MY2018 Tesla Model 3

Battery Management System (BMS) Analysis

June 2018

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MY2018 Tesla Model 3

Battery Management System (BMS) Summary

- Distributed battery management system is split into (1) master board and (4) module sense boards
- Main master control runs with two micros a Texas Instruments TMS570LS0432 processor and a Freescale SPC5746CSMKU6
- Each cell sense board uses two custom ASICs for cell voltage monitoring, probably made by Linear Technology
- Cell sense boards are in daisy chain connection and are connected to the battery cells through polyimide flexible printed circuit strips.
- Passive cell balancing is performed using 37.4Ω balance resistors

Architecture Advantages

- Simple cell voltage and temperature monitoring.
- High voltage measurement (pre/post contactors) increases safety and reliability
- Flexible polyimide strip eliminates the complexity of routing copper wires – The connection process can be fully automated to reduce assembly time
- Simple wire connections between individual cell sense board and to the master controller (BMS)

Architecture Disadvantages

- Distributed system is complex and increase costs
- All four cell sense boards are unique and therefore reduce the benefits of scale economy from manufacturing
- Flexible polyimide strip increases material cost and add more wire bounding – each wire should be inspected for defect – However, because of the existing bounding technique used by Tesla, the cost savings in automation may outweigh the material cost

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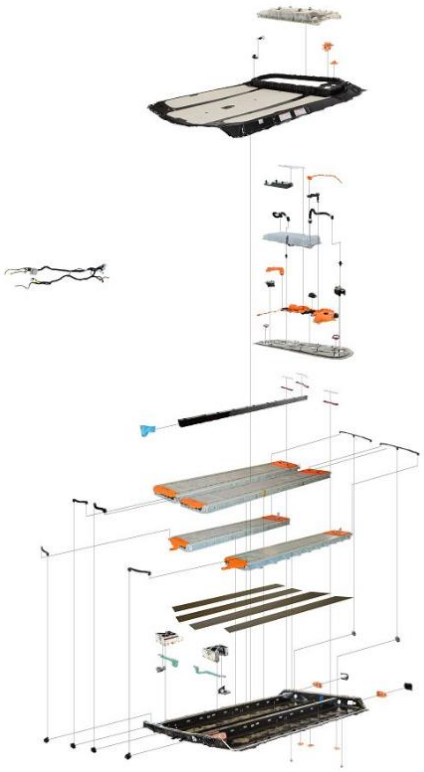
Battery Specification

- Cell manufacturer: Panasonic
- Battery Energy: ~75kWh
- Battery cells (total in pack): 4416
- Battery pack configuration: 96S46P
- Number of battery module: 4 blocks (2x Long Blocks (25S46P) and 2x Short Blocks (23S46P)
- Nominal battery voltage (total): ~355V
- Nominal cell voltage: ~3.7V
- Coolant: Liquid cooled

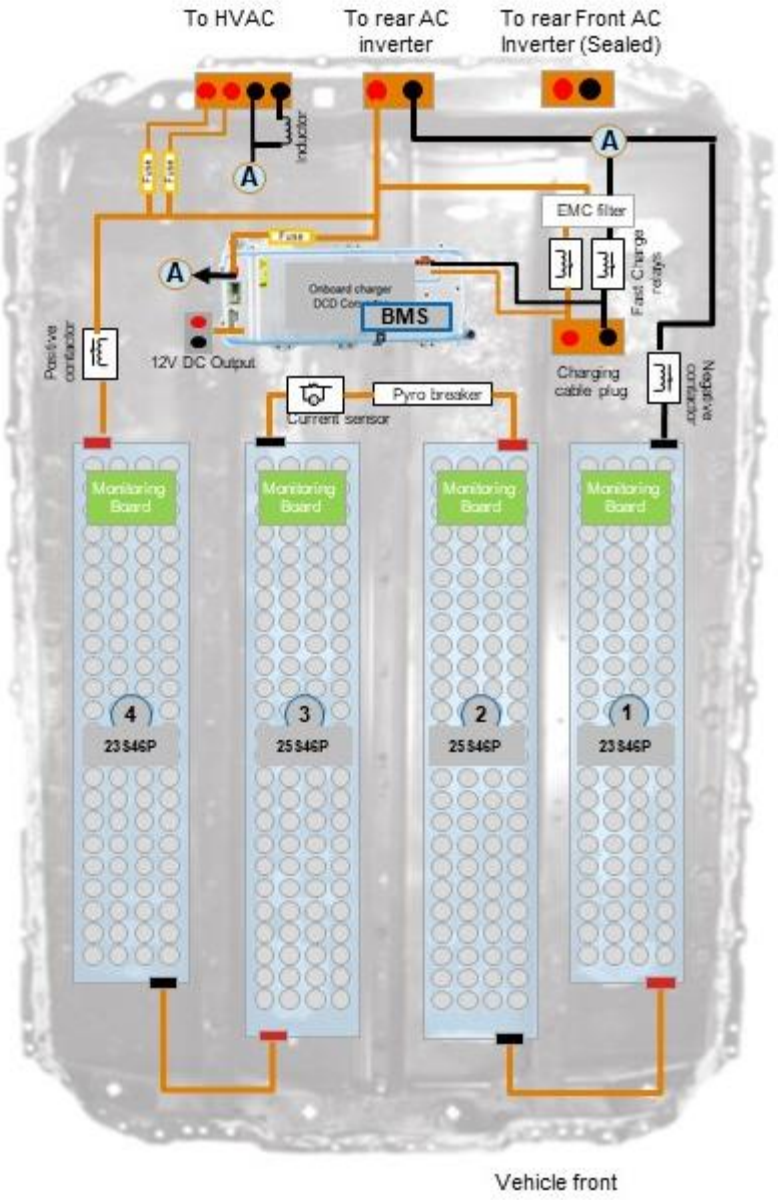
Battery Pack (Exploded view)



Battery Module

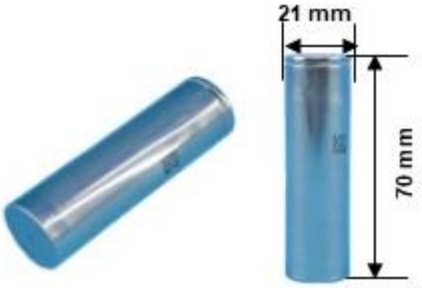
MY2018 Tesla Model 3

High Voltage Battery Electrical Schematic



High level specification

- 21700 cylindrical cells
- Est. 75kWh battery pack
- 4 Modules Blocks
  - 2x Long Blocks (25S46P)
  - -2x Short Blocks (23S46P)
- 96S46P pack configuration
- 4416 total cells
- Liquid cooled

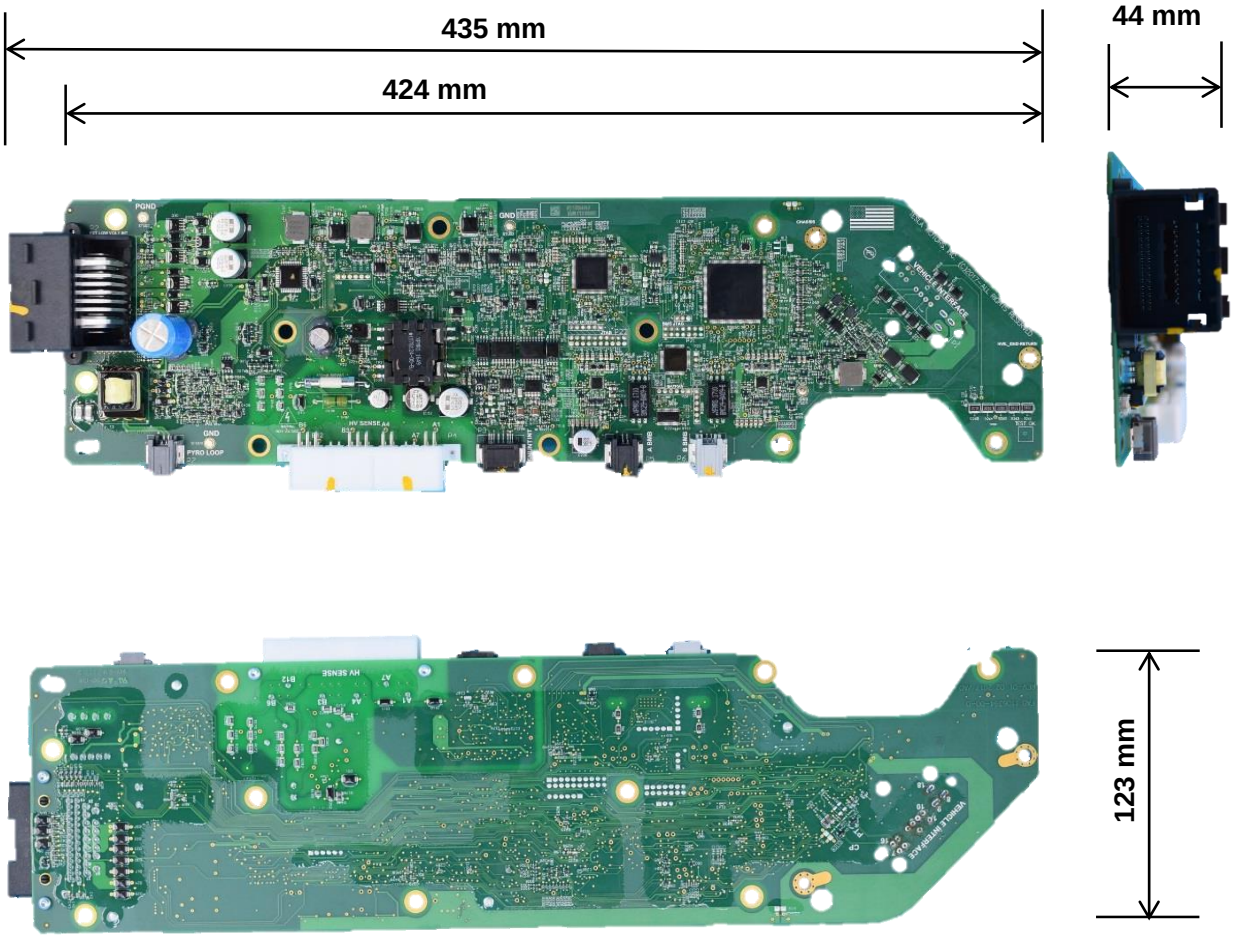


- Long Block Module voltage as tested: 86.2V
- Short Block Module voltage as tested: 79.2V

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION

- PCB dimension is 424 x 123 mm
- 4 layer PCB with conformal coating
- Total height of the board is 46mm (with the connectors)
- Board has components on both sides
- Board has milled edges
- On the board are electrolytic capacitors for switching power supplies



BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Connectors

Connectors:

- 7 connectors:
  - Vehicle Interface (black vertical, 13 pin)
  - External low voltage interface (black, 44 pin)
  - HV sense (white, 24 pin, 6 used)
  - Current Shunt interface (black, 8 pin)
  - Battery Management Board interface low (black, 2 pin)
  - Battery Management Board interface high (grey, 2 pin)
  - Pyro fuse loop (grey, 2 pin)

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Connections

Vehicle Interface

Cell Sense Control Board Interface High

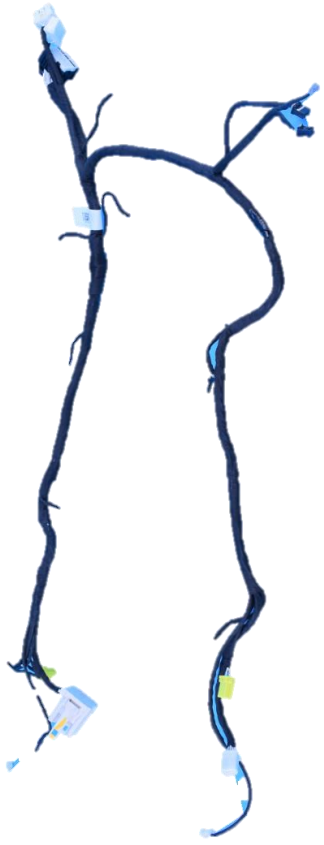
Cell Sense Control Board Interface Low

Current Sensor/ Shunt Interface

HV Sense and Contactor Drivers

Pyro Fuse

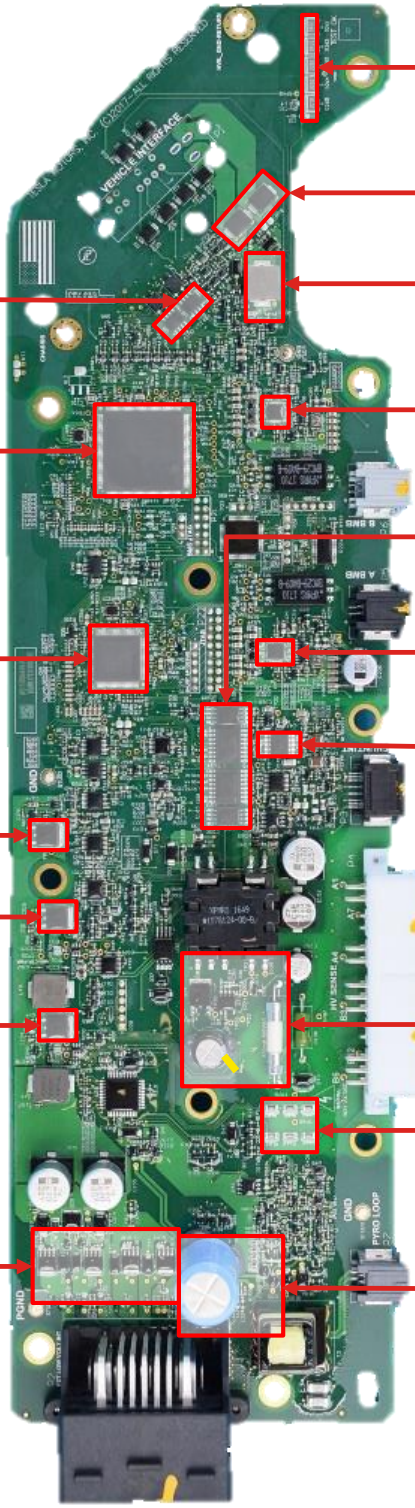
External Low Voltage Interface



BMS Wiring Harness 1694-36

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components Top (1/2)



HVIL Drive

12V Reverse Protection

2x TJA1042
CAN TXVR

12V Line Choke

MAX16993 5V/1.25V/3.3V
Buck (SPC5746)

SPC5746CSMK MCU

HV Isolation

TMS570LS0432 MCU

MAX16993 5V/1.2V/3.3V
Buck (TMS570)

AS8510 ADC
(Current Sense)

Contactor Power PFETs
(IPD50P04P4L-11)

UCC28730-Q1, 800mA
Input Fuse and
Isolation Transformer
For HV DC/DC

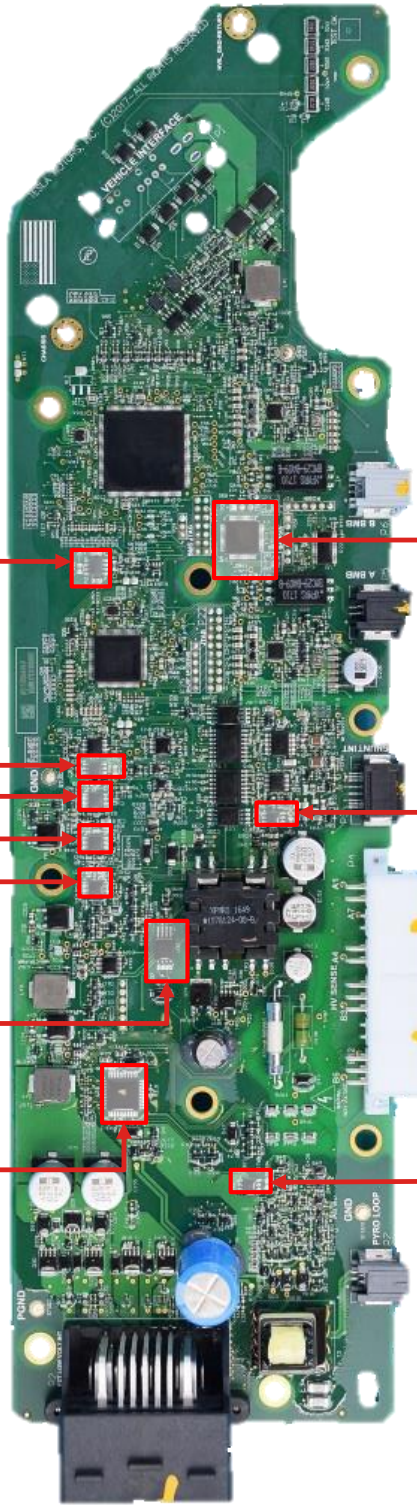
2 HV Analog Input
Channels (3x 3.4MΩ)

Contactor Driver
Switch NFETs
3x BUK9Y107-80E
2x BUK9Y25-60E

Thermistor Input
RC Filter

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components Top (2/2)



REF5030A-Q1
3V Reference

3x TLV2434A
Quad Op Amp

ACPL-K30T PV HV
FET Driver for
Insulation Monitor

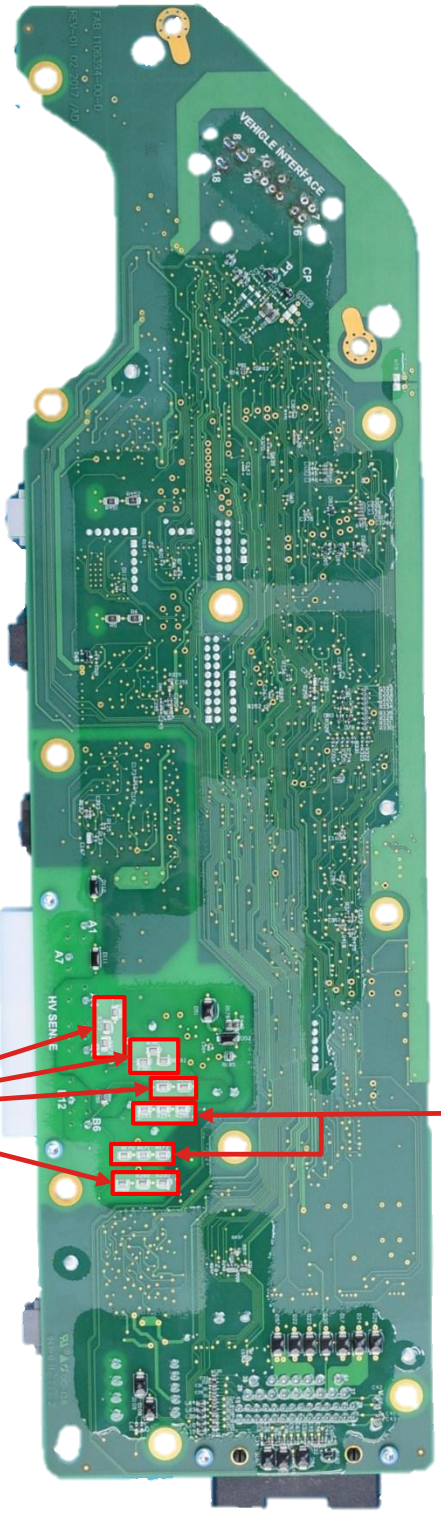
Bosch 48021
Pyro Driver

Communication Bridge
ASICS

TPS7A6950 LDO

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components Bottom



4 HV Analog Input Channels (3x 3.4MΩ)

2 Analog Input Channels (3x 2MΩ) Insulation Monitor

BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components

MCUs:

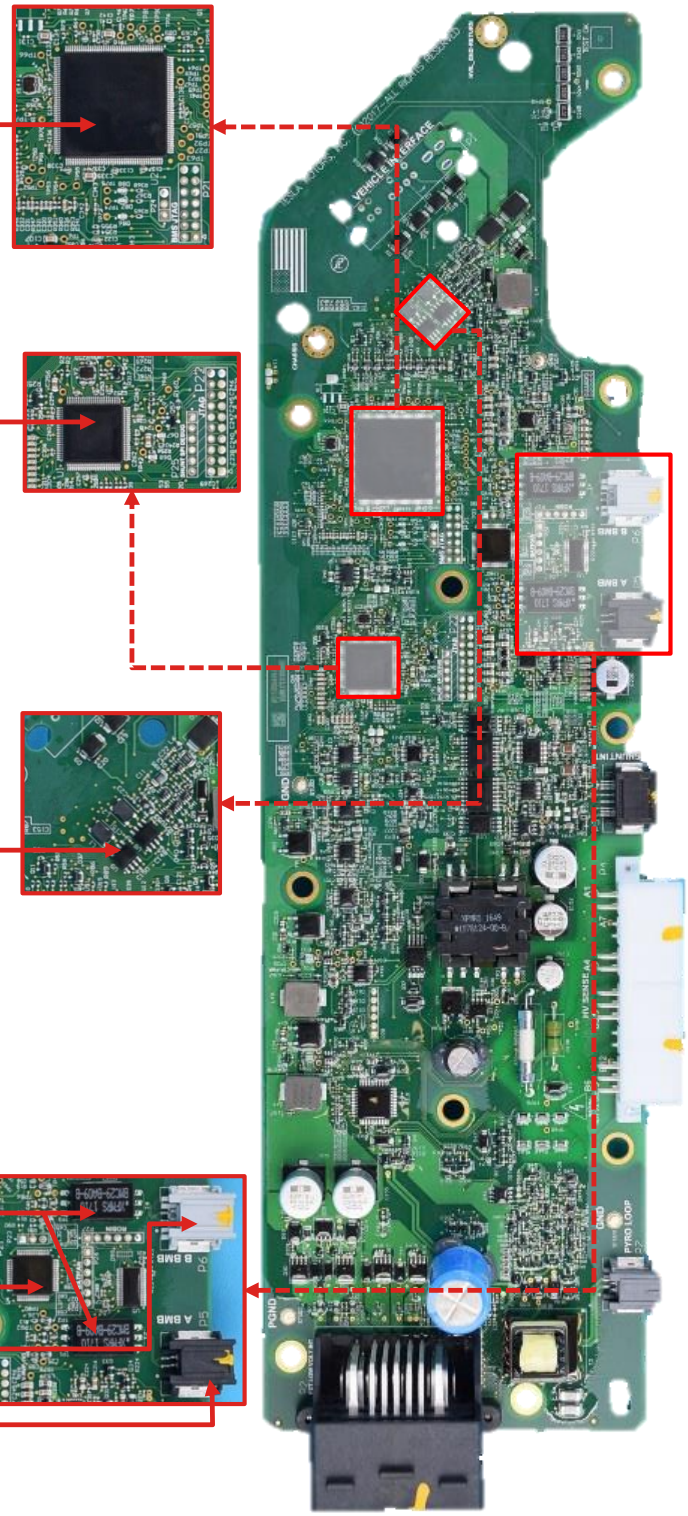
- Freescale SPC5746CSMKU6
  - LQFP176
  - 20MHz crystal
  - Custom build chip (SPC)
- TI TMS570LS0432
  - LQFP100
  - 20MHz crystal

CAN Interface:

- Two CAN transceivers (TJA1042)
  - One is terminated

Interface with Cell Sense Control Board:

- Master and cell sense control board interfaces
  - XFMRS isolation transformer (custom)
  - Custom Communication ASIC
  - Interface to high side of daisy chain
  - Interface to low side of daisy chain

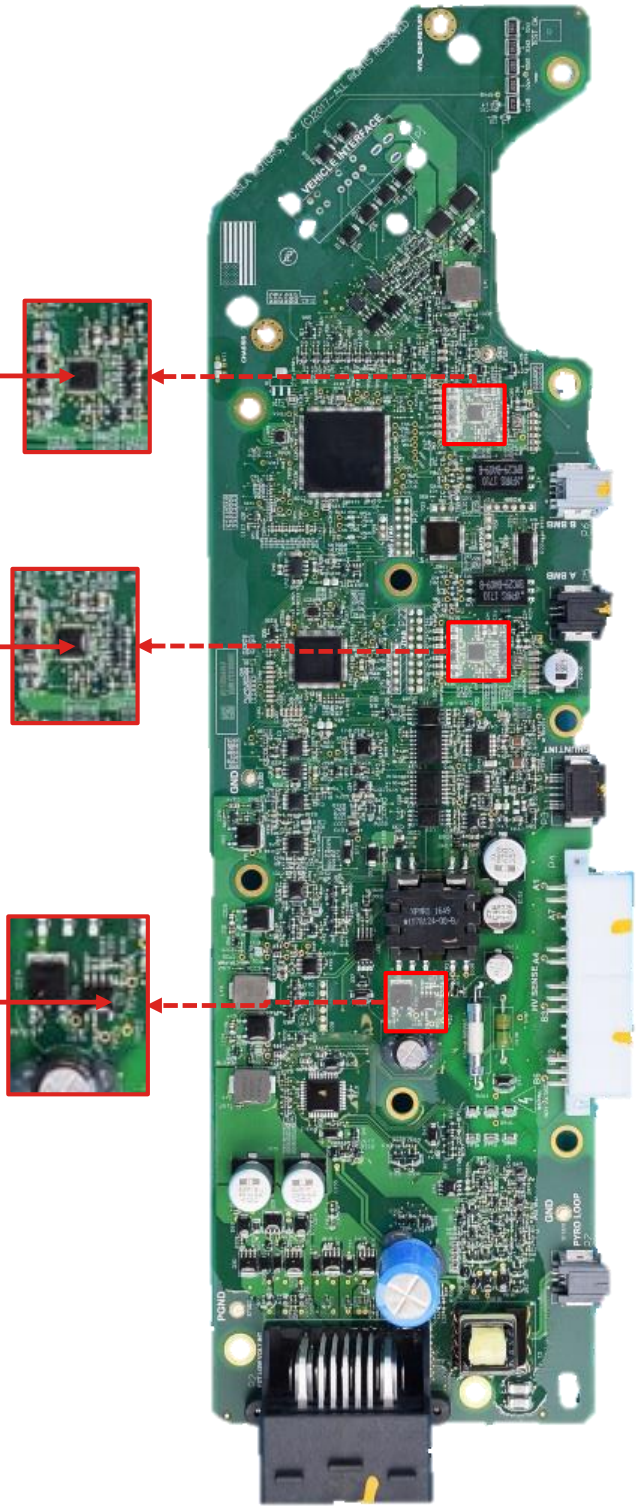


BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components

Power Supplies:

- Step-down MAX16993
  - 2.1MHz
  - 5V to 1.24V, 1.5A
  - 5V to 3.3V, 1.5A
  - Non-ASIL
- UCC28730-Q1 Isolated Supply from HV battery

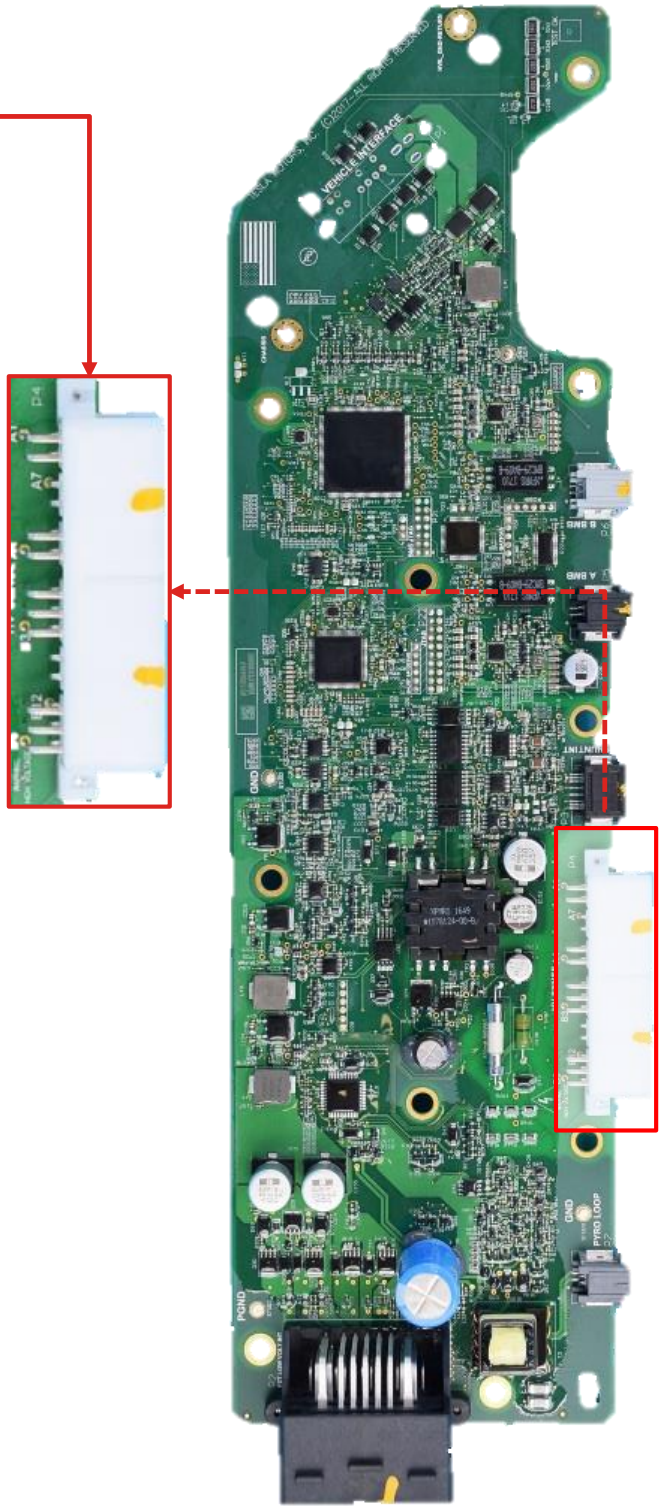


BMS MASTER CONTROL BOARD

MASTER PCB DESCRIPTION - Major Components

HV Measurements:

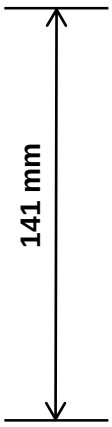
- Has non-isolated external HV analog measurement (6 channels)
  - 3x 3.4MΩ input divider
  - Assume 6 channels to measure both sides of each of the main and DC charge contactors
  - Connector is used to detect contactors close or open by measuring the voltage on both side of the contactors
  - Connector not assume to be high voltage rated – only 6 pins of 24 used for clearance



BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION – Module 1

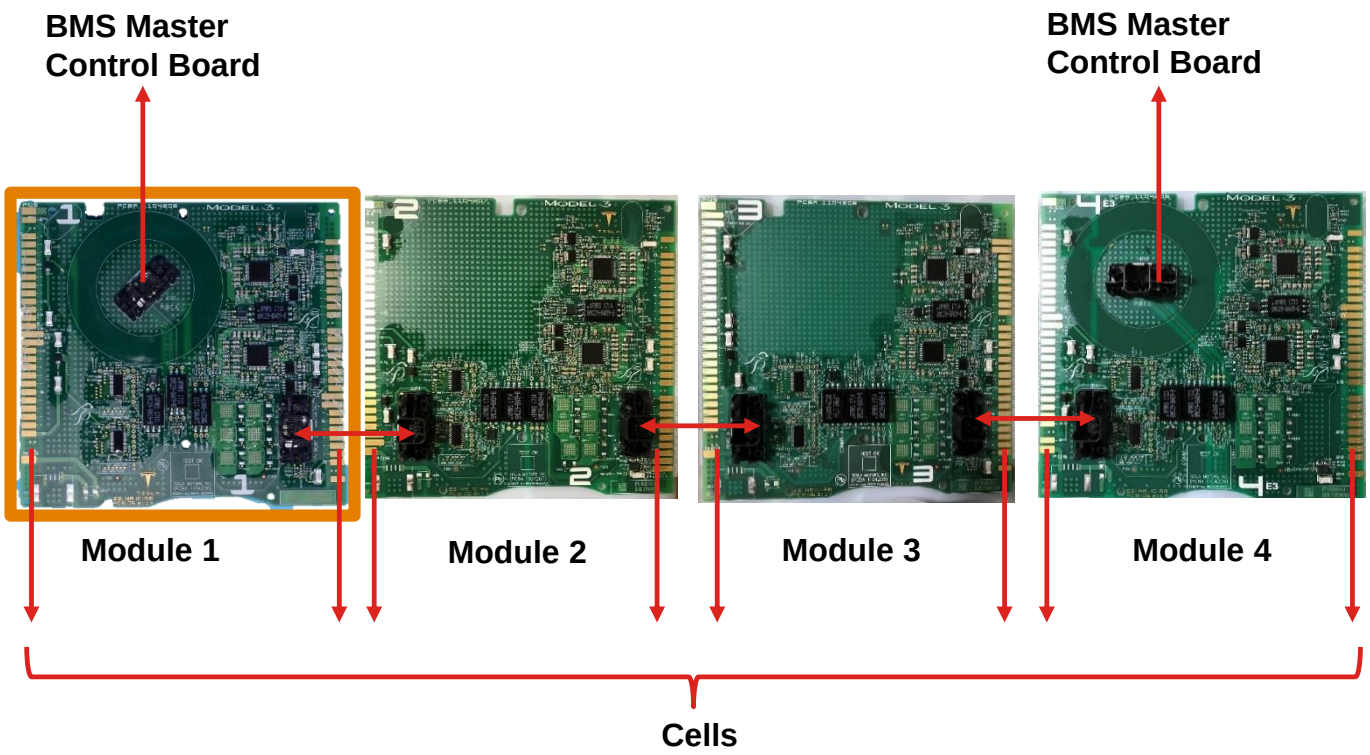
- PCB dimension is 141 x 149mm
- 4 layer PCB with conformal coating
- Total height of the board is 16mm (with the connectors)
- Board has components on both sides
- 4 boards per pack
- On the board are electrolytic capacitors for switching power supplies
- Board depicted below is used to monitor battery module 1 and can sense 23 series cells



BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Connections

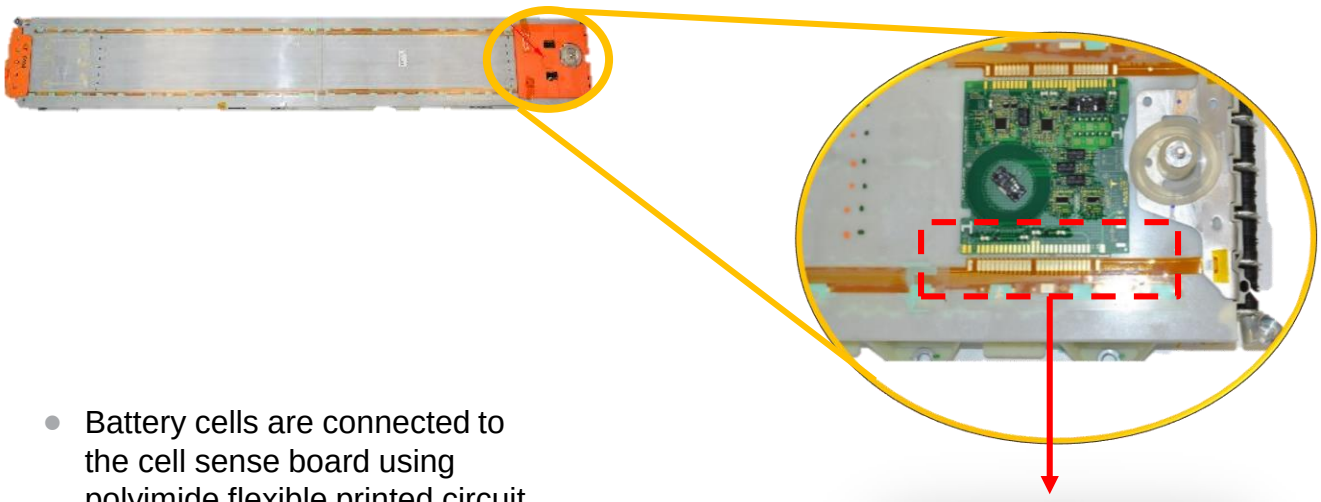
- There are 4 cell sense boards per battery pack
  - All connected in daisy chain
- Each board has unique layout but similar ASICs
  - Only #1 & #4 connect to master control board
  - #2 & #3 are in the middle of the communication daisy-chain
- Cells connect with bonded wires to 27 edge tabs
  - Cell monitor and protector, each have their own cell connections
- Keep-out area for plug seal interface



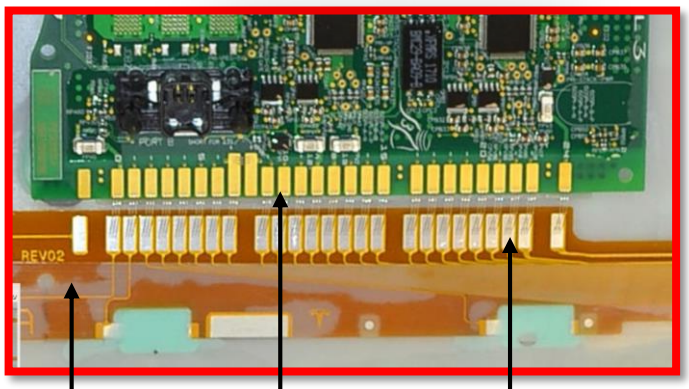
BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB Position – Module 1

- Cell sense board is mounted at the top end of the battery module



- Battery cells are connected to the cell sense board using polyimide flexible printed circuit strips.
- Two strips per pack. In case of the short block with 23 cells series, 24 connections to the cells are routed on each each strip.
- Strips are used to lead individual cell voltage sense line from the top or bottom tab of the battery cell to the cell sense board location
- 3x welded lines per tab connect the strip tabs to the cell measurement tabs for voltage monitoring



Cell sense board measurement tabs

Flexible polyimide printed circuit strip

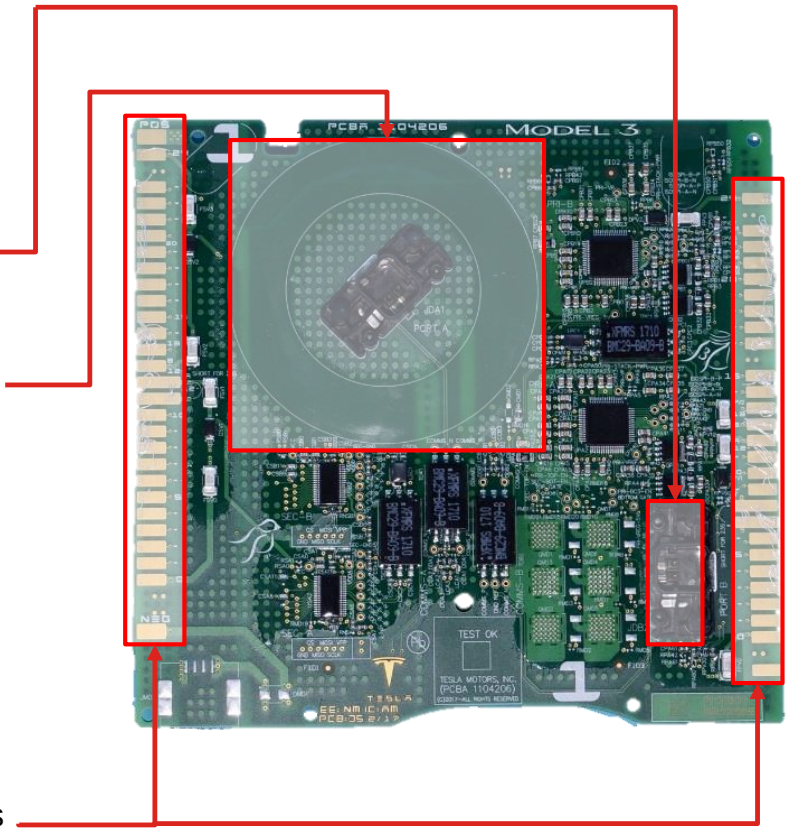
Flexible strip measurement tabs

BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Connectors

Connectors:

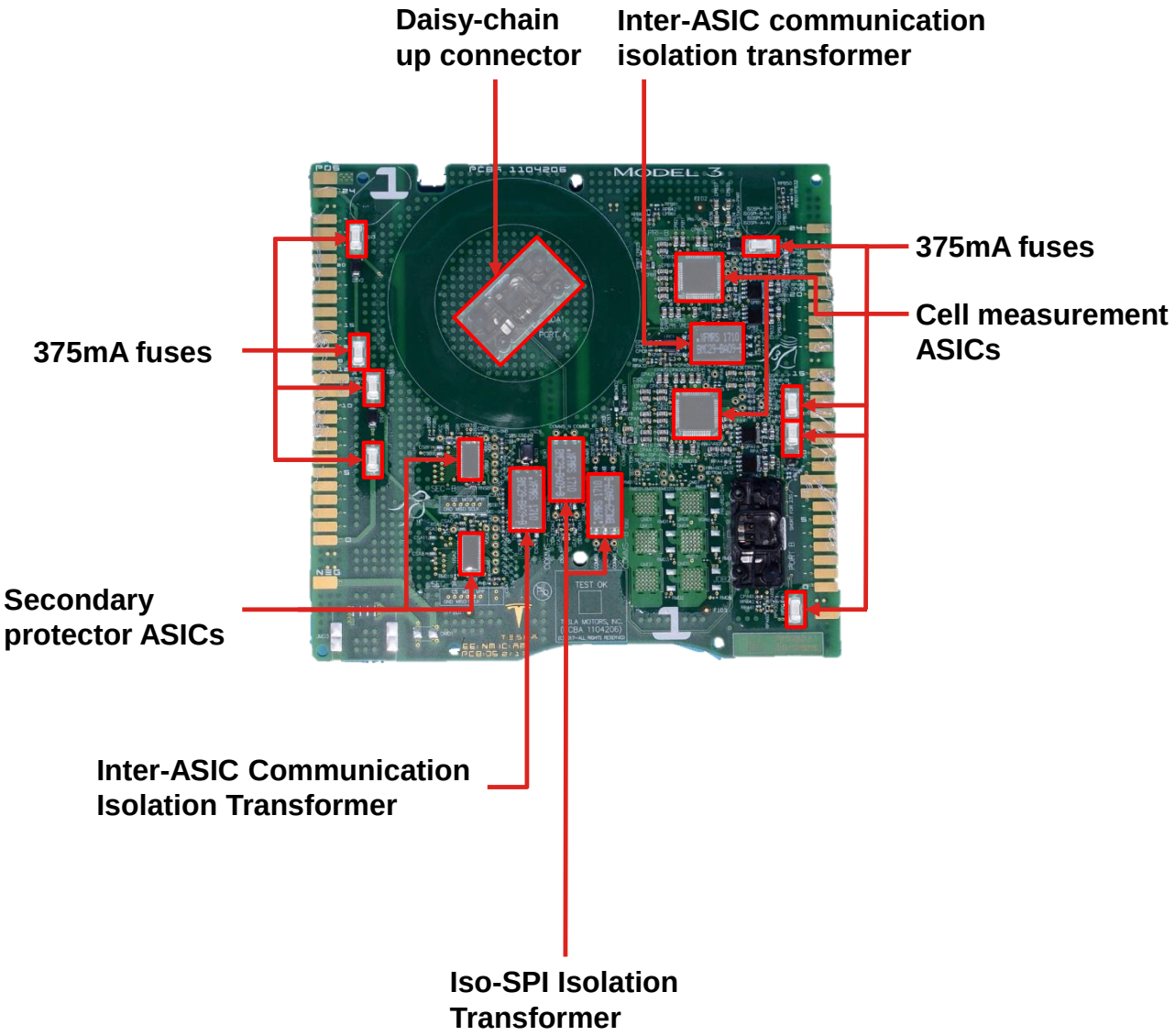
- Each cell sense board has 2 connectors;
  - Daisy-chain down interface (black vertical, 2 pin)
  - Daisy-chain up interface (black vertical, 2 pin)



- Each cell sense board has 2 edges with cell connection tabs
  - 27 tabs on each edge
  - 24 tabs are used for individual cell voltage monitoring

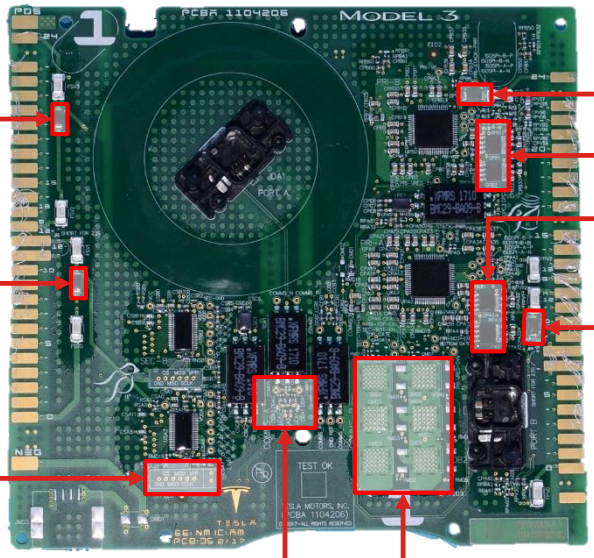
BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Major Components Top (1/2)



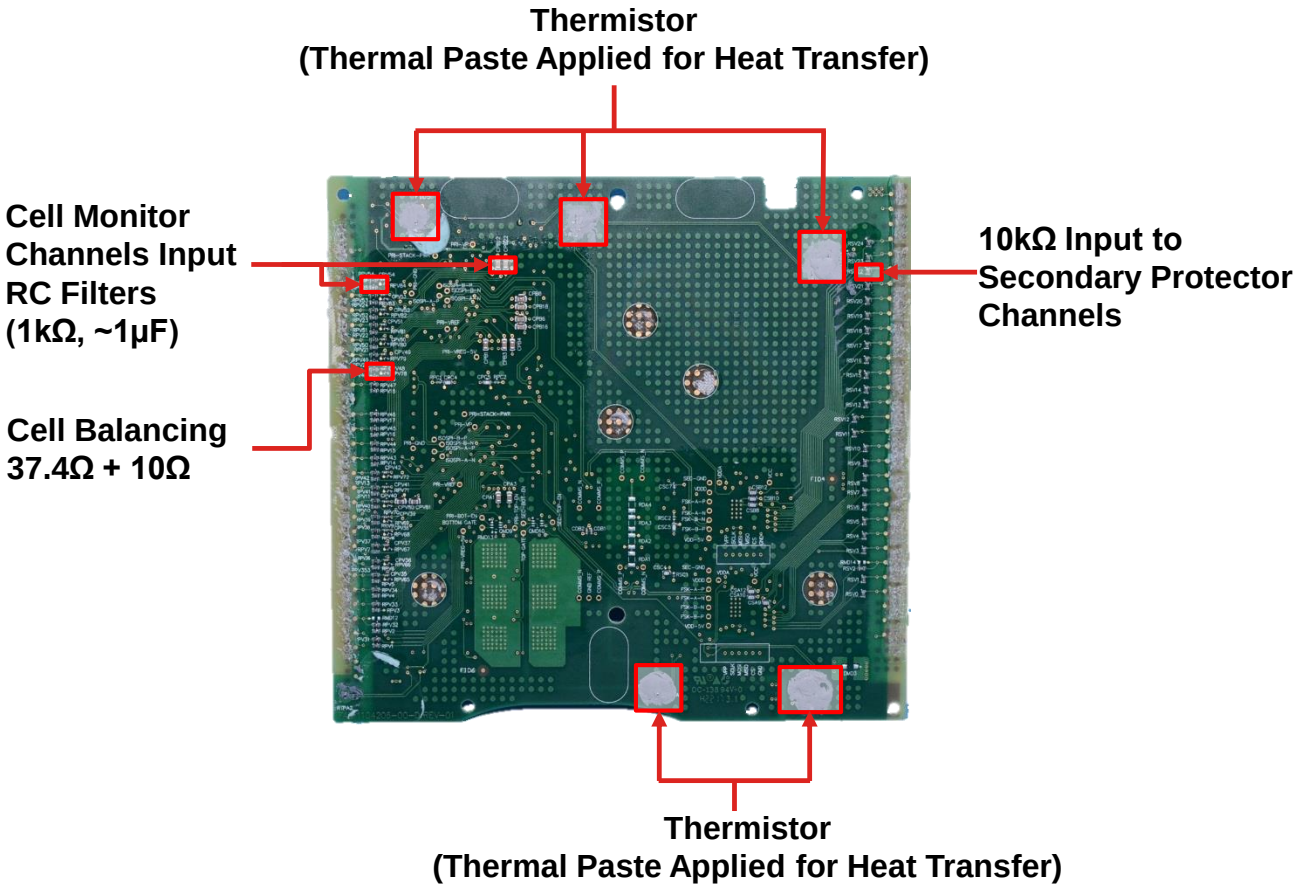
BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Major Components Top (2/2)



BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Major Components Bottom

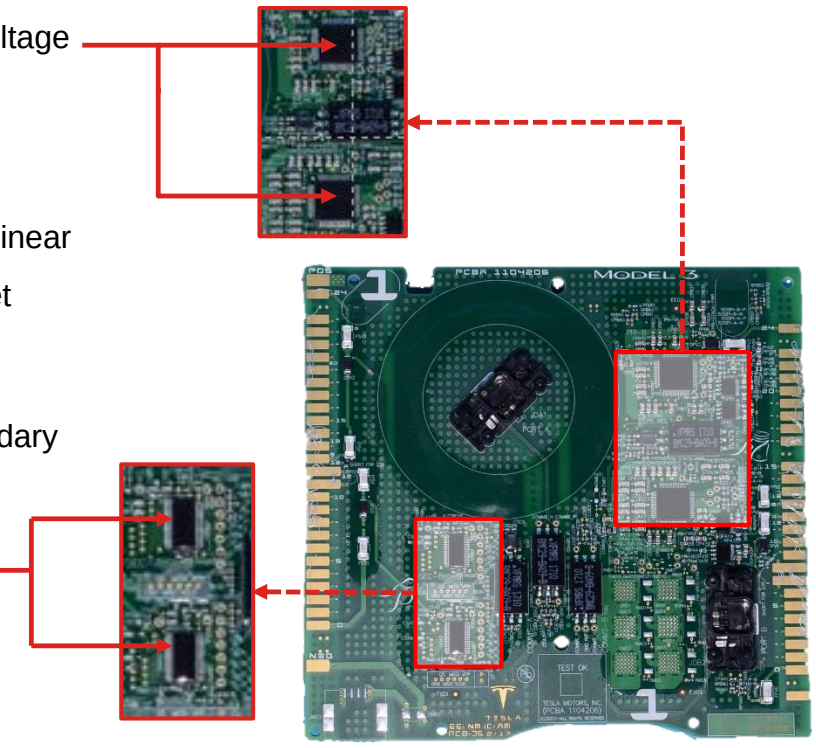


BMS CELL SENSE CONTROL BOARD

CELL SENSE PCB DESCRIPTION - Major Components

Cell Voltage Monitoring:

- Custom T2 ASIC used for cell voltage monitoring
  - LQFP64
  - Custom built chip (Assume Linear Technology due to isoSPI net labels)
- Custom T1 ASIC used for secondary protection
  - TSSOP38
- Cell monitor daisy-chain
  - isoSPI
  - Custom communication isolation transformer (XFMRS 1730 BMC29-BA09-B)



Cell Balancing:

- Passive cell balancing circuits
  - 37.4Ω balance resistors

BOM - BMS MASTER CONTROL BOARD

Bill of Material - BMS PCB

PART	DESCRIPTION	Quantity	Supplier
MCU (SPC5746CSMKU6, TMS570LS0432)	LQFP176, LQFP100	2	Freescale, TI
Connector	Tesla custom	2	?, JST
LDO (TPS7P6950)	5V, SO-8	2	TI
Single step-down controller with dual DC-DC controller (MAX16993)	5V, 1.2V/1.25V, 3.3V TQFN32	2	Maxim
CAN transceiver (TJA1042)	SO8	2	NXP
Common mode choke	CAN	2	
Inductors	SMD, power	3	
Ferrite bead	SMD, 1206, 0805, 0603	~33	
Electrolytic cap	SMD, TH	8	
Ceramic cap	0603, 0805, 1206	~206	
Resistors	0402, 0603, 0805, 1206, 1210, 1608	~337	
Diode	SMA, SMB	~53	
ADC	TSSOP20	1	AMS
Logic	SMD, SO-8	~3	
Xtal	SMD	2	
Quad opamp (TLV2343A-Q1)	SMD, TSSOP14	5	TI
3V precision reference (REF5030A)	SO-8	2	TI
Transistor/FET	NPN, PNP, SOT23, SOT-323, SO89, DPAK	~44	
Transformer	SMD, TH, Power, Signal	2	

Note:

- ~ mark shows estimation

BOM - BMS CELL SENSE CONTROL BOARD

Bill of Material - BMS PCB

PART	DESCRIPTION	Quantity	Supplier
Cell monitor ASIC	LQFP64	2	Linear
Secondary protector ASIC	TSSOP38	2	
Communication isolation transformer	SO-6 (custom)	4	XFMRS
Connectors	Vertical 2-pin	2	
Common mode choke	Inter-ASIC	2	
NPN BJT transistor (PHPT61003NY)	LFPAK56, 100V 3A	4	NXP
Fuse	SMD, SSQ 3/8A (375mA)	8	Bel Fuse
TVS Diode (SM4T68AY)	SMD, SMA, 58V	4	ST
Ceramic cap	0603, 0805, 1206	~132	
Resistors	0402, 0603, 0805, 1206	~137	
Diode	0402	2	

Note:

- ~ mark shows estimation