Topics

• Debugging handout
• Motor+ snubber/flyback diode
• Wiring (more)
• Battery cell balancing
• Power supplies
  – Linear regulator
  – Buck converter
Assume ideal diode, ideal switch, L = 100 μH. Time constant $\tau = 1$ ms. Steady state, constant velocity. Initial rate: $V/L = +8 \times 10^4$ amp/sec.

Diode reverse break down voltage.
Assume ideal diode, ideal switch, \( L = 100 \, \mu\text{H} \).
Time constant \( \tau = 1 \, \text{ms} \).
Steady state, constant velocity.
Assume \( i_{\text{min}} = 5 \, \text{amp} \).
On board: what does this look like electrically (as a schematic)?
Which is ``Star” config?
Which is "Star" config?
Battery Cell Balancing

Cell balancing
Supply waveforms with motor PWM?

- Battery model
- Waveforms on board
- Wiring to reduce voltage resistance effects of wiring
Voltage Regulators

Linear Regulator $V_{\text{IN}} > V_{\text{REG}}$

Boost Converter $V_{\text{IN}} < V_{\text{REG}}$

Buck Converter $V_{\text{IN}} > V_{\text{REG}}$

Power Supplies
Linear Regulator, e.g. KA378R05

LDO = low drop out
Caution: not all linear regulators are low drop out

Power Supplies - linear regulator
LDO linear regulator LM2940

Typical Application

- Required if regulator is located far from power supply filter.
- **C\text{OUT}** must be at least 22 µF to maintain stability. May be increased without bound to maintain regulation during transients. Locate as close as possible to the regulator. This capacitor must be rated over the same operating temperature range as the regulator and the ESR is critical; see curve.
Buck Converter

On-State

Off-State

https://en.wikipedia.org/wiki/Buck_converter

Power Supplies - buck regulator
Buck Converter
LM2678

Power Supplies - buck regulator
Power Supplies - buck regulator
DC-DC Gotchas

• Switch stuck on → 11V LiPo burns out everything
• High peak currents → big conductors, short leads
• 200 kHz radiation into sensor circuits or A/D
• Filter caps: low ESR, low inductance
• Feedback disconnect, noise on feedback line

Lin Reg Gotchas

• Inefficient: need heat sink
• Filter caps: low ESR, low inductance possible instability!
Approximate voltage regulator behavior

Linear Regulator
nominal output 5V,
Approximate voltage regulator behavior

\[ V_{IN} \xrightarrow{I_{in}} \text{regulator} \rightarrow V_{REG} \]

Boost Converter, nominal
Output 5V, \( V_{IN} < V_{REG} \)

\[ V_{REG} \]

\[ V_{IN} \]

\[ I_{in} \]

\[ P_{in} \]

\[ P_{\text{reg}} \]

Power dissipated in regulator
Approximate voltage regulator behavior

Buck Converter, nominal
Output 5V, $V_{IN} > V_{REG}$

Power dissipated in regulator

\[ V_{IN} \quad I_{in} \quad 2 \text{ ohm} \quad V_{REG} \]

\[ V_{REG} \quad V_{IN} \quad P_{in} \]

\[ I_{in} \quad V_{IN} \quad P_{reg} \]

\[ V_{IN} \quad V_{IN} \]
Extra Slides

(boost converter not used in 2019)
Boost Converter - LT1370

Caution: ESR!
Need special cap
Boost Converter

Waveforms on board
(also see boost converter notes)