THE MODULAR INTEGRATED STACKABLE LAYERS SYSTEM: A NASA DEVELOPMENT PARTNERSHIP

Tanner L. Perkins, Kelson G. Astley, Ty B. Navarrete, Paul B. Delaune, and Joseph A. Morgan

Electronic Systems Engineering Technology

Texas A&M University

Abstract

The need for more advanced and powerful microcontrollers within electronic systems has increased significantly over the last several decades. While many hobbyists, by default, seek out Arduino platforms, industry typically have electronic systems custom made to suit their processing needs. In order to give industry, as well as hobbyists, a more power and cost effective embedded processing solution, NASA and Texas A&M University's Electronic Systems Engineering Technology (ESET) Program have formed a partnership to further develop the Modular Integrated Stackable Layers (MISL) system, originally created by NASA. The MISL system is being expanded to utilize the RM48L952 microcontroller, produced by Texas Instruments. This "rack and stack" system was designed with standardized data and power buses so that additional boards, or layers, with specific functionality, may be stacked and easily integrated. This allows the user to mix-and-match hardware within the RM48 based system. MISL is being designed and developed as an open source hardware and software system to allow the technology community to continue development and customization of the system to meet their needs long after inception. Keeping the MISL system completely open source will in turn drive the cost of individual units down. This all provides a versatile, inexpensive, and space-qualified solution to the processing needs of new products and systems in a wide range of design and development environments including automotive, aerospace, medical, and oil and gas industries. This paper will provide an overview of the MISL systems' current status, its use within education, and the plans for the open community being developed by Texas A&M University in partnership with NASA.

Introduction

The use of microcontrollers and embedded systems within our technologically advancing world dominates realms including, but not limited to, industry, consumer market, and hobbyist sectors. Systems like Ardunio have taken a major role in a large amount of simple electronics projects within the hobbyist and academic realms. One feature that has added to Ardunio's success is their Shield system, which allows for added capability and expandability of the hardware. However, the Ardunio platform is only meant for simple projects because of its limited memory, lack of industry communication protocols, and its insufficient processing power needed for major projects. But, Adruino is not the only company that currently supplies "rack-and-stack" type systems. Texas Instruments has a system of interconnecting boards called LaunchPad. These boards are very inexpensive, but connect using large, fragile header pins. Freescale also has a system called Tower that is more robust and expensive, but is also quite large in size. Due to these constraints, there is a need for a new system that utilizes powerful microcontrollers that can be used by industry, academia, and other markets needing more advanced processing power, durability, is relatively inexpensive, and in a small form factor. For this reason, the Command and Data Handling (C&DH) branch at The National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) created the Modular Integrated Stackable Layer (MISL) system. NASA has created standards for data and power buses for connectivity between the multiple layers of this rack-and-stack type system. The Electronic Systems Engineering Technology (ESET) program at Texas A&M University (TAMU) is continuing the development of this system by creating a new processing board. This board is centered around the RM48L952 microcontroller manufactured by Texas Instruments (TI). In addition, the ESET program has begun creating a MediaWiki page to act as a resource for the MISL system open source community. Coupled with the drive for an open source system, the ESET program is currently making use of the MISL system in their Embedded Systems Development in C course. This sophomore level class focuses on an introduction to programming using the C programming language and the design and use of embedded microcontroller systems.

MISL Standards

The MISL system uses several standards to allow for multiple layers to connect easily. Figure 1 shows that the data bus connector is always positioned horizontally on the relative top of the board while looking at the face of the board. Similarly, the power bus connector is always positioned vertical at the left side of the board, again when looking at the top face of the board. This standard placement allows for the board to be any size but still keep the data and power bus connectors correctly located, which is depicted by dotted lines.

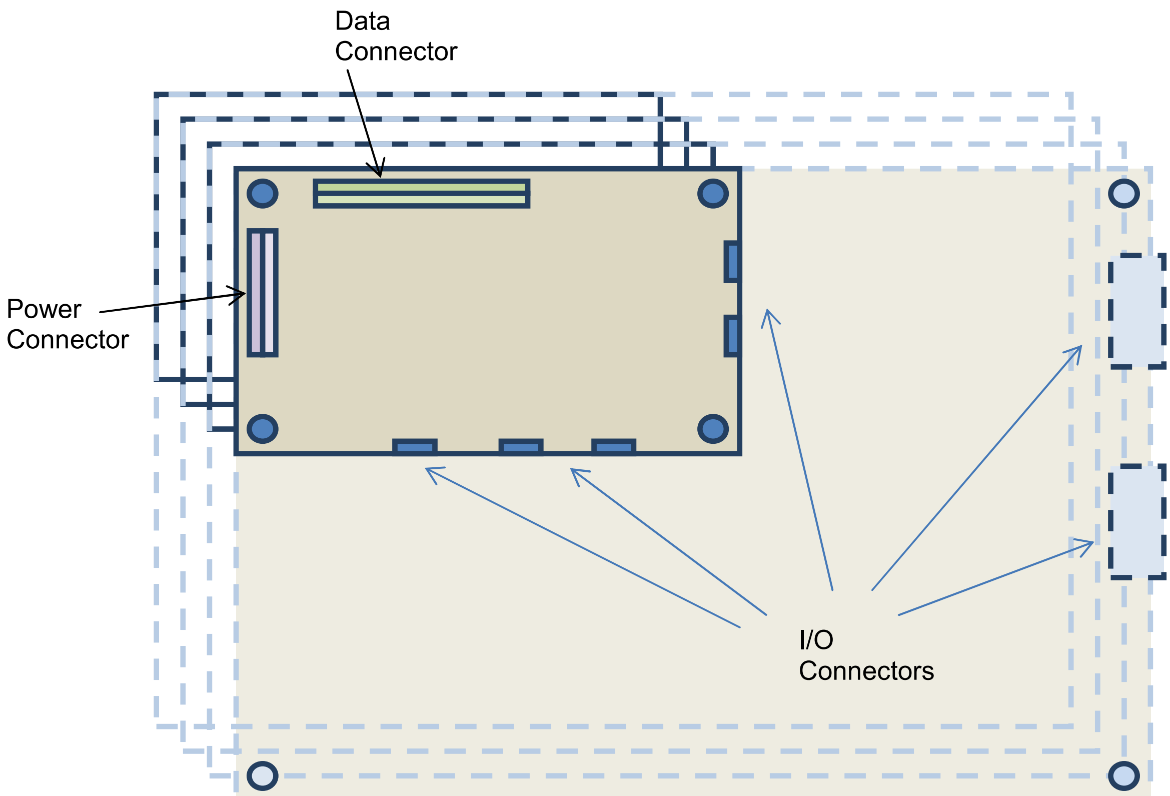


Figure 1: Connector and Board Layout

The height of the MISL stack will vary depending on the number of boards used and which connectors are appropriate for a given board. There are two possible heights to both the male and female connectors, which allow four possible heights between boards. For example, Figure 2 shows four layers with two different height dimensions between the layers, 0.354 and 0.276 inches. If both the short male (ERM8 & ERM5) and female (ERF8 & ERF5) connectors are used, the resulting board spacing is 0.276 inches, while a short male connector with a tall female connector will result in a height of 0.354 inches. The double red asterisk indicates the board thickness in this example is 0.062 inches. The bottom board in this example is the AA battery pack board which has a bottom height of 0.5 inches. After totaling all of the dimensions, the total stack height is just less than 2 inches in this example.

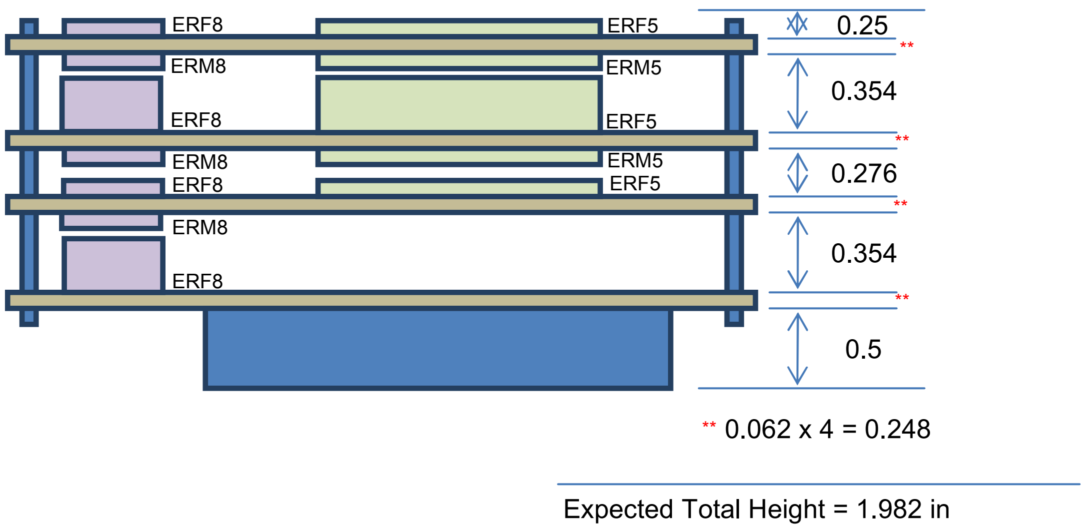


Figure 2: Stack Height

The height of the connectors chosen is determined by the max height of the components on the board. The potential problem of having a component height greater than the height of the tallest connector could arise. In response to this, several solutions have been found. The first would be to extend the board in one of the two available directions. An example is shown in Figure 3, where the board has been extended horizontally for a connector that would not fit in between the layers of the stack. The red area shows the board extensions with the two taller components shown in black.

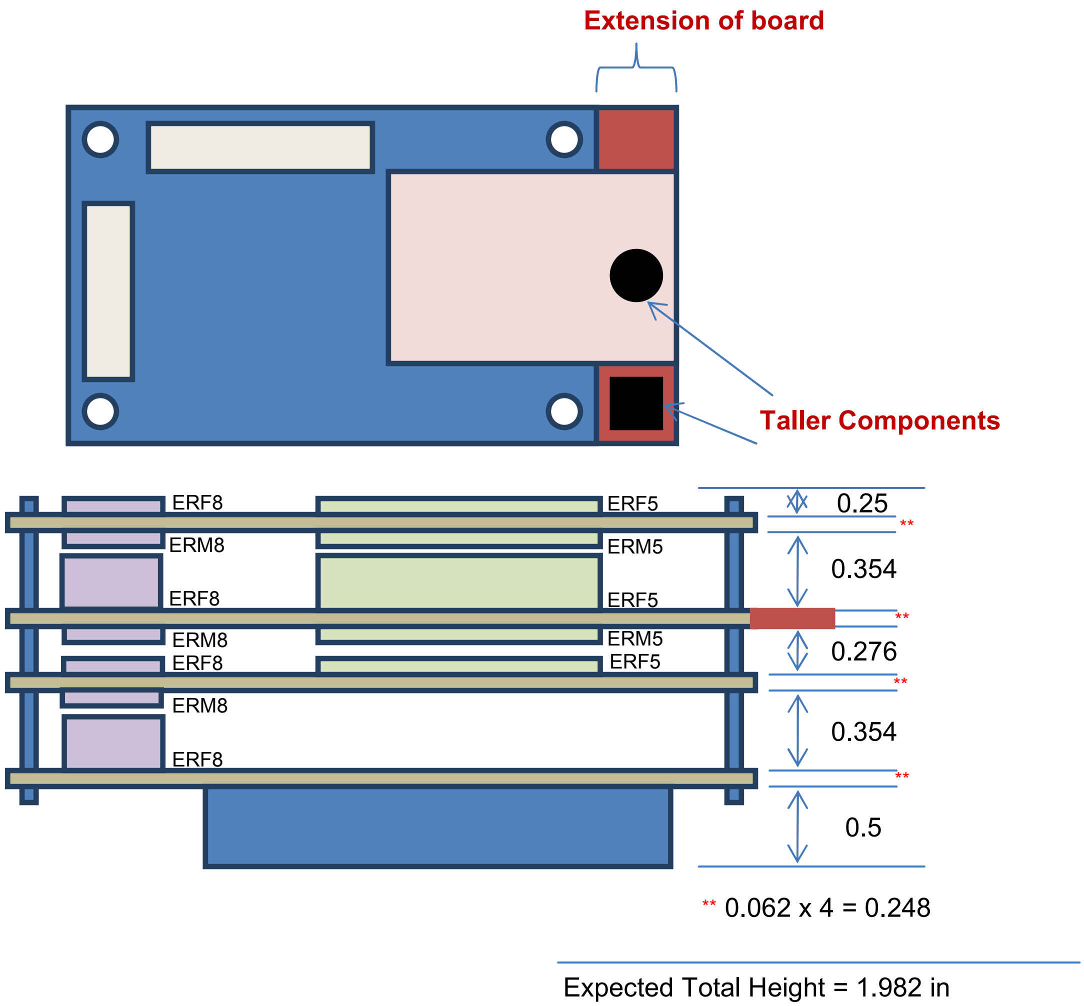
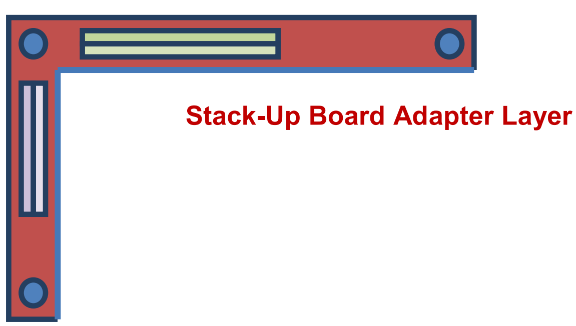


Figure 3: Board Extension for Taller Components

If a component on the interior of the board layout is too tall or board dimensions are a strict constraint, then using the stack-up board adapter may be the best solution. This will be the best solution for users that are not designing hardware for the MISL stack. The stack-up board adapter is shown in Figure 4, with the red sections highlighting the solutions to the height problems.



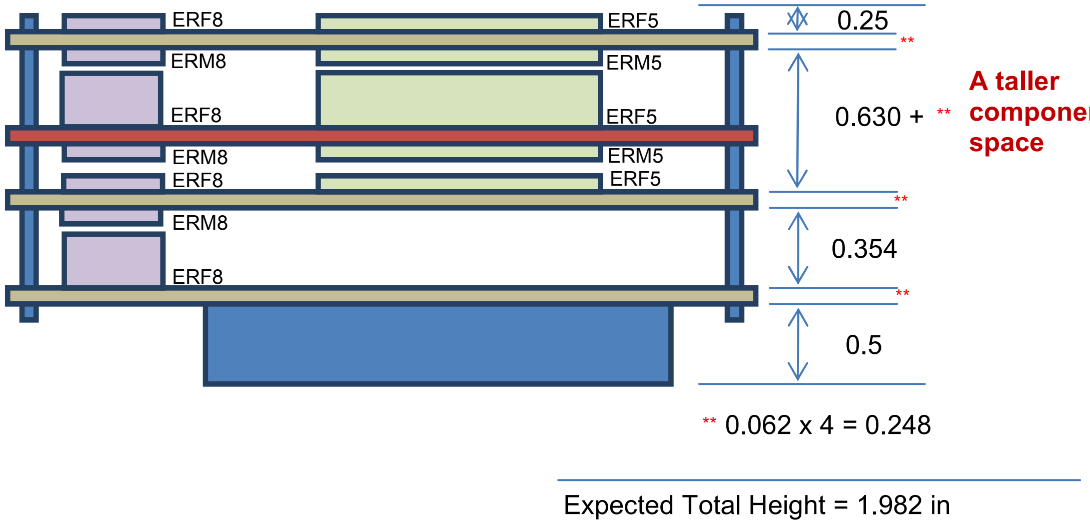


Figure 4: Stack-Up Board Adapter

The bus connectors being used are manufactured by SAMTEC. The ERF8 and ERM8 series are 50 pin connectors which act as the power bus for the MISL system. The ERF5 and ERM5 are 80 pin connectors which act as the data bus between layers for the MISL system. In Table 1, the various possible heights are illustrated.

Table 1: Data Bus Mated Connector Heights

	ERM5-02.0	**ERM5-05.0**
ERF5-05.0	0.276 in (7.0 mm)	0.394 in (10.0 mm)
ERF5-07.0	0.354 in (9.0 mm)	0.472 in (12.0 mm)

Table 2: Power Bus Mated Connector Heights

	ERM8-02.0	**ERM8-05.0**
ERF8-05.0	0.276 in (7.0 mm)	0.394 in (10.0 mm)
ERF8-07.0	0.354 in (9.0 mm)	0.472 in (12.0 mm)

Current boards being produced are now going to be 0.93 inches thick as opposed to the original boards which were 0.62 inches. This solves the problems associated with the alignment posts on the connectors. This problem arose because the posts are 0.43 inches long and had to be cut in half to properly align on a 0.63 inch board. Therefore, the standard board thickness will be 0.93 inches to accommodate the bus connectors properly.

Capstone Project

The ongoing project at Texas A&M University by three ESET students is to take the current MISL system and create a new processing board, developed around Texas Instruments' RM48L952 microcontroller. This processing board will be used with the existing 28 Volt power board and WizFi630 communication board to make up the MISL system for this project. This stack will then be mounted onto the Articulated Suspension Exploratory Platform (ASEP). The MISL system will allow the user to control the ASEP vehicle remotely using a gaming controller connected through a base station running a LabVIEW created Windows executable graphical user interface (GUI). This executable will allow the GUI to be run on any Windows machine, including Windows tablets. The GUI will also display Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data received from a sensor mounted on the ASEP robotic vehicle.

Figure 5 gives a high level pictorial description of the Capstone MISL project. Located in the center of the figure is the ASEP robotic vehicle which will have the MISL stack mounted onboard. To power both the vehicle and the MISL System, a Lithium Polymer battery will provide 7.4 Volts DC. The MISL system's 28 Volt power board will then regulate and convert this 7.4 Volts to 5 and 3.3 Volts DC which can be used by the other boards within the stack via the power bus. This same 7.4Volts will be supplied to the ASEP's motor driver board to power the left and right channels for the motors. Since a two channel design is being used, the vehicle will drive similar to a tank type vehicle which will give the capability to make sharp turns. The GPS and IMU sensor being mounted to the ASEP vehicle is manufactured by Microstrain and will be powered by and communicate directly to the RM48 processing board via an onboard 25 pin micro-D connector. The data from the sensor will be polled at 10Hz, giving sufficient IMU data for the GUI. The stack will use the WizFi630 board to wirelessly communicate with the base station running the Windows GUI over 802.11. The USB controller, wired directly to the GUI, will provide user input and the controls for the robot. These commands will be wirelessly relayed to the MISL system so that they can be interpreted on the RM48 processing board. The processing board will then provide appropriate signals to the motor driver board to control each channel of motors.

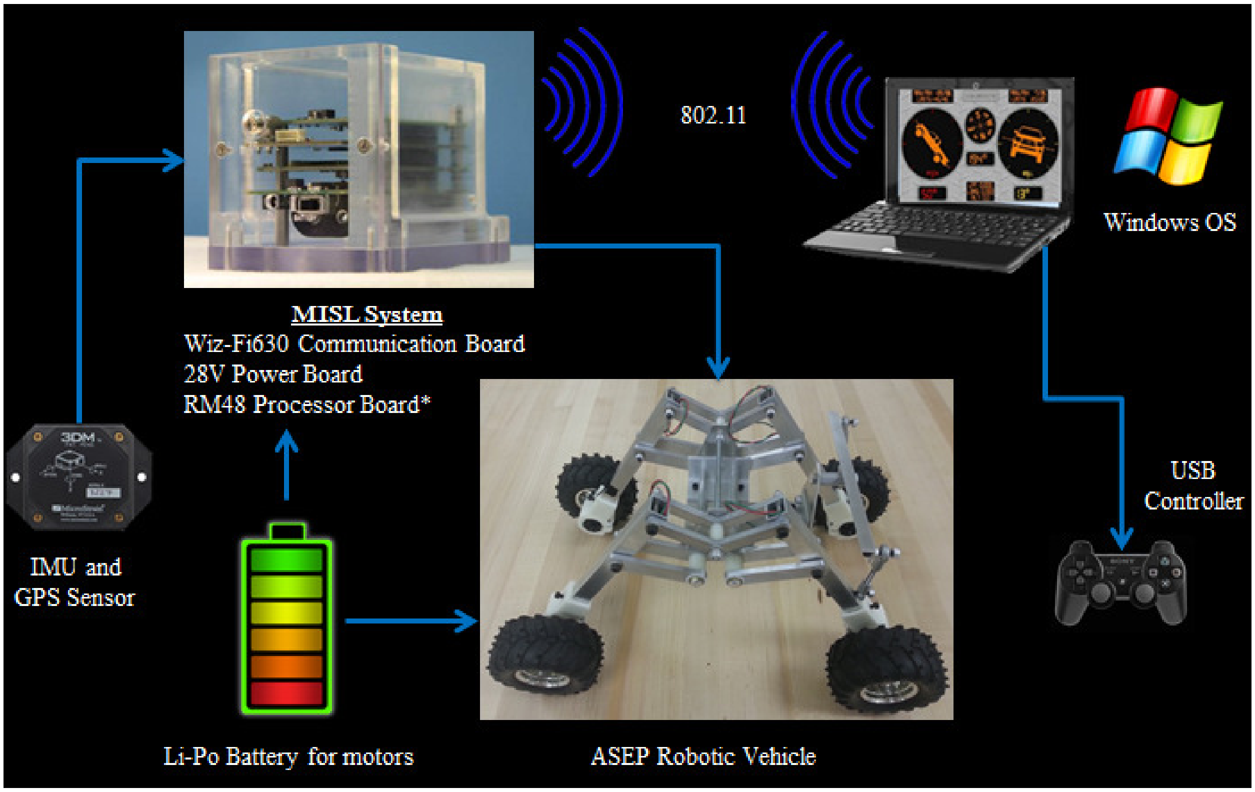


Figure 5: Conceptual Block Diagram

The processing board being developed will utilize the Ball Grid Array (BGA) package of the RM48L952. This microcontroller has 337 pins which will connect to several onboard peripherals as well as the data bus. Much of the controller's input/output (I/O) pins are mapped to the data bus so that other boards on any given layer can connect to the microcontroller. For example, the WizFi630 board being used in this project will communicate using the Serial Communication Interface (SCI) pins. Although the bus will be accommodating most of the I/O connections, several onboard peripherals will also be connected to the microcontroller. This includes: Ethernet, Controller Area Network (CAN), RS232, RS485, Universal Serial Bus (USB), Micro SD card slot, and the Joint Test Action Group (JTAG). The onboard Ethernet controller can be set to Reduced Media Independent Interface (RMII) or Media Independent Interface (MII), however when RMII is used a 50MHz oscillator must be soldered on the board instead of the 25MHz oscillator used for MII. USB can also be put in either host or device mode with the flip of a dip switch. The microcontroller's Universal Asynchronous Receiver / Transmitter (UART) pins are used for the RS232 / RS485 module. This module can be put into a given mode by the use of a set of four dip switches on the board. A few of the same microcontroller connections made onboard are also connected to the data bus. For example, the SCI pins mentioned before are available through the data bus as well as the RS232 circuitry. Therefore, depending on the user's requirements, one of the uses must be selected. Most of the onboard communications will be available through a 25 pin micro-D connector, which will allow for the use of custom cabling to connect the sensor and motor driver board to the MISL system.

CAN will be used to communicate from the RM48 board to the motor driver board, while RS232 will be used to communicate from the IMU/GPS sensor to the MISL stack.

Figure 6 shows the GUI that has been created in LabVIEW and converted to a windows executable. On the left side, the vertical and horizontal bars indicate the levels of joystick input from the USB controller. This will then be translated into vehicle motion through the MISL system. Below this, the current GPS data is displayed in Latitude and Longitude values along with a graph that tracks the movement of the vehicle with respect to a starting point. This starting point can be reset to the current location by the user at any time. On the right, a 3D model of the vehicle is displayed; this image will be rotated according to the IMU data received from the robot.

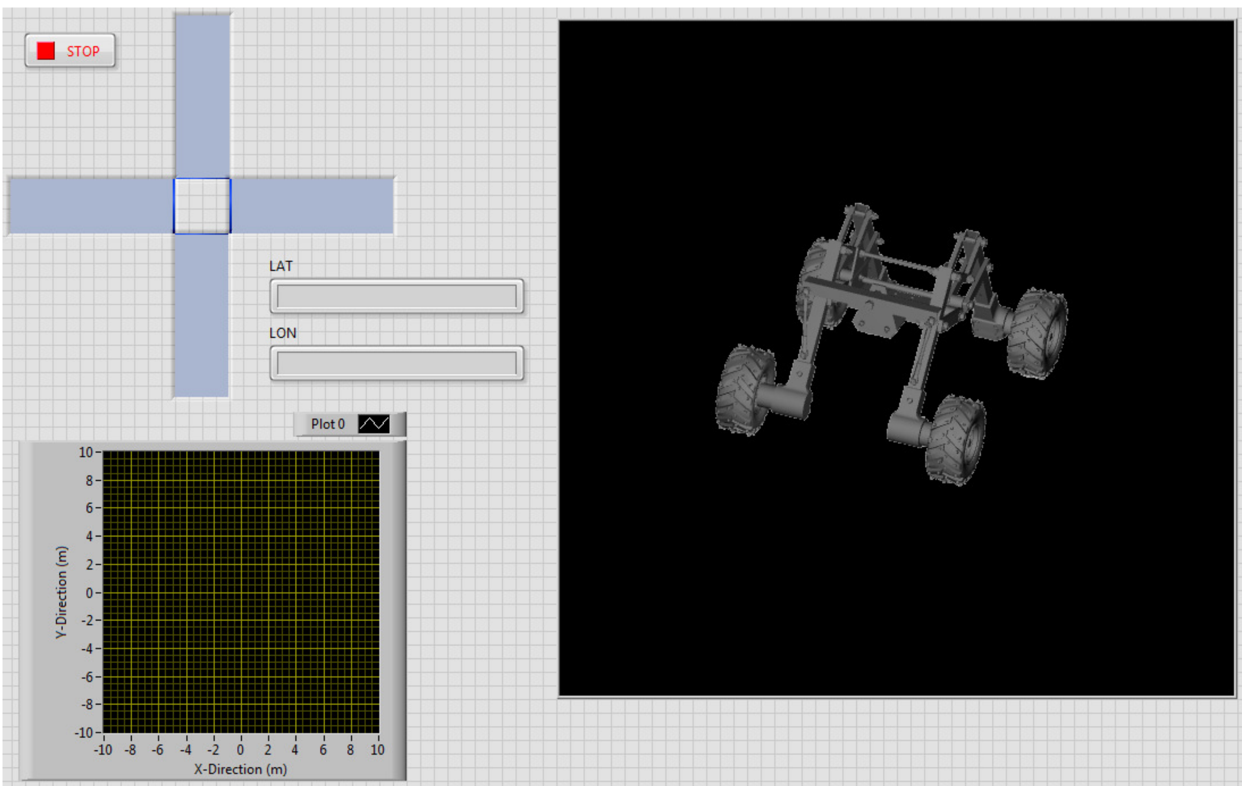


Figure 6: Graphical User Interface

MISL Open Source Community

In order to facilitate the open source community associated with the MISL system, the ESET department has been developing a MediaWiki. This Wiki page will contain information about the MISL system and its standards, hardware and software designs, current MISL boards in production, current and past projects that utilize the MISL system, a user forum, and a section outlining the use of MISL within the educational environment. The bus and connector standards, as discussed earlier, will be presented in value and pictorial format in order to allow users to design boards that will work with any boards produced previously. Currently, NASA has produced about a dozen boards to fill different power, communication, and intelligence requirements for a variety of projects. However, some of the boards will not be released to TAMU or the public. This is due in part to security reasons and also a few of the boards created would not be applicable to public use. For example the ISA100 communication board would not be of benefit because the ISA100 protocol is almost strictly used by NASA. This being said, most of the existing boards will be released for public use, which in turn will create a library of available boards for purchase. Having past and present projects displayed on the Wiki will allow potential users to see how the MISL system could meet their needs as well as displaying the wide range of capabilities of the MISL system. The opportunity of having a moderated forum could allow users to interact and help grow the support community and knowledge base of the MISL system. Finally, displaying the use of the MISL system within the educational environment will allow other educators to see how the MISL system could be integrated into their electronics, robotics, and/or embedded design courses. How the MISL system is being used currently within the educational realm will be discussed in the next section. Having a place that contains this wealth of knowledge will harbor an environment of cooperation that is the foundation of an open source community. This open source community would in-turn, allow for further rapid development of additional hardware and software for the MISL system, while at the same time driving cost down and making it an affordable system for all to utilize.

MISL within Education

The MISL system has had the opportunity to be used within the educational sphere when it was implemented by the ESET department in their sophomore level Embedded Systems Development in C course. This class is the first opportunity for ESET majors to be introduced to both the C programming language as well as the design and use of embedded systems. In this manner, the MISL system is a perfect platform to explore these two topics. The MISL stack being used contains the 5 Volt battery board, the Texas Instruments' MSP430 intelligence board, and a breakout board that allows for the complete pin-out of the data bus. This pin-out allows for the system to be connected to a breadboard which could connect a variety of circuitry containing numerous peripherals. The breakout board also has onboard light emitting diodes (LEDs) which will allow students to not only learn how to control pin outputs, but can also be used to debug more intermediate code. Many educators have chosen various Adruino systems to implement embedded design, however the ESET program at TAMU believes that MISL system gives students a more advanced and industry minded system to learn on. This will better prepare students for future job opportunities using an industrial grade microcontroller. This also adds the idea of assigning a specific pin an available function. For example, a given microcontroller may have a pin capable of communicating using the SCI protocol, however the pin may also have the capability to act as an Inter-Integrated Circuit (I^2C) communication line. In addition, almost all digital lines can act as a General Purpose Input and Output (GPIO). Therefore, the user must tell the microcontroller how each pin should behave. To do this with a Texas Instruments' microcontroller, the use of Halcogen is necessary to enable and assign pin functions to multipurpose pins. The use of this system in STEM education, both at a high school and college level, could greatly benefit our next generation of engineers.

Summary and Conclusion

To conclude, the MISL system is a versatile, space qualified system that is applicable in many environments including education, industry, hobbyist projects, as well as space applications. This multipurpose platform is composed of a layering system which allows for rack-and-stack, inter-board connections through a power and data bus. This gives the user the ability to choose the functionality they need for their specific project. The ability to swap space qualified hardware as well as the support of an open source community will set MISL apart as a versatile, high quality, inexpensive electronic solution for all users. Because of MISL's capabilities and the opportunities it presents to learn about embedded software development and electronics in general, the MISL system has been integrated into the ESET program at Texas A&M University. To demonstrate the newly created RM48 microcontroller board, Texas A&M is currently integrating the MISL system into the ASEP robotic vehicle to give remote control from a Windows laptop or tablet. On this windows laptop a LabVIEW base executable GUI will display IMU and GPS sensor data from the ASEP robot.