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BATTERY MODULE DROPOUT INVESTIGATION

Date: 23rd April 2021

Revision: 1.0

Author: Tony Little

Product: Electric Skateboard

Company: Globe Brand

1 CONTENTS

2 INTRODUCTION

5 boards were investigated for power dropout issues. 2 Compact and 3 Transporters.

3 BOARD #2863268203 / AAAA016B - JUSTIN SUDMEYER

Compact, dual motor, 65.6km.

2 battery modules.

Battery BBBB0461

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB0458

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

3.1 HISTORY

Customer reporting cutting out issues and VESC faults.

23rd Dec 2020

Customers first log, 1 hour ride time, on.

2nd Jan 2021

LHS motor temperature sensor shows disconnected at time of log. 43.7km. Trips didn't register a motor temperature sensor fault.

21st Jan 2021

Last received log, at which time the firmware was updated from V084 to V086.

Registrar entry added… “Customer reports VESC faults. Log shows both VESC registering under voltage. MC supports with under voltage readings. Battery disconnects.”

Firmware on V084 does not isolate with certainty which battery was registering dropouts.

13th Apr 2021

Board received for inspection.

3.2 INSPECTION LOG

```
dot Skateboard

Model                    : MC100
Hardware Version         : 35
Software Version         : 86
Bootloader Version       : 4
Serial Number            : AAAA016B
Paired Remote Serial     : DDDD018D
Remote Firmware          : -
Batch Number             : 17
Custom Change Index      : 0
Production Date          : 14-8-2020
EEPROM                   : Not Fitted
Factory Tested           : Yes


Battery Position: 0
Model                    : BM100
Hardware Version         : 22
```

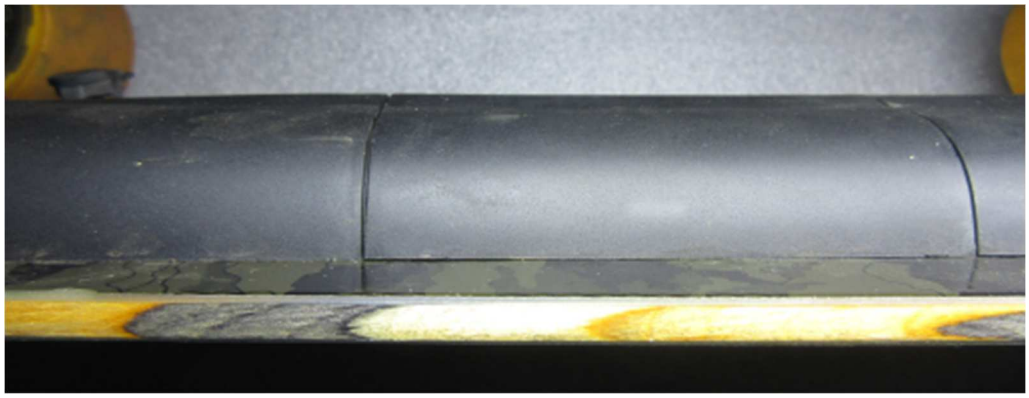
```
Software Version         : 19
Serial Number            : BBBB0461
Batch Number             : 26
Production Date          : 27-11-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 71.8%
- Current Capacity       : 51.71Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 187           --
- Cell Resistance 25C    : 192mohm    * FAIL *

Temperature Sensors
- PCB                    : 21.2'C        --
- Cells 0-4              : 21.0'C        --
- Cells 5-9              : 21.1'C        --

Measurements
- V_Bus                  : 39075mV       --
- Battery                : 39067mV       --
- V_Switch               : 39069mV       --
- V_Switch_Off           : 64mV          --
- VCC                    : 3301mV        --
- V_Offset               : 3004mV        --
- V_Current_Sense        : 1489mV        --
- I_Current_Sense        : 10mA          --

Cell Voltages
- Cell 0                 : 3894mV        --
- Cell 1                 : 3895mV        --
- Cell 2                 : 3896mV        --
- Cell 3                 : 3904mV        --
- Cell 4                 : 3909mV        --
- Cell 5                 : 3895mV        --
- Cell 6                 : 3908mV        --
- Cell 7                 : 3908mV        --
- Cell 8                 : 3908mV        --
- Cell 9                 : 3934mV        --

Battery Position: 1
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB0458
Batch Number             : 26
Production Date          : 27-11-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 73.0%
- Current Capacity       : 52.59Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 175           --
- Cell Resistance 25C    : 236mohm       --

Temperature Sensors
- PCB                    : 21.2'C        --
- Cells 0-4              : 21.3'C        --
- Cells 5-9              : 21.3'C        --

Measurements
- V_Bus                  : 39091mV       --
- Battery                : 39099mV       --
- V_Switch               : 66mV       * FAIL *
- V_Switch_Off           : 66mV          --
- VCC                    : 3288mV        --
- V_Offset               : 3002mV        --
- V_Current_Sense        : 1506mV        --
- I_Current_Sense        : 0mA           --

Cell Voltages
- Cell 0                 : 3897mV        --
```

```
- Cell 1                 : 3909mV        --
- Cell 2                 : 3907mV        --
- Cell 3                 : 3909mV        --
- Cell 4                 : 3909mV        --
- Cell 5                 : 3909mV        --
- Cell 6                 : 3909mV        --
- Cell 7                 : 3922mV        --
- Cell 8                 : 3909mV        --
- Cell 9                 : 3914mV        --

Settings
-Wheel Diameter (mm)x10  : 830
- Options                : 0009
- Auto Power Off Period  : 60000
- Power Down Timer       : 60000

Measurements
- V_Bus                  : 38969mV       --
- V_Aux                  : 6504mV        --
- V_Sys                  : 3969mV        --
- V_USB                  : 4326mV        --
- VCC                    : 3295mV        --

Battery Charger
- V_Charger_Input        : 131mV      * FAIL *
- V_Charger_Output       : 1623mV
- Temperature            : 21.3'C        --
- Connector Temperature  : 21.3'C        --
- Power Limit            : 168W
- Power Consumption      : 0W            --

Inertial_Module
- Module                 : Present       --
- Angular XYZ            : 220     -1556   -325
- Linear XYZ             : 84      -550    16765

LIN Bus
- Bus State              : Active        --
- Discovered Devices     : 2             --

Communications
- Wireless RF            : Present       --
- Packet Count Tx/Rx     : 0/0        * FAIL *
- Paired Remote Serial   : DDDD018D
- Paired Status          : Unsynced   * FAIL *

Motor Temperature Sensors
- Left Motor Temp        : 20.5'C        --
- Right Motor Temp       : 19.5'C        --


Metrics
- Trip Odo Left          : 1340 m
- Trip Odo Right         : 1340 m
- Trip Time              : 6.2 mins
- Number of trips        : 30
- Average Trip Distance  : 2.1 km
- Total Ride Time        : 4.1 hrs
- Odometer               : 65.5 km

Trip Data                Dist_km mins    Avg_kph Max_kph    Max_Bat_LHS/RHS    Min_Bat_LHS/RHS     TempMax_Bat_LHS/RHS
Motor_Temp_High_mins Features Used
Trip #0                : 0.24    1       12.2    17.5       3.7    2.6/2.5     -4.8   -2.8/-2.8    22    59/59
0/0                2 Eco
Trip #1                : 0.40    1       15.0    23.7       15.7   7.8/7.7     -7.8   -5.6/-5.5    25    59/59
0/0                2 Eco
Trip #2                : 3.60    10      21.5    28.7       23.7   11.7/11.7   -10.2  -6.5/-6.4    35    59/57
0/0                2 Eco
Trip #3                : 3.12    10      17.5    29.0       24.0   12.1/12.0   -9.1   -5.1/-5.1    32    53/52
0/0                3 Expert Eco
Trip #4                : 0.88    3       15.7    24.0       14.5   7.5/7.5     -7.6   -4.4/-4.4    36    55/52
0/0                2 Eco
Trip #5                : 0.40    1       14.7    23.0       10.2   5.2/5.1     -4.8   -2.3/-2.3    28    31/30
0/0                2 Eco
Trip #6                : 1.04    3       17.5    28.5       23.7   12.1/12.5   -8.6   -7.5/-7.5    29    34/32
0/0                3 Expert Eco
```

```
Trip #7                : 1.68    7       13.2    28.0       24.5   12.5/12.5   -7.1   -4.0/-4.0    35    40/39
0/0                 1 Expert


Fault Report
Log #0                 : 42      4       0       0       104    0       0       1088
Log #1                 : 17      1       7       32381   49297  228     32126   32382
Log #2                 : 43      2       1       49153   66     40968   1       1112
Log #3                 : 53      97      57618   2       803    21336   428     21700
Log #4                 : 54      126     57618   4       800    21336   445     21600
Log #5                 : 51      13      31197   15844   13     2948    2939    6505
Log #6                 : 50      10      40939   46849   9      3136    3115    6507
```

3.3 INSPECTION

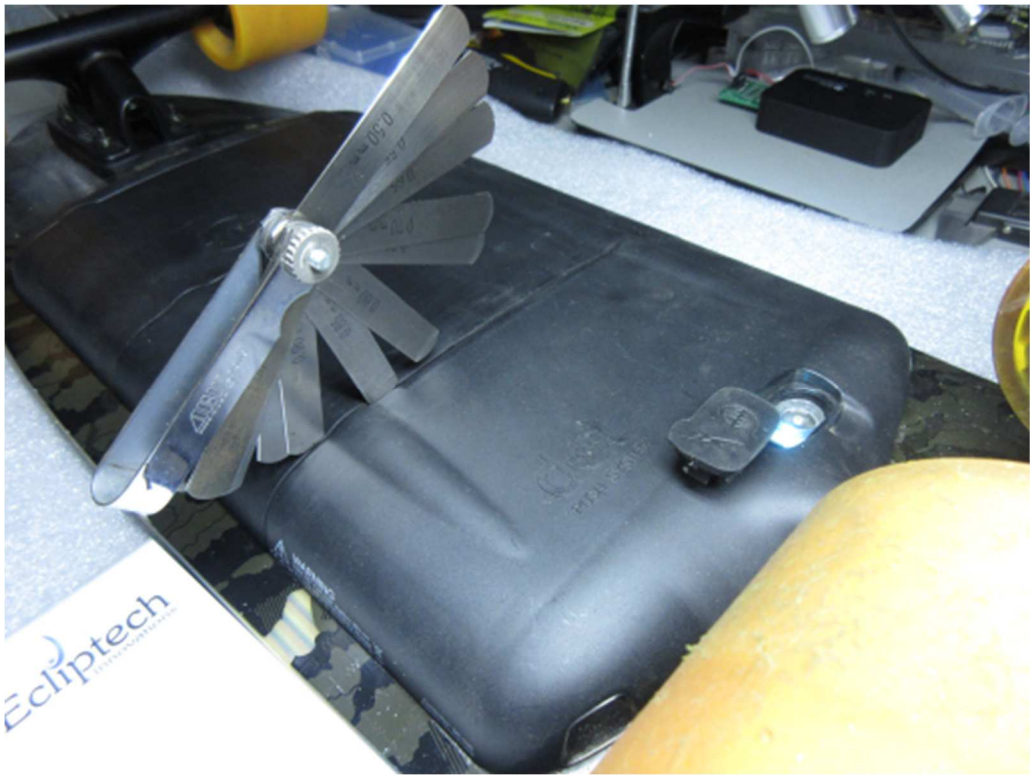
Modules are bolted flush to the deck.



The gaps between the modules is good.

MC to BM… 0.9, 0.9, 0.75, 0.85, 0.9mm.

BM to BM… 0.85, 0.5, 0.5, 0.65, 0.7mm.

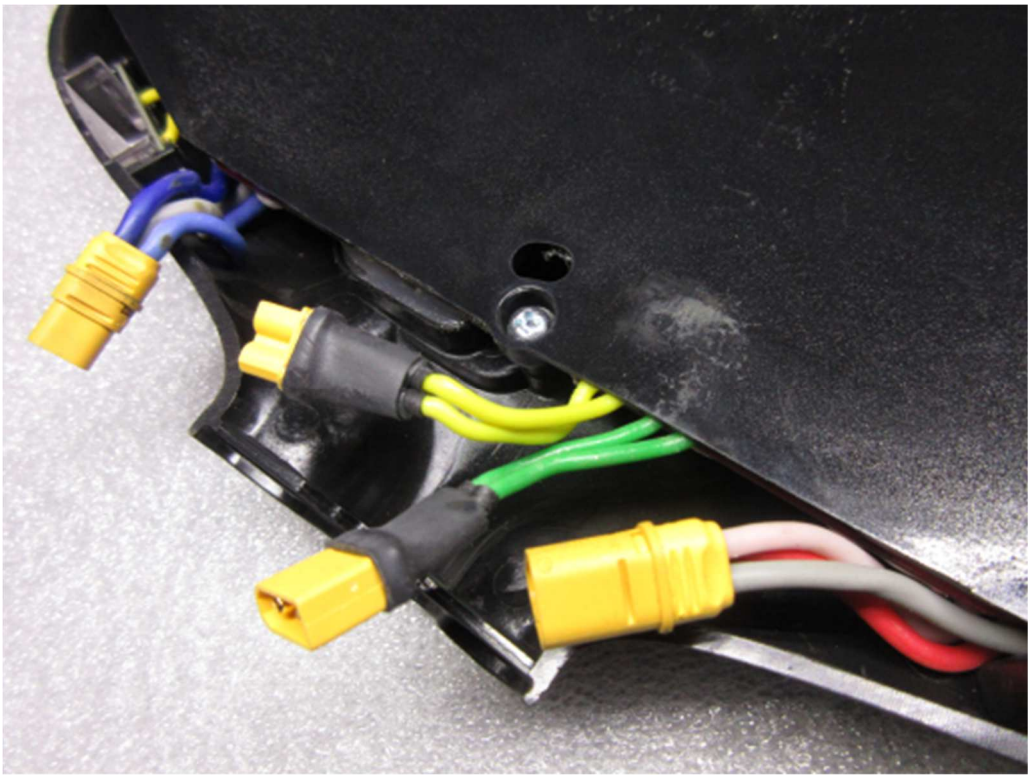


Module mounting bolts were loosened 2 turns. Modules bumped to re-settle, then bolts tightened ½ a turn in sequence. This was in an effort to ensure the least mutual mis-alignment during tightening. The gaps were re-checked. The process had neligiable difference to the gap measurements.

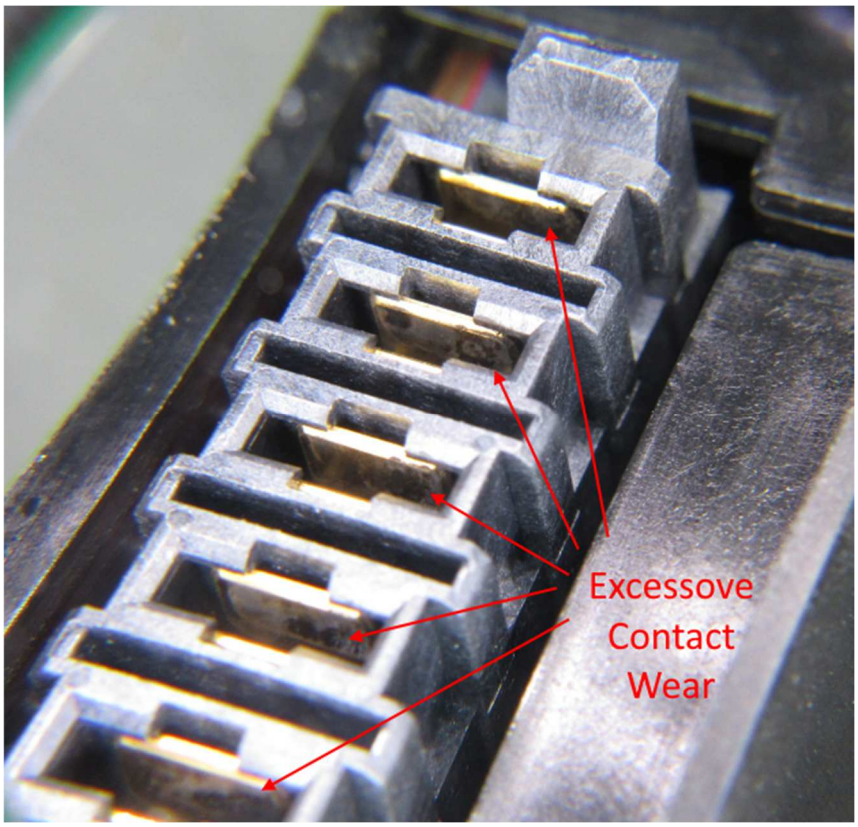
3.3.1 WIRING

Cables in hanger move with expected freedom. Not removed. No wiring damage or defect evident from external inspection, other than minor insulation dents.

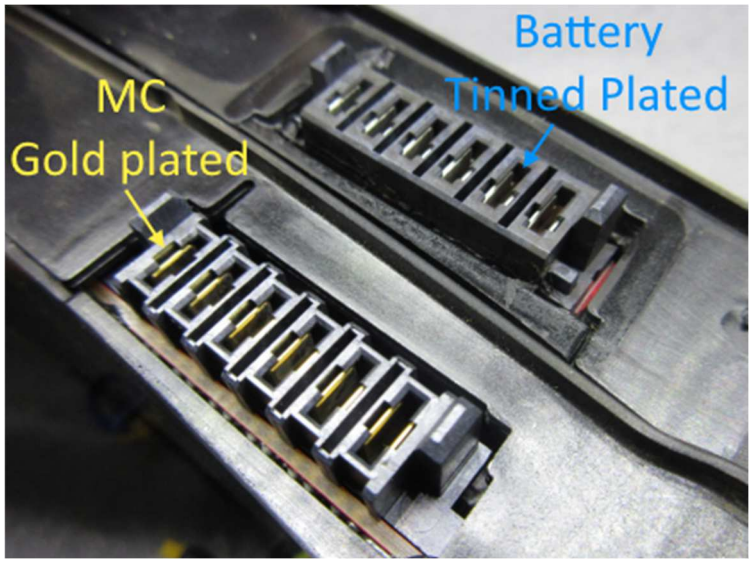
MC wiring looks in very good condition. Nothing to suggest a motor temperature sensor wiring issue.



3.3.2 MAIN CONNECTOR

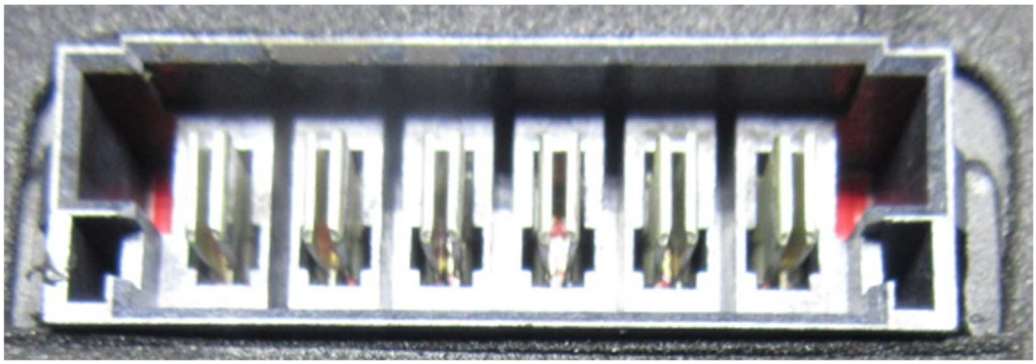


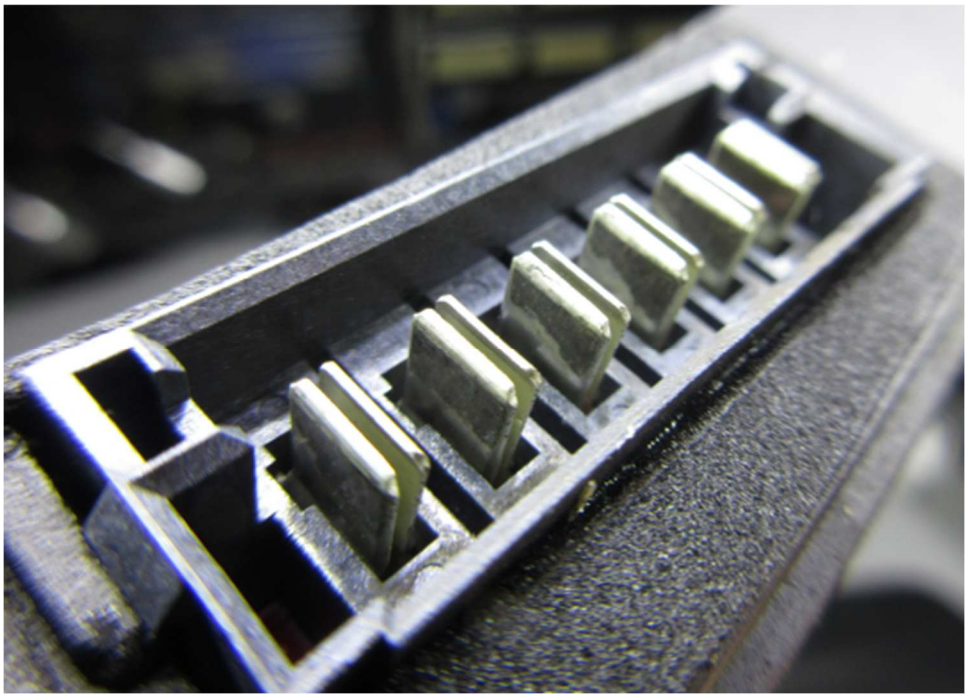
The MC connector is using the gold plated connector variant. Connector part specified MPS-06-01-01-L-RA-SD. Tin plated variant an option, MPS-06-01-01-T-RA-SD. However terminal wear is not significantly different. Possibly a fraction less.

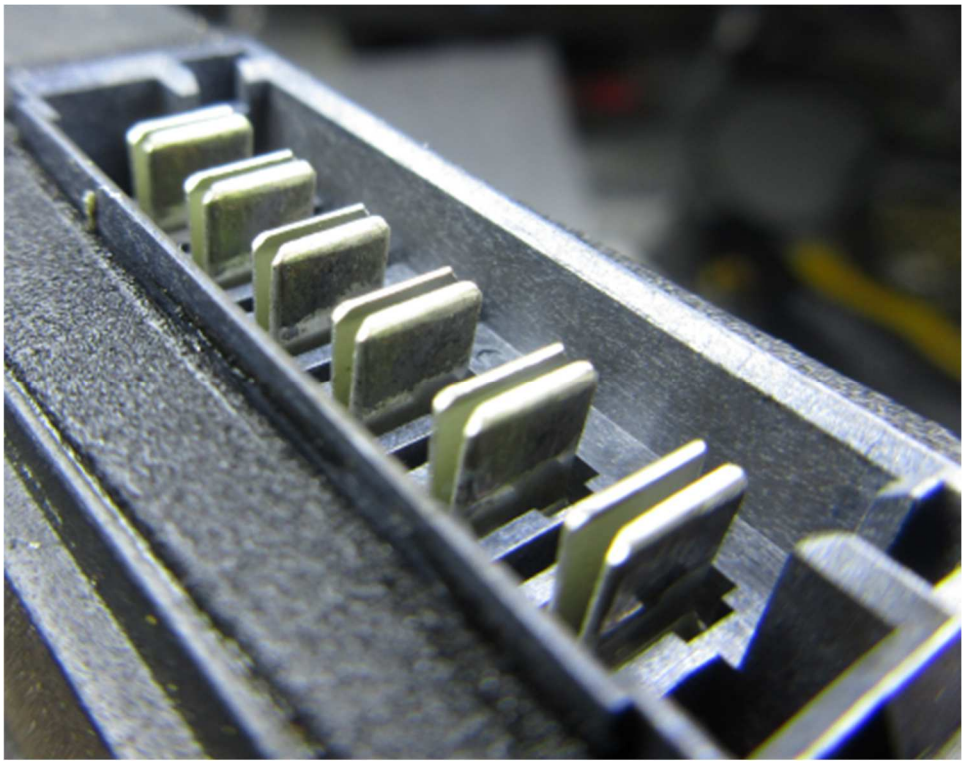


3.3.3 BATTERY CONNECTOR, 3149595736 / BBBB0458

Terminals straight, no di-electric grease.





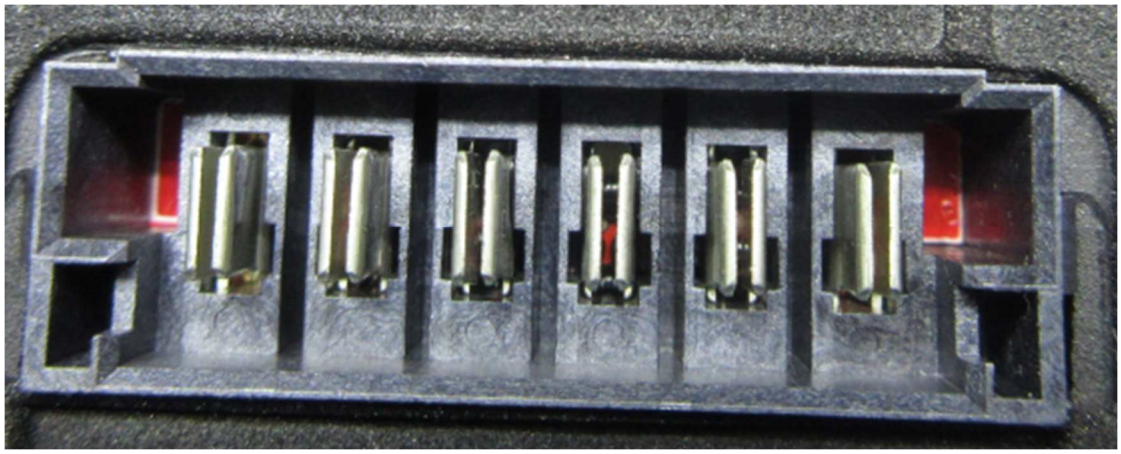


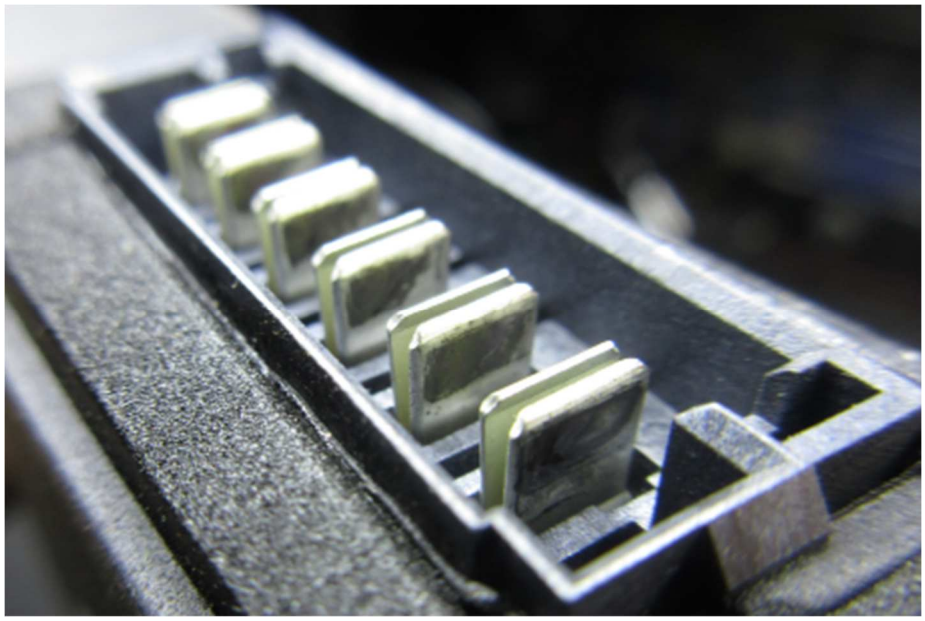
Excessive wear for only 65km riding.

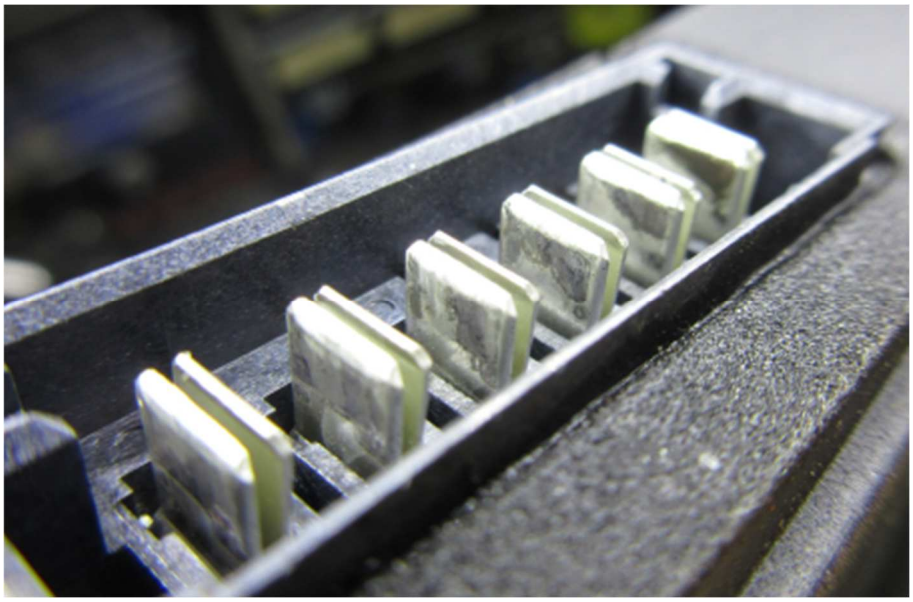
Distribution of wear marks are quite even and equal in abrasion on both sides. Slightly more abrasion on the bottom edge of the battery (road facing). This battery was in the front position on the board. The adjacent battery connector terminals showed comparable wear. Difficult to photograph given the surrounding shroud.

3.3.4 BATTERY CONNECTOR, 3149595745 / BBBB0461

Terminals straight, no di-electric grease.

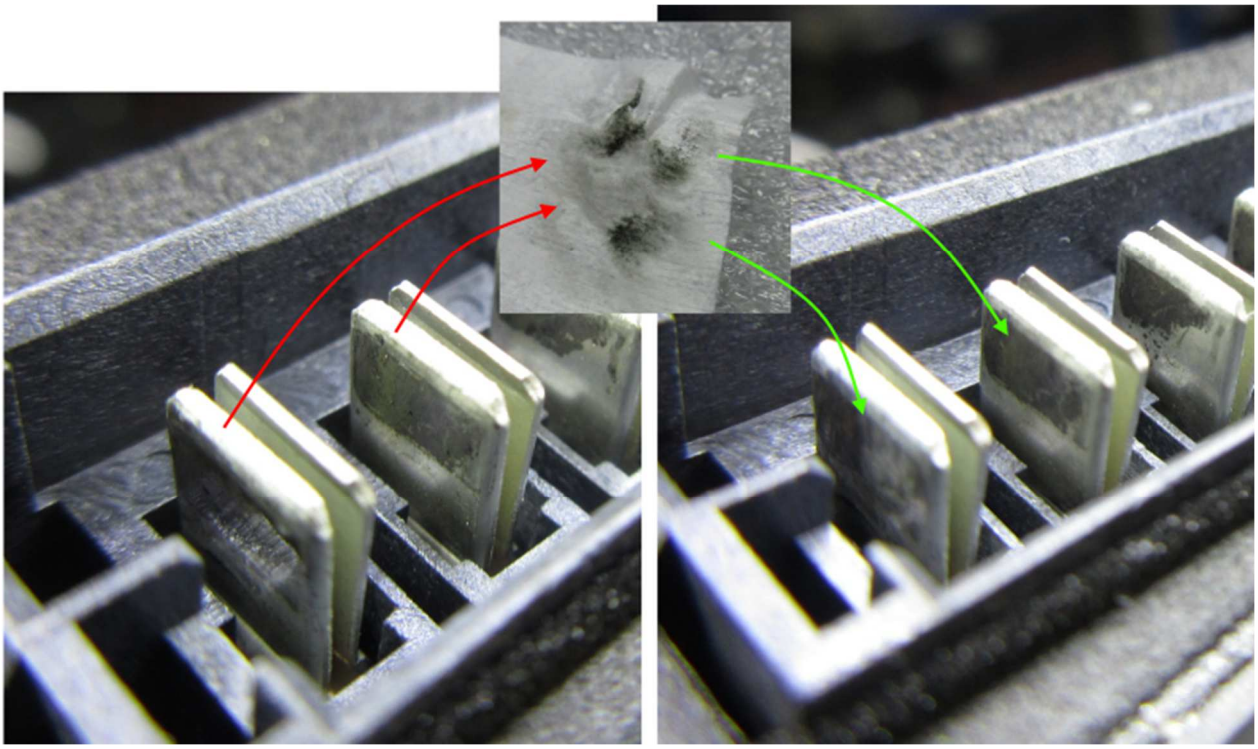






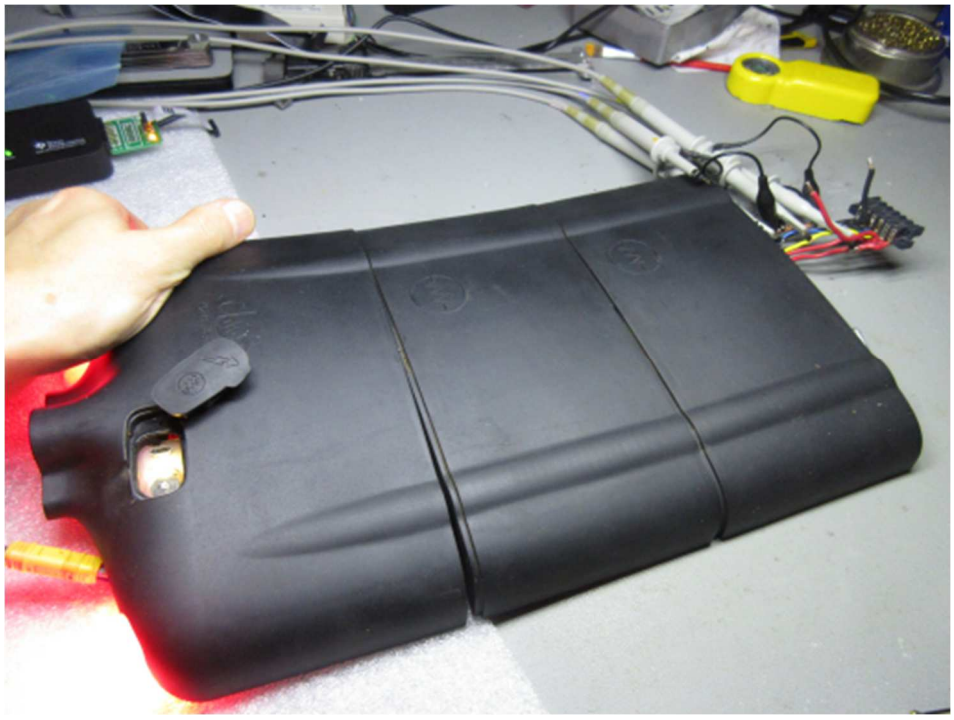
This battery was adjacent to the main controller. The wear is noticeably un-balanced. More wear on one face of the terminals than the other. Un-even wear across the blade surface. Contact wear is more triangular.

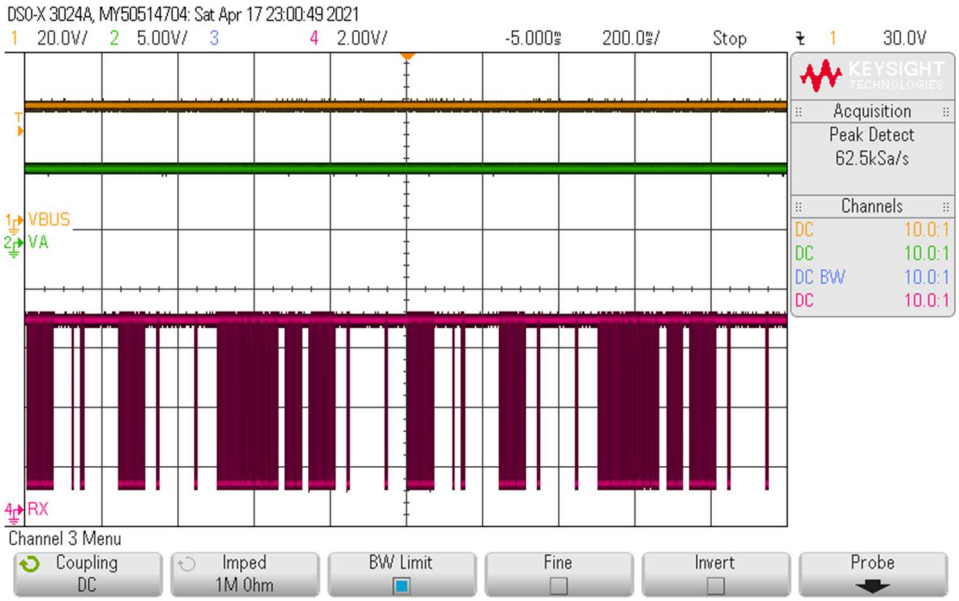
Cleaning two terminals shows little visual difference, however the removed residue is noticeable on the cleaning cloth.



3.4 MONITORING MODULE MOVEMENT

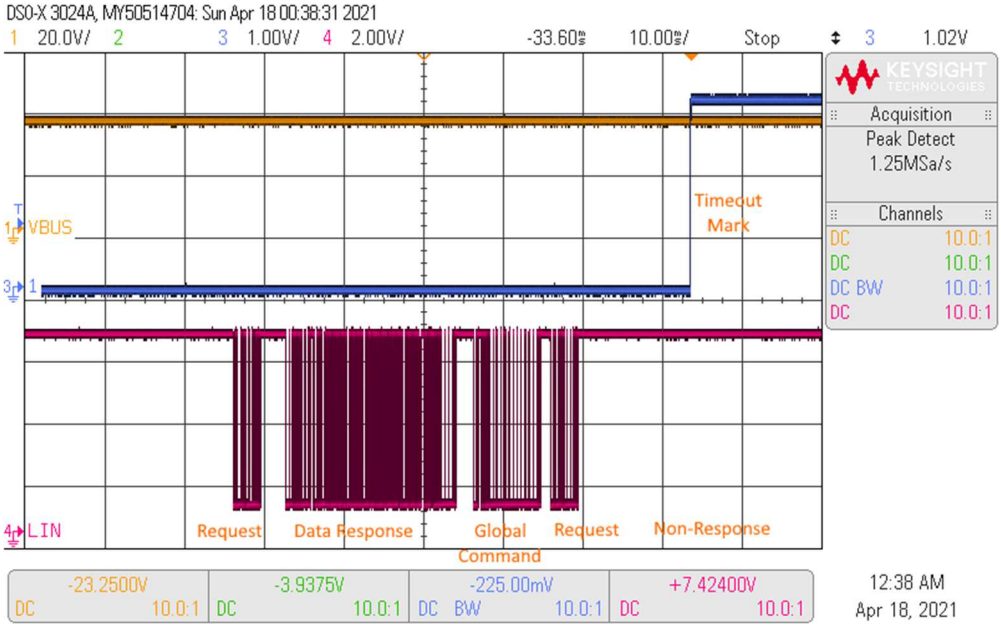
Specific software was implemented to monitor the LIN Bus non-responses, reception errors and battery reset events. While also monitoring the front connector signals, the modules were wreched around with a variety of movements. Despite more than realistic articulation, no faults were generated from the movement. In addition, no noticeable corrupting noise was evident in the connections, as monitored from the front connector.



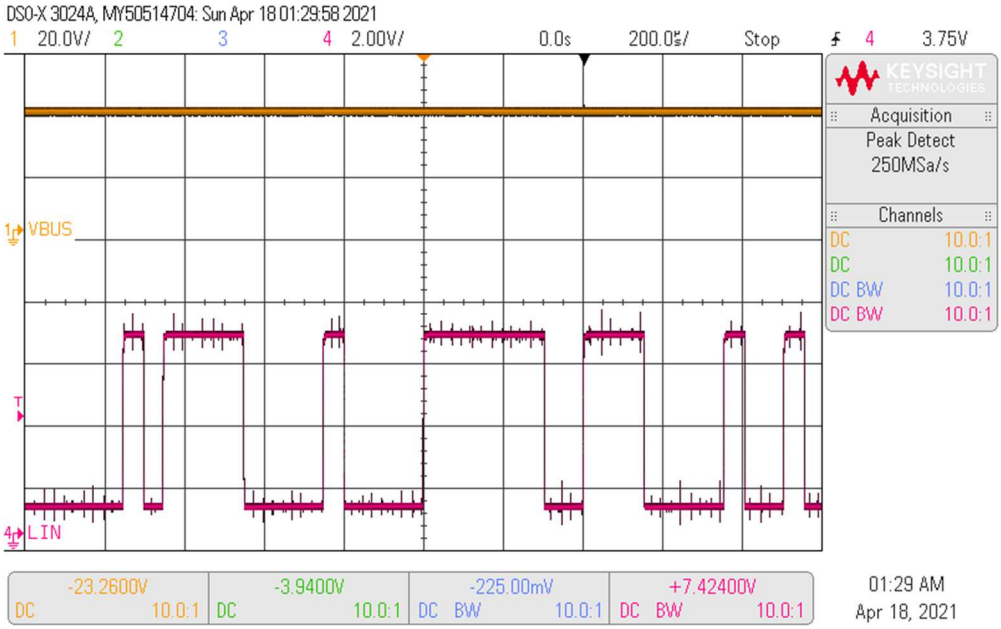


3.5 LIN BUS MONITORING

Rare instance of battery non-response observed to data request with preceding global battery command. 1 to 2 per minute. Idle time extended from 2.0ms to 2.5ms for future firmware. No further instance captured, 10+ minutes. Not deemed relevant to dropout investigation, as statistically insignificant to a timeout result.



LIN Bus (below) captured with motors unloaded, maximum speed. Zero timeouts, zero packet errors. Signal quality very good.



3.6 MOTOR / VESC

The VESCs and MC voltage monitoring were all registering under voltage faults. The main controller also registered high voltage > 45V. i.e. 47V during nominal 41V operation with near zero drive current. Plausible this caused the VESC to drop offline and subsequently register the reported VESC faults. Over-voltage likely a result of sudden battery dropouts.

Ran each motor separately precariously against a small inertia load. No dropout or fault occurred. Proper load testing was not available.

3.7 WIRELESS PERFORMANCE

Due to the evidence and nature of logged faults, the wireless link is not considered to be related.

4 BOARD #2863268287 / AAAA01BF - JAMES LAWIDK

Transporter, dual motor, 120mm wheels, 85.8km.

New motors -bj23 - x seals - potted hanger 120mm

3 battery modules.

Battery BBBB04BC (1st position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB04B5 (2nd position fitted, with front gasket)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB4A2 (not fitted, with front gasket)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

4.1 HISTORY

9th March

TL - Log shows excessive number of battery dropouts for both. Suspect connection issue. SMS'd Jesse

4.2 INSPECTION LOG – AS DELIVERED

Two battery modules fitted.

dot Skateboard

```
Model                    : MC100
Hardware Version         : 35
Software Version         : 86
Bootloader Version       : 4
Serial Number            : AAAA01BF
Paired Remote Serial     : DDDD01DA
Remote Firmware          : -
Batch Number             : 19
Custom Change Index      : 0
Production Date          : 12-10-2020
EEPROM                   : Not Fitted
Factory Tested           : Yes


Battery Position: 0
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB04BC
Batch Number             : 28
Production Date          : 30-12-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 44.8%
- Current Capacity       : 32.30Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 116           --
- Cell Resistance 25C    : 300mohm       --

Temperature Sensors
- PCB                    : 20.4'C        --
- Cells 0-4              : 20.6'C        --
- Cells 5-9              : 20.4'C        --

Measurements
- V_Bus                  : 36512mV       --
- Battery                : 36509mV       --
- V_Switch               : 36507mV       --
- V_Switch_Off           : 65mV          --
- VCC                    : 3301mV        --
- V_Offset               : 3011mV        --
- V_Current_Sense        : 1503mV        --
- I_Current_Sense        : 30mA          --

Cell Voltages
- Cell 0                 : 3638mV        --
- Cell 1                 : 3637mV        --
- Cell 2                 : 3650mV        --
- Cell 3                 : 3650mV        --
- Cell 4                 : 3650mV        --
- Cell 5                 : 3650mV        --
- Cell 6                 : 3661mV        --
- Cell 7                 : 3638mV        --
- Cell 8                 : 3650mV        --
- Cell 9                 : 3663mV        --

Settings
-Wheel Diameter (mm)x10  : 1200
- Options                : 0009
- Auto Power Off Period  : 60000
- Power Down Timer       : 60000

Measurements
- V_Bus                  : 36441mV       --
- V_Aux                  : 6487mV        --
- V_Sys                  : 4001mV        --
- V_USB                  : 4357mV        --
- VCC                    : 3299mV        --

Battery Charger
```

```
- V_Charger_Input        : 111mV      * FAIL *
- V_Charger_Output       : 1592mV
- Temperature            : 20.2'C        --
- Connector Temperature  : 20.4'C        --
- Power Limit            : 168W
- Power Consumption      : 0W            --

Inertial_Module
- Module                 : Present       --
- Angular XYZ            : 237     -261    -583
- Linear XYZ             : 129     -305    16664

LIN Bus
- Bus State              : Active        --
- Discovered Devices     : 1             --

Communications
- Wireless RF            : Present       --
- Packet Count Tx/Rx     : 0/0        * FAIL *
- Paired Remote Serial   : DDDD01DA
- Paired Status          : Unsynced   * FAIL *

Motor Temperature Sensors
- Left Motor Temp        : 19.5'C        --
- Right Motor Temp       : 18.8'C        --


Metrics
- Trip Odo Left          : 5810 m
- Trip Odo Right         : 5770 m
- Trip Time              : 35.0 mins
- Number of trips        : 52
- Average Trip Distance  : 1.6 km
- Total Ride Time        : 7.1 hrs
- Odometer               : 85.8 km
```

Trip Data	Dist_km	mins	Avg_kph	Max_kph	Max_Bat_LHS/RHS		Min_Bat_LHS/RHS		TempMax_Bat_LHS/RHS	
Motor_Temp_High_mins	Features Used									
Trip #0	0.24	2	4.7	7.5	0.2	0.0/0.0	-1.5	-0.0/-0.0	24	25/24
0/0	0									
Trip #1	0.48	2	14.5	21.0	8.7	5.5/5.2	-0.8	-0.0/-0.0	25	28/27
0/0	0									
Trip #2	0.56	2	12.7	19.5	7.5	4.0/4.0	-0.3	-0.0/-0.0	26	28/27
0/0	0									
Trip #3	0.32	1	12.0	18.5	8.2	5.0/4.8	-0.5	-0.0/-0.0	32	33/32
0/0	0									
Trip #4	0.72	7	5.0	37.0	12.5	9.3/9.7	-1.2	-2.3/-2.3	23	30/29
0/0	0									
Trip #5	0.40	1	13.5	17.2	6.2	5.2/5.0	-0.2	-0.0/-0.0	29	30/29
0/0	0									
Trip #6	0.40	4	5.2	7.0	0.5	0.0/0.0	-1.1	-0.0/-0.0	26	26/26
0/0	0									
Trip #7	0.56	2	13.2	41.2	9.2	8.3/7.6	-2.5	-1.5/-1.4	21	23/22
0/0	0									

Fault Report

Log #0	41	90	1	49153	65	36871	0	1212
Log #1	42	143	1	49153	51	36895	8192	1205
Log #2	38	1	215	2975	0	0	0	1205
Log #3	18	1	7	0	0	0	0	0
Log #4	51	27	26677	15992	5	2974	2971	6492
Log #5	54	25	57618	13	1422	19174	598	18800
Log #6	53	25	57618	11	1396	19174	578	19100

4.3 INSPECTION

Two batteries modules were fitted to the board (as delivered), however only BBBB04BC was reporting when logged.

BBBB4A2 was not fitted.

LHS motor has slightly more free spin drag.

Monitoring remote battery info, board untouched, battery 1 dropped out. This persistent after going to sleep mode and powering back up, however without intervention, power was restored a short period later. Still only 1 battery responding.

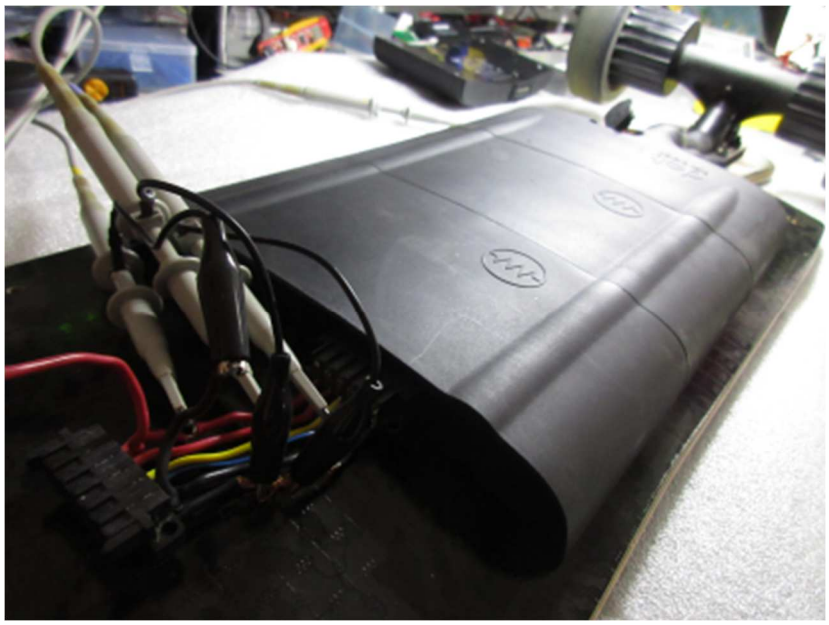
Log registered a current sensor and amplifier offset error fault. Most likely due to loss of V_Aux stability.

Updated MC to V089 firmware. No LIN Bus timeout/errors occuring. Second battery not responding.

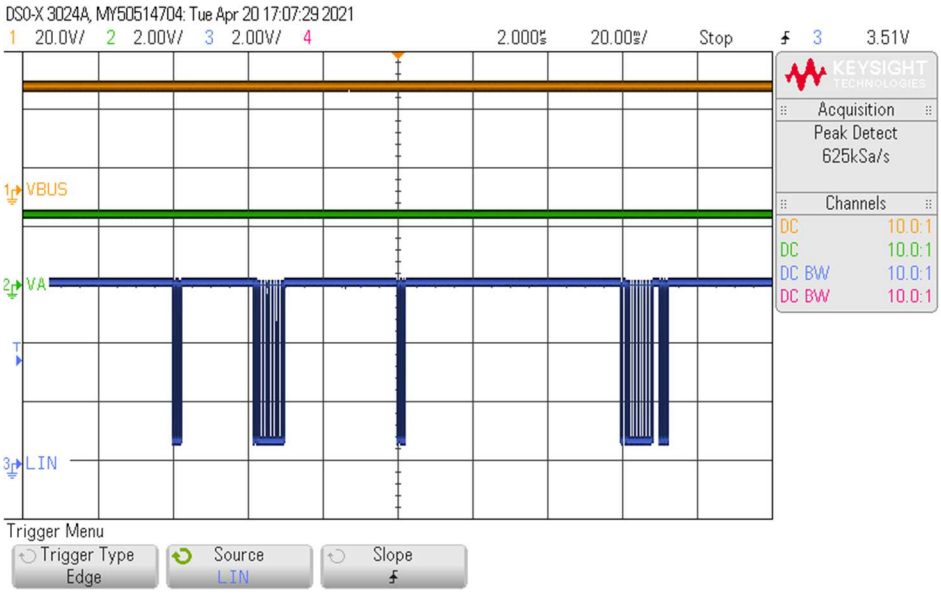
Removed bolts to second battery, lifting battery enough to remove nose cose. First battery no longer responding, prior to re-bolting.

Identified serial, BBBB04B5 (2nd position fitted, with front gasket).

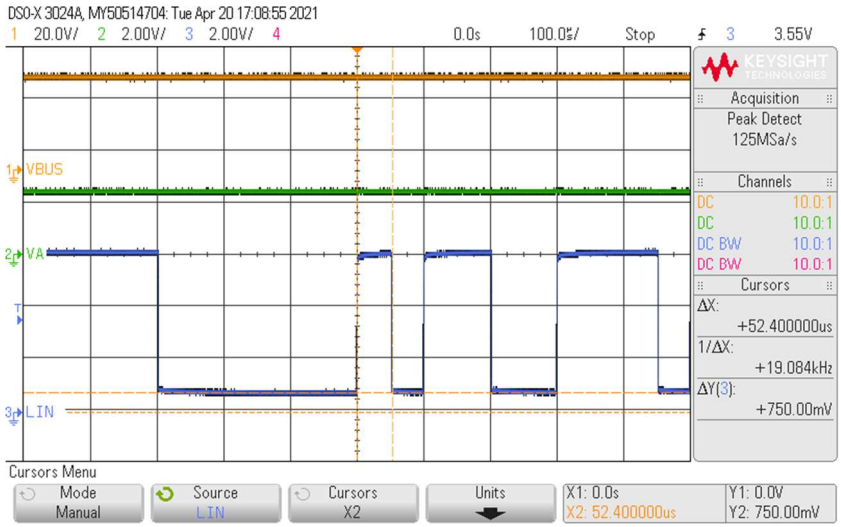
VBus, Vaux & LIN were monitored from the front most connector.



VBus and VAux are present. VAux is not at the expected or required level, <3V. LIN bus is present and at the required level. Batteries are non-responsive.



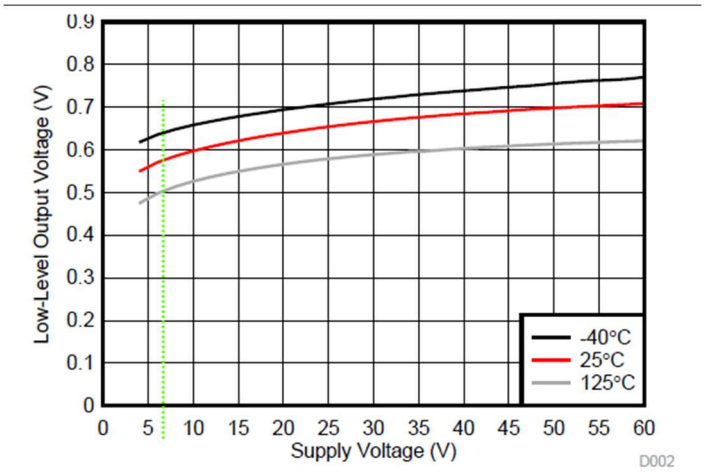
LIN Bus data rate measured at 19084Hz (high stability). Vhigh = 6.2V, Vlow = 0.75V.



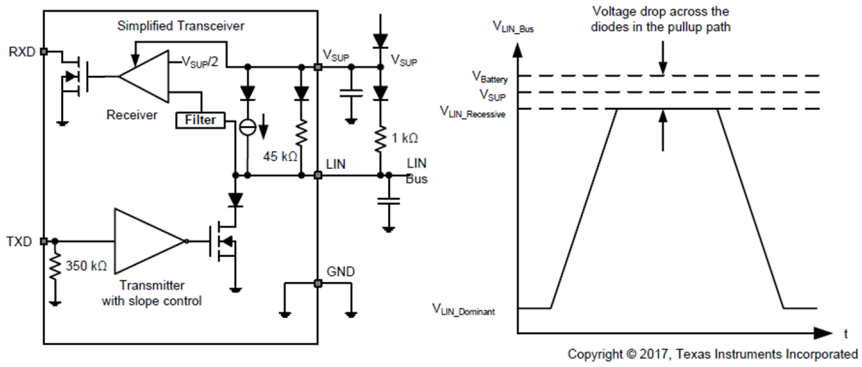
Specification…

- Operational supply voltage minimum 4.0V (undervoltage at 3.85V). Passes.
- LIN recessive 3.0V, minimum high level
- LIN dominant 1.2V, maximum low level.

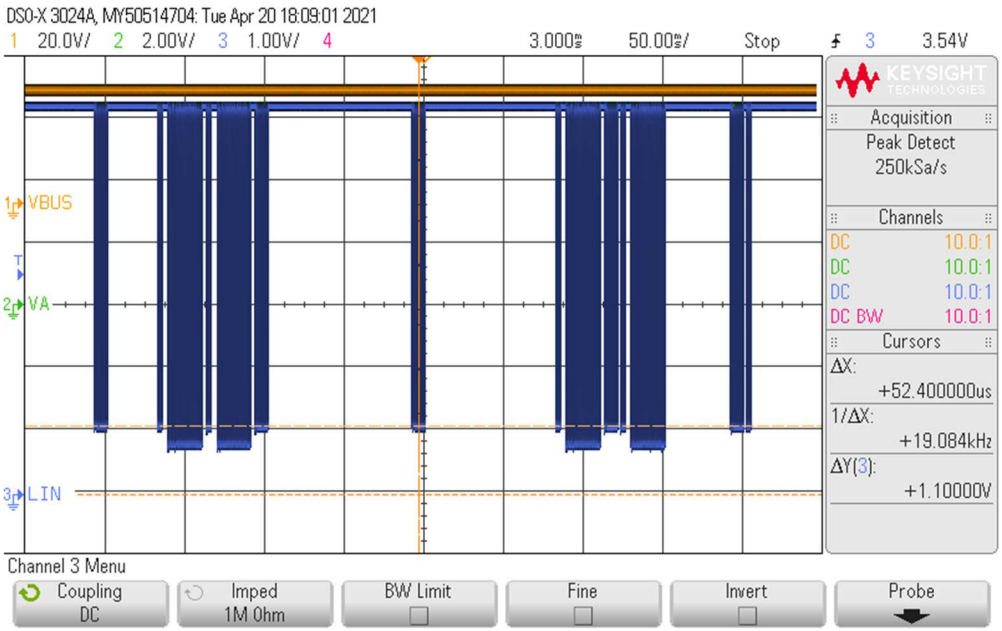
Low level well within specification, although further than found in expected deviation shown in typical characteristics.



Verified, master has required serial diode and 1k pull up.



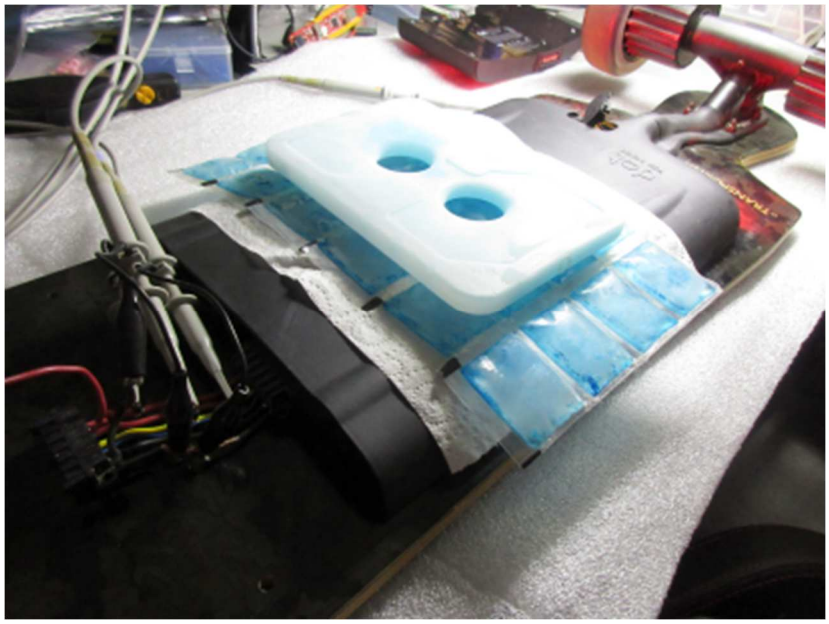
Master dominate level observed at 1.1V. This is very close to the 1.2V specification threshold. Dominant level not influenced by data traffic load. Second battery come online for the first time. Probe checked for ground and DC coupling setting.



During investigation, the second battery become responsive. The most obvious change to the test environment is a shift in ambient temperature… > 5'C due to internal room heater running the last 30..60mins (wife's influence).

Previous battery PCB temperature was logged at 20.4'C. Current temperature 23.5'C.

The second battery was subject to ice packs to reduce PCB temperature.

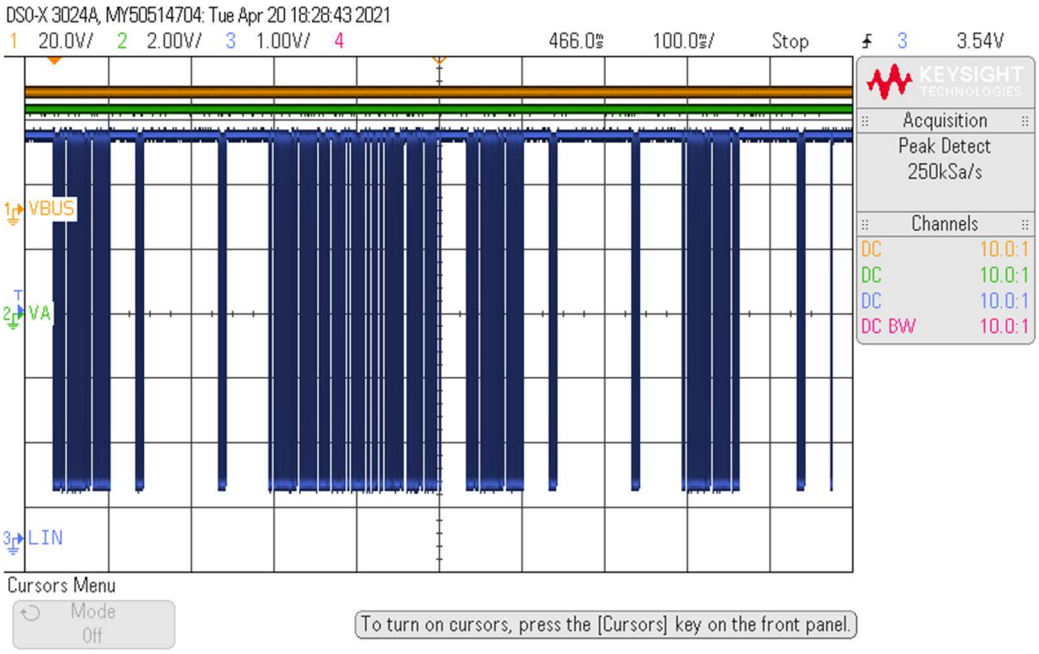


22.4'C → 21.1'C → 20'4'C → 18.8'C → 17.9'C → 14.9'C → 13.4'C → 13.0'C

The first battery wasn't specifically covered by the ice packs, however it reduced below 16.7'C.

Prior to ice pack, master dominate level had been noticeably higher, however within specification.

Dominant levels equalised at 8.1V with battery PCB temperature reduction. Note: USB monitoring during temperature test occurred. USB was disconnected at this point to rule out interference with the observation.



Throughout the extended period of reducing the temperature, there were zero LIN Bus non-responses, zero packet errors and zero dropouts. VAux at the expected level.

Dominate LIN state voltage level variance is not chipset related. Identical TLIN2029DRBRQ1 used on all modules. All driven by the same VAux supply level. Master has 1k pullup, slaves 47k pullup. All are subjected to the same bus load. Possible cause is an increase in impedance between MC ground and battery ground.

LIN Bus data rate was previous measured at 19084Hz for recessive bit, neligable jitter.

Sample measurement

- MC data rate Recessive 19157, Dominate 20921. Average 20039.
- BM#1 response data rate Recessive 19084, Dominate 20833. Average 19956.
- BM#2 response data rate Recessive 19231, Dominate 20921. Average 20076.

Check programming…

Main Controller

```
// UCSCTL5
// ACLK, SMCLK, MCLK Select clock dividers
mov.w   #DIVM__1 + DIVS__1 + DIVA__32, &UCSCTL5


// LIN UART Configuration
bis.b  #UCSWRST, &UCA0CTL1
mov.b  #UCMODE_0, &UCA0CTL0     // LIN LSB first, 1 stop bit, no partity, no address bit.
mov.b  #UCSSEL__SMCLK + UCSWRST, &UCA0CTL1 // SMCLK, send break with next transmission
mov.b  #0xE2, &UCA0BR0                     // 1250d = 20kbps
mov.b  #0x04, &UCA0BR1
bic.b  #UCSWRST, &UCA0CTL1
```

SMCLK = 25MHz Crystal
BR Divider 0x04E2 = 1250d

F(BRclk) = N*Baud

Baud = 20000bps

Battery

```
// UCSCTL5
// ACLK, SMCLK, MCLK Select clock dividers
mov.w   #DIVM__1 + DIVS__1 + DIVA__1, &UCSCTL5


// LIN UART Configuration
bis.b  #UCSWRST, &UCA1CTL1
mov.b  #UCMODE_0, &UCA1CTL0    // LIN LSB first, 1 stop bit, no partity, no address bit.
mov.b  #UCSSEL__SMCLK + UCSWRST, &UCA1CTL1  // SMCLK, send break with next transmission
mov.b  #0xC8, &UCA1BR0                      // 20kbps
mov.b  #0x00, &UCA1BR1
bic.b  #UCSWRST, &UCA1CTL1
```

SMCLK 4MHz DCO

BR Divider 0x00C8 = 200d

Baud = 20000bps

DCO based on REFOCLK, internal trimmed 32768Hz. DCO frequency is stablised/multiple by the FLL.

The FLLD bits configure the FLL prescaler divider value D to 1, 2, 4, 8, 16, or 32.

FLLREFDIV (n = 1, 2, 4, 8, 12, or 16)

bis.w #SELREF__REFOCLK + FLLREFDIV_0, &UCSCTL3

The divider (N + 1) and the divider value D define the DCOCLK and DCOCLKDIV frequencies.

fDCOCLK = D × (N + 1) × (fFLLREFCLK ÷ n)

fDCOCLKDIV = (N + 1) × (fFLLREFCLK ÷ n)

```
   mov.w  #FLLD_0 + 120d, &UCSCTL2  // (120 + 1) * 32768/1 = 3.965MHz
```

DCO drift 0.1%/'C

REFO drift 0.01%/'C

REFO 1.5%, 3V, Ta=25'C. 3.5% across full voltage/temperature range.

Software correct.

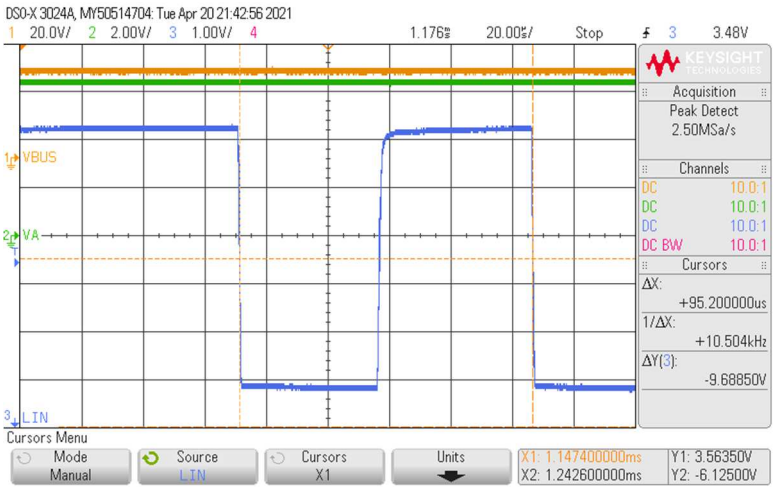
Consider REFO tolerance and drift with worse case tolerance.

3.965MHz +/- 5.7%.

LIN data rate (min) = 18695bps

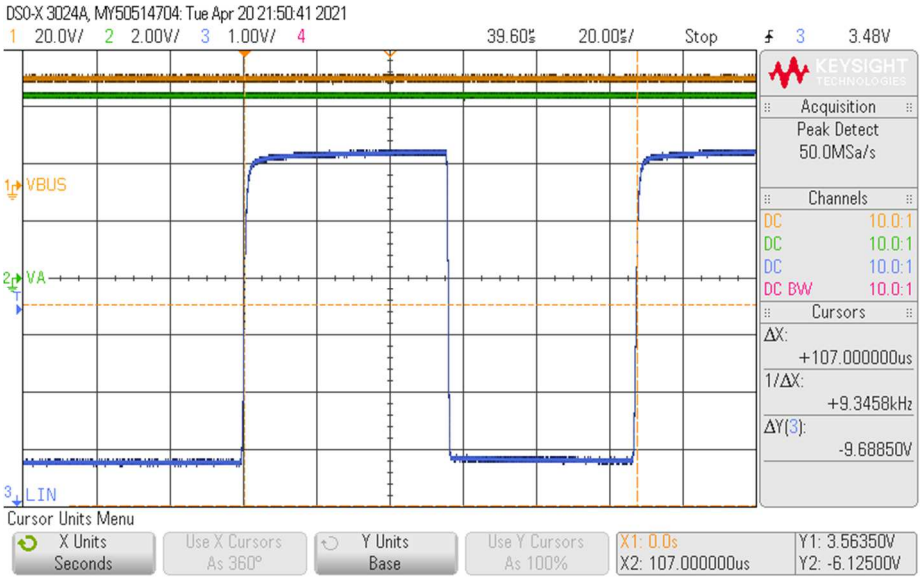
LIN data rate (max) = 20955bps

Alternative development MC used for LIN testing. Re-programmed to 20955bps. All 3 batteries loaded.



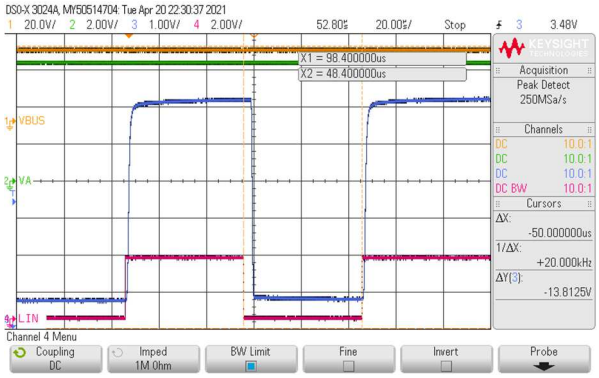
3149595829 / BBBB04B5 = Responding.

MC re-programmed to 18695bps. All 3 batteries loaded.

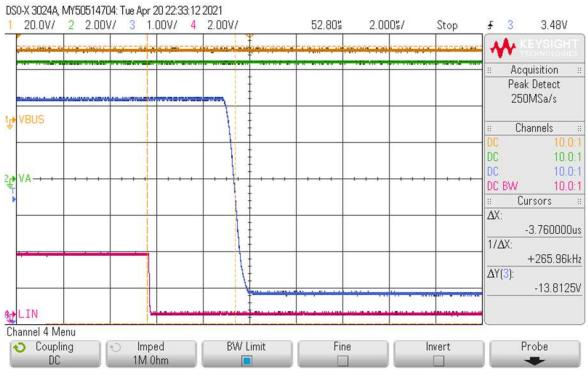


No batteries responding.

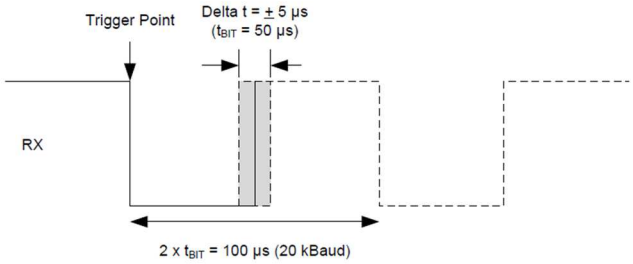
MCU firmware is generating 20000bps very accurately, 50% duty.



Recessive to Dominant transistion has 3.7us delay.



3.7us is within LIN 20kbps specification.



Application examples from manufacturer shows similar delay, however for both transistions.

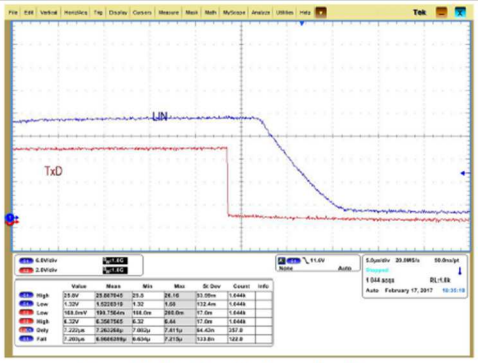


Figure 31. Dominant to Recessive Propagation

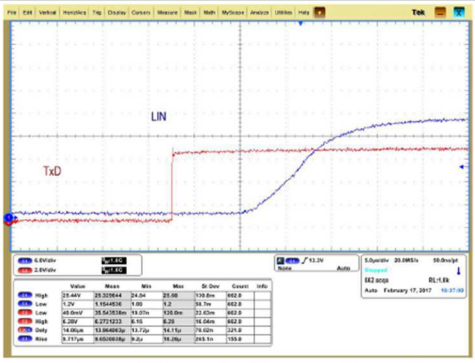
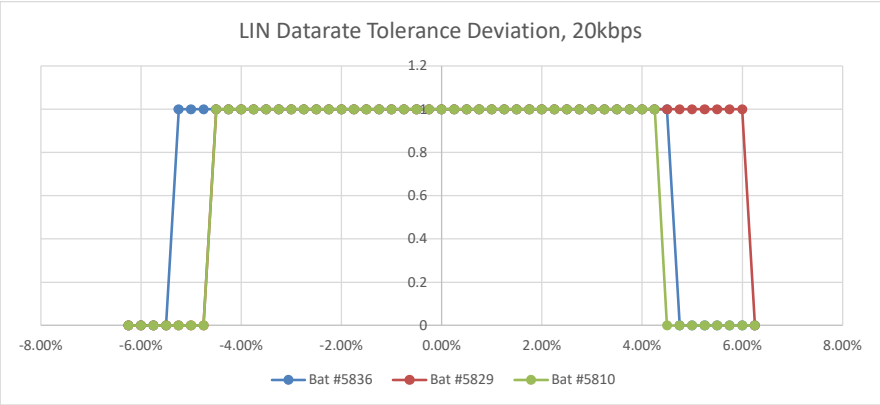


Figure 32. Recessive to Dominant Propagation

	us	us	P	bps	
MCU	52.2	47.8	100us	20000	-
B1	52.5	47.8	100.3us	19940	-0.3%
B2	51.9	47.2	99.1us	20181	+0.91%
B3	52.2	48.1	100.3us	19940	-0.3%

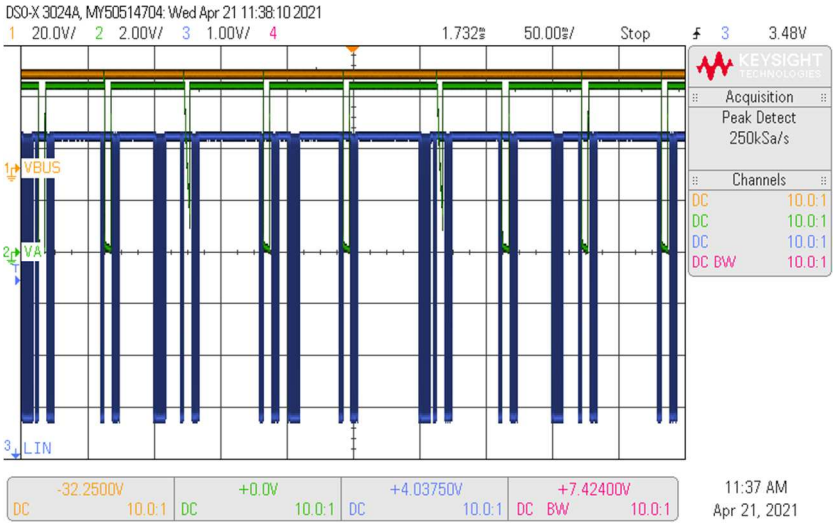
Analysis of datarate tolerance. Main controller datarate varied beyond +/-6%.

bps	bps %	BR Divider (SMCLK)	Hex	Bat #5836	Bat #5829	Bat #5810
18750	-6.25%	1,333	535	0	0	0
18800	-6.00%	1,330	531	0	0	0
18850	-5.75%	1,326	52E	0	0	0
18900	-5.50%	1,323	52A	0	0	0
18950	-5.25%	1,319	527	1	0	0
19000	-5.00%	1,316	523	1	0	0
19050	-4.75%	1,312	520	1	0	0
19100	-4.50%	1,309	51C	1	1	1
19150	-4.25%	1,305	519	1	1	1
19200	-4.00%	1,302	516	1	1	1
19250	-3.75%	1,299	512	1	1	1
19300	-3.50%	1,295	50F	1	1	1
19350	-3.25%	1,292	50B	1	1	1
19400	-3.00%	1,289	508	1	1	1
19450	-2.75%	1,285	505	1	1	1
19500	-2.50%	1,282	502	1	1	1
19550	-2.25%	1,279	4FE	1	1	1
19600	-2.00%	1,276	4FB	1	1	1
19650	-1.75%	1,272	4F8	1	1	1
19700	-1.50%	1,269	4F5	1	1	1
19750	-1.25%	1,266	4F1	1	1	1
19800	-1.00%	1,263	4EE	1	1	1
19850	-0.75%	1,259	4EB	1	1	1
19900	-0.50%	1,256	4E8	1	1	1
19950	-0.25%	1,253	4E5	1	1	1
20000	**0.00%**	**1,250**	**4E2**	**1**	**1**	**1**
20050	0.25%	1,247	4DE	1	1	1
20100	0.50%	1,244	4DB	1	1	1
20150	0.75%	1,241	4D8	1	1	1
20200	1.00%	1,238	4D5	1	1	1
20250	1.25%	1,235	4D2	1	1	1
20300	1.50%	1,232	4CF	1	1	1
20350	1.75%	1,229	4CC	1	1	1
20400	2.00%	1,225	4C9	1	1	1
20450	2.25%	1,222	4C6	1	1	1
20500	2.50%	1,220	4C3	1	1	1
20550	2.75%	1,217	4C0	1	1	1
20600	3.00%	1,214	4BD	1	1	1
20650	3.25%	1,211	4BA	1	1	1
20700	3.50%	1,208	4B7	1	1	1
20750	3.75%	1,205	4B4	1	1	1
20800	4.00%	1,202	4B1	1	1	1
20850	4.25%	1,199	4AF	1	1	1
20900	4.50%	1,196	4AC	1	1	0
20950	4.75%	1,193	4A9	0	1	0
21000	5.00%	1,190	4A6	0	1	0
21050	5.25%	1,188	4A3	0	1	0
21100	5.50%	1,185	4A0	0	1	0
21150	5.75%	1,182	49E	0	1	0
21200	6.00%	1,179	49B	0	1	0
21250	6.25%	1,176	498	0	0	0



Results show datarate variation tolerance for 3 battery packs within +4.25% to -4.5%. Given small sample size, this is considered a likely ideal 0% bias and a very good result. Good tolerance.

Beyond -5.5% tolerance, battery packs were observed detecting a shorter packet instruction associated with the discovery mechanism. Accummulated bit error was likely within the scope of tolerance. The batteries are cycling responses and not causing a down stream lockout.



Datarate tolerance and LIN bus within operational requirement. All batteries functioning, unlike initial testing.

Re-fitted original MC. Downgraded firmware to public release V086.

Articulating the battery modules (un-bolted), twisting, flexing, knocking caused no communication dropouts.

Cleaned terminals to reasonable effect with 1200 wet/dry. Females only contact cleaner. Added di-electric grease. Fitted all 3 batteries.

5 BOARD #2863268288 / AAAA01C0 - CODY BOWEN

Transporter, dual motor, 120mm wheels, 98.9km.

Lastest spec , as water proof as it can get as of feb 2021 120mm3 battery modules.

Battery BBBB04BF (1st position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB04C3 (2nd position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB04A5 (not fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

5.1 HISTORY

19th March

TL - A lot of power dropouts registered by the system and VESCs. RHS wasn't running last ride.

26th March

RHS VESC logged additional DRV faults. Undervoltage/dropouts logged.

26th March

Jesse reported the motor was f***** :-)

5.2 INSPECTION LOG – AS DELIVERED

```
dot Skateboard

Model                    : MC100
Hardware Version         : 35
Software Version         : 86
Bootloader Version       : 4
Serial Number            : AAAA01C0
Paired Remote Serial     : FFFFF000
Remote Firmware          : 46
Batch Number             : 19
Custom Change Index      : 0
Production Date          : 12-10-2020
EEPROM                   : Not Fitted
Factory Tested           : Yes


Battery Position: 0
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB04BF
Batch Number             : 28
Production Date          : 30-12-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 88.2%
- Current Capacity       : 63.52Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 216           --
- Cell Resistance 25C    : 259mohm       --

Temperature Sensors
- PCB                    : 20.8'C        --
- Cells 0-4              : 20.3'C        --
- Cells 5-9              : 20.1'C        --

Measurements
- V_Bus                  : 40739mV       --
- Battery                : 40737mV       --
- V_Switch               : 40739mV       --
- V_Switch_Off           : 71mV          --
- VCC                    : 3282mV        --
- V_Offset               : 3007mV        --
- V_Current_Sense        : 1495mV        --
- I_Current_Sense        : 20mA          --

Cell Voltages
- Cell 0                 : 4048mV        --
- Cell 1                 : 4068mV        --
- Cell 2                 : 4065mV        --
- Cell 3                 : 4067mV        --
- Cell 4                 : 4067mV        --
- Cell 5                 : 4079mV        --
- Cell 6                 : 4068mV        --
- Cell 7                 : 4076mV        --
- Cell 8                 : 4093mV        --
- Cell 9                 : 4092mV        --

Battery Position: 1
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB04C3
Batch Number             : 28
Production Date          : 30-12-2020
Factory Tested           : Yes
```

```
Battery Metrics
- State of Charge        : 83.1%
- Current Capacity       : 59.90Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32      : 196           --
- Cell Resistance 25C    : 291mohm       --

Temperature Sensors
- PCB                    : 20.4'C        --
- Cells 0-4              : 20.0'C        --
- Cells 5-9              : 19.9'C        --

Measurements
- V_Bus                  : 40712mV       --
- Battery                : 40146mV       --
- V_Switch               : 56mV       * FAIL *
- V_Switch_Off           : 56mV          --
- VCC                    : 3310mV        --
- V_Offset               : 3002mV        --
- V_Current_Sense        : 1481mV        --
- I_Current_Sense        : 0mA           --

Cell Voltages
- Cell 0                 : 3991mV        --
- Cell 1                 : 4011mV        --
- Cell 2                 : 4012mV        --
- Cell 3                 : 4011mV        --
- Cell 4                 : 4012mV        --
- Cell 5                 : 4011mV        --
- Cell 6                 : 4020mV        --
- Cell 7                 : 4011mV        --
- Cell 8                 : 4037mV        --
- Cell 9                 : 4025mV        --

Battery Position: 2
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB04A5
Batch Number             : 28
Production Date          : 30-12-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 90.2%
- Current Capacity       : 64.96Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32      : 161           --
- Cell Resistance 25C    : 283mohm       --

Temperature Sensors
- PCB                    : 20.2'C        --
- Cells 0-4              : 20.0'C        --
- Cells 5-9              : 20.0'C        --

Measurements
- V_Bus                  : 40733mV       --
- Battery                : 40751mV       --
- V_Switch               : 64mV       * FAIL *
- V_Switch_Off           : 64mV          --
- VCC                    : 3310mV        --
- V_Offset               : 3010mV        --
- V_Current_Sense        : 1516mV        --
- I_Current_Sense        : 0mA           --

Cell Voltages
- Cell 0                 : 4062mV        --
- Cell 1                 : 4062mV        --
- Cell 2                 : 4062mV        --
- Cell 3                 : 4076mV        --
- Cell 4                 : 4075mV        --
- Cell 5                 : 4075mV        --
- Cell 6                 : 4075mV        --
```

```
- Cell 7                 : 4088mV        --
- Cell 8                 : 4076mV        --
- Cell 9                 : 4088mV        --

Settings
-Wheel Diameter (mm)x10  : 1200
- Options                : 0009
- Auto Power Off Period  : 60000
- Power Down Timer       : 60000

Measurements
- V_Bus                  : 40628mV       --
- V_Aux                  : 6492mV        --
- V_Sys                  : 4059mV        --  USB Power Interfering
- V_USB                  : 4518mV        --
- VCC                    : 3303mV        --

Battery Charger
- V_Charger_Input        : 165mV      * FAIL *
- V_Charger_Output       : 1759mV
- Temperature            : 23.4'C        --
- Connector Temperature  : 24.9'C        --
- Power Limit            : 168W
- Power Consumption      : 0W            --

Inertial_Module
- Module                 : Present       --
- Angular XYZ            : 174     -272    -250
- Linear XYZ             : 316     -581    16658

LIN Bus
- Bus State              : Active        --
- Discovered Devices     : 3             --

Communications
- Wireless RF            : Present       --
- Packet Count Tx/Rx     : 273/307       --
- Paired Remote Serial   : FFFFF000
- Paired Status          : Synced        --

Motor Temperature Sensors
- Left Motor Temp        : 19.9'C        --
- Right Motor Temp       : 18.7'C        --


Metrics
- Trip Odo Left          : 340 m
- Trip Odo Right         : 260 m
- Trip Time              : 0.7 mins
- Number of trips        : 21
- Average Trip Distance  : 4.7 km
- Total Ride Time        : 4.2 hrs
- Odometer               : 98.9 km


Trip Data                  Dist_km mins    Avg_kph Max_kph    Max_Bat_LHS/RHS
Min_Bat_LHS/RHS     TempMax_Bat_LHS/RHS    Motor_Temp_High_mins Features Used
Trip #0                 : 0.32    0       29.5    43.7       6.2    4.7/8.1     -1.1   -
0.7/-0.3    19    20/19           0/0                 1 Expert
Trip #1                 : 7.12    14      30.2    48.2       41.5   23.3/23.3   -6.2   -
3.8/-3.8    37    69/67           0/0                 1 Expert
Trip #2                 : 0.16    1       9.0     27.0       19.0   8.0/8.1     -0.0   -
0.0/-0.0    25    32/31           0/0                 0
Trip #3                 : 1.12    3       19.2    34.7       14.2   6.8/6.8     -7.2   -
3.5/-3.5    24    31/30           0/0                 0
Trip #4                 : 0.32    0       37.0    43.2       3.2    5.5/6.2     -0.2   -
1.5/-1.5    25    32/-            0/0                 0
Trip #5                 : 1.84    4       23.0    36.2       14.0   7.7/7.7     -8.7   -
4.9/-4.8    26    32/31           0/0                 3 Expert Eco
Trip #6                 : 0.40    0       36.0    42.2       5.2    4.7/4.8     -0.6   -
1.5/-1.6    18    18/17           0/0                 1 Expert
Trip #7                 : 0.72    2       21.0    28.7       13.2   12.1/0.0    -6.7   -
5.5/-0.0    26    53/31           0/0                 1 Expert
```

```
Fault Report
Log #0                  : 42     7       1       49153   44      36224   0       1219
Log #1                  : 43     6       1       49153   51      36226   0       1189
Log #2                  : 30     1       1       3709    37203   21600   1501    1215
Log #3                  : 31     1       1       3612    36239   21600   1517    1189
Log #4                  : 29     1       1       3605    36237   21600   1543    1219
Log #5                  : 54     8       57618   16      728     19792   299     20400
Log #6                  : 53     8       57618   16      723     19792   280     20000
```

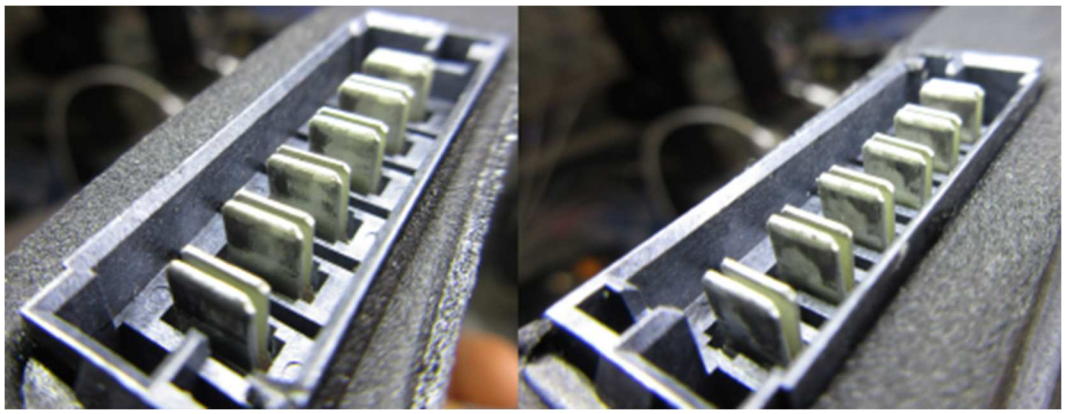
5.3 INSPECTION

The USB socket is damaged. USB has to be held to one side to establish connection to dot-hub.

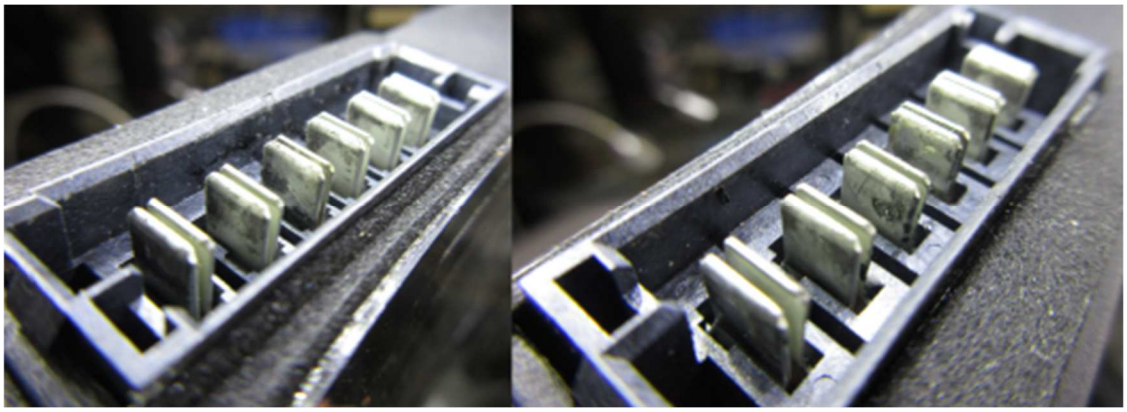
Board needs a new charge port cover (tether missing) and two new module bolts (sockets chewed out).

Not my doing!

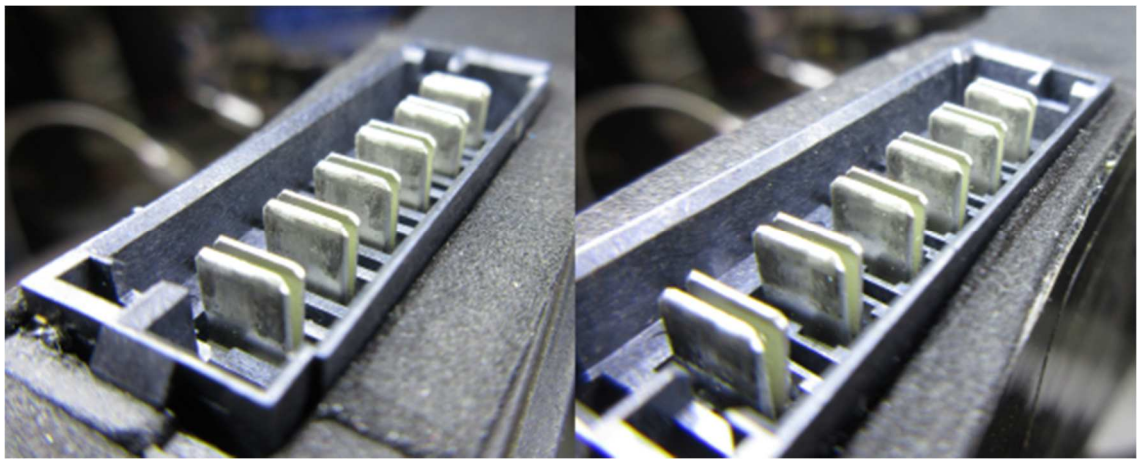
5.3.1 BATTERY 3149595839 / BBBB04BF (1ST POSITION)



5.3.2 BATTERY 3149595843 / BBBB04C3 (2ND POSITION)



5.3.3 BATTERY 3149595813 / BBBB04A5 (3RD POSITION)



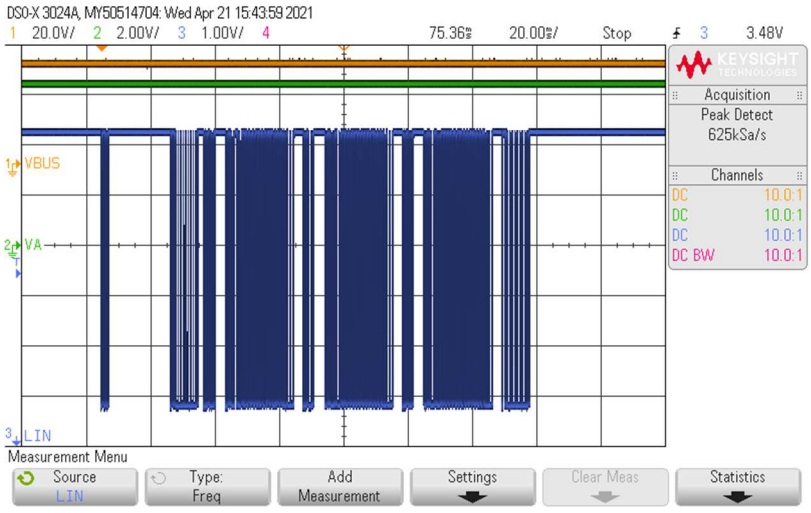
5.4 INVESTIGATION

3 batteries fitted.

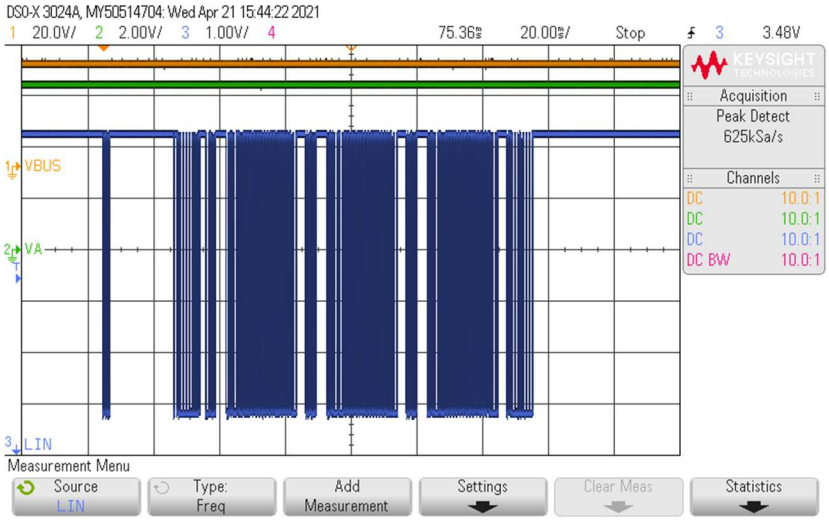
Turned on and off 30 times. Zero failures to detect all 3 batteries.

Articulating the battery modules to extremes caused no dropouts.

-4.0% BR=1302, 19200bps



+4.0% BR=1202, 20800bps

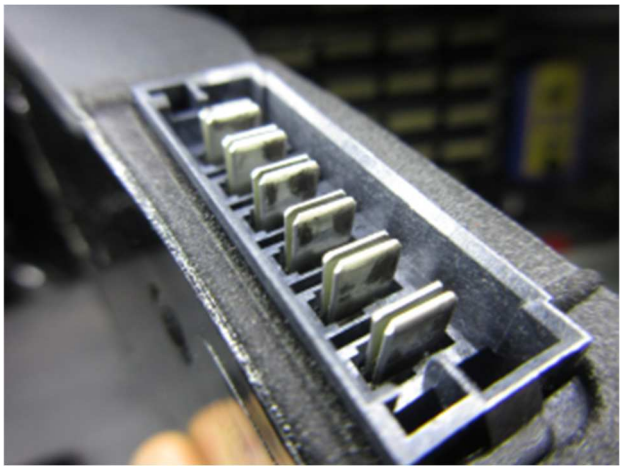


Limit was below -5.0% and above +4.25%.

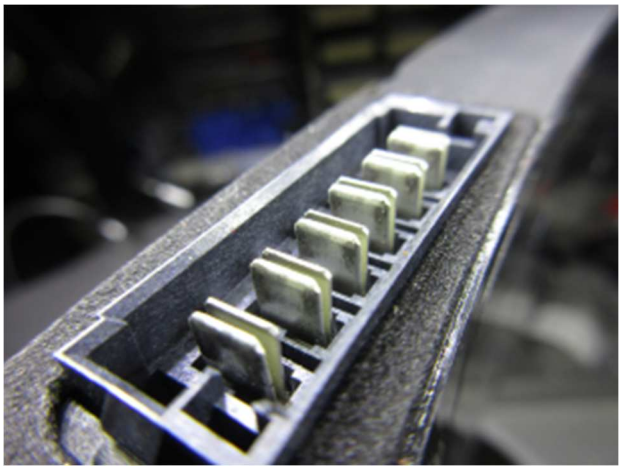
No variation in dominant level detected. 0.812V.

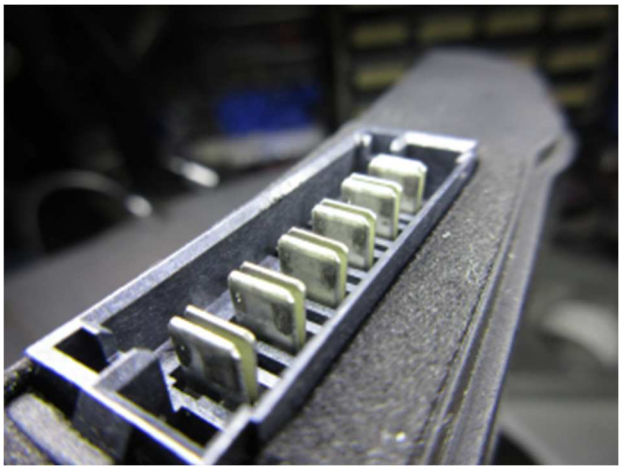
5.5 BATTERY TERMINALS

5.5.1 BBBB04BC

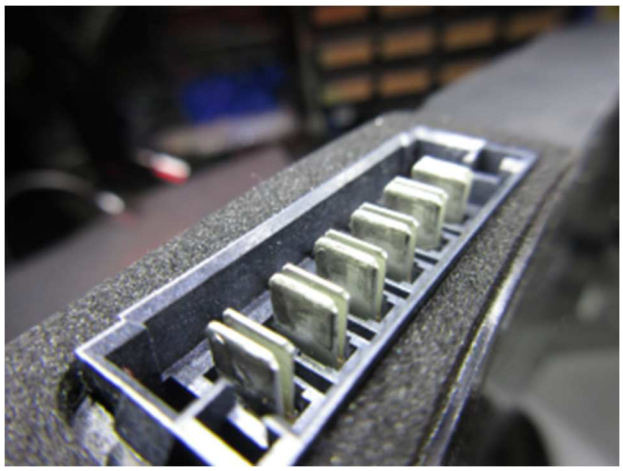


5.5.2 BBBB04B5



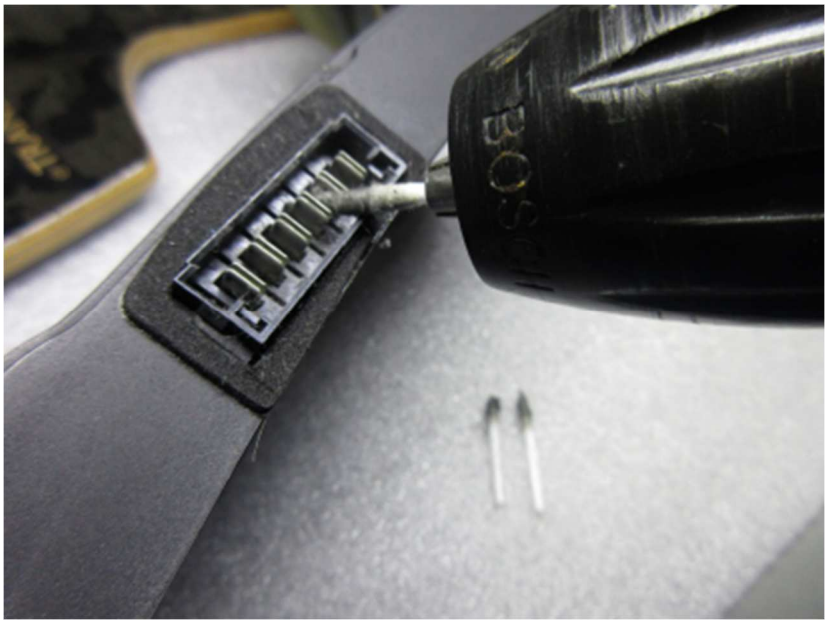


5.5.3 BBBB04A2

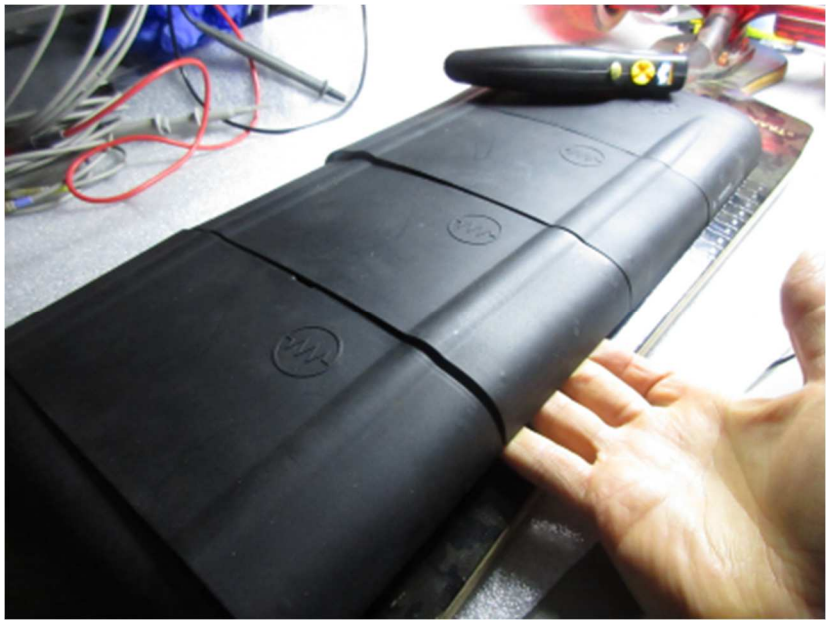


5.6 CONNECTOR SERVICING

All 3 battery packs had some connector cleaning done. Cotton buds with metal polish was used on the male connectors. Contact cleaner used on both male and female connector. Di-electric grease applied.



Massive battery flex, twist and gaps… still functioning.



6 BOARD #2863268288 / AAAA0166 - LEIGH WELLS

Transporter, dual motor, 120mm wheels, 4 batteries, 61.4km.

Battery BBBB04BB (1st position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB04BD (2nd position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB044C

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB0455

6.1 HISTORY

10th March

TL - Experiencing dropouts. Two of the batteries in-particular logged… BBBB044C, BBBB04BD.

24th March

TL - Lots of dropouts logged.

6.2 INSPECTION LOG – AS DELIVERED

First log missed last two fitted batteries.

```
- Discovered Devices     : 2            --
```

This repeated on USB connection.

Second log, direct diagnostic command (not USB)…

```
dot Skateboard

Model                    : MC100
Hardware Version         : 35
Software Version         : 86
Bootloader Version       : 4
Serial Number            : AAAA0166
Paired Remote Serial     : DDDD0194
Remote Firmware          : -
Batch Number             : 17
Custom Change Index      : 0
Production Date          : 14-8-2020
EEPROM                   : Not Fitted
Factory Tested           : Yes


Battery Position: 0
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB04BB
Batch Number             : 28
Production Date          : 30-12-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 88.6%
- Current Capacity       : 63.80Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 111           --
- Cell Resistance 25C    : 0mohm      * FAIL *

Temperature Sensors
- PCB                    : 20.3'C        --
- Cells 0-4              : 19.7'C        --
- Cells 5-9              : 19.8'C        --

Measurements
- V_Bus                  : 40685mV       --
- Battery                : 40685mV       --
- V_Switch               : 66mV       * FAIL *
- V_Switch_Off           : 66mV          --
- VCC                    : 3310mV        --
- V_Offset               : 2990mV        --
- V_Current_Sense        : 1504mV        --
- I_Current_Sense        : -10mA         --

Cell Voltages
- Cell 0                 : 4052mV        --
- Cell 1                 : 4060mV        --
- Cell 2                 : 4051mV        --
- Cell 3                 : 4072mV        --
- Cell 4                 : 4051mV        --
- Cell 5                 : 4076mV        --
- Cell 6                 : 4063mV        --
```

```
- Cell 7                : 4076mV        --
- Cell 8                : 4090mV        --
- Cell 9                : 4087mV        --

Battery Position: 1
Model                   : BM100
Hardware Version        : 22
Software Version        : 19
Serial Number           : BBBB04BD
Batch Number            : 28
Production Date         : 30-12-2020
Factory Tested          : Yes

Battery Metrics
- State of Charge       : 88.6%
- Current Capacity      : 63.80Wh       --
- Full Capacity         : 72.00Wh       --
- #Charge Cycles x32    : 108           --
- Cell Resistance 25C   : 316mohm       --

Temperature Sensors
- PCB                   : 20.1'C        --
- Cells 0-4             : 20.0'C        --
- Cells 5-9             : 19.6'C        --

Measurements
- V_Bus                 : 40700mV       --
- Battery               : 40700mV       --
- V_Switch              : 60mV       * FAIL *
- V_Switch_Off          : 60mV          --
- VCC                   : 3298mV        --
- V_Offset              : 3001mV        --
- V_Current_Sense       : 1489mV        --
- I_Current_Sense       : -10mA         --

Cell Voltages
- Cell 0                : 4049mV        --
- Cell 1                : 4067mV        --
- Cell 2                : 4054mV        --
- Cell 3                : 4053mV        --
- Cell 4                : 4067mV        --
- Cell 5                : 4067mV        --
- Cell 6                : 4066mV        --
- Cell 7                : 4093mV        --
- Cell 8                : 4079mV        --
- Cell 9                : 4105mV        --

Battery Position: 2
Model                   : BM100
Hardware Version        : 22
Software Version        : 19
Serial Number           : BBBB044C
Batch Number            : 26
Production Date         : 27-11-2020
Factory Tested          : Yes

Battery Metrics
- State of Charge       : 88.2%
- Current Capacity      : 63.52Wh       --
- Full Capacity         : 72.00Wh       --
- #Charge Cycles x32    : 104           --
- Cell Resistance 25C   : 0mohm      * FAIL *

Temperature Sensors
- PCB                   : 20.0'C        --
- Cells 0-4             : 19.7'C        --
- Cells 5-9             : 19.7'C        --

Measurements
- V_Bus                 : 40700mV       --
- Battery               : 40699mV       --
- V_Switch              : 40695mV       --
- V_Switch_Off          : 58mV          --
```

```
- VCC                    : 3285mV        --
- V_Offset               : 2993mV        --
- V_Current_Sense        : 1477mV        --
- I_Current_Sense        : 10mA          --

Cell Voltages
- Cell 0                 : 4044mV        --
- Cell 1                 : 4059mV        --
- Cell 2                 : 4050mV        --
- Cell 3                 : 4064mV        --
- Cell 4                 : 4062mV        --
- Cell 5                 : 4063mV        --
- Cell 6                 : 4076mV        --
- Cell 7                 : 4076mV        --
- Cell 8                 : 4076mV        --
- Cell 9                 : 4113mV        --

Battery Position: 3
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB0455
Batch Number             : 26
Production Date          : 27-11-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 88.2%
- Current Capacity       : 63.52Wh       --
- Full Capacity          : 72.00Wh       --
- #Charge Cycles x32     : 112           --
- Cell Resistance 25C    : 0mohm      * FAIL *

Temperature Sensors
- PCB                    : 19.9'C        --
- Cells 0-4              : 20.0'C        --
- Cells 5-9              : 19.9'C        --

Measurements
- V_Bus                  : 40687mV       --
- Battery                : 40708mV       --
- V_Switch               : 60mV       * FAIL *
- V_Switch_Off           : 60mV          --
- VCC                    : 3310mV        --
- V_Offset               : 3005mV        --
- V_Current_Sense        : 1510mV        --
- I_Current_Sense        : 0mA           --

Cell Voltages
- Cell 0                 : 4045mV        --
- Cell 1                 : 4052mV        --
- Cell 2                 : 4054mV        --
- Cell 3                 : 4059mV        --
- Cell 4                 : 4072mV        --
- Cell 5                 : 4061mV        --
- Cell 6                 : 4070mV        --
- Cell 7                 : 4086mV        --
- Cell 8                 : 4087mV        --
- Cell 9                 : 4098mV        --


Settings
-Wheel Diameter (mm)x10  : 1200
- Options                : 0009
- Auto Power Off Period  : 60000
- Power Down Timer       : 60000

Measurements
- V_Bus                  : 40607mV       --
- V_Aux                  : 6484mV        --
- V_Sys                  : 4066mV     * FAIL *  USB Power Interfering
- V_USB                  : 4532mV        --
- VCC                    : 3295mV        --
```

```
Battery Charger
- V_Charger_Input        : 150mV      * FAIL *
- V_Charger_Output       : 1705mV
- Temperature            : 22.2'C        --
- Connector Temperature  : 23.6'C        --
- Power Limit            : 168W
- Power Consumption      : 0W            --

Inertial_Module
- Module                 : Present       --
- Angular XYZ            : 203     -263    -272
- Linear XYZ             : 259     120     16840

LIN Bus
- Bus State              : Active        --
- Discovered Devices     : 4             --

Communications
- Wireless RF            : Present       --
- Packet Count Tx/Rx     : 24540/24573   --
- Paired Remote Serial   : DDDD0194
- Paired Status          : Synced        --

Motor Temperature Sensors
- Left Motor Temp        : 18.2'C        --
- Right Motor Temp       : 17.1'C        --


Metrics
- Trip Odo Left          : 210 m
- Trip Odo Right         : 170 m
- Trip Time              : 0.4 mins
- Number of trips        : 22
- Average Trip Distance  : 2.7 km
- Total Ride Time        : 0.2 hrs
- Odometer               : 61.4 km
```

Trip Data	Dist_km	mins	Avg_kph	Max_kph	Max_Bat_LHS/RHS		Min_Bat_LHS/RHS		TempMax_Bat_LHS/RHS	
Motor_Temp_High_mins	Features Used									
Trip #0	0.24	0	36.0	44.7	12.0	6.7/9.2	-0.3	-1.3/-1.3	23	23/22
0/0	1 Expert									
Trip #1	0.56	1	18.2	27.0	22.0	13.0/12.8	-9.0	-5.1/-5.1	28	73/71
0/0	1 Expert									
Trip #2	1.52	4	18.7	32.0	38.0	23.6/23.8	-11.5	-6.5/-6.5	28	67/66
0/0	1 Expert									
Trip #3	2.40	7	18.5	45.0	8.7	5.5/4.7	-4.1	-2.1/-2.0	28	35/34
0/0	1 Expert									
Trip #4	1.44	6	14.5	22.0	34.7	18.8/18.7	-6.2	-3.6/-3.5	30	34/33
0/0	1 Expert									
Trip #5	0.48	1	19.2	31.2	41.2	21.2/21.3	-9.5	-4.5/-4.6	37	76/76
0/0	1 Expert									
Trip #6	0.88	3	16.0	31.7	46.0	23.3/23.5	-9.3	-4.3/-4.3	23	36/35
0/0	1 Expert									
Trip #7	1.36	5	14.0	27.2	40.7	20.3/20.2	-8.6	-5.0/-5.0	28	41/39
0/0	1 Expert									

```
Fault Report
Log #0                  : 44     94     1      49153  86     41529  0      1109
Log #1                  : 43     104    1      49153  84     41523  0      1100
Log #2                  : 42     50     1      49153  73     41537  0      1213
Log #3                  : 41     40     1      49153  78     41510  1      1211
Log #4                  : 53     23     57618  484    1526   14663  613    22900
Log #5                  : 54     23     57618  506    1497   14663  879    14900
Log #6                  : 51     25     28853  13843  347    3353   3341   6483
```

Next log on direct diagnostic command reported only first two batteries.

Remote confirmed two batteries not detected.

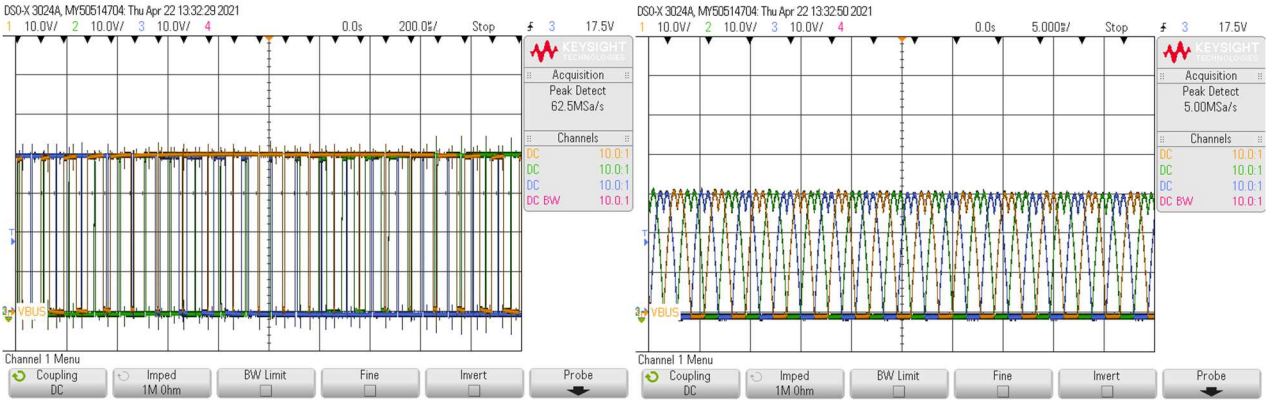
6.3 INSPECTION

These deck bolts have been screwed in SUPER HARD.

The deck bolts are contaminated with an unexpected hard material (thread lock?). It is not known if this may weaken or damage the Nyloc material. The bulk of the material is on the upper thread and useless for retention. It is recommend to consider whether this practice is acceptable from a service perspective in relation to warranty. Particularly if this is being applied unnecessarily by the dealer.

The LHS motor is TERRIBLE. Very noisy. Quite surprised WA sports note only states dropouts, not excessive motor noise. The wheel has wiggle room on the motor. Picture below show the gap pulling to one side.

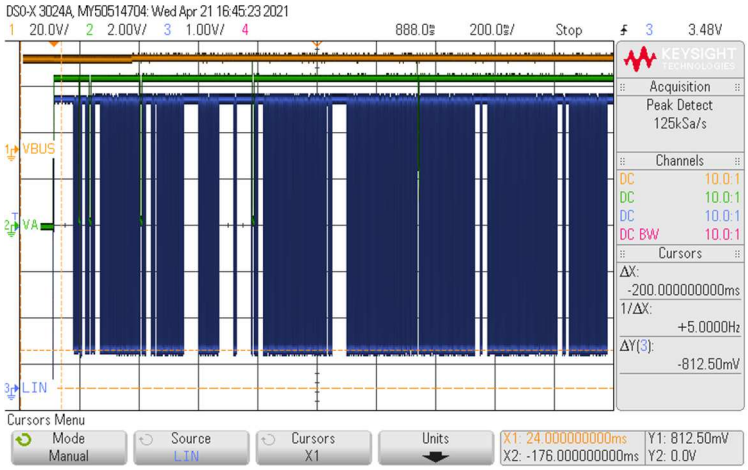
The motor commutation was electrically checked. The motor is electrically operating as expected and not causing any fault. It is considered a mechanical failure and not considered relevant to this current investigation.



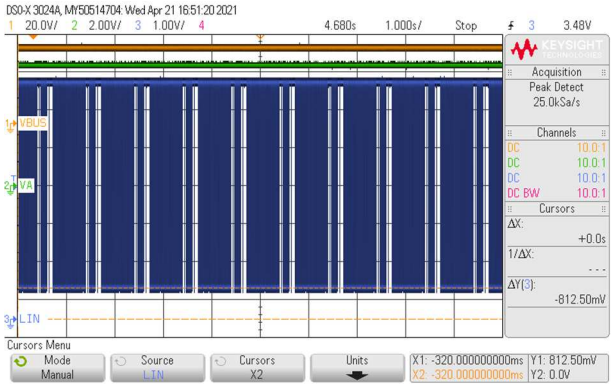
6.4 INVESTIGATION

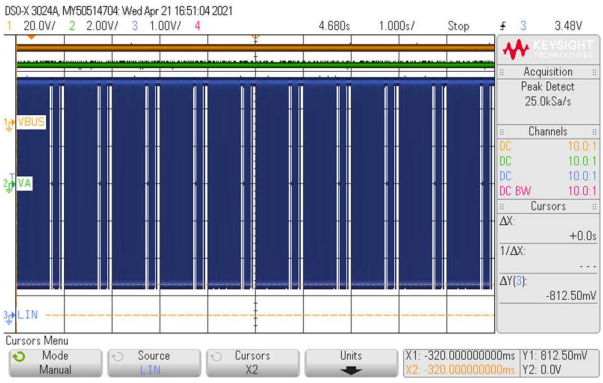
LIN data traffic, 4 batteries…

Startup.

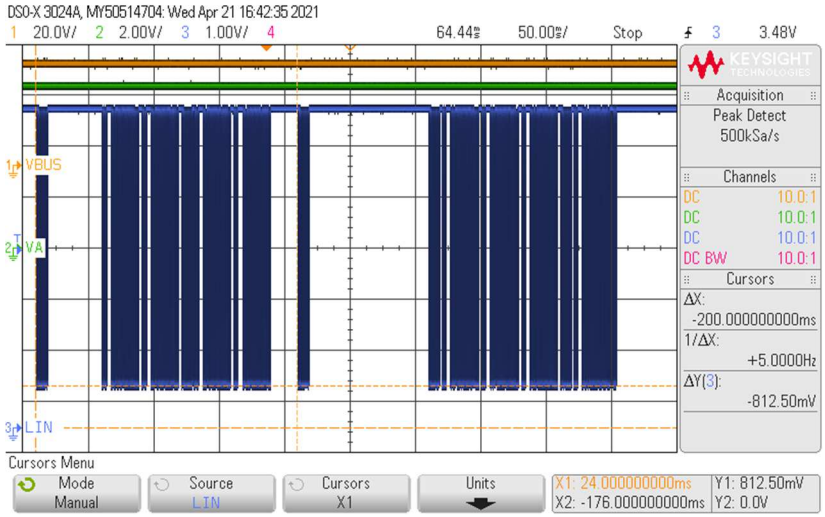


Communications at full load… 1s/div.

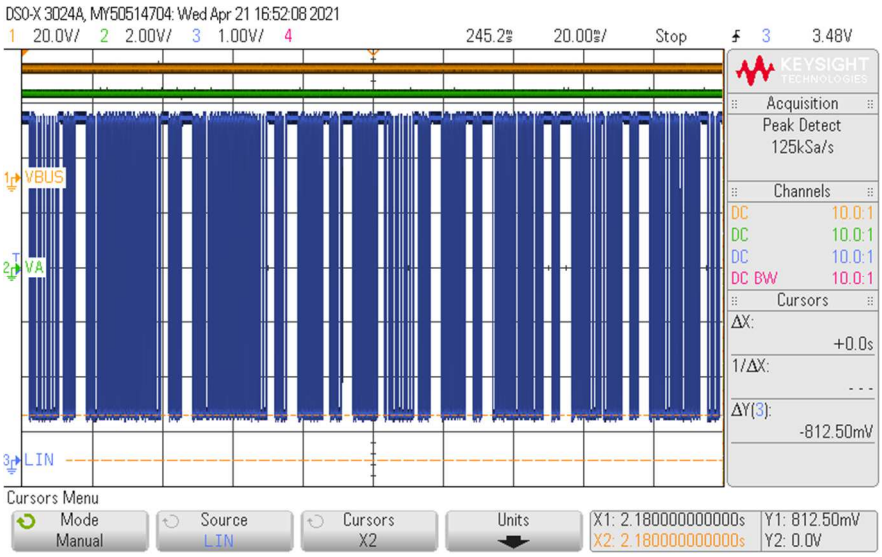




50ms/div



20ms/div



LIN data/communication as expected and operating efficiently. No overload.

Firmware updated to development revision, V089.

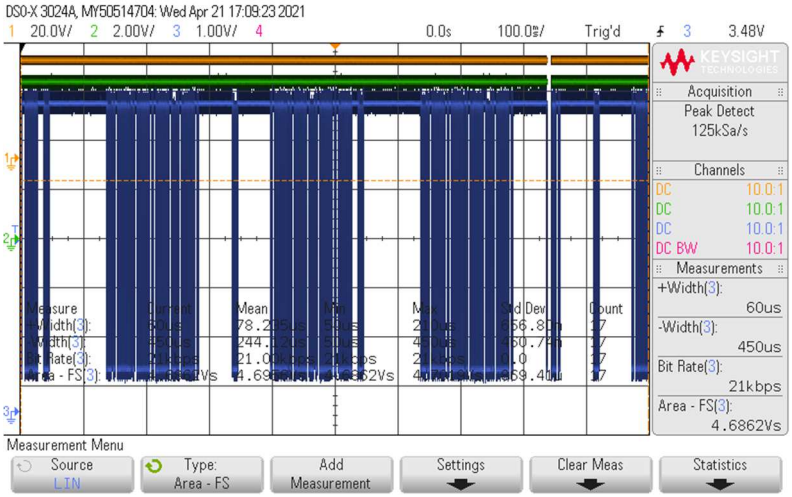
LIN data monitored. After several minutes, no motor use.

- Zero non-packet responses.
- Zero packet errors
- Zero dropouts

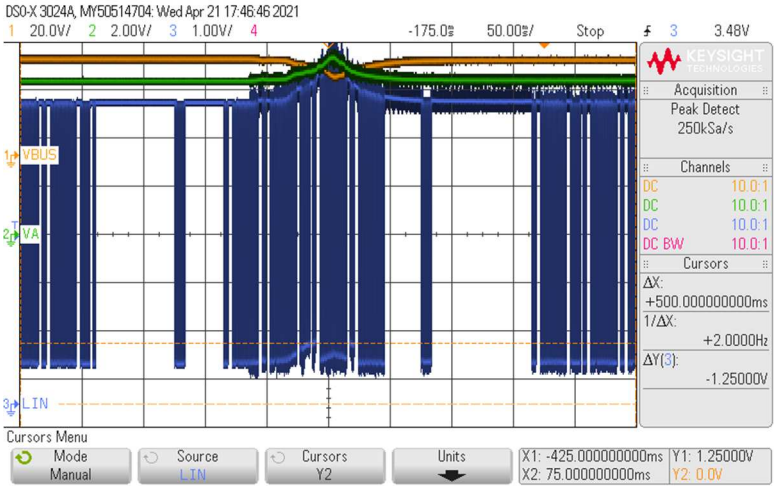
Full throttle, no load, 1+ (very noisy) minutes…

- Zero non-packet responses.
- Zero packet errors
- Zero dropouts

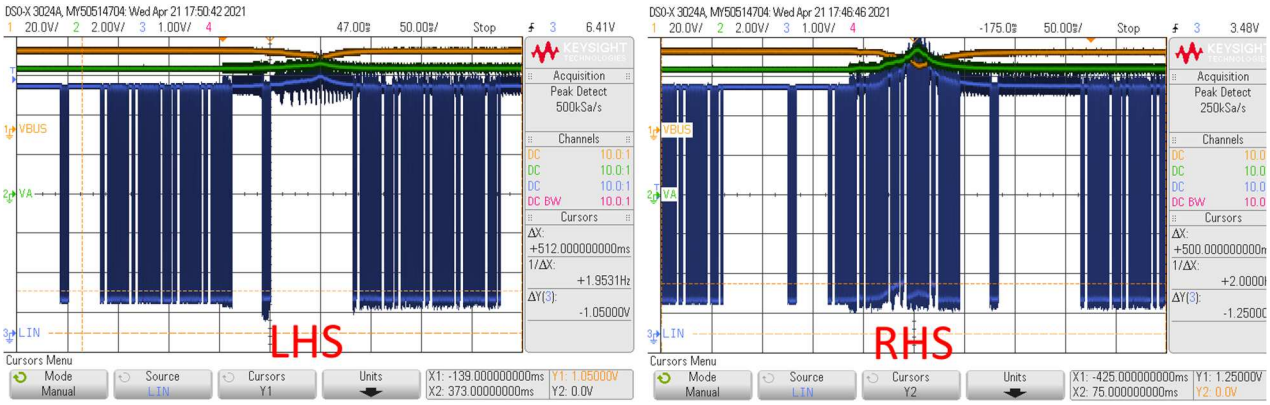
Increased electrical noise evident, but no impact to LIN data stability.



On application of the throttle, there was a noticeable perturbation in voltage levels.



The difference varied on successive tests. The noisy LHS was not significantly different to the RHS.



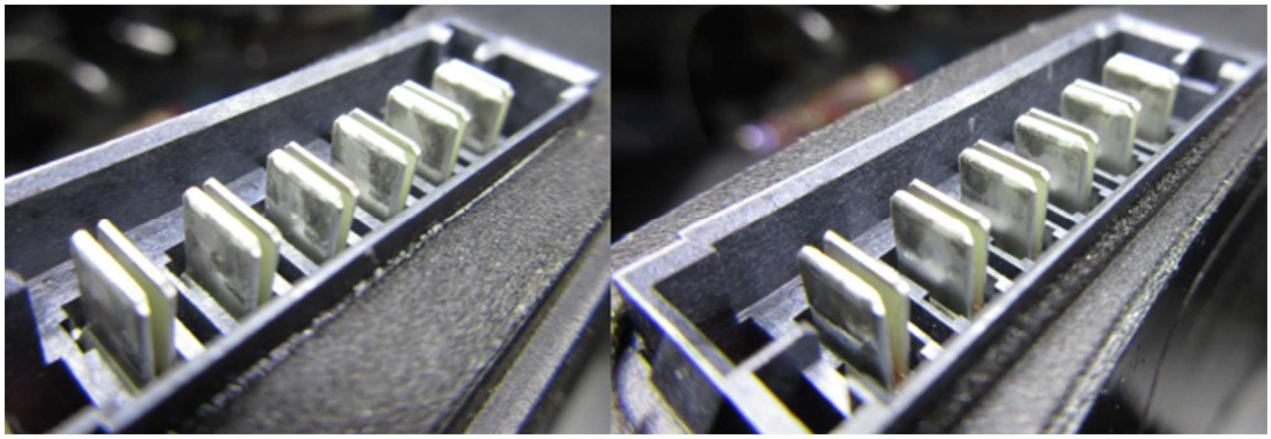
During the testing, the 3rd battery module has 1 non-response fault to a command.

Given ground offset relative, communications reliability does not appear to be impacted.

6.5 BATTERY TERMINALS

6.5.1 BATTERY 3149595835 – (POSITION 1)

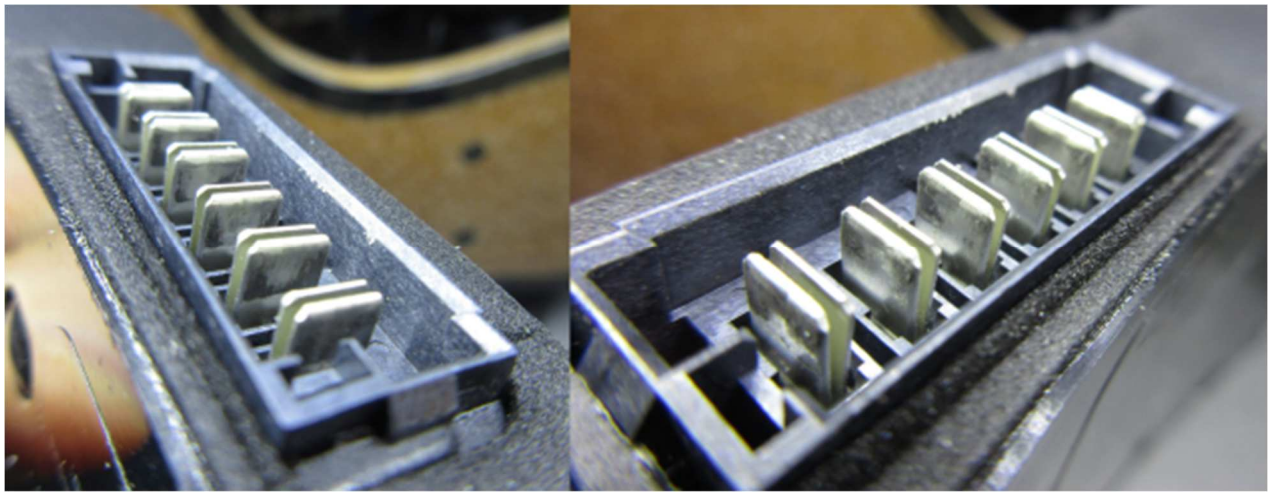
No di-electric grease.



6.5.2 BATTERY 3149595837 – (POSITION 2)

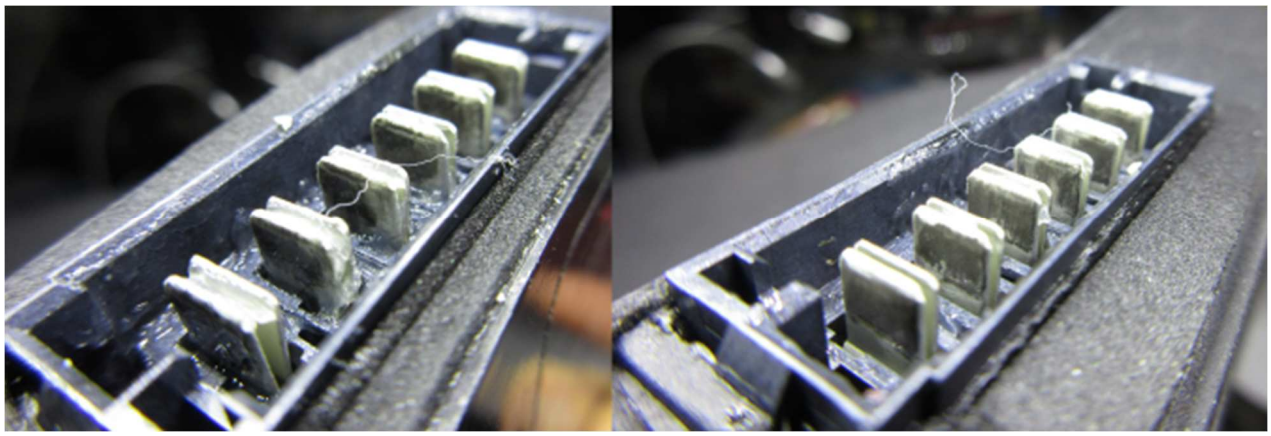
Male connector has no di-electric grease.

One bolt was very difficult to remove. Suspect bolt was over-torqued and Nyloc nut was free-spinning.



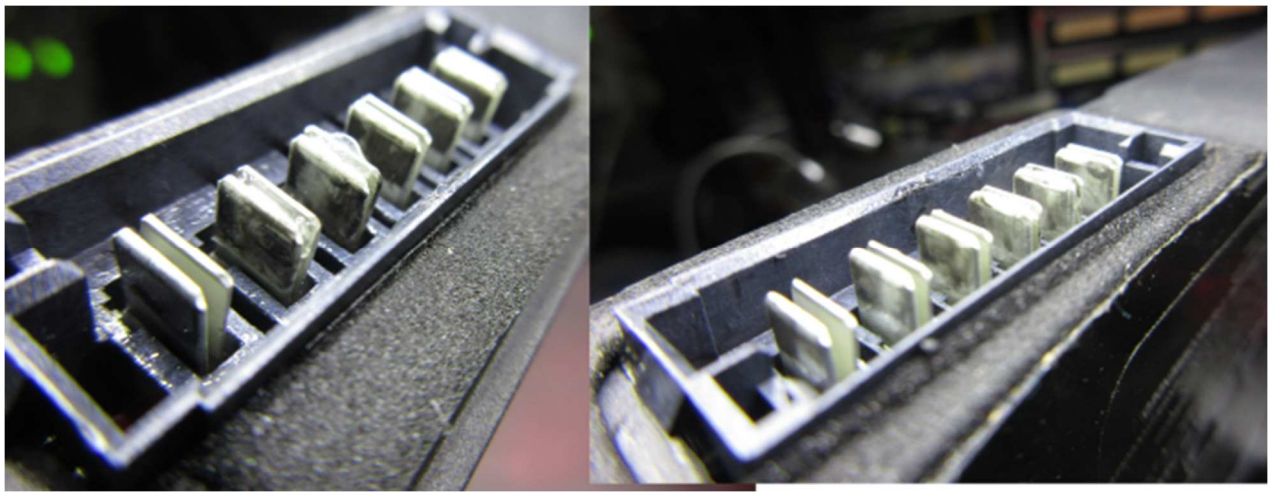
6.5.3 BATTERY 3149595724 – (POSITION 3)

Connectors greased. One terminal on female connector absent of grease.



6.5.4 BATTERY 3149595733 – (POSITION 4)

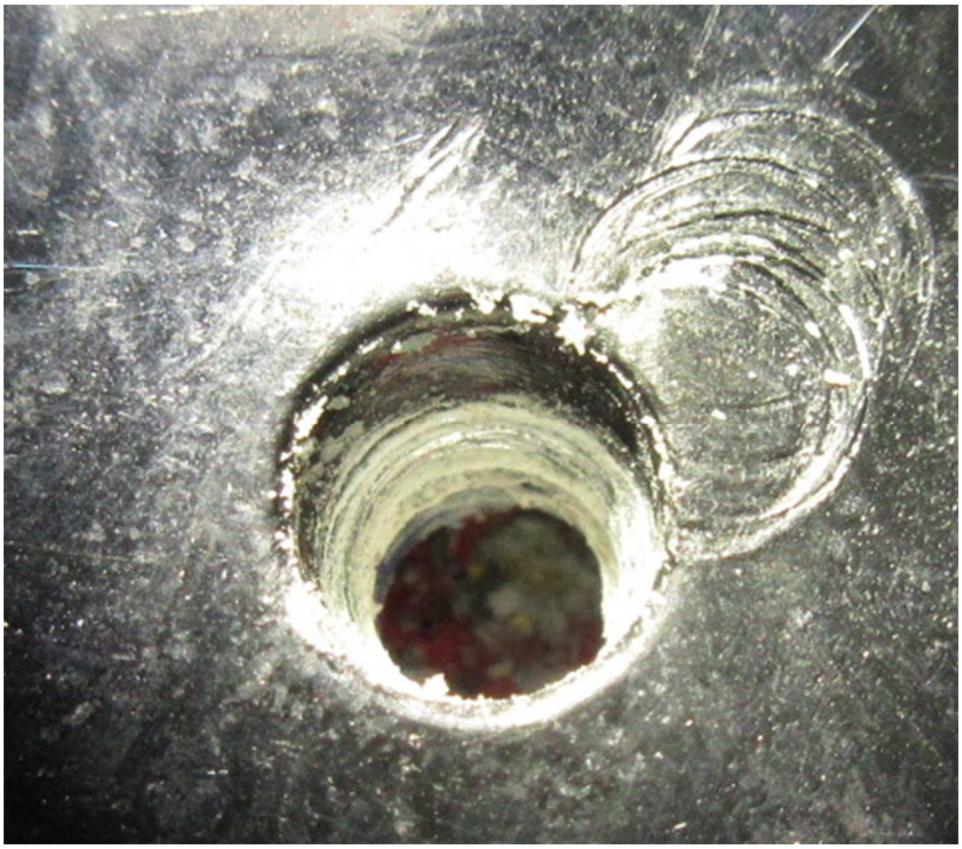
Small amount of di-electric grease on male plug only.



6.5.5 MAIN CONTROLLER

Bolts have a high amount of material applied.

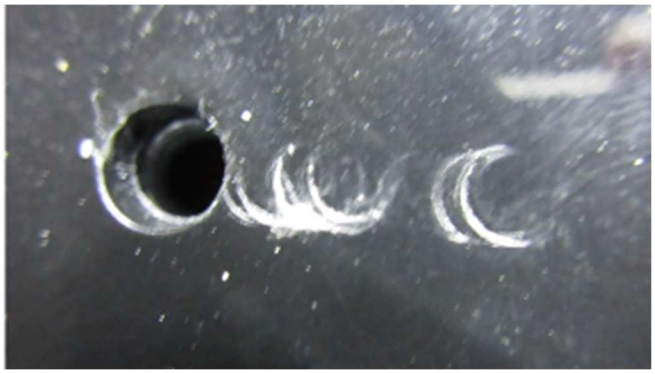
Noticeable debris inside.



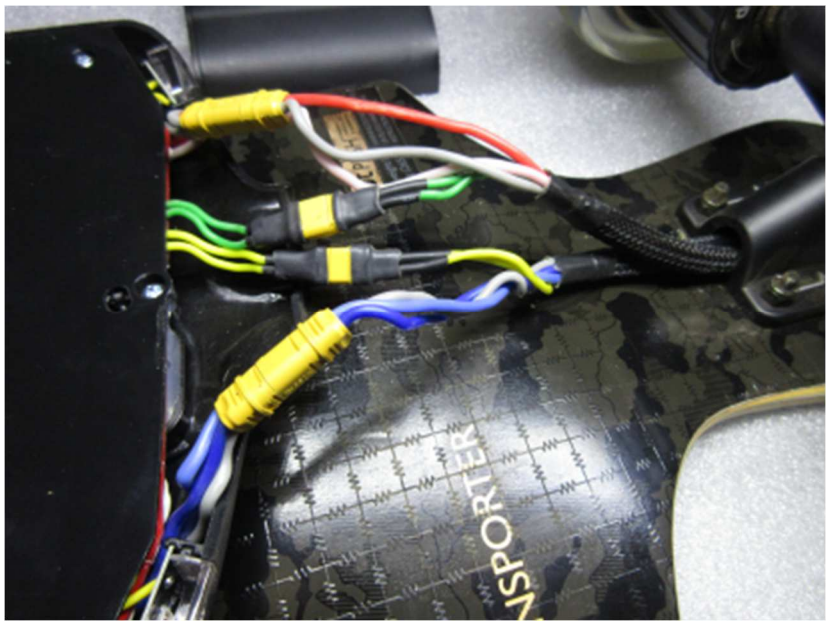
The enclosure was not opened. Some of the debris was removed. No evidence of PCB damage from the screw.

There is slight concern that using this much bolt adhesive could lead to it dripping into the main controller and on to the PCB. **This application of adhesive should be discouraged.**

User must have had some difficultly fitting the main controller. Excessive bolt marks on the MC evident.



Wiring looks in very good condition.



7 BOARD # 2863268258 / AAAA01A2 - KIARA KENNEDY

Compact, dual motor, 2 batteries, 171.3 km

Battery BBBB045A (1st position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

Battery BBBB0462 (2nd position fitted)

- VTC4
- V22 H/W, V19 S/W
- Sealed Unit, Drain hole blocked and connectors sealed, 2mm Gasket fitted,
- Resin coated - Marked with small dot logo

7.1 HISTORY

19th March

TL - RTD's not registering. Lot of dropouts logged. Batteries not present at the time of log, VBus=35V.

7.2 INSPECTION LOG – AS DELIVERED

Excessive dropouts logged.

```
dot Skateboard

Model                    : MC100
Hardware Version         : 35
Software Version         : 86
Bootloader Version       : 4
Serial Number            : AAAA01A2
Paired Remote Serial     : DDDD019C
Remote Firmware          : -
Batch Number             : 19
Custom Change Index      : 0
Production Date          : 12-10-2020
EEPROM                   : Not Fitted
Factory Tested           : Yes


Battery Position: 0
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
Serial Number            : BBBB045A
Batch Number             : 26
Production Date          : 27-11-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 67.1%
- Current Capacity       : 48.38Wh       --
- Full Capacity          : 72.07Wh       --
- #Charge Cycles x32     : 332           --
- Cell Resistance 25C    : 257mohm       --

Temperature Sensors
- PCB                    : 20.3'C        --
- Cells 0-4              : 20.4'C        --
- Cells 5-9              : 20.5'C        --

Measurements
- V_Bus                  : 38834mV       --
- Battery                : 38834mV       --
- V_Switch               : 38846mV       --
- V_Switch_Off           : 61mV          --
- VCC                    : 3292mV        --
- V_Offset               : 3010mV        --
- V_Current_Sense        : 1484mV        --
- I_Current_Sense        : 40mA          --

Cell Voltages
- Cell 0                 : 3856mV        --
- Cell 1                 : 3873mV        --
- Cell 2                 : 3860mV        --
- Cell 3                 : 3876mV        --
- Cell 4                 : 3873mV        --
- Cell 5                 : 3873mV        --
- Cell 6                 : 3881mV        --
- Cell 7                 : 3899mV        --
- Cell 8                 : 3898mV        --
- Cell 9                 : 3911mV        --

Battery Position: 1
Model                    : BM100
Hardware Version         : 22
Software Version         : 19
```

```
Serial Number            : BBBB0462
Batch Number             : 26
Production Date          : 27-11-2020
Factory Tested           : Yes

Battery Metrics
- State of Charge        : 67.1%
- Current Capacity       : 48.42Wh       --
- Full Capacity          : 72.07Wh       --
- #Charge Cycles x32     : 280           --
- Cell Resistance 25C    : 284mohm       --

Temperature Sensors
- PCB                    : 20.4'C        --
- Cells 0-4              : 20.3'C        --
- Cells 5-9              : 20.6'C        --

Measurements
- V_Bus                  : 38825mV       --
- Battery                : 38834mV       --
- V_Switch               : 60mV       * FAIL *
- V_Switch_Off           : 60mV          --
- VCC                    : 3299mV        --
- V_Offset               : 2995mV        --
- V_Current_Sense        : 1491mV        --
- I_Current_Sense        : 0mA           --

Cell Voltages
- Cell 0                 : 3854mV        --
- Cell 1                 : 3871mV        --
- Cell 2                 : 3871mV        --
- Cell 3                 : 3883mV        --
- Cell 4                 : 3883mV        --
- Cell 5                 : 3884mV        --
- Cell 6                 : 3884mV        --
- Cell 7                 : 3884mV        --
- Cell 8                 : 3898mV        --
- Cell 9                 : 3910mV        --

Settings
-Wheel Diameter (mm)x10  : 830
- Options                : 0009
- Auto Power Off Period  : 60000
- Power Down Timer       : 60000

Measurements
- V_Bus                  : 38806mV       --
- V_Aux                  : 6510mV        --
- V_Sys                  : 4268mV     * FAIL *  USB Power Interfering
- V_USB                  : 4747mV        --
- VCC                    : 3308mV        --

Battery Charger
- V_Charger_Input        : 120mV      * FAIL *
- V_Charger_Output       : 1628mV
- Temperature            : 20.8'C        --
- Connector Temperature  : 20.8'C        --
- Power Limit            : 168W
- Power Consumption      : 0W            --

Inertial_Module
- Module                 : Present       --
- Angular XYZ            : 102     -451    -281
- Linear XYZ             : 304     -1038   16729

LIN Bus
- Bus State              : Active        --
- Discovered Devices     : 2             --

Communications
- Wireless RF            : Present       --
- Packet Count Tx/Rx     : 256/288       --
- Paired Remote Serial   : DDDD019C
```

- Paired Status : Synced --

Motor Temperature Sensors
- Left Motor Temp : 19.6'C --
- Right Motor Temp : 18.7'C --

Metrics
- Trip Odo Left : 1000 m
- Trip Odo Right : 1010 m
- Trip Time : 3.9 mins
- Number of trips : 67
- Average Trip Distance : 2.5 km
- Total Ride Time : 1.6 hrs
- Odometer : 171.3 km

Trip Data	Dist_km	mins	Avg_kph	Max_kph	Max_Bat_LHS/RHS		Min_Bat_LHS/RHS	Temp	Max_Bat_LHS/RHS	Motor_Temp_High_mins	Features Used
Trip #0	0.40	1	18.2	23.7	8.5	3.0/3.0	-0.1 - 0.0/-0.0	22	22/20	0/0	0
Trip #1	0.56	2	11.5	18.5	11.5	4.7/4.8	-5.8 - 2.1/-2.1	22	27/26	0/0	0
Trip #2	0.40	2	10.2	22.5	12.5	5.8/5.8	-12.8 - 2.4/-2.4	32	25/24	0/0	0
Trip #3	1.12	3	17.7	27.0	12.0	6.2/7.3	-8.3 - 4.6/-4.6	21	66/28	0/0	1 Expert
Trip #4	2.40	13	10.5	25.7	14.5	8.1/8.2	-3.5 - 2.0/-2.0	255	-/-	0/0	1 Expert
Trip #5	5.84	25	13.5	28.5	19.0	10.8/11.1	-9.2 - 6.3/-5.5	26	-/-	0/0	1 Expert
Trip #6	0.24	2	5.2	16.5	4.0	2.2/2.1	-2.1 - 1.3/-2.6	25	-/-	0/0	1 Expert
Trip #7	0.16	1	6.7	13.0	8.5	4.5/4.3	-2.8 - 1.8/-1.9	26	32/24	0/0	1 Expert

Fault Report

Log #0	42	73	1	49153	60	38885	0	1122
Log #1	41	54	1	49153	66	39376	1	1114
Log #2	54	5	57618	9	451	18463	301	18500
Log #3	51	1	27176	18503	4	2987	2974	6507
Log #4	53	4	57618	7	361	20369	219	20400
Log #5	50	2	41898	44096	5	2982	2971	6511
Log #6	43	1	0	0	0	0	0	1090

7.3 INSPECTION

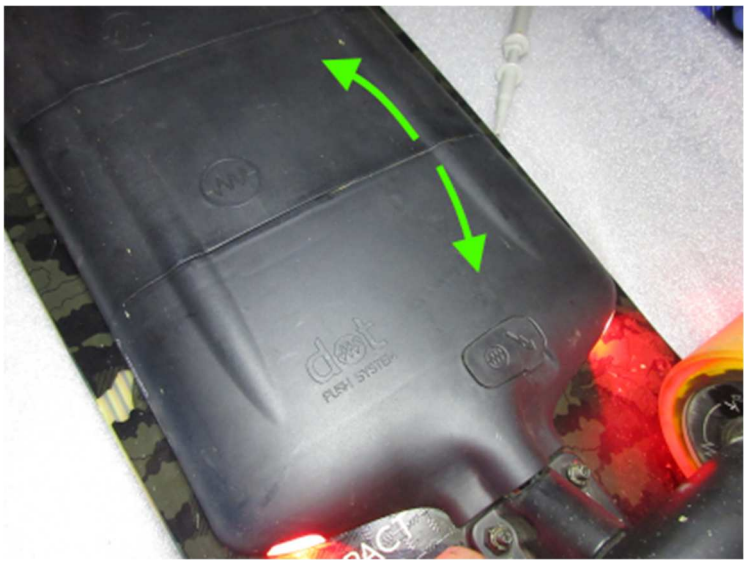
Both batteries functioning on delivery.

This board need a new charge port cover.

7.4 INVESTIGATION

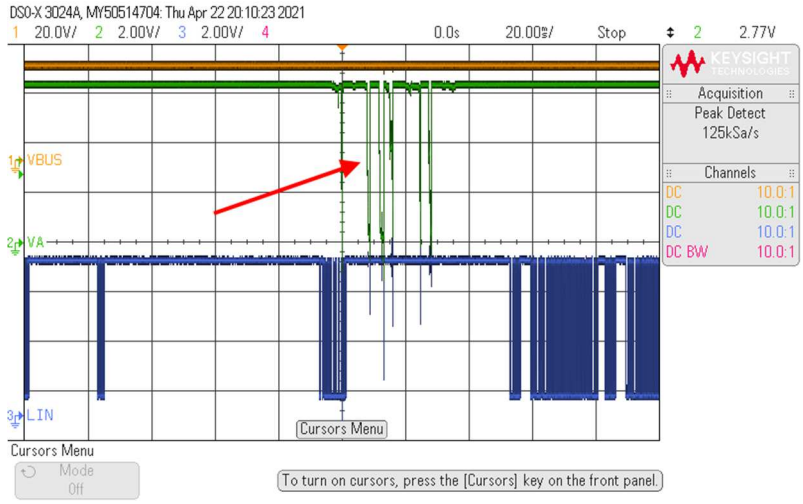
No LIN packet errors.

The board was highly sensitive to the first battery BBBB045A moving, specifically in the direction shown below.

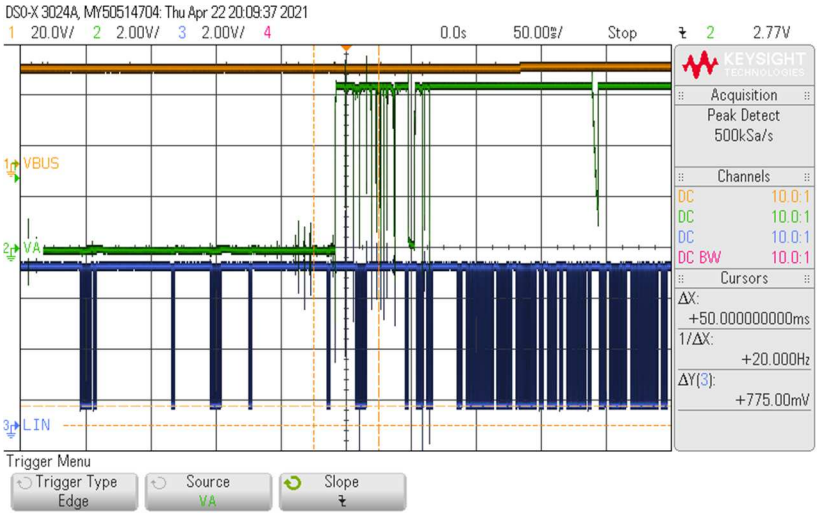


The board would lose power consistently when only a minor rotation was caused.

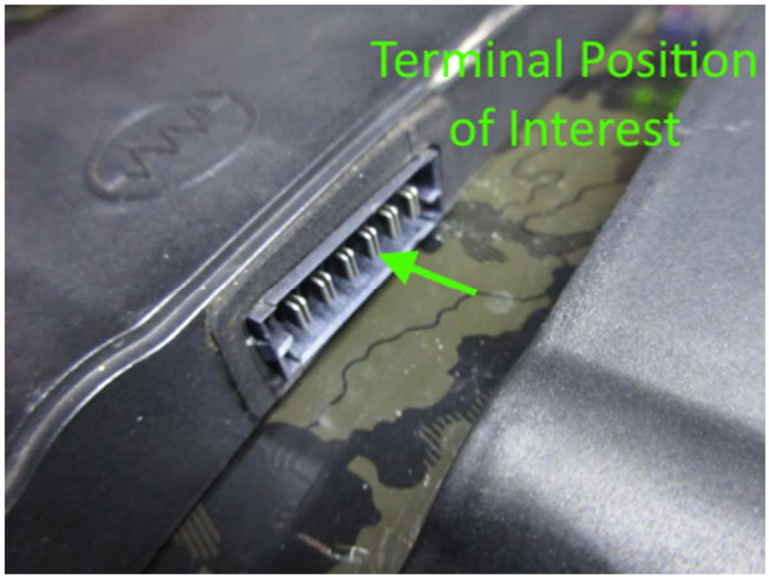
Examining the signals at the front most connector, it was quite evident the VAux signal was be disturbed. Slight movement would cause discontinuous power, however as shown below, the system tolerated this disturbance (LIN communications continued). The battery modules have a hold up time to accommodate this shown level of discontinuous power.



It was easy to cause far greater disturbances.

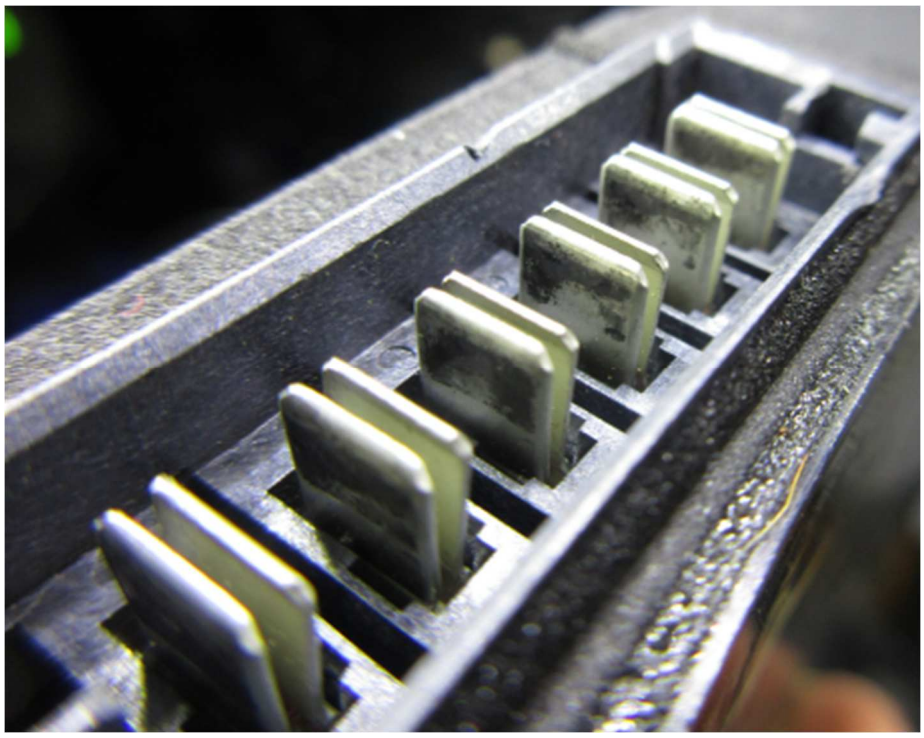


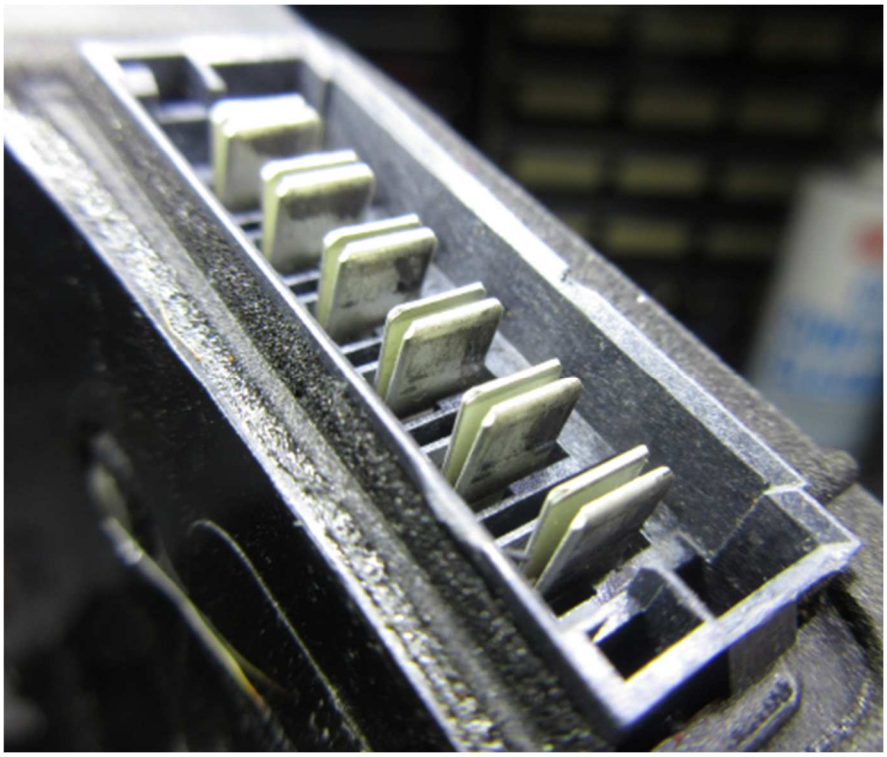
The failure at this location explains why both batteries were logging dropout faults.



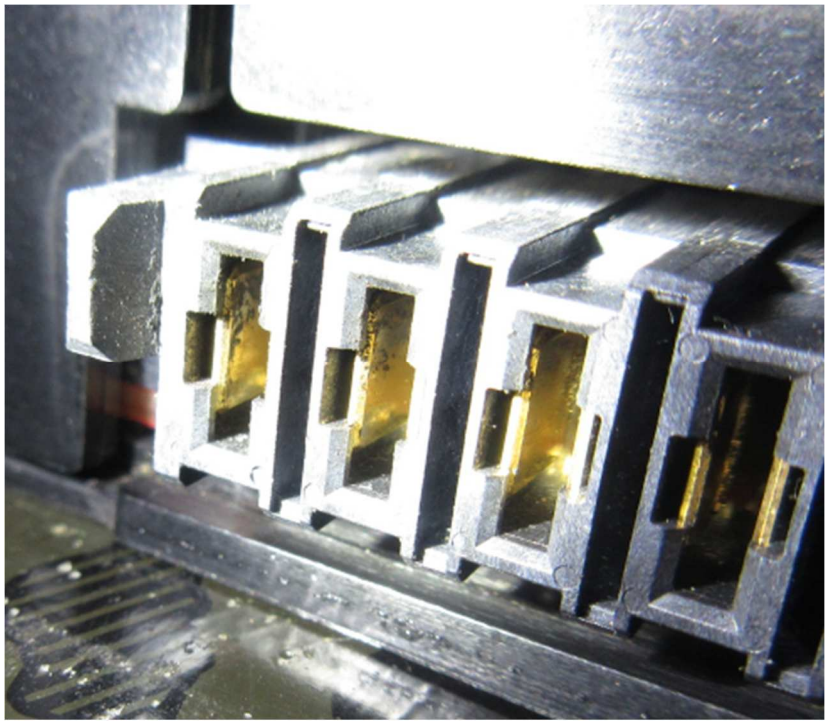
The fault only occurred with this battery. Swapping the batteries around did not generate the same fault, indicating the connector on the Main Controller was in better condition.

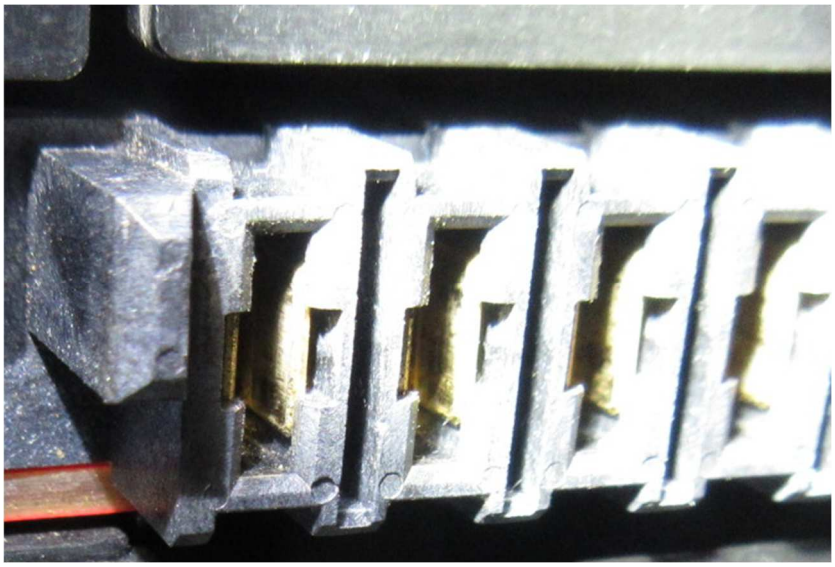
Quite noticeable terminal oxidization on the battery causing the dropouts.



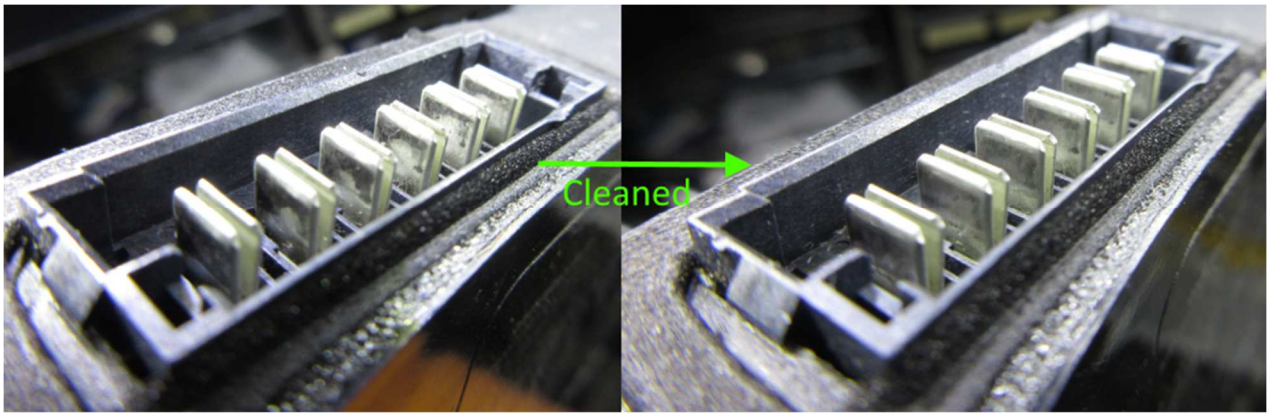


The associated terminal on the main controller was in better condition.





A process for effectively re-conditioning the terminals hasn't been established. The male terminals were sanded with 1200 wet/dry paper. Both male and female were cleaned with contact cleaner. Di-electric grease applied. This connector servicing is not considered full restored. Likely with a better process, the result could be better.

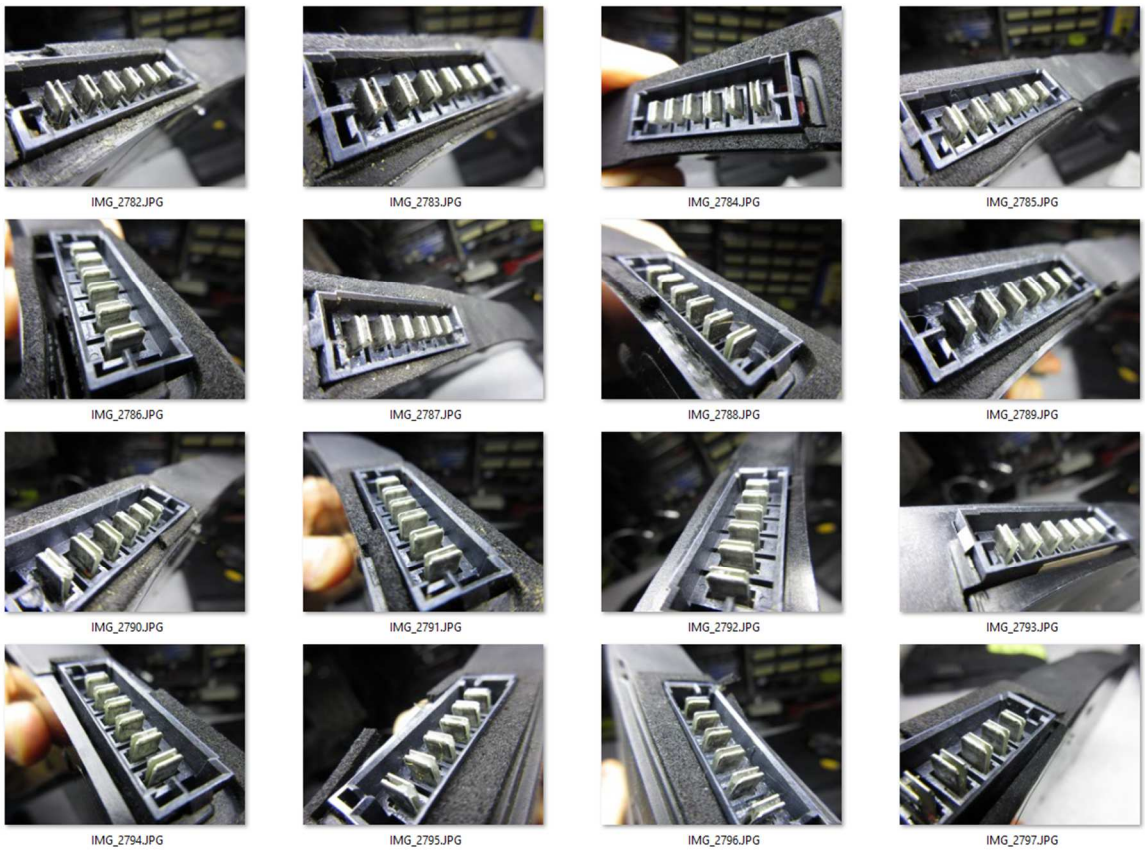


The board exhibited no sensitivity to module movement after connector servicing.

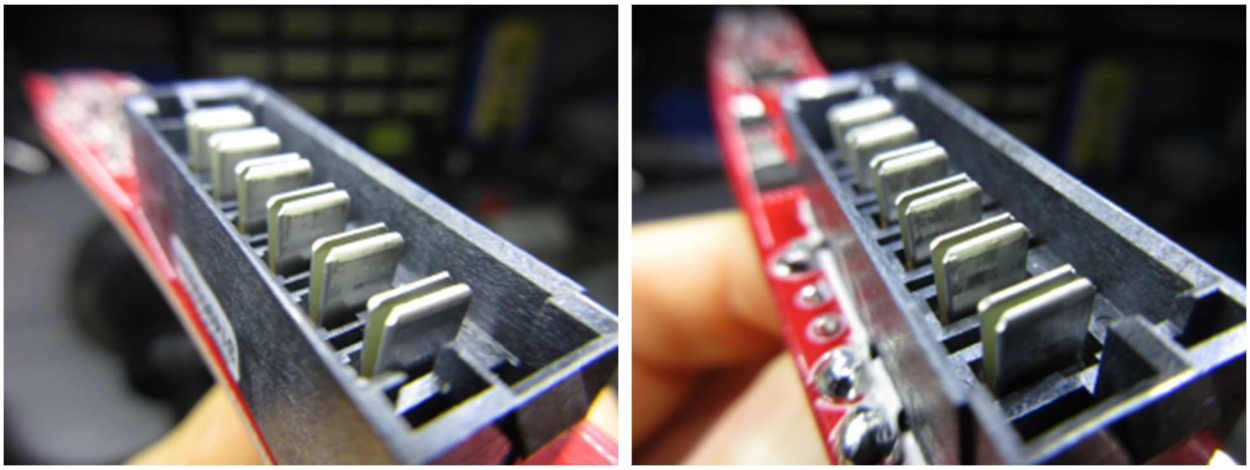
8 CONNECTOR INVESTIGATION

8.1 FIELD RETURN REVIEW

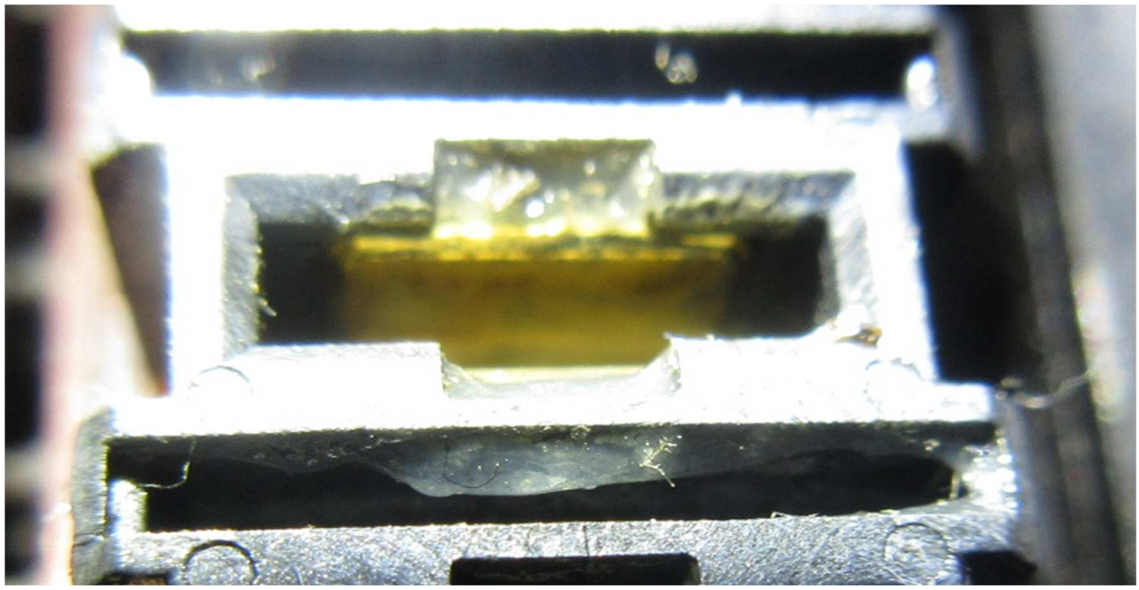
12 used field return battery modules were inspected for connector terminal damage. All had contact grease. It was quite evident that minimum damage to the plating had occurred. The wear marks observed were relatively consistent and evenly distributed. Only the male terminals shown. Females are difficult to photograph to show surface condition.



A brand new battery shows markings on the terminals. These will have been plugged/unplugged at least 4 times prior to this picture. Although marked, the plating looks good and there is no black oxidized residue.



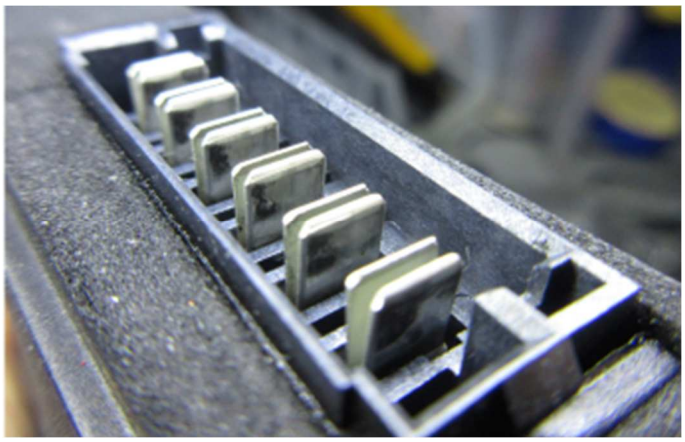
An MC that has gone through some mud was inspected. The connector terminals look in very good shape.



8.2 DI-ELECTRIC GREASE

To test the impact of the di-electric grease, the resistance of the LIN bus connection between two batteries was measured. This provides a suitable thin wire direct connection for accurate comparison.

The image below shows the male terminals for battery 3149595733, AFTER CLEANING. This board has done 61km.



The image below shows the female connector for battery 3149595724. The white cloth shows the oxidized contamination from cleaning this connector. It was a previously a clean cloth.

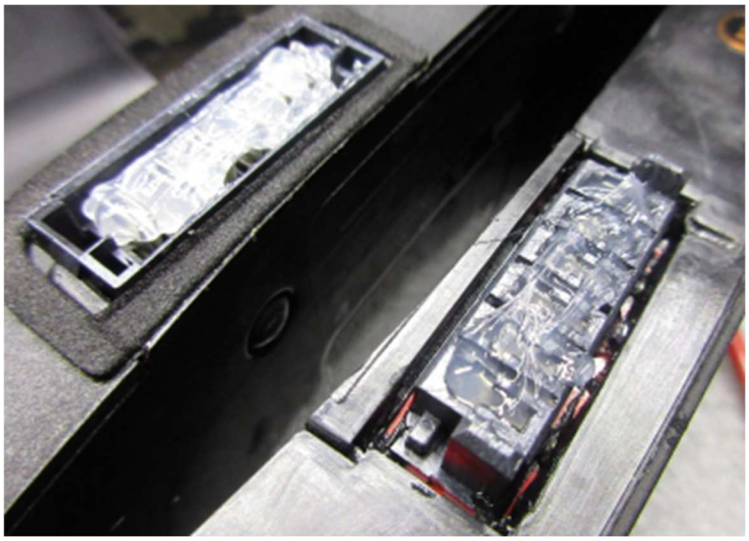
These two connectors were mated and the series connection through both batteries was measured.

Cleaned, this measurement was 26mohm. This is an expected result. The maximum contact resistance specification is 15mohm and this measurement includes a length of wire.

A minimal amount of CRC di-electric grease was added, as shown below. This is the same di-electric grease previously used in production.

The battery modules were re-plugged 10 times prior to measurement to ensure good distribution of the material. The measurement reduced from 26mohm to 23mohm.

A ridiculous amount of grease was then applied, as shown below.

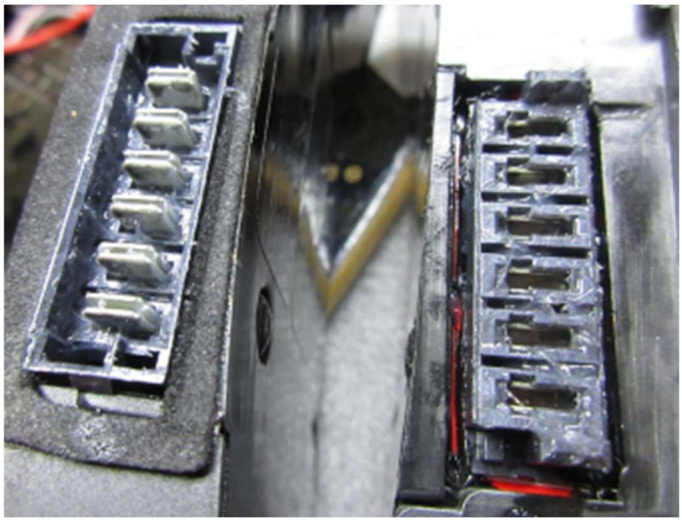


Re-plugged 10 times prior to measurement.

The measurement further reduced to 21mohm.

At least for the conductivity, the application of di-electric grease made an improvement.

The majority of the grease was pushed to coating the plastic shroud, where it is ineffective/wasteful.



8.3 CLEANING

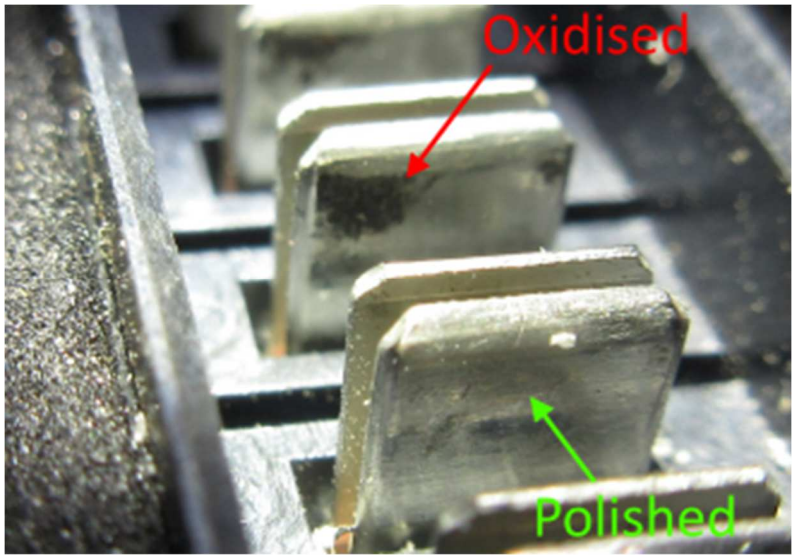
Isopropyl Alcohol pads and cotton buds was tested, as a cheap easy approach for the general user. This removes a lot of the contamination, however it did not remove the oxidized plagque.

CRC contact cleaner failed to remove the oxidization.

A padded emery nail file/polish was used. It was quick effective at polishing and removing the plaque, however very fiddly and time consuming.

A cotton bud in a cordless drill with metal polishing compound worked reasonably. However, it was not a good approach due to the residual cotton fluff distributed in the connector. Perhaps a Dremel or similar tool has an attachment better suited.

1200 wet/dry paper provided a reasonable approach to removing the oxidized plaque on the male terminals.



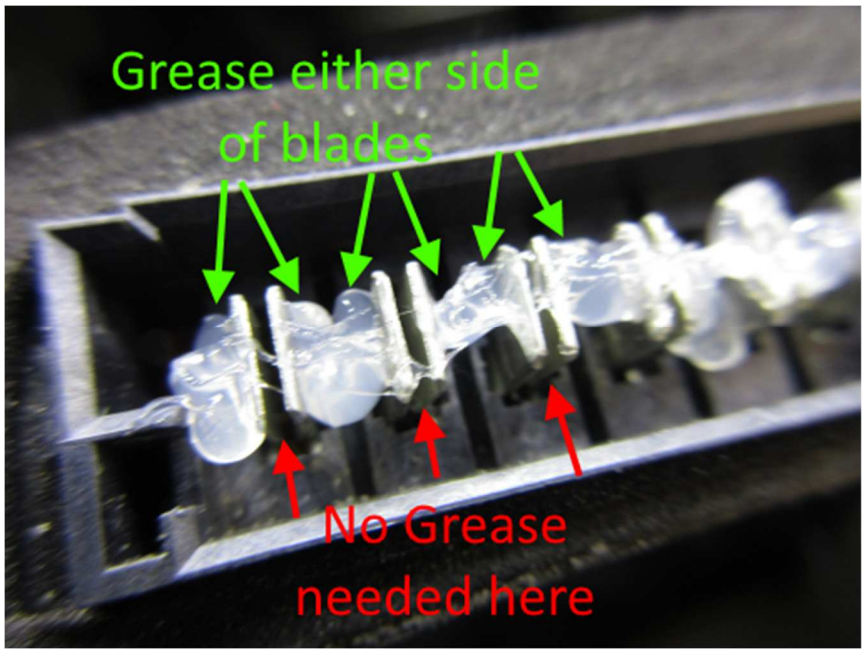
All these methods really only helped to address the male terminals. The female connector terminals are considerably more difficult to access.

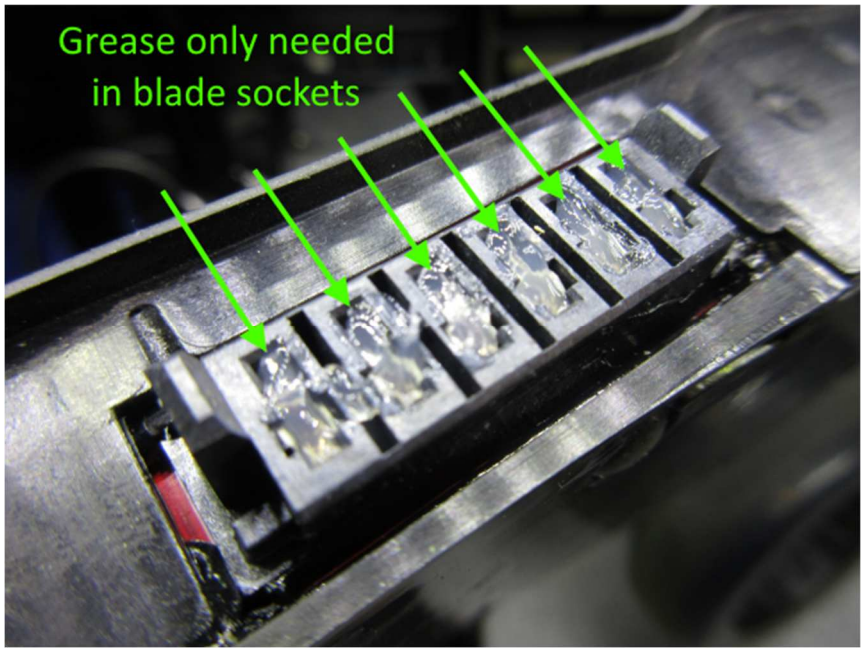
8.4 DI-ELECTRIC GREASE APPLICATION

Below images show an example of di-electric grease application.

Connectors with grease applied should be plugged into another module also with grease, to provide an initial spread. This will ensure a good coating and less chance for the grease to move before being loaded on a board.

Production test equipment should have periodic application of di-electric grease to minimize the number of dry mating cycles.





9 DISCUSSION

9.1 OCCURANCE

The dropout issue manifested for these 4 boards very quickly. It was detected in all 4 cases in dot-hub received logs. These all resulted in significant issues within the first 29.5km to 86.4km of use.

Board	Returned Odometer	Logged Dropouts
2863268203 / AAAA016B - Justin Sudmeyer	65.6km	53.8km
2863268288 / AAAA01C0 - Cody Bowen	98.9km	86.4km
2863268287 / AAAA01BF - James Lawidk	85.8km	85.8km
2863268288 / AAAA0166 - Leigh Wells	61.4km	29.5km
2863268258 / AAAA01A2 - KIARA KENNEDY	171.3km	169.2km

9.2 SOFTWARE

9.2.1 FRAME IDLE TIME

An very infrequent occurrence of battery non-response was detected. A command to a battery after a global broadcast was rarely ignored. Idle time after a global command increased from 2ms to 2.5ms. This rare occurrence is not associated with battery dropouts, as the occurrence is too infrequent and too insignificant.

9.2.2 MAIN CONTROLLER SOFTWARE

AAAA0166 had 2 out of 4 batteries dropout. AAAA01BF had 1 out of 2 batteries dropping out. Both boards did not have ALL batteries dropout. The main controller software was running and communicating to batteries at this time.

The battery non-response could occur if…

1. MC is not transmitting the correct address/data. Not proven, not suspected.
2. MC is no longer polling for the data from those batteries. Proven not to be the case.
3. The battery has lost is position index and is also not responding to discovery commands. Not proven, not suspected.

No LIN bus data corruption was detected. Communications was observed to run continuous for an extended period without recording a single received packet error.

9.2.3 LIN BUS COMMUNICATIONS

The LIN bus communications was tested for datarate timing tolerance. It accommodates more than +/-4% in the timing. The worse case battery was +0.9%. The system is operating well within the tolerance.

LIN bus timing is within specification.

The communications is normally operating for extended periods with zero non-response faults and zero packet response errors. The software and associated electronics is working very well.

9.2.4 BATTERY SOFTWARE

Battery firmware has been considered stable for quite some time. The current dropout issue seems to only be applicable to some boards.

If the battery software had locked up, a cause would need to be found to link this to only some batteries on some boards. Boards with dropout issues also often have multiple, but not all, batteries going offline. It is not consider realistic for a battery software fault to be the cause in these circumstances.

9.3 BOARD TYPE

There has been no history to suspect this is specific to Cruiser, Compact or Transporter designs. The only difference of relevance is the board flex/twist. The testing done during this investigation found no dropouts, LIN packet non-responses or LIN errors caused by excessive articulation of the battery packs.

Board flex/twist is not a cause of dropouts. It may actually provide a beneficial movement to help engage terminal surface contact.

9.4 BATTERY CONNECTION

9.4.1 MODULE BOLTED POSITION

Deck bolt holes and module positions have good alignment and relative pitch. There was also no noticeable difference with how the bolts where tightened, either one at a time or with sequential half turns.

9.4.2 UNEVEN CONTACT WEAR

Terminals inspected were all straight and with the same relative gap between opposing blades.

Uneven contact wear observed. Both triangular pattern as well as more wear on one blade than another. The enclosures and connector shroud do an excellent job of providing good alignment. It may be slight accummulated variations in production that results is less optimal terminal positioning.

9.4.3 SERIES CONNECTION

AAAA0166 was observed with the last 2 batteries out of 4 batteries dropping out. AAAA01BF had the last battery out of 2 dropping out, as well as both dropping out. Common to both, was the batteries exhibiting non-response were at the front most positions. There were no examples where the a non-responding battery was between an MC and another functioning battery.

Given AAAA01BF had logged faults associated with a significant drop in VAux, it is probably this was due to poor connection of the VAux terminals at some point. This was observed during testing, where VAux at the front connector was below 3V.

9.4.4 LIN BUS DOMINANT STATE LEVEL

The common level for the dominate state has been 0.8V. There was one example where the dominant state for the MC was temporarily 1.1V. This is not expected. As this differed from the BM level and with no significant battery load, it indicates the impedance on the LIN data line to the MC was quite high… estimating 48ohms. An example of 4 batteries in series measures <0.09ohm.

During battery load (motor current draw), VAux and the dominate level had been observed to fluctuate. This is likely ground offset under load. As it is common mode offset and zero LIN packet errors occurred, it is not considered an issue. In-particular, the prior battery non-response period were observed while no motor function was occuring.

9.4.5 DI-ELECTRIC GREASE

One board had di-electric grease on 1 battery module. All another module did not have di-electric grease applied. Absence of di-electric grease has caused accelerated and permanent damage to the terminal plating.

9.5 BOLT DEPTH

No evidence was found that bolts over tightened had caused damage or related to dropouts. AAAA0166 was the most excessive example of over torquing the bolts seen. Certainly an extreme, unlike the other 3 boards examined. This gives the most confidence that bolt torque is not associated with dropouts.

From previous history, the wrong bolt length on the wrong deck will cause failures. These are unique and have a different signature for log file diagnosis.

9.6 WIRELESS

The brief period of battery non-responses was detected and observed on the LIN bus traffic. This has no relevance to the wireless connection. In addition, the log files would not show battery dropouts and under voltage faults for an intermittent wireless connection. If wireless dropouts were a cause, it would be a completely separate cause for a dropout, however there is no suspicion to warrant effort to re-validate.

9.7 MOTOR FAULTS

Battery disconnects can cause VESC faults. The sudden loss of power can result in a VESC faulting, due to under voltage.

Motors and associated wiring have previously been diagnosed as the cause for dropouts. Particulary due to short circuits and intermittent connections/shorts. These present differently, along with different fault log data. Two of the boards examined were faulting for a short period of time, without the motors in operation.

While motors and hanger can cause dropouts, they are not believed to be the cause associated with this investigation.

10 RECOMMENDATIONS

1. Production should re-commence with the use of the CRC di-electric grease. There is currently no expected need to change the grease used. It is also recommend to continue using the same grease (or at least one with the same base material) to avoid cross contamination from causing a chemical reaction and failure of mixed grease. An alternative should only be considered if the current grease is found unsuitable and an alternative was proven to be superior.
2. Generate a user/dealer targeted connector cleaning/lubrication guide and/or video.
3. Source di-electric grease in a small tube to include with board sales, as well as to distribute to existing customers that currently do not have modules with grease applied. Consider if a maintenance kit is practical.
4. Preventing connector contamination is important. Dirt and other particles will also result in the same dropout issues. An alternative to foam gaskets would be to use the same approach as the front protective connector cap. Develop a double sided adhesive rubber boot to go between battery modules, which allows the flex but prevent ingress or dirt/water.
5. Consider if a software detection system for connector failure is feasible, with realistic remote warning for the user.

<end of report>