Senior Design Team 13

Measuring Voltage and Wire Continuity

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Outline

- The project
  - What is it
  - Why is it important
- Strategy
- Measuring Voltage
  - Difference op amp circuits
  - PCB Assembly
  - Testing
- Wire continuity
  - What we accomplished
  - How our device works
- What we learned

The Project - What Is It

- Check the presence of voltage in 3 phase distribution power line
- 3V-600V AC and DC
- When measuring less than 3 V be able to test to see if wires are connected or broken
  - Wire continuity test must work with 0V and preferably with 1 wire
- Techniques must be able to be run on battery power

The Project - Why Is It Important

- Patents on competitors equipment
- Saves cost and time when maintenance is performed
- Safety for technicians

Strategy

- Split team into groups to find solutions for measuring voltage, determining wire continuity, and programming the microcontroller
- Weekly meetings with faculty advisor
- Meeting with client every other week
- Meeting with group members every week

Measuring Voltage

- Report presence/absence of voltage above 3V RMS (AC and/or DC)
  - Voltage value does not need to be reported
- Maximum voltage the device will be exposed to is 600V RMS, line to line
- Device should work with delta or wye systems
  - No neutral in delta system
- Circuit shouldn’t dissipate more than 5W of power
- At the end of the last semester we were working to figure out a circuit which could measure both AC and DC

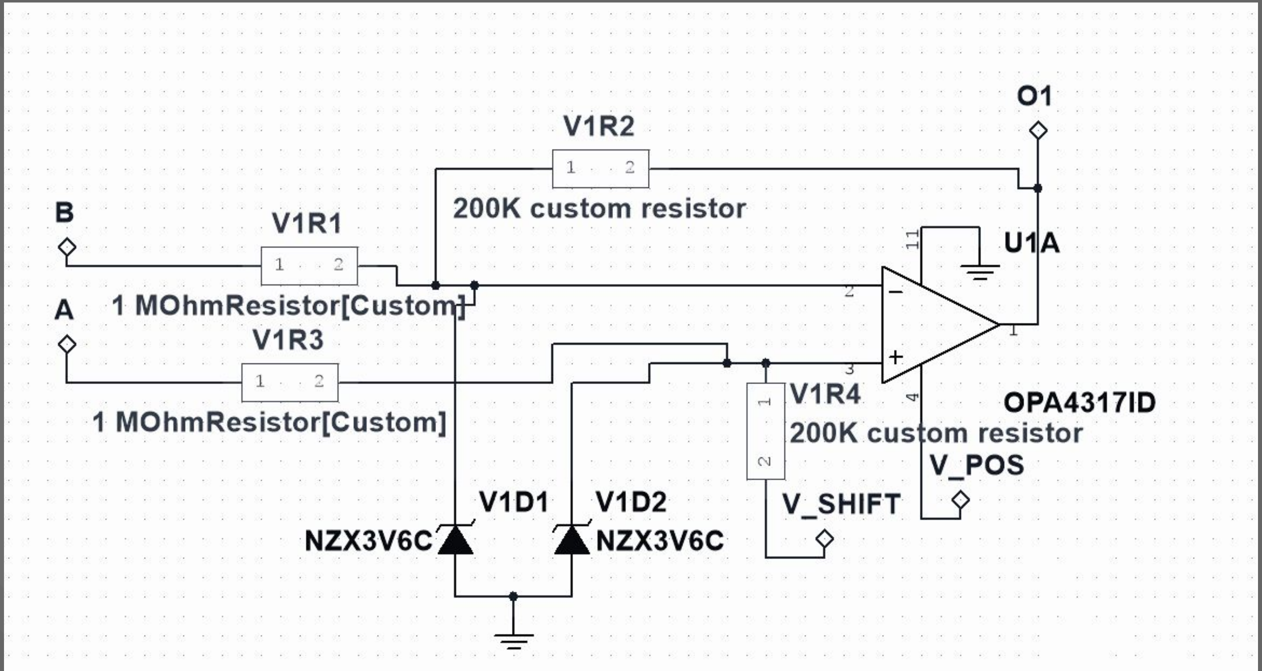
Measuring Voltage Approach

- 6 op amp circuits report the voltage differences between the wires with the function:

$$v_{out}=(v_1-v_2)/5 + 1.65$$

- When the users presses the button to measure the voltage, the device takes voltage readings over multiple 60 Hz cycles
- Riemann sums are used to approximate the RMS value from each output
- We had considered only using 3 circuits and calculating the other three voltages, but the math was more complex and error prone

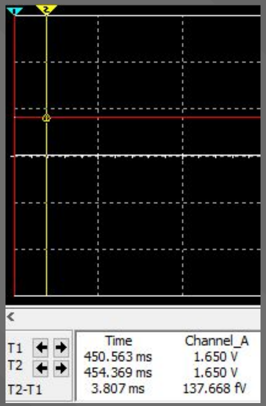
Difference Amplifier Circuit



Simulation Screenshots

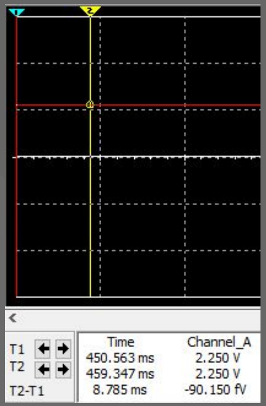
A. 0V
B. +3V DC
C. 3V AC RMS
D. 120V AC RMS

A.



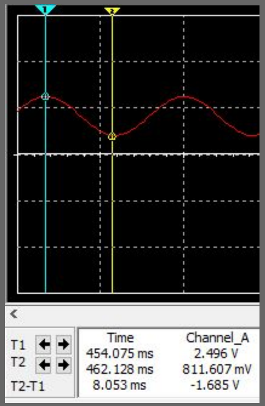
1.65V DC

B.



2.25V DC

C.



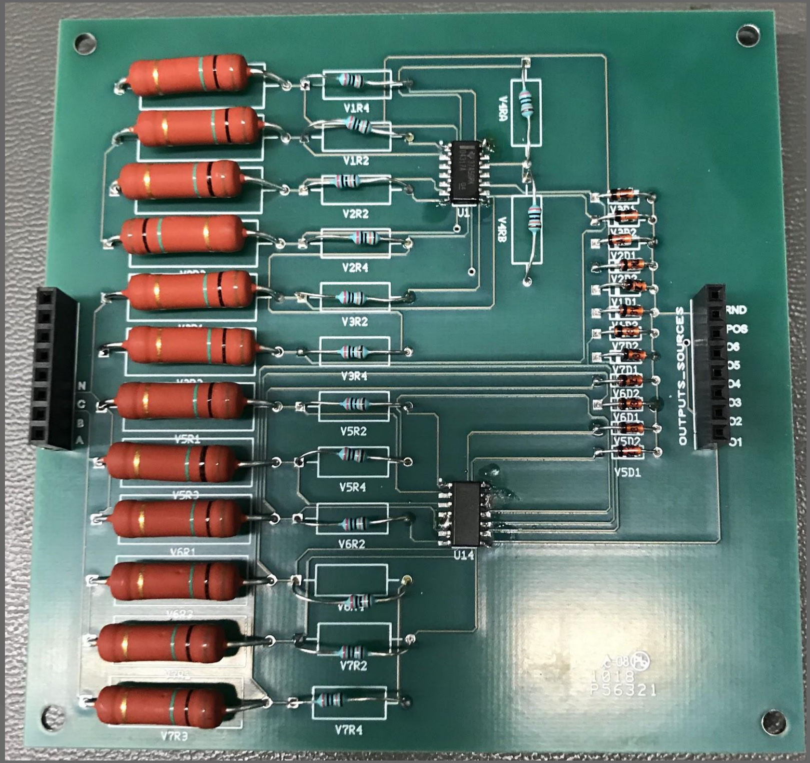
0.6V AC +1.65V DC

D.

1.65V AC Square Wave

Voltage Circuit Assembly

- We created a PCB for our voltage reading circuit
- Initial testing revealed that outputs 4-6 didn't have a DC voltage offset
- We realized this was due to an issue with the PCB design
- We managed to repair this issue by disconnecting three resistors from ground and then wiring them to the offset voltage



Voltage Circuit Testing

1. Low Voltage DC Testing
    1.1. Make sure circuit has correct output function
    1.2. Tested up to 25V
2. Low Voltage AC Testing
    2.1. Make sure launchpad correctly approximates RMS voltage
    2.2. Tested up to 6V RMS
3. Low Voltage Mixed Testing
    3.1. Make sure behavior doesn’t change with multiple inputs
    3.2. Various scenarios from 0 to 5V RMS
4. High Voltage AC Testing
    4.1. Make sure circuit isolation works at higher voltages
    4.2. Tested at 120V AC RMS

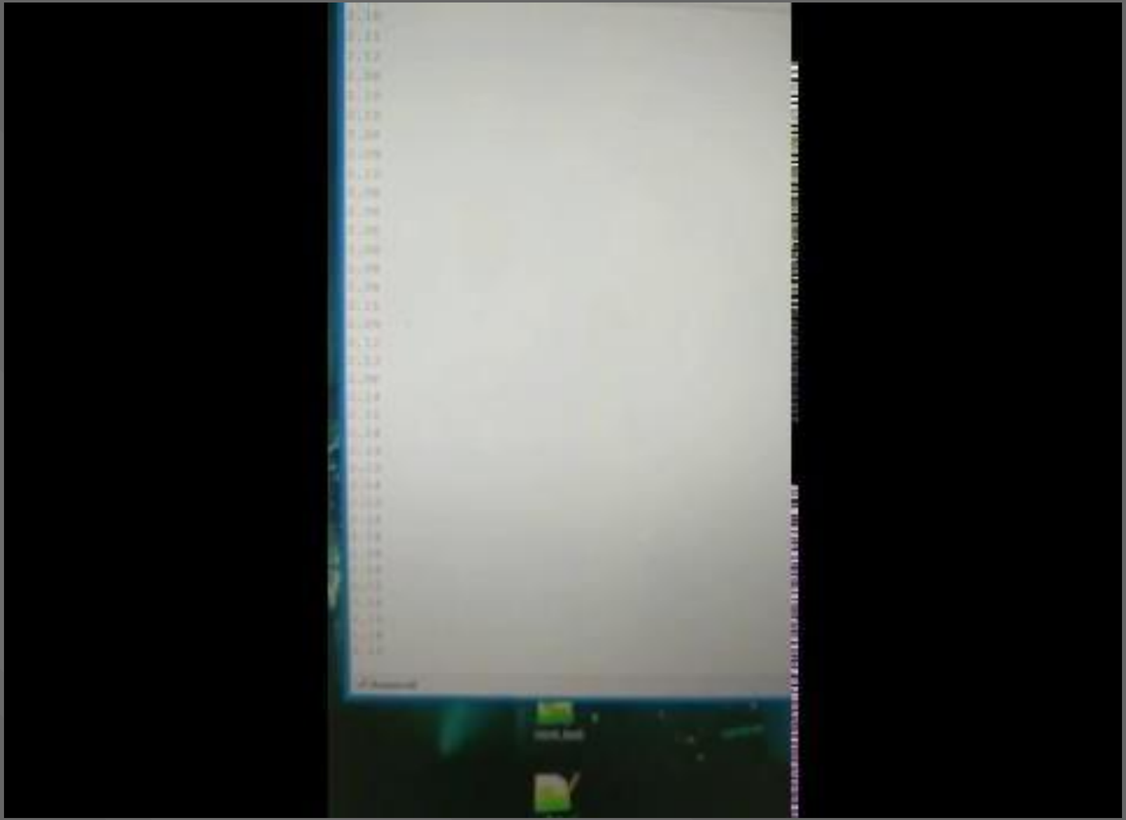
Wire Continuity

- Goal: come up with technique that will report if our device is connected to power lines or not
- Wire continuity test
  - Test will light up LED if device is not connected (fails wire continuity test)
  - 3 phases, 3 different tests, and 3 wire continuity circuits

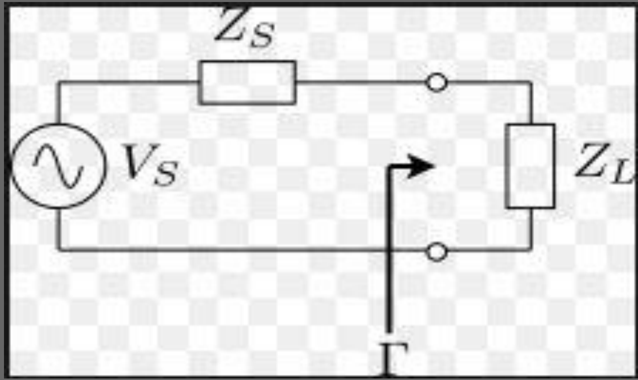
Wire Continuity - What We Accomplished

- Designed and tested a single phase prototype device
  - Sat on breadboard
    - Designed footprint for device to solder onto but didn't have time to have it delivered
  - Took input from a signal generator in the lab
- Device is able to light up LED when wire is disconnected and does not light LED when wire is connected
  - Demo

Wire Continuity - Demo



Wire Continuity - How Our Device Works



Reflectometry

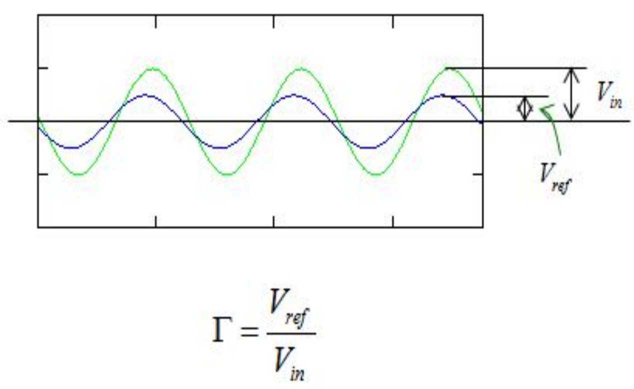
- Inject a signal at one end of the cable
- Signal reflects off of each impedance discontinuity it encounters

$\Gamma = \frac{Z_L - Z_s}{Z_L + Z_s}$ Z_s = 50 ohms Then: $V_{in} * \Gamma = V_{ref}$

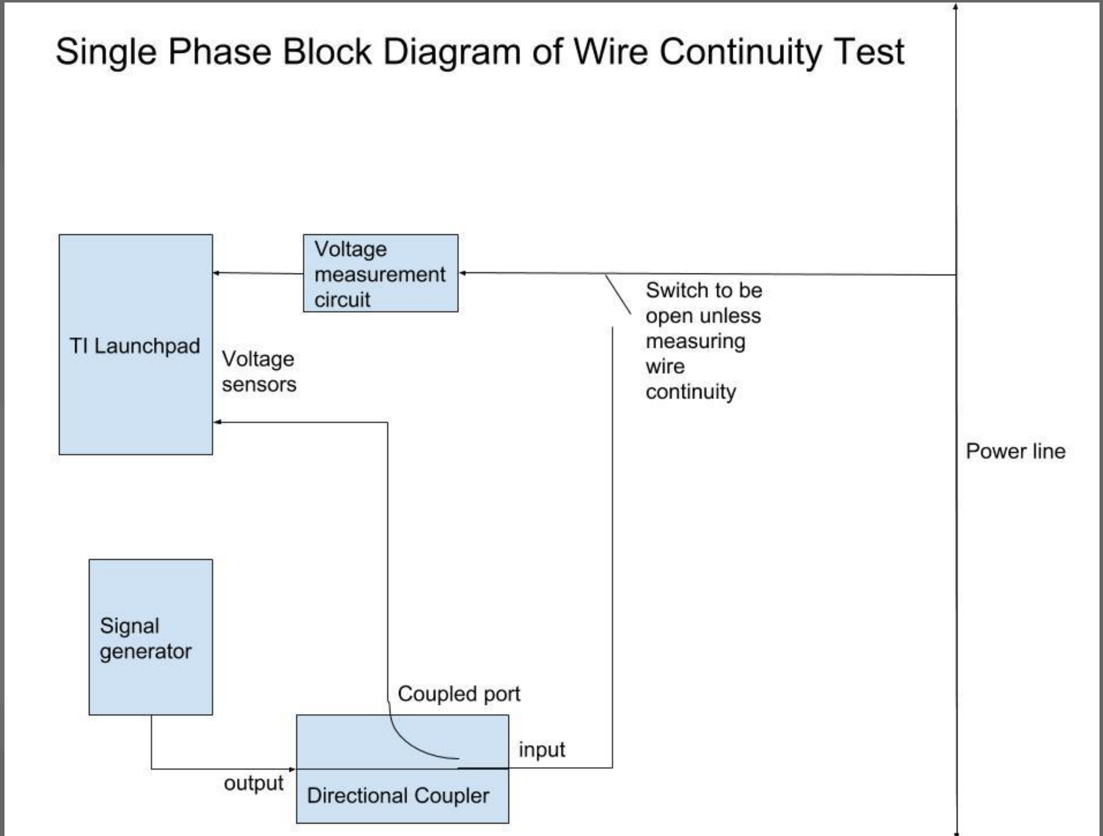
Connected circuit Z_L unknown but $Z_L > 1$, so $\Gamma < 1$, and $V_{ref} < V_{in}$

If disconnected $Z_L = 0$, so $\Gamma = 1$, and $V_{ref} = V_{in}$

V_{ref} disconnected > V_{ref} connected



Wire Continuity - Block Diagram



Wire Continuity - Testing and Results

- Used 5 MHz, 5V amplitude sine wave input signal
- Measured reflected voltage amplitude using TI launchpad
- Measured V_{ref} for: broken wire, short circuit, 10 ohm load, 50 ohm load, and 100 ohm load

Results:

Load	Broken wire	Short circuit	10 ohm	50 ohm	100 ohm
Output	2.1 V	1.76 V	1.37 V	1.1 V	1.09V

Software

- Voltage Detection: calculate RMS for each input
  - Acquire offset on device startup
  - Calculate time to measure specified number of wave oscillations (default 5)
  - Specified amount of time between measurements (default 150 micros)
  - If any of the inputs have rms > 3V, light LED
  - Up to 6 input pins, 1 output pin
- Wire Continuity: calculate average peak for each input
  - For each input, obtain the peak of a specified number of measurements a specified amount of times then take the average of the peak values
  - Defined amount of time between measurements (default 150 micros)
  - If the average peak for an input is greater than a defined voltage threshold (2.0V), light LED corresponding to that input
  - Up to 3 input and output pins

Conclusion

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  - What we accomplished
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What we Learned

- Take a ground up approach problem solving, don’t rely on a pre existing solution
- Ask as many questions as possible
- Don’t try and do something on your own when you can ask for help
- Defining the project scope clearly
- Identify what the expected outcome should be before testing

Questions?