

# Small Appliance Repair (Last chance before the landfill)

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## Why try to fix things

When something stops working, it is very common in our throwaway society to just buy a new one. Manufactures do not help this by making it difficult to repair a broken item by making it hard to access the internals of an appliance, have limited or no documentation, using custom parts and not selling replacement parts.

Surprisingly, many appliances do not stop working because they are worn out, but a simple to repair failure has occurred. Sometimes the hardest part of making a repair is just trying to get the darn thing open! With a little bit of observation skill and some basic tools many items can be repaired very inexpensively and will last for many more years.

## Safety

When working on appliances, safety cannot be overlooked. Many appliances run on electricity and there is always risk of electric shock even if it is unplugged. It would be nice to say that you should never work on an appliance that is plugged in, but that is not possible. Sometimes it is necessary to have the item partially disassembled and test it under power.

My Rules for working on electric appliances:

- Always have the item unplugged when assembling or disassembling. I physically pick up the cord and follow it to the socket to be sure that it is unplugged. I have seen situations where a fixer will accidentally unplug the wrong thing, leaving the item they are serviced plugged in. Always follow the cord.
- I use a dedicated outlet or power strip whenever possible. That way I can quickly see if that item is plugged in. A power strip with a switch and circuit breaker is nice. It can be faster to throw the switch on the power strip then try to unplug something in an emergency.
- If working on something under power, cover any open terminals that may contain high voltage. I will tape cardboard or electrical tape over areas that I could accidently touch.
- Be aware of items on your work bench or loose part on that appliance. It is very easy to move the appliance on your work bench for a better view or access and find that you have shorted out some circuitry or jammed something into the mechanism.
- Capacitors can store electricity. Especially electrolytic capacitors in power circuits can store a significant amount of voltage and can severely injure you if you touch the terminals. You must be aware of these devices and make sure they are discharged before working near them (see [Capacitors](#) section on how to discharge a capacitor).
- Lithium-Ion and LiPo batteries are appearing in more appliances. These batteries can explode or catch fire if they are ruptured, overcharged or shorted.

## How to troubleshoot almost anything

As fixers, we may not have all of the equipment or skills to troubleshoot circuit boards at the component level. Even with the tools and skill, it may be impossible without schematic diagrams, but there is still a lot that we can do!

- Not everything is repairable!

- Some appliances may have been recalled or replaced via warranty. If an appliance comes in and the power cord is cut off or if the manufacture label is missing. There is a good chance that the appliance was taken out of service and should have been disposed of. Do not fix these items! An internet search can possibly identify a recalled item, but warranty disposal is harder to determine.
- The internet is your friend!
  - YouTube can help you with almost anything!
  - Many manuals and parts diagrams are available online. Even if you do not find your exact model, you may find something close.
- Gather a set of tools
  - Muffin tins work great to organize screws when disassembling.
    - Sometimes screws are different lengths. Make notes or mark holes that use difference lengths. Sometimes putting a long screw in the wrong hole will create a new problem (something running on the screw or screw shorting electronics.
  - Have a good work surface (lay down newspaper or cardboard on work surface)
  - Screwdrivers, pliers, flashlights, paper towels, etc...
- Before and during disassembly, take pictures.
  - Especially if there are springs involved.
  - Take pictures from different angles.
- If you are trying to disassemble something, it looks really complicated. Stop and look again, there may be an easier way.
- Heat and movement can cause parts to fail.
  - Power supplies create a lot of heat, most often the problem can be found at or near the power supply.
  - Switches have moving parts and break.
  - Wires can be broken.
  - Power cables and connectors can work loose or be broken.
- Things that turn off! There may be multiple safeguards that prevent a machine from operating when something goes wrong. Sometimes the safeguards go wrong.
  - Interlocks and tilt switches – These are usually switches or levers that are on doors, food processor bowls, under space heaters, etc, that prevent the machine from operating when an unsafe condition may exist.
  - Fuses, circuit breakers, thermal fuses, etc.. These are devices that detect too high of current or temperature and will shut off. Sometimes they can be reset and other times they need replacement.
  - On/Off switches – Because these are usually mechanical, they can break or become intermittent.
- Use all of your **senses**
  - Burned parts may have a **smell**.
  - What do you **hear** (buzzing, humming, grinding, etc...)
  - **Look** for burned connectors, discolored wires.
  - **Look** for loose or broken wires
  - **Look** for metal shavings or black dust that may indicate wear
  - **Feel** if moving parts are loose or have slop in the movement.
  - **Watch/Listen/Look**, if moving parts slide smoothly or do they catch on something.
  - **Feel** if parts are hot that should not be.
  - When turning on a switch, does it **feel** right? Do you have to force it? Sticky? Sloppy?
  - Does something **look** bent?
  - **Look** for foreign objects.

- **Look** if there is corrosion on the battery terminals
- Many symmetrical parts are not the same on each end (Take notes/pictures).
  - Mounting holes may not be truly symmetrical from side to side. One or more holes may be slightly shifted preventing proper alignment.
  - There may be a notch or pin that keys two parts to proper alignment.
  - Springs may have a loop on one end, but a hook on the other.
  - If it is not going back together, try flipping it over.
  - Shafts or pins may be slightly tapered.
  - It is a good idea to mark parts with alignment marks for ease of reassembly.
- Troubleshooting steps
  - Identify the problem
  - Identify how to fix the problem
  - Fixing the problem
  - Figure out how to put it back together!
- When troubleshooting any problem:
  - The biggest mistake you can make is making an assumption. Listen to what someone (or yourself) tells you about the problem, but do not assume it is correct.
  - Ask the right questions
    - Is it worth fixing?
    - Is it repeatable?
    - Did something change?
    - How long has the problem been happening?
    - Was it working well before the latest problem?
    - Was it being used properly or for an unintended purpose?
    - Is there anything that makes the problem better or worse?
  - Before attempting to use the item, give it a once over and make sure there is nothing dangerous before attempting to test it. Quite often the problem can be found by doing this.
  - Before disassembly, Look for the obvious. **Nothing is too simple!**
    - Is it plugged in? (I fixed a toaster that way)
    - Does the receptacle have power? (Try plugging in something that you know works)
    - Is the switch on?
    - Are there interlocks, tilt switches, fuses or circuit breakers?
    - Is the light bulb good? (I fixed a lamp with 3 bad light bulbs)
    - Does any part of it work?
    - Are there missing parts? Screws?
    - Is anything loose or broken?
    - Is there noticeable corrosion?
    - Are there any error codes that can help identify the problem (blinking lights, display codes, tones, etc...)?
  - Don't change more than one thing at a time.
  - Anything with electronics, look around the power supply. Most problems can be attributed to power supply issues.
    - Is the power cord faulty (may be broken inside insulation). This will usually happen at bend points (At the plug or at the housing of the machine). Check the whole cord.
    - Bad power switch?
    - Are any of the switches stuck or in a half position?
    - Is there an interlock switch, like on the bowl of a food processor or under a space heater?
    - Blown fuse?

- Is the battery dead?
- Are the batteries installed in the correct direction?
- Is there a reset switch for the power or electronics?
- Burned or discolored connectors?
- Solder joints on printed circuit boards should look shiny. If there is a spot that looks dull gray and grainy, it may be signs of a bad connection (usually around power connectors).
- If it is safe to do so, wiggle wires to detect a bad connection.
- Dirty contacts can sometimes be cleaned with an eraser!
- For mechanical things, look for:
  - Excessive wear or misalignments.
  - Something rubbing on the case or another part.
  - Loose screws or parts at the bottom of the device.
  - Blobs of grease or oil where it should not be.
  - Excessive dirt
- Think outside the box when diagnosing the problem as well as finding a solution.
  - Many issues have a cause and effect that are not obvious.

## The Tool Box

Defining a basic set of tools is very difficult as it depends so much on what is being worked on as well as the skill level of the fixer. Repairing a car requires very different tools than repairing a cell phone.

When doing small appliance repair, the tasks can be broken down into three categories that may require unique tools:

1. Disassembly/Assembly
  - a. Screw drivers, wrenches, nut drivers
  - b. Pry tools (Spudgers)
  - c. Camera
2. Identification of problem
  - a. Magnifiers
  - b. Test meters
  - c. Power supplies
3. Correcting the problem
  - a. Soldering irons
  - b. Wire strippers/cutters
  - c. Epoxy/Glue
  - d. Spare parts

## Basic Tools (Required)

- Camera (cell phone).
- Set of screwdrivers
  - Include multiple types of bits for security screws
  - Long shafted Torx and Phillips screwdrivers
- Cell phone case opening pry bar kit (Spudger). I use the stainless blade most often.
- Flashlight
- Wire strippers

- Wire Cutters
- Small socket set
- Adjustable wrench (small)
- Tweezers
- Xacto knife
- White eraser (cleaning contacts). Pink will work, but white is a little more abrasive and clean better.
- Soldering Iron with 60/40 rosin core solder
- Heat shrink tubing
- Magnifier. A cell phone camera with zoom can act as a microscope.
- Needle nose pliers
- Slip Joint pliers
- Crimping Tool (Multi-tool - crimper, stripper, screw cutter)
- Digital Multimeter
- Non-contact Voltage Tester

## Consumables

- Isopropyl Alcohol (IPA) – Great overall solvent that cleans without leaving a residue and is not too harsh. Excellent for cleaning rosin on circuit boards after soldering.
- Cotton swabs and paper towels
- Contact cleaner (I like DeoxIT D5)
- Light oil (3 in 1 or sewing machine oil)
- WD40 (not for oiling)
- White lithium grease or silicone grease
- Glues: 2 part epoxy, super glue (recommend single use tubes in both gel and liquid).

## Advanced Tools (Nice to Haves)

- Digital SMD soldering microscope.
- Spring hook
- awl or icepick
- Set of nut drivers (nut drivers have a smaller profile than sockets which can help getting into tight places)
- Adjustable power supply
  - Universal power adapter <https://smile.amazon.com/gp/product/B08N4R48LJ>
  - Bench power supply
- 3D printer

## Advanced Electronic Testers (More Nice to Haves)

- Transistor tester (<https://smile.amazon.com//dp/B08K38XP8G>)
- Load tester (<https://smile.amazon.com/gp/product/B07HB3XK7L>)
- USB tester (<https://smile.amazon.com/gp/product/B07PWC7YMT> )
- ESR meter
- Variac
- Isolation transformer
- Analog multimeter (Simpson 260 or equivalent) - I find it useful sometimes

- Desoldering iron

## Vintage Electronic repair (Specialty)

- Dim Bulb tester
- Isolation Transformer
- Variac
- Corona Dope
- Analog VOM (Simpson 260). Has “A.F. Output” jack for measuring audio frequency voltage on plate of tube amplifier.
- Insulated tuning tools

## Resources

### Service Guides

- [Repair Manuals for Every Thing - iFixit](#)
- [Restarters Wiki](#)
- [Fix-It Guides | Free Repair Help | Fix-It Club \(fixitclub.com\)](#)
- [Inside my laptop – Easy to follow laptop disassembly instructions and tips for DIY repairs](#)
- [Need a repair? The Fixit Clinic will guide you to get things working again - Make: \(makezine.com\)](#)
- [DIY Audio Articles](#)
- [PIONEER TUNING FORK](#) - Series of documents on general and audio repair
- [What I've Learned Fixing Optical Drives](#)

### Schematics and Manual

- [Free Audio Service Manuals - Audio Service Manuals](#)
- [Lost manuals for free](#)
- [Pacific T.V. - Online Schematics](#)
- [Free Military Army Manuals! \(liberatedmanuals.com\)](#)
- [Manuals and circuit diagrams - Manuali e schemi radio \(radiomanual.info\)](#)
- [Service Manual free download,schematics,datasheets,eprom bins,pcb,repair info for test equipment and electronics \(eserviceinfo.com\)](#)
- [Service Manuals and Schematics: Sony, Panasonic, Sharp, JBL circuit diagrams](#)
- [Audio Tube Resources - www.thetubestore.com](#) - Guitar amp and HiFi schematics
- [Schematics \(amprepairparts.com\)](#) Amplifier schematics
- [Free Audio Schematics Download - Audio Schematics & Manuals](#)
- [Service Manual finder | Elektrotanya](#) Antique radios and more
- [Manuals - KO4BB](#) Ham radio and test equipment schematics
- [Bama Manual Archive \(edebris.com\)](#) Test equipment
- [Nostalgia Air](#) Vintage Radio Schematics
- <https://www.radiomuseum.org/> Vintage Radio Schematics
- [Schematics Unlimited :: Free Diagrams, Schematics, Service Manuals for download](#)
- [HiFi Database | Images, Specs, Manuals and Reviews \(hifiengine.com\)](#)
- [The Internet Pinball Machine Database \(ipdb.org\)](#) Pinball information and schematics
- [CB Tricks - Home Page](#) CB radio schematics
- [BMET Digital Library \(ewh.org\)](#) Medical equipment manuals
- [Electronics Search - Electronic Circuits, TV Schematics, Audio](#)

- [Radio Shack user manuals download](#) Radio Shack and other brands
- [RadioShack, Archer, Micronta, and Realistic Information Index](#)
- [Radio Shack User Manuals Download | ManualsLib](#)
- [RigPix Database - Schematics, manuals 'n' stuff](#)
- [Radio Schematics](#) - Many European radios
- <https://rtellason.com/excess.html> <- Sams index for many items
- [Encompass](#) Drill under manufacturer to find item, in the upper right corner there are often service manuals.

### Component Datasheets and appliance diagrams

- [eReplacement Parts](#) – Many exploded parts diagrams for appliances
- [searspartsdirect.com](#) - Many exploded parts diagrams for appliances
- [DigiKey Electronics - Electronic Components Distributor](#) - Datasheets for electronic parts
- <https://www.mouser.com> - Datasheets for electronic parts
- [LCSC Electronics](#) - Datasheets for parts from China that can not be found elsewhere
- [Data Books \(bunkerofdoom.com\)](#) Cross reference and old transistor datasheets
- [Frank's electron Tube Data sheets \(pocnet.net\)](#) Tube datasheets
- [Alltransistors.com](#)
- [NTE Semiconductors Cross Reference Guide](#) ECG & NTE cross reference
- [Integrated Circuits with 74 Logic ICs, Memory and Linear ICs](#) cross reference and datasheets IC's and transistors

### Reference and online tools

- [Online Conversion Calculators | DigiKey Electronics](#) - Many great calculators and converters
- [Ohm's Law Calculator | DigiKey Electronics](#)
- [Ohm's Law \(colorado.edu\)](#) - Great animated representation of ohms law
- [Conversion Calculator SMD Resistor Code | DigiKey Electronics](#) - (Surface Mount Device)
- [The SMD components marking codes database - Index page \(yooneed.one\)](#)
- [This to That \(Glue Advice\)](#)
- [Scheme-it | DigiKey Electronics](#) - Free Schematic Editor
- [Record Player Turntable Accessory, Stylus, Cartridge, Gear](#) <- cassette belts

### Turntables

- <https://www.dualturntablelube.com/guides-and-links>
- [Service & Support - DUAL](#)
- [Voice Of Music, V-M Audio Enthusiasts](#)
- BSR [A simple guide to fix BSR changers : r/turntables](#)
- [The 'Every Vintage Record Player' Failure](#) (BSR)

### Monitors

- [Sci.Electronics.Repair FAQ:](#)

### Laser Discs

- [LaserParts](#) Parts, Schematic and repair tips for Laserdiscs
- [Laserdisc Documentation | Laserdisc Plaza](#)
- [Pioneer Video Service Guide, CLD-S104 \(v2\)](#)

### Knowledge Database

- [DIY Audio Articles](#)

## Basic Electronics

### Voltage and Current

When working on anything using electricity, it is important to understand the relationship between voltage and current. Voltage is like the pressure that pushes electricity through a wire, and current is the measure of how much electricity is actually flowing.

Voltage is the driving force that pushes electrons through a conductor, such as a wire. Voltage is typically measured in volts (V).

Current, on the other hand, is a measure of the flow of electric charge. It is the rate at which electric charge flows through a conductor. to the appliance (load). The amount of current used depends on the load being applied. An example is the wall outlet: The wall outlet supplies 120 volts and up to 15 amps. The amount of current used depends on what is plugged into that outlet. A 60 watt light bulb will draw  $\frac{1}{2}$  amp while a toaster could draw 12 amps.

When plugging anything into a power source it is important to make sure that the power source can supply enough current. It is acceptable to have a power source that can supply a higher current than required, but is not acceptable to have a power source rated for a lower current rating.

### Ohm's Law

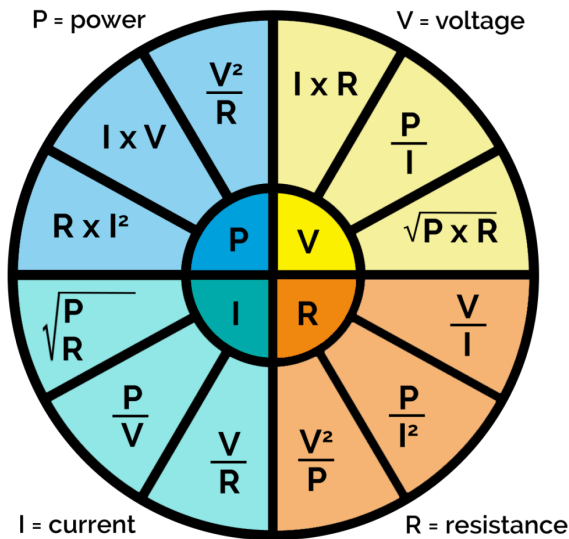
Two formulas can help you when working with electronics.

Ohm's Law

$$\text{Voltage} = \text{Current} * \text{Resistance}$$

$$\text{Power} = \text{Voltage} * \text{Current}$$

If you are not great with algebra, the "Ohm's law wheel" can be used to find any combination of these formulas.



If you have a 120V appliance that is rated for 1200 watts, you can calculate how much current it will draw.

$$I = P / V, \quad I = 1200/120, \quad I = 10 \text{ amps}$$

If you have a laptop that draws 2 amps at 24 volts, the power can be calculated:

$$P = V * I, \quad P = 24 * 2, \quad P = 48 \text{ watts}$$

## Multimeter Usage

Multimeters can be digital (DMM) or analog. Inexpensive digital multimeters can be packed with features and should not be overlooked. The old analog multimeter (with a moving meter), can still be a valuable tool in the toolbox.

When selecting a DMM, look for the following features (auto ranging, AC and DC voltage and current, resistance, diode mode and a beeper). Added functionality such as capacitance testing, frequency, is a plus! Below is an example of an inexpensive meter that can do most of what is needed. (not a recommendation, but only an example).

<https://smile.amazon.com/gp/product/B096M1XCSL>

A new class of meter that caters to people new to electronics with not only auto range, but will also determine what you are measuring. This is great because the user has less chance to make a mistake and have the meter set in the wrong mode.

<https://smile.amazon.com/gp/product/B07DPM27X4>

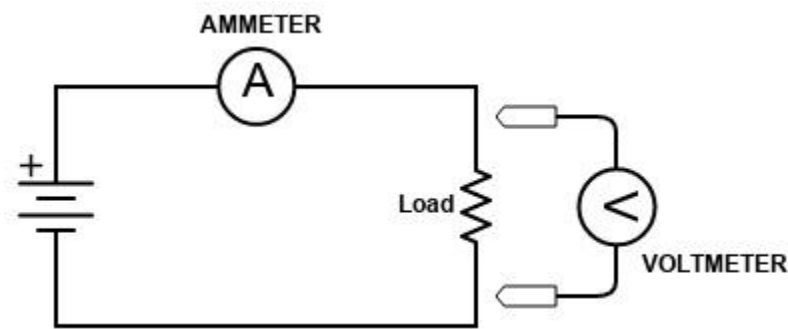
The multimeter is probably the most useful tool when working on anything that uses electricity. It is called a “multi” meter because it can perform multiple electronic testing tasks. The three most useful tasks that almost any multimeter can perform are: Voltage, Current and Resistance

When measuring voltage

- Set the meter to the appropriate AC or DC voltage setting.
- Plug meter leads in the Common and Volt/Ohms jacks. Never have the leads plugged into the AMPS jack when measuring voltage. This can blow up the meter at the very least!
- Touch meter leads across points to measure.

When measuring current

- Measuring current is an advanced measurement and should not be performed unless you understand exactly what you are doing. When measuring current it is necessary to break a circuit and the meter acts like a dead short across the leads. This can lead to dangerous conditions if done incorrectly.
- Set the meter to the appropriate AC or DC current setting. If the current to be measured is large, most meters have a separate setting for higher currents. Read the instructions for the specific meter being used.
- Plug meter leads in the Common and appropriate AMPS jacks. DO NOT USE THE VOLT/OHMS jack.
- Current must be measured “IN CIRCUIT”. This means that it is necessary to break one of the lines and put the meter in series as in the example below.



Measuring resistance

- Never measure resistance in a live circuit. Always make sure power is off.
- Set the meter to the resistance (ohms) setting.
- Some multimeters have a Beep or Buzz mode. This can be very handy when determining if two points are connected. The meter will beep when the leads are shorted, so there is no need to look at the scale.
- Plug meter leads in the Common and Volt/Ohms jacks.
- Touch meter leads across points to measure.

## Soldering/Desoldering

*I recommend saving scrap PCBs from things that are broken and **practice** unsoldering and soldering components!*

### Soldering

Overview

- Soldering is the process of joining metals by adding a filler metal of a lower melting point.

- Oxidation is the enemy of soldering. Oxidation is a poor conductor of heat and can prevent the solder from adhering to the other metals.
- Solder is used to hold two (or more) conductors in electrical contact with each other.
- Solder is not used to make electrical contact.
- Solder is not used to provide the main mechanical support for a joint.
- Solder is used to encapsulate a joint, prevent oxidation of the joint, and provide minor mechanical support for a connection.

#### Soldering Irons

- Soldering iron temperatures 600F-900F
- 25-60 watts good for electronics
- Types: Soldering irons (pencil), guns, stations, hot air, gas torch
- Soldering station (temperature controlled, can have a smaller/lighter handle)
- The wattage of the iron does not change the temperature, but the heat transfer.

#### Soldering tip:

- Chisel, Conical, Beveled, tweezer, etc. (I prefer the chisel style for most work)
- Larger the tip the more heat transfer
- Select tips based on the type of work to be done. Tip size should be about the size of the pad or wire to be soldered.

#### Solder:

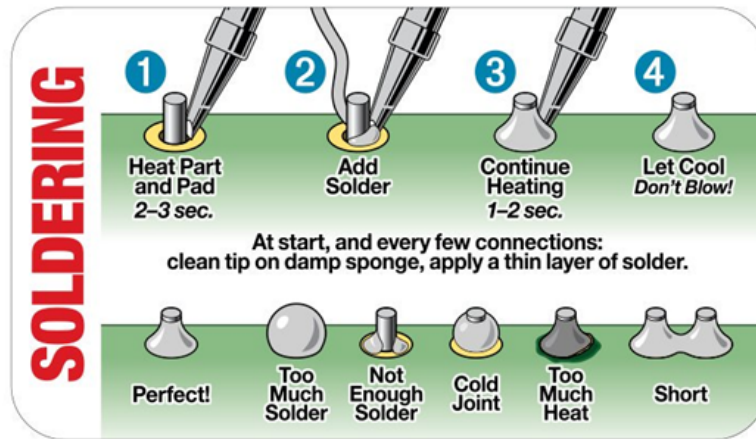
- Wire or paste.
- Lead based or lead free: Tin/lead 60/40, sn96 Tin/silver-copper
- Leaded solder melts ~365F, Lead-Free ~420F
- For most electronic 60/40 rosin core solders will melt and flow the best.
- For leaded solder use ~700F iron, non-lead use ~750F iron
- Diameter
  - .02"-.05" good for PCB
  - .06" and greater for heavy gauge wire
- Solder can be solid or have flux inside (flux core)

#### Flux:

- Cleans, removes oxidation. Flux allows solder to adhere to wire or surface.
- Rosin flux for electronics
- Acid flux for non-electronics
- Can be a liquid, paste or included in the core of the solder.
- DO NOT USE ACID CORE SOLDER ON ELECTRONICS!

#### Soldering Hints:

- It is better to use a hotter iron for a shorter period of time, than a cooler iron and stay on the joint longer.
- Make sure the iron tip is clean and tinned properly. Tinning is the process of having the tip of the soldering iron coated with a thin layer of solder. This promotes good heat transfer.
- Use a brass sponge or wetted sponge to clean the tip regularly (I prefer brass sponge).
- A proper joint is when the solder "wets" into the joint. This means that the solder bonds to the PCB and wire instead of sitting on top.
- Pre-tin any wires or pads before soldering.
- Use helping hands, alligator clips, small vise to hold parts in position when possible.
- Don't move wires when soldering is cooling. Let the solder joint cool naturally, don't accelerate the cooling as it can create a cold solder joint.
- Clean rosin residue with Isopropyl alcohol.



## Desoldering

Desoldering components can be achieved by multiple methods. If the part to be removed is not going to be reused, sometimes cutting the old part out makes desoldering the legs easier. The major concern when desoldering is to not damage the board. Applying too much heat or force can loosen the copper trace on the PCB.

- Often when trying to desolder, it can be difficult to get the old solder to melt. A simple trick is to add some new 60/40 solder to the old joint. This helps in remelting the old solder and the old solder can then be removed much easier.
- Heating joint and remove component
  - For components with only a couple legs, it can be expedient to just heat the joint while applying sideways pressure on the component from the other side. Doing this one leg at a time can quickly remove the part. The solder pad can be cleaned afterwards with “solder wick”.
  - For multileg surface mount devices such as Integrated circuits, adding lots of solder to bridge all of the pins can help. This allows moving the iron back and forth keeping all of the pins hot at the same time until the part comes free. I recommend practicing on a scrap circuit board until the technique is mastered.
- Solder wick (copper braid)
  - “Solder wick” comes in many sizes and is great for removing solder or cleaning solder pads.
  - Press the “solder wick” to the joint, then press the soldering iron on top of the wick and wiggle the wick back and forth. The solder from the joint should migrate to the copper braid.
- Hot Air station
  - A hot air station can help desolder SMD (Surface Mount Devices). Kapton tape or pieces of metal can be used to help shield neighboring parts.
- Solder sucker
  - Solder suckers can be effective, but sometimes it feels like you need three hands to operate the solder sucker and soldering iron at the same time.
- Desoldering iron

- Special irons with a built in vacuum pump work great. These are more expensive, but well worth the money if you find yourself doing a lot of desoldering.
- The desoldering iron with a built in solder sucker is less expensive and does work well.

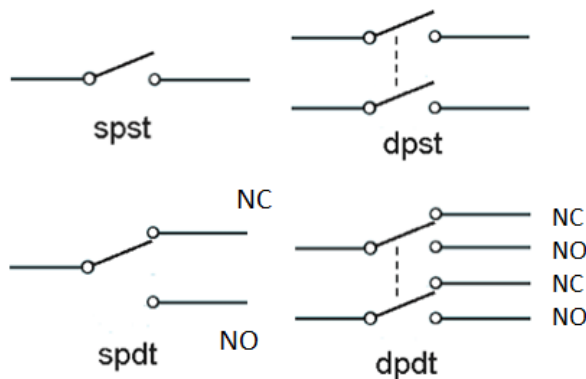
## Switches

A switch's main function is to make or break electrical contact. Switches can be mechanical or solid state and can have the ability to make or break more than one contact at a time.

Mechanical switches can come in many forms such as push button, toggle, limit, rotary, momentary. Sometimes mechanical switches are not controlled by physically moving a handle, but are controlled by other means. Relays are a mechanical switch that is controlled by electricity, thermal switches are controlled by temperature, tilt switches are controlled by the angle of the switch.

Common switch nomenclature stated how many contacts were switched (poles) and how many positions (throws).

- SPST (Single Pole, Single Throw ) - Simple on-off switch
- SPDT (Single Pole, Double Throw ) - Single contact that switch between a normally open and normally closed positions
- DPST (Double Pole, Single Throw ) - Two on-off contacts that move together
- DPDT (Double Pole, Double Throw ) - Two on-off contacts that that switch between a normally open and normally closed positions



Solid state switches are semiconductor devices that can turn on or off electricity from an electronic signal. Some of these can also "partially" turn on the switch thereby controlling the amount of current through a circuit. Some examples of solid state switches are SCR (for DC), TRIAC (for AC), Mosfet or bipolar transistor, SSR (Solid State Relay), optical switch.

## Dimmer switches and speed controllers:

Speed control or dimming may require a special kind of switch. The following are a few possible ways to implement dimming or variable speed.

- Variable resistive load
- Multiple taps on transformer
- Solid state control

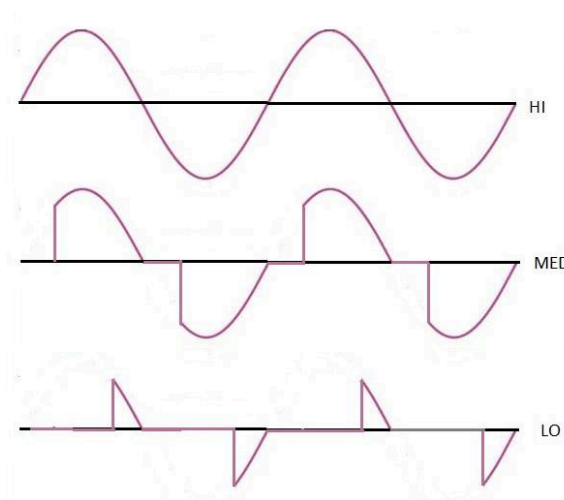
It is also possible to reduce the voltage to dim a light bulb or slow a motor by adding a resistive load, this can be very inefficient. This resistor must absorb the excess voltage creating heat. Also these resistors usually need to be large to dissipate that heat.

Some appliances using transformers will have different taps on their winding to change the speed or brightness via a multi position switch.

Solid state controls have the advantage that they can control a high voltage with a very small voltage. The solid state controls also can be built very small and are more efficient.

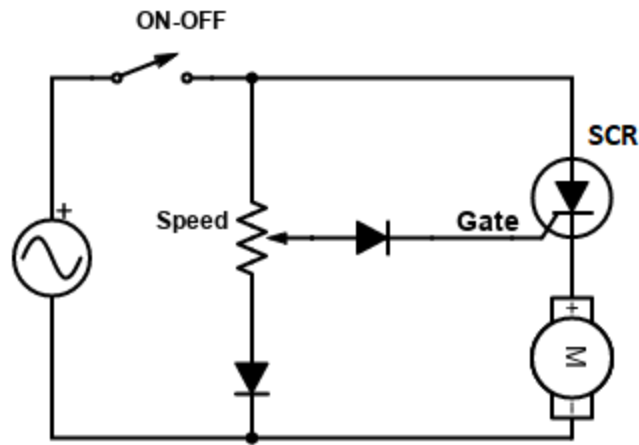
A better way to dim a bulb or slow a motor is not to reduce the voltage, but to vary the time the bulb/motor is turned on. In the example below, the “HI” waveform shows the normal AC voltage as it alternates at 60 cycles per second. The “MED” waveform shows that the voltage is delayed before turning on, thus reducing the effective voltage that the appliance will see. The “LO” waveform shows that the voltage is on for only a very short period of time.

For incandescent bulbs, this works very well as the human eye can not detect the light turning on and off that quickly. Unfortunately LED bulbs have a lot of electronics inside of them to operate on 120VAC. Unless the bulb is rated to be “dimnable”, it may not react well to having the voltage being turned on and off and will create a noticeable flicker or not work at all. Because the voltage must be turned on and off very quickly and precisely, this is done using solid state switching circuits.



Waveform of Electronic Dimmer

Below is a schematic for a variable speed control in a power tool. The SCR acts as a switch to enable power to the motor. The SCR is controlled by the “gate” pin reaching a certain voltage. The gate voltage is set by the variable resistor. As the trigger is pressed, the variable resistor changes when the SCR turns on. Similar to the dimmer waveform above (only the top half of the waveform is used with the SCR), the variable speed is achieved by chopping the AC waveform.



## Batteries and Battery Packs (Rechargeable)

Rechargeable batteries are becoming more common in appliances. There are significant differences in charging and servicing of different types. Some battery types can be very dangerous if handled improperly.

Type	Cell Voltage	Self Discharge	Charge Time	Notes
Lead Acid	2v	20% / Year	8-16 Hours	
Alkaline	1.5V			
NiCad	1.25v	10% / Month	1-2 Hours	High discharge rate. Best to fully discharge before storage or recharging.
NiMH	1.25v	3% / Year	2-4 Hours	
Li-ion	3.7v	15% / Year	1-2 Hours	Do not store fully charged
LiPo	3.7v	10% / Year	1-2 Hours	Do not store fully charged

Charging: Typically NiCad and NiMH battery packs are charged as a unit. An example 3.6v pack would be charged using approximately 3.6v and a constant current. The charger is going to regulate the current and shut off charging when a full charge is reached so that it will not overcharge.

For Lithium battery packs there is usually a BMS circuit (Battery Management System) that will charge each cell of the battery pack. This is important to keep all of the cells balanced to the same voltage. A BMS can also shut the battery pack off if the batteries get too low. If Lithium batteries drop below a specific voltage (~3v), it can damage the cells. Some BMS's can log this information and disable the pack permanently if a cell's voltage drops below this threshold, preventing the pack from ever being charged again.

If a battery has leaked, follow these steps for cleaning:

- Tools: Gloves, Paper towels, Cotton Swabs, pencil eraser, small file or fine sandpaper, toothbrush or acid brush
- Wear rubber gloves as the leaked material can be caustic.
- Determine the type of battery (lead acid, alkaline, NiCad, NiMH, Lithium).

- Remove all old batteries and safely dispose of them.
- Clean any loose deposits with a small brush.
- Some batteries leak an acid, while others leak a base, so it is important to use the proper agent to neutralize it. Use the table below for the proper neutralizing process by battery type.
- Once the deposits are neutralized and cleaned, the contacts should be polished as much as possible. A pencil eraser will usually work well, but for very pitted or corroded contacts fine sandpaper or file may be necessary.

Type	Cleaning solution	Process
Lead Acid	Baking Soda/water mix	Neutralize area with baking soda solution, clean and polish contacts
Alkaline	Vinegar or Lemon juice	Neutralize area with Vinegar, clean and polish contacts
NiCad	Baking Soda/water mix	Neutralize area with baking soda solution, clean and polish contacts
NiMH	?	
Lithium	Not recommended	It is not recommended to clean Lithium battery corrosion. Disposal is recommended.

## Power Adapters

Power adapters (Power Supply, Power converter, Wall adapter, Wall Warts) are typically used to convert (step down) the AC wall power (mains) to a lower voltage that a device can use. Most electronics devices require DC voltage to operate, so the power adapter converts the output to DC as well. Some manufactures have even mounted a power adapter inside their appliances (I have seen this in printers and scanners). They do this because it allows them to meet all of the UL certifications without extra work. Some power adapters output AC voltage and others convert the voltage to DC.

Power adapters come typically in two forms: linear and switching (switch-mode). Linear supplies (typically older) use a transformer to step down the voltage and some basic circuitry to convert the voltage to DC. These can be recognized by being bigger and heavier. The newer switching supplies eliminate the bulky transformer, but contain a lot of electronic circuitry to convert the power. Usually when a linear supply goes bad, they just quit working. Switching supplies can go completely bad or sometimes the voltage looks good when measured, but cannot provide enough current under load.

How to open a power adapter:

- It is good to practice on a few bad power adapters, if any are available. 😊
- Wall adapters often come on a two piece plastic clam shell that is glued together at the seam.
- It may be possible to soften the glue using acetone. Drizzle acetone along the seam and let it set a few minutes before attempting to separate it with a knife and hammer. Sometimes this helps the process, but not always.
- Place a hunting knife (thick backed blade with long straight sharp edge) on the seam and smack the blade with a hammer or wooden mallet. Repeat on each side until the case separates. It is not necessary to smack it very hard as you are not trying to cut through the case, but to break the glue bond.
- Reassemble by using a few drops of super glue.

## Common Problems and repair:

- The most common problem with power adapters will be broken wires at the output plug or at the wall adapter case. These problems can best be repaired by replacing the plug or re-soldering the wires inside the power adapter. The worst part of this is replacing the strain relief going into the power adapter as it is molded to the cord. If the strain relief cannot be removed from the cord, it can be rebuilt using moldable putty like “Sugru Mouldable Glue” or “Loctite Kintsuglue”. It might be possible to use hot glue as well.
- The second most common problem is that the power adapter is working fine, but the socket on the device is bad, therefore the power is not getting to the unit. Since this socket is under stress from the power cord, often the wires to the socket become detached or break from the PCB it is mounted on.

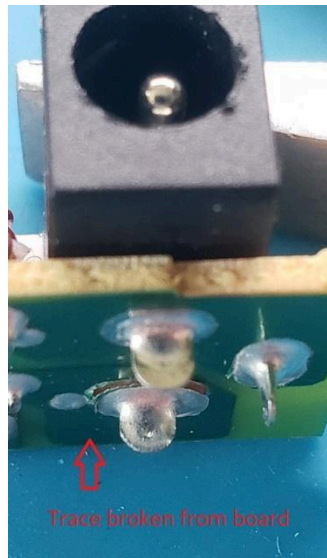


Figure 1: Power Socket Break

- It is possible that there is a fuse inside the power adapter. Also look and see if there is a fuse built into the wall plug (not common).
- Determining if the power adapter is operating properly can be difficult without the proper tools.
  - The ideal way to test the power adapter is with a load tester where the load can be adjusted while monitoring the voltage and current.
  - A voltmeter can be used to determine if the proper voltage is present. If it is possible to measure the voltage while the device is running (under load), that is even better. A bad power supply could see the voltage drop under load. It is possible to measure the supply under load by measuring the voltage inside the device. It is also possible to make a test cable that can go between the power adapter and device that allows a meter to be used. The test cable can also be used to measure current if one of the leads is broken to accept an ammeter.

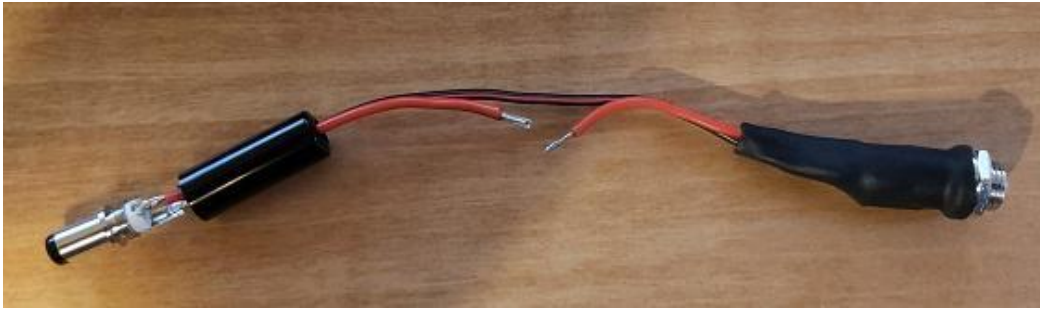


Figure 2: Test Cable

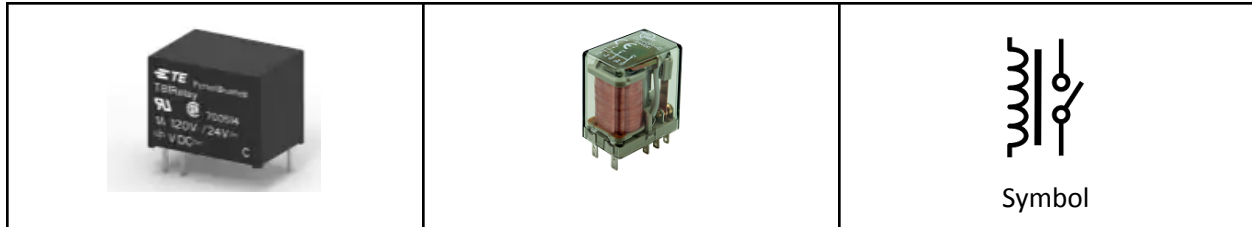
There are 3 important things to look for when replacing a power adapter; Output Voltage, Output current and polarity.

- The output voltage is critical for the proper working of the appliance. It is important to know if the output voltage is AC or DC. It will usually be marked 9VDC or there may show a straight line with a dotted line under it, signifying that it is DC output voltage (see picture below). When replacing a power supply to an appliance, make sure the voltage is the same value and type (AC or DC).
- An appliance will “draw” a certain amount of current and the power supply needs to be able to provide that much current. It is acceptable to have a power supply that is rated for a larger load (current), but never undersize the power supply. If an existing power supply is rated for 1A (amp), it is acceptable to use a power supply that is rated for 1.5A or more. Some power adapters will label the current in milliamps (mA). This is just 1/1000 of an amp. 1000mA is the same as 1A. 500mA is the same as 0.5A.
- If the power is DC, it is important to know the polarity (which pin is positive and which is negative). Most supplies have the center pin as the positive terminal (see picture below), but some have them reversed.



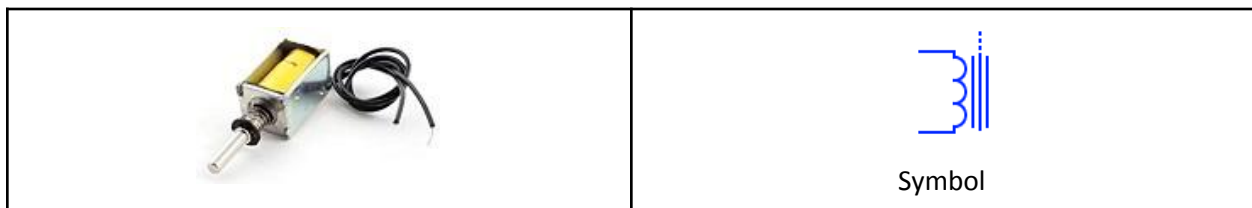
Figure 3: Power Adapter label

## Relays



Relays are typically electromagnetic devices that physically activate a switch. Relays are frequently used in appliances that require automatic switching of a high voltage source. When a small voltage is applied to the relay coil, an electromagnet will enable a switch on the high power circuit. Relays can be found in almost any appliance such as toasters, shredders and heaters.

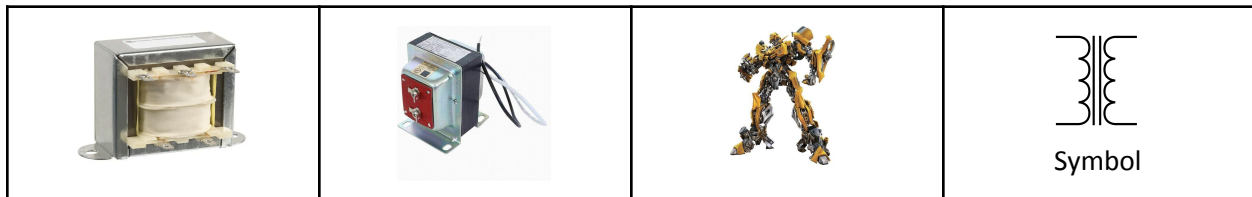
## Solenoids



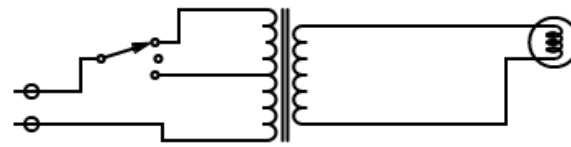
A solenoid is an electromagnet that moves a plunger when energized. It is used to create a mechanical movement from an electronic signal. When the electromagnet is energized, a plunger is moved. Usually this plunger is attached to a spring and when the magnet is released, it returns to its previous position.

Not all solenoids have a plunger. In some toasters, when the lever is pushed down, the solenoid is energized and the electromagnet continues to hold the lever down. When the toast is complete the electromagnet is released and the lever returns, popping the toast up and cutting power to the heating elements.

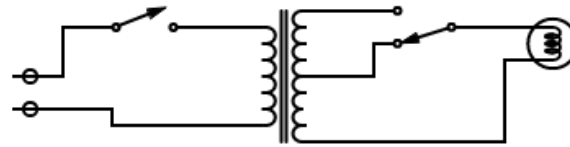
## Transformers



A transform passes AC voltage from one winding to another across an iron core via an electromagnetic field. The voltage passed can be changed based on the ratio of turns between the primary (input) and secondary (output) side. This is a common way that voltage is ‘stepped down’ from 120v to a smaller voltage such as 12v to run a lamp. The primary winding or secondary windings can have “taps” that allow different ratios to be selected. Taps on the primary are often used to select between 120v and 240v inputs, but can also be used to change the voltage to dim lamps as in the example below. Alternatively, taps on the secondary can also be used to change the voltage on a lamp or provide different voltages to different parts of an appliance.



Transformer Primary tap selection



Transformer Secondary tap selection

Transformer windings can be tested by measuring the resistance across the windings. The resistance will typically be under 10 ohms. There will be infinite resistance between the primary and secondary windings.

## Heating and Cooling Elements

The heating elements of most toasters are usually nichrome wire (alloy of nickel and chromium). Older heaters with the coiled wire heating element are also this type of wire. It has higher resistance than normal copper wire and also a higher melting point. This makes it great for heating elements.

Modern heaters may use a quartz heating element or PTC (Positive Temperature Coefficient) ceramic elements. These are much safer (cannot overheat) and more energy efficient.

Peltier devices also called ThermoElectric Cooling modules (TEC) are named after the Peltier effect and have no moving parts. It only requires a DC current to pass through the solid state component. The TEC consists of two plates, where one will get cool and the other will get hot. The cold plate is positioned next to the surface to be cooled and the hot plate has a heat sink and fan. TEC devices can be used to cool or heat. TEC devices are rated for a temperature difference between the two plates, so it is important to keep proper ventilation on the hot side to achieve good cooling (proper working fan and heatsink free of dust). Typically TEC modules can have a temperature delta (change) of around 36°F between the plates. TEC devices are often found in mini fridges and small dehumidifiers.

## Fuses

Some of the many fuse types:

- Fast blow fuses
- Slow Blow fuses (Can absorb short current spike).
- PTC fuse (Positive Temperature Coefficient), Polyfuse, Polyswitch (resettable fuse)
- NTC fuse (Negative Temperature Coefficient)
- Circuit Breaker
- Thermal fuse or Thermal cutoff (works on temperature instead of current).



- Induction
  - Low torque
  - Requires starting capacitor
  - May not run at an exact speed.
- Universal Motor
  - Has brushes on the armature
  - Higher torque

#### DC Motor type

- Permanent magnet DC
- Brushed DC
- Brushless DC (stepper motor, BLCD)
  - Requires motor controller

Servo motors are another type of motor. They can be AC or DC and are typically connected to a gearbox. They use a feedback mechanism to determine position. They are not used in continuous movement, but rotated until a specific angle is achieved.

### Remote Controls

Most remotes send signals via RF (radio Frequency) or IR (Infrared Light).

Digital cameras (cell phone cameras) are a great way to test most IR signals. Just point the remote to the camera and you should be able to see the light in the camera when you activate the remote. This works because digital cameras can see the infrared light spectrum, but displays it as visible light. You will not know if the signal being sent is correct, but you will be able to test if it is working. Some of the transistor testers will also read IR signals and even display the code being sent, if it is one of the known standard codes.

Testing an RF transmitter is a little harder unless you have special equipment like an SDR (Software Defined Radio). You can try tuning an AM radio to the bottom of the dial. Sometimes you can hear distortion when the remote is held close to the antenna.

### Resistors

A resistor is an electrical component that resists the flow of electricity. The amount that it resists is measured in ohms. A wire has resistance albeit very small and typically will measure zero ohms on a multimeter. Resistors can come in all shapes and sizes and can be combined with other components to perform interesting electrical functions that are well beyond what can be covered here.

### Capacitors

Without getting too technical, capacitors are electronic components that block DC voltage, but pass AC voltage. They also have the ability to store a DC charge and act kind of like a battery for a short period of time. For those of you that are Electronic Engineers, don't beat me up too bad on this simple explanation :-)

Many capacitors have a polarity ( plus and minus terminals) and it is important to install them correctly!

## How to spot a bad capacitor?

Electrolytic capacitors are a special type of capacitor (usually looks like a little can) that has two plates with a dielectric (insulator) between them. There is usually a type of liquid (oil) in them that can dry out or leak over time. When this happens, the capacitors will start to go bad. Many times (but not always) this can be detected by some residue around the base or top. The other symptom to let you know that the capacitor is bad is that it may bulge on the top. If you see this, replace the capacitor. One of the first things I do when looking at a bad circuit board is to check the electrolytic capacitors!

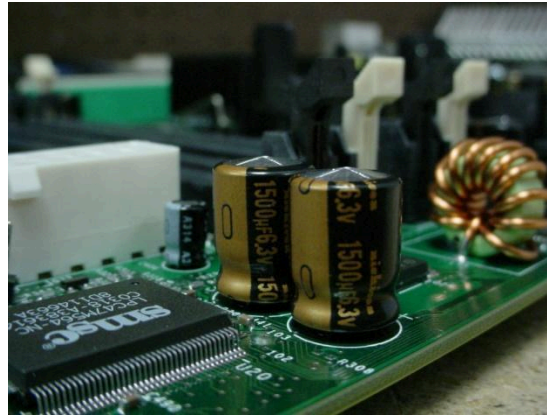


Figure 4: Capacitor with bulging top

Read on, if you want to know more technically!

For an AC signal, capacitors act like a short circuit (zero ohms) . In other words there is little or no resistance and it passes the AC signal. This is great for filtering noise on a DC power line. The problem is that if the capacitor starts to dry out, it no longer looks like a short (zero ohms) to an AC signal; instead it will act more like a resistor. This internal resistance creates heat and causes the capacitor to die. Part of the problem is that the capacitor might start having “resistance” that will cause the circuit to fail, but if you measure the capacitance, it will look to be OK.

Unfortunately you cannot measure the capacitor's "resistance" with an ohm meter. This is because an ohm meter uses DC voltage for the resistance measurement. There is a measurement device called ESR (Equivalent Series Resistance) meter. An ESR meter uses AC (typically 100khz) to measure the resistance of the capacitor. The cool thing is that many ESR meters only use a very small voltage (15mv) in the measurement. Because this voltage is so low, it will not activate other circuitry; therefore you do not even need to take the capacitors out of the circuit to measure them. You can just probe them in circuit (with power off and capacitor discharged).

<Add how to discharge a capacitor> Before working with electrolytic capacitors, it is important to safely discharge them. Although some people may discharge the capacitor by directly shorting the two terminals, this is not a recommended approach as this can create a large spark and the rapid discharge can stress the capacitor. The best way to discharge a capacitor is to apply a resistor (2k-2M ohms) across terminals for a few seconds. It is possible to build a discharge tool that will have an LED indicator light showing when the capacitor is safe to handle (See [Building Your Own Test Equipment](#))

## Diodes/SCR/Triac

Diodes (also called a rectifier) are semiconductor devices that act as a one way street. It will allow current to flow in one direction and block current flow in the other direction.

SCR (Silicon Controlled Rectifier) is a special form of a diode that has an extra pin (gate) that acts as a switch to turn the diode on and off.

Since Diodes and SCR only pass current in one direction, a Triac has two diodes that have a gate pin to turn it on and off. One of the diodes is reversed, so that it allows current to flow in either direction. This allows switching an AC voltage source.

## Transistors

Transistors are semiconductor devices that have the ability to work as an amplifier or an electronic switch. When a small signal is applied to the input, a larger signal can be seen at the output.

## General Repair Guidelines

In all of my years repairing electronics and appliances, I have found that most of the problems can be found using your basic senses (sight, smell, touch, listening).

- Smell if something has burned.
- Touch wires and connectors and see if anything feels loose (with power off!).
- Look for burned, discolored, broken or damaged parts. If there are any moving parts, look for any broken wires near them.
- Check if switches sound and feel correct when switched. If they feel spongy or do not click when moved, it may indicate a problem.

It is amazing how many problems can be found just by inspection. The things that usually go bad are things that move or get hot. These places should be the first place to look (power cords, switches, fuses, interlocks, power supplies, PCB connectors).

Here are the most common problems that I see:

- Power cords and power adapters are prone to failure. When they are unplugged by pulling on the wire, it will break the wires. Anything that can be plugged and unplugged is a point of wear or mishandling on both the cord and connector.
- Bad switches. Since switches move, they can break, or the contacts become burned.
- Broken wires, broken heating elements or bad circuit board pads. Anytime you see thick wires connecting to a circuit board, check where they connect to the board, the solder joint may have broken free.
- Bad interlocks and safety features. Many appliances have safety features like electrical fuses, thermal fuses, tilt switches, door switches that protect the appliance when something goes wrong. Many heaters have a tilt switch to turn off the unit if it falls over, food processors have a switch to prevent it from running without the bowl attached, and coffee makers have a thermal switch to shut down if the heating element gets too hot. Locating these may not always be easy but tracing the power wires can be a good start to locating them. These safety features often can be why the unit is not working.
- Corroded contacts. Battery terminals can be a real problem. I recently had an automatic soap dispenser that would not work. I found that one of the battery terminals had a blackish smudge on it. Once I cleaned it off, it worked great.

I would say that almost all of the items I have fixed recently have fallen into one of those 5 categories. The more you work on things, the more you will learn. My most valuable tools that I use for tracking down problems are a multimeter (measure continuity and voltage) and a power supply. Having a few "known to be good" power adapters is a great start. My cell phone camera is my best friend when it comes to repairs. Take lots of pictures before disassembly from multiple angles. It will help you get it back together!

## Disassembly

Often the most difficult part of the repair is the disassembly. At times it can be difficult to disassemble an appliance without damaging the case. Having the proper tools can go a long way to disassembling an appliance.

Tools:

- Flashlight
- Camera
- Screw organizer
- Spudgers
- Screwdrivers (many types)
- Long shafted Phillips #2 (for screws set in deep pockets)

What to look for:

- Some manufacturers have disassembly instructions in the manual. It never hurts to check. Google and YouTube can be your friend for disassembly.
- Not all screws should be removed! When looking at the back of an appliance, it is important to identify what screws should be removed. Some appliances will have exposed screws that are mounting an internal component and should not be removed as it may be very hard to put back together. If the back of the appliance has arrows pointing to specific screws, only remove those and do not remove screws without the arrow. Also there can be a mix of standard (such a Philips) and security screws on the same panel. Try only removing the standard screws first. Quite often the security screws are an indicator that they should not be removed.



Figure 5: Designating Screw to remove

- When removing screws always check the length of the screws being removed. Sometimes a specific screw is longer or shorter. Note which holes have these. Storing screws by sticking them in paper or cardboard is a great way to keep track of where they belong.

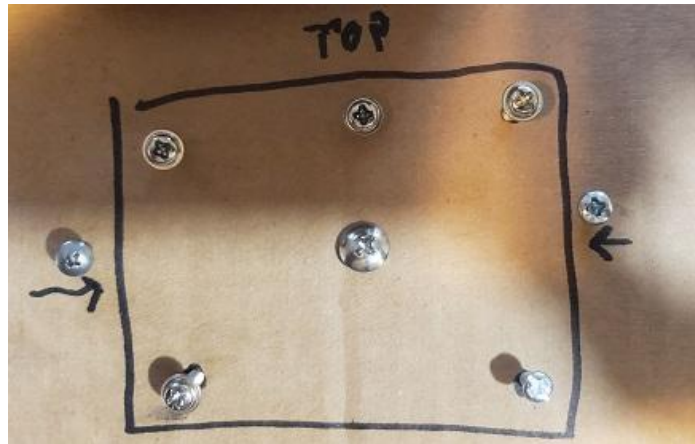


Figure 6: Screw Organizer




- Some manufacturers use specialty screw heads to minimize tampering. Using the wrong screwdriver can damage the screw head. Look carefully that the proper screw driver is being used.
- Look under labels and feet for hidden screws. By running your finger over a label, it may be possible to detect an indentation of a screw hole.
- Spudgers can really help separating cases of all sizes. Avoid using a screwdriver as a spudger as it will almost always leave marks in the case seam.
- Rule number one! Go slow and don't force anything to start with. Look to see if a corner or edge is not moving and look for more fasteners in that area. Sometimes it just requires a lot of force, but try the easy approach first.
- Take lots of pictures as you continue to disassemble. During the repair, it is easy to have wires break or become disconnected. If pictures were taken, it can help determine where broken wires came from or how cables should be routed during assembly.

## Cord Repair

An electrical cord or cable is a flexible insulated wire or group of wires that is used to transmit electrical power or signals. Physical damage can occur due to physical abuse, age or high temperatures to name just a few.

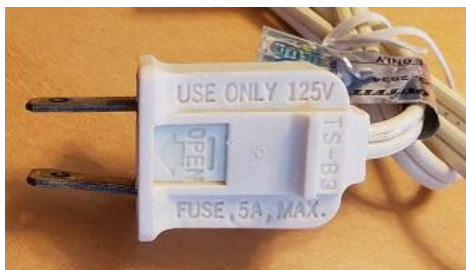
A common problem in power cords is to have a wire break or partially break inside the cord. This usually happens within a few inches of where the cord enters the device or plug. When this happens it can create an intermittent connection causing the wire or plug to heat up. Anytime a section of a power cord or plug feels hot, has exposed wires, or shows signs of heat or melting, unplug it immediately and replace the plug or whole cord.

Some pets like to chew on power cords, I way to help prevent this is to cover the wire with a "Split Wire Loom"

 A close-up photograph of a black power plug with a red arrow pointing to a severely charred and melted metal prong.	 A photograph of a copper wire with a red arrow pointing to a section where the insulation has been stripped away, exposing the metal.	 A photograph of a black, braided wire loom that has become frayed and split into individual strands.
Burned Power Plug	Exposed wire in Power Cord	Split Wire Loom

To replace a power plug, it is important to understand that the two wires are polarized. This means that they should not be reversed when rewiring the outlet. The [Lamps](#) section for information on correct wire connections.

Check the fuse! Some power cords have a fuse built into the plug. This is seen quite often on Christmas decorations as well as 12v car power adapters.



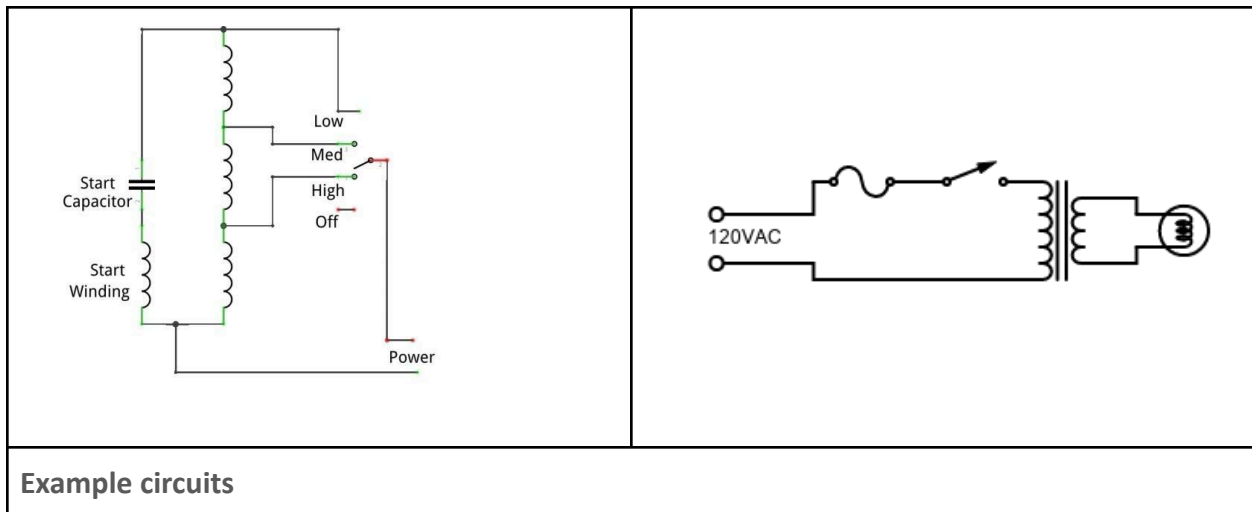
In some cases when replacing a cord or connector such as on a USB cable or power adapter, a molded strain relief will need to be replaced. Since these are molded onto the wire, they can not be reused. A strain relief can be recreated with moldable epoxy such as “Sugru Mouldable Glue” or “Loctite Kintsuglue”

### What can be tested at the power plug

Unfortunately everything using electricity is getting more complicated. Even a light bulb (LED), may have many electronic components inside it preventing you from doing quick continuity measurements.

Fortunately there are some appliances that can be tested rapidly, if you know how it is put together. Fans, lamps, blenders, heaters and toasters can be good candidates for this as long as they are not using circuit boards to control them.

A quick test is to measure the continuity between the terminals on the power plug (WITHOUT POWER). Turning on and off the power switch may tell you if the power cord, switch and motor is working. In many cases, a low resistance measurement will show that a circuit is being made to the bulb, heating element, motor or transformer. If no continuity is present, there could be a fault in the wiring, fuse, switch or open winding in a transformer or motor.



## Appliances

### Antique Radios

It is not recommended that anyone work on vintage electronics unless proper understanding and test equipment is available.

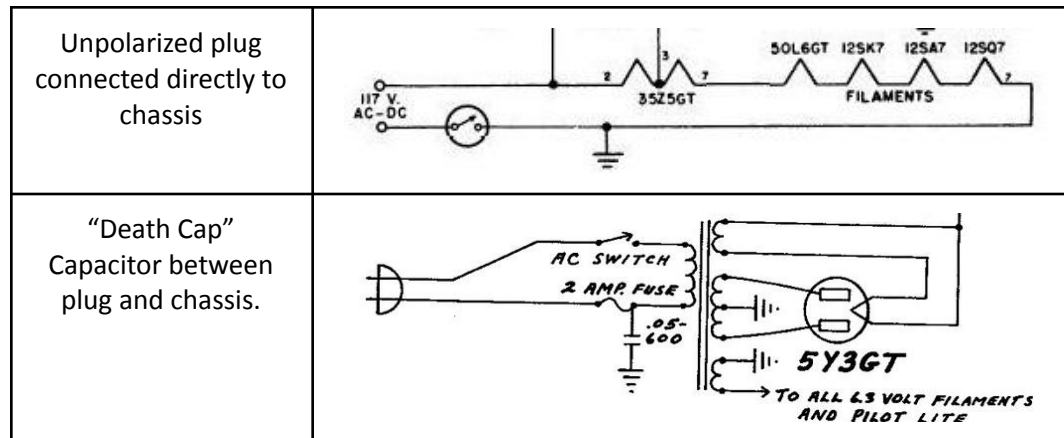
Danger! Tube radios can have very high voltages inside (>400 Volts)! Also, some radios can have a “hot chassis”, where the metal of the radio could cause a severe shock. Do not power an unknown radio without inline safety (Dim bulb tester, variac). Old tube radios, tv’s and amplifiers did not use polarized plug for power input and often tied one of the power lines to the chassis. Depending how the plug was inserted in the socket, there is a 50% chance the chassis could be tied to the hot power line.

- Older electrolytic, paper and wax capacitors dry up over time and go bad. Unfortunately this can result in the capacitor shorting internally, A common solution is to replace all Electrolytic, paper and wax capacitors. Bumble bee capacitors (dark cylinder with stripes) also have aging issues.



- Use a “Dim Bulb” tester and Variac to safely power up tube equipment for the first time. It is not uncommon for vintage equipment to have bad capacitors that short power to ground.
- A polarized line cord and fuse should be added for safety.
- Many old electronics switched (power switch) to the neutral line instead of the hot line. Rewiring to switch the hot line is a good idea.
- “Death Capacitor” - To reduce Radio Frequency Interference (RFI), manufacturers placed a capacitor between the one of the power terminals and chassis. Unfortunately if this capacitor goes bad and shorts, it could electrify the chassis. These capacitors should be replaced with a “Y2” type capacitor. This is a special type of capacity that will “open” not “short” if it fails.
- Old wiring can fray or crack over time. Some wiring can be treated with “Corona Dope” to protect the wiring.

- Discharge capacitors before working around them.
- Use an isolation transformer on vintage electronics when testing with any line powered test equipment. This is to isolate earth ground as some chassis (ground) may actually be hot.



## Clocks & Watches

Replacing watch batteries require the following steps:

- Identify type of back (snap on, screwed on or twist on).
- Removing the back.
- Remove and replace the battery.
- Check and replace the gasket if necessary.
- Replacing the back.

Tools required:

- Towel or soft surface to lay watch on.
- Small screwdriver to screw on back watches.
- Case knife or case pry tool for snap on back watches.
- Case opener wrench or ball (can use needle nose pliers, but not recommended).
- Tweezers.
- Back press for replacing hard to insert watch backs (optional).

When working on a watch, be careful not to scratch the front or back of the watch. Place the face on a towel or other soft surface. Removing the back on some watches can require a bit of force, be sure not to slip when using tools and scratch the watch.

For “Snap on” backs, it will not have any screws or notches visible, instead look for a slight indent or protrusion where the pry tool can be inserted. This can be very small and may require a magnifying glass to identify. Insert the pry tool and pry the top straight up. For “screw on” backs, locate the proper screwdriver tip for that screw and remove the screws. For “twist on” backs there will be small notches around the back. A case wrench can be used by placing the wrench in the notches and turning. a rubber ball can also be used if the back is not too tight. Place the ball on the back, press down firmly while twisting.

When removing the battery, be careful not to touch the red coil that may be inside the watch. This is very delicate and can easily break. The battery may be held with a small tab. This is usually spring loaded

and can be pushed slightly to release the battery. The tweezers can be helpful in removing and replacing the battery.

Once the battery is replaced and the watch is running, check the gasket on the back to back to make sure it is not damaged and reinstall the back. For “snap on” backs, there is usually an indentation on the back edge. This indentation should be aligned over the winding stem. Press the back back into place. Some backs may be very difficult to snap back into place. This is where a watch press can be used.

## Coffee Makers

Drip coffee makers such as Mr. Coffee do not actually have a water pump. The water goes from the tank down to a heating element (tube) . The element heats the water and the hot water rises up the drip tube to the coffee grounds. The hot water does not go back into the reservoir because there is a one-way valve on the supply side preventing the water to only go in one direction. This valve can be removed for cleaning or replacement by squeezing the tube to push the value out. Note the orientation and position in the tube for replacement as it should only be installed in one direction.



Keurig and Espresso machines are much more complex and may include pumps. In these coffee makers a pump moves the water from the tank through a heating element where the hot water is applied to the coffee pod. These units can contain multiple check valves to make sure the water never flows backwards. In the case of the Keurig, there is a check valve at the tank base as well as one in the head of the machine.

### Common Problems:

- If water is not moving up the drip tube (drip coffee) or waterline (Keurig/espresso machines), it could mean that the tubing or one-way valve is plugged or corroded.
- If a drip coffee maker is not getting hot, it could mean that one or more of the thermal fuses have blown. It is best to use non-insulated butt crimps to replace the thermal fuses.
- If a Nespresso machine is making a lot of noise or not pumping water, a common problem is that a bearing that spins the head could be bad. It is a relatively simple repair and there are good YouTube videos to guide the disassembly and replacement.
- Keurig machines have a couple failure points that prevent water from being pumped. There is a check valve at the water tank as one in the head of the unit. Also the port where water shoots into the pod can get clogged. IFIXIT has good instructions for troubleshooting specific Keurig models. Also the following site is very good: [Keurig Coffee Maker Troubleshooting - \(coffeevibe.org\)](http://coffeevibe.org)
- If the amount of water dispensed varies or short of what is expected, it is possible that the filter, tubing or water ports could be partially plugged. The amount of water dispensed is not measured, but is determined by the time the pump is on. If the water lines are restricted, less water will be dispensed.

- Check the filter and “check valve” in the water tank.
- Check the water lines for mineral scale buildup ( try running vinegar or descaling solution as directed by the manufacturer).
- Check the outlet port for obstructions (clean port with small wire or as directed by the manufacturer).

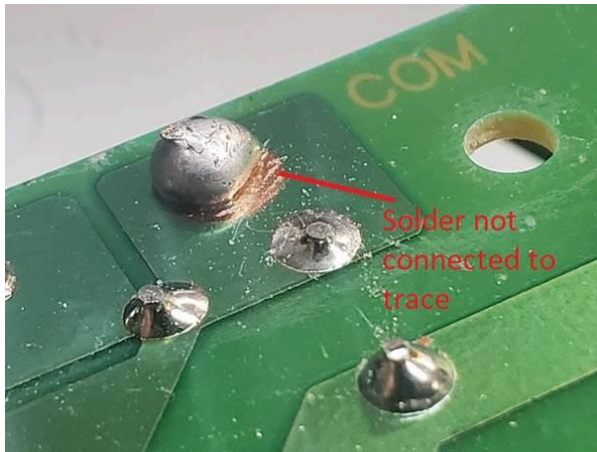
## Electronics

In depth electronic repair will be beyond most people without a lot of training and equipment. The good news is that a lot of problems can be identified through a quick visual inspection if you know what to look for. Do not assume that the device was manufactured correctly. It is not uncommon to see bad soldering from the manufacturing, wires that are pinched in the case, loose connectors. Having a digital microscope can aid in looking at and repairing PCB traces, but a cell phone camera with zoom can work also.

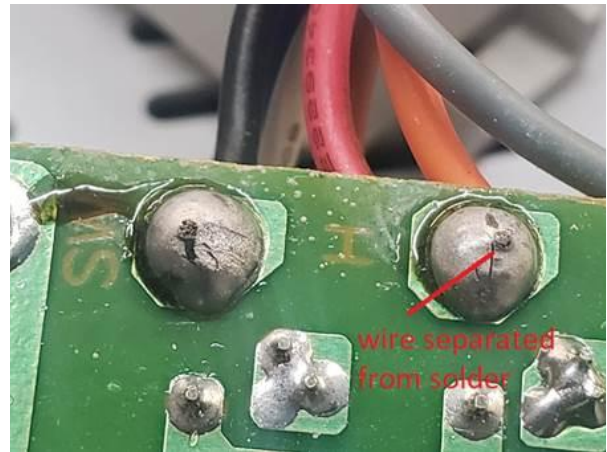
What to look for:

- Corroded battery connections or will not operate on battery. If the device has both batteries and a power jack, check the jack for proper operation. Some of the jacks have 3 pins and a switch built into them. When the jack is not used the device is powered by the battery. When a power plug is inserted, it breaks the connection from the battery.
- Broken wires or loose connections
- Broken traces or bad soldering on a printed circuit board.
- Burned components
- Bad switches.

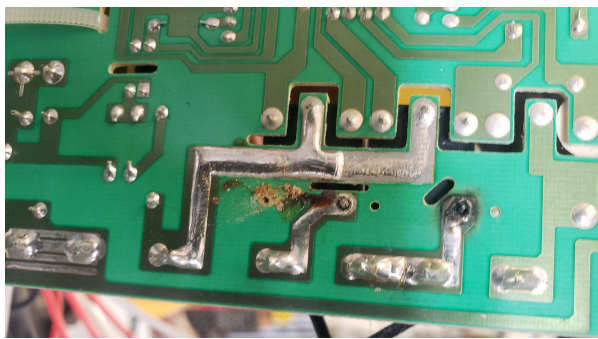
Visual Inspection of PCB:



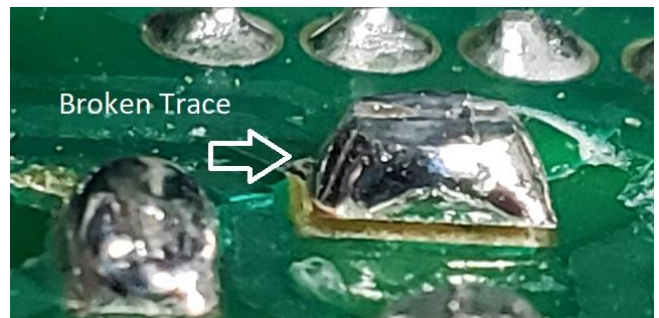
The large solder joint did not flow to the PCB. It is just sitting on top. The three smaller solder joints are good.



Dull gray or grainy joint could mean that it is a cold joint and not making a good connection. Inspect joints where large wires go into a PCB. Larger wires imply higher current and that can lead to failure.



Example of two burned contacts that needed to be resoldered. Always look around a PCB that has cutouts or traces that have been covered with solder. Both are indications of high current paths which can lead to failure.



Solder pad lifted from the PCB, breaking the trace.



Well There's your problem!



Cracked joint due to too little solder

## Fans

Fans come in many shapes and sizes. Some have multiple speeds or oscillate back and forth. In the simplest terms a fan consists of a power cord, a switch to turn it on or off and a motor to spin the blade. Fans also may have some hidden protection circuits. Quite often there is a thermal fuse that will shut the motor down if it overheats.

Most problems can be traced to either mechanical or electrical issues. For fans, the main mechanical issue that you may run into is seized motor bearings. This can happen especially if the motor overheats. It will cause the oil to turn sticky or hard. Often these can be identified by manually spinning the fan blades (while unplugged!). The fan should spin freely. If the fan blades do not spin freely, most motors can be disassembled with only 2 or 4 screws. If the motor is riveted together, there is not much you can do unless you find a replacement motor.

- Mark the orientation of the front and back plates to the core of the motor so that you can reassemble in the same locations.
- Remove the armature and clean the bearing surfaces with Isopropyl Alcohol (IPA). Scotch Brite pads work well also. It is also possible to chuck one end of the armature in a drill and clean the other end with a scotch Brite while it is spinning.
- Try to clean the bearing surfaces of the two end pieces with IPA.
- Use light machine oil on the two end bearings as well as a light coating on the armature bearing surfaces and reassemble. It should turn freely after reassembly.

Electrical issues are by far the most common:

Fans have a tendency to be moved around the house, repositioned and knocked over. Always check the cord as they have often been put under stress. The break in the cord may not be obvious as the wires may have separated inside the plug or insulation. If the fan is intermittent, this could be a great first place to look. Sometimes just jiggling the cord near the plug or at the base of the fan may show where the break is.

Multi speed fans typically use a special motor with multiple taps on the windings. There will be a common connection and some other colored wires that are used to select the appropriate speed. There may also be an additional wire that goes to a starting capacitor. If the fan does not have any special electronics, you can put the ohm meter between the two pins on the power plug. When you turn the switch between speeds, it should change the resistance. Here is an example of what you might see.

- Off – Infinite resistance
- Low – 150 ohms
- Med – 100 ohms
- High – 50 ohms

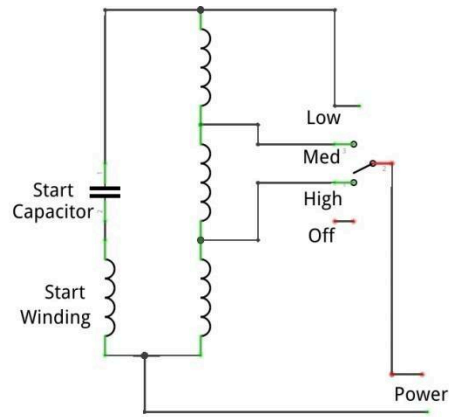


Figure 8: Motor Winding

If you do not see any resistance when the selector switch is on, this could be an indication that the wiring or switch is bad. It could also mean that the thermal fuse inside the motor windings is bad or that the winding itself is bad. Further inspection and resistance checking will need to be done to determine the problem.

If the resistances look good, it could mean the starting capacitor is bad. AC Induction motors (often used in fans) have an additional winding called a start winding that is connected to a capacitor. If this capacitor is not operational, it can cause the motor to not work.

An advanced repair (but very doable) is to replace the thermal fuse in the windings. It is usually in series with one of the wires in the motor.

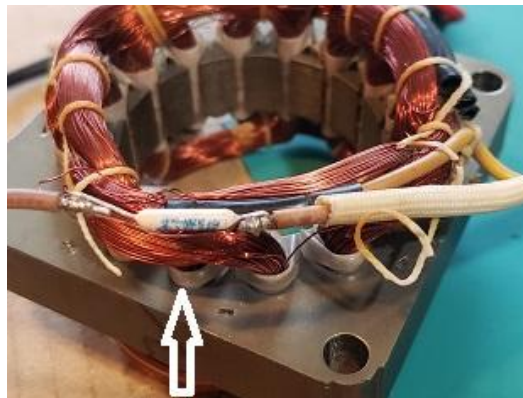


Figure 9: Motor winding with thermal fuse

- Note how free the motor spins before taking it apart. If it is stiff, this may be an indication why the thermal fuse blew. It can be a good idea to clean the armature shaft and re-oil the bearings while it is apart.
- When looking at the motor where all of the wires go into the windings, there will be string or zip ties holding the motor windings together.
- Look for the wire with the fuse. It will have some heat tubing over it and look a bit bulkier than the others.
- Be very careful with the small varnished wires from the windings as you do not want to break these.

- Take some pictures before cutting the ties so that you can route the wires back in the same place.
- Cut the tie holding these wires together and carefully inspect until you find the wire that has a small cylindrical component on it. This is a thermal fuse and is made to blow (open) when the temperature gets too hot. They will be labeled with a temperature like 115C.
- Check the resistance across the fuse, it will be zero ohms (short) if it is good, otherwise replace it. Solder in a new fuse, if the original one is bad.
- Carefully replace the wiring back together and zip tie it back into place.
- Reassemble.

## Food Processors/Blenders/Mixers

Many food preparation appliances have spinning blades, exposed heating elements or moving parts that could cause injury. Because of this manufacturers have installed interlocks to prevent the machine from operating unless it is operated in the exact manner specified. Unfortunately these interlocks (usually switches) can malfunction or wear. If any appliance is not operating, look for interlocks! There can be more than one. There could be a tilt switch in case it falls over, temperature cutoff if it gets too hot, position switch to make sure a bowl or lid is properly seated, or even a float switch for proper water level.

Common Problems:

- Bad power cord
- Interlock/protection device not working properly (very common in food processors).
- Bad power switch
- Blender blade stuck or hard to turn. There is a bearing surface in most blade assemblies and this bearing can get corroded causing the blender not to turn. Replace blade assembly.

Kitchenaid mixers:

< Add information here >

## Heaters

There are several types of heating elements that may be used in a portable electric heaters, including:

1. Infrared heating element: These elements use infrared radiation to heat objects and surfaces directly, rather than heating the air around them. Infrared heaters are generally more efficient and faster at heating up a room than other types of heaters.
2. Ceramic heating element: These elements are made of ceramics and typically have a high heating capacity and good heat transfer. They are often used in portable heaters because they are lightweight and durable.
3. Quartz heating element: These elements are made of quartz and use a tungsten filament to produce heat. They are typically more expensive than other types of heating elements, but they are also more efficient and have a longer lifespan.
4. Metal heating element: These elements are made of metal, such as steel or aluminum, and are heated by electricity or another heat source. They are often used in portable heaters because they are durable and inexpensive.
5. PTC heating element: PTC stands for "positive temperature coefficient," and these elements use electricity to generate heat. They are known for their high efficiency and safety, as they have a built-in temperature control that prevents overheating.

6. Oil heaters, also known as oil-filled radiators, are a type of portable heater that uses oil as a heat-transfer medium. They work by heating up a large volume of oil inside a sealed chamber, which then radiates heat into the surrounding air. Here are some additional things to know about oil heaters:

#### How they work:

Most portable heaters have a basic design, where power is applied to a heating element and a thermostat monitors the temperature. When the desired temperature is reached, power is disconnected from the heating element. Since the heating element can draw a lot of current, connecting and disconnecting power can cause arcing in the contacts. While basic heaters may be switching power to the heater directly from a thermostat, others may have more electronics that control the switching through relays or even solid state relays. Some have fans to help circulate the air.

#### Common problems:

1. Since most heaters draw a lot of current, it is not uncommon to find burned switches or wiring. Often the heater will have multiple heat settings (Low-Med-Hi). Some older units have a rotary switch to select these heat settings. Many just have "Push-In" wire connectors on the switch and they can make poor contact.
2. Any large wires going into a circuit board. The connection points are vulnerable to burning out or breaking.
3. Heaters will have multiple safety interlocks and fuses. Look for line fuses, tip-over interlock, thermal fuses, over temp sensors and timers. Some even have a switch on the bottom where if the unit is lifted up, will cause the unit to shut down. It is intended as a tip-over switch, but if it is not sitting on a firm surface, can act as though it is tipped over.
4. Heating elements can go bad. Check continuity.
5. Thermostats can go bad, but this is rare. Older thermostats used bi-metal strips that break contact as the temperature rises.
6. Check the cord and see if it is hot, especially around the plug and where it enters the heater. If it is hot, this may indicate a broken wire in the cord.
7. If the heater has a fan and the air flow is obstructed, it could cause the heater to overheat or turn off prematurely.

## Lamps

- Testing a lamp
  - Shock hazard eliminated/reduced by using contactless voltage tester
  - CHECK THE BULBS, number one cause of non-working lamps!
  - Before plugging into electricity, look for:
    - Use all your senses (sight, smell, feel)
    - Broken, loose or exposed wires
    - Damaged plug
    - Cracked or hard insulation
    - Signs of overheating
    - Broken or corroded socket or switch
  - If lamp parts are askew or loose
    - Align all parts (loosen base nut if necessary)
    - Make sure socket base is securely attached
    - Tighten nut at the base
  - If lamp is not working or intermittent
    - Check if bulb is bad
    - Wiggle cord (check for broken wire in cord)

- Is the cord hot near the plug?
  - Use contactless voltage tester on cord and socket.
  - Check switch
  - Use continuity tester between plug and socket
  - Is there power at the plug, switch and socket?
- Most common problems
  - Bad or incorrect bulb
  - Broken wire at plug
  - Faulty switch
  - Broken wire in cord
  - Bad socket or flattened center terminal
- Create or Rewire lamp (Hints and Tips)
  - Never repair a lamp when it is plugged in. ALWAYS DOUBLE CHECK
  - Always use polarized plugs when possible and connect properly
    - NEUTRAL: Wide plug prong -> ribbed wire -> Silver terminal (white wire)
    - HOT: Narrow plug prong -> smooth wire -> Brass terminal (Black wire)
    - GROUND: Round plug prong (Green wire)
    - Always switch the HOT wire
  - Use underwriters knot inside socket housing as a strain relief

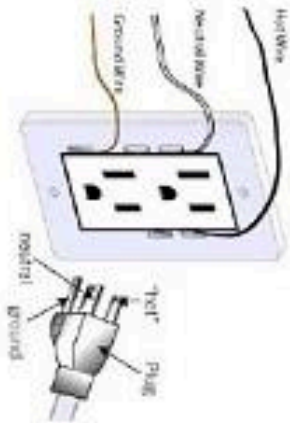


Figure 7: Underwriters Knot

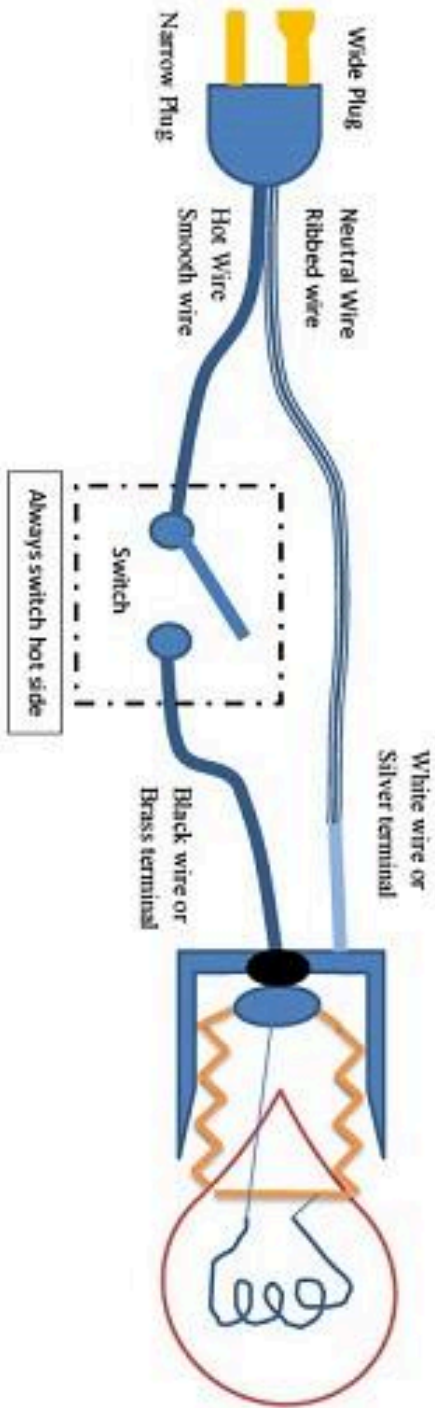
	<b>HOT</b>	<b>NEUTRAL</b>	<b>GROUND</b>
Wiring	Black	White	Green
Lamp cord	Smooth	Ridges	
Socket	Brass Terminal	Silver Terminal	Green screw
Plug	Narrow Prong	Wide Prong	Round

Table 1: Lamp Wiring Matrix

# Lamp Schematic



From: <http://gasworks.ca/suggestions-tips-56-reverse-polarity/>



Most modern appliances have a 3-prong or a polarized (2 prong) wall plug. It is important that these are wired correctly to prevent electrical shock.

A wall outlet has 3 terminals: Ground (Green, half circle), Neutral (White, wide prong) and Hot (Black, narrow prong).

The Hot wire should be the smooth wire on lamp cord and be switched in the appliance. It should connect to the brass colored terminals on a lamp socket or black wire in appliance (if color coded).

The Neutral wire should be the ribbed wire on lamp cord and connect to the silver terminals on a lamp socket or white wires in the appliance (if color coded).

If there is a separate ground wire, it will usually be Green and should connect to the chassis and/or to other Green or bare (no insulation) ground wires inside the appliance or lamp. The ground wire **SHOULD NEVER** be connected to the neutral wire inside the appliance.

## Refrigerators (Mini)

There are two main ways that mini fridges cool. One is the traditional compressor and the other is using a thermoelectric cooler (TEC).

TEC devices (see [Heating and Cooling Elements](#) ) for more details) are rated for a temperature difference between the two plates, so it is important to keep proper ventilation on

the hot side to achieve good cooling (proper working fan and heatsink free of dust). A common problem with TEC coolers is the power supplies going bad. Look for bulging capacitors.

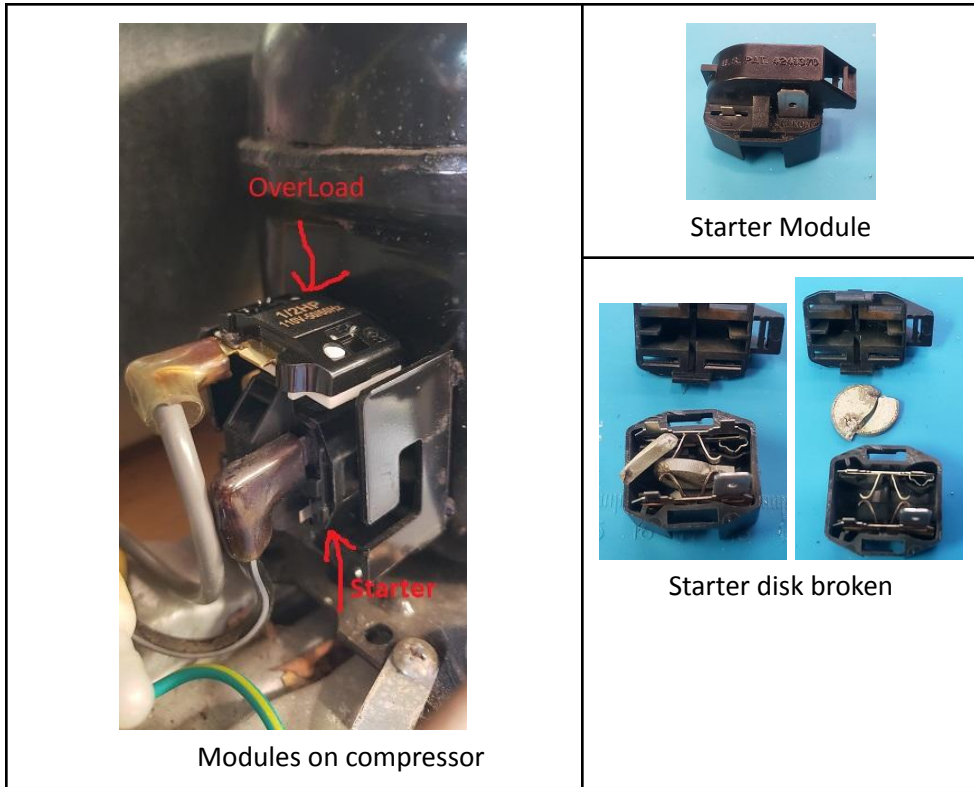
There are not a lot of serviceable parts in a compressor based mini-fridge. Basically there is the power cord, thermostat (inside the fridge), over temperature cutoff as well as a start winding relay that are mounted on the compressor. The compressor itself is a sealed unit that is not serviceable.

How it works: The big round black ball in the back of the refrigerator is the compressor. Inside that sealed ball is an electric motor, a pump, some oil and the refrigerant. When the compressor is turned on, the motor drives the pump and pushes the refrigerant through the lines to cool the refrigerator compartment.

Most common problems:

- If you detect oil inside the refrigerator or around the compressor, there is most likely a leak in the refrigeration lines and may not be repairable.
- Check the thermostat by turning it from min to max and listen if the compressor comes on. The thermostat can be tested when removed from the refrigerator by placing the probe in ice water and measuring continuity (resistance) while moving the dial back and forth. You should see the thermostat open (infinite resistance) and close (low resistance) as the dial is moved.
- On the compressor there is an over temperature cutoff as well as a start winding relay. These are both replaceable and are mounted where the wires go into the compressor. They should both measure low resistances when out of the circuit. If you shake the starter and it rattles, it needs replacement. (see pictures below).
- Check the resistance between each of the 3 terminals on the compressor (with relays disconnected). There should be resistance between each combination of the terminals and none of the terminals should have resistance to ground. If any of the terminals do not have resistance (open), it most likely means the motor winding is open and is not serviceable.
  - Lowest resistance between Run winding and Common (probably just a few ohms)
  - Medium resistance between Start winding and Common
  - Higher resistance between Start winding and Run winding (sum of run and start resistances)
  - Infinite resistance (open) between Ground and any compressor terminal
- After checking the start relay and over temp switches are functioning properly, if you hear the motor click, but do not hear the motor turning, it could be that the motor or pump is stuck or seized. There is a piece of test equipment called an "Annie" (Hermetic Analyzer) that some HVAC people may have to free the motor. It can be connected to the motor and then toggle between running the motor in forward then reverse (kind of like rocking a car that is stuck). Sometimes

this is enough to get the motor/pump unstuck and going again. Unless you have one of these available, it may not be serviceable.

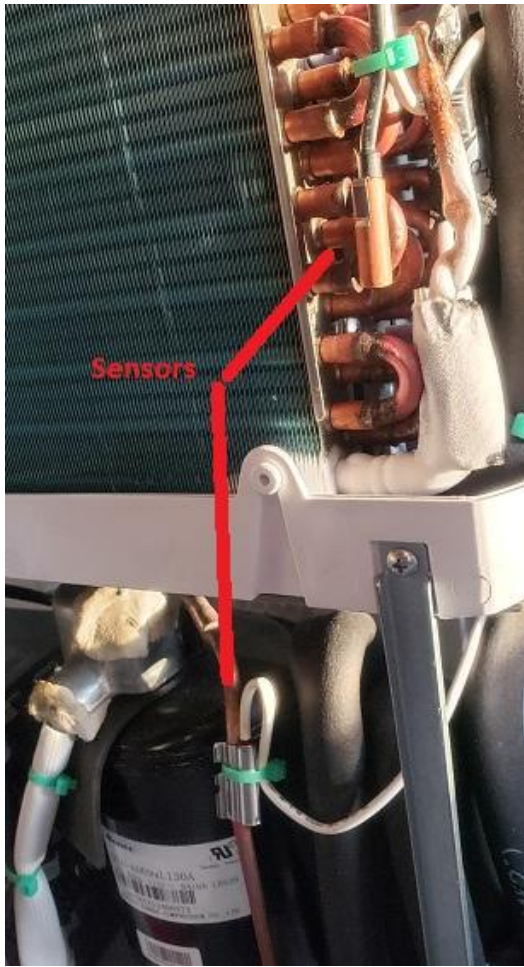


## Dehumidifiers

I have come across two types of dehumidifiers, TEC devices (see [Heating and Cooling Elements](#) ) and compressor types. Most often the problem with either type is the microswitch for the float or door is faulty preventing the dehumidifier from operating.

With any compressor based appliance, if you detect oil in the drain tube or coils, there is a good chance that the compressor is leaking oil due to a hole in the coils and it most likely not repairable.

I have run across a common problem with a Frigidare dehumidifier that is creating an “F0” error code. Unfortunately the manual is useless when it comes to this error code by telling you that you have bad power into the unit. More than likely you can just clean the sensors and it will start working. Carefully pull out the sensors described in the picture below and use a scotch brite or fine sandpaper to clean the sensors and the copper tube. Over time, the copper will create an oxide layer that prevents accurate monitoring. Using a small piece of sandpaper rolled up like a straw to clean the inside of the copper tubing for the upper sensor. Here is a great link to this dehumidifier repair: [Frigidaire Dehumidifier F0 Code: Causes & 10 Ways To Fix It \(funktionalhome.com\)](#)



## Sewing Machines

### SEWING MACHINE TROUBLESHOOTING

(or what to do BEFORE you take it in for repair)

#### Sewing machine motors and foot pedals

Vintage sewing machine motors are often AC universal motors. These motors have brushes that can wear down over time and the motor bushings can induce friction due to dried oil and dirt. Both the brushes and bushings can be inspected and the bushings oiled with a light machine oil. The speed is controlled by a foot pedal that is a simple variable resistor.

Newer sewing machines may have AC or DC motors and electronic controlled speed controllers ( [Dimmer Switches and Speed Controllers](#)).

#### Q&A

##### "My machine just stopped working"

Machines are designed to disengage the drive shaft when winding a bobbin. Some machines do this automatically when you engage the bobbin winder, others have a disc inside of the hand wheel that you

either turn or pop in or out to disengage the drive shaft. Double-check your bobbin winder or clutch disc to see if it is still in the bobbin-winding position.

### **"My tension is all messed up"**

- It is very important to make sure that your needle thread is fully seated between the tension discs. On many newer machines, the tension discs are hidden inside of the housing, making it difficult to know if the thread is seated properly. ALWAYS THREAD YOUR MACHINE WITH YOUR PRESSER FOOT RAISED. Raising the presser foot spreads the tension discs apart, which helps the thread to seat properly between the discs. Always think of "flossing your teeth" when running your thread through the tension assembly, to make sure the thread is properly seated.
- Your bobbin thread may not be going through the tension plate on the bobbin case. Double-check your manual or look for a video for your make and model on YouTube.

### **"It was working fine until I broke a needle"**

- Make sure you're pushing the needle all the way up in the shaft when tightening the needle clamp screw. A tiny shift in needle placement will prevent the stitch from forming.
- Needles have a front and a back. The machine will not stitch if the needle is in backwards. On the shank at the top of the needle, the flat side is the back (on domestic needles, not industrial). On some older machines, the needle goes in sideways. Double-check your manual or try to find a YouTube video for your specific model if you're not sure.
- Make sure you're using the correct needle type for your project. The wrong needle will cause skipped stitches. This is a helpful needle guide chart:  
<https://www.schmetzneedles.com/.../schmetz-needle-chart.pdf>

### **"My timing is off"**

- Oh, Dear Lord, everyone loves to tell me that their timing is off. Please, leave the diagnostic work to your mechanic. 60% of the time, it's a problem with the needle. Needles get worn out, causing skipped stitches. Change your needle, and see my needle trouble-shooting tips, above.
- Also, if your presser bar is not tight enough (for those of you with machines with an adjustable presser bar), or you're using a satin stitch presser foot instead of a standard one, your fabric may be flexing too much, which will cause skipped stitches. (A satin stitch foot looks similar to a standard foot, but has a raised area in the center on the underside.)

### **"There's something wrong in the bobbin area"**

- Make sure your bobbin is inserted correctly. (Again, check the manual, or look on YouTube for your model)
- Bobbins are not universal. There are over 12 different kinds of bobbin systems. Many look very similar, but using the wrong type for your machine will cause problems. Also, some of the cheaper bobbins are flawed. The outside of the bobbin must be completely smooth. If there are any burrs or ridges on the outside of the bobbin, the machine could malfunction. On plastic bobbins, you can use a nail file to smooth the edges of the bobbin. If you're not sure what kind of bobbin your machine uses, or where to get the correct bobbins, I love Sewing Parts Online. You can look up machine parts by your model #, and be assured that they are correct for your machine: <https://www.sewingpartsonline.com/>

### **"My thread keeps breaking"**

- Thread has a life span. If the thread is old, it may be "dead". If the thread breaks easily with a gentle tug, it's dead. All thread will break if you tug it hard enough, but if the thread is good, it should require a little force to snap it.
- If your machine has a sideways thread spool pin, double-check your thread as it comes off the spool. If it's a spool type with a notch in the end cap to hold the thread end (like Coats / Dual Duty brand), make sure that notch is to the right end of the spool when you put it on the machine. The thread can catch in the notch as it comes off the spool, and cause all kinds of problems.
- Also on machines with a sideways spool pin: Make sure your thread cap is larger than your plastic spool. The thread cap should be wide enough to draw the thread away from the outside of the spool edge. Most machines come with a large and small thread cap.

### **"The fabric isn't feeding through properly"**

- Many machines allow you to drop the feed dogs for free-hand sewing. You may have accidentally engaged in this feature. On older machines, it's done with a knob on the right of the machine bed. On newer machines, it's usually a little lever or switch near the bobbin housing, or on the back of the machine, close to the bobbin area.
- Does your machine have an adjustable pressure bar? Make sure your pressure is adjusted properly for your fabric thickness.
- If your needle plate is badly nicked by needle strikes, your fabric may be getting caught on it. You can try filing down any bad nicks (remove the needle plate first, so you don't get metal filings in your hook area), or buy a new needle plate from sewing.

### **"My thread keeps balling up under the fabric."**

- Did you remember to thread your machine with the presser foot up? If you do not have the presser foot up when you are threading the machine, the tension discs are engaged and you may not get the thread between them properly.
- Is there a buildup of lint under and around your feed dogs? If so this can interfere with the path of the thread.
- Are you sure your bobbin is threaded correctly? Each machine has a specific way to thread the bobbin into the bobbin case—double check that yours is threaded correctly for your machine.

## **Toasters**

A toaster typically does not vary the temperature (different from a toaster oven), but instead varies the time the toaster is on. When adjusting the setting to "Darker" allows the toaster to be on longer.

Most of the time toasters do not have a separate power switch. The mains supply usually has a leaf switch on both leads and is activated when the lever is pushed down. This initiates a timer of some type as well as energizing a solenoid to lock the lever in the down position. The heating elements are connected across the mains power. When the timer completes, it breaks the circuit to the solenoid, popping the toast up and turning off the elements.

The most common failures I have encountered are broken elements or mains leaf switches.

You should not solder a broken element. The heating element can easily achieve temperatures above the melting point of the solder.

Checking the resistance of the elements can be confusing based on the way they are wired. In general, the resistance should be under 100 ohms and as low as 8 ohms. It is usually necessary to look to see if the elements are wired in series or parallel. It is best to measure the resistance of each element by disconnecting one end if possible. For a two slice toaster, you have 4 sides, but the number of elements could vary. You could have the inside elements shared or separate. The left could be separate from the right or all shared. I have seen elements wired in many combinations.

Quite often if it only toasts on one side, it is a bad element.

Some toasters get their power for the electronics from the elements. They treat the element like a resistor divider to supply a lower voltage to the electronics. If the element breaks, it can prevent the electronics from working.

Toasters come with a couple timing mechanisms.

- Some have a simple mechanical timer.
- Some have a bi-metal contact that separates as it gets hot.
- Some have simple electronics R/C timers (Resistor/Capacitor).
- Some have complex sensors and electronics like a microcontroller.

Almost all toasters have a solenoid that will hold the lever down. When the timer completes, it releases the solenoid. That is why toasters will not stay down without power.

## Power tools

Most power tools (drills, sanders, saws) consist of a brushed or brushless motor that achieve high speeds and have strong torque. There is also a power switch and some form of a gearbox. Since many hand power tools allow the user to press a trigger to start the unit and that trigger needs to be ergonomically placed, there is quite often a mechanical linkage connecting the trigger to the actual switch.

Most common problems with power tools:

- Broken wire in cord.
- Stripped gear in gearbox or worn gear mounting hole.
- Bad switch or trigger mechanism. Worn or broken linkage from trigger to power switch.
- Frozen or sticky bearings on the motor shaft.
- Brush not touching motor armature. Brush worn down or stuck in brush housing.

Power tools can have a variable speed control. This is typically done with a very simple electronic circuit. The trigger moves a variable resistor that controls the SCR (See [Dimmer switches and Speed controllers](#)).

## Vacuums

Vacuums can contain 1 or more motors to create the suction as well as move brushes when applicable. It works by having a high speed fan blowing air out the exhaust port. This creates a low pressure on the intake side forming the vacuum. If there is anything restricting this airflow, the vacuum will lose suction.

Common problems:

- Cords and power switches are a common problem. If it is battery operated, check the connection to the battery as they can get hot and distort preventing good contact from being made.
- If a vacuum has reduced or no suction. Check for blocked air flow. There could be something jammed inside the hose or vacuum intake or exhaust. A common problem is a full bag or dirty filter. Vacuums can have more than one filter, look carefully if there are additional HEPA filters or filter discs or cartridges in the unit.
- If the vacuum cleaner smells or feels hot. It might mean that there is a restriction in the air flow. Vacuums require good airflow to keep it cool. Look for obstructions in the hoses, check all filters, and replace the bag. Some vacuums have a thermal cutoff. If it gets too hot, it will shut down until cooled.
- Check if the beater brushes are jammed. Anything from small objects to hair can get lodged or wound around moving parts, restricting free movement. Often these brushes are belt driven and the belt can slip or break.
- Hair is a real problem for vacuums. It will get tangled in the brushes, wheels or anything that moves or rotates. Over time the hair can bind the moving parts.

Roomba robot vacuums may first appear to be scary to work on, but Roomba designers have made them very serviceable even if you are not a robot engineer. Almost all of the modules in the 500-600 series can be quickly replaced by removal of just a few screws. There is even a diagnostics that can be run to identify issues:

Service manuals:

- [Microsoft Word - 20060901\\_Roomba Service Manual.doc \(hackaday.io\)](#)
- [Roomba 500 Series Service Manual | Manualzz](#)
- [Create 2 Open Interface Spec | iRobot Education](#) – Under the top cover of the 500-600 series robots, there is a port that can be connected to a computer. This document can help as well as many online tutorials for the truly adventurous.

## Building Your Own Test Equipment

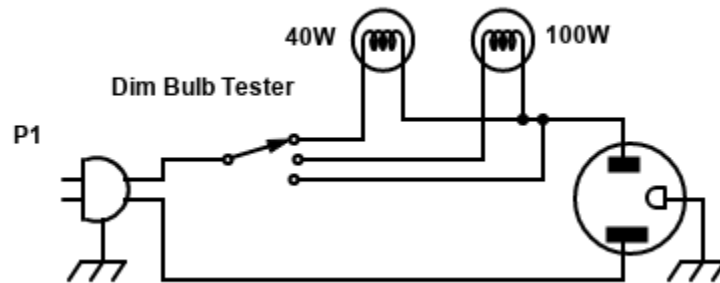
### Dim Bulb Tester

When working on vintage electronics (radios, amps) there is a real risk that the Device Under Test (DUT) could be shorted. Placing an incandescent light bulb in series with the DUT can prevent blowing fuses or letting the magic smoke out of the DUT. The series bulb acts as a current limiter. If the DUT is shorted the light bulb will take the full load and shine bright, but also limit the current passing through the radio. If the DUT is not shorted, the bulb will be dim as the load is shared between the bulb and the DUT. This can be as simple as one bulb or have multiple bulbs to incrementally test higher loads.

There are many ways to design and wire a dim bulb tester. The circuit diagram below is just one example. The advantage of having multiple bulbs is to be able to change the load. Lower watt bulbs will have higher resistance and limit the current through the DUT, but may not be able to power the DUT. It is best to pick a bulb wattage that is the same or slightly higher than the wattage of the DUT being tested. Often a switch is included to bypass the bulbs and allow full power to the radio.

As long as the bulb remains dim (not fully bright), the radio must be part of the load, therefore it should be OK to plug it in directly.

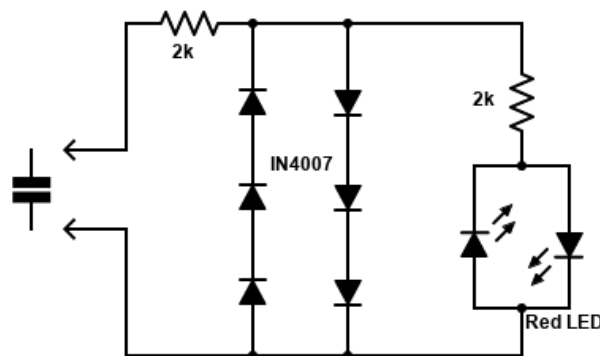
DUT	Suggested Bulb
AA5 Radio	25-40W
6 Tube with Transformer	40-75W
BW TV or large Amplifier	75W-150W



### Capacitor Discharge Tool

This is an easy to build tool that can help safely discharge capacitors without creating sparks. This tool will discharge the capacitor through the diodes and bleed resistor (2k-10k ohms). One of the LED's will light until the capacitor is discharged depending on polarity. The diodes and LED are duplicated so that the capacitor will discharge when the probes are connected in either direction. This circuit can be built with 6 diodes (groups of 3) and the resistors do not have to be exact.

The circuit works by connecting a bleed resistor (nearest the probe) across the capacitor. Each diode drops about 0.6 volts, so the voltage across the diodes will be around 2.4v. This voltage is enough to power the LED. The resistor in series with the LEDs is used to limit the current through the LEDs.



## Voltage/Current meter for wall adapters

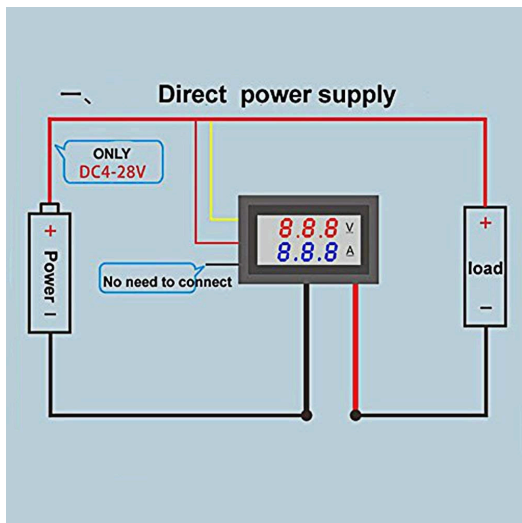
Since so many appliances now are powered with wall adapters and almost all of the wall adapters use the same connector, it is very useful to be able to measure/monitor the voltage and current from these devices. A very simple, yet valuable piece of test equipment for under \$20 that can measure the voltage and current without the need to cut any lines. It is like having two multimeters connected at the same time!

Parts: ( Not recommendations, but shown as examples)

- LED Digital Voltmeter Ammeter
  - <https://smile.amazon.com/Eiechip0-28-Digital-display-Volt-Meter/dp/B079L33VG2> -
  - <https://smile.amazon.com/DROK-Accuracy-0-33-00V-0-999-9mA-3-000A-Voltmeter/dp/B00IZTTAKO> - Optional: This one is more accurate, but costs a little bit more.
- 2.1x5.5mm pigtail
  - <https://smile.amazon.com/Pigtail-Connectors-Security-Lighting-Adapter/dp/B07PS8T2KM>
- Small container to mount your project (3D printed, plastic or even a small cardboard box)!

Wiring:

- Solder Black lead from male connector to thick Black wire of meter
- Solder Black lead from female connector to thick Red wire of meter
- Solder thin red and yellow wires from the meter and the two Red wires from both jacks together
- That is it!



Operation:

- Since the meter is being powered by the power adapter, it is important to stay within the specification of the meter. Most of these meters can support 28V, which is higher than most power adapters.
- Connect power adapter to female connector
- Connect male plug to appliance
- Monitor the voltage and current on the meter.