



Module 5

Introduction: Battery and Voltage Regulation



Introduction: Battery and Voltage Regulation

Educational Objectives:

MEASURE Voltage, current, and energy for a battery

UNDERSTAND Voltage regulation for the robot

INTERFACE The circuits needed to power the robot from batteries

Prerequisites (Module 2)

- Voltage, current, energy, power (Module 2)
- Resistance, capacitance (Module 2)

Recommended reading materials for students:

- Volume 1 Section 1.1
Embedded Systems: Introduction to the MSP432 Microcontroller, ISBN: 978-1512185676, Jonathan Valvano, copyright © 2017
or
- Volume 2 Section 9.2
Embedded Systems: Real-Time Interfacing to the MSP432 Microcontroller, ISBN: 978-1514676585, Jonathan Valvano, copyright © 2017

Every embedded system needs power to operate. The source of power could be

- 120 VAC 60 Hz, with an AC to DC converter
- DC power, like +5V on USB or +12V in an automobile
- Battery
- Energy harvesting like solar or EM field pickup

When debugging the LaunchPad, you use +5V from the PC via the USB cable. However, to run the robot autonomously, it will need battery power. The battery voltage is not constant; it decreases with age and use. Therefore, you will use a **regulator** to provide a constant voltage to power most of the electronics for the robot. In this module, we will introduce two types of regulators: linear and switching. There are many considerations when choosing a regulator, and we will discuss some of these considerations.

You will power the robot motors directly off the battery voltage. The Romi Chassis (Pololu part #3502) can hold 6 AA batteries. If you use NiMH batteries (1.2V each), this will create a +7.2V source for the robot. The motors do not need a constant voltage to operate, and running directly off the batteries is the most

efficient use of energy. As you might imagine, the motors use most of the power required by the robot.

The robot will take the battery +7.2V input and create a +5V regulated power source. In particular, you will use the Motor Driver and Power Distribution Board for Romi Chassis (Pololu part #3543). We will explain the battery and voltage regulation in this module. You will connect the +5V regulated power source to the LaunchPad, and the LaunchPad will create a +3.3V power source using its own regulator. The LaunchPad powers the MSP432 with this +3.3V. The MSP432 itself has regulators inside the chip. For example, V_{CORE} is the internal voltage at which the processor operates, and it is typically +1.2V. You will power the motors directly off the battery, some of the external devices with +5V and others with +3.3V.

The **energy** (E in joules) stored in a battery can be calculated from voltage (V in volts), current (I in amps), and time (t in seconds). Energy has neither polarity nor direction. The energy rating for the battery is given in amp-hr, because the assumption is the voltage is constant. The NiMH batteries listed in the lab bill of materials (BOM) are rated at 1900 mA-hr. This means the battery can supply 1 amp for 1.9 hours. Six of these batteries, placed in series, can supply 7.2V at 1 amp for 1.9 hours.

In the lab associated with this module, see Figure 1, you will study the batteries, measuring their energy storage. Next, you will build/interface the circuits needed to power the LaunchPad off batteries.

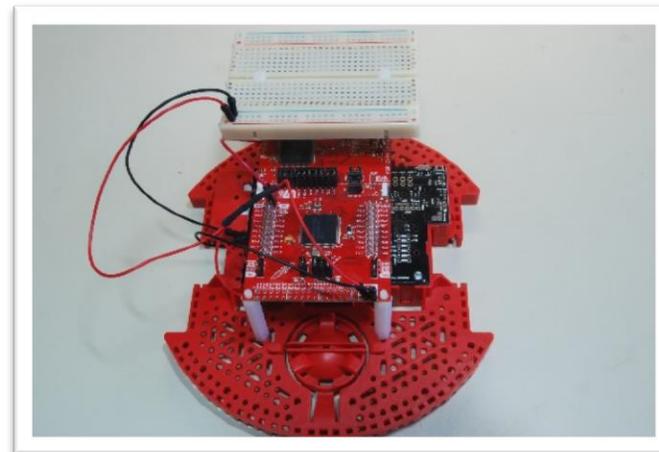


Figure 1. Romi Chassis, Motor Driver and Power Distribution Board, LaunchPad, and small protoboard.

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>), [evaluation modules](#), and [samples](http://www.ti.com/sc/docs/sampterm.htm) (<http://www.ti.com/sc/docs/sampterm.htm>).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated