Introduction to the BQ77915, three- to five-cell stackable primary protector

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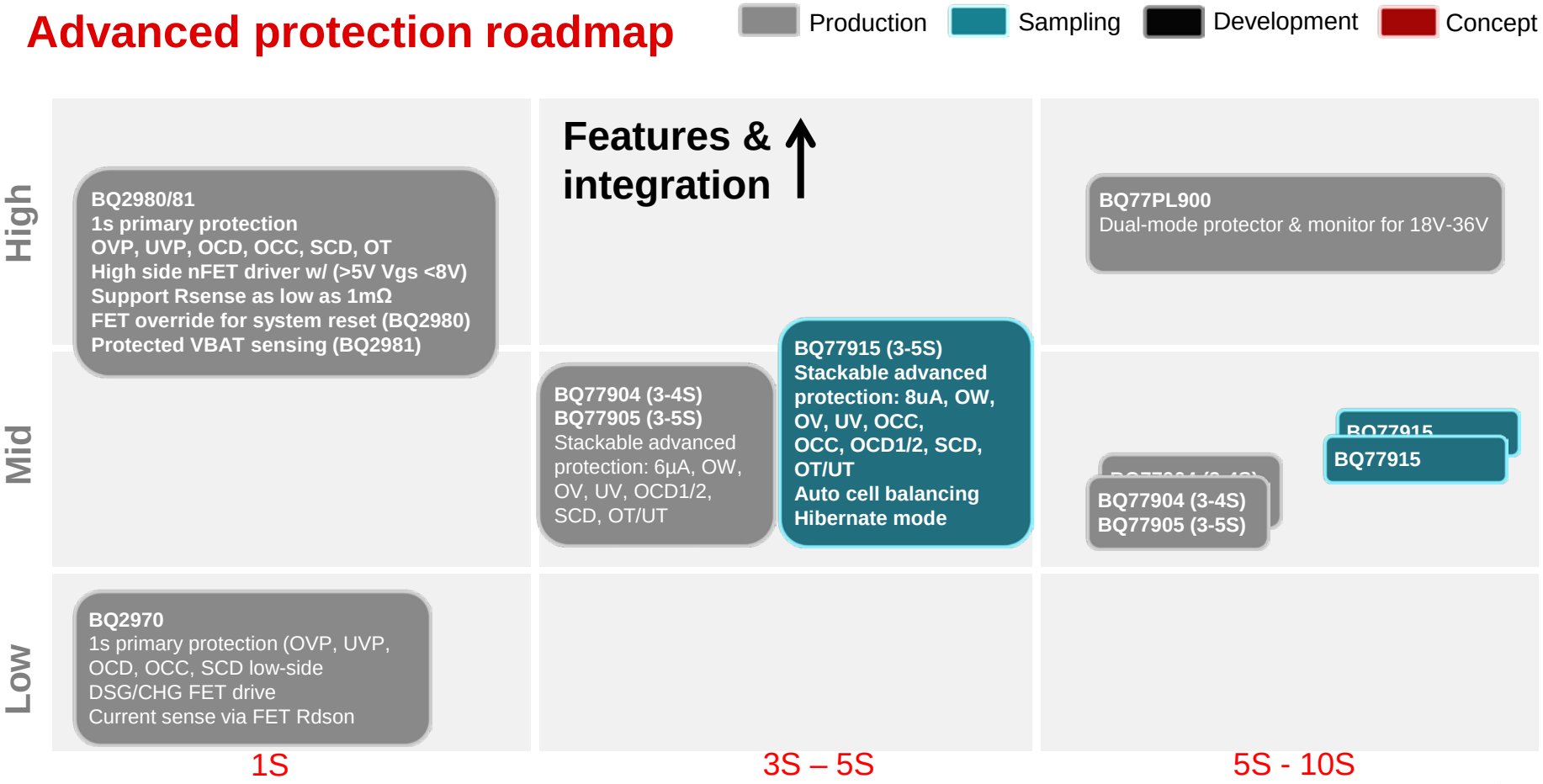
Willy Massoth

Agenda

- Protector roadmap
- Value proposition
- New vs TI today
- BQ77915 features:
  - Protection
  - Cell balancing algorithm
  - Power modes
    - Hibernation mode
- Example schematics
- Companion devices
- 1 page overview

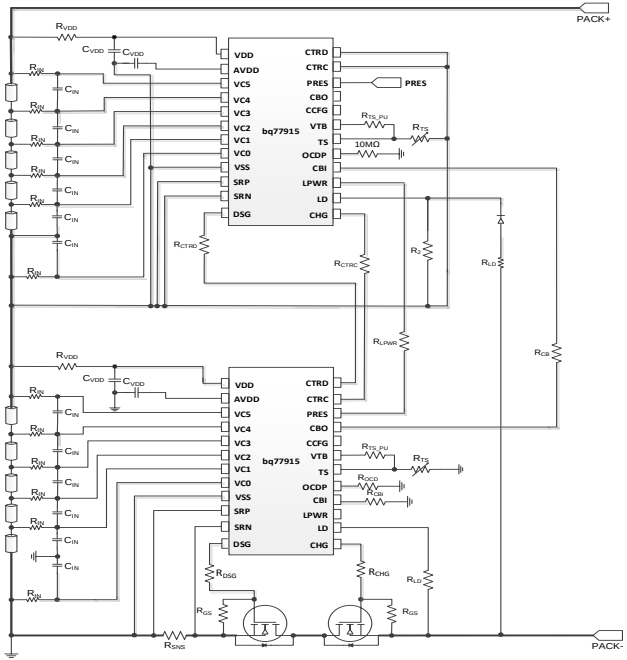
Advanced protection roadmap



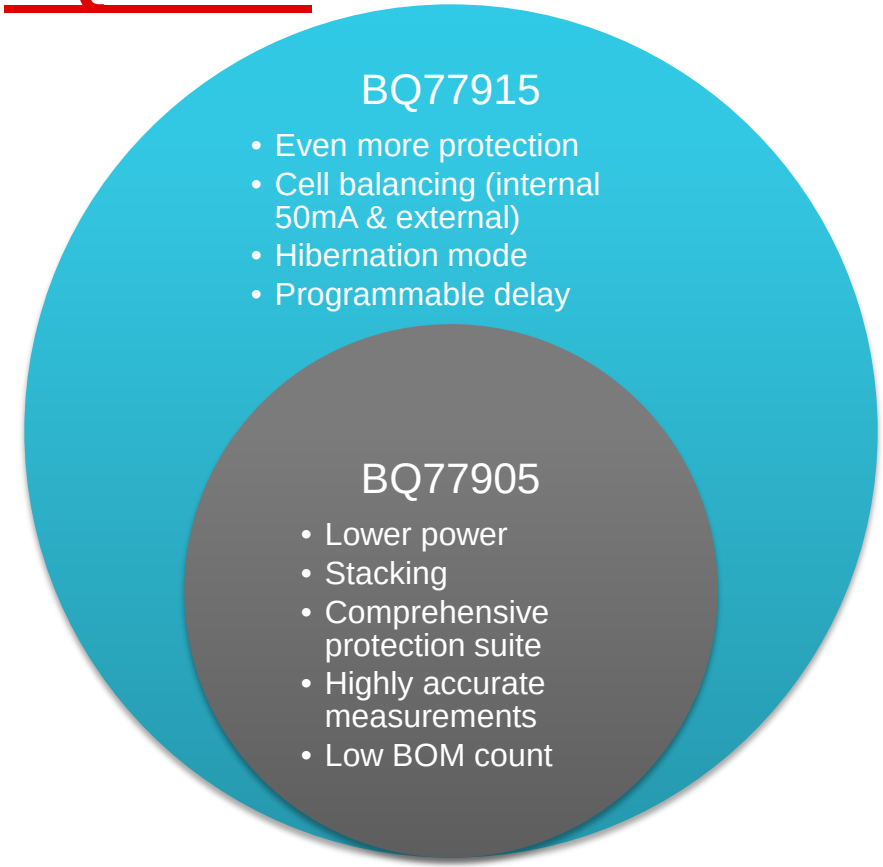
BQ77915: Value proposition

The BQ77915 advanced stackable protector is a quick and easy solution for multi-cell applications. It has the highest accuracy and lowest power among the competition.

Feature highlight	System benefit
Low power consumption (8µA typ. In normal mode 2µA typ. In hibernate mode)	• Longer shelf-life, better user experience • Dedicated hibernate mode for storage and shipping to aid in meeting battery regulations • Relaxing external component tolerance to meet power budget (e.g. component leakage/cell quality) • Minimal cell group imbalance in stack configuration
Full suite of V/I/T protection functions with best-in-class accuracy	• Simple schematic allowing quick design cycle • Including open wire, OT/UT protections to meet higher/new safety requirements
Autonomous smart cell balancing	• Extract maximum battery capacity • Supports both internal and external cell balancing FETs for small and large capacity packs
Scalable from 3S to 20S+	• Easy stacking with “copy-paste” schematic to support quick design across wide range of applications
Support random cell connection	• Ease of manufacturing/production



BQ77905 vs. BQ77915



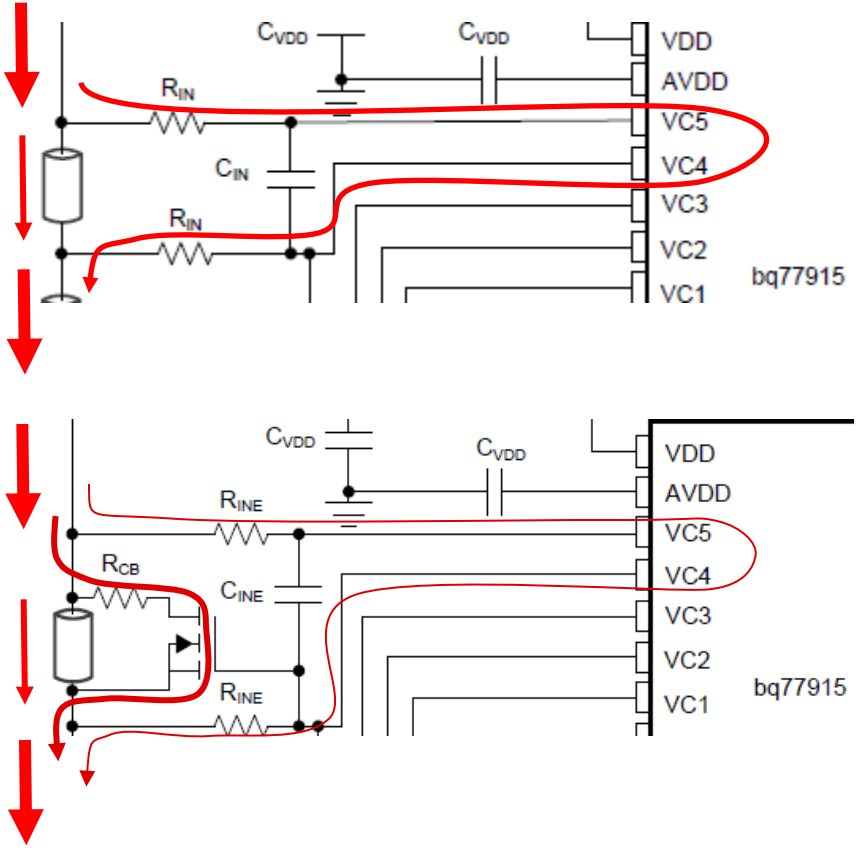
BQ77915: Protection

	Parameter					Delays	Recovery method	Recovery details
	# Steps	MIN	MAX	STEP	UNITS			
OV	64	3000	4575	25	mV	0.5, 1, 2, 4.5 sec	Hysteresis	0, 100, 200, 400 mV
UV	24	1200	3000	100 (< 2.5V), 50 (≥ 2.5V)	mV	1, 2, 4.5, 9 sec	Load removal and hysteresis	0, 200, 400, 800 mV
OW(1)	4	0	400	0 (disabled), 100, 200, 400	nA	4.5 sec	Restore bad VCx	VC_X > 500mV (typ.)
OTD(2)	2	65	70	5	ºC	4.5 sec	Hysteresis	10ºC
OTC(2)	2	45	50	5	ºC			
UTD(2)	2	-20	-10	10	ºC			
UTC(2)	2	-5	0	5	ºC			
OCD1	16	10	85	5	mV	10, 20, 45, 90, 180, 350, 700, 1420 ms	Timer auto-release and load removal, timer auto-release only, load removal only	Timer options: 250ms, 500ms
OCD2	16	20	170	10	mV	5, 10, 20, 45, 90, 180, 350, 700 ms		
SCD	16	40	340	20	mV	400 µs		
OCC	16	5	80	5	mV	10ms	Timer auto-release and load detection, timer auto-release only, load detection only	
V_{OV}-V_{FC}	4	50	200	50	mV		Difference between OV and cell balancing full-charge voltage	
V_{STEP}	4	50	200	50	mV		Difference between cell balancing threshold voltages	

(1): These are not detection thresholds but rather operation configuration
(2): These thresholds are targets based on temperature, but they are dependent on external components that could vary based on customer selection. Circuit is based on 103AT NTC thermistor connected to TS and VSS, and a 10kΩ resistor connected to VTB and TS. Actual thresholds must be determined in mV.

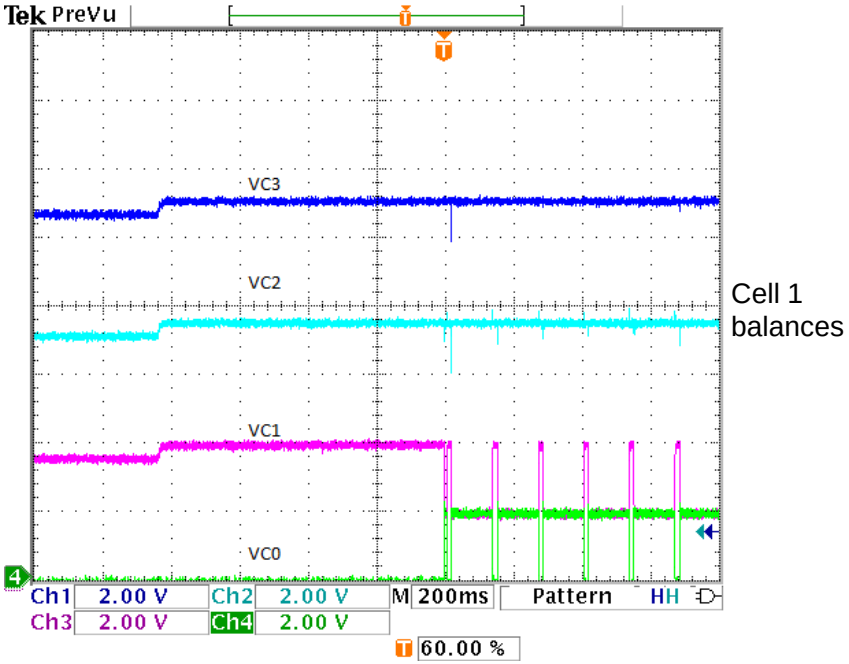
BQ77915 cell balancing mechanism

- Passive balancing
  - Lossy
    - Power dissipated in resistors
    - Done during charge
  - Internal current set by input filter resistors
  - External balancing possible
- Voltage balancing
- Enable signal available

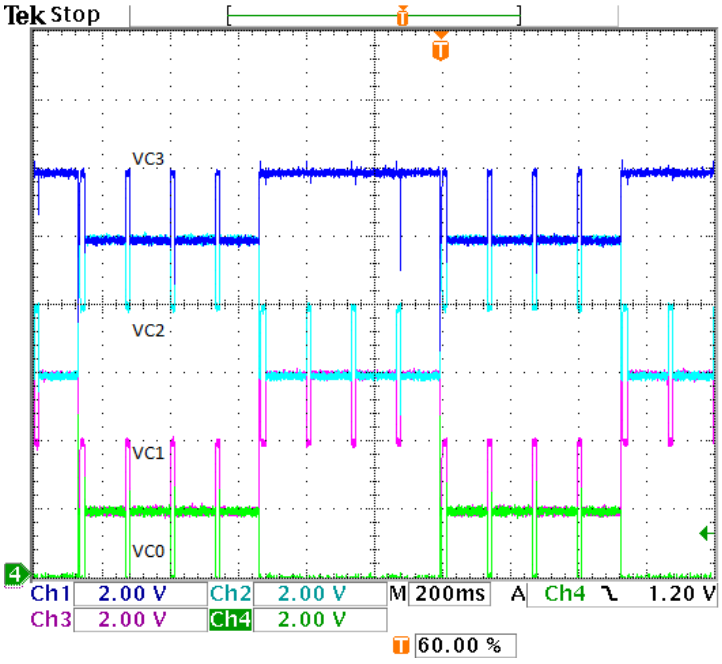


BQ77915 cell balancing

- Duty cycles to measure cells
- Interleaves balancing to avoid adjacent cells



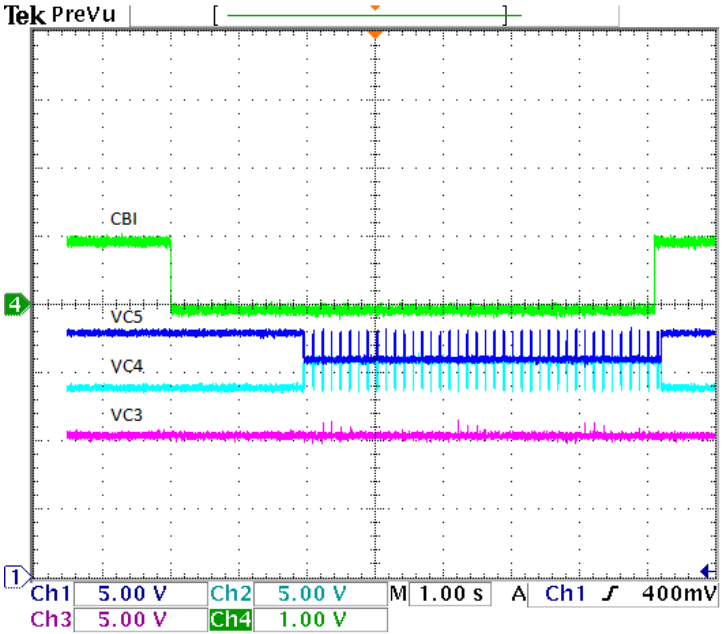
Cell 1 balances



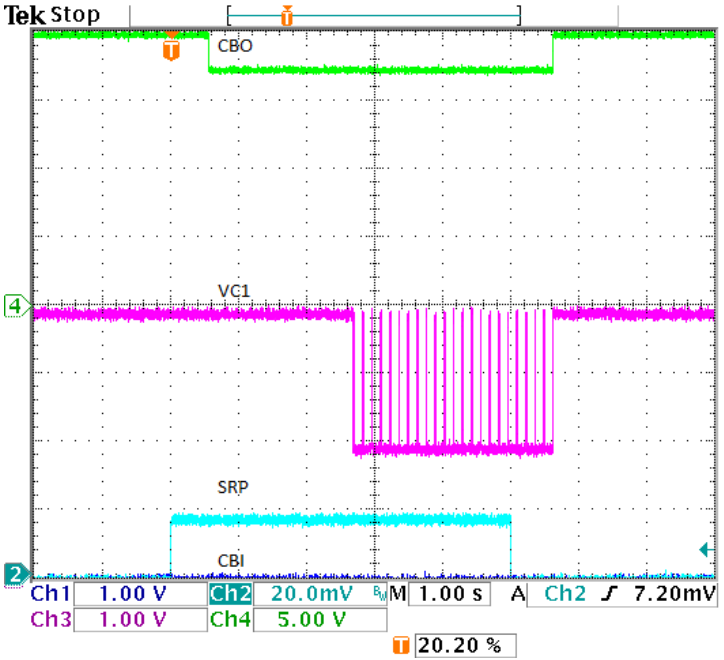
Cells 1, 2, & 3 balance

BQ77915 cell balance enable

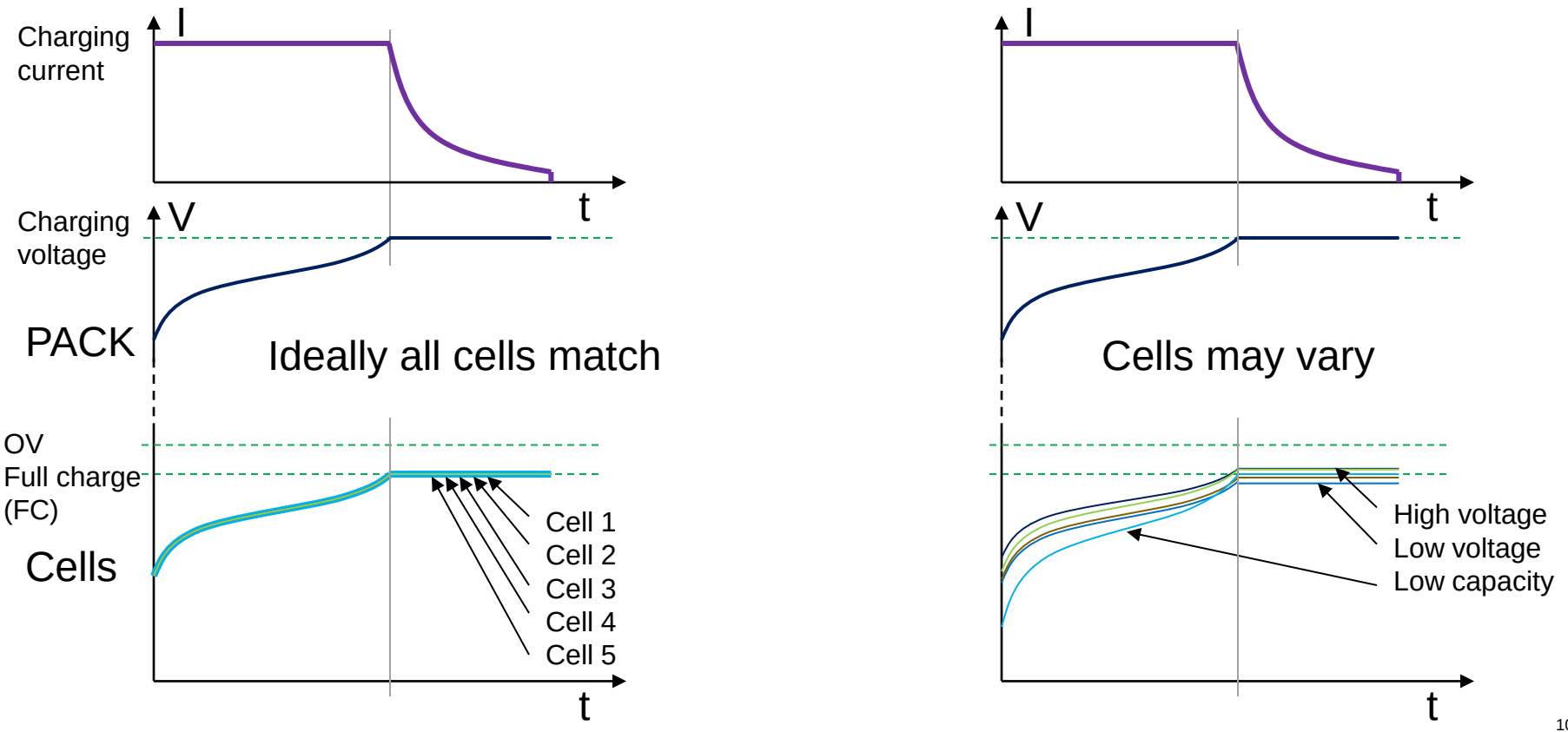
- Enabled through CBI pull down
  - Primarily for configuration and stacking



- Requires current
  - No balance when idle or discharge

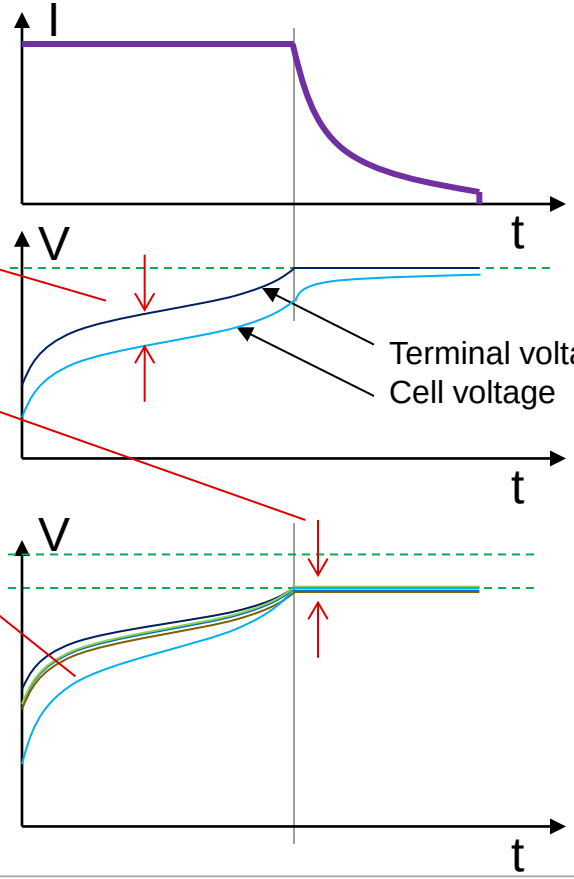


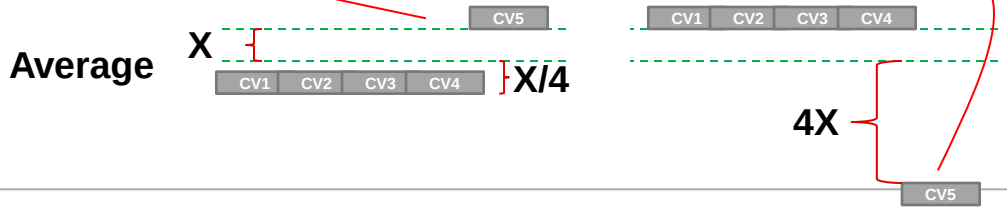
Charging series cells



Voltage cell balancing challenges

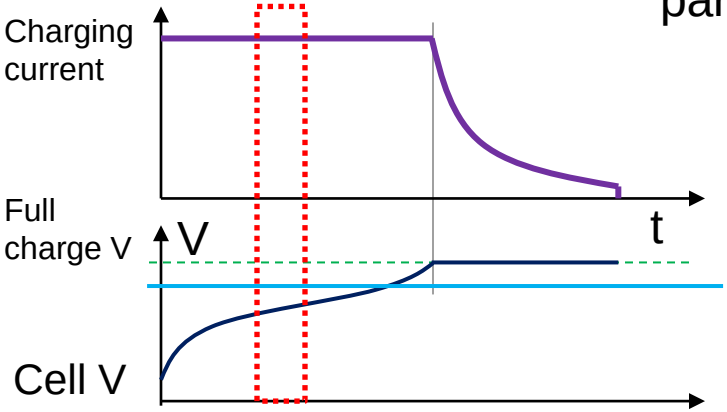
- IR drop
  - May balance wrong cell
- Balancing matched cells
  - If they are the same, don't need it
- Capacity difference
  - Large voltage difference at low voltage
- Voltage excursion to a fixed threshold
  - 1 cell high gives small voltage difference
  - 1 cell low gives large voltage difference



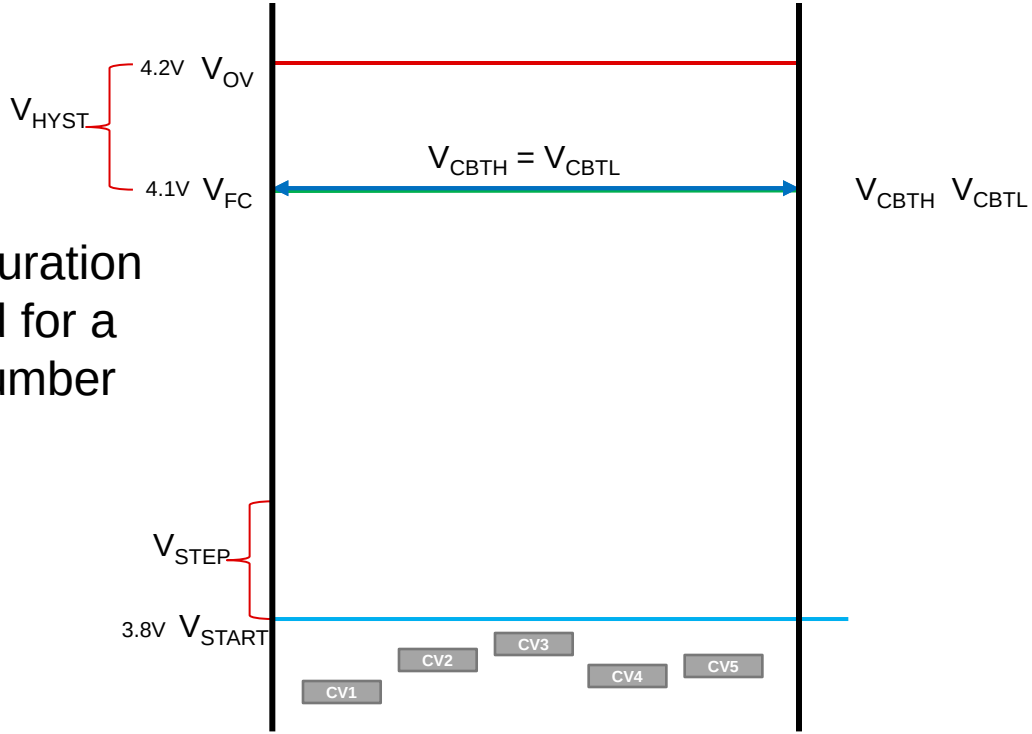


BQ77915 balance algorithm - below balance

- V_{Start} voltage threshold
  - No balance until above threshold
  - Thresholds are parked
  - 3.8 or 3.5V options
- V_{HYST} and V_{STEP} options
  - 50 to 200 mV, 50 mV steps

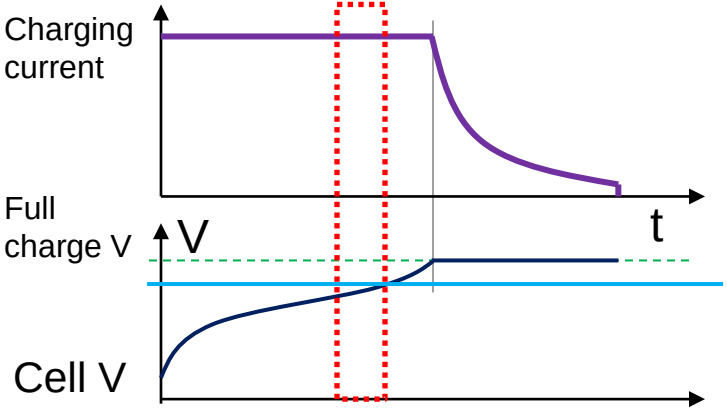


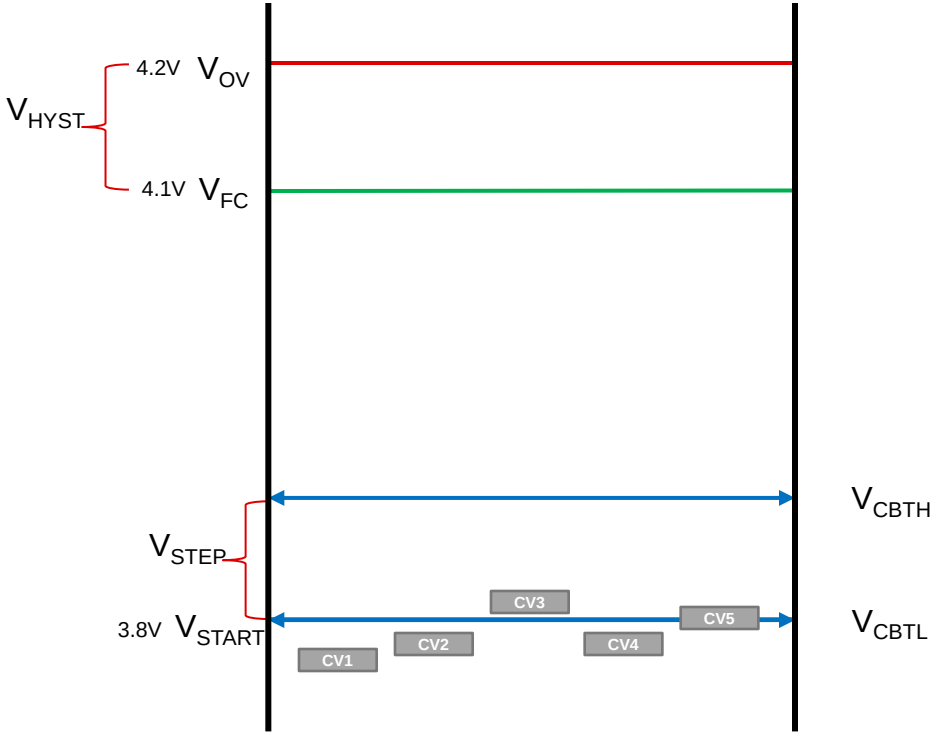
Configuration is fixed for a part number



Balance start region

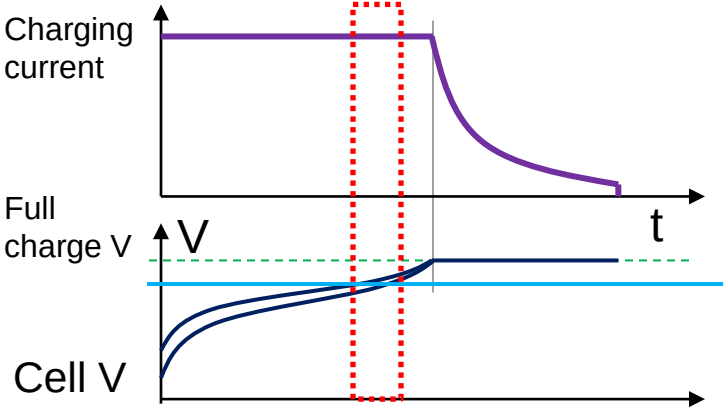
- Cell(s) cross the V_{Start} threshold
  - Thresholds are set:
    - V_{CBTL} at V_{Start}
    - V_{CBTH} at V_{Step} above

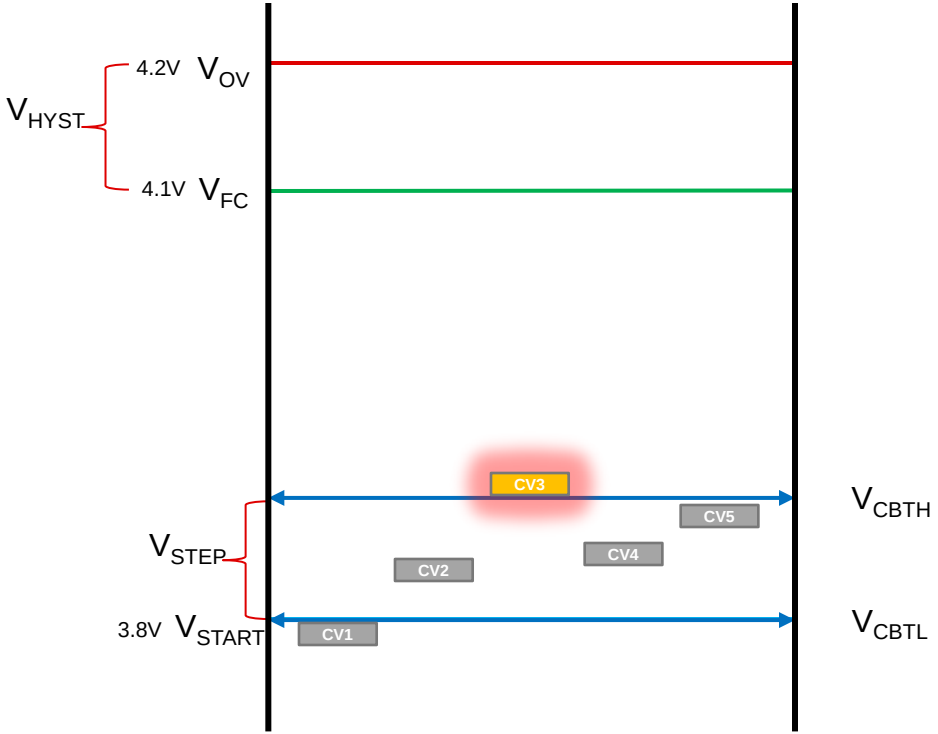




Balance with voltage separation

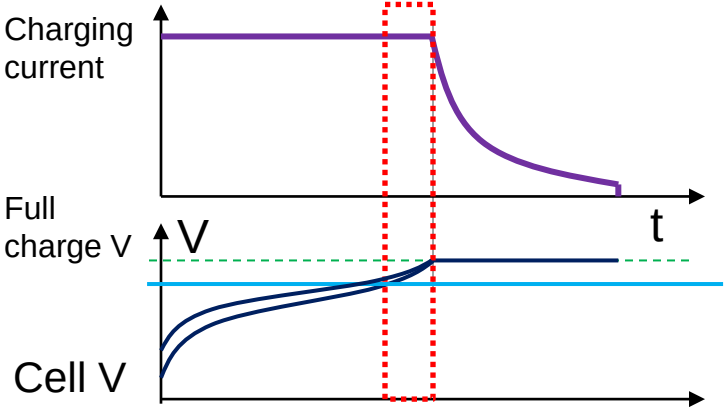
- Cell voltages are widely separated
  - Cell(s) above V_{CBTH}
  - Cell(s) below V_{CBTL}
- Cells above V_{CBTH} balance if:
  - Charge current is present
  - No faults are present

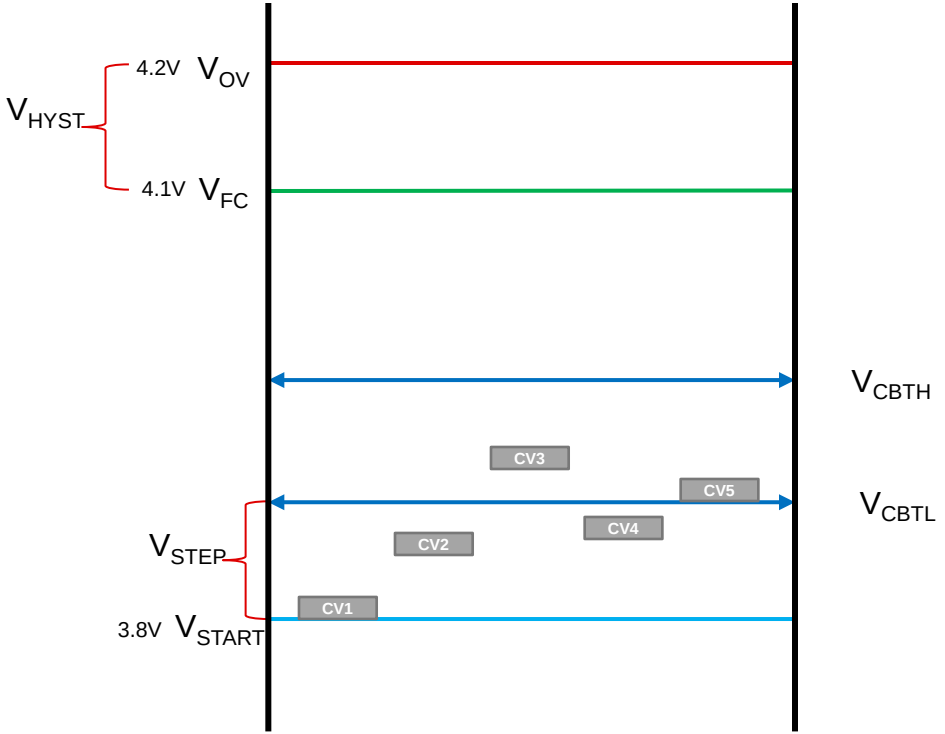




Balance window increment

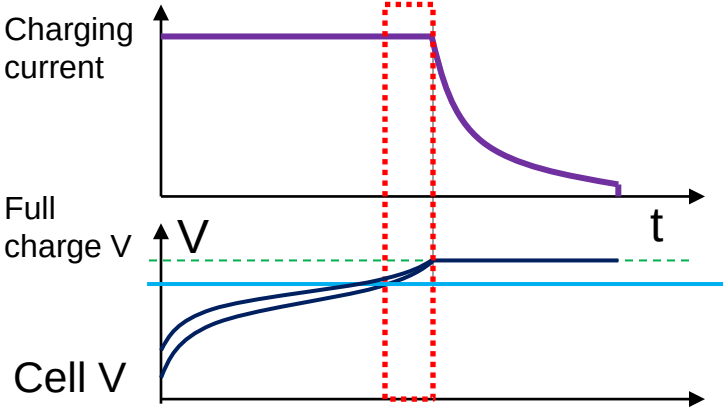
- When cells are above V_{CBTL}, both thresholds increment by V_{STEP}
  - Balancing may stop

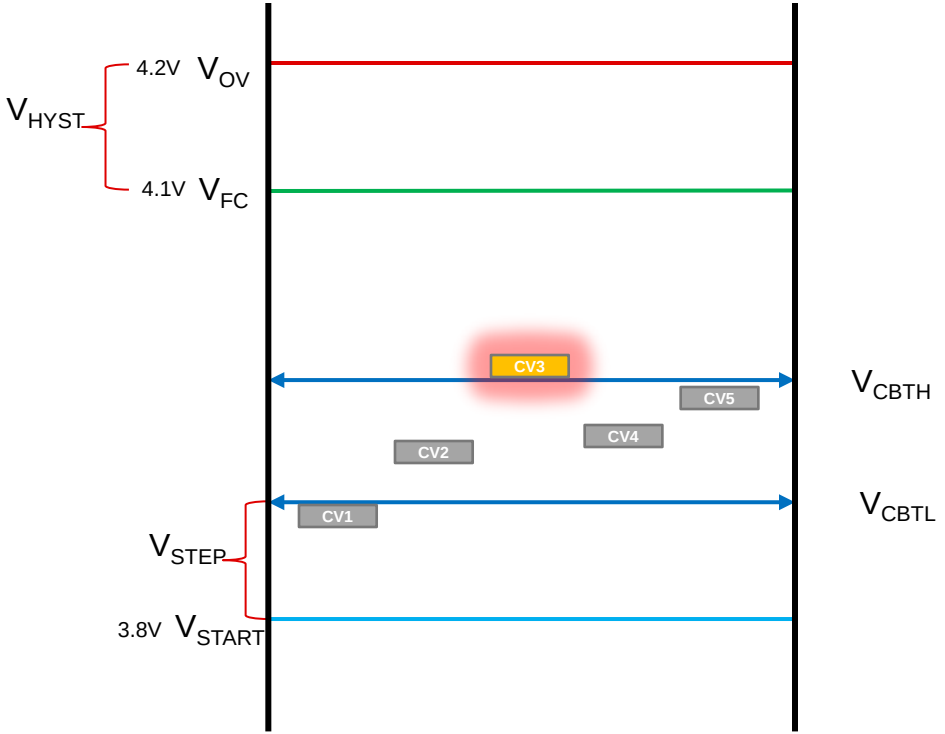




Balance resume

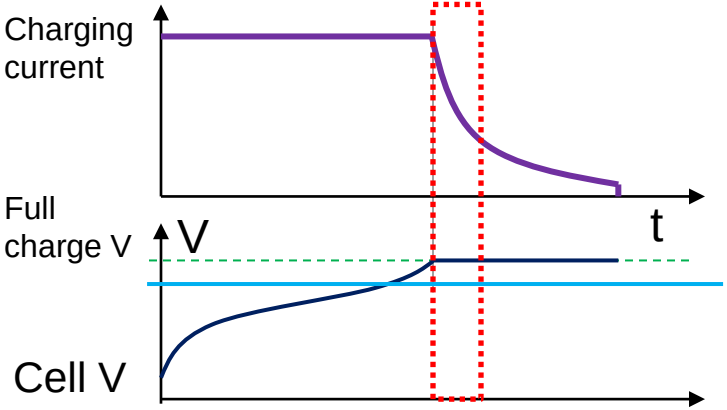
- Balancing resumes if cell voltage separation persists
  - Cell(s) above V_{CBTH}
  - Cell(s) below V_{CBTL}
  - Charge current is present
  - No faults are present

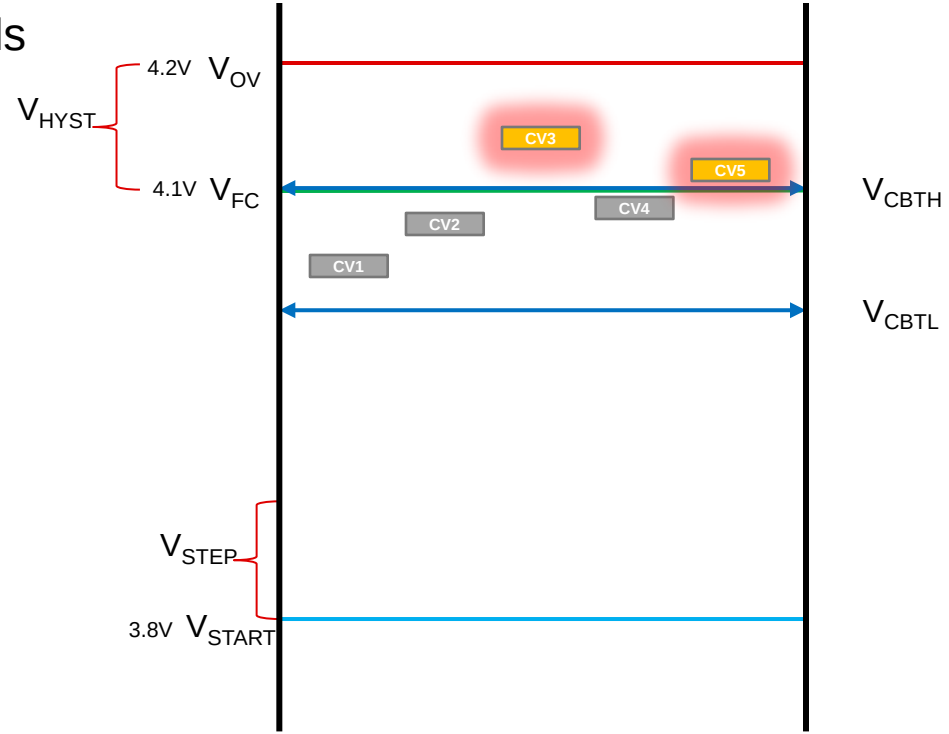




Balance at V_{FC}, full charge

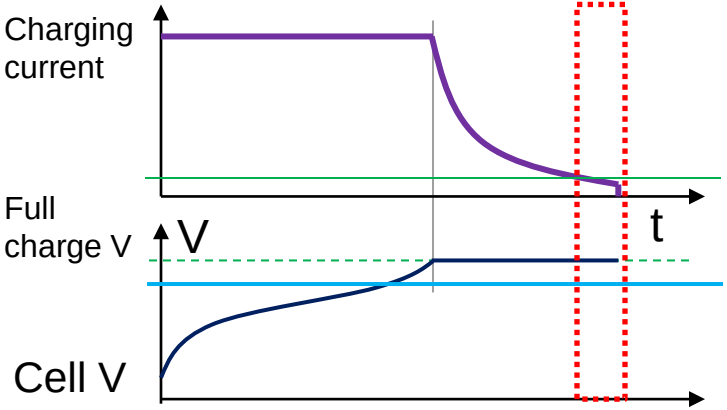
- When V_{CBTH} advances to V_{FC}, all cells above V_{FC} balance
  - Cell(s) can be above V_{CBTL}
  - Charge current is present
  - No faults are present

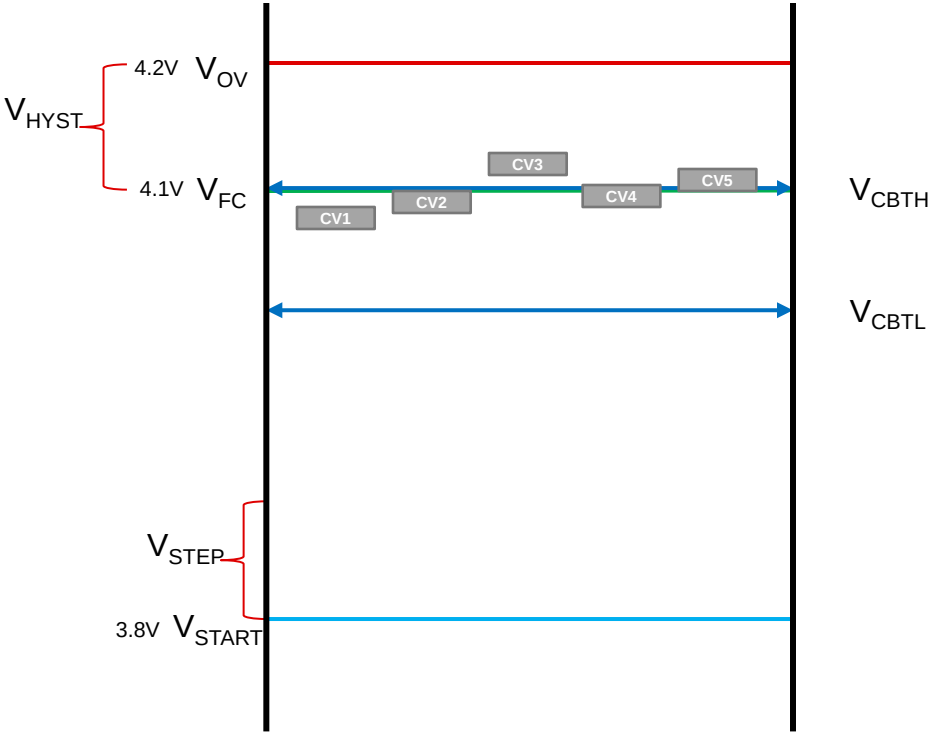




Balance stop

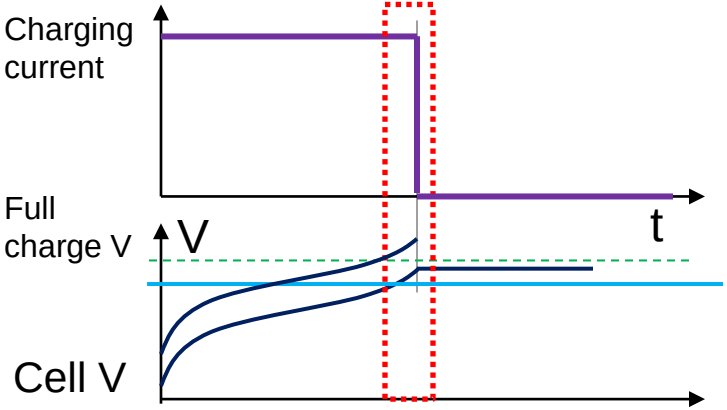
- When current falls below state comparator hysteresis, balance will stop
  - Level will depend on sense resistor

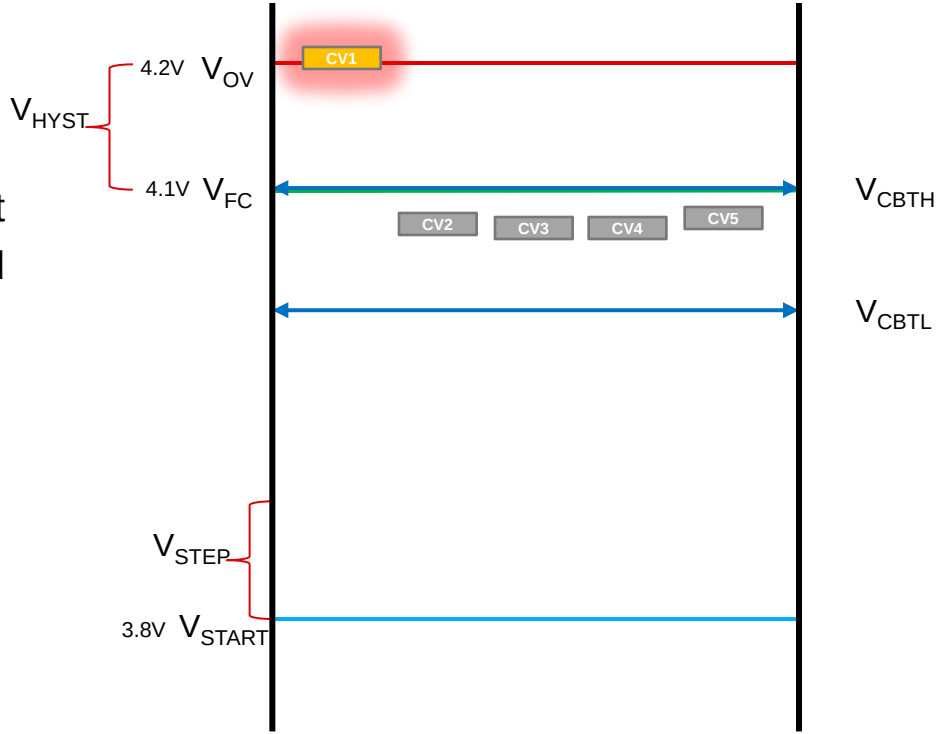




Balance in OV

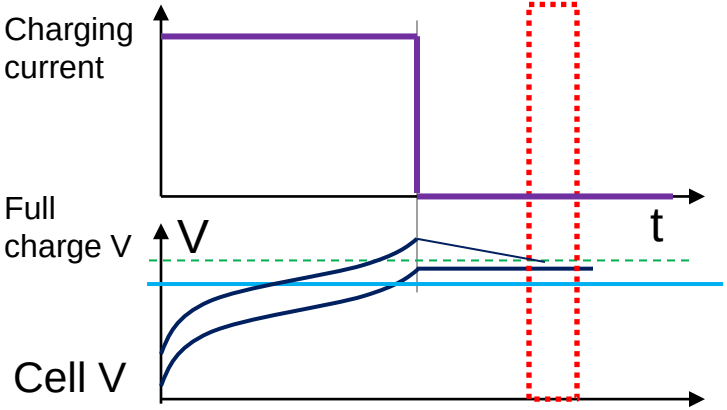
- If a cell reaches V_{OV}
  - CHG FET off from OV
    - Current stops
  - Other balancing stops because of fault
  - The OV cell balances if CBI is enabled

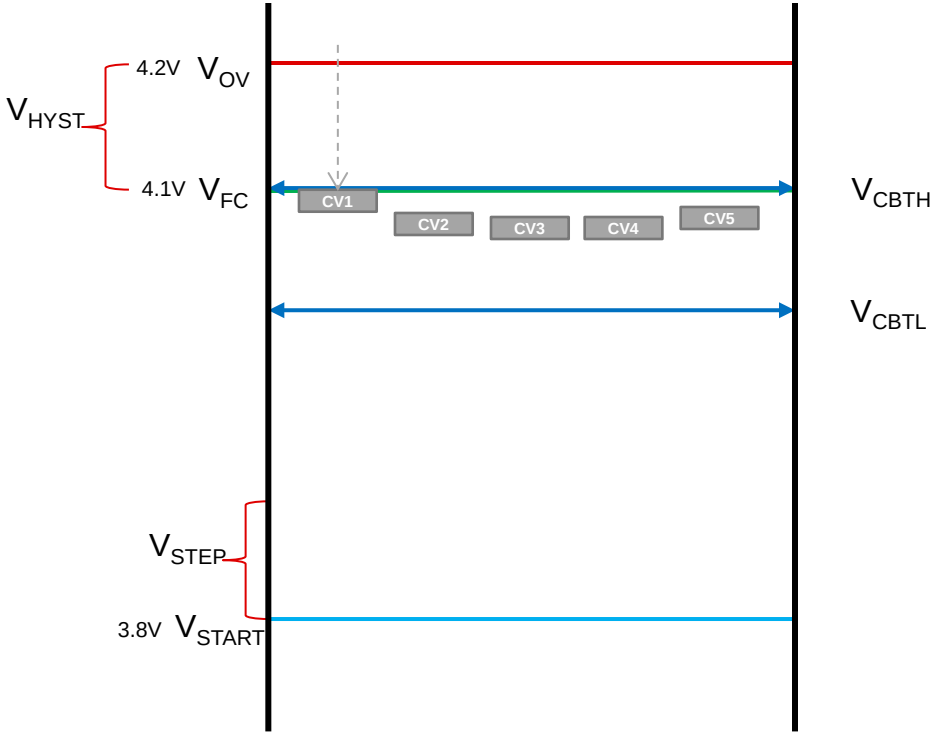




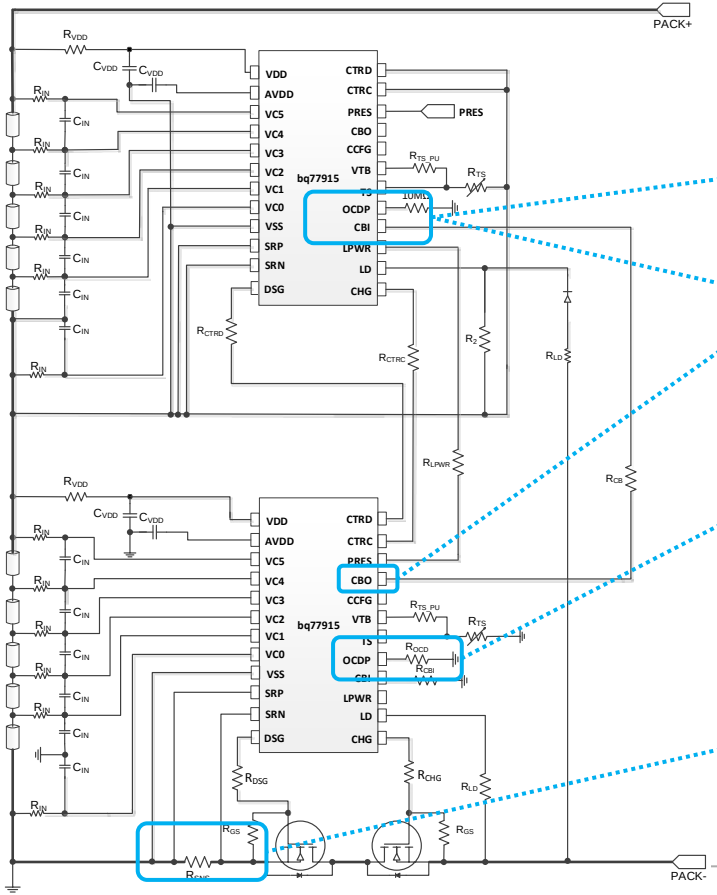
Balance in OV stop

- The OV cell balances until
  - Voltage is reduced to below V_{FC} (or OV hysteresis)
  - CBI is disabled
  - Hibernation





BQ77915: Cell balancing during stacking



OCDP with a 10M resistor indicates device is a top device

CBI from upper device communicates CB enabled / disabled

OCDP must be <500k OR leave floating to indicate device is at bottom of stack

State comparator will monitor Rsense to indicate when charging is occurring where then cell balancing can occur

BQ77915: Power modes

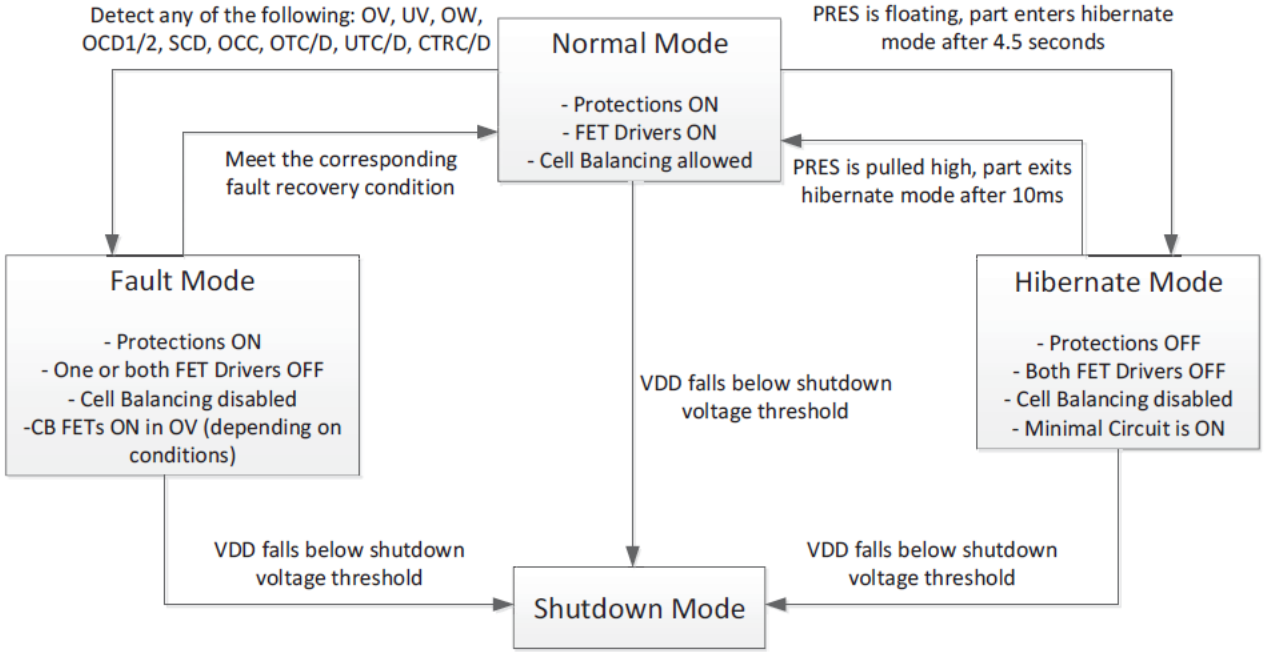
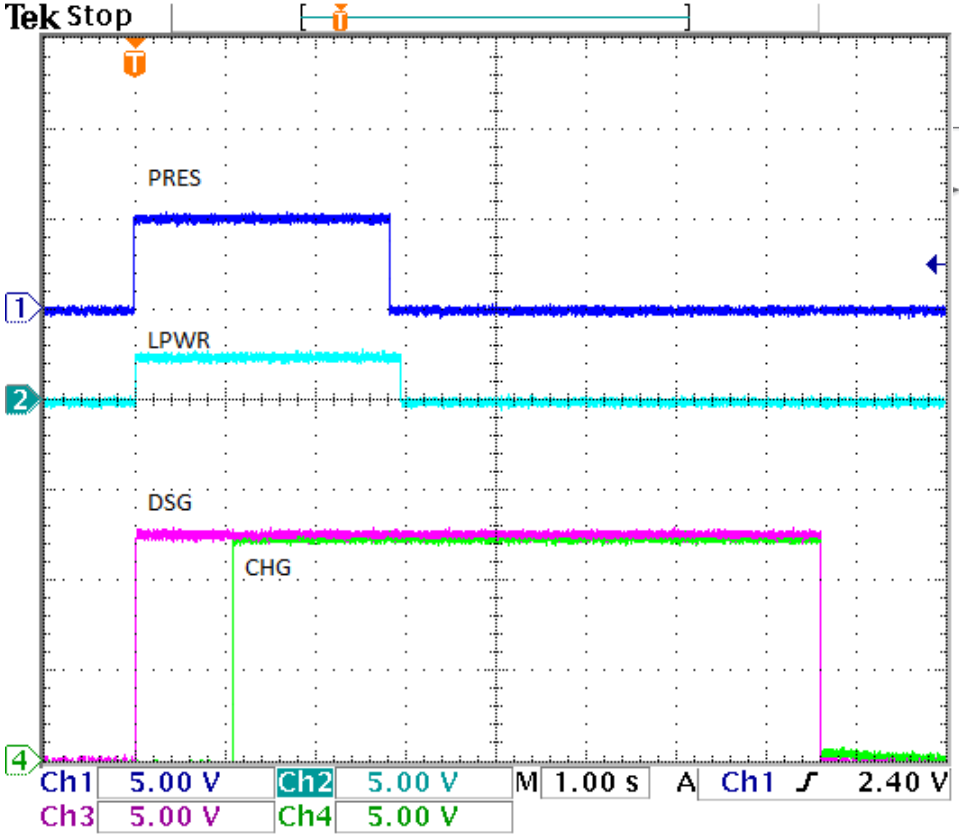
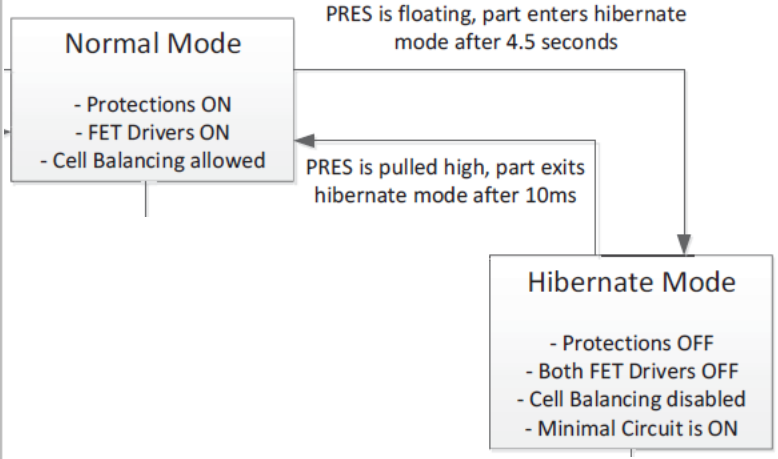


Figure 7: Various Operational Modes

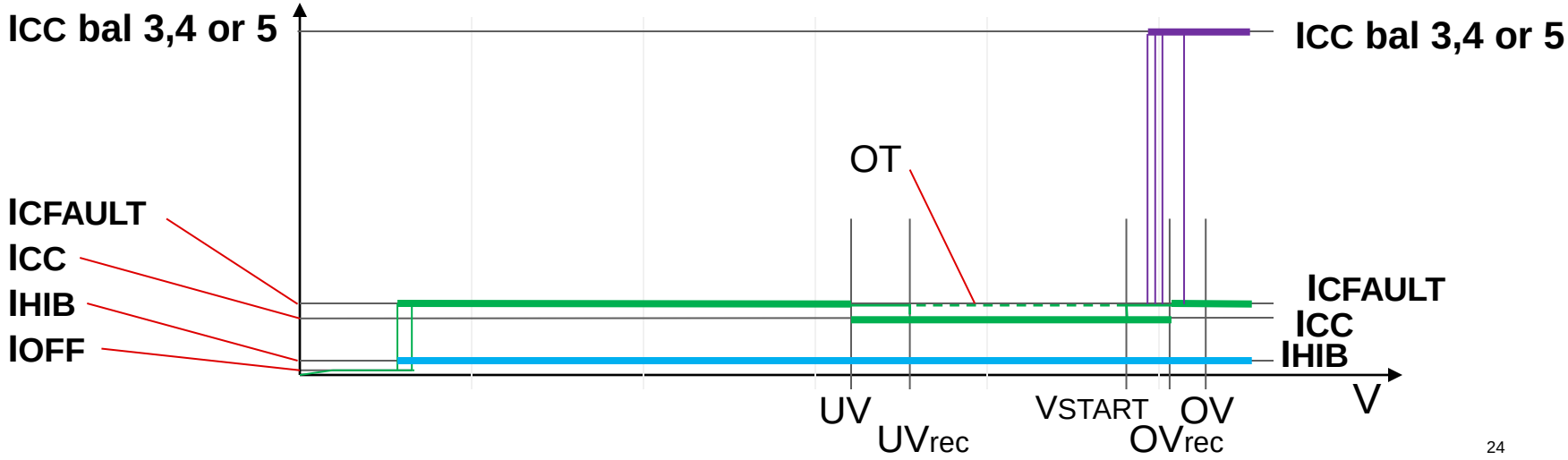
BQ77915: Power modes, normal – hibernate





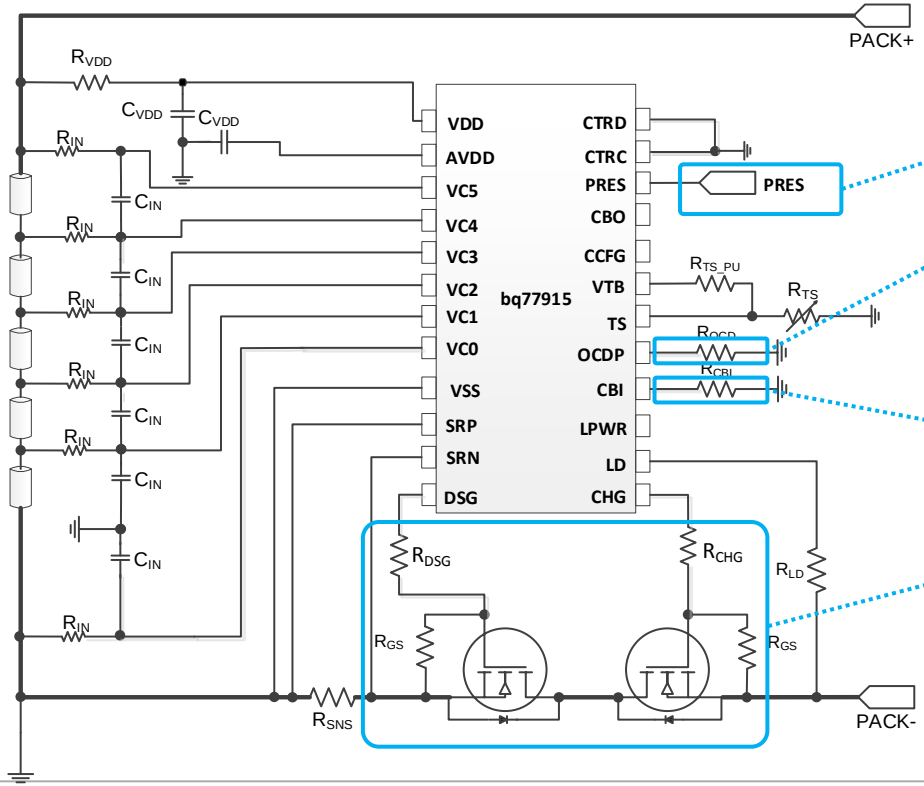
BQ77915: Power mode current

- Supply current does not include load currents
- Supply current will vary with faults and which cell is balancing



Example schematic: 5S (18V)

Low BOM overhead



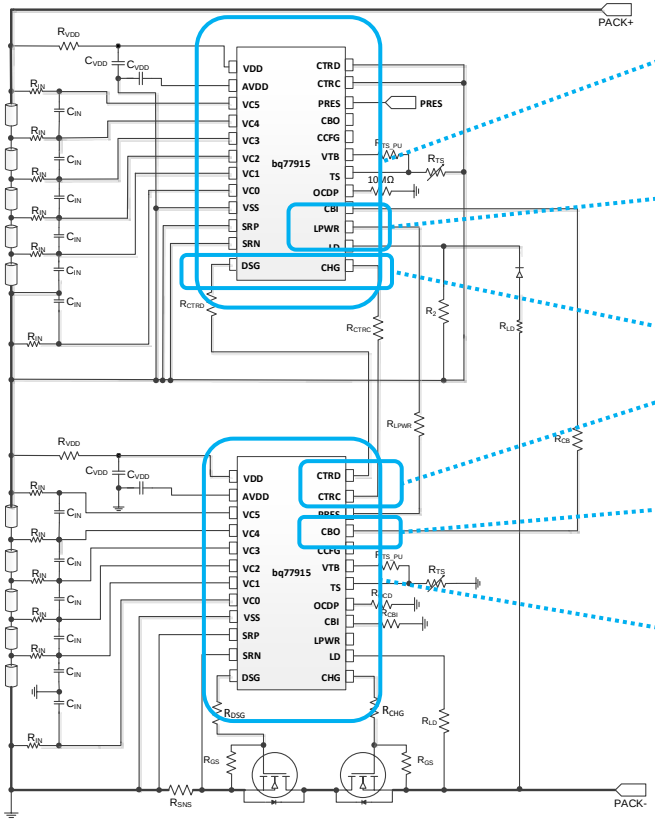
PRES pin is driven high for normal mode operation, left floating for hibernate mode

OCDP pin programs OCD1/2 delay

CBI pin is connected to VSS to enable cell balancing

Directly drives low-side NCH FETs, or high-side FETs with BQ76200

Example schematic: 10S (36V)



Upper device monitors OV, UV, OT and UT

Upper device LPWR pin feeds to lower device PRES input

Upper device CHG, DSG pins feed to lower device CTRC, CTRD inputs

Lower device CBO pin feeds to upper device CBI input

Bottom device monitors OV, UV, OT and UT and current (OCC, OCD1/2, SCD)

Key companion BMS devices

BQ76200	•High voltage battery pack front-end charge/discharge high-side NFET driver
BQ34z100-G1	• Stack-based impedance track fuel gauge
BQ34110	• Multi-chemistry CEDV gas gauge for rarely discharged applications

Bolt on gauge/high side driver to transform from a **basic standalone protected battery pack** to an **advanced smart battery system**

BQ77915 overview

Advanced stackable protector with cell balancing and hibernate mode

Features

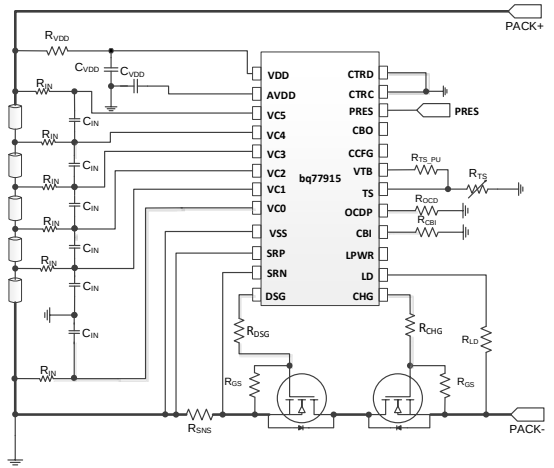
- **3-5S cells per device**
- Supports **from 3S to 20S (or more)** battery packs through **stacking**
- **Low power** consumption (8 µA typ. in normal operation, 2 µA typ. in **hibernate**)
- **Autonomous smart cell balancing**
- Numerous protection features:
  - Overvoltage (**OV**) and undervoltage (**UV**)
  - Charge overcurrent (**OCC**)
  - Discharge overcurrent – 2 levels (**OCD1 & OCD2**)
  - Discharge short circuit (**SCD**)
  - Over-temperature during charging (**OT-C**) and discharging (**OT-D**)
  - Under-temperature during charging (**UT-C**) and discharging (**UT-D**)
  - **Open wire** cell disconnection
  - **Programmable overcurrent delay**
  - **Built-in self-test function for high reliability**
- TI-programmed (EEPROM) – contact TI for specific configurations
- 24-pin TSSOP package

Applications

- Power tools and garden tools
- Handheld vacuum/robotic cleaner/hoverboard
- Low-end eBike

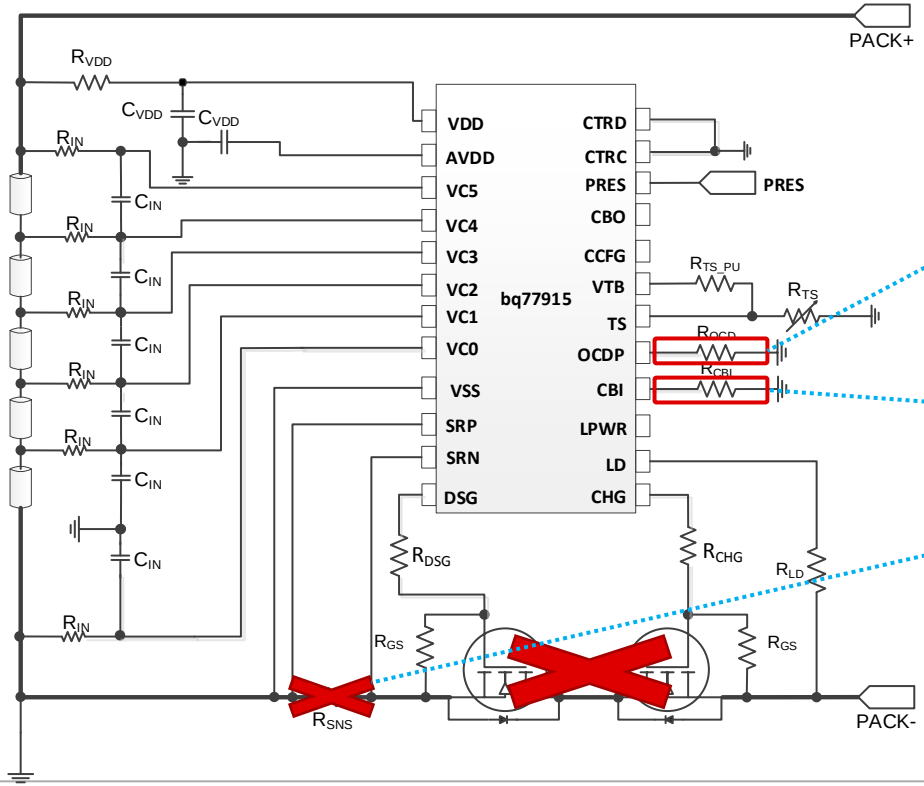
Benefits

- **Simple** to use
- **Cost-effective** for 3S to 20S+ packs due to stackable architecture
- **Extract maximum battery capacity** by charging higher thanks to great overvoltage accuracy and wider temperature protections in charge and discharge and by featuring smart cell balancing scheme
- **Extends storage time** with low quiescent current by enabling hibernate mode
- **Reduced customer production time** due to TI programmed EEPROM



Typical 5-cell application (internal cell balancing)

Cell Balancing without Current Sense



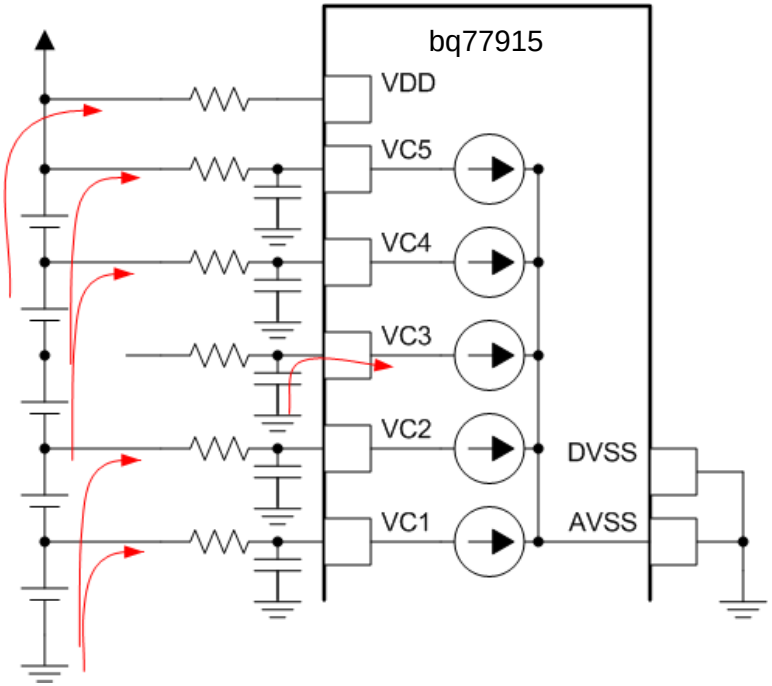
Set OCDP resistor to 10-Mohm

CBI pin can be controlled to enable balancing

Tie SRP and SRN pins together

Open Wire detection

- Each input is loaded with low current sink
  - 100, 200, 400 nA or disabled options
- Higher open wire currents will respond faster but typically more appropriate for larger capacity batteries



Thank you