INTRODUCTION

As a project for Embedded 2, I designed a system capable of measuring resistance, inductance (and ESR), and capacitance. A design goal of this project is to limit the total cost of the daughterboard and components added to the TM4C123GXL evaluation board to $3 in 10k quantities. Since connectors have significant associated cost, two shared connections will be used for the device under test (DUT), regardless of whether a resistive, an inductive, or a capacitive device is measured, so any commutation must also be included to allow any attached device to be measured. The virtual COM port on the evaluation board talks with PUTTY to provide a command line user interface.

Note: The PC boards, tools, and any optional items are not included in this collection of parts

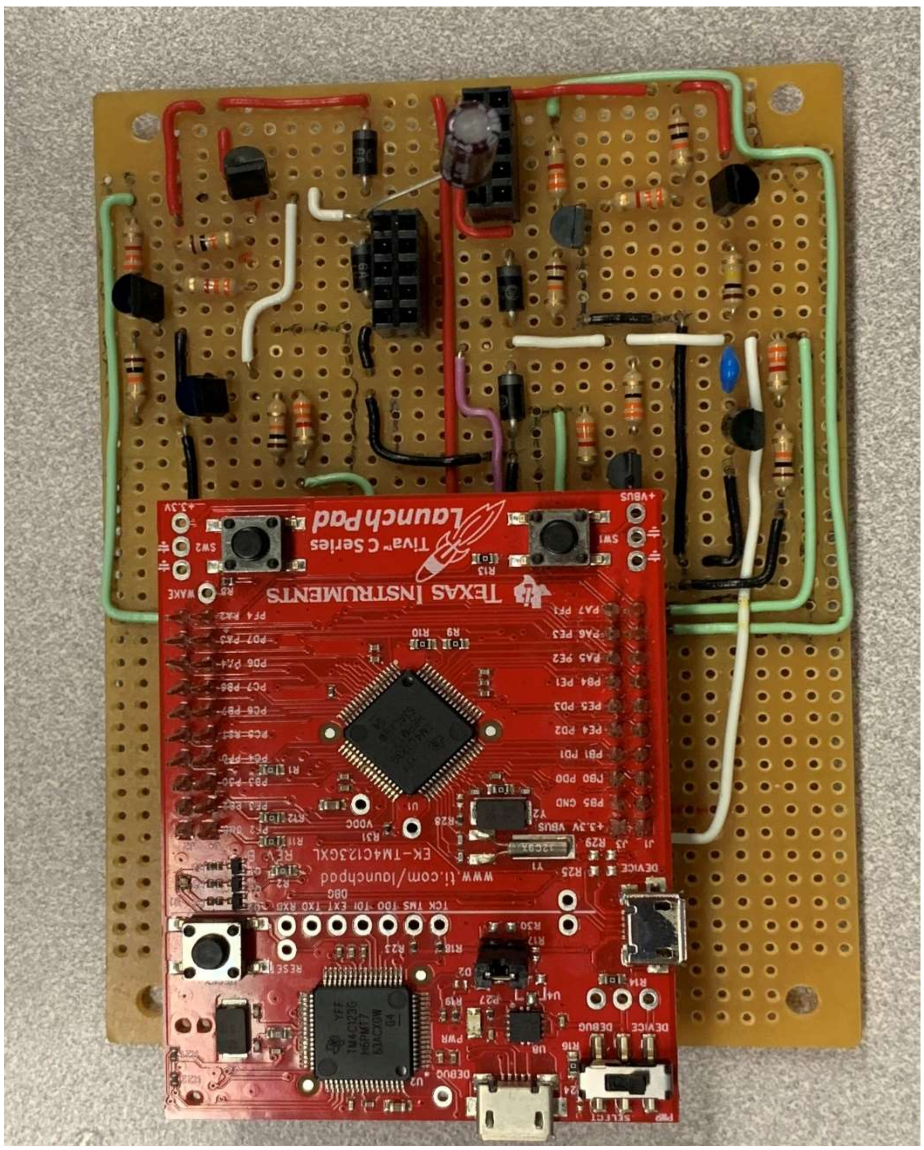

Fig 1: Project Hardware

Theory of Operation

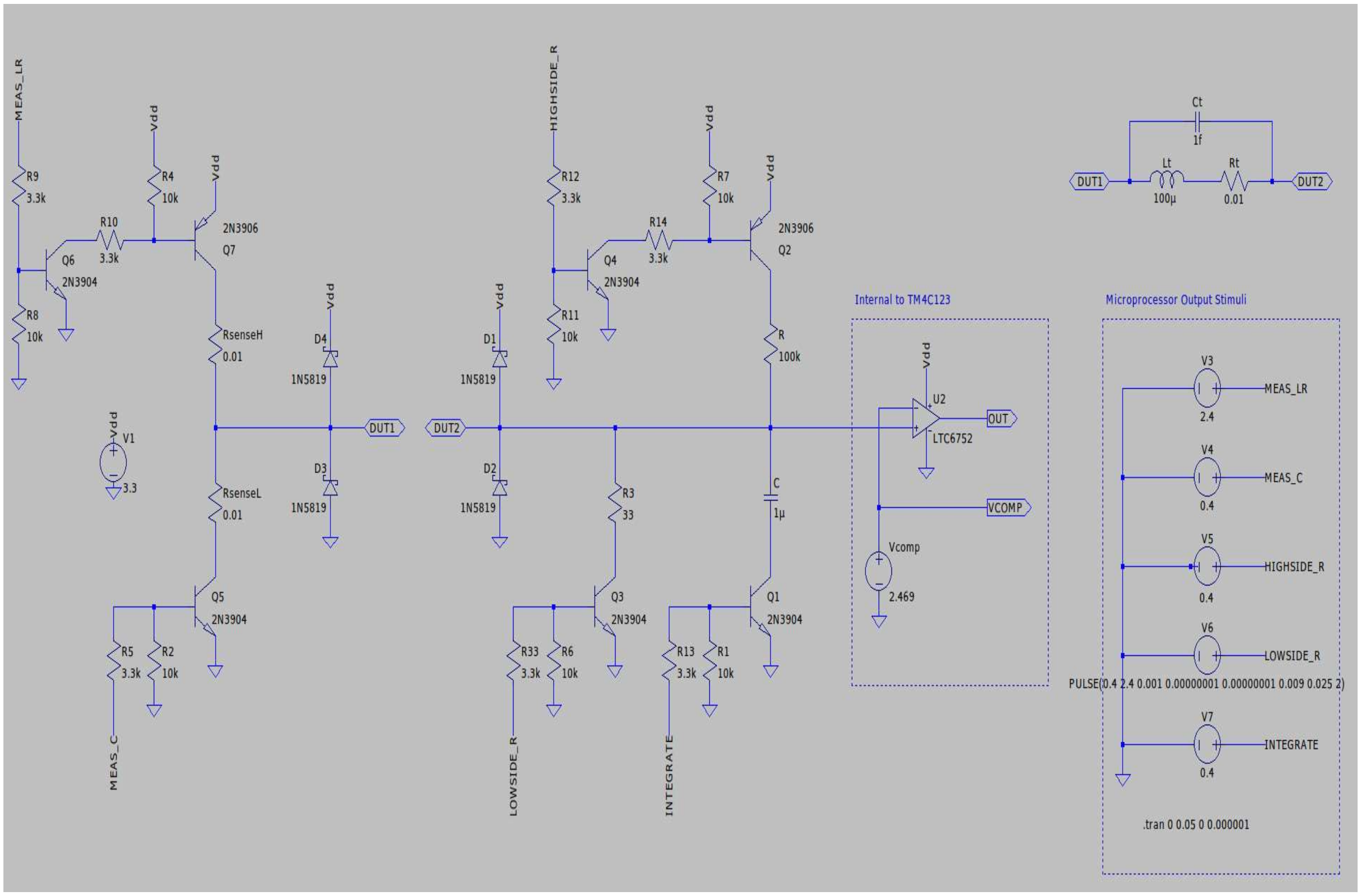

Fig 2: Project Schematic

As we can see in the project schematic, five pins (MEAS_LR, MEAS_C, HIGHSIDE_R, LOWSIDE_R, INTEGRATE) connects the circuit to the RedBoard using GPIO pins (PA2, PD6, PA6, PD0, and PA7 respectively). The DUT is connected to the comparator internal to the RedBoard using the PC7 pin. The comparator is set up to trigger an interrupt when the PC7 pin reaches Vref = 2.469 V. The 4 diodes are installed for protection from large voltages destroying the device. The 5 GPIO pins are connected to the 5 transistors that turn on/off depedning upon the DUT(inductor, capacitor, reisstor).

To measure resistance, MEAS_C and HIGHSIDE_R are turned off as we do not need those circuits while measuring resistance. INTEGRATE is turned on for capacitor(1uF) to charge/discharge. We create a LOWSIDE_R pulse by turning LOWISDE_R on, MEAS_LR off and turning LOWSIDE_R off after some time that discharges the 1uF capacitor. Then, we start the timer and turn on MEAS_LR that charges the capacitor, and the comparator interrupt is triggered when the voltages reaches 2.469 V. In the interrupt handler, we record this time it takes for the capacitor voltage to reach 2.469 V and this time is directly proportional to the resistance value. As we can see, to measure resistance, we use a known capacitance(1uF) and an unknown R.

While measuring capacitance, we use a known resistance(100kΩ) and an unknown C. In this case, INTEGRSTE and MEAS_LR circuits are turned off. MEAS_C is always on to charge/discharge the capacitor. A LOWSIDE_R pulse is created to discharge the capacitor. Then, HIGHSIDE_R is turned on that integrated the DUT(capacitor) through the 100kΩ resistor. This time it takes for the capacitor to reach 2.469V and trigger comparator interrupt is directly proportional to the capacitor value.

To measure inductance and its effective series resistance(ESR), MEAS_LR and LOWSIDE_R circuits are used. First, we discharge the inductor by turning off the MEAS_LR and LOWSIDE_R ciruits. Then, if the current through the inductor is 0A, we turn on MEAS_LR and LOWSIDE_R circuit and integrate, and when the voltage reaches 2.469V, the comparator triggers an interrupt. This time is again proportional to the inductor value. As for the ESR, we charge the inductor for some time until it reaches the maximum voltage. This voltage at Vdut = 3.3*33/(33+ESR) using the voltage divider law. In this way, we can calculate the ESR of the inductor.

While measuring the voltage at DUT, we use the Analog-to-Digital(ADC) converter internal to the RedBoard.

The program can also automatically detect whether the DUT is an inductor, a capacitor or a reisstor. To do this, the DUT is measured in all the modes(measureResistance, measureCapacitance, measureInductance), and the initial Voltages and final Voltages are recorded to create a decision matrix. Analyzing these voltages and fine tuning them, we can automatically detect the DUT and carry out our measurements.

The device uses UART interface to transmit commands and receive output in the CLI. The following commands are supported:

- reset – Hardware resets
- voltage - returns the voltage across DUT2-DUT1. The voltage is limited to 0 to 3.3V.
- resistor - returns the resistance of the DUT
- capacitance - returns the capacitance of the DUT
- inductance - returns the inductance of the DUT
- esr - returns the ESR of the inductor under test
- auto - returns the value of the DUT that is most predominant (i.e. an inductor with 1Ω ESR and 10µH inductance will return the inductance and ESR values, a 100kohm resistor will return the resistance, and a 10µF capacitor will return the capacitance.

CONCLUSION

This project was simple and fun. Concepts regarding how serial communication such as UART, Analog Comparator, ADC converter works are needed to be used for this project, and I have got a good understanding of those due to this project. The end goal was to create a measurement device that costs less than $5 instead of using real world measurement devices than costs thousands of dollars. This goal was achieved. However, as an endnote, the device we built is certainly not perfect and cannot measure all ranges of voltages, inductance, capacitance, and resistance, although further fine tuning can be done to increase the ranges. As of now, resistors in the range of 10Ω to 1MΩ, capacitors in the range of 1nF-100uF, and inductors in the range of 10uH-10mH are supported.