User Manual

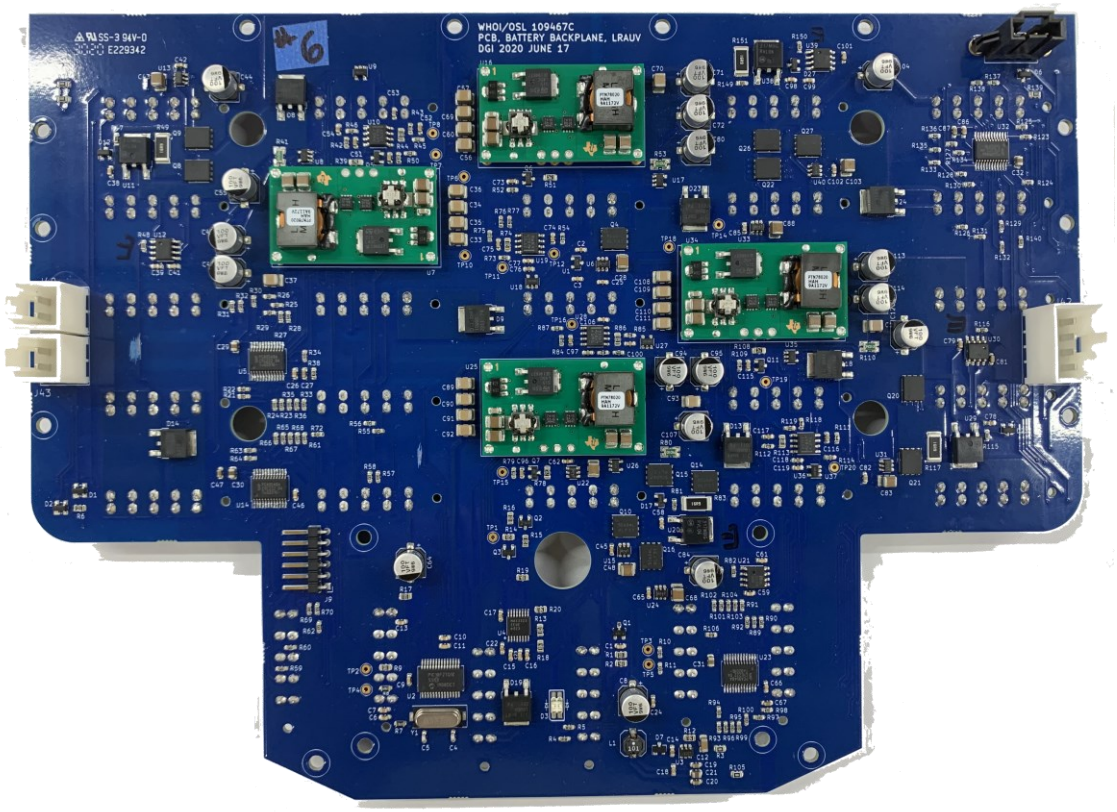
WHOI Scibotics 109467 rev C, PCB, Battery Backplane, LRAUV

Daniel Gomez-Ibanez 2021-AUG-23

The 109467 Backplane PCB is a printed circuit board assembly which merges the power outputs of 31 Inspired Energy NH2034 battery packs, feeding the vehicle discharge bus via ideal or-diodes. 109467 regulates charge current and voltage when supplied with power from the vehicle shorepower bus. 109467 provides status information, including state of charge, to the LRAUV main vehicle computer. 109467 is responsible for starting and stopping the charging process and it does this autonomously: without requiring any commands over the serial interface.

109467 is designed to replace the legacy LRAUV battery backplane, MBARI 10021057BPC, which was based on an obsolete OceanServer PC-104 battery charger stack. The new backplane provides similar functionality and electrical interfaces compatible with the legacy backplane, but the serial interface protocol is different.

This document describes the operation of and serial interface to the new backplane PCB 109467. For more information about packs, see also the Inspired Energy NH2034HD34 battery data sheets and the associated Inspired Energy *Smart Li Ion Battery User Notes* document[1].



[1] https://www.inspired-energy.com/wp-content/uploads/Smart-Battery-User-Notes.pdf

Backplane Functions

The Backplane provides the following functions:

Charge DC-DC converters, based on Texas Instruments PTN78020HAH converter module, regulate voltage and current supplied to the battery packs during charging. There are four banks of packs regulated separately. Nominal charge current is 2A per bank.

Charge ideal diodes to avoid discharge into the shorepower cable, protecting the cable, power supply and batteries from unintentional energy release. Based on NVMFS5C604NLAFT1G MOSFET and LM74700 ideal diode IC.

Discharge ideal diodes so the battery banks provide redundancy for each other, and the banks do not charge or load each other. Also based on LM74700 ideal diode IC.

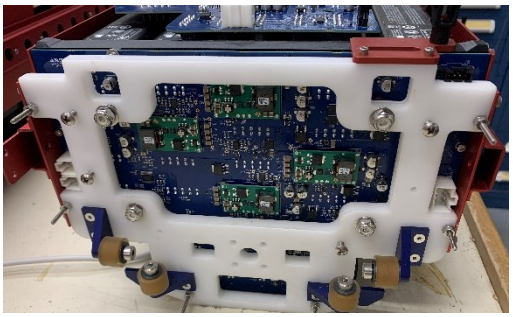
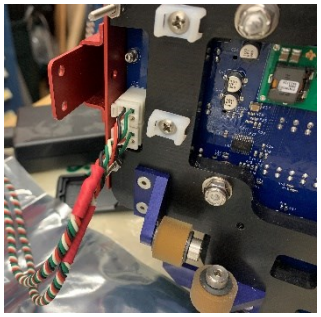
Backplane Electrical Connections

Backplane has two input connectors, J40 and J43, which match the legacy MBARI backplane. There is a single output connector, J42, which matches the legacy MBARI output connector.

The backplane includes RS-232 serial on a four-pin Molex C-grid connector J8. A Microchip ICD header (J9, right angle) is also accessible for programming the PIC.

Power Supply Considerations

Shore supply can be up to absolute max 36VDC, and it might make sense to run at 24 or 30V if shore power supply ampacity or cable heating is a bottleneck. However, higher voltages are not possible if the LRAUV power input filter board is present, as it clamps the shorepower voltage to 22V and will be damaged by higher voltages. Even if this board is removed and shorepower rerouted, higher shorepower voltages will lower efficiency of converters and will therefore put more heat into the housing. Converters are most efficient when the shore power supply is current limited and therefore buck regulator dropout voltage is minimized.


Charger Autostart and Termination Thresholds

	Autostart/ Autoterminate $BMLCI Status Bit	Backplane Charge Start Criteria	Backplane Charge Termination Threshold	IE NH2054 Pack Protection Action Threshold
Pack/Cell Temperature	0x01	< 40 °C	> 45 °C	>54 °C
Highest Pack Cell Voltage	0x02	< 4.100 V	> 4.200 V	>4.300 V
Pack Charge Current	0x04	< 0.5 A	> 2.5 A	>3.5 A
Backplane PCB Temperature	0x08	< 40 °C	> 50 °C	n/a
Pack Data Age	0x10	< 11 seconds	> 25 seconds	n/a
Shorepower Voltage	0x20	> 17 V	< 12 V	n/a
Cell Overdischarge	0x40	> 2.800 V	< 2.600	unknown
Reserved	0x80	n/a	n/a	n/a

Backplane Serial Interface

The Backplane communicates with host vehicle computer via multidrop RS232 at 57600 baud (N81).

Messages are composed of ASCII characters in NMEA-like sentences and can be typed by hand to facilitate testing. Backplane does not send any message unless it receives a valid request with matching address and checksum from the bus master. Example:

#CCBMQ,0001,LST*FE

$BMLST,0001,24.9,23.0,22.5,3.442,3.177,13.711,201.24,20.16,31*7A

Message Conventions

$ttllQ,BBBB,sss*CS<CR><LF>

tt – Talker identifier (ID for the system sending the message = “CC”)

ll – Listener Identifier (ID for the system a message is being requested from = “BM”)

Q – Defines the message as being a query sentence

BBBB - Board address for battery board a message is being requested from. 16 bits, hex

sss – Sentence Identifier (ID for the type of state message being requested)

Possible sentence IDs: LST, PST, BVN, LCI

CS – NMEA 0183 style checksum

<CR><LF> – Carriage return/line feed terminator

Note the checksum follows NMEA convention and is the exclusive-or of all characters between the “$” and the “*” not including the delimiters themselves.

Optional Multidrop Addressing

The four-hex-character 16-bit bus address defaults to 0001 when the microcontroller is erased and re-programmed. The address should be changed before multiple modules are connected in a serial bus. The address can be left as 0001 if each backplane has its own point-to-point serial port as in the legacy

vehicle configuration. The Backplane serial transmitter is enabled only when Backplane replies to a correctly addressed message. To find out what addresses are connected to the bus, use the special Board Probe (BPR) message. All connected batteries respond, with their addresses, after a random delay of at most 1 second.

Example: Vehicle probes multidrop bus
$CCBPR*2C<CR><LF>

Battery Modules Respond After Random Delay
$BMBPR,0001*62<CR><LF>
$BMBPR,0002*61<CR><LF>

The address can be changed by using the special ACH message:

Example: Vehicle Requests Battery 0001 change its address to 00AA:
$CCACH,0001,00AA*2C<CR><LF>

Battery Module 0001 Confirms Address Change:
$BMACH,0001,00AA*44<CR><LF>

Message Definitions

The native data word for the Inspired Energy Smart Battery pack data bus is 16 bits. For consistency, the Backplane also uses 16-bit words for all communication and preserves other conventions of the Smart Battery Data format such as voltage, current and date binary formats. The Backplane queries its local battery packs via I2C bus. The backplane controller uses this pack-level status to manage the charging process and also buffers these data words so they are ready to transmit when the PST message is polled by the main vehicle controller.

LST – Lrauv battery backplane STatus

$BMLST,BBBB,TH,TL,TB,PB,VS,VH,VL,I.III,CAP,REMAIN,PC*CS<CR><LF>

- BBBB - Board address, specified in hexadecimal. 16 bits, 4 chars.
- TH, TL – Highest and lowest Smart Battery pack temperature, degrees Celsius.
- TB – Temperature of battery backplane. Degrees Celsius.
- VH, VL – Highest and lowest Smart Battery pack cell voltage in decimal volts.
- VS – String voltage measured at the battery backplane. Decimal volts.
- CAP - Sum of Smart Battery FullChargeCapacity in decimal amp hours.
- REMAIN – Sum of Smart Battery RemainingCapacity in decimal amp hours.
- PC – Decimal count of “packs”—small modules that each have their own state. Normally=31. This is the number of $BMPST replies to expect every time PST is requested (see below)
-

Example: $BMLST,0001,24.9,23.0,22.5,3.442,3.177,13.711,201.24,20.16,31*7A

PST – Pack STatus

$BMPST,BBBB,B,M,TTTT,MD,SN,T,V,A,FCC,RC,CC,SB,NC,V1,V2,V3,V4*CS<CR><LF>

- BBBB - Board address, 16 bits, 4 hex characters.
- B – Bank index of the pack reporting data, zero-referenced decimal 0,1,2, or 3
- M – Parallel index of the pack reporting data, zero-referenced decimal 0-7
- TTTT – Timestamp for the remaining pack data in this message – seconds, hex
- MD – Pack Manufacture Date, hex
- SN – Pack Serial Number, hex
- T – Pack temperature, kelvin, tenths, hex
- V – Pack voltage, volts, hex
- A – Pack current, milliamps, hex
- FCC – Pack full charge capacity, milliamp hours
- RC – Pack remaining capacity, milliamp hours
- CC – Pack cycle count
- SB – Status bits defined in Smart Battery Data Specification.
- NC – Number of cells in this pack (=4)
- V1,V2,V3,V4 - Individual cell voltages.

Example:

$BMPST,0001,0000,0000,0302,5077,0B8D,0B9E,3292,0000,19B2,013F,0001,02C0,0004,0CB0,0CA2,0C9F,0CA1*21
$BMPST,0001,0000,0001,0302,5077,0B8B,0B9D,3291,0000,19D0,015E,0001,02C0,0004,0CB0,0CA2,0C9F,0CA0*24
$BMPST,0001,0000,0002,0302,5077,0B60,0B99,328E,0000,199D,0145,0001,02C0,0004,0C90,0CB2,0CA0,0CAC*2E
$BMPST,0001,0000,0003,0302,5069,0B58,0B95,328E,0000,195B,010F,0001,02C0,0004,0CB9,0CAC,0C69,0CC1*54
$BMPST,0001,0000,0004,0302,5077,0B84,0BA4,3290,0000,199F,011E,0001,02C0,0004,0CA8,0C9C,0CB0,0C9C*55
$BMPST,0001,0000,0005,0302,5077,0B70,0B9D,328D,0000,19D8,015E,0001,02C0,0004,0CA9,0CA1,0CA6,0C9D*2C
$BMPST,0001,0000,0006,0302,5077,0B64,0B9B,328F,0000,19D2,015C,0001,02C0,0004,0CA7,0CA3,0CA7,0C9F*2D
$BMPST,0001,0000,0007,0302,5077,0B71,0B9C,328D,0000,19CD,015E,0001,02C0,0004,0CA3,0CA6,0CA2,0CA3*55
$BMPST,0001,0001,0000,0302,5077,0B94,0B9E,339C,0000,1972,017C,0001,02C0,0004,0CEE,0CE1,0CE4,0CEA*5A
$BMPST,0001,0001,0001,0302,5077,0B63,0B99,339D,0000,19B8,01CE,0001,02C0,0004,0CF1,0CE4,0CDD,0CEA*26
$BMPST,0001,0001,0003,0302,5077,0B6C,0B9D,339A,0000,1981,0187,0001,02C0,0004,0CEC,0CE4,0CE2,0CE8*29
$BMPST,0001,0001,0004,0302,5077,0B81,0B9C,339B,0000,197C,0198,0001,02C0,0004,0CF3,0CE7,0CDE,0CE3*28
$BMPST,0001,0001,0005,0302,5077,0B83,0B9A,339D,0000,1980,019F,0001,02C0,0004,0CEE,0CEF,0CE9,0CD7*51
$BMPST,0001,0001,0006,0302,5077,0B86,0B9E,339D,0000,19B9,01D1,0001,02C0,0004,0CF3,0CE1,0CE4,0CE5*26
$BMPST,0001,0001,0007,0302,4E68,048D,0B93,339C,FFFD,1915,013A,0001,02C0,0004,0CFB,0CF0,0CC1,0CEF*51
$BMPST,0001,0002,0000,0302,4E68,0478,0B97,35B1,0000,1939,03D6,0001,00C0,0004,0D72,0D70,0D6F,0D61*57
$BMPST,0001,0002,0001,0302,4E68,048B,0B92,35B7,0000,190A,0398,0001,00C0,0004,0D6D,0D6E,0D6E,0D6E*5C
$BMPST,0001,0002,0002,0302,4E68,0498,0B94,35B6,0000,1938,03BC,0001,00C0,0004,0D6F,0D6E,0D6C,0D6D*5C
$BMPST,0001,0002,0003,0302,4E61,0444,0B9B,35B2,0000,1910,0395,0001,00C0,0004,0D6F,0D6D,0D69,0D6E*5A
$BMPST,0001,0002,0004,0302,4E68,048F,0B97,35B5,0000,18F9,038A,0001,00C0,0004,0D70,0D6F,0D6C,0D69*21
$BMPST,0001,0002,0005,0302,4E68,049C,0B96,35B1,0000,18FE,0383,0001,00C0,0004,0D6D,0D6D,0D6B,0D6C*23
$BMPST,0001,0002,0006,0302,4E68,04A6,0B95,35B3,0000,18E2,0379,0001,00C0,0004,0D6C,0D70,0D6F,0D67*5F
$BMPST,0001,0002,0007,0302,4E61,045E,0B94,35B1,0000,194E,03B4,0001,00C0,0004,0D69,0D6D,0D6E,0D6D*53
$BMPST,0001,0003,0000,0302,4E5B,0405,0B98,3599,0000,19F4,0443,0001,00C0,0004,0D68,0D67,0D66,0D63*2C
$BMPST,0001,0003,0001,0302,4E61,044B,0B96,359C,0000,18E6,036A,0001,00C0,0004,0D6F,0D5B,0D68,0D6B*5A
$BMPST,0001,0003,0002,0302,4E61,0450,0B91,35A0,0000,1902,0378,0001,00C0,0004,0D6E,0D64,0D67,0D67*22
$BMPST,0001,0003,0003,0302,4E68,04A9,0B92,359F,0000,1A27,047D,0001,00C0,0004,0D69,0D68,0D66,0D68*20
$BMPST,0001,0003,0004,0302,4E68,04A7,0B92,359E,0000,18C4,0346,0001,00C0,0004,0D6E,0D5E,0D6C,0D65*2D
$BMPST,0001,0003,0005,0302,5077,0BA1,0B9A,359D,0000,1952,03A0,0001,00C0,0004,0D69,0D67,0D67,0D67*2D
$BMPST,0001,0003,0006,0302,4E68,0484,0B95,35A7,FFFC,18FA,036B,0001,00C0,0004,0D63,0D6D,0D6A,0D6E*5D
$BMPST,0001,0003,0007,0302,4E68,0491,0B98,359D,0000,18DF,032D,0001,00C0,0004,0D68,0D67,0D65,0D68*2D

LCI – Lrauv Charger Information

$BMLCI,BBBB,DATE,STARTUP,UPTIME,I2CERR, AGE,PPMSW,PPLSW,
GHIGH, HIGH0,HIGH1,HIGH2,HIGH3,PCBT,SHOREPOWERV,ASTMSW,ASTLSW,
AS01,AS23,TERM01,TERM23,CHARGEN *CS<CR><LF>

- BBBB - Board address, specified in hexadecimal. 16 bits, 4 hex characters.
- DATE - Firmware date code, SBS format, 4 hex characters.
- STARTUP - pic_startup_condition, 4 hex characters.
- UPTIME - local_uptime_val, 4 hex characters.
- I2CERR - i2cerr_count, 4 hex characters.
- AGE - seconds_since_last_complete_data
- PPMSW - pack_presence>>16 (high word)
- PPLSW - pack_presence & 0xFFFF (least significant word)
- HIGHG – highest pack temperature out of all packs
- HIGH0,1,2,3 - high_cell_v_bank0 etc
- PCBT – backplane PCB temperature kelvin
- SHOREPOWERV - analog_shorepower_mv
- ASTMSW - pack_presence>>16 (high word)
- ASTLSW - pack_presence & 0xFFFF (low word)
- AS01 – autostart_bank0_flags + autostart_bank1 _flags<<8
- AS23 – autostart_bank2 _flags + autostart_bank3 _flags<<8
- TERM01 – bank0_term_flags + bank1_term_flags<<8
- TERM23 – bank2_term_flags + bank3_term_flags<<8
- CHARGEN – charging enabled word, 1 bit per bank

Example: $BMLCI,0001,DC27,0000,03C9,0000,0009,FFFF,FBFF,0BA6,
0CD4,0D0B,0D77,0D75,0BB2,5901,0000,0000,0000,0000,000F*45

BVN – Battery VersioN message

$BMBVN,BBBB,VN*CS<CR><LF>

- BBBB – Board address, specified in hexadecimal. No fixed length, but max length of 8 characters (4 bytes)
- VN – Board firmware version information, human readable text string

Board Reset Sentence

One backplane microcontroller can be commanded to reset using a special message $CCRST. The single parameter of this message is the address of a single battery module to be reset. This can be useful if all packs are not detected during initial module assembly, because it triggers re-detection of installed packs. If a pack has been removed or become nonfunctional, a reset will allow the backplane to ignore its absence.

<u>Example: Vehicle Requests Battery 000C Reset:</u>
$CCRST,000C*2C<CR><LF>

<u>Battery Module 000C Confirms Reset:</u>
$BMRST,000C,*44<CR><LF>

ERRATA

Rev A of 109467 has all banks or-diode outputs connected in parallel on the backplane, so there is no "emergency" battery bank partitioned from the rest of the batteries. Another revision could split off 7 packs for use as an emergency battery so this energy could be kept in reserve.

APPENDIX

Microchip PIC18 startup codes. These are passed thru from the Combiner microcontroller. Values are defined by Microchip. For troubleshooting microcontroller only, not intended to be used for anything else.

Startup Cause	**SBD Value**
Reset Instruction	0000
Watchdog Timer timeout from Sleep	0003
Watchdog Timer timeout from Run	0007
Master Clear Reset from Sleep	000B
Normal power up	000C
Brownout Restart	000E
Master Clear Reset from Run	000F

SBDS (Smart Battery Data System) Date Encoding

The date value is calculated as = ((year-1980) * 512) + (month * 32) + day. Due to the 1980 offset, there is no 'Year 2000' bug with the encoding of dates. Instead there is a "year 2108" issue! Here is the SBD date encoding expressed as a table:

Field	Bits	Format	Allowable Values
Day	0..4	5 bit unsigned int	1-31
Month	5..8	4 bit unsigned int	1-12
Year	9..15	7 bit unsigned int	0-127 (year biased by 1980)

Pack Status bits, reproduced from SBDS Manual

Bit (start with zero)	**NAME**	**Bit Set When**	**Cleared When**
0,1,2,3 (low nibble)	RESERVED	Not used	Not used
4 (0x10)	FULLY DISCHARGED	Battery capacity is depleted	RelativeStateOfCharge() value is greater than 20%
5 (0x20)	FULLY CHARGED	Battery is full and further charge is not required	Battery is no longer considered in a full state. (May or may not request to be charged.)
6 (0x40)	DISCHARGING	Battery is discharging. This may include selfdischarge so it does not always	Battery is accepting a charge current

		indicate that a discharge current is present.	
7 (0x80)	INITIALIZED	Battery electronics are first calibrated or configured at time of manufacture	Battery electronics have determined that calibration or configuration information has been lost and accuracy is significantly impaired. (User should be notified to be skeptical of battery data.)
8 (0x0100)	REMAINING TIME ALARM	Value of AverageTimeToEmpty() is less than the value of RemainingTimeAlarm().	Value of RemainingTime Alarm() is zero or is less than the value of AverageTimeToEmpty()
9 (0x0200)	REMAINING CAPACITY ALARM	Value of RemainingCapacity() is less than the value of RemainingCapacity Alarm().	Value of RemainingCapacity Alarm() is zero or is less than the value of RemainingCapacity()
11 (0x0800)	TERMINATE DISCHARGE ALARM	Battery capacity is depleted	Discharge is no longer detected
12 (0x1000)	OVER TEMP ALARM	Temperature is above pre-set limit	Temperature drops into acceptable range.
14 (0x4000)	TERMINATE CHARGE ALARM	Charging should be suspended temporarily	Charging is no longer detected and condition causing alarm is removed
15 (0x8000)	OVER CHARGED ALARM	Battery is fully charged and charging is complete	Charging Charging is no longer detected and condition causing alarm is removed

Typical Pack Status:

0080 = Initialized (80)
00C0 = Initialized (80) and Discharging (40)
00E0 = Initialized (80) and Discharging (40) and Fully Charged (20)
40E0 = Terminate Charge (4000) and all of the above.
40A0 = Fully Charged, Terminate Charge, but Still Charging.

0890 = Terminate Discharge, Fully Discharged (and initialized)
03D0 = Remaining time alarm, remaining capacity alarm, fully discharged, discharging.
0AD0 = Terminate Discharge, Remaining Cap Alarm, initialized, fully discharged, discharging.
0BD0 = All of the above plus Remaining Time Alarm.
02D0 = Remaining capacity alarm, fully discharged.
02C0 = Remaining capacity alarm, discharging.