ZuiDesigns: Hardware in the Loop

Modular Test Proof of Concept

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INTRODUCTION

Hardware in the Loop (H.I.L.) is a method of vetting the software that controls a piece of equipment by simulating the inputs that that equipment will receive when fully assembled. These inputs are interpreted by the device under test (DUT) as if it were being used in the real world. The H.I.L. test monitors the outputs generated by the DUT to further ensure that the software controlling the DUT is behaving as intended. Figure 1 shows this in a high-level block diagram. Even though the DUT is not connected to any real-world sensors or peripherals, it will not know any better. Currently, H.I.L. testing is typically done on a case-by-case basis, and testing devices are made to order for each DUT that requires extensive software testing. This makes testing a device expensive. By combining many of the potential requirements that a DUT might need into a single unit, however, ZuiDesigns's H.I.L. Modular Test Proof of Concept helps to save on testing by offering interfaces including GPIO, SPI, I2C, and CAN, among others. With such a variety of testing potential, this product can be used to test devices featured in many different industries.

ELECTRICAL/PCB DESIGN

The project's electrical design had to accommodate for five different voltages that could be sent to the DUT: 1.8VDC, 3.3VDC, 5VDC, 12VDC, and 50VDC. The H.I.L. testing device was fed from a standard 120VAC receptacle, with the signal passing into a 120VAC-15VDC converter. The voltage was then stepped down appropriately to the specified voltages, with the 50VDC outputs fed from an external power supply which was not within the scope of the project. A 15VDC internal power supply was required so that headroom for the electrical components were met and did not compromise the integrity of the 12VDC output signals.

The H.I.L. testing device required three separate printed circuit boards (PCBs) in order to meet spatial requirements inside the mechanical enclosure. These boards were organized so that one was for the various output voltages, the second for the various input voltages, and the third for different communication protocols, ADC/DAC, and other miscellaneous items. All three boards had to be designed for a four-layered board in order to meet all project specifications while maintaining signal integrity and speed. Figure 2 shows the board for the miscellaneous items. Due to COVID-19 pandemic, the PCBs were not manufactured.

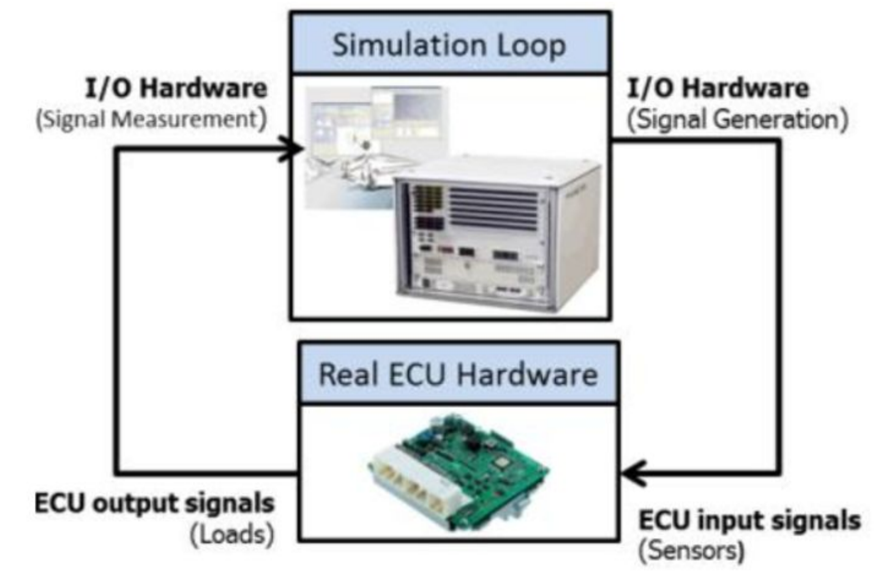

Figure 1. H.I.L. functionality with a Device Under Test

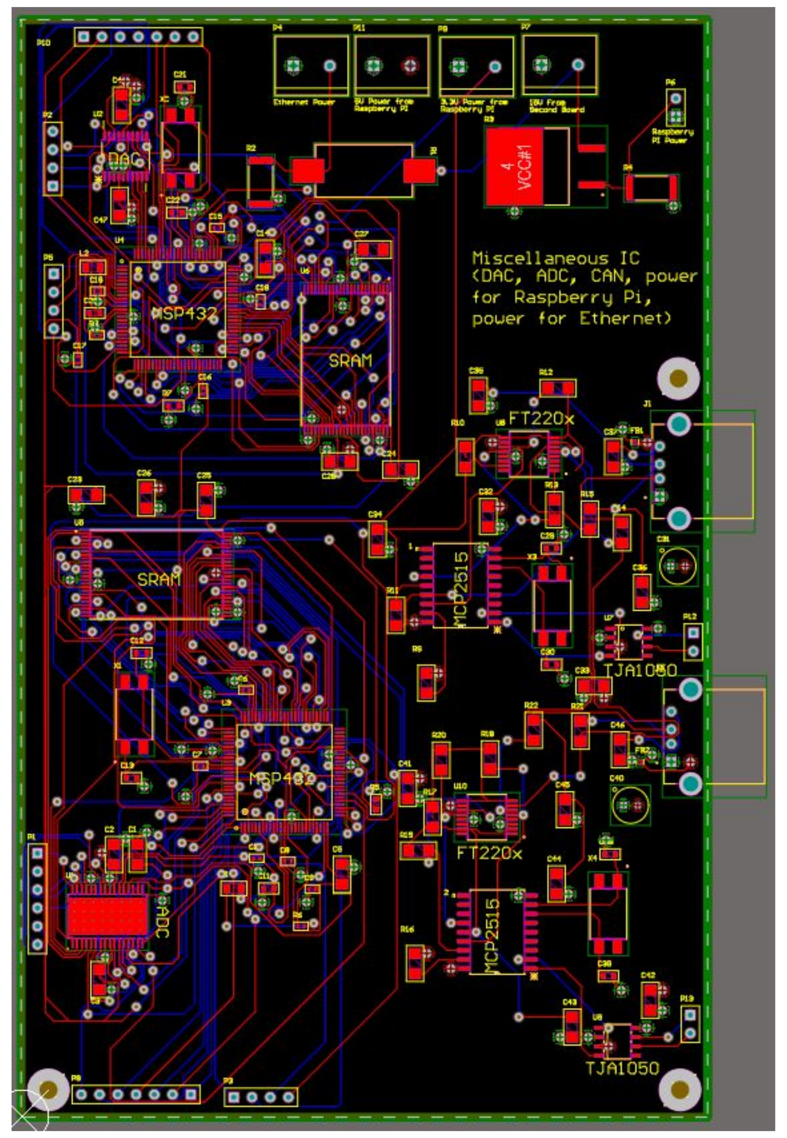

Figure 2. PCB for the miscellaneous modules. Items such as ADC/DAC chips, communication protocols are found on this board.

Figure 3. Mechanical rendering of finished H.I.L. Modular Test Proof of Concept from the front.

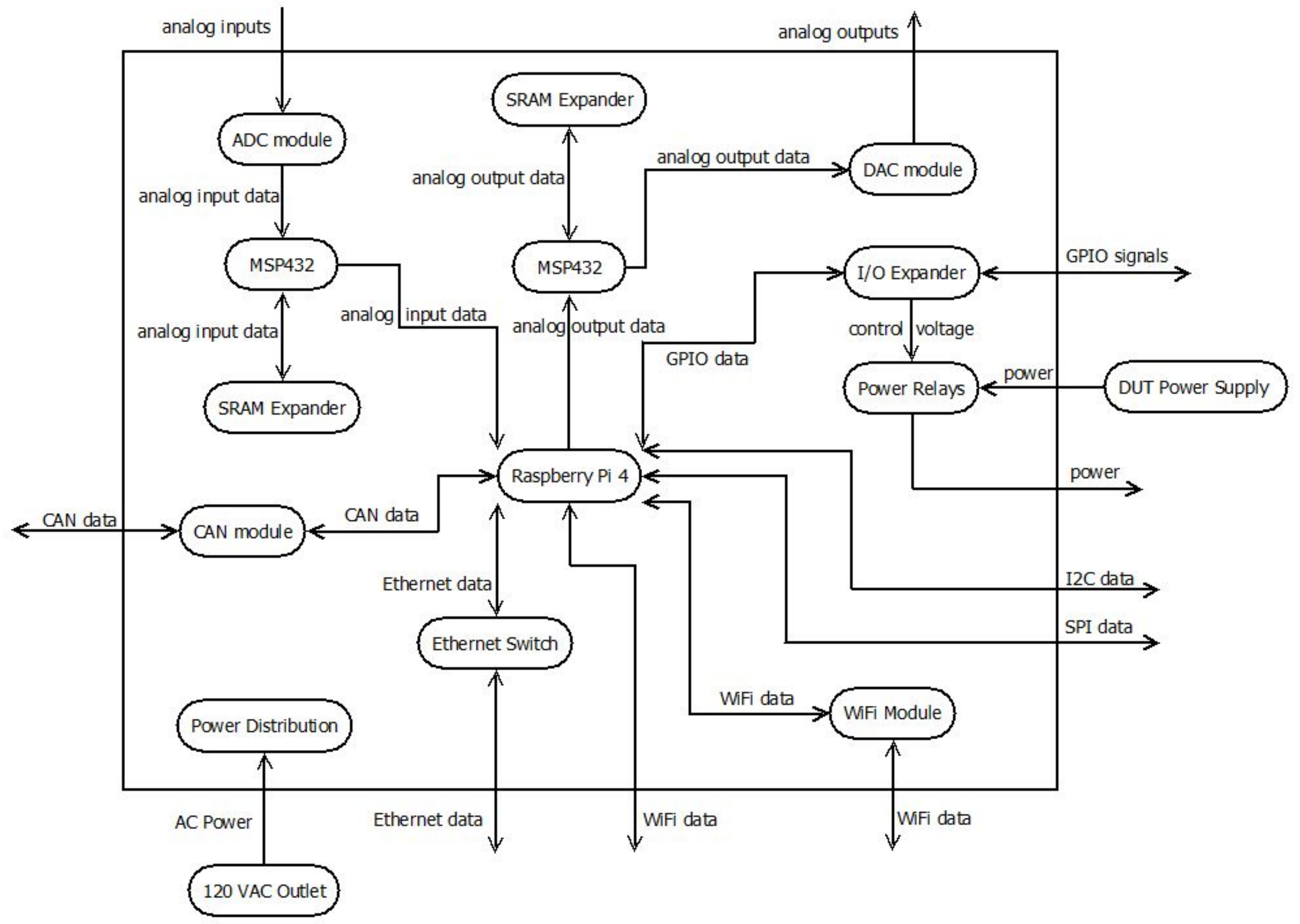

Figure 4. H.I.L. Modular Test Proof of Concept block diagram

MECHANICAL DESIGN

The H.I.L. testing device also required housing for the power converter, PCB's, and other necessary components. This enclosure was designed out of polycarbonate and has the spatial dimensions: 15.97in x 9.16in x 6.38in. Figure 3 displays a SolidWorks rendering of the housing from the front. Nearly all end user connections will be made from this side of the housing. The housing is fastened together by corner brackets and #8 screws.

The interior of the housing features space for a 120VAC-15VDC converter, an ethernet switch, a USB hub, three PCBs, and cabling to interconnect all of the components. In order to facilitate connections to the DUT with the components on the interior of the housing, DB connectors were used extensively. DB-9 connectors are used for CAN, SPI, and I^2C communication protocols (2 channels each) as well as for 1.8VDC, 3.3VDC, and 5VDC inputs and outputs (4 channels each). The DB-37 connectors were used to facilitate 12VDC inputs and outputs (15 channels each). The 50VDC terminals required banana connectors. USB, HDMI, and ethernet connections are made through their associated ports. Due to COVID-19 pandemic, the housing was not manufactured.

SOFTWARE DESIGN

The software design was centered around five common use cases – running a script from git repository, running a script via remote connection, running software updates, and system logs and test result emails. In addition to this, the software behind the ADC/DAC, GPIO, and various communication protocols also had to be written. Figure 4 shows the overall block diagram for the H.I.L. Modular Test Proof of Concept. One of the many benefits of using a Raspberry Pi 4 as the project's single board computer is that the open-source community is very large, making any future software updates to the H.I.L. testing device significantly easier.

With using the Raspberry Pi 4 as the single board computer, however, only a select few of the Pi's pins can be directly used. As a result, the GPIO and CAN communication protocol must interact with the Pi through USB protocol to maintain speed specifications. Communication conversion ICs are required to make this transition, which added to the software overhead. In order to mitigate this, multithreading is used. Due to the nature of software design, the development of this aspect of the project was not impacted by the COVID-19 pandemic.

CONCLUSION AND ACKNOWLEDGEMENTS

ZuiDesigns's H.I.L. Modular Test Proof of Concept allows for customers to test their product in an environment that appropriately replicates the product's end use. The project's modularity allows for the Hardware in the Loop testing device to be used across many industries, including but not limited to automotive, aerospace, and embedded systems.

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