Team 13: Measuring Voltage and Wire Continuity

Members: Aaron Eaton, Chris Williams, Matt Kelly, Mohamed Almansoori, Sam Kline
Faculty Advisor: Nathan Neihart
Client: Grace Engineered Products

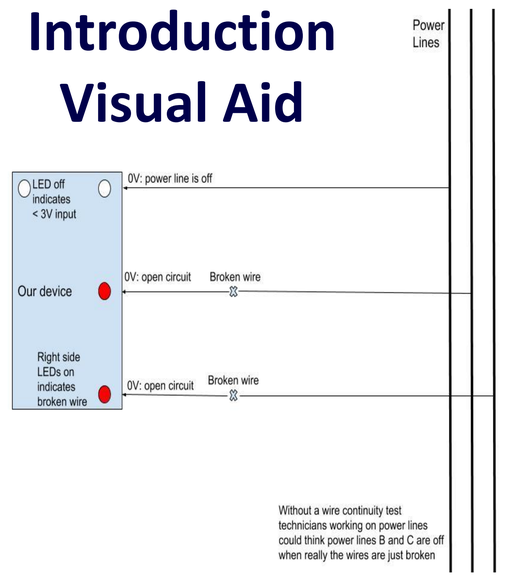
Design Requirements

- Functional Requirements:
  - report presence or absence of voltage down to 3V
  - able to test for broken wires
- Non-functional Requirements:
  - doesn't infringe on existing copyrights
  - consistently accurate in measurements
  - sensitive data must be kept secure
- Operating Environment:
  - permanently mounted in an electrical cabinet
- Engineering Constraints:
  - Doesn't exceed price of similar products
  - Proven through testing to be acceptably safe for intended users

Introduction / Motivation

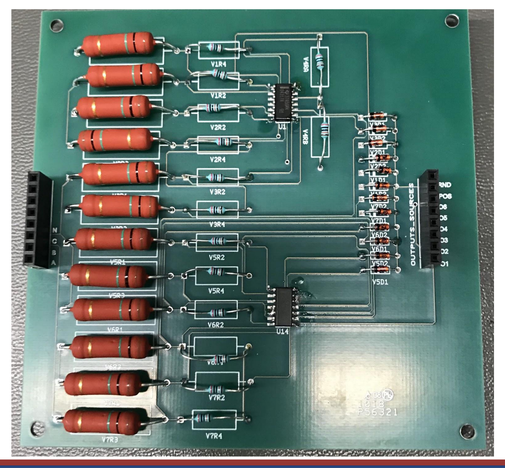
- Check the presence of voltage in a 3 phase system
  - Report presence/absence of voltage 3V-600V AC and DC
- Check for broken wires if absence of voltage reported
  - Wire continuity test must work with 0V and preferably with 1 wire
  - Techniques must be able to run on battery power
  - Permanently mounted in an electrical cabinet
- Why is this project important?
  - Patents on equipment made by our client's competitors
  - Saves cost and time when maintenance is performed
  - Increases safety for technicians, our intended users

Introduction Visual Aid



Voltage Detection Circuit Design

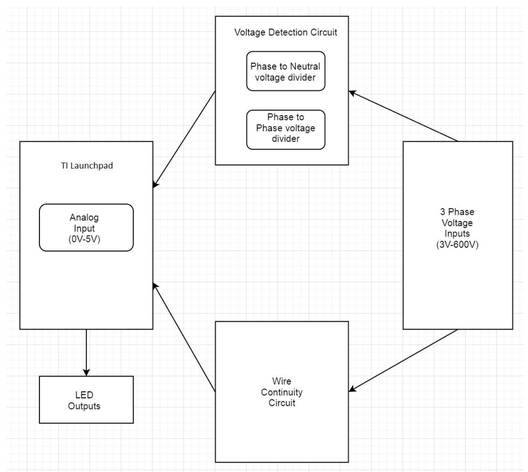
- 6 voltage difference circuits were needed
- The subcircuits were implemented using opamps
  - Allowed for DC offset to read negative voltage on ADC
  - The output was guaranteed to be within the supply range (isolation)
- Zener Diodes protected the op amps from high voltage



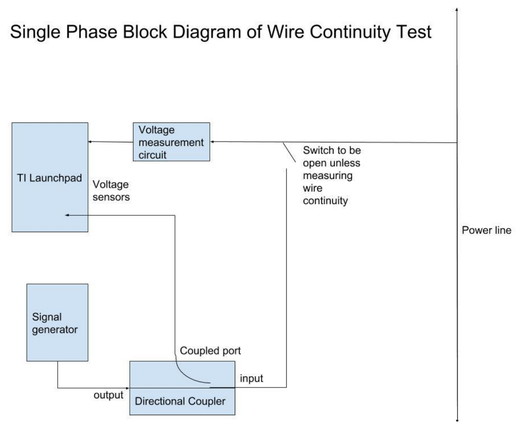
Design Approach

- Voltage Detection
  - Use 6 subcircuits to output the DC voltage difference between each of the lines
  - Take samples over a cycle to estimate the RMS voltage value for each of these
  - Light an LED if any of the circuits report greater than 3V RMS
- Wire continuity test
  - Measure voltage amplitude of the reflection of a signal sent toward power lines using directional coupler
- TI Launchpad MSP432P401R receives input from voltage detection and wire continuity circuits, and provides appropriate output for the user

System Block Diagram



Wire Continuity Block Diagram



Relevant Standards

- **IEEE 1801 - Unified Power Format**
- **4-2013 - IEEE Standard for High-Voltage Testing Techniques**

Wire Continuity Circuit

- Send a 5V amplitude 5MHz sine wave through a directional coupler so the reflection of the sine wave will be coupled and sent to TI Launchpad to be measured and analysed
- Reflected voltage = $\frac{Vin((Zload - 50)}{(Zload + 50)}$
  - A broken wire (open circuit) gives Zload = 0 so reflected voltage = Vin
- Reflected voltage amplitude of broken wires (fails test) will be the same in every system: 2.3V
- Reflected voltage amplitude of connected wires (passes test) will be different in every system because Zload is different in every system, but Zload will always be > 0, so reflected voltage for connected wires will always be lower than reflected voltage of broken wires
- Look at wire continuity under software to see how we determine if the test pases or fails

Software

- MSP432 receives input from the two different circuits through 9 analog pins, provides output through 4 analog pins
- Voltage Detection: calculates RMS value for each of the 6 input voltages, if any are above 3V, light 1 output LED
  - Measurements are taken when the device is turned on to determine an offset for each pin, the value is subtracted during RMS calculation
  - Voltage is sampled every 150 microseconds (~6666 Hz)
  - RMS function takes measurements for enough time to capture several wave oscillations, then returns calculated RMS value
- Wire Continuity: calculates average voltage for each of the 3 inputs, if any are above a specified threshold (2.3V), light corresponding LED
  - Voltage is sampled every 150 microseconds
- Used Energia as IDE

Testing

- Wire Continuity
  - Did all testing in the labs at Iowa State
  - sed a signal generator to send 5V amplitude 5 MHz sine wave signal
  - Used TI launchpad to read output and used oscilloscope to verify output reading
- Voltage Detection
  - Used DC Power Sources in lab to verify circuit output
  - Used AC Power Sources in lab to verify AC RMS detection on Launchpad
  - Used high voltage AC power from wall outlet to test circuit isolation