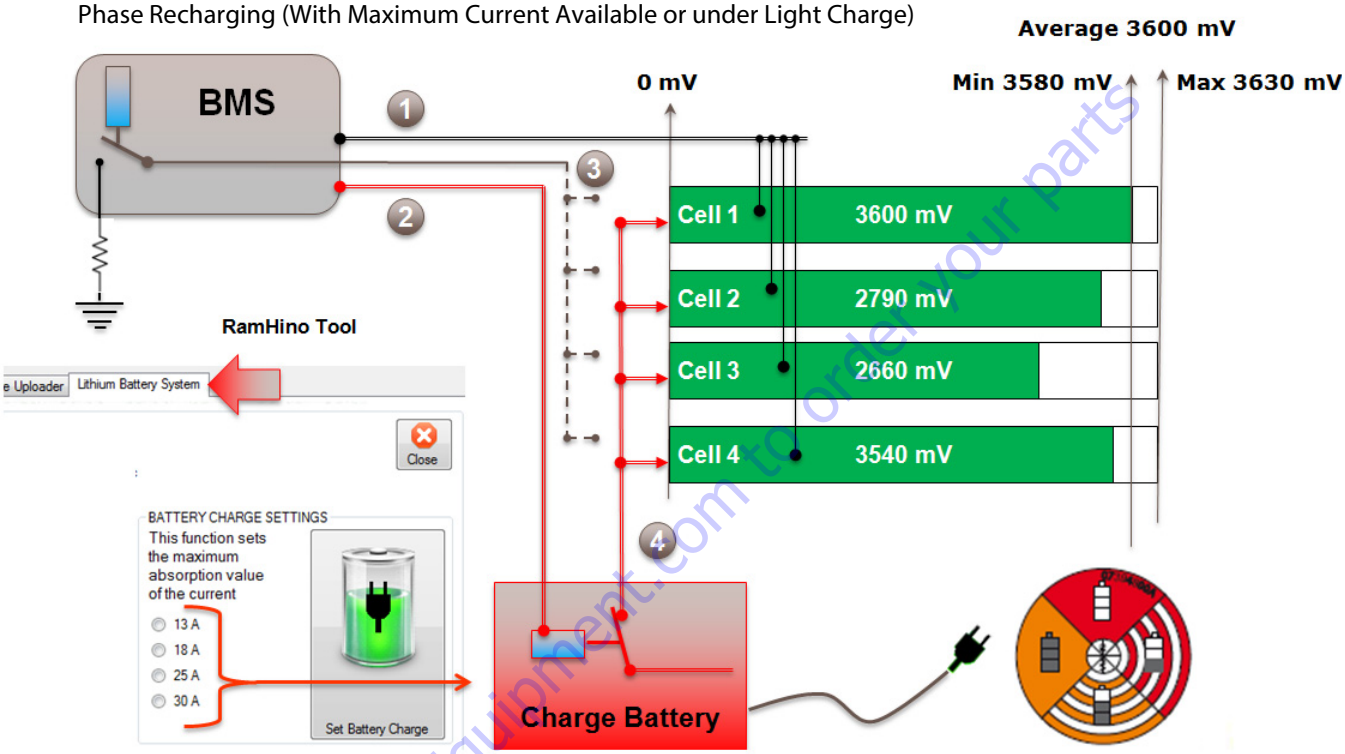
Theory of Battery Charging Condition

The Lithium ION Battery charging operation is a critical phase because all cells are connected in series and a single bad cell could effect the cycle time and the life of the battery pack.

At the start of battery charge, the BMS controls the charger to provide the maximum current (as per setting) and as soon as one cell reach the 3630 mV the BMS adjusts the charger to reduce the current supply.

Phase Recharging (With Maximum Current Available or under Light Charge)



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- 1 - Cells Voltage Measurement
- 2 - Signal to activate the charger and regulate the delivery amount of current
- 3 - Line connected to the resistance
- 4 - Power Supply Line

Figure 2-26. Charging Phases

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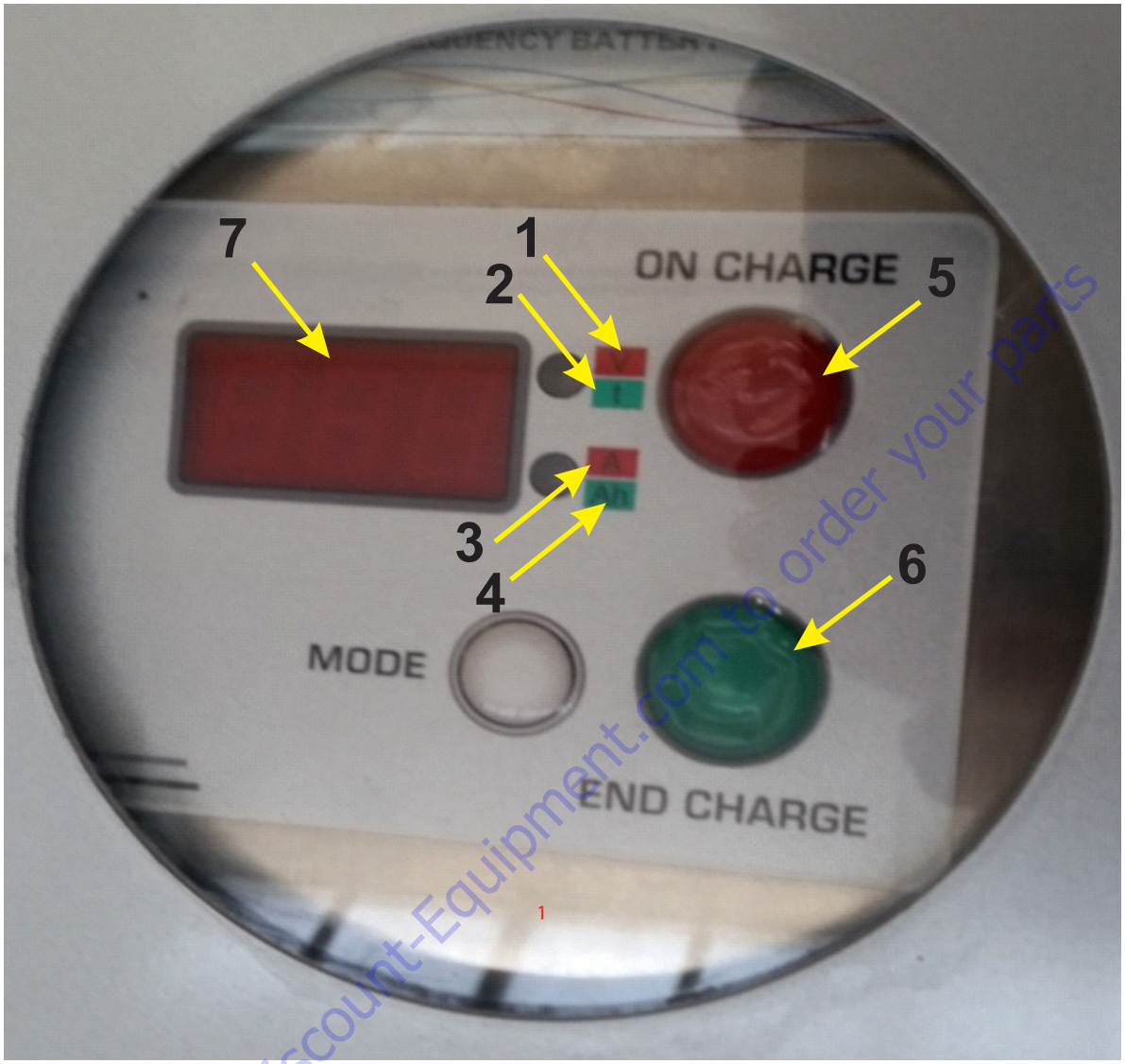

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1 - V - Battery Voltage

2 - t - Time remained on charge

3 - A - Actual current supplied

4 - Ah - Total current supplied

5 - Red Light - Steady On when charging

6 - Green Light - Blinking when Balancing

- Steady On when charged

7 - Display

Figure 2-27. Charge Indicator (76 Volt 100 or 150 Amp only)

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38Volt and 48Volt Battery Charger	
LED Light	Meaning
Red	1st charge step - Cells fully charged with the maximum current possible
Red Flashing	2nd charge step - Cells under charge with reduced current
Yellow Flash	3rd charge step - Cells under light charge
Yellow	4th charge step - Balancing and Maintenance
Green/Red Flash	Error - The Battery pack is disconnected

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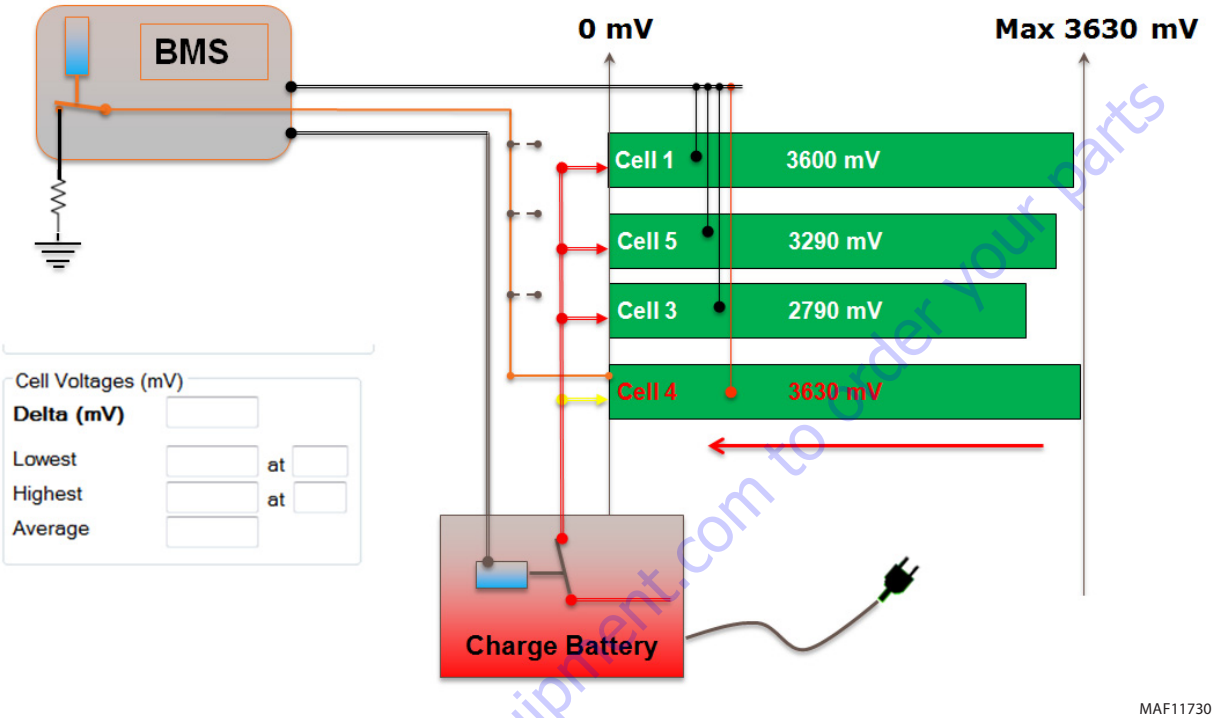
Phase - Equalization or Standby

When the condition of one cell reaches the maximum value admitted (3630 mV), the BMS connects the cell to the resistance; as a result, the cell changes the condition from charge to discharge for the time enough to drop the cell below 3630 mV, while the charger is always charging all other cells.

As soon as another cell reaches 3630 mV, the BMS connects the new high voltage cell to its resistance as described earlier.



Equalization or Standby Algorithm Charging

1st Generation BMS Algorithm Charging

1st generation BMS tries to get an average voltage cell of 3600 mV, so the result is; highest cell at 3630 mV and average is 3600 mV. The maximum difference between the highest and the lowest cell should be 50 mV or less. The last phase of the charging process is called “Equalization”. During this phase, the BMS manages the charger to send intermittent current feed to keep the cells at the same voltage level.

2nd Generation BMS Algorithm Charging

2nd generation BMS tries to get all the cells to minimum 3580 mV, so the perfect result is; highest cell at 3630 mV, Lowest cell at 3580 mV.The maximum difference between the highest and the lowest cell should be 250 mV or less. The last phase of the charging process is called “Equalization”. During this phase, the BMS manages the charger to send a very low current to keep the cells at the same voltage.

3rd Generation BMS Algorithm Charging

3rd generation BMS tries to get all the cells to minimum 3600 mV. The BMS The last phase of the charging process is called “Equalization”. During this phase, the BMS manages the charger to send a very low current to keep the cells at the same voltage. If a cell exceeds 3650 MV, the BMS connects it to resistance. If a cell exceeds 3700 mV, the BMS opens the internal contactor and Emergency State is initiated.

NOTE: *Maximum output voltage is 84,5 mV (each cell 3520 mV max, one charger for 120/230 V)*

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Charging Current

Maximum current required for the battery charger depends on the battery pack voltage and on the local network voltage 110 -230V.

For CE spec machines, the maximum current is set at:

- 25A for 48V battery pack
- 30A for 72V and 83V battery pack
- 18A for 38V battery pack
- 13A for 76V battery pack

For ANSI marked machines, the maximum current is set at:

- 18A for 48V battery pack
- 13A for 72V and 83V battery pack
- 18A for 38V battery pack
- 13A for 76V battery pack

NOTE: *These values are factory set, but can be changed locally by means of the RamHino Tool.*

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Battery Charging - Lithium ION

The condition of the Lithium ION battery is shown on the remote control display with the machine power ON, Icon shown below is displayed on the remote control display.

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If the machine is ON while charging, the LCD display on the platform control station also shows the machine charge indicator.

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The charge indicator is also displayed on the Lithium ION side case for 48V and 83V battery pack, while on undercarriage top frame next to the case, for the 72V battery pack as shown below. This indicator shows the current charge state of the Lithium ION battery pack.

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Lithium ION Charge Indicator

The indicator shows the present charge condition of the Lithium ION battery pack as specified in table below.

Table 2-5. Lithium ION Battery Charge Indicator

Battery Pack	1st Generation	2nd Generation	3rd Generation
38V and 48V Systems			
1st phase - recharging with max current available	Red Steady		
2nd phase - recharging with reduced current	Red Flashing		
3rd phase - Cells under light charge	Yellow	Yellow Flash	Yellow Flash
4th phase - Equalization/standby	Yellow Flash	Yellow	Yellow
72V and 83V Systems			
1st phase - recharging with max current available	Red Steady		-
2rd phase - Cells under light charge	Orange Flash		-
3th phase - Equalization/standby	Green Steady		-
76V Systems			
1st phase - recharging with max current available	-		Red Steady
2rd phase - Equalization/standby			Green Flash
3rd phase - End of charge			Green Steady
38V, 48V and 72V Systems Fault			
The battery pack is disconnected (contactor open)	Green/Red Flash		
83V Systems Fault			
The battery pack is disconnected (contactor open)	-	Green	-

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Lead-Acid Battery

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The Lead-acid Battery supplies power to switch on the ECM1-2 (1st & 2nd Gen) ECM 1 (3rd Gen) and the BMS. When BMS is ON, it closes the internal contactor and turns ON the DC-DC Transformer which then provides the 12-volt power for the machine system, demanding energy of the lithium pack. If the Lead-acid battery does not have sufficient charge or is fully discharged, the main board and the BMS will not be switched ON and the machine cannot start.

If the main key is ON and the voltage level of the battery pack is less than 20%, the EMC1-2 will turn OFF all the system after one hour of no implements activation.

If the key switch is left in the ON position, the Lead-acid battery will be preserved from complete discharge.

DC-DC Transformer

MAF11780

Figure 2-28. DC-DC for 38V/48V Battery Pack

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Figure 2-29. DC-DC for 72V/76V/83V Battery Pack

The BMS is powered by the 12V auxiliary battery, to ensure proper functionality even if the battery pack is completely discharged. It also powers the other ECM of the platform.

The charging process of this Lead-acid 12V battery is performed by an electronic board (DC-DC) which transforms the DC 38V/48V/72V/76V/83V of the battery pack into DC 12V to keep the auxiliary battery charged. DC-DC transformer is ON when the BMS is ON. When the machine is OFF and the battery pack is under charged DC-DC remains ON. The output voltage is approximately 13. 5 Volt. When DC-DC is ON, it supplies current to all the boards and the devices of the platform.

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Electric Motor

The electric motor is a three phase AC motor. It drives the tandem gear pump which supplies the hydraulic oil to the valve blocks of the hydraulic circuit, in the same method as on the twin power units.

On a CCB machine using Lithium ION Battery Pack, there is only one power system and hence one electric motor and one tandem hydraulic pump. The Inverter controls the electric motor RPMs according to input received from ECM1-2.

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Table 2-6. Electric Motor Characteristics

	38V Battery Pack	48V Battery Pack	72V Battery Pack	76V Battery Pack	83V Battery Pack
Electric Motor	3 Phase AC				
Nominal Voltage	38V	48V	80V	76V	80V
Power	2000 W	2000 W	3500 W	76 Volt 100 Amp 3500 W 76 Volt 150 Amp 6000 W	3500 W
Maximum RPM	2550			2550	2550

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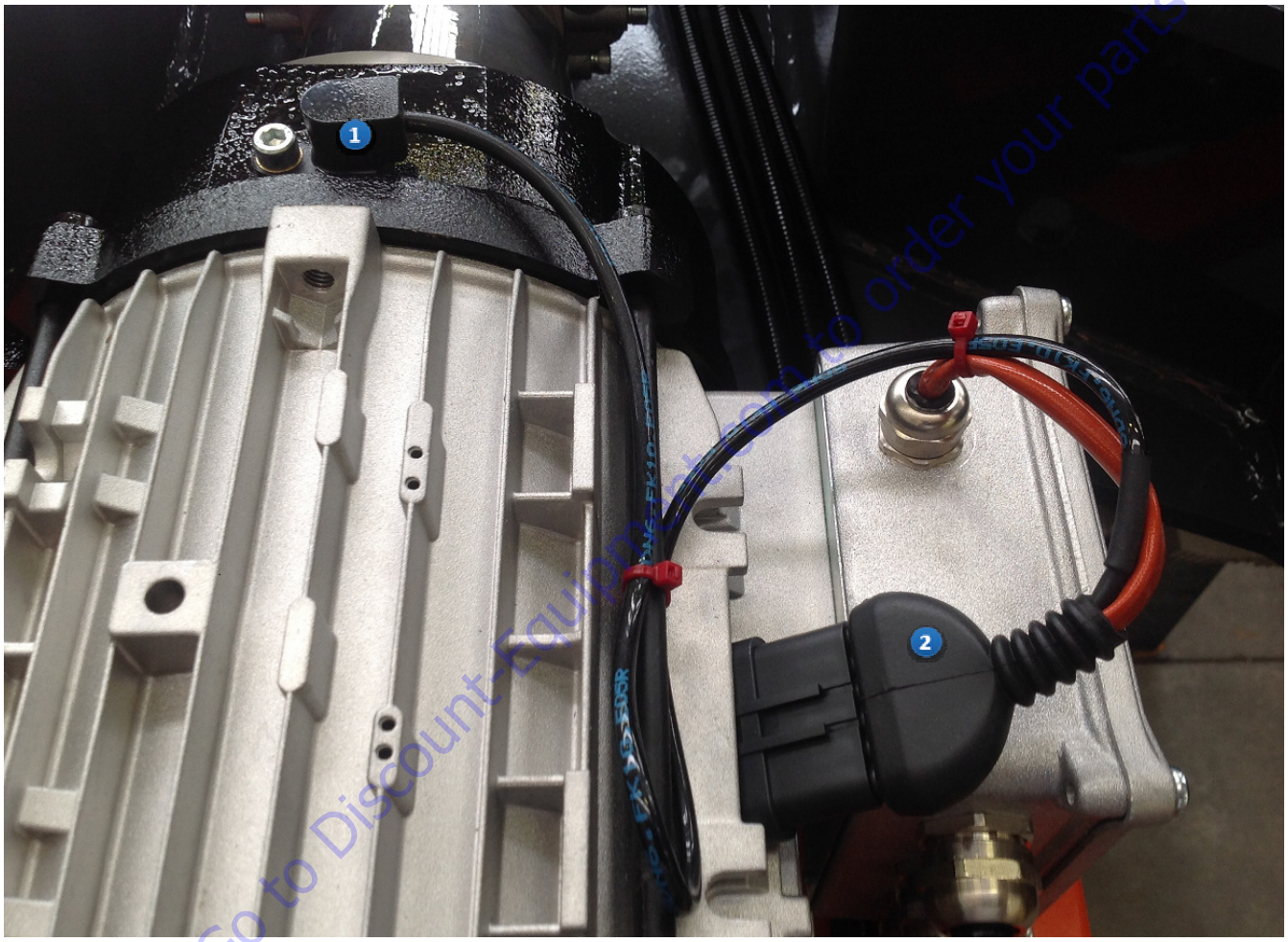
RPM Speed Sensor and Temperature Sensor

The electric motor has a RPM speed sensor (1) and a temperature sensor (2). The RPM speed sensor notifies the inverter about the actual rpm, and according to oil request from the system, the inverter adjusts the rpm.

Managing the RPMs allows for optimal performance and less current or battery consumption. For example, while driving, the motor must run at the highest RPMs, while movements such as jib arm or platform rotation need requires lower RPMs.

Reducing the rpm saves energy and extends the operational autonomy of the battery.



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NOTE: *On 3rd Gen it is also possible to check the motor RPMs in the menu INPUT.*

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Inverter and Main Relay

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Figure 2-30. Inverter - 38V/48V Battery Pack

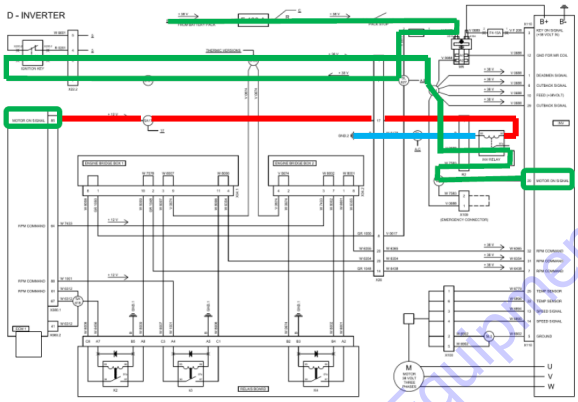

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Figure 2-31. Inverter - 38V/48V/76V RPM Management

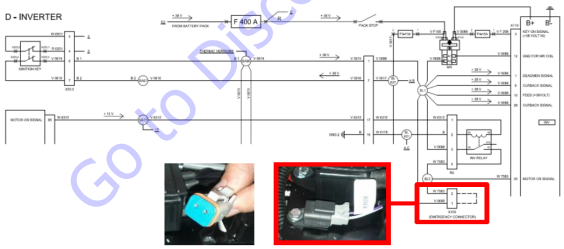

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Figure 2-32. Inverter - Emergency Motor 38V/48V/76V

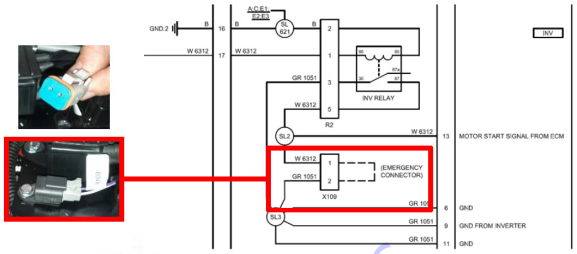

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Figure 2-33. Inverter - 72V/83V/76V 100Amp

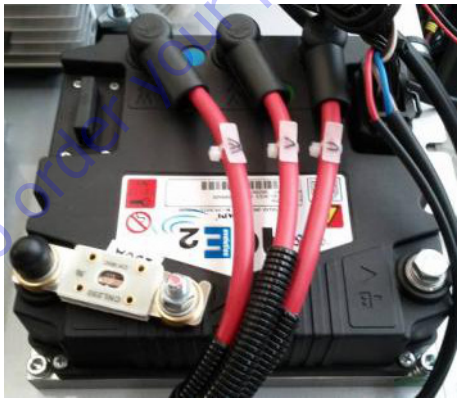

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Figure 2-34. Inverter - 72V/76V/83V Battery Pack

NOTE: *72V/76/V/83V 100Amp RPM motor adjustment by relay contacts.*

NOTE: *76V 150 Amp RPM motor adjustment via CAN BUS.*

Inverter has the following functions:

1. To Transform the Direct Current coming from the Battery pack into 3 phase Alternating Current.

   The 3 phase AC electric motor controls on the rpm (and the current or battery consumption), and operate on the frequency without restrictive torque and machine's performances.

2. To feed the external main contactor.

   Under the normal conditions (no errors) the inverter supplies power to the external main contactor (relay) to close the line. This contactor is connected in series with the internal contactor controlled by the BMS, located inside the battery pack. If the contactor is not closed while the machine is operating, the movements are not possible as the electric motor cannot get power supply.

NOTE: *Inverters have the same hardware but different software.*

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Figure 2-35. External Main Contactor

3. To supply and control the electric motor.

   The inverter controls the electric motor through an rpm sensor and a temperature sensor located on the motor. It reduces the rpm when power required is high. If the motor torque required is high, the inverter constantly reduces the rpm to avoid excessive battery consumption which is detrimental for battery performance.

   Ground module ECM1-2 controls the rpm through the inverter according to the function activated by the operator. To optimize the performances and keep the movements smooth, these communications are performed by a series of switches inside ECM1-2.

   The Inverter controls the condition of low level battery pack. When the battery charge level reaches 10% of the total capacity (this information is provided by the BMS through CAN BUS), the inverter reduces the motor rpm and reduces operation speeds.

   Thus, the operator is informed about the need to charge the batteries even if the machine can be operated for limited time.

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2.8 RELAYS

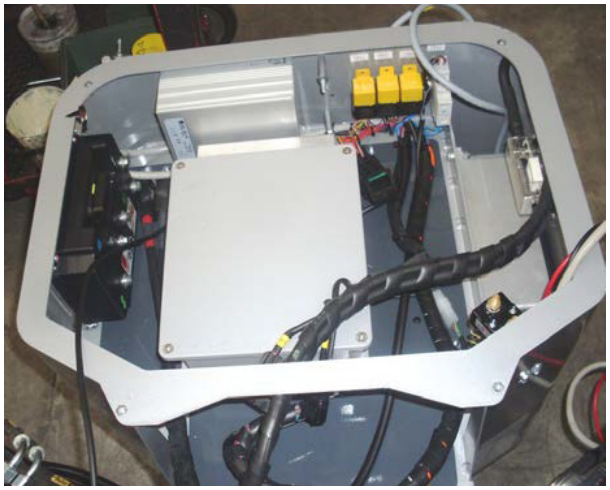

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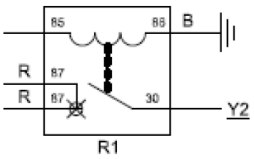
Figure 2-36. Relay Location



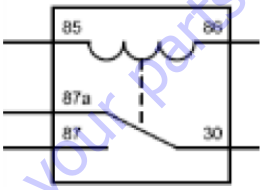


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Figure 2-37. Relay

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Table 2-7. Relay Function

Relay Number	48VBattery Pack	72V/83V Battery Pack	38V/76V Battery Pack
R1	BMS Activation	BMS Activation	BMS Activation
R2	Connection Lead-acid Battery to DC-DC	Connection Lead-acid Battery to DC-DC	Inverter Running Consent
R3	BC Activation from BMS	-	-

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CAN BUS Communication

The battery pack has a CAN BUS line that connects the BMS to the Battery charger and Inverter. This CAN BUS System is connected to the CAN BUS machine system.

For 1st & 2 Gen - Unique CAN BUS cable for machine and lithium system, as connected together.

For 3rd Gen - 5 CAN BUS lines. The CAN BUS cable number 4 is for lithium system.

CAN Bridge Box (X700AJ and X23J only)

The CAN Bridge Box is installed only on the 72 Volt Battery Pack. The function of the CAN Bridge Box is to link machine system CAN BUS cable with Lithium Battery pack CAN BUS cable to avoid too many messages in the CAN network. This reduces the possibility of wrong messages. The CAN Bridge Box is an opto-isolator component that supplies electrical signal between two isolated circuits by using light.

NOTE: *ECM1-2 supplies power to the CAN Bridge Box. If the Machine is OFF, the CAN Bridge Box will not function.*

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NOTE: *On 2nd Gen X23JP /X700AJ only and on 3rd Gen all models is not possible read data of the lithium system with the machine OFF. On 1st & 2nd Gen all models (Except the X23J/ X700AJ) even with machine OFF it is possible read data from the lithium system once the battery charge is ON.*

MAF11870

Figure 2-38. CAN Bridge Box (X700AJ and X23J only)

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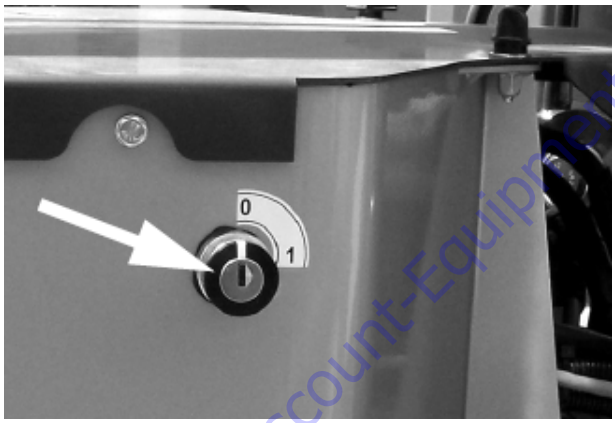
Lithium Battery Condition Display Icon and Warning Purposes

On LITHIUM ION machines, during start and machine operation there are additional icons displayed on the main LCD screen than those shown for the machine operation status. These icons are selected for the operation of the battery pack system.

MAF11910

Make sure to connect the local supply power cable to the machine when key is in OFF position only. If it is not connected with key in OFF position, the display will show an error code.



MAF11920

MAF11930

NOTE: *It is possible to use all functions and the system error icon disappears when the machine is restarted.*

Some icons displayed on LCD display screen are shown below.

1. Battery Under Charge

   The Battery Under Charge icon appears when the plug socket is connected to local electrical supply network. The machine can be used in this condition.

MAF11940

2. Battery Pack Charging Level

   This displayed appears when the battery pack voltage level is below 10%. In this condition, the machine runs at limited speed and requires the operator to connect the local supply power cable to charge the battery.

MAF11950

3. System Error Alert

   Restart the platform from the main key when this icon appears on the display.

MAF12000

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4. Extra Low Speed

Check the Error Menu in remote control diagnostic when this icon is displayed.

MAF12010

5. Battery Percentage

When the lower temperature of any cell falls below 0 °C (32 °F), the machine runs in low mode only; then the icon "battery cold " is shown on the display.

MAF12020

MAF11910

SOC	CHARGE LEVEL ICON
0-10%	
11-20%	
21-50%	
51-80%	
81-100%	

6. BMS Logic - Discharging

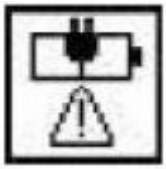
1st Step : Battery Level <20% = Beep on Remote Control

2nd Step : Battery Level <15% = Low speed (Only (72V/150Ah)

2nd Step : Battery Level <10% = Extra Low Speed (No 72V/150Ah)

3rd Step : Battery Level <4% = Ultra Low speeds (Only for 3rd Gen)

4th Step : Battery Level <0% = Connect the Plugs



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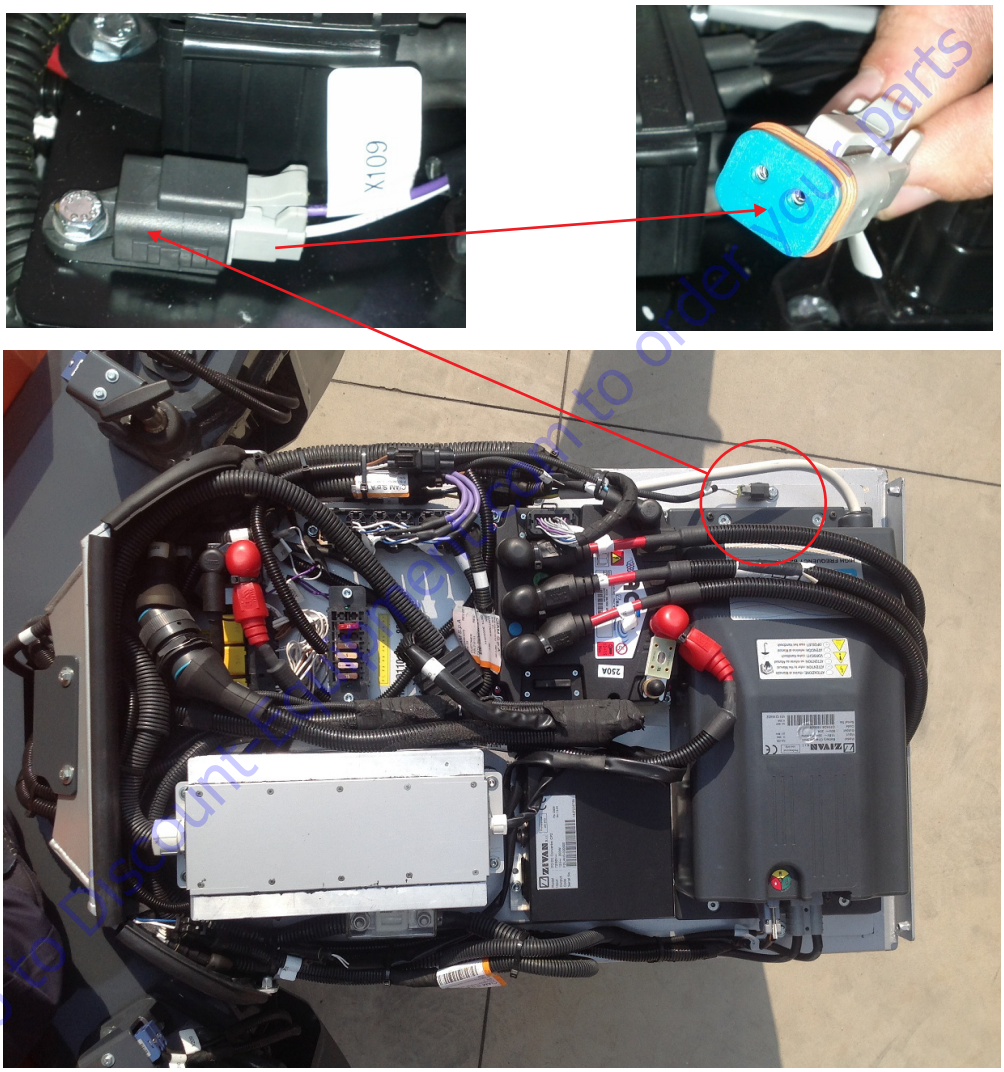
2.9 EMERGENCY ELECTRIC MOTOR OVERRIDE

The electric motor can be activated in an emergency (running at min RPM) with a by-pass on the electrical system. The override procedure is as follows:

1. Turn OFF the Battery Switch
2. Bridge the points as shown below
3. Turn ON the Battery Switch

NOTICE

DURING THE OVERRIDE, THE SAFETY CONTROLS OF THE MACHINE ARE NOT ACTIVE. USE THE OVERRIDE METHOD FOR EMERGENCY ONLY. REMOVE THE JUMPER BRIDGE AS SOON AS THE OPERATOR REACHES THE GROUND.



MAF12030

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NOTICE

In case of failure of the master board (ECM modules), BMS does not start as the supply for BMS comes from ECM modules. If BMS is off, it is not possible to turn on the motor as the inverter does not get any supply from the cells. In such case, connect the battery charger to the local network to start the electric motor. The BMS will be switched on by the battery charger. If the local network is not available, the BMS can be switched ON manually by connecting the wires on the pins A29 and A30 to the ECM modules.

NOTE: *JP series machines have a connecter plug X109 to make the emergency override easy. Remove the connector X109 from its housing and put a bridge by - pass.*

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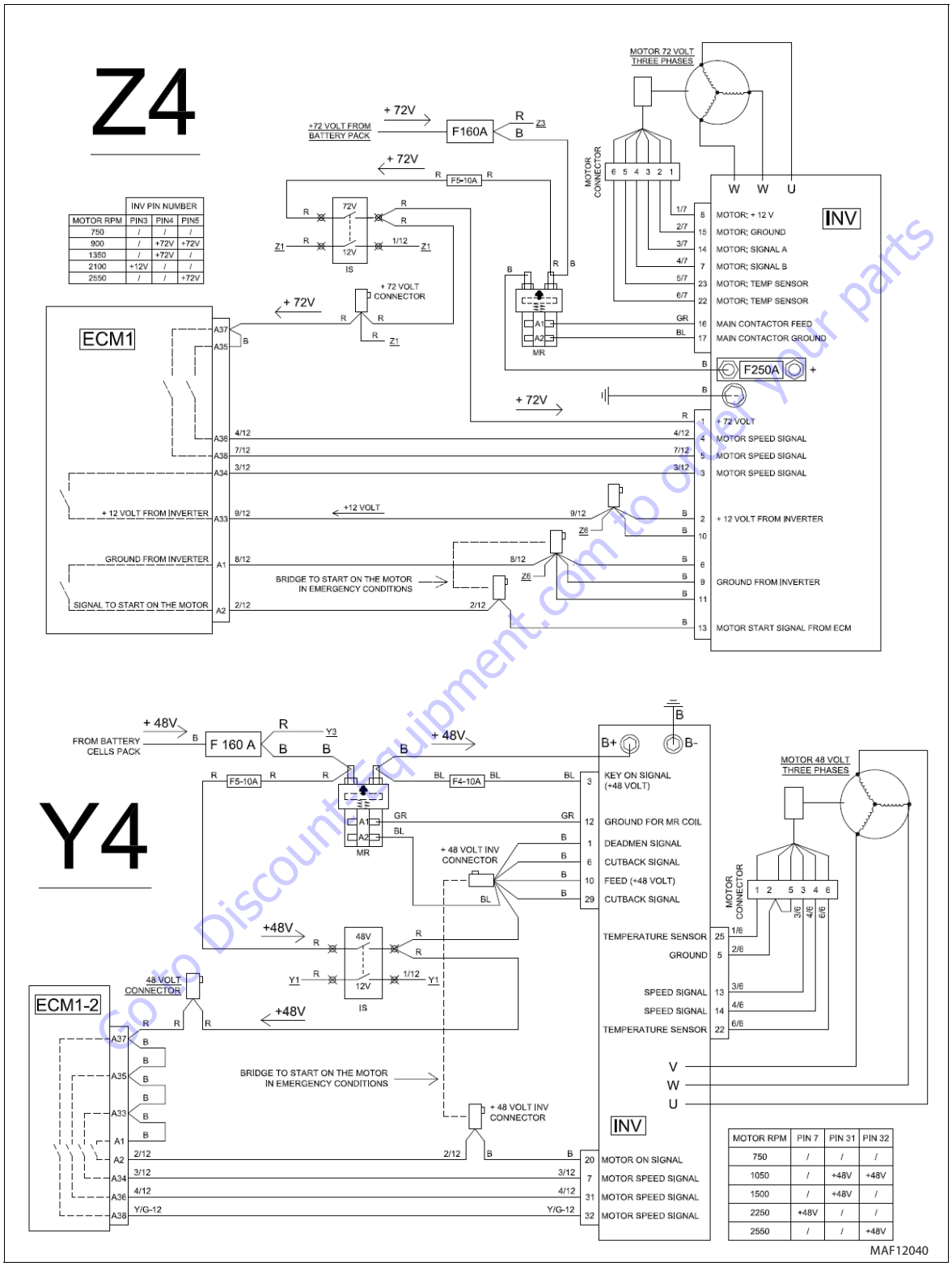

Figure 2-39. Electrical Motor Bypass

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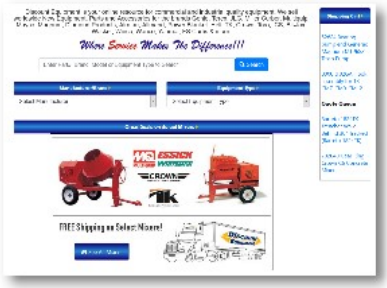

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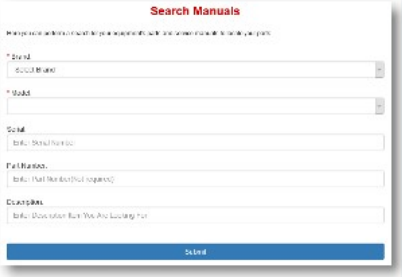

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SECTION 3. TROUBLESHOOTING AND FAULT CODES

3.1 FAULT CODES

Battery charger, Inverter and BMS have a self diagnosis system and trouble codes are displayed in case of failures. These trouble codes are displayed on the remote control display.

The display shows a key icon when there is an error.

MAF12000

When the key icon is displayed, switch OFF the machine and switch ON. If the key icon disappears, machine operation can be continued. If the key icon is still displayed, refer trouble failure code using the instructions below.

Press Button 6 on the remote control (service), then press button 3 (errors), then press button 1 (prev) until the below page is on display.

9

The page shows the BMS, Inverter and battery charger trouble codes. Zero means there is no error.

- BMS - BMS trouble codes
- INVER - Inverter trouble codes
- CARIC - Battery Charger Trouble codes

NOTE: *In case of BMS failure, it is possible to diagnose the system by connecting the RamHino device tool only.*

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Table 3-1. BMS Fault Codes (1st and 2nd Generation Battery Pack)

Error Code	Error Description
01	System Configuration Error
02	Unexpected Voltage
03	Unexpected Temperature
04	Overcurrent Discharge
05	Overcurrent Charge
06	Pre-charge Error
07	No 12 Volt Supplies
08	No 12 Volt Supplies
09	Battery Over temperature
10	Electronics Over temperature
11	Bad Temp Sensor Auto Shut Off Mode
12	All Temp Sensor Broken
13	Broken Temperature Sensor Detected
14	Grunding Fault Error
15	No Bootloader Error
16	Second Protection
17	Watchdog Error
18	Power Board Alarm
19	I2C Module Not Ready
20	I2C TX Error
21	I2C RX Error
22	I2C RX Error 2
23	AD Error
99	General Error

NOTE: *When the display shows a BMS fault code, analyze the system by connecting RamHino software to the machine.*

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Below are some examples of BMS error

- 02 - Unexpected Voltage

  When one cell reaches 3650 mV, the BMS will disconnect the lithium pack and the system will show the “UNEXPECTED VOLTAGE” error. This could be caused by BMS failure to not identify one cell or cannot connect it to the discharging resistance.

- 05 - Overcurrent Charge

  If the lithium pack is warm, and one cell is at the maximum voltage, and the battery charger is suddenly connected for a while, one impulse of current will be supplied to the pack. This could cause the system to show the “OVERCURRENT CHARGE” error.

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Table 3-2. BMS Fault Codes (3rd Generation Battery Pack)

CODE (DEC)	CODE (HEX)	Error Description
1	0001	OVER-VOLTAGE: HIGHEST CELL >= 3650mV (till 3800mV is allowed the discharge at the next connection)
2	0002	UNDER-VOLTAGE: LOWEST CELL <= 2850mV (till 2000mV is allowed the charge at the next connection)
4	0004	OVER-TMPERATURE: HIGHEST TEMPERATURE > 70°C
8	0008	UNDER-TEMPERATURE: LOWEST TEMPERATURE < -25°C
16	0010	OVER RESISTANCE: Internal resistance estimation value has a greater variation than 10 mOhm in 1 second
32	0020	DISCHARGE OVER CURRENT: 200A for more than 1 sec. or CHARGE OVER CURRENT: 120A for more than 1 sec
64	0040	NO ERROR IS MAPPED NOW
128	0080	OVER-TMPERATURE: BOARD TEMPERATURE > 100°C
4096	1000	Despite attempts to self-restore, the communication loss with internal electronics devices persists for more than 10 seconds
16384	4000	(ONLY for MASTER-SLAVE configuration) If the BMS SLAVE is in SAFE the error is triggered
32768	8000	BMS CAN BUS restore failed for more than 10 consecutively times

NOTE: *When the display shows a BMS fault code, analyze the system by connecting RamHino software to the machine.*

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Table 3-3. Inverter Fault Codes

Error Code	Error Condition	Error Description	Corrective Action
1	Wrong Config	Eeprom memory not configured.	Contact JLG.
8	Watch Dog	The inverter is not able to activate or turn off the electric motor.	Control connections and continuity of the electric motor. If they are OK replace the inverter.
8	Flash Checksum	Software is corrupted or inverter is damaged.	Replace the inverter.
13	Eeprom KO	Hardware or Software problem in Eeprom.	Replace the inverter.
16	Aux output KO	Electromechanical brake problem.	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
17	Logic failure #3	Activates in case of high peak of current in the inverter.	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
18	Logic Failure #2	Fault in the inverter.	Replace the inverter.
19	Logic failure #1	An overvoltage or a sudden voltage drop occurred.	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
26	Current Sens KO	Current sensor for the motor phases is damaged.	Replace the inverter.
27	Phase KO	One of the motor phases is open.	Check the connection from the inverter to the motor.
28	Pump Vmn Low	Pump motor output is too low.	Check the electric motor connection.
29	Pump Vmn High	Pump motor output is too high.	Check the electric motor connections.
30	VMN low	Inverter supply voltage is lower than the batteries' one, or the connection with the positive terminal of the battery is not correct.	Control the connection with the positive terminal of the battery. If the anomaly persists, replace the inverter.
31	VMN High	One motor phase is not correctly connected or is broken.	Control motor phases and motor internal connections. If the anomaly persists, replace the inverter.
37	Contactor closed	The relay remains closed with power to the coil disconnected.	Control the relay.
38	Contactor Open	The inverter supplies power to the relay coil, but the contact does not close.	Control the relay and the power to the coil.
40	Aux driv Shrt	When the mos of EB is shorted.	Check the battery feed.

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Table 3-3. Inverter Fault Codes

Error Code	Error Condition	Error Description	Corrective Action
41	Wrong Set Battery	The battery voltage is too low or too high.	Check the battery voltage.
42	Aux driver open	Driver of EB coil is damaged (not able to close).	Replace the inverter.
47	Epv2 not ok	Evp2 driver is failed shorted.	Check the inverter feed.
48	Epv1 not ok	Evp driver is failed shorted.	Check the inverter feed.
49	I=0 Ever	Feedback current from motor's sensor not constantly kept at 0.	Control the connection with the motor
50	Evp1 coil open	Evp1 coil in not connected.	Check the main relay; replace the inverter
51	Evp2 coil open	Evp2 coil in not connected.	Check the main relay; replace the inverter.
53	STBY I high	Fault detected in the inverter.	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
53	Wrong Zero MDI Can Code Alarm	Wrong voltage signal from amplifiers.	Replace the Inverter.
54	Logic Fail #1	Overvoltage/ Under voltage condition has been detected.	Check the feed on the inverter (12V and 48/72V).
55	Logic fail #2	Motor Voltage feedback circuits are damaged.	Replace the inverter.
60	Capacitor Charge	Problem in the inverter.	Control the inverter connections and supply; replace the inverter.
61	High temperature	Temperature rise in the inverter.	Allow better cooling to the inverter. If the anomaly remains, contact JLG.
65	Motor temperat	High motor temperature.	Stop the machine temporarily to enable motor cooling.
67	Can Bus KO	The inverter does not receive any information from CAN BUS line.	Control the connections with the multi-function tool
68	Smart Driver KO	Smart driver is open, not able to provide EB positive.	Check the inverter supply and connections; replace the inverter.
70	Encoder Error	Anomaly detected on encoder (= engine rpm sensor).	Control the rpm sensor connection. The anomaly may also be caused by a bearing fault.
72	Vmn low	Motor output voltage lower than expected.	Check the connections from the inverter to the electric motor; check the internal electric motor connections.
73	Thermis sensor KO	The signal from the temperature sensor is higher than 4.95 Volt or lower than 0.1 Volt.	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.

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Table 3-3. Inverter Fault Codes

Error Code	Error Condition	Error Description	Corrective Action
74	Driver shorted	Anomaly to the relay supply.	Control relay supply. Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
74	Aux Batt short	Coil on the AUX output is not correctly connected.	Check the connections with the main relay, check the inverter supply; replace the inverter.
75	Driver shorted	Anomaly to the relay supply.	Control relay supply. Usually it is a temporary anomaly due to a working condition. In case the anomaly remains replace the inverter.
76	Coil shorted	Anomaly detected in the relay coil.	Control the integrity of relay support.
76	Key off shorted	Key-off signal is low at key-on.	Check the 12-volt battery and its connections, check the DC-DC and its connections, check the inverter connections; replace the inverter.
77	Contactor open	Main contactor is not closed even if fed by the inverter.	Check the main contactor.
77	Tiller Error	Input mismatch between hard & soft switch input and tiller input.	Check the CAN BUS Line connections.
78	VACC not OK	-	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
79	Incorrect start	Starting procedure not correct.	Control the electric connections. Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
80	Emergency MDI CAN code alarm	Emergency MDI code alarm	Check the inverter feeds.
82	Encoder Error	Problem on the encoder.	Check the connections from the inverter to the electric motor; replace the inverter
86	Pedal wire KO	-	Usually it is a temporary anomaly due to a working condition. In case the anomaly persists replace the inverter.
86	Pos EB shorted	Output not correct.	Check the inverter connections; replace the inverter.
89	Power MOS shorted	Short circuit in the power mosfets.	Replace the inverter.

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Table 3-3. Inverter Fault Codes

Error Code	Error Condition	Error Description	Corrective Action
93	Wrong set batt	With supply ON, the control test detected batteries not in conformity.	Replace the batteries with the original one only.
94	Current sensor KO	Max current setup procedure active.	Contact JLG.
96	Analog Input	Problem on the A/D conversion of uC.	It should be a temporary error, if the problem occurs permanently replace the inverter
99	Checkup needed	-	Contact JLG.

NOTE: *Before starting the diagnosis with fault research, control the voltage level of the battery pack.*

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Table 3-4. Battery Charger Fault Codes (38/48/72/83V Battery Pack)

Error Code	Error Description	Status	Corrective Action
8	Internal logical Fault	Battery charger stops working.	Contact service dept. Or change product.
13	Communication problem with external memory	Battery charger stops working.	Contact service dept. Or change product.
18	Extended shutdown or power failure	Battery charger stops supplying power. Operation resumes as soon as alarm conditions are no longer present or after restarting.	If problem is a power failure, check battery charger mains power supply.
19	Internal logical Fault	Battery charger stops working.	Contact service dept. Or change product.
240	Digital input is open and managed as hardware start.stop	Battery charger stops charging until digital input closes	Close digital input.
241	Problem in CAN BUS communication with other systems in the network	The way this is managed may change based on different firmware releases.	Check correct operation of CANBUS system.
242	Error when reading internal memory on microcontroller	Battery charger stops working.	Contact service dept. Or change product.
242	Error when reading internal memory on microcontroller	Battery charger stops working.	Contact service dept. Or change product.
244	Mains voltage lower than maximum operating range tolerance	Battery charger won't start charging until mains voltage returns within normal operating range.	Make sure mains voltage is within correct operating parameters.
245	Abnormal current draw in primary section	Battery charger stops supplying power. Operation resumes as soon as alarm conditions are no longer present.	If problem persists, contact service dept. or change product.
246	Stage 1 ended by timeout without reaching control voltage	Battery charger stops working.	Make sure battery capacity is compatible or check that battery is compliant with Battery charger. If battery is correct and problem persists, contact service dept.
248	Temperature inside battery charger too high	If internal temperature exceeds 80°C, battery charger reduces power to 80%, while it stops operating altogether if internal Temperature exceeds 90°C.	Battery charger starts at full power again when internal temperature falls below 70°C
249	Battery temperature too high	If temperature exceeds 55°C or is less than -20°C, battery charger stops working.	When battery temperature falls below 45°C or exceeds -10°C battery charger resumes normal operation.

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Table 3-4. Battery Charger Fault Codes (38/48/72/83V Battery Pack)

Error Code	Error Description	Status	Corrective Action
251	Power failure detected	Battery charger stops supplying Power. Operation resumes as soon as alarm conditions are no longer present.	If problem persists, check battery charger mains power supply.
252	Short-circuit in battery charger output	Battery charger stops working.	Turn off battery charger and resolve short-circuit at output. If problem remains, contact service dept. Or change product.
253	Mains voltage higher than maximum operating range tolerance	Battery charger won't start charging until mains voltage returns within normal operating range.	Make sure mains voltage is within correct operating parameters.

Table 3-5. Battery Charger Fault Codes (76V Battery Pack)

Error Code	Alarm Type	Description	Stop
A01	Logic failure #1	Trouble on current detection	Yes
A02	CAN BUS KO	Trouble on CAN communication	No
A03	Watchdog	Logic board mis-working	Yes
A05	High battery temperature	Battery temperature higher than 55°C	Temporary
A07	Overcurrent	Over current	Temporary
A08	High temperature	Battery charger high temperature	Temporary
A09	Mismatch Voltage	Battery voltage sensing error	Temporary
A10	Timeout	Phase 1 finished for timeout	Yes
A11	No mains presence	Input grid failure	Yes
A13	Battery Disconnected	Battery disconnected	Temporary
A14	Short output	Short circuit at output stage	Yes
A15	Thermal sensor failure	Thermal sensor not connected or failed	No
A16	Logic failure #2	Logic supply failure	Temporary
A17	Low mains level	Mains level too low	Temporary
A18	Eeprom checksum	Eeprom memory corrupted	Yes
A20	RTC/Eeprom KO	RTC/Eeprom handling error	Yes
A21	Flash checksum	Microcontroller flash corrupted	Yes
A22	High main level	Mains level too high	Temporary
A23	Power failure #1	Output current sensing circuit damaged	Yes
A24	Wrong input mains	Input mains level out of operating range	Yes

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3.2 BATTERY SYSTEM TROUBLESHOOTING (1ST & 2ND GEN)

NOTICE

IN CASE OF BATTERY PACK PROBLEMS PLEASE REFER TO THE TROUBLESHOOTING FOR 48 VOLT BATTERY PACK OR 72 VOLT BATTERY PACK AS APPLICABLE. CONNECT RAMHINO DEVICE TO THE MACHINE BEFORE WORKING ON THE PACK COMPONENTS.

NOTICE

TO RUN DIAGNOSTIC ON THE LITHIUM SYSTEM, IT IS NECESSARY TO HAVE THE COMPLETE WIRING DIAGRAM AND THE RAMHINO SOFTWARE (5.0 OR LATEST VERSION) INSTALLED. ONLY AUTHORIZED PERSONNEL CAN MANAGE AND OPEN THE BATTERY PACK.

48V Battery Pack (Prior to SN C170000330)

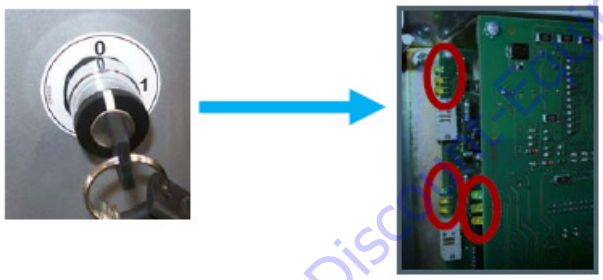
Some potential concerns and possible corrective actions are listed below for 48 Volt battery pack.

A - Remote control display is always OFF

1. With the key switch in ON position, open the main board electric box and check the LED on the main board.

   If ON go to step 2

   If OFF go to step 3



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2. LED on the main board are ON

   If the LED are ON then the main board is also ON, so the remote control failure is not because of the Lithium system. Refer the wiring diagram to check the remote control feed.

3. LED on the main board are OFF

   Check the 12V Lead-acid battery; it supplies power to all the boards during the ignition. If Lead-acid is not OK, the machine will remain off.

   Check the voltage on the 12V switch under the key switch. IF red wire to the ground has 12 Volt, go to step 4, if not go to step 5.

MAF12070

4. Red wire has 12 Volt

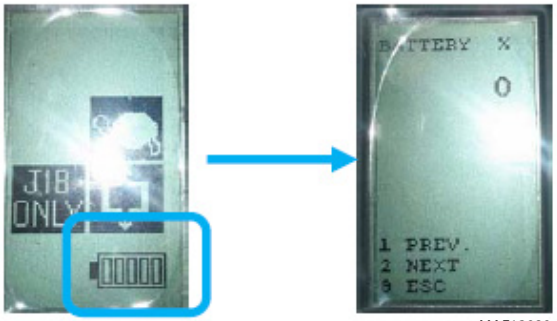
   Check the 12 Volt switch under the key switch, and check the connection of the wire 1/12, from the key switch to the pin B1 in the master board.

5. Red wire does not have 12 Volt

   Check fuse F6, then check the supply from 12V Lead-acid battery to fuse F6 (= ead-acid battery + feed connector + R1 + 2 ways connector).

B - Battery package level is "zero" even after the charge

Check the value in the INPUT menu, press button number 6 "service", then press 1 "input", then 1 "previous". Press button number 9 "Esc" to go back.



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If external electrical power is available, connect the 110-220V power cord and check the battery charger light after two minutes.

If the battery charger light flashes red, go to step 6.

If the battery charger light flashes green/red, go to step 7.

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6. Connect the power cable, the battery charger light is red after two minutes.

The system works correctly. Keep the power cable connected until the light on the battery charger will flash yellow. Test the machine again, if the problem remains, go to step 9.

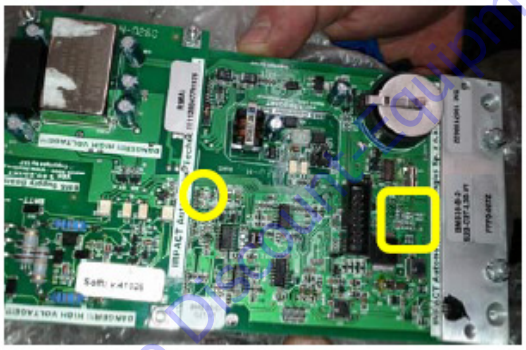
7. Connect the power cable, the battery charger light flashes red/green after two minutes.

This condition indicates the battery charger does not find the 48V battery package. Check fuse F1, then check fuse F3, then check the gray/red wire connected from the pin no. 5 of the "6 ways BC connector" to the pin no. 2 of the "5 ways BMS connector of the BMS. Check the connection from the "5 ways BMS connector" of the BMS.

If all the connections and supplies are ok, go to step 8, if not go to step 9.

8. All the connections and the supply are ok.

Check Relay no. 3 (or 2, depending on the serial number of machine) and its connection, open the BMS cover and check if the feed to red LED are ON (yellow circle) and check if the Can Bus green LED are ON (yellow square) as shown below.



MAF12090

If all the connections are ok but there is no supply to LED on the BMS, replace the BMS.

If the supply to the connections and LED are ok, but the CAN BUS LED are OFF, check the CAN BUS connections.

9. Battery charger works ok, but the battery level indicated on the display remains "zero".

If wrench icon appears on the display as shown below, go to step 10, if not go to step 17.

MAF12000

10. Wrench icon is shown on the display.

Check the trouble codes, push button no. 6 (service), and then no. 3 (errors), then no. 1 (previous).

If trouble code "80" is shown on the inverter, go to step 11, if not go to step 14.

11. Inverter trouble code is number "80".

Check fuse F4, then check the electric line of the fuse F4. If the fuse F4 and its line are ok, check fuse F160, then check if fuse F160 48 Volt to the ground.

If fuse F160 shows 48 Volt, go to step 12, if not go to step 13.

12. Fuse 160 A has 48 Volt.

Check the Inverter connections.

13. Fuse 160A does not show 48 Volt.

If Fuse 160A does not receive supply, BMS can be OFF, so the internal contactor is also OFF. go to step 7. If everything is ok check the internal contactor.

14. Inverter trouble code is not number "80".

If the inverter trouble code is number "74", go to step 15. If not go to step 16.

15. Inverter trouble code is number "74".

Check the connections from the inverter to the "MR" and check the "MR" coil.

16. See explanation on Service Manual table list.

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17. Wrench icon does not show on the display.

Check fuse F1, then check if the relay coils of R1 and R4 have 12 volts with the key switch ON.

If the coils show supply, go to step 18, if not go to step 19.

18. Coils of R1 and R4 receive no supply with the key switch ON.

Check the connections from 12V Lead-acid battery to R1 and R4 coils, then check pin A30 and A29 of the ECM 1-2.

19. Coils of R1 and R4 receive suply.

Check relay R4, then check the connection from wire GR/R of R4 to pin no. 2 of "5 ways BMS connector", if failure remains go to step 7.

C - Electric Motor does not run

If battery package level is "zero", go to failure description B. If other trouble codes are displayed, please refer to the Service Manual.

If there are no troubles codes shown, check the connections from the Inverter to the electric motor.

D - It is not possible to charge the battery package

If Red/green light is present on the battery charger LED during the charge, go to step 7.

E – It is not possible to charge the battery package at 100%, even after several hours of charge

If after connecting the 110-220V power cable, the light on the battery charger is red after two minutes, go to step 6, if not go to step 20.

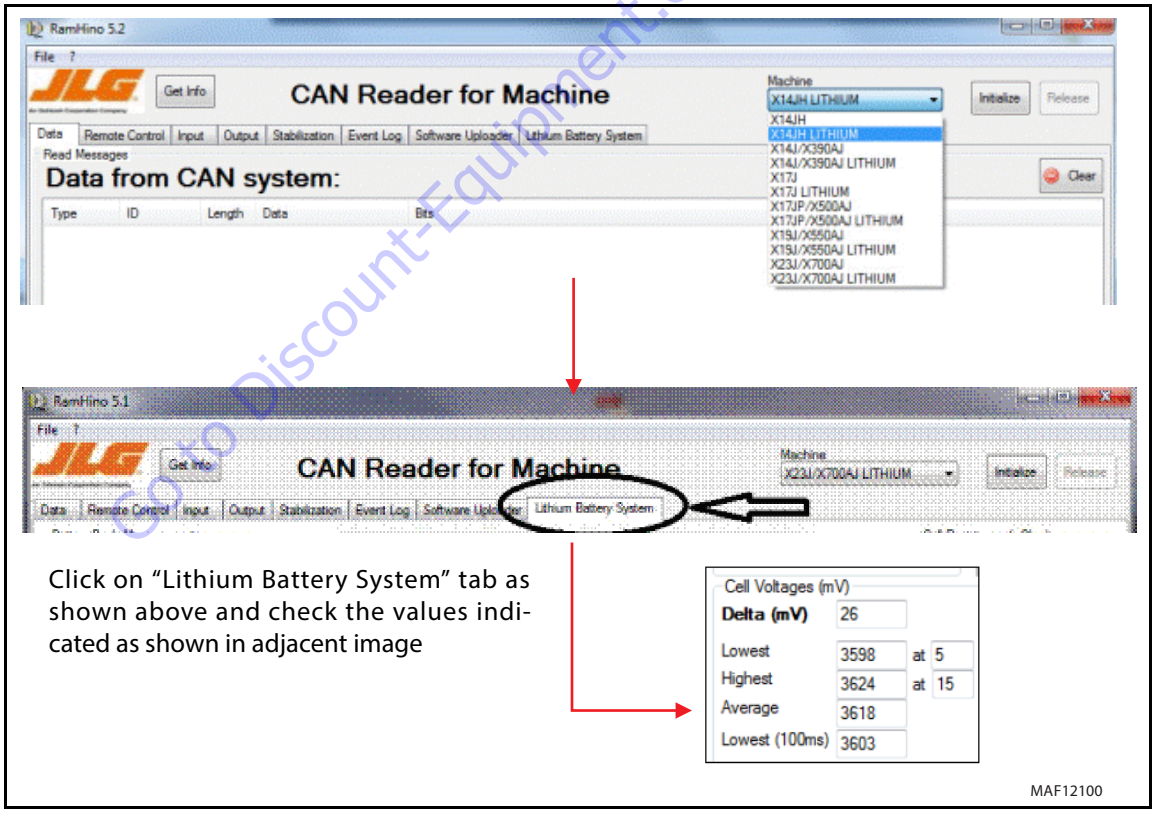
20. Battery charger works correctly, but the battery level never reaches 100%.

Connect the 120-220V power cable and keep it connected to the machine until the light on the battery charger will flash yellow, then leave it connected for at least 2 more hours.

If failure remains, go to step 21.

21. Battery charger lamp flashes yellow, but the battery pack level never reached 100% of charge.

Connect the RamHino tool to the machine, and select the accurate LITHIUM model on window menu Machine as shown below.



At the end of Battery Charge, values as shown in above image are displayed.

a. Delta (mV): it is the difference between the highest cell and the lowest cell (Volt). It should be approximately 50 (mV) or less.

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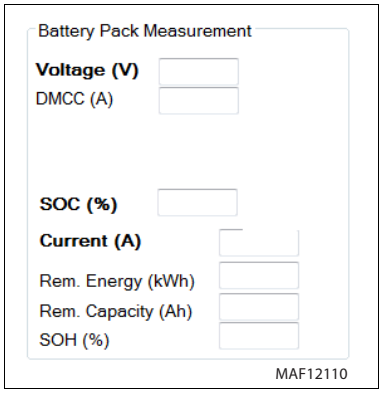
b. Lowest: It is the lowest cell (Volt). It should be more than 3550 mV. Normally this data concerns only one cell. Cell number is indicated in the box "at" (in above case cell number is 5).

c. Highest: It is the highest cell (Volt). It should be approximately 3620/3630 Volt. Normally the highest cell indicated in the box "at" changes after a while.

d. Average: It is the average of the total cell values (Volt). Normally at the end of the equalization phase, it should be between 3600 mV to 3630 mV.

After reading the above values, check the below window:



At the end of the charge (cells equalization operation), the following values are shown on the above window:

e. Voltage: It is the total level of the battery pack voltage.

f. DMCC (A): It is the current required from the BMS. For the period of the equalization operation, it should change from 0 to 6-7 Ampere.

NOTE: *If the power cable is not connected or at the start of charge or as soon the power cable is connected, the current required is the maximum. It should be 25A or 18A depending on the country setting.*

g. SOC (%): It is the level of the battery pack charge. It should be 100% when fully charged.

h. Current (A): It is the real value of the current measured by the LEM sensor. If there is the sign "-" the current is going OUT from the battery pack, if the sign is not present, the current is going IN. Other values are not important.

The BMS allows the charger to provide the maximum current (18A or 25A) until the first cell reaches 3630 mV and then it reduces the current. All the cells are connected in series, so BMS must control the charge of all cells together. However it can discharge the highest cell, connecting it to a resistance (there is one resistance in BMS for every cell).

When a new cell reaches 3630 mV, the BMS will connect it to its resistance, so at the end all the cells will be charged at the same level and have the same performances. Normally a fine battery pack should have (at the end of the equalization phase) the value Delta (mV) less than 50 mV, and average value of approximately 3600 mV.

With a resulting Delta (mV) value more than 150 mV, and the highest cell already reached 3630 mV, record the voltage and the number of the highest cells. Leave the machine under charge overnight. If Delta condition remains the same, replace the BMS.

F - Lead-Acid Battery is not charged by the system

Check the voltage of the Lead-acid battery. If it is more than 12 Volt go to step 23, if not go to step 22.

22. Lead-acid battery voltage is less than 12 Volt.

Charge the battery by an external battery charger and test the machine again.

23. Lead-acid battery voltage is more than 12 Volt.

Record the correct voltage on the Lead-acid battery and turn ON the machine. If the voltage value is higher (12.8 Volt or more), go to step 24, if not go to step 25.

24. Lead-acid battery voltage is higher when the machine is ON (12.8 Volt or more).

To charge the Lead-acid battery, it is necessary to leave the machine ON for some hours or it is necessary to connect the power cable for some hours. If the Lead-acid battery does not receive charge, replace the Lead-acid battery.

25. Volt at the Lead-acid battery with the machine ON is the same with the machine OFF.

In such case the DC-DC does not work. Check fuse F7 if present and check Relay R1. If everything is ok, check connections from the Lead-acid battery and the DC-DC.

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G - Ventilation fans do not work

Check fuse F2 and check the fan timer "T1". If they are ok, check connection from the 12 Volt Lead-acid battery to the BMS (Feed connector – R1 – R4 – T1 5 ways BMS connector – BMS).

H - Battery Charger does not work correctly

Connect the power cable and check the battery charger light after two minutes, if it is red go to step 6, if it is red/green go to step 7.

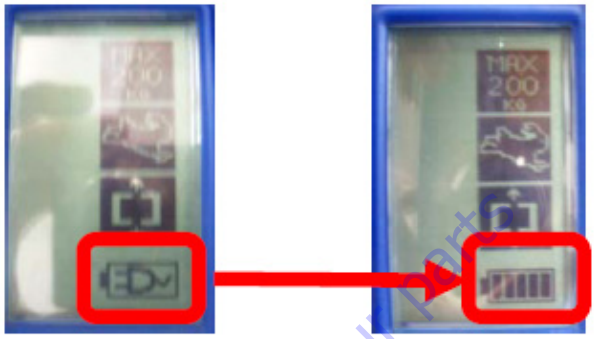
26. Light on battery charger is red, two minutes after connecting the power cable.

If the light on battery charger is red, go to step 6.

27. Light on the battery charger is flashing red/green two minutes after connecting the power cable.

If the light on battery charger flashes red/green, go to step 7.

I - Plug icon on the display interchanges continually with the battery icon while charging



MAF12120

Check the value "battery %" in the INPUT menu, press button number 6 "service", press 1 "input", and 1 "previous". Press 9 "Esc" to go back.

MAF12020

If during charge, the battery level is changing irregularly from 100% to another value, go to step 21. If during charge, the battery level is not 100%, leave the machine under charge overnight.

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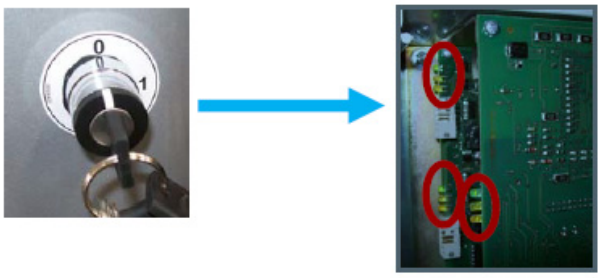
48V Battery Pack (SN C170000330 to Present)

A - Remote control display is OFF

1. With the key switch in ON position, open the main board electric box, and check the LED on the main board.

   If ON go to step 2

   If OFF go to step 3



MAF12060

2. LED on the main board are ON

   If the LED are ON then the main board is also ON, so the remote control failure is not because of the Lithium system. Refer the wiring diagram to check the remote control feed.

3. LED on the main board are OFF

   Check the 12V Lead-acid battery; it supplies power to all the boards during the ignition, so if it is not OK, the machine will remain off.

   Check the voltage on the 12V switch under the key switch. IF red wire to the ground has 12 Volt, go to step 4, if not go to step 5.

MAF12070

4. Red wire has 12 Volt

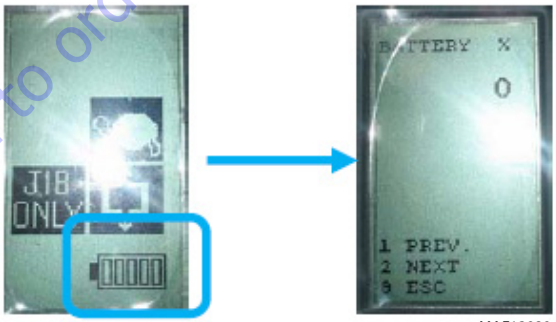
   Check the 12 Volt switch under the key switch, and check the connection of the wire OR0400 (or 1/12), from the key switch to the pin B1 in the master board.

5. Red wire does not have 12 Volt

   Check fuse F6, then check the supply from 12V Lead-acid battery to fuse F6 (= Lead-acid battery + feed connector + R1 + 2 ways connector).

B - Battery package level is "zero" even after the charge

Check the value in the INPUT menu, press button number 6 "service", then press 1 "input", then 1 "previous". Press button number 9 "Esc" to go back.



MAF12080

If external electrical power is available, connect the 110-220V power cable, and check the battery charger light after two minutes;

If the battery charger light flashes red, go to step 6.

If the battery charger light flashes green/red, go to step 7.

6. Connect the power cable, the battery charger light is red after two minutes.

   The system works correctly. Keep the power cable connected until the light on the battery charger will flash yellow. Test the machine again, if the problem remains, go to step 9.

7. Connect the power cable, the battery charger light flashes red/green after two minutes.

   This condition indicates the battery charger does not find the 48 Volt battery package. Check fuse F1, then check fuse F3, then check the wire "123" connected from the pin no. 5 of the "6 ways BC connector" to the wire "111" pin no. 2 of the "5 ways BMS connector" of the BMS. Check

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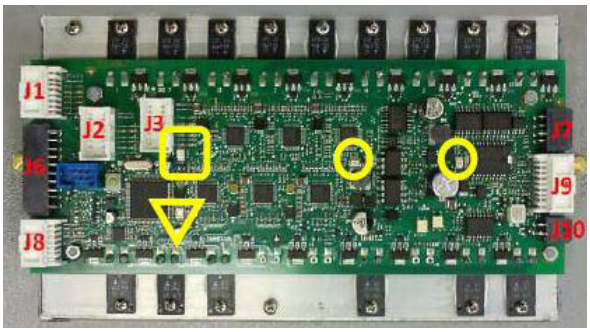
the connection from the “5 ways BMS connector and the BMS.

If all the connections and supply are ok, go to step 8, if not go to step 9.

8. All the connections and the supply are ok.

Check Relay no. 3 and its connection; remove the BMS cover and check if the feed to green LED are ON (yellow circle) and check if the feed to red LED is flashing (yellow square).



MAF12140

If all the connections are properly but there is no supply to LED on the BMS, replace the BMS.

NOTE: *Red led flashing after the start (yellow triangle), indicates a BMS failure. Connect RamHino tool to the machine to read BMS failure codes.*

9. Battery charger works properly, but the battery level indicated on the display remains “zero”.

If wrench icon is shown on the display as shown below, go to step 10, if not go to step 17.

MAF12000

10. Wrench icon is shown on the display.

Check the trouble codes, push button no. 6 (service), and then no. 3 (errors), then no. 1 (previous).

If trouble code “80” is shown on the inverter, go to step 11, if not go to step 14.

11. Inverter trouble code is number “80”.

Check fuse F4, then check the electric line of the fuse F4. If the fuse F4 and its line are ok, check fuse F160, then check if fuse F160 has 48 Volt to the ground.

If fuse F160 shows 48 Volt, go to step 12, if not go to step 13.

12. Fuse 160 A has 48 Volt.

Check the Inverter connections.

13. Fuse 160A does not show 48 Volt.

If Fuse 160A does not receive supply, BMS can be OFF, so the internal contactor is also OFF. go to step 7. If everything is ok check the internal contactor.

14. Inverter trouble code is not number “80”.

If the inverter trouble code is number “74”, go to step 15. If not go to step 16.

15. Inverter trouble code is number “74”.

Check the connections from the inverter to the “MR” and check the “MR” coil.

16. See explanation on Service Manual table list.

17. Wrench icon does not show on the display.

Check fuse F1, then check if the relay coils of R1 and R4 have 12 volts with the key switch ON.

If the coils show supply, go to step 18, if not go to step 19.

18. Coils of R1 and R4 receive no supply with the key switch ON.

Check the connections from 12 Volt Lead-acid battery to R1 and R4 coils, then check pin A30 and A29 of the ECM 1-2.

19. Coils of R1 and R4 receive supply.

Check relay R1, then check the connection from wire “111” or R1 to pin no. 2 of “5 ways BMS connector”, if failure remains go to step 7.

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C - Electric Motor does not run

If battery package level is “zero”, go to failure description B. If other trouble codes are displayed, please refer to the Service Manual.

If there are no troubles codes displayed, check the connections from the Inverter to the electric motor.

D - It is not possible to charge the battery package

If Red/green light is present on the battery charger LED during the charge, go to step 7.

E – It is not possible to charge the battery package at 100%, even after several hours of charge

If after connecting the 110-220V power cable the light on the battery charger is red after two minutes, go to step 6, if not go to step 20.

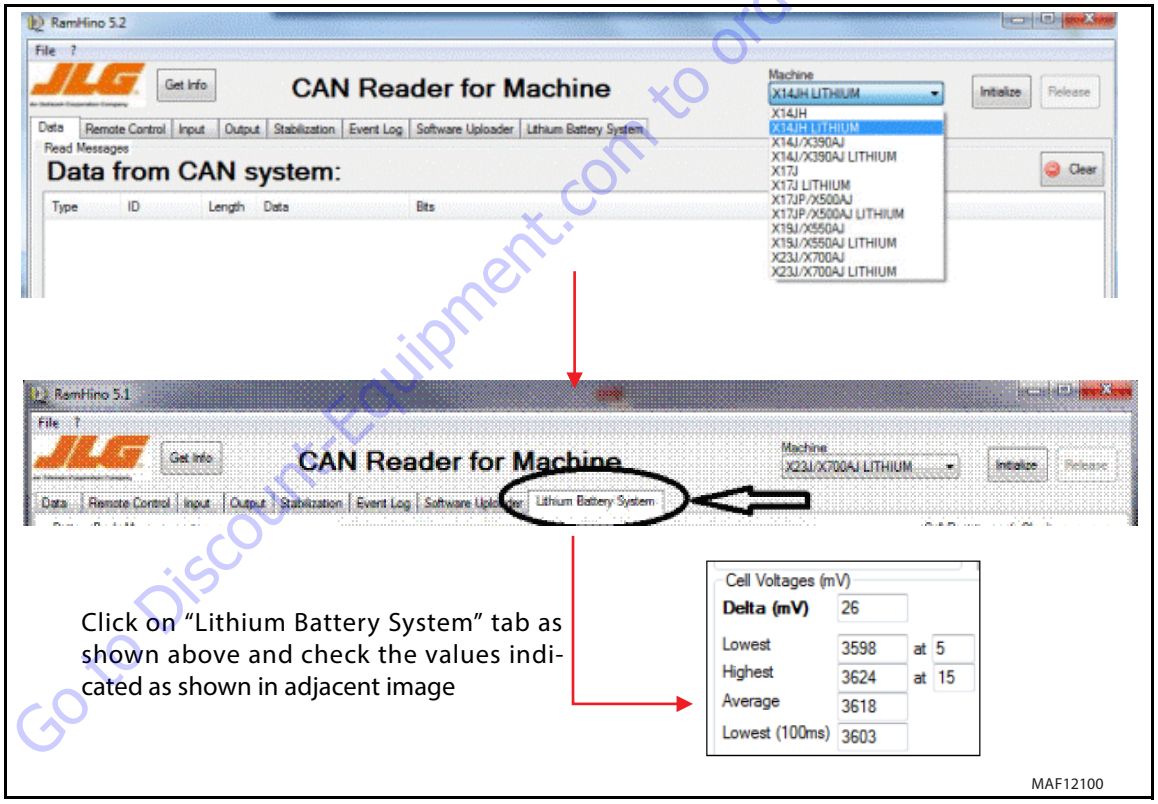
20. Battery charger works correctly, but the battery level never reaches 100%.

Connect the 120-220V power cable and keep it connected to the machine until the light on the battery charger will flash yellow, then leave it connected for at least 2 additional hours.

If failure remains, go to step 21.

21. Battery charger lamp is yellow for many hours, but the battery pack level never reached 100% of charge.

Connect the RamHino tool to the machine, and choose the accurate LITHIUM model on window menu Machine as shown below.



Click on “Lithium Battery System” tab as shown above and check the values indicated as shown in adjacent image

At the end of Battery Charge, values as shown in above image should shown on the display.

a. Delta (mV): it is the difference between the highest cell and the lowest cell (Volt). It should be approximately 100 (mV) or less.

b. Lowest: It is the lowest cell (Volt). It should be more than 3570 mV. Normally this data concerns only one cell. Cell number is indicated in the box “at” (in above case cell number 5).

c. Highest: It is the highest cell (Volt). It should be approximately 3620/3630 (Volt). Normally the highest cell indicated in the box “at” changes after a while.

d. Average: It is the average of the total cell values (Volt). Normally at the end of the equalization phase, it should be between 3580 mV to 3620 mV.

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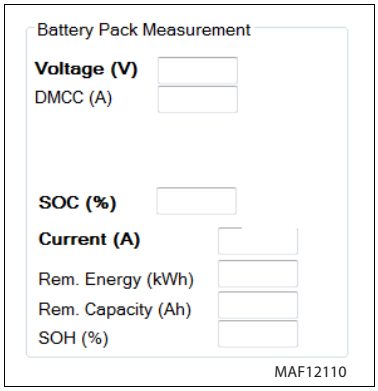
After reading the above values, check the below window:



At the end of the charge (cells equalization operation), the following values are shown on the above window

e. Voltage: It is the total level of the battery pack voltage.

f. DMCC (A): It is the current required from the BMS. For the period of the equalization operation, it should change from 0.1 to 1 Ampere.

NOTE: *If the power cable is not connected or at the start of charge or as soon the power cable is connected, the current required is the maximum, so it should be 25A or 18A depending on the country setting.*

g. SOC (%): It is the level of the battery pack charge. It should be 100% when fully charged.

h. Current (A): It is the real value of the current measured by the LEM sensor. If there is the sign "-" the current is going OUT from the battery pack, if the sign is not present, the current is going IN. Other values are not important.

The BMS allows the charger to provide the maximum current (18A or 25A) until the first cell reaches 3630 mV and then it reduces the current. All the cells are connected in series, so BMS must control the charge of all cells together. However it can discharge the highest cell, connecting it to a resistance (there is one resistance in BMS for every cell).

When a new cell reaches 3630 mV the BMS will connect it to its resistance, so at the end all the cells will be charged at the same level and have the same performances. Usually a fine battery pack should have (at the end of the equalization phase) the value Delta (mV) less than 50 mV, and average value of approximately 3600 mV.

With a resulting Delta (mV) value more than 150 mV, and the highest cell already reached 3630 mV, record the voltage and the number of the highest cells. Leave the machine under charge overnight. If Delta condition remains the same, replace the BMS.

F - Lead-Acid Battery is not charged by the system

Check the voltage of the Lead-acid battery. If it is more than 12 Volt go to step 23, if not go to step 22.

22. Lead-acid battery voltage is less than 12 Volt.

Charge the battery by an external battery charger and test the machine again.

23. Lead-acid battery voltage is more than 12 Volt.

Record the correct voltage on the Lead-acid battery and turn ON the machine. If the voltage value is higher (12.8 Volt or more), go to step 24, if not go to step 25.

24. Lead-acid battery voltage is higher when the machine is ON (12.8 Volt or more).

To charge the Lead-acid battery, it is necessary to leave the machine ON for some hours or it is necessary to connect the power cable for some hours. If the Lead-acid battery does not receive charge, replace the Lead-acid battery.

25. Voltage at the Lead-acid battery with the machine ON is the same with the machine OFF.

In such case the DC-DC does not work. Check fuse F7 if present and check Relay R2. If everything is ok, check connections from the Lead-acid battery and the DC-DC.

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G - Ventilation fans do not work

Check fuse F2 and check the fan timer “T1”. If they are ok, check connection from the 12 Volt Lead-acid battery to the BMS (Feed connector – R1 – R4 – T1 5 ways BMS connector – BMS).

H - Battery Charger does not work properly

Connect the power cable and check the battery charger light after two minutes, if it is red go to step 6, if it is flashing red/green go to step 7.

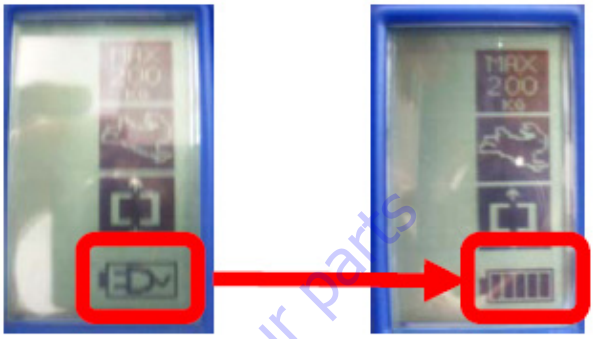
26. Light on battery charger is red, two minutes after connecting the power cable.

If the light on battery charger is red, go to step 6.

27. Light on the battery charger is flashing red/green two minutes after connecting the power cable.

If the light on battery charger flashes red/green, go to step 7.

I - Plug icon on the display interchanges continually with the battery icon while charging



MAF12120

Check the value “battery %” in the INPUT menu, press button number 6 “service”, press 1 “input”, and 1 “previous”. Press 9 "Esc" to go back.

MAF12020

If during charge, the battery level is changing irregularly from 100% to another value, go to step 21. If during charge, the battery level is not 100%, leave the machine under charge overnight.

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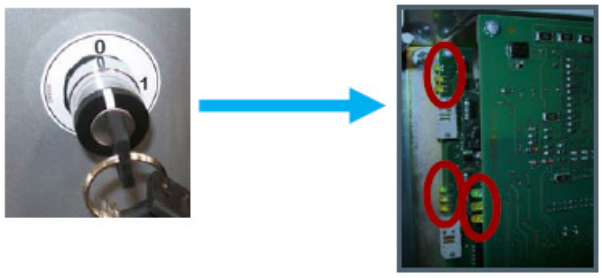
72V Battery Pack (Prior to SN C170000352)

A - Remote control display is OFF

1. With the key switch in ON position, open the main board electric box, and check the LED on the main board.

   If ON go to step 2

   If OFF go to step 3



MAF12060

2. LED on the main board are ON

   If the LED are ON, the main board is also ON, so the remote control failure is not because of the Lithium system. Refer the wiring diagram to check the remote control feed.

3. LED on the main board are OFF

   Check the 12V Lead-acid battery; it supplies power to all the boards during the ignition, so if it is not OK, the machine will remain off.

   Check the voltage on the 12V switch under the key switch. IF red wire to the ground has 12 Volt, go to step 4, if not go to step 5.

MAF12070

4. Red wire has 12 Volt

   Check the 12 Volt switch under the key switch, and check the connection of the wire 1/12, from the key switch to the pin B1 in the master board.

5. Red wire does not have 12 Volt

   Check fuse F6, then check the feed from 12 Volt Lead-acid battery to fuse F6 (= Lead-acid battery + feed connector + R1 + 2 ways connector).

B - Battery package level is “zero” even after the charge

Check the value in the INPUT menu, press button number 6 “service”, then press 1 “input”, then 1 “previous”. Press button number 9 “Esc” to go back.

MAF12080

If external electrical network is available, connect the 110-220V power cable, and check the battery charger light after two minutes.

If the battery charger light flashes red, go to step 6.

If the battery charger light flashes green/red, go to step 7.

6. Connect the power cable, the battery charger light is red after two minutes.

   The system works correctly. Keep the power cable connected until the light on the battery charger will flash yellow. Test the machine again, if the problem remains, go to step 9.

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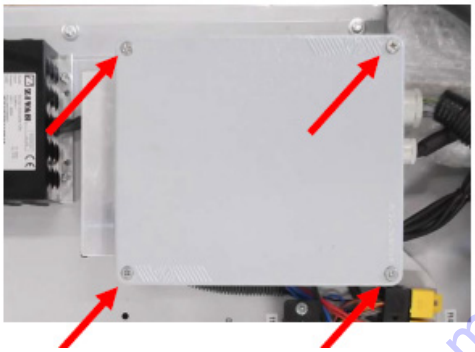
7. Connect the power cable, the light on the battery charger flashes red/green after two minutes.

This condition indicates the battery charger does not find the 72V battery package. Check fuse F1, then check fuse F3, then check the gray/red wire connected from the pin no. 5 of the "6 ways BC connector" to the pin no. 2 of the "5 ways BMS connector of the BMS. Check the connection from the "5 ways BMS connector" of the BMS.

If all the connections and supply are ok, go to step 8, if not go to step 9.

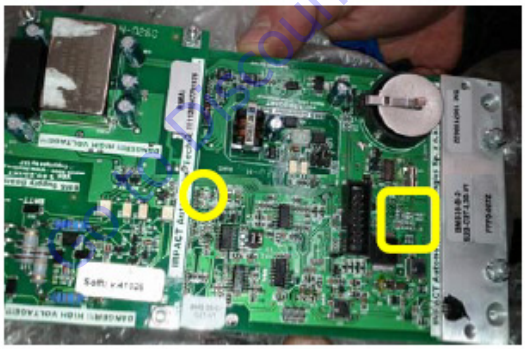
8. All the connections and the supply are ok.

Remove the four screws and the cover of the BMS.



MAF12130

Check if the red LED are ON (yellow circle), and check if the CAN BUS green LED are ON (yellow square).



MAF12090

If all the connections are ok but there is no supply to LED on the BMS, replace the BMS. If the supply connections and LED are ok, but the CAN BUS LED are OFF, check the CAN BUS connections.

9. Battery charger works correctly, but the battery level indicated on the display remains "zero".

If wrench icon appears on the display as shown below, go to step 10, if not go to step 17.

MAF12000

10. Wrench icon appears on the display.

Check the trouble codes, push button no. 6 (service), and then no. 3 (errors), then no. 1 (previous).

If trouble code "80" is shown on the inverter, go to step 11, if not go to step 14.

11. Inverter trouble code is number "80".

Check fuse F160, then check if fuse F160 has 72 Volt to the ground.

If fuse F160 shows 72 Volt, go to step 12, if not go to step 13.

12. Fuse 160A has 72 Volt.

Check the Inverter connections.

13. Fuse 160A does not show 72 Volt.

If Fuse 160A does not receive supply, BMS can be OFF, so the internal contactor is also OFF, go to step 7. If everything is ok check the internal contactor.

14. Inverter trouble code is not number "80".

If the inverter trouble code is number "74", go to step 15. If not go to step 16.

15. Inverter trouble code is number "74".

Check the connections from the inverter to the "MR" and check the "MR" coil.

16. See explanation on Service Manual table list.

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17. Wrench icon does not show on the display.

Check fuse F1, then check if the relay coils of R1 and R4 have 12 volts with the key switch ON.

If the coils show supply, go to step 18, if not go to step 19.

18. Coils of R1 and R4 receive no feed with the key switch ON.

Check the connections from 12 Volt Lead-acid battery to R1 and R4 coils, check pin A30 and A29 of the ECM 1-2.

19. Coils of R1 and R4 receive feed.

Check relay R4, check the connection from wire GR/R of R4 to pin no. 2 of "5 ways BMS connector", if failure remains go to step 7.

C - Electric Motor does not run

If battery package level is "zero", go to failure description B. If there are other trouble codes displayed, please refer to the Service Manual.

If there are no troubles codes displayed, check the connections from the Inverter to the electric motor.

D - It is not possible to charge the battery package

If Red/green light is present on the battery charger LED during the charge, go to step 7.

E - It is not possible to charge the battery package at 100%, even after several hours of charge

If after connecting the 110-220V power cable the light on the battery charger is red after two minutes, go to step 6, if not go to step 20.

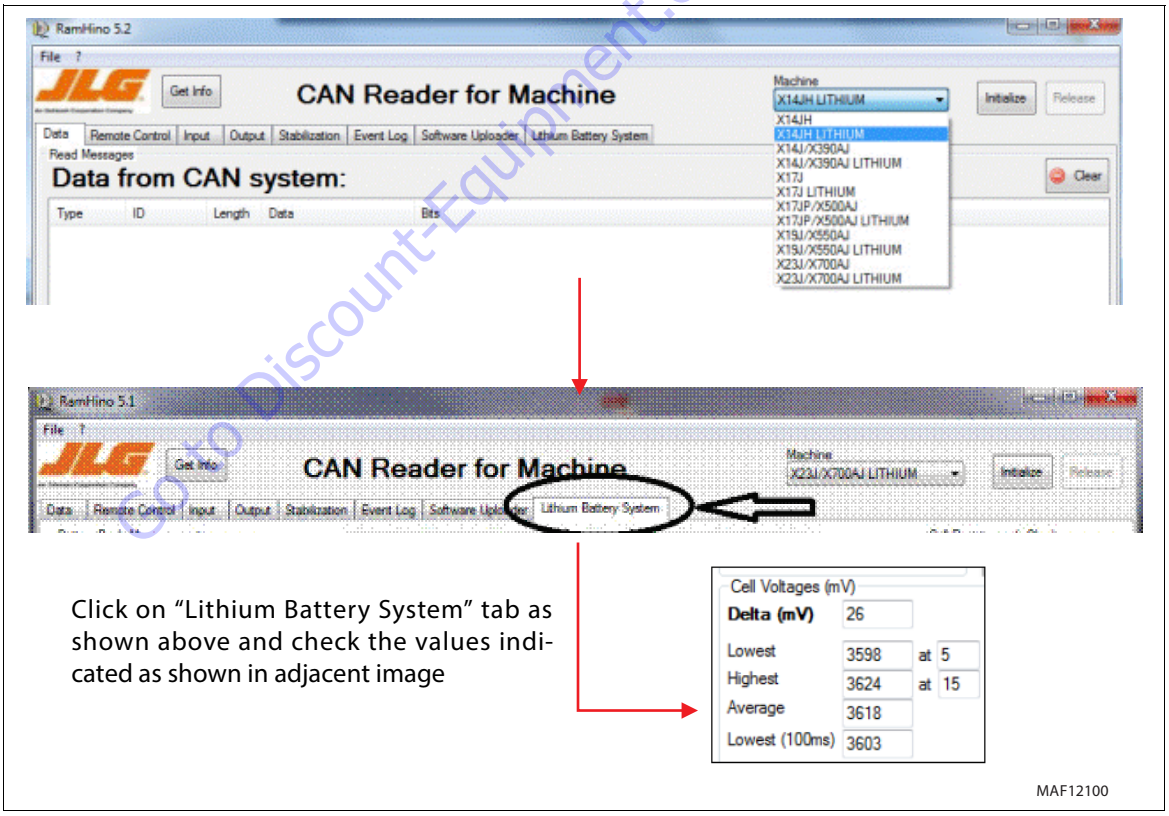
20. Battery charger works correctly, but the battery level never reaches 100%.

Connect the 120-220V power cable and keep it connected to the machine until the light on the battery charger will flash yellow, then leave it connected for at least 2 more hours.

If failure remains, go to step 21.

21. Battery charger lamp flashes yellow, but the battery pack level never reached 100% of charge.

Connect the RamHino tool to the machine, and select the accurate LITHIUM model on window menu Machine as shown below.



Click on "Lithium Battery System" tab as shown above and check the values indicated as shown in adjacent image

At the end of Battery Charge, values as shown in above image are displayed.

a. Delta (mV): it is the difference between the highest cell and the lowest cell (Volt). It should be approximately 50 (mV) or less.

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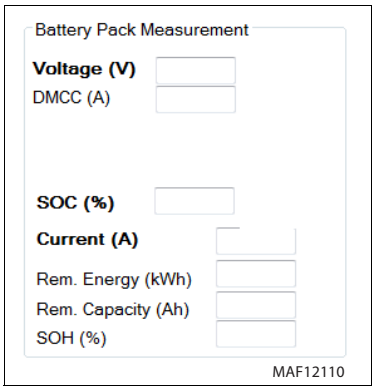
b. Lowest: It is the lowest cell (Volt). It should be more than 3550 mV. Normally this data concerns only one cell. Cell number is indicated in the box “at” (in above case cell number is 5).

c. Highest: It is the highest cell (Volt). It should be approximately 3620/3630 (Volt). Normally the highest cell indicated in the box “at” changes after a while.

d. Average: It is the average of the total cell values (Volt). Normally at the end of the equalization phase, it should be between 3620 mV to 3630 mV.

After reading the above values, check the below window:



At the end of the charge (cells equalization operation), the following values are displayed on the above window

e. Voltage: It is the total level of the battery pack voltage.

f. DMCC (A): It is the current required from the BMS. For the period of the equalization operation, it should change from 0 to 6-7 Ampere.

NOTE: *If the power cable is not connected or at the start of charge or as soon the power cable is connected, the current required is the maximum, so it should be 13A or 30A depending on the country setting.*

g. SOC (%): It is the level of the battery pack charge. It should be 100% when fully charged.

h. Current (A): It is the real value of the current measured by the LEM sensor. If there is the sign “-” the current is going OUT from the battery pack, if the sign is not present, the current is going IN. Other values are not important.

The BMS allows the charger to provide the maximum current (13 or 30 A) until the first cell reaches 3630 mV and then it reduces the current. All the cells are connected in series, so BMS must control the charge of all cells together. However it can discharge the highest cell, connecting it to a resistance (there is one resistance in BMS for every cell).

When a new cell reaches 3630 mV, the BMS will connect it to its resistance, so at the end all the cells will be charged at the same level and have the same performances. Normally a fine battery pack should have (at the end of the equalization phase) the value Delta (mV) less than 50 mV, and average value of approximately 3600 mV.

With a resulting Delta (mV) value more than 150 mV, and the highest cell already reached 3630 mV, record the voltage and the number of the highest cells. Leave the machine under charge overnight. If Delta condition remains the same, replace the BMS.

F - Lead-acid Battery is not charged by the system

Check the voltage of the Lead-acid battery. If it is more than 12 Volt go to step 23, if not go to step 22.

22. Lead-acid battery voltage is less than 12 Volt.

Charge the battery by an external battery charger and test the machine again.

23. Lead-acid battery voltage is more than 12 Volt.

Record the correct voltage on the Lead-acid battery and turn ON the machine. If the voltage value is higher (12.8 Volt or more), go to step 24, if not go to step 25.

24. Lead-acid battery voltage is higher when the machine is ON (12.8 Volt or more).

To charge the Lead-acid battery, it is necessary to leave the machine ON for some hours or it is necessary to connect the power cable for some hours. If the Lead-acid battery does not receive charge, replace the Lead-acid battery.

25. Volt at the Lead-acid battery with the machine ON is the same with the machine OFF.

In such case the DC-DC does not work. Check fuse F7 if present and check Relay R1. If everything is ok, check connections from the Lead-acid battery and the DC-DC.

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G - Ventilation fans do not work

Check fuse F2 and check the fan timer “T1”. If they are ok, check connection from the 12 Volt Lead-acid battery to the BMS (Feed connector – R1 – R4 – T1 5 ways BMS connector – BMS).

H - Battery charger does not work correctly

Connect the power cable and check the battery charger light after two minutes, if it is red go to step 6, if it is red/green go to step 7.

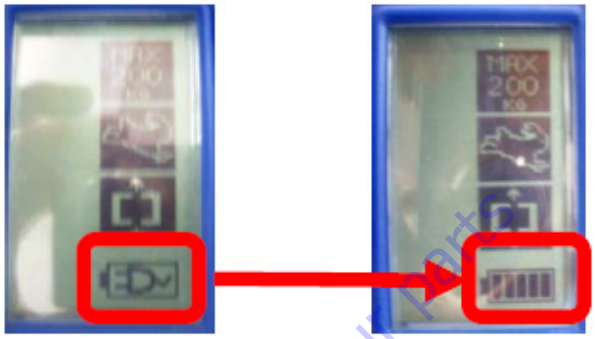
26. Light on battery charger is red, two minutes after connecting the power cable.

If the light on battery charger is red, go to step 6.

27. Light on the battery charger is flashing red/green two minutes after connecting the power cable.

If the light on battery charger flashes red/green, go to step 7.

I - Plug icon on the display interchanges intermittently with the battery icon while charging



MAF12120

Check the value “battery %” in the INPUT menu, press button number 6 “service”, press 1 “input”, and 1 “previous”. Press 9 "Esc" to go back.

MAF12020

If during charge, the battery level is changing irregularly from 100% to another value, go to step 21. If during charge, the battery level is not 100%, leave the machine under charge overnight.

L - Battery package level is “zero” on the remote control, however the machine works properly

Check all the connections and the feeds on the “Can Bridge Box”.

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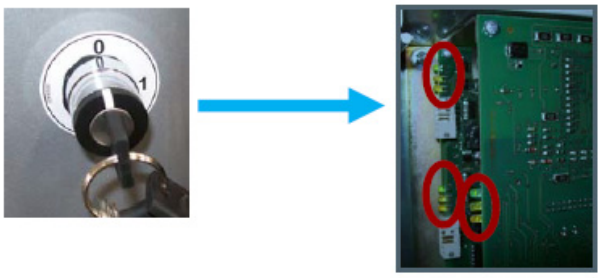
72V Battery Pack (SN C170000352 to Present)

A - Remote control display is OFF

1. With the key switch in ON position, open the main board electric box, and check the LED on the main board.

   If ON go to step 2

   If OFF go to step 3



MAF12060

2. LED on the main board are ON

   If the LED are ON, the main board is also ON, so the remote control failure is not because of the Lithium system. Refer the wiring diagram to check the remote control feed.

3. LED on the main board are OFF

   Check the 12V Lead-acid battery: it supplies power to all the boards during the ignition, so if it is not OK, the machine will remain off.

   Check the voltage on the 12V switch under the key switch. IF red wire to the ground has 12 Volt, go to step 4, if not go to step 5.

MAF12070

4. Red wire has 12 Volt

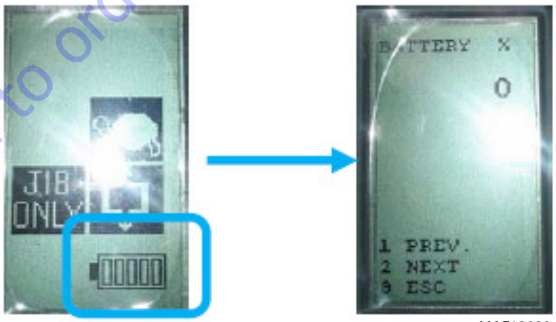
   Check the 12 Volt switch under the key switch, and check the connection of the wire OR0400 (or 1/12), from the key switch to the pin B1 in the master board.

5. Red wire does not have 12 Volt

   Check fuse F6, then check the feed from 12 Volt Lead-acid battery to fuse F6 (= Lead-acid battery + feed connector + R1 + 2 ways connector).

B - Battery package level is "zero" even after the charge

Check the value in the INPUT menu, press button number 6 "service", then press 1 "input", then 1 "previous". Press button number 9 "Esc" to go back.



MAF12080

If external electrical network is available, connect the 110-220V power cable, and check the battery charger light after two minutes.

If the battery charger light flashes red, go to step 6.

If the battery charger light flashes green/red, go to step 7.

6. Connect the power cable, the battery charger light is red after two minutes.

   The system works correctly. Keep the power cable connected until the light on the battery charger will flash yellow. Test the machine again, if the problem remains, go to step 9.

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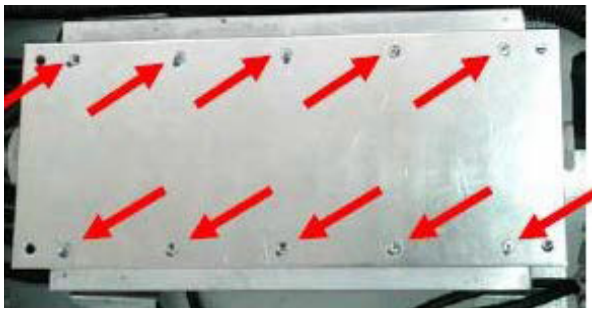
7. Connect the power cable, the light on the battery charger flashes red/green after two minutes.

This condition indicates the battery charger does not find the 72V battery package. Check fuse F1, then check fuse F3, then check the wire "123" connected from the pin no. 5 of the "6 ways BC connector" to the pin no. 2 of the "5 ways BMS connector" of the BMS. Check the connection from the "5 ways BMS connector" of the BMS.

If all the connections and supply are ok, go to step 8, if not go to step 9.

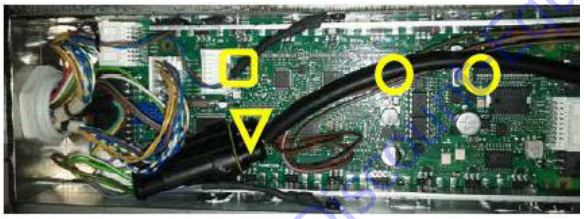
8. All the connections and the supply are ok.

Remove the BMS cover as shown below



MAF12150

Check if the green LED are ON (yellow circle), and check if red LED is flashing (yellow square).



MAF12160

If all the connections are ok but there is no supply to LED on the BMS, replace the BMS.

NOTE: *Red led flashing after the start (yellow triangle), indicates a BMS failure. Connect RamHino tool to the machine to read the BMS failure codes.*

9. Battery charger works ok, but the battery level indicated on the display remains "zero".

If wrench icon appears on the display as shown below, go to step 10, if not go to step 17.

MAF12000

10. Wrench icon appears on the display.

Check the trouble codes, push button no. 6 (service), and then no. 3 (errors), then no. 1 (previous).

If trouble code "80" is shown on the inverter, go to step 11, if not go to step 14.

11. Inverter trouble code is number "80".

Check fuse F160, then check if fuse F160 has 72 Volt to the ground.

If fuse F160 shows 72 Volt, go to step 12, if not go to step 13.

12. Fuse 160A has 72 Volt.

Check the Inverter connections.

13. Fuse 160A does not show 72 Volt.

If Fuse 160A does not receive supply, BMS can be OFF, so the internal contactor is also OFF, go to step 7. If everything is ok check the internal contactor.

14. Inverter trouble code is not number "80".

If the inverter trouble code is number "74", go to step 15. If not go to step 16.

15. Inverter trouble code is number "74".

Check the connections from the inverter to the "MR" and check the "MR" coil.

16. See explanation on Service Manual table list.

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17. Wrench icon does not show on the display.

Check fuse F1, check if the relay coils of R1 and R2 have 12 volts with the key switch ON.

If the coils show supply, go to step 18, if not go to step 19.

18. Coils of R1 and R2 receive no feed with the key switch ON.

Check the connections from 12 Volt Lead-acid battery to R1 and R2 coils, check pin A30 and A29 of the ECM 1-2.

19. Coils of R1 and R4 receive feed.

Check relay R1, check the connection from wire "111" to pin no. 2 of "5 ways BMS connector", if failure remains go to step 7.

C - Electric Motor does not run

If battery package level is "zero", go to failure description B. If there are other trouble codes displayed, please refer to the Service Manual.

If there are no troubles codes displayed, check the connections from the Inverter to the electric motor.

D - It is not possible to charge the battery package

If Red/green light is present on the battery charger LED during the charge, go to step 7.

E - It is not possible to charge the battery package at 100%, even after several hours of charge

If after connecting the 110-220V power cable the light on the battery charger is red after two minutes, go to step 6, if not go to step 20.

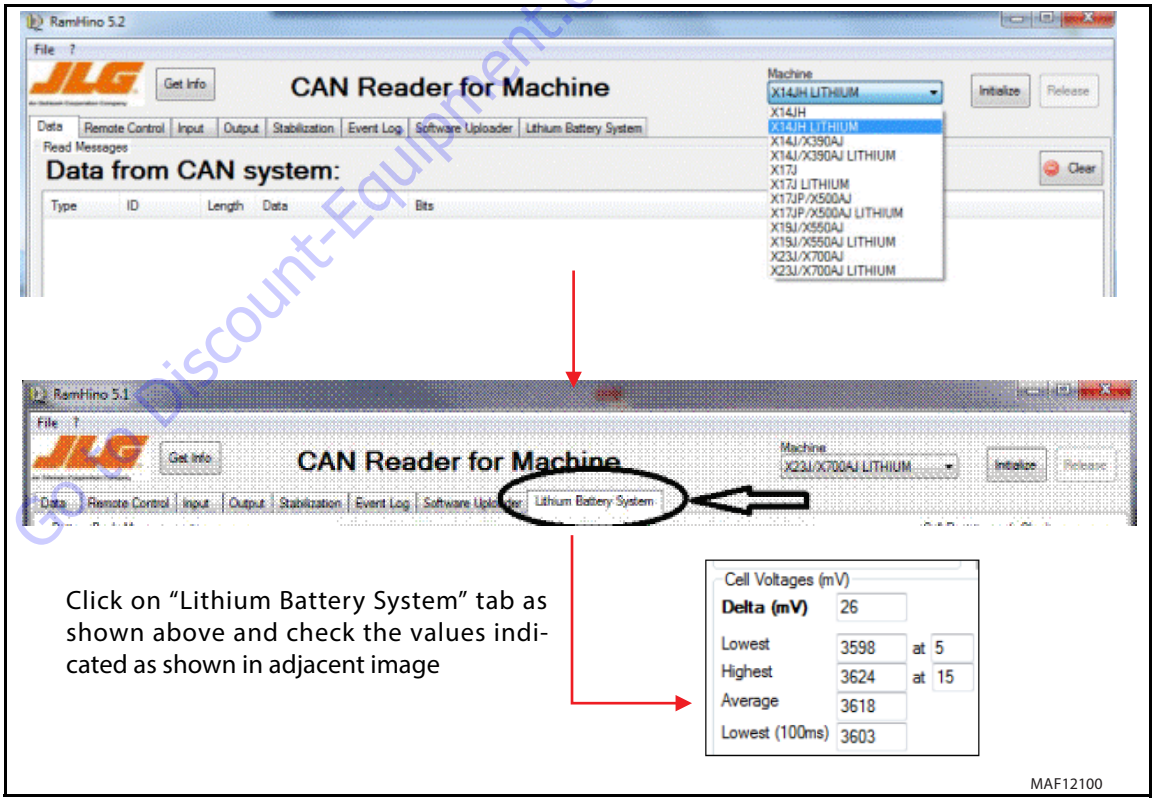
20. Battery charger works correctly, but the battery level never reaches 100%.

Connect the 120-220V power cable and keep it connected to the machine until the light on the battery charger will flash green, then leave it connected for at least 2 additional hours.

If failure remains, go to step 21.

21. Battery charger lamp flashes yellow, but the battery pack level never reached 100% of charge.

Connect the RamHino tool to the machine, and choose the accurate LITHIUM model on window menu Machine as shown below.



Click on "Lithium Battery System" tab as shown above and check the values indicated as shown in adjacent image

At the end of Battery Charge, values as shown in above image are displayed.

a. Delta (mV): it is the difference between the highest cell and the lowest cell (Volt). It should be approximately 100 (mV) or less.

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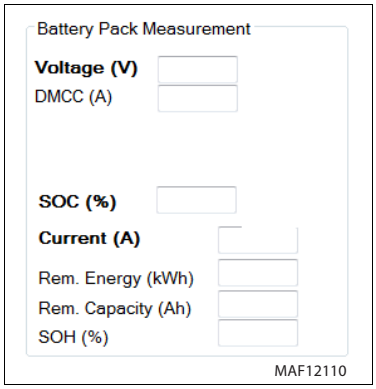
b. Lowest: It is the lowest cell (Volt). It should be more than 3570 mV. Normally this data concerns only one cell. Cell number is indicated in the box "at" (in above case cell number is 5).

c. Highest: It is the highest cell (Volt). It should be approximately 3630 (Volt). Normally the highest cell indicated in the box "at" changes after a while.

d. Average: It is the average of the total cell values (Volt). Normally at the end of the equalization phase, it should be between 3580 mV to 3620 mV.

After reading the above values, check the below window:



At the end of the charge (cells equalization operation), the following values are displayed on the above window

e. Voltage: It is the total level of the battery pack voltage.

f. DMCC (A): It is the current required from the BMS. For the period of the equalization operation, it should change from 0.5 to 1 Ampere.

NOTE: *If the power cable is not connected or at the start charge or as soon the power cable is connected, the current required is the maximum, so it should be 13A or 30A depending on the country setting.*

g. SOC (%): It is the level of the battery pack charge. It should be 100% when fully charged.

h. Current (A): It is the real value of the current measured by the LEM sensor. If there is the sign "-" the current is going OUT from the battery pack, if the sign is not present, the current is going IN. Other values are not important.

The BMS allows the charger to provide the maximum current (13A or 30 A) until the first cell reaches 3630 mV and then it reduces the current. All the cells are connected in series, so BMS must control the charge of all cells together. However it can discharge the highest cell, connecting it to a resistance (there is one resistance in BMS for every cell).

When a new cell reaches 3630 mV the BMS will connect it to its resistance, so at the end all the cells will be charged at the same level and have the same performances. Normally a fine battery pack should have (at the end of the equalization phase) the value Delta (mV) less than 100 mV, and average around 3600 mV.

With a resulting Delta (mV) value more than 250 mV, and the highest cell already reached 3630 mV, take a note of the voltage and the number of the highest cells. Leave the machine under charge overnight. If Delta condition remains the same, replace the BMS.

F - Lead-acid Battery is not charged by the system

Check the voltage of the Lead-acid battery. If it is more than 12 Volt go to step 23, if not go to step 22.

22. Lead-acid battery voltage is less than 12 Volt.

Charge the battery by an external battery charger and test the machine again.

23. Lead-acid battery voltage is more than 12 Volt.

Record the correct voltage on the Lead-acid battery and turn ON the machine. If the voltage value is higher (12.8 Volt or more), go to step 24, if not go to step 25.

24. Lead-acid battery voltage is higher when the machine is ON (12.8 Volt or more).

To charge the Lead-acid battery, it is necessary to leave the machine ON for some hours or it is necessary to connect the power cable for some hours. If the Lead-acid battery does not receive charge, replace the Lead-acid battery.

25. Volt at the Lead-acid battery with the machine ON is the same with the machine OFF.

In such case the DC-DC does not work. Check fuse F7 if present and check Relay R1. If everything is ok, check connections from the Lead-acid battery and the DC-DC.

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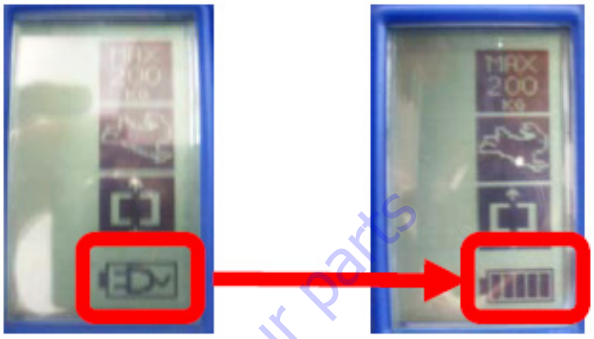
G - Ventilation fans do not work

Check fuse F2. If ok, check connection from the 12 Volt Lead-acid battery to the BMS (Feed connector – R1 – R4 – 5 ways BMS connector – BMS).

H - Battery Charger does not work properly

Connect the power cable and check the battery charger light after two minutes, if it is red go to step 6, if it is flashing red/green go to step 7.

I - Plug icon on the display interchanges intermittently with the battery icon while charging



MAF12120

Check the value “battery %” in the INPUT menu, press button number 6 “service”, press 1 “input”, and 1 “previous”. Press 9 "Esc" to go back.

MAF12020

If during charge, the battery level is changing irregularly from 100% to another value, go to step 21. If during charge, the battery level is not 100%, leave the machine under charge overnight.

L - Battery package level is “zero” on the remote control, however the machine works properly

Check all the connections and the supply on the “Can Bridge Box”.

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3.3 RAMHINO DIAGNOSTIC TOOL

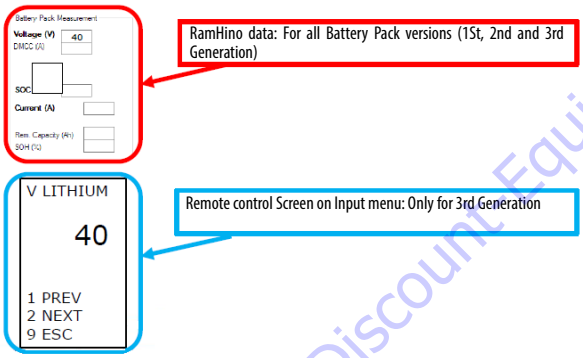
RamHino is an application which allows communication with the CAN BUS circuit of the machine. A Peak CAN device is used for connection between the PC/laptop and the machine CAN BUS circuit.

The tool is useful for service on lithium machines, as it shows detailed overview of the battery pack status and how the pack components are working. On the lithium machine, the settings and the information for the diagnostics about the components of the battery pack group can be found by RamHino only.

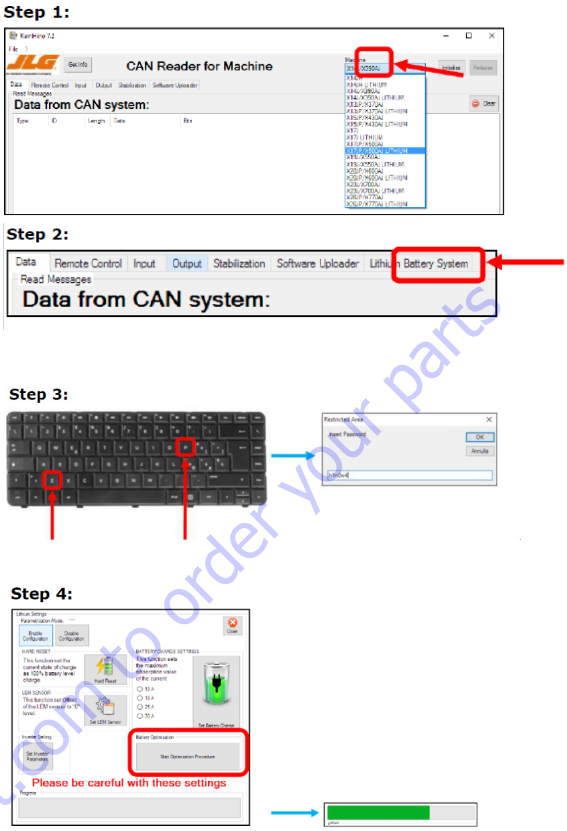
Only for 48V Lithium Battery Pack, when the battery charger is connected and the BMS is ON, the RamHino Lithium page can be seen even if the machine is OFF.

For X23J machine, the battery Pack has a specific CAN BUS cable for the Lithium main components (BMS, Inverter, Battery Charger); this CAN BUS Line is connected to the platform CAN BUS Line by a CAN Bridge Box. CAN Bridge Box is switched On by the main board (ECM1- 2), so RamHino connection by the emergency remote control plug can be used only when the machine is ON.

For instruction on the installation of the Peak CAN device and the use of the RamHino application refer “RamHino Tool Instructions for use”.



MAF17030



MAF17040

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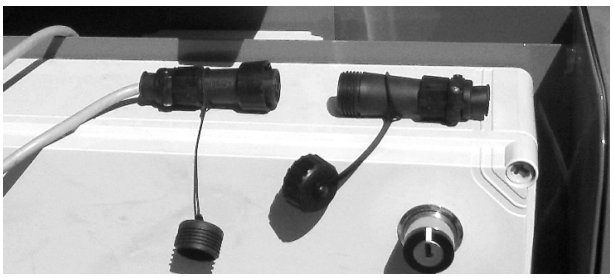
Peak CAN Device Connection

For models X14J, X19J, X23J, X390AJ, X550AJ and X700AJ

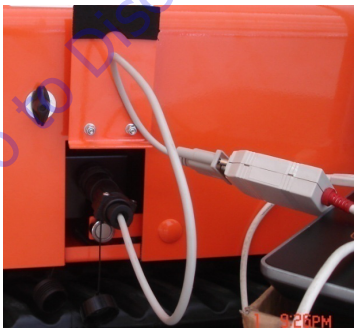
Connect Pack Can device to the cable of remote control at the ground port on the side.



MAF12170

For modelsX17JP, X500AJ, X20JP, X600AJ, X26JP and X770AJ

Connect the Peak Can device to the port of the remote control at the ground port on the side.



MAF12180

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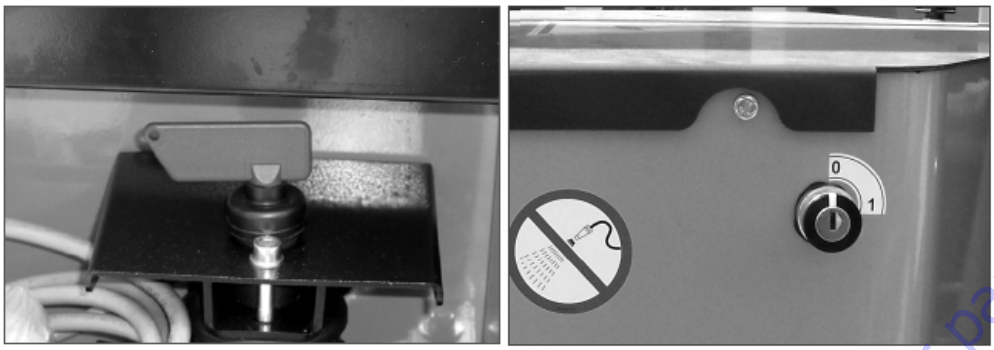
Turn ON the Battery Switch and turn ON the Circuit Breaker Switch.



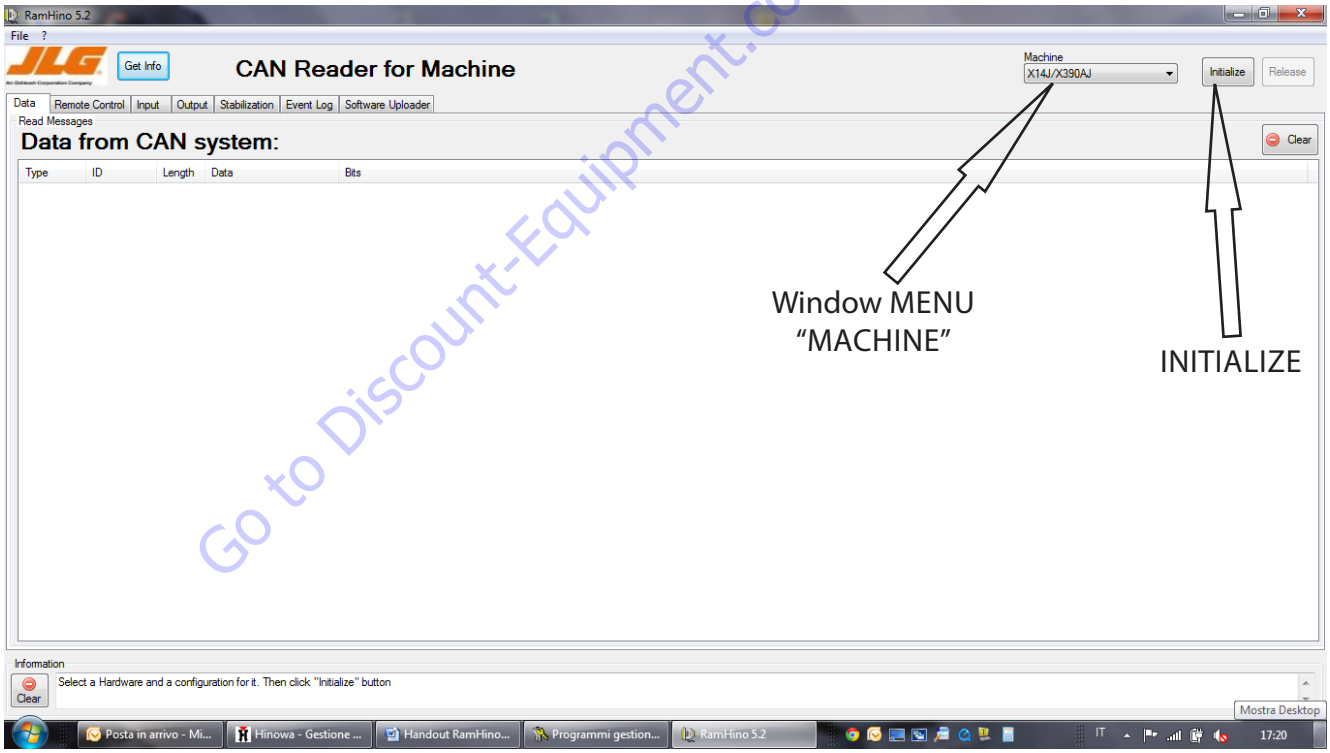
MAF12190

RamHino Startup Procedure

Run the RAMHINO Flash Program through the

icon on desktop. Below screen will appear.

- Select the applicable machine model from the window menu "Machine".
- Click on "INITIALIZE" button to activate PC/laptop-machine communication.



MAF12200

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Folder Data

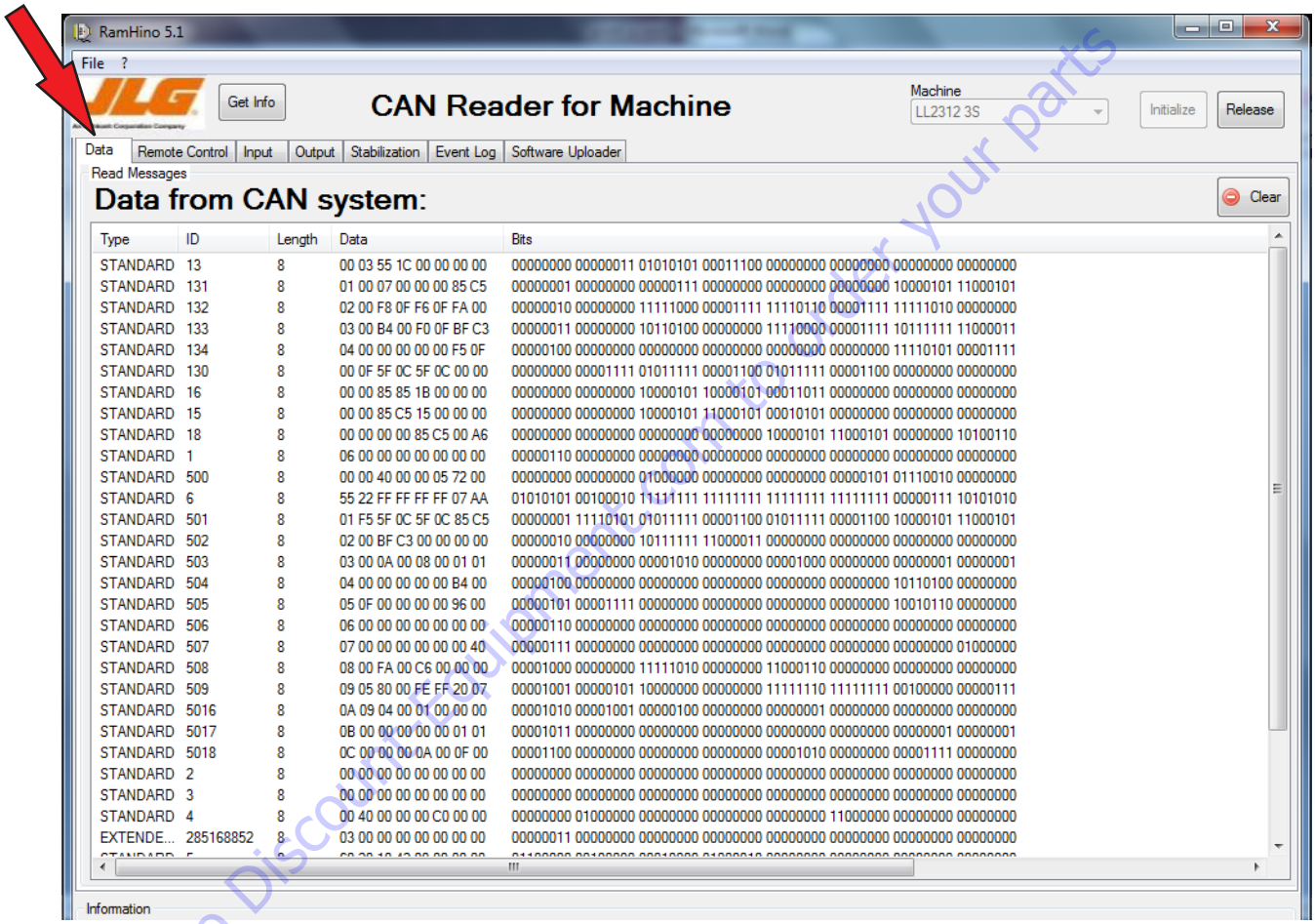
The first screen indicates the data exchange between the machine system and the PC/laptop. Communication is activated when lines appear with numbers (binary language) as shown below.

If there is no communication between PC/laptop and machine system, data will not be displayed on the screen. In such case do the following:

a. Check the USB port on PC/laptop. Try different ports.

b. Restart the RamHino program.

c. For X17J model only, check the correct wire connections (Pins 2 and 6).



Type	ID	Length	Data	Bits
STANDARD	13	8	00 03 55 1C 00 00 00 00	00000000 00000011 01010101 00011100 00000000 00000000 00000000 00000000
STANDARD	131	8	01 00 07 00 00 00 85 C5	00000001 00000000 00000111 00000000 00000000 00000000 10000101 11000101
STANDARD	132	8	02 00 F8 0F F6 0F FA 00	00000010 00000000 11111000 00001111 11110110 00001111 11111010 00000000
STANDARD	133	8	03 00 B4 00 F0 0F BF C3	00000011 00000000 10110100 00000000 11110000 00001111 10111111 11000011
STANDARD	134	8	04 00 00 00 00 00 F5 0F	00000100 00000000 00000000 00000000 00000000 00000000 11110101 00001111
STANDARD	130	8	00 0F 5F 0C 5F 0C 00 00	00000000 00001111 01011111 00001100 01011111 00001100 00000000 00000000
STANDARD	16	8	00 00 85 85 1B 00 00 00	00000000 00000000 10000101 10000101 00011011 00000000 00000000 00000000
STANDARD	15	8	00 00 85 C5 15 00 00 00	00000000 00000000 10000101 11000101 00010101 00000000 00000000 00000000
STANDARD	18	8	00 00 00 00 85 C5 00 A6	00000000 00000000 00000000 00000000 10000101 11000101 00000000 10100110
STANDARD	1	8	06 00 00 00 00 00 00 00	00000110 00000000 00000000 00000000 00000000 00000000 00000000 00000000
STANDARD	500	8	00 00 40 00 00 05 72 00	00000000 00000000 01000000 00000000 00000000 00000101 01110010 00000000
STANDARD	6	8	55 22 FF FF FF FF 07 AA	01010101 00100010 11111111 11111111 11111111 11111111 00000111 10101010
STANDARD	501	8	01 F5 5F 0C 5F 0C 85 C5	00000001 11110101 01011111 00001100 01011111 00001100 10000101 11000101
STANDARD	502	8	02 00 BF C3 00 00 00 00	00000010 00000000 10111111 11000011 00000000 00000000 00000000 00000000
STANDARD	503	8	03 00 0A 00 08 00 01 01	00000011 00000000 00001010 00000000 00001000 00000000 00000001 00000001
STANDARD	504	8	04 00 00 00 00 00 B4 00	00000100 00000000 00000000 00000000 00000000 00000000 10110100 00000000
STANDARD	505	8	05 0F 00 00 00 00 96 00	00000101 00001111 00000000 00000000 00000000 00000000 10010110 00000000
STANDARD	506	8	06 00 00 00 00 00 00 00	00000110 00000000 00000000 00000000 00000000 00000000 00000000 00000000
STANDARD	507	8	07 00 00 00 00 00 00 40	00000111 00000000 00000000 00000000 00000000 00000000 00000000 01000000
STANDARD	508	8	08 00 FA 00 C6 00 00 00	00001000 00000000 11111010 00000000 11000110 00000000 00000000 00000000
STANDARD	509	8	09 05 80 00 FE FF 20 07	00001001 00000101 10000000 00000000 11111110 11111111 00100000 00000111
STANDARD	5016	8	0A 09 04 00 01 00 00 00	00001010 00001001 00000100 00000000 00000001 00000000 00000000 00000000
STANDARD	5017	8	0B 00 00 00 00 00 01 01	00001011 00000000 00000000 00000000 00000000 00000000 00000001 00000001
STANDARD	5018	8	0C 00 00 00 0A 00 0F 00	00001100 00000000 00000000 00000000 00001010 00000000 00001111 00000000
STANDARD	2	8	00 00 00 00 00 00 00 00	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
STANDARD	3	8	00 00 00 00 00 00 00 00	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
STANDARD	4	8	00 40 00 00 00 C0 00 00	00000000 01000000 00000000 00000000 00000000 11000000 00000000 00000000
EXTENDE...	285168852	8	03 00 00 00 00 00 00 00	00000011 00000000 00000000 00000000 00000000 00000000 00000000 00000000

MAF12210

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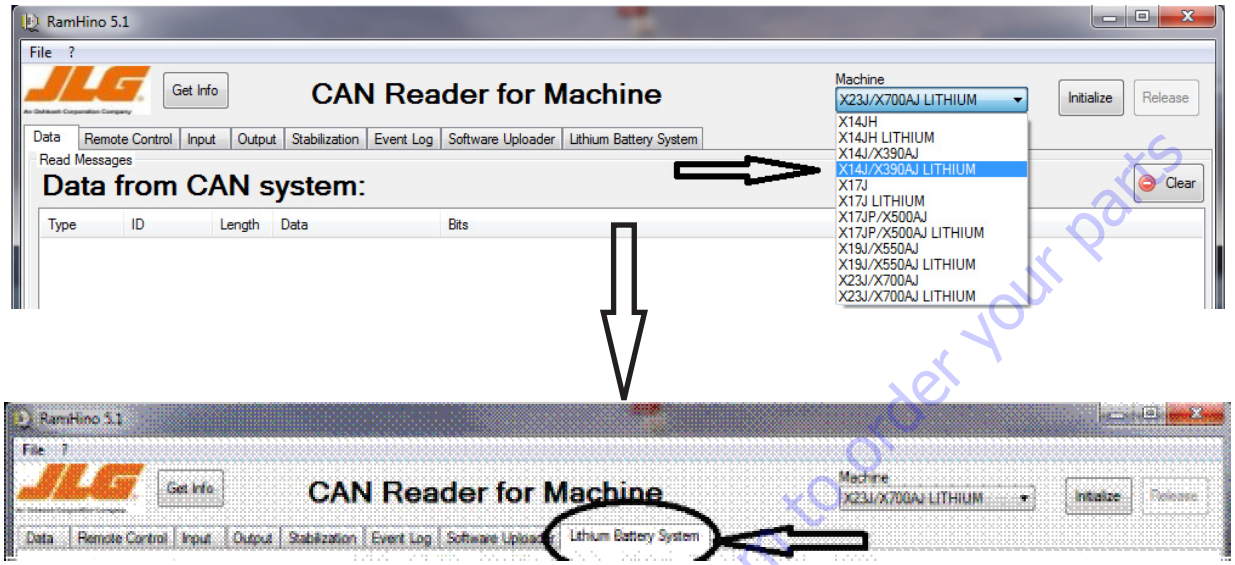
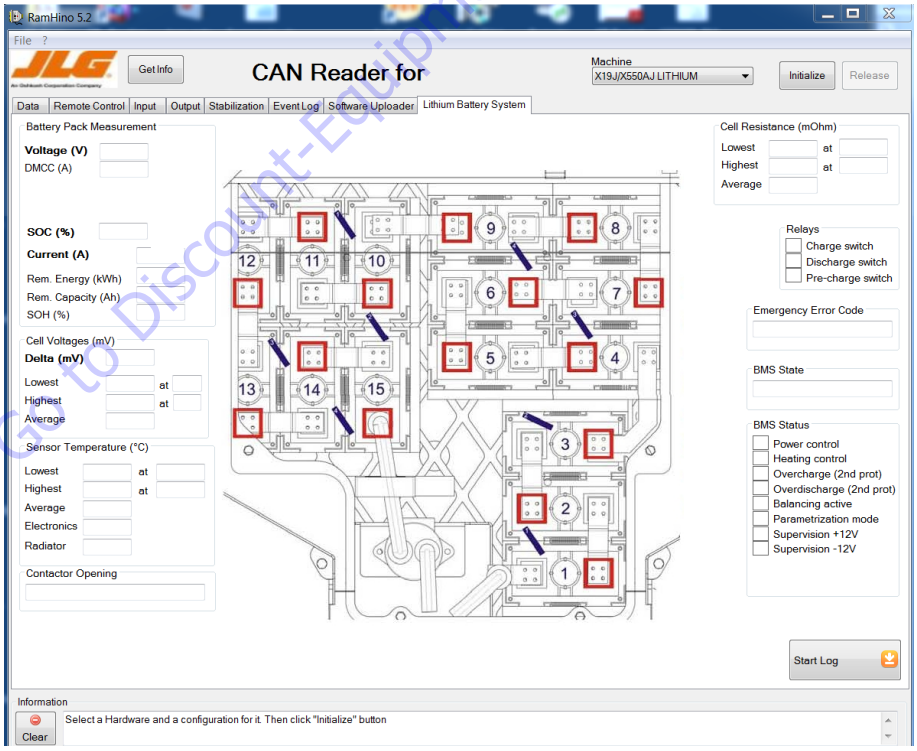
Select the applicable machine model and click on "Lithium Battery System" tab.

NOTE: *48V battery pack and 72/83V battery pack have the same data on the RamHino Lithium page. The only difference is the pack drawing. The Cell number and temperature sensor location are shown on 48V battery pack page while cell number and temperature sensor position are shown on 72/83V battery pack page.*



MAF12220

Lithium Battery System Page



MAF12230

Figure 3-1. 48V Battery System page - 1st and 2nd Generation

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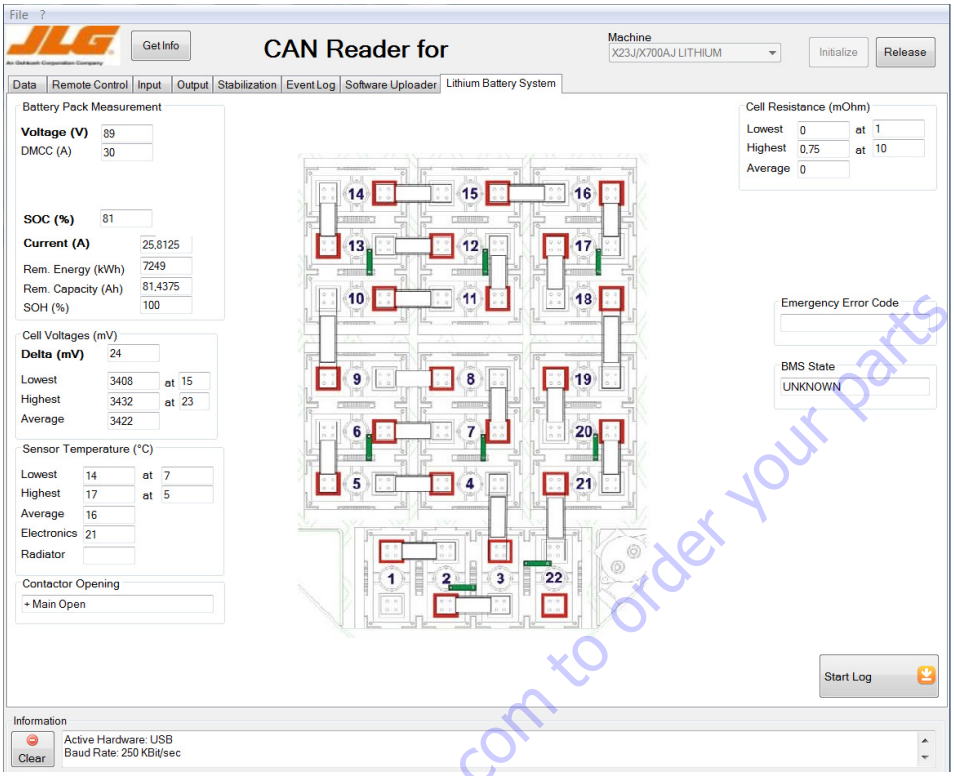

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Figure 3-2. 72/83V Battery System page - 1st and 2nd Generation

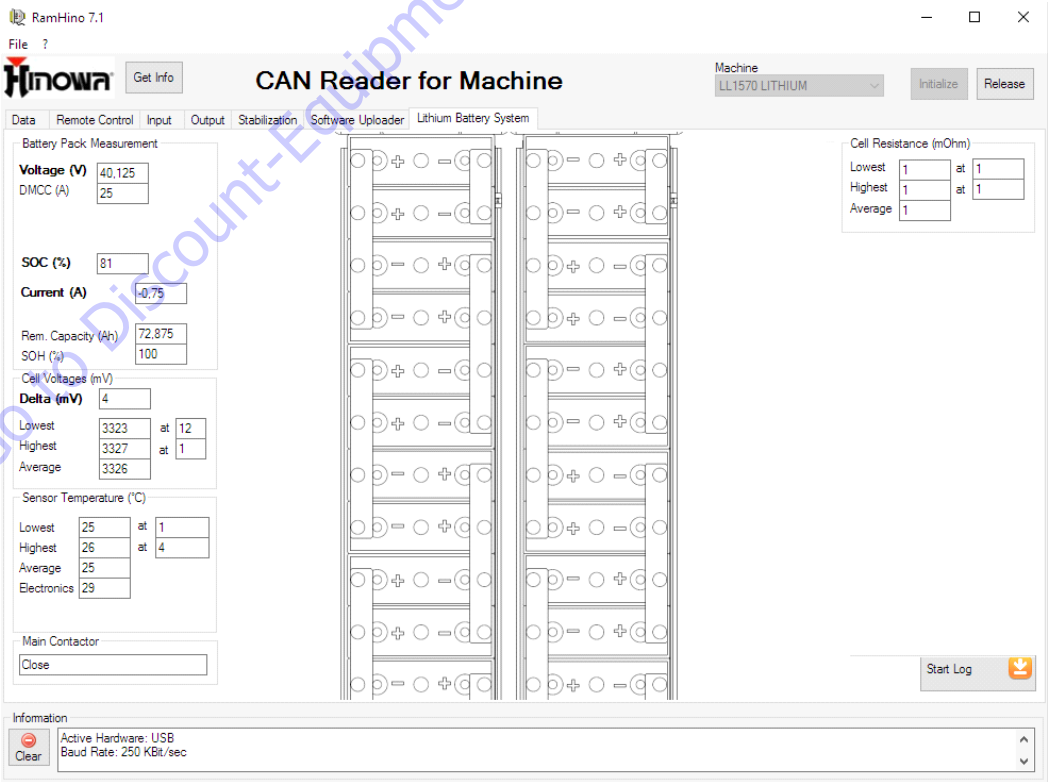

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Figure 3-3. 38V Battery System page - 3rd Generation

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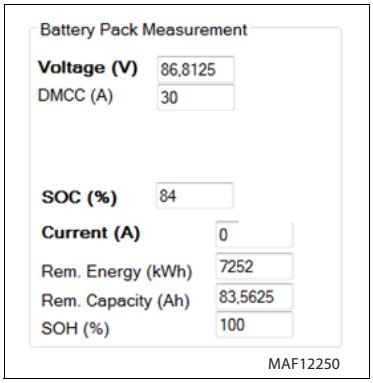
RamHino Parameters

Lithium System parameters for RamHino Lithium system are shown below

RamHino First group:



1. Voltage (V): It is the total level of the cells voltage. As the cells are connected in series, this is the total pack voltage considering the 12, 15, 22, 24 or 26 cells. The minimum voltage for every cell is 2800 mV, while the maximum voltage is 3600 mV (average value). Figure 3-6 shows the range of admissible voltages.

NOTE: *When the cells are not under charge or under discharge for some time, they try to reach a nominal value of approximately 3300 mV irrespective of their charge status.*
*The Voltage (V) when checked on a machine that is not working or that is not under charge is approximately 39.6V on 38V battery pack (3.3*12), 49.5V on 48V battery pack (3.3 X 15), 72.6V on 72V battery pack (3.3 X 22), 79.2V on 76V battery pack (3.3*24) and about 85.8V on 83V battery pack (3.3*26).*
To check the minimum real value of voltage, the battery pack must be under discharge. An arm or one or more stabilizer can be moved for some time so that there is a voltage drop and the voltage value measured is real.
To check the maximum value of voltage, the battery pack must be under charge. 110-220V power cable must be connected for at least five minutes to measure the voltage.

Table 3-6. Admissible Voltage Range

Battery Pack	Minimum (Battery Pack discharge)	
38V Battery Pack	~33V (2.8 Volt X 12 Cells)	~43V (3.6 Volt X 12 Cells)
48V Battery Pack	~42V (2.8 Volt X 15 Cells)	~54V (3.6 Volt X 15 Cells)
72V Battery Pack	~64V (2.8 Volt X 22 Cells)	~84.5V (3.6 Volt X 22 Cells)
76V Battery Pack	~67V (2.8 Volt X 24 Cells)	~86V (3.6 Volt X 24 Cells)
83V Battery Pack	~72.8V (2.8 Volt X 26 Cells)	~93.6V (3.6 Volt X 26 Cells)

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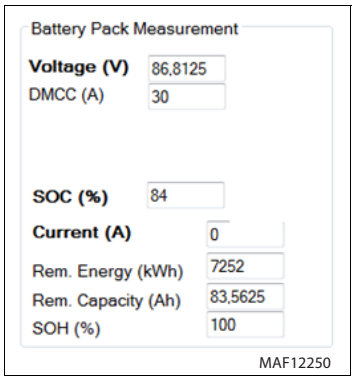
2. DMCC (A): It is the current by the BMS from the battery charger. It depends on the cells and charging status.



When machine is not under charge, the current required by BMS is always maximum. The required current detail is listed in below table.

In the beginning of the charging process, BMS requires the maximum current to the battery charger, independently from the cells voltage.

After some time if a cell voltage is already 3630 mV, the current required is reduces according with a series of parameters (state of the other cells, temperature, current absorbed etc).

In the last charging steps (equalization phase), the current required to the battery charger should be reduced.

When the battery pack is completely charged and Equalized, 1st generation BMS requires a current of around 4-5 ampere for initial few seconds, then requires zero ampere for next few seconds. The 2nd generation BMS requires a fixed current of around 0.5-1 Ampere.

Table 3-7. BMS Current Requirement

Battery Pack	CE Machines	ANSI Machines
38V Battery Pack	18A	18A
48V Battery Pack	25A	18A
72V Battery Pack	30A	13A
76V Battery Pack	30A	13A
83V Battery Pack	30A	13A

3. SOC (%): It is the level of battery pack charge and corresponds to the value showed by the remote control display.
   If the SOC value is not 100% and the current required is not maximum, there is a problem with one cell.
   The cells maximum level is100% and minimum level is 0%. However the value 0% is not the complete cells discharge point, there is some residue cells power to avoid the excessive low voltage od cells. SOC (%) depends on the status of all the cells.
4. Current (A): It is the value of the current measured by the LEM sensor. With sign "-" the current is going out from the battery pack (discharge). If there is no sign, the current is going inside the pack (charge).
   During charge, if the machine is not moving, Current (A) value should be close to the DMCC (A) value, as the current required to the battery charger is almost the same as the current going inside the battery pack.
   For example, if DMCC (A) value is 25 Amp, and the Current (A) value is -1.5 Amp, the battery charger is disconnected, or one contactor is open.
   If the main key is on with machine not under charge, Current (A) value should be around -1.5 to 2 Amp, that is the current absorbed from all the ECM and the remote control.
   In the same condition, if the Lead-acid battery level is low, the Current (A) negative value increases because the system also has to recharge the Lead-acid battery.
5. Rem. Energy (kWh) (1st and 2nd Generation): Power still available in the battery pack
6. Rem. Capacity (Ah): Capacity still available in the battery pack
7. SOH (%): State of health (SOH) of the battery pack shows how good the battery pack performance is as compared to when the pack was new.
   When the battery pack is new, this value should be 100. Cycles of charges and discharges, temperatures and other elements effect SOH.
   SOH (%)= "0" means the pack still has 80% of the capacity compared with a new battery pack. For example when we read SOH (%) value as 1%, it means that the performance of this battery pack is approximately 80% as compared to a new battery pack.

NOTE: *SOH (%), Rem. Energy (KWh) and Rem. Capacity (Ah) are the same data showed in different ways.*

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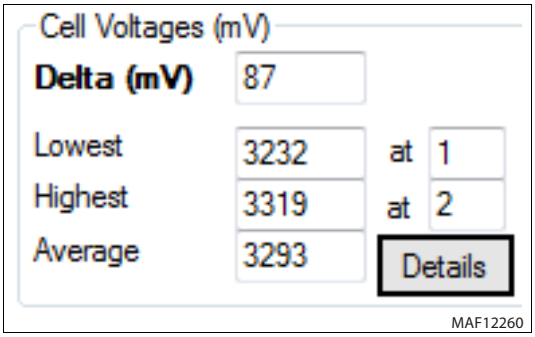
Second Group - Cell Voltage (mV)

1. Delta (mV): It is the difference between the highest cell and lowest cell (mV).



Discharge phase: The cells supply the same level of current as when they are connected in series. For this reason, the cells should have the same voltage drop and the voltage difference should be below 150 mV (100 mV on 1st generation BMS). If Delta (mV) value during the discharge increases more than 250 mV (200 mV on 1st generation BMS), it is necessary to discharge and recharge the battery pack completely and check the value again.

Charging phase: Delta (mV) value during the charge operation is an important data for the diagnosis. During the charge, this value can increase to more than 400 mV. However at the end of the equalization operation it should be approximately 100 mV (50 on 1st generation BMS) or in any case fluctuating to 250 mV or less (this will not be due to a machine problem).

To make sure that the system is well equalized, it is recommended to periodically leave the machine under charge for at least one night. If the Delta (mV) value is not decreasing below 250 mV even after charging for one night, it is necessary to check which cell is the highest one, completely discharge and recharge the system and check again.

2. Lowest - at: It is the voltage at the lowest cell. The number of the corresponding cell is indicated on side.

During the charge: As the lithium cells do not have the same characteristics at 100%, even when they are charged with the same current level, it is possible that one cell reaches the maximum charge level quicker than the other cells. This characteristic is normal and it does not mean that there is a failure. However, at the end of the charging process, if the lowest cell is always the same, its value should be approximately 3450 mV.

During the Discharge: During the discharge, the cells voltage should decrease in the same way, so the Delta (mV) value should decrease. If one cell voltage decreases quickly compared to the other cells, this can be a defective cell.
For example, if the highest cell is at 3.3 Volt, and the lowest cell is at 2.8 Volt, there is possibility of a problem. In this case, it is important to analyze the value “average”, because it shows if the other cells are closer to the higher cell or to the lower cell showing where the problem is.
If only one cell in a battery pack is replaced after many years, this new cell will decrease voltage slowly than other cells, but the BMS can control that characteristic.

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3. Highest - at: It is the voltage at the highest cell. The number of the highest cell is indicated on side.

   During the Discharge: During discharge, this value is not important, it is normal that the decrease in cells voltage is different.
   During the Charge: This is important data. During the charge, the highest cell can change with time, but when one cell reaches 3630 mV the BMS connects it with an electrical resistance to allow other cells to reach 3580/3600 mV without any overcharge. However, the lowest cell should be at minimum 3450 mV.
   When another cell reaches also 3630 mV, BMS connects it to a resistance. At the end of the equalization operation, the highest cell changes after few seconds, because when the BMS connects a cell to the resistance its voltage decreases.
   If a cell reaches 3630 mV and after many hours under charge the highest cell is still the same, without increase in the "average" value, there is a failure because the BMS is not able to discharge that specific cell. In this case it is seen that

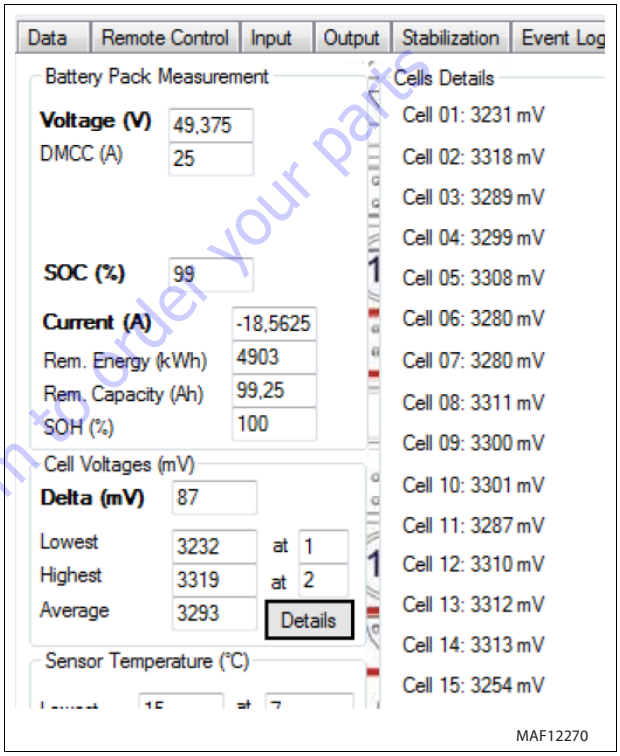
   - SOC never reaches 99-100%
   - Delta (mV) is more than 250 mV
   - Average voltage does not reach 3580/3600 mV
   - Highest cell is the same
   - After every charge of battery pack, final SOC level is lower than the charge earlier

   If above conditions are seen, it is necessary to replace the BMS.

   A new BMS will need more time to get equalization of cells as the cells have different level of charge. However, it is sufficient to leave the machine under charge for at least 48 hours to allow BMS to reach a good pack balance.

4. Average: It is the average of the total cell values (Volt). At the end of the equalization phase, it should be around 3580/3600 Volt.

   The image below shows the details of voltage values of all cells in 48V battery pack. The cells voltage is read while the system is ON or during charging or discharging.



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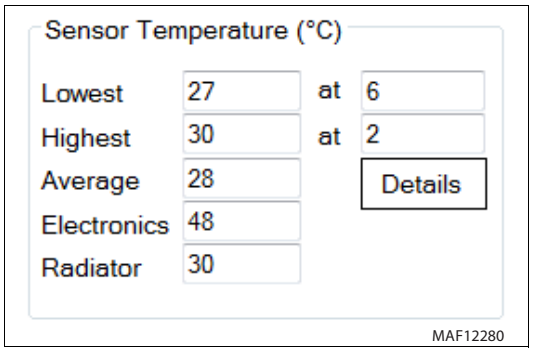
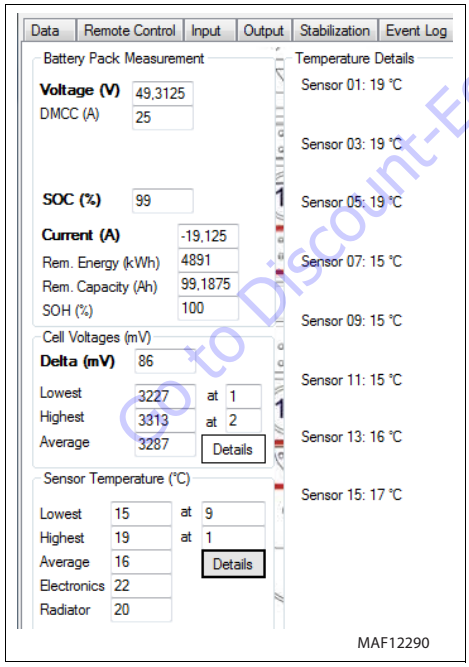
Third Group - Temperature Sensors

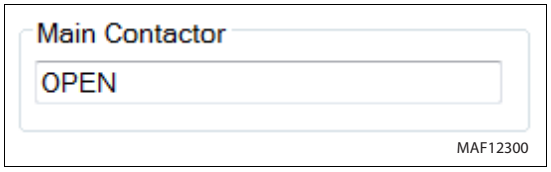


1. lowest - at: It is the lowest temperature. The sensor number is indicated on the side.
2. Highest - at: It is the highest temperature. The sensor number is indicated on the side.
3. Average: It is the average value of temperature.
4. Electronics: It is the internal temperature of the BMS.
5. Radiator (only for 1st generation BMS): It is the temperature of the BMS cooler. During the equalization phase, the radiator temperature increases as one or more cells are connected to the resistance to be discharged.
   See below image for details of all temperature sensors on a 48 Volt battery pack.



NOTE: *The highest and the lowest temperature value must be approximately same.*

Fourth Group - Contactor Opening (only for 2nd Generation BMS)



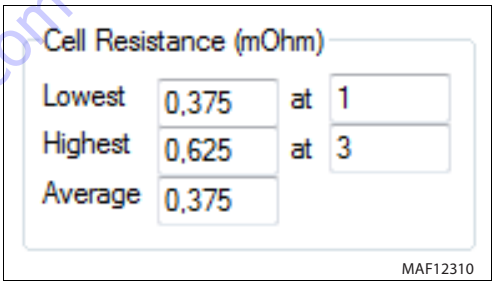
Open: Current supply is not allowed.

Closed: Current supply is allowed.

Internal contactor status called "Main Contactor", is controlled by the BMS.

NOTE: *In the battery pack, temperature sensors are used to switch ON/OFF. They close the lines if the internal temperature reaches 70 °C. In this case, or if a sensor detects a high temperature, a specific failure code is shown in the window Emergency Error Code.*

Fifth Group - Cell Resistance (mOhm) (only for 1st Generation BMS)



1. Lowest - at: It is the lowest resistance of the cells. The cell number is showed on side.
2. Highest - at: It is the highest resistance of the cells. The cell number is showed on side.
3. Average: It is the average of all cell resistance.

NOTE: *Cells resistance is important to identify a defective cell or a bad cell connection. The value of the resistance can be different depending on many causes. However, a warm cell normally has a resistance value of 1 ohm or less.*
To make sure a cell is moderately hot, it is sufficient to move the machine for some minutes, or to leave the battery pack under charge for some hours. At the end of the charge, the cells resistance value increases.

NOTE: *The cell resistance also depends on the how tight the cell screws are tightened. In case one or more cell resistance is high, it is necessary to open the battery pack and check to make certain the screw are tight of the cells.*

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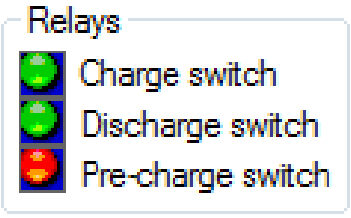
Sixth Group - Relays (only for 1st Generation BMS)

The relays are inside the BMS and hence cannot be accessed. However their status is helpful when replacing the BMS in case of failure.



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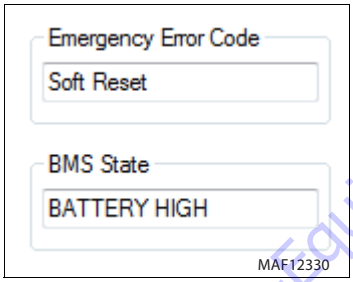
1. Charge Switch: Charge contactor open/closed.
2. Discharge Switch: Discharge contactor open/closed.
3. Pre-charge Switch: Pre-charge contactor open/closed.

Seventh Group - Code and State



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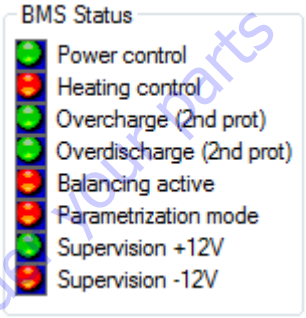
1. Emergency Error Code (only for 1st generation BMS): Emergency code present, see MS fault codes.

NOTE: *Soft Reset means ok.*

2. BMS State: It is the status of the BMS. It is helpful when replacing BMS in case of failure. For 2nd generation BMS it is UNKNOW.

Eighth Group - BMS Status (only for 1st Generation BMS)

The following parameters are internal to the BMS, hence cannot be controlled. However, their status is helpful when replacing BMS in case of failure.



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1. Power Control: Microcontroller supply ON/OFF.
2. Heating Control: Heating Control ON/OFF.
3. Overcharge (2nd prot): Secondary Protection overcharge reached.
4. Over discharge (2nd prot): Secondary protection over discharge reached.
5. Equalization active: Equalization active on minimum one cell.
6. Parameterization mode: Parameterization mode ON/OFF.
7. Supervision +12V: +12 Volt confirmation.
8. Supervision -12V: -12 Volt confirmation.

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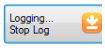
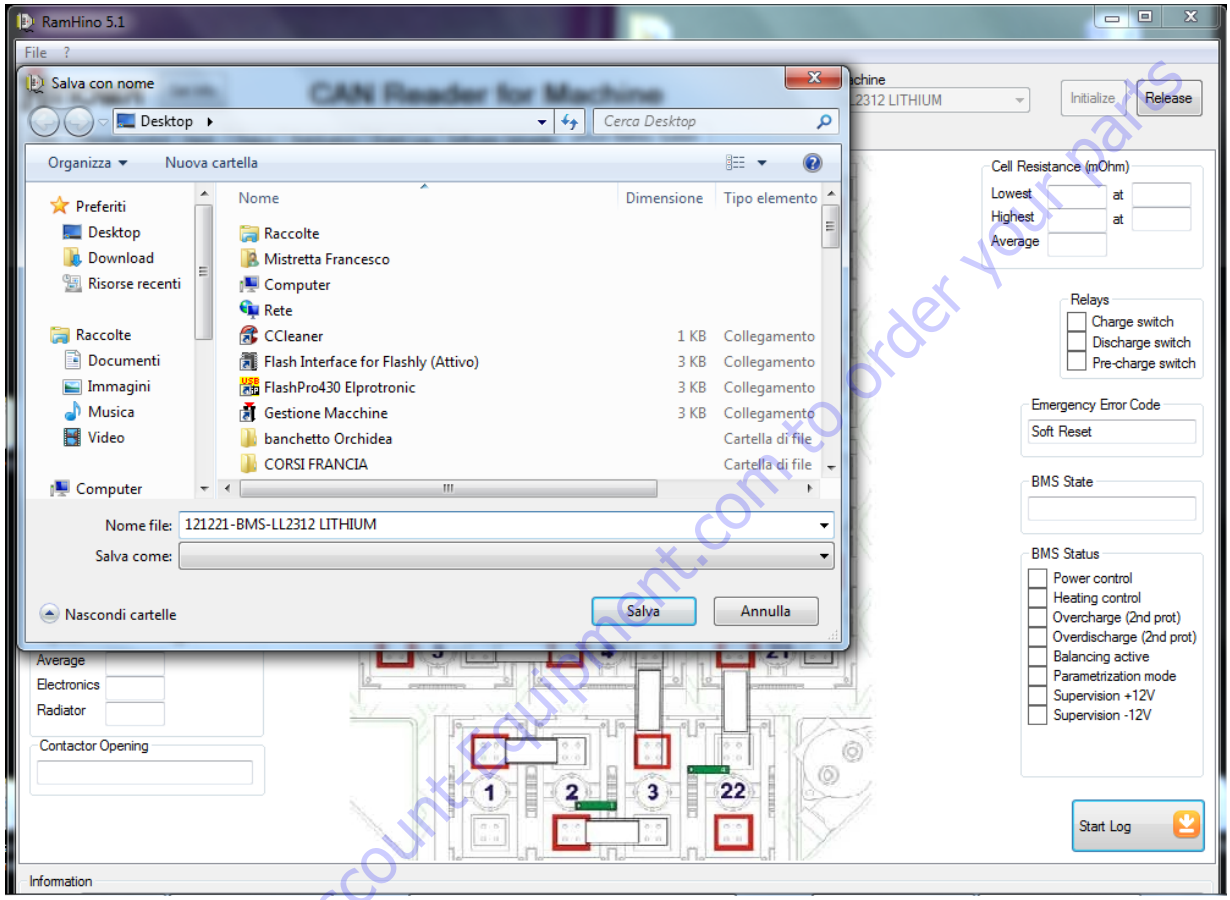
3.4 START LOG

Click the

icon to start recording the data applicable to the Lithium Pack Battery System. Before recording, a window as shown below is displayed to select the name and folder where the “Log” file will be saved. Click on “Save” to start the recording.

Click the 

icon to stop recording data. The file generated should be opened in Excel format and the Lithium battery pack data stored every second can be visualized with the time [hhmmss]. date is already shown in the default name of the file. LOG file is useful for the diagnostic of the Lithium system.



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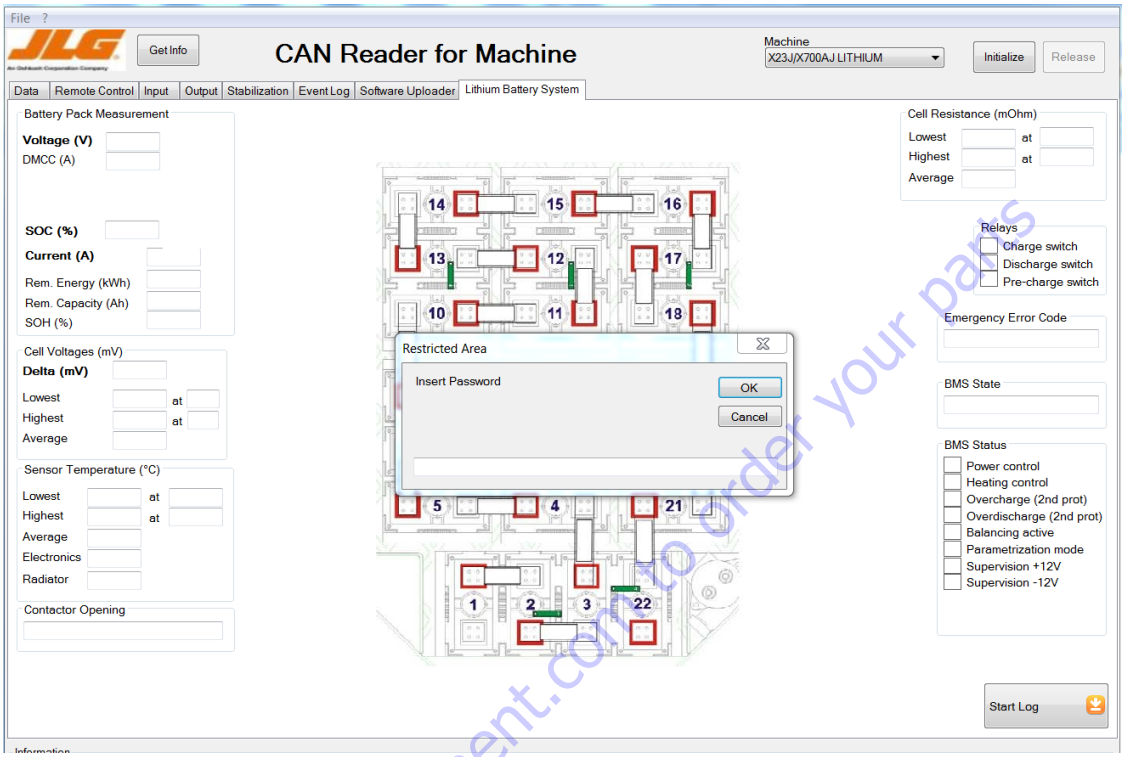
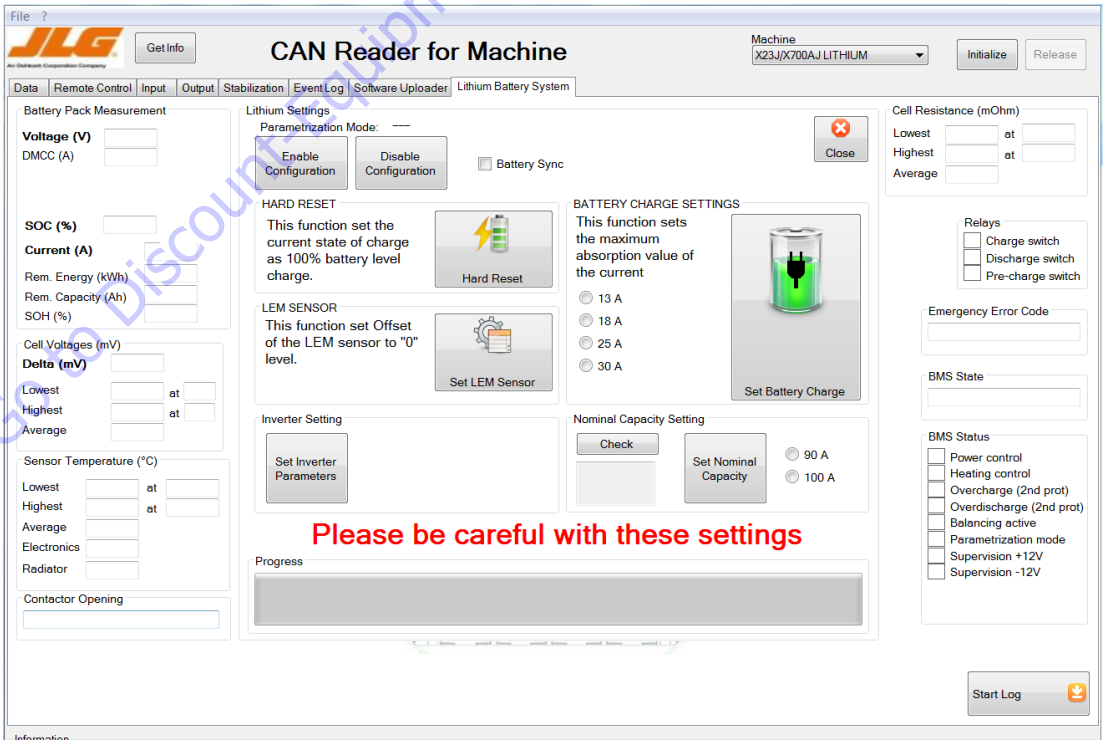
DMCC (A) and Cell Capacity Setting





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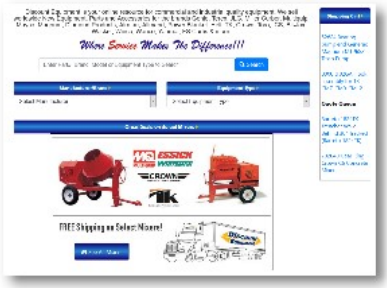

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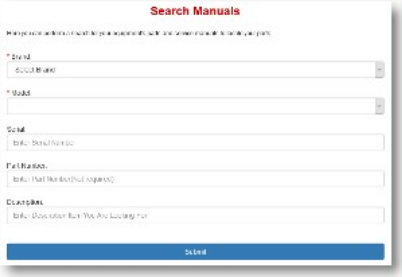

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