EECS 192: Mechatronics Design Lab

Discussion 4: Project Proposal Feedback & Power Systems

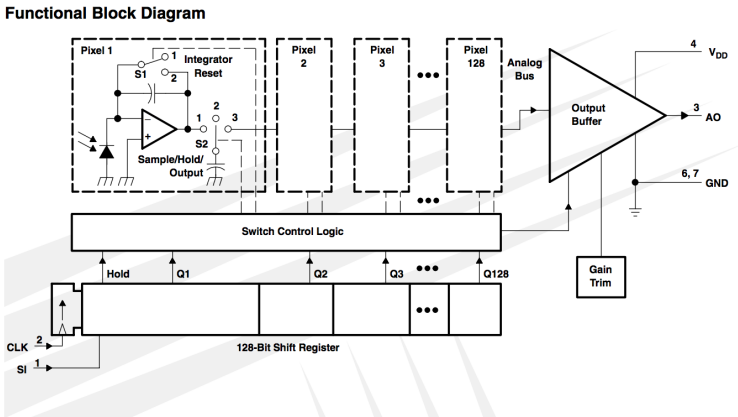
GSI: Ducky Lin, Derek Chou

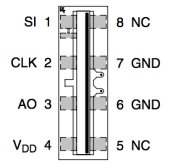
7 & 8 Feb 2017 (Week 4)

Project Proposal Feedback

IO

- Beaglebone Blue pins
- Sensors
  - Line scan camera(s)
  - encoder/ back emf sensor
- Links
  - Line Scan Camera 1, Line Scan Camera 2
  - Optical encoder coming soon

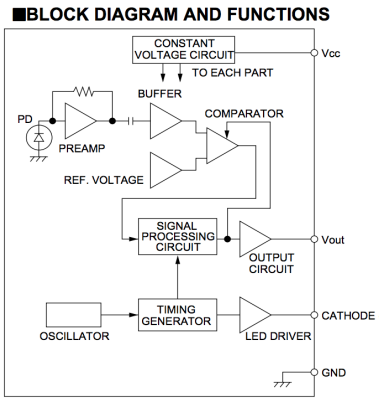




NC – No internal connection

Package Drawing is Not to Scale

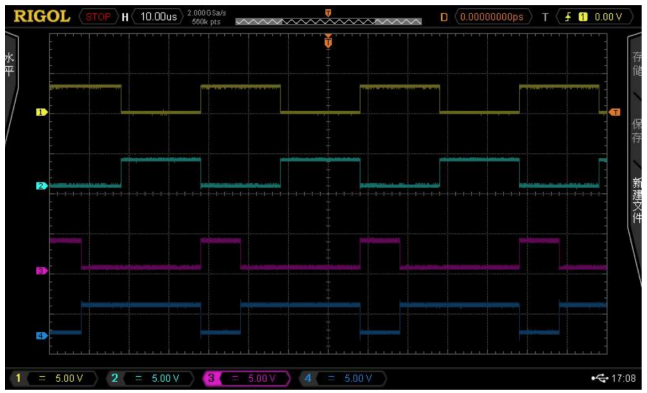
TSL1401CL



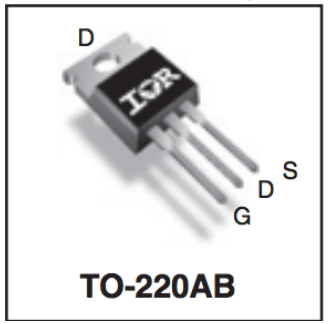
Optical Encoder

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



Complimentary PWM

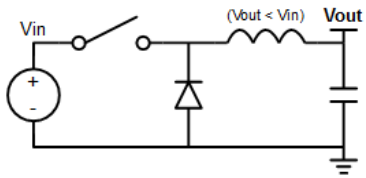


Mosfet Package

Switching Power Supply

DC-DC Converter

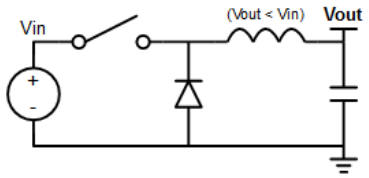
- 3 Cell LiPo Battery provides 11-12V
  - Good for motor, driver chip/ op amp
- We also need 5V?
  - Servo, optical encoder, camera, etc.
- How to consistently get 5V?
  - DC-DC converter!
  - **Step Down**
    - Buck Converter, Linear Regulator
  - Step Up
    - Boost Converter



Buck Converter

Buck Converter Circuit

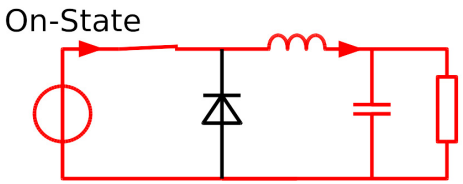
- DC-to-DC switching power supply generating output voltage lower than input
- Uses inductor as storage element
- Efficient, no losses in ideal case
  - Non-idealities: wire resistance, diode and transistor losses
- Capacitive filter to smooth output voltage



Buck Converter

Buck Converter Operation

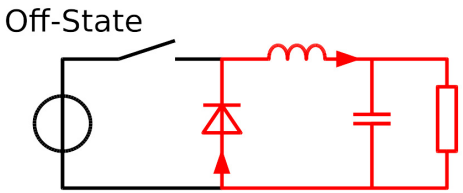
- Inductor charges when switch is closed
  - Energy stored in inductor by magnetic field, current through inductor increases
  - Diode does nothing here



Switch Closed

Buck Converter Operation

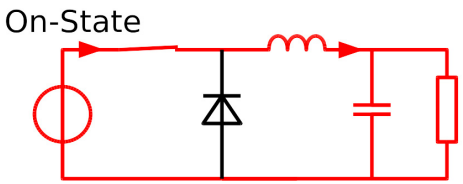
- Inductor charges when switch is closed
  - Energy stored in inductor by magnetic field, current through inductor increases
  - Diode does nothing here
- Inductor discharges when switch is open
  - Magnetic field dissipates, current through inductor decreases
  - Inductor voltage polarity reversed, generating voltage over input
  - Current flows through diode, output capacitor charged



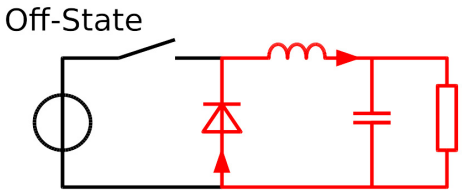
Switch Open

Buck Converter Control

- If switch cycled fast enough, inductor does not fully discharge
- Output voltage is function of duty cycle D and efficiency η (link)
  - $V_{out} = \eta D V_{in}$



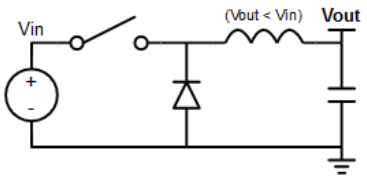
Inductor charging



Inductor discharging

Check your Understanding

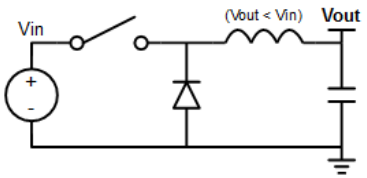
- I've got a buck converter set up...
- A magic chip (LM2678) regulates the output to 5v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \eta D V_{in}$
- What happens if I...



Buck Circuit

Check your Understanding

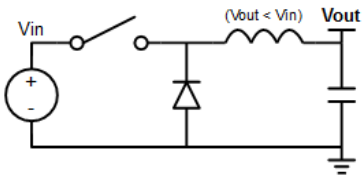
- I've got a buck converter set up...
- A magic chip (LM2678) regulates the output to 5v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \eta D V_{in}$
- What happens if I...
  - Increase the input voltage?



Buck Circuit

Check your Understanding

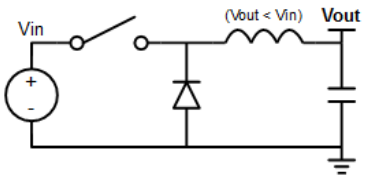
- I've got a buck converter set up...
- A magic chip (LM2678) regulates the output to 5v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \eta D V_{in}$
- What happens if I...
  - Increase the input voltage?
    - Duty cycle decreases, current decreases



Buck Circuit

Check your Understanding

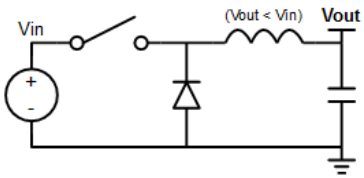
- I've got a buck converter set up...
- A magic chip (LM2678) regulates the output to 5v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \eta D V_{in}$
- What happens if I...
  - Increase the input voltage?
    - Duty cycle decreases, current decreases
  - Decrease the input voltage?



Buck Circuit

Check your Understanding

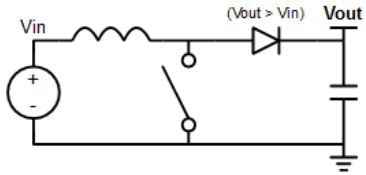
- I've got a buck converter set up...
- A magic chip (LM2678) regulates the output to 5v
  - Duty cycle is adjusted to maintain voltage
  - Remember: $V_{out} = \eta D V_{in}$
- What happens if I...
  - Increase the input voltage?
    - Duty cycle decreases, current decreases
  - Decrease the input voltage?
    - Duty cycle increases, current increases



Buck Circuit

Boost Converter Circuit (for your reference)

- DC-to-DC switching power supply generating output voltage *lower* than input
- Similar principle to buck converter
  - $V_{out} = \frac{1}{1-D} V_{in}$
- Also exists buck-boost converters, where output can be greater than, equal to, or less than the input



Boost Converter

Questions?

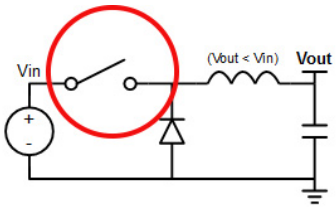
got it?

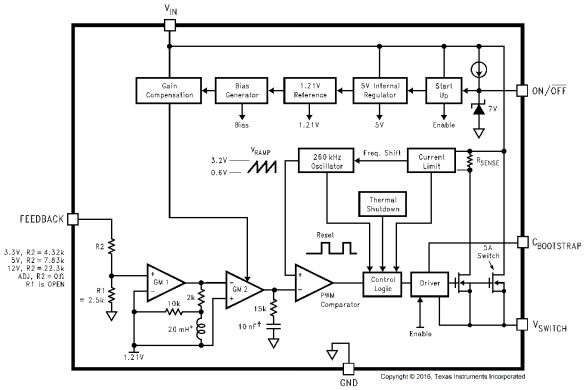
power supply pros, right?

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 $V_{FB} = 1.21V$ reference
- $V_{out} = V_{FB}(1 + \frac{R_2}{R_1})$
- $R_1 \approx 1k\Omega$ recommended





LM2678 Block Diagram

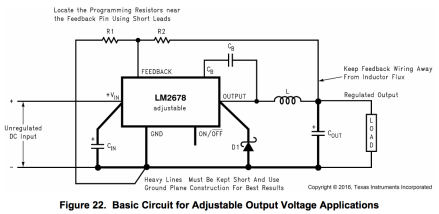
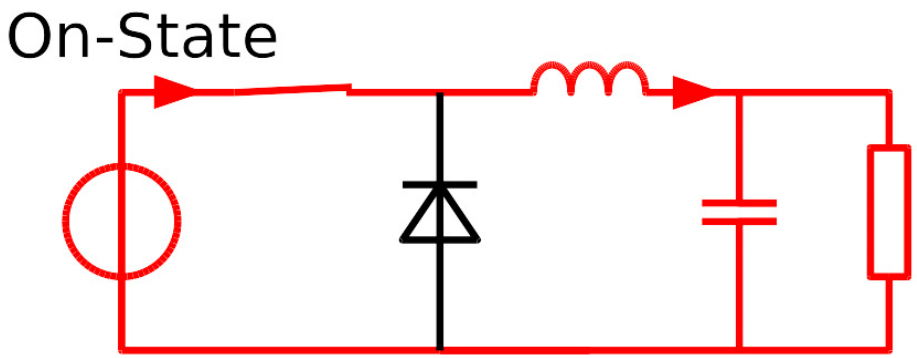


Figure 22. Basic Circuit for Adjustable Output Voltage Applications

Application circuit

Problematic?

- What happens if the switch get stucks in the closed position?



Boost Circuit

Layout is Important!!!

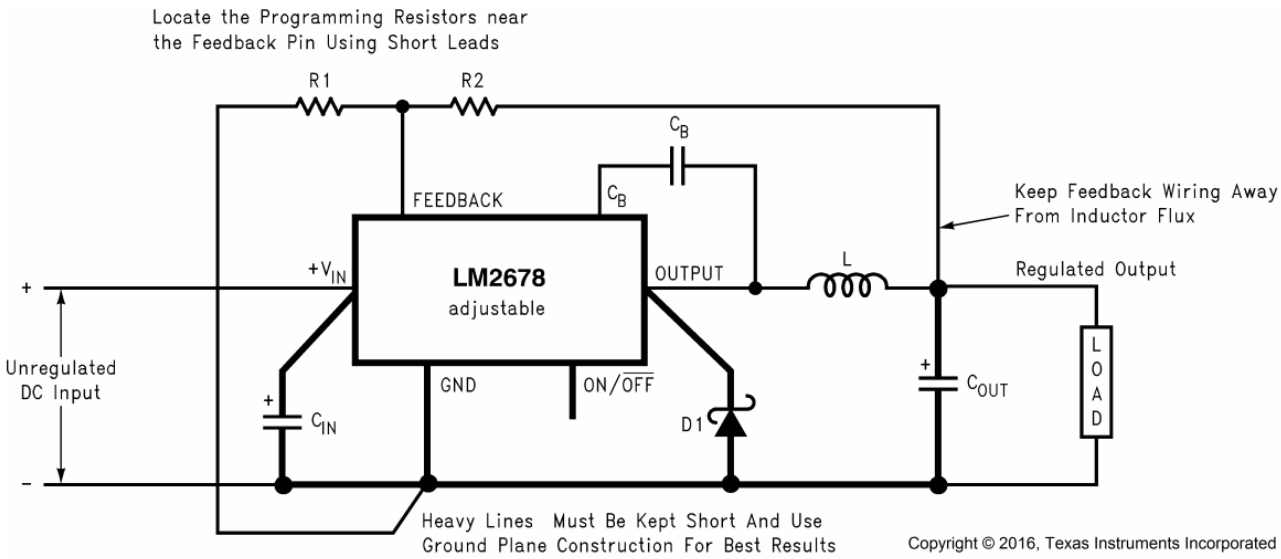


Figure 22. Basic Circuit for Adjustable Output Voltage Applications

Circuit

Layout Guidelines

- Switching power supplies are layout sensitive
  - Part placement and routing matters!
- Tips from the datasheet:
  - Keep diode and filter capacitor connections as short as possible
  - Minimize high frequency current path (switch, diode, capacitor)
- Read the datasheet!

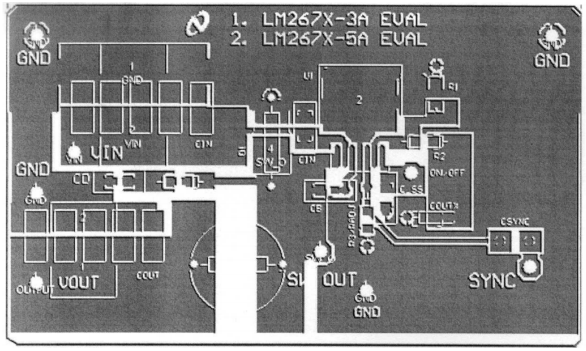
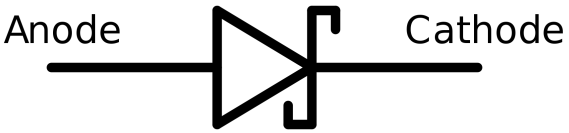


Figure 24. Top Layer Foil Pattern of Printed-Circuit Board

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

Supporting Componenets

- Capacitors
  - Ceramic, film, polarized (tantalum, aluminum, etc.)...
- Diodes
  - Shottky
- Inductor
  - Toroid



Toroid Inductor

Summary

Summary

- Buck converters step down a DC voltage to a lower DC voltage
- LM2678 uses feedback control to do voltage regulation
- Follow recommended layout guidelines during PCB design
- Very difficult to make work on perfboard- just design it on the pcb.

Parts Handout Office hours for the rest of the section