*** *
NOTES ON REPAIR OF AUDIO EQUIPMENT AND OTHER MISCELLANEOUS STUFF *
* * * **** Version 2.40 **** * *
 Samuel M. Goldwasser * * Corrections or suggestions to: sam@stdavids.picker.com * *

**************** INTRODUCTION ****************

Why is all that junk in your attic?: ----------------------------------

If you have ever tried to get a piece of consumer electronic equipment repaired, you understand why so much dead stuff is likely to be gathering dust in your attic or basement closet or junk box. It does not pay! This may be partially by design. However, to be fair, it may take just as much time to diagnose and repair a problem with a $20 Walkman as a $300 VCR and time is money for a repair shop. It is often not even economical to repair the more expensive equipment let alone a $40 answering machine. The cost of the estimate alone would probably buy at least one new unit and possibly many more.

However, if you can do the repair yourself, the equation changes dramatically as your parts costs will be 1/2 to 1/4 of what a professional will charge and of course your time is free. The educational aspects may also be appealing. You will learn a lot in the process. Many problems can be solved quickly and inexpensively. Fixing an old boombox to take take to the beach may just make sense after all.

This document provides maintenance and repair information for a variety of consumer electronic devices not covered by other chapters in the "Notes on Repair of" series. Suggestions for additions (and, of course, correction) are always welcome.

You will be able to diagnose problems and in most cases, correct them as well. As most difficulties encountered with this type of equipment are mechanical, there is significant emphasis on dirt, lubrication, deteriorated rubber parts, broken doohickies, and so forth. With minor exceptions, specific manufacturers and models will not be covered as there are so many variations that such a treatment would require a huge and very detailed text. Rather, the most common problems will be addressed and enough basic principles of operation will be provided to enable you to narrow the problem down and likely determine a course of action for repair - or decide that replacement is indeed the better option. However, in many cases, you will be able to do what is required to repair a piece of equipment for a fraction of what would be charged by a repair center. Perhaps, you will even be able to revive something that would otherwise have gone into the dumpster - or remained in that closet until you moved out of your house (or longer)!

Should you still not be able to find a solution, you will have learned a great deal and be able to ask appropriate questions and supply relevant information if you decide to post to sci.electronics.repair. It will also be easier to do further research using a repair book or guide. In any case, you will have the satisfaction of knowing you did as much as you could before finally giving up or (if it is worthwhile cost-wise) taking it in for professional repair. With your new-found knowledge, you will have the upper hand and will not easily be snowed by a dishonest or incompetent technician.

If you are just getting started, you should refer to "Repair Briefs, an Introduction" for additional troubleshooting tips, recommended test equipment, suggested parts inventory, and other general information.

Information on consumer electronics technology: --

Your local public library (621.384 if your library is numbered that way) or technical bookstore represents a valuable resource for books on both the technology and repair of a large variety of consumer electronics devices.

For an on line introduction to a variety of equipment, point your web browser to the Magnavox reference page at the following URL:

http://www.magnavox.com/electreference/electreference.html

There you will find links to a number of articles on the basic principles of operation of CD players, laserdisc and optical drives, TVs, VCRs, camcorders, loudspeakers, satellite receivers, and other consumer A/V equipment.

************** MAINTENANCE AND TROUBLESHOOTING GUIDE **************

SAFETY: ------

The only danger to you in most of these devices is the AC line connection (if any) and getting sucked into any mechanical people traps. Before you plug in the unit with any covers removed, make note and cover up any exposed AC line connections. The rest of the circuitry is low voltage and while you can destroy your equipment by your actions, you should be fairly safe. Exceptions to this are noted where appropriate.

However, you never can tell where an exciting troubleshooting expedition will lead. The following Safety Guidelines are included for your survival when working on line connected or high voltage equipment (and your reading enjoyment).

Safety guidelines: -----------------

These guidelines are to protect you from potentially deadly electrical shock hazards as well as the equipment from accidental damage.

Note that the danger to you is not only in your body providing a conducting path, particularly through your heart. Any involuntary muscle contractions caused by a shock, while perhaps harmless in themselves, may cause collateral damage - there are many sharp edges inside this type of equipment as well as other electrically live parts you may contact accidentally.

The purpose of this set of guidelines is not to frighten you but rather to make you aware of the appropriate precautions. Repair of TVs, monitors, microwave ovens, and other consumer and industrial equipment can be both rewarding and economical. Just be sure that it is also safe!

* Don't work alone - in the event of an emergency another person's presence may be essential.

* Always keep one hand in your pocket when anywhere around a powered line-connected or high voltage system.

* Wear rubber bottom shoes or sneakers.

* Wear eye protection - large plastic lensed eyeglasses or safety goggles.

* Don't wear any jewelry or other articles that could accidentally contact circuitry and conduct current, or get caught in moving parts.

* Set up your work area away from possible grounds that you may accidentally contact.

* Know your equipment: TVs and monitors may use parts of the metal chassis as ground return yet the chassis may be electrically live with respect to the earth ground of the AC line. Microwave ovens use the chassis as ground return for the high voltage. In addition, do not assume that the chassis is a suitable ground for your test equipment!

* If circuit boards need to be removed from their mountings, put insulating material between the boards and anything they may short to. Hold them in place with string or electrical tape. Prop them up with insulation sticks - plastic or wood.

* If you need to probe, solder, or otherwise touch circuits with power off, discharge (across) large power supply filter capacitors with a 2 W or greater resistor of 100-500 ohms/V approximate value (e.g., for a 200 V capacitor, use a 20K-100K ohm resistor). Monitor while discharging and/or verify that there is no residual charge with a suitable voltmeter.

* For TVs and monitors in particular, there is the additional danger of CRT implosion - take care not to bang the CRT envelope with your tools. An implosion will scatter shards of glass at high velocity in every direction. There is several tons of force attempting to crush the typical CRT. Always wear eye protection.

* Connect/disconnect any test leads with the equipment unpowered and unplugged. Use clip leads or solder temporary wires to reach cramped locations or difficult to access locations.

* If you must probe live, put electrical tape over all but the last 1/16" of the test probes to avoid the possibility of an accidental short which could cause damage to various components. Clip the reference end of the meter or scope to the appropriate ground return so that you need to only probe with one hand.

* Perform as many tests as possible with power off and the equipment unplugged. For example, the semiconductors in the power supply section of a TV or monitor can be tested for short circuits with an ohmmeter.

* Use an isolation transformer if there is any chance of contacting line connected circuits. A Variac(tm) is not an isolation transformer! The use of GFCI (Ground Fault Circuit Interrupter) protected outlet is a good idea but will not protect you from shock from many points in a line connected TV or monitor, or the high voltage side of a microwave oven, for example. A circuit breaker is too slow and insensitive to provide any protection for you or in many cases, your equipment. The GFCI may protect your scope probe from smoking if you accidentally connect its ground to a live chassis.

* Don't attempt repair work when you are tired. Not only will you be more careless, but your primary diagnostic tool - deductive reasoning - will not be operating at full capacity.

* Finally, never assume anything without checking it out for yourself! Don't take shortcuts!

Troubleshooting tips: --------------------

Many problems have simple solutions. Don't immediately assume that your problem is some combination of esoteric complex convoluted failures. For a tape deck, it may just be a bad belt or a bad tape. Try to remember that the problems with the most catastrophic impact on operation (a dead AC adapter) have the simplest solutions (repair the wires broken due to flexing in the power cable).

If you get stuck, sleep on it. Sometimes, just letting the problem bounce around in your head will lead to a different more successful approach or solution. Don't work when you are really tired - it is both dangerous and mostly non-productive (or possibly destructive).

Whenever working on precision equipment, make copious notes and diagrams. You will be eternally grateful when the time comes to reassemble the unit. Most connectors are keyed against incorrect insertion or interchange of cables, but not always. Apparently identical screws may be of differing lengths or have slightly different thread types. Little parts may fit in more than one place or orientation. Etc. Etc.

Pill bottles, film canisters, and plastic ice cube trays come in handy for sorting and storing screws and other small parts after disassembly.

Select a work area which is well lighted and where dropped parts can be located - not on a deep pile shag rug. Something like a large plastic tray with a slight lip may come in handy as it prevents small parts from rolling off of the work table. The best location will also be relatively dust free and allow you to suspend your troubleshooting to eat or sleep or think without having to pile everything into a cardboard box for storage.

Another consideration is ESD - Electro-Static Discharge. The electronic components in a some devices like cassette decks, Walkmen, and portable phones, are vulnerable to ESD. There is no need to go overboard but taking reasonable precautions like not wearing clothing made of wool that tends to generate static. When working on larger devices like cassette decks, get into the habit of touching a ground like the metal chassis before touching any circuit components.

A basic set of precision hand tools will be all you need to disassemble and perform adjustments on most consumer electronics equipment. These do not need to be really expensive but poor quality tools are worse than useless and can cause damage. Needed tools include a selection of Philips and straight blade screwdrivers, needlenose pliers, wire cutters, tweezers, and dental picks. A jeweler's screwdriver set is a must particularly if you are working on compact equipment. For adjustments, a miniature (1/16" blade) screwdriver with a non-metallic tip is desirable both to prevent the presence of metal from altering the electrical properties of the circuit and to minimize the possibility of shorting something from accidental contact with the circuitry.

A low power fine tip soldering iron and fine rosin core solder (never never use acid core solder or the stuff for sweating copper pipes on electronic equipment) will be needed if you should need to disconnect any soldered wires (on purpose or by accident) or replace soldered components.

For thermal or warmup problems, a can of 'cold spray' or 'circuit chiller' (they are the same) and a heat gun or blow dryer come in handy to identify components whose characteristics may be drifting with temperature. Using the extension tube of the spray can or making a cardboard nozzle for the heat gun can provide very precise control of which components you are affecting.

For info on useful chemicals, adhesives, and lubricants, see "Repair Briefs, an Introduction" as well as other documents available at this site.

Test equipment: --------------

Don't start with the electronic test equipment, start with some analytical thinking. Many problems associated with consumer electronic equipment do not require a schematic (though one may be useful). The majority of problems with consumer electronics equipment are mechanical and can be dealt with using nothing more than a good set of precision hand tools; some alcohol, degreaser, contact cleaner, light oil and grease; and your powers of observation (and a little experience). Your built in senses and that stuff between your ears represents the most important test equipment you have.

A DMM or VOM is necessary for checking of power supply voltages and testing of sensors, LEDs, switches, and other small components. This does not need to be expensive but since you will be depending on its readings, reliability is important. Even a relatively inexpensive DMM from Radio Shack will be fine for most repair work. You will wonder how you ever lived without one! Cost: $25-50.

Unless you get deep into electronic repair, a high bandwidth oscilloscope is not required. However, a relatively inexpensive 5 or 10 MHz dual trace scope is very handy and you will find all kinds of uses for it. Such a scope should cost less than $150 on the used market.

There are several specific pieces of test equipment that you may already own which are required depending on the devices being fixed.

Audio equipment:

* Stereo tuner or other audio signal source. An audio signal generator is nice but not really essential.

* An audio amp connected to a loudspeaker. The input should be selectable between line level and mic level and be brought out through a shielded cable to a test probe and ground clip. This is useful for tracing an audio circuit to determine where a signal is getting lost. Inexpensive signal tracers are also available but this option is likely free.

* Prerecorded and garbage cassettes or tapes for testing of component and walkman tape transports.

Video games, cable boxes, and other video sources:

* A TV (preferably color) with RF (antenna) inputs connected to a VCR with a working tuner and RF modulator or a TV with both RF and A/V (RCA jacks) inputs.

* A known good game cartridge to confirm that the problem is in the game console.

Telephone equipment:

* A working tone dialing phone. If I had a choice, it would be a good old reliable ATT Touch Tone desk phone.

* A dual connector phone jack. Two independent phone lines are desirable for answering machine or modem testing.

* A PC or laptop with a fax-modem (for modem and fax machine testing).

* A low voltage DC power supply or wall wart to perform certain tests without a telephone connection or phone line simulator.

Getting inside consumer electronic equipment: --

Yes, you will void the warranty, but you knew this already.

Note: the sections on loudspeakers, cameras, and watches have additional 'getting inside' info.

Manufacturers seem to take great pride in being very mysterious as to how to open their equipment. Not always, but this is too common to just be a coincidence.

A variety of techniques are used to secure the covers on consumer electronic equipment:

1. Screws. Yes, many still use this somewhat antiquated technique. Sometimes, there are even embossed arrows on the case indicating which screws need to be removed to get at the guts. In addition to obvious screw holes, there may be some that are only accessible when a battery or cassette compartment is opened or a trim panel is popped off.

These will often be of the Philips variety. (Strictly speaking, many of these are not actual Philips head screws but a slight variation. Nonetheless, a Philips screwdriver of suitable size will work on them.) A precision jeweler's screwdriver set including miniature Philips head drivers is a must for repair of miniature portable devices.

Sometimes, you will find Torx or a variety of security type fasteners. Suitable driver bits are available. Sometimes, you can improvise using regular tools. In the case of security Torx, the center post can usually be broken off with a pair of needlenose pliers allowing a normal Torx driver to be used. In a pinch, a suitable size hex wrench can substitute for a Torx driver. Places like MCM Electronics carry a variety of security bits.

2. Hidden screws. These will require prying up a plug or peeling off a decorative decal. It will be obvious that you were tinkering - it is virtually impossible to put a decal back in an undetectable way. Sometimes the rubber feet can be pryed out revealing screw holes. For a stick-on label, rubbing your finger over it may permit you to locate a hidden screw hole. Just puncture the label to access the screw as this may be less messy then attempting to peel it off.

3. Snaps. Look around the seam between the two halves. You may (if you are lucky) see points at which gently (or forcibly) pressing with a screwdriver will unlock the covers. Sometimes, just going around the seam with a butter knife will pop the cover at one location which will then reveal the locations of the other snaps.

4. Glue. Or more likely, the plastic is fused together. This is particularly common with AC adapters (wall warts). In this case, I usually carefully go around the seam with a hacksaw blade taking extreme care not to go through and damage internal components. Reassemble with plastic electrical tape.

5. It isn't designed for repair. Don't laugh. I feel we will see more and more of this in our disposable society. Some devices are totally potted in Epoxy and are throwaways. With others, the only way to open them non-destructively is from the inside.

Don't force anything unless you are sure there is no alternative - most of the time, once you determine the method of fastening, covers will come apart easily. If they get hung up, there may be an undetected screw or snap still in place.

The most annoying (to be polite) situation is when after removing the 18 screws holding the case together (losing 3 of them entirely and mangling the heads on 2 others), removing three subassemblies, and two other circuit boards, you find that the adjustment you wanted was accessible through a hole in the case just by partially peeling back a rubber hand grip!

When reassembling the equipment make sure to route cables and other wiring such that they will not get pinched or snagged and possibly broken or have their insulation nicked or pierced and that they will not get caught in moving parts. Replace any cable ties that were cut or removed during disassembly and add additional ones of your own if needed. Some electrical tape may sometimes come in handy to provide insulation insurance as well.

Getting built up dust and dirt out of a equipment: ---

This should be the first step in any inspection and cleaning procedure.

Do not be tempted to use compressed air!

I would quicker use a soft brush to carefully dust off the circuit boards and power supply. Work in such a way that the resulting dust does not fall on the mechanical parts.

For intricate mechanisms, using compressed air could dislodge dirt and dust which may then settle on lubricated parts contaminating them. High pressure air could move oil or grease from where it is to where it should not be. If you are talking about a shop air line, the pressure may be much much too high and there may be contaminants as well.

A Q-tip (cotton swab) moistened with politically correct alcohol can be used to remove dust and dirt from various surfaces of the deck (in addition to the normal proper cleaning procedures for the guides, rollers, heads, wheels, belts, etc.)

What to do if a tiny tiny part falls inside: --

We have all done this: a tiny washer or spring pops off and disappears from sight inside the guts of the unit. Don't panic. First - unplug it if AC powered. Remove the battery pack if possible from a portable device.

Try to locate the part with a bright light without moving anything. You may have gotten lucky (yeh, right). Next, over an area where a dropped part will be visible (not a shag carpet!), try any reasonable means to shake it loose - upside down, a little gently tapping and shaking, etc. A hard surface is better in some ways as you might hear the part drop. On the other hand it may bounce into the great beyond.

If this does not work, you have two options:

1. Assume that the part has landed in a place that will not cause future problems. There could be electrical problems if it is metallic and shorts out some circuitry or there could be mechanical problems if it jams some part of the mechanism. There is an excellent chance that the part will never cause any harm. What chance? I don't know, maybe 99%. It is not worth taking the unit to pieces to locate the part. You are more likely to damage something else in the process. Obtain a replacement and get on with your life. The exception is, of course, if you now begin experiencing problems you **know** were not there before.

2. Take the unit to pieces in an attempt to locate the part. For all you know, it may be clear across the room and you will never find it inside. If all the gymnastics have not knocked it loose, then it may be really wedged somewhere and will stay there - forever. If the unit behaves normally, then in all likelihood it will continue to do so.

To prevent this sort of thing from happening in the future you will no doubt be much more careful. Sure you will! Keeping one finger on a little part like an E-clip as it is removed will tend to prevent uncontrolled ejection as well.

*********** AUDIO CASSETTE AND OPEN REEL TAPE TRANSPORTS ***********

Parts of an audio tape transport: --------------------------------

The following description applies to most cassette and open reel tape transports including those used in portable and microcassette recorders, Walkmen, and telephone answering machines.

Looking at the top of the deck such that the tape heads are at the bottom:

* Supply reel table - left hand side platform on which the supply tape reel sits. Edge which contacts idler tire (if used) should be cleaned.

* Takeup reel table - right hand side platform on which the takeup tape reel sits. Edge which contacts idler tire (if used) should be cleaned.

* Idler - assembly which swings between supply and takeup reels and transfers power to the appropriate reel to wind the tape up during play and record and often to drive FF and REW. In some designs, this uses gears or some other type of mechanism. In very expensive decks, individual motors are used for each reel and there is no intermediate drive.

* Idler tire - the black rubber ring on the outside of one part of the idler which actually contacts the reel edges. This is not as common in audio tape decks as VCRs. If one is used, it should be cleaned and inspected for deterioration, dirt, and wear.

* Capstan - right side after tape exits from area of record/playback/erase heads. The capstan is a shaft (about 1/16" diameter in cassette decks, recorders, and Walkmen, 3/16" or larger diameter in open reel machines) which during play and record modes precisely controls tape movement when the pinch roller is pressed against it. For autoreverse transports, there will be two capstans - one on each side of the head assembly so that the tape is always pulled across the heads as this is most precise. (In a VCR, there is only one capstan and it is also used for reverse play or search modes.) Clean to assure proper tape movement during play and record modes.

* Pinch Roller - black rubber roller which spins freely and is pressed against the capstan during play, record, and search modes. For autoreverse decks, there will be two pinch rollers, one for each capstan. A hard, shiny, cracked, or dried out pinch roller can lead to tape edge munching and erratic or wavering sound. Clean thoroughly (until no more black stuff comes off). Inspect for cracked or deteriorated rubber.

* Tape heads. Most low to mid priced tape decks have two - an erase head and a combined record/playback head. High-end decks will have separate record and playback heads supporting sound-on-sound mixing to the same track and allowing recording quality to be monitored off of the tape. These may be physically independent assemblies or combined into a single unit. Autoreverse decks often have a head assembly that rotates 180 degrees depending on tape direction. This is less expensive than having two erase heads and two record/playback heads or a single record/playback head that shifted position to align with the appropriate tracks and electronic switching of the record and playback signals.

Play-only transports such as found in car cassette decks and Walkmen do not need an erase head. Autoreverse play-only decks often do just shift the position of the playback head a fraction of a mm depending on playback direction to line up with the tracks and interchanges the connections for L and R channels.

Clean the polished surfaces thoroughly (DO NOT use anything abrasive!).

* Various other guide posts - vertical stationary metal posts which tape contacts. Should be cleaned but rarely need adjustment.

* Belts - various size black rubber bands - a typical transport will have between 0 and 4 belts, usually below decks. These will require replacement after a few years. Clean and inspect.

General guide to tape deck cleaning and rubber parts replacement:

The following procedures apply to boom boxes, cassette decks, microcassette and other portable tape recorders, open reel tape decks, and telephone answering machines. While the tape transports used in these devices are less complex than those used in VCRs and other helical scan recording equipment, some routine maintenance can go a long way towards preventing future problems. All the guideposts, wheels, and rubber parts should be inspected and cleaned periodically - how often depends on usage. Of course, no one really does this unless something goes wrong.

Qtips and alcohol (91% medicinal is ok, pure isopropyl is better. Avoid rubbing alcohol especially if it contains any additives) can be used everywhere EXCEPT on the rotating heads of VCRs and camcorders (and other helical scan devices like 8mm and 4mm (DAT) storage drives) - see the "Notes on VCR Failure Diagnosis and Repair" for detailed procedures on cleaning of video heads - you can destroy the most expensive part of your VCR by improper cleaning techniques. Dry quickly to avoid leaving residue behind. Sometimes good old fashioned water (just a damp cloth) will work better on sugar based gunk and other kids' grime.

Cleaning may get your machine going well enough to get by until any replacement rubber parts arrive.

Things to clean:

(Some of these components may not be present in your particular equipment).

1. Capstan and pinch roller. These collect a lot of crud mostly oxide which flakes off of (old) tapes. Use as many Q-tips (wet but not dripping with alcohol) as necessary to remove all foreign matter from the capstan (the shiny shaft that pulls the tape through the unit for play and record). Just don't get impatient and use something sharp - the crud will come off with the Qtips and maybe some help from a fingernail. On autoreverse decks, there will usually be two capstans and pinch rollers.

Clean the pinch roller (presses against the capstan in play and record) until no more black stuff comes off. Use as many Qtips as necessary.

If the pinch roller is still hard and/or shiny or has a cracked surface, it will probably need replacement. Many are available from the sources listed in the section: "Recommended parts suppliers".

2. Various guideposts that the tape contacts. Clean like the capstan.

3. Idler tire (idler swings between reels and transfers motor power to reels - clean until no more black stuff comes off. A dirty or worn idler tire may prevent the takeup reel from turning resulting in spilled tape.

Also, the idler assembly includes a slip clutch. If this weakens, the idler may not have enough force to press on the reel table edges.

4. Reel table edges - surface on the reel tables where the idler contacts.

5. Audio head(s) and erase head. Q-tips and alcohol are ok for these. Do not use anything sharp or abrasive!

6. Anything else that the tape contacts on its exciting journey through your machine.

7. Rubber belts. Access to some of these may require the services of a Swiss watchmaker (if any still exist). Some boomboxes seem to be designed specifically to be difficult to service. After noting where each belt goes, remove them individually (if possible) and clean with alcohol and Qtips or a lint free cloth. Dry quickly to avoid degrading the rubber from contact with the alcohol. If a belt is trapped by some assembly and not easy to remove, use the Qtip on the belt and/or pulley in place. However, if it is stretched, flabby, or damaged, you will need to figure out how to free it.

Note that on some equipment like dual cassette boomboxes and telephone answering machines, the belt(s) may follow a highly circuitous path - make a detailed diagram!

Any belts that appear loose, flabby or do not return instantly to their relaxed size when stretched by 25% or so will need to be replaced and may be the cause of your problems. Belts cost about $.30-$2.00. Meanwhile, the belts will function better once they are cleaned, maybe just enough to get by until your replacements arrive.

Lubrication of electronic equipment: ----------------------------------

The short recommendation is: Don't add any oil or grease unless you are positively sure it is needed. Most parts are lubricated at the factory and do not need any further lubrication over their lifetime. Too much lubrication is worse then too little. It is easy to add a drop of oil but difficult and time consuming to restore a tape deck that has taken a swim.

NEVER, ever, use WD40! WD40 is not a good lubricant despite the claims on the label. Legend has it that the WD stands for Water Displacer - which is one of the functions of WD40 when used to coat tools for rust prevention. WD40 is much too thin to do any good as a general lubricant and will quickly collect dirt and dry up.

A light machine oil like electric motor or sewing machine oil should be used for gear or wheel shafts. A plastic safe grease like silicone grease or Molylube is suitable for gears, cams, or mechanical (piano key) type mode selectors. Never use oil or grease on electrical contacts.

Unless the unit was not properly lubricated at the factory (which is quite possible), don't add any unless your inspection reveals the specific need. Sometimes you will find a dry capstan, motor, lever, or gear shaft. If possible, disassemble and clean out the old lubricant before adding fresh oil or grease.

Note that in most cases, oil is for plain bearings (not ball or roller) and pivots while grease is used on sliding parts and gear teeth.

In general, do not lubricate anything unless you know there is a need. Never 'shotgun' a problem by lubricating everything in sight! You might as well literally use a shotgun on the equipment!

Tape Head demagnetizing: ----------------------

With audio tape decks, demagnetizing is often recommended to improve sound quality and frequency response. There is some debate as to how much benefit there is to this practice but if done properly, there is little risk. Demagnetizing removes the residual magnetic fields that can build up on ferrous pole pieces of the tape heads and various guideposts and other parts in the tape path which may affect frequency response.

Use a small demagnetizer designed for a tape deck or cassette deck. Do not use anything homemade that might be too powerful or a bulk tape eraser which would certainly be too powerful.

Make sure the tip is covered with a soft material to prevent damage to the finely polished surfaces in the tape transport.

Turn power on to the demagnetizer when a couple of feet away from the unit. Then, slowly bring it in close and slowly go over all surfaces of anything that the tape contacts or comes close to in the tape path. The key word here is **slowly**. Move fast, and you will make the magnetic fields stronger. When finished, slowly draw the demagnetizer away to a distance of a couple of feet before turning it off.

Tape or cassette deck, recorder, or Walkman transport problems: ---

The following are common problems with audio tape transports:

1. No movement in PLAY or REC - most likely capstan is not turning or not engaged. If the motor is not working (listen for a hum from inside the transport), refer to the sections on motor problems. Otherwise, see the list below.

2. Tape eating - the capstan is turning but the takeup reel is stationary or not turning rapidly enough to take up the tape as it feeds from the capstan/pinch roller.

2. FF and/or REW are inoperative or sluggish - assuming the motor is working, the driven reel is not being powered at all or does not have sufficient torque to overcome the tape friction. The driven reel alone must pull the tape through the transport.

Note that the required torque for the driven reel is much less for PLAY and REC compared to FF and REW as the capstan in contact with the pinch roller pulls the tape from the supply reel.

The most likely causes are similar for all of these symptoms. The driven reel and/or capstan is not turning due to:

* A broken or stretched belt, an old and deteriorated, dirty, or worn idler tire. Refer to the section: "General guide to cleaning and rubber parts replacement".

* Worn or broken. For example, a spring may have popped off an idler clutch or a press-fit gear or pulley may have split.

* Gummed up lubrication which is preventing the idler gear or tire that operates the takeup reel from engaging. See the section: "Lubrication of electronic equipment".

* A solenoid that is not engaging properly due to a weak spring, insufficient drive, or lubrication problems.

If the cause is not immediately evident once the bottom of the transport is visible, try to observe exactly what is happening when you play a garbage tape or run the deck with no tape present. Look for broken parts or bits of parts that may have failed off.

If the transport shuts down shortly after entering any mode, check for a missing or stretched tape counter drive belt or a defective reel rotation sensor. The tape eating protection circuits are shutting down the unit improperly due to a lack of reel sensor pulses. A related symptom will be that the tape counter (mechanical or electronic) does not change during the period when the tape is moving.

If the logic is not properly controlling the various solenoids or other actuators in a 'soft touch deck', then a service manual will be needed to proceed much further.

Tape transport azimith adjustment: ----------------------------------

When prerecorded tapes or tapes recorded on another deck sound muddy, the azimith alignment of the suspect deck may have shifted or be misadjusted. Azimith refers to the angle that the record/playback head gap makes with respect to recorded audio tracks. This angle should be exactly 90 degrees. If it is not, than high frequencies will tend to be reduced in amplitude during playback of a tape not recorded on this machine. Similarly, a tape recorded on a transport with an improper azimith setting will sound muddy on a properly adjusted deck.

A simple test to determine if azimith alignment is your problem is to record some music on your machine and immediately play it back. If this recording sounds fine but it sounds muddy on another deck, then improper azimith alignment is the likely cause.

If the recording is still muddy, your deck may have electronic problems like excessive bias (check to make sure you have selected the proper type of tape or bias setting), a worn record/playback head, or the heads or other parts may be magnetized (see the section: "Tape head demagnetizing"., However, dirty heads as well other mechanical problems can also result in weak muddy sound. See the section: "General guide to tape deck cleaning and rubber parts replacement".

The best way to adjust azimith is while playing a recording that was made on a known good deck - commercial tapes are usually (but not always) a good choice.

Warning: once you adjust the azimith, any tapes previously recorded on this transport may sound muddy. If you only record and play your own tapes on this deck, you may want to just leave it alone.

The azimith adjustment is usually a screw that pivots the record/playback head. It may be spring loaded and possibly fixed in place with a some Loctite or varnish. Often it will be accessible through a hole without removing any covers but not always. Look for it while in play or record mode in back of any holes (which you had no idea had a purpose until now). If there are no access holes, you will have to remove the loading door, cover, or front panel. Be sure you have the correct screw before turning wildly - others may affect critical height or simply be mounting screws.

Play a tape with lots of good highs - classical instrumental music or jazz are excellent. Now, simply set the azimith adjustment for best sounding and strongest high frequencies which should result in most natural sound. Go slow - a 1/16 of a turn is significant. Turn the screw back and forth and leave it in the best sounding position. Carefully put a dab of Loctite or nail polish on the screw to prevent it from moving.

Walkman/Discman power or sound intermittent: --

Note: for actual tape speed, operation, or sound quality issues, see the sections on tape transports.

The socket that the AC adapter or headphones plug into is often quite abused during normal operation. This can lead to broken solder connections where it joins the circuit board inside the unit. Test for this possibility by wiggling the plug without moving or flexing the cable itself. If the sound cuts in and out or the tape player starts and stops or the radio goes on and off, or the CD player resets or stops, then there is likely a bad connection here. Note: eliminate the alternate possibility that the AC adapter or headphone cable is bad by wiggling and tugging on the cable while holding the plug steady. Further verify that it is not simply a matter of dirt or grime interfering with a good connection.

The connections can be easily resoldered but you will need to open up the case using. Hopefully this will only require jeweler's screwdrivers and great care. (However, some Walkmen are constructed such that access to the interior is virtually impossible without a hand-grenade.) To repair the connections, use a low wattage iron and fine rosin core solder. Make sure you do not introduce any solder bridges. Try not to lose any of the microscrews.

Cassette or tape playback - one channel dead: --

This could be a bad playback head, bad connections, or a bad component in the playback electronics.

First, confirm that the problem is not in your headphones, patch cables, or the remainder of your audio system - try an alternate audio source where possible.

To determine if the playback circuitry is working, gain access to the terminals on the playback head - a metal cased little cube near the center of the tape side of the cassette. There should be four wires coming from it. While the machine is supposed to be playing, touch the end of a jeweler's screwdriver gently to each of the four terminals in turn. When you touch the good channel, you should hear a buzz from the appropriate speaker. If you touch one terminal and get a buzz from the 'dead' channel, then it is possible that the head is bad for that channel. If you can touch two different terminals and get a buzz in the bad channel for both, the it is likely that the ground connection to the input preamp has fallen off. If you do not get anything from the bad channel, then there is likely an electronic problem in that channel. Bad connections aside, the most common problem area would be the audio amplifier - bad IC or capacitor.

Distorted or erratic recording: ------------------------------

First determine if it is a record or playback problem - play a tape recorded on another machine or a commercial prerecorded tape. Try a tape from this machine on another known working tape player.

If record is the problem and it has very distorted sound, this may be a sign of a bad bias oscillator or switching circuit or record switch. The bias is an ultrasonic signal that is impressed on the tape along with the input signal. Without it, the sound will be highly distorted. In effect, it is a linearizing signal.

Check that the record select switch is clean - it may have many contacts and may have collected a lot of crud. If behavior changes with each activation of the record switch, get some contact or tuner cleaner spray and use the extension tube to spray inside the switch (with the power off), put the switch through its paces several times and allow to dry before powering it up.

If it is a portable subject to abuse, check for bad connections as well, especially if, say, one channel comes and goes.

Beyond this, you can try to measure the signal going to the record heads while in record mode. You should be able to see a high frequency signal in addition to the input signal. If the either of these is absent, then you need to trace back to its source and at this point will probably need a schematic.

Cassette player erratic autoreverse: ------------------------------------

Some of the autoreverse decks use a rotating magnet under or part of the each reel and a reed switch or hall effect device to detect lack of motion and do the autoreverse thing.

I had one from a Toyota where the plastic drive gear which included the magnet and was part of the reel split and was getting stuck at the broken tooth causing a reverse and eventually eating the tape. It was $9 for that little plastic gear.

Others are entirely mechanical and if there is a lack of lubrication, dirt, tired belts or idlers, or broken parts they may start acting erratically.

Although there could be an electronic fault, carefully examine the mechanism for obvious or subtle problems before breaking out the 'scope.

The following methods are use for autoreverse:

1. Optical sensor detecting the clear leader on the cassette. Better tape decks use this for sensing at the end so that the reverse occurs just quickly at the end of the tape rather than waiting for the leader to go by and a second or two for the tape to stop.

2. Totally mechanical where a lever arm presses against the tape and when the tension increases with the reel stopped, it trips a mechanism to reverse.

3. Optical sensors on reel rotation.

4. Magnetic sensors on reel rotation - either hall effect devices or simple reed switches.

If the transport will run without a tape in place, see if the takeup reel is rotating properly and whether the reverse still occurs. If reel rotation is normal but it still reverses, the either you have the optical tape end sensor or there is some fault in the sensors for the reel rotation. If the takeup reel does not rotate, then as suggested above, check for bad belts or idler tire.

Belts and idler tires are readily available from places like MCM Electronics.

General tape speed problems - slow, fast, or dead: --

Are the speed problems sudden or gradual? Over what period of time? Seconds, minutes? For portable devices, are you using a good set of their recommended type of batteries?

Did this problem start suddenly or was this a tape recorder you found buried under an inch thick layer of dust in an attic?

If the latter, then there could very well be multiple mechanical problems due to deteriorated rubber parts - replace then or toss it.

Fast play could be an indication of a hard deteriorated pinch roller.

Clean and lubricate the mechanism.   Check for dry or tight bearings.

Is there any pattern to the problems - like with respect to the start and end of cassettes?

If the tape speed has suddenly become excessive:

1. Mechanical. If you had a recent tape eating episode, there may be a wad of tape wrapped around the capstan. Remove it. Alternatively, the pinch roller may not be fully engaging against the capstan and the takeup reel is simply pulling the tape through without any speed control. Clean the mechanism, check for tired belts and springs.

2. Electrical. The motor speed control is not working. This may be either a mechanical governor inside the motor or a voltage regulator or other electronic control often also inside the motor. In the latter case, you may be able to disassemble the motor and repair it. One possibility is that the series regulator has decided to turn into a short circuit. This may be external or internal to the motor.

Slight tape speed error may simply mean that an adjustment is needed. There may be an access hole on the motor or an external pot. Keep in mind that any tapes you recorded on this machine (assuming it can record) recently will play at an incorrect speed once you adjust the speed.

Is it slow and steady - no more wow and flutter than normal? Or slow and erratic indicating that (1) the speed regulator is faulty, (2) some bearings may need oil, (3) the pinch roller is glazed.

If the mechanics seem ok, then check for electronic problems with the motor or regulator. Sometimes there is a trimpot for speed adjustment inside or external to the motor. A faulty regulator or even a bad connection may be the cause.

A variety of techniques are used to regulate the record/playback speed:

1. Mechanical governor inside motor - centrifugal contacts open at correct speed reducing current to motor. If speed is too low, than springs could have weakened or contacts could be bad - open. If speed is too high, contacts may be welded closed. There may be a resistor and/or capacitor across the contacts. An open resistor could conceivably cause unstable speed fluctuations. A capacitor may be present to reduce electrical noise.

2. Voltage regulator inside motor case or external to motor. The regulator or transistor may be faulty. If power for the motor seems to come directly from an unregulated supply, check across the motor terminals with an ohmmeter. A low reading which is identical in both directions would indicate a direct connection to the motor brushes with no internal regulator. A high reading or one that is different in each direction indicates an internal electronic regulator - or you could just use your eyeballs to determine if there are any electronics inside the motor. These can be disassembled and bad parts replaced. There may be an access hole on the motor for an adjustment. Alternatively, you could remove the guts and install an external regulator using an LM317 or similar part.

3. Active regulator with tachometer feedback from motor winding - there would be 4 wires instead of two coming out of the motor - 2 for power and 2 for tach. Control circuitry could be bad or the tach output could be dead (speed too high).

4. If an optical strobe disk is located on the motor shaft, then it may be part of a speed control circuit. If it is on one of the reels - probably the takeup reel - then it simply operates the (electronic) tape counter or signals the controller that the takeup reel is turning - to catch tape spills.

Tape speed adjustment made easy: ------------------------------

OK, you have found the magic screw, but how to set the speed accurately? Sometimes, there will be strobe disks on tape decks which will appear stationary under fluorescent lighting (magnetic ballasts only - electronic ballasts are usually high frequency and do not modulate the light intensity at the power line frequency) but not usually. So, you do it by ear:

Make a recording of a single tone on a tape recorder you trust - one with accurate speed.

Suitable sources include: a signal generator, electronic instrument, Touch-Tone phone tone, PC sound card output or PC speaker, etc. A frequency around 400-1000 Hz should work well.

Then, adjust the speed while listening to this same source simultaneously with the tape being played back on the unit to be adjusted. As you adjust the speed, you will hear the pitch change. As it approaches the correct setting, you will hear the tones beat against each other. When you are set correctly, the pitches will be equal and the beat frequency will go to zero. Even if you are tone deaf, you will easily be able to adjust pitch accuracy to better than 1/10 of a semitone using this method.

Sudden increase in flutter on tape decks or Walkmen: --

If your prized Walkman suddenly develops a severe case of warbling sound check:

1. Batteries (where appropriate). Almost dead batteries will greatly increase flutter. Use of Nickel-Cadmium rechargeable batteries in place of alkalines may result in problems due to their lower voltage (1.2 V vs, 1.5 V per cell).

2. Tired belts - loose flabby deteriorated belts will produce varying, probably slow, speed as well.

3. Dirt or goo on pulleys. Sometimes a glob of stuff gets stuck to a pulley and produces a periodic variation in speed. I picked one up at a garage sale that had this problem. I thought it was a bad motor until a careful examination revealed that the belt was jumping a mm or so on each rotation of an idler pulley.

4. Lack of lubrication - a dry or worn bearing may result in a variety of speed problems.

5. Bad speed regulator - either mechanical or electronic including bad solder connections or cracks in circuit board traces.

6. Bad power supply.

7. Bad tape. Don't overlook this obvious possibility, try another one.

*************** TURNTABLES ***************

Turntable (record changer) maintenance: -------------------------------------

Here are general comments on oiling dinosaurs, oops sorry, turntables.

Usually there is a 'C-clip' or 'E-clip' which holds the platter (the thing that rotates) onto the spindle. It may be covered with a decorative piece which can be easily removed. The clip can be pryed off (gently) with a small screwdriver (just don't lose it, though even this is not a biggie so long as you never turn the thing up-side-down).

The platter can then be lifted straight up and off the spindle. You will see several things (this will vary depending on your particular unit):

1. A flat washer, sitting on a ball bearing race sitting on another flat washer (one or both of these washers may be missing. Also, the top one may stick to the platter when it is removed.) The ball bearings, shaft, washers, etc. should all be cleaned with degreaser and then lubed with a light grease. If either the steel balls or the flat washers are corroded, replacement will be necessary or else there will be terrible audible rumble. For now, it will at least work well enough to determine what else, if anything, needs attention. Also clean and lubricate the platter bushing (center hole) and shaft (vertical post on which it rotates).

2. Changer gears etc. These will have varying amounts of grease on them if it is not gummed up, leave them alone. Put a drop or two of light oil on the shafts. Inspect other linkages as well. If the grease is gummed up on the gears or sliding linkages, you will need to clean it off thoroughly with degreaser and then use a small amount of high quality grease suitable for delicate mechanisms. One cause of a changer failing to activate at the end of a record is gummed up grease.

3. Motor. Check to see if the motor shaft turns freely and smoothly even if spun quickly between your fingers. If it does - without squealing, don't do anything else. If it is tight or makes noise, then you will need to carefully disassemble the motor and clean and lubricate the bearings at each end with light oil. Don't lose any of the various washers/spacers that may be present on the shaft as it is removed from the end pieces and make sure to lubricate and return them to exactly the location and the same order they were in originally.

4. Clean the rubber parts with isopropyl alcohol and Q-tips or a lint free cloth until no more black stuff comes off and then dry thoroughly. Now, inspect the belts (if any). If belts are flabby or cracked or if they don't instantly return to their relaxed length if stretched 25% and released, they will need replacing. Check the idler tire (if present). If hard or cracked, it will need replacing as well.

Note: Light oil here means electric motor oil or even 3-In-One but NOT WD40. Light grease means something that is suitable for fine mechanisms and is safe for plastics. Automotive bearing grease may not qualify.

Speed control in turntables: --------------------------

Most inexpensive turntables/changers will use a synchronous motor or even just an induction motor. The only maintenance for the motor is cleaning and lubrication.

Servo controlled turntables utilize a feedback technique which locks the platter speed to a stable reference - either the power line (50/60 Hz) or more commonly a crystal oscillator. Here is one example:

A Sony turntable I repaired used a magnetic stripe pattern on the inside of the platter which was sensed by a magnetic pickup. The resulting signal was phase locked to a stable reference and used to control a brushless DC direct drive motor. Speed would become erratic if (1) the magnetic pattern were damaged, (2) the pickup position was moved too far from the surface of the platter, (3) the Hall-effect sensors in the motor were bad, or (4) the control electronics went bad. In one case, it turned out that one of the Hall effect sensors had failed in the motor. This required disassembling the motor and replacing the sensor - $4 from Sony.

Wow, flutter, and rumble in a turntable: -------------------------------------

Wow and flutter refer to undesirable periodic variations in pitch caused by changes in turntable (or tape deck) speed. Wow would be a slow variation (e.g., once per rotation) while flutter would be rapid (e.g., a motor pulley with a bump). Even if very slight, these faults will be all too obvious with music but may go undetected at much higher levels for voice recordings.

Rumble is a very low frequency noise added to the audio caused by vibration due to cheap, worn, dirty, or dry spindle bearings or by vibrations coupled in from some other motor driven component or even from loudspeakers if the volume is turned way up. If really bad, rumble may sound like a freight train in the next room.

For anyone only used to listening to CDs, even very small amounts of and of these will prove very obvious and extremely objectionable. Wow, flutter, and rumble are undetectable - for all intents and purposes nonexistent - with even the cheapest junkiest CD player.

For a common motor driven turntable, the following are likely causes:

1. Bad belt or idler. Rubber 'rusts'. If it is old, then almost certainly the rubber parts have deteriorated and will need replacement. Unfortunately, replacement parts are not as readily available as they once were. The places listed at the end of this document may have some and there are many other sources but it is not as easy as one would like.

2. Dirty or worn spindle bearing. This will cause rumble. The thrust ball bearing can be cleaned and lubricated or replaced. The platter bushing can be cleaned and lubricated.

3. Lump of crud stuck to motor pulley or idler, usually of unknown origin.

4. Dried up lubrication in motor, idler, or other rotating part. These can be cleaned and lubricated.

5. Bad motor (not that likely) except for lubrication in which case the motor can be disassembled, cleaned, and lubed.

6. Physical damage to platter - something heavy was dropped on it upsetting the delicate balance.

If you are attempting to restore a 20 year old turntable from Aunt Annie's attic, don't even bother to power it up before replacing all the rubber parts and cleaning and lubricating the motor, idler, and spindle bearing.

Erratic sound from turntable: ----------------------------

Sound that varies randomly in intensity or where one channel drops out will usually be due to bad connections in the various units. This could be:

1. At the pickup itself. There may be small press fit connectors at the cartridge. These sometimes become loose. Gently remove each one (one at a time! so that you do not mix up the wiring) and squeeze with a pair of tweezers or needlenose pliers. Snap in cartridges may have dirty contacts the springiness may have disappeared.

2. At the RCA plugs under the turntable which connect to the tonearm. Depending on your design and problem, you may need to simply clean with contact cleaner or squeeze the metal shell or center contact.

3. At the receiver, preamp, or amplifier. Same as (2) above.

4. Sometimes the cables themselves will develop broken wires at one end or the other. Easiest is to try a different set of cables.

Turntable tracking and skating force adjustment: ---

Tracking force keeps the stylus in the record's groove. Too little is as bad as too much. It is best to follow the recommendations of the cartridge/stylus manufacturer. If you do not have this information, start low and increase until you eliminate skipping or excessive distortion, buzzing, or stuttering. If too low, the stylus will make only partial contact with the groove during high amplitude segments - it will jump from peak to peak (or other portion) of the wave rather than smoothly and continuously following it. If too high, it will gouge the vinyl (or the shellac or whatever depending on the vintage of your records) or in extreme cases, bottom out on the cartridge's suspension.

Skating force compensation is applied to compensate for the fact that except at one distance from the spindle (or with a linear drive tone arm where this does not apply), the tone arm is not tangential to the groove. Imagine a perfectly flat record without any grooves. If you 'play' this, the tone arm will be stable at only one position somewhere in the middle - where a line drawn through its pivot point and the stylus is just tangential to a circle at that distance from the spindle. The skating is usually a simple spring which attempts to compensate for this in such a way that the side force tending to move the stylus is minimized at all positions. Otherwise, the inner and outer walls of the groove will experience a different force which will add distortion and affect stereo separate and balance.

Skating force compensation is usually set based on the tracking force.

Note that if you are used to CDs or high quality cassettes, all the horrors of records will be all to obvious unless you are using high-end equipment (the kind that likely costs as much as your automobile) and meticulously maintain your vinyl record collection. Sonic defects like wow, flutter, rumble, distortion, noise, imperfect stereo separation, skipping, and limited frequency response are all facts of life for this technology which has not changed in any fundamental way since Edison's time.

********************* LOUDSPEAKERS *********************

Loudspeaker anatomy: -------------------

In this document, we use the terms 'loudspeaker' or 'speaker system' to denote a unit consisting of one or more drivers in an acoustic enclosure perhaps along with a frequency selective crossover, tone controls and switches, fuses or circuit breakers. Connections to the amplifier or receiver are via terminals on the rear. The front is covered with an (optically) opaque or semitransparent grille which provides protection and improves the appearance (depending on your point of view).

A 'driver' is the actual unit that converts electrical energy into sound energy. Most drivers use voice coil technology: a very low mass coil wound on a light rigid tube is suspended within a powerful magnetic field and attached to a paper, plastic, or composite cone. The audio signal causes the coil to move back and forth and this motion causes the cone to move which causes the air to move which we perceive as sound.

The typical driver consists of several parts:

* Frame - a rigid steel or composite structure on which the driver is constructed. The frame holds the magnet and core, cone suspension, and connection terminals.

* Magnet - this includes a powerful (usually ceramic, AlNiCo, or rare earth) magnet including a core structure provide a very narrow cylindrical air gap. This accounts for most of the mass of a driver.

* Voice coil - a one or two layer coil of fine wire wound on a light rigid cardboard, plastic, or composite tube suspended within the air gap of the magnet and connected via flexible wires to the electrical terminals.

* Cone - a roughly cone shaped very light and rigid structure that does the actual work of moving air molecules. The cone in a woofer may be 12 or more inches across. The cone in a tweeter may only be an inch in diameter. This is the part of the driver you actually see from the front of the speaker system with the grille removed. The center is usually protected with a small plastic dome.

* Suspension - a corrugated flexible mounting for the voice coil called a 'spider' and outer ring of very soft plastic or foam. Together, these allow the voice coil/cone combination to move readily in and out as a unit without tilting or or rubbing. For most designs, there is a certain amount of springiness to this suspension. Acoustic suspension loudspeaker, however, use the trapped air in a totally sealed speaker enclosure to provide the restoring force.

Inexpensive 'LoFi' devices like portable and clock radios, many TVs, intercoms, and so forth use a single, cheap driver. Some have a coaxial pair of cones but this does little to improve the frequency response.

HiFi speakers systems will divide the audio frequency spectrum into several bands and use drivers optimized for each. The reason is that it is not possible to design a single driver that has a uniform response for the entire audio frequency spectrum. A 'woofer' is large and massive and handles the low base notes. A 'tweeter' has a very low mass structure and is used for the high frequencies. A 'mid-range' handles the mid frequencies. There may also be 'sub-woofers' for the very very low notes that we feel more than hear. Some systems may include 'super-tweeters' for the very highest frequencies (which few people can hear. This may make for some impressive specifications but perhaps little else.)

A 'crossover' network - a set of inductors and capacitors - implements a set of filters to direct the electrical signal (mostly) to the proper drivers.

Various controls or switches may be provided to allow for the adjustment of low, mid, and high frequency response to match the room acoustics more faithfully or to taste. Fuses or circuit breakers may be included to protect the speaker system from intentional (high volume levels) or accidental (amplifier output stage blows) abuse.

Loudspeaker problems: --------------------

If you have a high quality and expensive set of loudspeaker, then the cost of professional repair may be justified. However, if the problem is with speaker systems you might not write home about, then read on.

Playing your music system at very high volume levels, especially CDs which may have peaks that way exceed the ratings of your loudspeakers is asking for trouble - but you knew that! CDs can be deceiving because the noise floor is so low that you are tempted to turn up the volume. A peak comes along and your speaker cones are clear across the county (remember the movie 'Back to the Future'?). Loudspeaker systems are generally pretty robust but continuous abuse can take its toll.

Problems with loudspeakers:

1. An entire speaker system is dead.

Verify that the connections both at the speaker system and at the source are secure. Check circuit breakers or fuses in the speaker system. Reset or replace as needed. Make sure it is not the amplifier or other source that is defective by swapping channels if that is possible. Alternatively, test for output using a speaker from another system or even a set of headphones (but keep the volume turned way down). Assuming that these tests confirm that the speaker system is indeed not responding, you will need to get inside.

It would take quite a blast of power to kill an entire speaker system. Therefore, it is likely that there is a simple bad connection inside, perhaps right at the terminal block. You should be able to easily trace the circuitry - this is not a missile guidance system after all - to locate the bad connection. If nothing is found, then proceed to test the individual drivers as outlined below. 2. One or more drivers (the name for the individual speakers in a loudspeaker enclosure) is dead - no sound at all even when you place you ear right up to it. The cause may be a bad driver, a bad component or bad connection in the crossover network. Test these components as outlined below.

3. One or more drivers produces distorted or weak sound. Distorted may mean fuzzy, buzzing, or scratchy a various volume levels. Most likely this is due to a bad driver but it could also be a defective component in the crossover - a capacitor for example or even a marginal connection.

Getting inside a speaker system usually means removing the decorative grille if it snaps off or unscrewing the backpanel and/or terminal block. Use your judgement. With the grille removed, you will be able to unscrew the individual drivers one at a time. With the back off, you will have access to all the internal components. If sealing putty is used, don't lose it or expect to obtain some replacement putty (non-hardening window caulking like Mortite is suitable).

Test the components in the crossover network with a multimeter. These are simple parts like capacitors, inductors, and potentiometers or reostats. Confirm that any circuit breakers or fuse holders have continuity.

Test the drivers on the low ohms scale of your multimeter. Disconnect one wire so that the crossover components will not influence the reading. Woofers and midrange drivers should measure a few ohms. If their impedance is marked, the reading you get will probably be somewhat lower but not 0. If possible compare your readings with the same driver in the good speaker system (if this is a stereo setup). Some tweeters (very small high frequency drivers) may have a series capacitor built in which will result in an infinite ohms measurement. Other than these, a high reading indicates an open voice coil which means a bad driver. In a comparison with an identical unit, a very low reading would mean a partially or totally shorted voice coil, again meaning a bad driver. Except for expensive systems with removable voice coil assemblies, either of these usually mean that a replacement will be required for the entire driver. Sometimes an open voice coil can be repaired if the break can be found.

To confirm these tests, use an audio source to power just the suspect driver. Your stereo system, a small amplifier attached to an audio source, or even a pocket radio (use its speaker output if the headphone output does not have enough power) will suffice. The resulting sound will not be of high quality because you do not have the enclosure sealed and it is only one of the drivers in the system, but it should give you some idea of its condition. Again, comparing with an identical unit would be another confirmation.

Repairing loudspeaker drivers: ----------------------------

As noted above, if you are dealing with a high quality system, leave these repairs to professionals or obtain an entire replacement as some reduction in audio quality may result from the abuse you are about to inflict on the poor defenseless driver.

We will address two types of repairs: physical damage to a speaker driver cone and an open voice coil (actually, wiring outside the voice coil). However, serious damage to the cone or just plain deterioration of the suspension components may require replacement of the entire driver unless a close enough match can be found.

Various sizes of paper cones and foam-edge replacements are available from MAT Electronics @ 1-800-628-1118. I just got their Spring 96 catalog and these are new products. They range in price from less than a dollar to about $5 for the largest (15") drivers. The downside is there is a $25 minimum. However, they also sell electronic components like flybacks, video heads and belts, ICs and transistors, etc. So coming up with a minimum order may not be too difficult. (Raymond Carlsen (rrcc@u.washington.edu))

Minor damage to the cone can be repaired using a flexible adhesive like weatherstrip cement and a piece of thick paper to reinforce the seam or hole if necessary. Since this will not totally perfect match with the original paper cone, there could be audible distortion at certain frequencies particularly at higher volume levels. However, such a repair will be better than nothing. Cut the paper in a shape and size to just overlap both sides of the torn area or completely cover the puncture. Use just the smallest amount of adhesive to fasten your 'splint' to the cone. The less material you add, the more likely that the audio effects will be minimal.

An open driver can sometimes be rescued by tracing the input wires through the cone and under the center protective dome. The most likely places for these wires to break are right at the place where they pass through the cone and just after they pass under the dome. Note: some drivers have replaceable voice coil units. If this is the case, you should probably just replace the entire unit.

First, scrape away the insulating varnish on the front of the cone where the wires emerge and head toward the center. Use your ohmmeter to test for continuity here. If you find that you now are measuring a reasonable resistance - a few ohms, then trace back to determine which of the two wires is broken or has had the solder connection come loose. If it is still infinite, you will have to go under the dome.

Use an Xacto knife to carefully remove the dome. Use a shallow angle and cut as near the edge as you can. Take care not to puncture the paper cone which may continue under the dome as the voice coil may be of a smaller diameter than the dome. The shallow cut will also provide a base to reattach the dome if you are successful. Carefully scrape off a bit of the enamel insulation as near to the voice coil as possible and test with your ohmmeter once again. If the resistance is still infinite, there is nothing more you can do but salvage the magnet for fun experiments or erasing floppy disks. There is essentially no way to replace just the voice coil unless your driver has a removable voice coil unit (in which case you would not be reading this).

If the resistance now measures normal - a few ohms, trace back to determine which wire is broken and use some fine (e.g., #30 gauge) wire to bridge the break. You will have to scrape off the enamel insulation to permit the solder to adhere. Make sure it is secure mechanically first - a speaker cone is a rather violent environment for soldered connections. Finally, use some flexible adhesive to protect and reinforce the solder connections, to glue down your new wire along its entire length, to protect and reinforce the place where the wire passes through the cone, and finally, to reattach the central dome. Let the adhesive dry thoroughly before playing the 1812 Overture.

Loudspeakers - repair or replace?: --------------------------------

Assuming that the cabinet is in reasonable condition, the question arises: is it worth replacing broken, damaged, or worn out drivers or faulty crossover components that are not repairable rather than just dumping the speaker systems?

It is very straightforward to swap drivers as long as you get ones with similar characteristics. It all depends on what you want out of a loudspeaker. If you are basically happy with them, then it will be a lot cheaper than replacing the entire speaker system(s). However, speaker system quality has improved considerably in the last 15 years so now may be the time to upgrade.

As far as crossover components are concerned, these are basically common electronic parts and replacement is probably worthwhile.

However, if one driver has a deteriorated suspension, it is likely that its mate does as well and that other drivers may not far behind. Replacing **all** the internal components of a loudspeaker may not be worth it.

Radio Shack as well as places like MCM Electronics and Dalbani have a variety of replacement drivers, and crossovers and parts.

******************** TELEPHONE EQUIPMENT ********************

Answering machine comments: -------------------------

Most answering machines still use one or two tape decks. Most problems are mechanical. Refer to the sections on the relevant tape player/recorder problems. The newest ones are fully digital electronic - forget repairs unless obvious bad connections, physical damage, power supply, or phone line side failure.

Many non-mechanical problems with answering machines are related to the circuitry connected to the phone line. This is subject to the high on-hook and ringing voltage and possible voltage spikes due to lightening, etc.

Testing of the components on the phone line side of the coupling transformer is a worthwhile exercise and may reveal a shorted semiconductor or capacitor.

With endless loops outgoing message cassettes, the metal strip that is used to sense the beginning can wear or become dirty. Try a new cassette or clean it.

Mechanical problems unique to answering machine tape transports are also possible. Some very clever engineering is often used to share parts where two tape transports are used. Parts may have popped off or broken. Springs may have sprung. Sliding parts may have jammed. Look for loose parts or broken pieces when the unit is disassembled. Careful inspection during operation may reveal whether it is getting stuck due to a mechanical failure

Answering machine picks up then hangs up: --

1. If it has a 'telco' and a 'phone' connector verify that you are plugged into the 'telco'. Otherwise, it may hang itself up. Who knows. If someone else attempted a repair, these jacks could even have been replaced interchanged.

2. Measure voltage on the relay coil. If it actually disappears when the relay cuts out, then something is telling the relay to turn off. If it is just reduced, then there may be a power problem. If it is relatively stable, then the relay may be bad.

3. Test components near the telephone connection for shorts/opens. Parts connected to the telephone line get abused by the ringing voltage and other transients. Maybe you will get lucky and find a fried part.

4. If you can identify the power supply outputs, verify their voltages if possible. Check the 'wall wart' if it uses one for proper output.

5. Make sure that the tape mechanisms have completed their cycles. While unlikely, it is possible that the logic gets confused if one of the tape units has not reset itself due to a mechanical fault like a bad belt.

6. As usual with cheaply made consumer stuff (as well as cheaply made expensive industrial stuff), check for bad connections.

Beyond this, circuit diagrams would be a definite plus.

Answering machine does not complete cycle: --

This is often a mechanical problem. As it goes through the cycle, see if the mechanism is perhaps getting hung up at a certain point do to a weak spring or motor. A cam may get stuck or a solenoid may fail to engage. Gently prodding the uncooperative part (or any likely parts if the appropriate one is not obvious) may convince it to continue and allow you to make a diagnosis.

For endless loop outgoing cassettes make sure that the metal sense strip is not worn off and that the sensor is making good contact. Try a new outgoing message cassette or manually short the sensor contacts to see if it will then shut down.

Newly installed phone will not tone dial: ---------------------------------------

If a Touch Tone phone that was previously working now does not tone dial from a new jack or new residence (the button presses are totally ignored, but all other functions are unaffected), the red and green wires are probably interchanged at the new jack, or the phone itself is miswired (the wires inside the phone may have been interchanged to compensate for an incorrectly wired jack at the old location).

Newer electronic phones will utilize either polarity. The older ATT battlewagons will only dial when hooked up with the correct polarity. This does not affect conversation, ring, or rotary phones.

Cordless phone problems: -----------------------

There are several types of problems with cordless phones that can be diagnosed and repaired without sophisticated test equipment. Anything involving problems with the RF or digital circuitry is not likely to be within the scope of your capabilities, at least not without complete schematics (yeh, right), test equipment, and a miracle or two.

1. Bad rechargeable battery - dead, shorted cell(s), or reduced capacity. The NiCd battery packs in cordless phones are usually easily replaced for around $5-10. This really is the best solution. The problem is almost never in the charging circuits. Replacing individual cells is not recommended. Battery packs can be built up from individual NiCd cells with solder tabs for a modest cost savings. Reuse the old battery pack connector (you may need to do this with a replacement pack as well if the new connector is not identical to the old one), double check polarity, and tape and insulate your homemade pack after soldering to prevent shorts.

A NiCd battery pack with shorted cells will either prevent operation totally or keep the 'battery low' light resulting in a weak, noisy, or intermittent connection. If the voltage measured on the battery pack after 24 hours of charging is less than 1.2 V times the number of cells in the pack, it is most likely bad.

2. Dirty keypad - resulting in intermittent, incorrect, or no operation of buttons on handset. This may be due to internal migration of some unidentified substance (how else to describe disgusting sticky gunk that has no right being there on multiple samples of the same model phone) or from external spills. If you are lucky, the keypad can be disassembled without resorting to drastic measures. There may be screws or it may snap apart once access is gained to the inside of the handset. Clean contact surfaces on both

the rubber button panel (or plastic keys) and the circuit board first with soap and water and then with isopropyl alcohol. Dry thoroughly. If the keypad is assembled with 'upset' plastic (fancy term for little melted plastic posts), then you should probably try contact cleaner sprayed as best as possible through any openings before attempting to cut these away since reassembling the keypad without the plastic posts will be difficult (read: impossible).

3. Bad AC adapter on base station - see the sections on AC adapters.

4. Bad phone line connection - don't ignore this possibility - test with another phone.

5. Bad circuitry on phone line side of interface (coupling transformer) - inspect for blown or shorted components.

6. Bad connections or broken circuit board - if the handset has seen violent service, these are likely possibilities. See the section on: "Equipment dropped or abused".

7. You forgot the code number - some phones use a multidigit code number as a marginal security feature which must match on handset and base station. If the battery goes dead in the handset or the AC adapter is pulled on the base station, this code may be forgotten. You do have the user's manual, right? (BTW, do set this code to a non-default value. I was once able to dial out on my neighbor's cordless phone using my phone from my house as a result, I suspect, of their phone being set to its default code!)

Checking phones and answering machines for electronic problems:

Most signal problems will be related to failed components on the telephone line side of the coupling transformer including components in the phone line derived power supply (if used). Phone lines are subject to all kinds of abuse including lightening strikes (although something significant may do extensive damage beyond reasonably hope of repair).

Test all the components on the telephone line side of the coupling transformer when line connect, detect, or dial problems are encountered. There may be shorted semiconductors due to a voltage spike or just bad luck.

Some units extract power from the phone line and the rectifiers or other related components can go bad. This can result in either power problems - telephone is dead - or dialing problems.

Make sure you are using the proper AC adapter and test it for correct output.

There could be a defective power supply inside the phone - the regulator could be shorted or a filter capacitor could be dried up. See the sections on power supply problems.

Check for loose or broken connections - phones get dropped.

For erratic dialing problems, inspect and clean the keypad and other switch contacts. Also see the section: "Cordless phone problems".

Modem problems: --------------

First, confirm that your modem settings are correct - reset the modem to factory defaults using the Hayes AT commands (e.g., AT&F1<ENTER>) or dip switch settings. Confirm that your software is set up correctly and that there are no IRQ or IO address conflicts.

If the modem starts to dial but aborts and hangs up, confirm that you do not have the wiring of the 'telco' and 'phone' connectors interchanges.

Most actual problems (that are not software related), will be on the phone line side of the coupling transformer. There will be various diodes, transistors, capacitors, opto-isolators, and relays for routing the incoming and outgoing signals, or for protection and these can fail. This phone line is subject to all kinds of abuse.

A lightening strike is likely to obliterate components in the modem beyond even your abilities to salvage it. However, in many cases, damage is minor.

If you have signal problems - a modem will try to dial out but not make its way to the phone line, testing on each side of the couping transformer with a scope or Hi-Z headphones should be able to determine if the problem is on the logic or phone line side of the device.

Check that the proper AC adapter is being used (if relevant) and that is is putting out the proper voltage. Check the internal power supply components for proper output. They are often common IC regulators like the 7805 and are easily tested. Replacements are inexpensive and plentiful.

***************** CALCULATORS, CLOCKS, AND WATCHES *****************

Problems with calculators: -------------------------

Small hand held and desk calculators share many of the same afflictions as hand held IR remote controls. In particular, battery and keypad problems are common.

Caution: many devices using LCD displays utilize a printed flex cable to interconnect the electronics and the display. Often, this is simply glued to the LCD panel and possibly to the logic board as well. The cables are quite fragile and easily torn. They are also easily ripped from the adhesive on the LCD panel or logic board. If the unit is fairly old, this adhesive may be very weak and brittle. Repair or replacement should this occur is virtually impossible. The material used for the conductors is a type of conductive paint that cannot be soldered. It may be possible to use a similar material like the conductive Epoxy used to repair printed circuit boards but this would be extremely tedious painstaking work. Be extremely careful when moving any of the internal components - LCD, logic board, keyboard, battery holder/pack, and printer.

The following problems are likely:

1. Batteries - one or more cells are dead, weak, or have leaked. Try a new set if normal primary cells (e.g., alkaline) are used. Clean the battery contacts. Where rechargeable (usually NiCd) batteries are used, one or more cells may have shorted resulting in a dead calculator or dim display, or printer that doesn't work reliably. See the sections on batteries. Test each cell after charging for the recommended time or overnight. NiCd cells should be about 1.2 V when fully charged. If any are 0 V, the cell is shorted. This is particularly likely with a unit that has been left in a closet unused for an extended period of time. It is generally recommended that the entire battery pack be replaced rather than a single cell as the others are probably on their way out and the capacities will not be equalized anyhow. Rechargeable batteries may be the cause of a calculator that does not work properly on AC power as well since they are usually used like a large filter capacitor and shorted cells will prevent the required DC voltage from being provided to the electronics. Open cells or bad battery connections will prevent this filtering as well and may result in erratic operation or other symptoms. For this reason, it may not be possible to run a unit of this type reliably or at all with the rechargeable batteries removed.

Some calculators that use rechargeable batteries like older HPs and TIs have a battery pack of 24.4 to 3.6 V with a DC-DC invertor to obtain the 9 V or so that the NMOS chipset required. These rarely fail except possibly due to leakage of neglected dead batteries. However, good batteries need to be in place for the calculator to work properly. If you are not interested in using these types of calculators on batteries, disconnect the DC=DC convertor and substitute a suitable AC adapter. Check the voltage and current requirements for your particular model.

2. Keypad - dirt, gunk, and wear may result in one or more keys that are intermittent or bounce (result in multiple entries). Disassemble, clean and restore the conductive coating if necessary. See the section (or companion document) on hand held remote controls.

3. Printer (where applicable) - in addition to replacing the ribbon when the print quality deteriorates, cleaning and lubrication may be needed periodically. Dust, dirt, and paper particles collect and gum up the works. Clean and then relube with light machine oil or grease as appropriate. Sometimes, gears or other parts break resulting in erratic operation or paper or other jams. Locating service parts is virtually impossible.

4. AC adapter - if the calculator does not work when plugged into the AC line, this may be defective - broken wires at either end of the cord are very common. However, shorted cells in an internal NiCd battery will likely prevent the proper voltage from being supplied to the electronics even when using AC power since the battery is often used like a large filter capacitor at the same time it is being charged. Open cells or bad connections to the battery pack may result in erratic operation or other symptoms as well.

Don't overlook the obvious: are you using the proper adapter and if it is a universal type, is the polarity and voltage set correctly? Check the specifications. With the proliferation of AC adapters, it is all to easy to accidentally substitute one from another device.

Battery powered digital clock problems: --------------------------------------

First, try a fresh battery and clean the battery contacts if necessary. If the battery is very low or dead, well.... When the battery is low or the connections are bad, the countdown logic may run erratically - fast as well as slow. Give it a week and then see if the problem still exists.

If it does - and the error is only a few minutes a week - then an adjustment may be all that is needed. If the error is much worse - like it is running at half speed - then there is a problem in the logic - time for new clock (or at least a new movement).

There should be a recessed screw for fine speed adjustment accessible from the back - possibly after a sticker or outer cover is removed. It may be marked with a couple of arrows and if you are lucky, with the proper direction for speed increase and decrease.

Without test equipment, the best you can do is a trial and error approach. Turn the screw just the tiniest bit in the appropriate direction. If this is not marked, use counterclockwise to slow it down and vice-versa.

Wait a week, then readjust if necessary.

If you have frequency counter with a time period mode, you can try putting it across the solenoid terminals and adjusting for exactly 1.000000 second. Hopefully the load of the counter will not affect the oscillator frequency.

With sensitive equipment, it may even be possible to do this without any connections by detecting the fundamental frequency radiation of the quartz crystal oscillator and adjusting it for exactly 32,768 Hz (most common).

However, keep in mind that the clock's quartz crystal accuracy required to gain or lose less than 1 minute a month is about +/- 1 part in 43,000 which may be better than that of your frequency counter's timebase. One alternative is to perform the same measurement on a clock that is known to be accurate and then match the one you are adjusting to that.

AC powered digital clock problems: ---------------------------------

Common problems include totally dead, missing segments in display, running at the wrong rate, switches or buttons do not work. (Also applies to the clock portions of clock radios.)

Note that these is often a battery - possibly just an 9V alkaline type for backup in the event of a power failure. If this is missing or dead, any momentary power interruption will reset the clock.

Although a totally dead clock could be caused by a logic failure, the most likely problem is in the power supply. The power transformer may have an open winding or there may a bad connection elsewhere. A diode may be defective or a capacitor may be dried up.

Often, the secondary of the power transformer is center tapped - test both sides with a multimeter on its AC scale. Typical values are 6-15 VRMS. If both sides are dead, then the primary is likely open. There may be a blown fusable resistor under the coil wrappings but a burnt out primary is likely. Although generic replacement transformers are available you will have two problems: determining the exact voltage and current requirements (though these are not usually critical) and obtaining a suitable regulatory (UL. CE, etc) approved transformer - required for fire safety reasons.

If the transformer checks out, trace the circuit to locate the DC outputs. These power supplies are usually pretty simple and it should be easy to locate any problems.

Missing segments in the display are most likely caused by bad connections. Try prodding and twisting the circuit board and inspect for cold solder joints.

A clock that runs slow on 50 Hz power or fast on 60 Hz power may not be compatible with the local line frequency since these clocks usually use the power line for timing rather than a quartz crystal. This is actually a more precise (as well as less expensive) approach as the power line frequency long term accuracy is nearly perfect. Sometimes there is a switch or jumper to select the line frequency.

Dirty switches and buttons can be cleaned using a spray contact cleaner.

Replacing batteries in digital watches: -------------------------------------

About the only type of service you can expect to perform is battery replacement but even this can save a few dollars compared to taking the watch to a jeweler. The typical watch battery will last anywhere from a year (alkaline) to 5 years (lithium). The most likely cause of a watch that has a dead or weak display, or has stopped or is not keeping proper time is a weak or dead battery.

The batteries (actually single cells) used in most modern watches (they used to be called electric watches, remember the Accutron?) are either alkaline or lithium button cells. Some are quite tiny. You will need to open up the watch to identify the type so that a replacement can be obtained.

How you go about doing this will depend on the watch:

1. Screws. If there are visible screws on either the front or rear, then removing these will probably enable the cover to be popped off. These will be teeny tiny star (sort of Philips) head type - use a precision jeweler's screwdriver with a Philips head tip. Immediately put the screws into a pill bottle or film canister - they seem to evaporate on their own.

2. Snap off back. This is probably most common. Look for an indentation around the edge. Using a penknife or other similar relatively sharp edged tool in this indentation or at any convenient spot if there is none. It is best to use the wristband mounting rod as a lever fulcrum if possible. The back should pop off. Note the orientation of the back before you set it aside so that you can get it back the same way.

3. Cover unscrews. The entire back may be mounted in a screw thread around its edge in which case you will have to somehow grab the entire back and rotate counter clockwise. An adjustable wrench with some tape to protect the finish on the watch may work.

If there is an O-ring seal (like on the space shuttle), be careful not to nick or otherwise damage it (you know what happens when these are damaged!).

Once the back is off, you will see a lot of precision stuff - though not nearly as much as in an old fashioned mechanical watch. DON'T TOUCH! You are interested in only one thing - the battery. Sometimes, once the back is off, the button cell will simply drop out as there is no other fastener. In other cases, one or two more teeny tiny screws will hold it in places. Carefully remove these and the button cell. Replace the screws so you will not loose them. Make a note of the orientation of the button cell - it is almost always smooth side out but perhaps not in every case.

Test the battery with a multimeter. The voltage of a fresh battery will be about 1.5 V for an alkaline cell and as high as 3 V for a lithium cell. A watch will typically still work with a battery that has gone down to as little as half its rated voltage.

Replacement batteries can be obtained from Radio Shack, some supermarkets, large drug outlets, electronic distributors, or mail order parts suppliers. Most likely, you will need to cross reference the teeny tiny markings on the old battery - places that sell batteries usually have a replacement guide.

Cost should be about $2.00 for a typical alkaline cell and slightly more for the longer lived lithium variety.

Note: some watches bury the battery inside the works requiring further disassembly. This is usually straightforward but will require additional steps and some added risk of totally screwing it up.

Install and secure the replacement battery and immediately confirm that the display is alive or the second hand is moving. If it is not, double check polarity. Sometimes, the back will need to be in place for proper contact to be made.

********************* PHOTOGRAPHIC EQUIPMENT *********************

Light meters: ------------

First check the batteries (if any). Self powered meters like the old Westons and their clones could also cause damage to the delicate meter movement if the light regulating lid was left open in bright light. Bad connections were also common. I have repaired the meter movements on these but it is not much fun.

Hand held light meters are subject to damage from being dropped.

Problems with internal light meters include bad batteries and corroded battery contacts, dirty or worn potentiometers.

Pocket camera repair: --------------------

It seems that in the last few years, the amount of circuitry crammed into a compact 35 mm camera has grown exponentially. Auto-film-advance, auto- exposure, auto-film speed detection and loading, auto focus, auto-flash selection, auto-red-eye reduction - just about everything that could be put under computer control has been. Next thing you know, the photographer will be replaced with a auto-robot!

For the most part, modern cameras are very reliable. However, when something goes wrong, it is virtually impossible to attempt repair for two reasons:

1. The circuitry is so crammed into a tiny case that access is difficult and convoluted. Many connections are made with relatively fragile flexible printed cables and getting at certain parts means removing a whole bunch of other stuff.

2. Much of the circuitry is surface mount and many custom parts are used. Schematics are nearly impossible to obtain and with all the computer control, probably not that useful in any case. Most parts are not available except from the manufacturer and then possibly only to authorized service centers.

However, some problems can be addressed without resorting to the camera repair shop or dumpster.

If the camera is still under warranty, don't even think about attempting any kind of repair unless it is just a bad battery. Almost certainly, evidence of your efforts will be all too visible - mangled miniature screw heads and damaged plastic seams - at the very least. There are no easy repair solutions. Let the professionals deal with it.

If out of warranty and/or you don't care about it and/or you want an excuse to buy a new camera, then you may be able to fix certain (very limited) types of problems.

Getting inside a pocket camera: -----------------------------

For anything beyond the battery, you will need to get inside. However, before you expend a lot of effort on a hopeless cause consider that unless you see something obvious - a broken connection, bent or dirty switch contact, or a motor or other mechanical part that is stuck, binding, or in need of cleaning and lubrication - there is not a lot you will likely be able to do. One exception is with respect to the electronic flash which is usually relatively self contained and simple enough to be successfully repaired without a schematic.

As with other consumer electronics equipment, getting inside may be a challenge worthy of Sherlock Holmes. In addition to many obvious very tiny screws around the periphery, there may be hidden screws inside the battery compartment and under the hand grip (carefully peel it back if that area is the last holdout). Also see the section: "Getting inside consumer electronic equipment".

This is the time to make careful notes and put all the tiny parts in storage containers as soon as they are removed. If you never follow any of these recommendations for other types of equipment, at least do so for pocket cameras!

Caution: the energy storage capacitor for the electronic flash may be located in an unexpected spot way on the other side of the camera. Accidentally touching its terminals when charged will be unpleasant to say the least. Even if the camera is 'off', some designs maintain this capacitor at full charge. In addition, it may retain a painful charge for days - with the battery removed. Once you get the skins off of the camera (if you ever succeed), identify this capacitor - it will be about the size of a AA battery - and put electrical tape over its terminals.

Pocket camera problems: ----------------------

The following malfunctions may sometimes be successfully dealt with without an army of camera repair technicians at your disposal:

Caution: never open the back of a 35 mm camera anywhere there is light of any kind if there is a chance that there is film inside. If the camera is dead, there may be no way of knowing. Doing this even for an instant may ruin all of the film that has been exposed and two (usually) additional pictures. Opening the back of any other kind of roll film camera will only expose a few frames as the exposed film usually has a backing (120) or is inside a cartridge (110).

If a 35 mm camera failed with a roll of film on which you have taken irreplaceable photographs inside, the pictures can still be saved even if the camera never works again. First, wash your hands thoroughly to remove skin oils. Use a closet with a tightly fitting door (at night is better or stuff something in any cracks to block all light - it must be pitch black) for a darkroom. Open the back of the camera and carefully remove the film cassette. Gently pull the exposed film from the takeup spool (on the shutter release side of the camera). It should unwind easily. Avoid touching the film surface itself with your fingers (the edges are ok). Then, turn the plastic shaft sticking out of the film cassette clockwise to wind the exposed film entirely into the cassette.

(For items (2)-(4), you will need to get inside of the camera. See the section below: "Getting inside a pocket camera".)

1. General erratic or sluggish operation, weak display, camera pooped out during film advance or rewind. Most likely cause: the battery died.

Test the battery and/or try a new one. It is possible that the battery simply decided to go flat at an inconvenient time or that a replacement was defective. If possible, check the voltage on the battery while it is in the camera and the affected operations are performed. If the voltage drops substantially, there could be an overload - a motor that is binding or a shorted component. If the camera had been dropped, a mechanical problem is likely.

2. Flash inoperative or excess current drain - runs down batteries. Other functions may or may not work correctly. Most likely cause: a shorted invertor transistor. The electronic flash or strobe is usually a self contained module near the actual flash window but the energy storage capacitor may be mounted elsewhere - like the opposite side of the case. See the warning below - you could be in for a surprise!

3. Mechanical problems with focus, exposure, film advance, or rewind. Likely causes: binding due to damage from being bumped or dropped, bad or erratic motor operation, gummed up lubrication or dirt, or defective driver or control logic. Locate the motor for each function (right, good luck) and confirm that they spin freely and move the appropriate gears, levers, cogs, wheels, or whatever. If there is any significant resistance to movement, attempt to determine if it is simply a lubrication problem or if something is stuck. Test the motors - see the section: "Small motors in consumer electronic equipment".

4. Auto-film-loading, film advance, or rewind do not operate at all or do not terminate. Most likely cause: defective motor or mechanical problems, dirty, corroded, or faulty sensor switches or bad controller. If there is no action or something seems to get stuck or sounds like it is struggling, check the battery and motor (see (1) and (3) above). Inspect the various microswitches for broken actuators, bent or deformed contacts, or something stuck in them like a bit of film that broke away from the roll. Dirt may be preventing a key contact closure. Sometimes, improper cable routing during manufacture can interfere with the free movement of a leaf type contact.

5, Exposure too light or too dark. Check the film speed setting and/or clean the contact fingers under the cassette that sense the film (ASA or ISO) speed. Clean the light meter sensor. Check the batteries, Look for evidence of problems with the lens iris and/or shutter mechanism. If the shutter speed can be set manually, see the section: "Testing shutter speed".

Testing of camera shutter speed: -------------------------------

If you suspect shutter speed problems, there are several easy ways to measure this for your camera. The most accurate require some test equipment but you can get a pretty good idea with little or no equipment beyond a stopwatch (for slow shutter speeds - above 1/2 to 1 second and a TV (for fast shutter speeds - below about 1/60 of a second (NTSC 525/60).

Some of these approaches assume that you have access to the film plane of the camera - this may be tough with many highly automated compact cameras which will be unhappy unless a roll of film is properly loaded with the back door closed.

Note that the behavior of focal plane and leaf (in-the-lens) shutters is significantly different at high shutter speeds and this affects the the interpretation of measurements.

Some simple homemade equipment will enable testing of the intermediate shutter speeds.

1. Testing slow to medium shutter speeds - the use of a stopwatch is self evident for really long times (greater than .5 second or so). However, viewing or photographing the sweep hand of a mechanical stop watch or a homemade motor driven rotating white spot or LED can provide quite accurate results. Accurate timing motors are inexpensive and readily available. Mount a black disk with a single small white spot at its edge on the motor shaft and mark some graduations around its perimeter on a stationary back board. For a high tech look, use an LED instead. Use your creativity.

Making measurements from the photographic images of the arcs formed by the spot as it rotates while the shutter is open should result in accuracies better than 1 or 2% for shutter speeds comparable to or slower than the rotation frequency of the motor. In other words, shutter speeds down to 1/10th of a second for a 600 rpm (10 rps) motor or down to 1/60th of a second for a 3600 rpm (60 rps) motor.

At these speeds, focal plane and leaf shutters should result in similar results since the open and close times are small compared to the total exposure time.

2. Testing fast shutter speeds - view a TV (B/W is fine) screen on a piece of ground glass at the focal plane or take a series of snapshots of a TV screen (a well adjusted B/W TV is best as the individual scan lines will be visible).

Note: If your camera has a focal plane shutter (e.g., 35 mm SLRs), orient the camera so that the shutter curtain travels across - horizontally (rather than up or down).

If you are photographing the screen, take a few shots at each speed in case the timing of your trigger finger is not quite precise and you cross the vertical blanking period with some of them.

For a focal plane shutter, you will see a bright diagonal bar. (The angle of the bar can be used to estimate the speed of the shutter curtain's traversal.)

For a leaf (in-the-lens) shutter, you will see a bright horizontal bar. but the start and end of the exposure (top and bottom of the bar) will be somewhat fuzzy due to the non-zero time it takes to open and close the shutter leaves. You will have to estimate the locations of the 'full width half maximum' for each speed.

In both cases, there will some additional smearing at the bottom of the bar due to the persistence of the CRT phosphors.

The effective exposure time can then be calculated by multiplying the number of scan lines in the bar at any given horizontal position by 63.5 uS (the NTSC horizontal scan time).

If you cannot resolve individual scan lines, figure that a typical over- scanned (NTSC) TV screen has 420-440 visible lines. If you can adjust your TV (remember this can be an old B/W set when knobs were knobs!) for underscan, about 488 or so active video lines will be visible.

If you have an oscilloscope or electronic counter/timer, fairly accurate measurements can be made at all shutter speeds using a bright light and a photodetector circuit.

3. Using an electronic counter/timer or oscilloscope. Construct the IR detector described in the document: "Notes on the Repair of Hand Held Remote Controls". (Note that the fact that it is called an IR detector is irrelevant since the typical photodiode is sensitive to visible wavelengths of light as well.) Connect its output to your scope or counter. Put a diffuse light source (i.e., light bulb) close to the lens so that it is not in focus. Position the detector photodiode in the center of the focal plane - mount it on a little piece of cardboard that fits on the film guide rails. Using this setup, it should be a simple matter to measure the shutter timing.

For a focal plane shutter, the time response will be the convolution of the photodetector area and the slit in the shutter curtain. The smaller the aperture of the photodiode, the less this will be a factor. Masking it with black tape may be desirable when testing fast shutter speeds. In simple terms, make the photodiode aperture narrow.

For between-the-lens shutters, the finite open and close times of the leaves will show up on the oscilloscope in the rise and fall times of the trace. The measurement on the electronic timer will be affected by its trigger level setting for this reason. However, since this photodetector is not linearly calibrated, the open and close times cannot be accurately determined from the waveform.

Electronic flash fundamentals: ----------------------------

All modern electronic flash units (often called photographic strobes) are based on the same principles of operation whether of the subminiature variety in a disposable pocket camers or high quality 35 mm camera, compact separate hot shoe mounted unit, or the high power high performance unit found in a photo studio 'speed light'. All of these use the triggered discharge of an energy storage capacitor through a special flash tube filled with Xenon gas at low pressure to produce a very short burst of high intensity white light.

The typical electronic flash consists of four parts: (1) power supply, (2) energy storage capacitor, (3) trigger circuit, and (4) flash tube.

An electronic flash works as follows:

1. The energy storage capacitor connected across the flash tube is charged from a 300V (typical) power supply. This is either a battery or AC adapter operated invertor (pocket cameras and compact strobes)

or an AC line operated supply using a power transformer or voltage doubler or tripler (high performance studio 'speed' lights). These are large electrolytic capacitors (200-1000+ uF at 300+ V) designed specifically for the rapid discharge needs of photoflash applications.

2. A 'ready light' indicates when the capacitor is fully charged. Most monitor the voltage on the energy storage capacitor. However, some detect that the invertor or power supply load has decreased indicating full charge.

3. Normally, the flash tube remains non-conductive even when the capacitor is fully charged.

4. A separate small capacitor (e.g., .1 uF) is charged from the same power supply to generate a trigger pulse.

5. Contacts on the camera's shutter close at the instant the shutter is fully open. These cause the charge on the trigger capacitor to be dumped into the primary of a pulse transformer whose secondary is connected to a wire, strip, or the metal reflector in close proximity to the flash tube.

6. The pulse generated by this trigger (typically around 10 KV) is enough to ionize the Xenon gas inside the flash tube.

7. The Xenon gas suddenly becomes a low resistance and the energy storage capacitor discharges through the flash tube resulting in a short duration brilliant white light.

The energy of each flash is roughly equal to 1/2*C*V^^2 in watt-seconds (W-s) where V is the value of the energy storage capacitor's voltage and C is its capacitance in. Not quite all of the energy in the capacitor is used but it is very close. This energy storage capacitor for pocket cameras is typically 200-300 uF at 330 V (charged to 300 V) with a typical flash energy of 10 W-s. For high power strobes, 1000s of uF at higher voltages are common with maximum flash energies of 100 W-s or more. Another important difference is in the cycle time. For pocket cameras it may be several seconds - or much longer as the batteries run down. For a studio 'speed light', fractional second cycle times are common.

Typical flash duration is much less than a millisecond resulting in crystal clear stop action photographs of almost any moving subject.

On cheap cameras (and probably some expensive ones as well) physical contacts on the shutter close the trigger circuit precisely when the shutter is wide open. Better designs use an SCR or other electronic switch so that no high voltage appears at the shutter contacts (or hot shoe connector of the flash unit) and contact deterioration do to high voltage sparking is avoided.

Note that for cameras with focal plane shutters, the maximum shutter speed setting that can be used is typically limited to 1/60-1/120 of a second. The reason is that for higher shutter speeds, the entire picture is not exposed simultaneously by the moving curtains of the focal plane mechanism. Rather, a slit with a width determined the by the effective shutter speed moves in front of the film plane. For example, with a shutter speed setting of 1/1000 of a second, a horizontally moving slit would need to be about 1/10 of an inch wide for a total travel time of 1/60 of a second to cover the entire 1.5 inch wide 35 mm frame. Since the flash duration is extremely short and much much less than the focal plane curtain travel time, only the film behind the slit would be exposed by an electronic flash. For shutter speed settings longer than the travel time, the entire frame is uncovered when the flash is triggered.

See the section: "Photoflash circuit from pocket camera" for the schematic of a typical small battery powered strobe.

Red-eye reduction provides a means of flashing the lamp twice in rapid succession. The idea is that the pupils of the subjects' eyes close somewhat due to the first flash resulting in less red-eye - imaging of the inside of the eyeball - in the actual photograph.

Automatic electronic flashes provide an optical feedback mechanism to sense the amount of light actually reaching the subject. The flash is then aborted in mid stride once the proper exposure has been made. Inexpensive units just short across the flash tube with an SCR triggered by a photosensor. With these units, the same amount of energy is used regardless of how far away the subject is and thus low and high intensity flashes drain the battery by the same amount and require the same cycle time. The excess energy is wasted as heat. More sophisticated units use something like a gate turnoff thyristor to actually interrupt the flash discharge at the proper instant. These use only as much energy as needed and the batteries last much longer since most flash photographs do not require maximum power.

Failure of red-eye reduction or the automatic exposure control circuits will probably require a schematic to troubleshoot unless tests for bad connections or shorted or open components identify specific problems.

Remotely triggered 'fill flashes' use a photocell or photodiode to fire an SCR which emulates the camera shutter switch closure for the flash unit being controlled. There is little to go wrong with these devices.

Problems unique to battery or AC adapter powered electronic flash units:
----

* Power source - dead or weak batteries or defective charging circuit, incorrect or bad AC adapter, worn power switch, or bad connections.

Symptoms: unit is totally dead, intermittent, or excessively long cycle time.

Test and/or replace batteries. Determine if batteries are being charged. Check continuity of power switch or interlock and inspect for corroded battery contacts and bad connections or cold solder joints on the circuit board.

* Power invertor - blown chopper transistor, bad transformer, other defective components.

Symptoms: unit is totally dead or loads down power source when switched on (or at all times with some compact cameras). No high pitched audible whine when charging the capacitor. Regulator failure may result in excess voltage on the flash tube and spontaneous triggering or failure of the energy storage capacitor or other components.

Test main chopper transistor for shorts and opens. This is the most likely failure. There is no easy way to test the transformer and the other components rarely fail. Check for bad connections.

Problems unique to AC line powered electronic flash units: --

WARNING: Line powered units often do not include a power transformer. Therefore, none of the circuitry is isolated from the AC line. Read, understand, and follow the safety guidelines for working on line powered equipment. Use an isolation transformer while troubleshooting. However, realize that this will NOT protect you from the charge on the large high voltage power supply and energy storage capacitors. Take all appropriate precautions.

* Power source - dead outlet or incorrect line voltage.

Symptoms: unit is totally dead, operates poorly, catches fire, or blows up. Spontaneous triggering may be the result of a regulator failure or running on a too high line voltage (if the unit survives).

Test outlet with a lamp or circuit tester. Check line voltage setting on flash unit (if it is not too late!).

* Power supply - bad line cord or power switch, blown fuse, defective rectifiers or capacitors in voltage doubler, defective components, or bad connections.

Symptoms: unit is totally dead or fuse blows. Excessive cycle time.

Test fuse. If blown check for shorted components like rectifiers and capacitors in the power supply. If fuse is ok, test continuity of line cord, power switch, and other input components and wiring. Check rectifiers for opens and the capacitors for opens or reduced value.

Problems common to all electronic flash units: ---

WARNING: the amount of charge contained in the energy storage capacitor may be enough to kill - especially with larger AC line powered flash units and high power studio equipment. Read and follow all safety guidelines with respect to high voltage high power equipment. Discharge the energy storage capacitors fully (see the document: "Capacitors: Testing with a Multimeter and Safe Discharging") and then measure to double check that they are totally flat before touching anything. Don't assume that triggering a flash does this for you! For added insurance, clip a wire across the capacitor terminals while doing any work inside the unit.

* Energy storage capacitor - dried up or shorted, leaky or needs to be 'formed'.

Symptoms: reduced light output and unusually short cycle time may indicate a dried up capacitor. Heavy loading of power source with low frequency or weak audible whine may indicate a shorted capacitor. Excessively long cycle time may mean that the capacitor has too much leakage or needs to be formed.

Test for shorts and value. Substitute another capacitor of similar or smaller uF rating and at least equal voltage rating if available.

Cycling the unit at full power several times should reform a capacitor that has deteriorated due to lack of use. If the flash intensity and cycle time do not return to normal after a dozen or so full intensity flashes, the capacitor may need to be replaced or there may be some other problem with the power supply.

* Trigger circuit - bad trigger capacitor, trigger transformer, SCR (if used), or other components.

Symptoms: energy storage capacitor charges as indicated by the audible invertor whine changing frequency increasing in pitch until ready light comes on (if it does) but pressing shutter release or manual test button has no effect. Spontaneous triggering may be a result of a component breaking down or an intermittent short circuit.

Test for voltage on the trigger capacitor and continuity of the trigger transformer windings. Confirm that the energy storage capacitor is indeed fully charged with a voltmeter.

* Ready light - bad LED or neon bulb, resistor, zener, or bad connections.

Symptoms: flash works normally but no indication from ready light. Or, ready light on all the time or prematurely.

Test for voltage on the LED or neon bulb and work backwards to its voltage supply - either the trigger or energy storage capacitor or invertor trans- former. In the latter case (where load detection is used instead of simple voltage monitoring) there may be AC across the lamp so a DC measurement may be deceptive.)

* Trigger initiator - shutter contacts or cable.

Symptoms: manual test button will fire flash but shutter release has no effect.

Test for shutter contact closure, clean hot shoe contacts (if relevant), inspect and test for bad connections, test or swap cable, clean shutter contacts (right, good luck). Try an alternate way of triggering the flash like a cable instead of a the hot shoe.

* Xenon tube - broken or leaky.

Symptoms: energy storage and trigger capacitors charges to proper voltage but the manual test button does not fire the flash even though you can hear the tick that indicates that the trigger circuit is discharging.

Inspect the flash tube for physical damage. Substitute another similar or somewhat larger (but not smaller) flash tube. A neon bulb can be put across the trigger transformer output and ground to see if it flashes when you press the manual test button shutter release. This won't determine if the trigger voltage high enough but will provide an indication that most of the trigger circuitry is operating.

Electronic flash dead after long time in storage: --

The unit may be totally dead or take so long to charge that you give up.

For rechargeable units, try charging for the recommended time (24 hours if you don't know what it is). Then, check the battery voltage. If it does not indicate full charge (roughly 1.2 x n for NiCds, 2 x n for lead-acid where n is the number of cells), then the battery is likely expired and will need to be replaced.

Even for testing, don't just remove the bad rechargeable batteries - replace them. They may be required to provide filtering for the power supply even when running off the AC line or adapter.

For units with disposable batteries, of course try a fresh set but first thoroughly clean the battery contacts.

See the sections on batteries.

The energy storage capacitor will tend to 'deform' resulting in high leakage and reduced capacity after long non-use. However, I would still expect to be able to hear sound of the invertor while it is attempting to charge.

Where the unit shows no sign of life on batteries or AC, check for dirty switch contacts and bad internal connections. Electrolytic capacitors in the power supply and invertor may have deteriorated as well.

If the unit simply takes a long time to charge, cycling it a dozen times should restore an energy storage capacitor that is has deformed but is salvageable. This is probably safe for the energy storage capacitor as the power source is current limited. However, there is no way of telling if continuous operation with the excessive load of the leaky energy storage capacitor will overheat power supply or invertor components.

Photoflash circuit from pocket camera: -------------------------------------

This schematic was traced from an electronic flash unit removed from an inexpensive pocket camera. Errors in transcription are possible.

Note that the ready light is not in the usual place monitoring the energy storage capacitor voltage. It operates on the principle that once nearly full charge is reached and the invertor is not being heavily loaded, enough drive voltage is available from an auxiliary winding on the invertor transformer to light the LED. It is also interesting that the trigger circuit dumps charge into the trigger capacitor instead of the other way around but the effect is the same.

```
                Invertor                                                               Flashtube
+------------------------------+---------------------+--+--------+---+      |      1 K     Ready LED
 |                 | |       |  |      |  +--/\/\-----+--|<|-----+   |         ______ On |  +-+    +-+   | Batt. _
|        |        |  |        |     \___|     )||(     |  3 V ___  | || +------|--/\/\---+  |        |   __ Off      )||(
 +| 2-AA  _   | ||(2 .4   |    10       | Energy   |  |         )||(     _|_     ___  | || +-------------+      | Storage
|  +-------+---+ ||(    | | |      |  | ||(5 .2   |     |     +|  280 uF  |         |     ||(   ||   |       +---+ || +------+
   |    __|__ 330 V  |    Fire -|      ||(   ||   |      |     ||(1      |     |     _____        | (Shutter) |       +--||   |
 +---+ ||(      |      |      |         |     +-----+   Trigger ||   |          3)||( 142  -|47 uF |      -|        |    |    |
      || _ |       <.1 )||(      _|_ 6.3 |      |         |     \    _|_  Trigger  |_|_|          )||(      ___   V  |      |
| 1 M /    ___ .02 uF      |         +-+ || +-+    |     |      |         |     \     |   400 V     -|       C| 4    6 |   +|
 |      |        |     /    |            |      B|/        |    |     |      |          |     |     |              |    +--| 2SD879
+--------------|<|--+----------------+-----+--------------+    |  |\           |     | HV Rect.       |    |   E|
           |      |                  |    |    +-------------+------|------------------+    |                          |
+-------------------------+
```

Note:

```
     |                              |     ---+--- are connected;    ---|--- and ------- are NOT connected.
|                              |
```

The invertor transformer winding resistances measured with a Radio Shack DMM. Primary resistance was below .1 ohms.

Darkroom timers: ---------------

Developing timers only provide a display or clock face (possibly with an alarm) while enlarging timers include a pair of switched outlets - one for the enlarger and the other for the safe light. These are usually self resetting to permit multiple prints to be made at the same exposure time setting.

Where the device plugged into a controlled outlet does not come on, first make sure these units are operational (i.e., the bulbs of the enlarger and/or safelight are not burned out and that their power switches are in the 'on' position. The problem could also be that one of these devices is defective as well.

Two types of designs are common:

1. Electromechanical - using an AC timing motor and gear train with cam operated switches controlling the output circuits directly or via relays.

If the hands fail to move or it does not reset properly, the timing motor or other mechanical parts may require cleaning and lubrication. The motor may be inoperative due to open or shorted windings. See the sections on "Small Motors". Where the timer appears to work but the controlled outlets (e.g., enlarger and safe light) do not go on or off, check for a loose cam or bent linkages and dirty or worn switch or relay contacts. If the dial fails to reset after the cycle completes, it may be binding or require cleaning and lubrication or a spring may have come loose or broken.

2. Electronic - digital countdown circuits and logic controlling mechanical or solid state relays or triacs.

Where the unit appears dead, test as with AC line powered digital clocks (see the section: "AC powered digital clock problems"). If the buttons have the proper effect and the digits count properly but the external circuits are not switching, then test for problems in the power control circuits. If the unit is erratic or does not properly count or reset, there could be power supply or logic problems.

********************* AC ADAPTERS *********************

AC adapter basics: -----------------

It seems that the world now revolves around AC Adapters or 'Wall Warts' as they tend to be called. There are several basic types. Despite the fact that the plugs to the equipment may be identical THESE CAN GENERALLY NOT BE INTERCHANGED. The type (AC or DC), voltage, current capacity, and polarity are all critical to proper operation of the equipment. Use of an improper adapter or even just reverse polarity can permanently damage or destroy the device. Most equipment is protected against stupidity to a greater or lessor degree but don't count on it.

The most common problems are due to failure of the output cable due to flexing at either the adapter or output plug end. See section below on repair procedure.

1. AC Transformer. All wall warts are often called transformers. However, only if the output is stated to be 'AC' is the device simply a transformer. These typically put out anywhere from 3 to 20 VAC or more at 50 mA to 3 A or more. The most common range from 6-15 VAC at less than an Amp. Typically, the regulation is very poor so that an adapter rated at 12 VAC will typically put out 14 VAC with no load and drop to less than 12 VAC at rated load. To gain agency approval, these need to be protected internally so that there is no fire hazard even if the output is shorted. There may be a fuse or thermal fuse internally located (and inaccessible).

If the output tested inside the adapter (assuming that you can get it open without total destruction - it is secured with screws and is not glued or you are skilled with a hacksaw - measures 0 or very low with no load but plugged into a live outlet, either the transformer has failed or the internal fuse had blown. In either case, it is probably easier to just buy a new adapter but sometimes these can be repaired. Occasionally, it will be as simple as a bad connection inside the adapter. Check the fine wires connected to the AC plug as well as the output connections. There may be a thermal fuse buried under the outer layers of the transformer which may have blown. These can be replaced but locating one may prove quite a challenge.

2. DC Power Pack. In addition to a step down transformer, these include at the very least a rectifier and filter capacitor. There may be additional regulation but most often there is none. Thus, while the output is DC, the powered equipment will almost always include an electronic regulation.

As above, you may find bad connections or a blown fuse or thermal fuse inside the adapter but the most common problems are with the cable.

3. Switching Power Supply. These are complete low power AC-DC converters using a high frequency invertor. Most common applications are laptop computers and camcorders. The output(s) will be fairly well regulated and these will often accept universal power - 90-250 V AC or DC.

Again, cable problems predominate but failures of the switching power supply components are also possible. If the output is dead and you have eliminated the cable as a possible problem or the output is cycling on and off at approximately a 1 second rate, then some part of the switching power supply may be bad. In the first case, it could be a blown fuse, bad startup resistor, shorted/open semiconductors, bad controller, or other components. If the output is cycling, it could be a shorted diode or capacitor, or a bad controller. See the "Notes on the Diagnosis and Repair of Small Switchmode Power Supplies" for more info, especially on safety while servicing these units.

Also see the sections on "Equipment Power Supplies".

AC adapter testing: ------------------

AC adapters that are not the switching type (1 and 2 above) can easily be tested with a VOM or DMM. The voltage you measure (AC or DC) will probably be 10-25% higher than the label specification. If you get no reading, wiggle, squeeze, squish, and otherwise abuse the cord both at the wall wart end and at the device end. You may be able to get it to make momentary contact and confirm that the adapter itself is functioning.

The most common problem is one or both conductors breaking internally at one of the ends due to continuous bending and stretching.

Make sure the outlet is live - try a lamp.

Make sure any voltage selector switch is set to the correct position. Move it back and forth a couple of times to make sure the contacts are clean.

If the voltage readings check out for now, then wiggle the cord as above in any case to make sure the internal wiring is intact - it may be intermittent.

Although it is possible for the adapter to fail in peculiar ways, a satisfactory voltage test should indicate that the adapter is functioning correctly.

AC adapter repair: -----------------

Although the cost of a new adapter is usually modest, repair is often so easy that it makes sense in any case.

The most common problem (and the only one we will deal with here) is the case of a broken wire internal to the cable at either the wall wart or device end due to excessive flexing of the cable.

Usually, the point of the break is just at the end of the rubber cable guard. If you flex the cable, you will probably see that it bends more easily here than elsewhere due to the broken inner conductor. If you are reasonably dextrous, you can cut the cable at this point, strip the wires back far enough to get to the good copper, and solder the ends together. Insulate completely with several layers of electrical tape. Make sure you do not interchange the two wires for DC output adapters! (They are usually marked somehow either with a stripe on the insulator, a thread inside with one of the conductors, or copper and silver colored conductors. Before you cut, make a note of the proper hookup just to be sure. Verify polarity after the repair with a voltmeter.

The same procedure can be followed if the break is at the device plug end but you may be able to buy a replacement plug which has solder or screw terminals rather than attempting to salvage the old one.

Once the repair is complete, test for correct voltage and polarity before connecting the powered equipment.

This repair may not be pretty, but it will work fine, is safe, and will last a long time if done carefully.

If the adapter can be opened - it is assembled with screws rather than being glued together - then you can run the good part of the cable inside and solder directly to the internal terminals. Again, verify the polarity before you plug in your expensive equipment.

Warning: If this is a switching power supply type of adapter, there are dangerous voltages present inside in addition to the actual line connections. Do not touch any parts of the internal circuitry when plugged in and make sure the large filter capacitor is discharged (test with a voltmeter) before touching or doing any work on the circuit board. For more info on switching power supply repair, refer to the Notes on the Diagnosis and Repair of Small Switchmode Power Supplies.

If it is a normal adapter, then the only danger when open are direct connections to the AC plug. Stay clear when it is plugged in.

AC adapter substitution and equipment damage: --

Those voltage and current ratings are there for a reason. You may get away with a lower voltage or current adapter without permanent damage but using a higher voltage adapter is playing Russian Roulette. Even using an adapter from a different device - even with similar ratings, may be risky because there is no real standard. A 12 V adapter from one manufacturer may put out 12 V at all times whereas one from another manufacturer may put out 20 V or more when unloaded.

A variety of types of protection are often incorporated into adapter powered equipment. Sometimes these actually will save the day. Unfortunately, designers cannot anticipate all the creative techniques people use to prove they really do not have a clue of what they are doing.

The worst seems to be where an attempt is made to operate portable devices off of an automotive electrical system. Fireworks are often the result, see below and the section on: "Automotive power".

If you tried an incorrect adapter and the device now does not work there are several possibilities (assuming the adapter survived and this is not the problem):

1. An internal fuse blew. This would be the easiest to repair.

2. A protection diode sacrificed itself. This is usually reverse biased across the input and is supposed to short out the adapter if the polarity is reversed. However, it may have failed shorted particularly if you used a high current adapter (or automotive power).

3. Some really expensive hard to obtain parts blew up. Unfortunately, this outcome is all too common.

I inherited a Sony Discman from a guy who thought he would save a few bucks and make an adapter cord to use it in his car. Not only was the 12-15 volts from the car battery too high but he got it backwards! Blew the DC-DC converter transistor in two despite the built in reverse voltage protection and fried the microcontroller. Needless to say, the player was a loss but the cigarette lighter fuse was happy as a clam!

Moral: those voltage, current, and polarity ratings marked on portable equipment are there for a reason. Voltage rating should not be exceeded, though using a slightly lower voltage adapter will probably cause no harm though performance may suffer. The current rating of the adapter should be at least equal to the printed rating. The polarity, of course, must be correct. If connected backwards with a current limited adapter, there may be no immediate damage depending on the design of the protective circuits. But don't take chances - double check that the polarities match - with a voltmeter if necessary - before you plug it in! Note that even some identically marked adapters put out widely different open circuit voltages. If the unloaded voltage reading is more than 25-30% higher than the marked value, I would be cautious about using the adapter without confirmation that it is acceptable for your equipment. Needless to say, if you experience any strange or unexpected behavior with a new adapter, if any part gets unusually warm, or if there is any unusual odor, unplug it immediately and attempt to identify the cause of the problem.

**************** EQUIPMENT POWER SUPPLIES ****************

AC (plug-in) power supplies: --------------------------

Reread Safety info before tackling any power supply problem in a VCR!

If you equipment uses an AC adapter (wall wart), read the sections on AC adapters first.

Consumer electronic equipment typically uses one of four types of power supplies (There are no doubt others):

1. Power transformer with linear regulator using 78/79XX ICs or discrete components. The power transformer will be large and very near the AC line cord.

2. Power transformer with hybrid regulator like STK5481 or any of its cousins - multioutput with some outputs switched by power on. If it has one of these, check ECG, SK, or NTE, or post to sci.electronics.repair and someone can probably provide the pinout. Again, the power transformer will be large and very near the AC line cord.

3. Small switching power supply. Most common problems: shorted semiconductors, bad capacitors, open fusable resistors. In this case there is usually no large power transformer near the line input but a smaller transformer amidships. This is rare in audio equipment as the switching noise is difficult to keep out of the audio circuits. These are more often found found in some VCRs, TVs, monitors, fax machines, and printers.

Some comments for each type:

1. Troubleshooting is quite straightforward as the components are readily identified and it is easy to trace through from the power transformer, bridge or centertapped full wave rectifiers, regulators, caps, etc.

2. Failures of one or more of the outputs of these hybrid regulators are very common. Use ECG/STK/NTE cross reference to identify the correct output voltages. Test with power switch in both positions. Any discrepancy indicates likely problem. While an excessive load dragging down a voltage is possible, the regulator is the first suspect. Replacement cost is usually under $10.

3. Switching supplies. These are tougher to diagnose, but it is possible without service literature by tracing the circuit and checking for bad semiconductors with an ohmmeter. Common problems - dried up capacitors, shorted semiconductors, and bad solder joints. See 'Notes on Diagnosis and Repair of Small Switchmode Power Supplies' for more detailed information.

Totally dead power supply (non-switching type): --

Don't overlook the possibility of bad solder connections or even a bad line cord or plug. Maybe Fido was hungry.

First, make sure the outlet is live - try a lamp. Even a neon circuit tester is not a 100% guarantee - the outlet may have a high resistance marginal connection.

Check for blown fuses near the line cord input. With the unit unplugged, test for continuity from the AC plug to the fuse, on/off switch and power transformer. With the power switch in the 'on' position, testing across the AC plug should result in a resistance of 1 to 100 ohms depending on the size of the equipment (see the section: "Internal fuse blew during lightening storm (or elephant hit power pole") for typical resistance readings of transformer primary windings.

If the fuse blew and the readings are too low, the transformer primary may be partially or totally shorted. If the resistance is infinite even directly across the primary of the power transformer, it may be open or there may be an open thermal fuse underneath the outer layer of insulation wrapping.

If the fuse blew but resistance is reasonable, try a new fuse of the proper ratings. If this blows instantly, there is still a fault in the power supply or one of its loads. See the section: "About fuses and circuit breakers".

If these check out, then the problem is likely on the secondary side. One or more outputs may be low or missing due to bad regulator components. A secondary winding could be open though is is less common than primary side failure as the wire (in transistorized equipment at least) is much thicker.

Low or missing power supply outputs (non-switching type):

Once the line input and primary circuits have been found to be good (or at have continuity and a resistance that is reasonable, the problems is most likely in the secondary side - fuses, rectifiers, filter capacitors, regulator components, bad connections, excess load due to electronic problems elsewhere.

Depending on the type of equipment, there may be a single output of several outputs from the power supply. A failure of one of these can result in multiple systems problems depending on what parts of the equipment use what supply.

Check for bad fuses in the secondary circuits - test with an ohmmeter. (I once even found an intermittent fuse!) Try a new fuse of the same ratings. If this one blows immediately, there is a fault in the power supply or one of its loads. See the section: "About fuses and circuit breakers". The use of a series current limiting resistor - a low wattage light bulb, for example - may be useful to allow you to make measurements without undo risk of damage and an unlimited supply of fuses.

Locate the large electrolytic filter capacitor(s). These will probably be near the power transformer connections to the circuit board with the power supply components. Test for voltage across each of these with power on. If they are in pairs, this may be a dual polarity supply (+/-, very common in audio equipment). Sometimes, two or more capacitors are simply used to provide a higher uF rating. If you find no voltage on one of these capacitors, trace back to determine if the problem is a rectifier diode, bad connection, or bad secondary winding on the power transformer (the latter is somewhat uncommon as the wire is relatively thick, however).

Dried up electrolytic capacitors will result in excessive ripple leading to hum or reduced headroom in audio outputs and possible regulation problems as well. Test with a scope or multimeter on its AC scale (but not all multimeters have DC blocking capacitors on its AC input and these readings may be confused by the DC level). If ripple is excessive - as a guideline if it is more than 10 to 20% of the DC level - then substitute or jumper across with a good capacitor of similar uF rating and at least the same voltage rating.

If you find voltages that are lower than expected, this could be due to bad filter capacitors, an open diode or connection (one side of a full wave rectifier circuit), or excessive load which may be either in the regulator(s), if any, or driven circuitry.

Disconnect the output of the power supply from its load. If the voltage jumps up dramatically (or the fuse now survives or the series light bulb now goes out or glows dimly), then a short or excess load is likely.

If the behavior does not change substantially, the problem may be in the regulator(s). Transistors, zener diodes, resistors, and other discrete components, and IC regulators like LM317s or 7809s can be tested with an ohmmeter or by substitution. The most common failures are shorts for semiconductors, opens for resistors, and no or low output for ICs.

Where the supply uses a hybrid regulator like an STK5481, confirming proper input and then testing each output is usually sufficient to identify a failure. A defective hybrid regulator will likely provide no or very low output on one or more outputs. Confirm by disconnecting the load. Test with any on/off (logic) control in both states.

Uninterruptible power supplies (UPSs) and power invertors:

Caution: reread safety guidelines as portions of these devices can be nasty.

Note: inexpensive UPSs and invertors generate a squarewave output so don't be surprised at how ugly the waveform appears if you look at it on a scope. This is probably normal. More sophisticated and expensive units may use a modified sinewave - actually a 3 or 5 level discrete approximation to a sinewave (instead of a 2 level squarewave). The highest quality units will generate a true sinewave using high frequency bipolar pulse width modulation. Don't expect to find this in a $100 K-Mart special, however.

A UPS incorporates a battery charger, lead-acid (usually) storage battery, DC-AC invertor, and control and bypass circuitry.

Note that if finding a UPS that provides surge protection is an important consideration, look for one that runs the output off of the battery at all times rather than bypassing the invertor during normal operation. The battery will act as a nearly perfect filter in so far as short term line voltage variations, spikes, and noise, are concerned.

A DC-AC power invertor used to run line powered equipment from an automotive battery or other low voltage source is similar to the internal invertor in a UPS.

For a unit that appears dead (and the power has not been off for more than its rated holdup time and the outlet is live), first, check for a blown fuse - external or internal. Perhaps, someone was attempting to run their microwave oven off of the UPS or invertor!

(See the section on: "Fuse post mortems" to identify likely failure mode.)

If you find one - and it is blown due to a short circuit - then there are likely internal problems like shorted components. However, if it is blown due to a modest overload, the powered equipment may simply be of too high a wattage for the UPS or invertor - or it may be defective.

Failures of a UPS can be due to:

1. Battery charging circuit - if the battery does not appear to be charging even after an extended time, measure across the battery with the unit both unplugged and plugged in. The voltage should jump up some amount with power on - when it is supposed to be charging. Disconnect the battery and try again if there is no action - the battery may be shorted totally. Check for blown fuses, smoked parts, and bad connections.

2. Battery - deteriorated or abused lead acid batteries are very common. If the battery will not charge or hold a charge, battery problems are likely. A UPS (or any kind of lead-acid battery powered equipment) that lies idle for a long time (say a year or two) without power to top off the battery will likely result in a dead - not salvageable - battery due to sulfation. Symptoms will be: voltage on battery climbs to more than 2.5 V per cell when first put on charge and even after a long charging period, the battery has essentially no capacity. If the battery voltage is at its nominal value - even when the invertor should be running from it (and there is no or low output), then there is a problem in the invertor or its connections or there is excess load.

3. Invertor - troubleshooting is similar to that required for a switchmode power supply. Common problems: shorted power semiconductors, open fusable resistors, dried up electrolytic capacitors, and bad connections. See the document: "Notes on the Diagnosis and Repair of Small Switchmode Power Supplies". A visual inspection may reveal parts that have exploded or lost their smoke.

4. Line bypass circuit (if used) - check for problems in the controller or its standby power supply, or power switchover components, and bad connections.

About fuses, IC protectors, and circuit breakers: --

The purpose of fuses and circuit breakers is to protect both the wiring from heating and possible fire due to a short circuit or severe overload and to prevent damage to the equipment due to excess current resulting from a failed component or improper use (i.e., excess volume to loudspeakers).

Fuses use a fine wire or strip (called the element) made from a metal which has enough resistance (more than for copper usually) to be heated by current flow and which melts at a relatively low well defined temperature. When the rated current is exceeded, this element heat up enough to melt (or vaporize). How quickly this happens depends on the extent of the overload and the type of fuse.

Fuses found in consumer electronic equipment are usually cartridge type - 1-1/4" mm x 1/4" or 20 mm x 5 mm, pico fuses that look like green 1/4 W resistors, or other miniature varieties. Typical circuit board markings are F or PR.

IC protectors are just miniature fuses specifically designed to have a very rapid response to prevent damage to sensitive solid state components including intergrated circuits and transistors. These usually are often in TO92 plastic cases but with only 2 leads or little rectangular cases about .1" W x .3" L x .2" H. Test just like a fuse. These may be designated ICP, PR, or F.

Circuit breakers may be thermal, magnetic, or a combination of the two. Small (push button) circuit breakers for electronic equipment are most often thermal - metal heats up due to current flow and breaks the circuit when its temperature exceeds a set value. The mechanism is often the bending action of a bimetal strip or disc - similar to the operation of a thermostat. Flip type circuit breakers are normally magnetic. An electro- magnet pulls on a lever held from tripping by a calibrated spring. These are not usually common in consumer equipment (but are used at the electrical service panel).

At just over the rated current, it may take minutes to break the circuit. At 10 times rated current, the fuse may blow or circuit breaker may open in milliseconds.

The response time of a 'normal' or 'rapid action' fuse or circuit breaker depends on the instantaneous value of the overcurrent.

A 'slow blow' or 'delayed action' fuse or circuit breaker allows instantaneous overload (such as normal motor starting) but will interrupt the circuit quickly for significant extended overloads or short circuits. A large thermal mass delays the temperature rise so that momentary overloads are ignored. The magnetic type breaker adds a viscous damping fluid to slow down the movement of the tripping mechanism.

Fuse post mortems: -----------------

Quite a bit can be inferred from the appearance of a blown fuse if the inside is visible as is the case with a glass cartridge type. One advantage to the use of fuses is that this diagnostic information is often available!

A fuse which has an element that looks intact but tests open may have just become tired with age. Even if the fuse does not blow, continuous cycling at currents approaching its rating or instantaneous overloads results in repeated heating and cooling of the fuse element. It is quite common for the fuse to eventually fail when no actual fault is present.

A fuse where the element is broken in a single or multiple locations blew due to an overload. The current was probably more than twice the fuse's rating but not a dead short.

A fuse with a blackened or silvered discoloration on the glass where the entire element is likely vaporized blew due to a short circuit.

This information can be of use in directly further troubleshooting.

Fuse or circuit breaker replacement: ----------------------------------

As noted, sometimes a fuse will blow for no good reason. Replace fuse, end of story. In this situation, or after the problem is found, what are the rules of safe fuse replacement? It is inconvenient, to say the least, to have to wait a week until the proper fuse arrives or to tromp out to Radio Shack in the middle of the night.

Even with circuit breakers, a short circuit may so damage the contacts or totally melt the device that replacement will be needed.

Four parameters characterizes a fuse or circuit breaker:

1. Current rating - this should not be exceeded (you have heard about not putting pennies in fuse boxes, right?) (The one exception to this rule is if all other testing fails to reveal which component caused the fuse to blow in the first place. Then, and only then, putting a larger fuse in or jumpering across the fuse **just for testing** will allow the faulty component to identify itself by smoking or blowing its top!) A smaller current rating can safely be used but depending on how close the original rating was to the actual current, this may blow immediately.

2. Voltage rating - this is the maximum safe working voltage of the circuit (including any inductive spikes) which the device will safety interrupt. It is safe to use a replacement with equal or high voltage rating.

3, Type - normal, fast blow, slow blow, etc. It is safe to substitute a fuse or circuit breaker with a faster response characteristic but there may be consistent or occasional failure mostly during power-on. The opposite should be avoided as it risks damage to the equipment as semiconductors tend to die quite quickly.

4. Mounting - it is usually quite easy to obtain an identical replacement. However, as long as the other specifications are met, soldering a normal 1-1/4" (3AG) fuse across a 20 mm fuse is perfectly fine, for example.

********************* BATTERIES *********************

Battery technology: -----------------

The desire for portable power seems to be increasing exponentially with the proliferation of notebook and palmtop computers, electronic organizers, PDAs, cellular phones and faxes, pagers, pocket cameras, camcorders and audio cassette recorders, boomboxes - the list is endless.

Two of the hottest areas in engineering these days are in developing higher capacity battery technologies (electrochemical systems) for rechargeable equipment and in the implementation of smart power management (optimal charging and high efficiency power conversion) for portable devices. Lithium and Nickel Metal Hydride are among the more recent additions to the inventory of popular battery technologies. A variety of ICs are now available to implement rapid charging techniques while preserving battery life. Low cost DC-DC convertor designs are capable of generating whatever voltages are required by the equipment at over 90% efficiency

However, most of the devices you are likely to encounter still use pretty basic battery technologies - most commonly throwaway Alkaline and Lithium followed by rechargeable Nickel Cadmium or Lead-Acid. The charging circuits are often very simple and don't really do the best job but it is adequate for many applications.

For more detailed information on all aspects of battery technology, see the articles at:

http://www.paranoia.com/~filipg/HTML/FAQ/BODY/F_Battery.html

There is more on batteries than you ever dreamed of ever needing. The sections below represent just a brief introduction.

Battery basics: --------------

A battery is, strictly speaking, made up of a number of individual cells (most often wired in series to provide multiples of the basic cell voltage for the battery technology - 1.2, 1.5, 2.0, or 3.0 V are most common). However, the term is popularly used even for single cells.

Four types of batteries are typically used in consumer electronic equipment:

1. Alkaline - consisting of one or more primary cells with a nominal terminal voltage of 1.5 V. Examples are AAA, AA, C, D, N, 9V ('transistor'), lantern batteries (6V or more), etc. There are many other available sizes including miniature button cells for specialty applications like clocks, watches, calculators, and cameras. In general recharging of alkaline batteries is not practical due to their chemistry and construction. Exceptions which work (if not entirely consistently as of this writing) are the rechargeable Alkalines (e.g., 'Renewals'). Advantages of alkalines are high capacity and long shelf life. These now dominate the primary battery marketplace largely replacing the original carbon-zinc and heavy duty types. Note that under most conditions, it not necessary to store alkaline batteries in the 'fridge to obtain maximum shelf life.

2. Lithium - these primary cells have a much higher capacity than alkalines. The terminal voltage is around 3 volts per cell. These are often used in cameras where their high cost is offset by the convenience of long life and compact size. Lithium batteries in common sizes like 9V are beginning to appear. In general, I would not recommend the use of lithiums for use in applications where a device can be accidentally left on - particularly with kids' toys. Your batteries will be drained overnight whether a cheap carbon zinc or a costly lithium. However, for smoke alarms, the lithium 9V battery (assuming they hold up to their longevity claims) is ideal as a 5-10 year service life without attention can be expected.

3. Nickel Cadmium (NiCd) - these are the most common type of rechargeable battery technology use in small electronic devices. They are available in all the poplar sizes. However, their terminal voltage is only 1.2 V per cell compared to 1.5 V per cell for alkalines (unloaded). This is not the whole story, however, as NiCds terminal voltage holds up better under load and as they are discharged. Manufacturers claim 500-1000 charge-discharge cycles but expect to achieve these optimistic ratings only under certain types of applications. In particular it is usually recommended that NiCds should not be discharged below about 1 V per cell and should not be left in a discharged state for too long. Overcharging is also an enemy of NiCds and will reduce their ultimate life. An electric shaver is an example of a device that will approach this cycle life as it is used until the battery starts to poop out and then immediately put on charge. If a device is used and then neglected (like a seldom used printing calculator), don't be surprised to find that the NiCd battery will not charge or will not hold a charge next time the calculator is used.

4. Lead Acid - similar to the type used in your automobile but generally specially designed in a sealed package which cannot leak acid under most conditions. These come in a wide variety of capacities but not in standard sizes like AA or D. They are used in some camcorders, flashlights, CD players, security systems, emergency lighting, and many other applications. Nominal terminal voltage is 2.0 V per cell. These batteries definitely do not like to be left in a discharged condition (even more so than NiCds) and will quickly become unusable if left that way for any length of time.

Battery chargers: ----------------

Each type of battery requires a different type of charging technique.

1. NiCd batteries are charged with a controlled (usually constant) current. Fast charge may be performed at as high as a .5-1C rate for the types of batteries in portable tools and laptop computers. (C here is the amp-hour capacity of the battery. A .5C charge rate for a 2 amp hour battery pack would use a current equal to 1 A, for example.) Trickle charge at a 1/20-1/10C rate. Sophisticated charges will use a variety of techniques to sense end-of-charge. Inexpensive chargers (and the type in many cheap consumer electronics devices) simply trickle charge at a constant current. Rapid chargers for portable tools, laptop computers, and camcorders, do at least sense the temperature rise which is one indication of having reached full charge but this is far from totally reliable and some damage is probably unavoidable as some cells reach full charge before others due to slight unavoidable differences in capacity. Better charging techniques depend on sensing the slight voltage drop that occurs when full charge is reached but even this can be deceptive. The best power management techniques use a

combination of sensing and precise control of charge to each cell, knowledge about the battery's characteristics, and state of charge.

Problems with simple NiCd battery chargers are usually pretty easy to find - bad transformer, rectifiers, capacitors, possibly a regulator. Where temperature sensing is used, the sensor in the battery pack may be defective and there may be problems in the control circuits as well. However, more sophisticated power management systems controlled by microprocessors or custom ICs and may be impossible to troubleshoot for anything beyond obviously bad parts or bad connections.

2. Lead acid batteries are charged with a current limited but voltage cutoff technique. Although the terminal voltage of a lead-acid battery is 2.00 V per cell nominal, it may actually reach more than 2.5 V per cell while charging. For an automotive battery, 15 V is still within the normal range of voltages to be found on the battery terminals when the engine (and alternator) are running.

A simple charger for a lead acid battery is simply a stepped down rectified AC source with some resistance to provide current limiting. The current will naturally taper off as the battery voltage approaches the peaks of the charging waveform. This is how inexpensive automotive battery chargers are constructed. For small sealed lead acid batteries, an IC regulator may be used to provide current limited constant voltage charging. A 1 A (max) charger for a 12 V battery may use an LM317, 3 resistors, and two capacitors, running off of a 15 V or greater input supply.

Problems with lead acid battery chargers are usually pretty easy to diagnose due to the simplicity of most designs.

Substituting NiCds for Alkalines: --------------------------------

First note that rechargeable batteries are NOT suitable for safety critical applications like smoke detectors unless they are used only as emergency power fail backup (the smoke detector is also plugged into the AC line) and are on continuous trickle charge). NiCds self discharge (with no load) at a rate which will cause them to go dead in a month or two.

For many toys and games, portable phones, tape players and CD players, and boomboxes, TVs, palmtop computers, and other battery gobbling gadgets, it may be possible to substitute rechargeable batteries for disposable primary batteries. However, NiCds have a lower terminal voltage - 1.2V vs. 1.5V - and some devices will just not be happy. In particular, tape players may not work well due to this reduced voltage not being able to power the motor at a constant correct speed. Manufacturers may specifically warn against their use. Flashlights will not be as bright unless the light bulb is also replaced with a lower voltage type. Other equipment may perform poorly or fail to operate entirely on NiCds. When in doubt, check your instruction manual.

NiCd batteries and the infamous 'memory effect': --

Whether the NiCd 'memory effect' is fact or fiction seems to depend on one's point of view and anecdotal evidence. What most people think is due to the memory effect is more accurately described as voltage depression - reduced voltage (and therefore, reduced power and capacity) during use.

(The next section is from: Bob Myers (myers@fc.hp.com) and are based on a GE technical note on NiCd batteries.)

The following are the most common causes of application problems wrongly attributed to 'memory':

1. Cutoff voltage too high - basically, since NiCds have such a flat voltage vs. discharge characteristic, using voltage sensing to determine when the battery is nearly empty can be tricky; an improper setting coupled with a slight voltage depression can cause many products to call a battery "dead" even when nearly the full capacity remains usable (albeit at a slightly reduced voltage).

2. High temperature conditions - NiCds suffer under high-temp conditions; such environments reduce both the charge that will be accepted by the cells when charging, and the voltage across the battery when charged (and the latter, of course, ties back into the above problem).

3. Voltage depression due to long-term overcharge - Self-explanatory. NiCds can drop 0.1-0.15 V/cell if exposed to a long-term (i.e., a period of months) overcharge. Such an overcharge is not unheard-of in consumer gear, especially if the user gets in the habit of leaving the unit in a charger of simplistic design (but which was intended to provide enough current for a relatively rapid charge). As a precaution, I do NOT leave any of my NiCd gear on a charger longer than the recommended time UNLESS the charger is specifically designed for long-term "trickle charging", and explicitly identified as such by the manufacturer.

4. There are a number of other possible causes listed in a "miscellaneous" category; these include -

* Operation below 0 degrees C. * High discharge rates (above 5C) if not specifically designed for such use. * Inadequate charging time or a defective charger. * One or more defective or worn-out cells. They do not last forever.

To close with a quote from the GE note:

"To recap, we can say that true 'memory' is exceedingly rare. When we see poor battery performance attributed to 'memory', it is almost always certain to be a correctable application problem. Of the...problems noted above, Voltage Depression is the one most often mistaken for 'memory'.....

This information should dispel many of the myths that exaggerate the idea of a 'memory' phenomenon."

Care and feeding of NiCds: -------------------------

Here are six guidelines to follow which will hopefully avoid voltage depression or the memory effect or whatever:

(Portions of the following guidelines are from the NiCd FAQ written by: Ken A. Nishimura (KO6AF))

1. DON'T deliberately discharge the batteries to avoid memory. You risk reverse charging one or more cell which is a sure way of killing them.

2. DO let the cells discharge to 1.0V/cell on occasion through normal use.

3. DON'T leave the cells on trickle charge for long times, unless voltage depression can be tolerated.

4. DO protect the cells from high temperature both in charging and storage.

5. DON'T overcharge the cells. Use a good charging technique. With most inexpensive equipment, the charging circuits are not intelligent and will not terminate properly - only charge for as long as recommended in the user manual.

6. DO choose cells wisely. Sponge/foam plates will not tolerate high charge/discharge currents as well as sintered plate. Of course, it is rare that this choice exists.

Author's note: I refuse to get involved in the flame wars with respect to NiCd battery myths and legends --- sam.

Zapping NiCds to clear shorted cells: ----------------------------------

Nickel-Cadmium batteries that have shorted cells can sometimes be rejuvenated - at least temporarily - by a procedure affectionately called 'zapping'.

The cause of these bad NiCd cells is the formation of conductive filaments called whiskers or dendrites that pierce the separator and short the positive and negative electrodes of the cell. The result is either a cell that will not take a charge at all or which self discharges in a very short time. A high current pulse can sometimes vaporize the filament and clear the short.

The result may be reliable particularly if the battery is under constant charge (float service) and/or is never discharged fully. Since there are still holes in the separator, repeated shorts are quite likely especially if the battery is discharged fully which seems to promote filament formation,

I have used zapping with long term reliability (with the restrictions identified above) on NiCds for shavers, Dust Busters, portable phones, and calculators.

WARNING: There is some danger in the following procedures as heat is generated. The cell may explode! Take appropriate precautions and don't overdo it. If the first few attempts do not work, dump the battery pack.

ATTEMPT ZAPPING AT YOUR OWN RISK!!!!

You will need a DC power supply and a large capacitor - one of those 70,000 uF 40 V types used for filtering in multimegawatt geek type automotive audio systems, for example. A smaller capacitor can be tried as well.

Alternatively, a you can use a 50-100 A 5 volt power supply that doesn't mind (or is protected against) being overloaded or shorted.

Some people recommend the use of a car battery for NiCd zapping. DO NOT be tempted - there is nearly unlimited current available and you could end with a disaster including the possible destruction of that battery, your NiCd, you, and anything else that is in the vicinity.

OK, you have read the warnings:

Remove the battery pack from the equipment. Gain access to the shorted cell(s) by removing the outer covering or case of the battery pack and test the individual cells with a multimeter. Since you likely tried charging the pack, the good cells will be around 1.2 V and the shorted cells will be exactly 0 V. You must perform the zapping directly across each shorted cell for best results.

Connect a pair of heavy duty clip leads - #12 wire would be fine - directly across the first shorted cell. Clip your multimeter across the cell as well to monitor the operation. Put it on a high enough scale such that the full voltage of your power supply or capacitor won't cause any damage to the multimeter.

WEAR YOUR EYE PROTECTION!!!

1. Using the large capacitor:

Charge the capacitor from a current limited 12-24 V DC power supply.

Momentarily touch the leads connected across the shorted cell to the charged capacitor. There will be sparks. The voltage on the cell may spike to a high value - up to the charged voltage level on the capacitor. The capacitor will discharge almost instantly.

2. Using the high current power supply:

Turn on the supply.

Momentarily touch the leads connected across the shorted cell to the power supply output. There will be sparks. DO NOT maintain contact for more than a couple of seconds. The NiCd may get warm! While the power supply is connected, the voltage on the cell may rise to anywhere up to the supply voltage.

Now check the voltage on the (hopefully previously) shorted cell.

If the filaments have blown, the voltage on the cell should have jumped to anywhere from a few hundred millivolts to the normal 1 V of a charged NiCd cell. If there is no change or if the voltage almost immediately decays back to zero, you can try zapping couple more times but beyond this is probably not productive.

If the voltage has increased and is relatively stable, immediately continue charging the repaired cell at the maximum SAFE rate specified for the battery pack. Note: if the other cells of the battery pack are fully charged as is likely if you had attempted to charge the pack, don't put the entire pack on high current charge as this will damage the other cells through overcharging.

One easy way is to use your power supply with a current limiting resistor connected just to the cell you just zapped. A 1/4 C rate should be safe and effective but avoid overcharging. Then trickle charge at the 1/10 C rate for several hours. (C here is the amp-hour capacity of the cell. Therefore, a 1/10 C rate for a 600 mA NiCd is 50 mA.)

This works better on small cells like AAs than on C or D cells since the zapping current requirement is lower. Also, it seems to be nearly impossible to reliably restore the quick charge type battery packs in portable tools and laptop computers that have developed shorted cells.

Problems with battery operated equipment: ---------------------------------------

For primary batteries like Alkalines, first try a fresh set. For NiCds, test across the battery pack after charging overnight (or as recommended by the manufacturer of the equipment). The voltage should be 1.2 x n V where n is the number of cells in the pack. If it is much lower - off by a multiple of 1.2 V, one or more cells is shorted and will need to be replaced or you can attempt zapping it to restore the shorted cells. See the section: "Zapping NiCds to clear shorted cells". Attempt at your own risk!

If the voltage drops when the device is turned on or the batteries are installed - and the batteries are known to be good - then an overload may be pulling the voltage down.

Assuming the battery is putting out the proper voltage, then a number of causes are possible:

1. Corroded contacts or bad connections in the battery holder.

2. Bad connections or broken wires inside the device.

3. Faulty regulator in the internal power supply circuits. Test semiconductors and IC regulators.

4. Faulty DC-DC invertor components. Test semiconductors and other components.

5. Defective on/off switch (!!) or logic problem in power control.

6. Other problems in the internal circuitry.

Battery juice and corroded contacts: ----------------------------------

Unless you have just arrived from the other side of the galaxy (where such problems do not exist), you know that so-called 'leak-proof' batteries sometimes leak. This is a lot less common with modern technologies than with the carbon-zinc cells of the good old days, but still can happen. It is always good advice to remove batteries from equipment when it is not being used for an extended period of time. Dead batteries also seem to be more prone to leakage than fresh ones (in some cases because the casing material is depleted in the chemical reaction which generates electricity and thus gets thinner or develops actual holes).

In most cases, the actual stuff that leaks from a battery is not 'battery acid' but rather some other chemical. For example, alkaline batteries are so called because their electrolyte is an alkaline material - just the opposite in reactivity from an acid. Usually it is not particularly reactive (but isn't something you would want to eat).

The exception is the lead-acid type where the liquid inside is sulfuric acid of varying degrees of strength depending on charge. This is nasty and should be neutralized with an alkaline material like baking soda before being cleaned up. Fortunately, these sealed lead-acid battery packs rarely leak (though I did find one with a scary looking bulging case, probably due to overcharging - got rid of that is a hurry).

Scrape dried up battery juice from the battery compartment and contacts with a plastic or wooden stick and/or wipe any liquid up first with a dry paper towel. Then use a damp paper towel to pick up as much residue as possible. Dispose of the dirty towels promptly.

If the contacts are corroded, use fine sandpaper or a small file to remove the corrosion and brighten the metal. Do not an emery board or emery paper or steel wool as any of these will leave conductive particles behind which will be difficult to remove. If the contacts are eaten through entirely, you will have to improvise alternate contacts or obtain replacements. Sometimes the corrosion extends to the solder and circuit board traces as well and some additional repairs may be needed - possible requiring disassembly to gain access to the wiring.

Automotive power: ----------------

While it is tempting to want to use your car's battery as a power source for small portable appliances, audio equipment, and laptop computers, beware: the power available from your car's electrical system is not pretty. The voltage can vary from 9 (0 for a dead battery) to 15 V under normal conditions and much higher spikes or excursions are possible. Unless the equipment is designed specifically for such power, you are taking a serious risk that it will be damaged or blown away.

Furthermore, there is essentially unlimited current available from the battery (cigarette lighter) - 20 A or more. This will instantly turn your expensive CD player to toast should you get the connections wrong. No amount of internal protection can protect equipment from fools.

My recommendation for laptop computers is to use a commercially available DC-AC invertor with the laptop's normal AC power pack. This is not the most efficient but is the safest and should maintain the laptop's warranty should something go wrong. For CD players and other audio equipment, only use approved automotive adapters.

********************* MOTORS AND RELAYS *********************

Small motors in consumer electronic equipment: ---

A variety of motor types are found in audio and other electronic equipment. For the additional information on the specific types of motors used in VCRs and CD players, see the documents for these types of equipment.

Types of motors:

1. Small brush-type permanent magnet (PM) DC motors similar to those found in battery operated appliances. Such motors are used in cassette decks and boomboxes, answering machines, motorized toys, CD players and CDROM drives, and VCRs. Where speed is critical, these may include an internal mechanical governor or electronic regulator. In some cases there will be an auxiliary tachometer winding for speed control feedback.

These are usually quite reliable but can develop shorted or open windings, a dirty commutator, gummed up lubrication, or dry or worn bearings. Replacement is best but mechanical repair (lubrication, cleaning) is sometimes possible. Also see the sections on tape speed problems.

Additional info on these types of motors can be found in "Notes on CD Technology and the Repair of CD Players and CDROM Drives".

2. A low profile or 'pancake' brushless DC motor may provide power for a in some Walkman type tape players, direct drive capstans and general power in VCRs or tape decks. Since these are electronically controlled, any non-mechanical failures are difficult to diagnose. In some cases, electronic component malfunction can be identified and remedied.

3. AC induction motors - shaded pole or synchronous type used in inexpensive turntables. These motors are extremely reliable and are easy to disassemble, clean, and lubricate. Just do not lose any of the spacer washers on each end of the shaft and make notes to assure proper reassembly.

4. Miniature synchronous motors used in mechanical clock drives as found in older clock radios or electric clocks powered from the AC line, appliance controllers, and refrigerator defrost timers. These assemblies include a gear train either sealed inside the motor or external to it. If the motor does not start up, it is probably due to dried gummed up lubrication. Getting inside can be a joy but it is usually possible to pop the cover and get at the rotor shaft (which is usually where the lubrication is needed). However, the tiny pinion gear may need to be removed to get at both ends of the rotor shaft and bearings.

Motor noise in audio equipment: ------------------------------

Of course you expect your audio equipment to be absolutely silent unless told to perform. Motor noise should not be objectionable. However, what if it is? There are several kinds of noise: rotating noise, vibration, and electrical interference:

If the noise is related to the rotating motor shaft, try lubricating the motor (or other suspect) bearings - a single drop of electric motor oil, sewing machine oil, or other light oil (NOT WD40 - it is not a suitable lubricant), to the bearings (at each end for the motor). This may help at least as a temporary fix. In some cases, using a slightly heavier oil will help with a worn bearing. See the section: "Lubrication of electronic equipment".

For AC motors in particular, steel laminations or the motor's mounting may be loose resulting in a buzz or hum. Tightening a screw or two may quiet it down. Painting the laminations with varnish suitable for electrical equipment may be needed in extreme cases. Sometimes, the noise may actually be a result of a nearby metal shield or other chassis hardware that is being vibrated by the motor's magnetic field. A strategically placed shim or piece of masking tape may work wonders.

If the noise - a buzz or whine - is actually coming from the audio output but only occurs with the motor running, the interference filter on the motor power supply may have failed. This is often just a capacitor across the motor terminals and it may be defective or there may be a bad connection.

Finding a replacement motor: ---------------------------

In many cases, motors are fairly standardized and you may be able to find a generic replacement much more cheaply than the original manufacturer's part. However, the replacement must match the following:

1. Mechanical - you must be able to mount it. In most cases, this really does mean an exact drop-in. Sometimes, a slightly longer shaft or mounting hole out of place can be tolerated. The pulley or other drive bushing, if any, must be able to be mounted on the new motor's shaft. If this is a press fit on the old motor, take extreme care so as not to damage this part when removing it (even if this means destroying the old motor in the process - it is garbage anyway).

2. Electrical - the voltage and current ratings must be similar.

3. Rotation direction - with conventional DC motors, this may be reversible by changing polarity of the voltage source. With AC motors, turning the stator around with respect to the rotor will reverse rotation direction. However, some motors have a fixed direction of rotation which cannot be altered.

4. Speed - for tape players and turntables - this may not be feedback controlled. With a little care you should be able to determine the normal rpms of the motor. For example, with a cassette deck, knowing the tape speed (1-7/8" inches per second is standard), it is straightforward calculate the motor shaft speed based on simple measurements of pulley and capstan diameter ratios.

MCM Electronics, Dalbani, and Premium Parts stock a variety of generic replacement motors for tape decks, Walkmen, boomboxes, and CD players.

Relay basics: ------------

The ubiquitous electromechanical relay is a device that is used in a large variety of applications to switch power as well as signals in electrical and electronic equipment. Operation is quite simple: An electromagnet powered by an AC or DC coil pulls on an armature having a set of moving contacts which make or break a connection with a set of stationary contacts.

Most common relays can be characterized by three sets of parameters:

1. Coil - voltage; resistance, current, or power consumption; and whether it is AC or DC. For AC coils only, the VA (volt-amps) rating may be used instead of or in addition to power consumption due to the inductive coil. Typical coil voltages range from 5 V to 480 V (AC or DC) - and beyond. Current and power consumption depend on the size of the relay.

2. Contact configuration - number of sets of contacts and whether they are their type. The designation will be something like SPST-NO, DPDT, 4PST-NC, 6PDT, etc. The first two letters refers to the number of sets of simultaneously activated contacts (S=1, D=2, numbers are usually used for more than 2 sets of contacts). The second two letters refers to the contact configuration (ST=NO or NC but no common terminal, DT will have a common - there will be both an NO and NC terminal). Where contacts are ST, the last two letters indicate NO or NC. An almost unlimited number of variations are possible. Typical relays have anywhere from 1 to 6 or more separate sets of ST or DT contacts or a mixture of the two.

3. Contact ratings - this may be specified for a number of types of applications. For example: in amperes at a particular voltage for DC resistive loads, or in horsepower at various voltages for AC inductive loads. Like fuse ratings, these are maximum ratings and lower values are almost always acceptable. Small relays may be able to switch only a few hundred mA at 32 V while large industrial contactors can switch 1000s of A at 1000s of V. Even the contactor in your automobile's starter must control hundreds of amps to the starter motor.

The common (C) contacts connect to the normally closed (NC) contacts when the coil is unpowered and to the normally open (NO) contacts when the coil is powered.

Miniature and subminiature relays are used to switch phone line signals in modems, fax machines, and telephone answering machines; audio amplifier speaker protection circuits; multiscan monitor deflection components; and many other places.

Small relays control power in lighting equipment, TVs and other home appliances, automotive systems and accessories, and the like.

Large relays (often called contactors) are used for the control of central air conditioning systems (compressor and blower motors), all types and sizes of industrial machinery - as well as in the starter of your automobile.

Relay identification: --------------------

A relay without a pin connection diagram can usually be identified with a multimeter and variable power supply - or by eye. Many have the critical information printed on the cover. However, for detailed specifications, referring to the manufacturer's databook (or WEB page) really is best!

(The following assumes a subminiature (DIP) relay. Lower coil resistances, higher coil voltages, and other variations may exist for larger relays.)

1. If the case of the relay is transparent or you can pop the top, examine the pole piece of the electromagnet. If there is a (copper) ring around half the pole piece, the relay coil is designed for AC (usually line frequency - 50 or 60 Hz) operation. An AC relay operated on DC will overheat very quickly but can be tested on DC.

2. Determine the coil pins. Use your eyeball if possible or your multimeter on the low resistance scale. For a small relay, the coil will most likely be a few hundred ohms. All other combinations of pins will be zero or infinity. If the resistance is under, say, 100 ohms, you may have an AC coil rather than a DC coil.

3. Power the relay from a variable DC supply (I am assuming it has a DC coil which is likely for a DIP relay. You can still do this with an AC coil but it will heat up quickly). Start at zero and increase the voltage until you hear the contacts close. This will probably be at around 3 volts (for a 5 V coil) or 8 volts for a 12 V coil - this will be roughly 60% of nominal coil voltage. If you do not hear anything, reverse the polarity of the coil and try again - you may have a latching relay. Alternatively, put your multimeter on the resistance scale across one of the pairs of pins that measured zero ohms as it is likely to be a NC set of contacts. This will change to infinity ohms when the relay switches.

4. Now that you can switch the relay on and off, you can use your multimeter on the resistance scale to determine which contacts are normally open (NO) and which contacts are normally closed (NC). (Normally here means unpowered.)

5, The power rating of the contacts can be estimated by their diameter (if they are visible). Rough current estimates (resistive loads): 20 A - 5 mm, 10 A - 3 mm, 5 A - 2 mm, 1 A - 1 mm. These must be derated substantially for inductive loads.

For latching relays, the polarity of the coil voltage determines whether the relay is switched on or off. In other words, to switch to the opposite state requires the polarity of the voltage to the coil to be reversed. Other types are possible but not very common.

Relay testing and repair: ------------------------

If the relay is totally inoperative, test for voltage to the coil. If the voltage is correct, the relay may have an open coil. If the voltage is low or zero, the coil may be shorted or the driving circuit may be defective. If the relay makes a normal switching sound but does not correctly control its output connections, the contacts may be corroded, dirty, worn, welded closed, binding, or there may be other mechanical problems.

Remove the relay from the circuit (if possible) and measure the coil resistance. Compare your reading with the marked or specified value and/or compare with a known working relay of the same type. An open coil is obviously defective but sometimes the break is right at the terminal connections and can be repaired easily. If you can gain access by removing the cover, a visual examination will confirm this. If the resistance is too low, some of the windings are probably shorted. This will result in overheating as well as no or erratic operation. Replacement will be required.

Relay contacts start out bright and shiny. As they are used, arcing, dirt, and wear take their toll. A sealed relay used at well below its rated current with a resistive load may work reliably for millions of cycles. However, this will be significantly reduced when switching high currents - especially with inductive loads which results in contact arcing. One speck of dirt can prevent a contact from closing so cleanliness is important. Excessive arcing can result in the contacts getting welded together as well.

The resistance of closed contacts on a relay that is in good condition should be very low - probably below the measurable limits on a typical multimeter - a few milliohms. If you measure significant or erratic resistance for the closed contacts as the relay is switched or if very gentle tapping results in erratic resistance changes, the contacts are probably dirty, corroded, or worn. If you can get at the contacts, the use of contact cleaner first and a piece of paper pulled back and forth through the closed contacts may help. Superfine sandpaper may be used as a last resort but this is only a short term fix. The relay will most likely need to be replaced if the contacts are switching any substantial power.

**************** GENERAL EQUIPMENT ****************

IC and hybrid power audio amplifiers: -----------------------------------

(Note: troubleshooting of large audio amplifiers constructed with discrete output stages is left to a separate document.)

The audio amplifiers found in small radios, Walkmen, portable cassette recorders, and other low power devices are often single chips with few external components. Obtain a pin diagram, test inputs and output(s) with an audio signal tracer and/or oscilloscope. A dead output where inputs and power are present usually indicate a defective IC - as does one that becomes excessively hot - assuming that the output is not overloaded.

Larger audio amplifiers may use ICs (up to 10 or 20 W) or hybrid modules (up to 100 W per channel and beyond). Purists may argue about the quality of the sound from these compared to discrete component designs but they are being used in many designs - at most price points (except perhaps the stratosphere of audiophile land).

Hybrids modules (called 'blocks' or 'bricks' by some) may be totally self contained requiring just power and line level inputs or may be just the final stage in an overall system including external amplifier circuitry which is effectively a power op amp - high gain with negative feedback. Failure of these bricks is quite common.

Note that testing of these op amp designs - whether discrete or brick based - can be very confusing due to the high gain and feedback. Intermediate signals in a working channel may look like power supply ripple and noise. In a dead channel these same points may appear to be normal or highly distorted audio depending on which stage you test. In addition, since extensive negative feedback is used, power supply ripple and noise is much less important significant and there may be substantial amounts of both in a normally operating amplifier.

With stereo amplifiers, it is normally safe - and most effective - to swap components between the working and dead channels as long as you are sure there is no short circuit on the output. This is by far the quickest way to confirm a dead brick. (I would be a lot more reluctant to make this recommendation for a large audio amplifier constructed with discrete transistors in the final power stage as multiple cascade failures are possibly and likely if **all** defective parts are not located before power is reapplied.)

Noisy or intermittent switches and controls: --

Symptoms include audible noise when rotating knobs, erratic operation of mode selectors, random changes in volume, switches, or controls that need to be jiggled or tapped to make them cooperate.

The causes are likely to be either dirt or wear.

First, try a spray control/contact cleaner - even the stuff from Radio Shack may make a remarkable difference iff (1) dirt is the problem and (2) you can get the cleaner inside the troublesome part.

Some types of contact and control cleaners can be used safely with low voltage circuits while they are powered but not always - read the label directions. Select a product that specifically states that is it safe for switches and controls.

Use the extension tube that comes with the spray can and snake it into or near any visible access holes. Operate the control or switch to help the cleaning action. Don't overdoe it - if you get to the right spot, a little is all that is needed.

Resist the urge to use sandpaper or steelwool (ack!) on switch or connector contacts. However, pulling a piece paper through a set of contacts or the occasional gentle use of a soft pencil eraser (e.g., Pink Pearl) may be helpful.

If this does not help - or only helps short term - the part may be worn. Sometimes, repair is possible (a slide switch with contacts that have loosened with use, for example) but replacement is better - if you can find an exact or suitably close match. See the section: "Interchangeability of components".

General intermittent or erratic behavior: ---------------------------------------

Any intermittent problems that cause random sudden changes in performance are likely due to bad connections, internal connectors that need to be cleaned and reseated, or dirty switches and controls. First, see the section: "Noisy or intermittent switches and controls".

Bad solder joints are very common in consumer electronic equipment due both to poor quality manufacturing where cost reduction may be the most important consideration. In addition solder connections deteriorate after numerous thermal cycles, vibration, and physical abuse. Circuit board connections to large hot parts or parts that may have mechanical stress applied to them are most likely be suffer from hairline solder fractures (often called 'cold solder joints' when they result from poor quality soldering at the time of manufacture). However, since the solder is often the only thing anchoring these components, mechanical stress can eventually crack the solder bond as well.

To locate cold solder joints, use a strong light and magnifier and examine the pins of large components and components that are subject to physical stress (like headphone jacks and power connectors) for hairline cracks in the solder around the pin. Gently wiggle the component if possible (with the power off). Any detectable movement at the joint indicates a problem. A just perceptible hairline crack around the pin is also an indication of a defective solder connection. With the power on, gently prod the circuit board and suspect components with an insulated tool to see if the problem can be effected.

When in doubt, resolder any suspicious connections. Some device may use double sided circuit boards which do not have plated through holes. In these cases, solder both top and bottom to be sure that the connections are solid. Use a large enough soldering iron to assure that your solder connection is solid. Put a bit of new solder with flux on every connection you touch up even if there was plenty of solder there before.

In addition to soldering problems, check for loose or corroded screw type ground (or other) terminals, and internal connectors that need to be cleaned and reseated.

Need to turn up volume to get sound to come on: ---

If at times, it is necessary to turn the volume way up or possibly to tap or whack the unit to get the sound in one or both channels to come on when the unit is first powered up, the speaker protection relay could be faulty. Receivers and audio amplifiers often include a set of relay contacts in series with each output to protect the loudspeakers from power-on and power-off transients as well as damage due to a fault in the audio circuits. However, these contacts may deteriorate after awhile resulting in intermittent sound.

While this set of symptoms could be the result of general bad connections or even dirty controls or switches, the relay is often at fault. This is exacerbated by switching the unit on and off at high volume levels as well as this may cause contact arcing.

To determine if the relay is at fault, either test it as outlined in the section: "Relay testing" or with the unit on, very gently tap the relay to see if the sound comes as goes. If the relay is bad, you can try cleaning its contacts or replace with one that has similar electrical specifications as long as you can mount is somehow. Don't be tempted to bypass the relay as it serves a very important protective function for both the amplifier and your loudspeakers.

If it is not the relay, see the sections: "General intermittent or erratic behavior" as well as "Noisy or intermittent switches and controls".

Equipment hums or buzzes: -----------------------

Assuming there are no other symptoms and the sound is coming from inside the unit and not the loudspeakers, this is probably simply due to vibrating laminations in the power transformer or motor(s) or nearby sheetmetal that is affected by the magnetic fields from the power transformer or motor(s). Most of the time, this is harmless but can definitely be quite annoying especially when one expects total silence from their audio equipment. If the noise is coming from any motors or their vicinity, refer to the section: "Motor noise in audio equipment".

Sometimes, simply tightening the screws that hold the transformer or motor together or the mounting screws will be all that is needed. Placing a toothpick or piece of plastic in a strategic location may help. It is also possible to coat the offending component with a varnish or sealer suitable for electronic equipment but be careful not to use so much that cooling is compromised or getting any in bearings or locations that would interfere with rotating parts.

If the hum or buzz is in the audio, there could be a bad filter capacitor in the power supply, other power supply problems, bad grounds inside the unit or general ground problems with external equipment, or other bad connections. Disconnect all external devices (except the speakers if you do not have a pair of headphones) and determine if the problem still exists. Proceed accordingly.

Overloads can also cause a hum or buzz but would generally result in other symptoms like a totally or partially dead amplifier, severe distortion, smoke, six foot flames, etc.

Sometimes, simply tightening the screws that hold the transformer or motor

If the problem is only annoying when the equipment is not in use, as a last resort (where no memory or clock functions run off the AC line), putting in an AC line switch may not be such a bad idea.

Internal fuse blew during lightening storm (or elephant hit power pole):

Power surges or nearby lightening strikes can destroy electronic equipment. However, most of the time, damage is minimal or at least easily repaired. With a direct hit, you may not recognize what is left of it!

Ideally, electronic equipment should be unplugged (both AC line and phone line!) during electrical storms if possible. Modern TVs, VCRs, microwave ovens, and even stereo equipment is particularly susceptible to lightening and surge damage because some parts of the circuitry are always alive and therefore have a connection to the AC line. Telephones, modems, and fax machine are directly connected to the phone lines. Better designs include filtering and surge suppression components built in. With a near-miss, the only thing that may happen is for the internal fuse to blow or for the microcontroller to go bonkers and just require power cycling. There is no possible protection against a direct strike. However, devices with power switches that totally break the line connection are more robust since it takes much more voltage to jump the gap in the switch than to fry electronic parts. Monitors and TVs may also have their CRTs magnetized due to the electromagnetic fields associated with a lightening strike - similar but on a smaller scale to the EMP of a nuclear detonation.

Was the unit operating or on standby at the time? If was switched off using an actual power switch (not a logic pushbutton), then either a component in front of the switch has blown, the surge was enough to jump the gap between the switch contacts, or it was just a coincidence (yeh, right).

If it was operating or on standby or has no actual power switch, then a number of parts could be fried.

Many devices have their own internal surge protection devices like MOVs (Metal Oxide Varistors) after the fuse. So it is possible that all that is wrong is that the line fuse has blown. Remove the case (unplug it!) and start at the line connector. If you find a blown fuse, remove it and measure across the in-board side of fuse holder and the other (should be the neutral) side of the line. With the power switch off, this reading should be very high. With the switch on, it may be quite low if the unit uses a large power transformer (a few ohms or less). For example (assuming power transformer operated supply):

* Small AC adapter - 100 to 500 ohms. * Large AC adapter - 10 to 100 ohms. * VCR - 15 to 30 ohms. * Cassette deck or CD player - 25 to 100 ohms. * Stereo receiver or amplifier - .5 to 10 ohms.

Some may be outside these ranges but if the reading is extremely low, the power transformer could have a partially or totally shorted primary. If it is very high (greater than 1 K ohms), then the primary of the power transformer may be open or there may be blown thermal fuse under the outer insulation wrappings of the transformer windings. This may be replaceable.

If the unit has a switching power supply, see the document: "Diagnosis and Repair of Small Switchmode Power Supplies".

If the resistance checks out, replace the fuse and try powering the unit. There will be 3 possibilities: 1. It will work fine, problem solved.

2. It will immediately blow the fuse. This means there is at least one component shorted - possibilities include an MOV, line filter capacitor, transformer primary.

3. It will not work properly or still appear dead. This could mean there are blown fuses or fusable resistors or other defective parts in the power supply or other circuitry. In this case further testing will be needed and at some point you may require the schematic.

Use of surge suppressors and line filters: --

Should you always use a surge suppressor outlet strip or line circuit? Sure, it shouldn't hurt. Just don't depend on these to provide protection under all circumstances. Some are better than others and the marketing blurb is at best of little help in making an informed selection. Product literature - unless it is backed up by testing from a reputable lab - is usually pretty useless and often confusing.

Line filters can also be useful if power in you area is noisy or prone to spikes or dips.

However, keep in mind that most well designed electronic equipment already includes both surge suppressors like MOVs as well as L-C line filters. More is not necessarily better but may move the point of failure to a readily accessible outlet strip rather than the innards of your equipment if damage occurs.

It is still best to unplug everything if the air raid sirens go off or you see an elephant wearing thick glasses running through the neighborhood (or an impending lightening storm).

Equipment dropped or abused: --------------------------

I have heard of someone fighting off a would-be mugger with a tape deck but this is generally not a recommended practice. However, once it happens - your cassette deck fell off its shelf or you prized walkman fell from your hang glider (ok, maybe that will be too much even for miracles) - what should you do?

Overall, electronic equipment - especially portable devices - are quite tough. However, falling or being beaten in just the wrong way can do substantial and possibly not immediately visible damage.

If you take it in for service, the estimate you get may make the national debt look like pocket change in comparison. Attempting to repair anything that has been dropped is a very uncertain challenge - and since time is money for a professional, spending an unknown amount of time on a single repair is very risky. There is no harm is getting an estimate (though many shops charge for just agreeing that what you are holding was once a - say - tapedeck!)

This doesn't mean you should not tackle it yourself. There may be nothing wrong or very minor problems that can easily be remedied.

First, unplug the unit even if it looks fine. Until you do a thorough internal inspection, there is no telling what may have been knocked out of whack or broken. Electrical parts may be shorting due to a broken circuit board or one that has just popped free. Don't be tempted to apply power even if there are no obvious signs of damage - turning it on may blow something due to a shorting circuit board. If it is a portable, remove the batteries.

Then, inspect the exterior for cracking, chipping, or dents. In addition to identifying cosmetic problems, this will help to locate possible areas to check for internal damage once the covers are removed.

Next, remove the covers and check for mechanical problems like a bent or deformed brackets, cracked plastic parts, and anything that may have shifted position or jumped from its mountings.

Carefully straighten any bent metal parts. Replace parts that were knocked loose, glue and possibly reinforce cracked or broken plastic. Plastics, in particular, are troublesome because most glues - even plastic cement - do not work very well. Using a splint (medical term) or sistering (construction term) to reinforce a broken plastic part is often a good idea. Use multiple layers of Duco Cement or clear windshield sealer and screws (sheetmetal or machine screws may be best depending on the thickness and type of plastic). Wood glue and Epoxy do not work well on plastic. Some brands of superglue, PVC pipe cement, or plastic hobby cement may work depending on the type of plastic.

Cycle the the mechanism and check for free movement of the various moving parts.

Inspect for any broken electronic components - these will need to be replaced. Check for blown fuses - the initial impact may have shorted something momentarily which then blew a fuse.

There is always a slight risk that the initial impact has already fried electronic parts as a result of a momentary short or from broken circuit traces and there will still be problems even after repairing the visible damage and/or replacing the broken components.

Examine the circuit boards for any visible breaks or cracks. These will be especially likely at the corners where the stress may have been greatest. If you find **any** cracks, no matter how small in the circuit board, you will need to carefully inspect to determine if any circuit traces run across these cracks. If they do, then there are certainly breaks in the circuitry which will need to be repaired. Circuit boards in consumer equipment are almost never more than two layers so repair is possible but if any substantial number of traces are broken, it will take a great deal of painstaking work to jumper across these traces with fine wire - you cannot just run over them with solder as this will not last. Use a fine tipped low wattage soldering iron under a magnifying lens and run #28-30 gauge insulated wires between convenient endpoints - these don't need to be directly on either side of the break. Double check each connection after soldering for correct wiring and that there are no shorts before proceeding to the next.

If the circuit board is beyond hope or you do not feel you would be able to repair it in finite time, replacements may be available but their cost is likely to be more than the equipment is worth. Locating a junk unit of the same model to cannibalize for parts may be a more realistic option.

Once all visible damage has been repaired and broken parts have been replaced, power it up and see what happens. Be prepared to pull the plug if there are serious problems (billowing smoke would qualify). Determine if it appears to initialize correctly - without shutting down. Play a garbage tape to determine if there are any problems that might damage the tape. Listen carefully for any evidence of poor tracking, tape speed instability, or weak or muddy audio that might indicate that tape path alignment requires further attention. Listen as well for any unexpected mechanical sounds that were not there before.

Very likely, the unit will be fine, you can replace the covers, and now find a more secure spot for it to prevent this sort of event in the future. Maybe hang gliding is just not for you!

Boombox or other equipment went to the beach (sand and/or surf):

A (former) relative took your boombox to the beach this summer and now it has sand or perhaps salt in it. Or, maybe you could not resist "sing'n in the rain" and a big bus went by without slowing. Now neither of the tape decks will play. Can this possibly be fixed? Will it be worth the effort?

Unless this is a really expensive sophisticated unit, I doubt whether it will pay you to take it anywhere for repair. Furthermore, as with equipment that has been dropped or physically abused, few repair shops will be inclined to touch the job. They really don't like challenges of this sort.

That leaves you!

If saltwater was involved in a significant way, you can probably forget it. Without immediate attention, saltwater corrosion can set in very quickly and attacks electronic components, circuit board traces, cable wiring, and mechanical parts. The only thing worse is damage caused by forgotten, leaky batteries.

Although it is probably too late, the first thing to do when electronic equipment gets wet is to remove the power source - switch it off and pull the plug or remove the batteries if possible. Don't be tempted to apply power until you have determined that it is completely dried out. If power was on when the 'incident' took place, then electronic damage may have already resulted which will not be apparent until after cleaning, drying, and lubrication.

The following description assumes a dual cassette boombox. Adjust as appropriate for your patient:

If the tape decks are totally dead, you may have serious electronic or corrosion which will make any salvage unlikely. If they sort of move (or even twitch a bit) but the sound is erratic, weak, fluttery, etc. then there may be hope. (Of course, if it got wet, you should not have done this test until everything was cleaned and dried!)

NEVER use strong solvents for any cleaning. These may attack plastic parts or cause internal damage to electronic components.

Mechanical intensive care:

1. Remove the tape decks. This will be a pain but otherwise you will not be able to get at everything. Make as many as drawings as needed so you will be able to reassemble.

2. Make a drawing of the belt routing, remove the belt(s), wash and dry them, label and set them aside.

3. Use a soft brush (like a paintbrush) to dust out as much sand as possible. Hopefully, you can get it all this way. A vacuum cleaner with a wand attachment may prove handy to suck out sand. Don't use high pressure compressed air - it will just spread the sand around. Any grease or oil on which sand has collected will need to be totally removed and replaced with fresh lubrication.

4. If there is evidence of salt (remember, I said forget it...but), you will need to wash it off. Yes, wash it. Keep water out of the motors. Use low pressure compressed air (a blow dryer on low heat should be fine) to dry so that it does not rust. Ditto if it is still wet with contaminated liquid (we won't say where this came from), wash with fresh water to remove all traces of it as quickly as possible. A final rinse with 91% or pure isopropyl alcohol will decrease drying time and should not damage mechanical assemblies. Degreaser may be used if it is safe for plastic and rubber parts.

Lubricate all bearing points with a drop of light machine oil - electric motor oil, sewing machine oil, etc. (Never never never WD40). Lubricate gears, cams, and sliding parts with a light plastic safe grease.

5. Replace the belts and reinstall the tape decks.

Electronic intensive care:

1. Remove the circuit boards and label the connectors if there is any possibility of getting them mixed up. If the circuit board(s) are soldered to the rest of the equipment, then you will have to improvise.

2. Wash with water and dry thoroughly. This does work. I use it routinely for degunking remote controls and rubber membrane keypads, for example. The most important objective should be to get corrosive liquids off the components and circuit traces as quickly and completely as possible. A final rinse with isopropyl alcohol will decrease drying time. However, there is a slight risk of damage to sensitive

electronic components should some be trapped inside. Moisture will be trapped in controls, coils, selector switches, relays, transformer cores, connectors, and under large components like ICs. Pat dry, then use warm air from a hair dryer (or heat gun on low) to completely dry every nook and cranny. DO NOT operate until everything inside and out is thoroughly dry.

3. Inspect for damage due to short circuits including blown fuses, fried components, and melted traces. These will need to be repaired or replaced.

4. Use spray contact cleaner on the switches and control cleaner on the user controls and adjustment pots. DO NOT turn the internal adjustments without precisely marking the original positions - else realignment will be needed. Exercise the user controls to help the cleaning process.

Once everything is reassembled, power the unit up and see what happens. Be prepared to pull the plug or pop the batteries if there are serious problems. Attempt to play a garbage tape to determine if there are any problems that might damage the tape. Look and listen for any abnormalities which may require additional attention. There could still be electronic faults not repairable without schematics and test equipment.

Obviously, this description is very simplistic. The important thing is to get every last grain of sand, salt, and other contaminants off of the mechanisms quickly.

Similar comments apply to equipment that went for an actual swim - you dropped your portable CD player in the toilet. The most important objective is to clean and dry it as quickly as possible and then relube any motor and other bearings. Use your judgement as to the severity of the dunking in terms of how deeply the liquid penetrated. Surface moisture will not hurt anything as long as it is dried up quickly. If you left it soaking on the other hand....

As noted above, moisture may collect inside certain electronic parts and it is essential that these be dried completely before attempting to apply power to the unit. If you do not, at best it will not work properly and you may do additional serious damage due to short circuits.

For the mechanics, the same applies though this is trickier since certain parts need to be lubricated and these may not be readily accessible or obvious. Don't be tempted to overdo the lubrication either - too much is worse that too little.

For high tech devices like CD players, some parts of the internal optics or shielded DC-DC convertors may be impossible to access and clean of scum.

Reviving old (antique) equipment: --------------------------------

If you have a true antique - really old, and valuable, you should refer to the extensive literature available on this subject. The following applies more to that 30 year old record player/amp found in the storage loft of your garage during spring cleaning.

Common problems relate to two types of components: vacuum tubes (valves for all of you on the other side of the lake) and capacitors (paper and electrolytic type). Thorough cleaning of all socket and switch contacts, and controls will also be needed.

Warning: the voltages inside tube type equipment can exceed 400 V - and contact with that can be real painful not to say dangerous. AC-DC type sets are not isolated from the power line. (In some really old equipment, even the chassis may be tied to one side of the line). This could also happen as a result of a shorted component. The electrolytic capacitors can hold a charge for quite a while. Read, understand, and follow the recommendations in the Safety document. Use extreme care when probing or even touching anything. This isn't 5 V logic!

Vacuum tubes:

It is not possible to fully test vacuum tubes without proper equipment but the inspection and tests below will find most bad tubes but will not pick up weak tubes. As a side note, when a repair shop replaced tubes, perhaps 20 % of the tubes they replaced were actually bad (I know because the local TV repair shop's trash can was a favorite hangout on pickup day and nearly all the tubes I scrounged tested perfectly good on a real tube tester once they were washed of coffee grounds and cigarette ash!) Whether this represented legitimate preventive maintenance or just IPM - Increased Profit Margin, I really do not know.)

1. Look for a silvery metallic spot somewhere inside the tube. This is the getter and is there to remove the last traces of gasses. If you see this, the vacuum is intact. If it is milky white or red, the tube has lost its vacuum and is dead-dead.

2. Use an ohmmeter to test for filament continuity. The nice thing about tubes (aside from their cheery glow) is that you can see inside (at least for the ones with a glass envelope) and locate the filament connections by tracing from the pins - it will be the whitish fine wire in the center of each of the tube sections. (The filament is almost always pins 3 & 4 on a 7 pin tube, 4 & 5 on a 9 pin tube, and 2 & 7 on an 8 pin tube.)

3. You can check for inter-element shorts (but not at normal operating conditions) with a VOM or DMM. For glass tubes, even without a tube manual, you should be able to deduce which elements are supposed to be isolated by visual examination.

Now, just jump into your time machine, back about 20-30 years should do it (remember?) when every corner drugstore and TV repair shop had a tube tester. There is, of course a good chance that your local TV repair shop still has one (if they can find it under an inch layer of dust) and it may even work.

Capacitors and resistors:

If you just dug this thing out of the attic, it is very likely that electrolytic capacitors have dried up and paper capacitors have turned leaky. Professional restorers will often install modern replacements for all of these capacitors without even testing the old ones.

Old carbon resistors can absorb moisture and change value. If your measurements do not agree with their marked rating based on their tolerance, consider replacements. However, if within, say, 20 %, for now, leave them alone.

Sockets, switches, and controls:

Vacuum and/or use a small paintbrush to remove dust, spider webs, dead insects (and anything larger).

Use contact cleaner on all the tube sockets and selector switches. Use control cleaner on all the potentiometers and reostats. Apply a drop of oil to any variable capacitor bearings and mechanical dial pointers.

Testing (use an isolation transformer with AC-DC line connected sets):

Much of this old equipment had schematic diagrams pasted to the cover - really handy if the paper hasn't totally disintegrated.

Turn on the power but be prepared to pull the plug in a hurry if, for example, a capacitor should decide to blow up (this shouldn't be a problem if you replaced them all unless some electrolytics are in backwards).

Do the filaments light up? If your equipment has a power transformer, the filaments are probably wired in parallel, so if one tube is out, that tube is bad (or its socket). If they are all out, then the power transformer or AC line input is bad.

If it is an AC-DC set like a table radio, then the tube filaments are wired in series. If one is bad, they will all be out. Get out your ohmmeter, pull each tube, and check it for filament continuity.

Assuming the filaments check out - all sections glowing (for metal tubes, feel the case for warmth after a few minutes though this won't guarantee that all sections are alive) when power is applied:

Check for DC voltages out of the power supply. There will be big filter capacitors - check across those. Watch out: we are talking several hundred volts and BIG capacitors - ouch.

With no signal, check plate voltages on the various stages - there should something. If you measure 0, then a plate resistor or coil could be open or the tube may be shorted.

The rest is just basic troubleshooting. Think of the vacuum tubes as oversize high voltage depletion mode FETs (field effect tubes, why not?). This is not much different than modern equipment except for the bites the relatively high voltages can take out of your hide.

TV/VCR combos: -------------

These hybrids which include both a TV and VCR (and sometimes other stuff as well) seem to combine the worst of all possibilities. Although, in principle, the idea of a combination TV/VCR sounds good - no cabling to worry about, ease of use, compatibility assured, the result may be less than meets the eye. While TV/VCR combo units do include both a TV screen and a VCR transport, very often there is only a single shared tuner so that viewing and recording of different programs is not possible unless one is from an external baseband video source (assuming there is a suitable input jack) like - you guessed it - a VCR or laserdisc player.

If either the TV or VCR poops out and needs repair, the entire unit may be unusable either because of shared circuitry or because the whole thing is in the shop. Construction quality tends to be shoddy and some designs are poor to begin with. Finally, as if this is not enough, servicing is difficult and painful because everything is crammed into a single compact (at least that is a good feature!) unit.

Refer to the appropriate documents for your particular problems - not only TVs and VCRs, but also Audio and Miscellaneous for shared systems like the power supply.

Boomboxes and compact stereo systems: -----------------------------------

These combine a stereo receiver and a single or dual cassette deck, and/or a CD player or changer, and a pair of detachable speakers, into a single unit. Most are fairly portable but larger boomboxes and compact stereos may require a forklift to move any great distance.

While the individual subsystems - CD player for example - are usually relatively self contained electrically except for a common power supply, mechanically, everything tends to be jumbled together - even on units that have an outward appearance of separate components. Both cassette transports are usually driven from a single motor. Getting at the CD player may require removal of both cassette decks, audio amplifier, and power supply. Working on these is not fun. As usual, take careful notes as you disassemble the unit and expect it to require some time just to get to what you are after. Be especially careful when removing and replacing the individual modules if printed flex cables are used for interconnections.

Refer to the relevant sections on cassette transports, loudspeakers, and power supplies for problems with these units. Refer to the document: "CD Technology and the Diagnosis and Repair of CD Players and CDROM Drives" for CD specific problems.

Since these do get abused - bumped, dropped, dunked, etc., bad connections, and other damage is very common. See the sections: General intermittent or erratic behavior" as well as "Noisy or intermittent switches and controls".

Revival of dead or tired remote control units: --

There are two types of problems with hand held remote controls: they have legs of their own and they get abused or forgotten. I cannot help you with walking remotes.

Where response is intermittent or the reliable operating distance is reduced, first check the batteries and battery contacts. If some buttons are intermittent or dead, than the most likely cause is dirty or worn contacts under the rubber buttons or on the circuit board.

If there is no response to any functions by the TV or VCR, verify that any mode switches are set correctly (on both the remote and the TV or VCR). Unplug the TV or VCR for 30 seconds (not just power off, unplug). This sometimes resets a microcontroller that may have been confused by a power surge. Confirm that the remote has not accidentally been set to an incorrect mode (VCR instead of TV, for example). If it a universal type, it may have lost its programming - reset it. Make sure you are using the proper remote if have multiple similar models.

Test the remote with an IR detector. An IR detector card can be purchased for about $6. Alternatively, construct the IR detector circuit described in the companion document: "Notes on the Repair of Hand Held Remote Controls".

If the remote is putting out an IR signal, then the remote or the TV or VCR may have forgotten its settings or the problem may be in the TV or VCR and not the hand unit. The following is just a summary - more detailed information is available in the companion document: "Notes on the Repair of Hand Held Remote Controls".

Problems with remote hand units:

All except (1) and (2) require disassembly - there may be a screw or two and then the case will simply 'crack' in half by gently prying with a knife or screwdriver. Look for hidden snap interlocks.

1. Dead batteries - solution obvious.

2. Corroded battery contacts, Thoroughly remove chemical deposits. Clean contacts with pencil eraser and/or sandpaper or nailfile.

3. Broken connections often between battery contacts and circuit board, possibly on the circuit board - resolder.

4. Bad resonator or crystal - replace, but diagnosing this without an oscilloscope may be tough. Broken connections on resonator legs are common.

5. Dirt/spills/gunk preventing keys from operating reliably. Disassemble and wash rubber membrane and circuit board with water and mild detergent and/or then alcohol - dry completely.

6. Worn or corroded contact pads on circuit board. Clean and then use conductive Epoxy or paint or metal foil to restore.

7. Worn or dirty pads on rubber keypad. Clean. If worn, use conductive paint or metal foil to restore.

8. Cracked circuit board - can usually be repaired as these are usually single sided with big traces. Scrape off insulating coating and jumper breaks with fine wire and solder.

9. Bad LED. If IR tester shows no output, remove LED and power it from a 9V battery in series with a 500 ohm resistor. If still no output, replace with readily available high power IR LED. Otherwise, check driver circuits.

10. Bad IC - if it is a custom chip, forget it! Failure of the IC is usually quite unlikely.

(The following is from Duane P Mantick:)

An awful lot of IR remotes use IC's from the same or similar series. A common series comes from NEC and is the uPD1986C which, incidentally is called out in the NTE replacements book as an NTE1758. A lot of these chips are cheap and not too difficult to find, and are made in easy-to-work-with 14 or 16 pin DIP packages. Unless you have no soldering or desoldering skills, replacement isn't difficult.

There are a large variety of universal remotes available from $10-$100. For general TV/VCR/cable use, the $10 variety are fine. However, the preprogrammed variety will not provide special functions like programming of a TV or VCR. Don't even think about going to the original manufacturer - they will charge an arm and a leg (or more). However, places like MCM Electronics do stock a variety of original remotes - prices range from $9 - $143 (Wow $143, for just a stupid remote! It doesn't even have high definition sound or anything exotic). The average price is around $40.

Problems with keypads or touchpanels: -----------------------------------

Most common are moisture problems followed by physical damage:

Very often, a little overzealous cleaning results in moisture trapped inside a not quite perfectly sealed membrane keypad or touchpanel.

First, of course, dry off the exterior as best you can. Any moisture that seeped inside may be difficult to remove without surgery - which is definitely not something you want to undertake as the long term reliability will be compromised.

I would recommend waiting a while - a week may be required - for it to totally dry out. You could also try confirming across the touchpad contacts with an ohmmeter that there is still low resistance (even 10s of K ohms may look like a button press). It is nearly impossible to speed up this process without subjecting the device to conditions that may harm the device - heat and/or vacuum. You possibly try something like isopropyl alcohol in the hope that it will displace the water and dry quickly. I do not know if this will be safe in every situation, however.

Of course, it is also possible that are other problems but I have seen these things take a very long time to dry out.

However, significant damage - a membrane type touchpad is punctured - may require replacement unless you can repair the internal wiring. The connections are usually made with flex-cables which are difficult or impossible to repair. See the section: "Repairing flexible printed cables". Damage to any membrane buttons may result in stuck buttons or improper operation of other buttons.

Repairing flexible printed cables: --------------------------------

It seems that more and more consumer devices from pocket cameras to laptop computers are being built with miniature multiconductor flexible printed cables. Very often one or more traces to develop hairline cracks due to repeated flexing. In addition, damage from moving circuit boards and modules during servicing is all to common.

Caution: many devices like calculators have printed cables that use a material that will not take solder and are glued rather than soldered at their ends - the logic board and LCD panel, for example. Repair of problems with the cables is virtually impossible. Take great care when working inside of devices with this sort of cabling to prevent damage to the cables or their termination.

Needless to say, repairing any kind of flex cable is a real pain. I have succeeded by carefully scraping the plastic off with an Xacto knife and then soldering fine wire (#30 gauge wire wrap for example) to the traces. This presumes that the conductors on your cable will even take solder. I then cover up the joints with a flexible sealer for electrical and mechanical protection.

However, you need to make sure that the wire you use can be flexed or that the joint is set up in such a way that the wire does not flex much - else you will just end up with broken wires pretty quickly.

Soldering from end point to end point if possible may be preferable. Even going to only one endpoint would reduce the risk of immediate damage and reliability problems in the future.

With multiple traces broken or damaged, you are probably better off replacing the cable entirely.

**************** SPECIFIC PROBLEMS AND REPAIRS ****************

Classic ATT Touch Tone phone 'battlewagon' will not dial properly: --

Typical symptoms are: everything works fine except erratic or no dialing. For some buttons, dial tone would not go away. For others, tones would be accepted but will be erratic and result in incorrect digits. Certain digits may sound weak, wavery, or single frequency (rather than the proper DTMF dual tones).

While the internal wiring of these old phones is intimidating, the basic tone dialing circuitry is an amazing example of simplicity. About the only things that fail yet still permit some tone generation are the pot core coils that determine tone frequency. Therefore, this is the first thing to check.

There are two cores which each consist of two halves glued together. Breaks seem to be a common problem due to both the age and the brittle cement used on some revs of this model phone, and probably, as a result of rough treatment when hanging up the handset, or dropping or throwing of the desk phone.

These cores must be aligned before being glued back together. In addition, there is an adjustment plug which may need to be tweaked. I align by ear as follows: Put a known good tone dialing phone and the bad phone on the same phone line. Momentarily depress the hook switches to silence the dial tone. You will now have about 25 seconds before the nice polite operator recording tells you how to make a call. Depending on which core is bad, depress either an entire (same) row or column of buttons on both phones. (Adhesive tape is handy to hold down the buttons unless you have four hands.) By depressing the entire set of buttons, you are disabling the other tone generator so you hear a pure tone. Without turning the fine adjustment plug (assuming it was not disturbed; if it was, set it mid-range or the same as the one in the other core), rotate the loose core top until a zero beat is obtained. As your rotate the core, you will hear the pitch change. As it approaches the correct setting, you will hear the tones beat against each other. When you are set correctly, the pitches will be equal and the beat frequency will go to zero. Mark the position of the core with a pen or pencil and then glue with Epoxy or other general purpose adhesive (around the outside - not on the mating surfaces as this will affect the tone frequencies). After the glue sets, confirm and adjust the plug core if needed. These cores use a strange triangular core tool - I made mine by filing down an aluminum roofing nail (do not use a ferrous material).

These classic ATT Touch Tone phones are virtually indestructible. However, broken cores (or actually, just broken joints on the cores) are common but easily repaired once you know what to look for. Setting the tones by referencing a known good phone seems to be a very reliable technique as the zero beat permits an adjustment to better than .1%. Note that if the reference phone is a more modern (and flimsy digital one), then pushing multiple buttons may not work as it does with the old analog models. Setting the frequency using the normal dual tones will work - it is just not as easy.

ATT classic dial phone will not dial: ------------------------------------

I know, you haven't seen one of these in years, but I just had to throw this in.

Most likely it was dropped - these phones simply do not seem to fail any other way. When dropped, assuming there is no obvious damage, a little plastic stop inside the dial mechanism which is on a pivot flips the wrong way. This normally prevents dialing pulses from being generated when the dial returns to its home position but when flipped, prevents dialing totally. It is real easy to flip it back into place.

Jerrold 400 Cable Converter Problems: -------------------------------------

The most common symptoms for these cable boxes relate to their not staying on or acting erratically when the buttons are pressed. The causes are usually quite simple:

1. Cold solder joints around the power supply regulator ICs (on chassis heat sink).

2. Dried up main filter capacitors - two large electrolytics in power supply on main board.

Be careful disassembling the main board from the chassis as at least one of the regulator ICs clipped to the side of the chassis is insulated from this heatsink and the insulation is easily damaged.

Original Nintendo console erratic or dead: --

While the original Nintendo game machine is a couple of generations out of date, many are still in use. And, hey, kids usually don't care.

The most common problem with these units is a worn or dirty cartridge connector. In this case, the red power/status light will continue to flash even after the RESET button is pressed with a game cartridge in place. Replacements are available for about $9 from the sources listed at the end of this document.

First, try another game cartridge - the one that is not working may just have dirty contacts or may be defective. Clean the contacts with a Qtip moistened with water followed by isopropyl alcohol. (The water will remove the sugar from the candy that may have made its way onto the connector.)

To get inside, you first remove the 6 screws on the bottom and then about 12 screws which fasten the circuit board and shield to the bottom of the case. (Note: there are two screws which are longer and silver colored - make sure they get back to their original location when you put everything back together.) Once all these screws are removed, the black connector can be slid off the edge finger on the circuit board Inspect these connections - they just may be a bit corroded or dirty. Use contact cleaner and/or a pencil eraser and see if that makes any difference. Use contact cleaner on the dual rows of fingers that connect to the game cartridge as well. A dental pick can be used to gently spread the fingers apart ever so slightly and thus improve the connection when the cartridge is inserted.

Even if this only makes a slight improvement - you can press down on the cartridge and the machine will respond to the RESET button - you have confirmed that the connector is indeed the problem. In many cases, just this cleaning will result in reliable operation for a long time to come.

**************** SERVICE INFORMATION ****************

Determining belt type and size: ------------------------------

Belts are normally specified by their cross section - square, flat, round, and their inside circumference (IC). The IC is used since it is virtually impossible to accurately measure the diameter of a belt.

Assuming you cannot locate an actual part number, determine the type of belt; square, flat, or round. If you do not have the old belt, this is usually obvious from the pulleys. Most small belts (as opposed to V-belts on 1 HP shop motors!) used in consumer electronic equipment are of square cross section though flat types are sometimes found in the main drives of VCRs, cassette/tape decks, and turntables (remember those?). Measure or estimate the thickness.

The IC is always specified with the belt fully relaxed. This can be measured by hooking the old belt on one end of a ruler and pulling it just tight enough so that it more or less flattens out. Read off the length, then double it for the IC. Get a new belt that is 5% or so smaller to account for the old one be somewhat stretched out. Of course, if the belt broke, measurement is real easy. Or, if you do not care about the old belt, just cut it and measure the total length.

If the old belt decomposed into a slimy glob of jellatinous black goop or is missing, you will need to use a string or fine wire around the appropriate pulleys to determine the IC. Reduce this by 10-25% for the replacement. Very often the match does not need to be exact in either thickness or length - particularly for long thin belts. A common rubber band may in fact work just as well for something like a tape counter!

However, there are cases where an exact match is critical - some VCRs and belt driven turntables or tape decks do require an exact replacement for certain drive belts but this is rare.

Some parts suppliers make determining replacement belts very easy with the PRB system in which the part number fully codes the shape, size, and thickness.

Interchangeability of components: --------------------------------

The question often arises: If I cannot obtain an exact replacement or if I have a VCR, tape deck, or other equipment carcass gathering dust, or I just have some extra parts left over from a previous project, can I substitute a part that is not a precise match? Sometimes, this is simply desired to confirm a diagnosis and avoid the risk of ordering an expensive replacement and/or having to wait until it arrives.

For safety related items, the answer is generally NO - an exact replacement part is needed to maintain the specifications within acceptable limits with respect to line isolation, X-ray protection and to minimize fire hazards. However, these components are not very common in audio equipment or other consumer devices (other than TVs, monitors, and microwave ovens) except for possibly in their power supply.

For other components, whether a not quite identical substitute will work reliably or at all depends on many factors. Some designs are so carefully optimized for a particular part's specifications that an identical replacement is the way to return performance to factory new levels.

Here are some guidelines:

1. Fuses - exact same current rating and at least equal voltage rating. I have often soldered a normal 3AG size fuse onto a smaller blown 20 mm long fuse as a substitute. Also, they should be the same type

- slow blow only if originally specified. A fuse with a faster response time may be used but it may blow when no faults actually exist.

2. Resistors, capacitors, inductors, diodes, switches, trimpots, lamps and LEDs, and other common parts - except for those specifically marked as safety-critical - substitution as long as the replacement part fits and specifications are met should be fine. It is best to use the same type - metal film resistor, for example. But for testing, even this is not a hard and fast rule and a carbon resistor should work just fine.

3. Potentiometers - user knobs usually control one or more of these. There are four considerations in locating a suitable replacement: resistance, and taper, power rating, configuration, and mechanical fit. Configuration refers to the number of ganged pots, concentric knobs, etc. Matching this from your junk box may prove to be the toughest challenge! Many of the controls for audio equipment use what is known as an 'audio taper'. This means that the resistance change with knob rotation is not linear but is designed to produce a uniform incremental change in perceived volume, for example. Replacement with a linear taper pot will squish all of the effect towards one end of the range but it will still work. If measuring the resistance of a (good) potentiometer with its wiper set in the middle results in significantly different readings from center to each end, it is most likely an audio taper pot (though some other weird taper or other peculiarity is possible).

4. Rectifiers - many are of these are high efficiency and/or fast recovery types. Replacements should have equal or better PRV, If, and Tr specifications. For line rectifiers, 1N400x types can usually be used.

5. Transistors and thyristors (except power supply choppers) - substitutes will generally work as long as their specifications meet or exceed those of the original. For testing, it is usually ok to use types that do not quite meet all of these as long as the breakdown voltage and maximum current ratings are not exceeded. However, performance may not be quite as good. For power types, make sure to use a heatsink.

6. Switching power supply transistors - exact replacement is generally best but switchmode transistors that have specifications that are at least as good will work in many cases. See the documents on TV, monitor, and SMPS repair for further info.

7. Audio and erase heads - may be possible if the mountings are reasonably compatible. However, there could be other unknowns like coil impedance and drive requirements. The connectors are not likely to be similar either. There are usually significant differences in head configuration and mounting arrangement between 2 head, 3 head, and autoreverse cassette or open reel tape decks.

8. Motors - small PM motors may be substituted if they fit physically. Make sure you install for the correct direction of rotation (determined by polarity). Capstan motors - especially the direct drive type - are probably not interchangeable. However, generic speed regulated cassette drive motors are available.

9. Sensors - many are sufficiently similar to permit substitution.

10. Power transformers - in some cases, these may be sufficiently similar that a substitute will work. However, make sure you test for compatible output voltages to avoid damage to the regulator(s) and rest of the circuitry. Transformer current ratings as well as the current requirements of the equipment are often unknown, however.

11. Belts, tires, and pinch rollers - a close match may be good enough at least to confirm a problem or to use until the replacements arrives.

12. Mechanical parts like screws, flat and split washers, C- and E-clips, and springs - these can often be salvaged from another unit.

The following are usually custom parts and substitution of something from your junk box is unlikely to be successful even for testing: SMPS (power supply) transformers, interstage coils or transformers, microcontrollers, other custom programmed chips, display modules, and entire power supplies unless identical.

Recommended parts suppliers: ---------------------------

For general electronic components like resistors and capacitors, most electronics distributors will have a sufficient variety at reasonable cost. Even Radio Shack can be considered in a pinch.

However, for consumer electronics equipment repairs, places like Digikey, Allied, and Newark do not have the a variety of Japanese semiconductors like ICs and transistors or any components like tape heads or belts.

The following are good sources for consumer electronics replacement parts, especially for VCRs, TVs, and other audio and video equipment:

MCM Electronics (VCR parts, Japanese semiconductors, U.S. Voice: 1-800-543-4330. tools, test equipment, audio, consumer U.S. Fax: 1-513-434-6959. electronics including microwave oven parts and electric range elements, etc.)

Dalbani (Excellent Japanese semiconductor source, U.S. Voice: 1-800-325-2264. VCR parts, other consumer electronics, U.S. Fax: 1-305-594-6588. Xenon flash tubes, car stereo, CATV). Int. Voice: 1-305-716-0947. Int. Fax: 1-305-716-9719.

Premium Parts (Very complete VCR parts, some tools, adapter U.S. Voice: 1-800-558-9572. cables, other replacement parts.) U.S. Fax: 1-800-887-2727.

Computer Component Source (Mostly computer monitor replacement parts, also, some electronic components including semiconductors.) U.S. Voice: 1-800-356-1227. U.S. Fax: 1-800-926-2062. Int. Voice: 1-516-496-8780. Int. Fax: 1-516-496-8784.