TI-RSLK MAX
Texas Instruments Robotics System Learning Kit
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)
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

\[
\text{Power} = V \times I \text{ (watts)} \\
\text{Energy} = V \times I \times \text{time (Joules)}
\]
Power Budget

Battery-powered embedded system

- Power Budget => Battery Life
  Average Current < Energy Storage/t_life

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

\[ \text{Energy} = V \cdot I \cdot \text{time} (J) \]
\[ \text{Storage} = I \cdot \text{time} \text{ (amp-hr)} \]

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

Inside a Battery

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

7.2V requires 6 batteries
## Batteries

### AA Sized Batteries

<table>
<thead>
<tr>
<th>Battery</th>
<th>Voltage (V)</th>
<th>Energy Storage (Ah)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline</td>
<td>1.5</td>
<td>2</td>
<td>Primary</td>
</tr>
<tr>
<td>Lithium</td>
<td>1.5</td>
<td>3</td>
<td>Primary</td>
</tr>
<tr>
<td>NiCad</td>
<td>1.2</td>
<td>1.2</td>
<td>Secondary</td>
</tr>
<tr>
<td>NiMH</td>
<td>1.2</td>
<td>1.8</td>
<td>Secondary</td>
</tr>
<tr>
<td>Li-ion</td>
<td>3.6</td>
<td>1.9</td>
<td>Secondary</td>
</tr>
</tbody>
</table>

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

Most energy for the same size battery

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

\[ t_{life} = \frac{\text{Energy Storage}}{I} \]
\[ = \frac{1.8}{0.5} = 3.6 \text{ hr (NiMH)} \]
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 = $7.2 \text{ V} \times 100 \text{ mA} - 5 \text{ V} \times 100 \text{ mA} = 0.22 \text{W}$ of Power Loss !!!
Voltage regulation using a Linear Regulator

Example +5V regulator

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

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

Build this circuit if you do not have the TI-RSLK MAX chassis board from Pololu
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

\[ V_{in} \cdot I_{in} \approx V_{out} \cdot I_{out} \]

Efficiency = \( \frac{(V_{out} \cdot I_{out})}{(V_{in} \cdot I_{in})} \)

Or \( \frac{P_{out}}{P_{in}} \)

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 TI-RSLK Chassis board 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

These features provide circuit protection!

Build this circuit (or 7805) if you do not have the TI-RSLK chassis board.
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 TI-RSLK chassis board
Batteries and Voltage Regulation

Summary

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

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

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

Power = \(V \cdot I\)
Energy = \(V \cdot I \cdot \text{time}\)
Energy Storage = \(I \cdot \text{time}\)
Power Budget:
Average Current < \(\frac{\text{Energy Storage}}{t_{\text{life}}}\)
Module 5

Lecture: TI-RSLK chassis board
**TI-RSLK Chassis Board features**

- Male-pinned connectors for the TI LaunchPad
- Battery input section with on/off switch and latching button
- TI 5V Switching Regulator TPS568230
- TI 3.3V Linear Regulator TLV1117
- TI Op Amp TLV9004
- TI Motor Drivers DRV8838
- TI Hall Effect Sensors on the Motors themselves, DRV5013
TI-RSLK Chassis Board features

- Male-pinned connectors for the TI LaunchPad
- Battery input section with on/off switch and latching button
- TI 5V Switching Regulator TPS568230
- TI 3.3V Linear Regulator TLV1117
- TI Op Amp TLV9004
- TI Motor Drivers DRV8838
- TI Hall Effect Sensors on the Motors themselves, DRV5013

TI-RSLK Chassis Board features

- Male-pinned connectors for the TI LaunchPad
- Battery input section with on/off switch and latching button
- TI 5V Switching Regulator TPS568230
- TI 3.3V Linear Regulator TLV1117
- TI Op Amp TLV9004
- TI Motor Drivers DRV8838
- and the TI Hall Effect Sensors on the Motors themselves, DRV5013
TI-RSLK Chassis Board features

- Male-pinned connectors for the TI LaunchPad
- Battery input section with on/off switch and latching button
- TI 5V Switching Regulator TPS568230
- TI 3.3V Linear Regulator TLV1117
- TI Op Amp TLV9004
- TI Motor Drivers DRV8838
- TI Hall Effect Sensors on the Motors themselves, DRV5013
TI-RSLK Chassis Board features

- Male-pinned connectors for the TI LaunchPad
- Battery input section with on/off switch and latching button
- TI 5V Switching Regulator TPS568230
- TI 3.3V Linear Regulator TLV1117
- TI Op Amp TLV9004
- TI Motor Drivers DRV8838
- TI Hall Effect Sensors on the Motors themselves, DRV5013
TI-RSLK Chassis Board features – Power and Gnd

- **+3.3V**
- **+5V**
- **+7.2V**
- **Gnd**

**Power to sensor**

**Important safety feature**

TI-RSLK chassis board
TI-RSLK Chassis Board features – Power and Gnd

- +5V
- Gnd
- +3.3V

Important safety feature
Switching Regulator Circuit: TI-RSLK MAX chassis board

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

TI-RSLK chassis board uses a TI TPS568230 4.5 to 18-V input, 5V 8-A output, synchronous step-down voltage regulator

VSW=+7.2V

5V
**Linear regulator circuit: TI-RSLK MAX chassis board**

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

**TI-RSLK chassis board uses a TI TLV1117 4.7 to 15-V input, 3.3V 800 mA output, linear regulator**
Texas Instruments Robotics System Learning Kit: The Maze Edition:

TI-RSLK MAX overview

- CC2650/CC3100 BoosterPack
- MSP432 LaunchPad
- 6 NiMH batteries
- Chassis board
  - Six bump switches
  - Two tachometer
  - Three IR distance sensors
  - Microphone sound
  - Two DC motors
  - LCD or OLED display
  - Speaker output

TI-RSLK MAX kit
- Not in kit
- Optional purchase
TI-RSLK Chassis Board

Summary

- **Power**
  - Battery
  - +5V and +3.3V regulators

- **Interfaces**
  - 2 DC motor drivers
  - 2 tachometer interfaces
  - 3 analog log pass filters
  - Extra analog op amp
  - I2C connectors
  - LCD/LED connectors

- **Systems approach to robotics**
  - Power and interface board
  - MSP432 LaunchPad and software
  - BoosterPacks for wireless communication

Important safety feature
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated