Basic Troubleshooting of Electronic Devices and Equipment

Basic troubleshooting involves approaching a failure in a logical and consistent manner. In many cases, only the most rudimentary test equipment will be needed, while in other cases some more involved test equipment is called for. In any event, we always start with the basics. None of what follows is meant to describe high-level radio analysis and repair, but is designed instead to help the novice troubleshooter get started.

While an in-depth study of the complete range of test equipment is beyond the scope of this article, we will discuss the basics that anyone who does more than just occasional troubleshooting will want to have. A list of that equipment might look something like this:

- Digital Multimeter
- Analog Multimeter (VTVM or FET VOM)
- Continuity Tester
- Universal Component Tester
- Infrared Thermometer
- Signal Generator/Sweep Generator
- Signal Tracer – AF and RF
- Logic Probe
- RF Probe
- Frequency Counter
- Oscilloscope
- Digital Camera
- Test Leads and Jumper Wires
- 50Ω 100W Dummy Load

A more advanced list of test equipment might include the following additional items:

- Capacitance Meter
- Inductance Meter
- Capacitor Leakage Tester
- Capacitor ESR Meter
- Transistor Tester
- Tube Tester
- Logic Analyzer
- Curve Tracer

Not to be forgotten is the subject of troubleshooting safety. To that regard, an isolation transformer, a variable AC supply (often called a Variac®), and a series current limiter are all necessary items whenever any mains-powered equipment is being serviced or repaired. These three items, taken together, are called the “trinity” and are an absolute must-have for mains-powered equipment repairs. Bench repair of DC-powered equipment will often require the use of a regulated bench power supply, generally with adjustable output (both current and voltage) and a current capability of at least one ampere. If not adjustable, fixed outputs of 5VDC, 9VDC, 12VDC, 15VDC, and 18VDC are recommended – can you see why an adjustable supply is better? It is easy to cobble together a regulator for intermediate voltages such as 6 volts, 4.5 volts or 3 volts. Another good choice is a so-called “battery replacement box” such as the Elenco XP-100 Battery Eliminator. If you are planning to do transmitter output testing of ham radios, a power supply capable of delivering much higher current, often up to 40 amperes and generally at 13.8 volts, will be needed.

Personal safety also includes the mandatory use of eye protection. There are many eye hazards in electronic repair work, ranging from flying clipped leads to exploding capacitors. You only get one set of eyes in your lifetime – protect them against avoidable injury.

Finally, the troubleshooter will want to have a decent set of basic electronics hand tools, including screwdrivers – both large and miniature (jeweler’s), tweezers for SMT devices, pliers of various types but especially needle nose and diagonal cutting, wire cutter/stripper/crimper pliers, nut drivers in Imperial and metric sizes, and some small wrenches in both Imperial and metric sizes. Soldering and de-soldering equipment will also be necessary, as will some good lighting and magnification. Solder and rosin flux are also necessary – NEVER use acid-core solder or acid flux when working on electronics!

Of course, all of the things that we have already discussed means that a suitable workstation should be made available. A non-conductive workbench with an anti-static mat is best, and suitable mains power – with GFI receptacles or on a GFI breaker – should be available nearby the bench. Circuit board holders of some type are also a boon to the bench technician.

One more word of caution that is very important when working with mains power – DO NOT work alone! Always make sure that there is someone available in case of emergency, and preferably that person should be CPR trained and capable! Electricity can be very dangerous, even lethal. Take the proper precautions to preserve your life and safety.

OK – now that all of that is out of the way, let’s get down to the meat of this article – troubleshooting!

The first step in any troubleshooting endeavor is to verify the problem and ascertain the operational status, if any, of the device. Take for example a recent problem that I encountered with one of my signal tracers. Upon switching it on, it appeared to come alive, that is the power LED lit up and the signal strength LED string went through their normal countdown sequence. All good, right? Not so fast… when we attempted to follow a signal with the unit, there was no response in the tracer, either from the speaker or from the signal strength LED string. So… how do we troubleshoot something like that, when the defective item is one of the tools that would normally be used in such a diagnosis? I started out by trying to verify what did and what did not operate as it was supposed to. In this case, it was apparent that the DC supply voltages were present, as the power pilot lamp LED came on, and the signal strength LEDS lit up as well. This would seem to indicate that the problem was in the signal path somewhere. I then employed a methodology that I like to call a *system of halves*, which is an effective means of locating a faulty stage or component.

The system of halves simply divides the failed device into rough halves – not exactly into two equal parts, but into two logical parts for troubleshooting. Select a logical dividing point somewhere in the unit and begin testing there. If the test shows a positive result, then everything from the dividing point forward through the signal path must be operational, and the problem exists somewhere between the input and the dividing point. Once you have identified which "half" of the unit has the failure, work deeper by dividing *that* section in half and repeating the test. This method is followed until the fault is isolated to a specific stage or component. The size and complexity of the unit is the governing factor as to how many steps it will be likely to take to find the failure.

Going back to my signal tracer example, I injected a 1 kHz sine wave from a signal generator into the input of the audio amplifier, going through the coupling capacitor at the amplifier input pin. This did not produce any output at the signal tracer speaker, indicating that the audio path was defunct somewhere. The next logical division was at the output of the audio amplifier stage, which also failed to produce a tone in the loudspeaker. OK – now we are down to the audio driver or output, so I injected a signal there and still had no response. Hmmm… is it possible that a low-failure item like the speaker had failed? I then clipped a test speaker with alligator clips to the speaker wires right on the integral speaker, and voilà! A clean 1,000 hertz tone was emitted by the test speaker. Moving the signal injector back to the starting point – the input of the audio amplifier, I verified that the audio chain was intact and operational, including the volume or audio gain control. Job done! Right? …Wrong! Just for completeness of testing, I wanted to verify the operation of the sensitivity control, which is in the signal input processing area. To do that, I injected the same 1 kHz sine wave signal directly into the input port of the signal tracer, and guess what? No response from the speaker, and no response from the signal strength indicator LED string. There was *another* problem with this puppy. I had to find it to call the job done for sure.

I went back to the last point at which I knew I had a working path, which was at the audio amplifier input. I then worked backwards toward the input BNC jack, one stage at a time, checking for signal passage through each stage. At each step of the way backwards through the signal tracer, I had a complete signal path. In other words, the injected signal was audible in the test speaker that was still clipped in place. Finally, I got to the last stop on the bus route, the BNC connector and its coupling capacitor. Because the capacitor was difficult to reach without disassembling the entire unit, I jumped over it to the BNC jack, which I tested at its solder point to the PCB. The path *through* the BNC jack had already been tested. Interestingly, when I injected the signal at the BNC jack center conductor solder pad on the PCB, I had no signal continuity. This meant that the fault had to be between that point and the input of the first transistor in the input processing chain. The only component in that short path was the BNC jack's input coupling capacitor.

OK – I have it narrowed down to a single component, I think. I dismounted the PCB from the housing so that I could get to the suspect capacitor, and then powered up the unit. Next, I injected the 1kHz signal at the downstream leg of the cap and the signal passed perfectly. Shifting the injector to the upstream leg of the cap showed that the signal was indeed being lost at that capacitor. Time to remove and replace it, which I did. Immediately after replacement of the capacitor, I injected the signal into the BNC jack again. This time, all functioned properly. I installed a replacement 40mm 8Ω 2W speaker to the unit cover as well as a new pair of speaker leads, reassembled the PCB into the housing, and buttoned it up. Job really done this time!

Let’s analyze that repair a little bit. First of all, two concurrent failures like this are quite rare unless one is triggered by the other. There is no way that is the case here. In this situation, the speaker failure is most likely the result of disassembly of the two halves of the equipment enclosure and handling of the pieces once open. The speaker leads as built were 22 AWG solid wire, which is quite stiff. I believe that the stiff wires put undue stress on the speaker connection pad, causing it to move and break the tiny voice coil wires going into the speaker cone. In other words, the first failure identified was actually the second one that occurred, and it happened as a result of going in to diagnose the first failure. The stiffness of the solid wire is also what led me to replace those leads with equivalent stranded wire, which is much more flexible.

So let’s talk about that first failure. Without testing the cap, I can be quite sure that the failure mode of the capacitor was that it went open, as that is how that cap, installed in the signal path, would have blocked the input signal. Not a very common occurrence, but it does happen from time to time. This cap was a low-value ceramic disc, which was also most likely a very low-cost part. There is truth in the saying that you get what you pay for.

What does all of this show us? It demonstrates that failures are not always what they may seem to be at first glance, and neither are the solutions. Sometimes it becomes necessary to re-engineer a unit to prevent future failures that are due to design features.

When troubleshooting an electronic circuit, it helps immensely to have some service literature, including a schematic diagram, a parts list, a PCB component map, and even “see-through” PCB diagrams that allow us to see the positions and shapes of the various lands and traces on the PCB and how they relate to the installed components. There are several sources of schematics available on the web, many of which – but certainly not all – are available at no charge. Also, when searching for schematics, don’t limit your search to “schematic” – search also for “user manual” and “service manual’. Always include the manufacturer name and the model number in your search string, such as “Majestic Radio 5A410 schematic” and then vet the hits to make sure that the returned pages apply to the unit on your bench. Sometimes the closest you can come is to a device family, such as the CSI 600/700 series for the CSI 710 handheld 2-meter radio. In such cases, be prepared for slight differences, or for multiple circuit iterations to be shown.

Another very useful piece of documentation is one that you might sometimes have to draw for yourself. It is called a *block diagram*. A block diagram breaks a device down into its logical or functional subsections. For example, a typical radio receiver block diagram might show the front end (antenna) and RF amplifier, the oscillator/mixer, the first IF amplifier, the second IF amplifier, the detector, the audio amplifier, the audio driver, and the loudspeaker. Each of these sections would be shown as a block in a chain of blocks that depicts the signal path through the unit. Feedback loops such as AFC or AGC would then be shown as a path from its source back to its target stage. Ancillary blocks like the power supply would also be shown, together with their attendant connections to the various stages.

The block diagram is your best resource when choosing the logical system of halves dividing line as your starting position as well as the other points at which to do your basic circuit testing.

So what then would the basic troubleshooting process look like? In most cases, it would look something like this:

1. Verify the complaint…
    a. Ascertain what works and what does not work.
    b. Do the panel illuminating lamps or LED's come on?
    c. Is there any sound at all from the speaker?
    d. Do front panel indicators (frequency, LCD, waterfall, etc.) work?
    e. If a transceiver, does it switch between RX and TX (use a dummy load)?
2. How is the device powered?
    a. Battery only?
    b. DC from an external power supply?
    c. AC from the mains powering an internal DC power supply?
3. Is the device solid state, or does it utilize vacuum tubes?
4. With the device unpowered and switched off, open the enclosure and do a thorough inspection for anything obviously burned, blown fuse, pinched wire, and so forth.
5. Take several detail-revealing photos before disturbing anything so that you can re-position leads *etc.* as the factory had placed them.
6. Take note of the apparent age and condition of the various problematic capacitors in the unit – particularly polarized capacitors.
7. ***Starting at this point, anything found to be other than correct during any of the testing done must be tracked down and corrected before moving on. For example, if an immediate short circuit is indicated on power-up, that fault MUST be located and cleared before any further steps are taken.***
8. Using proper precautions – isolation transformer and current-limited variable AC supply, slowly bring the voltage up on the unit. Watch the current drawn by the device. An immediate HIGH draw will usually indicate a direct short in the unit.
9. Assuming all is OK on startup, bring the unit to full line voltage and check the LOW VOLTAGE supplies for proper output. DO NOT ATTEMPT TO MEASURE HIGH VOLTAGES! Any low-voltage supply found to be dead or off by more than ten percent of its specified value MUST be corrected before continuing. Thus, a 5 volt supply

reading 4.4 volts is too low and must be corrected. However, if the service manual provides different advice on this issue, the service manual values should prevail.

10. Using voltage indications from the schematic or service manual, begin checking voltages across the functional sections of the unit, testing the LOW voltages only.
11. Think about the symptoms. For example, does the unit consistently blow a fuse? If so, find the fuse on the schematic diagram and look to see what is protected by the fuse. The fault must lie somewhere in the protected circuit(s) after the fuse. Of course, if the fuse is a main fuse, there's a lot of ground to cover – the entire device.

Let's take a break for another bench-top repair tale. I was presented with a Tektronix 465 scope – an early one, with a low serial number. On power-up through the current limiter and the isolated transformer/Variac® combination, all was well, except that there was no hint of activity on the CRT face. The beam finder on the scope failed to find any trace or even a dot – absolutely nothing. Everything else on the unit appeared to be OK. Graticule illumination worked, the indicators in the voltage select switches worked, and all other front panel indicators seemed to work just fine. I powered it down and opened it up. Just for peace of mind, I checked all of the low voltage supplies, and the + 5V, the -8V, the +15V, the +55V, and the +110V supplies all checked out OK. I then looked at the fuse on the +15V unregulated supply rail and found that it was blown. This was fuse F1419, in the charge pump circuit for the CRT. Downstream from this fuse were an inductor L1419, a capacitor C1419, and a transistor Q1418, as well as the primary of a transformer T1420. This capacitor is a 47µF Tantalum type of polarized capacitor – notorious for failing shorted. I decided to play the odds and start there, removing the blown fuse and measuring resistance to ground from the "out" or protected side of the fuse holder. I found a direct short to ground, as expected – the fuse blew, after all. Next I removed the suspect capacitor and measured to ground again from the fuse holder. No more direct short! I replaced the capacitor with something a little bit beefier – a 100µF 50V aluminum electrolytic – and put a new 1.5A fuse into the holder. Now, on power up I got a beam immediately after CRT warm-up. Success!

The point of that story is that sometimes you have to play the odds and go after the common failure items. In older equipment, capacitors are often a weak area, especially polarized capacitors. ESR creeps up, caps go open or short, or capacitance varies from its rated value. In equipment of any age at all, capacitors should be early suspects, especially in cases of short circuits or signal loss.

OK – back to the troubleshooting steps…

12. If all operating voltages seem to be correct, you may be looking for a failed component that is not affecting the operating voltages – in other words, what I call a "quiet" fault. Now might be a good time to start checking temperatures, using either a very accurate non-conducting thermometer probe or an infrared thermometer. Check for the chip that is cold by comparison to all the others on the board. When integrated circuits or even discrete actives operate, heat is produced as an unavoidable side effect. Therefore, if

you find no heat on a component while everything else around it shows some degree of heat, you have probably found an inoperative component.

13. How about popping static noise in a receiver? Sometimes these can be found by physically tapping on the various components – capacitors and resistors especially. The popping noise often comes from a tiny fracture or intermittent open circuit inside a component. By tapping on the component, you can aggravate that open circuit, increasing the popping noise.
14. Don’t overlook odors. Failing electronic components will often emanate foul or harsh odors, making them easier to find. Sniff around the board if you can do so safely.
15. Another tool in your arsenal is thermal change. You can try heating components slightly by bringing a hot soldering iron near the part and watching for a change in status. The same thing can be done with cooling sprays made for just this purpose – you spray it on the components to cool them and watch for a change.
16. Signal tracing through a device is done using either a signal tracer or an oscilloscope. Remember that oscilloscopes are ALWAYS connected with respect to chassis ground. Thus, it is very important to have an isolation transformer when diagnosing mains-powered equipment. A hot chassis can blow the ‘scope lead clip right off the lead! Furthermore, when using a signal tracer, it is sometimes necessary to couple the signal via a capacitor to maintain isolation of the tested circuit from the test equipment.
17. The signal source used for signal tracing can come off an antenna or may be injected into the device under test. It is also possible to couple a signal into the antenna or antenna jack using a two- or three-turn coil across the signal generator output lead. Alternatively, capacitive coupling may be necessary to maintain isolation. Also, it is always best to use the lowest amplitude signal that you can to get the job done. Too much signal can overdrive circuits and can activate automatic level controls, distorting the test results.

Time out again for another anecdotal repair. Very recently, I was working with one of my universal component testers when it quit in the middle of the job. This particular tester is a Velleman K8115 unit that I assembled from a kit. It is a two-board open design with the PCB’s stacked and spaced. The upper PCB is a display board, carrying an LCD display, a single current limiting resistor for the LCD backlight LED, ten 1µF monolithic capacitors, and a six-pin inline header socket for interconnection to the main board. The main PCB incorporates two voltage regulators (3.3VDC, and 5.0VDC) in TO-92P packages and a nine-volt battery as the power source. The remaining semiconductors include a 2.5VDC voltage reference diode in a TO-92P package, a pair of TO-92P BC547 NPN transistors, a single TO-92P BC557 PNP transistor, a CD4050B CMOS non-inverting hex buffer in a DIP-14 package, and an Atmel ATmega328P microcontroller in a DIP-28 package. The whole foil side of the lower PCB is exposed, as there is no enclosure on this device. There are five rubber feet on the lower PCB to keep it elevated off a possible conductive bench or table top. Now, on to the failure.

I was holding the tester in my left hand, with a transistor attached to the test lead mini-clips, and I had pressed to “Start” pushbutton switch with my right hand. The test began as it normally would, but then, just as the LCD screen began to display the results, the screen went white and began flickering slowly. Obviously, some component went bad during the test. Now… I had previously tested and characterized this same type of transistor (a 2N3904) on numerous occasions, so I knew that the problem was not any sort of overload or error due to the device type under test. How does one even begin to troubleshoot something like this? I started out with the schematic diagram, as usual.

I knew that the battery was good, because as a part of the initialization routine, this tester displays available battery voltage on-screen, and it had shown 8.97 volts. The initialization routine also displays the output level of the 5VDC regulator, which had shown as 5.03 volts. However, the voltage regulator could have failed, so I looked a bit more closely at the schematic diagram. The fact that the LCD backlight was operational meant that both the 5.0VDC and the 3.3VDC voltage regulators were operational, as the backlight is supplied off the 3.3VDC rail, and the 3.3VDC regulator takes its input directly from the output of the 5.0VDC regulator. A quick check of the operating voltages showed that the VCC (pin 7) and AVCC (pin 20) of the ATmega328P µC were at the nominal 5VDC supply voltage with respect to device ground (pin 8 for GND and pin 22 for AGND) of the ATmega328P, and that the VCC pin (pin 1) of the CD4050B hex buffer was at the nominal 3.3VDC supply voltage with respect to device ground (pin 8 of the CD4050B).

With normal operating voltages present on the IC's and all other active devices, where do we turn from here? Using the equipment that I had available to me at the time, I did something that might seem strange, but really is not. Using my infrared thermometer, I took a quick temperature reading on the µC and the hex buffer IC's, which showed that the hex buffer IC was running at a temperature (63°F) that was 22 degrees Fahrenheit colder than the temperature at which the µC IC was running (85°F). This indicated to me that the hex buffer IC was either not working at all or was working poorly. The next step was to test the signals through the hex buffer, of which only four of the six buffers onboard the IC were in use in this circuit design.

Another quick look at the schematic showed the following signal paths:

- µC pin 2 runs directly to hex buffer pin 9, which outputs non-inverted to hex buffer pin 10, which then runs directly to pin 4 of the 6-pin header to the LCD screen;
- µC pin 3 runs directly to hex buffer pin 7, which outputs non-inverted to hex buffer pin 6, which then runs directly to pin 3 of the 6-pin header to the LCD screen;
- µC pin 4 runs directly to hex buffer pin 5, which outputs non-inverted to hex buffer pin 4, which then runs directly to pin 2 of the 6-pin header to the LCD screen; and
- µC pin 5 runs directly to hex buffer pin 3, which outputs non-inverted to hex buffer pin 2, which then runs directly to pin 1 of the 6-pin header to the LCD screen.

Thus, whatever signal is present on pin 2 of the µC should also appear at pin 10 of the hex buffer, and so forth through µC pins 3, 4, and 5. This, however, was not the case. For example, a high-level signal at pin 7 of the buffer produced a low-level signal at pin 6 and thence also at pin 3 of the LCD connector. In fact, when tested with a logic probe, all four of the individual buffer sections in use in the CD4050B were outputting logic low signals. This validated the temperature test and proved conclusively that the CD4050B had failed. The most likely failure cause was a zap of static electricity into or across the CD4050B hex buffer IC. As with all CMOS devices, this IC is extremely sensitive to static electricity, and is easily damaged or destroyed by static hits. There is a high probability that this could have been avoided had the entire foil side of the PCB been covered with a layer of insulating tape, which has now been done. Replacement of the CD4050B non-inverting hex buffer IC with a new one repaired the tester and brought it back to fully operational status.

What does this repair show us? It reveals how a little bit of out-of-the-box thinking can sometimes reduce the diagnosis and repair time, and that it is important to use any and all of the tools and test equipment that you have available, which in turn brings up another important aspect of the troubleshooting process.

In some cases, the only – or at least the first – tools that are needed are the ones that most of are gifted with at birth. I am, of course, referring to your vision, your hearing, your sense of smell, and your sense of touch, all used in conjunction with your ability to think and reason. Through your senses and some critical thinking, it is often possible to posit a failure scenario that reasonably explains the failure indications observed.

Look for physical indications of the failure, such as but not limited to:

- swollen or ruptured capacitors,
- chafed or pinched wires,
- indications of excessive heat,
  - solder joints where the solder has been melted and displaced,
  - discoloration of resistors and/or semiconductor devices,
  - lifted PCB traces,
  - burned wires and/or plugs,
- blown fuses, and
- broken components.

Pay attention to any unusual odors coming from the failed equipment. Electronic components that have been seriously overheated to destruction will often emanate harsh odors that are quite unmistakable.

Occasionally, the need will arise to locate an open circuit in a wire or cable, which can sometimes be accomplished by feel, flexing the cable along its length until the break is felt. It is also possible to find open or intermittently open circuits through touch, by attempting to wiggle components soldered to a board. Those components that wiggle easily are probably not soldered securely.

Hearing is useful as a diagnostic tool either alone, or in conjunction with other equipment such as a signal generator/injector. It is also used to identify, as was mentioned earlier, partial open circuits within components by tapping on them and listening for noise in the audio output stream.

Of course, coming full circle, we are back to the eyes and their utility in reading the meters and indicators on various pieces of test equipment.

To return to our numbered list of troubleshooting “steps”…

18. Use the *system of halves* whenever possible to localize the fault to an increasingly smaller area of the failed equipment. Guided by a schematic diagram, identify logical points in the circuit to divide the circuit for testing as described earlier.
19. Look for commonality when addressing a fault. For example, if the “dead” portion of a piece of equipment includes only those sub-circuits powered by a 3.3VDC source, identify and explore the point where the 3.3V supply is developed. A shorted smoothing capacitor downstream from the 3.3V voltage regulator will kill the entire 3.3V source.
20. *When you hear the sound of hoofbeats, think horses, not zebras!* Go with the odds when troubleshooting. While the unusual or uncommon failures can and do happen, they happen much less frequently than do the common or usual failure modes. Logic dictates that we should start with those common or usual failure types, and then move on to the less common failure modes afterwards if necessary.
21. Bridging suspected capacitors with known good ones can be helpful in cases of signal loss due to an open capacitor. For example, suppose that you have, using the system of halves, tracked a dead receiver to an inter-stage coupling capacitor in the IF chain. If you suspect that the capacitor is open, you can quicky verify that by simply “dead bug” connecting a good capacitor of the same value and at least the same voltage rating across the suspect capacitor. If the receiver comes alive, your premise is verified. Replace the capacitor in circuit to make the repair. Note that the bridging method is not helpful at all in the case of a shorted capacitor, as the short will still be there behind the bridging capacitor. However, remember that a shorted capacitor will yield a different set of failure circumstances and symptoms than will an open capacitor. With time and experience, you will learn to easily differentiate between the two failure modes.
22. While modern resistors seldom fail on their own, that is not so true of some older resistor types, especially the “roundie” type of carbon composition resistors. These resistors, recognizable in older equipment by their brown bodies and rounded body shoulders, were very susceptible to moisture encroachment as time went by, leading to some wide variations in effective resistor values. In tube-type equipment, it is often possible to measure the resistors *in situ* because of the extremely high internal resistances of the tubes. On the other hand, in transistorized equipment, it will usually be necessary to desolder one end of a resistor to isolate it for accurate measurement. Any resistor found to be outside its tolerance limit by a substantial amount should be replaced with a modern replacement resistor.

OK – we’ve talked about having and using schematic diagrams in our troubleshooting efforts. So… where does one source these schematics? There are several good and reliable online sources for service manuals and schematics, some of them free of charge and others where a fee applies. Here are my favorites, in no particular order:

- Boat Anchor Manual Archive… a free source of contributed service literature and schematic diagrams… https://bama.edebris.com/
- The Schematic Man… a fee-based provider of service literature, including the SAM'S Photofact line of products… https://theschematicman.com/
- The Manual Man… another fee-based service literature provider with an extensive catalog… https://www.manualman.com/

Another good option on the web is https://www.ve3kbr.com/op_aids/manuals.html which offers a listing of additional web resources for service literature.

Of course, obtaining the schematic diagram is only a part of the job. You also need to know how to read and understand such diagrams. That knowledge starts with a clear understanding of the meaning of each of the symbols used on the schematic diagrams. A quick Google search for *"schematic symbols"* will provide a plethora of examples of the various symbols and what each symbol represents in the diagram.

It must be understood that a schematic diagram depicts the electrical connections of each individual component in a circuit, but most often NOT the physical locations of those components. A different diagram is needed for that information. *Component location diagrams* will often show a "map" of each circuit board in a device, and will quite often go so far as to show an "X-ray" view of each board, allowing the placement of each component with respect to the foil traces on the circuit board to be clearly seen.

A third diagram type is the *device wiring diagram* that depicts the physical connections between the various circuit boards and the off-board components of the equipment. These diagrams will often include such information as wire color, plug types, and plug locations.

The fourth diagram type is the block diagram already mentioned. In terms of a further discussion of the block diagram, it must be understood that these diagrams indicate the *logical* breakdown of the equipment into operational stages or sections. These stages may be all or in part on a single circuit board, or they may be physically located across multiple boards. The diagram indicates the key signal paths through the equipment, and will usually show the various stages or features that process the signal(s) in some manner. These stages or features can include oscillators, mixers, amplifiers, detectors, filters, and so forth.

Some time spent in studying the various diagrams will go a long way towards building an understanding of the operation of the circuits at hand, and can also reduce the actual diagnosis and repair time because of that increased understanding. For example, and going back to our earlier example of a dead 3.3V supply, simply understanding the voltage development process and the locations of the involved components will make it easier to go right to that physical portion of the device and identify those components. From there, some basic voltage and resistance measurements will aid in the final fault diagnosis.

If you get confused or simply do not understand the operation of a given circuit, *ask somebody!* There are numerous help sources available online. Almost any common equipment type will usually have a user's group established somewhere, with a web presence and usually with a chat or forum structure wherein questions and answers can be exchanged. However, I will caution the reader against a common ploy that is found very often on the web, wherein a student is asking for the answer to a school assignment. If you are a student, get help with the understanding, but do your own work! If you are a ham or a hobbyist, make that status known when asking the question(s) that you have. The more completely you can explain the problem, including the results of any diagnostic measurements made, the more likely it is that you will get a useful response.

Most amateur radio clubs will have a list of club "Elmers" who are available and willing to help a neophyte with almost any aspect of amateur radio, including electronic troubleshooting or diagnosis.

Often, the Internet can also be a huge help in identifying and resolving failures that have turned out to be common or endemic issues. One such case is the experience that I had with a Yaesu FT-736R base station transceiver. This unit has an integrated FP-1274A 120VAC to 13.8VDC power supply unit installed to its chassis. The power supply plugs into the main radio chassis via a six-pin Molex® plug carrying two red wires and two black wires. Upon receipt in the shop, the unit was completely dead – no response of any kind at all at all when the power switch was turned on. The radio was marked as taking a 13.8VDC input there, so I unplugged the built-in power supply unit and connected a bench power supply. On activation of the power switch, the radio came alive and everything worked as it should. Obviously, then, the integrated power supply unit had failed. I removed the PSU from the main chassis and removed its cover. Immediately noticeable was a darkened area on the printed circuit board (PCB). A closer look at that area showed that there were two 33-ohm two-watt resistors (R17 and R18) at that location. OK – so the PCB got hot enough to discolor it quite a bit. What else might have been heat-damaged as well? In the immediate vicinity was a couple of aluminum electrolytic capacitors. Actually, there are four of them id near proximity, but two of them – C8 (56µF/50V) and C9 (220µ/16V) are really close. I decided to start there, so I desoldered and removed those two capacitors. A quick capacitance test showed that the 56µF capacitor was down to 4µF, and the 220µF one was down to about 25µF. They obviously had to go, and there was no sense in even measuring their ESR's. (ESR or Equivalent Series Resistance is a capacitor failure mode where an internal resistance develops within a capacitor as it ages.) Just for assurance purposes, I removed and tested the other nearby electrolytics, which were C12 (1µF/50V) and C22 (1,000µF/25V). They both tested well within capacitance tolerances for ±20% capacitors, and their ESR's were extremely low. Testing them with my capacitor leakage tester revealed no leakage to be concerned about. (There is almost always *some* leakage, especially in electrolytics, but these were well within acceptable limits.)

The net result was the replacement of two capacitors, C8 and C9, with 105°C versions of identical capacitance ratings as the originals. For the 220µF capacitor, I had a 35V type on hand, so I used that instead of sourcing a 16V device for this job. The 35V capacitor was slightly longer in length than the original 16V one, but it was the same diameter, so original inter-component spacing was maintained. Replacement of the capacitors repaired the PSU. It was closed up and installed back into the radio, where it was connected and tested with positive results.

This repair illustrates the value of observation and critical thinking in the troubleshooting process. The use of test equipment was simply to verify the conclusions drawn through that observation and the associated thought processes. The testing of the additional two capacitors was a means of ensuring that there would not be a need to disassemble the PSU a second time.

One other thing about the Yaesu FT-736R repair. I used the term endemic" earlier in reference to certain repairs. This repair is one of those endemic types. It affects many radios out there, making it almost a no-brainer when one of these comes in dead. Chances are good that this frequent failure will be at the root of the problem with a good number of these sets. As I learned afterwards, it is common-enough of a problem that there have been a few pieces written and posted online about it. Had I looked online first, I might have found one of those articles and learned about the failure that way instead.

Back to the list again…

23. Make sure that you find the *cause* of a failure, *not just the symptoms of it!* Sometimes, an active component will be discovered early on. The technician will replace that failed active device, believing that the problem is fixed. The unit gets returned to service, and a short time later it is back, this time for repair at no charge to the customer! "Why so?" you ask. It is really quite simple. The failed active device – say maybe a transistor – was a *symptom* of the failure rather than being the failure in and of itself. So… what caused the transistor to fail? Picture a circuit where a transistor is being used as a switch to control the activation of a relay – maybe the relay used as a T/R switch in a ham radio transceiver. That relay, as many do when installed in similar circuits, has a diode installed across its coil. The diode is there for spike suppression when the relay coil is de-energized. It is placed in circuit in a reverse direction, such that no current flows through the diode under normal circumstances, but whenever the transistor goes into cutoff and turns the relay coil current off, the magnetic field created by the normal coil current collapses, inducing a reverse spike in the coil winding. The spike suppression diode shorts the coil's ends to each other when that reverse spike current flows, effectively cancelling the spike within the coil itself and preventing the current from getting to the transistor. But… what happens if the diode (or diode circuit) fails open? It would not be evident at all during normal operation, but at transistor cutoff, when the spike occurs, there is no longer a working diode there to suppress that spike. This allows the spike to travel back to the transistor, often destroying the transistor in the process. Thus, a failed transistor that is symptomatic of the actual failure, but is *not* the root cause of the failure at all. It should be noted that it may not be the first or even the tenth or twentieth spike that finally cooks the transistor, but eventually, it happens. It

is far more likely to cause a failure if there are multiple spikes in rapid succession, as when the mic is keyed and released several times.

24. If two or more seemingly unrelated systems fail simultaneously, look for something that is common to all of those systems which, if failed, would in turn cause the concurrent failure of those “unrelated” circuits. An example can be found in the Velleman K8115 component tester discussed earlier. Failure of the 3.3V voltage regulator will take out the display and the CD4050B non-inverting hex buffer. The display failure would be obviously evident; the CD4050B failure would require some further investigation to substantiate. However, a simple voltage measurement would reveal the lack of the 3.3V supply to either the display board or to the CD4050B IC. A quick peek at the schematic would show that the only other component on the 3.3V rail is a 1µF electrolytic capacitor at the output of the 3.3V voltage regulator. Therefore, a dead 3.3V rail has one of three possible causes… a shorted 1µF capacitor as above, a failed voltage regulator IC, or a loss of the 5VDC rail input into the 3.3V voltage regulator. Aren’t schematic diagrams just great?

Time for another repair case history, this time with a CONAR Model 255 6MHz Analog Oscilloscope. This is a kit-built solid-state oscilloscope from the mid- to late-1970’s, that uses a CRT. The unit had worked well for many years before suddenly failing. The failure indication was a lack of the oscilloscope trace on-screen, though the front panel pilot lamp, a neon tube, illuminated on power-on. There are no other power indicators available to the user, and in fact, the only other positive indication of power being present at all was the illumination of the CRT heater. Unfortunately, the only thing that these two illuminations told me were that the power cord and switch were good, as evidenced by the neon tube across the switched line cord, and that the power transformer was operable to some extent, as the filament voltage is drawn from a dedicated secondary winding on the power transformer. This meant that some exploration was in order.

Apart from the high voltages used in the horizontal and vertical deflection circuits, the only voltages produced by the power supply section of this unit are +5VDC and -5VDC, which are derived from the +12VDC and -12VDC outputs produced from a full-wave rectified AC source obtained from a secondary winding on the main power transformer. The -5VDC supply and +5VDC supply were both found to be dead. Upon investigation, the +12VDC and the -12VDC sources were approximately correct, if slightly off at +13.1 volts and -12.8 volts respectively. A few words about the power supply design are required at this point. The -5VDC supply is designed to track the +5VDC supply, being equal but opposite in polarity to the output voltage of the +5VDC supply. Because of the fact that the positive and negative twelve-volt sources were approximately correct, and because of the low probability that both five-volt supplies had failed, I decided to start with the +5VDC supply. The +5VDC is produced via a standard LM7805 three-pin 1.5A fixed voltage regulator IC (IC6) fed by the +12VDC source described above. Pin 1 of the LM7805 is the input pin, pin 2 is the output pin, and pin 3 is a ground pin. Connected directly to the LM7805 output at pin 2 is a 1µF electrolytic capacitor (C52), and also a test point, TP1. The voltage at TP1, of course, measured 0.01 volts… nominally zero volts.

With the oscilloscope powered down and after short wait, a resistance reading was taken from TP1 to chassis ground, which indicated a direct short circuit to ground.

Because of the age of the oscilloscope and the fact that capacitor C52 was apparently an original part, I decided to start with it, and thus removed it from the circuit. Repeating the earlier TP1-to-ground resistance measurement with the capacitor out of circuit, a reading of about 180 ohms was obtained. I installed a replacement capacitor at the C52 location and checked the circuit operation, and found all to be well. The oscilloscope operated normally in every regard… almost. I noticed that the beam trace was a little bit wide and slightly unfocused. Some additional repairs were necessary to bring the unit back to top condition.

Before going any further, however, I began by replacing the +5VDC voltage regulator IC6 as a prophylactive measure against potential early failure. This IC, the LM7805, is designed with short-circuit or overload protection and in theory should have been suitable for continued use, but I was there and the part cost is a mere fifty-nine cents.

Now let's continue with the other repairs to the oscilloscope. All of the capacitors in this unit except the main filter capacitor were original parts some fifty-five years later. Many of them, especially the electrolytics, were undoubtedly showing signs of (internal) current leakage. I decided to re-cap the entire oscilloscope. I left the mica and ceramic disc capacitors alone (with one exception), but replaced all of the tantalum, aluminum electrolytic, mylar and poly film capacitors. The excepted disc capacitor that I replaced was a 0.01µF 1.4kV disc that was installed across the line cord. I replaced this with a modern 0.1µF X1/Y2 safety capacitor. Safety capacitors are designed to only fail open-circuit, not short-circuit, and are made specifically for line suppression use. This amounted to a total of eighteen discrete capacitors (one poly film, five mylar, six tantalum, and five aluminum electrolytics, plus the safety capacitor) in addition to the two-section 30µF/30µF x 350V electrolytic filter can capacitor. Replacing the capacitors restored the nice crisp and narrow beam trace. I then performed a calibration in accordance with the original build manual for the unit, cleaned the graticule and CRT face, and cleaned all controls and switches with DeoxIT®, which brought the unit into top condition again.

The owner of this oscilloscope was rather pleased when she saw the operational condition of the unit. She had gotten used to the wide, fuzzy trace over time and had not realized just how bad it really was until she saw the "new" look of her old benchtop tool.

This repair highlights the endgame of all troubleshooting jobs – the eventual and final repairs to the failed unit. In most cases, it is not enough to simply replace the failed part. A good technician will go the extra mile to clean the unit as necessary to ensure that the entire unit can be examined for evidence or indications of failure, either current or imminent. It is then incumbent upon that technician to do what is possible to mitigate the imminent failures, thus preventing as many of them as possible. Now I am not suggesting that every unit brought in for a minor repair should be renovated or refurbished, but at the same time, anything leaving your shop should look as if somebody spent some careful time and attention on that unit. I maintain that it is nearly impossible to do a thorough inspection of a PCB that is covered in dust.

OK – so you have made the repairs deemed necessary based upon your troubleshooting and diagnosis, supplemented by circuit testing and evaluation. Is the unit ready to go back into service? Maybe… but then again, maybe not! Before returning the unit to service, test its operation in all modes offered, and to the maximum degree practical with the test equipment available. The average technician is not expected to have a service monitor or a full complement of test equipment, but do what you can do to assure yourself that the problem has truly been located and repaired.

Make every attempt to verify that you have truly located the real source of the failure and not just the gross symptoms of a more insidious failure that can continue to do further damage.

There are some rules to be followed when choosing and installing replacement components, depending upon the component type that needs replacement. The list below provides some of the most basic of these rules.

- Resistors
  - When replacing resistors, so long as available space allows, it is acceptable to use a resistor of greater power capacity, but not one of reduced capacity. Thus, it is OK to replace a ¼-watt resistor with a ½-watt version, but not the other way around.
  - Never replace any resistor with a wire-wound type unless the original was of a wire-wound design. The additional inductance of a wire-wound resistor can cause severe frequency issues.
  - It is acceptable to use a resistor of lesser tolerance than the original, but do not use a resistor of greater tolerance. For example, it is OK to replace a 5% tolerance resistor with a 1% replacement, but not the other way around.
  - If a design or schematic calls for a flame-proof resistor, be sure to install that type as a replacement.
  - If a design or schematic calls for a low PPM value (thermally stable) resistor, be sure to use a resistor of that thermal rating value or better.
- Capacitors
  - Replacement capacitors should always have a working voltage rating that is at least equal to that of the capacitor being replaced. Thus, it is OK to replace a 16V electrolytic capacitor with a 25V version of the same capacitance, tolerance, and temperature rating.
  - When refurbishing older equipment, it may be necessary to select a slightly different value for a capacitor than what was originally installed. It is acceptable to do so, selecting the closest available value from the modern capacitor offerings. For example, if a 0.005µF capacitor was originally installed, it is acceptable to replace that capacitor with a modern 0.0047µF model of the same or higher working voltage. Remember that most unmarked capacitors have a tolerance of ±20%, so the change from 0.005µF to 0.0047µF will not harm the circuit operation.

- When replacing multi-section can-type filter capacitors, my inclination is to search for an exact replacement as regards capacitance, and at the same or a higher working voltage. Thus, the original design appearance of the device chassis can be maintained. However, this is not always possible, or the equipment owner may not be happy about spending $35 to $45 for a replacement filter capacitor. In that case, it is still possible to maintain the factory appearance while replacing the working parts of the filter capacitor with discrete modern electrolytics. Be sure to disconnect the leads from the original capacitor so that it is completely out of the circuit, or else “gut” the can and place the new discrete capacitors inside that original can. With insulating ceramic standoffs, the original capacitor terminals can be used as tie points for the new capacitors, so long as there is no electrical conductivity between the new capacitor leads and the previously-connected wires or component leads.
- Similarly, it is possible to maintain the factory appearance of an antique device by gutting the wax and paper capacitors and then placing modern axial polyfilm/foil capacitors inside the original tubes and wax-sealing the ends. Thus, the capacitors will *look* like originals, but will actually be modern replacements.
- In tuned circuits, always replace capacitors with high-quality replacements of the same or better dielectric type and rating to avoid frequency creep. Most frequency-sensitive circuits will use NP0-rated or better capacitors.
- When replacing capacitors that are installed across the power line, ***always*** use only *safety capacitors* as replacements. Standard capacitors, while probably originally installed, are no longer considered to safe for use in those applications. Safety capacitors will have what is termed an X1/Y2 rating marked on the capacitor body. The X1/Y2 rating indicates that the capacitor is designed for high-pulse applications up to 4kV (X1) and general-purpose applications up to 5.0kV (Y2). In addition, safety capacitors are designed to fail only in the open condition, not in a shorted condition. Note that other variants of the X/Y ratings also exist, such as X1/Y1, X2/Y1 and X2/Y2. The X1/Y2 ratings are the more common types used today.
- When replacing older tubular wax-and-paper capacitors, be sure to observe the orientation of the banded or outside foil end of the capacitor. Then, it is proper practice to identify the outside foil or shielded end of the replacement capacitor and install it with the same orientation. Normally, the outside foil end of the capacitor will go to the lower impedance point in the circuit, often to chassis ground. The outside foil provides RF shielding for the capacitor, shunting off any induced signals to ground.

- Line cords
    - When replacing line cords, a three-wire grounded cord is always preferred. If the three-wire line cord is used, the black wire must go feed to the power switch, the white to the return side of the power input circuit, and the green wire to chassis ground.
    - If replacing a line cord with a two-wire replacement cord, it should be a polarized cord that is installed. In this case, the wire connected to the narrow blade should go to the power switch, while the wire from the wider blade should be connected to the return side of the power input circuit. This side of the circuit is sometimes connected to the chassis ground of the equipment, but not always. The wire lead from the wider plug blade is generally the ribbed wire.
- Switches
    - When replacing power switches, always make sure that the replacement switch is rated for at least the same ratings as the original switch as regards both voltage and current. Switch ratings are often marked directly on the switch, and are also most always found in the manufacturer’s datasheet for the specific switch at hand.
    - When replacing signal path switches, the most important aspect is the circuit paths through the switch. Make sure that the replacement switch is functionally the same as the original switch. For custom wafer switches, there are specialized companies that will repair, rebuild, or remanufacture these switches. They can be found online or often in the advertisement sections of electronics and amateur radio magazines.
- Fuses – ALWAYS replace a fuse with the same type and rating fuse as the original or circuit design fuse (if different than the fuse that has failed). Bear in mind that someone else may have installed an incorrect fuse, so always go by the schematic diagram or service manual fuse information when selecting a replacement fuse.
- Semiconductors
    - In the case of discrete semiconductors, exact replacement, especially in older equipment, may not always be possible. In those cases, it becomes necessary to identify the salient characteristics of the original device. This data then can be used to help select a suitable replacement from the devices available today. In most cases, it is OK to substitute a more capable transistor of the same basic type for one that has failed and is no longer readily available, so long as the important characteristics are closely matched, *e.g.,* gain and frequency response. Voltage and/or current ratings that are slightly higher will often still be acceptable, as they are maximum values and the device will most likely function properly in-circuit.

- In the case of integrated circuits, replacement can become more difficult. For any given base model of IC, the same base model from a different manufacturer will usually have a different developed part number. Sometimes, though, there will be two different but similar parts from a single manufacturer that are not directly interchangeable. Consider the LM1458 and the MC1458, both from Texas Instruments. These IC's are both dual op-amps with identical pinouts, but they do have slightly different operating voltage ranges and current needs. One can always be used in place of the other, but not *vice-versa*. The LM1458 has a wider operating voltage and a slightly higher current requirement than does the MC1458. However, in most cases, the LM1458 can successfully be used to replace the MC1458, but depending upon circuit values, the MC1458 *may not* be suitable as a replacement for the LM1458. This can become even more confusing when other manufacturers are in the mix, as the ST Micro MC1458 is NOT a direct replacement for the TI MC1458, but is closer to the TI LM1458! In many cases, though, the base number tells the story, such as in most logic devices. In general, a 74AC14 from any manufacturer should be usable to replace a 74AC14 from any other manufacturer. Note however, that a 74AC14 and a 74AH14 are *not* the same devices. The letters on these devices are an important part of the device definition. The prefix and the suffix may change from one chip builder to another, but the root number should remain the same for a given device type.
- When replacing soldered IC's, start out by *carefully* de-soldering the original IC, using a de-soldering tool to remove the solder from the pins. If it is necessary to use solder wick, be careful not to apply too much heat in the process. Once all of the solder is removed, the IC should fall out of the PCB easily. If it is still stuck, solder is still in place and should be removed. Sometimes, it is necessary to apply directed hot air heat to the PCB to achieve the final removal of the IC. With the original IC out, clean the solder pads carefully with solder wick and then 99% isopropanol to remove the burned rosin flux. Carefully insert the new IC, ensuring that all pins enter their PCB holes and that the IC is correctly oriented. Solder it in place carefully, using limited heat and a fine tip pencil-type iron. Avoid making any solder bridges between pins. When the install is complete, carefully inspect for proper seating of the IC and that no solder bridges exist between pins.
- When replacing socketed IC's, make sure that the pins are in straight rows and angled *slightly* toward the longitudinal center line of the IC. Then, carefully align the IC with its socket, taking care to orient it properly. With all of the pins aligned to their socket slots, press the IC into place, making sure that all of the pins actually go into their slots and are not bent to the outside or bent under the IC

body. IC orientation is accomplished by the use if an indentation on one end of the IC body or by a dot adjacent to the first pin at one end of the IC. The dot aligns with Pin 1 of the IC, and the indentation or notch indicates the Pin 1 end of the device. Look for a matching notch in the IC socket and in the screen-printed outline of the IC on the PCB.

- While coils and transformers have relatively low failure rates, they do nonetheless fail from time to time. One of the more common failure modes is that situation wherein the whisker-thin lead inside a stage-coupling transformer has gone open, often because of time and corrosion. Failures of this type can often be repaired by first disassembling the transformer. *i.e.,* removing the working parts from within the "can" in which the are enclosed. Once you can see the open lead – and it is often a break between the winding coil and the connection pin – all that is necessary is to clean and resolder the ends of the wire together. However, it is *very* important to first make a solid physical connection between the broken wire ends before applying solder. That will prevent the re-opening of the joint when the transformer is soldered back into the circuit. A simple lap-and-solder connection may well open immediately while soldering the can back in place, but a proper physical connection will remain in place and the solder, if melted during transformer installation, will simply solidify back onto the joint as it cools. If a wire is broken off too short for reconnection, piece in a short length of appropriate-gauge magnet wire in place of the missing transformer wiring.

Time for another bench repair anecdotal report. This time, the repair was on a DOSY TFC-3001 multi-gauge radio evaluation center. This is a desktop meter set that includes a wattmeter, an ASWR meter, and a percent of modulation meter. The owner brought it to me stating that he had heard a "POP" and the unit quit working. He said that he opened it up to look for a fuse, but found none, so he brought it to me for repair, but that he noted a violet wire with one end not connected to anything. When I asked him if the unit had made any rattling noises before he opened it up, he replied in the affirmative, but said that he never saw what was causing the noise. There was nothing floating free in the enclosure and no rattle when I got it, but my visual inspection told me that there had to have been such a noise at some point.

I was able to repair this unit without the use of a schematic diagram because I could pretty much see what went wrong. On the PCB in this unit is a standard three-pin LM7805 voltage regulator IC. What caught my attention was the obvious fact that the IC was not in its original installed position. This was evident by the fact that there was white thermal compound on the back side of the IC body and on the PCB underneath the IC, but the IC itself was sitting at a forty-five degree angle upwards away from the PCB surface. Further inspection showed that there was only the tiniest amount of solder still holding the IC to the PCB, and that most of the solder had melted and dropped away from the pin joints at the PCB. It was these solder balls that I suspected would have caused a rattle; hence my question to the owner. It is my belief that they simply fell out unnoticed when he opened the enclosure.

OK – so I have a 5-volt voltage regulator IC that got hot enough to melt its retaining solder and make the IC move in its mounting. It was the same old question – was this the cause of the problem, or was it a symptom of the problem? I decided to apply some power and find out. The unit operated from a wall-wart power supply that provides a regulated 12VD output at 1000 mA. I plugged it in and turned the unit on, and of course nothing happened. That was, after all, what the owner reported in the first place, but verification is a big part of my methodology. I then checked the power supply for output and found it to be dead – no output at all. So, now I had two pieces of the puzzle – a hot 5VDC regulator and a dead 12VDC power supply. I then applied 12VDC from my bench power supply to the power inlet jack of the unit and tried it again. This time, it dragged my bench power supply right down to almost nothing, a sure sign of a dead short in the supplied circuit. Already suspecting the problem, I rem oved the LM7805 voltage regulator IC from the circuit and connected it to the bench supply in an isolated condition, resulting in the same condition as when it was installed. The LM7805 was shorted internally. I cleaned the old thermal compound off the PCB and verified that the heatsink area of the PCB was connected to the PCB ground plane, using an ohmmeter. Then, I installed a new LM7805, applying new thermal compound to the back side of the IC. This time, I also added a 6-32 x 0.375" machine screw with a nut and lock washer combination to the heatsink tab of the IC, securing it through the provided hole in the PCB. Now, when I applied the 12VDC bench supply to the unit, it came up and worked normally. I ordered a new power supply of the correct specification and counted the job done.

So… what was the failure sequence here? I would have to guess that because of a poor attachment of the IC heatsink to the PCB and the level of voltage overhead in this circuit, the IC simply overheated and failed, causing the failure of the power supply. When dropping the 12VDC input voltage to an output voltage of 5VDC, the voltage regulator has to get rid of those extra seven volts, which is done in the form of heat that is dissipated by the IC. Had the IC been properly secured to the heatsink area of the PCB, this failure most likely would not have happened. I believe that this was an assembly error in that the securing hardware was omitted. Consider the fact that the PCB had a clearly defined heatsink area with adequate metal surface area to carry away heat from the IC, and the fact that a hole for securement was provided in that heatsink area. It quickly becomes apparent that the designer intended for the IC to be secured to the PCB. If so, it was designed that way for a reason, which is most likely that the additional heatsinking provided by the PCB structure is required to keep the voltage regulator IC properly cooled. Oh yeah – by the way – that violet wire with the one end disconnected? It is an antenna lead within the structure of the meter enclosure, and is thus intended to be free at that end.

Sometimes, the repair technician has to think beyond the limits of just what is placed before him/her to come up with the best and most permanent solution for any given problem. I am going to wrap this up by leaving the reader with a single thought. Do not ever go into a test and repair situation with a closed mind or a pre-conceived idea of what the problem is, especially if what you really want is to achieve a solid and reliable repair.