MOBILE INTEGRATED SOLUTIONS LABORATORY
ECETDHA MINI-GRANT
SENSORTAG POWER DRIVER DEVPACK

Introduction

The Mobile Integrated Solutions Laboratory (MISL) is a rather unique applied research laboratory housed within the Electronic Systems (ESET) and Mechatronics (MXET) Programs of the Department of Engineering Technology and Industrial Distribution at Texas A&M University. Projects are undertaken by this lab that primarily focus on space-based prototype development and STEM outreach and recruiting. Although many projects are externally sponsored, undergraduate students who work in MISL do have the opportunity to define development projects that they will accomplish as internally funded or MISL-supported activities. A number of these types of projects have led to educational products used at a wide range of educational levels from middle school through undergraduate courses. Examples of these include the Krisys Robot, the Digital System Teaching and Research (DSTR -- pronounced “Disaster”), and the Articulated-Leg Suspension Evaluation Platform (ASEP). In addition, systems have been developed for small local businesses such as Texas Space Technology, Applications and Research (T STAR). These systems include Strata-1, Hermes, Helix, and Cardinal. All of these systems were developed for the T STAR customer, NASA, and two (Strata-1 and Hermes) have (or soon will be) operated on the Internal Space Station. MISL’s mission is to provide undergraduate students with the opportunity to further their education outside of the classroom/teaching laboratory environment.

MISL also participates regularly in an NSF-funded ITEST summer STEM workshop for secondary education math and science teachers. The workshop exposes these math and science teachers to many engineering and technology concepts including 1) the engineering process, 2) additive manufacturing, 3) building monitoring and energy management concepts and processes, and 4) Internet of Things (IoT) technologies applied to energy monitoring and management. Now in its third year of conducting teacher workshops, the ITEST team continues to be supported by Texas Instruments with technology to create IoT edge devices to monitor environmental variables within a building/room and to remotely control actuators to open/close blinds, turn on/off fans and lights, etc. Expanding on this set of easy-to-use building blocks will assist secondary education students as they apply their math and science knowledge to engineering data collection, decision making, and control of the monitored environment.

In the typical fashion of taking on specialized design/development efforts, MISL proposed a project to the ECETDHA to provide support for the development of a power driver devpack for the SensorTag embedded intelligence device manufactured by Texas Instruments. The primary need for such a device was to support the STEM outreach activities undertaken by MISL. These workshops represent one of the most successful activities is the development and delivery of a series of summer mobile robotic camps conducted for middle, junior and high school students.

Students work in teams of four to design, build and compete a small form factor robot. Each student must participate as a team member, but also take on a leadership position in electronics, mechanics, embedded intelligence programming, or project management/communications.

One of the embedded intelligence devices that MISL used for its DSTR Robot was the SensorTag, a Bluetooth capable intelligent device that had the ability to provide control signals necessary to control the speed and direction of a differentially steered mobile platform. With funding provided by ECETDHA, a plan was put in place to develop a devpack for the SensorTag that would provide the infrastructure for the SensorTag to be a complete embedded controller capable of powering two different motor pairs. Shortly after the project initiation, discussion with Texas Instruments resulted in a functional change to the target environment. Texas Instruments had just released their new series of Launchpad devices and indicated a higher level of interest in having the functional capabilities of the devpack migrated to a BoosterPack for their Launchpad CC3200 board. After reviewing the SensorTag and Launchpad architectures, MISL decided that the CC3200 provided a more desirable set of features for use in their robot workshops as well as in other IoT prototyping projects. In addition, the software development environment, Energia, was a more straightforward, Arduino-like, easy-to-use interface to program the embedded intelligence than that needed for the SensorTag. Therefore, the target system for the project was changed from the SensorTag to the new CC3200 Launchpad device.

Background

Mr. Matt Seago began working in MISL as a sophomore and now as a senior continues to be involved in a number of MISL projects and contributes regularly to the MISL robot and IoT workshops during the summer. His initial efforts in Printed Circuit Board (PCB) design was his RGB LED Board. This board has been adopted by MISL for most workshops and is currently being used in a number of academic courses offered at high schools, junior colleges and Texas A&M. Although fairly straightforward in its operation, students learn both thru-hole and surface mount soldering techniques prior to taking on larger, more complex PCB population tasks.

Matt became very interested in the BoosterPack project and applied his newly developed schematic capture and circuit board layout talents to create the much-needed Power and Motor Driver PCB that meets TI specifications as a BoosterPack. This project was recently completed and MISL plans to order a large number of the boards to support numerous CC3200 Launchpad robot controller projects as well as a many of its IoT workshop activities.

Functional Requirements

The functional requirements for the DSTR SensorPack are

1. Must have power on/off capability
2. Must regulate 9-18V input to +5V/2A minimum and +3.3V/500mA minimum
3. Polarity protection for input power
4. Accept Direction and PWM signals from the Launchpad and power amplify these to control the direction and speed of two independent motor channels providing up to 36V and 2A continuous power to each channel.

5. Plug directly into the LaunchPad expansion buss while providing all signals to other plug in modules
6. Provide convenient add-on features and access to power for other external devices
7. Appropriate connectoring to support easy integration of battery, motors and other add-on devices.

Functional Block Diagram

Figure 1 depicts the functional block diagram for the Power/Motor Driver BoosterPack designed and developed by Mr. Matt Seago which meets the set of functional requirements established by a group of MISL student workers for the project.

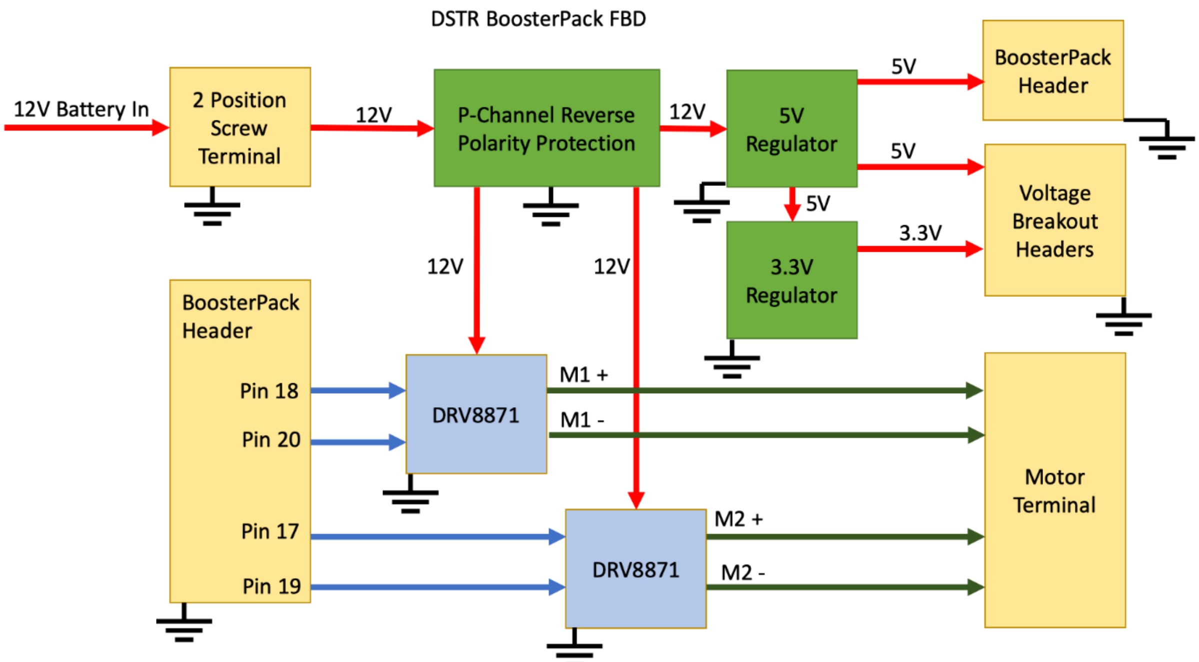

Figure 1. Functional Block Diagram.

The design accepts an input voltage up to 36 volts and provides reverse polarity protection for this connection. The input power is used to create both a +5V and +3.3V regulator power to the board in addition to directly powering the CC320 to which it is attached. The input power is also routed to the two DRV8871 H-Bridge devices to power the two motor driver ports. Although the intent is to power two motor channels, these circuits can be used to control the direction and magnitude of current flow to any high-powered device using Pulse Width Modulated (PWM) signaling from the LaunchPad. Finally, the design provides multiple and convenient connection capabilities for power and outputs. The design uses the LaunchPad BoosterPack headers to interface to the launchPad and to pass through the signaling to another BoosterPack installed on this board.

Schematic

Schematic capture and board layout were performed using Altium design tools. Figures 2 provides the overall schematics and Figure 3 provides the layout of the board.

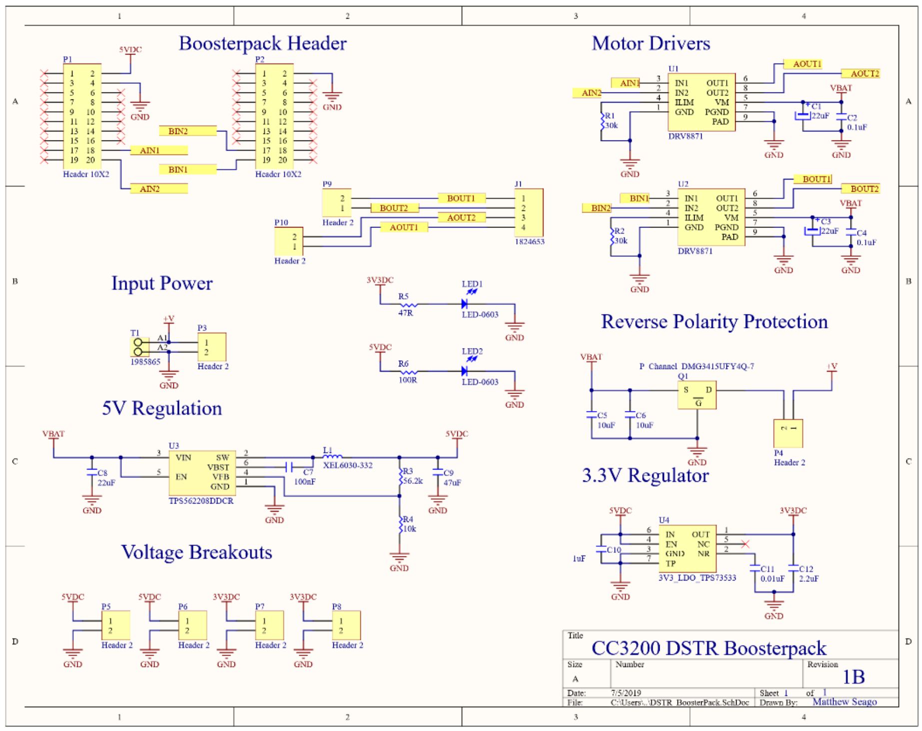

Figure 2. Power/Motor Driver Schematic.

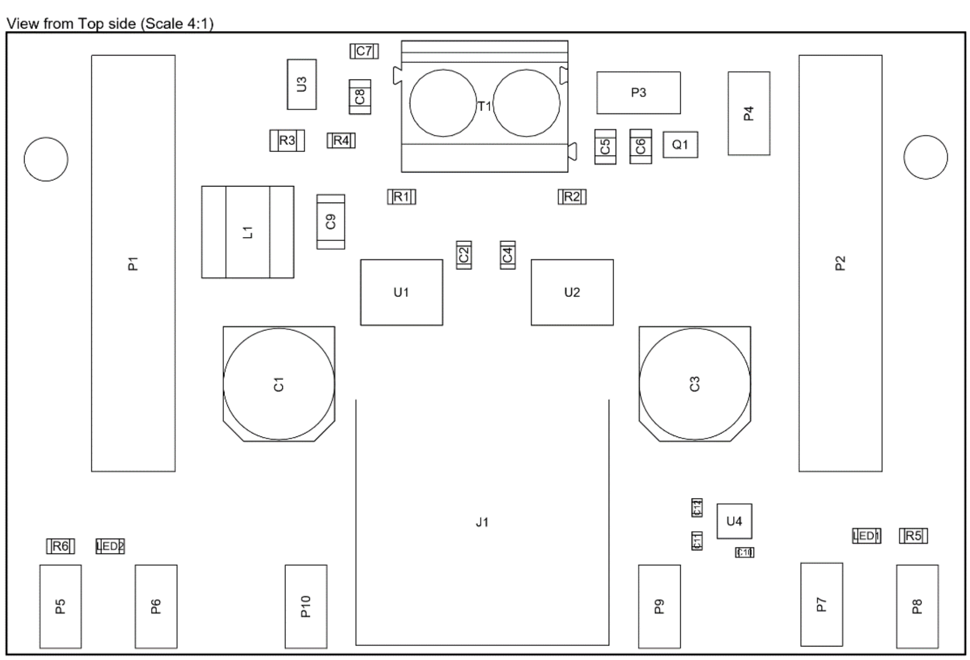

Figure 3. Power/Motor Controller Board Layout.

Figure 4 shows the top and bottom of the Power/Motor Driver BoosterPack as well as it mounted to the CC3200 LaunchPad board.

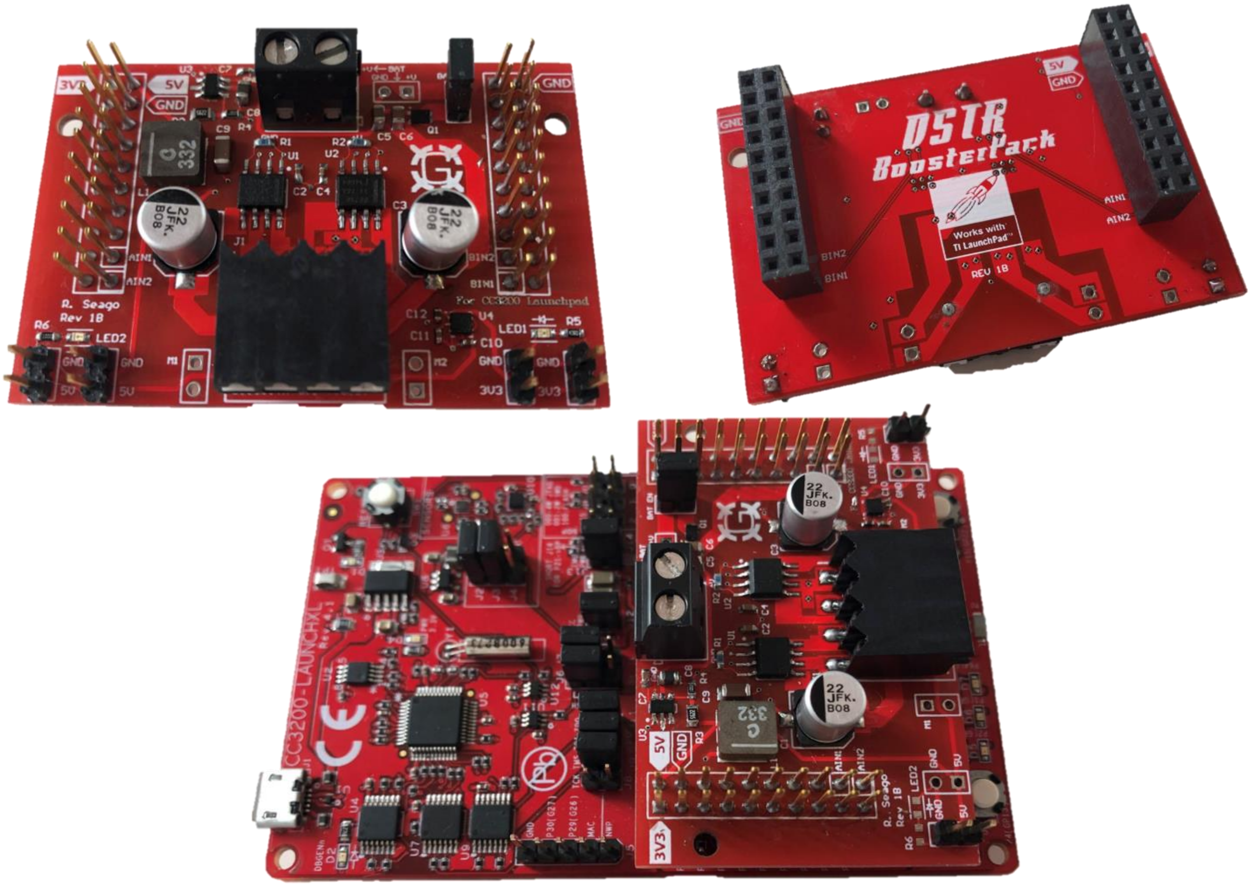

Figure 4. Power/Motor Driver BoosterPack – Top, Bottom and Mounted to CC3200.

Bill of Materials

A complete Bill of Materials necessary to construct the BoosterPack is provided in Table 1. As can be seen, the one-off cost for the materials necessary to build a Power/Motor Driver BoosterPack is approximately $35.00 which includes a $3.00 PCB cost. Population of 50 boards is approximately $10 per board. Obviously, higher quantity lot sizes would significantly reduce the per unit costs.

Future Plans

Now that the Power/Motor Driver BoosterPack has been developed and tested, plans are being formulated for the use of this new resource. MISL plans on procuring a small quantity of these boards (50 to 100) to use in its summer DSTR Robot and ITEST IoT workshops. Based on these experiences, the design, if required, will be refined and finalized. Working with Texas Instruments, MISL and Mr. Seago will look at how best to advertise the availability of the new BoosterPack. As part of these efforts, Mr. Seago will be generating an article/video for GitHub or similar online presence that will fully describe the functionality of the BoosterPack.

Table 1. Bill of Materials.

DSTR BoosterPack							
	Bill of Materials			Rev 1B	ravita	7/5/2019	
Find Number	Label:	Description:	Footprint:	Board Reference	QPB	Unit Cost	Extended Cost
1	**Inductors:**	Fixed Inductors 3.3uH 20% 8A 20.81mOhms AEC-Q200	SMD/SMT	L1	1	$2.04	$2.04
2	**Capacitors:**	Multilayer Ceramic Capacitors MLCC - SMD/SMT SOFT 0603 25V 0.1uF X8R 10% AEC-Q200	0603	C2, C4, C7	3	$0.25	$0.75
3		Multilayer Ceramic Capacitors MLCC - SMD/SMT 0805 16V 10uF X7S 20% Gen Purpose	0805	C5, C6	2	$0.69	$1.38
5		Multilayer Ceramic Capacitors MLCC - SMD/SMT 0805 10V 22uF X7S 20% T: 1.25mm	0805	C8	1	$1.06	$1.06
6		Multilayer Ceramic Capacitors MLCC - SMD/SMT 1206 6.3V 47uF X5R 20% T: 1.6mm	1206	C9	1	$0.52	$0.52
		Multilayer Ceramic Capacitors MLCC - SMD/SMT 0402 35V 1.00uF X5R 10% Soft Term	0402	C10	1	$0.20	$0.20
		Multilayer Ceramic Capacitors MLCC - SMD/SMT SOFT 0402 50V 0.01uF X7R 10% T: 0.5mm	0402	C11	1	$0.17	$0.17
		Multilayer Ceramic Capacitors MLCC - SMD/SMT 0402 25V 2.20uF X5R 10% Soft Term	0402	C12	1	$0.37	$0.37
7		Aluminum Electrolytic Capacitors - SMD 22UF 63V FK SMD	D8	C1, C2	2	$0.53	$1.06
9	**Voltage Regulators:**	Switching Voltage Regulators 4.5V to 17V Input, 2A Output, Synchronous Step-Down Converter 6-SOT-23-THIN -40 to 125	SOT-23-Thin-6	U3	1	$1.01	$1.01
		LDO Voltage Regulators Sgl Out,500mA,Fixed Lo Quies Crnt	SMD/SMT	U4	1	$1.63	$1.63
10	**ICs:**	Motor / Motion / Ignition Controllers & Drivers RAPTOR AUTOMOTIVE 8871	SMD/SMT	U1, U2	2	$2.65	$5.30
15	**Resistors:**	Thick Film Resistors - SMD 30K OHM 1%	0603	R1, R2	2	$0.11	$0.22
16		Thick Film Resistors - SMD 1/8Watt 56.2Kohms 1% Commercial Use	0603	R3	1	$0.18	$0.18
17		Thick Film Resistors - SMD 1/10Watt 10Kohms 1% Commercial Use	0603	R4	1	$0.16	$0.16
18		Thick Film Resistors - SMD 1/10Watt 47ohms 1% Commercial Use	0603	R5	1	$0.10	$0.10
19		Thick Film Resistors - SMD 1/10Watt 100ohms 1% Commercial Use	0603	R6	1	$0.10	$0.10
27	**LEDs:**	Standard LEDs - SMD Red Clear 631nm	0603	LED1, LED2	2	$0.26	$0.52
30	**Connectors/Headers:**	Fixed Terminal Blocks SPT-SMD 1,5/4-H-3,81 R44	SMD/SMT	J1	1	$4.05	$4.05
31		Fixed Terminal Blocks MKDSN 1.5/ 2-5.08 HT	Through Hole	T1	1	$1.02	$1.02
32		Board to Board & Mezzanine Connectors .100" Tiger Buy Socket Strip	Through Hole	P1, P2	2	$3.70	$7.40
33		Headers & Wire Housings 02 MODII HDR SRST B/A .100CL	Through Hole	P3, P4, P5, P6, P7, P8, P9, P10	8	$0.26	$2.08
38	**MOSFETs:**	MOSFET P-Ch -16V Enh FET 8Vgss -12A 0.65W	SMD/SMT	Q1	1	$0.50	$0.50
39	**Shunts:**	Headers & Wire Housings ECONOMY SHUNT ASSY	N/A	N/A	1	$0.15	$0.15
					39		**$31.97**

One of the exciting aspects associated with MISL activities is the possibility of creating entrepreneurial opportunities. Mr. Seago and a small group of other MISL student workers have begun discussions with local small businesses such as T STAR to work with them in commercializing this product. T STAR has already taken on responsibility for marketing and supporting the DSTR Robot and is currently considering undertaking similar support for the Krisys Robot. Having the Power/Motor Driver Board would be a valuable addition to this set of educational and applied research products and provide incentives to current and future MISL students to take work they do as part of their undergraduate studies and translate it into producing similar types of products. What better way to learn engineering than actually developing and supporting the development of a new product?

Summary

The Mobile Integrated Solutions Laboratory would like to thank the ECETDHA for its investment in experiential learning opportunities for undergraduates in engineering technology. The provided funding enabled Mr. Matt Seago to work on a real-world project that allowed him to not only apply the knowledge and capabilities he has obtained through his education, but inspired him to extrapolate that knowledge into other important engineering design tools and processes. The skills and confidence he has achieved through this project will serve him well as he takes on the electronic hardware design responsibilities and leadership for his capstone design project starting this fall. In addition to the value that was added to Matt's education, the new Power/Motor Driver BoosterPack for the CC3200 and other LaunchPad devices will create a more compact and capable module for most of MISL's educational robots, its IoT-based systems used in teacher workshops and a new building monitoring capability being implemented by MISL students this summer for the ETID Department. The investment made by ECETDHA will pay significant dividends both today and tomorrow.