How to Design Multi-kW Converters for Electric Vehicles

Part 1:	Electric Vehicle power systems
Part 2:	Introduction to Battery Charging
Part 3:	Power Factor and Harmonic Currents
Part 4:	Power Factor Correction
Part 5:	The Phase Shifted Full Bridge
Part 6:	How the PSFB works
Part 7:	A High Power On Board Charger Design
Part 8:	MOSFET gate driver considerations and References

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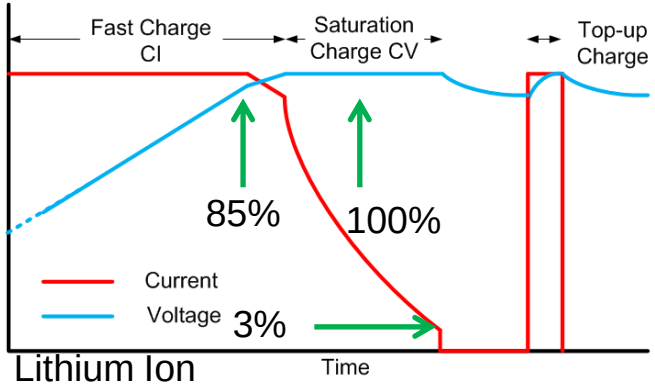
Batteries

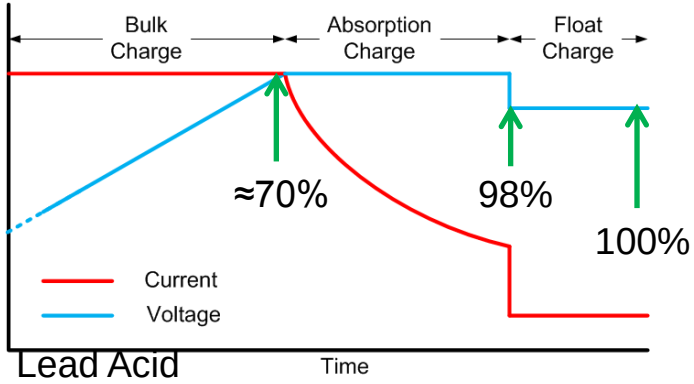
Li-Ion:
- Charged to 4.2V/cell, discharged to 2.5V/cell
- 400V battery discharged to 230V,
- 1.75:1 ratio

Lead Acid:
- Charged to 2.35V/cell, discharged to1.9V/cell
- 12V battery, 14.1V charged, fully discharged to 11.4V
- 1.25:1 ratio

Considerations:
- Tight voltage tolerances and maintaining charged state
- Temperature rise during charging → OTP
- Battery pack cell balancing – not considered here
- Charge Rate vs Charge Time vs Battery Life
- Charger must operate in CI and CV modes



Lithium Ion



Lead Acid

Batteries

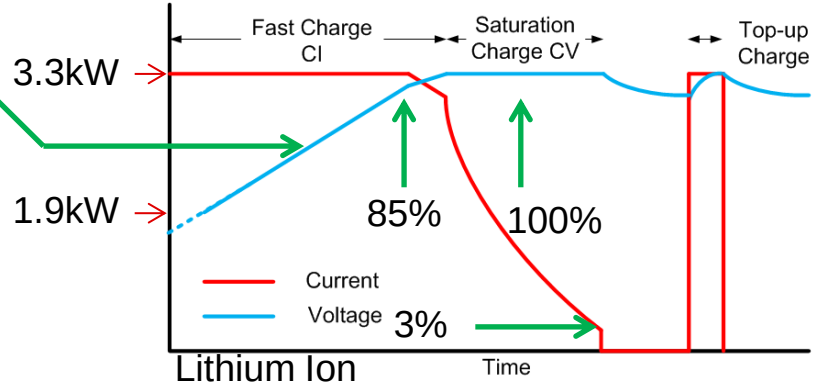
Volt/Time characteristic is approximately Linear
- Power delivered is therefore a linear function of time during CI phase

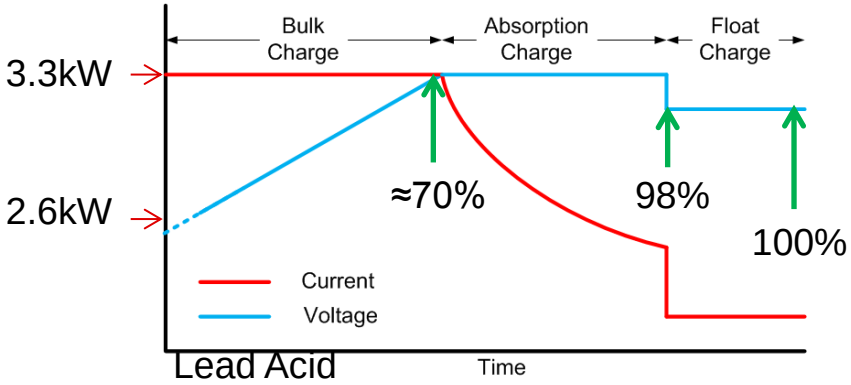
Charging time is long compared to thermal time constants in charger – typ 8 hour charge cycle

Power dissipated in charger is as important as efficiency

Good efficiency needed over wide Vout/Iout range

Not Considered here:
- Initial charging, battery stack management, thermal issues, battery lifetime





Typical Battery Charger Specifications

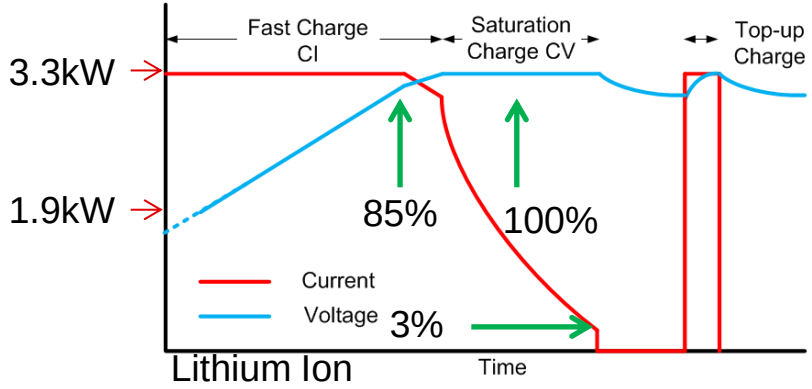
Input: Universal Single Phase Line with PFC

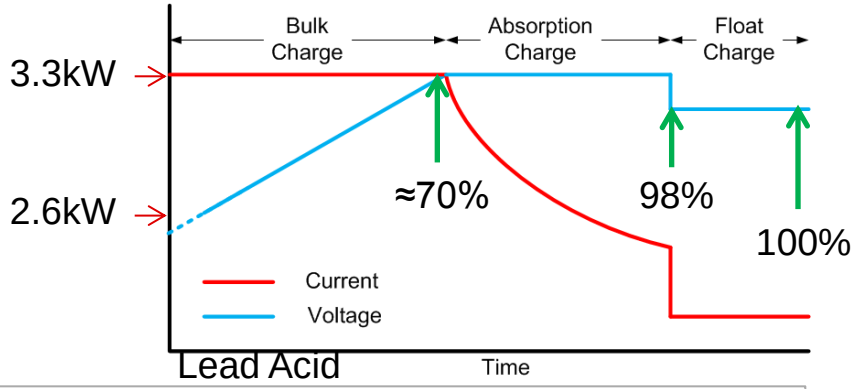
Output Voltage:
- 1.75:1 range (Li-Ion), 400V/230V
- 1.25:1 range (Lead Acid), 14.1V/11.4V

Output Power
- Pout: 3.3kW (typ), increases during charging

CI and CV modes
- ‘Normal’ protections (OCP, OTP etc…)

Topologies
- AC/DC: Boost PFC
- DC/DC: PSFB

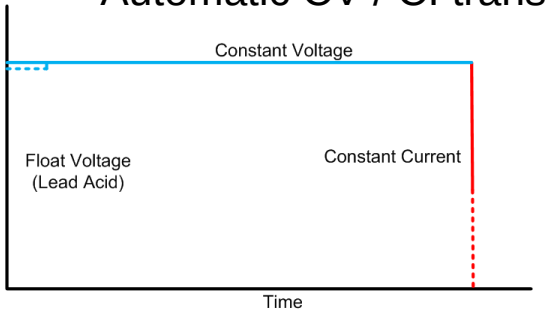




CI / CV operation

Two feedback paths

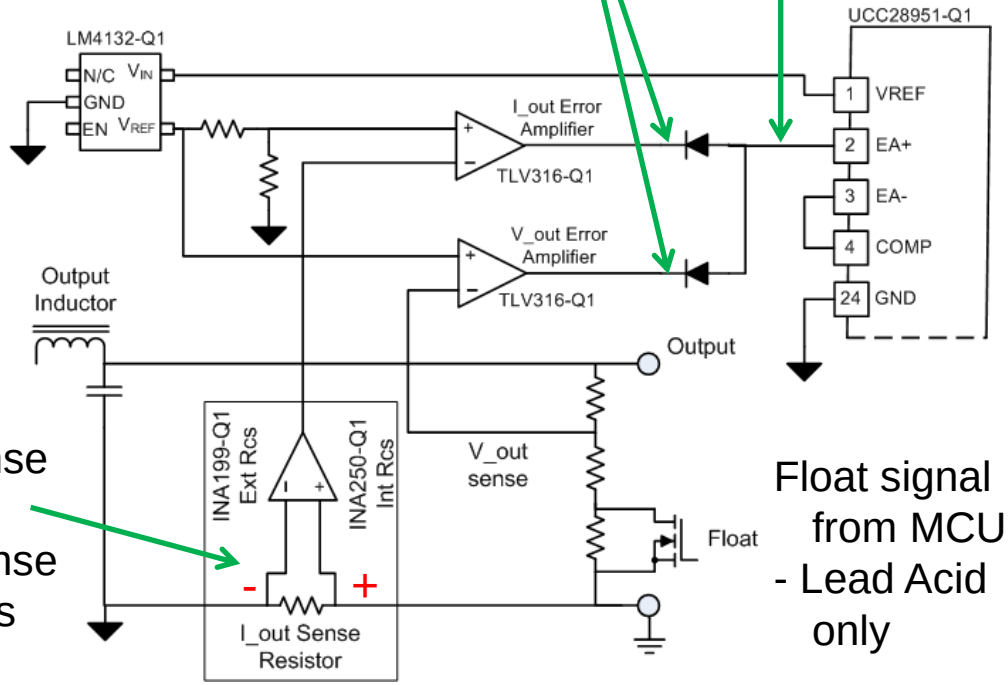
- One measures output current
  - Compare to reference
  - Output error signal (power demand)
- One measures output voltage
  - Compare to reference
  - Output error signal (power demand)
- Diode ‘or’ errors – lowest error ‘wins’
  - Automatic CV / CI transition



Low side sense at 400Vout
High side sense at 12Vout is possible

Lowest error ‘wins’

& Controls the output



Float signal from MCU
- Lead Acid only

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Thank You

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