SMPS Recap

Practical Application

Summary
Switching Power Supply Recap
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

Switch 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 \( D \)
  - \( V_{out} = \frac{1}{1-D} V_{in} \)
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?
Check your Understanding (Live Demo Edition!)

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- Which scope waveform is the switch?
- Is the output waveform what you expect?
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Is the output waveform what you expect?

On the switch waveform…
  ▶ Which part is the switch closed?
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- On the switch waveform...
  - Which part is the switch closed?
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So I’ve got a boost converter set up...
- One probe on the switch
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- A magic chip regulates the output to 12v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \frac{1}{1-D}V_{in}$
- What happens if I...

Boost Circuit
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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
  - \( V_{\text{out}} = D V_{\text{in}} \)
- Also exists buck-boost converters, where output can be greater than, equal to, or less than the input
Questions?

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
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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
Noise (Live Demo Edition!)

- 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?

Boost Circuit
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:
    \[
    Gain = \frac{1}{\sqrt{1+(\omega RC)^2}}, \quad \phi = \text{atan}(-\omega RC)
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    (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

RC filter demo circuit

Ducky (UCB EECS)  Mechatronics Design Lab  11 & 12 Feb 2015 (Week 4)
Practical Application

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!