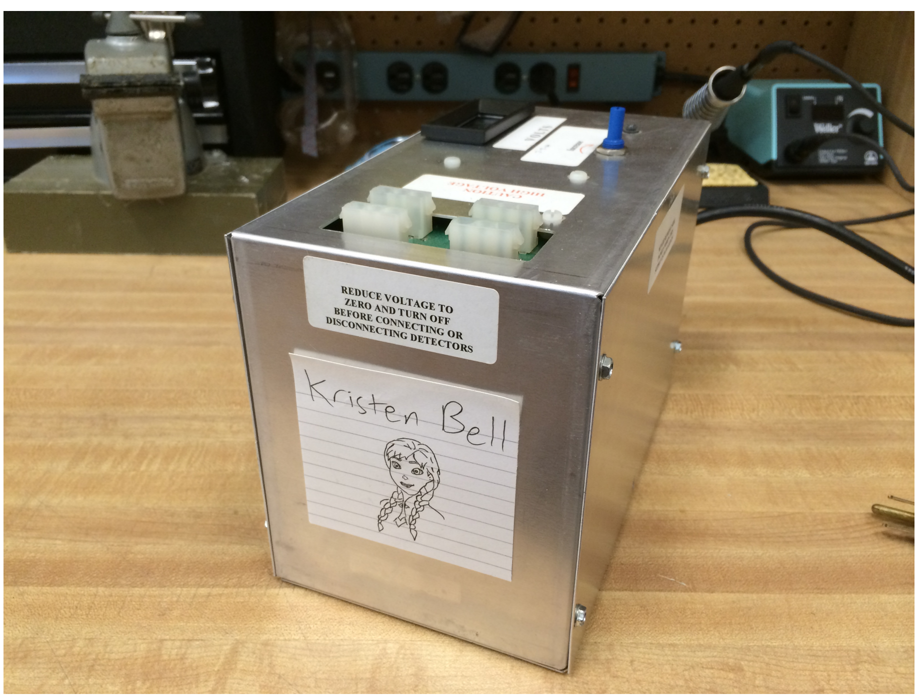
CROP Power Supplies

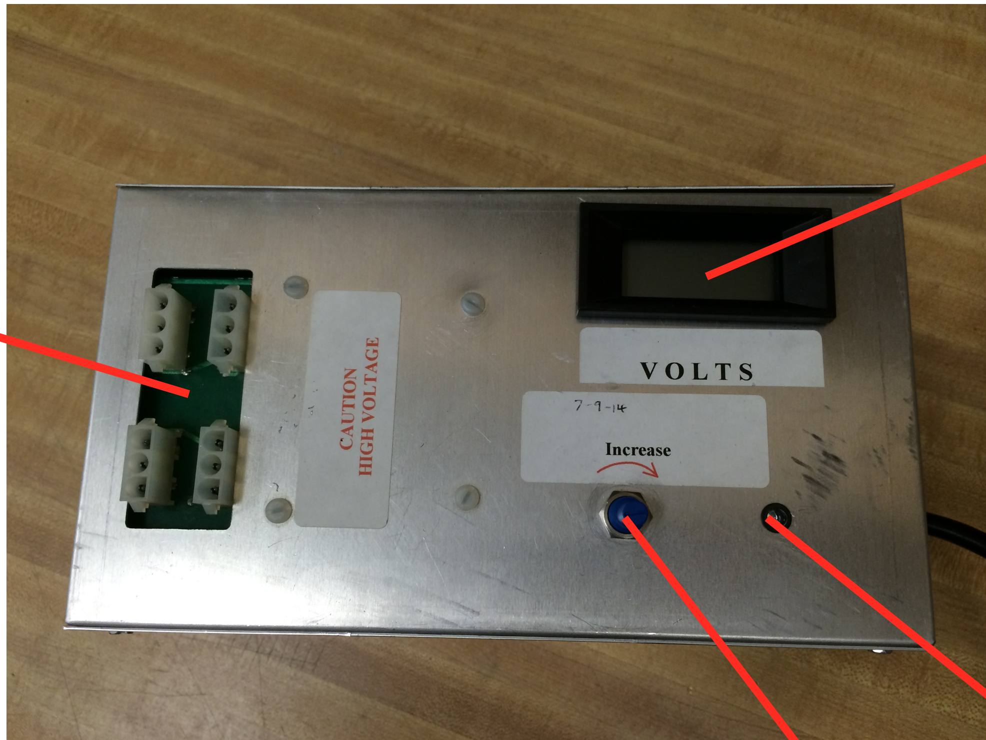
Chapter 1: Introduction to Power Supplies

Power supplies are a vital piece of equipment for us with the Cosmic Ray Observatory Project. The function of the power supply is to set a voltage threshold in our detectors above which we can collect data and filter background noise. Having extended our project outwards to other schools, we need to maintain and build new equipment so we can provide those schools with the tools they need to continue our research. We don't always expect to have our supplies returned in working order or at all. Here in the CROP lab, we have everything we need to build these power supplies to replace the ones we loan out. The building process can be the most tedious and frustrating part of CROP. At times, it seems like an uphill battle as if it's in the nature of electricity to play against us and make our work difficult. Having worked with power supplies for three years, I'd say that there is still a lot to be learned about how to tame these capricious contraptions. What is written here is what I hope to be an efficient and frustration-free way of creating, testing, and fixing power supplies.

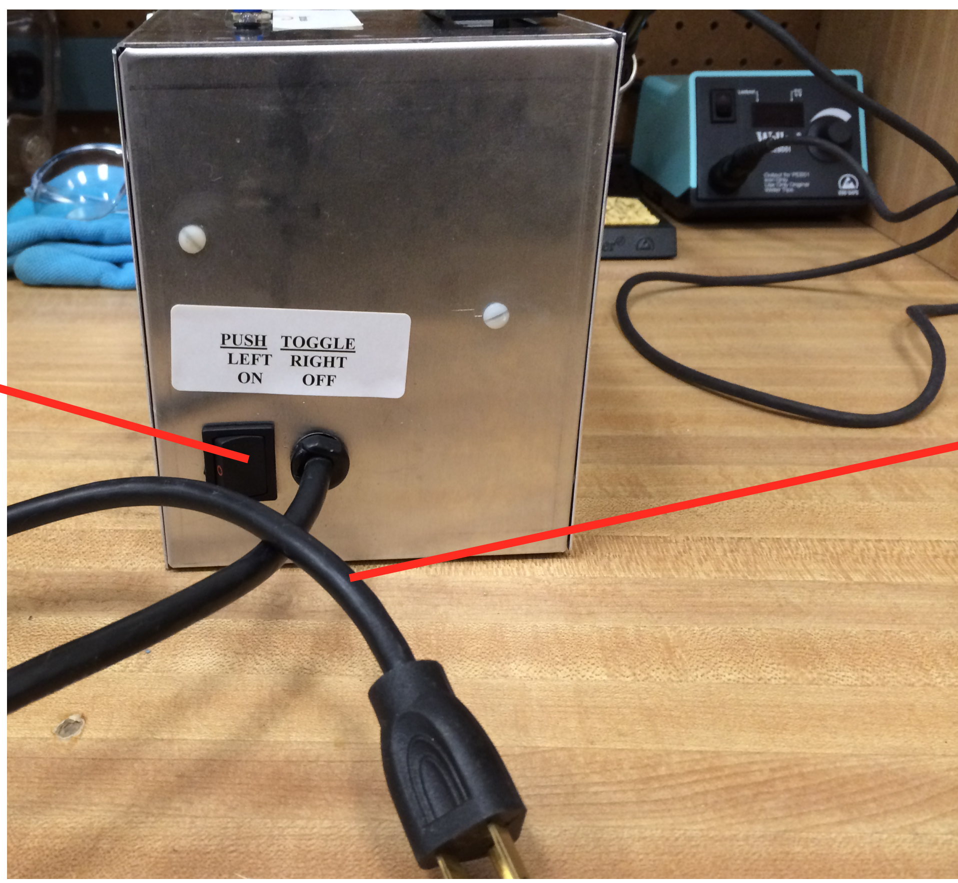
Below you can see a completed power supply named Kristen Bell. It's a tradition in our lab to give a name to every power supply we create. In my case, every one I've made is named after an actress.



Front View



Top View

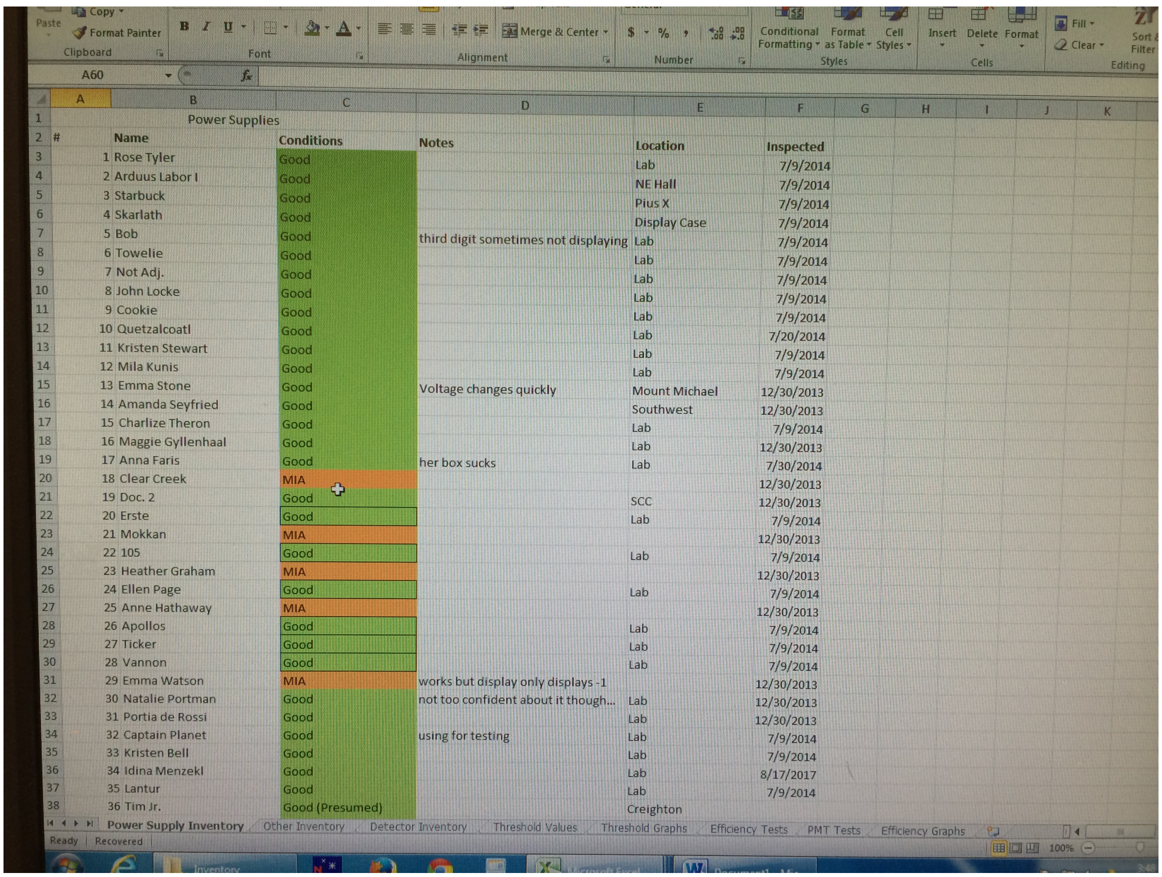


Rear View

We keep an **inventory** list of every power supply we create. This list includes its name, condition, location, and the date of its last inspection. As you can see on the top view, the dates of inspection are also recorded on a sticker on top of the power supply.

This inventory list is kept on the computer against the far wall on an Excel sheet titled “Inventory and Scan Data.” The way to access this file is this:

On the desktop, open folder “Google Drive” -> open folder “CROP” -> open folder “Inventory” -> right click on file “Inventory and Scan Data” and open with Microsoft Excel



Power Supplies

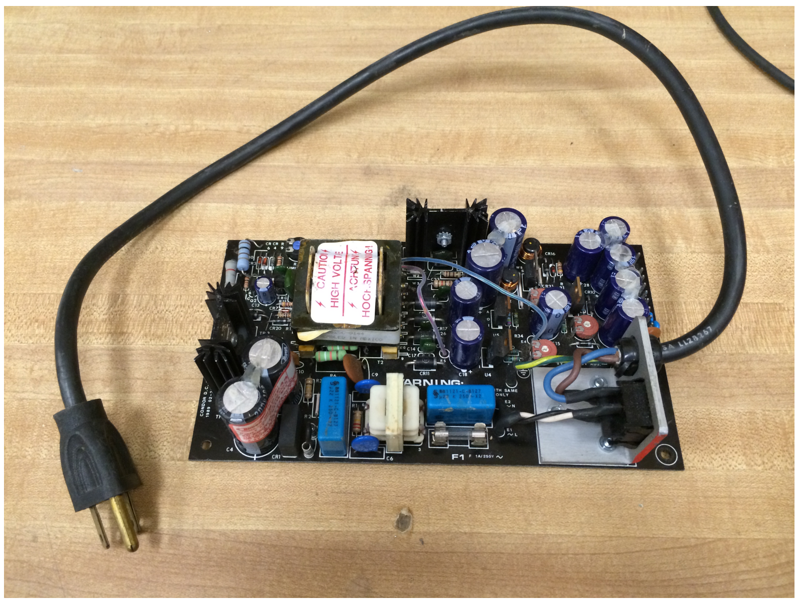
#	Name	Conditions	Notes	Location	Inspected
1	Rose Tyler	Good		Lab	7/9/2014
2	Arduus Labor I	Good		NE Hall	7/9/2014
3	Starbuck	Good		Pius X	7/9/2014
4	Skarlath	Good		Display Case	7/9/2014
5	Bob	Good	third digit sometimes not displaying	Lab	7/9/2014
6	Towelie	Good		Lab	7/9/2014
7	Not Adj.	Good		Lab	7/9/2014
8	John Locke	Good		Lab	7/9/2014
9	Cookie	Good		Lab	7/9/2014
10	Quetzalcoatl	Good		Lab	7/20/2014
11	Kristen Stewart	Good		Lab	7/9/2014
12	Mila Kunis	Good		Lab	7/9/2014
13	Emma Stone	Good	Voltage changes quickly	Mount Michael	12/30/2013
14	Amanda Seyfried	Good		Southwest	12/30/2013
15	Charlize Theron	Good		Lab	7/9/2014
16	Maggie Gyllenhaal	Good		Lab	12/30/2013
17	Anna Faris	Good	her box sucks	Lab	7/30/2014
18	Clear Creek	MIA			12/30/2013
19	Doc. 2	Good		SCC	12/30/2013
20	Erste	Good		Lab	7/9/2014
21	Mokkan	MIA			12/30/2013
22	105	Good		Lab	7/9/2014
23	Heather Graham	MIA			12/30/2013
24	Ellen Page	Good		Lab	7/9/2014
25	Anne Hathaway	MIA			12/30/2013
26	Apollos	Good		Lab	7/9/2014
27	Ticker	Good		Lab	7/9/2014
28	Vannon	Good		Lab	7/9/2014
29	Emma Watson	MIA	works but display only displays -1		12/30/2013
30	Natalie Portman	Good	not too confident about it though...	Lab	12/30/2013
31	Portia de Rossi	Good		Lab	12/30/2013
32	Captain Planet	Good	using for testing	Lab	7/9/2014
33	Kristen Bell	Good		Lab	7/9/2014
34	Idina Menzekl	Good		Lab	8/17/2017
35	Lantur	Good		Lab	7/9/2014
36	Tim Jr.	Good (Presumed)		Creighton	

Here you can see a small part of our current inventory. Our goal is to make every power supply “**Good**.” Ones that need immediate fixing will be marked “**Bad**” and highlighted red. Orange “**MIA**”s are power supplies that have been made but we don’t know where they are. Sometimes, name labels fall off so we may have the original power supply counted twice in the list. Some are labeled “**Good (Presumed)**” meaning that we know they’ve been lent out and haven't been returned. Work in progress ones can be highlighted “**WIP**” in blue. As power supplies are made, fixed, or found, **be sure to update the inventory.**

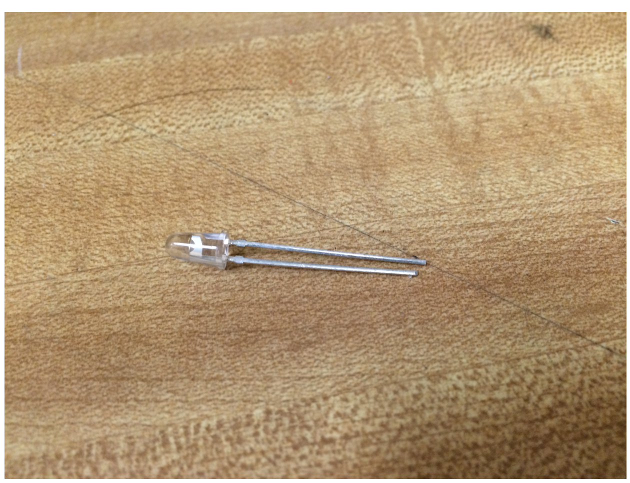
Chapter 2: Power Supply Components

There are seven parts that make up a complete power supply: **the low voltage supply, light-emitting diode, LCD display, potentiometer, resistor board, high voltage supply, and voltage divider**. Below, you'll see what each part looks like and what it does. Be aware of where to find each part and later we'll learn how to test if they work.

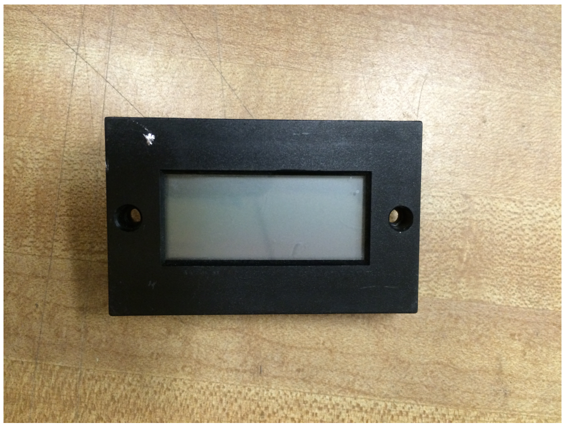
1. **Low Voltage Supply (LVS)** - large black board with a bunch of wires, capacitors, and junk on it. This LVS has the power cable attached and the fuse connected.

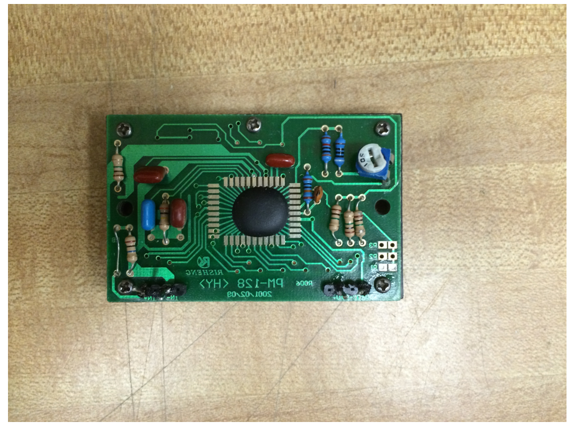


2. **Light-Emitting Diode (LED)** - small red light that signals that the power supply is on.

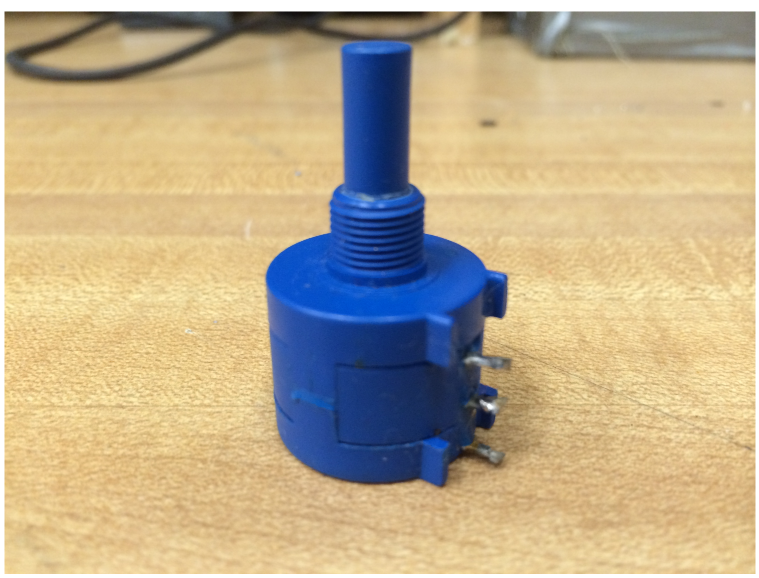


3. **LCD Display** - small green circuit board with black case and four metal terminals on the back. It displays the voltage that the power supply is outputting. There are three pairs of square terminals on the bottom right. Depending on which pair is soldered, the decimal point will be displayed differently. If the display shows a decimal point, **ignore it.**

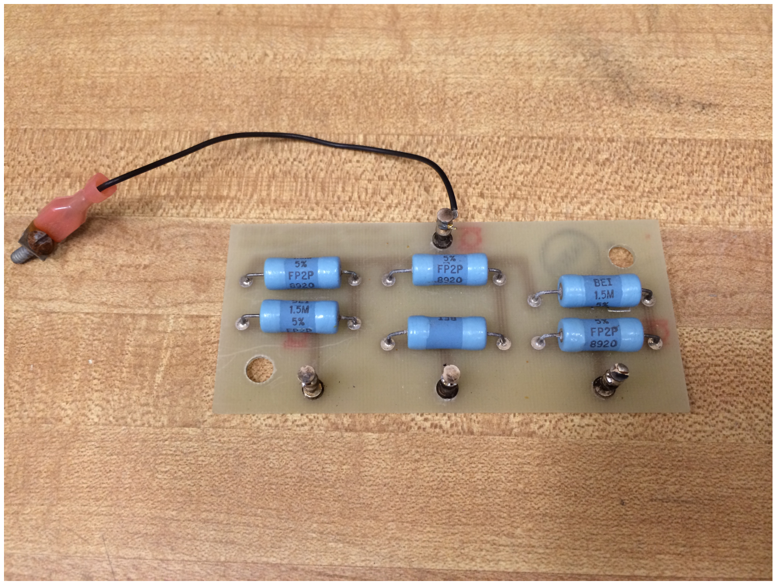




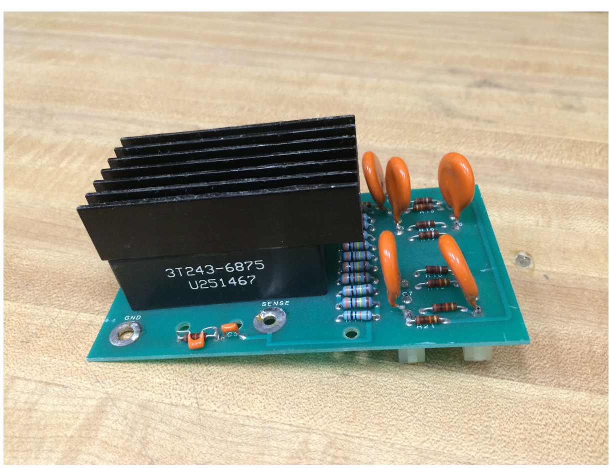
4. **Potentiometer** - blue screw-like piece with three metal terminals on the side. It changes the output of the power supply. Some are made of metal instead of plastic but the terminals aren't changed

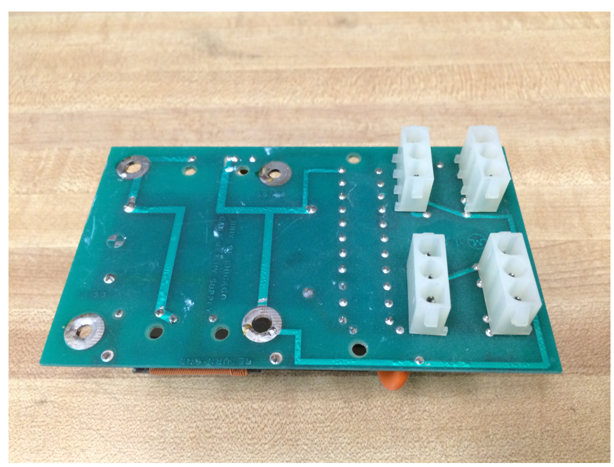


5. **Resister Board** - tan board with six blue cylinders arranged on top. May also have a pink grounding connector on the end of the single black wire

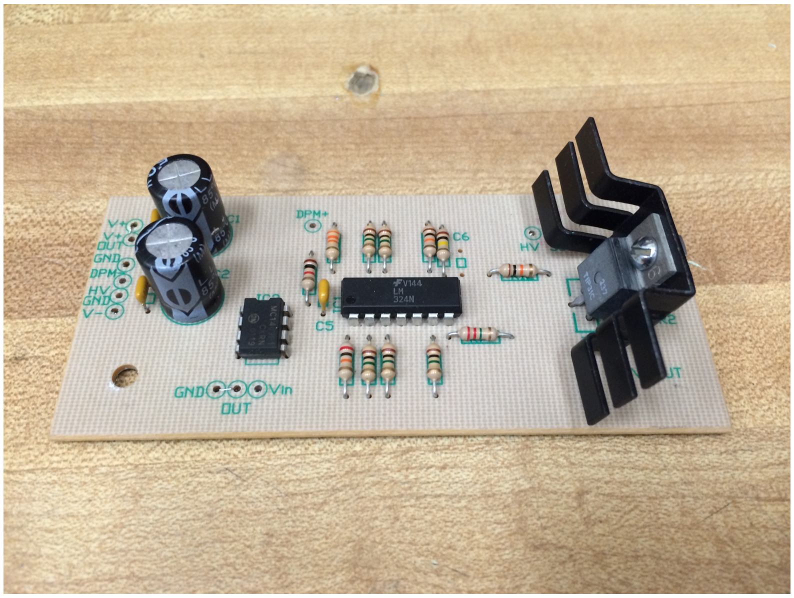


6. **High Voltage Supply (HVS)** - big black box on green circuit board with orange capacitors. Receives voltage from other components and amplifies it through the white cable connectors





7. **Voltage Divider (VD)** - green on the bottom, tan on the top with a bunch of places for wires to connect to. It just divides the voltages, I guess? No one really knows.



As you work, you'll notice some parts become harder and harder to find. Our stock of these parts is constantly changing and replenishing these supplies is important to continuing our work. Later, we'll talk about potential suppliers and how we can find new ones.

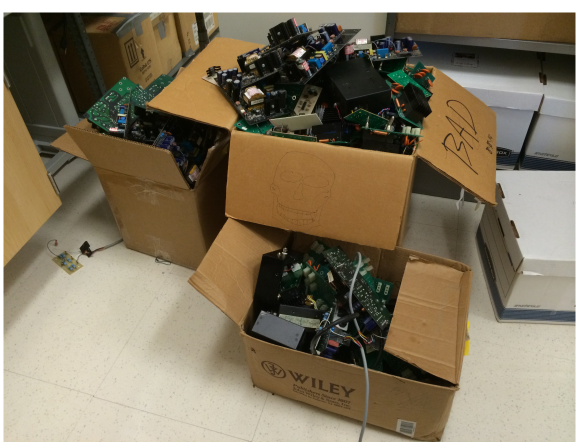
Chapter 3: Safety

Safety is really important in this lab. Working with power supplies especially requires caution to avoid solder burns, high voltage shocks, chemical exposure, and other physical injury (yeah, it happens). Here, we'll go over some general safety tips for working with our equipment to reduce the risk of harm.

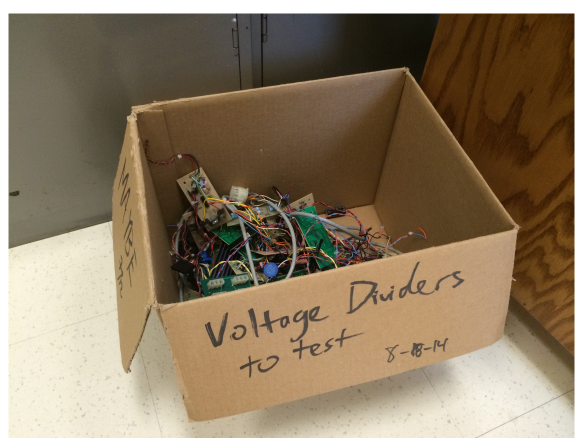
One really important thing to safety is **getting to know your work environment**. Being familiar with your work space improves efficiency and should increase your sense of safety within the lab. All the parts and tools related to power supplies are situated in the designated working area stuffed into drawers and toolboxes. You'll also find many cardboard boxes stuffed under or around the workbench so pay close attention to the labels written in marker on them. Some boxes get relabeled, but look for the most recent date written next to them to find its current purpose.

"Maybe" Box: Contains assortment of parts. Test to make sure they work

"LV" Box: Contains low voltage supplies to test



"BAD" Box: This stuff is broken. Don't use it



"VD" Box: Contains all the voltage dividers, some hooked to other parts. These require testing

The workbench. Keep it clean and don't bring food over here

Blue box of various screws, nuts, and other parts on the right side of the bench

The fume vent located right above and behind the bench. Turn on by pushing U-shaped lever

Nut drivers - Yellow for plastic nuts, orange for small metal nuts, red for metal enclosure screws

Wrench for potentiometer screw, needle-nose pliers, and wire cutter/stripper

Screwdrivers. The small blue one can be used to adjust potentiometers on LVS and display

Various tapes, zip ties, razors, solder wick, and adhesives are on the top left shelf

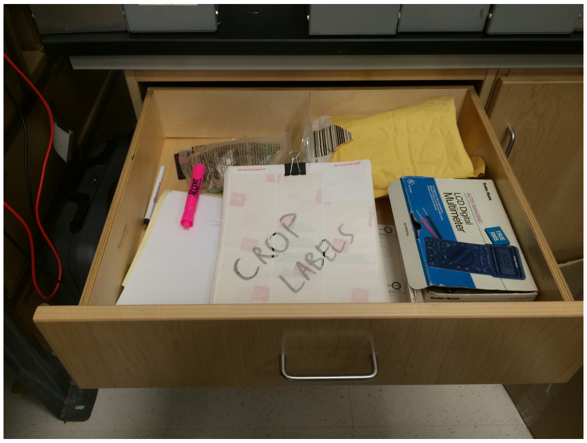
Other working power supplies are placed along the far counter

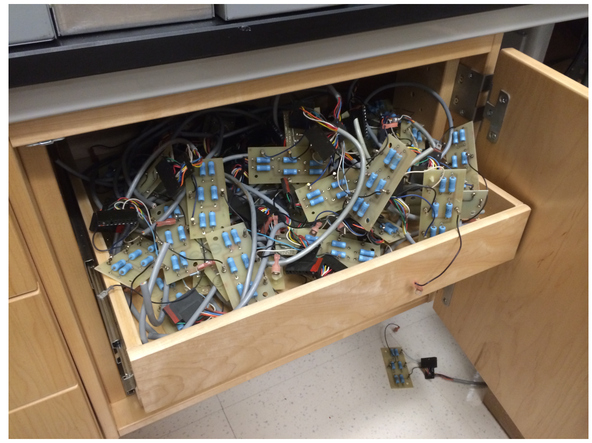
Some are stored in the white boxes under the metal shelves

Power cables for the LV's are kept in the bottom two labeled drawers

In the large metal cabinet are a few empty enclosure boxes. You might also find a small popcorn can placed in the back. DO NOT OPEN IT

These parts have some physical defect that we may be able to fix. These should be brought to the electronic shop on the 2nd floor





Markers and adhesive labels are located in the drawer above the power cables. Some preprinted labels include important safety notes that should be placed on the enclosures

Plugs and resistor boards are found in the cabinet next to the power cables. Trim and strip the gray covering to expose the colored wires.

Pay close attention to all the notes hanging around the workbench. Some have operating instructions, warnings, or reminders on them. I encourage you to leave your own.

Soldering Safety:

An important skill to learn while working with power supplies is how to solder. Soldering involves bonding two pieces of metal using a molten different metal; in our case, bonding wires together or attaching them to the other components. Our solder setup looks like this:

On the right is the soldering iron and the control box. The box has a dial on the right side that changes the temperature of the iron. Around 600 degrees Fahrenheit is adequate to melt the soldering wire seen left. Simply touch the wire to the iron to melt it and apply to the metal parts you want to bond. The holder for the soldering iron also includes a sponge which the iron is brushed against to remove excess solder. Keep the sponge moist.

Below is a list of hazards and precautions to take when soldering:

- ***Always wear gloves and safety goggles when handling the wire or the iron.***

- ***The wire contains lead so it shouldn't be handled with bare skin.***

- ***Never directly touch the iron when it is on.***

- ***Never solder on a power supply that is powered on. It can cause a short and disable the wall sockets as well as damage the power supply.***

- ***Always keep the fume vent on. The wire releases toxic fumes when melted.***

- ***The solder has a tendency to spit flakes of molten metal from the iron that can damage skin and clothing.***

- ***Always turn the soldering device off when not in use.***

- ***Don’t eat where you solder.***

The **Environmental Health and Safety Department** was kind enough to give us a safety pamphlet for working with the soldering iron. The next page lists these general safety rules they’ve provided in a more complete form. I highly recommend becoming familiar with these rules as they can save you from a lot of pain.

Environmental Health and Safety

Soldering Safety

Soldering Iron Safety

- Never touch the element or tip of the soldering iron. They are very hot (about 400°C) and will burn.
- Hold wires to be heated with tweezers or clamps.
- Keep the cleaning sponge wet during use.
- Always return the soldering iron to its stand when not in use. Never put it down on your workbench.
- Turn unit off or unplug it when not in use.

Work Safely with Solder, Flux and Cleaners

- Wear eye protection. Solder can "spit".
- Use lead free solder.
- Keep cleaning solvents in dispensing bottle to reduce inhalation hazards.
- Always wash your hands with soap and water after soldering.
- Read and understand the MSDS for all materials before beginning work.

Dangers of Lead Exposure

- Lead on your skin can be ingested and lead fumes can be given off during soldering. Other metal fumes can also be hazardous. Lead can have serious chronic health effects, such as reproductive problems, digestive problems, nerve disorders, memory and concentration problems, muscle and joint pain.

Avoid Toxic Fumes

- Work in a well-ventilated area. The smoke formed is mostly from the flux which can be irritating, a sensitizer and aggravates asthma. Avoid breathing it by keeping your head to the side of, not above, your work.
- A benchtop fume extractor may be necessary to remove harmful fumes caused by solder and flux from the soldering workstation by filtering the air.

Reduce Risk from Electricity

- Always use a grounded outlet and grounding prong to reduce the risk of electrical damage if a short circuit occurs in the equipment.
- Prevent damage to electrical cords during soldering. Keep them away from heated tips.

Fire Prevention

- Work on a fire-proof or nonflammable surface that is not easily ignited.
- Wear nonflammable or 100% cotton clothing that covers your arms and legs to help prevent burns.
- Know where your fire extinguisher is and how to use it.

First Aid

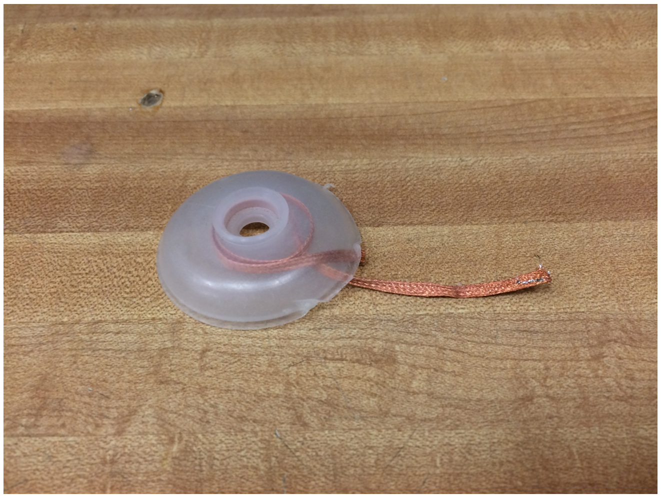
- Immediately cool the affected area under cold water for 15 minutes.
- Do not apply any creams or ointments. Cover with a band-aid.
- Seek medical attention if the burn covers an area bigger than 3 inches across.

Waste

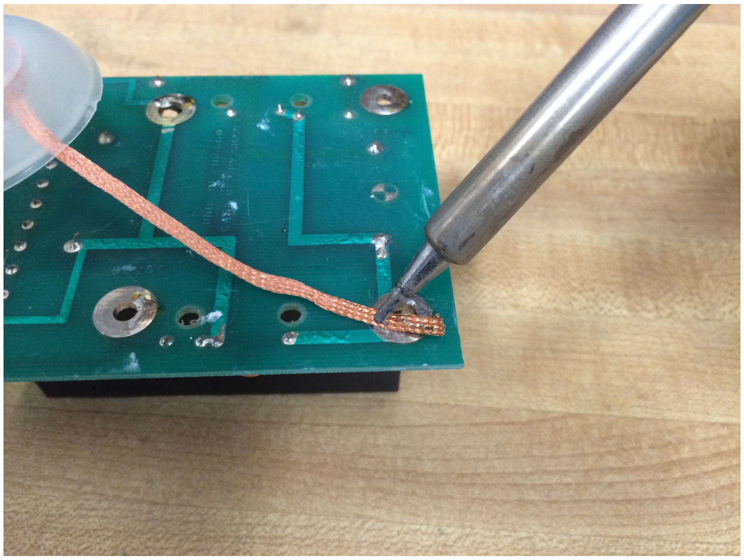
- Discard lead and silver solder and dross in a container with a lid.
- Label the container: "Lead (Silver) Solder Waste for Recycling".
- Used solder sponges and contaminated rags must be disposed of as hazardous waste.
- Keep a lid on waste solder containers when not adding or removing material.

Removing Solder:

Using too much soldering metal can also pose a safety risk. Having the metal cross two terminals can result in a short. Use just the right amount of solder to bond the parts so they can't be pulled apart. In the case that you used too much solder, there is a tool called **solder wick** that can be used to remove excess solder. Below, you can see what solder wick looks like:



To use, place a length of wick on top of the solder you want to remove and press the solder iron on top of the wick. Hold the iron there and the heat will conduct to the solder metal and melt it. Continue to hold the iron on the wick as the molten metal will be drawn upwards into the threads of the wick and be trapped there like so.



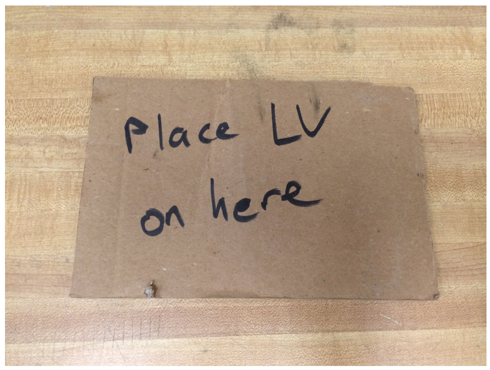
Be sure to trim off wick as it becomes covered in metal.

Electrical Safety:

Getting shocked is not fun. Even 5 millivolts hurts when it goes through your hand. One can be understandably nervous when working with power supplies as it seems like getting shocked is a job requirement. There a few precautions we take to minimize the risk of electric shock:

**Note: most of these tips have to do with the LVS or HVS*

- ***Place the LVS on a nonconducting surface before turning on. There are cardboard slides like the one below to put under the LVS or it can be suspended on plastic standoffs.***



- ***Cover exposed wires with electric tape or heat shrink so you don't touch it.***

- ***Immediately turn the device off if it gives off smoke, blows a fuse, or if a capacitor pops on it.***

- ***Listen carefully for noises the devices give off. A low, very quiet hum is alright for it signals that it is on. Turn it off if there is a loud buzzing or clicking noise.***

- ***Try not to confuse working and broken parts. Place electrical components in the respective boxes.***

- ***Dab a cloth over the device after it is turned off to discharge any electricity that is stored. This step is quick, it doesn't have to be a long wait.***

- ***On a complete power supply, do not come into contact with cable terminals. They can supply over 1800 volts.***

Using Heat Shrink:

Heat shrink is a black plastic covering we use when connecting straight wires together. It slides over the exposed metal and when heat is applied, the plastic contracts and secures itself over the soldered portion. Heat shrink is more durable than electric tape and comes in two different sizes. Simply cut off the length of heat shrink you need and slide it down the wire to the connection.

To apply heat quickly, we use a heat gun. It's basically a big hair dryer, but **DO NOT POINT IT AT YOUR FACE OR HAIR**. Plug it in and turn it on by pressing the yellow switch all the way up. Keep it pointed at a close distance to the heat shrink. It should only take seconds for the heat shrink to shrink.

First Aid:

No laboratory is complete without a first aid kit. In the CROP lab, our first aid supplies are located in the top metal drawer marked “First Aid Kit Here!” It’s pretty easy to find with that sign on it.

Inside is an assortment of bandaid sizes, gauze wrap, non-latex gloves, antibiotic ointment like Neosporin, face masks, and other supplies in the various kits. Immediately seek first aid if you receive any injury like dropping a hammer on your leg. One shouldn’t be in the lab alone in case assistance is needed.

Just be safe here. Don't do anything stupid.

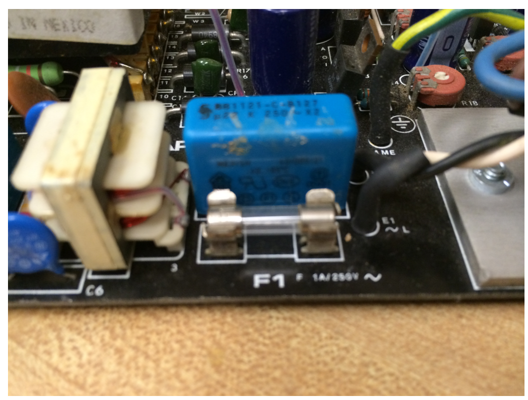
Chapter 4: Part Testing

Knowing that the part is working before you put it on the power supply assembly makes this job easier. Pay attention to any writing on the part itself to see if someone has recorded that the certain piece is “*BROKEN AS #&*%.*” Be sure to place broken parts in the boxes labeled “BAD” and don’t confuse them with working ones later.

As a reminder of safety rules, if there is any immediate indication that the part is malfunctioning, remove the power source immediately.

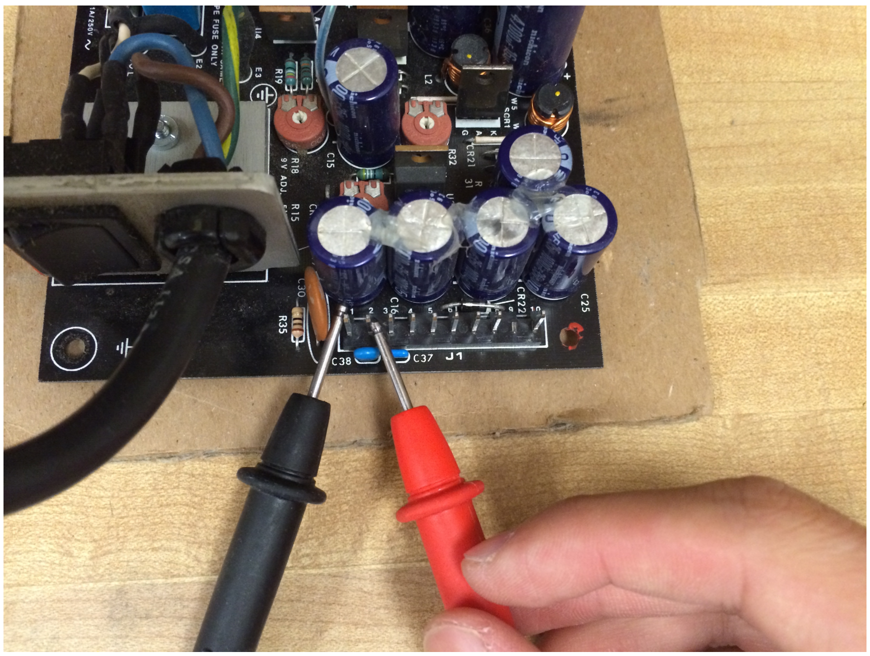
Testing the LVS:

Testing the LVS requires a special tool called a **multimeter** (left). Ours is a big orange brick thing with a dial that measures current, voltage, resistance, etc. Make sure it is set to measure voltage and use the low voltage pins pictured below. Also make sure the LVS has a 1A 250V fuse attached (right). Fuses are in the blue box with the label “**1A 250V Fuses**”



Place the LVS on the cardboard or plastic standoffs and plug in the power cable to the wall socket. Turn the LVS around so the on/off switch and the row of pins is facing you like so.

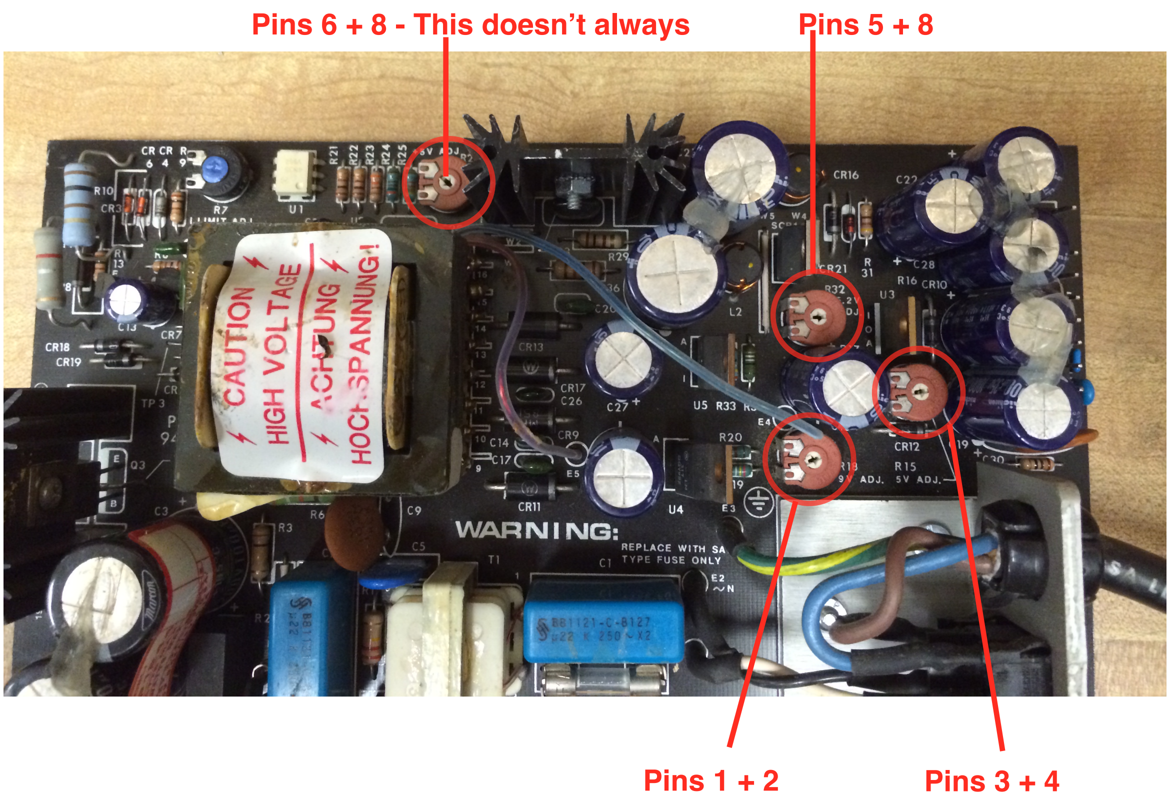
From left to right, the pins are numbered 1 - 10. Pin 9 is missing because they're clipped off many years ago, and pin 10 is not actually used in our power supplies, so we will only worry about pins 1 - 8. In order for the LVS to work in our power supply, the voltage between certain pins must be near a certain value. Turn on the LVS. If you see a bright flash, that means the fuse has busted and the LVS is malfunctioning. **Do not reuse the LVS. Find a new one before proceeding.** If there's no flash, place the ends of the low voltage probes to the following pins and see if the voltage reading on the multimeter is in accordance to the numbers in the table below.



Pin #s	Voltage
1 + 2	9V
3 + 4	5V
5 + 8	5V
6 + 8	17V

**Note: Depending on which pins the red and black probes are touched to, the voltage reading will be positive or negative. Just disregard the numeral sign and look at the numbers. They don't have to be exact. Honestly, if the number before the decimal point is the same as on the table, it's fine.*

If the voltages are off by 1-3 volts, it is possible to correct them. As you can see below, there are four pink potentiometers on the LVS. These control the voltage that is supplied to the pins.



To adjust them, stick the small flat screwdriver into the groove and rotate it very slowly. Clockwise increases the voltage and counter-clockwise decreases it. Immediately stop turning in one direction if you hear a buzzing noise and turn it the other way.

If the LVS tests badly, before putting in the "Bad box," make sure to remove the power cable and the fuse if it's still intact. Go to page 30 for instructions on removing the power cable.

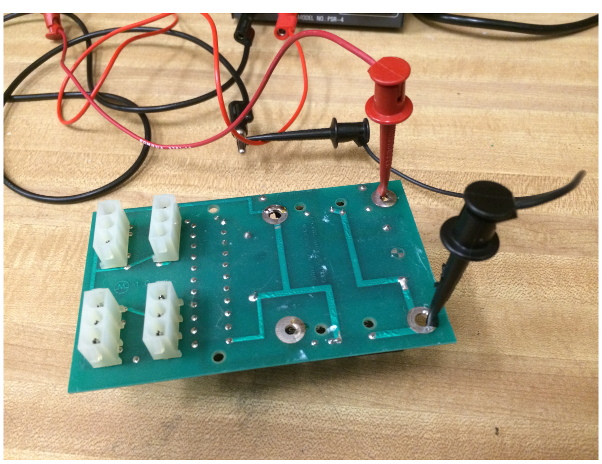
Confirmation:

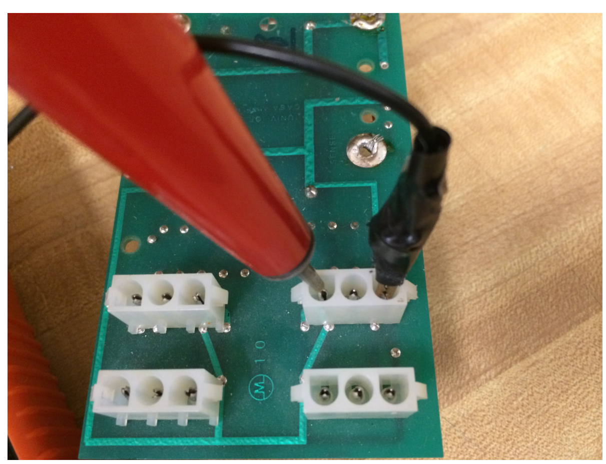
If the LVS tests well, hook it up to a working power supply. Simply disconnect the original LVS, connect the new one, turn it on, and see if it works. The pins don't always dictate if the LVS will work on a power supply. One issue you might encounter is that the voltage in the HVS changes at twice the rate that the display does. This is caused by the LVS and you'll have to replace it. **You should do this step to make sure there is nothing internally wrong with the LVS.**

Testing the HVS:

Testing the HVS takes less time than testing the LVS. Since we're dealing with high voltages, we need the multimeter with the **high voltage probe** (left). We also need a **small power supply** (right) with two leads connected.

First, start by placing the HV with the cable terminals pointed upwards on a nonconductive surface. Take the red lead from the power supply and connect it to the metal ring labeled "**DC IN**" and connect the black lead to the ring labeled "**GND**." Turn on the power supply and connect the small black clip of the high voltage probe to a metal pin on the side of one of the cable terminals. Do not connect it to a pin in the middle. Use the big red probe and touch it to a pin on the opposite side of the cable terminal to get a voltage reading. If there is any reading at all, normally ~3.87 V, then the HVS is working, unless it's making frightening noises.





Testing the Display and Potentiometer:

These two components can be tested using the **swap-in** method, like I mentioned with the LVS. This involves taking a working power supply out of its enclosure, removing the original display or potentiometer, and swapping it with one that you want to test. Turn on the assembly and see if it still works. Only swap in one part at a time to avoid confusion if something goes wrong. If the whole assembly still works, congratulations. You've found a working component.

For example, I use a power supply named Captain Planet to swap parts with. I keep it on the right side of the workbench, separate from the power supply I'm working on. Because I swap parts on it so frequently, I shape the wires into easily removable shapes like wide rings that can hook onto the pins of the display and potentiometer and stay with minimal solder.

Testing the LED and Resistor Board:

There's hardly ever anything wrong with these parts. If the LED doesn't turn on, replace it. In all my years, I've never encountered a problem with resistor boards. They shouldn't be a problem.

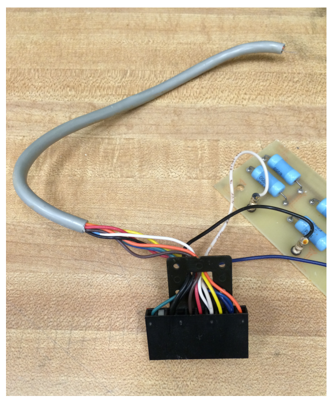
Testing the Voltage Divider:

I'll say it: I hate this piece. The voltage dividers we currently have are all located in the labeled box. Voltage dividers are often the problem if the power supply doesn't work. Because it cannot be tested individually, it has to be hooked up to everything else to see if it works. Yes, that means replacing twelve wires every time you swap one.

Chapter 5: Assembly

Having gathered all the necessary parts needed for the power supply and tested them all fine, it's time for us to assemble them together. Have the solder ready, the fume vent open, and safety glasses and gloves on. Time to get crackin'.

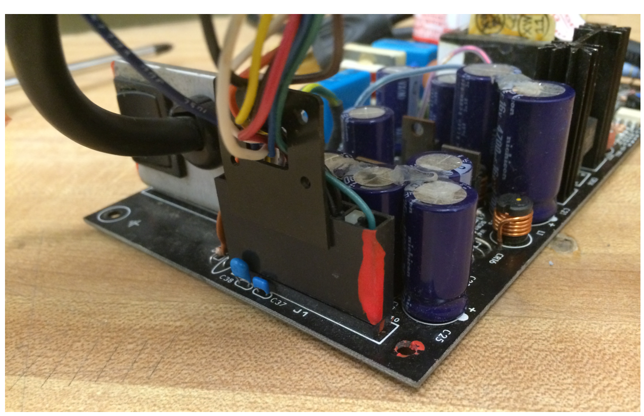
The first thing we need to find is the connector plug. Below, you can see what it looks like. You can find them in the wooden cabinet below the side desk next to the power cable drawer. Often times, the colored wires are covered with a gray plastic sheath. Simply take a razor blade or knife and cut along the sheath to expose the wires. You don't have to remove the entire sheath; at least six inches will do. They might also have the resistor board already attached. In any case, you should have two white, two blue, one black, one red, one orange, one brown, and one green wire. We don't use the green wire so cut it off. Use the wire stripper to expose enough wire on the tips to solder to the other components.



**Note: These next steps can be done in any order.*

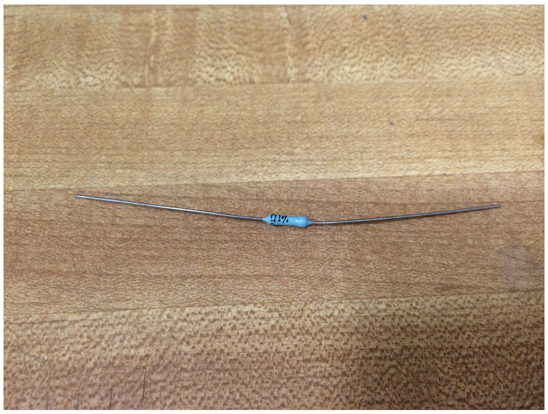
Connect the Plug to the LVS:

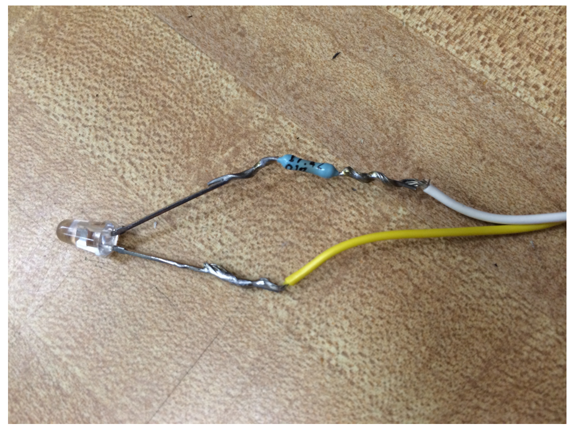
One side of the plug should have a spot of red paint. Line this up with the paint by pin 10 on the LVS like so.



Connect the LED to the Plug:

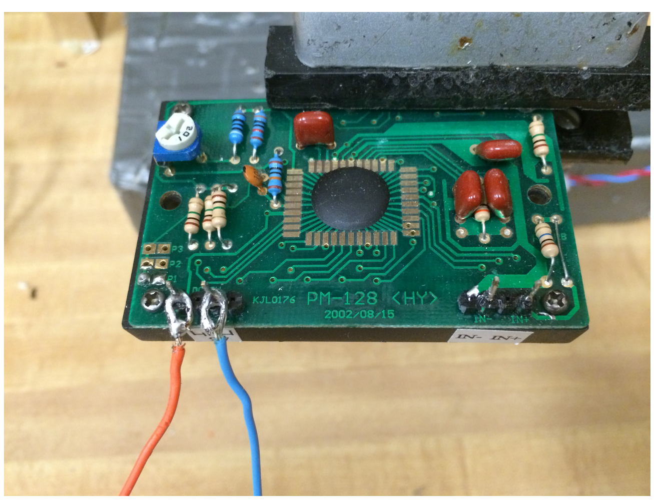
In the blue box on the workbench with all the screws, bolts, and nuts, there should a container labeled “***Resistors, Capacitors + Diodes.***” Inside, take a blue resistor like the one below and twist one end around the **longer** metal lead of the LED. Then attach the white wire to the other end of the resistor and the yellow wire to the shorter lead of the LED.





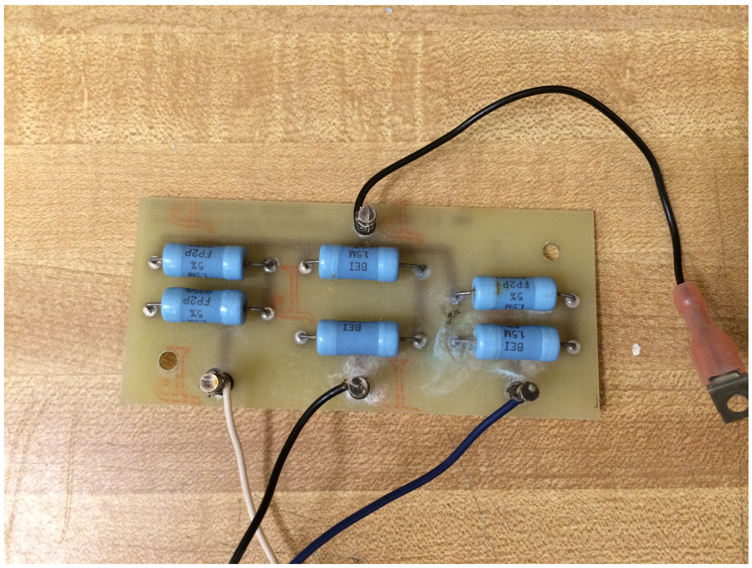
Connect the Display to the Plug:

This connection provides power for the display to turn on. Position the display face down with the four pins on the back closest to you. There should be a sticker underneath the left pair of pins reading “9V.” Take the orange wire and connect it to the far left pin. The blue wire will connect to the pin adjacent to the one with the orange wire.



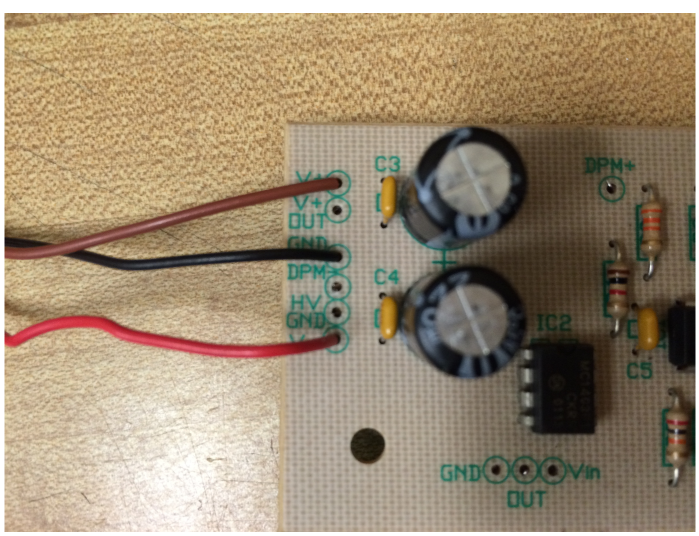
Connect the Resistor Board to the Plug:

Most of the time, this piece will already be connected. If it's not, orient the resistor board so the three terminals are closest to you. From left to right, the wires will go white, black, then blue. Also make sure that the resistor board has the pink grounding piece attached to the single terminal on the other side.



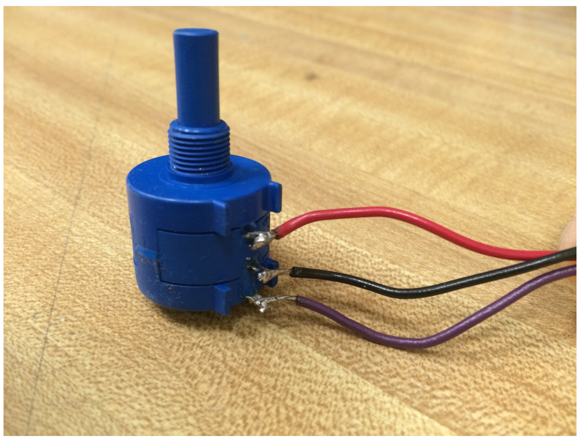
Connect the Voltage Divider to the Plug:

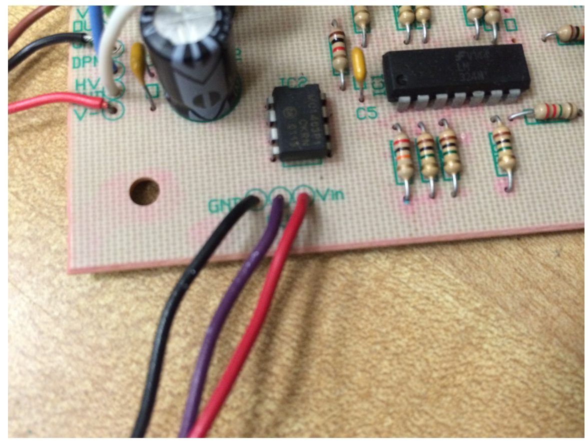
On one side of the voltage divider, there should be a line of connecting ports with labels on the front and metal rings on the back. Place all wires through the tan front side and solder them onto the metal rings from the back. Connect the red wire to **V-**, the black wire to **GND**, and the brown wire to **V+**.



Connect the Potentiometer to the Voltage Divider:

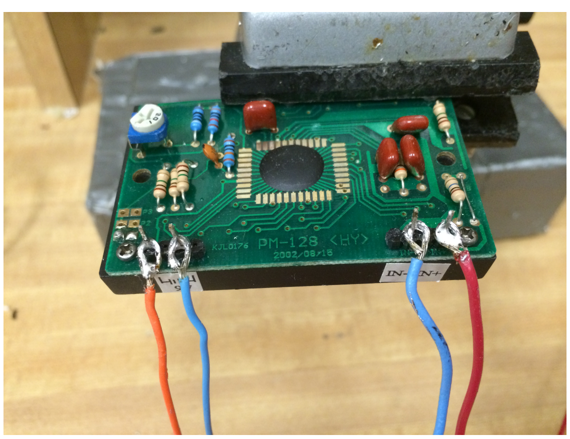
You need a red, black, and purple wire. On the long edge of the voltage divider, there is a group of three connecting ports. Connect one end of the red wire to the top terminal of the potentiometer and the other end to $\mathbf{V_{In}}$. Connect the black wire to the middle terminal and to **GND**. Connect the purple wire to the bottom terminal and to **OUT**. Make sure the potentiometer is turned all the way counter-clockwise.

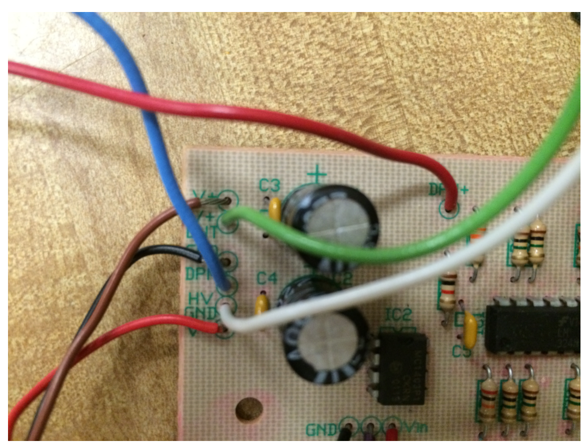




Connect the Display to the Voltage Divider:

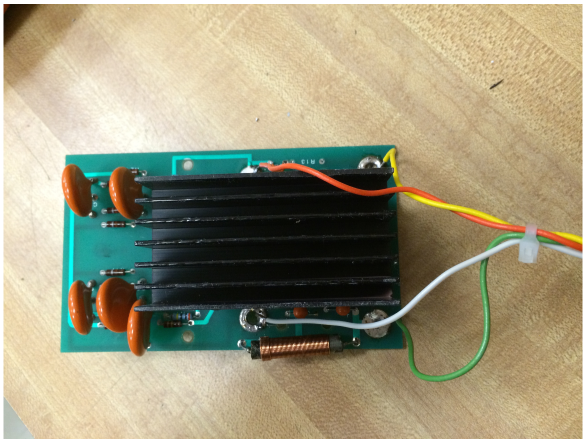
This connection is what changes the display reading within the potentiometer. Find a red and blue wire. Connect the red wire to the far right pin **IN+** on the display and the other end to **DPM+**. Connect the blue wire to the adjacent pin **IN-** and to **DPM-**.

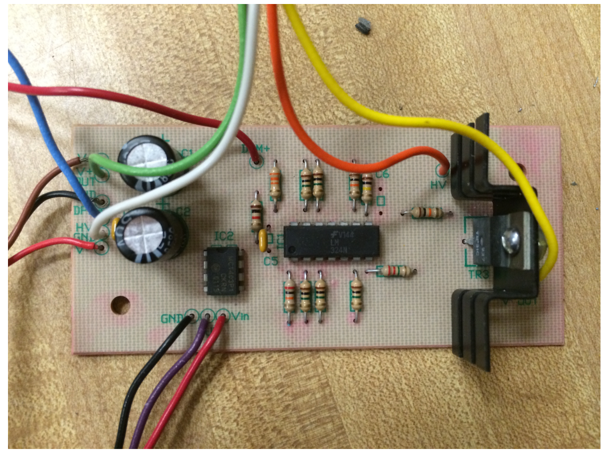




Connect the HVS to the Voltage Divider:

Find a green, yellow, orange, and white wire. Connect the green wire to the metal ring on the HVS labeled **DC IN** and to **V+OUT** on the voltage divider. Connect the orange wire to ring **SENSE** and to **HV Sense**. Connect the yellow wire to ring **GND** and to **V-OUT**. Connect the white wire to the last ring and to **HVGND**.

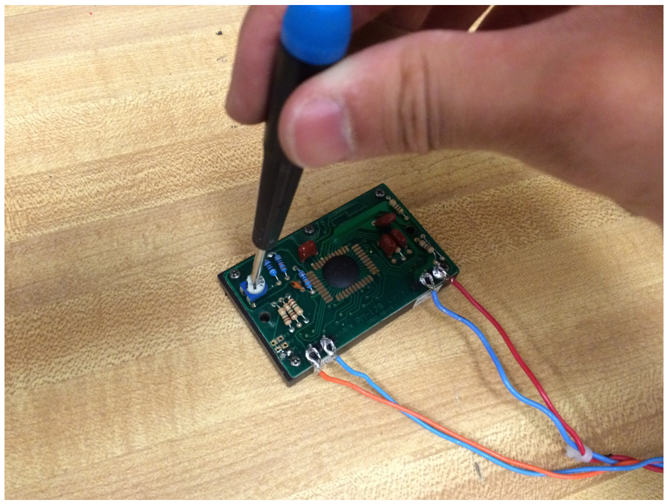




Before you turn it all on, make sure the solders are stable and can't be pulled out. Also make sure the potentiometer is turned all the way counter-clockwise. This will be the base voltage for the power supply. Now turn it on. The assembly must pass three impressions before it can be deemed working.

- **First Impression: The LED is shining red and the display is reading a base voltage anywhere between 1 and 40V.**
- **Second Impression: Turning the potentiometer clockwise causes the display reading to increase.**
- **Third impression: Using the high voltage probe and multimeter hooked to the HVS, the voltage coming from the HVS is changing at about the same rate as the display from turning the potentiometer. We will calibrate the display to match the HVS in the next step.**

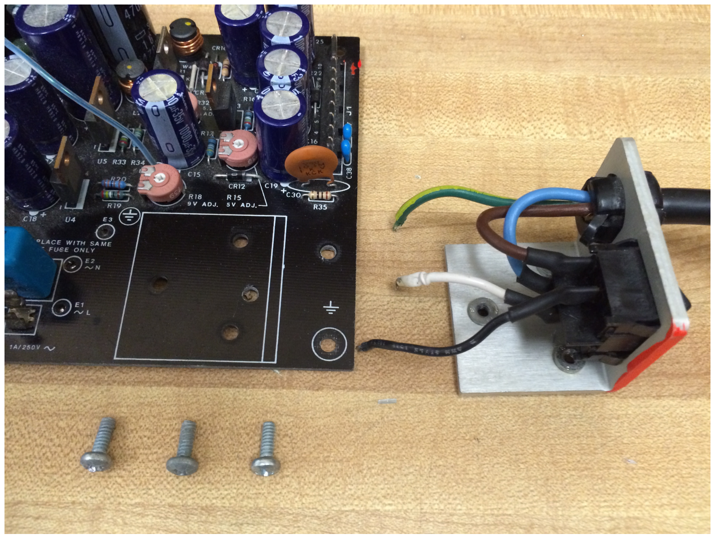
Now, we can correct the difference between the display and the HVS reading. On the back of the display is a white potentiometer. During this process, keep the assembly powered on and the multimeter connected to the HVS. Stick the small flat screwdriver into the groove and turn clockwise to increase the display reading and counter-clockwise to decrease the display reading. Start by raising the voltage to about 600V. Measure the HVS and correct the display. Then go to about 1200V and do the same. Repeat again at 1500V and that should be an adequate calibration. **Turn the potentiometer all the way back down before powering it off.**



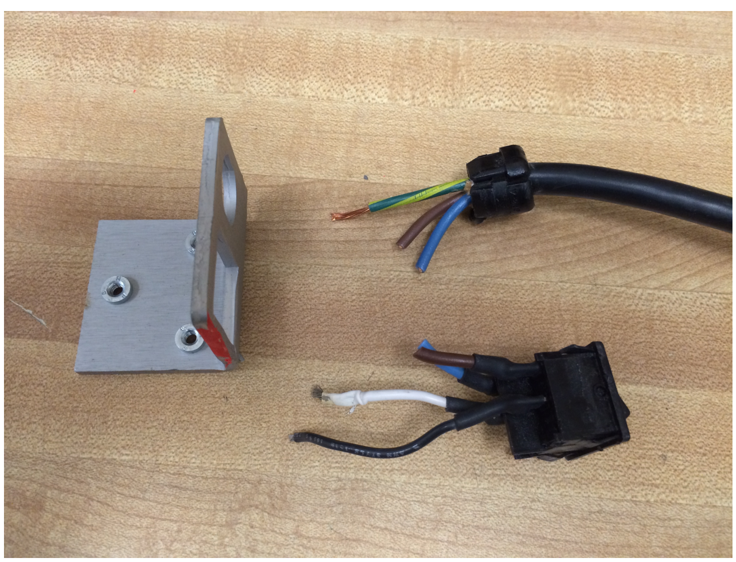
Finally, we're ready to get this assembly into the enclosure boxes. You can find these in the large metal cabinet behind the workbench. **Not all enclosures in the cabinet have the necessary holes drilled. The ones that are okay to use are marked on the inside. ONLY use these**. You will also need two metal side panels that will be screwed in place as the last step. These are also located in the same cabinet. Some have many large holes drilled in them. Try to only use ones that don't have extra holes besides the six along the edges.

Preparing the power cable:

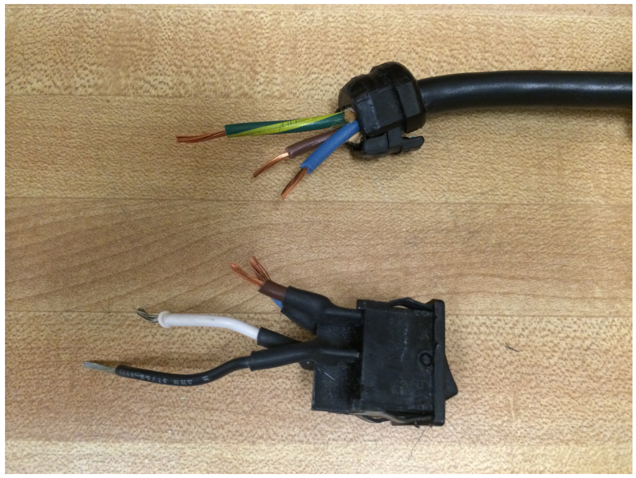
Take out the power cable on the LVS by unscrewing the metal base and using the solder to release the three wires. Do this delicately so as not to damage the metal rings on the bottom of the board. Sometimes, the wires are connected to a piece of metal that goes down into the LVS. Make sure this comes out too.



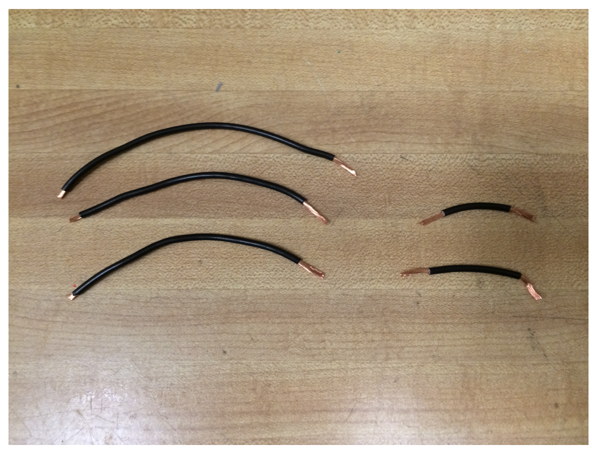
Now we need to remove the cable and the on/off switch from the metal bracket. Cut the blue and brown wires somewhere in the middle. Then, pry out the switch and the cable. You can use one end of the pliers as leverage.

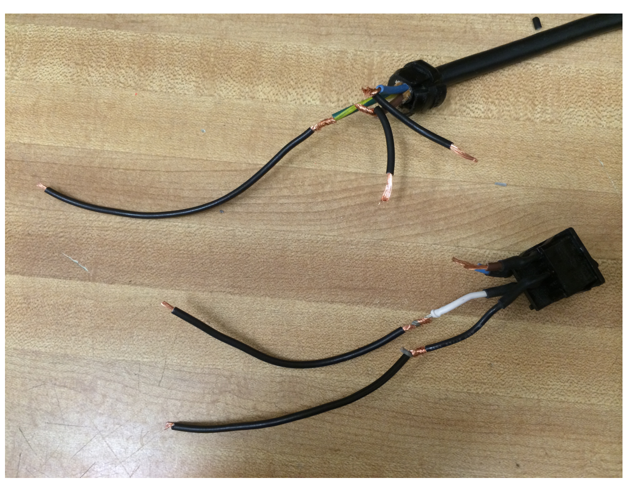


Use the wire cutters and strip the covering off the wires like so. Cut off the metal things at the ends of the three LVS wires if they are there first.

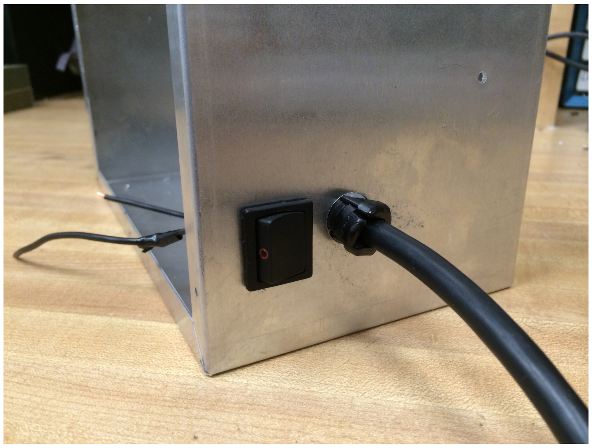


On the shelf above the black counter against the wall is a bag full of thick wires. Cut two lengths of about 2 inches and three lengths of about 5 inches. Strip the ends of them and connect the shorter ones to one side of the blue and brown wires. Connect the longer ones to each of the three LVS wires. Use electric tape to cover the solder.

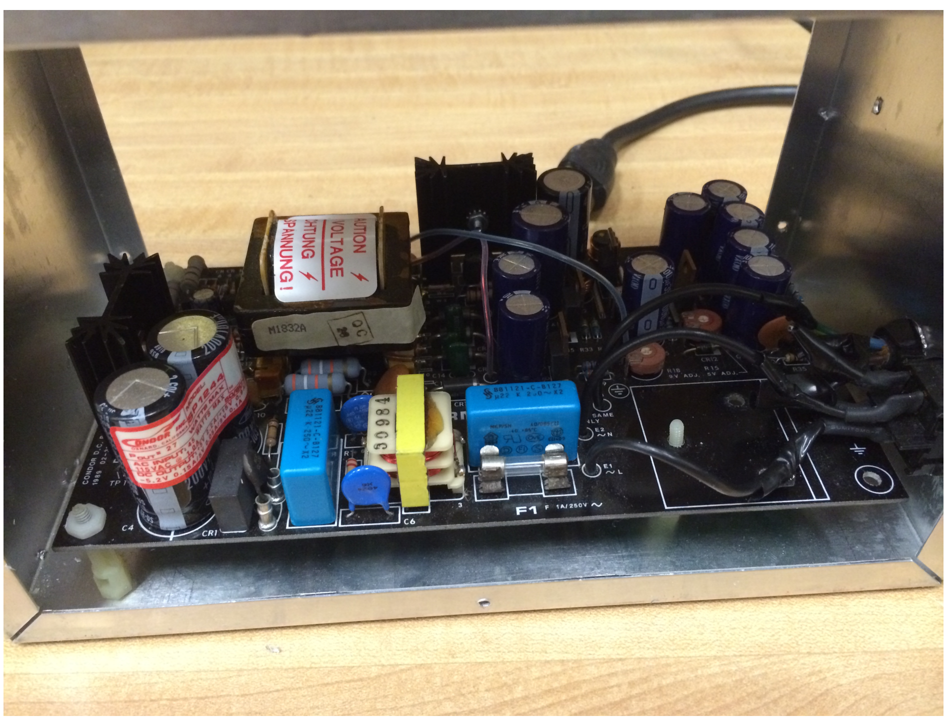




Force the on/off switch and the cable into their respective holes in the enclosure box like so. Don't put the switch in upside-down. Reconnect the blue and brown wires as below.

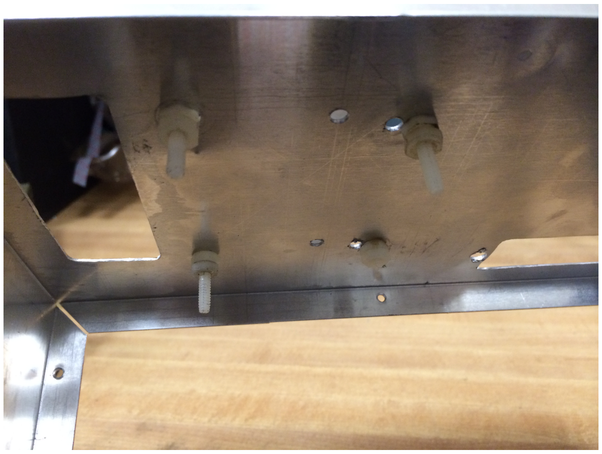


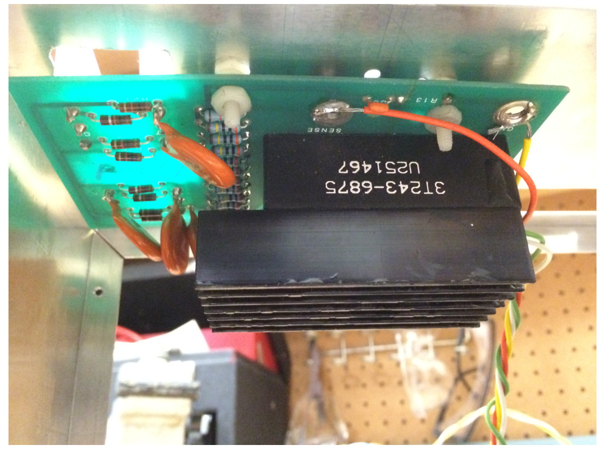
Secure four plastic standoffs through the underside of the enclosure and set the LVS on top of them. Sometimes, the white and black wires on the switch are reversed. If this is the case, remember that the lower wire on the switch goes to the nearest port to you as in the photo below. Then the upper wire goes into the next one further. The green wire from the cable will go to the farthest one.



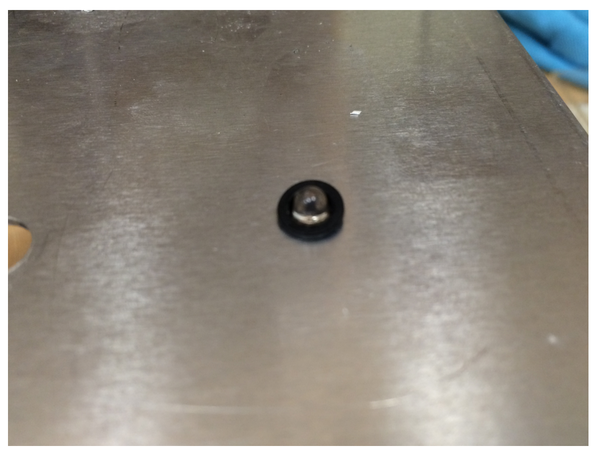
Shoving the rest in:

Reattach the plug to the LVS. Now, hold the HVS inside using long plastic screws through the top spaced by two plastic nuts on each screw between the HVS and the top panel.

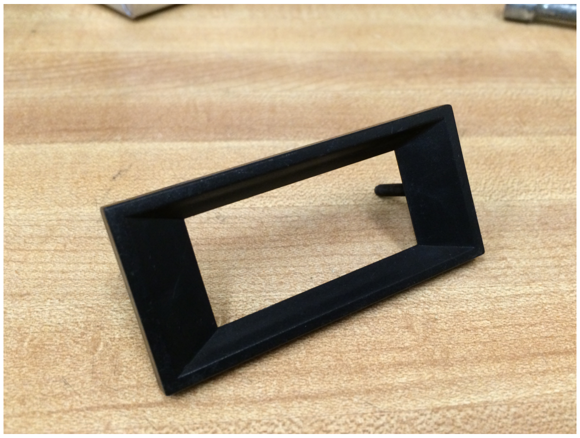


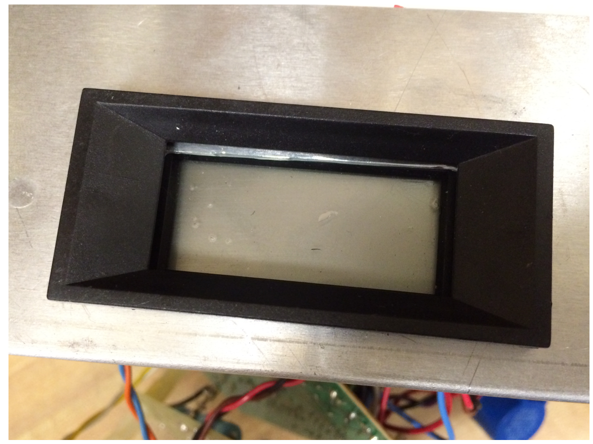


Find "**LED Holders**" in the blue box. Each one should consist of a black plastic holder and ring. Place the holder through the top of a fitting hole flexible part first. Place the ring on the LED and poke the the LED through the flexible parts of the holder. When it stops, push the ring around the flexible parts all the way up to secure the LED.

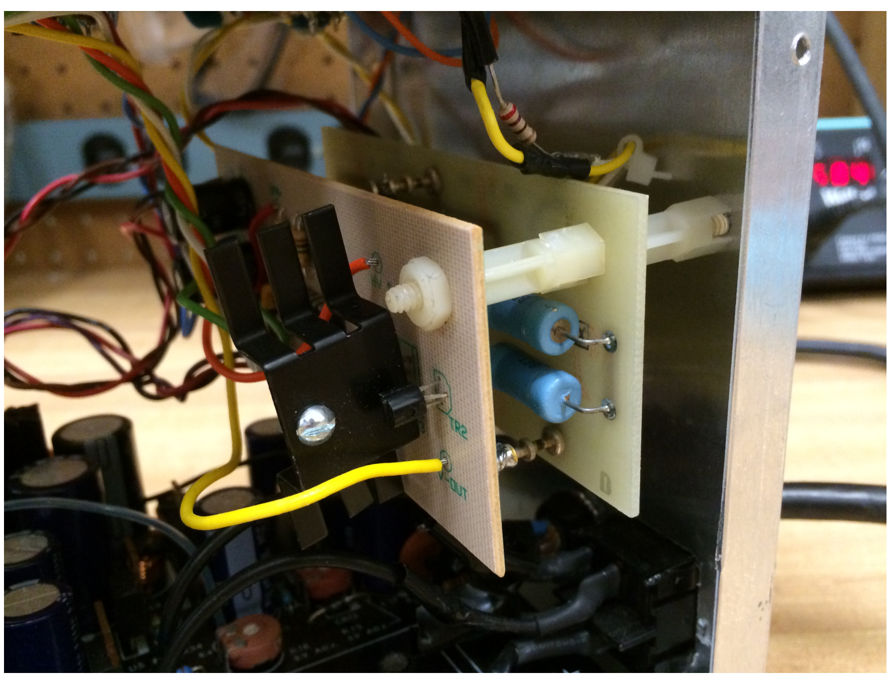


Next to the thick wires on the shelf should be a stack of black display holders. Put the two long screws down into the top of the enclosure and through the holes on the display from the bottom. Go to the blue box and find "**Small Metal Nuts**." Use the orange nut driver to secure the metal nut up the screw to the bottom of the display.



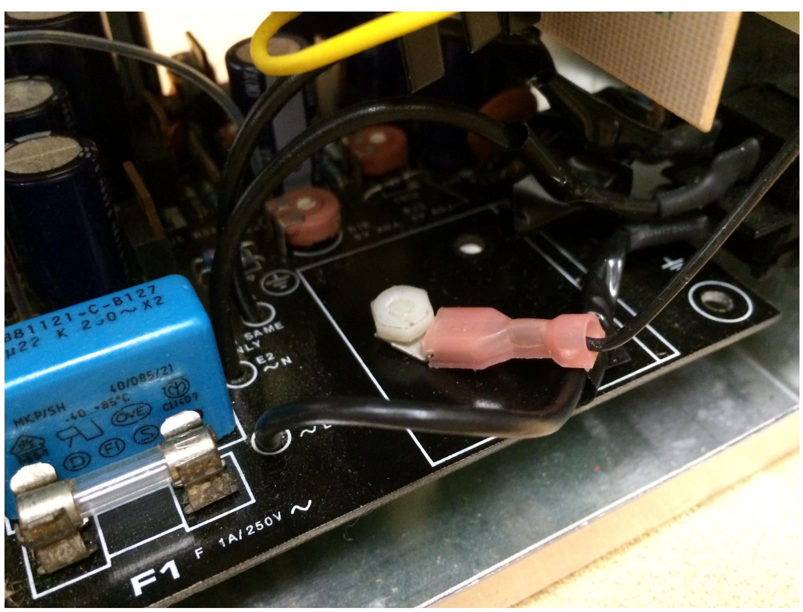


The resistor board and voltage divider should go in like this:



Find “**Potentiometer Screws**” in the blue box. Take a hexagonal one and screw it on top of the potentiometer. Use the wrench to tighten it.

Secure the pink grounding part anywhere you can.



CAUTION: *Always inspect your wires after you put the parts in the enclosure. It's possible that some have been pulled loose so reattach those that are before proceeding.*

Go ahead and plug it in, turn it on, and bask in the glory of having completed a power supply. After you make sure it still works, of course. If it does, find "**Power Supply Enclosure Screws**" in the blue box and use the red nut driver to secure the side panels on. Find the packet of labels in the drawer above the power cables and attach them to the enclosure. Just follow the example of the other power supplies in the lab.

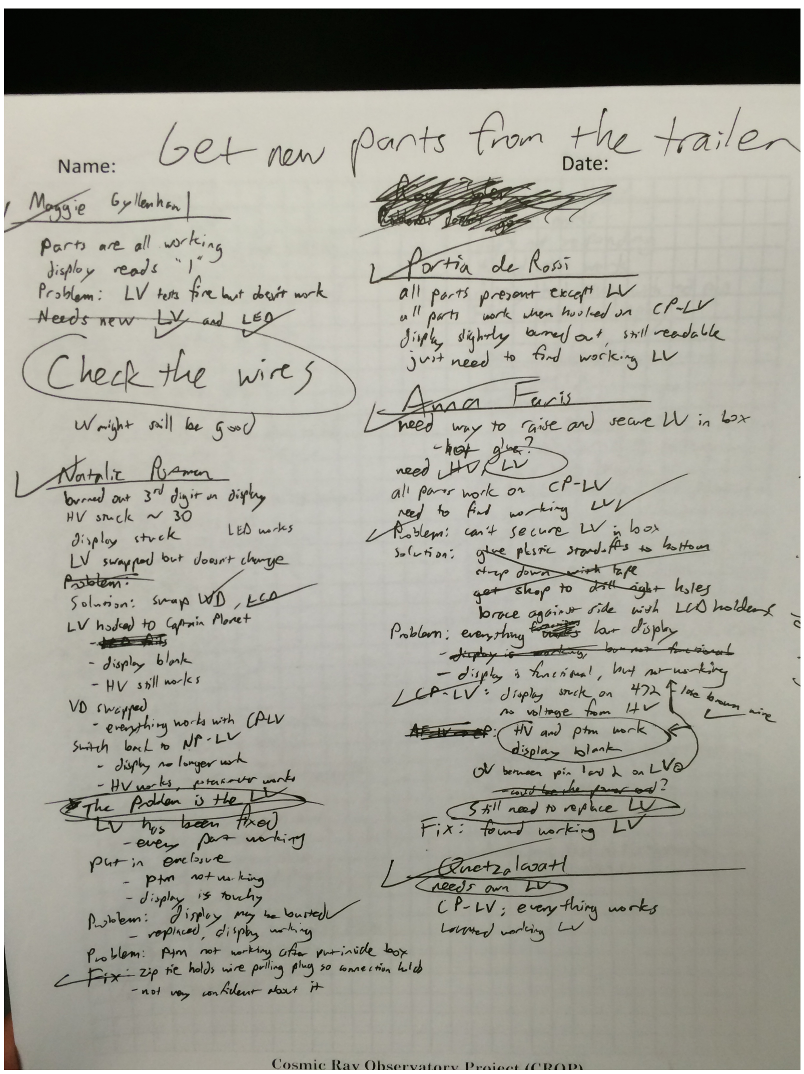
**Note: Completely reduce the voltage before turning the power supply on or off.*

Now you can give your power supply a name. You don't have to name them after actresses like I did. But if you do, I'd go with Anna Camp if she hasn't been made yet. Add the name to the power supply inventory and keep on making more. We've still got a lot of work to do.

Chapter 6: Problems and Fixes

Undeniably, there's a lot that can go wrong with power supplies. That's why being on top of inspecting and fixing them is important. The problem is that there are millions of ways that it can break and only a few ways to fix it. Learning how to fix problems in the power supplies is the cumulation of years of experience working with them. I've worked hard to boil it down into a simple and practical method to diagnose what exactly is wrong and how to fix it. Here goes nothing.

Here's the first tip to fixing power supplies: **write everything down**. I use a large notepad to record everything about the power supply I'm working on. Every thought I have about how to fix it gets written down. Every problem that exists or arises gets written down along with potential solutions. Keeping notes like this helps keep your thoughts in order and lead you in the right direction.



The Most Common and Annoying Problem:

Let me introduce you to one word: "***Touchy***." This is defined as,

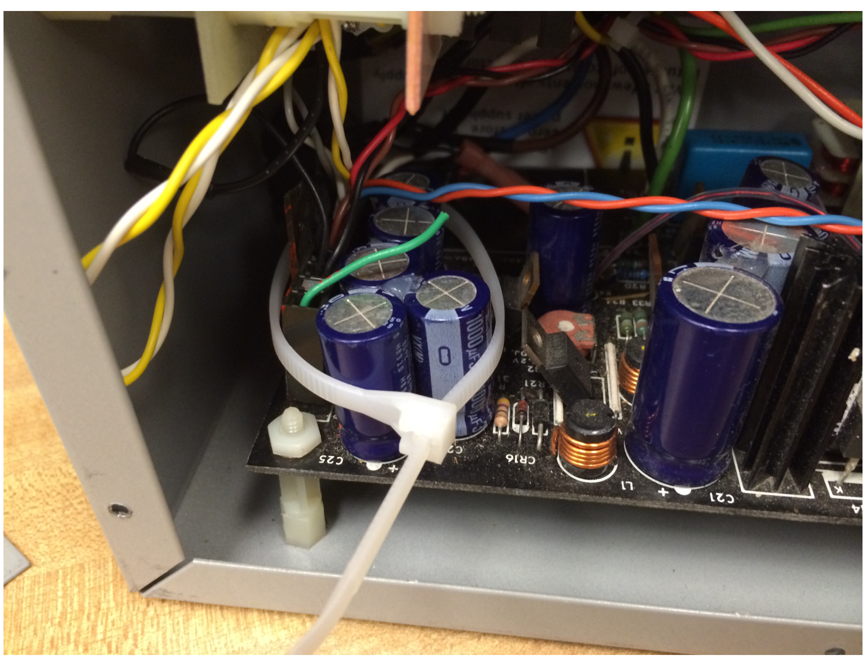
> "*the condition being that any disturbance to the position of the plug on the LVS caused by vibrations, bending the plug, or hitting the device or the nearby ground results in large fluctuations or failures in the power supply, most evident in the display.*"

Want an example? Take a power supply. Turn it on and turn up the voltage a bit. Now make a fist and bang on the table next to it. Did the display jump around or shut off? Sometimes it's only temporary. Oh, did the display stay off? Go ahead, hit the table a few more times until it comes back on.

Want another example? Turn it on and turn it up again and this time, take hold of the plug and wiggle it around on the LVS. Is the same thing happening? Sometimes, the power supply is VERY picky about the position of the plug. When putting it into the enclosure, sometimes the bending wires force the plug slightly out of position. You can notice this problem by tugging on some of the wires and seeing the display magically turn back on.

A power supply being "*touchy*" is a problem caused only by the LVS. The only surefire fix is to replace the LVS with another working one. Other quick but not so confident fixes include securing the plug in the right position so it isn't affected by vibrations. This is often accomplished by tightly zip tying the plug to the nearby capacitors on the LVS.

**Note: This can only work if the power supply works with the plug in this position.*



Hit It Until It Works:

Sometimes, a touchy LVS is unavoidable. In rare cases, it seems as though the "touchiness" spreads to other parts. If you can live with it, for a quick fix, hit it until it works. Was the power supply you were using a moment ago now not displaying anything? Hit it until it works. Is the display now not moving at all? Hit it until it works. Is the power supply giving you jack *^%&? Hit it until it works.

Process of Elimination:

There's a real process to diagnosing actual problems with the power supply components. It just requires a bit of logical thinking and **follow the wire**. Start with the immediate problem and trace the wires backwards until you get to the source.

For example:

> The display doesn't seem to be on. All the wires seem to be secure. We know that the power to the display is provided by the orange and blue wire coming from the plug. Let's go back and check the pins under those wires to see if we're getting a correct reading. If we suspect the LVS is the problem, let's swap it out with an LVS from another working power supply.

Another example:

> The display is stuck on it's base voltage. All the wires appear to be secure. It's reading something so we know it's receiving power. The red and blue wire regulate the voltage reading so the problem could be the voltage divider and/or the potentiometer. Let's use the high voltage probe and test the voltage coming from the HVS. The HVS isn't responding to the potentiometer either. Let's swap the potentiometer onto our other working power supply. It still works so the problem isn't there. There may be an issue with the LVS since the red, brown, and black wire connect to the voltage divider. We'll swap another working LVS on this power supply. The problem persists so the LVS is not the problem. It must be the voltage divider that's faulty.

This is the kind of thinking it takes to fix a power supply. For instance, if you think a wire is faulty, disconnect it completely and see if anything changes. If something does, then the wire is fine. Do what comes logically and you'll have it fixed in no time. Don't be afraid to take apart working power supplies to help you fix another. Test all your parts beforehand, except the resistor board, voltage divider, and LED. More often than not, the problem WILL be the voltage divider, but follow this process to make sure. Also, **WRITE EVERYTHING DOWN**.

Become familiar with issues unique to each component. Below are some quick diagnoses of common problems, assuming you've done the normal tests and always remember to **check the wires**:

PROBLEM	SOURCE
Display flickers on and off	LVS
Display stuck on ± 1	LVS, VD
Display stuck, but HVS responds just fine	VD
Display and HVS stuck	VD
HVS changes much more quickly than display	LVS
Display stuck reading very high voltage	VD

Also, be on the lookout for signs of damage to the component. Deep burn marks in the circuit board can mean it's shorted in the past. Sometimes, the metal rings on the part connecting to the wires can tear off. If they do, there's no way for the wire to stay on and provide the voltage. Similarly, the pins on the display can fall out. Corrosion can also be seen on many parts and it can interfere with their functioning. Make sure that all the parts attached to the component like capacitors and resistors are accounted for and that they too don't have signs of damage.

Some of these mechanical issues are fixable, except for short-circuit burns. If a component is missing some part like the connecting terminals, those metal rings, pins, capacitors and such, place it in the box labeled "**Possibly Fixable Power Supply Parts**." These can be fixed with the expertise of the **Electronic Shop**, room 358 on the third floor. You can ask for Dr. Bob Kelty's opinion on whether or not they're fixable.

Chapter 7: Getting New Parts

We are at that stage where we are running out of working parts to make power supplies with in this lab. The problem with these parts being very old is that most of their suppliers no longer exist. So, we have to keep searching online for them. The search has not gone well. Finding a new supplier will be the long term solution to this problem. As for short term, we can grab more parts from the **CROP trailer**.

The trailer is located alongside Y street between 20th and 21st street. It's filled with boxes and boxes stacked on more boxes of power supply parts, PMT's, scintillators, oscilloscopes, and other things we may need. All the boxes are labeled with what's inside so you can definitely find what you're looking for.

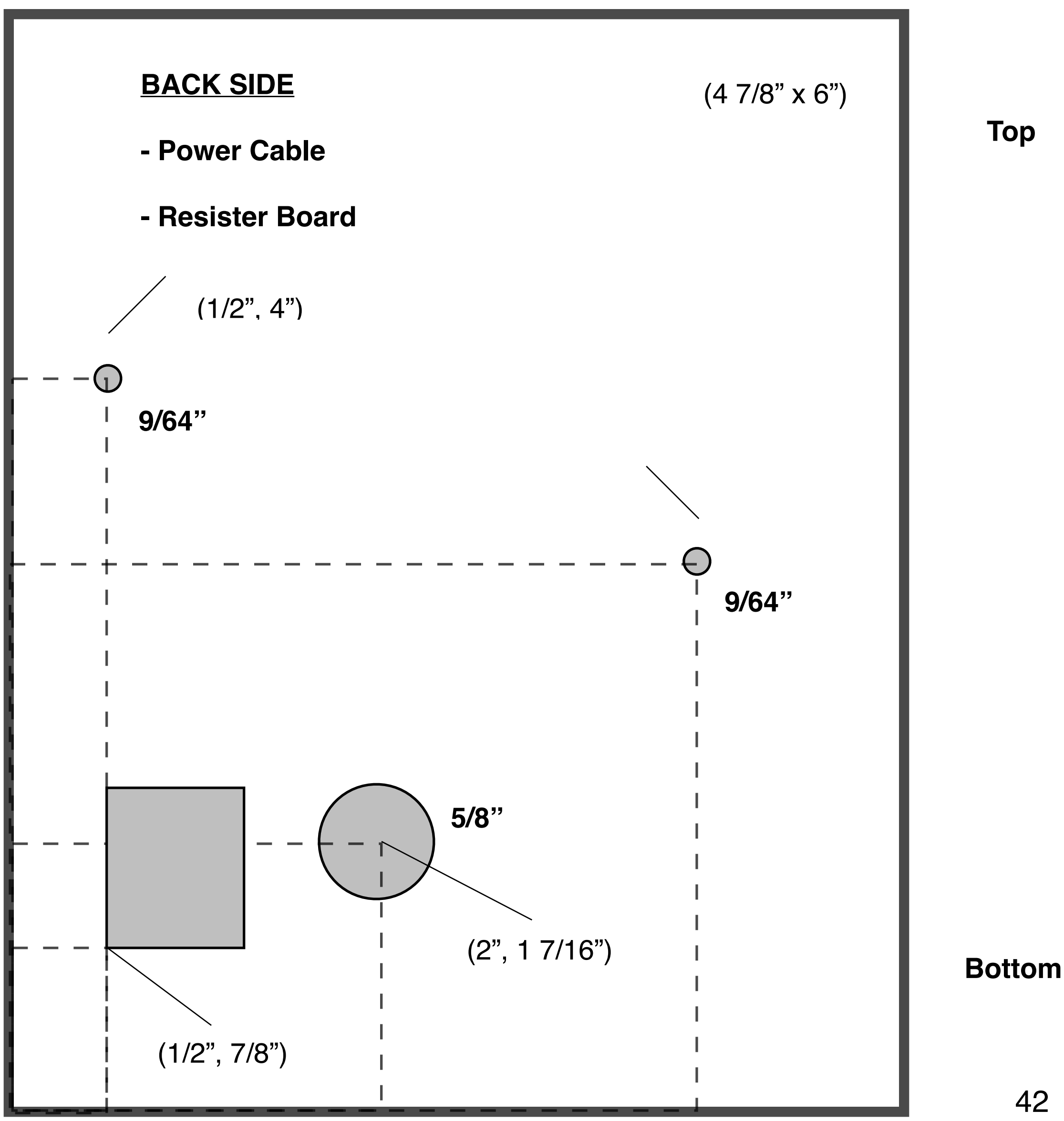
The trailer has two combination locks so ask Dr. Claes first before going there. He'll have the right combinations to unlock them. If you're looking to haul back quite a few boxes, you'll also need a car. Don't go there alone because getting stuff out of there will require crawling on top of a lot of stacked supplies and through some tight spaces. Keep in mind what exactly you need to bring back.

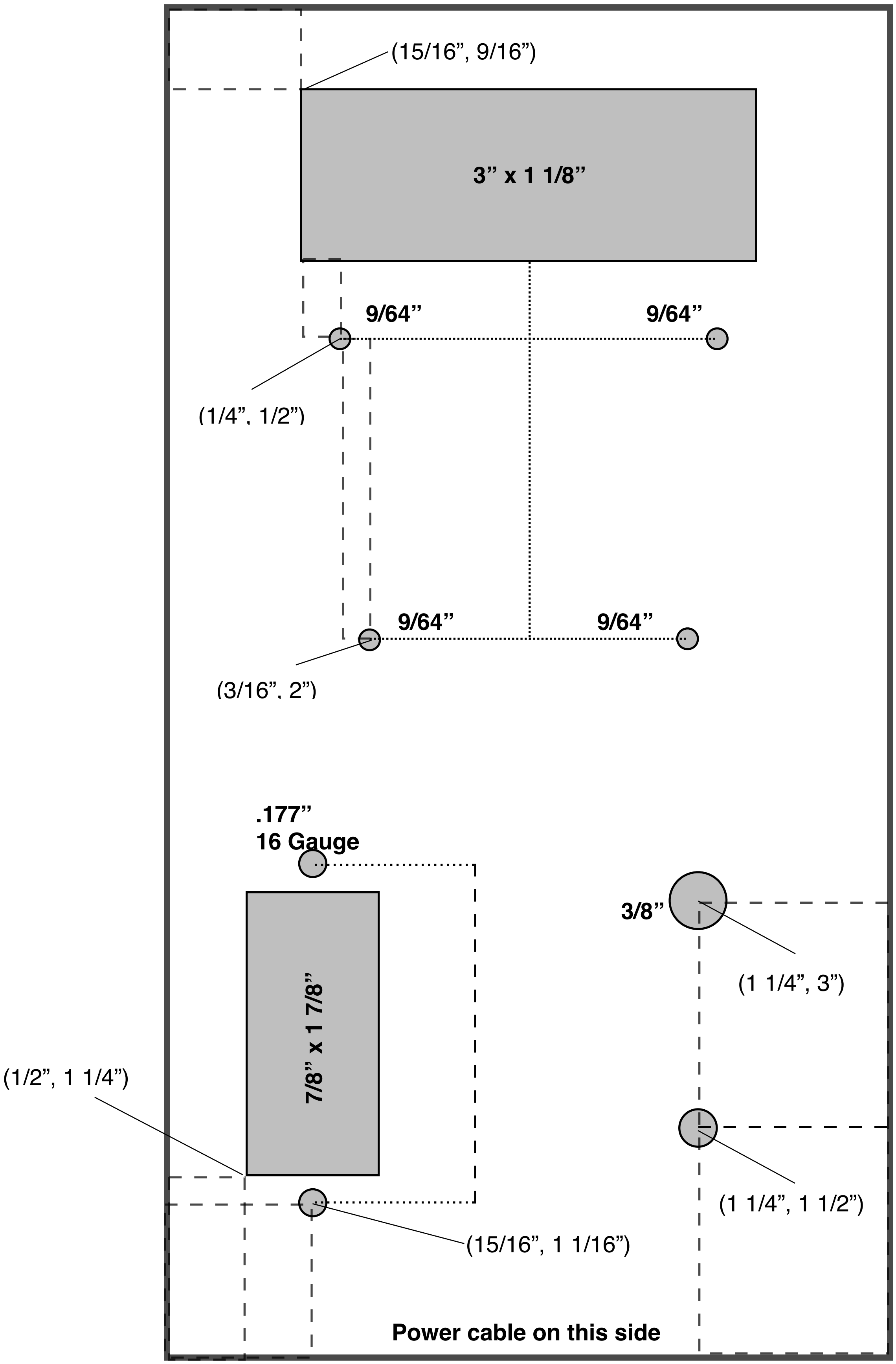
Making New Enclosure Boxes

We only have a handful of enclosure boxes left. Only very few have all the necessary holes drilled. In order to fully utilize our supplies, we'll have to get the boxes to the **machine shop** and get everything drilled correctly. The machine shop is located at the end of the hallway from this lab. We are permitted to use the student shop under the right training and supervision. You don't need a full safety course on how to use every machine in there. You only need one: the **milling machine**. It's basically a drill press with a movable table. Just ask the people in the shop about using it and someone will give you a run-through of how to use it.

Below are the templates for drilling the enclosure boxes. **The originals are located in the same drawer as the CROP labels, above the power cable drawer**.

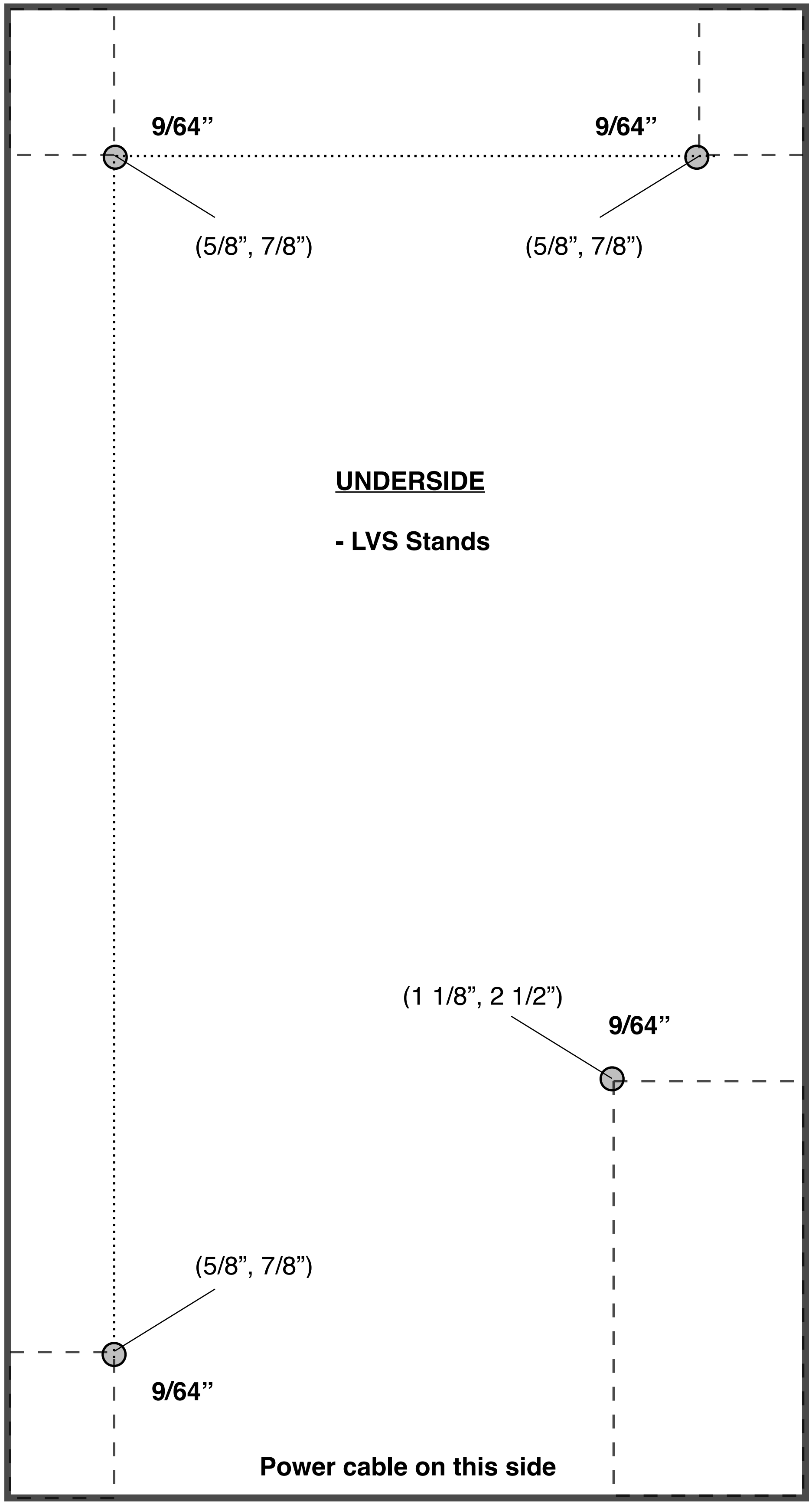
Note: All measurements are like this:* *(horizontal length, vertical length)***





TOP SIDE

- HVS
- Potentiometer
- Display
- LED


9/64”
9/64”
(5/8”, 7/8”)
(5/8”, 7/8”)
UNDERSIDE
- LVS Stands
(1 1/8”, 2 1/2”)
9/64”
(5/8”, 7/8”)
9/64”
Power cable on this side

The next step should be to find how we actually make the entire enclosure. These templates should help us correct the ones we already have, but that won't last us very long. Talk to Dr. Claes and the guys in the machine shop about getting more. The same goes for the side panels. Look around the lab first to see if there are extras lying around.

We need to stay on top of finding a stable supplier of our power supply components. Keep searching online and stay in touch with Dr. Kelty in the electronic shop. The parts we have may have names of their producers that could lead us to similar companies that can get us what we need.

Now, you've been thoroughly introduced into the world of power supplies. Tricky things, these are. Working with these will become easier as you gain experience. Always remember to work safely and be organized. Keep the inventory up to date and don't let things fall into disrepair. As you work, keep in mind how to approach things from a practical standpoint and keep learning along the way. All the knowledge in here is cumulative so add to it what new things you discover. When I started working here, I hardly knew what I was doing, so don't worry about feeling lost at first. If you follow all the instructions here, you'll soon be the new expert on power supplies. *Good luck*.

- John Hao 8-22-14