Gauge Design Configurations for High Charge / Discharge Rate Applications

Thomas Cosby

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TEXAS INSTRUMENTS

Agenda

- Special pack applications
  - High charge and discharge rates
  - High capacity packs
  - High cell count packs
- Hardware considerations
  - Design consideration for boards
  - Sense Resistor Choices
  - FET selection for gauge + protectors
  - Calibration
- Parameter configuration
- Products (bq78350, bq34z100-G1)

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Special Pack Applications

- High charge and discharge rates
  - The current reporting registers can support up to 32A charge or discharge current.
  - Current scaling can be used to support higher current applications.

- High capacity packs
  - The gauge can typically support up to 29Ah Design Capacity.
  - Current scaling can be used to support higher capacity applications.

- High cell count packs
  - The bq34z100-G1 can support up to 65V pack voltage and the bq78350 can support up to 15S application with VSCALE.
  - Voltage scaling can be used to support higher voltage applications.

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High Charge and Discharge Rates (> 32A)

- If we need to support a 48A discharge current, then that pack will be scale by 48A/32A = 1.5 $\Rightarrow$ Scale factor rounded up to 2x.

- We can fool the gauge by current calibration: for a 5 mohm Rsense, if we calibrate at an actual current of 4A, we can use the value 2A for calibration so the CC Gain and CC Delta would become 10 mohm. We now have a calibration ratio of 50%

- Modify all current and capacity related data flash values by the scale factor, example: 1st level OC from 6000mA to 3000mA; pay attention to sleep current/quit current, as these are impacted as well; also modify DesignCapacity, DesignEnergy

- Exception is AFE OC Dsg, AFE SC Chg and Dsg: calculate these values based on the voltage = true Rsense * true current

- All reported current and capacity parameters will need to be scaled up by the scale factor to restore the true values.

TEXAS INSTRUMENTS

High Capacity Packs (>29Ah)

- If we need to support a 80Ah capacity, then that pack will be scale by 80Ah/29Ah = 2.75 $\Rightarrow$ Scale factor rounded up to 3x or 4x.

- You will scale the current during calibration: for a 5 mohm Rsense, if we calibrate at an actual current of 20A, we can use the value 5A for calibration so the CC Gain and CC Delta would become 20 mohm. We now have a calibration ratio of 25% for a 4x scale factor.

- Modify all current and capacity related data flash values by the scale factor, example: 1st level OC from 6000mA to 1500mA; pay attention to sleep current/quit current, as these are impacted as well; also modify DesignCapacity, DesignEnergy

- Exception is AFE OC Dsg, AFE SC Chg and Dsg: calculate these values based on the voltage = true Rsense * true current

- All reported current and capacity parameters will need to be scaled up by the scale factor to restore the true values.

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High Cell Count Packs (>65V)

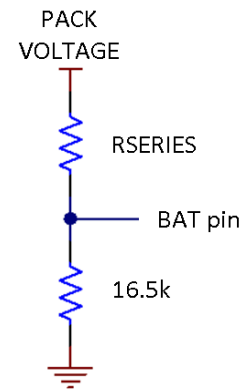The bq34z100-G1 can support a pack voltage up to 65V.

- The input to the IC (BAT pin) must be <1V, so the external divider ratio will be set to support the Maximum Pack Voltage. As an example, if we have an 18S Li-Ion pack, then we should set the Maximum Pack Voltage to the Recommended Single Cell Maximum Voltage (eg: 5V) x Actual Number of Series Cells (e.g: 18) = 90V

- Setup the voltage divider to support a 90V pack voltage using the equation:

$$\text{Rseries} = 16500\ \Omega \times (\text{Maximum Pack Voltage mV} - 900\ \text{mV}) / 900\ \text{mV}$$

- The bottom leg of the divider resistor should be in the range of 15 KΩ to 25 K, using 16.5 KΩ:

$$\text{Rseries} = 16500\ \Omega \times (90000\text{mV} - 900\ \text{mV}) / 900\ \text{mV} = 1.634\ \text{Mohm}$$

- A standard value 1.62 Mohm resistor will support an 89V pack voltage. This will provide adequate cell voltage measurement margin for a Li-Ion cell.

PACK VOLTAGE

RSERIES

BAT pin

16.5k

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High Cell Count Packs (>65V)

The data flash configuration must be scaled to ensure that the maximum reported voltage does not exceed 65535mV.

This additional scaling is created by scaling the value stored in Number of Series Cells. The calculation is: Maximum Pack Voltage (e.g.: 90000mV) / Maximum Reportable Value (65535mV) = 1.38 The Number of Series Cells are an integer units so the value will be rounded up, use a 2x scaling factor.

Stored Number of Series Cells = actual number of series cells / scaling factor $\Rightarrow$ 18 / 2 = 9

You will need to divide the voltage by 2x when calibrating. E.g. If the applied voltage is 80V, then you will enter 40000mV in the program.

In this configuration, the host device that is reading the reported voltage value must also know that the voltage is scaled so that it can rescale the voltage to the true pack voltage.

Note: There is a limitation as to the actual number of series cells that can be scaled. The result of the equation must be an integer. The result cannot rounded up or down, because this would cause the gauge to calculate the wrong cell voltage. As an example, if the actual number of series cells were 17, then the Number of Series Cells must be set to 17 and the voltage will be reported as a single cell. The VOLTSEL bit must be set in the Pack Configuration register.

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TEXAS INSTRUMENTS

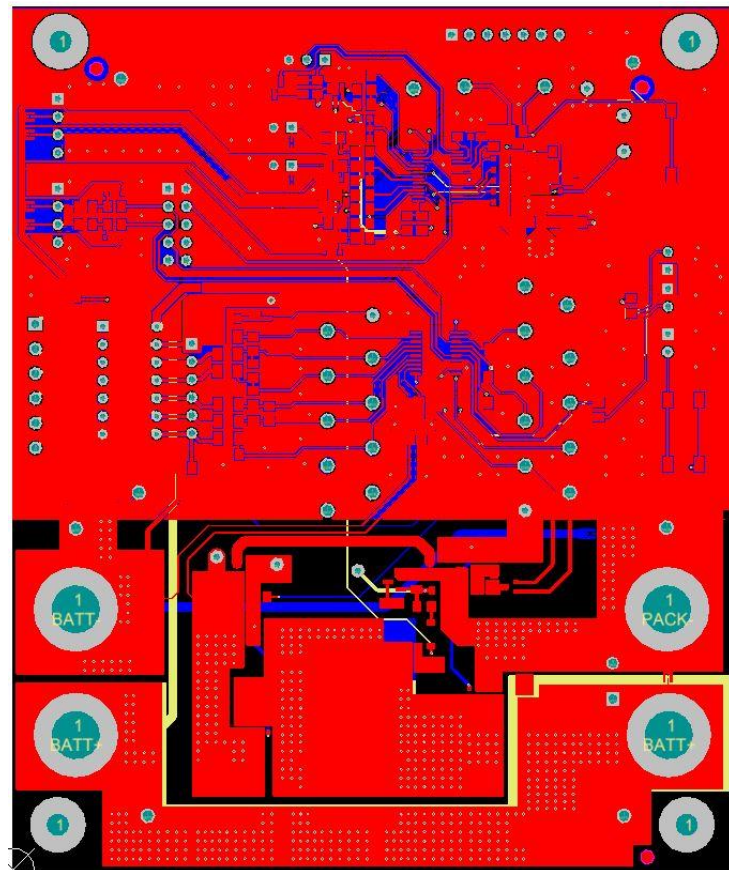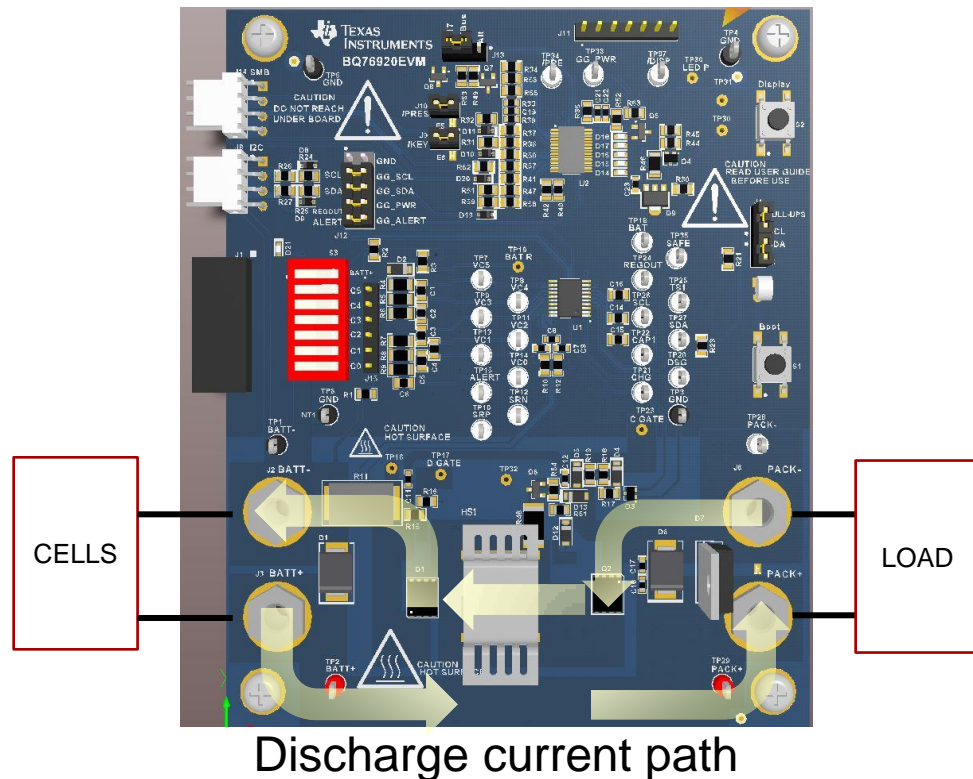# Hardware considerations

- Design consideration for boards

  - Layout for high current paths.

  - ESD

- Sense resistor choices and layout

- FET selection for gauge + protectors

- Calibration

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Design Consideration for Boards

- The coulomb counting network is probably the most important section to consider in the layout.

- The high current paths are the next most important.

- The gauge should be not placed inside the current loop for the best gauging accuracy. Transients and fields can induce error into current and voltage measurements.

- Use high frequency bypass capacitors and spark gaps to shunt ESD transients.

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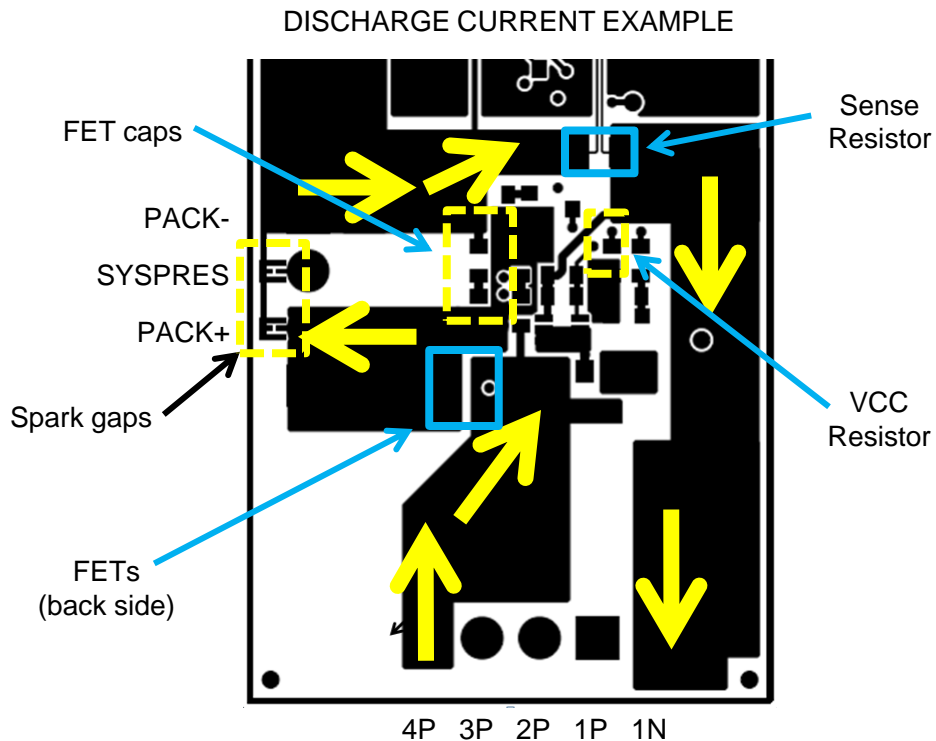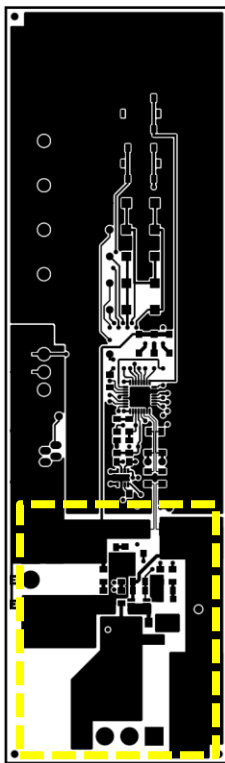
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bq76920 / bq78350 EVM Layout

CELLS

LOAD

Discharge current path

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bq40z50 EVM Layout

Gas Gauge

Power Stage

Cell Inputs

Top Layer

Signal Plane

GND Plane

2nd Layer

GND Plane

3rd Layer

GND Plane

High Temp Section

Bottom Layer

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bq40z50 EVM Layout

DISCHARGE CURRENT EXAMPLE

FET caps

PACK-

SYSPRES

PACK+

Spark gaps

FETs
(back side)

Sense Resistor

VCC Resistor

4P   3P   2P   1P   1N

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TEXAS INSTRUMENTS

bq40z50 EVM Layout

DISCHARGE CURRENT EXAMPLE

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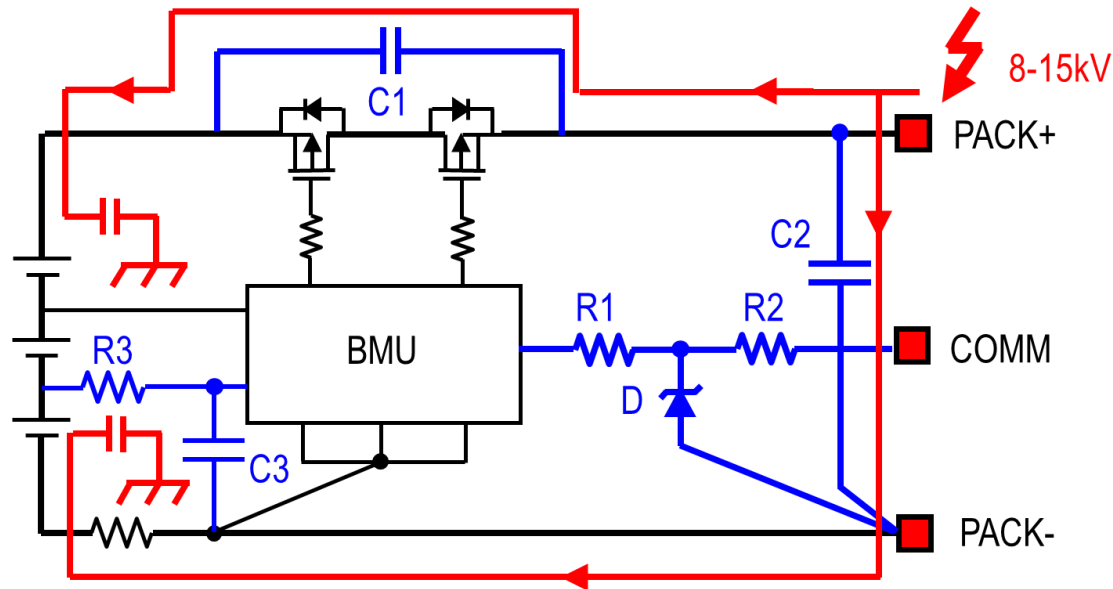**TEXAS INSTRUMENTS**

Battery Pack ESD Hit

- Pin Exposure will get ESD Hit
- ESD damages Protection FETs and BMU

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Battery Pack ESD Protection – PACK+

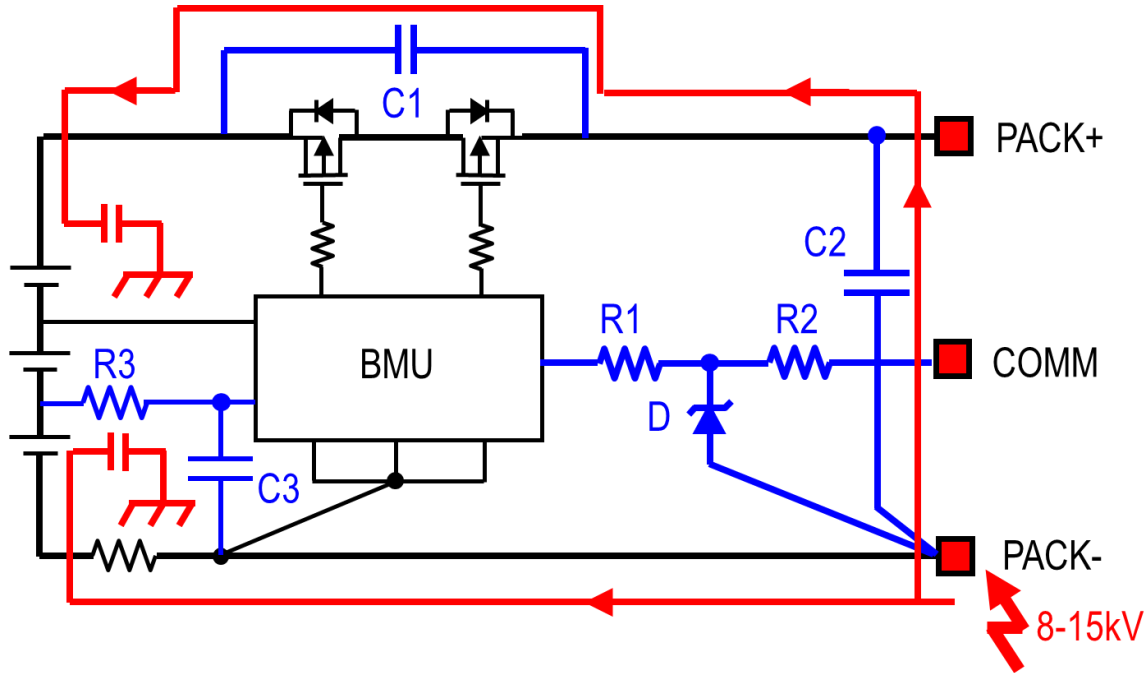

- Preferred diverting path for a ZAP to Pack +: Capacitors C1 & C2

- Ensure caps can absorb 2.5 micro coulombs

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Battery Pack ESD Protection – PACK-

- Preferred diverting path for a ZAP to Pack-: Capacitors C1 & C2

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Battery Pack ESD Protection – Other

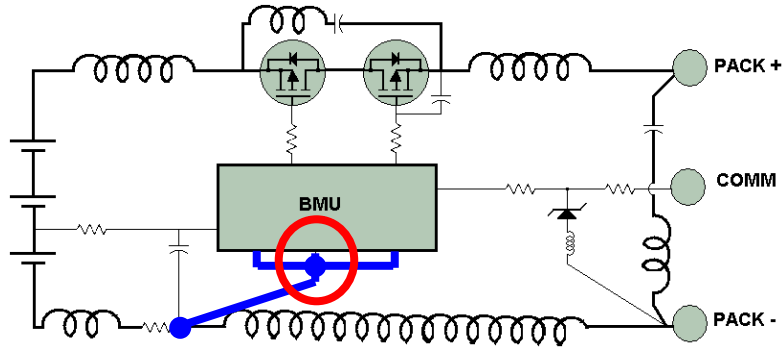- Preferred diverting path for a ZAP to COMM: R1, R2 and D

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Use Proper Grounding
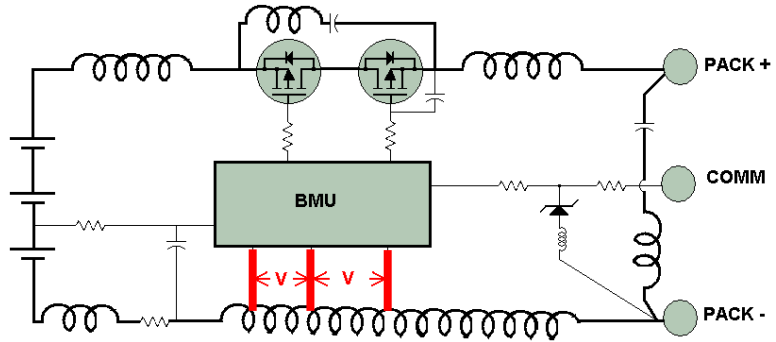
Avoid Inductive Voltage Drop

Wrong

$V = L \, di/dt$

Right

Low level ground systems must connect to a single point at the sense resistor

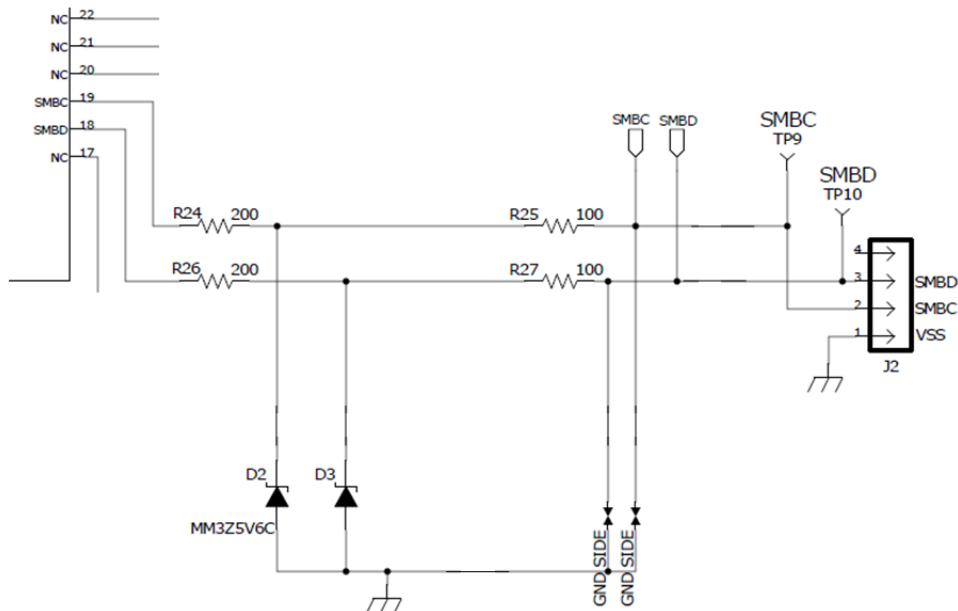TI Information – Selective Disclosure. Battery Management Deep Dive 2015

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Use Spark Gaps

Spark gap after a few strikes.
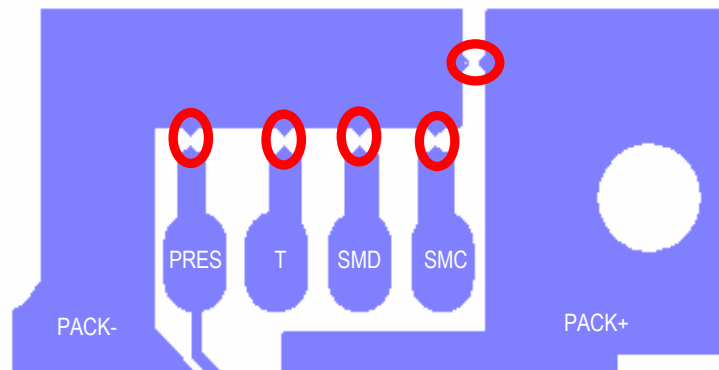
Spark gap on the right has been exposed to multiple ESD strikes.

PRES T SMD SMC

PACK-

PACK+

- Use a spark gap at the pack connector
- Reduce Peak Voltage seen by the internal circuit (IC)
- Must be PCB external Layer
- Must be free of solder mask or other non-conductive coating
- A 10-mil (0.2 mm) gap has a voltage breakdown about 1500 volts

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Communications Line Protection

- 100 ohms keeps signal edges sharp, but Zeners may not survive continuous short

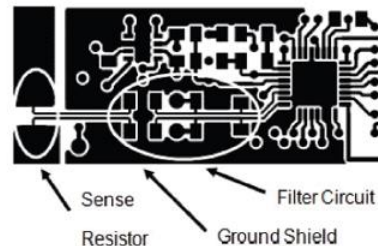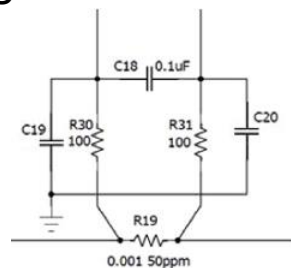- Insure that diodes returns to Pack – not to low current ground

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Sense Resistor Choices

- The sense resistor is one of the most critical components for good gauging performance.

- All of the gauge use a differential input stage to measure the voltage across the sense resistor to count coulombs.

- A filter is added to reduce the effects of noise and transients on current measurements. The filter should be placed close to the device.

- An additional high frequency capacitor can be placed between C18 and the device, if very fast transients are present.

- The signal traces should be routed parallel to one another and an close a possible to help with common-mode rejection.

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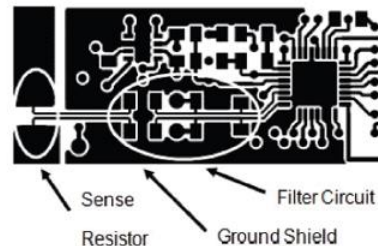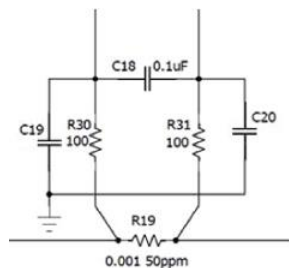
Sense Resistor Choices

- We recommend that a 50ppm Temperature Coefficient of Resistance (TCR) resistor be used to improve accuracy.

- The value of the resistor will depend on the device. You must consider the voltage drop and coulomb counter offset.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(SR)}$	Input voltage range, $V_{(SRN)}$ and $V_{(SRP)}$	$V_{(SR)} = V_{(SRN)} - V_{(SRP)}$	−0.125		0.125	V
t_{SR_CONV}	Conversion time	Single conversion		1		s
	Resolution			14	15	bits
$V_{OS(SR)}$	Input offset			10		µV

$R_{SENSE} < V_{(SR)} / I_{MAX}$; 125mV / 100A = 1.25mΩ
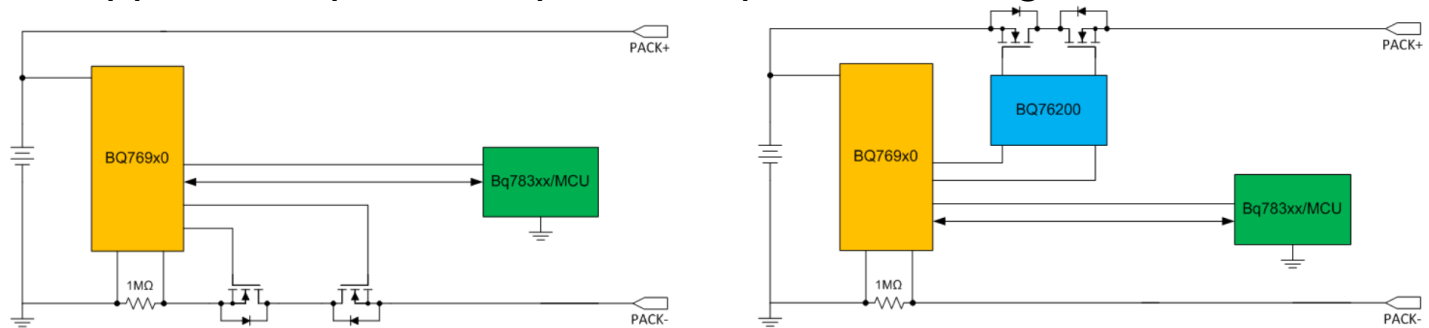
Input Offset / R_{SENSE}; 10uV / 1.25mΩ = 8mA

- A filter is added to reduce the effects of noise and transients on current measurements. The filter should be placed close to the device.

- The signal traces should be routed parallel to one another and an close a possible to help with common-mode rejection.

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FET selection for gauge + protectors considerations

- Most of the gauges support high-side n-channel FETs for the charge and discharge paths.

- The gate drive current capability depends on the AFE device, but it is typically in the 20uA range.

- The bq769x0 devices support a low-side CHG / DSG FET architecture. The bq76200 will be released to serve as a pre-driver to support high-side FETs and the device can support multiple FETs placed in parallel for high current applications.

TEXAS INSTRUMENTS
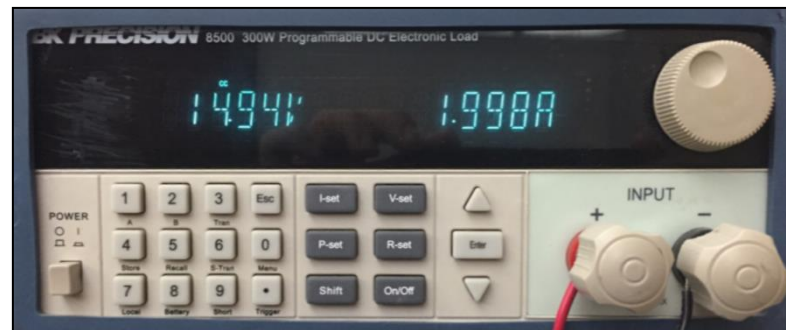
Calibration

Name	Private	Value	Unit
▲ Data			
CC Gain		20.350	mohm
CC Delta		20.314	mohm
CC Offset		-1356	num

- Pack is calibrated for a 2x Scale Factor.
- Apply a -2000mA discharge current.
- Enter -1000mA in the *Applied Current* field.
- *CC Gain* and *CC Delta* set to 20 mohm for a 10 mohm sense resistor.
- *Current* reported at ½ actual value.

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Parameter Configuration – bq34z100

Parameter name	Parameter Value	Display Units
Taper Current	100	mAmp
Min Taper Capacity	25	mAmpHr
CC Threshold	900	mAmpHr
Design Capacity	1000	MilliAmpHour
Design Energy	5400	MilliWattHour
SOH Load I	-400	MilliAmp
SOC1 Set Threshold	150	mAh
SOC1 Clear Threshold	175	mAh
SOCF Set Threshold	75	mAh
SOCF Clear Threshold	100	mAh
Sleep Current	10	mAmp
User Rate-mA	0	MilliAmp
User Rate-Pwr	0	mW/cW
Reserve Cap-mAh	0	MilliAmpHour
Reserve Energy	0	mWh/cWh
Dsg Current Threshold	60	mAmp
Chg Current Threshold	75	mAmp
Quit Current	40	mAmp
Qmax Cell 0	1000	mAmpHr
CC Gain	10.123	mohm
CC Delta	10.147	mohm
Deadband	5	mAmp

- Each current and capacity parameter must be scaled by the Scale Factor.
- Small values, such as Deadband may be left alone, because they will be too small.
- The CC Gain and CC Delta will be scaled when the current is calibrated. Their values will be set to the Scale Factor x Rsense.

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Parameter Configuration – bq78350

Subclass name	Parameter name	Parameter Value	Units
Current	CC Gain	1	mOhm
Current	Capacity Gain	1	mOhm
Current Deadband	Deadband	3	mA
OCC	Threshold	6000	mA
OCC	Recovery Threshold	-200	mA
OCD	Threshold	-6000	mA
OCD	Recovery Threshold	200	mA
PTO	Charge Threshold	2000	mA
PTO	Suspend Threshold	1800	mA
PTO	Reset	2	mAh
CTO	Charge Threshold	2500	mA
CTO	Suspend Threshold	2000	mA
CTO	Reset	2	mAh
OC	Threshold	300	mAh
OC	Recovery	2	mAh
SOCC	Threshold	10000	mA
SOCD	Threshold	-10000	mA
VIMR	Check Current	10	mA
CFET	OFF Threshold	5	mA
DFET	OFF Threshold	-5	mA
Fast Charging	Current	3000	mA
Pre-Charging	Current	100	mA

Subclass name	Parameter name	Parameter Value	Units
Termination Config	Charge Term Taper Current	250	mA
Current Thresholds	Dsg Current Threshold	100	mA
Current Thresholds	Chg Current Threshold	50	mA
Current Thresholds	Quit Current	10	mA
Design	Design Capacity mAh	4400	mAh
Design	Design Capacity cWh	6336	cWh
State	Learned Full Charge Capacity	4400	mAh
CEDV cfg	FCC Learn Up	512	mAh
CEDV cfg	FCC Learn Down	256	mAh
CEDV cfg	OverLoad Current	5000	mA
CEDV cfg	Electronics Load	0	3uA
CEDV cfg	Near Full	200	mAh
CEDV cfg	Reserve Capacity	0	mAh
Sleep	Sleep Current	10	mA
Data	Remaining AH Cap. Alarm	300	mAh
Data	Remaining WH Cap. Alarm	432	cWh

THESE PARAMETERS ARE NOT SCALED.

Subclass name	Parameter name	Parameter Value	Units
AOLD	Threshold and Delay	0	hex
ASCD	Threshold and Delay	0	hex

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Products

bq34z100-G1

- Supports **Li-Ion, LiFePO4, PbA, NiMH, and NiCd** Chemistries

- Capacity Estimation Using Patented **Impedance Track™ Technology** for Batteries from 3 V to 65 V

- **Supports Battery Capacities up to 29Ahr** with Standard Configuration Options

- **Supports Charge and Discharge Currents up 32A** with Standard Configuration Options configurations.

- External NTC Thermistor Support

- Supports Two-Wire I2C™ and HDQ Single-Wire Communication Interfaces with Host System

- SHA-1/HMAC Authentication

- One- or Four-LED Direct Display

- Five-LED and Higher Display Through Port Expander

- Reduced Power Modes (Typical Battery Pack Operating Range Conditions)
  - Normal Operation: < 145-µA Average
  - Sleep: < 84-µA Average bq34z100-G1
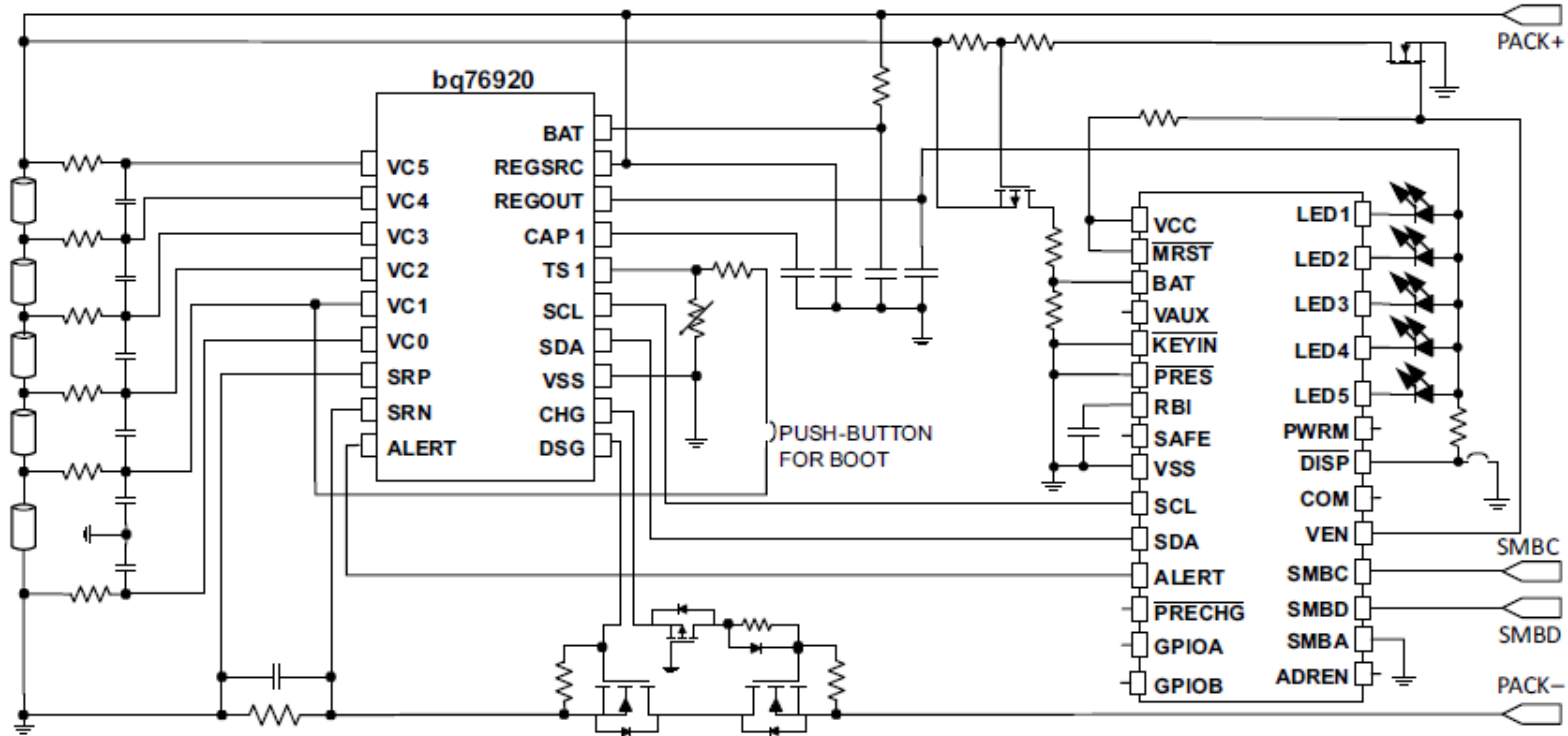 - Full Sleep: < 30-µA Average

bq78350

- Flexible Configuration for 3 to 5 Series (bq76920), 6 to 10 Series (bq76930), and 9 to 15 Series (bq76940) **Li-Ion and LiFePO4** Batteries

- Compensated End-of-Discharge Voltage **(CEDV) Gauging Algorithm**

- **Supports Battery Configurations up to 320 Ahr**

- **Supports Charge and Discharge Current Reporting up to 320 A**

- External NTC Thermistor Support from Companion AFE

- Supports SMBus Host Communication

- Offers an Optional Resistor Programmable SMBus Slave Address for up to Eight Different Bus Addresses

- SHA-1 Authentication

- Drives up to a 5-Segment LED or LCD Display for State-Of-Charge Indication

- Full Array of Programmable Protection Features
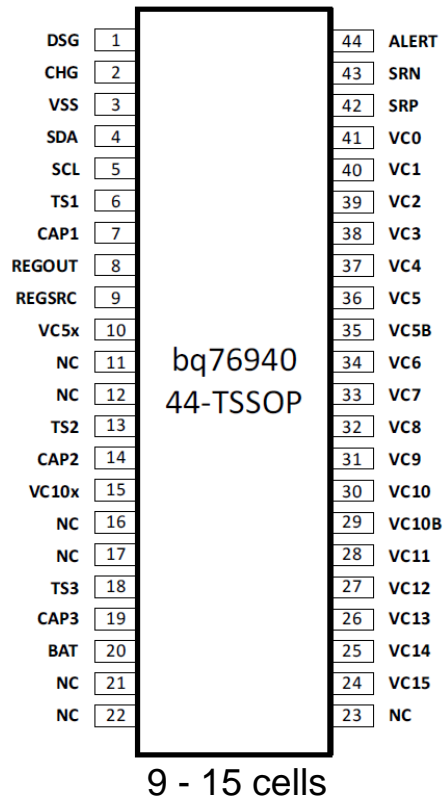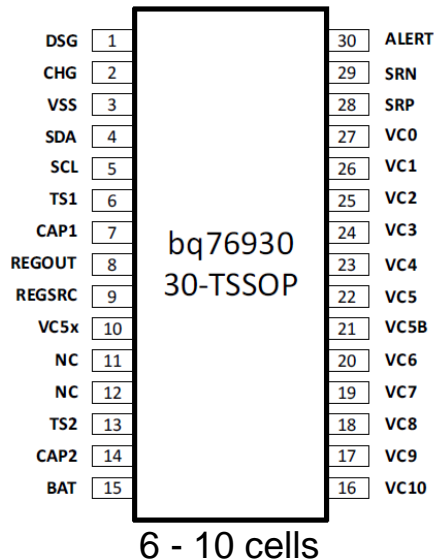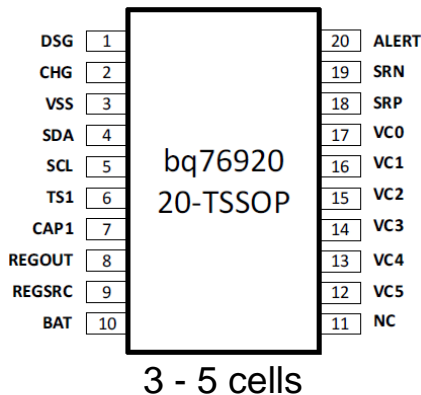 - Voltage
  - Current
  - Temperature
  - System Components

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bq34z100-G1
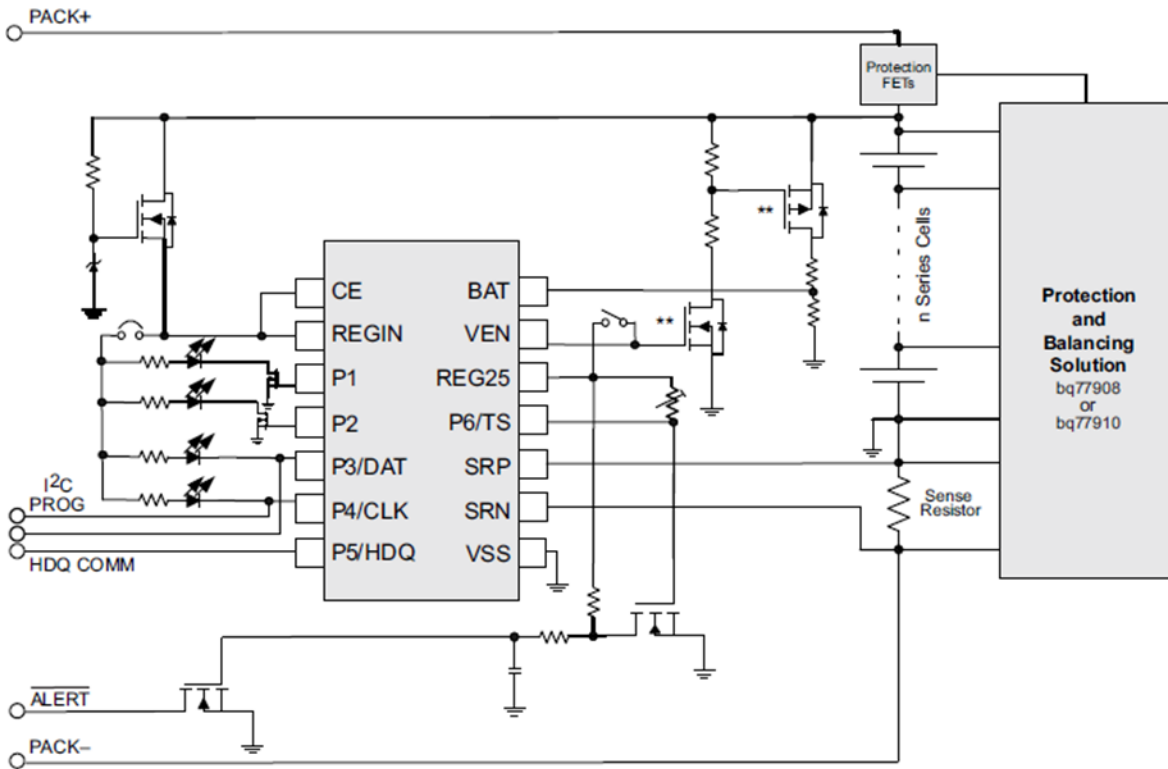
** optional to reduce divider power consumption

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bq78350-R1 // bq76920 / bq76930 / bq76940

bq78350-R1 // bq76920 / bq76930 / bq76940

AFE Options:

bq76920
20-TSSOP
3 - 5 cells

bq76930
30-TSSOP
6 - 10 cells

bq76940
44-TSSOP
9 - 15 cells

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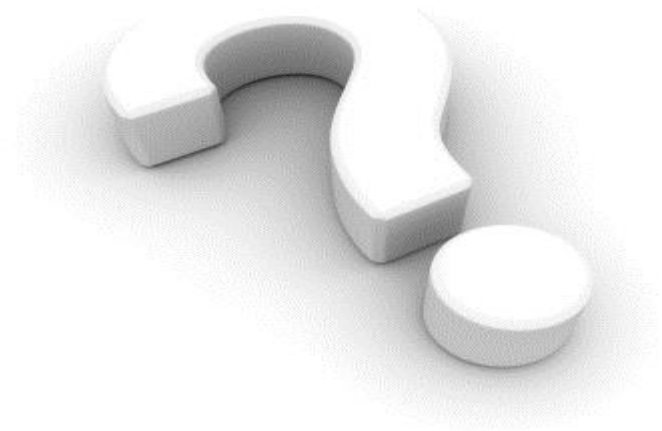
30

Representative equipment

- Energy Storage Systems
- Cordless home appliances
- General 12–48V battery packs
- Light electric vehicles (LEV): eBikes, eScooters, Pedelec and pedal–assist bicycles)
- Battery backup/UPS systems
- Telecom Power systems
- Robotic or handheld vacuum cleaners, other tools
- Drones

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Questions

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