Module 5

Lecture: Battery and Voltage Regulation

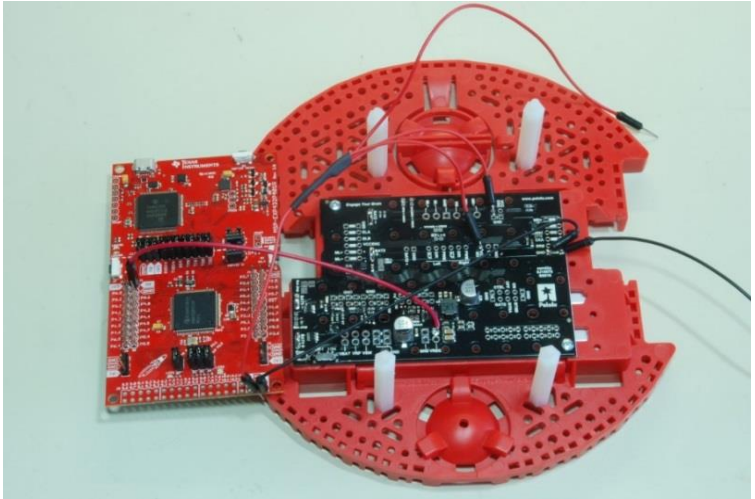
Battery and Voltage Regulation

You will learn in this module

- Power sources - Batteries
  - Voltage, V (volts)
  - Current, I (amps)
  - Energy, E (joules)

- Voltage regulation (Constant Voltage)
  - Purpose
  - Types
  - Circuits

- Performance measurements (Lab)
  - Monitoring Battery Voltage, Current, Storage
  - Voltage regulation (DC voltmeter)
  - Noise (AC voltmeter, oscilloscope)



Motor Driver and Power Distribution board Powering TI's Launchpad Development board

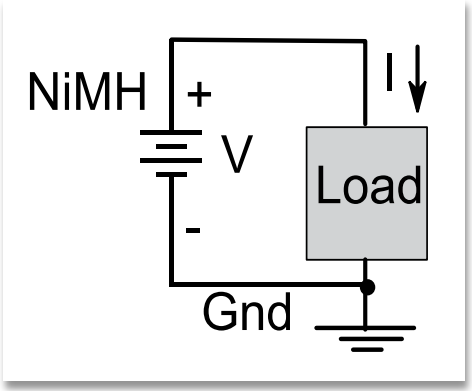
Power and Energy

Sources of Power

- 120/220 VAC 50/60 Hz
  - Needs an AC to DC converter
  - Needs a voltage regulator
- DC power supply (+5V on USB, +12V used in automotive)
  - USB power used to power TI‘s Launchpad (5V)
- Battery
  - Need to drive robot autonomously
  - Provide power to TI’s Launchpad, motors, sensors
  - Voltage, energy, size, weight
  - Needs a regulator for **constant voltage**

- Energy harvesting like solar or EM field pickup

Power = V*I (watts)
Energy = V*I*time (Joules)



Power Budget

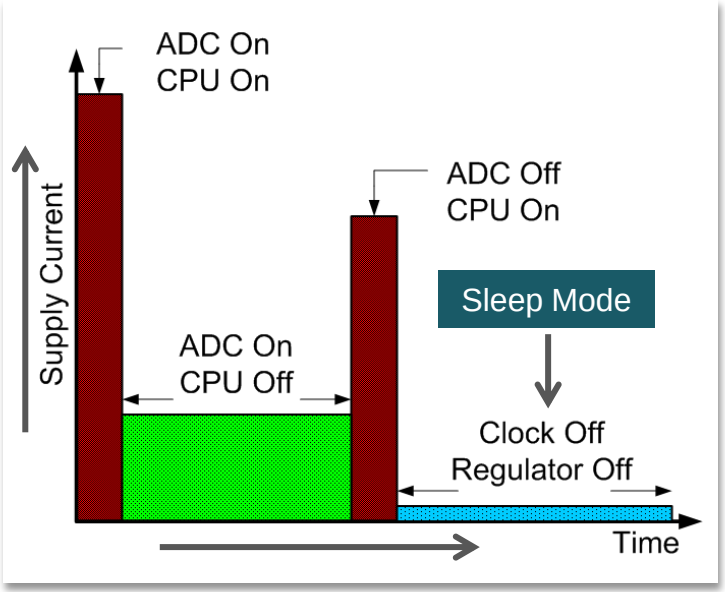
Energy = V*I*time
Storage = I*time (amp-hr)

Battery-powered embedded system

- Power Budget => Battery Life
  Average Current < Energy Storage/t_{life}

- Save Power :
  Reduce voltage, Sleep modes, Clock, CPU,

TI's Launchpad MSP432 Low Power MCU



MSP432 : Supply current under different modes of operation

Batteries

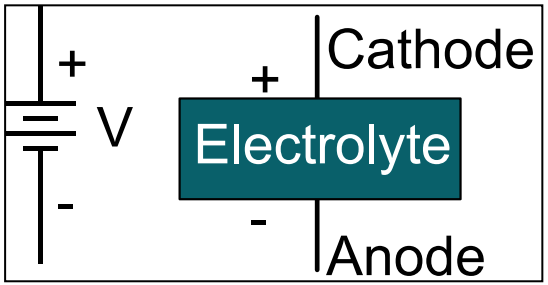
Types of batteries

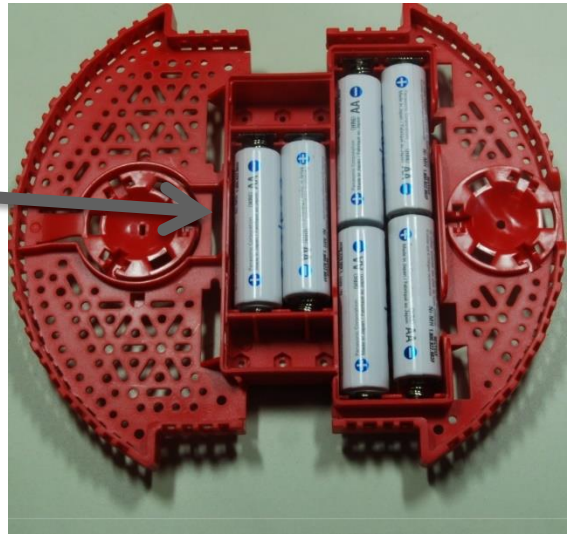
- Primary (not re-usable)
  - Heavy duty
  - Alkaline
  - Lead-acid
  - Lithium

- Secondary (rechargeable)
  - NiCad
  - NiMH
  - Li-ion
  - Supercap

Energy = V*I*time
Storage = I*time (amp-hr)

Inside a Battery





Batteries

AA Sized Batteries

Energy Storage = V*I*time
= I*time (amp-hr)

Battery	Voltage (V)	Energy Storage (Ah)	Type
Alkaline	1.5	2	Primary
Lithium	1.5	3	Primary
NiCad	1.2	1.2	Secondary
NiMH	1.2	1.8	Secondary
Li-ion	3.6	1.9	Secondary

Most energy for the same size battery

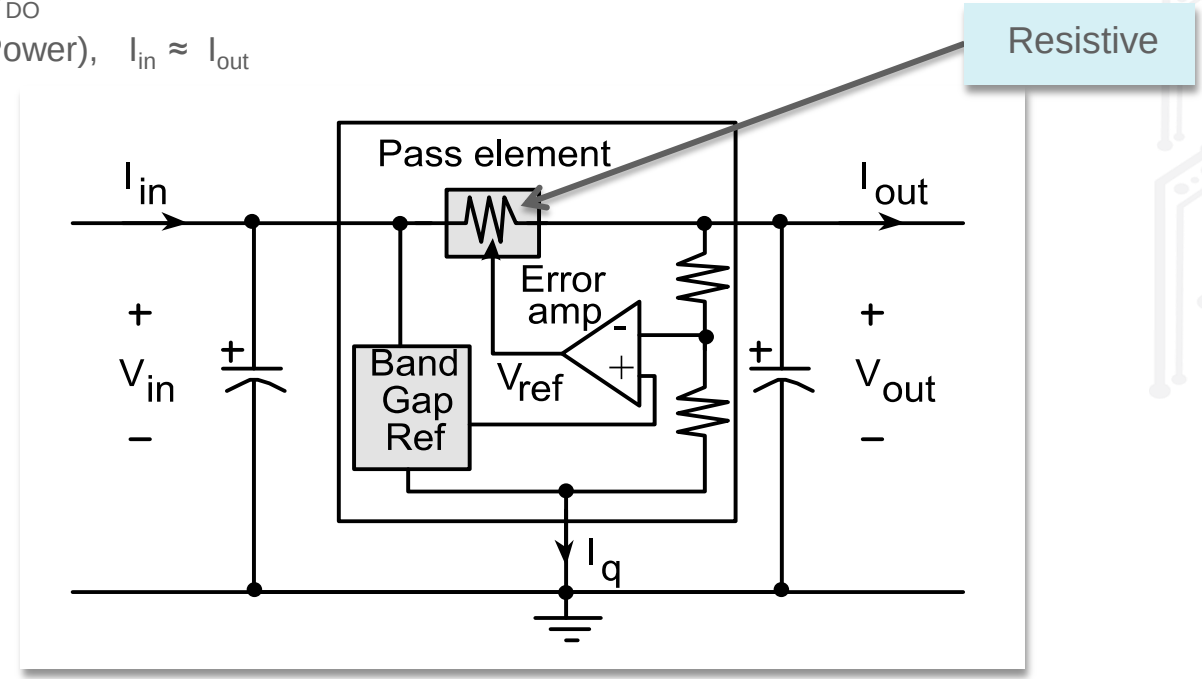
Running at a ½ amp, your robot will run for 3.6 hours

t_{life} = Energy Storage/ I
= 1.8/0.5 = 3.6 hr (NiMH)

Voltage regulation using a Linear Regulator

Properties

- Generates a constant output voltage V_{out} for varying, input voltage V_{in} & load I_{out}
- Dropout voltage, $V_{in} > V_{out} + V_{DO}$
- Inefficient (dissipating more Power), $I_{in} \approx I_{out}$
- Low noise



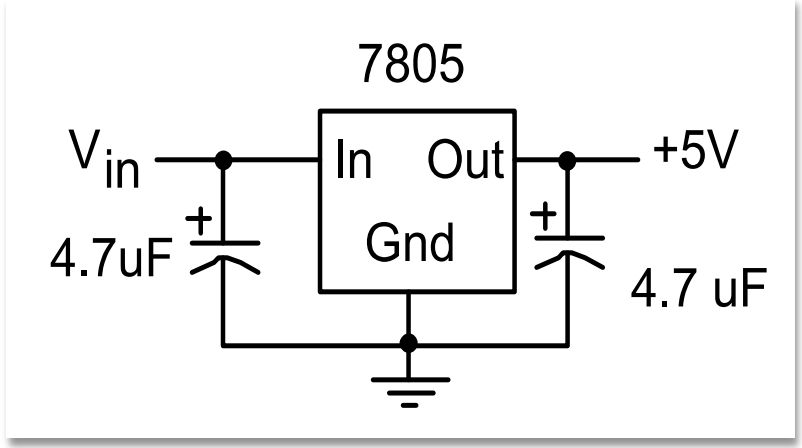
Input Power – Output Power = 7.2 V X 100 mA – 5 V X 100 mA = 0.22W of Power Loss !!!

Voltage regulation using a Linear Regulator

Example +5V regulator

Specifications:

- V_{in} > 7V (V_{DO} = 2V)
- I_{out} < 1 amp



Build this circuit if you do not have the Motor Driver Power Distribution board from Pololu

WEBENCH® is a free design tool from Texas Instruments you can use to design power supply circuits (link to **WEBENCH Power Designer**)

Voltage Regulation using Switching regulators

Properties

- Buck: Step-down (Vin > Vout)
- Boost: Step-up (Vin < Vout)
- Buck-boost: either/both
- Noisy due to switching

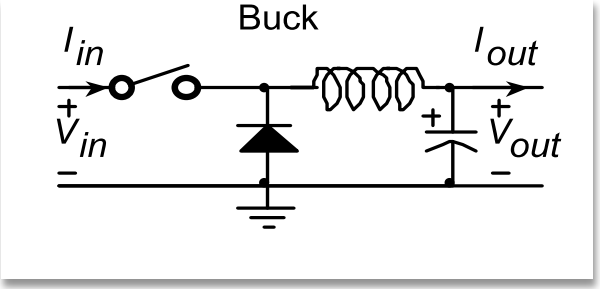
Power In ≈ Power Out

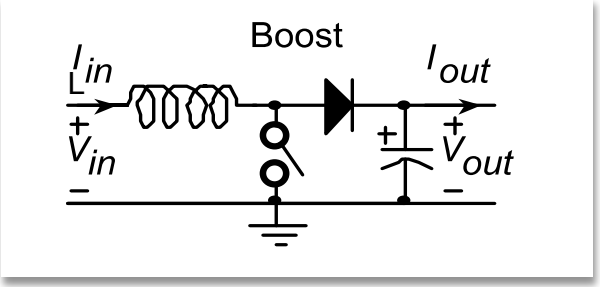
$V_{in} * I_{in} \approx V_{out} * I_{out}$

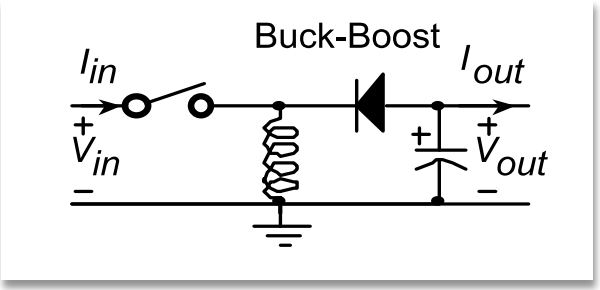
Efficiency = $(V_{out} * I_{out})/(V_{in} * I_{in})$

Or P_{out} / P_{in}

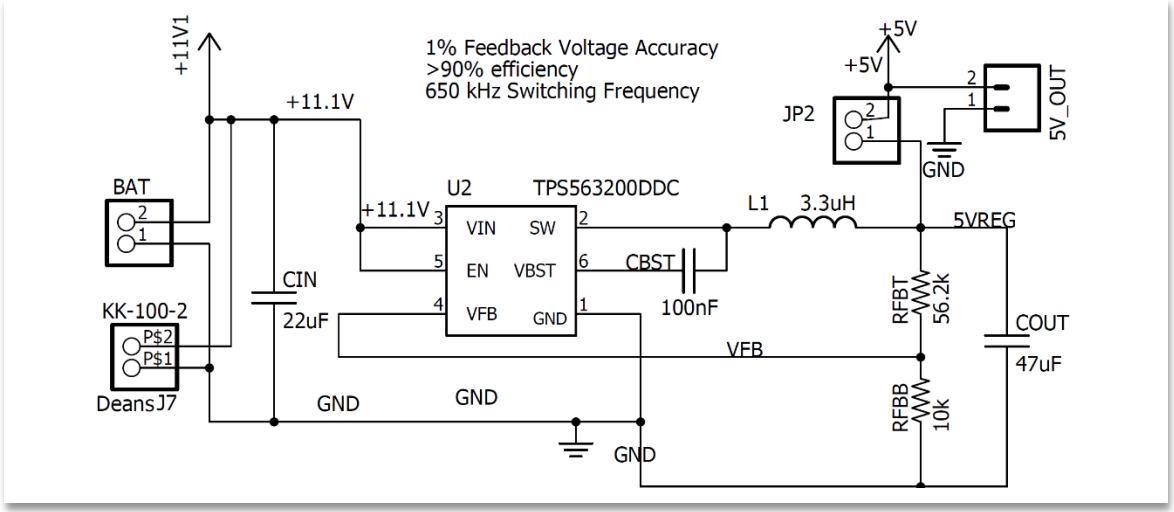
To learn more about regulators go to ti.com/PMLK



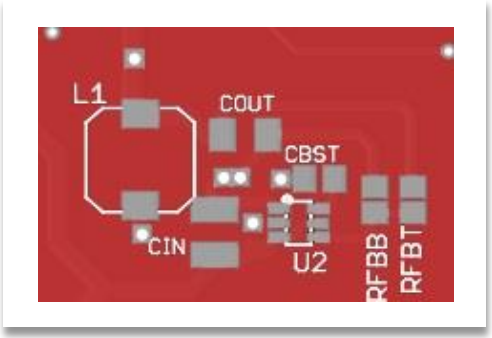




Switching Regulator Circuit : An Example



Warning :
Pay careful attention not to connect the wire from output of the regulator to ground.!!



Switching Regulator schematic & PCB using TI TPS563200 17-V Input, 2- A Synchronous Step-Down Voltage Regulator

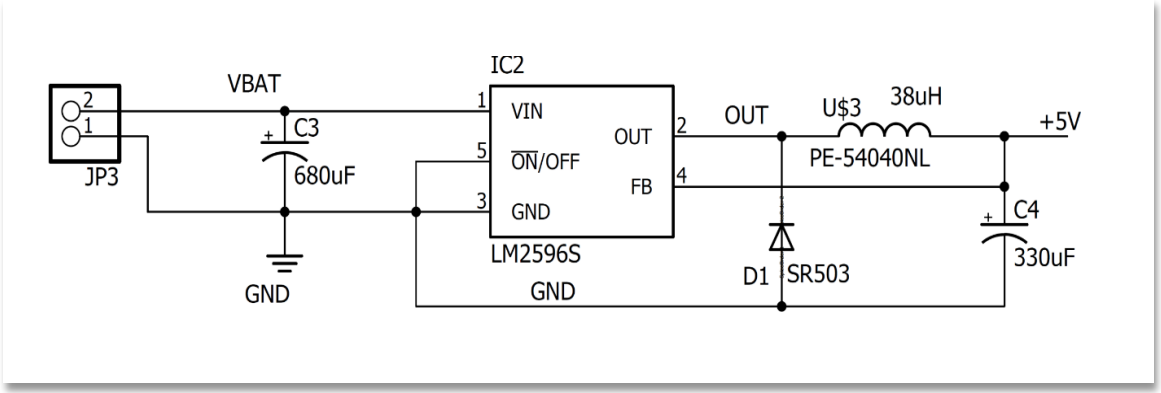
The Motor Driver and Power Distribution Board (from the lab) uses a similar regulator

Switching Regulator Circuit : An Example

- 3.3V, 5V, 12V, and Adjustable Output Versions
- Step-down (buck) switching regulator
- Available in TO-220 and TO-263 Packages
- Ensured 3A Output Load Current version.
- Requires Only 4 External Components
- 150 kHz Fixed Frequency Internal Oscillator
- High Efficiency
- Thermal Shutdown and Current Limit Protection

TO-220-5 package

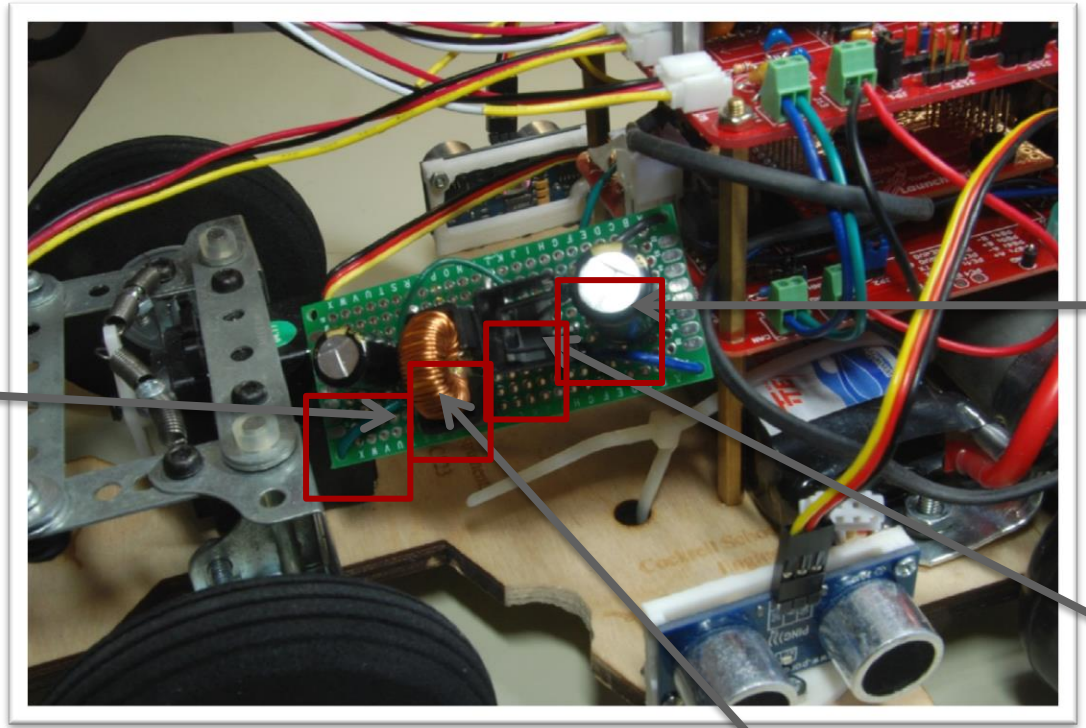
These features provide circuit protection!



Build this circuit if you do not have the Motor Driver Power Distribution board from Pololu or use 7805
For more information on the power supply design go to **http://www.ti.com/tool/lm2596s-adjevm**

Switching regulator circuit board using TI's LM2596

- LM2596T-5.0
- All through-hole parts
- Student-proof



Build this circuit if you do not have the Motor Driver Power Distribution board from Pololu.

Batteries and Voltage Regulation

Summary

- Power Sources - Battery
  - Primary versus secondary
  - Power budget and Energy Storage

- Voltage Regulation - Linear Regulator
  - Low noise
  - Wasted power = $(V_{in}-V_{out})*I_{out}$
  - Dropout voltage, $V_{in} > V_{out}+V_{do}$

- Voltage Regulation - Switching Regulator
  - Large voltage drop
  - Voltage increase
  - Higher Efficiency

Power = V*I
Energy = V*I*time
Energy Storage = I*time
Power Budget:
Average Current < Energy Storage/t_{life}

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