EEL 4914
Summer 2023
Group 12

PCB Short Circuit Locator

Department of Electrical Engineering and Computer Science

University of Central Florida

Senior Design Summer 2023

Group 12

Group Members (Major and Track)

Mohammed Al Mazrouai	Electrical Engineering (Power and Renewable Energy)
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Project Sponsors

Precision Test Solutions

Precision Test Solutions is a company that tests and analyzes a wide range of electrical and mechanical parts for clients like NASA. They are located in Orlando and are 20 minutes away from the University of Central Florida. As the sponsor of our project, all the physical parts of the PCB Short Locator will be compensated for by Precision Test Solutions.

Review Panel Information

Dr. Sahawneh
Dr. Wei
Dr. Chan

Project Narrative Description

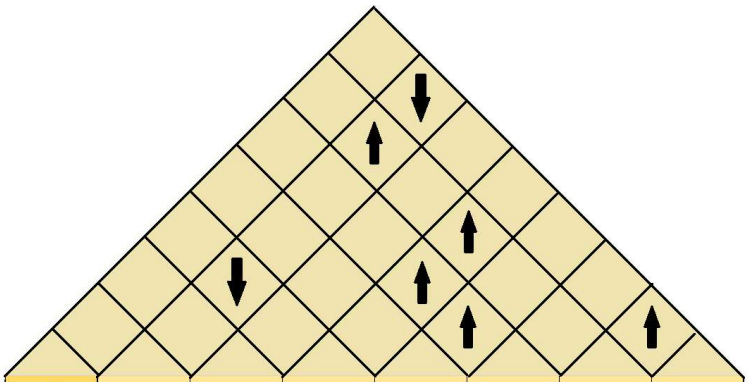
With millions of printed circuit boards (PCBs) created every year, it is ideal to avoid short circuits in PCBs, yet it's nearly impossible to avoid. There are multiple reasons that can cause a short circuit, which can occur during the manufacturing and/or the assembly of a PCB. While it is possible to detect shorts on a PCB using a multimeter, one of the hardest challenges with PCB short circuits is physically locating them, especially if they are relatively high resistance or are not noticeably visible. The PCB will not work as intended, and any short circuits can lead to permanent damage to the PCB that may be very costly to fix or replace. The worst-case scenario may even be discarding the entire PCB and having to order or build a new PCB, which can significantly set back a project based on factors like component availability. The last thing anyone would want to happen to their PCB is to have it burn or melt which, speaking from firsthand experiences, does not smell the greatest.

The PCB Short Circuit Locator will be a portable device that is able to both detect and precisely locate distinct types of short circuits on PCBs. Once located, short circuits are usually easy to repair, but the hardest part is finding them! Like using a multimeter, it'll be as easy as repeatedly moving contact probes until a short is located! The familiarity of using such a device means that no extensive training would be needed to be able to use a Short Locator. Another highlight of the Short Locator device is to be able to locate various degrees of PCB short circuits for a much lower cost than other existing methods. Combined with an embedded system, the device will be easy to use, making it accessible for even more users. One of the main goals of the Short Locator is to make the process of finding shorts simple. To accomplish this, the device will integrate an LCD display and sound speaker to give the user visual and audio feedback. These features will help guide the user toward the area that may contain the short and alert them once the short is found.

Project Requirements and Specifications

- Product should be powered using 120 VAC source, which is the voltage of a standard electrical outlet in the US. This product will most likely be used in a production/test setting, which usually requires nearby power. It will be most economical and practical to use this method of power. To use the 120 VAC, it will require us to step down and regulate this supply voltage to be compatible with the device's circuitry.
- Must weigh less than 10 lb, and no larger than 8"x 8". The goal is to make the device easily portable and not take up excessive room on a work bench. It will also benefit sales if the product is mass produced, since less size and weight will reduce shipping costs to consumers.
- Audio/speaker for functions like user guidance and low battery. Audio feedback will support guiding the user toward the location of the short, and alert them once the short is found.
- Display (possibly LCD) to show when short is detected and support user guidance. Visual feedback will support guiding the user toward the location of the short, and alert them once the short is found. This will be critical for making the product easily usable to any operator.
- Generates 2 Hz AC for driving signal. This requirement is based on our proposed detection scheme, which will help us avoid some practical considerations when it comes to measuring shorts on populated/assembled PCBs, particularly the thermoelectric effects that DC would contribute.
- Able to detect down to 10 nV peak-to-peak. This will be required to be able to measure small voltage drops along planes of the PCB, as we follow the path of the current to the short. The worst case scenario was calculated using a PCB with 2 oz copper and a 500 ohm short.
- Band-pass filter for noise higher than 2Hz. In order to get stable and accurate measurements, we will need to filter out any undesired signals beyond our target bandwidth.
- Detection must reject inductive and capacitive reactances. Since we are using an AC signal, if these reactances are low enough then AC current will flow through those components, diverting current away from the short we are trying to locate.

House of Quality

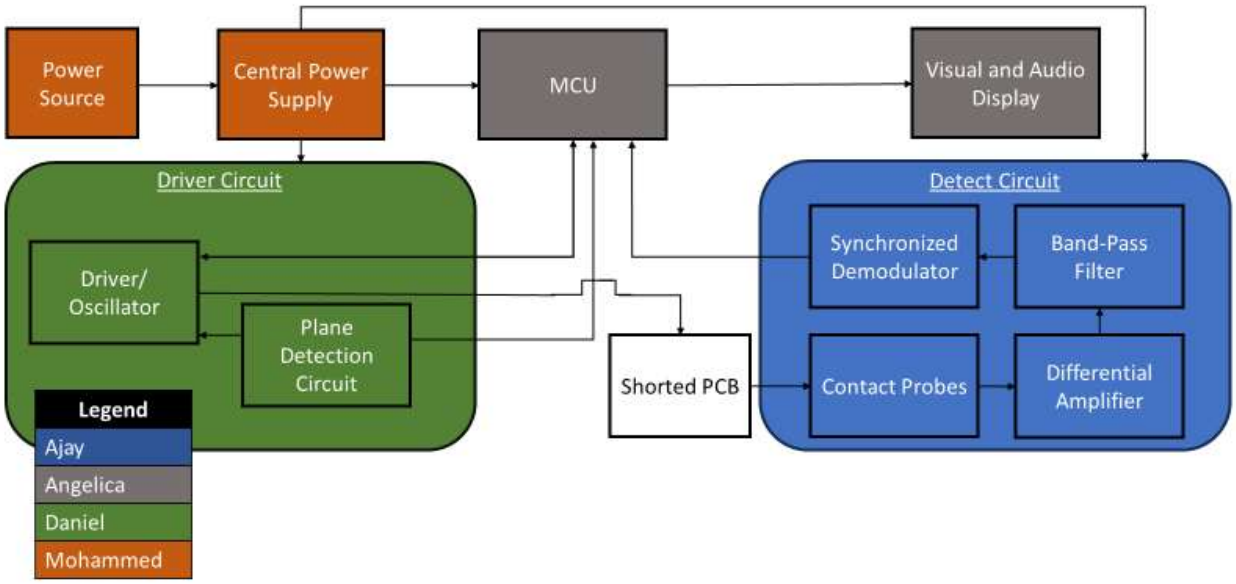


Marketing Requirements	Engineering Requirements	Cost	Don't harm Circuit	Power Consumption	Weight	Size	Sensing Range	Noise
		-	+	-	-	-	+	-
Cost	-	↑↑	↓		↓	↓	↓	↓
Easy to Use	+	↓			↓	↑		
Accurate	+	↓	↓	↓			↑↑	↓↓
Portable	+	↓		↓	↑↑	↑↑		
Power Consumption	-			↑↑		↑	↓	↓
Durable	+	↓			↑	↑		
		<$500	Unaffected PCB	<5 Watts	< 10 lb	Handheld	up to 10nV	< 1%

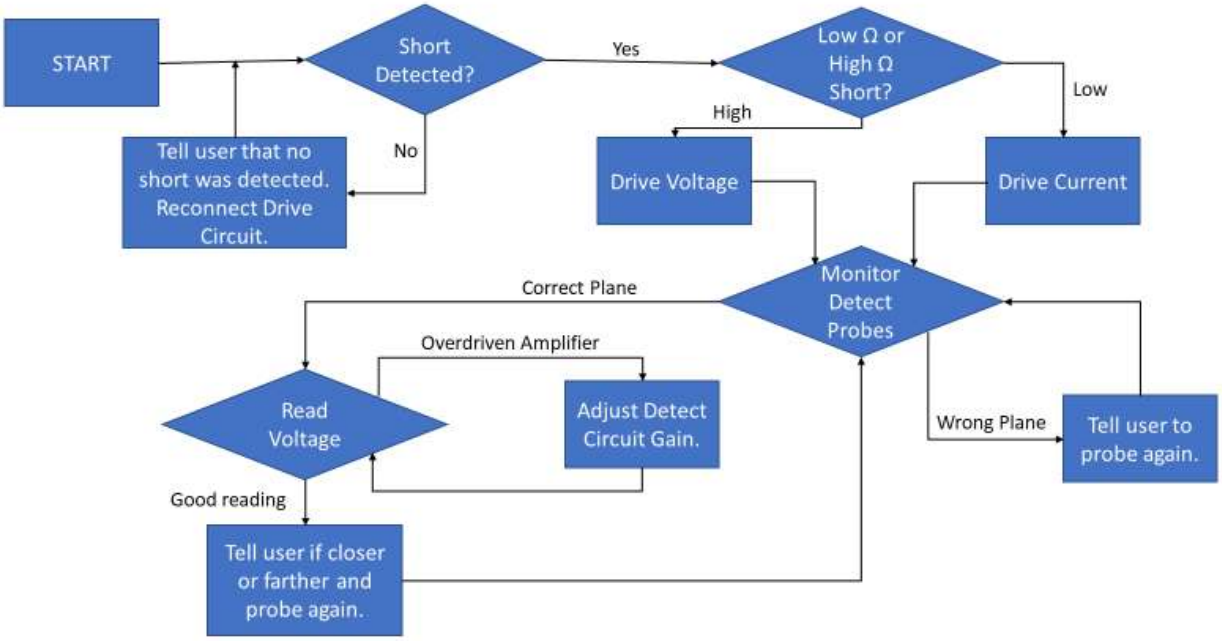
Legend:

+ = Positive Polarity
- = Negative Polarity
↑ = Positive Correlation
↓ = Negative Correlation
↑↑ = Strong Positive Correlation
↓↓ = Strong Negative Correlation

Block Diagrams



Project Hardware Diagram



Project Software Flowchart

Budget and Financing

Item	Quantity	Estimated Cost
Microcontroller	1	$50
LCD Display	1	$10
Audio Speaker	1	$10
Test Probes	1	$25
Power Supply	1	$60
Connectors/Headers	N/A	$20
Other Components/ICs	N/A	$50
PCB Fabrication	1	$50
Housing/Enclosure	1	$30
Total	-	**$305**

The table above shows the estimated costs to build our prototype. The items listed in the table are things we anticipate using in our design but are subject to change throughout the design process. The first thing we will certainly need is a microcontroller to add automation features, as well as read and process the input analog data, and send instructions to the operator. Our product may not require a very high-performance microcontroller, so we estimate $30 will be sufficient. LCD display and an audio speaker are two items that will be used to provide a more user-friendly experience and will cost about $10 each. We will need one set of fine point test probes, which are estimated to cost $25. We plan on powering the device with 120 VAC,so we will need a power supply to convert this voltage to something we can regulate for our circuits. We estimate $60 will be needed for a central power supply unit. Connectors and headers will be needed for assembling the final product, which is estimated to cost $20. All other various components and ICs required for the circuits are estimated to cost $50. The estimated cost to fabricate and ship the PCB prototype is $50. Finally, an enclosure for the PCB and final product is estimated to cost $30. That brings us to a maximum estimated total cost of $305.

Our sponsor, Precision Test Solutions, has agreed to provide us with a budget of $305 towards any items purchased to build this prototype. The team members will not be required to contribute any additional funding on the condition that Precision Test Solutions will reserve the rights to the final design and product.

Initial Project Milestones

Senior Design I - Summer 2023			
Number	Task Description	Duration	Date
1	Introduction to senior design I.	2 Days	5/16-5/18
2	First group meeting and brainstorming ideas.	1 Week	5/18-5/23
3	Divide and conquer.	1 Week	5/23-6/2
4	Idea development including research and DC meeting.	1 Week	6/2-6/8
5	Selecting and comparing possible technologies to use for software and hardware and exploring suitable designs.	3 Weeks	6/8-6/26
6	Writing and finalizing the 60-page draft	4 Days	6/26-6/30
7	ChatGPT comparison, Professor Meeting, Studying the selected parts and identifying the possible design constrains.	1 Week	6/30-7/5
8	Moving in-depth and finalizing the hardware and software design.	10 Days	7/5-7/15
9	PCB layout and system testing.	6 Days	7/15-7/21
10	Concluding and submitting the 120-page report.	4 Days	7/21-7/25

Senior Design II - Fall 2023			
Number	Task Description	Duration	Date
1	Parts Ordering.	TBD	TBD
2	Building a prototype and design testing.	TBD	TBD
3	Experimenting possible prototypes to ensure best efficiency and accuracy.	TBD	TBD

4	Assembling the final design.	TBD	TBD
5	Final Product Presentation.	1 Day	TBD

Decision Matrix

	Group Interest (Weight: 1)	Cost (Weight: 2)	Complexity (Weight: 3)	Final Weighted Score
AM/FM Radio	2	2	3	15
Chromatic Tuner	1	2	3	14
Home Theater Seat	1	1	1	6
Metal Detector	3	2	2	16
PCB Short Locator	4	5	4	26
Pinball Machine	2	3	1	8

Using a scale from 1-5, with 5 being the best, the chart above represents the various faactors that were taken into consideration when the group chose a senior design project idea. Each category is described as:

- Group Interest: Once everyone in the group came up with project ideas, one of the first things we did was pick the ones that were the most appealing to us. Out of all the ideas that the group initially came up with, only half of them garnered individual interest from half of the members, with the PCB Short Locator attracting the most interest.

- Cost: This includes factors such as costs for purchasing/fabricating components and sponsorships. The PCB Short Locator was also the most appealing project in this category due to it being sponsored by Precision Test Solutions.

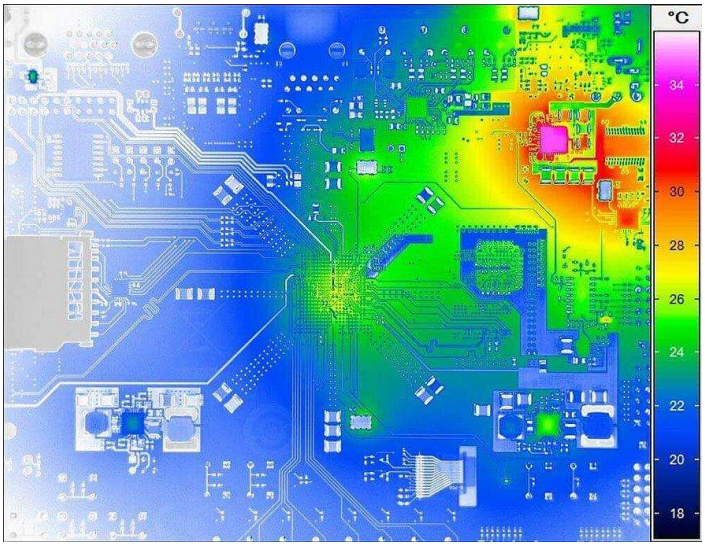
- Complexity: Given that the project is to span over two semesters, there is only so much that can be achieved during that time frame. This category accounts for familiarity with technology and individual project complexity. For example, projects like the home theater seat and the pinball arcade machine are physically bigger and may be difficult to transport for the final project presentation at the end of Senior Design II. We also did not want to spend a significant amount of effort on the mechanical aspects that those projects would require.

Existing Products

There are existing methods that allow or assist people to locate short circuits on a PCB. One of them is just by using a voltmeter. Using the voltmeter probes, a user can trace the voltage drops along a powered pcb to locate a short, but this only works if the short is very low resistance so that you can drive enough current through the PCB to get readable voltage drops. If the short was a higher resistance, then you could use more sensistive equipment such as a nano-voltmeter, but those are priced at several thousands of dollars and are much less user friendly than the PCB short circuit locator for locating shorts.

https://pixabay.com/photos/fluke-179-true-rms-multimeter-4623180/
(Existing multimeter via pixabay.com)
https://www.tek.com/en/products/keithley/low-level-sensitive-and-specialty-instruments/nanovoltmeter-model-2182a

Another method of detecting short circuits is through thermal imaging. With circuit shorts, the board will be significantly warmer at those spots, making it easier for infrared technology to detect and locate. In comparison to the multimeter, this may be a more efficient method for detecting and locating shorts. However, the cost of existing thermal imaging cameras on the market are significantly higher than the costs for existing multimeters. Another drawback to this method is that it requires running a significant amount of current through the PCB to heat it up, which could potentially cause permanent damage to the PCB by overheating the traces. Excess current can even open up the short making it unfindable.



https://www.infratec-infrared.com/thermography/industries-applications/electronics-electrical/
(Existing closeup of electronics board underneath a thermal camera from infratec-infrared.com)

The worst-case scenario for locating the circuit is to dismantle the board, even with one of these two existing products. By breaking away components, even stripping away layers of the board, this would isolate the part of the circuit where the short is located.

The ShortSniffer is another existing product that has the same functionality as the PCB Short Locator but executes the process differently. The ShortSniffer is also a small device that has some probes to detect the locatin of a short on a PCB. The difference with this product is that it uses an audio current that is sent through the circuit and picked up on an inductive coil probe. The drawback of this product is that they do not specify the degree of short circuits it can detect, and this method would be very difficult to detect the magnetic field if there is a high resistance short that will limit the current you can drive through the PCB.
https://shortsniffer.com/