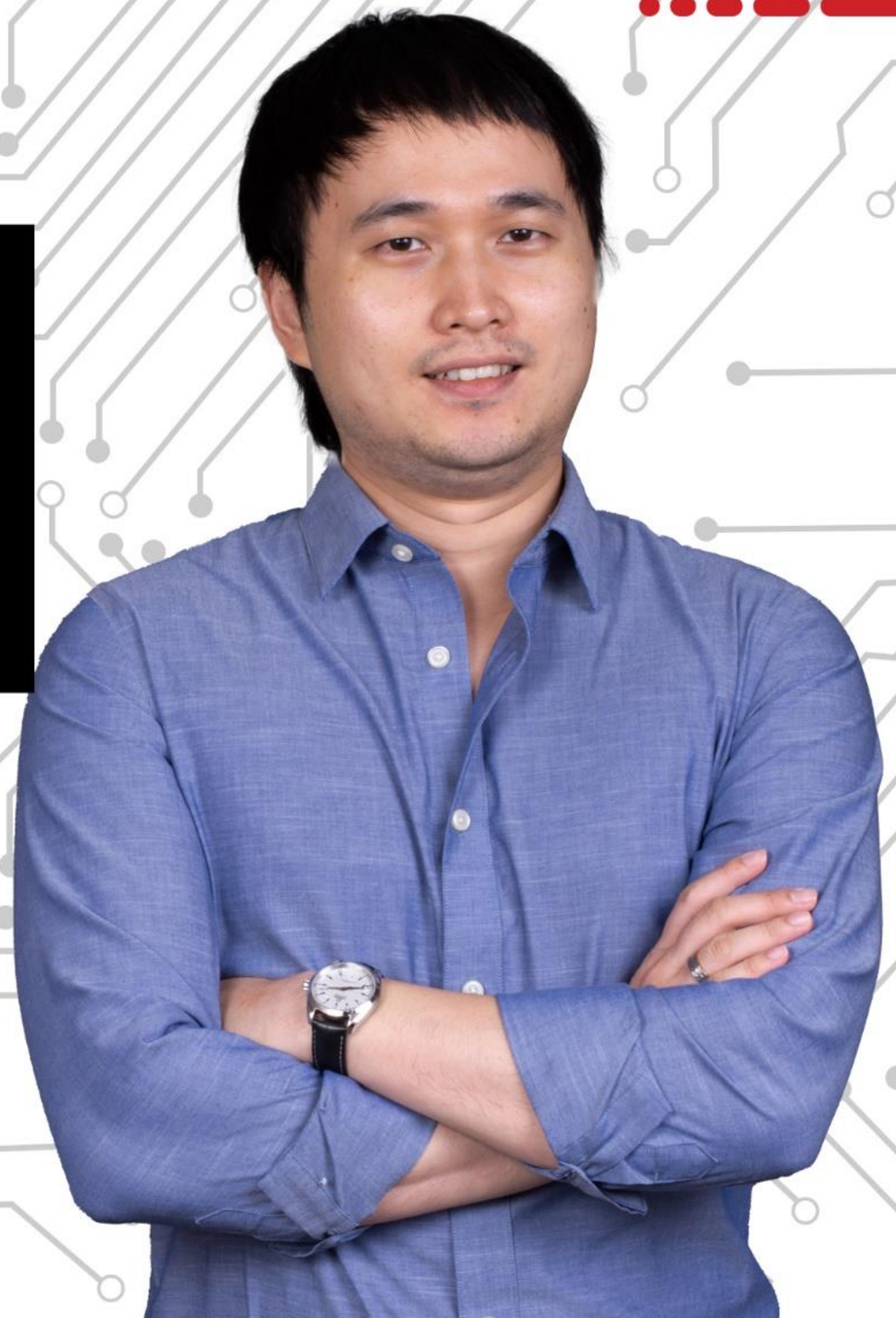
Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

XIAODONG CAI

BATTERY GAUGING FOR HIGH-CELL-COUNT INDUSTRIAL SYSTEMS



Background

High cell-count industrial battery packs

- Many industrial battery applications require high voltages for system operation, from 30 V to over 100 V
- Packs use a wide variety of series cell configurations
  - From lower numbers (5 -10) for power tools and vacuums
  - Medium numbers (10 - 23) for e-bikes and scooters
  - Higher stacks (25+) for larger power and garden tools, battery backup systems and energy storage systems
- These systems usually draw fairly high currents
- The packs often have multiple cells in parallel, making them physically large

High cell-count industrial battery packs

- These packs will, at minimum, integrate protection features to meet requirements for safety and standards compliance
- Battery gauging may be needed for different reasons
  - Displaying state of charge to the user, whether with LEDs or a numeric display
  - Estimating remaining system runtime (time to empty) or remaining charge time (time to full)
  - Allowing optimized system control to extend runtime (by reducing load) or take emergency action (returning to base)

High cell-count industrial battery packs

- Gauging can be implemented in several different approaches, including:
  - A proprietary algorithm based on cell voltage, current and temperature measurements
  - A discrete top-of-stack gauge, measuring pack voltage, current and temperature, and calculating averaged gauging parametric for the entire pack
  - A per-cell gauge, which measures each individual series cell voltage, pack current, and potentially multiple temperatures, to calculate gauging parametrics for each series cell

- TI offers products to support each of these approaches, which are described in detail in the following slides

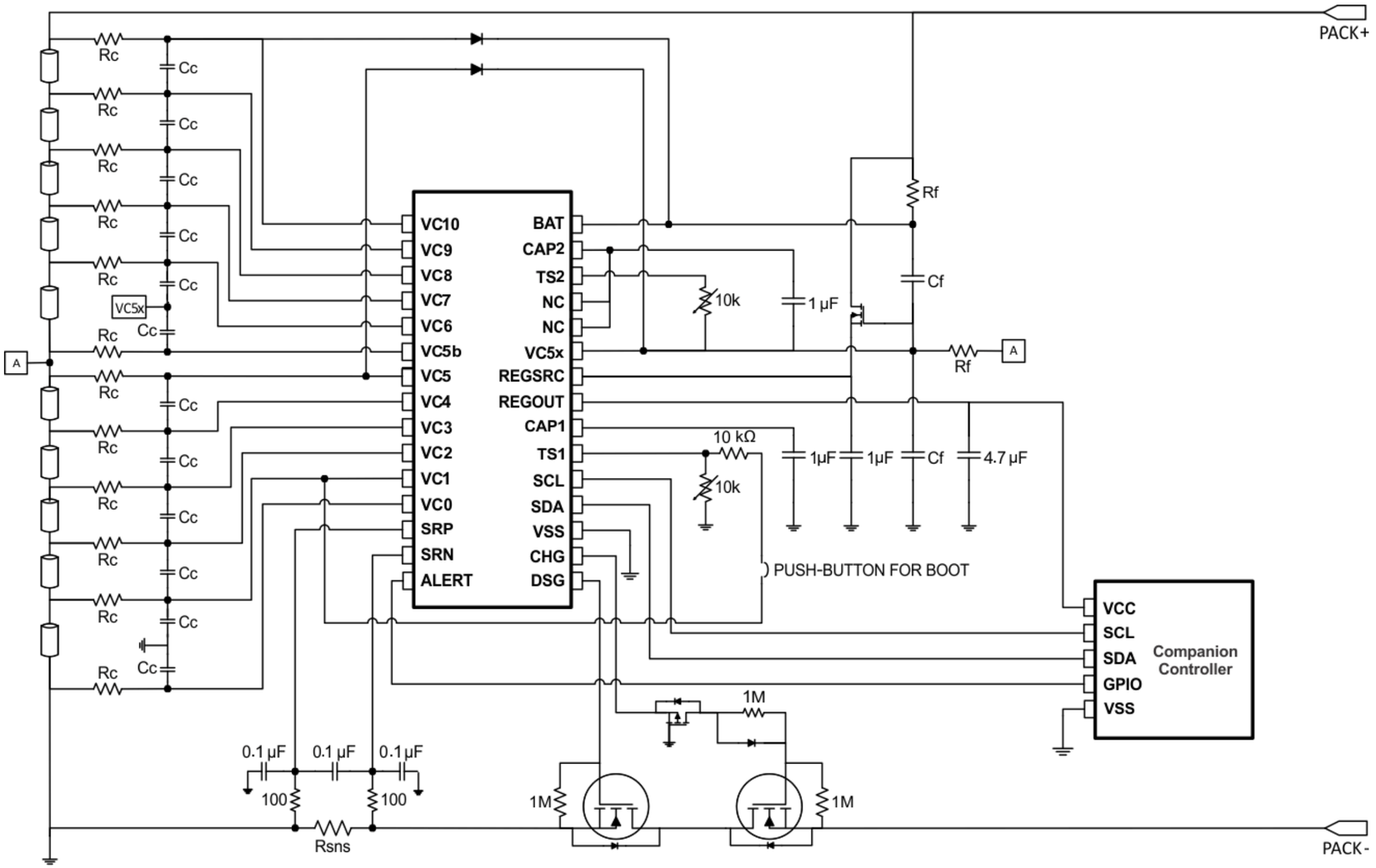
Battery monitoring for use with a proprietary gauging algorithm

Battery gauging for high cell-count systems

- Proprietary gauging algorithms
  - Algorithms may use voltage, current and temperature information from various sources
    - E.g., Algorithm may get temperature info from MCU-controlled thermistors, voltage and current from monitor
  - Allows optimization of parameters important to specific end applications (e.g., typical System-On-Chip, SOC accuracy vs. predicting end of life)
  - High cell-count systems may have peaky loads, necessitating a better understanding of effective impedance to ensure pack does not enter unsafe conditions under load
  - Newer chemistries like LiFePO4 and higher peak currents may necessitate higher accuracy measurements
- TI offers a variety of battery monitors for high cell-count systems, providing measurement of each individual series cell voltage, pack current, and multiple thermistors for pack temperature.

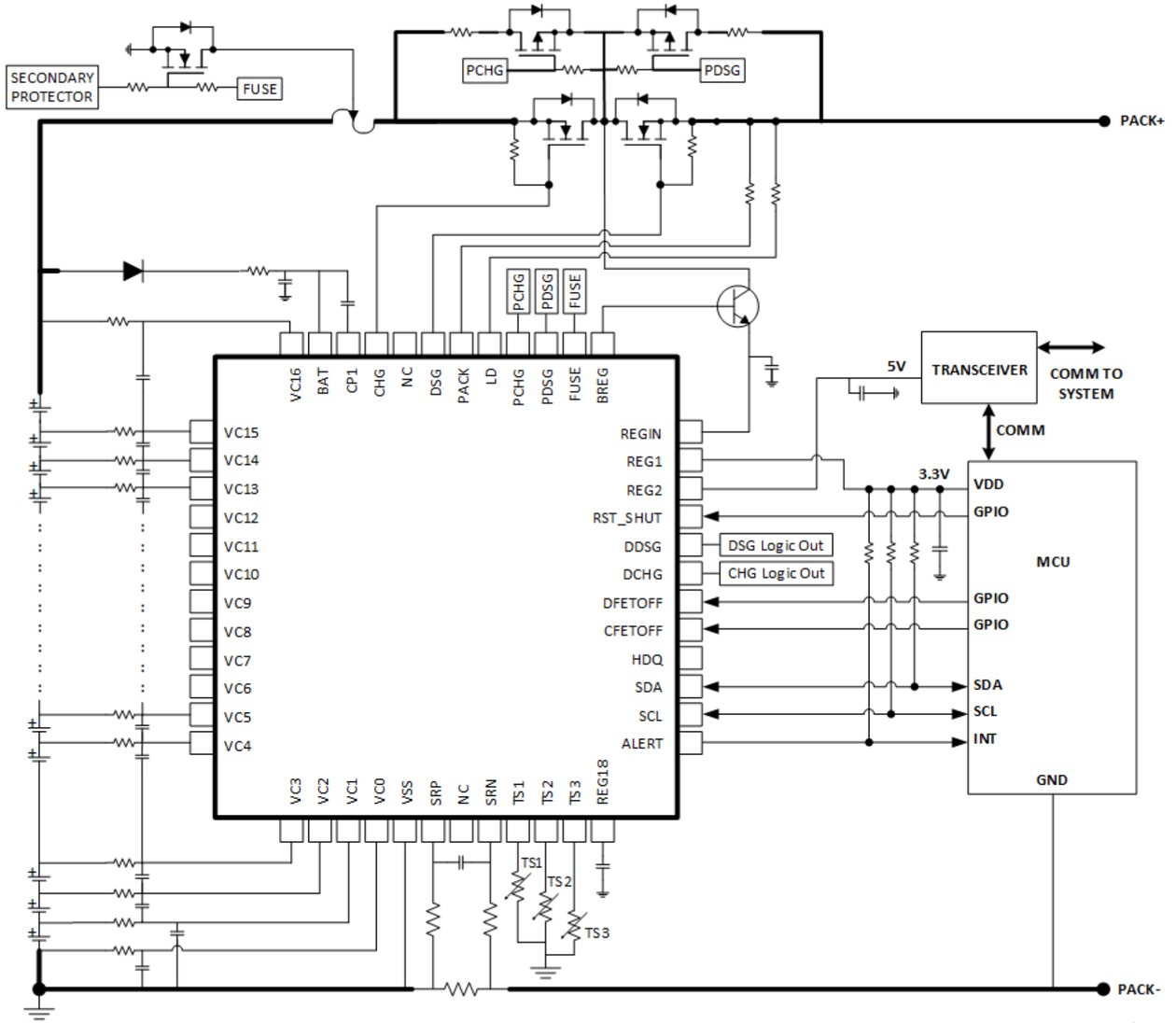
BQ76930 (10s) battery monitor and protector

- Measurement and protection of each individual series cell voltage
- Pack current measurement through low-side sense resistor
- Supports two thermistors for pack temperature monitoring



BQ76952 (16s) battery monitor and protector

- Includes simultaneous sampling of cell voltage and current with raw 24-bit data for pack analytics
- Coulomb counter integration of passed charge (64-bit data)
- Support for up to 9 thermistors provides measurements at different locations around a pack for cells or FETs



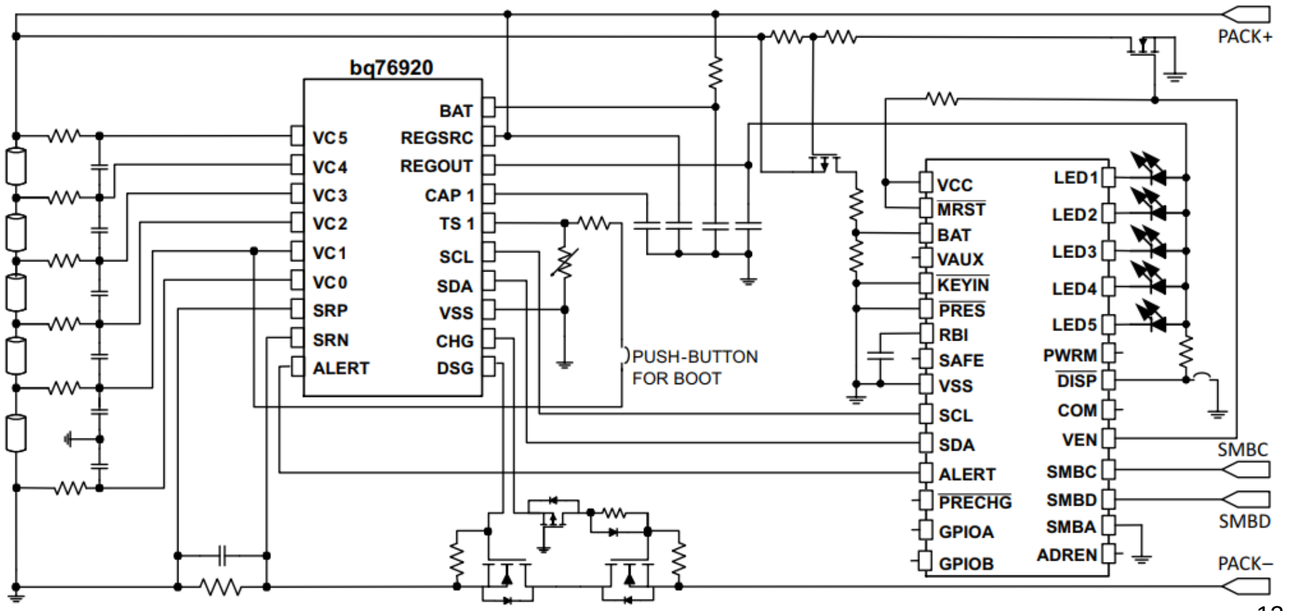
BQ769X2 features

Monitoring	•Digital voltage, current and temperature measurements; integrated coulomb counter
Protections	•Primary protection for OV, UV, OTC, OTD, UTC, UTD, OTF, OW, SCD, OCD1,2,3, OCC, cell balancing, watchdog, and more; integrated secondary protection
FET drivers	• Integrated charge pump and drivers for high-side protection NFETs
Cell balancing	•Integrated passive cell balancing up to 50 mA and support for external passive balancing
Prechg / Predsg	•Support for high-side PFET-based pre-charge and pre-discharge modes
Integrated LDOs	•Programmable LDO (external FET) as 5 V / 3.3 V / 3.0 V / 2.5 V / 1.8 V up to 45 mA •Second programmable LDO (same output options) up to 45 mA (10s, 14s, 16s)
Communications	•Support for I2C and HDQ in all products; adds SPI in 10s, 14s and 16s products
High voltage tolerance	•High voltage tolerance of 60 V (BQ76922) and 85 V (10s, 14s and 16s products)

Per-cell battery gauging

Battery monitoring for high cell-count systems

- For example, the BQ78350 integrates per-series cell gauging using data generated from the BQ76920 (5s), BQ76930 (10s), or BQ76940 (15s) battery monitors
- Turnkey solution – no need to develop a proprietary algorithm
- The device uses compensated end of discharge voltage (CEDV), which utilizes the integrated coulomb counter data to integrate passed charge and estimate the state of charge of the pack
- The device works exclusively with the BQ769x0 family
- SMBus outputs to an external controller
- LED outputs for easy gauge display



BQ78350

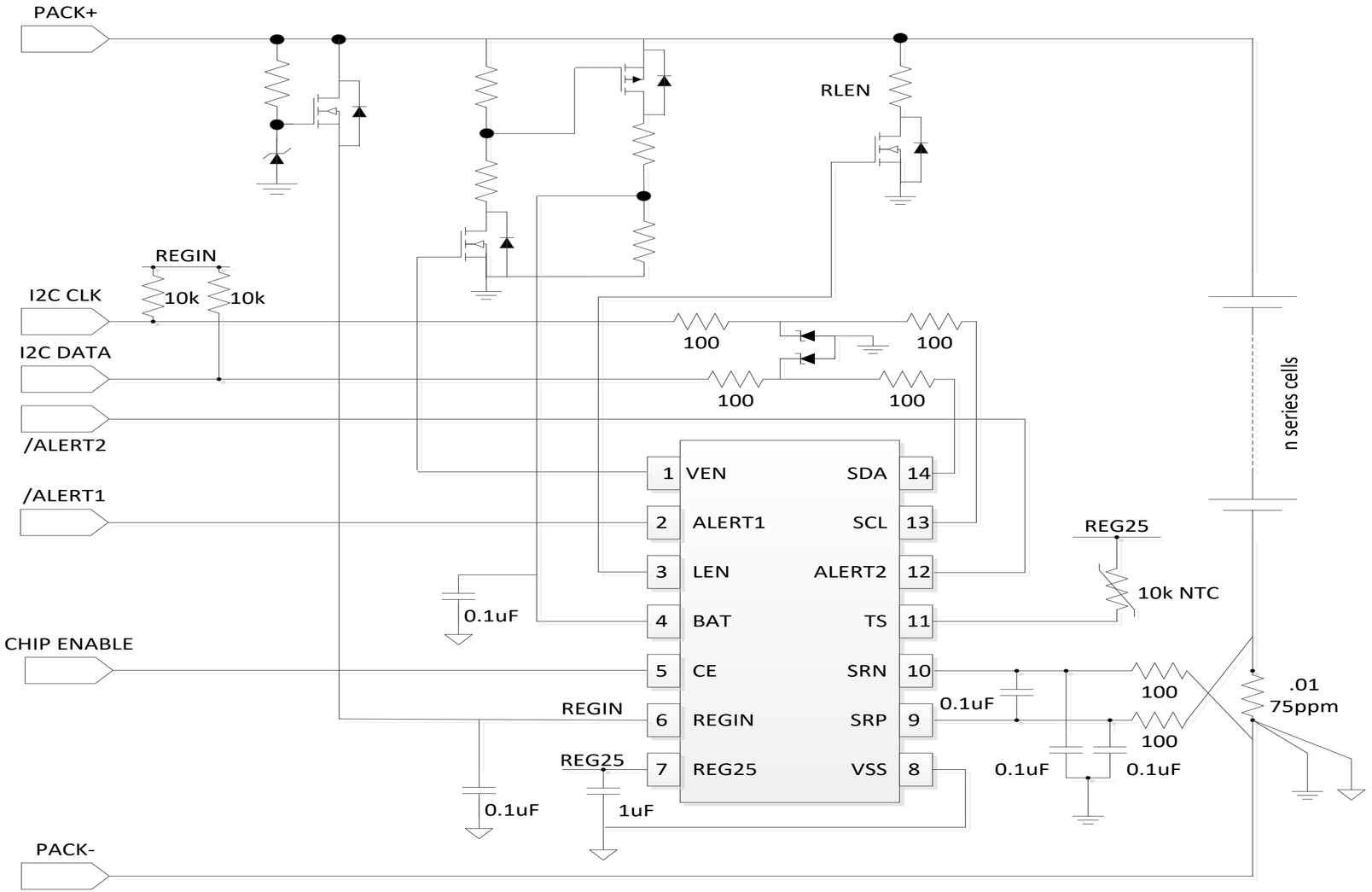
- User can choose the gauging based on TOS(Top of Stack) or individual cells
- BQ78350 provides more protection features such as FUSE drive, FET recovery, etc than other parts.
- Top gauge features include:
  - State of Charge, SOC
  - Remaining capacity
  - Time to empty
  - Time to charge
  - State if Health, SOH

Top-of-stack battery pack gauging

Top-of-stack battery pack gauging

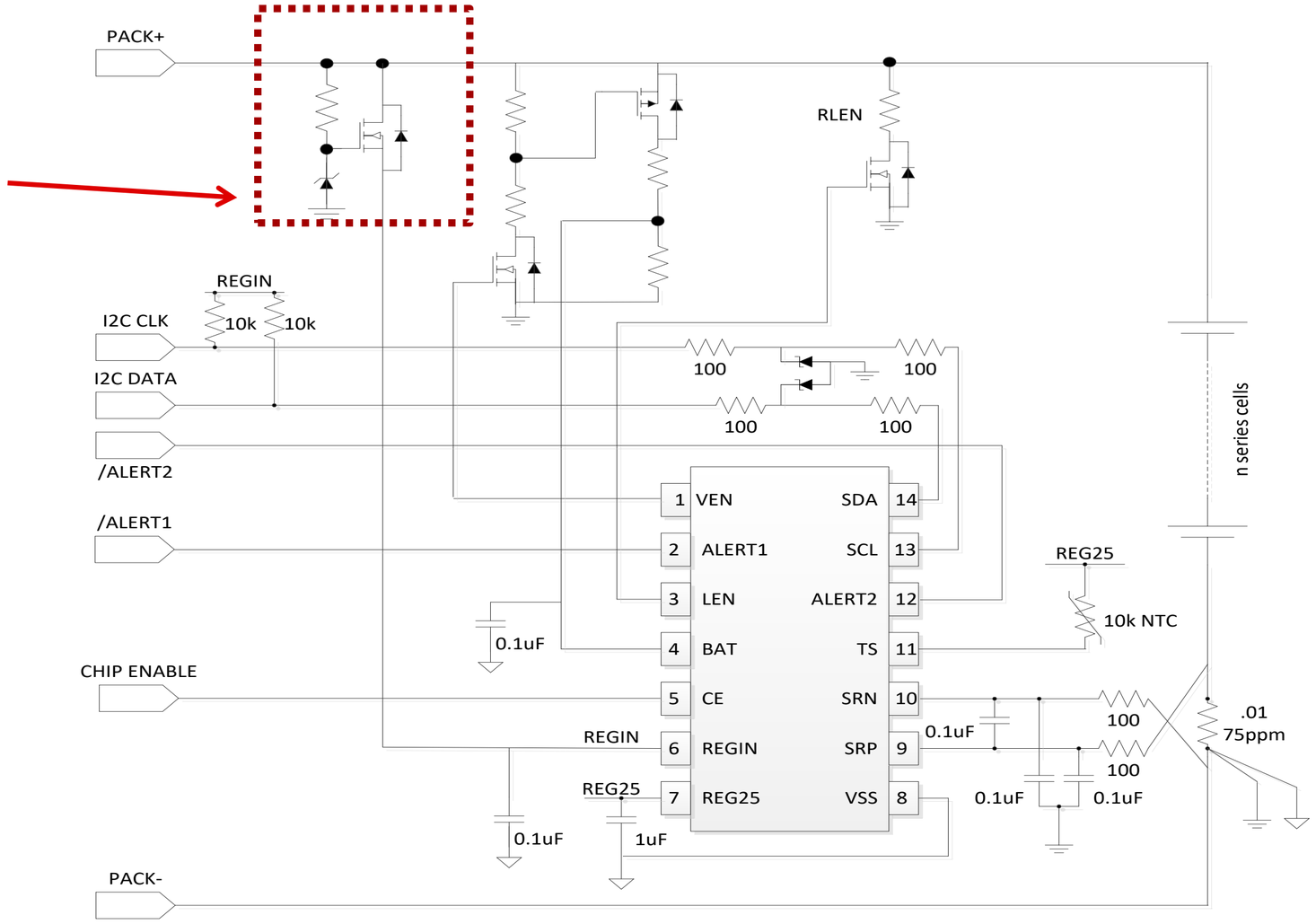
- Another approach to treat the pack as a single cell for gauging purposes.
- The device measures the top-of-stack voltage, divides it by the number of cells and treats this number as the voltage of a single cell
  - The pack scales to an arbitrary number of cells
- An integrated gauging algorithm uses the stack voltage, pack current and pack temperature to calculate parameters such as state of charge, state of health, time to full, time to empty, and more

Simplified multicell TOS diagram



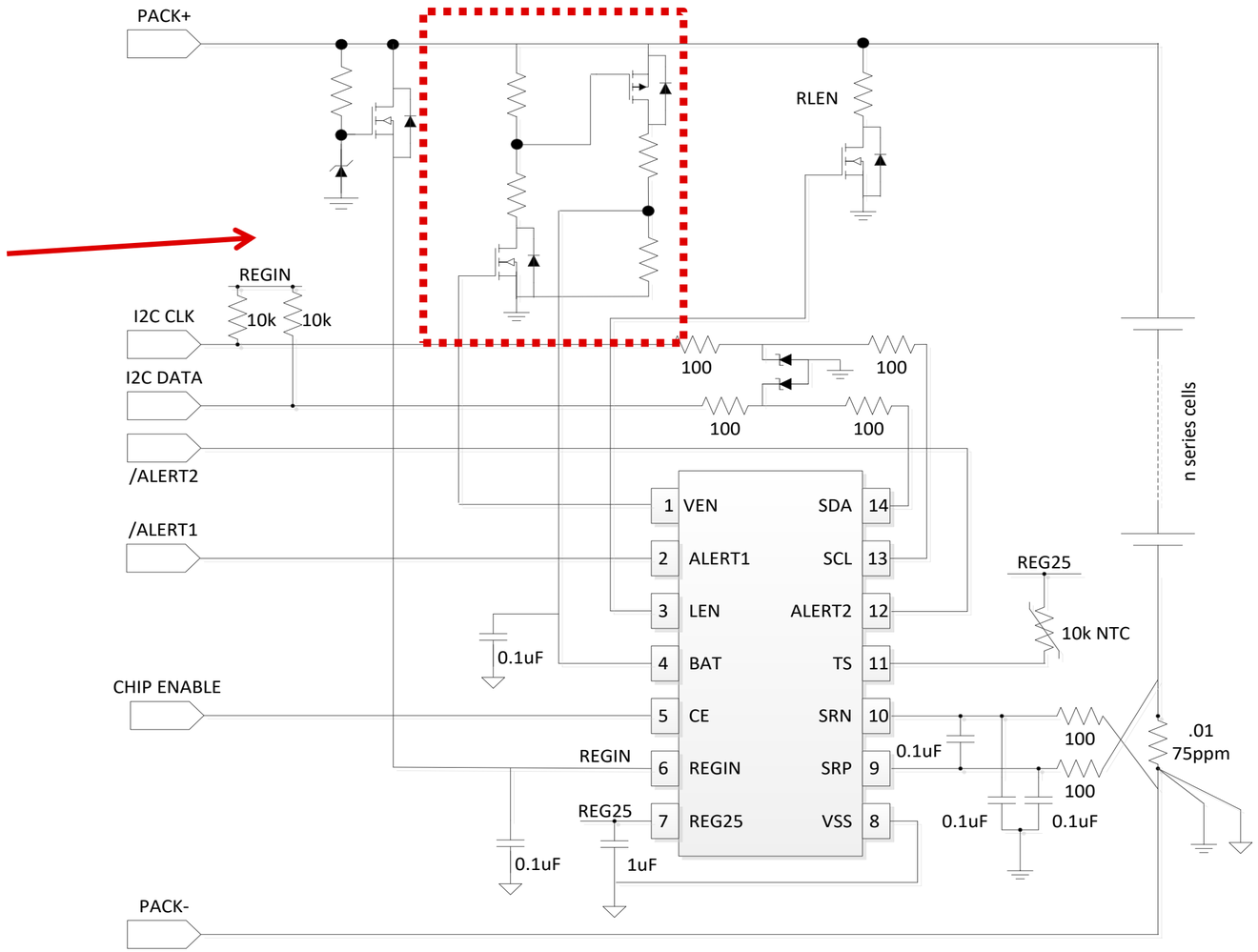
Simplified multicell TOS diagram

Implements a simple supply for the device power supply (REGIN pin, 2.7V ~ 4.5V)



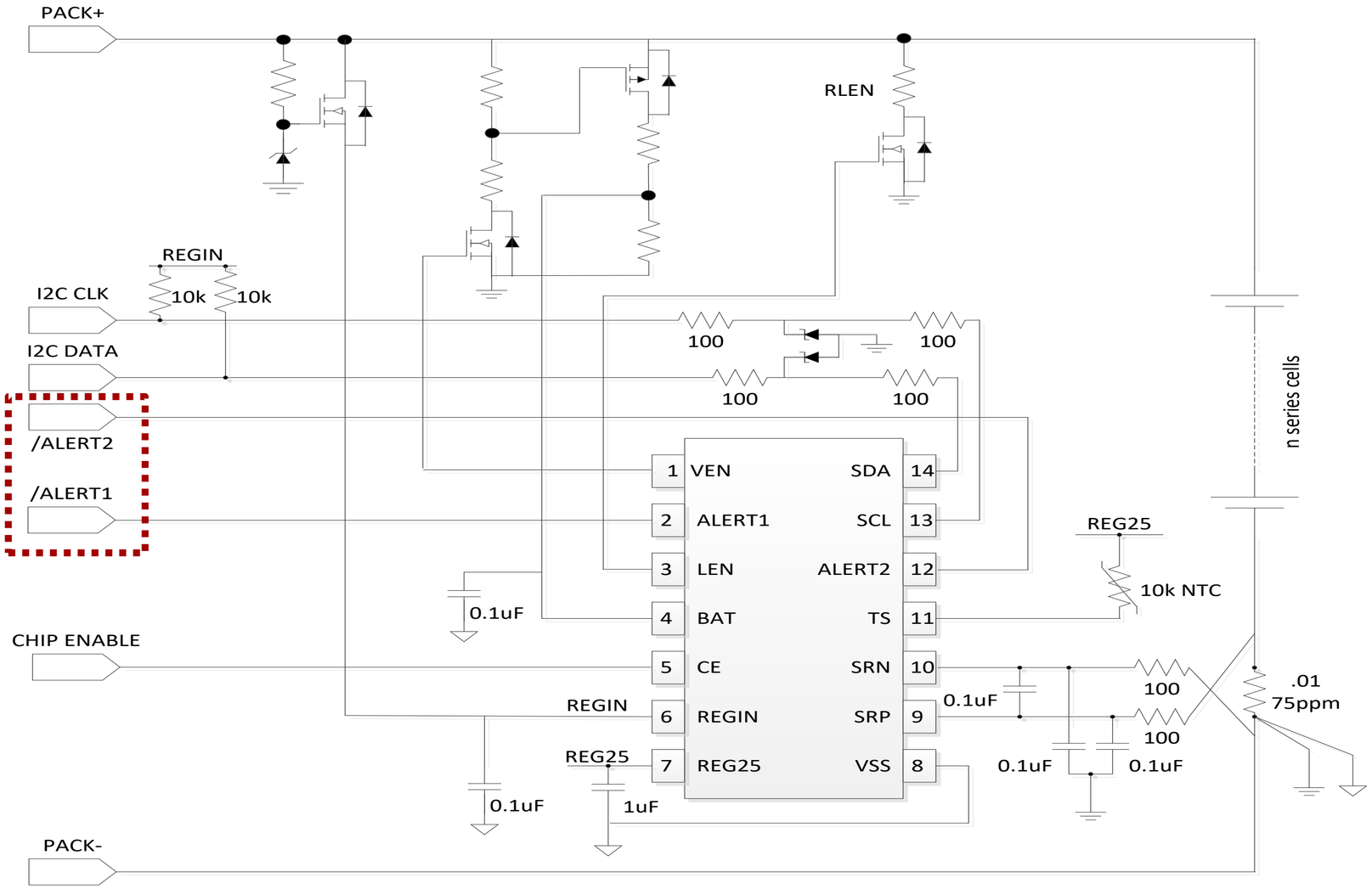
Simplified multicell TOS diagram

Resistor divider is switched on/off by VEN pin to measure stack voltage at BAT pin (divides down to < 1V)

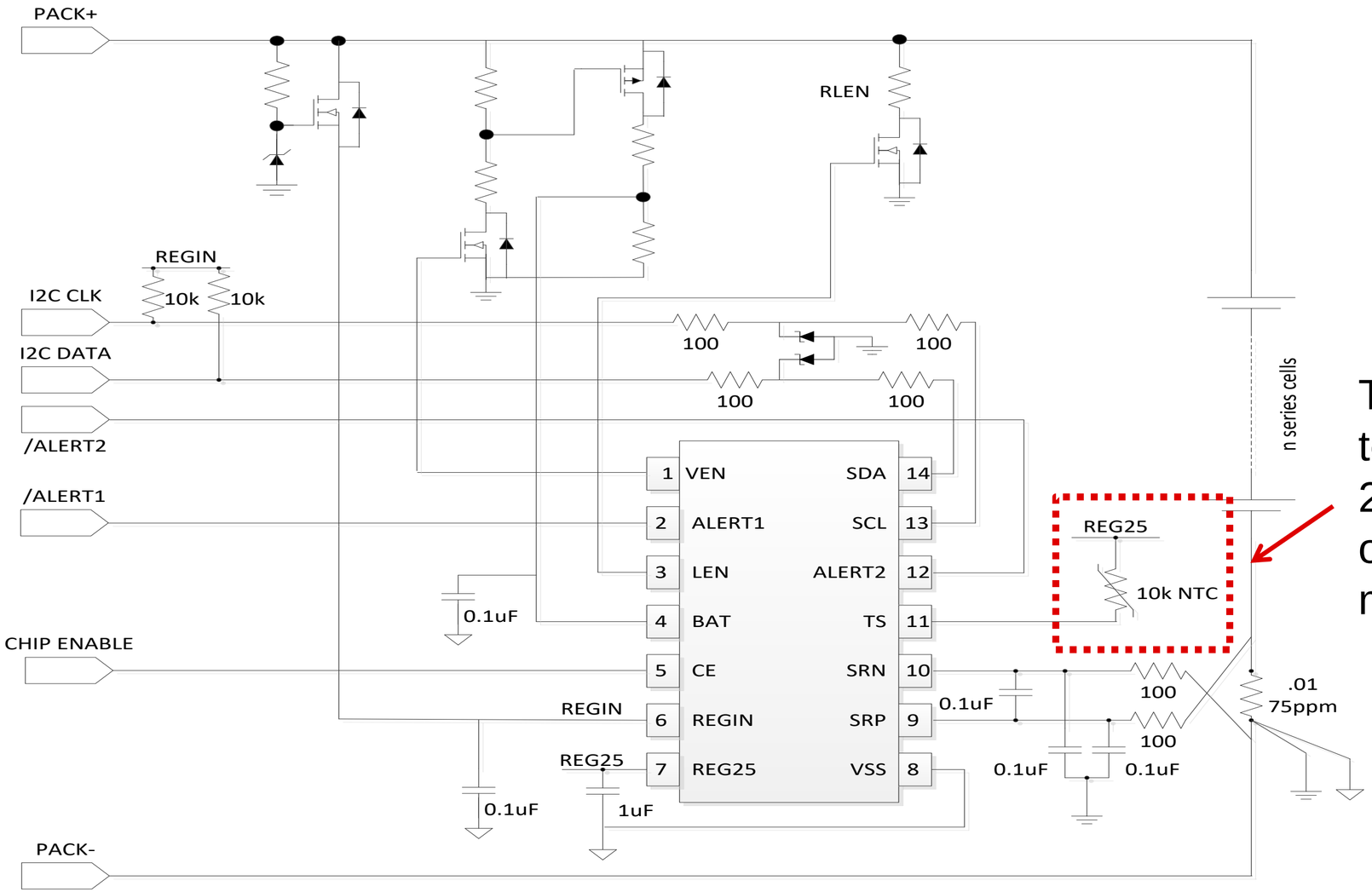


Simplified multicell TOS diagram

Dual alert pins for interrupts or signals to a host processor or external circuitry

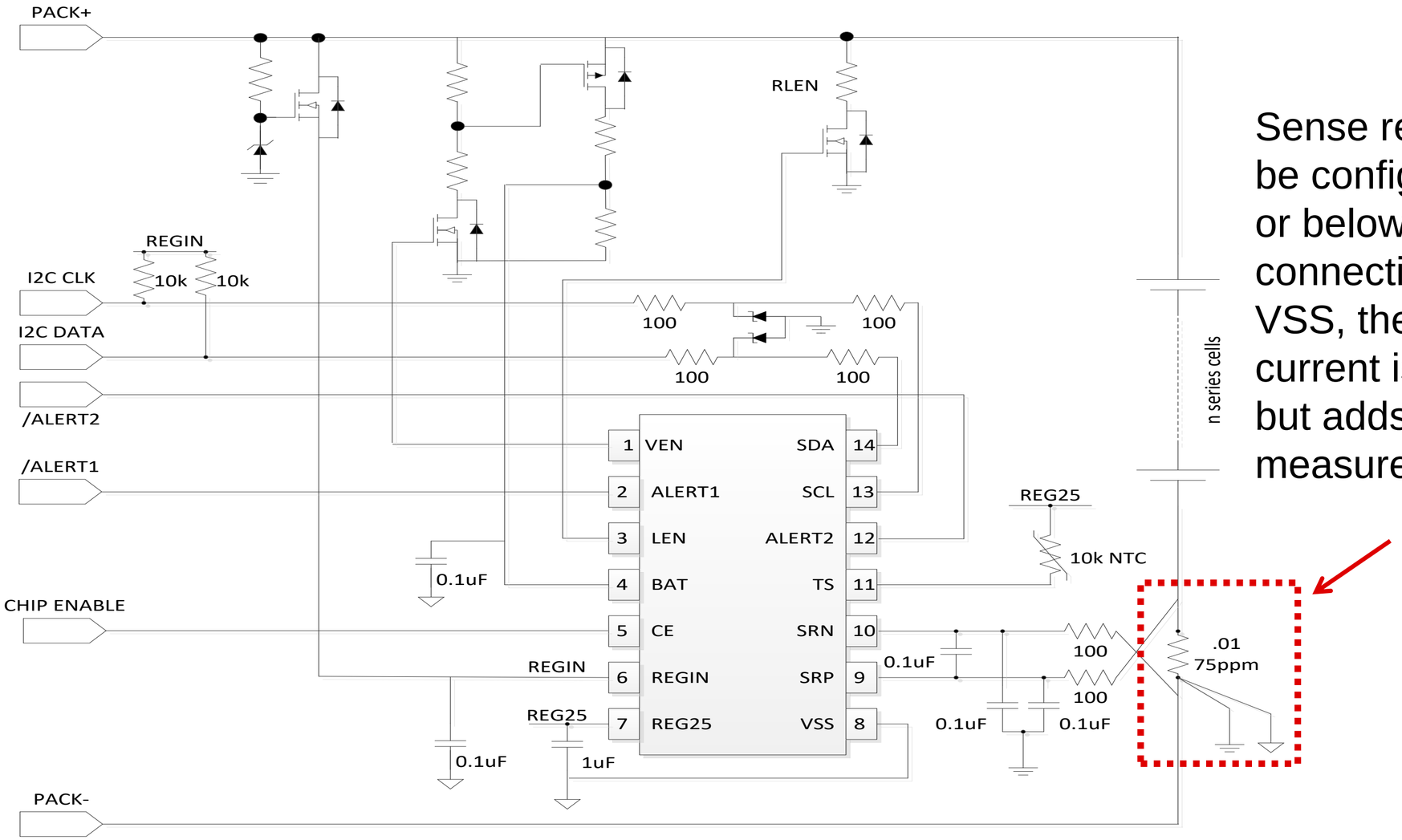


Simplified multicell TOS diagram



Thermistor pulls up to REG25 (internal 2.5-V LDO), is biased only during measurements

Simplified multicell TOS diagram



Sense resistor can be configured above or below VSS connection. If above VSS, then gauge current is measured, but adds stack measurement error.

BQ34Z100-G1

Multi-Chemistry Impedance Track™ Fuel Gauge

Features

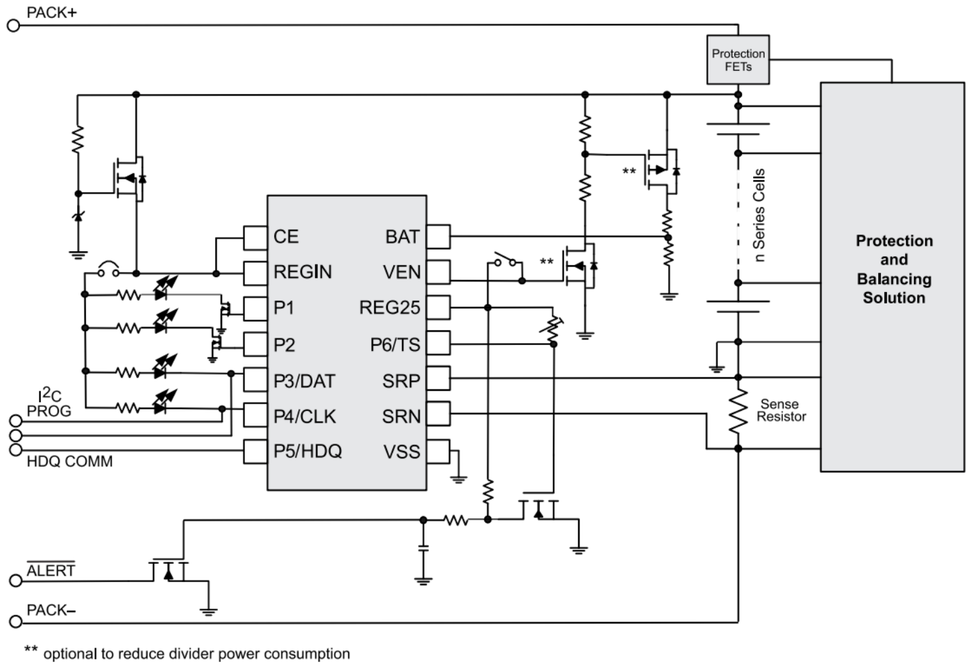
- Impedance Track™ Fuel Gauge capacity estimation for **Li-Ion, Polymer and LiFePO4, Update to BQ34Z100 and BQ34Z110**
- **Large capacity** batteries supported (>65Ahr)
- **High current a**pplications supported (>32A)
- Suitable for packs **2.5V to 65V**
- Low operating current of <140uA, Sleep <64uA
- SHA–1 authentication
- External thermistor supported
- Single wire (**HDQ**) / two-wire (**I2C**) communication
- 1 or 4 LED display – more with expander IC
- 14-pin TSSOP

Applications

- Energy storage systems
- Battery backup, UPS and wireless base stations
- Power assist, eBike
- Cordless home appliances
- General 12–48V battery packs

Benefits

- Very simple setup and configuration
- Accurate fuel gauging
- Independent of protection solution and cell balancing requirements
- Capable of gauging very high series cell batteries



Special pack applications: high power

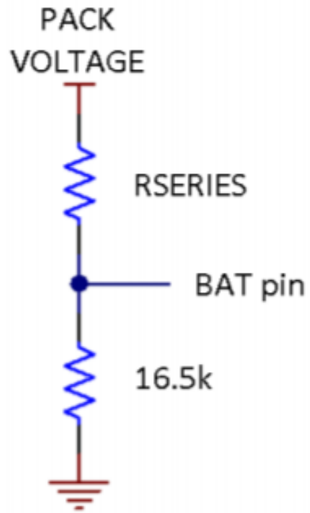
- High charge and discharge rates
  - The current reporting registers can support up to 32-A charge or discharge current
  - Current scaling can be used to support higher current applications
- High capacity packs
  - The gauge can typically support up to 29 Ah design capacity.
  - Current scaling can be used to support higher capacity applications.
- High cell count packs
  - The BQ34Z100-G1 can support up to 65-V pack voltage and the BQ78350 can support up to 15 S applications.
  - Voltage scaling can be used to support higher voltage applications.

High power pack scaling example

- Current
  - If we need to support a 48-A discharge current, then that pack will be scaled by 48 A/ 32 A = 1.5 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 4 A, we can use the value 2 A for calibration so the CC gain and CC delta would become 10 mohm. We now have a calibration ratio of 50%.

High power pack scaling example

- Voltage
  - If we need to support a 90 V pack voltage, set up the voltage divider to support a 90 V pack voltage using the equation: Rseries = 16500 Ω x (maximum pack voltage mV – 900 mV) / 900 mV
  - The bottom leg of the divider resistor should be in the range of 15 KΩ to 25 K, using 16.5 KΩ: Rseries = 16500 Ω x (90000mV – 900 mV) / 900 mV = 1.634 Mohm



Q&A

Thank you for attending!

TEXAS INSTRUMENTS

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