SMPS Recap

Practical Application

Summary
Project Proposal Feedback
Feedback

- IO
- Motor Drive
- Software
- Sensors
  - Line scan camera(s)
  - encoder/back emf sensor
- Other
  - Bluetooth
- Links
  - Line Scan Camera 1, Line Scan Camera 2
  - Optical Encoder
  - Bluesmirf Chip
Motor Drive

- G_en
  - Needs 5V!!!!
  - Pull down resistor (6.8k good)
- Shoot through protection
  - Logic protection circuit
  - Inverted PWM via code
- General
  - Heatsinks
  - Layout
Software

- **Timing**
  - Timers
  - Main/threads
- **Frequencies**
  - 100s of hz
- **General**
  - Keep it simple!!!
Switching Power Supply
DC-DC Converter

- 3 Cell LiPo Battery provides 11-12V
  - Good for motor, driver chip/ op amp
- We also need 5V?
  - K64F, servo, optical encoder, camera, etc.
- How to consistently get 5V?
  - DC-DC converter!
  - **Step Down**
    - Buck Converter, Linear Regulator
  - Step Up
    - Boost Converter
Boost Converter Circuit

- DC-to-DC switching power supply generating output voltage higher than input
- Uses inductor as storage element
- Efficient, no losses in ideal case
  - Non-idealities: wire resistance, diode and transistor losses
- Capacitive filter to smooth output voltage
Boost Converter Operation

- Inductor charges when switch is closed
  - Energy stored in inductor by magnetic field, current through inductor increases
  - Diode prevents higher output voltage from flowing back to source

Swich Closed
Boost Converter Operation

- Inductor charges when switch is closed
  - Energy stored in inductor by magnetic field, current through inductor increases
  - Diode prevents higher output voltage from flowing back to source
- Inductor discharges when switch is open
  - Magnetic field dissipates, current through inductor decreases
  - Inductor voltage polarity reversed, generating voltage over input
  - Current flows through diode, output capacitor charged
Boost Converter Control

- If switch cycled fast enough, inductor does not fully discharge
- Can do a lot of math, but output voltage is function of duty cycle $D$
  - $V_{out} = \frac{1}{1-D} V_{in}$

Inductor charging

Inductor discharging
Check your Understanding (Live Demo Edition!)

- So I’ve got a boost converter set up...
  - One probe on the switch
  - Another probe on the output
- It’s running at steady-state
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- Which scope waveform is the switch?

Boost Circuit
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- Which scope waveform is the switch?
- Is the output waveform what you expect?
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On the switch waveform...
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Check your Understanding (Live Demo Edition!)

▶ So I’ve got a boost converter set up...
  ▶ One probe on the switch
  ▶ Another probe on the output
▶ A magic chip regulates the output to 12v
  ▶ Duty cycle is adjusted to maintain voltage
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▶ What happens if I...

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A magic chip regulates the output to 12v
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What happens if I...
  ▶ Increase the input voltage?
    ▶ Duty cycle decreases, current decreases
  ▶ Decrease the input voltage?
    ▶ Duty cycle increases, current increases
Buck Converter Circuit (for your reference)

- DC-to-DC switching power supply generating output voltage lower than input
- Similar principle to boost converter
  - \( V_{out} = DV_{in} \)
- Also exists buck-boost converters, where output can be greater than, equal to, or less than the input
got it?

power supply pros, right?
Practical Application
Automatic Feedback Control

- So, what is the switch-controlling magic?
- Feedback control: chip has logic to regulate the voltage on the feedback pin to an internal 1.245v reference
- Pop quiz: what resistor divider do I use to regulate the output to 7.2v?
  - Use 8.2kΩ for the lower resistor

LT1370 Block Diagram

Application circuit
source: datasheet, Linear Technology
Automatic Feedback Control

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Pop quiz: what resistor divider do I use to regulate the output to 7.2v?

- Use 8.2kΩ for the lower resistor
- ... and 39kΩ For the higher resistor
- Why these numbers? Preferred numbers!

LT1370 Block Diagram

Application circuit
source: datasheet, Linear Technology
Let's take a closer look at the output.

- Specifically, note the ripple near the switch toggling.

What issues might this cause?

What do you think are some ways to reduce noise?
Capacitors at High Frequencies (Live Demo Edition!)

- Output smoothing is critical for proper operation, depends on output capacitors
- Not all capacitors are created equal
  - Ceramic, tantalum, aluminum, ...
- Live demo
  - Expect both filters to behave the same:
    \[ \text{Gain} = \frac{1}{\sqrt{1+(\omega RC)^2}}, \ \phi = \text{atan}(-\omega RC) \]
    (gain and phase dependent on only RC)

RC filter demo circuit
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  - As frequency increases, behavior diverges
  - Capacitors become inductive - no longer a good filter
Layout Guidelines

▶ Switching power supplies are layout sensitive
  ▶ Part placement and routing matters!
▶ Tips from the datasheet:
  ▶ Keep output diode, switch pin, output capacitor as short as possible
  ▶ Minimize length and area of switch pin
  ▶ Minimize high frequency current path (switch, diode, capacitor)
▶ Read the datasheet!

Figure 3. Layout Considerations — R Package

Recommended layout
(uses surface-mount components)
source: datasheet, Linear Technology
Summary

- Boost converters step up a DC voltage to a higher DC voltage
- LT1370 uses feedback control to do voltage regulation
- Follow recommended layout guidelines during PCB design

Parts Handout

- Get a battery and charger!
  - Please, keep explosions and flames to a minimum

Office hours for the rest of the section

- PCB deadline coming up in a week! Need help? Get it now!
- Need tips on mechanical fabrication? Get some here!