Basic techniques of fault finding

Fault finding in electronic gear is like solving a murder mystery – the clues abound, but the 'red herrings' confuse the issue. However, many faults can be traced without needing expensive equipment and a high degree of technical knowledge. Too good to be true? Read on, and find out the things the text books don't tell you!

by PETER PHILLIPS

To set the stage, consider this short but true story that may illustrate the point of this article – a story related to me by a highly qualified electronics engineer.

Some years ago, I spent more time than I should have agonising over a fault in a popular model TV set. After a week of fruitless searching using all kinds of test equipment, circuit manuals, text books and theorising, I had to admit I could not find the fault.

I needed help, despite the embarrassment of this admission. So, on the pretext of inquiring about his health, I phoned a friend whose livelihood was TV servicing.

Following his advice and a spot of soldering around a terminal post totally remote to the area where the fault 'should have been', the set was soon working perfectly. Duly humbled, the obvious question I asked my friend was how he had originally discovered this fault.

His reply included comments on 'unnecessary theorising' and the appropriate use of 'basic methods'. In fact, he suggested that a lot of fault finding was best done with the 'non text-book' approach, and we theorists were wasting our time.

Of course, the 'bash it till it works' philosophy is not what this article is all about. However, there are many useful basic techniques that can help solve some very difficult fault problems – techniques that are rarely described. Certainly there is no substitute for technical knowledge, and readers cannot assume that all faults will yield their secrets by using the methods about to be described.

This article is therefore about fault finding, but based primarily on down-to-earth methods that servicemen have developed over the years. It purposely stays away from hi-tech methods, and may just provide you with a few ideas that could prove useful.

Faulty electronic equipment will either be commercially manufactured or home-built. As many readers get involved in building published projects, a separate article is being prepared for next month on how to fault-find projects. This type of equipment is more likely to have faults, either initially or subsequently, and, as such, it deserves an article of its own. For now, we concentrate on fault finding commercial equipment, although many of the techniques would apply to projects anyway.

I have always followed a few basic rules in servicing – rule 1 is always check the easy things first, even if this seems a waste of time. The second rule is to be methodical, and the third is to refer to rules 1 and 2. And now to elaborate...

Fault categories

A fault in a piece of equipment can be classified in three ways. The first is the problem occurring in a unit that, prior to the fault, worked normally. Called a *breakdown*, this type of fault is the most typical, and is generally the result of a component failure.

Another fault category is a construction error in a circuit, and is one likely to be encountered by hobbyists, both experienced or otherwise. The final type – the design error, is the nastiest and is often assumed by frustrated project builders.

Within the three categories given, there are sub-categories, such as the intermittent fault. Another is the possibility of two or more independent faults occurring simultaneously.

The breakdown

A fault in previously proven equipment will either be one or more compo-

Fault finding using high tech! Here the Polar B3T micro tester is being used in a microprocessor-based circuit.

nents, faulty connections, or a printed circuit board problem and may result from internal or external causes. Internal causes include ageing, poor design or even normal component failure. External causes can range from water damage (from the decorative pot plant sitting on top) to a lightning strike.

Commence by examining the events surrounding the fault – but don't always trust a third party description, particularly from the owner. Few people can be truly objective in describing a fault, particularly if they are embarrassed about the circumstances. Dropping the thing down two flights of stairs will often be described as 'a minor bump'.

Details to establish include any previous history of the fault, other related problems, even weather conditions at the time. Like solving a crime, any information that can give a lead should be sought.

Before removing covers, determine for yourself what faults the device is exhibiting. Identify unusual sounds, smells, visuals, vibrations, or behaviour of any sort. Try all controls, determine exactly what is working and what is not, and become very familiar with the specific problems.

Once clear on the symptoms, remove the necessary covers and visually examine the internals of the unit. As well, a bit of gentle probing may bring to light possible problems. For example, ensure all plug-in cards are correctly positioned, and test the integrity of any plug and socket combinations.

Also apply pressure to any components (ICs etc.) that are socketed, and generally satisfy yourself that the problem is not of the poor connection variety. Poor connections are a common cause of trouble. Naturally, do all of this with great care, turning off the power if any doubt exists as to safety for yourself or the equipment.

If the device is more than a few years old, it often pays to spray contact cleaner on all switches, plugs and sockets. Do this with the power off, and methodically separate all connectors, applying the spray (non-oily variety) to both sides of a connector pair.

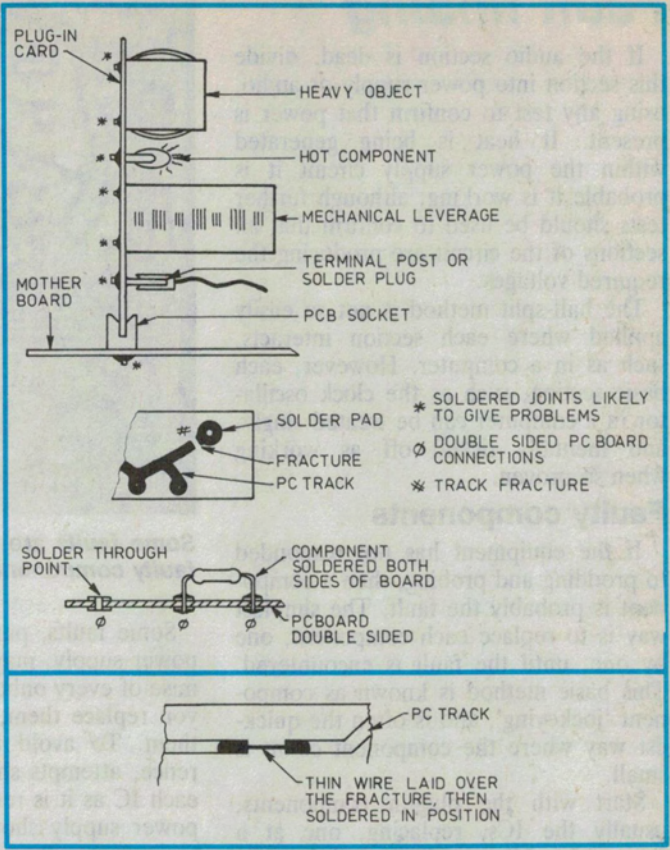
Removing ICs from their sockets (using an IC extractor), and spraying the sockets is a part of this exercise, which even if unsuccessful in establishing the fault, represents maintenance of a useful type. Observe the orientation, and don't mix the ICs around.

PCB faults

Having ensured that the problem is more than a bad connection in a plug

PCB soldering faults are very common. If there is heat or mechanical stress around a solder point, sooner or later it will fail. Also, any plug and socket combination is a potential source of trouble, such as the PCB socket. Look also for track breaks around lands and other stress points. Another trouble spot can be plated-through holes that connect double sided PCBs.

Track repair should make the track physically strong as well as electrically sound.



and socket, try the 'stress' test. The aim is to find any bad solder connections, or physically unsound components. Tapping lightly with the plastic end of a small screwdriver can often bring to light a poor soldered joint, as my engineer friend would agree. Sometimes, the tapping will even cause a faulty component to 'come good', even if only momentarily.

Because solder has little mechanical strength, likely soldering problems will probably be in areas where some physical strain is involved. Soldering associated with things like heavy components, areas subject to heating, PCB-mounted plugs or sockets should be examined carefully. Gently wobbling large components or terminal posts and observing the soldered joint can often identify a dry or broken connection.

Bad soldered joints may not manifest themselves for a number of years, and are the cause of many problems. Fig.1(a) shows some typical instances where soldered joints are likely to fail.

Flexing the board (gently) can identify possible problems with PCB tracks or connection points. If the fault is apparently corrected by distorting the board, localise the area as much as possible, then go to work with a magnifying glass and a soldering iron. Double-sided PCBs are prone to problems around the through-hole plating used to connect tracks on either side, and can be very difficult to find.

Careful resoldering of all connections in the suspect area often does wonders. Breaks in PCB tracks are not uncommon, particularly at the point where the track joins to the solder land. Some servicemen, after having tried everything else, run solder over every track in the hope of fixing invisible fractures.

Repair of a track fracture should be done by overlaying a piece of wire across the break, soldering it into position after first cleaning the track where soldering is to occur. Fig.1(b) illustrates the technique.

Isolating the fault

Sometimes the faulty section can be isolated using the 'half-split method'. As the name implies, the faulty area is found by first identifying which half of the circuit contains the fault. Having found which half, subsequent divisions of the suspect area may eventually lead you to the fault. This method is useful for audio equipment, where each section is relatively independent of the other.

For example, if the equipment contains an audio amplifier, applying a signal to the volume control will help identify if the fault is before or after the volume control. If before, don't waste your time on the later section.

Fault finding

If the audio section is dead, divide this section into power supply or audio, using any test to confirm that power is present. If heat is being generated within the power supply circuit it is probable it is working, although further tests should be used to confirm that all sections of the circuit are producing the required voltages.

The half-split method is not so easily applied where each section interacts, such as in a computer. However, each basic section, such as the clock oscillator in a computer can be treated singly, and mentally ticked off as working when so proven.

Faulty components

If the equipment has not responded to prodding and probing, then a component is probably the fault. The simplest way is to replace each component, one by one, until the fault is encountered. This basic method is known as component 'jockeying', and is often the quickest way where the component count is small.

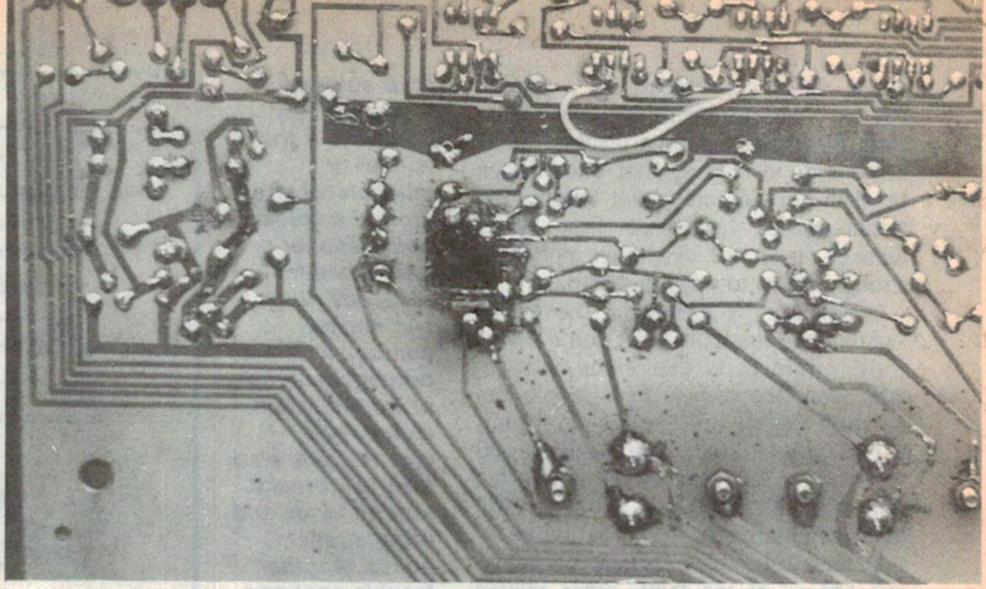
Start with the plug-in components, usually the ICs, replacing, one at a time, those ICs you have replacements for. Sometimes two ICs of the same type on the board can be swapped, and the effect noted. Always observe the behaviour of the unit after each component change, and be continually on the lookout for clues that may present themselves.

As a basic rule, try all the active components first. If a replacement is not available, test each component as thoroughly as possible, either in circuit or otherwise. Where there are a large number of components, an attempt should be made to identify the area containing the fault as already described.

Touching each component to determine its operating temperature can often identify either a faulty component or the problem area. A component that is 'stone cold', or one that is too hot may provide a clue.

Active components

Active components are basically more prone to breakdown than passive ones. As ICs are often in sockets, searching for a faulty chip is usually the best place to start. The quickest way to establish if an IC is faulty is to replace it, but it should be remembered that there may be more than one fault. Subsequently, when replacing an IC, leave it in the circuit even if the problem is not found, then go onto the next.



Some faults are obvious to the eye and the nose. Apart from replacing the faulty components, PCB repairs are also often needed.

Some faults, particularly those in the power supply, may have caused the demise of every onboard IC, and as fast as you replace them, so the fault destroys them. To avoid this expensive occurrence, attempts should be made to test each IC as it is removed. Naturally, the power supply should have been tested for correct voltages first anyway.

Testing a range of ICs is often difficult, but may avoid disaster on your stock of components. Trying each chip in another known piece of equipment can help find the faulty one, or at least prove that the ICs are working.

Device replacement, such as any transistors or FETs, should follow the IC replacement/testing process. However, if all the ICs are soldered in, then leave the ICs till last. Remember, do the easiest things first!

There are a few simple tests that can be applied to transistors before removal. For example, if the forward bias voltage between base and emitter exceeds 0.8V or so, it is almost definite that this junction is open circuit. Onboard ohmmeter tests are not always reliable, as parallel paths are likely, but lifting two of the three leads will allow correct testing.

However, the 'replace first, question afterwards' method is often the quickest way where the devices involved are cheap and available. I always compare my time against the component cost, particularly if the job is for money.

Where replacement devices are unavailable, methodical removal and testing becomes necessary. Ohmmeter testing of transistors is fairly well documented, and requires the testing of the two PN junctions. When using an analog meter, set it to its low ohms range, and remember that the polarity of the leads is generally reversed for ohms measurement. That is, the black lead becomes the positive potential. A digital multimeter retains the indicated polarity on ohms, but should be switched to its 'diode check' setting.

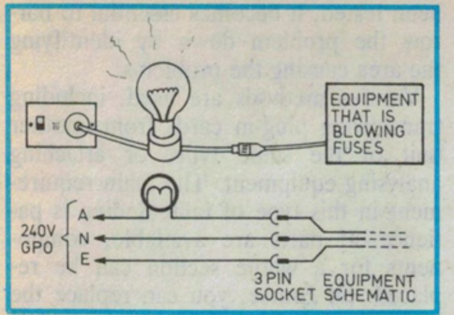
If all the ICs and transistors appear to be working, and checks have proven there is no bad connection, PCB track break or power supply problem, then the remaining components should be examined. Of great importance is to be wary of not accidentally introducing more faults during component replacing. Take care not to bridge PCB tracks, or to put a component in the wrong way. Only deal with one device at a time to prevent mixing them around, and always test the unit after each component replacement.

Capacitor faults

A valuable hint in fault finding equipment exhibiting peculiar faults is to test the capacitors associated with the power supply. If hum is present in a loudspeaker, a likely cause is a filter capacitor. Many a strange fault has been found by substituting a known good electrolytic capacitor across each of those in the circuit in turn.

Ensure the polarities match when the substitute is being attached and always discharge the test capacitor before reapplying it to another section. This is necessary in case the stored voltages obtained from one part of the circuit do damage to the next.

Electrolytic capacitors are the passive components most likely to fail with time. Equipment over ten years old that is being restored should have all the electrolytic capacitors replaced, as they



Simple, but effective means to protect fuses and equipment.

'dry out' or depolarise over the years, and lose their capacitance value.

Capacitors required to operate with voltages over 100 volts or so can become leaky, a problem very prevalent in valve equipment. Again replacement of the lot is recommended. Some capacitors can develop an intermittent open circuit – typical in the polystyrene variety.

Always replace a capacitor with one having a working voltage equal to or better than the original, and use the same type as far as possible. Paper capacitors can usually be replaced with polyester types, but inductance and stability considerations usually mean the original type must otherwise be observed.

Resistor faults

Resistors, diodes, transformers, wiring and so on can all become faulty. The possibility of this occurring is lower compared to the components already discussed, suggesting that these items are best checked last.

Resistors, particularly old style types, can change their value, and high value resistors are more prone to this than the low value types. Normally a resistor will increase its resistance with time and use. If a resistor indicates an in-circuit value higher than its marked value, replace it; if lower, lift one end and re-check.

In general, resistors are reliable unless their power dissipation rating is exceeded. Wire wound resistors are prone to becoming open circuit, even under normal operation, and this can often be found by noting that they are cold after the unit has been running for some time.

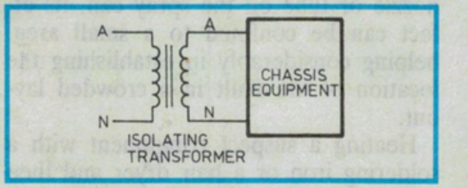
Power supply faults

Power supply faults are very common, and often hard to find, as the symptoms may suggest anything but a power supply problem. Digital equipment will behave very erratically if the power supply has excessive ripple, or if there is a bad connection between the power supply and the rest of the equipment.

I always examine the power supply first, mainly to confirm correct voltages and secure connections. As this section dissipates heat, faults are most likely to occur over time, depending on the thermal stresses within the section.

Power supply faults and the effects they cause could probably fill a decent sized book, as experienced technicians would no doubt agree.

Transformers and inductors usually go open circuit. Alternatively, transformers can 'burn out', usually obvious by the smell. In this case, find out why the transformer burnt out before replacing it.



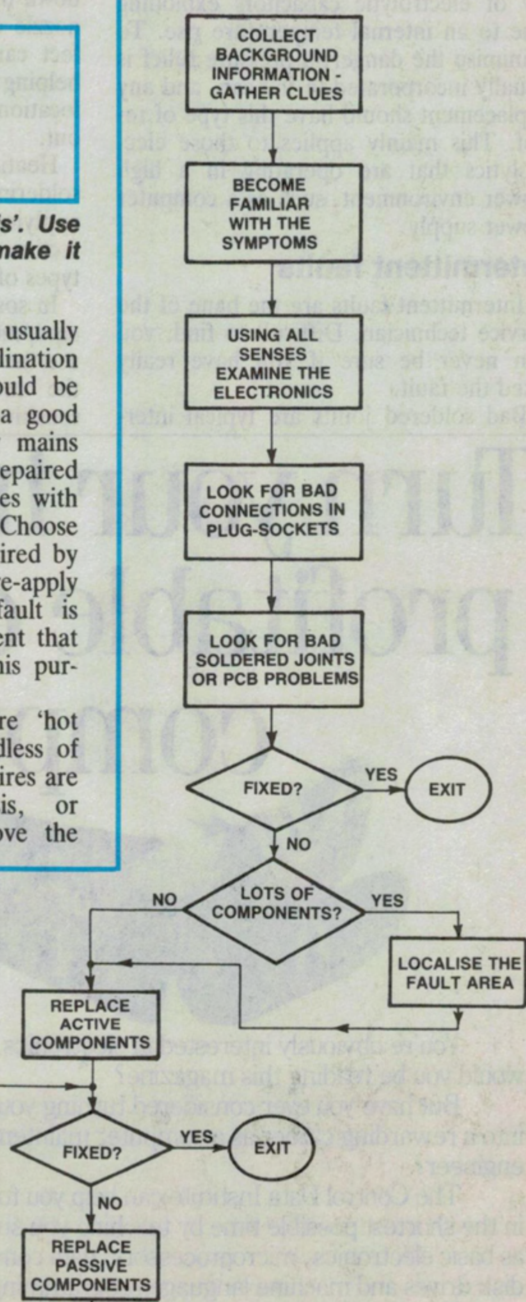
Many TV sets are 'hot chassis'. Use an isolating transformer to make it safe to work on.

Power supply transformers are usually protected by a fuse, and the inclination to increase the fuse rating should be avoided. If fuses are blowing, a good servicing technique is to apply mains power to the unit being repaired through a 240 volt lamp in series with the power point and the device. Choose a wattage up to twice that required by the unit under test, and don't re-apply the mains directly until the fault is fixed. Fig.2 shows an arrangement that can be easily constructed for this purpose.

Many domestic appliances are 'hot chassis'. This means that regardless of the way the active and neutral wires are connected, the metal chassis, or 'ground' of the device, is above the earth potential. Connecting an earth wire from a piece of test equipment can result in damage to the device being repaired, blown mains fuses, or destruction of the test equipment.

Also, the technician is exposed to a very dangerous situation, running a great chance of receiving a lethal electric shock. This makes the use of an isolating transformer (240V to 240V) essential. The power rating of this transformer should equal or exceed that of the equipment. *Note particularly that a 'Variac', or variable auto-transformer is NOT suitable for this task.*

Diodes can become either open or



Rules:
1. Don't rush in. Examine the symptoms first.
2. Do the easy things first.
3. Locate the faulty section.
4. Be methodical.

A fault-finding flow chart that must work.

short circuited. Power diodes in a bridge circuit usually go faulty in pairs, but it is good practice to replace the lot anyway. Be careful to use diodes that match the original, particularly in terms of their PIV (peak inverse voltage) and current ratings.

As already mentioned, power supply capacitors often become faulty, especially the main filter capacitors. It is important to replace any such capacitor with one having the same temperature and current ratings (match the physical size) as well as voltage rating.

Another consideration is the possibility of electrolytic capacitors exploding due to an internal temperature rise. To minimise the danger, a pressure relief is usually incorporated in the can, and any replacement should have this type of relief. This mainly applies to those electrolytics that are operating in a high power environment, such as a computer power supply.

Intermittent faults

Intermittent faults are the bane of the service technician. Difficult to find, you can never be sure if you have really fixed the fault.

Bad soldered joints are typical intermittent faults, and it often pays to simply spend the time to carefully resolder every connection on the board. Special care is needed, as long term oxidisation effects can make the faulty connection difficult to repair properly.

An intermittent fault in a component can often be found using a can of freezer spray. If the general area of the fault can't be identified, spray methodically over the whole board. If the component is temperature sensitive, this technique will often find the problem.

If the fault only appears after a certain operating temperature has been reached, normal operation will follow when the faulty component is cooled down by the spray. By using a localising nozzle or tube on the spray can, its effect can be confined to a small area, helping considerably in establishing the location of the fault in a crowded layout.

Heating a suspect component with a soldering iron or a hair dryer and then applying the freezer spray is another effective method for seeking out these types of problems.

In some cases, particularly in complex equipment, it becomes impracticable to use the methods described above. When the intermittent is not temperature sensitive, and all soldered joints have been tested, it becomes essential to narrow the problem down by identifying the area causing the problems.

Various methods are used, including transferring plug-in cards from another unit of the same type, or attaching analysing equipment. The main requirement in this type of fault finding is patience. If parts are available, components for a whole section can be replaced. Of course, you can replace the lot to begin with anyway, in the hope the fault is a component.

Handy flow chart

Fig.4 shows a flow chart that summarises the fault finding techniques described so far. No flow chart can cover all situations, but the suggested 'plan of attack' is a good place to start. Experience will soon show you how to adapt the chart to particular situations, and its presentation is included merely as a pictorial means of summarising this article.

Included with the chart are four basic rules. The rules are not in any specific order, but the intended message is to be scientific and logical about the task. Luck has always played a part in servicing, but you can never rely on it.

Remember that if the device used to work, then it will again – given enough time and effort. EA