3458a multimeter user's guide pdf freede pdf free

Unfortunately, by bypassing the adjust circuitry, I give up the ability to lock it to an external reference. A short time later, I found a replacement oscillator board used on the A model for $20, bought that, and used the crystal from that board to get the frequency spot on and recover the ability to externally clock the unit. Finally, the three main electrolytic caps do run warm - about 120 deg F - which is not to my liking, so perhaps they were "BAD" after all. A weaker version of the HP 3575A, but does what you would expect. Keithley 414A: Solid-state picoammeter from 100 pA to 10 mA full-scale in seventeen ranges (1-3-10). Accuracy is +/-2% down to 10 nA range, and +/-4% below that. I already had the Keithley 261 pico-current source, so naturally I had to have the matching meter. The photo shows both units with a 10 pA source being correctly measured on the 414A. Unlike a lot of other analog meters whose accuracy seems to drop off markedly below about 1/4-full-scale, the 414A seems abundantly accurate all the way down to zero. Even though my HP 4140B pA meter is more capable, more accurate (and more expensive), it uses pesky triaxial connectors and my collection of triax cables isn't very good. Thus, I cannot get the 4140B down as far as I can with the Keithley. Of course, my Keithley 602 Electrometer (shown below) has everybody beat - providing you can figure out how to properly use it! (PDF) Grade: AAdvertised as working, it basically was when I received it. Of course, they were the last two left on the board that I pulled. So I built my own "universal" reference card which is shown in the picture sitting in the drawer waiting to be pushed inside the 10529A. HP 3468B: Modern 5-1/2 digit multimeter. The unit also contains two independent voltage sources (to +/-100 volts) with three digit resolution. All the usual functions plus amps. I haven't decided whether it is worth replacing the battery as this piece will never have enough use to keep it charged. I put the 8981A uP board back and it still worked. ($CD) Grade: A-Advertised by the eBay seller as "powers up, does not work." But the listing photo showed a row of dashes on the display. Not only is that the default behavior, but you can't even get to that display unless the unit passes the internal self-test. Oh well, his loss, my gain. Upon receipt, the only casualties were a blown input fuse on the C channel, a broken lef spring on one of the pushbuttons and a smashed front panel. The latter two maladies were remedied while I wait to order the 50 cent fuse. As for the OCXO, a buddy had given me a small HP board marked 05334-6003 a few years ago. I threw it in a drawer back then. Turns out that this is the support board that is required to install the HP OCXO. Lucky me. Wavetek 195: Two channel, 40 MHz arbitrary waveform generator. OK, first of all, the Wavetek 195 is an elaborate function generator that has arbitrary waveform generation capabilities. The "40 MHz" represents the fastest one can clock through the waveform memory. Since any interesting waveform better have at least two points, that gets you down to 20 MHz signals. And so on, you get the point. As a function generator, the 195 will do sine, square, triangle, ramp up, ramp down, pulse trains, sin(x)/x, haversine and more. Sine and square go to 16 MHz, pulse trains to 10 MHz and ramps, triangles to 100 kHz. Amplitude is a very nice 10 Vp-p into 50 ohms. Has an elaborate set of auxiliary functions including modulation, gating, triggering, channel synchronization and sweep. It can also sum the two channels with a flick of a button. Has 256K of waveform memory, but entering an arbitrary waveform manually is tedious at best. I really should download and try a Windows based RS-232 waveform editor. My general opinion of Wavetek function generators is that they do a lot, but none of it with any fidelity. This piece, much to my surprise and delight, does everything well. There are no transients at the corners of triangle waveforms like there are with most RC-based function generators. And there is no perceivable jitter from clocking out the waveform RAM like there is in the HP 8904. The distortion at 1 kHz was -64 dBc. The efficacy of this unit is probably why it is still being sold today (~$4,400) as the rebadged Fluke 282. (---) Grade: AAdvertised as "no output on either channel," I took a chance for $60 + shipping. Upon power up, I was greeted with error 127: "system ram error check battery." OK, thanks for the heads-up. The CR2032 battery was toast, so I replaced it with two AA alkalines. The error disappeared as expected, but there was no output just like the seller said. There were correct voltages present and a few red LEDs lit, but I couldn't get any relays to click and really couldn't find any signals poking around with the scope. Not even the sync outputs were present. While the front panel and uP functions all seemed correct, it really acted like the main board was dead. I can't locate a service manual, not that it would have really helped, because the board is all surface mount with a bunch of Xilinx FPGAs. I pretty much sat and played with the thing for two hours hoping some front panel setting would at least get one of the attenuator relays to click. No luck. Finally, I gave a few ribbon cables a nudge and all of a sudden, the thing sprang to life. Works perfectly now. I suppose I should go back and start wiggling the IDE connectors to see where the mechanical fault was. Since I can find absolutely nothing about the SP5110, and it is virtually identical to the 296, we'll go with that. I put an AC power supply inside just for fun. And there are how many over the air TV broadcasts now? (---) Grade: D+ Sencore LC53: Inductance and capacitance meter circa 1980. With absolutely no chance of even identifying the proper part, let alone actually getting another, I was about to relegate this piece to the "It's Dead, Jim" pile.But then I saw another 6160B on eBay for $20, so I picked that unit up. My intent was simply to pull out the module with the inductor that I needed and swap the "B"-unit's module into my "A"-unit. But when I did this, it not only didn't fix the problem, it made everything worse. So I put the B-module back into the B-unit and turned it on. Nothing worked right. So now I have two units that don't work. At this point, I decided to start putting A-modules into the B-unit and see what happens. Through trial and error, I was able to get the B-unit to work correctly. I also swapped in the ovenized oscillator and changed the B-unit from rear output to front output. The DC bias from front panel switch was faulty and was replaced. The fault seemed to be located around a set of 3 ICs which shape the Schmitt trigger pulse generator on its way to the output amplifier. All in all, a real nice addition to my other calibrators and a fairly good buy at $75. (OM) Grade: A-The seller did not offer any description of the condition other than it needed a new (captive) power cord. Which it certainly did and which it certainly got. When you open up this piece, however, it is somewhat disconcerting since the power cord doesn't seem to go to a main transformer; the wires just disappear into a big harness. In fact, there isn't any main transformer to be found! The piece consists basically of five modules, basically all sealed in their own metal containers: 1) voltage reference (ovenized), 2) range resistors (ovenized), 3) K-V divider, 4) preamp, and 5) power amp. Except for the K-V divider, the modules all need power and they all get it by a dedicated power supply that is contained within it. Anyway, back to the repairs. All of the switches were noisy and the initial current readings therefore were also. The output switch is particularly important because the internal voltage reference goes through it. After a thorough cleaning, things looked good except for two of the three neon lamps on the front panel which were marginal (new ones are on order). As far as calibration, the 1965 manual says there are adjustments for the 10 V reference and the zero current offset. So I found the analogous two pots on my somewhat different unit and the CS-152-7 adjusted nicely.Postscript: The output switch was still a bit noisy, so I decided to replace it at the same time I replaced the three neon bulbs. It is a 2-pole, 3-throw rotary switch and I replaced it with a 4-pole, 3-throw rotary switch, doubling up each contact. Hopefully this will keep the switch resistance low and stable over the years. It looks as though about 1 ma comes off of the 10 V reference and through the switch. I estimate the parallel contact resistance of the switch would drift no more than 25 milliohms. So the switch could drop 25 uV which is an acceptable 2.5 ppm error at 10 volts. When HP later came out with the 5345A counter, they realized people might still want to use the old plug-ins. The HP 1345A display is basically a vector display that is programmed by the host. My card has a 16 pin DIP socket and two 8-position DIP switches whose individual switches are set to off for any output line. The piece was missing the fuse/holder and the previous owner had rigged up some strange fuse arrangement. Krohn-Hite broke the mold on this one when it came to "specmanship." The brochure would have you believe that the basic accuracy is 0.1 degrees. More perplexing, however, was that the amplitude entered on the keyboard produced the correct signal, whereas the signal frequency was always truncated to 1 kHz (000.0). I measured the residual capacitance at 20 pF. Quality construction inside with 100V, 5% tolerance capacitors throughout. Heathkit IG-18: Sine and square wave generator to 100 kHz. After collecting (and mostly repairing) over 360 pieces, I noticed that I didn't have anything from Heathkit. Not that this is a big disadvantage, since one expects any piece of "test equipment" from Heathkit to be pretty abysmal. And so it is. The IG-18 uses a well known oscillator circuit with a lamp in the feedback. The sine waves are squared up with a Schmitt trigger. The distortion is rated to -60 dBc and it will put out about 10 volts open circuit. These things have somewhat of a cult following since many people have proposed mods to improve the circuitry. For instance, the meter loads down the oscillator and will increase the distortion as there is a meter buffer mod. Many of these mods are offered on-line as kits including the printed circuit boards. As expected, the untouched IG-18s are laughable compared to a good professional sine/square generator (such as HP). But I do like the big knobs! (PDF) Grade: B-The eBay buy consisted of two of the IG-18s for $42, not too bad. The seller had a description which almost begged a potential buyer not to buy these due to the extremely rough condition. But I needed something to do for a couple of hours. Mechanically, they were filthy and many of the control shafts were frozen. Some WD-40 cured that. Electrically, one of the units had a cold solder joint on the output attenuator. The biggest problem is the adjustment procedure. There is the "feedback" pot which has to be set just right. And I mean just right. If it is off one way, the thing won't oscillate. If it is off the other way, the distortion goes way up. I managed to get both of them in spec, but there may still be some fiddling around I can do. However, given the efficacy, is it really worth it? I think not.Postscript: OK, I fiddled around some more. One of these units barely passed the -60 dBc distortion test. I changed out the light bulb in the oscillator circuit with a 10V bulb from the junkbox. Now this unit is even better than the other one. HLCS HS1010: This is a 0-200,000 Lux meter with auto-ranging and measurement storage, with a claimed +/-5% basic accuracy. The basic accuracy is in the 0.1% class which is good, but not super-good. The thing now works flawlessly, calibrated properly and passed all the performance tests. Ohms, on the other hand, was putting out too much current, so that everything read high and by the time you put more than 10K across it, the thing would overload. I spent a weekend checking everything around the FET hybrid module and my worst fears were realized as it looked like there was no other conclusion than a bad hybrid. Fluke only gives a functional block diagram of the hybrid, so I took a guess on the resistor values and FET parts and decided to build a replacement board for the hybrid module. A buddy at work produced the Gerber files for me and I procured the board from Oshpark for less than $10 (see picture below). Problem solved.Postscript: One day I noticed that all of the measurements were very noisy. I proved that the culprit was the signal conditioner, not the A/D. Since there are three Fluke hybrid daughterboards in the unit, and two of them had already blown (and were fixed/replaced), I suspected the third. But before I got to check that, the whole unit locked up and became unresponsive. The outguard uP was running at 230 deg F, so that's no good! I replaced the uP, the associated P8243 expander IC and the 74LS373 address latch (shorted), but to no avail. Further investigation shows that the addresses to the program ROM are cycling through the same 10 instructions. When I pulled the ROM and put it on the reader, it was clear that the first two bits of the ROM were stuck at 1 for all memory locations. The piece truly is dead, Jim! I kept the piece around for a while hoping to find another one cheap, or some replacement ROM code, but no luck. Given that even if I could replace the ROM, there still is an analog fault (the original problem I was trying to diagnose before the digital side crapped out), the best course of action was to strip it for parts. There were three electrolytics from the same manufacturer that were highly suspect. However, one look at the front panel shows that there are a lot of wonderful things being done somewhere. The thing is supposed to be within 5 Hz at 1 MHz, and I was 34 Hz low. Marconi 2305: Modulation meter good to 2 GHz. Pretty much a copy of the HP 8901A/B meters including a substantial set of secondary menu items. After fixing that, I attempted the cal procedure which passed with exception of the frequency accuracy. Nice and portable. Digitally controlled through a ROM based state machine. Resistance measurements must use the 4-wire configuration - a pain. Cute self-test functions. This was the predecessor to the microprocessor controlled 3455A. Or should I say "nanoprocessor" controlled since the 3455A processor was a special limited instruction set gizmo designed by HP. The 3490A does an admirable job, however, and the circuitry is very understandable. (PDF) Grade: BTwo of these, one worked, one didn't. The faulty one needed a new 30V regulator and the wire from the AC to the FET board reseated.Postscript: Whenever I'm bored and looking for something to fix, I start with a piece that I haven't turned on in a few years. And the 3490A didn't disappoint. Although both units worked flawlessly (for a few minutes), one made a big pop and smoke poured out the back. The usual Rifa suppression caps across the AC plug let out the magic smoke. The other 3490A's cap was still intact, but had a large crack down the middle revealing the metal inside - so that one wasn't long for this world either. Both were replaced (with non-Rifa 0.22uF X2 versions) and all is well. I did pretty well at the end of the surgery, achieving about 0.0105 ohms with the CA1624 set to the full range of 0.01 ohm on the 0.001 ohm scale (it was 0.006 ohms before). That seems to have cured all the problems and the 3466A functioned nicely and calibrated properly. Moreover, everything worked fine when negative voltages were input. Also replaced blown diode in 17V P/S circuit. Exchanged a few pots, knobs, etc. One has to be careful when looking at weak harmonics of a strong fundamental not to overload the mixer by down-ranging the amplitude control. B : Ballantine, BBC, Beco, Biddle Gray, Biomation, BK Precision, Boonton Ballantine 323: True RMS AC voltmeter from 30 MHz, 0.3 uV to 300 V full scale. This unit runs very cool - I've dumped 100 watts into it for hours and could feel no heat anywhere. (OM) Grade: B+This piece came to me with a defective P/S which was due to an open AC transformer - a very rare situation indeed. If that wasn't enough, three of the sixteen load transistors were blown (one had a hole burned through the TO-3 case). And the voltmeter didn't work either. I gutted the P/S and built a new one, replaced all sixteen load transistors, exchanged the old voltmeter mechanism with a new one (keeping the existing meter face). Very simple to operate and very useful to quickly diagnose faulty logic chips. I use this mostly in timing mode since I don't have much call for state machine analyses. (OM) Grade: B+I first bought an HP 1630D. That unit had problems in state mode (worked OK in timing mode). It took several weeks to trace it down to a single faulty ECL chip among hundreds and hundreds. In the meantime, I bought the 1630G with the intention of swapping boards to help isolate the problem. After I fixed the first 1630D unit, I sold it to a friend for what I paid for it and kept the 1630G.Postscript: Preemptively replaced the 0.022 uF Rifa Y-capacitor on the main P/S board with a non-Rifa 0.01 uF Y-capacitor. Has some hidden menu items that control filtering, averaging time, etc., and can store/recall 12 configurations. Aten 5011: DC-1.1 GHz spectrum analyzer. BK Precision 830: Automatic capacitor tester in 10 ranges from 199.9 pF to 199.9 mF full-scale with 0.1% best case accuracy. Not much to do except put a capacitor into the clips (or use the banana plugs with clip leads) and read the meter. Takes a few seconds with large capacitors to do the auto-up-ranging and I question the accuracy for small caps < 50 pF (seems to read a bit low). But it is small and portable (runs on four C-cells) and is convenient when I don't feel like using my good LCR meters across the room. Came with case, original manual and original warranty card. I wish to commend BK Precision (Dynascan) because not only is the internal construction first class, but the manual (with schematic and parts list) fully explains the design in very understandable terms. (OM) Grade: A-There was really nothing to do except Dremel off the corrosion on the battery clips and install a new set of batteries.Postscript: Went back and did the calibration procedure. The thing was horribly out of adjustment. The readings, especially at low values, are much more accurate now. Has I and R modes but no V mode like the more expensive units. My only complaint is that the smallest range is 10A, so adjusting the load from very small currents (e.g., batteries) is hard. The front panel is a bit confusing, but the thing counts as advertised. (PDF) Grade: B-This unit was unresponsive when received. There is an overvoltage protection circuit inside whose SCR had fired and blew an internal fuse. I replaced the fuse but the unit's P/S still was not producing correct voltages. I put it aside for a couple of days while I fixed the Tektronix FG501 and FG502. When I plugged the DC503 back in, it worked fine. Must be magic or something (maybe the SCR finally let go). The big problem with this unit was that it was all smashed up. I straightened it out as best I could and also manufactured a new red plastic window for the display. ESI CA1624: This is a "Dekastat" milli-ohm decade resistance box with a total resistance of 1.11 ohms. When calibrating/adjusting a piece, always mark the pots/caps/inductors etc. No input current is drawn when the input equals the reference, which is really the only "advantage" of a differential voltmeter: at null, the input impedance is infinite. After studying the schematic, I was sure the problem was in one of the 1:8 decoder ICs. But, alas, probing with a scope showed every IC, from the 6802 uP through to the LCD display, was happily toggling bits. I would have graded this piece higher, but the front panel mechanics aren't very good. As shown in the photo, the cable terminates in four banana plugs. I did do a post-mortem on the numeric LED I pulled out. The HP 4140B is basically a very sensitive ammeter with measurement capability from about 20 mA down to 1 pA, with 1 fA resolution on the 1 pA range. LED power lamp added. This was cheap and like many of the things I have, pretty useless. My initial thought was to use it to route signals all over the lab. However, the frequency response is horrific. No sense routing a 10 MHz signal if I'm going to lose 5 dB. But I have enough plug-ins in this unit to route probably 50 signals around. (PDF) Grade: B HP 3490A: AC, DC, ohms digital 5-1/2 digit meter. G : General Electric, Genrad, Gigatronics, Global Specialties, Guildline General Electric P-3: Sent to me by an anonymous donor, this is a vintage AC voltmeter built in 1950 (most likely in the West Lynn, MA plant). It has three full-scale ranges, 150, 300 and 600 VAC and is responsive from DC to 133 Hz (a DC measurement is possible by taking the mean of the two readings with the leads reversed). GE made a number of meters under the P-3 nomenclature, including voltmeters, ammeters, wattmeters, power factor meters, and probably a whole lot of custom versions; they were made at least from the early 1910s through the 1950s. The AC voltmeter is an iron-vane type which directly measures RMS (without the customary rectifier found in VOMs) and the accuracy is outstanding: 0.2% of full-scale. That accuracy is achieved courtesy of a calibration correction chart affixed to the wooden lid. You would be hard pressed to find any modern piece of test equipment with an analog meter that advertises a 0.2% spec. About the best I've seen is 1.0% and most are >2.0%. The insides consist of 1) the massive meter movement, 2) a simple shorting bar acting as an on/off switch, and 3) a set of 10 wirewound resistors (each about 5" long) that make up the three range resistors. The wooden box has ventilation holes on the back for these resistors, because they will warm up at full-scale voltages. What I got was a unit that powered on but was completely unresponsive to any input. Noteworthy is one of these functions which directs the 8520A to run in a burst mode which then mathematically can calculate the ACV of sine waves with frequencies as low as 0.5 Hz. Certainly one of Fluke's better efforts, after calibrating it at the endpoint of the ranges, it was extremely accurate throughout the range. nothing. I'm running it off of an external 12V supply and the supply showed zero current draw. I was ready to throw this in the "It's Dead, Jim" pile since the boards are extremely corroded and I had hard-wired all of the boards together (since the connectors were shot) making disassembly a chore. But I was able to fold back the power board and quickly found a defective Q235 that feeds the bases of the switching transistors in the pseudo-switching 214's power supply. A new 2N3906 restored the unit to whatever rotten shape it was in previously. N/O : Nida, North Hills, Ono Sokki Nida 413: Decade capacitance box. The 9301 has a built in 50 ohm termination that gets internally routed to the probe. One of two. The build quality on the TR6845 (and the TR6847 below) is very good. Don't let the cheap plastic look fool you, Advantest knew what they were doing. (---) Grade: B Advantest TR6847: A cute DMM that for some reason does not have a continuity tester (actually it does by combining the ohms function and the "beep" function). But HP decided while that was good for text and grids, they wanted to improve the analog display, not drown by computing x-y vector points. Used to debug most HP instruments of the 1980's. Marconi TF-2013: 800 - 960 MHz FM signal generator. This is a very odd piece, both visually and functionally. It will generate up to 30 kHz FM deviation with up to a 3 kHz modulation frequency over the 800 to 960 MHz band. That's basically it. It has some very odd controls, however. The RF frequency is set from the large (vernier ganged) dial on the left. However, next to that is a fine-tune control and another labelled knob and switch that also alter the frequency. The output amplitude is set from the main dial in the middle and covers nominally 0 to -130 dBm. The modulation frequency and deviation are set from two calibrated dials and switches. At the right are two meters and knobs that calibrate the modulation and RF. Of course, I'm just guessing here as I can find no manuals or descriptions of the TF-2013 at all. Seems to work just fine, although things are slightly off calibration. The insides are just as odd looking as the outside. Gears, shafts, sliding carrier table gizmos, and on and on. The mechanics of this piece would even mystify the insane engineers at Tektronix. The bulk of this unit is a sealed cavity oscillator with two shafts that plunge into it (one to control frequency and one to control attenuation). There are only about five very small circuit boards, but each is manufactured with a lot of attention to detail (resistors are lifted off of the board, parts are cradled, etc.) And Marconi spared no expense because they used silver BNC and N connectors throughout. (--) Grade: B+I bought this on eBay for $9.99 because it was so old looking. Moreover, the front panel was absolutely filthy and looked like a challenge to rejuvenate. The seller claimed it powered on and the meters moved. When I went to plug it in, I found the AC connector on the back panel to be a small circular 3-pin male plug. I was about to rig up some clip leads once I identified the brown (hot) and blue (neutral) wires typical of British pieces. But then I remembered I saw the same plug on my Marconi TF-2333 - unplugged that cord and used it for the TF-2013. I really doubt the seller had the right cord so I don't believe his description. Oh well, powered up fine and worked fine. Cleaned up very nicely too. Maybe someday I will locate a manual because there are 15 adjustment pots inside just begging to be turned. Postscript: I experimented around with all the adjustments and have things pretty well set now. The frequency was off about 6%, but was brought down to within 1% by uncoupling the control rod going into the cavity from the gear mechanism and sliding inwards. A similar action was performed for the amplitude, which was about 7 dB too low and is now good to about 0.1 dB. The FM deviation was about 5% too high, but I found the magic pot that controls it and got it to be spot on. The remaining adjustments I'm guessing may have something to do with the distortion of the audio modulation, but since the output of the TF-2013 fed into the HP 8901A with its modulation analyzer fed into the HP 8903A audio analyzer shows the recovered audio signal has distortion less than -60 dBc, it's close enough for government work! So all seems well except the RF frequency which could be a little closer to the front dial reading. However, given that Marconi put two additional controls on the front panel to tweak the RF frequency and the fact that there is a separate "counter" output on the front panel, I'm guessing they realized there was no way to achieve a high accuracy to the dial. Genrad 1685: General Radio digital impedance bridge. (OM/PDF) Grade: C+When I received this unit, everything seemed to work except the single pulse button on the 1906A rate generator. An inspection showed a massive amount of previous repair work on all three units, so I was a bit suspect. The rate generator circuit is based entirely on a single 20 ma tunnel diode which looked like it was previously replaced. In the process of trying to diagnose the faulty single pulse control, I must have done something really bad, because the tunnel diode went open and the entire 1906A ground to a halt. Now, the chances of getting another 20 ma tunnel diode are about the same as the chances that President Obama fixes the economy. But I did have a 10 ma tunnel diode (with a similar 500 mV swing) in a defunct Tektronix 7000-series plug-in. Of course, trying to switch a 10 ma tunnel diode with 20 ma isn't a good thing since you are off of the desired hysteresis curve. So I changed a bunch of resistors in the 1906A and re-biased everything down to 10 ma. That restored the 1906A - except, you guessed it, the single pulse circuitry still didn't work! After a few days of probing around, the problem seemed to be what HP called a "differential delay" circuit, which is simply a differential pair of transistors with a 1 nsec delay between the bases. This delay is accommodated by a long trace on the board. I tried replacing both the transistors, but in simple terms, it just looked like the delay wasn't long enough. So I cut the delay trace and soldered in another one foot of wire. Not particularly a good solution, because my wire can't be close enough to the board to act against the ground plane on the other side of the board. But good enough, since my single pulse now works and everything else seems to be OK. Well, almost everything else. If you are very careful and turn the pulse width down to the minimum on certain ranges, you get a double pulse out of the thing. But if you switch the rate generator to the next highest range, and throttle back on the frequency vernier, you can get the same rate and pulse width without the double pulse. I'll simply have to live with it. The "A" model fixed some P/S issues in the original 2213 and added some more trigger options. And so that is what I did. Basic DCV accuracy (24 hr) is about 0.003% which puts it in the class of some of HP's DMMs, notably the HP 3455A. You have had it can't use all of them at once (fixed decimal point in the middle). Guildline (and Solartron) made a big, big deal about how their design, which is counter based, is soooo much better than the dual slope integration design that HP and most everyone else used at the time. They claim specs that exceeded HP's. But in my experience, it is simply not true. For instance, the linearity is simply horrid. Adjust the 1V and 10V calibration pots to be spot on and then watch the thing be off 1/4 mV at 3V. The only spec that is exceeded is the low frequency AC response. Finally, this is one of the hardest pieces to service because the two analog boards are placed one on top of the other with a myriad number of connector cables wrapping around the outside edges. It is virtually impossible to access the bottom board with the rest of the unit intact. Shame on whoever designed this piece. (PDF) Grade: BHad a bunch of problems when it arrived (like disconnected wires), the most troubling of which was a tendency to drift wildly after a few hours. Despite replacing a bunch of ICs, the best solution was simply to add a small muffin fan to keep it cool.Postscript: Was playing around with unit recently and noticed that on ohms, an open circuit would read about 5 Mohms and then slowly ramp up to the overflow value of 14 Mohms. Took about 10 seconds. At first I thought the ohms current generator circuitry was faulty, but a few measurements showed the current was rock solid at the correct value. So I suspected something wrong with the input circuitry. Moreover, putting 30V through a 10 Mohm resistor into the 9577 should produce a reading of 15V since at that range, the input impedance is also 10 Mohms. And it did, after about 30 seconds, ramp down from 30V to 15V. It felt as though a capacitor was somehow connected to the input circuitry. And that was exactly the case, because a faulty 7406 relay driver chip had failed and permanently switched in the relay to the ACV circuitry, regardless of whether I was in DCV, ohms or ACV. The schematic was not exactly correct, and I'm not sure whether it was the input relay going to the ACV circuit or the output relay coming back from the ACV. Doesn't matter, because both sides have big capacitors hanging off them. A new 74LS06 restored the unit back to correct functionality. H : HDW, Heathkit, HLCS, HP, Huntron HDW T2000: Time Domain Reflectometer (TDR) circa 1993. Basically a TDR is just like a radar. It sends out a pulse along a cable under test; any fault in the cable causes an impedance change which produces a pulse reflection. This unit has a moderately low bandwidth so the reflections are not very sharp. One must also enter in the velocity factor of the cable in order to accurately convert time to distance. The TDR2000 is very easy to use: 1) set the max distance range, 2) adjust the level control to see the reflections and 3) position the end marker to highlight the reflection peak. Read out the distance on the LCD. (---) Grade: B+This unit was advertised as "doesn't power up." I suspected it had a switching P/S and would be difficult to fix without the unobtainable service manual. But for $25, I was willing to take a chance. However, upon receipt it powered up just fine. All I did before I plugged it in was to check and reseat the fuse. Could this have been the problem? Probably not. But the end marker pot was extremely noisy, so at least I can claim a "repair" on this one since I replaced it. Worked flawlessly. However, due to their age (up to 50 years), all the mechanical parts had pretty much frozen. Only the SP5110 and the HP 4328A milliohmmeter have enough resolution to see the discrepancy on any single resistor. As the voltage was turned up, the 3400A meter pegged. No rhyme or reason to the numbers and no rhyme or reason to the parts numbering. The panel neon light for the oven heater stayed off when I first powered it up, but the oven was getting warm and putting a voltmeter across the heater pins proved that eventually it started to cycle on/off properly. The matching stimulus unit to the HP 1630G logic analyzer. Somewhat cumbersome to use. (PDF) Grade: B+There is an expensive option to the HP 8175A that adds two channels of arbitrary analog waveform generation. At first, nothing came out of the two analog output ports, so I just figured the option wasn't installed (it wasn't advertised by the eBay seller as having the option). But after I dissected the unit, I saw the waveform generator board (it was pretty well hidden beneath the motherboard) and then discovered that whoever installed the board forgot to hook up any of the cables coming off of it. D'oh.Postscirpt: Preemptively replaced the Rifa 0.022 uF Y-capacitor in the power supply with non-Rifa 0.01 uF Y-capacitor. Everyone bitched and bitched at me because I didn't have one of these. Bitch no more. (PDF) Grade: B+The battery terminals had corroded badly and the glass was loose. Par for the course with the 260s.Postscript: The 260 developed a fault where the 100K ohm scale would peg the meter with shorted leads and could not be correctly adjusted to zero with the potentiometer. When I opened up the unit, I saw a lot of corrosion and junk on the main board which I never cleaned off years ago when I first got it. Some de-greaser and a toothbrush seems to have restored things back to normal. Adret CS-201SB: 2 MHz synthesizer. This was a replacement piece for the broken Adret 201 described in detail in the "It's Dead, Jim" section near the bottom of this web page. The "SB" model omits the AM/FM modulation capability, but does have more precise control over the amplitude. It also works with the Adret 211 external control box also described below. I bought this with the idea of using the parts to fix the original 201. But it works fine right out of the box, so we will stay with this one. While the original one had 1966 date codes on some of the parts, this newer SB version has 1986 date codes. Adret also cleaned up the layout quite a bit. From what I can ascertain, Adret was well known for its synthesizers 50 years ago, and I must confess that their early pieces were way ahead of HP and Tektronix at that time. (PDF) Grade: A- Advantest R6871E-DC: 7-1/2 precision DMM from the Japanese. This is a real sleeper. I would put it on par with any of my top HP, Fluke or Datron DMMs. Advantest made a full 6871E model (DCV, ACV, DCI, ACI, ohms) and the more modest 6871E-DC model which only does DCV and ohms. Unfortunately, mine is the latter, but if I ever see a good price on the full model, I won't hesitate to buy it. The best-range 24 hour DCV and ohms specs are about 0.0012% and 0.002% respectively at 24 hours, rising to 0.0037% and 0.006% at 180 days. Calibration is via software controlled by the front panel. The user gets much more control over sampling interval, number of power-line cycles and averaging than is usually found in DMMs. There is also a small set of math and statistic functions as well as auto-zero and auto-cal functions. The only downside to this meter is that it is HUGE - 12" x 6" x 18". Whereas a lot of non-rackmountable DMMs, such as the Advantest TR6845 and TR6857 models shown below, could be considered portable and shuffled around the lab bench, the R6871E is much too large for that. All in all, a fantastic buy at $50. (PDF) Grade: A.I took somewhat of a gamble on this because there is no service manual available (and maybe no service manual in existence). The seller said, "When unit powers on, no lights on display." But the back panel showed the thing set for 220 VAC, so no wonder. The operator's manual was obtainable on-line and said that the AC line voltage is set at the factory at the time of purchase (separate options for 100, 120, 200, 220 or 240 VAC). I gambled that I could reset the line voltage to 120 VAC as my other two Advantest DMMs had clearly labeled jumpers for that on the circuit board. But when I opened up the R6871E-DC, all I found were six wires going to a six-pin terminal strip with a jumper between pins 2 and 4. I took a guess that that was the two primaries run in series, so I jumpered 1-4 and 2-5 to (hopefully) put the primaries in parallel. I have no clue what pins 3 and 6 are for. The piece sprang to life, passed all tests and calibrated nicely. I've since found a picture of the terminal strip from an eevblog user who posted teardown pictures and his 120 VAC unit was jumpered the way I guessed. Advantest TR6845: At least this unit has a continuity tester. The average of the grades is 3.14 - a solid "B." This chart was made at about piece #170. I haven't bothered to update it since and I doubt that the overall average would change much anyway.If you feel that you disagree with a piece's letter grade, I suggest you remember what happened to you when you went up to the professor after class and asked that your grade be changed. Maybe you never did that, but I once went up to the professor in college after receiving a 99 on a math exam. I looked all through the exam paper for the stupid algebra mistake I must have made to cost me one point, but there wasn't a red mark anywhere to be found. So I asked the professor why I got a 99 instead of 100. His reply was simply, "I don't give 100s."I know what you are thinking - where does he put all this stuff? Well, believe it or not, it all fits in a small corner of my basement. But that means I basically have to stack stuff from floor to ceiling. Most of the stuff I use frequently is plugged into AC and near my (small) work area. The outlying pieces generally are not plugged in, but things are arranged so I can easily get to the back to plug in power cords. JUMP TO: A B C D E F G H I K L M N/O P R S T V/W Z DEAD DISPOSED REPAIR A : AC/DC, Adret, Advantest, Associated Research, Atten, Audiolab, AUL AC DC EL750B: Dynamic DC electronic load. The front panel switches are not heat staked; they are removable intact. HP 3320B: 13 MHz synthesizer with very precise control of amplitude in dB. This is the lower cost version of the HP 3330B and shares much of the design. The one I have must have been a special telco order since it is set for 600 ohm output impedance; this option doesn't seem to have been offered to the general public. (PDF) Grade: A-Other than the annoyance of a 600 ohm output, the only thing functionally wrong was the inability to correctly control the frequency in the third digit. This was traced to two 50 pin IDC edge connectors whose pins had permanently receded to the point of not making contact with the board. These two connectors were replaced and new (non-HP) knobs were also installed since many of the old knobs were missing and/or cracked. Finally, removal of one resistor on the output board, changing one resistor on the amplitude reference board, and reconfiguring several jumpers on the control board put the 3320B back to 50 ohms. (OM) Grade: B+It all seems to work, but I did remove the flickering power-on light bulb, file the crap off the contact, and reinstall. Wavetek 2510A: Synthesized RF signal generator, 0.2 to 1100 MHz. Wavetek is best known for function generators, but over the years dabbled in pieces outside their area of expertise. Such is found in the 2510A and the 2520A (which adds a doubler to 2200 MHz). The specs are approximately equal to HP's low end 8656B signal generator, but the Wavetek has an actual tuning knob and who doesn't love that? The display is LCD, not LED, and even with the anemic backlight, is not very readable in different lighting conditions. The buttonology is adequate (and the keyboard has a nice click to the buttons), but Wavetek did a few curious things in the firmware that had me scratching my head even after confirming everything in the user manual. The "autocal" is a nice feature that aligns all the oscillators and lets the user make output power adjustments at about 30 points. All in all, probably as good as Wavetek is capable of, but somewhat laughable if you are an HP RF engineer. ($CD) Grade: B+The seller said the unit died after 10 seconds, so I took a chance at $50. I disconnected the load on the power supply and all the voltages were wrong. There was a burn mark on the Molex connector coming from the main transformer, so I cleaned that out. Still, the voltages were nuts and off I went into a several hour wild good chase. Bottom line was that despite my attempts to clean the Molex connector, it was intermittent. So rather than screw around, I cut off the connector and permanently wired the transformer to the P/S board. Everything then worked fine. The only other "modification" was to get rid of the key-lock used to switch the unit from normal to calibrate modes; this was replaced with a toggle switch.Postscript: Fast forward a couple of years and the 2510A now displays an unlock message. The output frequency was tens of MHz away from what is dialed in and was unstable. After verifying that the internal/external reference switch on the back panel is set to internal, the service manual suggests trying the automatic frequency calibration; but all that did was immediately fail and issue an error message. There's a word for this kind of behavior: broken! The main loop in the 2510 uses a VCO that is mixed with a quadrature DDS pair and then divided down to the phase detector and loop filter. Seemingly, the DDS was outputting nearly zero which would tend to make the mixing quite bad. I substituted my own quadrature signals using the Wavetek 195 (poetic justice) and the 2510A suddenly worked perfectly. So now it was clear that the DDS circuitry was malfunctioning. It is basically done by stepping through (at different rates) a wavetable ROM containing a single sine wave. I pulled the ROM and read it and it looked correct, although the waveform is in the memory in groups of ten points, which is a bit odd. But in reality, it isn't odd if you realize that they are using BCD adders to step through the addresses and the BCD outputs only count from 0 to 9. The ROM outputs go to a D/A and the output of the D/A (through an op-amp) was completely wrong. My conclusion was that the ROM was not being addressed correctly. I hooked up my HP 1650A logic analyzer to the five 74HC583 BCD adders that generate the ROM addresses and found one that was faulty (stuck bits). I managed to find a cheap 74HCT583 on eBay and in it went. All fixed. Sounds easy in hindsight, but it took a few days to diagnose all of this. I also want to describe getting the main board out so I could remove and replace the chip. The main board sits next to the doubler control board and the two are wedged into the chassis. It is such a tight fit that you can see where the previous repairman had to punch a hole through the edge of the board with a screwdriver so he could pry the boards loose. While doing so, he managed to dislodge a 3-terminal regulator that was sitting perilously close to the chassis (it needs to be insulated). I fixed that problem and sanded the edges of the boards down a bit so they would fit back in without too much difficulty. A little more quality control from Wavetek would have been appreciated. Just the placement of the leads made a huge difference in the stability of the power supply. The picture shows the unit supplying 0.12 volts to a resistor I pulled out of a defunct Simpson VOM. He then claimed that he wasn't sure if the unit was working. time. One would use this to characterize VCOs for instance. There are two basic modes: 1) frequency vs. Close enough. Does 1500 Gauss. The display portion is a modified HP 1345A and I had a manual that was close enough. The NiCd batteries had leaked and caused the regulator board to catch fire. Burnt a hole clean through the board. I removed all (about 80) parts from the board, rebuilt the board jumpering over the now non-existent traces, and replaced all of the parts. That only fixed the regulator board. One of the three pass transistors in the main P/S had also blown, so I replaced all three. Similarly for the 6.2V Zener in the main P/S. Then the 400 Hz filter didn't align correctly, so I replaced C106 through C109 on that board. I also added a 12V regulator and a CTS 10 MHz OCXO.Postscript: One day, the 3586B started up and threw error E3.1. Normally, I wouldn't care, except that it prevented me from seeing the amplitude display. But the unit seemed to be OK otherwise. The service manual says that E3.1 means that the 2nd LO is unlocked and indeed when I took the cover off, there was a lit red LED on the A11 board meaning "unlocked." The 2nd LO is a phase locked oscillator using an inductor, crystal and a varactor for tuning. Evidently over the years, one or more of them has drifted in such a way that the varactor needed to show about 10 volts on a certain test point to achieve lock. But there is a comparator on this voltage line that throws the unlock condition if the voltage is greater than 8 volts. There is a 2.4 pF capacitor in parallel with the varactor and I removed it. This dropped the tuning voltage at the test point to -0.5 V (it is nominally supposed to be -1.5 V), the E3.1 went away, and all seems OK now. I could probably achieve the desired -1.5 V by tuning the inductor; however, the tuning slug has cracked and I'm afraid I will really screw it up if I try to move it. HP 3708A: Noise and Interference Test Set. This is a rather specialized piece, used predominantly for bit error rate testing, that adds controlled levels of noise and interference to a signal. Built for insertion typically between a down-converter and a digital radio, it only offers capability for 70 and 140 MHz carriers. Basically, the 3708A has three functions: 1) power meter, 2) noise generator and 3) C/N or C/I summation. The power meter measures signals in the range 10-180 MHz, +6 to -55 dBm, with a typical error of 0.1 dB. The noise generator produces band-limited Gaussian noise from about 6 to -80 dBm with four choices of internal bandwidth filtering. The C/N or C/I summation function is really what this piece was designed for, however. Input a signal into the IF-in connector (or use the built-in 0 dBm reference signal at 70/140 MHz), dial in what carrier-to-noise ratio you would like, and voila, the IF-output jack produces the signal plus noise. Moreover, if the IF-in power changes, the 3708A senses the new input power in a few msec and adjusts the additive noise to maintain the same C/N. The same basic principle is used by the 3708A if one takes a second signal generator and inputs an interferer into the I-input jack. There are numerous other input/output jacks and assorted functions that you can guess by looking at the front panel. Suffice it to say that the 3708A can also measure cable loss, filter bandwidths, and can accommodate external filters. Unfortunately, my unit is the standard 75 ohm version - I would have liked the 50 ohm option. Having said all of this, the 3708A essentially contains a noise generator, a power meter, an attenuator, a simple oscillator and a signal adder. All the functions mentioned above can be performed with these five elements. So why did HP charge about $25,000 for this piece in the mid-1990s? Well, the answer actually is quite simple. Sure, one can build those five elements for not much money. But try to get anywhere near the accuracy that the 3708A advertises. This thing is a good order of magnitude more accurate than a normal power meter, normal attenuator, normal signal generator, etc. And for good reason; indeed, just 0.5 dB of C/N error can often induce a times-ten change in bit error rate. So in order to test digital radios, you really do need exquisite accuracy and stability that maintains that accuracy over temperature. One peek inside and you will be convinced (if not, read the July 1987 HP Journal article). Gee, now I have something to use with my HP 3764A Transmission Analyzer! (PDF & OM) Grade: A-Advertised by the seller as "coming from a working environment." I gave that as much weight as a used car salesman saying "only used by Grandma to drive to church on Sundays." But I was willing to risk $100, because, quite frankly, I'm running out of cheap things to buy. The seller's picture showed one front panel button missing, and closer inspection upon receipt revealed that the switch was pretty much toast and the LED inside the switch was faulty. I used one of my spare HP switches (see the description for the HP 3437A) without incident. But when I went to remove the LED, I found that one of the leads was sticking through the hole with no trace of solder. I mean, it wasn't like the solder cracked. There simply was a pristine gold through-hole with no trace of solder. I'm really surprised that this got by the HP Quality Control Inspector. The red front panel plastic window was glued down by the previous owner with some homemade clips because the trim piece between the window and the top of the main panel was missing. A new trim piece was therefore manufactured on a 3-D printer. Seems pretty accurate and doesn't suffer from the two faults I see a lot with cheap DMMs: 1) flipping the leads to get a negative DC voltage gives a different absolute value than the positive voltage, and 2) while it might calibrate nicely at one value, the non-linearity of the measurements is apparent elsewhere. All was going according to plan until I tried to verify the ripple spec on my HP 3400A RMS voltmeter. HP 10529A: HP called this a logic comparator and was only produced a few years in the era right before full logic analyzers became mainstream. About the only thing that could go bad are the op-amps. Has plenty of digits as the photo (LED test mode) shows. But instead of using an edge connector, Biomation simply drilled a slot through the mother board and stuck the edge of the daughterboard through the slot. Obviously I jumped all over that. One of my better buys at a mere $14.99 + shipping. (PDFs courtesy WA1MIK) Grade: A-This was your typical "doesn't power up" eBay listing. However, with Tek TDRs, all that usually means is that the battery is toast (it runs the P/S through the battery). In my case, the battery was not even present. The rumor is that you can run the 1502/3 off of AC if you fool it into thinking it has a battery with a 2,200 uF cap in parallel with a 200 ohm resistor across the battery terminals. The rumor is true and the 1503 runs like a champ. Now, let me take this opportunity not only to condemn the Tektronix mechanical engineers for their needlessly complex designs, but also the authors of their calibration procedures. The right way to do cal is the way HP does it - for each subprocedure, tell you what you are trying to do, tell you the instrument settings, and suggest the external equipment. But not Tektronix. They only tell you what Tek pieces to use and what dials on them to set. So if you don't have them, you have to figure out what the pieces are doing and then search around the lab for something suitable. OK, I suppose that's not too bad. But then they tell you how to set the controls of the piece you are calibrating, and you march your way through the various subprocedures. God forbid you miss or skip a step. Because most often, the instrument needs to be set a certain way and that way was described initially 50 steps ago and modified 10 times since that in the previous procedures. Simply atrocious. Rant completed. Tektronix 7603 (Horiz): Has the 7D20 digitizer which can store 6 waveforms, compute envelopes, averages, etc. Wandel & Goltermann PS-19: Companion signal generator to the SPM-19 Selective Level Receiver. The last true analog (Wien) oscillator HP produced (~1979). This is one of the lowest distortion oscillators HP ever produced. I guess their last was their best. A close variant is also used in the HP 339A distortion meter. I bought it to test the HP 8903A audio analyzer which can measure down to -100 dBc as the only other signal generator I had produced about -70 dBc best case (HP 3326A). ($CD) Grade: APretty easy fix. It had a loose cable from the amplitude vernier pot to the main board. Also repaired the knobs. Built like a tank with precision hand adjusted wire-wound resistors (except on the 1M range). They don't make them like they used to I guess. I actually have no idea when these were made - my guess is around 1960 (if not earlier). These are extremely handy when calibrating DMMs. (---) Grade: A-The lower unit was fine. The upper unit, purchased about two years later, had one blown 1 Meg resistor. The resistor was marked 0.03% but I replaced it with a 0.05%, 10 ppm/degC temperature coefficient resistor for a couple of bucks. It actually measured 1.0003 Mohms on a calibrated HP 34401A DMM at work, so I guess I was lucky. I can go for the 0.02%, 5 ppm/degC Caddock resistor if I want to spend more than I paid for the whole unit. Maybe someday. Biomation 1015: Biomation (also known as Gould) produced some specialty equipment decades ago, most notably some of the first logic analyzers. There are about 20 assorted tantalum capacitors hooked up to these two rails and I pulled them all out until I found the two shorted ones. HP 3403C: This is a very nice true RMS digital AC voltmeter. It would have been even nicer had the thermocouple inside not been burned up. And this is despite HP putting in a protection circuit to prevent just that. My guess is that the protection circuit failed shortly before someone overloaded the input. Note that there are dozens of 3403Cs listed on eBay, all showing pictures of nicely powered up units with nothing attached to the input. I wouldn't buy one of these unless I saw it being fed with a signal generator. Anyway, with no chance of getting a replacement thermocouple, this piece is now a source of spare components. After numerous complaints I suspect, HP came out with a "universal" reference card that provided the output line disconnects via DIP switches. 25 MHz state analysis and 8 channels of 100 MHz timing analysis. The tie-wrap slipped and so did the board. HP 6113A: Precision power supply. HP made a few different models of these - mine is 10V, 2A, which is a bit obnoxious. However, the regulation is on the order of 0.001%, the stability is less than 0.01% over 8 hours and the ripple is less than 40 uV RMS. You would be hard pressed to find even a modern power supply that good. The "secret" is that they put the transistors controlling the feedback regulation inside an oven. This approach is similar to the Power Designs 2005 model described later on this web page. Built all with discrete transistors, it is everything you would expect from a 1968 piece. My only complaint is the thumbwheel switches which give your thumbs a good workout. (PDF) Grade: A-The seller advertised this piece as producing 2.5V output regardless of setting. But, for twenty bucks, why not take a chance? Sure enough, the voltmeter read about 2.5 VDC and would only change to zero if I turned down the current limit. But after spending about an hour checking the various transistors, it dawned on me to hook up a scope to the output. As I have commented in the repair notes below, one should always check a power supply with an oscilloscope, because an ordinary DC voltmeter will just show you the average voltage even if the output is varying. And that's just what was occurring - a 10V AC signal at a frequency of about 10 kHz was the output of the 6113A regardless of front panel setting. Bottom line was one of the 1450 uF electrolytics right at the output had dropped down to about 100 pF and was causing something to oscillate. A new 1000 uF cap was the cure, but I probably should replace the five or so electrolytics that still remain in this unit. But someone had gone where no man had gone before, because the previous repairman took the trouble to disconnect all three pass transistors and write "BAD" on top of all three main electrolytic capacitors. This little innocuous piece is probably one of the most useful things I own. It has diagnosed problems countless of times. The best thing about it is that it will do in-circuit tests (as long as shunt resistances are high enough). I also have the accompanying 3-prong probe in case I don't want to fiddle with three separate clip leads. (OM) Grade: A- BK Precision 801: Capacitance tester for the 1960's TV repairman. Meanwhile, the three main electrolytic capacitors seemed a bit too warm for me, so I decided to replace all the electrolytics in the unit. Keithley 485: 4-1/2 digit digital picoammeter. This is one of Keithley's better attempts at a picoammeter having accuracy specs of 0.1% (high ranges) to 0.4% (low ranges). This comfortably beats my HP 4140B which used to be the best picoammeter I had. Unlike the Keithley 480, this one autoranges. It also can show relative and log values. As mentioned in some of the previous picoammeter descriptions, I bought a Keithley 172, 414S, 480 (two) and 485 all for $50. One of my better buys since the 485 alone usually goes for $150-$200. But if you are shopping for a low current measurement device, the 485 is the one to get. HP 6226A: Another one of a variety of Harrison single output power supplies. This one is rated for 36V @ 1.5A but will do 50V @ 2A. The transformer makes a nice humming noise. It draws 25W with no load due to Harrison's tendency to stick high wattage power resistors in the circuit for no apparent reason. Maybe the germanium transistors of that era needed to stay warm. (OM) Grade: C+Despite being serial number 101, manufactured in 1962 and with a cracked resistor and many bulging capacitors, this thing actually worked when I received it. Ronan X86: Portable calibrator/generator for industrial applications. This odd piece both generates and measures volts, current and ohms with 4-1/2 digit resolution. The basic accuracy is on the order of 0.025%. Uses jacks that are not used in the test equipment field.If I recall, I got two of these in a single buy. Sold one and kept the other. But at some point, I must have either gotten bored, or the thing broke, because I remember dissecting it. It was so long ago, I can't even find the boards I pulled out of it. Whether it was simply a reseating problem or a corrupt RAM that I cleared, who knows. One measured OK, but one was leaking and one had separated from one of its leads. (PDF) Grade: A-Offered by the seller as working, it almost was when I received it. This provides a basic stability of 0.001% and an excursion of less than one millivolt per week, all with an advertised ripple of 100 microvolts peak-to-peak. HP 3336B: Called by HP a "level generator," was built for telco and has 75 ohm output impedance (plus 124, 600, etc.). Fluke 8600A: 4-1/2 digit DMM. At least this model does volts, current and ohms and has auto-ranging. It would be a pretty good offering from Fluke if only it had decent accuracy. The specs are laughable: 0.01% for DCV and 0.1% (or worse) for all other measurements. The lack of fidelity is also apparent when you go to the calibrate the unit. There are only a few adjustments and you just know that the thing can't be fine tuned very much. A very low end model that was hardly worthy of the $10 I spent for it. (PDF) Grade: CThis was advertised as "erratic on ACV" and it certainly was. After a lot of substituting parts, the problem was traced to a current limiting diode on the ACV board. I thought I tested it right at the start, but I guess I was fooled by my in-circuit test and should have pulled the part. The diode is supposed to source 5 ma. Since these things are essentially a JFET with the gate tied to the source, I pulled a JFET out of my junkbox and managed to get about 1.5 ma out of it. So I installed that and the thing gave accurate ACV readings. However, it wouldn't auto-range to the next higher range because the current wasn't enough. So I installed a second JFET in parallel with the first. Nice of Fluke to even give me a spare set of holes on the board right next to the original part. Everything works now to "spec," if you can call it that. Let's just say it looks a whole lot better when it is sitting in the darkest corner of the lab. And somewhat later, that same buddy gave me his HP 5334A!.Postscript: One of the differences between the HP 5334A and 5334B models is that the A-version can store user settings. That means there is a RAM with a backup battery inside. Who knew? Anyway, one day upon power up, the 5334A threw error 5.2 which means it couldn't obtain the correct HPIB address. Normally, HPIB addresses are selected by a set of DIP switches on the back panel, but in the 5334A, they are stored in the RAM. That was the clue to go looking for a battery inside. Fortunately, the 3.6V rechargeable NiCd hadn't leaked too badly. It was replaced with my normal setup of two AA alkalines in a plastic holder with a Schottky diode in series to prevent recharging. The second 5334A I have fared somewhat better as its NiCd battery tested OK. Built by HP Germany. I've seen many of these go on eBay for very little money because nobody seems to know what they are. If you don't need precise control of frequency, they are a very good deal. (PDF) Grade: A-This was not really a repair as much, but deserves note because all of the initial problems were corrected once I properly aligned the unit. I've never seen any HP piece this far out of whack. Also reworked the battery backup into a remote enclosed battery holder.Postscript: Did a preemptive replacement of the Rifa suppression 0.022 uF capacitor. (PDF) Grade: B+I didn't expect too much to be wrong with this when I received it. I replaced them with low impedance, high ripple caps and also replaced the three P/S pass transistors whose leads had been snapped off 1 mm from the case by the previous repairman. (OM) Grade: B-The seller advertised this as "output incorrect and switches noisy." OK, if you count the output being zero as incorrect, then the seller was right. Wandel & Goltermann SPM-19: Selective level measuring receiver to 27 MHz. Has both a digital meter and an analog meter/demodulator. But the build quality is simply outstanding, even better than most other HP pieces (this one was made by Japan's HP-Yokogawa). (PDF) Grade: A-This was advertised by the seller as "powers on but malfunctions." No further explanation or details. Cosmetically, this piece was very nice. And it turns out that you can coerce it up to 2000 uF by entering a "special" mode from the front panel. The unit is very large, heavy and well-built. (OM) Grade: A-The seller advertised this piece as working, except a few ranges are off value. And that's exactly how I found it upon receipt. Moreover, some of the higher ACV ranges were not only off, but fluctuated excessively. Remember, always look for mechanical failures first. In this case, always look for mechanical failures first, second, third, ..., twenty-first. Indeed, there are 21 relays (mostly 4PDT) in this unit and all the signals go through most of them all of the time. I pulled out one relay and measured one of the contacts at about 200 ohms. So my methodology was to measure all the contacts and then apply 400 ma across any with a resistance greater than 0.2 ohms until I burned the crud off and the resistance fell to 0.2 ohms. Well, wasn't that exciting to do that on 21 relays? Sure thing. Anyway, all seems perfectly normal now. There are a couple of random voltages that are slightly out of spec, but then again the HP 3456A DMM that I'm using with this doesn't have sufficient accuracy to determine if I'm out of spec on those ranges.Postscript: Well, it looks like my current burning technique didn't last long. About one day to be exact. Nor did a dip in Tarn-X. Nor did a soak in alcohol. The only long term solution was to replace all 21 relays. The replacement relays are about $20 a pop, so that was out of the question. However, I did find a seller on eBay and bought 33 3PDT relays for $20. That's my kind of price. Of course, the new relay pinouts didn't match the old relay sockets. But luckily, all but two of the 4PDT relays in the calibrator use fewer than 4 poles. I desoldered all the relay sockets and hard wired in the new relays using two 3PDTs to pick up the 4th pole where necessary. The entire transfusion took about 20 hours and the Rotek 320 is as good as new. Well, a lot of it is new! S : Sadelco, Sencore, Simpson, Singer, Solartron, Soltec, Systron Donner Sadelco 900: A TV/CATV receiver and level meter. What were they thinking? I've read that it was used by field technicians who were simply told to "set the knob to here, make sure the reading is 4.0, etc." Tektronix 2213A: Your basic Tektronix two channel 60 MHz scope. Also emits high and low tones in case you are blind. Resistance from 200-ohms to 20 Mohms in 6 ranges. Thanks, Dan. Krohn-Hite 5400B: 5 MHz function generator. Well, the schematic was close, but not perfect, so I hooked up the ohmmeter across the 15V line and started clipping capacitors until the short disappeared. This meter will measure C, L, C-leakage at voltages up to 600 WVDC and inductor ringing. Anyway, I replaced the 3.6V lithium with two alkaline AAs. The unit passes the functional checks but I tweaked all of the cal pots just because I could. If you turn off the surrounding lights and look carefully, you can see some dimly lit segments that are supposed to be dark. ESI SP5110: "A microprocessor controlled automatic LRC meter" says the manual for the ESI 296. HP 54522A: 500 MHz (2 GS/s sample rate), 2-channel digital oscilloscope. HP introduced their 54520/40 series scopes around 1993 and finally abandoned the single knob man-machine interface of the 5450x and earlier versions (see the entry above for the HP 54112D). These newer scopes have more of the traditional knobs for vertical, horizontal and trigger, yet still retain plenty of soft-menus and keypad/knob entries for those throwbacks to the earlier era. HP made the 54520, 54522, 54540 and 54542 models in both the A (monochrome CRT) and C (color LCD) versions. The fourth digit of the model number refers to the number of channels and the fifth digit is proportional to the sample rate (higher means a higher rate among all channels). So this model is the best 2-channel CRT scope they made. About the same time, HP came out with the 54600 series (see the entry for the HP 83475B which equates to the 54610B). The principal advantage of the newer 54600 series was a smaller package and a much faster waveform/sec update rate. Their best model, the HP 54616B, is analogous to my HP 54522A, both having 500 MHz bandwidths. But HP chose to remove all the math functions, the HPIB, the data interfaces and everything else they could so they could sell them all back as options. The specifications for the 54600 series also aren't quite as good as the 54520/40 series. For instance, the two specs for the 54616B and 54522A are, respectively, 1) min V/div: 2 mV vs. HP long ago proved that such a technique yields approximately the correct statistics for the waveform and can thus be used to estimate the power. HP 8642B: High fidelity signal generator, 100 kHz to 2,115 MHz. The 8642A/B generators were designed as a "replacement" for the universal, but aging, HP 8640B (see entry above), which achieved excellent phase noise and spurious specs due to its cavity tuned oscillator. The 8642 series claims to beat the 8640's phase noise by 6 dB even though it is a digital synthesizer; it uses a surface acoustic wave resonator, whatever the hell that is. HP claimed it was the best signal generator on the market in the late 1980s, although their 8662A signal generator had slightly better phase noise at 10 Mohms). Five slots are populated. He then relied upon a physical connection on the top side of the board between the pad and the socket pin. I reinstalled the cable and the green blob on the CRT disappeared. A decent standalone generator too, but the Knobology leaves a little to be desired. Typical W&G German overengineering - all the circuit boards are in their own little sealed compartments. (---) Grade: A-Replaced T13 LED driver transistor on frequency display board.Postscript: One day I turned the piece on and I heard a pop. Moreover, the display kept flashing error 1-103 and there was no output. When I opened it up, I was met with the stench of a blown tantalum capacitor, despite the fact that most of the circuitry is in little sealed compartments. When I finally located the right board, the tantalum had obviously caught on fire and had charred many of the surrounding parts. I don't have a schematic for the PS-19, so all I could do was throw in a 22 uF tantalum and hope for the best. Seems to be fully functional now. One of the best HP produced. Exquisite control of all functions. My "go to" signal generator. ($CD) Grade: AGotta love pieces like this. When received, the A channel worked fine, the B channel was dead. Opened up the unit, saw a dangling coax connector, plugged it back in, presto! HP 3330B: 13 MHz sweeping synthesizer for use with 3570A tracking receiver as a network analyzer. Even though I have this permanently connected via rear panel jacks to the 3570A, it is a very good signal generator by itself. Has a front panel that rotates upwards for ease of use. (PDF) Grade: A-Postscript: Turned the thing on after a year or so of being dormant and the amplitude display read "XX.00" (X = blank) and the frequency display's last four digits were stuck at zero. Racal 5900: This is a very mediocre 5-1/2 digit DMM. When it was first working I gave it a grade of C+. After the initial fix, it developed a problem on the digitizer board that I could simply not track down. However, as I was trying, I blew up some of the power supply chips, and then it developed display problems. Since this was such a poor piece, I decided to relegate it to the "It's Dead, Jim" pile. I still have the Racal 6000 6-1/2 digit DMM, but that is only marginally better. Racal did make some very nice pieces - their DMM's, in my opinion, are universally poor.Postscript: A few more transistor replacements and the thing started to work again. For how long, who knows. So I removed it from the "It's Dead, Jim" pile and reinstated it as part of the main collection. (PDF) Grade: C+This piece took about one month to eventually fix. At some point, some of the power supply failed in an overvoltage condition and took out a Zener, electrolytic cap and a pass transistor. There was also some considerable rework necessary on the switching board thanks to the previous repairman. But most of the problems centered on the digitizer board. Conceptually, the digitizer passes the input signal, charges up a capacitor, and then discharges it (and measures the discharge time on the main digital mainboard) by switching in either the +10 or -10 volt reference (depending upon the polarity of the input). I determined that one of the four transistors making up two flip-flops in the polarity detect circuitry was bad. After replacing that, the discharge cycle works properly, but the digitizer still had some issues and the display tended to read too many as the input voltage went to zero. Turns out that the op-amp that was controlling the integrator was flaky. I replaced it with a decent one. However, the LM301 had odd behavior where it would oscillate. When I looked at all of the datasheets for the LM301 specify a maximum of +/-18 volts. And most likely, the -20 volt supply reached -26 volts when the P/S failed. So I replaced the LM301 with the military LM101 version that can take the higher voltage. Everything appeared to function, except the display read about a 0.6 mV offset between a +1 and a -1 volt DC input. No matter which adjustment pots I twiddled, I couldn't get rid of this offset. Then it occurred to me that I had earlier replaced two JFET switches that feed in the +10 or -10 volt references into the discharge cycle thinking that had something to do with the funky behavior. I should have looked at the parts list because Racal specified a matched set for the two JFETs, not a random set from my junkbox. So I dug out a bunch of identical JFETs, tied gate to drain and measured the resistance from source to drain until I found a pair that were only off about 2 ohms (300 ohms was the nominal Rds). Put those in and my 0.6 mV offset disappeared. Gee, what a surprise! So the 5900 is now essentially fixed. However, I'm sure there are still some marginal solder joints somewhere because once in a while the leading digit of the display will turn off until you rap the case good and hard. But, enough already.Postscript: Turned it on, worked for about one minute, then crowbarred on the -20 volt rail. I have reworked the digitizer board so many times that it is falling apart. At this point, this piece is what we call "beyond economical repair." After a few days, it has calmed down so it doesn't overload and the readings are approximately right. But there is a lot of random noise on the readings (presumably coming from the digitizer board), so the piece is, for all extensive purposes, unusable. Finally, one day in desperation, I purposefully grounded the gate of the JFET that feeds the input to the digitizer board because I suspected the input signal was not getting through. The noise abruptly stopped and the piece now functions perfectly. I have no explanation other than I shook the guts of the JFET loose? People always ask, "Do you ever sell anything?" Occasionally I do, but I generally hate to part with something that I've fixed and has a story behind it. But here are a few that I have disposed of.... Hook it up to virtually any semiconductor and you get a scrolling readout of who, what, where, and why. This is a great device for identifying components in your junkbox. It really gets quite confused if you hook it up to a device in-circuit. (OM) Grade: A- Peak ESR60: This unit does work in-circuit and measures the C and ESR of electrolytics at the industry standard 100 kHz. Also can serve as a milliohmmeter for measuring small resistances. I know ESR seems to be the rage these days, but I don't think I ever found a capacitor whose capacitance was in spec yet the ESR was too high. Either the cap is good or the cap is hosed. But at least this does in-circuit testing and is quite useful. The unit came with alligator clips which I couldn't stand. I then wrote to Peak and asked them if there was any problem with me replacing the leads with minigrabbers. They wrote back and basically said "we wish we had thought of that." (OM) Grade: A Philips PM2525: 5-1/2 digit DMM. Well, it mostly is a 4-1/2 digit DMM, but it can be coerced into 5-1/2 digits in some functions and ranges. On the positive side, it will do a lot, namely DCV, ACV, peak V, DCI, ACI, ohms (2W and 4W), frequency, capacitance, continuity, diodes, and probably a few more I've missed. But that's about all I can say positively about the 2525. Now for the negatives! First of all, look at the picture and you will see that even though it is a high-end instrument, the on/off switch is almost impossible to see unless the lighting is perfect because it is so understated. Moreover, Philips put the on/off switch on the back - there should be a law against that. The specs are horrendous, for example, 0.03% reading + 0.01% range on the most accurate DCV range with a response time of 6 seconds on two digits. Four wire ohms can only be done through the probe socket. But I've saved the best negative for last, for when you press a front panel button to change a function (or range), it turns on a motor that rotates an internal function switch - a rotary switch just like you would find in a handheld DMM. This piece deserves to win the Nobel prize for stupidity. (PDF) Grade: CAs received, the unit basically worked. But I'm pretty sure an internal part of the motor has broken and is rattling around inside the motor case. So I'm not too optimistic in the long term and will start looking around for a cheap DC motor that will fit.Postscript: I was fooling around with the PM2525 one day because it seemed like it was out of spec. Moreover, with a shorted input, the thing was drifting all over the place between +/-10 mVDC. I spent three or four days with futile attempts at debug, but the full schematics are nowhere to be found (even from a copy purchased from a manual dealer). Finally, I pulled the battery backed-up RAM and that cleared the stored calibration constants. BIG mistake! Indeed, Philips requires you to completely calibrate the unit twice - cold and hot - in order to get rid of the annoying "NC" (not calibrated) message that is now permanently affixed to the end of every reading in every mode. The cold calibration is not difficult enough, but they want you to heat the calibration to be done at 90 - 105 deg F and suggest you throw it into an oven for an hour or so. I don't think they are kidding because it seems like Philips is reading the internal temperature (via a transistor) and so will fail all attempts at a hot calibration unless it really is at the right temperature??? Preposterous if so. One might argue such a comprehensive calibration might be required for a very accurate meter. But the PM2525 has terrible specs and if they can't get 0.02% DCV accuracy with a simple calibration (zero and full-scale), something is wrong with them. Anyway, I spent another three or four days trying at least to calibrate the DCV function to no avail. Finally, I simply let the thing run for about 12 hours. Seemed much better behaved, with only a few tens of uV offset, and I was ultimately able to calibrate the DCV (cold and hot without changing the temperature). I may get around to the other functions one day, but I really have no intentions of ever using this piece. In a word this piece was thoroughly mangled by the Fluke accountants; they decided to offer the base model with DCV only. I then looked at the total collection of 54 errors. HP 3400A: The ACI meters came along in the same bay with HP 410C VOMs, an HP 435A power meter and an HP 4328A milliohmmeter. See the description above for the disposition on the HP 410Cs. When I turned this HP 3400A on, the meter pegged and stayed that way on all ranges. When I took off the cover to take a look, I saw a board floating inside with a cut coax cable. So I opened up my existing working HP 3400A to see where the coax cable should go. Only then did I see the real problem. Someone had removed the whole back end of the range switch (wafers and resistors). So this piece will serve as spare parts for the working one should the need ever arise. Totally bulletproof. These things go for 1000VDC. Courtesy of WA1MIK who supplied two non-working units. Fixed both, kept one, sold the other on eBay for over $200. A third parts unit was sold on eBay to a buyer in Japan for about $25. I calibrated this against a newly purchased HP34401A DMM I borrowed from work. I guess that will have to do. I mean it's not like I'm running a cal lab in my basement. (PDF) Grade: AThe unit I kept had a faulty open power resistor in the high voltage feedback circuit. The second unit had several faulty electrolytic caps in the chopper amplifier circuitry. The third unit was way beyond any repair.Postscript: The range switching board is connected via about a dozen push-pins. These have been working loose over the years and causing some problems with the 343A, especially with the 10 setting in the left-most knob. So I dropped some solder on all the pins and the 343A seems much better. So of course, I'll never be able to remove any of the boards again.Postscript^2: After many years, I noticed that the 343A was slightly out of calibration. The cal procedure went OK except for the highest digit on the first knob. Most likely, one or more of the Fluke-made custom precision resistors in the sample string have drifted. It is not really of concern because it only effects the 10 digit and is easily worked around. For instance, if you want 10 volts, you have at least three choices: 1) 10 V range and 10 on the first knob, 2) 10 volt range and 9X on the first two knobs, or 100 volt range and 1 on the first knob. The latter two are fine; it is only the first choice that will read slightly out of spec high. So I padded one of the adjustment pots with a 100 ohm resistor. This made the distinction OK on the 10V range, i.e. 10 and 9X now read the same. Unfortunately, the discrepancy still exists on the 100V range. So I just have to be careful to use 9X when I want 100 volts, or use 1 on the first digit in the 1000V range, no big problem. Tektronix 7A16A, 7A18A, 7A24: Various Tektronix vertical amplifier plug-ins for the 7000 series. ($CD) Grade: BSee the comments for the Tektronix 7A12, 7A13. That I have to agree with the 1985 Racal catalog where they say "The model 5002 is the most versatile wideband AC voltmeter available." (PDF) Grade: A-The eBay listing photo showed a blank LCD display and none of the front panel LEDs lit except for the power-on LED. I soldered two of the six current shunts on the front panel 10A range. Didn't know the half of it "A" is this. This piece was donated by a retired colleague (Dan) and came with Tek P6122 and P6112 100 MHz x10 probes. A colleague at work was looking to experiment with electronics and needed a starter scope. So I donated the 2213A to him. No real complaints - does exactly what it is supposed to do with minimal fuss. I also replaced the load adjust pot with a three turn pot for finer control. The resistor actually measured 446 ohms when I pulled it. HP 4800A: Vector impedance meter, good to 500 kHz. Hook up to the front panel jacks and measure the magnitude and phase of the (complex) impedance - that's pretty much it. The accuracy is not particularly good, about 2% for magnitude and +/-6 degrees for phase. Of course, it is left up to the user to translate the impedance into a component's value (for example, inductors or capacitors). However, if you look carefully at the main frequency tuning knob, you will see a little mark labeled "LC" at 15.92. Now look left of the tuning dial and you will see two formulas for L and C. When the tuning knob is set at 15.92, these formulas provide the component value. For example, the picture shows a capacitor that gives an impedance of -30j ohms (the phase angle should be exactly -90, but it is good enough). The frequency range knob is pointing to 1, so the formula to use is C(uF) = 1/30 x 10^1 = 0.33 uF. And since the capacitor was marked "334", that's exactly right. Even though I've already quoted the basic magnitude and phase accuracies, the calculations of component values, when done as just described, is only about 7%. Given that all this thing is doing is running an oscillator through a DUT and measuring the voltage and current, I'm not at all clear why HP took 20 circuit boards to do that. Moreover, one of the detectors uses a sealed light/photodetector unit which will take a bit of experimentation when the bulb finally burns out. And you really have to be careful with components hooked up via test leads to the front panel jacks - the inductance and capacitance of your test leads are perfectly happy to screw with the complex impedance and the 4800A is perfectly happy to display it to you. This piece was my second attempt at an HP 4800A. The first one (see the "It's Dead, Jim" section below) was unrepairable; this one was in excellent shape and looks like at least the cabinet and front panel were professionally restored. (PDF) Grade: BThis piece was advertised as condition unknown, but repairable upon receipt. It was, however, quite a bit out of adjustment and required changing one factory-selected resistor. But then after a day, the thing acted flaky, which was boiled down to a faulty A7 Schmitt Trigger board. The previous repairman had already replaced the six transistors on the board, and if he could, then so could I. After replacement, the unit was much better, but the phase alignment is very touchy and ends up being a compromise across all frequencies and impedance ranges.Postscript: After some more playing around with this unit, I noticed that it takes about an hour to achieve accurate readings. A quick look at the source oscillator output showed that it was not oscillating correctly during this warm-up period. Really the only thing that could account for this is the light bulb(s) in the feedback of the Wien oscillator circuitry - a special HP sealed unit containing three incandescent bulbs. The ohmmeter showed that the bulbs were not open, but something was definitely wrong. I noticed that if I touched a soldering iron to the three connection points on the board, the oscillation immediately began. HP describes the innards of this bulb set twice in the manual - and the descriptions do not agree. At one point, they talk of a 3V bulb and at another a 10V bulb. I pulled the sealed unit and experimented with a variety of discrete bulbs. However, while this cured the lack of oscillation during warm-up, I could not achieve oscillation across all frequencies with the limited variety of bulbs in my junkbox. Luckily, an eBay seller had a new old stock unit. Unluckily, he wanted $50 for it. We compromised at $35, which is still outrageous for three incandescent bulbs. But you do what you need to do when you need something you need it. And that cured the problems with the HP 4800A. HP 5005B: Called a signature multimeter, this is a combination of a signature analyzer, a counter, a voltmeter and an ohmmeter. Like most FFT functions in oscilloscopes, it is a bit of a pain to use, but for the HP 54522A for how an FFT should be implemented in a scope). But it is nice to have it in the TDS520 and the price, of course, was right.The seller showed a picture of the boot-up of the machine with the "Self-Test Passed" message. That's good. He also claimed that the unit was unresponsive to inputs on both channels. That's bad. So I took a chance for $79. All of the Tek TDS500s and TDS600s suffer from leaking surface mount electrolytic capacitors whose electrolyte is very eager to chew through traces and corrode IC pins/pads. In fact, the official word is that you shouldn't even power one of these puppies up until after you have replaced all the capacitors, scrubbed the board with de-greaser, alcohol, hot water, and anything else you might have lying around. When I took it out of the box, I stayed true and didn't power it up - I removed the cabinet and took a look. What I saw were absolutely pristine boards with not a drop of electrolyte anywhere. So I figured that someone had already done the cap replacement. I did see some evidence of corrosion on the capacitor pads, but I saw no board rework. A lot of the caps are installed slightly crooked and my guess is that this 520 was re-capped prophylactically before any had leakage occurred. All it really does is continue. (OM) Grade: B-Another "two-for-one" deal. Both not working. The "better" one I chose to fix using parts from the other. The other one I chose to part out. Some of the resistors in the attenuator circuitry were burnt and seemed. Not bad, but simply not there. The 4280A was usually sold as part of a multi-piece HP 4062B Semiconductor DC Parametric Set, but it stands on its own for basic capacitance testing. My only complaint was that the analog meter was a bit low. Like the current situation in higher education, it reveals some grade inflation. I did some further dissection to get to the display board, disconnected the board and measured from the 15V test point to ground. Fluke/Philips PM3390B: 200 MHz Combiscope operates as both an analog scope and as a digital storage scope with a push of a button. In the digital mode, will do all kinds of measurements. Have a couple of the matching Phillips 10:1 probes. The only thing wrong when I received it was a banged-up case. Good thing it didn't really need repair, because it is all VLSI gate arrays. This is a wonderful scope - probably the best overall scope I have. There are times you need analog and times you need digital capability, plain and simple. (PDF) Grade: A The repair of the case was more than simply straightening it out. I had to pop all the rivets out of the case just to get it all straightened out. The back was great for banging on it with a hammer while the scope was inside! After I fixed the case, I basically reshaped it and then put machine screws where the rivets were in order to close the case back up. The scope slid back into the case with a little persuasion. I hope I never have to get it out again.Postscript: Haven't had too much desire to use this scope given some of my other ones, but recently I fired it up and it seemed a bit off in the calibration. I checked the two AA memory-backup batteries (in a little compartment on the back panel) and they were greened with globs of dried up battery acid. Cleaned it all up, installed fresh batteries, ran through the calibration, and all is well. 500 ps; 4) H-resolution: 20 ps vs. Also has Option 002 - analog arbitrary waveform generator. The Rigol is spec-ed for phase noise of -80 dBc//Hz at 10 kHz and a DANL of -135 dBm (100 Hz RBW). The 5262A is a time interval counter that produces a start/stop trigger for signals up to 1 MHz. As the 5245L counter is a 50 MHz unit, all three of these plug-ins work fine in the 5245L. Evidently, the battery voltage goes through a comparator to develop a logic signal that disappears into the uP circuitry. Electrically, there was a brief period where the amplitude gyrated wildly by merely tilting the unit. Take an IR 15 UV/RA transformer, threw it in a pretty Bakelite box with a switch and voila. However, all the wafer switches needed a shot of alcohol in order to get the contacts to stabilize. I was a bit scared to use more aggressive tuner cleaner. Even so, the meter would fail accurate on all ranges below about 10 nA for about an hour until the alcohol dried. Keithley 414S: Solid state analog picoammeter. This came in a buy of 5 Keithley picoammeters, but the seller's picture only showed four. It wasn't until I opened the box that I saw I received one of these. I already had the 414A model, but I instantly noticed the two extra controls on the front panel. The "S" in 414S stands for suppression - a really cute feature. Suppose you are measuring 1.000 uA and want to see if the current jumped to, say, 1.001 uA. You aren't going to see this 1 part in 1000 change on an analog meter set on the 1 uA scale, and if you switch to the 1 nA scale, the meter will peg. So you use the suppression controls essentially to notch out your 1.000 uA so you can see the 1 nA range. Architecturally, the 414S starts out the same as the 414A - namely a range switch with a pile of very accurate, high value resistors to provide the exact current (in the opposite direction) for the suppression feature. It's almost like getting two picoammeters in one! (PDF) Grade: ANothing to do except put a fuse in the empty fuse holder and run through the adjustment procedure. Keithley 480: 3-1/2 digit picoammeter. I guess Keithley decided to continue their very nice picoammeters into the digital realm. And they cranked the accuracy down to 0.5% (high ranges) and 0.8% (low ranges), rather than the typical 2% of the analog meters. Not much to say - press the button, read the numbers. (PDF) Grade: A-Two of these came in a buy of 5 picoammeters. Both had notes describing the malfunction written in indelible red magic marker on the case (thanks a bunch for that). One of the units sprang to life after I cleaned the switches, but the other had a pretty bad offset. When I looked inside, there was evidence of a previous repair attempt. But as I dug deeper, I found the repairman had decided the switches were the culprit, and rather than clean or replace them, he cut a bunch of traces and ran a bunch of jumper wires - almost as though there were unused switch sections he was borrowing for a bad one. Whether or not there are, I wasn't about to spend the time pouring over the schematics to find out. So I delegated this second piece as a parts mule (which came in handy for the Keithley 485 described below).Postscript: Even though I took a couple of JFETs out of the second 480 parts mule, there were only two left over for overload protection. So I revisited the piece and found that the ohms section was fine. It was a defective Intersil ICL7103 digital voltmeter chip that was sourcing voltage back out the input. I took and ordered Simpson 145 digital panel meter, which was removed from the front panel of the 480, and wired in the Simpson. Works fine. Until I need a part out of the 480... Philips PM5193: 50 MHz synthesizer/function generator. This is a somewhat odd piece that generates sine, triangle, square, haversine, sawtooth and pulse waveforms. The PM5193 uses a DDS with a waveform lookup table for frequencies up to about 2.1 MHz; higher frequencies use a VCO/PLL with various waveform shapers. It will do 50 MHz for sine and pulse; the other waveforms are derated down to as little as 20 kHz. It also has internal AM and FM modulation capabilities as well as provisions to generate burst waveforms and to do frequency sweeps. So the PM5193 is actually quite a capable little piece. The specifications, however, are strictly middle-of-the-road and are somewhat disappointing given the look and feel of the piece. I suspect the PM5193 may comfortably beat these mediocre specs, but I'm not going to run through and measure them out. Similarly, the man-machine-interface is a bit awkward, but easy to navigate once you get used to it. The build quality is very good and so is the serviceability for the most part. I'll go out on a limb and give it a slightly higher grade only because it probably is better than Philips advertised. (PDF) Grade: A-The photo from the seller showed the unit powering up with Error #3, but made no other claims about the working status. Error #3 implies means the 3V Lithium coin cell battery that keeps alive the RAM storing user configurations is dead. So a new battery fixed that and the 5193 booted up nicely. However, the waveforms were way too low in amplitude and the negative sides severely clipped. That usually means one of the two push-pull output transistors is bad. But before looking there, I heeded my own advice which says to always check the power supplies. Indeed the 20V was fine, but the -20V read about -1.6V. There is a 5.6 ohm current limiting resistor on the output of the -20V supply's pass transistor and the resistor had migrated to about 70 Kohms. This forced the 4-terminal adjustable regulator controlling the pass transistor basically to shut down. A new 5.1 ohm, 5-watt resistor from my junkbox fixed all this. I then ran through the ~80 step calibration procedure which looks a bit daunting until you realize that all the adjustment pots can be reached through holes drilled in the bottom of the board. Nevertheless, most of the pots had dead spots where they had been sitting for 30 years, but fortunately the unit was out of adjustment and the pots needed a little bit of rotation. With the output stage repaired, I was getting output but the pushbutton switches and pots were very noisy and required an extra good cleaning. Error #3 is back (...) So the bottom line is that all the tactile switches were treated and the 8520A works very nicely. HP 4328A: Low resistance meter from 100 ohms down to 1 milliohm full-scale. Seeing as I already had the high resistance meter (HP 4329A), I had to have this piece also. Seeing as it uses a 4-wire measurement technique, but unlike regular ohmmeters, whose ability to measure very low resistances is compromised by the minute induced DC voltages from the galvanic reaction of the test leads with the DUT, the 4329A uses a 1 kHz AC measurement. Shown in the picture measuring 1.6 ohms internal resistance of a weak 9V battery (try that measurement with a standard VOM!). Fairly accurate as far as I can tell, except in the lower 1/4 of the range. But since it uses a 1-3-10 range scale, you should never be operating less than 1/4-full scale anyway. (PDF) Grade: AThe unit came with Option 001 (battery) and without the Kelvin leads. The batteries, ca 1985, hadn't leaked (what a pleasant surprise) and still held a charge. But the unit won't work with a discharged battery, even off of AC, and I will never use it enough to keep the batteries charged, so I gutted the P/S board, threw two 7815 regulators in there, and converted the unit permanently to AC power. The leads, I purchased the proper male connector and a set of Kelvin clips. The leads actually run first to banana plugs so I can use Kelvin clips, banana-to-minigrabbers, or whatever else I decide to use in the future, without disturbing the main cable and connector to the unit. The only other electrical problem came when I was doing the alignment. I needed to change one factory-selected resistor to improve the linearity of the meter. However, the accuracy specs are not improved in high resolution mode, so what's the point? Wandel & Goltermann SG-4: Display unit working in conjunction with SPM-19 and PS-19. Set the SPM-19 frequency span and sweep rate, then it controls the PS-19 generator and the SG-4 graphs the results. Instant spectrum analyzer with tracking generator. Nowhere near the build quality as the SPM-19 and PS-19. (---) Grade: B+When I received this, it powered on, immediately stopped and displayed "SPM-19?" That's because it wasn't hooked up to the SPM-19 with the correct cable. The connection requires a 14 pin analog cable and a 24 pin GP-IB-like cable, neither of which I had. After making those up, I got past the initial hangup and it now said "GP-IB?" There are three possible GP-IB boards that can go in the SPM-19 with 10 configurable jumpers on it. In fact, the SPM-19 also didn't properly have a GP-IB board - I pulled it out of the PS-19 since I knew the PS-19 could be controlled with analog cables (confused yet?). Obviously the GP-IB board was configured for the PS-19, not the SPM-19. In fact the part number for the right GP-IB board for the SPM-19 did not match the PS-19's GPIB board that I stuck in. But a GP-IB board is a GP-IB board... So what I did was to hook up a National Instruments USB-GP-IB controller to it and moved the jumpers around until my computer showed I was communicating successfully. Once I did that, the hookup to the SG-4 went successfully and the SG-4 works fine. Fluke 845AR: DC null voltmeter. Measurements from 1 uV to 1100 V in 19 ranges. This is what you need if you want to calibrate a DC voltage to a standard. Hook both up differentially and tune for a null. If you look at virtually any calibration procedure from the 1970s and 1980s, you will see the 845 called out in the equipment list. Because unless you have an 8-1/2 digit DMM, this is the way everybody does it (and did it for decades). My unit is the rack-mount version which differs in form factor from the 845A and 845AB (the latter has batteries). Mine wanders a little (about 1/3 uV) but that's not bad given the age (late 1960s) and the amount of rework done to the piece. Could probably benefit from a thorough board cleaning. [Note added later: after a thorough scrubbing of the range resistors, the drift is substantially better]. (PDF) Grade: A-Sold as previously a calibrator, it had a perfect reputation in the field. I got it, the meter was totally dead, unresponsive to any input on any range. I will compress about a week's worth of debug for you. The previous owner(s) had already replaced the two neons (used in the chopper AC amplifier) and several of the electrolytic capacitors. Thanks for that, but what took a while to realize is that they replaced not only did he not use what is called out in the parts list, but he also threw in a few PNPs where NPNs should go, and vice versa. There are several transformers in an old 1960s design that are used to chop the signal - the culprit seemed in my scope the chopper transistors (chopper transistors have higher Vbeo specs). People on eevblog have recommended suitable silicon chopper transistor parts, so that is what I used. But even when I had all of the transistors correctly installed, the thing was way off on positive inputs and zero on negative inputs. Then it occurred to be my observation that current was not propagated from the power supply throughout the rest of the circuit. I have absolutely no explanation for this. No wires seem to be missing and no traces were cut. You can follow the ground trace from the P/S and it abruptly dead-ends with the remaining circuit grounds isolated. Obviously there was some where the voltage that has not got moved without leaving a trace. So I jumpered the two grounds together and now all is well. HP sold a couple of special test fixtures for the 4140B (which obviously have vanished off the face of the Earth) that really need to be used at very low currents. HP 1220A: 15 MHz, 2 channel oscilloscope. HP occasionally decided to compete in the low-end category and the 122x-series of oscilloscopes were a prime example ($750 in 1975). HP was almost apologetic in their catalog description of these scopes by advertising them as good for educational purposes or TV repairmen, while assuring folks that they were "produced using the same construction and design techniques used to achieve laboratory measurement accuracy." My particular 1220A model is a 2-channel (automatic alt/chop selection) 15 MHz (although will trigger to 30 MHz) version with only the basic set of controls. As such, it works fine since there aren't a lot of extra features to break. I have always thought that the HP scopes of the 1970's and early 1980's lagged far behind Tektronix offerings of the day (although Tek did have a few "dogs" too) and nothing about the 1220A changes my opinion. (PDF) Grade: BThe photo of the unit from the seller showed a small blob at the center of the CRT. That is how I found it when I powered it up: no response to any controls or input. A quick check of the +12, -12 and +95V power supply test points showed that all 1 MHz noise bursts at 120 Hz. Most DMMs won't be affected since the frequency is beyond their normal AC response, but it is quite discomforting to view the 382A output on a scope. The bursts aren't real because I then discovered that the 382A acts somewhat like a switching power supply (and we know those things have noisy outputs). In order to keep the power dissipation on the main pass transistor low, they use an SCR to charge up a capacitor which keeps the C-E voltage to about 8 volts; this SCR fires at 120 Hz. Whether there is some fault in the unit that I haven't found (and I did try), or this thing is suppose to produce these pulses, I have no idea. It's difficult to assign a grade for this piece because it probably deserved an A in 1964, but is barely worth a C today. So I'll compromise. (PDF) Grade: BBought as condition unknown, the 382A fired right up and produced some output. But the numeric selection switches on the front panel were extremely intermittent and so were doused in alcohol. The thing came to life, and I thought this was it. Then I looked at the output on a scope, I saw the bursts. Trying to fix them, I managed to come across a burnt diode, a burnt resistor, and a damaged trace. Those were all fixed, but did not affect the output noise. With all this, given its 50 year age, I also replaced all the electrolytics, the germanium transistors, etc.Postscript: I knew that some sort of bypass capacitor would probably fix my high frequency noise bursts on the output. But I learned an important lesson, namely, it matters a whole lot exactly where you place such a thing. After a lot of trial-and-error, I managed to remove these bursts and now the output noise is 50 uV like it is supposed to be. Fluke 540B: AC-DC thermal transfer standard. This is a specialty piece that was used by many labs to calibrate AC voltages. The idea is fairly simple. Take a DC standard, run it into the 540B (set to DC transfer) and null the galvanometer. Then, without touching anything, input your AC voltage (set to AC transfer) and adjust the input until the galvanometer nulls. What you have now done is "sync-ed" the internal thermocouple first to DC and then to AC. The AC accuracy can be achieved is about 0.01% with the 540B. A similar technique to calibrate currents provided you have the proper current shunts (I don't). My unit has an earlier A54-1 thermocouple plug-in without the protection disable switch. Why it doesn't have the display switch (the hole on the front panel is simply plugged), I don't know. And the previous owner decided to put a neon light in the front panel and then promptly didn't connect it. The 540B has slightly better specs than the later Fluke (8506A), but of course, is much trickier to use. (PDF) Grade: B+Picked this piece up for twenty bucks. Pretty good deal until I realized it would cost me thirty bucks to replace all the defunct batteries. The 540B uses 20 NiCd Sub-C cells and a 1.35 V mercury cell. For the latter, I used the same technique as I did for the Keithley 602 - an LP2951 low-power, low-dropout adjustable regulator powered off of two AA-cells. It was throwing the protection relay upon turn-on, but it seems to have settled down to correct operation now. The protection circuit is extremely sensitive to leakage currents and the board was pretty corroded from the leaking batteries. It may require a more careful cleaning than I've done already.Postscript: The protection circuitry was sporadically malfunctioning and was cured by replacing the four 1N270 germanium diodes in the bridge leading up to the transistors firing the protection relays. In my opinion, Fluke did a pretty bad design job, because the entire protection circuitry rests upon how much voltage drop there is through the diodes when passing 10 uA of current through the diode. For instance, more modern silicon diodes will not function in this circuit (I know because I tried). Nor probably will most other diodes that aren't 1N270s.Postscript^2: The protection circuitry still sporadically was malfunctioning and no matter how hard I tried, I could not get to the bottom of the problem. Apparently there is some leakage somewhere and I am beginning to think that it is coming directly from the board material itself. No matter, because I replaced the protection circuit with an op-amp acting as a comparator (I used positive feedback to make the protection circuit latch up like on the original). Seems to work great.Postscript^3: The "seems to work great" ending of the previous Postscript was a bit optimistic because the 540B started throwing the protection relay when turned on with no input. I ripped out my comparator circuit and restored everything to original. Obviously, this did not fix the problem. I removed the board and noticed some very strange resistance measurements. For instance, with certain parts removed such that a particular trace was totally isolated, I got about 25K ohms resistance to an adjacent trace. This time, rather than the simple alcohol rub I gave the board when I first acquired the unit, I really went to town with a Brillo pad, muriatic acid and a toothbrush. This seems to (keep your fingers crossed) finally have fixed the protection circuit. I also bought the A54-2 plug-in thinking that maybe my A54-1 plug-in was the culprit. In retrospect, it wasn't, so now I have two plug-ins for this piece. The A54-2 required some circuit cleaner to get the functioning properly. Besides the high frequency option, mine also has the fast measuring option. Has an "uncalibrated" analog meter for use when peaking a signal. Tektronix 7B53A: The "canonical" time bases that do all of the intensity, delay functions. (OM) Grade: BSee the comments for the Tektronix 7A12, 7A13. Tektronix 7B70, 7B71: Some more 7B70 series time bases. The +/-20 V supplies can autotrack. So I slipped the coupling hex screws and set it correctly. Build quality is so-so with lots of problematic transistor sockets and a very fragile switching P/S transformer. (PDF) Grade: C+Advertised as "plugged in but nothing happened," I surmised that the batteries were toast. Normally in portable scopes like this, the batteries need to be functional because they act as the voltage regulator. So I took a chance and spent $45 shipped. When the batteries were indeed toast, but for one, the seller, not knowing any better, applied AC voltage which instantly blew half the parts on the power supply board. I spent several hours replacing parts and finally got the P/S board up and running. The battery acid, in addition to destroying the traces and component leads, also created some leakage paths on the board so that my -1000 VDC to the CRT was only about -600 VDC (this took a lot of time to find). Plugged the P/S board in, turned on the scope, and .... While the 5002 looks like a piece from the late seventies, the chip date codes show it was built in 1990. I guess the moral to the story is: those pesky electrons will always find a way to get from one place to another.Postscript (2nd unit): While my original front panel fix was adequate, it was far from perfect because a small section near the calibrator display switches tended to push in beneath the front panel. The proper solution would have been to buy another 8520A and use its front panel. And so I was fortunate enough to find two broken 8520As listed on eBay with perfectly good front panels. My buddy and I split the purchase - a whopping $20 for both! Upon receipt, I switched front panels with my good unit. But then I still had a broken 8520A remaining and I can't have that, can I? The tag on this 2nd piece said "unit will not zero on any range or function." Well, I suppose that was true if you could actually power the thing on without blowing the main fuse, which has blown. Took me a few days to find what was broken, but now at least it's fixed.Postscript^2 (3rd unit): To make matters even more confusing, I picked up a new front panel board for two bucks which meant that I had reworked for the first unit and then transferred to the second unit. Now I have two pristine 8520As that can sit on the shelf unused.Postscript^3: I don't remember which of my units is which, but one of them recently had a problem on the 15V rail which was easily traced to a shorted tantalum in the AC measuring circuitry. If I recall, the other unit had the same defect at one point.Postscript^4: Many months later, I found yet another shorted tantalum on one of my 8520As. There are two tantalums on the +/-15V rails in the AC measuring circuitry. These 10 uF, 20 V caps are pretty much guaranteed to fail eventually if my experience is correct. Preemptively replace them if you have a working 8520A. It settles fine now and passes the performance specs. But I have several modern DVMs with input impedances of 10 Gohms, so I guess when I measure the 9V battery in my smoke detector, I will have to settle for a reading of 8.999999991 volts. The top unit required a little rework to the power switch. What they really should have done is add a trimmer to the 10K resistor and use the trimmer to translate that calibrated range into 10-20V. Has an actual vacuum tube inside. What was happening is that too much current was being drawn and Vcc was dropping through the resistor to about 3.5V. But what do they know? It also wouldn't indicate an over-range on the 20 volt range if initially presented with a voltage > 21V. I haven't bothered testing the accuracy of this beast - I really don't want to know. HP On-Off Switch Bonus Rant: It has long been my suspicion that HP engineers participated in a company-wide inside joke to make sure that they varied their on-off switches as much as possible. How else can you explain the fact that the look and feel of most of these pieces are identical (at least across common decades) with the exception of the on-off switches? Not convinced? Scroll down to the "Z" section near the bottom of this web page. Well, the 3253A takes this lunacy to a whole new level. Look carefully at the upper left corner of the picture - see the red dot next to the "OFF" text? That seems kind of strange, to put a red LED next to the word "off." But it's not an LED, rather it is a painted red dot. And why is it there? Because there is also a red dot on the top of the actual power button. As the red dot is visible only when the button is out, i.e., the unit is off. But unless you are standing up and looking down at the unit, you can't see it. All the painted red dot on the front panel does is confuse the user into thinking that the unit has been left powered on. I mean, really, whoever approved this scheme in the HP design review for the 3253A should be forced to track down every one of these units in the field and paint over the red dot with some black paint. I bet they sell a lot of their color-coded scales." Unfortunately, the meter is so small, it is anything but easy to read. 2 mV; V-accuracy: 2% vs. Virtually every piece runs too hot for my taste. Fluke 8840A: 5-1/2 digit DMM with VDC, VAC, ohms and current. The box (I still have it) says "easy-to-read mirrored meter with color-coded scales." This meter is a little more accurate than the usual Fluke benchtop models and enjoys a fairly respectable reputation. Best case (24 hour) accuracies are 0.002% (DC), 0.07% (AC), 0.0028% (ohms) and 0.04% (current). The features are minimal, but there is the convenient reading-rate selection and an offset null. (PDF) Grade: A-For forty bucks, I got two of these: an 8840A and an 8840A/AF. The AF model has DC ratio and some extra filtering on the AC line. But whoever had these last attempted to mix and match boards, so I'm not even sure which is which anymore. Nonetheless, both were offered as non-working. The first one powered up fine, but the display was intermittent and the ACV readings were incorrect. The intermittent display was traced to cold solder joints on the main transformer (a common problem according to the Fluke newsgroups). The ACV problem was traced to a faulty NE5532 op-amp on the AC board. The second unit rattled when shaken, and that was traced to loose wires that the previous owner had simply thrown back in the unit after he unsoldered them from the AC input socket. Moreover, all the wires to the front panel were disconnected. So it was clear that attempts were made to substitute major components between the two units. After I hooked everything up, relays clicked, and the display was dead. I waited an hour on digital/display debug, I pulled off the plastic display cover only to see the very nice Vacuum Fluorescent Display had two enormous cracks in it. So much for the vacuum, so much for the display, and so much for this unit. Oh well, at least I have some spares for the working unit.Postscript: I re-mixed and re-matched the boards and put the working unit in the full "AF" version. It has slightly better specs. Fluke 8921A: AC RMS Voltmeter, 10 Hz to 20 MHz, 180 uV to 700 V. There are 14 board-mounted pushbutton switches ranging from 2PDT to 6PDT and each and every pole that I checked was faulty (high resistance). Luckily I found the 4 $40 minicircuits amplifier, a $25 HP power supply, and sell it for $1,500. Having two channels (phase locked) is very nice. Too bad HP retreated from two channel designs for the most part ever since. (PDF) Grade: B-Had one open resistor and one bad transistor (2N3053 was replaced with 2N2102).Postscript: Turned this thing on after a few years and it failed to oscillate. Part of the -20V supply is a pair of transistors forming a differential amplifier. One had a bad emitter and the 2N3906 fixed the problem. Tenma 72-3060: Basic 20 MHz oscilloscope with built-in function generator. The Tenma model is a rebadge of the Goldstar OS9030G-G and is a no-frills oscilloscope with all the basic controls usually found in an oscilloscope, and nothing else. This would be an excellent teaching scope for high school students as there aren't a lot of extra specialized controls found in higher-end HP, Fluke and Tektronix models such as dual time-bases and advanced triggering. The function generator that will do sine, triangle and square up to frequencies of 1 MHz and 14 Vp-p open circuit (as you can imagine, the sine wave distortion is spec-ed at a pretty lousy 1%). Built in Korea in 2000, it is everything you would expect of a consumer grade piece of equipment (see the BK Precision Bonus Rant below the BK Precision 1570 entry earlier on this web page), namely moderate quality PC boards and dozens of wiring connectors. I don't know how much Tenma got for this thing 20 or so years ago, probably only a few hundred dollars. But everything seems to work just fine. (PDF) Grade: B+This unit was only $20, so how could I resist? It was advertised as having a trace, but condition otherwise unknown. When it arrived, it was unresponsive to any signal input on both channels and the vertical position knobs did nothing. The horizontal sweep, however, seemed to be working correctly. I dissected the unit and found that the four transistors in the vertical CRT amplifier were mounted to heat sinks and located in the breeze; they had actually ripped many of the transistor leads out of their holes and destroyed many of the solder landings and nearby traces. I managed to put it all back together and point-to-point wire everything back. Now I had some signal traces, but they were pretty bad. I checked the 140 V power rail and found about 50 V of ripple on it. When I pulled the main filter cap, I saw the puddle of electrolyte beneath it and one of the traces had crumbled into dust. That cap was suitably replaced and now everything sprang to life. Except all was not right as the traces had a bit of echo on them. In other words, one saw the trace with a dimmer set of traces reaching about 1 mm to the left and right. A day was spent tracing through the horizontal circuitry and everywhere I looked, I saw the sweep ramp signal with a small amount of ~250 kHz oscillations. As there was nothing in the scope that ran that fast (at low time/div settings), I was led back to the 140 V power supply. Indeed, the op-amp controlling the pass transistor must not be happy. All this was caused by the 10 uF, 250 V output electrolytic that was also looking - it measured only about 300 nF with an ESR of ≈1 Kohm. I removed it and inserted a 330 uF (all I had in the junkbox rated for 250 V). That was the cure. And then, as I was troubleshooting I nearly pushed that much current in startup that it caused the resistor that I replaced the 2.2 ohm current limiting resistor so I replaced the resistor, left the 10 uF cap out of the circuit and all my ghost traces disappeared. Went through the cal procedure and everything checked out fine. Some day, one of these days I will replace the cap. Cheap, no-name 85 degC caps - worthless!Postscript: Since two of the 5 electrolytics on the 195 and 140 volt power supplies were bad, I decided to replace those and all the remaining caps on the power supplies. Good thing I did since 10 out of 11 tested at least 50% low and/or had high ESRs. The entire scope should probably be re-capped, but I will leave that for another day. Y display. The HP 8980A does it correctly and is probably why it cost $25,000 in the 1990s. I would be the proper vector signal generator, but at least I can give it two identical pulse trains offset in time. The picture shows one particular display, the Vector display, where one observes the HH, HL, LH, LL possibilities hitting the four 45 degree quadrant points (this is similar to what QPSK would produce). The 8980A is rated DC-350 MHz, but in typical HP fashion, I've run it to 420 MHz without problems. (PDF) Grade: A-I'm glad I didn't start my TE repair career with this piece after having plunked down $60 for the service manual since it might have ruined me right there and then. The manual contains some brief adjustment information, then runs through page after page of procedures to isolate problems to a particular board (this involves a lot of menus setting internal parameters). The conclusion to each procedure, once the board has been found faulty, is to send it back to HP for exchange. NO schematics. NO parts list. NO layouts layout. Just a few overall block diagrams and page after page of procedures. RLC AT-201-SR: Step attenuator, 0 to 120 dB in 10 dB steps. Step attenuators are like BNC cables - you can never have enough and they always seem to wear out eventually. I can't find anything specific to this model in the literature, although RLC seems to still be in business. This one acts as though it is 50 ohms and is relatively flat from 0 to 1.5 GHz (as measured on the Rigol DSA-815 spectrum analyzer). The measured accuracy is < 1 dB, and the switching doesn't exhibit any noise from undue wear. It was built in the 1970s and was intended to calibrate 3, 4 and 4-1/2 digit DMMs of that era. The best case accuracy is about 0.006% for DCV, 0.05% for ACV and 0.05% for ohms. It also has a vernier control with digital readout of percentage error. Certainly it is not as accurate as the Fluke 343A (DCV) or the Fluke 5200A (ACV) or the Biddle resistance box (ohms), but it is nice to have everything in one box. And it is the only accurate current source I have (other than a precision voltage and resistor). However, the cure was short lived, since the unit was unresponsive to any input voltage. Lower unit has the 1 GHz prescaler and the 5V digital power supply. Option 001 is a good deal cost. I brought it in, I noticed that that unit (it cost (noisy rails)) was not found. However, he claimed that the three voltage pots were noisy and/or hard to turn. To make a long story short, four tantalums had shorted and blew out two of the resistors to the rails. FM recording DC-3 kHz. I bought this piece shortly after acquiring a Racal 14DS recorder. I guess I was in my "tape recorder phase." My initial thought was to use recorders to instrument test equipment, particularly the Guildline 9577 that was drifting when it warmed up. Never did that however. (OM) Grade: BNo manual for this one. The pinch roller had turned to glop so I had it re-rubberized (Terry's rerubber). But he used the wrong dimensions, so when I received the rebuilt roller, it wasn't hitting the capstan correctly. Fortunately, I figured out how to adjust the mechanics.Postscript: Came across a recent post from a manual vendor in the Yahoo HP newsgroups in which he was offering to give away the hard-copy manual for the cost of postage. Like all W&G equipment, the PMG-13 is superbly engineered and the level of workmanship is something to behold. The thing fired up but was missing some segments of the last four 14-character alphanumeric LEDs. Moreover, the front panel keys were in very poor shape with some cracked, some dysfunctional, some loose, etc. The left display provides reactance measurements (L and C), while the right display provides loss measurements (D, Q, S, ohms). I'm easily beating the 0.005% DC spec at this particular moment (subject to change). It basically samples 4 channels at up to 100 kHz with a total storage capacity of 4096 10-bit samples. Lucky for me that the op-amp, an OPA111BM, was good because they sell now for about fifty bucks. At least it has an auto-ranging function, but it can take a couple of seconds to arrive at the final range. Mercury 501: A substitution box for the 1960's TV repairman. HP 3456A: 6-1/2 digit voltmeter, DCV, ACV, ohms. Pretty accurate, but running it in the "manual" mode using the level control is wishful thinking. I would put the performance of this unit midway between the HP 8901A and the Marconi TF2304. Nothing special. ($CD) Grade: B+ Someone decided that the unit might like to measure the modulation of a few hundred watt signal. Front end - poof! The input board was actually burnt to a crisp. I removed all the parts, cleaned the board up, added jumpers where the traces had vaporized, and installed new parts. I also had to replace the level potentiometer and repair a short on the GPIB board.Postscript: See the "Remote" light on the front panel in the picture? I thought I had completely fixed the GPIB board, but the thing sporadically will come up this way (with the front panel locked out). I tested a lot of the chips on the GPIB board, but could find nothing wrong. Then it occurred to me to check the 5V rail - it was 4.5V. So no wonder the GPIB circuitry was flaky. I didn't think at first to check the voltages because the rest of the machine had the correct 5V. But after consulting the schematic, turns out that Boonton ran a dedicated isolated supply for the GPIB board which consists of a bridge rectifier and cap providing 10V unregulated and a 5V regulator on the GPIB board itself. Turns out that the cap was bad and was only supplying about 8V to the regulator through a 5 ohm resistor. The current drawn by the GPIB board then reduced the input voltage to the regulator to about 6V - not enough. A new cap cured all ills. I also replaced the 5V bulb and the amplitude vernier pot (taken from a spare HP 8012B parts unit) that was very noisy and I removed two plastic circular 1-10 scales that were glued to the front panel. The op-amps are supplied by two transistor current sources from +/-35V feeding two zeners. There should have been a sticker on the schematic that said "This schematic was drawn 100% wrong." If you want to see how NOT to draw a schematic, check it out. Mine has Option 10 which adds several math functions to the standard list. Has some cute math functions, but otherwise is not as accurate as the HP 3455/6 series, despite Solartron's claim. I'm not at all impressed with this DMM. I guess that's why Solartron is not exactly a household name in test equipment anymore. (OM) Grade: BThis meter had a bad TR704 and a bad power switch. Those were easy. The hard part was bending back the front panel that looked like someone had hit it with a sledge hammer.Postscript: I hadn't used this unit for a few years and when I finally did get around to turning it back on, I noticed that the 100K ohm and greater ranges were quite noisy. I spent a few fruitless hours trying to convince myself that the ohms current source was at fault, but voltage measurements across several of the resistors in the circuit were perfectly stable. However, measuring the voltage on the output jacks showed that they were varying. And that led me on another wild goose chase looking for noisy power rails. At one point, I thought I had cured the problem with a 0.1 uF capacitor on the 36V line. But then, without thinking, I lifted one end of the capacitor and tried it on the other voltage rails, namely 5V. My capacitor still had a 36V charge and discharging it on the 5V line made for very unhappy TTL chips. All the unit would subsequently do is continually reset. I lifted the reset pin of the MC6800 uP but it was to no avail - after a manual reset of the uP, the unit hung with a blank display. Figuring I must of blown out dozens of chips, it then occurred to me that the 5V digital P/S is isolated from the 5V analog P/S, and so I only could have blown out about 10 chips, not 50. Randomly probing around with a scope looking for non-TTL levels proved nothing. But then my hand felt a little warm as I passed over a couple of chips. Got out the Fluke IR thermometer and sure enough, two 74LS74s were about 135 degrees. Replaced those and the thing sprang back to life. Now for the noisy resistance measurements? I wasn't making a good connection across the sense and guard jacks. The thing is extremely sensitive, more than most of my DMMs, but it seems perfectly fine now.Postscript^2: I spoke too soon, because this thing is still fluctuating in the 100K and greater ohms ranges. For instance, a 100K resistor will read anywhere from 99,970 and 100,000, with the fluctuation going steadily up and down over a period of a few seconds. Moreover, it would only be like this for certain orientations of my test leads. A bit of experimentation proved that it was a result of 60 Hz interference, and the fact that the fluctuating readings were periodic led me to believe that the 60 Hz synchronization of the A/D was not being done properly. A quick check of the various jumpers in the unit showed that it had been set to run off 50 Hz! So I correctly jumpered it for 60 Hz - and - it still fluctuated! The primary of the AC transformer is tapped and the 60 Hz line frequency goes through a PLL to sync the overall system clock (about 15 MHz). The scope showed that the PLL was not locking and a few hours of pointless replacement of ICs boiled it down to the real problem. The VCO in the PLL is controlled by two MV2110 varactors. I pulled them out and stuck two MV2109s in (about 3 pF lower than the MV2110s), since that is all I had. The PLL locked right up, the fluctuations are gone, and life is back to normal. I've hardly ever seen anything other than those two cases. A high ESR on an otherwise OK electrolytic is a nice theoretical concept, but I've only seen it once or twice. Sometimes you get lucky and the cap is leaking goo or has left white powder residue. Your biggest problem is that the modern replacement electrolytics are half the size of the old ones. But that's a happy problem to have.Rifa Capacitor Bonus Rant: Let's talk about AC line suppression capacitors. Most of my equipment falls into one of the following three categories: 1) no AC filtering (the AC socket goes through a fuse, on/off switch to the primary of the transformer); 2) sealed line filter (usually a small box containing the fuse and the filters with no serviceable parts); 3) discrete suppression capacitors and/or inductors. It is the third case that is the problem, especially when these components are ahead of the on/off switch and hence are active whenever the piece is plugged in (and even worse - sometimes the capacitors are ahead of the fuse!). Among these discrete parts, the gold-colored Rifa capacitors are notorious for blowing up. They should be replaced on sight regardless of apparent condition. I've had a few blow up and the stench is terrible, not to mention the goo that gets sprayed all around. This is why I have a master kill switch in my lab that cuts power to all of my outlets and why I throw it at the end of every day. Although none of my exploding Rifa caps have started a fire, why take a chance. HP was fond of using Rifa caps in the 1980s and I am currently going through my pieces looking for them. For instance, my HP 8080A has six of them!!! The Rifa "problem" is even worse in Europe where the 240 VAC is close to the rated voltage of the cap, unlike here in the USA where it is only half of that. Replacing these caps can be very difficult, especially in the most dangerous case where they are mounted directly on the backside of the AC power receptacle. Many manufacturers rivet the receptacle to the back panel and then surround it with so much stuff, you have pull the entire back panel off just to get to it. This often leads to an hour or so of nervous disassembly and reassembly. At the time of this writing, I have replaced 64 of the Rifas. It is usually the X-capacitors that go bad and are in the worst condition if they haven't already blown up. I don't think I've ever had a Y-capacitor blow up.Always look for signs of previous repairs. There's a good chance that the previous repairman screwed it up. Even if he didn't screw it up, many times it will lead you to the area of the circuit that may still have problems.Pray that there aren't any backup batteries in the piece. If there are, they will have leaked. Pray that they didn't leak all over the board. Pray that the leakage didn't cause a fire and destroy half of the board before you got the piece (that has happened to me). Because many of my pieces sit idle for long periods of time, I often replace rechargeable NiCd RAM backup batteries with a pair of AA or AAA batteries with a series Schottky diode in an enclosed plastic holder. That way, when they eventually leak, the goo is contained. Rumor has it that Duracell batteries are the worst leakers. I concur.A scope can be used to look for faulty TTL/CMOS devices. You can often just probe around looking for a logic level that is floating between high and low. But a logic analyzer is the way to go. You don't need anything flashy. A simple 8 channel timing mode logic analyzer can spot bad chips in a flash.Always attempt a calibration/adjustment when you think you have repaired a piece. A failure to properly calibrate is a pretty good warning sign that something is still wrong. The K-H 5400B is a standard issue analog function generator with absolutely no distinguishing characteristics. I also have a no-name Taiwanese unit that is much better (see PDI LPP-610B). (PDF) Grade: B HP 546A: Your basic logic pulser. It had all four feet, the tilt-up bail and the two pull-out instruction sheets. HP 334A (special telco version): Automatic distortion meter, fundamental to 150 kHz. This is a curious piece that I can find no information on. Presumably it was built for the telco industry. They removed all the manual controls from the stock HP 334A and made everything pushbuttons. The real reason to do this is so they could parallel a port on the back panel for computer control. Why they reduced the frequency response from 600 kHz to 150 kHz is beyond me. This unit is packed to the brim with boards, much more than the stock 334A. (OM) Grade: B+This piece continues to be a maintenance nightmare. I have already fixed some loose push-on connectors and replaced the faulty bulbs in the bridge circuit. But one day, the distortion function didn't work at all. I traced it to two reed relays that were showing near infinite when closed. One of them was cured by banging on it. The other one was cured by hooking up a 1 pulse per second square wave and letting the relay cycle for 30 minutes. But there about 75 reed relays in this thing and I'm betting I'm not done yet. Because of the 1 MHz measurement frequency, the 4280A will only go up to about 1900 pF, so you ain't gonna be testing power supply electrolytics with this puppy. Di-Bar MTS-300L: Dynamic electronic load. I can find absolutely no information about Di-Bar or this particular model. But, judging from the 50V electrolytic capacitor across the output, I would venture a guess that this piece is limited to 50 volts. And because one of the front panel buttons is marked 0-300A, I would also speculate that it will handle 300 amps (actually, probably a bit less given the 0.5 ohm emitter ballast resistors). The total power limit is unknown, but given the fact that this beast has 42 2N5886 power transistors, I would estimate that it is in the 1500 watt range. Architecturally, this piece is very similar to the Power-Mate load (see that entry below). The buttonology is similar in that it will do constant current or constant resistance, and also has both static and dynamic (pulse) loading. I like this unit better than the Power-Mate because of the dual metering and 10-turn pots, and it seems to do just what a load should. The build quality is a bit bizarre, however. The load block looks very well engineered. The two digital displays were clearly bought from a third party. The control board uses a puzzling mix of DIP ICs, metal can op-amps and discrete transistors and is filled with bodges. (---) Grade: B+I picked this unit up (condition unknown) for $50. I figured I needed a challenge given that no manual was available. But the faults were readily apparent. First up, there was a dead short across the input terminals. Normally this would mean that one of the power transistors was shorted. But in this case, the transistors were fine and the fault was a shorted SCR. Second, the front panel pushbuttons were pushed back into the case and this was because the main circuit board had sheared off its plastic mounting standoffs and was floating inside the chassis. Finally, the big relay, used to short the input, had cracked in half and was sitting on the bottom of the unit. So this piece, at some time during its storied life, really took a massive shock. All three of these faults were easily remedied, although epoxying the relay housing back together was a bit dicey.Postscript: One day, this unit acted up whereby the current meter was fine, but the voltage meter was reading about 2x high. Both these meters are old Digitec panel meters and the schematic is nowhere to be found. So I pulled them both out, took the covers off, and hooked them up in parallel to the incoming voltage line. By comparing voltages on the various IC pins, there was a discrepancy on the AD650 voltage-to-frequency converter. I swapped the two ICs and the fault followed suitably. Mouser wanted $30 for the AD650, but I took a chance and found five for $20 on eBay. Normally I don't like to buy ICs on eBay; the ones from China are almost always counterfeit and even the ones from a USA seller are risky because he might have obtained them from China! But the label on the ICs looked fine and it turned out the ICs were fine too. Dytronics RT-1: AC Ratio Transformer. The RT-1 is the AC equivalent of a DC divider (for example, my ESI RV622A), Gertsch was the number one manufacturer of these things years ago (before they got bought, and bought again, and bought again). Unfortunately, I can find absolutely nothing on the Dytronics versions. But if it is anything like most of the Gertsch models, it operates best between 50 and 10,000 Hz (400 Hz is the optimum), and will take AC input voltages up to 0.35*freq(Hz) or 350V, whichever is smaller. My unit has seven decades which is pretty amazing if you think about it. In fact, it is so amazing that I have no AC voltmeter that really can see all of the digits at once. I don't know the accuracy and linearity specs, but my guess is that they are in the 10 ppm range (if not slightly better). A particularly nice feature of this unit, unlike the DC dividers, is that you can set the output slightly higher than the input (about x1.1). You can, of course, also run it in reverse at your own risk (my unit is unfused on both sides). Quality 1960s-era construction using double and triple redundant switches and a set of transformers in about 1/2-gallon of potting compound. Tegam still makes a very similar unit (DT72B) for $15,000, so the $45 I spent for mine was a good buy! (---) Grade: A E : Electronic Development Corp, EH Research, EIP, E-Jin, ESI, ETS, Exact, EZ Digital Electronic Development Corp 501: DC calibrator a la the Fluke 343A. A quick check of the power supply showed excessive 120 Hz ripple on all rails. The interesting thing about this piece is that the critical elements of the regulator are encased in a thermostatically controlled oven. The 5370A is pretty accurate by itself, so I don't often use the 5363B. (PDF) Grade: BDiscovered a flaw in the thumbwheel switches many months after I first acquired this. Simple open diode. The Krohn-Hite boards have 1/8-inch holes that are filled with solder; connecting wires are simply jammed somewhere in the hole. HP 8011A: Basic no-frills 20 MHz pulse generator. And this is from a test equipment dealer! Upon receipt, the unit's output was all screwed up - wrong voltages, some frequencies didn't work, etc. It was a simple matter to check the parts along the signal path until the end of the carnage had been reached. In this case, it was only the terminating resistors, two of the four diodes in the mixer and the FET buffer. At least it wasn't as bad as the Boonton 82AD. Spans 6 decades with multipliers x100 pF, x1000 pF, ..., x1 uF, x10 uF. Of course, once you've done this, the reference card can only be used with another IC if the output pins are the same. HP 4204A: "Digital" Oscillator from 10 Hz to 999.9 kHz, 10 volts into 600 ohms, 80 dB amplitude range. Introduced in 1967, HP called this a digital oscillator even though it is entirely an analog unit. The frequencies are selected by four 0-9 digit knobs which can select 39,600 resistor combinations in the feedback loop of a Wien oscillator. Frequency accuracy is +/-0.2% and repeatability is +/-0.01%. Mine has a distortion at 1 kHz of about 0.2%. Designed and built by HP-Japan (Yokogawa), the Japanese must have been trying to impress mother-HP because the build quality is superb. The frequency selection switches look sort of like the turret of a revolver pistol. As the knob is turned, the proper resistor rotates into position and makes contact with leaf springs on the bottom of the switch. (PDF) Grade: B+The unit produced no output on arrival because the switch assembly needed cleaning. But the cleaning was trivial because I only needed to dab a little alcohol on the leads of the resistors that make the contact with the springs. The switch, properly cleaned, should last forever. The NE-2 bulb was burned out, so I replaced it with an LED dropped down from the 36V supply. And while I was poking around, I inadvertently shorted a couple of pins on the P/S edge connector and managed to put 60V forward bias across a Zener (with no real current limiting): poof. HP 4260A: Universal bridge for those who couldn't afford an HP 4262A. Sort of a pain to use like all bridges. This was built by HP-Japan and is very nicely done, with electrolytic capacitors cradled in their own little plastic buttresses. (PDF) Grade: B HP 4261A: LCR meter. A junior version of the HP 4262A, it has 120 Hz and 1 kHz measuring frequencies. The right-hand display only does dissipation, so you need to have a calculator handy if you want to derive the parameters that the HP 4262A or HP 4274A can show you. The basic accuracy is about 0.2%. Straightforward to use. (PDF) Grade: A-The eBay photo showed random garbled characters on both displays. And that's the norm for a fraction of a second when the unit first powers up. But my unit was totally stuck and not stepping through the algorithmic state machine. The state machine is ROM-based and a pal at work had a similar problem where the latch/counter holding the program address and feeding the ROM was faulty. So that's the first place I looked. The relevant chips were a pair of 74C163s and both were in sockets. Funny how the only chips (other than the ROMs) in the 4261A that were socketed were these two. And even funnier is that the sockets are not shown in the manual (although I don't have all the change sheets). What isn't at all funny is that the chips were marked National Semiconductor. Yet another example of the absolutely atrocious quality of National Semi parts (see my rant on the HP 3581C). The sockets definitely were original, not a later rework. Anyway, two new 74C163s solved the problem and the unit works fine. The only other problem was a cracked banana jack on the front panel. I was going to leave it alone since it was being held in place by the shorting bars, but there was a ground ring with protection diodes attached that wasn't making good contact with the chassis as a result of the breakage, so I ended up replacing the connector. Also replaced the Rifa suppression cap with a non-Rifa brand. Just insert the component and read the numbers. It's certainly much easier to use than the HP 4260A, the GR 1685B or just about anything else. Systron Donner 110: Basic pulse generator. I bought this very early in my repair "career" and if I had 10 or a slightly different model, I'm not even sure if I had 110 or a used it 110 on this piece. The construction was terrible and the boards were about 95% of the boards were replaced 1A. I donated this piece to the lab where I used to work. Not that they needed an old pulse generator, but it soothed my conscience when somehow a $20 gizmo in their lab that I needed for a repair mysteriously found its way to my lab at home. Don't have a clue how that happened! Tektronix 115: General purpose 50 MHz pulse generator. Duplicates plenty of others that I have. Hope someone could use it.Had a bad transistor. I didn't have the right one, so I just kept popping in junkbox transistors until the thing worked at 50 MHz. Tektronix 851: See the Systron Donner Versatester. This part must have been designed by the same person. My decision was to replace the 28 chips on the digital board as I was pretty sure the analog board and display board were functioning. HP 3467A: Four-channel logging DMM. This somewhat unique piece starts out with a basic 4-1/2 digit DMM (circuit design similar to the HP 3466A above) capable of DCV, ACV, ohms, diode and temperature (with an external thermistor). Then it adds a four-channel reed relay based scanner that allows the unit to automatically step through any or all of the four selected inputs. Moreover, the fourth channel can be set as a "reference," and the unit can be configured to display various mathematical relationships on the first three channels (e.g., delta). Normally, all the channels are set to make the same type of measurement. However, it is possible to configure two channels to measure temperature and two channels to measure another DMM function at the same time. Finally, HP added a printer that can also be configured to automatically print at desired time intervals or immediately as the user desires. The chief utility of the 3467A seems to me to be the multi-channel capability. For instance, I once needed to monitor three oven voltages in the Fluke 5440B calibrator plus a certain op-amp voltage. I certainly have four voltmeters and that is what I used. But with the 3467A, I could have done it all. Rather than looking at four separate voltmeters, I could have simply watched the 3467A step through the voltages at about one reading per second. The construction of this piece is kind of strange, having a lot of plastic where HP would normally have used metal or the like. But the real reason I bought this piece is that it gave me an "HP straight flush." That's right - now I have the HP 3465, 3466, 3467, 3468 and 3469. Beat that! (PDF) Grade: B+Advertised by the seller as working, and it basically was. The reason I'd give it a lower grade is that the construction is kind of strange, having a lot of plastic. The printer isn't working and it had to fix several issues in the display cabling and there was a problem with the cable connecting the plug board to the mother board. There was a sticking button on the front panel and this was fixed by filing the edges of the hole (thanks HP for making the front panel plastic). The alignment went smoothly and all seemed well, so I turned my attention to the printer. Right before I was going out to buy some thermal printer rolls, the printer mechanism self destructed and ground one of the plastic gears that moves the print head into dust. End of printer. At least I don't have to buy thermal paper. I suppose it is possible to machine another gear. All I would need is a multi-thousand dollar computer controlled lathe. Not that I really have much use for the print capability, but after all, the 3467A is supposed to be a logging DMM. Mine isn't.Postscript: Hold on there! You know I couldn't live with a malfunctioning printer. The "correct" replacement gear was identified by a fellow on eevBlog and suitably procured. I put the word "correct" in quotes, because although the replacement gear had the correct number of teeth (30) and the right diameter, the shaft hole was 2 mm instead of 2.5 mm and the height was a lot larger than the required 4.5 mm. A pal at work had the right machinery to mill the gear to the proper dimensions, and all was good. Well, not quite, as the printer only printed a portion of each character. I disassembled the printer and stared at the guts for about 30 minutes before I figured out what to do. Loosened a few screws, moved the head until it clicked into place, and tightened the screws. Perfecto.Postscript^2: One day the print button didn't work. Nor for that matter did half of the front panel buttons. This was easily traced to the MM74C922N keyboard encoder chip which was suitably replaced. And who made the broken IC? Well, National Semiconductor of course! Need I say more?Postscript^3: Preemptively replaced the two Rifa 0.001uF suppression capacitors from Line-Gnd and Neutral--Gnd. Funny, those are supposed to be Y-class caps, but they were marked X-class. The Panasonic replacements were class X/Y. My experience with Racal, in particular, is a bit inconsistent - some of their stuff is excellent and some is rather poor. Keithley made some very good specialty equipment, such as their picoammeters, as well as a slew of DMMs of varying cost. Genrad and ESI make some fine component testers and resistance standards if you can find them cheap. Wandell-Goltermann makes exquisite gear, but they are aimed at the telco industry and do not have universal appeal (their service manuals are also tough to obtain). EIP (now Phase Matrix) makes very nice under-appreciated microwave counters. The Datron line of DMMs are also very nice, but used to be quite rare and expensive. In addition to Fluke DMMs, Fluke has and continues to dominate the calibrator market (not that mere mortals can usually afford such things, or get them calibrated if you are so lucky as to stumble upon one). And Gigatronics makes some nice microwave signal generators. Brands that I would definitely stay away from, based on my limited experience, include Systron Donner, Krohn Hite and Ballantine. As this web page illustrates, there are plenty of offerings from companies not very well known. This, of course, is a hit-or-miss proposition - the biggest stumbling block is usually the lack of service information. On the other hand, these off-brands usually sell for peanuts, so if you are unsuccessful in your repairs, it's not the end of the world. Besides, one can usually strip a piece for parts and build up your junkbox.If you have read this web page in its entirety, thanks and congratulations - you have an interest in vintage test equipment that rivals my own!Perhaps some of the repair notes might even help you fix your stuff. Remember, use caution when working on equipment. I specifically shy away from vintage tube-type test equipment, because the voltages encountered are often quite dangerous. Similarly, working on or near CRTs make me cringe. But, as long as you are methodical and know what you and your hands are doing, it really isn't hard fixing things. Remember, I have absolutely ZERO formal training in electronics - all my skills (if any) were acquired through experience. So there you have it. Dave Hubbard, WA1MIK (who passed away in June, 2021), for technical editing and his recitation of the immortal words... Fluke 6160B: Frequency synthesizer generating 1-160 MHz in two bands: 1-12 MHz with 0.1 Hz resolution and 10-160 MHz with 1 Hz resolution. The amplitude range is only -3 to +13 dBm, meaning you need an external attenuator if you are going to use this piece for any serious RF work. At the time, the 6160B was one of the lowest phase noise VHF signal generators and I have no reason to doubt this given the circuit complexity. At least my unit has the ovenized oscillator option. Read my "Old-Time Fluke Bonus Rant" right below the description of the Fluke 887A. The 6160B is a prime example of circuitry that is designed right on the hairy edge. Everything is based on a bunch of hand-selected, matched varactors with dozens of variable inductors in the numerous oscillator circuits. It probably took Fluke a lot of manufacturing time to dial in every unit. And I'm going to give this piece a fairly low grade to the horrendous serviceability. (PDF) Grade: B-This piece took quite a bit of effort. When received, the unit only output a single frequency regardless of the dial settings. A bit of signal tracing led to the discovery that the previous owner had swapped the cables from the master oscillator to the rest of the circuit with the cable outputting the reference frequency on the back panel. Thus the digital circuitry was not being clocked and the frequency dials were not being read. After that was corrected, the unit mostly worked, but there were occasional frequencies where it was not locked properly. For instance, you could dial in 1.00 MHz, it would be correct, dial in 1.01 MHz and it would be wrong, switch rapidly to 1.02 MHz and then back to 1.01 MHz and it would be correct. So this led me to try and align the piece since it looked like the PLLs were operating right on the edge of their capture range.The 6160B consists of about a dozen modules, each in a sealed aluminum box. So you have to remove a module, take the box apart to get to the board inside, and then figure out how to connect the board back to the unit. Not too bad if you have a bunch of SMB cables and jumper wires. But most often, you can't get everything to reach and the board ends up being upside down. Anyway, I thought I isolated the module that was suspect and while turning the slug in a multi-tap inductor, the entire slug decomposed into dust. But like most other units, all it really needed was a thorough cleaning, lubrication and calibration. I bought this to test the Racal 1405 and HP 3964A instrumentation recorders. It works very nicely and proved that the capstan re-rubberizing was done very well on the recorders. (---) Grade: B+ M : Marconi, Mercury Marconi 893C: Audio frequency power meter, 20 Hz to 35 kHz. This totally passive meter (no AC power required) is useful not only for measuring audio amplifier power output, but also for determining source impedance. There are 10 power ranges and 48 internal impedance loads. To determine source impedance, simply dial in the impedance that gives the maximum power reading on the meter. The circuit is basically one large multi-tap transformer followed by a selection of over 140 resistors (0.25% tolerance). Some diodes and caps round out the meter circuitry. While Marconi is long gone, an almost identical unit is still being sold by IET Labs (GenRad 1840A) for $4,145. The Marconi 893C that I purchased, in absolutely mint condition inside and out, was a bit cheaper - $20. (PDF) Grade: A+ Marconi 2018: 520 MHz synthesized RF signal generator. This is basically a clone of HP 8656/7 series with pretty much the same features and specifications. There was a 2019 version that doubles the frequency to 1024 MHz. Later on, they made a 2018A and 2019A that have a few more mostly useless buttons on the front panel. The general claim on these units is that their phase noise is superior to the HP versions. But my spectrum analyzer says that ain't so at offsets < 1 kHz. Very nicely made, similar to Wandel & Goltermann's construction with all boards in separate modules and easily accessible without extender cards. Oh, then there is that pesky attenuator (see the repair comments). Marconi had the good sense to include (as standard) an ovenized oscillator. The piece uses an EAROM instead of a battery backup meaning you have to physically store the configuration if you want it to start that way the next time it is powered up. The internal audio oscillator for the AM/FM modulation, which can be selected from 5 internal frequencies, is superb: -75 dBm distortion at 1 kHz. Unlike my HP 8657A, the 2018 only draws 54 watts and has no fan. (PDF) Grade: A-Advertised as "LCDs dark, button LEDs lit, and has a burnt capacitor smell." Other than blown up tantalums, I didn't know that capacitors had a smell. But that description was mostly correct upon receipt, although I didn't smell anything because I was afraid to power it up. So I removed the covers and looked for burned parts - none to be found. I then ohm-ed out the electrolytics on the P/S board and found the main cap on the -15V line shorted. I replaced the cap and flicked the power switch. The front panel LCDs lit with the error code "L" which means a checksum error in the EAROM (which also stores cal constants). But the manual says that the unit will still work fairly well even with that error. My problem was that there was absolutely no RF output. The problem was quickly isolated to the mechanical 120 dB step attenuator. The attenuator consists of five sections, 10, 20, 30, 30, and 30 dB, each with two microswitches to place the section in or out. This is all in a sealed metal box with ten little plastic posts coming out from the ten switches. Sitting above each pair of switches is a solenoid with some metal ears that press down on the posts. I could see that some of the solenoids were not plunging the posts down far enough and some were not releasing the posts enough when non-energized. The solenoids have adjustment screws and by also bending the ears, I was ultimately able to align everything. Except that the attenuator still did not work correctly. The manual warns the user not to try to dissect the attenuator, but I took that as an insult and reached for the screwdriver. 2-1/2 hours later I had successfully disassembled the attenuator, soaked all the switches in alcohol and reassembled it. Everything works fine, but I bet the attenuator ends up being quite a maintenance headache. My other gripe is that I can see lots of adjustments on the various boards. Other than seeing them on the schematics, the service manual says nothing about them. The calibration is done via software and retained in the EAROM. So perhaps it would be possible to tweak the oscillator's phase noise a little. I'll never know. As far as the EAROM error, the EAROM was actually fine given that I could see all of the cal constants the previous owner had stored. I could also see a -2 dB stored level adjustment which explained why the spectrum analyzer was 2 dB low. I removed the offset and followed the procedure to compute and store a new checksum. Problem solved.Postscript: Well, my comment that the attenuators would ultimately be a maintenance headache was prophetic. Despite several cleanings and adjustments, the thing simply wouldn't output the correct levels. I'm afraid - go ahead, sing along - "it's dead, Jim." The attenuator is really a stupid design because it uses switches inside the sealed unit and external solenoids to mechanically actuate the switches. Why not simply put relays inside like everybody else? [Note: I'm being a little harsh here, because I more recently got an HP 3335A which uses a somewhat similar design and the one I have is about the most accurate attenuator I've ever seen]. Now there are a lot of step attenuators on eBay (I'm obviously not going to pay retail from a real vendor) and I was extremely fortunate to find (for $35) EXACTLY what I needed, a 120 dB attenuator with 10, 20, 30, 30, and 30 dB sections. Of course, it required 12 VDC and TTL-level control inputs, but that was easy to supply by modifying the Marconi's control board with some pull-up resistors and throwing in a 7812 regulator off of the existing 20 VDC. The cabling had to be altered a bit as the old attenuator used an SMC plug on the input and the new one used an SMA jack. The output cable had the proper SMA connector, but the whole connector came off in my hand as I was positioning it. Thus, a new SMA to bulkhead N assembly was used. All in all, works very well. But not quite as good as the attenuator in my HP 8657A which shows about a 0.2 dB variation on the spectrum analyzer as I step from 0 to -60 dBm in 10 dB increments. The one in the Marconi has more like a 0.5 dB variation. Makes sense as the manufacturer spec (JFW) is about 1 dB for similar models (the one I bought on eBay was originally a special order from JFW which makes it even more remarkable that I found it)Postscript^2: Originally, I simply bypassed the original attenuator assembly and used the replacement attenuator. Upon further reflection, it occurred to me that the original attenuator had a reverse power protection relay and associated circuitry inside which was probably worth keeping. So I opened up the attenuator and simply ran a wire from the input jack to the protection relay, bypassing the five attenuator sections (I learned the hard way that it wasn't quite that simple, because the attenuator sections were still in-line in parallel with the wire; I therefore had to physically cut the traces to the first and last section). Then I took the output of my replacement attenuator and ran it into the old attenuator. So I essentially have the old assembly with just the five attenuator sections replaced by the new one. Voila. Postscript^3: One of the digits on the LCD frequency display was acting up (stuck segments), so the digit's CD4056 driver chip was replaced. But, alas, when I received the unit, I couldn't find anything malfunctioning. Tektronix DM501A: 4-1/2 digit digital multimeter for a TM500x chassis. The DM501A Multimeter Module measures DC voltage from 200 mV to 1000 V in 5 ranges. After discovering the missing fuse and bypassing the malfunctioning power switch, the 3466A powered up but was completely hosed - stuck on ohms, erratic measurements, etc. I guess that this thing sat for 10 years unused and the switch contacts completely tarnished. Anyway, everything behaved properly except the time base was off by a factor of 10 for the 1 us through 50 us settings. The timing capacitors tested OK, so that, unfortunately, led me to the main timing cam switch. I had cleaned dozens of these things in my Tek 7000-series plug-ins, so I knew the drill. Except when I removed the cover, it looked like someone had poured varnish on the circuit board beneath the cams - several were fused open or fused shut. It is amazing that any of the time bases were working. So with the help of some acetone and some dental picks, I managed to get the cam switch fully functional. For how long, I can't tell you. Then I ran through the calibration procedure and everything aligned nicely. (PDF) Grade: B+This piece was a real mess when I received it. After I fixed the unit (see below), the low end was spot-on, but the lowest range was about 35% too low. I did my best to clean it up, fix the broken knobs, fix the broken input jacks, etc. Boonton 82AD: A weak version of the HP 8901A modulation analyzer. HP 8683B: Microwave signal generator, 2.3 to 6.5 GHz. HP made several variants of these generators. There was the 8683 series in an A-variant which was designed for communications testing and the B-variant which had extensive pulse modulation capability designed for radar testing. They also made a similar 8684 model with higher frequencies and also a slightly more capable D-variant. These generators were built in the mid 1980s and served as a bridge between the earlier klystron-based microwave signal generators and the microwave synthesizers that came later. The 8683B uses a cavity-based oscillator like the HP 8640B and thus have very good non-harmonic spurious outputs. The specs are OK, but of course look horrendous compared to your ordinary 0-1 GHz RF synthesizer; I simply don't have enough microwave experience to adequately judge them. For instance, the power goes from +9 to -130 dBm with an accuracy of +/-3 dB. The phase noise spec is AC voltmeter A/D --> oscillator control --> oscillator --> etc. Something wasn't stable and no matter where I measured, I saw the instability. Not surprising given that I am measuring within a loop. So I "broke" the loop apart and measuring things with various external stimuli. The instability seemed to be coming from the AC voltmeter A/D board. This circuit is the usual charge/discharge an integrating capacitor. I've seen those caps go bad and create similar havoc, even though the caps test OK on a component analyzer. So I replaced the cap. While doing that, I temporarily removed and reinstalled a plug-in daughterboard. Bottom line is that the 5200A now works perfectly. Whether it was the cap or simply dirty contacts to the daughterboard, who knows. Incidentally, while I was testing the fix, I noticed that the 5200A was stable across one hour (at 1 VAC, 1 kHz) with a standard deviation of about 1 uV. The 1 ppm stability rivals that of the three-oven Fluke 5440B DC calibrator and is almost too good to be true, but it seems so.Postscript^3: Another day, another shorted tantalum. This one was on the optional GPIB board and dragged the 5V line to zero. I also replaced the tantalum on the GPIB regulator board for the 5V supply since that one was obviously the exact same vintage and is the one that would be next to go out. Similarly, you can transfer a capacitor with a pulse and make a voltage vs. The frequency accuracy is +/-1%, but the repeatability is at least an order of magnitude better. Once a signal is caught, a trace can be routed to, for instance, a scope for playback. The calculations and display are done by a Fluke custom IC. If you know that means, you've really got too much time on your hands. I don't know if Fluke eventually abandoned this design, but I would put the performance on par with the HP 3455A. (---) Grade: C+This was advertised by the seller as working, but noisy on the lowest range. Keithley 199: Basic 5-1/2 digit DMM. Pretty vanilla, but does DCV, ACV, DCI, ACI and ohms. Best case 1 year DCV accuracy is about 0.007%. Extremely boring with only moderate build quality. (PDF) Grade: B+Advertised by the seller as working, he was obviously lying. Although it seemed OK on current and AC voltage, the DC was way off. On the 300 mV range, a shorted input produced 275mV and the thing would over-range with so much as 1 mV of supplied voltage. The 3V and 30V ranges were inaccurate and would not read any higher than about 17V. And the 300V range read 000.000 and was unresponsive to any inputs. The ohms was equally as screwed up with every range reading a constant 100 mV at the test leads. The current (both AC and DC) was fine. This all pointed to a problem with the input ranging, not the A/D. The entire machine is controlled by four daisy-chained CD4094 8-bit shift/store registers that control each relay (both reed and FET) and FET switches. I checked that the AC and I worked, but DC and ohms didn't, pointed to a problem with the input ranging, not the A/D. And the 300V range read 000.000, and relays, and shows which switches should be open or closed. Starting out with the faulty 300 mV range, I immediately found one switch that was being commanded to close, but not listed in the service manual's table as being closed for that range. Looking at the schematic, it didn't match which switches were closed, as it turned out the entire surrounding circuit was isolated from the rest of the circuitry through a properly open FET. But that led me on a wild-goose chase since I suspected one or more of the 4094's was bad. I switched two of the four and it had absolutely no effect. So that left me scratching my head until I got the bright idea to check the input impedance of the unit. On all the DCV ranges, the input impedance was 1.37K ohms - clearly wrong! It didn't take me long to find a shorted reed relay that was keeping the ohms circuitry on-line along with the DC circuitry. I pulled the relay and things started to improve on the DCV side. But, however, the 300V range was still reading 000.000 for all input voltages and the 300mV range was stuck reading 275 mV with a shorted input. Finally it dawned on me that the previous idiot owner may have tried to calibrate this thing without realizing the ohms relay was shorted. The calibration is done via stored software constants, so I re-calibrated it and now the DCV worked flawlessly on all ranges. I found a replacement reed relay in my parts bin and installed that, but the ohms was still screwed up. It turns out a protection transistor hung off of the ohms line that measured 70 ohms C-E. I clipped that out and now ohms works fine (after I did the requisite calibration). My guess is that the idiot had the 199 in ohms mode and then put several hundred volts across it. Living homeless on the street kind of poor. Average noise level about -135 dBm//Hz. A selection of measurements and menus that would keep anyone occupied for hours. If you want to do audio analysis, this is the piece. Distortion, channel correlation, time, frequency, you name it - the 3562A does it. I only wish it went higher than 100 kHz. The CRT brightness control needs to be turned up to about 75%. I hope this doesn't mean the tube is on its way out. (PDF) Grade: APostscript: Having later acquired the HP 8980A Vector Analyzer, I realized that the HP 3562A also has the HP 1345A display. I have been familiar with those adjustments, I was able to properly align the display on the 3562A and achieve normal CRT brightness.Postscript^2: One day, I turned on this piece and about five minutes later, the CRT flashes and then goes dark. Having fixed a few of these HP 1345A displays, my guess was that another 2.2 uF tantalum. A quick check of the 15V rail on the 1345's strobe board showed a short to ground. But this time, I kept my eye on a 6-1/2 digit ohmmeter while I was touching the tantalums and settled on the one with the smallest resistance. Popped that out, put in a 1 uF electrolytic, and everything is back to normal. Took me about 5 minutes. All in all, a very nice piece. My only gripe is the CHEAP front panel which Gigatronics made out of plastic (feels more like vinyl) which easily pulls away from its thin metal backing. Really? For a piece that had to cost at least ten grand when new, you couldn't have given us a proper painted metal front panel? Grade: A- (OM)I spent $200 (a lot) on eBay from a seller who said the level light does not come on below 8 GHz. The level light indicates that the desired amplitude can adequately be supplied by the circuitry. Upon receipt, when set to 0 dBm power, the spectrum analyzer read -36 dBm for signals below 2 GHz and less than -60 dBm for signals between 2 and 8 GHz. I don't have a spectrum analyzer that can see the 8 - 12 GHz band, but my EIP microwave counter seemed to indicate adequate power was being generated. Tracing the various microwave paths, I determined that the 2 - 8 GHz "coupler/modulator" was faulty. This was one of the parts built by Gigatronics and I was lucky to find one from a Chinese seller for $25. After installation, the unit sprang to life and high level signals were now seen but only between 50 MHz upwards. However, from about 2 GHz to 6 GHz, the unit can only make about -2 dBm on average (anywhere from about 0 to +4 dBm through the range). Outside of this frequency range, the maximum levels are from about 1 dBm to 12 dBm. I checked the output of the 2 - 8 GHz YIG and it was only about 5 dBm, so there was never going to be any way to achieve the 5 dBm output spec anyway due to the various losses through the microwave couplers, splitters, etc. Whether the YIG was damaged by feeding it into a faulty coupler/modulator before I got it, who knows. I guess I will have to live with it and I suppose I could always add a cheap Mini-Circuits broadband amplifier on the output if I really needed some oomph. At least I'll be able to replace it with a rear-panel output SMA jack - I installed an N-connector on the front panel and re-routed the internal piping.Postscript: I simply couldn't live with the 2 - 8 GHz band and not meeting the amplitude spec. Plus, when cold, the output sometimes only got to about -10 dBm in the lower regions of the band. So I bought a replacement Avantek YIG from a seller in Australia and installed it. It had a 22 ohm resistor to the FM- coil unlike the YIG that was in there. But the schematic shows the resistor, so I left it in. Now I'm getting > 5 dBm across the 2 - 8 GHz band like I'm supposed to. In fact, across 100 MHz to 12 GHz, the average power is 10.0 dBm, the max power is 13.8 dBm at 700 MHz, and the min power is 5.7 dBm at 6.8 GHz.Postscript^2: One day, the leveling circuit malfunctioned and I was unable to get below 10 dBm output regardless of how I set the fine attenuator (1 dB) switch, the amplitude vernier knob, or the AM modulation. The leveling circuit is an enormous feedback loop where these settings and the detector output are all summed at the (negative) input of an op-amp. Signals are switched around using an ICS010 CMOS switch and I was convinced that it was the culprit. However, the new one not only did not fix the problem, all my outputs were now down at 10 dBm output and no response from the controls. To make a long story short, the detector that monitors the output goes through an amplifier board and a log-amplifier board before going to the main summing junction. An ordinary 25K resistor in the feedback path of one of the op-amps on the log-amplifier board opened up. The result was that the log-amplifier output dominated the main summation junction and rendered all the other summands useless. Once the resistor was replaced, all was good.Postscript^3: The unit is misbehaving slightly now. Everything seems to be fine below 8 GHz. Above 8 GHz, the amplitude leveling does not work quite right. I spent a morning trying to figure it out, but got nowhere fast, especially since all the circuitry is pretty much the same whether one is below or above 8 GHz. It isn't that you can't adjust the amplitude to whatever you want. It is that over 8 GHz, you have to turn on the vernier control and manually adjust that and the 1 dB step dial on the front panel - you can't use the "0 dB" reference button. So the unit is perfectly usable, just annoying. I'll keep working on it some day...Postscript^4: In retrospect, the amplitude levelling might not be fixable. I can adjust things correctly in the 2-8 GHz band, but the 8-12 GHz band is wacky and vice versa. The service manual states that there is a ROM that has correction values stored for the amplitude levels and not to exchange or replace the ROM. Now since I have replaced some of the microwave components in early repairs, it may be that these stored amplitude values are incorrect for the new hardware. In that case, there is little I can do further that can be done. It's not like I am going to send that unit back to Gigatronics for repair. My guess is that even if I did, they wouldn't know what to do with such an old piece of gear.Postscript^5: I put a 7 dB attenuator inline with the 8-12 GHz signal generation to try and coerce the unit to level out the amplitude. Seems to be a lot better, although I obviously can't get to 10 dBm out of it anymore. Still, there are occasional amplitude settings on the 1 dB/div knob that it doesn't like. It is frequency dependent and my guess is that there is probably some degradation in either the power detector or the amplitude/modulator units. I will have to live with it.Postscript^6: Forget Postscript^3, Postscript^4 and Postscript^5. I spent two weeks going through every inch of the digital circuitry and finally came to the conclusion that the microwave attenuator/modulator block was faulty. The schematic shows this part as M163, but my unit's module is marked M184. Luckily, I found a used one on eBay that had both of them for about $20 each, so I bought both. When I installed the M184, the Gigatronics 900 worked perfectly and the amplitude leveling problems are now gone. Ono Sokki CF-200: Portable FFT Analyzer. This piece basically performs a 1024-point FFT over a maximum 0 - 20 kHz band. Presumably it was manufactured by Ono Sokki to do audio and vibration measurements. In some sense, it is a very watered-down version of my HP 3562A or HP 35665 Dynamic Signal Analyzers. However, in addition to being highly portable (it sits in its own suitcase), it is designed to run off of a 12V, 2A sealed lead acid rechargeable battery. Fortunately, it has an external 11.5 - 30 VDC input jack, because the battery is long gone. Without any documentation whatsoever, here is what I can ascertain about this unit. The selectable amplitude scales range from 10V to 10 uV. The upper frequency limit can be set from 20 kHz down to 1 Hz. The displayed noise floor (50 ohm termination on input) is about -127 dBV at 20 kHz and -147 dBV at 20 Hz and it has a maximum of 80 dB on the y-axis. (PDF) Grade: B (see below for update)OK, my unit did have an option: GPIB. HP 3575A: Gain and phase meter. Simply booooring. Simpson 269: 7" meter VOM between measuring 3.04VDC against 3VDC input. 10 ps; 5) record length: 5K vs. Racal recommends this procedure unless you absolutely can't do it this way (like probing a circuit board). The operation and concept is pretty basic - put the 10529A clip on a suspected defective IC in the unit under test. Naturally, I suspected the probe, but was unable to disassemble it and so I took the covers off the main unit and started to poke around. So I went on Krohn-Hite's web page and downloaded a random manual from 2002. Sold for very little cash in its day. (OM) Grade: C+Had several faulty electrolytic capacitors. Replaced them. Instead of continuous tuning, you get 4500 discrete frequencies (with three digit selection). As far as accuracy and repeatability, my unit seems to be consistent about 0.5% low in frequency. Tektronix 2215A: 60 MHz analog oscilloscope. You can't have a Tektronix 2213A scope but gave it away to a pal a couple of years ago. Too bad because the V/div knobs are the same as in my Tek 2232 and my replacement of the latter's knob failed over time. So rather than spend $30 for a new knob/shaft, I bought a whole 2215A for $50 which, of course, has two knobs! But as long as I have it, I might as well fix it. And it is a little better than the 2213A because it has a delayed time base. I won't bore you with the specs - Tek sold a zillion of the 2200-series scopes and almost everybody has one. (PDF) Grade: B+This scope came from the Physics Department of a university and was advertised as "won't focus." That typically means one (or more) of the six 510K resistors in the HV supply to the control grid of the CRT has opened up. And that was exactly the case. All six resistors were replaced (although probably just one or two were bad) and I fired the unit up. So I pulled the vertical board out (a job and a half) and did the usual cleaning on the cam switches. That cleared up all the noise and everything worked fine with the single exception of the trigger slope button - it would only trigger on a positive slope, not negative. After verifying the front panel switch was OK, a quick glance of the schematic led me to U460, a CA3102E dual differential amplifier. The inputs to the IC were all fine, but the outputs disappeared the moment the slope was set to negative. The CA3102E is obsolete, but there are a few out there for a few dollars apiece, so I ordered three of them (Tek used this IC in several places in the 2215A) just in case. And while I was waiting for these to arrive, I came across one in my junkbox (from a board of the HP 3325A). In it went and the 2215A is all fixed.Postscript: I have seen on occasion some ~25 kHz oscillations (from the switching P/S?) on the 2 mV/div and 5 mV/div scales with nothing connected to the input. It is much more noticeable on channel #1 than channel #2 and seems to abruptly go away if I twist the scope's metal frame a bit. I did notice a little spring clip at the rear of the CRT's shield that serves presumably as a ground. There was some corrosion there so I filed the clip and shield a bit. Magically, the oscillations went away.Postscript^2: Preemptively replaced the Rifa 0.0022 uF Y-capacitors with non-Rifa 0.0015 uF Y-capacitors in the power supply.Postscript^3: I finally got it all "persistent." I removed my 0.1 uF cap and hooked up a capacitor substitution box. Will handle 750 watts (up to 50V and up to 150A). Can vary from 10 Hz or 1 kHz dynamic switching. Uses a mechanical cooling tunnel oscillator and achieves phase noise specs that are outstanding. Want current measurements? And thanks, Fluke, for painting numbers on the knobs with paint that flakes off if you so much as look at it. These were among the few that used Tunnel diodes. However, poking around I did see one CMOS chip whose output levels seemed suspicious. So that left the problem on the 8981A RAM board. I don't know what's the story, but it's more like the middle layer was disintegrating before my very eyes. I just needed some more resoldering of a couple of cold joints. HP 4800A: Low frequency (500 kHz) vector impedance (0 to 10 Mohms) meter. I don't exactly know which version I got because the impedance range knob wouldn't turn to the last three ranges. When I dissected the switch, there was a stop purposely put in there. I removed the stop, but whoever put it in really wanted it to be there, because the parts required to make the two upper ranges were absent. So I was really bummed out, because even if I were to fish out parts and get it to work, it is only half of the capability it should be. The sealed lamp unit used in the feedback circuitry of the oscillator was burned out as was the lamp for the photodetector in the AGC circuit. Rumor has it you can fix the oscillator lamps, but the photodetector is a bit more dicey. I spent two days trying to get the thing to work properly with an external oscillator and a lamp shining at the photodetector (after I sawed the sealed unit in half) and then gave up. So I pulled out all the useful parts and threw the chassis away. Probably got $20 worth of parts: knobs, pots, and about 100 2N3904/6s. Oh, and a couple of very nice 5M and 50M precision resistors. HP 8005A: One of HP's mid-range pulse generators, this piece was simply beyond repair. All the circuit boards suffered from the most corrosion I've ever seen in a piece of test equipment. This thing left out in the jungle or something? Would have been a total waste of money, but it does have lots of 1 and 2 watt resistors to scavenge. So he "verified" that 5V was being supplied to a presumably burnt out front panel bulb. HP 1200B: Dual channel, 500 kHz, low amplitude oscilloscope. This is one strange beast. There are three banana jack inputs (+, -, gnd) on each of the two channels. You can run single ended (+ and gnd, or - and gnd for inverted) or differential (+ and -). OK, that's cute, but the real advantage of the 1200B is that the vertical scale goes down to 100 uV/div. That's an order of magnitude better than any other oscilloscope I've seen. Sure, this all comes at some expense, namely a 500 kHz bandwidth. In the 1200B seems to be most famous for audio work and the low noise and good, not hardware. Another strange feature is the ability to run it in "free run" mode whereby the sweep runs continuously unaffected by triggering. And you can also control the horizontal sweep by an external signal by hooking it up to the trigger input jacks and selecting a particular time/volt setting. Other than that, the scope has the usual dual trace functionality (alt, chop, etc.). My 1200B was built in Singapore as evidenced by the "S" in the serial number - that's a first for me! The build quality is OK, but the various boards are interconnected by wiring harnesses with dozens of push-on connectors to pins on the various boards. Better snap a few pictures if you ever want to disconnect everything and pull a board out. (PDF) Grade: A- (for novelty and the 100 uV/div)The seller said "powers up and the oscilloscope works, but the horizontal section is not functioning so no horizontal expansion of the Channel 1 and 2 beams." Well, that's a bit of an oxymoron, but it is exactly how I found it when I first powered it up. Moreover, the vertical line that was on the screen (with a signal attached) shortly disappeared off the bottom of the screen. I opened it up and did a visual inspection. The P/S board has about 15 posts with wires leading off in various harnesses. One of the wires was dangling in the breeze, not pushed on to one of the pins. There is no way to know which portion of the circuitry was hurt without dissecting the harnesses and following the wire. In any event, I now got horizontal sweeps, but I still had a problem where the trace would suddenly disappear off the screen. By turning the V/div setting way down, I could see a bit of the top of the waveform at the bottom of the CRT. Moreover, often times, as soon as I returned the V/div to something more reasonable, the trace was back. This went on for a few head-scratching hours as I could not put my finger on what was causing the intermittent problem. And to make things worse, without touching anything, the trace would disappear off the bottom only to return a few minutes later for 30 seconds or so before disappearing again. This kind of intermittent behavior made it difficult to debug, but I quickly homed in to one of the final vertical deflection amplifier transistors. Indeed, when the trace disappeared, I was getting a 21 volt drop across the NPN's B-E junction - not good! I thought maybe it was heat related, but cold spray and a heat gun did not prove conclusive. It seemed like the transistor (2N3440) had a mind of its own. Finally, I pulled out the transistor and replaced it with a 400V, 1A power transistor I had in the junkbox. Surprisingly, this cured the problem and the scope then ran for four hours straight with no problems while I successfully ran through the calibration procedure. Some 2N3440s are on order, but I may just leave the junkbox transistor in there permanently. The only other things needing attention were replacement of one of the input jacks, cleaning some pots, tightening the harness, knobs in the side panel that had been pushed in one inch, and putting a few layers of heat shrink tubing over the metal lever switch tabs (whose plastic caps were missing). Postscript: As I said in the previous paragraph, the 2N3440 would abruptly shut off and the surrounding circuitry was putting 21 V across the B-E junction. How the transistor survived is beyond me (well, obviously it didn't fully survive). It almost seems like it was acting as some kind of capacitor that would charge up, make the transistor "work," and then discharge. I did notice that when I got the 1200B, someone had taped cardboard pieces over all the top and bottom ventilation holes. Perhaps the 2N3440 simply cooked itself into oblivion (it did have a heatsink). Anyway, I obviously removed the cardboard obstructions. I also took out my junkbox transistor and put in the proper 2N3440 when I received a few.Postscript^2: The unit was missing its CRT implosion shield so I put a piece of 1/16" Lexan in there. Probably won't stop any glass fragments, but at least it will stop me from getting fingerprints directly on the CRT. HP 1200B Bonus Rant: Careful readers of this website will ascertain that I am not a big fan of HP oscilloscopes from the 1970 - 1995 time period. I think that HP lagged behind Tektronix during this era and if you look at a few HP company memos that are lurking around online, HP also admitted that they were playing catch-up with Tektronix (by around the year 2000, everybody had moved to digital scopes with proprietary ASICs and DSP chips and the disparity between HP (Agilent) and Tektronix disappeared). However, I can make an exception for the HP 1200B which is quite nice. Sure, a Tektronix 7A22 plug-in into a 7000-series mainframe can get you down even further to 10 uV/div, but that solution is more cumbersome and costly. Good job (back then), HP. HP 8657A: Highly popular $10K synthesizer, good to 1 GHz, -140 dBm. Nowhere near the purity of the HP 8640B, but certainly easy to use. Would be easier to use if it didn't have the rear panel output jack option. (PDF) Grade: A-I love this one! It was advertised as "doesn't power up." Just what I like! I turned it on - and nothing. Well, at least the LED got power. Then I looked at the back panel and saw the 110/220V switch set to 220V. From now on, that's the first thing I check. Now that it powered up, it still didn't work. I didn't yet have the manual, so I opened it up. I found five wires coming off a harness going to one of the main boards. All five were floating in mid-air. Now where do they go? Luckily, I found a picture of the insides of an HP 8657A on someone's web site. Used the picture to connect the wires. Works like a champ.Postscript: After many years, I got tired of the rear-panel output option and so removed the N-connector on the front panel and re-plumbed the insides. Now I don't have to waste a 6' BNC cable getting the signal from the back of the unit. HP 8660C: Synthesized Signal Generator configured to 1300 MHz. The HP 8660C is the mainframe and mine is configured with the HP 86632B AM/FM modulation generator and HP 86602B RF section. Amplitude is controlled by both a step attenuator and vernier pot and ranges from +10 to -136 dBm with a basic accuracy of about +/-2 dB. FM deviation goes from 1 MHz in three ranges. The unit has a moderate amount of sweep capability and also has a real front panel tuning knob, something many HP generators lack. The frequency resolution is 1 Hz and there is an ovenized oscillator which takes about 20 minutes to warm up unfortunately. The phase noise is about -105 dBc at 10 kHz, which is OK. I certainly can't see the difference between the 8660C and the HP 8657A on my Rigol DSA815 spectrum analyzer (and that's probably because the analyzer's phase noise is much worse than both generators). My only complaint is the strange man-machine interface. If you want to generate a signal at 456 MHz, I punch in 4, 5, 6, MHz and CF on the front panel. OK, but while I'm doing that, I see absolutely no change on the display. The keyboard entries go into a buffer and aren't made available to the main display until the last button is pressed. Same deal for sweep width and frequency step. But, see the three little buttons in the top left corner? They hold the register contents so you can see what you are typing them in. But how about putting them on the main display? Forget about it. Very strange. And not particularly obvious if you are trying to fix a broken one and can't figure out why no key press shows up on the display! The basic control is a state machine and they give you LEDs and a single step button so you can follow the program as it moves along. (PDF/OM) Grade: A-Postscript: Spent a little more money and recently upgraded to the HP 86603A RF plug-in. That now gives me frequencies up to 2.6 GHz, but with relaxed specs compared to the 1.3 GHz HP 86602B. I also got a good deal on another HP 86632B modulation plug-in which allowed me to replace the sticky meter in mine (see the repair notes below). As now configured, this beast sold for more than $30,000 in its last years at HP. Good grief!Bought this advertised as keyboard not responsive. But it truly was broken, not just an artifact of the keyboard/display action as described above. A fair amount of digital debug isolated the problem to one (or possibly two) boards, and I was pretty sure that one or more of the nine 74150 multiplexers on one board was faulty. This prevented the state machine from correctly obtaining the various data pieces and hung the machine up. Rather than scrounge around for a bunch of ICs, the simplest thing to do was spend another $75 and buy a parts mule for the 8660C mainframe that was advertised as working, but the OCXO was subsequently ripped out. Meanwhile, the main bridge rectifier for the 5V supply opened up on one half and I was getting a lot of ripple. Also, the attenuation knob on the 86602B was dirty and made the step attenuator's relays gyrate like crazy. A shot of cleaner fixed that. When the parts unit arrived, I replaced a few boards and the rectifier. Problems mostly solved, but the meter on the 86632B modulation plug-in was frozen. I dissected the meter only to find the entire magnetic torus surrounding the movement was filled up with tiny metal slivers. It took a long time to remove them all (they are magnetic after all and like to stick), but the meter movement is now mostly cured (a small tendency to stick at full scale). HP 8672A: Microwave synthesized signal generator, 2 - 18 GHz. Sold for over $40,000 in its later years, this is a very nice synthesizer that uses a YIG oscillator running at 2 - 6 GHz, followed by a YIG multiplier that either doubles or triples that baseband. Does AM and FM modulation as long as you supply the modulating signal to the front panel jacks. However, the FM deviation is restricted to a maximum of about 5x the modulating frequency, so you can't, for instance, use a 1 kHz sinewave input to the front panel and select 300 kHz FM deviation. Most of my other signal generators are much less restrictive. Nominally, the 8672A will output 0 dBm maximum, but my unit has Option 008 which boosts the output power to +8 dBm (or higher). In later years, HP abandoned this option and simply included it in all 8672As. The thing is built with typical HP-overengineering of the 1980s with about 25 PCBs and a slew of microwave modules, yielding a unit that weighs 60 lbs. The only bad thing is the lack of readable service manuals online. HP made the 8672 (and the junior version 8671) for so long, there are about six different manual versions - only one of them has readable schematics and, of course, it isn't the one I need. Shown in the photo with the RF turned off so that it lit up a few more of the front panel lights. Hook up a signal and watch. Even though there is a substantial set of "special" functions to set various internal parameters, you basically only get a couple of measurements and not a whole lot you can do about them. (PDF) Grade: B+Preemptively replaced the Rifa 0.47 uF X-capacitor in the power supply with a non-Rifa 0.47 uF X-capacitor. HP 34401A: 6-1/2 digit DMM. The 34401A was HP's most successful "low cost" general purpose bench DMM. I won't go into any detail on the specifications, because you either own one, use one at work, or know someone who has one. If you really need to know the specs, google it and you will get 50,000 hits. HP categorized this DMM as a 15 ppm class device. That may be true on the 10 VDC range, but I consider it mostly to be a 30 ppm device. I don't like the 34401A as much as my comparable Keithley 2015THD or Keithley 6500DMM in terms of navigating through the various settings. And I find the 34401A takes a good 60 minutes to warm up, a lot longer than the Keithley meters or other HP bench DMMs like the 3456A and 3457A. (PDF) Grade: B+The unit passes all self-tests and seems perfectly accurate, although a 10.00000 VDC calibration source will read 9.99980 when first powered up and takes a good 60 minutes to hit 10.00000. I did find one other anomaly, however. I let the 34401A sit for an hour measuring DCV and when I returned, the unit had switched itself to ACV. Hit the DCV button, went back one hour later and it had switched back to ACV yet again. A suggestion as to the fault said that a momentary power interruption could possibly cause the switching. So after I verified that the 5V analog, 5V digital and +/-18 volt power rails had negligible ripple, I put a scope on the 5 volt analog rail and set the scope to trigger on a downward edge to 4 volts. Let the 34401A run for four hours and it never switched to ACV, nor did the scope trigger. I've since run it for another couple of hours and it didn't switch. So I am at a loss at this point. If it starts happening again, I will dissect the front panel and look for debris near the ACV button contacts. Plus, it calibrated nicely which usually proves everything works. People have claimed that the SPM-19 has no equal and I sort of have to agree. It truly is superb. However, I can always find something to complain about, namely that when you switch to digital meter mode, it won't demodulate signals. So if you want to use this thing as an ordinary radio, you have to leave it in analog mode. The only thing I can compare it to is the HP 3586B and the SPM-19 handles the AGC much better and is more accurate. Now selective level receivers were designed for FDM measurements and as such, once the attenuation has been set, are optimized for a very small amplitude range, sacrificing the intercept point. So before one decides to use these as general purpose receivers, one might consider investing in a preselection filter, especially if you live near a 10 kW broadcast transmitter. (OM) Grade: AWhen first received, the very nicely sealed switching P/S was malfunctioning. That's because one of the oil-filled electrolytics had blown its plug and sprayed oil over EVERYTHING. Fixed the P/S, which was dicey because the oil had dissolved a lot of the urethane coated wire insulation. So once it was powered up, the SPM-19 had some flaws. These were traced eventually to A14U1 (CD4028), A22U42 (CD4077) and A21U71 (CA3096). After replacing these, the unit worked until one day - bam - dead P/S. At this point, the hell with it. I ripped out the P/S and built my own using a Meanwell 120W switching supply, an external 6V regulator and a transistor switch. Works like a champ.Postscript: I took the covers off one day to snap a photo of my replacement power supply. Good thing since the two AA-batteries used for memory backup had leaked. The batteries were in a sealed plastic case, but the acid managed to leak through that too. I put in a new holder and batteries. The digital display is a Newport 400A/S-3 which uses 150V plasma tubes. That's an option. HP 5334B: 100 MHz universal counter with 1.3 GHz prescaler option. So I pulled out the CRT Switch Board from the working 8980A and tried that - no luck. In fact, the HP 4140B is listed in the HP catalog in the semiconductor testing section. Rated to 20 kHz in narrowband mode and 50 kHz in broadband mode with measurements from +22 to -90 dBm (re 600 Hz). This unit has no options installed. (OM) Grade: B+This piece was advertised as "powered up, then shut down, no further testing could be done." That's kind of an ambiguous statement. When turned on cold, did it always power up for a few minutes, or did it eventually just permanently stop functioning altogether? Well, I guess I will just have to fork over the $5.99 and find out! On receipt, the fan came on, the power supply diagnostic LEDs all lit properly, the uP activity LED blinked like it should, but the front panel was completely dark and unresponsive. This piece was a classic example of fix-by-inspection. On the middle of three boards mounted to the front panel is a toroidal inductor. This inductor passes the 5V to the display/keyboard controller board. Only problem was that one of the leads of the inductor was pulled out of the board and the inductor was waving in the breeze. Remounted the inductor, unit works fine. Total diagnostic and repair time: 30 minutes. Update: OK, I guess I need more than 30 minutes - I recently found a problem with the front panel Receive Monitor Jack. This was traced to a faulty relay, A11K6. Fixed that too. While I was inside, I modified the unit to take 2xAA alkaline batteries for backup.Postscript: Preemptively replaced the two Rifa 0.01 uF Y-caps used after the bridge rectifier with non-Rifa 0.01 uF Y-caps. I'm not sure why HP used suppression caps - they really only needed 0.01 uF caps with a 250 VDC rating. Perhaps that's what they had in stock. T : Tekpower, Tektronix, Tenma, Topward, Transistor Devices, TrigTek, Triplett Tekpower TP3016M: Handheld 50 watt switching power supply. Sold under a variety of names, this little P/S will do 0.3V-12V @ 0-3.75A or 0.3V-30V@ 1.6A with VC and CC control. Simple intuitive controls and a nice piece to have in a pinch for experiments. Will also supply 5V @ 2A out USB jacks on the front panel. Unfortunately, as many people have noted (and complained), there is no on/off switch - you must unplug it from the AC outlet to turn it off. Also (see the repair notes below), it will output -0.6V when the output is switched off (with the unit still powered up). (PDF) Grade: B+These things are currently being sold with a street price of about $120. I bought one off of eBay for $20 with the description warning that the unit will only output about 100 mV regardless of setting. But I was betting it had to be something simple. Indeed, after verifying the seller's description (actually, the display showed 0.14V but the output was 0V), I found that the resistance across the two output jacks was zero ohms - not good! I took the thing apart and there is a Zener diode across the output terminals (probably for overvoltage protection of the DUT) and my guess was that the Zener was the offending part. And so it was, because after I removed, the resistance jumped up to about 50K. Put everything back together and presto - it still didn't work. One would press the output enable button only to have it light up momentarily as the output voltage jumped to 30V, and then immediately extinguish the light giving an output voltage of about -1V. Then it dawned on me that maybe the previous owner tried to calibrate it (you hook up an external DMM and punch in the readings) and essentially set the internal constants to nonsense (this is consistent with the erroneous 0.14V reading I first got on the display, despite the output being 0V). So I ran through the calibration and presto - works fine. Now the fact that I removed the Zener was what was letting the thing get past its nominal -0.6V with the output disabled. There is a published mod from the manufacturer that allows the supply to go back to 0V (remove a transistor and replace two capacitors with resistors). I found a couple of 50 ohm SMD resistors in the junkbox and did the mod. Much, much better now. I didn't have a Zener (and who knows what the value was anyway), so I tacked in a 1N4004, 400V, 1A diode across the output jacks. That at least will protect against inductive kickbacks or reverse polarity. I lose the overvoltage protection, and maybe someday I will tack on a 35V, 1W Zener in its place. Guess what, same semiconductor exclusion. Rigol DS1104Z: Brand new 100 MHz 4-channel oscilloscope from the Chinese. Despite the fact that I have at least 10 other oscilloscopes, I decided to treat myself to one that wasn't more than 20 years old. And it didn't hurt that my insurance company decided that they had been overcharging me for decades and out of the blue sent me a refund check for $3,100. The DS1104Z set me back $780 and you do get quite a bit for that amount. Unlike most older digital scopes, this one has a decent waveform update rate - as much as 50,000 waveforms/sec. Contrast that to the rather putrid 30-100 on some of the 1980-1990 scopes. Plus the scope has a 1 GHz sampling rate and 24 Mpoints of memory, an extensive set of automatic measurements, dozens of trigger types, math functions (e.g. FFT) and a waveform record/playback function. I won't bore you with the specs (which can be found on Rigol's site), but the combination of high update and gradient intensity (see an example of the gradient intensity in the photo) and very bright, crisp LCD make for a pleasing display. While rated to 100 MHz, the 3 dB bandwidth is more like 200 MHz and the scope will easily trigger up to 450 MHz or so (obviously with reduced amplitude). There are a few quirks in the software, typical of the Chinese, but on the whole, the button-ology is adequate. There have also been reported quirks in the firmware involving jitter on delayed waveforms (my unit doesn't exhibit this) and jitter on AC-coupled triggers (my unit does exhibit this). (OM) Grade: A-Postscript: Rigol released a firmware upgrade to address the delayed-jitter and AC-coupling problems. At least on my unit, the new firmware appears to correct any problems. There is still considerable discussion as to whether or not Rigol correctly implemented in hardware the phase-locked-loop that controls the A/D sampling. I personally haven't come across any artifacts of that, but one has to suspect that the Chinese engineers are in no way as good as, say, their USA Agilent or Tektronix counterparts. So I guess it all boils down to "you get what you pay for." Rigol DSA815-TG: Brand new 1.5 GHz spectrum analyzer from the Chinese (with an assist from Agilent). Can pull out a sub uV signal in the presence of many volts of noise. The PMG-13 is not as good, however, as the HP 3581C because it lacks sweep capability and has about 10 dB worse dynamic range. HP 6115A: Precision power supply. This is the big brother of the HP 6113A shown above. But this time, the voltage goes up to a little more reasonable 100 volts. The 6115A will do 0.8A at 50V and 0.4A at 100V. The specs are similar, but not quite the same, as the 6113A. While the 6113A has more digits of resolution, the 6115A is more accurate, achieving a 0.025% + 1 mV spec. Unlike the 6113A, there is no oven in the 6115A. The accuracy is provided by a 1N829 temperature compensated Zener (0.0005% per deg C) and a bunch of 0.1%, 0.025% and 0.01% precision resistors. No finger-hurting thumbwheels on this one; simple + and - buttons change the voltage. Has the usual over-voltage control/crowbar and current limiting pot. My only complaint (because I have to complain about something) is why did HP use red binding posts for both plus and minus? Couldn't they have used red, black and green for plus, minus and ground like everyone else? This supply had a long lifetime at HP. The manual I have is dated 1972, but my unit was made in 1985. I give that an A+. Tektronix 5110: Low frequency (2 MHz) oscilloscope with two 5A15N (vertical) and 5B10N (horizontal) plug-ins. Here's where it gets confusing. Tektronix first sold these things (in the early 1970s) with a modular approach. One chassis contained the power supply and the three slots for the plug-ins. The other chassis contained the CRT and associated driver circuitry. The two chassis could be mated either side-by-side or on top of one another. The idea was that one could select from a variety of single, dual, non-storage or storage displays; Tek sold about eight different ones. Mine is the least capable D10 model. Tek originally branded my scope as a 5103/D10, but confusion soon reigned and they relabeled all of the 5103/Dnn models simply to 51nn. It gets even more confusing because they later came out with the higher bandwidth 5400 series. Now, none of the 5100-series plug-ins should be confused with the plug-ins for the TM500 or TM5000 chassis - they might be the same physical size, but they are completely incompatible. I assume these low bandwidth scopes were marketed to people needing instrumentation for low frequency sensors, such as geological transducers, or perhaps for audio applications. They are, of course, pretty useless in a general lab situation. But the lack of high frequency response actually could be a blessing in certain situations in terms of noise reduction. In fact, at 1 mV/div, the trace is much cleaner than my more modern "better" scopes. The CRT is an 8×10 division screen where each division is 0.5 in instead of the standard 1 cm per division. Simple to operate and unlike the vast majority of Tektronix scopes, simple to service with hardly any custom ICs. (PDF) Grade: B+I specifically bought this because the eBay photo showed the trace completely screwed up with all kinds of echos and retraces. At least I hoped to get several hours of entertainment out of it. When received, the traces were even worse than shown in the photo and virtually none of the controls functioned correctly. It was so screwed up that I surmised the problem had to be improper power supply voltages. And so it was, as I found the 30 V rail oscillating at 120 Hz between 12 V and 30 V. After replacing the obviously faulty main electrolytic cap, things started to look reasonable. This scope is >45 years old and you can imagine how dirty all the switches were, so the plug-ins were removed and cleaned (a few times). Going through the alignment, I noticed that the trace rotation potentiometer had no effect (and the trace was annoyingly tilted about 5 degrees). The pot has 30 V and -30 V across it and the wiper sends the selected voltage through the trace rotation coil surrounding the CRT and then to ground. The wiper of the pot was producing the correct voltage, so I pulled the wire off of the pot going to the coil and found that the coil was open. No wonder I did not get any trace rotation. At this point, I figured I had nothing to lose so I removed the CRT and yanked out the trace rotation coil. Dissecting my way through all of the insulation surrounding it, I soon found the open solder joint connecting the coil lead to the wire going to the pot. Soldered it, reinstalled everything, and now my trace can be rotated. I'm kind of glad I did this surgery because when I removed the main connector from the CRT, I found three bent pins (courtesy of a previous incompetent repairman). I'm amazed that they actually were making contact. The only other fault I found was a burned out bulb in the "ready" indicator on the 5B10N for single sweep. Replacing that was even harder than my rotation coil fix.Postscript: Further experimentation revealed that the channel #1 5A15N plug-in was intermittent with a baseline that would shift around randomly. I tested the transistors in-circuit and found one (2N4249) that did not test correctly. I pulled it and threw it on my Peak Component Analyzer which concluded it was a Darlington with a 1.4 volt B-E drop. That's strange, because it isn't supposed to be a Darlington. I popped another one out just to be sure and the second transistor tested fine with the expected 0.7 V drop. I didn't have a 2N4249, so I threw in a 2N4403 which isn't a "low noise" transistor like the 2N4249. But it seems to have fixed the problem with no increase in noise at the 1 mV/div setting that I can see.Postscript^2: I have noticed that Channel #1 exhibits the behavior that the trigger level knob will only trigger an input if it is set just right - with about 5 degrees of slop. Channel #2, on the other hand, will trigger with about 30 degrees of movement of the level knob. I replaced the three 2N3565 transistors making up the trigger pickoff circuit in Channel #1 with 2N3904s and now it behaves correctly. A forensic analysis showed that one of the 2N3565 had severely reduced beta.Tektronix Scope Collection Bonus Rant! With this latest acquisition, I now have Tektronix oscilloscopes from the 200, 300, 400, 2000, 5000, 7000, T900 and TDS series! That pretty much does it unless I am interested in the early vacuum tube models (I'm not) or want to spend thousands on a post-2000 manufactured model (I don't). Unfortunately, LEDs #1 and #8 lit, as well as the power on LED, and the three LEDs were quite dim. Wandel & Goltermann PKN-1: The PKN-1 is a cable simulator for digital communications, notably T1 lines. I thought I was all done, but then I noticed that the display's text was kind of fuzzy - almost like the characters had echoes. frequency. This piece graphs frequency vs. HP 3964A: Four channel instrumentation recorder using 1/4" tape, speed to 15 ips. LATEST ADDITIONS TO THIS WEBSITE: Wavetek 110 (May, 2022) Wavetek 202 (May, 2022) Tektronix 314 (April, 2022) Wavetek 157 (April, 2022) Philips PM5193 (March, 2022) Wavetek 98 (February, 2022) HP 54502A (January, 2022) Kaiweets KM601 (December, 2021) HP 4265B (December, 2021) BK Precision 3010 (November, 2021) Tektronix 308 (October, 2021) Leader LFG-1300S (September, 2021)Note: New/modified repair notes are not individually listed as latest additions since they occur too frequently to keep track of them all!---This is my (ever changing) collection of old test equipment. Most of the collection dates from what I consider to be the peak period in repairable semiconductor based test equipment, 1970 to 1990. (PDF) Grade: BI originally used this for spare parts to fix mechanical things in the other Tek 500 series plug-ins (see below). But then I figured what the hell - some metal scraps, a Dremel tool, epoxy... Good as new. So they run the vector generated x- y- and z- signals out of the 1345A display into the 8981A CRT Switch Board where it is multiplexed with the x- y- and z- analog signals and the whole mess is put right back into the 1345A display. And here is a histogram of MSRPs up to about $20,000. I have a few items more expensive, but they weren't included in this plot. Using the latest catalog price is somewhat iffy since some manufacturers, in particular HP, often skyrocketed their prices right before they discontinued an item. Whether this cost increase was due to the difficulty in obtaining parts, or whether it was used as an inducement to buy the replacement model, isn't exactly clear to me. The neon power lamp was burned out and so was replaced. (PDF) Grade: B-The usual faulty electrolytic story. Works very well for moderate values of C. I have two things with vacuum tubes - this unit and the GenRad noise generator. Maybe now I need to buy a tube tester? (PDF) Grade: C This was a simple fix. It just needed a dual pot replaced. All measured with my HP 4262A and who knows how accurate that is. On a hunch that the numeric LEDs were at the root of the problem, I found two 2-digit and one 1-1/2 digit seven segment common cathode numeric LEDs on eBay. Wavetek 395: One channel, 100 MHz arbitrary waveform generator. This is the (very) big brother of my Wavetek 195 (see above) and consists of a highly diverse function generator with arbitrary waveform capabilities. In short, the 395 can generate sine, square, triangle, ramp, haversine, sin(x)/x, pulses, analog noise, digital noise and on and on. I especially like the comb function which puts equally spaced lines on a spectrum analyzer. It uses 12 bit vertical resolution, 64K waveform storage (with 1M as an option), a 100 MHz clock and has the usual gate and trigger modes, sweep generation, AM/FM modulation, etc. In fact, there is so much capability in this piece, that I really have only scratched the surface describing it. Sine wave distortion is -68 dBc proving that their table-based waveform generation scheme is very good (you can, however, see the "glitches" due to the address rounding error on the HP 53310A modulation analyzer). The man-machine interface is also pretty good and for the most part self-explanatory (it has on-line "help" on the display too). Build quality is excellent and consists of mix of surface mount and through-hole parts with several ASICs doing the hard work. All in all, a simply wonderful piece (that is still being sold today as the Fluke 291 for $4,400). I have been somewhat critical of earlier Wavetek pieces as having a lot of functionality, but none of it done with much fidelity. The 395 (and the 195 above) are fine examples of state-of-the-art function generators. In fact, I don't think any other piece comes close to the 395 in terms of how many things can be done in one box. If I was stranded on the proverbial desert island with only one function generator, this would be it! (PDF) Grade: AThis piece was your standard "doesn't power on." It uses a 3rd party 200+ watt switching power supply similar in form factor to that found in a desktop PC. That is kind of odd as the 395 only draws about 40 watts. The secondary of the supply was absolutely dead and I checked virtually every part inside except the SG8050 controller. So I ordered a few from China hoping that I didn't get counterfeits. When I received them, they had no effect on the power supply. So either the Chinese ICs were faulty or there is a mysterious failure I simply cannot find. At that point, I simply bought four $10 Meanwell supplies, gutted out the old supply, so I could still use the existing line filter, power switch and fan, and dropped in the new

Meanwells (see picture below). Works like a champ although once in a while I get a "didn't power down correctly" message on the 395 upon startup. That's because the old supply had a circuit to detect shutdown and I'm no longer providing that signal. Perfectly OK, however, since one would only get in trouble if one shuts off the 395 while writing an arbitrary function into memory - I'm not that dumb. Wavetek 452: Two identical (active) filter channels, each of which has separate input/output terminals (front and rear). It is pretty amazing that you can now get a full featured spectrum analyzer with tracking generator for $1,495. Be very careful, however, as some chemicals can lift the paint off the front panel (try to test first in some inconspicuous area). Everyone has their favorite chemical for cleaning/lubricating switches, pots and edge connectors. I've tried two of the Caig De-Oxitproducts, but I always seem to keep coming back to good old Radio Shack tuner cleaner even though it leaves an unholy mess. Oh yes, do let the stuff dry before using the equipment. Be careful when adjusting pots (or anything else for that matter): 1) use a dedicated pot-adjusting tool, 2) put heat-shrink tubing over the shaft of any 1/8 inch or smaller screwdriver, 3) be careful about letting tools slip. Also be careful when using several pieces of equipment simultaneously to adjust your unit. It is easy to get confused and swap cables or leads which can ultimately lead to unintended shorts. Don't be afraid to retrace your steps. On one of my pieces, the microprocessor was locking up (unknown to me) because the RAM backup batteries had leaked and failed. Soon after I got the piece, I put new batteries in, but it did not cure the microprocessor problem, so I pulled the batteries back out. Turns out that there was corrosion on the board where the wiring from the batteries entered. After I cleaned up the corrosion surrounding those wires and other nearby parts, I didn't go back and reinstall the batteries, thinking that I had fixed my locked-up microprocessor. I was wrong. Had I gone back and retraced my steps, I could have saved myself many hours of fruitless debug time. After you have fixed a power supply, look at the output on a scope - that's why you have a scope. All the P/S voltages checked out, so I started to delve into the schematics. Pretty perplexing because I would have thought if the switches were screwed up, the resistance would increase, not decrease. Solartron 7150W: 6-1/2 digit DMM. Well, it is really 5-1/2 digits, but for some functions and ranging, flicking the FILT button will give you 6-1/2 digits. Does all the functions: VDC, VAC, IDC, IAC, ohms, and diode, with nulling capability as the only "math" function. Mine is the "W" model and I have no idea what that means. Solartron made a 7150 and a 7150plus, that much I know. The specs are OK, about 30 ppm basic accuracy. People have tried to claim that the 7150 is a good alternative to the HP 34401A, but I don't see that at all. A more fair comparison are the HP 3468/78 meters. The build quality is very nice, but Solartron did some stupid things. First of all, the power switch is on the rear panel - I absolutely hate that. I guess Solartron saved 25 cents by not running the usual plastic post from a front panel button to wherever the actual power switch is. Second, the minimum ohms range is 10K, so you can forget about seeing fractions of an ohm on the display. Third, the DCV input impedance is 10M for all ranges (the 7150plus version has a more reasonable 10G impedance for the two lowest ranges). And finally, you can only calibrate this thing over the GPIB interface. Moreover, before you can get the thing into cal mode, you have to insert a 2.5 mm shorting plug into a jack on the back. Gee, could you make it any more cumbersome? (PDF) Grade: B-A few things were wrong with this meter upon receipt. The display backlight was very dark and the old yellow LEDs were replaced with super-bright white ones. The front/rear input switch was toast and was also replaced. Finally, the Schaffner line filter, which is known to be highly problematic in this series, was replaced as a precaution. The thing was also way out of calibration, so it was re-calibrated.Solartron Bonus Rant: With this piece, I have now experienced the Solartron 7050, 7065, 7150W and the Guideline/Solartron/Schlumberger 9577 DMMs. With the exception of the 7050, which never claimed to be a great DMM, the other pieces are certainly wonderful, with performance equaling Fluke or HP. Simply not true. Not even close. Unless you can get one real cheap, they are not worth your money. HP 6621A: Two output system power supply. Each of the HP 6621A outputs is an independent 80W power supplies. Each can operate in one of two modes that are automatically selected: 1) 7V, 10A or 2) 20V, 4A. The supply is intended to be used primarily through the GPIB interface, but can be operated adequately from the front panel. Mine has Option 750 which brings an extra connector out the back with signals related to various faults within the supplies (the intent is then to use these signals to protect the load with relays for example). Agilent still sells this model for about $9,000, along with the 6622A, 6623A, 6624A, ... Solartron 7065: 6-1/2 digit DMM. The tactile switches were vanilla, so I decided to drill small cutouts for LEDs underneath where the switches would pop through. The highest range resistor is 1 teraohm! I'd like to look at the range resistors, but they are encapsulated in a steel box. Audio range to 50 kHz. Dynamic range > 80 dB. Can be used tediously but accurately to measure THD, for instance. This little throw-away piece is actually very capable and I like it a lot. The tuning mechanism is a true HP mechanical masterpiece. (OM) Grade: A-Replaced faulty A3U4 and A7U8 that were causing the AFC and the sweep functions to malfunction. Also replaced the power light bulb. Postscript: After sitting dormant for a few years, I fired this puppy up only to find that the AFC was not working. Consulting the block diagram led me back to the A7 board and the problem was isolated to only a few ICs. But one of them looked like the "double squiggle" markings of National Semiconductor, so that was the one I surmised was the problem. And so it was (a CD4019). I've learned the lesson the hard way - National Semi ICs of the late 1970s suck big time. They should always be your first suspect in any faulty logic. In fact, the only parts that are guaranteed to be even more problematic are Sprague (electrolytic) capacitors. Funny, National Semiconductor was essentially started by Peter Sprague. I rest my case. Wavetek 4101: Basic no frills modulation meter covering 1.5 MHz to 2 GHz. Will measure peak and trough FM deviation to 100 kHz and AM modulation to 100%. Has a few selections for audio filtering and FM de-emphasis. Wavetek bought the RF board from a Korean manufacturer; the exact same board can be found in several other modulation meters from reputable test equipment manufacturers. Despite all the potential drawbacks, it actually is reasonably accurate and agrees with my gold standard HP 8901A to within about 0.5% everywhere I've tried it. (OEM) Grade: B+Not responsive to any input when I received it. The input terminating resistors had been burnt to a crisp, so that's your first clue Sherlock. The manual is truly a piece of work - one of HP's best. I once had the piece up for at least a half dozen times. The most likely explanation is that the old capacitors needed some time to reform. But competing theories lead to tin whiskers burning off, The Force, God, or what have you. I think what I am trying to say is give a newly acquired vintage piece some time to be reborn. If the problem is truly old capacitors that need to reform, there is a recommended procedure where you slowly step-up the AC line voltage (through a Variac). But life is too short for that.This is not so much a repair note as a safety warning. Having a lot of gear, I run a lot of (cheap) power strips. The cheap ones have a tendency to lose the ground connections (and possibly hot or neutral) because the plug makes contact with the inner springs of the metal. The metal eventually bends out of the way. Do yourself a favor and put one ohmmeter lead on the chassis of one piece that is plugged in, and then put the other lead on your scope or other chassis in turn- you should see a short (generally, nothing needs be powered on). If not, start looking at the power strips. Just open it up and gently compress the contacts on the outlets a bit.As mentioned in many of these notes, Sprague (electrolytic) capacitors are a true blight on the vintage test equipment repair landscape. Now, perhaps they were the only game in town 40 years ago, but really? Also, when you are looking at a board of 1970-1980 TTL/CMOS logic, look for any chips with National Semiconductor markings. They are second only to Sprague capacitors in guaranteed problems. Uh, wait a moment - wasn't National Semiconductor essentially started by Peter Sprague? I rest my case. As far as Mr. Sprague goes, as Al Capone said in the movie, The Untouchables, " I want him DEAD! I want his family DEAD! I want his house burned to the GROUND!" Don't be afraid to study the schematics. I know it is tempting to dive right into a fresh piece with your voltmeter in one hand and your scope in the other. But I have fixed many pieces essentially "on paper" by first observing the symptoms of the fault and then consulting the schematics and circuit descriptions to figure out what component must be responsible. Obviously, this doesn't always work and there is a tradeoff between study time and poking-around time. But it is extremely satisfying to be able to point to a part, replace it, and have the piece fixed in a minute or two, after doing your homework.Here is a couple of warnings about IC sockets and used IC's. With a good de-soldering gun, you can generally remove DIP IC's intact. There may be some residual solder on the leads which normally isn't a problem except in two instances I've found. The first is when you try to use an IC tester having a ZIF socket. I have found that sometimes not all the leads will electrically connect to the tester because the solder on one or more leads prevents the ZIF socket from closing with adequate pressure. The second instance is the following: Whenever I pull an IC, I usually install an IC socket before putting a new chip back in. But what about putting the old IC back in? As before, the used IC may not make good contact with the socket. In other words, if you want to put a pulled DIP IC back, simply solder it back in. I've been burned by both of these instances (see the Tektronix T912 entry).I haven't discussed tools very much on this site. Besides all the hand tools such as pliers, cutters, screwdrivers, etc, I consider the following three tools the most useful things I own: 1) de-soldering gun, 2) electric screwdriver, and 3) small LED flashlight. For de-soldering, I've tried braid and hand-operated vacuum pumps. Although they work, nothing compares to a good de-soldering gun. I use the Hakko FR-301 ($275 street price). You go through a fair number of tips and filters, so you can expect to spend another $25/year on maintenance. Sure, you can de-solder a 16-pin through-hole IC the hard way - I can do it in about 30 seconds. Plus, I don't destroy the chip I'm removing. Similarly, if you've been opening up a typical HP piece and an inner cover with 40 screws is staring you in the face, you will be happy you have an electric screwdriver. Nothing fancy needed, although I do like the ones with a torque clutch. Something less than $50 will do fine. Finally, buy a small LED flashlight because lab lighting is never good enough to see way inside a piece. Spend about $20.With today's modern smartphones and tablets, it is really easy to snap a few pictures of a piece or a board that you are about to start repairing. For instance, I was given a small 10.5V, 5A switching power supply to repair that had popped its AC fuse. I had to desolder a few parts in order to isolate the short at the front end of the supply (two rectifiers). I replaced the fuse and the diodes and the supply came back to life. However, I was only getting about 9.5V and the output voltage dropped precipitously as soon as any load was placed on it. That led me on a weekend wild goose chase hunting down problems in the secondary. Turns out that the input voltage doubler had been disabled, so the supply was running at "half-speed" and could barely achieve its rated voltage open-circuit. And why was the voltage doubler not working? Because the way the doubler is enabled is by shorting two solder landings on the board with a blob of solder. And when I was removing parts, my desolder gun happily removed this blob. It never occurred to me to short two landings when I put parts back - Really, aren't solder shorts to be avoided normally? If I had snapped a photo before I started, I would have seen it. But I didn't and it took me a fair amount of head scratching to figure out how this power supply had ever worked in the first place.I've found it useful to have my Kindle sitting next to the piece under repair so I can have access to the service manual and also be able to download component information from the web. But the Kindle is so slow, I've grown frustrated and recently upgraded to an iPad. And I came across an app ($5.99) by Marcus Roskosch called "Electronic Toolbox." This has databases, formulas and pretty much everything you need while repairing a vintage piece. Get it - you won't be disappointed. Grade: A SOME STATISTICS...Knobs, buttons, switches, meters, displays,... Tektronix TM503: Three bay mainframe for the Tektronix 500 series plug-ins. Furnishes various AC and DC voltages and also has an NPN and a PNP power transistor on each bay for use by the plug-ins. (PDF) Grade: B-There was nothing electrically wrong with the mainframe when I received it. However, it was pretty banged up and the front frame was cracked in half. I buttressed it with a small piece of aluminum and some screws.Postscript: I must have tried to hot switch some plug-ins, because the fuse blew and the left compartment suddenly didn't work. A visual inspection showed two traces on the board were fried to a crisp. Oh well, I like to use de-solder braid to jumper burnt traces - it's nice and thick. (OM) Grade: A- Peak DCA55: Unfortunately this unit only works out-of-circuit. I ripped out all the soldered ICs and also discovered, when I decided to remove the previously replaced chip's socket, that the repairman had lifted a few pads on the top of the board. Extensive self-test. I'm using this in the two wire configuration with the sense leads connected to the output terminals at the source. So I do get a voltage drop with high current draw. But at least the 10 amp capability is nice. (PDF) Grade: B+This unit produced no voltage among other things. The switching FETs had shorted from source to gate and blew up everything in its path. Had to rebuild the driving circuitry to the gate and install new FETs. The optical encoder also needed new light bulbs and the over-voltage protection circuitry was malfunctioning because a wire had come off. HP 5314A: Basic counter to 100 MHz. And when I say "basic," I'm being generous. This was one of those c.a. 1990 pieces where HP decided to compete in the "cheap" market. Fortunately, the competition didn't last long and HP seemingly went back to state-of-the-art stuff. The HP 5314A is a single-chip, non-interpolating, direct-count with a 10 MHz timebase. Pretty simple, but a lot better than I expected. Confirmed the operation, did the alignment and tightened all the loose hardware.Postscript: Not that this is a further repair note, but I was perusing the service manual and came across Krohn-Hite's one-year "warranty" statement. This one will do 40 V at 0.75 A. Global Specialties 4001: 5 MHz pulse generator. The 4001 is a basic pulse generator covering 0.5 Hz to 5 MHz with continuously variable pulse widths and spacings from 100 nsec to 1 sec. Has the usual trigger, gate and one-shot functions and has an open circuit amplitude of up to 10 V and rise times of about 20 nsec. Global Specialties is known for producing instruments and accessories primarily directed at the educational market, so one doesn't expect the 4001 to be laboratory-grade. I bought this for $20 (condition unknown) primarily because there was a "Made in the USA" sticker on the back, not "Made in China," and I was curious to see the build quality - it worked fine right out of the box. The build quality is very nice, but it is still six ICs and six transistors, so it is pretty minimal. In fact, although there is a split power supply producing +18 and -18 VDC, the 4001 uses a single output transistor and can only output positive voltages. For another dollar, they could have built a push-pull output stage and included a DC offset function. My biggest complaint is the cheap plastic pulse spacing and pulse width outer knobs. They have small plastic tabs that meet slots in the metal shaft. The tabs have already worn a bit so there is a tremendous amount of slop in the knobs. All in all, a good hobby piece. (PDF) Grade: BHad an hour or two to waste one day, so I desoldered the two rotary switches, dissected them, bent the spring pawls to loosen the tension and reinstalled. Now it doesn't take excessive force to turn them. Guildline 9577: 7-1/2 digit DVM. L : Leader Leader LFG-1300S: Analog function generator to 2 MHz. In addition to the normal sine, square and triangle waveforms, the 1300S will do AM modulation and frequency sweeps. Beyond that, it is pretty much what you would expect from a mid 1980's consumer grade function generator. (PDF) Grade: B+Advertised as making a "BZZZZ on the output," the seller's description was a bit baffling. Anyway, upon power-up, the thing had no output regardless of setting. A quick check of the 5, -5, 15, -15, 10 and -10 volt supplies showed the 5V was about 4.2V. Switching the voltmeter from DC to AC revealed a huge ripple, so the faulty electrolytic capacitor on the 5V supply was replaced. The 1300S then seemed to function OK, but needed a lot of cleaner squirted into the switches. And while I was going through the various frequency ranges, I noticed what looked like oscillation when the unit was set at 200 kHz to 600 kHz. After a day of fruitless debugging, I happened to take a look at the 10V rail, and noticed it was oscillating. This rail was what is used in the basic triangle generator integrator circuit. And what was the oscillation. The two local (10V -10V) supplies take 15V inputs and use pass transistors with op-amps in feedback. The 47 uF output capacitor on the 10V rail had dropped down to about 1 nF and the 10V supply started to oscillate. Once the capacitor was replaced, all was well. See the Repair section at the bottom of this web page where it says to always look at the power supply with a scope just to make sure there isn't some high frequency stuff going on that your DCV and ACV meter can't see. A very wise recommendation in this case! Leader LFM-39: Wow and Flutter meter. Simply not as good. Also have a 630-PL2 (not shown). I guess some people like the Triplett meters better than the Simpson meters, but not me. It must be a Coke vs. HP 6227B: Dual 50 watt power supply. The HP 6227B has two independent 25V, 2A power supplies. They can be set to tracking mode so that the right (slave) power supply follows the left (master). Also has SCR-based overvoltage crowbars whose level can be set from the front panel. The specifications are OK, nothing spectacular. It weighs about 25 pounds and consumes about 45 watts with the voltages set to zero. I would give this a grade of "B" for "Boring," but the fact that HP put the plus and minus binding posts next to each other, rather than putting the ground post between them, earns them a slight positive adjustment. (PDF) Grade: B+This piece was offered for $40 as a parts unit because it had been dropped onto the floor and the whole frame was severely bent out of shape. The seller also indicated that the V/A meter switch on the slave supply did not work. Fortunately, when I received it, the slave supply did output voltage, so the fact that the meter read zero really was due to the V/A switch. The switch took some damage in the fall to the floor, but I managed to bend things back, squirt in some contact cleaner, and it seems OK now. The big repair on this unit, however, was the chassis. The side frames had been bent so badly that one of them actually cracked in half. But HP used the same basic chassis components in a lot of their 1970 vintage units and I had a nice straight set of side frames in the junk pile. HP at its very best. Most of my HP power supplies easily exceed their maximum ratings. In fact, the upper range of the meter scales are grayed out meaning that the supply will work, but the specs may not be met. I can get to >30V using resistance programming on the back panel of the 6227B, but under front panel control, 25V is all I get. R16 on the 6227B are padding resistors, hand-selected at manufacture, that control the voltage going into the main comparator that drives the pass transistors. The 13.1K and 19.1K resistors on the master and slave boards were both changed to 4.7K. Now I get the full 30V out of both supplies. However, I have to bump up the grade a bit since it was truly an "ArcherKit" and I got to build it. Finally, as I was trying various pulldown resistors, I guess I shorted something because the display turned off, the unit groaned, and smoke poured out the back of the display board (all the components are on the front side!). A replacement fan from the junkbox fixed that. The odor of a defective tantalum capacitor. The -15V rail measured 4.4 ohms to ground, and as I was getting ready to isolate the bad cap, I noticed one whose color was brown, not the normal yellow. Replaced C171 and all is well. The CF-200 has four different displays: 1) spectrum, 2) histogram, 3) time, or 4) waterfall. There are selections for an anti-aliasing pre-filter on the A/D converter, Hanning or Rectangular windows, and some triggering and cursor functions too. There is a built-in thermal printer and the unit draws about 6 watts when running (15 V at 0.39 A). Ono Sokki still manufactures these FFT analyzers, albeit now with a much more modern design and much more money. And they're worth it, as "advertises," the CF-200 works quite nicely. One can argue that the same functionality can be achieved with the sound card in a laptop running a freeware FFT program. But most sound cards that I've seen do not have a flat frequency response especially below 50 Hz where they roll off considerably. All in all, a good buy at $14. (--) Grade: A- The battery was completely dead upon receipt. I cut it open with a Dremel tool and all the cells had turned to powder. There is no part number on the battery case so there is probably no hope of ever getting a replacement (unless I make my own). No worries, I'll just power it up externally (my TekPower TP3016M portable power supply makes a good sub). It took Teledyne Acoustic Research about 10 hours to (with no published alignment procedure). Having said all of this, the 8502A is very well constructed and easy to work on. I did pull the chassis out of the suitcase and confirmed the construction is first-rate. P : PDI, Peak, Philips, Power Designs, PowerMate, Princeton Applied Research PDI LPP-6108: I have no idea who PDI is and it really doesn't matter as this identical logic probe is available from many different vendors. Also measures D and ESR, however HP tired (and failed) to introduce a new measurement unit, ohms-farad, for ESR that requires the user to divide by the capacitance to obtain the true ESR reading. Finally, everyone is entitled to their own opinion. HP 6202B: Harrison and/or HP built a dozen different variants. The second test card shorts the upper and lower halves together and keeps all the LEDs off. Tektronix 7603 (Vert): Basic 100 MHz scope configured with a 7A12 vertical amp, a 225 MHz 7D15 counter and a 2ns/div 7B70 time base. (PDF) Grade: B+Scope worked fine. The problem was with the plug-ins. See the discussions below. Since more modern meters use an AC signal and measure the complex impedance. which have up to four outputs using either 40W or 80W supplies. Hooking the 2005 up to the scope revealed a 1.2 MHz sine wave at several hundred millivolts peak-to-peak. I "interpreted" the manual's calibration procedure and everything went smoothly. (PDF) Grade: B+Advertised as doesn't power up. HP 241A: 1 MHz pushbutton oscillator. Not usually a problem, except the 5253B/5254B use tuned cavities and these required disassembly, cleaning, reassembly and realignment (with no published alignment procedure). Having said all of this, the 8502A is very well constructed and easy to work on. Even after all the work, there was still a small 1.2 MHz signal when I put my probe across Q4, so it shall remain in the circuit. All 18 were replaced with LEDs and some resistors were changed to set the proper current. BBC M2050: Digital Scope Multimeter. A (very) poor man's version of the Fluke Scopemeter. It is a scope. It is a meter. It is a very limited scope. For instance, the scope time base only goes down to 0.025 msec/div and the optional interface software requires some weird old version of Windows. It has the ability to scroll the scope up to 60 minutes and also has two memories and the ability to zoom through them. AC and DC coupling, different triggering options. Seems accurate from about 10 to 40 kHz. Not quite sure what they were thinking. But you have to admit, it is cute. And at seven bucks, how could I resist? (--) Grade: B The four NiCd C-cells were still inside and four years of leaking. Put regular alkaline batteries in, despite the warning label, because I don't have the charger. I don't know what kind of charger to use anyway seeing as I can find out absolutely nothing about this unit. (PDF) Grade: A- North Hills CS-152-7: Precision six digit current source to 150 ma, 25 volts. Evidently, North Hills made this piece from about the mid-1960s to about 1990. The unit I have has a date of 1989. Nor do I know what the "-7" suffix in the model number means. I know mine has an open circuit compliance of well past 40 volts, not the 25 volts listed in the manual. The accuracy spec is listed at "0.01% full scale" and that's about what I am seeing. The stability is listed as typically +/-2 ppm +/-1 nA. I haven't done a stability test, but it certainly looks rock solid on my Fluke 8502A DMM. The CS-152-7 has a modulation input jack on the back that allows the current to be (AM) modulated. It also has a (10 V) reference jack that either outputs the internal ovenized reference or allows you to supply an external 10 V reference (you then must set the front panel output switch to 0). Finally, two new neon bulbs, a new current limit knob and a repair of the power cord and the unit is fine.Postscript: Well, I really annoyed me that the ripple wasn't meeting the 100 uV-p-p spec. This switching is controlled by a sync pulse from the 1345A display and I was seeing that or the correct signal on the CRT Switch Board test point. It often bundled with other logic analysis devices such as the HP 545A logic pulser, HP 546A logic pulser and HP 547A current tracer. Not much inside except about 100 precision resistors, 40 precision capacitors, six op-amps, a bunch of rotary switches and a small power supply. Power Designs TP340: A triple output power supply similar to the TP343B listed below. Before pulling out boards to put in my HP 8980A, I at least owed it to myself to take a look at what was going on. So HP gave you 10 blank reference cards and sold additional ones for 50 volts. Think about the consequences of some idiot putting several hundred volts into any one of the many (unused) input jacks (including the ones on the back panel). That should get you started with a lot of repairs. Occasionally that same idiot might loosen his cable of death to an output jack, but he usually isn't quite that dumb. This is a common occurrence, for instance, with modulation or power meters.Tighten every screw you can find - board mounting screws, back panel screws, frame screws, transformer screws, fan cover screws, doesn't matter. They will all be loose. For those truly suffering from obsessive-compulsive-disorder, you might want to gently push every single capacitor so that it is exactly perpendicular to the board or de-solder and flip any resistors whose color codes aren't aligned left-to-right.HP pieces in the 1980's all seem to have the front panel pushbuttons that give a little click. The click comes from a tiny leaf spring inside the actual switch. It is very common for those springs to come out of their mountings. I think it is a poor design on HP's part, because even the springs dig into the plastic housing with about 0.00000001 inch of plastic serving to retain them. You will know when the springs are dislodged because the button won't snap back (even though the switch will still work if you tap it lightly). So be very careful when dissecting an HP front panel. The spring may be loose in there somewhere. You do NOT want to lose the spring as it is very difficult to manufacture one out of some piece of metal (rumored that the right metal is inside cheap RF-ID tags you find in department stores).Everyone has their favorite chemical for getting off sticker residue. I like Carb/Choke cleaner the best. I poured out my bucket of 74LS chips and found a 74LS164 on the 60th pick. Now, I'm probably making this sound easier than it was. The modules are a pain in the ass to get in and out. And for some unknown (to me) reason, several modules are interconnected with 34-conductor ribbon cables whose connectors are soldered to the board. These cables only pass digital control data; there are no signal integrity problems, so WHY aren't these connectors socketed? Ask Fluke. Fluke 8050A: Basic 4-1/2 digit DMM with a couple of extras, such as dB display and relative display. Uses the NiCd batteries in an unusual way. LCD display means I can't use it in the dark. (PDF) Grade: B Part of the motherboard, and the NiCd batteries of the two were purchased in one buy. The 4 NiCd batteries in each were bad and these batteries are integral to the power supply (one of the regulators floats over the battery voltage). While waiting for batteries to arrive, an external P/S allowed me to verify and calibrate both units. But that's not until a lot of cleaner was sprayed into all of the pushbutton switches. The designers of DMMs like to route the input signal through multiple switches at the front - the switches all have to work flawlessly or the unit will be erratic.Postscript: Fast forward a few years and the unit became erratic. I was convinced that there was a problem with the electronics, but it ended up being the switches, which seem to be nearing their end of life. With a lot of repeated cleaning, the unit seems OK now. Tektronix TM5006: Six slot mainframe for the Tektronix 500 and 5000 series plug-ins. I have six 500-series plug-ins (as shown in the photo), so my three old TM503 wasn't going to hack it anymore. Tek also made a TM506 that only services the 500 plug-ins. The 5006 is a much more complicated beast with a full switching power supply and a fan that is way too loud. (PDF) Grade: B+Picked this up for $25 from a seller that claimed "the power supply was broken." Gee, that pretty much means all of it, right? But, alas, upon receipt it worked perfectly fine. The only fault I found was a small chip on one of the edge connectors that caused one of the counters with the plug-ins not to be in its place. I shimmed it up, but if it persists, the workaround is to use one of my plug-ins that contains its own power supply, since the bad connection will then be back to an unused pass transistor in the mainframe.Tektronix Plug-in Bonus Rant: Tek made a slew of 500-series plug-ins and followed up their "successes" with the more capable 5000 series. I can only speak to the 500-series since that is all I have. Although there are some nice ones, e.g. the AA501 distortion analyzer and the SG505 ultra low distortion signal generator, most of the plug-ins are pretty useless. I, for instance, never use my collection of plug-ins shown in the photo above to calibrate ANYTHING - the performance is way too poor. I view a mainframe populated with 500-series plug-ins as student grade, possibly useful in a trade school. If I really need a DMM, I'm going to use one of my good ones. I don't care how convenient having a lot of capability in a "one-piece" set of plug-ins is. And of course, since it is Tektronix, we have the usual needlessly complicated mechanical designs, way too small buttons, constant cam-switch maintenance problems, faulty transistor and IC sockets and thoroughly horrendous calibration procedures. Not that you can calibrate these things without having an extender cable (which I actually do!). I know some people rave about the 500/5000 setup. Either they don't get it or I don't get it. tacked on to the original board. The horizontal timing board has a little circuit board that was added by hot gluing it on standoffs to the timing board and the underside of the board is a nightmare of tacked-on circuitry. All in all, someone at BK Precision must have spent hours and hours making all the mods. Y mode, but the problem with a scope is that while the vertical bandwidth is usually quite high (hundreds of MHz), the horizontal bandwidth is quite low (tens of MHz); this leads to a distortion in the scope's X vs. Given that adjustments are made by padding capacitors, I shall leave it that way. One of two units. Fixed one, used the other for parts. Rumor has it that the Military needed impedance bridges and BECO managed to get around some patent infringements. Like all manually controlled bridges, it helps to know approximately what the answer is before you start. But the thing does do what it is supposed to. Has a very funky AC adapter that clips onto the side panel. BECO really intended it to be run on batteries. (---) Grade: C- No repair really required on the first unit. It just needed some adjustments so that the oscillator would start. The second unit is faulty and the fault was traced to a shorted transformer. Most likely some previous owner had dumped a lot of volts through the external oscillator input. Seeing as I have no schematic, I don't know what to replace the transformer with. Besides, it's not worth spending the money. BK Precision 2832: This is a basic 3-1/2 digit multimeter measuring voltage, current, resistance and limited capacitance. Nowadays you can get something similar at Radio Shack for under $20. I thought I was buying one of these, but five actually showed up in various states of disrepair. It is the only thing I have that has a diode tester. And that's the only time I ever use it. Battery powered. (---) Grade: C Most of the fixes were simple stuff like broken wires. Kept a couple and threw the rest in the garbage. HP 5253B, 5254B, 5262A, 10590A: These are plug-ins for the HP 5245L and HP 5345A counters. HP 332A: Manual distortion meter. This piece is virtually identical to the HP 334A (see below) except that it is absent the automatic notch tuning feature. Everybody should be forced to do distortion measurements at least once manually before having the luxury of automatic tuning - it builds character! Mine has the label Option H01, which usually means it was built for the telephone company or some Government agency. What is strange, however, are the markings surrounding the meter range switch. On all the other HP distortion analyzers (331A, 332A, 333A and 334A), the dB markings follow the percentage markings. In other words, a distortion of 1% is -40 dB. But if you look at my piece, you will see 1% corresponds to -50 dB, clearly wrong as are all of the other dB values. I scratched my head for a while until I realized that the scale is dBm, not dB, on my unit. Why HP marked it this way might have something to do with the Option H01, but I really don't know. Has a fixed 10 nsec rise time, positive/symmetric/negative amplitudes and a whopping 16V maximum output. This entry is one of their waveform digitizer/recorders. HP 4274A: Multi-frequency LCR meter. This piece is the big brother to the HP 4262A (see above). Not only can it do more measurements (C, L, R, Z, D, Q, ESR, G, X, B, theta, deviation, %deviation), but it can do them at a choice of 11 different frequencies from 100 Hz to 100 kHz and with a continuous range of test voltages up to 5 volts. Mine does not have the internal DC bias option, but biases can be added externally through a back panel jack. The accuracy is on the order of 0.1%, but that is best case. The manual devotes more than 5 pages to completely specify the accuracy among the various ranges. Like the HP 4262A, it is pretty much plug-and-play. But as with all better LCR meters, you sort of have to know the approximate answer before you start because it is easy to select a frequency, voltage, or mode where you can get an erroneous reading. Unlike the 4262A which uses banana jacks in a 4-wire configuration, the 4274A uses four BNC cables to carry the Kelvin arrangement. However, unlike most Kelvin clips, the outer shields of the four BNC cables have to be tied together at the DUT. So I took the Kelvin set I was using with my ESI SP5110 LCR meter, scraped away the outer jacket and tied all the grounds. This is quite annoying so I have on order a Chinese clone of the test fixture one normally uses with the 4274A. As is often the case, this page's technical adviser/editor offered the explanation: think temperature! Yup, stuck the thing in a 150 deg oven for 5 minutes and the 0.001 ohm increments measured 0.001 ohms. HP 8447A: The 8447A is a very simple 0.1-400 MHz 20 dB RF amplifier, plain and simple. Power Designs TP343B: Triple output power supply, providing 20V@2.5A on the upper two supplies and 6V@5A on the bottom supply. All three are rated to higher voltages at the expense of lower current. The upper two supplies can either be set to independent or tracking. A very curious design that switches pass transistors around at higher voltages (hence the lower current ratings). Makes no sense to me why they did it that way (unless it was to lower the power dissipation of the transistors). Volt and amp metering, current limit adjustments and overvoltage adjustments. The voltage knobs control 10-turn pots which are good for precision, but real annoying to adjust. Big and hefty. (PDF) Grade: A-Advertised by the seller as "A supply works OK, B supply only reaches 18V, and C supply starts up and then shuts down." And that is exactly what I received. The C supply fault was traced to a defective bridge rectifier (2 open diodes) that actually shut down the negative portion of the following split supply and charged the electrolytics with the wrong polarity. Not surprising that the bridge blew, since the previous repairman put in an underrated part. The B supply fault was traced to a faulty voltage reference, but it abruptly fixed itself as I was poking around. There was also a shorted 5V Zener diode in the A supply that provides the negative rail of an op-amp. This was replaced with a 4V junkbox zener - close enough, the op-amp doesn't need to output negative voltages anyway.Postscript: Pureness of body and mind would dictate that the 4V junkbox zener be removed and replaced with the proper value. HP 1980B: Four channel 100 MHz oscilloscope, the first uP-based scope HP (or anyone else) built. This is basically an analog oscilloscope, but all the controls are run through a uP which then sets the hardware. The uP also permits GPIB communication to and from the machine and would allow automated measurements as part of a test fixture. The digital control also allows the scope to have an "autoset" button that examines the waveform and selects the optimal voltage and timebase settings. As an analog scope, it's nothing particularly noteworthy and the bandwidth certainly wasn't state-of-the-art at the time. Has the optional HP 19860A rudimentary waveform storage function (~500 points). One has to get used to this style of scope where a single knob controls all parameters. This "feature" was repeated on later HP scopes like my HP 54112D. I don't like it! Once again, my theorem which states that "HP = spectrum analyzer and Tektronix = oscilloscope," is proven out. Some of the internal HP documents from the 1970s and 1980s bemoan the fact that HP was desperate to catch up to Tektronix in the oscilloscope market. I'm not sure they ever did (although some of them that they built after 2010 aren't too bad). (OM) Grade: B+When received, most of the light bulbs behind the front panel were toast, so I meticulously replaced about 90 of them with red LEDs. The channel 1&2 vertical preamp hybrid also required reseating. A while later, the thing acted up and the problem was a leaking timing capacitor in the horizontal circuit.Postscript: Turned on the HP 1980B after about five years and all hell broke loose. Nothing seemed to work right and the thing threw cal error after cal error. The calibration of the 1980B is all done via software and it was throwing four (hardware) errors for the channel balance/baseline cal procedure and the remaining calibrations, although passed, seemed highly problematic (I had to often turn the adjustment knob many, many turns, which was clearly wrong). After a weekend of cleaning and reseating the many hybrids, all of which use troublesome elastomeric connectors, I have the thing 99% functional now. It go so bad at one point, that I got disgusted and moved this entry into the "It's dead, Jim" section below. But I put it back into the main web page since it is perfectly usable now. The 1% that doesn't work right is the baseline which shifts as a function of the V/div setting. Since this happens on all four channels, across two separate vertical preamp hybrids, I have to figure out what is common to all of them. The 600 page service manual is of no particular help, but maybe I will get lucky someday. Given my 11 other scopes, I really have no intention of ever using this thing, so I'm in no hurry. Postscript^2: Well, of course I'm in a hurry. One of the hybrid ICs with the elastomeric connectors that I didn't pay too much attention to was the trigger IC, especially since one wouldn't think this would have any effect on the vertical preamp balance/baseline (now that I think of it, HP must have used the trigger level as an easy way to figure out input voltage levels). But after cleaning the trigger hybrid, the balance calibration passed, the remaining calibration of the unit was MUCH easier, and everything now works flawlessly. Although there are warnings in the manual about clean-handling the elastomeric connectors (they tell you to wear cotton or latex gloves), I was so frustrated that I ended up using 220 grit sandpaper wetted with tuner cleaner. So much for their warning... However, the eslastomeric connectors are also used in the front panel and ultimately this scope will prove to be a maintenance nightmare (unless I can find a cheap replacement source for the connectors).Postscript^3: Many years later the scope started behaving badly. The chief symptom was that the text was scrambled and randomly flashing all over the screen. You can select "characters off" from the front panel, but the random characters remained (and they chop the signal trace also). Moreover, the 1980B would randomly change the character intensity, randomly lock-up, randomly not boot, etc. About four days of debug led to the conclusion that the two SRAM chips, A4U32 and A4U33, were bad. These chips are primarily used by the video controller to store the characters put on the screen, but the main microprocessor also puts some stack information in these two SRAMS. So if these SRAMs are bad, all kinds of bad things can happen. A new set of SRAMs seemed to fix everything, but the calibration was way off since I had already cleared out the other battery-backed-up RAM chips holding the cal constants. I've gone through the cal procedure a few times now and the 1980B seems to be relatively intact.Postscript^4: Right after I reworked the uP board and installed the two SRAMs, I noticed that the digitizer option (HP 19860A) no longer worked. Dropped a few bucks on the service manual and it looked like the digitizer boards were operating properly. Basically, the scope tries to digitize, then hangs. Moreover, when it starts to digitize, it throws the scope into the intensified mode. And the intensified mode no longer works correctly anyway. And then channel #4 started to act funny on certain V/div ranges. What a complete mess. I dissected channel #4's attenuator and cleaned the contacts; that restored the channel's functionality. Why the intensified mode no longer worked was eventually traced to a set of ECL chips whose logic levels (particularly the low level) was not correct. And this was caused by me inadvertently when I went through the adjustment procedure days earlier. Long story short - there is a pot that, among other things, defines the ECL-low voltage. Once I set the pot correctly, the intensified function worked correctly. Moreover, the digitizer now worked perfectly. Amazing what happens when the logic levels are correct! This one taunted me for about 10 days until I got it all working. HP 3253A: Analog Stimulus Unit. This rather bizarre piece is a component of the HP 3060A board test system, which itself was a monster system sold by HP to board manufacturers. The 3060A (and later 3065A, 3070A) contained both an analog stimulus unit and a digital stimulus unit hooked (via HPIB) to a computer. The stimulus units were designed to run cables from their back panels to a special "board of nails" text fixture. However, it is possible to run the 3253A as a self-contained piece from the front panel using the front panel jacks - and that's what I've got. As to the 3253A, I'll try to summarize things in a few hundred words. One can view the 3253A as having the following: 1) a source generator which can be DC or a basic function generator, with both voltage and current settings; 2) a range resistor (1, 10, 100, ..., 1M); 3) an op-amp; and 4) a detector, which can be an AC voltmeter, DC voltmeter or a frequency counter. The idea is to configure the 3253A to measure something across the front panel jacks. Now it is not quite that easy, however. For instance, suppose you put a 2K resistor between the S and I jacks. You set the test number to 1, set the source to 1 VDC, set the range resistor to 1K, and set the detector to a 5-1/2 digit DC voltmeter. This configures things so that the source is going through the range resistor to the feedback terminal of the op-amp, with the "unknown" 2K resistor going between the op-amp output and the same feedback terminal. Nominally then you would read -0.5 volts on the display. In other words, an unknown resistance equals -S*R/V, where S is the source voltage, R is the reference resistor and the V is the displayed voltage. Clear as mud? I thought so. The 3253A is configured with about 15 pre-arranged tests, but I'm sure you could dream up some more. For instance, test #4 is a diode test and the photo shows the 3253A measuring a cheap nominal 6.2V Zener (remember, the voltage will appear negative due to the inverting op-amp). Having said all of this, one has to realize that this is not a precision piece. In other words, you wouldn't use the source as an accurate waveform generator, nor the detector as an accurate voltmeter. But I guess for an automated board tester, HP figured it was good enough. And it is built with typical HP overkill - a massive 50 lbs including separate power supplies for the source and detector circuitry. HP didn't skimp on parts either. My favorite is the dozen or so mercury reed relays with a "warning - Hg" stamped on their cases. Finally, I was only able to locate a partial operation manual. With over 40 adjustments inside, I sure would like the cal procedure. I'll tentatively give it a yawning grade - if I ever get the service manual some day, I'll bump the grade up. (---) Grade: BWhen received, everything seemed to work. Which is good because without a service manual, there's no chance. The front panel was quite worn with a lot of buttons not clicking. I dissected the front panel and found two leaf springs missing and a bunch dislodged. Everything was put back in order. Wavetek 98: High power, 1 MHz synthesizer. The Wavetek 98 is an odd piece that generates sine waves from 1 uHz to 1.1 MHz with up to 30 Vp-p (50 ohm output into high-Z load). It also has 600 ohm balanced/unbalanced outputs in addition to the nominal 50 ohm output (frequencies and amplitudes are restricted to lower values at 600 ohms). There are some sweep capabilities and an external reference jack, but that's about it. Pretty simple to use and the architecture is the standard phase accumulator driving a sine wave look-up ROM driving a D/A driving a filter and power amplifier. Typical of these look-up table synthesizers, I'm measuring about -75 dBc distortion at 1 kHz. The Wavetek 98 is also very well constructed and quite easy to service. (PDF) Grade: A-Advertised as a parts unit, there was a tag on the machine that said "fails frequency accuracy, possibly needs a new reference." But it was only $75 shipped, so I took a chance as the only unobtainable part is the custom Wavetek phase accumulator IC. Upon receipt, everything functioned fine, but all frequencies were 34 ppm low. The frequency accuracy spec on the unit is +/-30 ppm, yet the performance tests say +/-25 ppm. Doesn't matter because as the seller's tag said, it is out of spec. The reference is a standard 10 MHz crystal oscillator in a DIP-14 can. These things can be had for about $3, but most that I could find online were the lower grade 100 ppm stability versions. Looking around in my collection of spare parts, I came across a TXCO from my HP 5350A counter where I had replaced it with an OXCO years ago. Moreover, the TXCO was marked 10.000 MHz, had a TTL-compatible output, an adjustment screw, and ran off of 5V, just like the crystal oscillator that was in the Wavetek 98. So I pulled the crystal oscillator and installed the TXCO. As the picture shows, perfecto! Wavetek 110: Function generator to 1 MHz. This piece is very similar to the Wavetek 112 described in the next entry and, in fact, shares much of the same circuitry. It came as part of a two-piece buy, the Wavetek 110 and the Wavetek 202 (described below). Unfortunately, the two pieces, although bolted together and easily separated, share a common top cover. So they will remain forever married. (PDF) Grade: BAdvertised in unknown condition, the 110 worked when powered on. However, seeing as it is a piece from the 1960's, it is full of leaky capacitors, weak transistors, drifty resistors, dirty sealed pots, etc. I'll just count my blessings that I didn't really have to repair this unit. Wavetek 112: Triggered VCG. This is essentially a 1 MHz function generator doing the usual sine, square, triangle and ramp waveforms. But Wavetek calls this a triggered VCG because 1) it can be triggered or gated externally, and 2) a front panel input voltage can control the frequency. Both these "features" are commonplace with more modern function generators, but I guess in the early 1970s, maybe they were novel. The 112 does have one nice front panel control that allows the starting phase of a triggered waveform to be changed. The specs are typical Wavetek, meaning nothing very good. In fact, Wavetek refers to this piece in the manual as a "semi-precision source." However, the 112 does generate 32.5 volt peak-to-peak outputs (open load) which is somewhat rare for a function generator. They also made close variants with slightly different features, namely the Wavetek 115 and 116, as well as battery versions. Other than that, it is a pretty boring piece, although nice and compact, and just about worth the $20 I paid for it. (PDF) Grade: BAdvertised by the seller as missing a fuse holder cap, yet the front panel light glows red when powered on. Kind of impossible don't you think? Well, the little circular window in the upper left does show red when the power switch is rotated on, but that's due to the fact that it is simply a little piece of red metal that is swung into place. Anyway, I replaced the fuse holder cap and powered the unit on. It basically generated waveforms but they had a large positive bias and an even larger 120 Hz negative pulse. The output amplifier runs off of +24 and -24 volt rails and clearly the culprit was the -24 volt rail. And since the pulsing was at 120 Hz, that points to the main filter capacitor for that negative power supply. And so it was. A simple replacement of the 1000 uF cap fixed the unit (the old cap tested completely open). I do want to comment on the construction of this piece. For the most part, it is pretty well designed for an early 1970s piece. But they mount the (rotary) power switch on the back panel and the front panel knob is connected to a metal shaft running the length of the piece to the switch on the back. But the internal circuit construction uses a backplane on the bottom and five PCBs sticking up vertically from that. So they simply drilled a hole through all of the boards and ran the shaft through all of them. Kind of funny.Postscript: I should have tested these thing a bit more thoroughly. Although spec-ed to 1 MHz, it will only achieve 700 kHz. I tried changing the integrating capacitor (on the highest 100K range) and I could get it up to 1 MHz. But then, the low end wouldn't go down to 100 kHz. There are some padding resistors and I played a bit with those without real success. However, virtually every old carbon resistor in this unit tests about 50% high - some were 3x the nominal value. Moreover, there seems to be about 50 pF of residual capacitance across the circuit with the integrating capacitor removed (possibly due to contamination inside the sealed range switch or on the circuit board). In light of these observations, there probably isn't an easy fix and I will simply live without the extra 300 kHz at the top. Otherwise, the unit performs flawlessly. HP 1630G: 65 channel state/timing logic analyzer. time and 2) histogram of frequency; the picture shows the first mode. Control-wise, the unit acts sort of like an oscilloscope in that there are timebase controls, amplitude controls and triggers. However, one must remember that the y-axis and the triggers are based on frequency, not voltage. It gets sort of confusing. Fortunately, there is an "auto-scale" button that pretty much takes care of all the settings. The 53310A is based on a custom HP hybrid counter chip that is capable of doing >1 million measurements per second (each measurement is the result of a much higher basic count). The signal inputs are capable of handling a 200 MHz signal. As an example, the photo shows my HP 8904A function generator outputting a 50 kHz square wave into the 53310A. Remember that the 8904A is a strange beast in that it is all table-based waveform lookup. The basic rate into the table is 1.67 MHz meaning that a 50 kHz waveform is a 33.4 multiple of that basic interval. The 0.4 in the 33.4 means that the table lookup has fractional addresses which results in picking the nearest integer address into the table. This induces at most a 1/1.67MHz = 600 nsec jitter to the square wave (which is clearly visible on a scope). Because of this jitter, not every successive T units of time are going to see exactly the same number of pulses. And that is exactly what the 53310A shows, with the frequency dipping down to 49.34 kHz somewhat periodically. I am going to deduct a full grade from this because HP in their infinite wisdom decided to put the power switch on the back panel. I've often seen HP put a master switch on the back, but at least then they always had the courtesy to put a secondary power switch on the front panel. Not on this piece. (PDF) Grade: BPostscript: Perhaps I should increase the grade back up from a B to an A, because I am less annoyed with the rear panel power switch. I am, however, extremely pleased with the capabilities of this unit. HP didn't do a very good job of marketing this piece, because in reality, it can do some amazing things like 14 digit frequency measurement and sub 1 nsec rise time measurements. But that's if you take the time to understand how to use it. Unlike 99% of the stuff I have, the 53310A functionality cannot be duplicated by my other pieces.Advertised as working, it basically was when I got it. It was failing the cal procedure, but a fresh cal wrote new values into the NVRAM and fixed that problem.Postscript: A couple of weeks after I got this, the unit suddenly powered off. A quick check of the 3A line fuse showed that it had popped. I put in another only to see a big flash emanating from the partially sealed switching P/S. Dissecting the supply, the internal 5A fuse had popped. I replaced it with a 6A fuse (the closest value in my junkbox) and powered it up through the Sencore isolation transformer. The Sencore meter showed a small inrush current, followed by zero current draw. These power supplies are from a third party vendor (something HP did a lot in the 1990s) and are also used in the HP 545xx oscilloscopes. Someone had reverse engineered the supply and conveniently posted a schematic online Probing my way through the primary circuitry to the switching transistor, everything looked OK. But the transistor showed a short across base-to-emitter. I pulled the transistor, but the short remained on the board. Luckily, I tested the transistor - totally open on all three leads. So besides a blown transistor, I still had a B-E short on the board. From the schematic, the only component that could cause the short was something labeled S1. I pulled that component and it was shorted (and the short disappeared from the board). The component is marked MTS90A, and from the various forums, seems to be a thermal switch. The idea is that if the P/S overheats, the switch closes and shorts the transistor B-E, turning off the transistor and thus the supply. Nowhere can I find anything about the MTS90A, nor can I find one for sale. So out it goes, period. As far as the blown transistor, it is a TIPL755A 420V/10A/180W NPN and all I had in the junkbox was a BU208A 1500V/8A/150W. Close enough for me. The new transistor was installed and the unit seems fine nowPostscript^2: The "unit seems fine now" in the above Postscript was a bit too optimistic, I'm afraid. After being left on for about 15 minutes, the CRT on the 53310A went dark. Moreover, the LEDs on the front panel were flickering slightly. I dissected the P/S once again and found nothing visibly wrong. A check of the 5 volt test point showed the voltage randomly varying between about 2 and 4 volts. There was also a very faint crackling sound. I was about to check the switching waveform on the base of the main transistor when I noticed that the heat sink was red hot. This was followed shortly by smoke and the supply went totally dead. A check of the transistor showed a C-B short which of course fried some resistors in the base circuitry. After scratching my head all morning and finding nothing wrong with the primary circuitry, I began looking at the secondary side. What's that, a little black discoloration under one of the 220uF/50V output caps? I pulled the cap only to find a puddle of electrolyte ooze sitting beneath it. So leaving nothing to chance, I pulled all 29 output caps. Nine of them had leaked, and, in fact, all seven 220uF/50V caps were among the leakers. Must have been a real bad batch. Leaking electrolyte might explain the crackling noise, lack of regulation and the overheating of the switching transistor (it is on an fairly anemic heat sink). Luckily I pulled that temperature protection switch so I could see the transistor fry in front of me New caps and transistors are now on orderPostscript^3: 29 new electrolytic caps were installed, but I didn't yet have the TIP755A from Hong Kong. So I ran some jumper wires to an NPN TO-220 transistor pulled from an old computer power supply and fired the thing up. Immediately popped the transistor with a C-E short. Tried a second transistor and the same thing happened. Eventually, I received the TIP755A and that didn't pop, but the P/S didn't start either - it simply ticked. So there are definitely more problems. As a last resort, I bought an HP 1650A logic analyzer for $35 which, according to the service manual, has the same P/S. But the service manual also mentions a "Type 1" and "Type 2" supply, and as luck would have it, the supply I got in the 1650A was the wrong one. It had an adequate amount of power and produced 5, -5, 3.5, 12 and -12 VDC - everything I needed except 15 volts for the chassis fan (which can run fine on 12V). The output connector was 16 pin, not 20 pins like in the correct 53310A supply. So I had to manufacture a cable that went from 16 pins to 20, duplicate some connections, and then wire up 12 volts to the fan. I also needed some sheet metal work to get the thing to fit into the 53310A. Seems to work fine now. Any more problems and I'm going to buy two Meanwell switching supplies and build my own.Final Postscript: I was bored and I didn't like removing the supply from the HP 1650A (which was also not the correct one for the 53310A), so I spent about $35 and bought a Meanwell RT-65B to supply 5, 12 and -12 (and also 3.5V with two diodes from the 5V) and an RS-25-5 to supply the -5 volts. Mounted everything on the top cover of the old switching supply turned upside down with some minor sheet metal refabrication. Works great and I shouldn't have any problems for the next 20 years. And it now only draws 85 watts from the AC line rather than the original 120 watts (the original Boeschert switching supply had its fair share of regulators and pass transistors on the secondary) Runs nice and cool.Final, Final Postscript: Well, my buddy needed a display board for his 53310A and I could always use the correct P/S, so we shelled out $35 for a unit described as "interpolation calibration failed." Turns out that the error was caused by a marginal P/S (I should have guessed this) which died about 5 minutes after I turned it on. Great - remember the last time I tried to fix this Boeschert supply (see above)? I wasn't exactly successful. So I opened up the P/S only to find electrolyte all over the place. I removed the 29 caps and I would say at least 20 of them were bulging/leaking. At that point, I removed the 29 new caps from my previously attempted fix and installed them into this supply. Still no joy as the 5V supply could only reach about 4.5V and was very touchy if I tried to adjust the switching oscillator frequency. I exchanged a lot of active components with the old supply, but nothing helped. At one point, I removed the optoisolator which then cuts the feedback loop only to find that nothing changed. At that point, it was clear that something was simply bringing the 5V line down a bit. I found an SCR on the control board and in desperation clipped two of the three leads. Voila, the 5V line came up and I was able to properly adjust the 12, -12, 3.5 and -5V rails (only after I replaced the adjustment pot on the -12V line that I had damaged by chiseling off the epoxy seal). Just for fun, when I was all done, I hooked back up the SCR. Still worked perfectly - go figure. The best explanation I can come up with is that all the voltages or "or"-ed into the SCR and the thing was way out of adjustment (since I turned all the pots many times in a futile attempt to get the thing to work). That dragged down the 5V supply which serves as the reference for the SCR trigger and the thing got stuck since one or more voltages was then too high with respect to the reference. Only after I removed the SCR was I able to properly adjust everything and then the voltages were OK after reapplying the SCR. I prefer this original P/S to the one I built because the homebrew supply is very noisy and causes the 53310A to exhibit a few artifacts in the count with signals near the switching frequency (~50 kHz). None of the artifacts with the original supply. Stay tuned...Final, Final, Final Postscript: Saw a post on the web about installing Option 001, Expanded Memory. Bought four CY7C194-20 64Kx4 memory chips, configured a few jumpers, and voila - expanded memory. HP 54112D: Four channel, 100 MHz digital sampling oscilloscope. The 54112D (and its big brother, the 500 MHz 54111D) were developed in the late 80's and were among HP's first foray into digital scopes. Sort of like the Chevy Vega and Ford Pinto were GM and Ford's first foray into fuel efficient cars - we all know how that turned out. This unit samples at 400 MHz so it truly has a one-shot bandwidth of 100 MHz. The bandwidth is not restricted to repetitive signals as many "compromise" digital scopes are (those scopes essentially sample a waveform asynchronously so that it builds up completely over many cycles). However, it feels like HP figured out how to build a digitizer and put the waveforms on a color CRT. It was only then that they thought, "hey, we can make an oscilloscope out of that." The user controls are not what a scope user really wants. Every function must be selected from menus via soft-keys on the bottom and/or right of the CRT and then the knob (or keypad) used to make the adjustment. Real scope users want separate knobs for vertical, horizontal, trigger, etc., that are easily accessible without a lot of punching keys. And find me another real scope that has a numerical keypad. Although, I have to admit that it is nice to be able to type in 234 mv/div when I want to. The scope has a nice auto-configure function that examines the inputs and also has an extensive automatic measurement capability. There are a few odd trigger functions that look like they were borrowed from a logic analyzer. On the other hand, there are some missing things like the ability to ground a channel. All in all, very nice for 1988; not so nice afterwards. HP quickly came out with the 54600 series about five years later and they put the 54112D to shame by comparison (although their one shot bandwidth is low). The improvement in the 54600 series is most apparent in the waveform update rate which is orders of magnitude higher than the rather paltry (~30) update rate of the 54112D. The 54112D certainly deserved an A grade back in the day, but I have to deduct points for the user interface and for only effectively a 6-bit digitizer. Grade: B+ (PDF)This is going to be a long description, so take a deep breath. But based upon the amount of time and effort I spent with this unit, the long description is entirely justified. I paid $80 on eBay for this from a seller who advertised only two of the four channels working correctly. His description was perfectly accurate: channel #1 and channel #2 were fine, channel #3 and channel #4 were "noise." While I was pondering that, I noticed that the display wasn't very bright. Moreover, the colors in the top third of the display were a bit off and the rectangular background grid was a bit compressed, but only between the 7th and 8th divisions. I tweaked every one of the about 20 pots on the display driver boards to no avail. The CRT (a Sony Trinitron) takes 120VDC from the main P/S and I measured only 95V at the test point. I disconnected the P/S and pulled it out. Unloaded, I still was only getting 95V, so that's the good news (P/S fault, not display fault). In my past experience, I noticed that HP often put Zeners on the output of their supplies as over-voltage protection and I've seen them partially fail and drop down the supply voltage. Perusing the board, I didn't see any Zeners close to the 120V output, but I did see two 3-terminal TO-92 devices. The transistor tester lit up on one but not the other. So I pulled them both out and put them on the Peak Component Tester. Again, one was "OK" (identified as two diodes) and one was "No Component Detected." Looking up the HP part number, the devices were found to be TL431 adjustable shunt regulators, i.e., an adjustable Zener. So my initial Zener guess was correct. I ordered some replacements and the new one brought the 120V supply back to 120V and cured all my display problems.The next order of business was to take care of the probe calibration terminal on the front panel that had snapped off. Fortunately, a simple capacitive feedthrough I found in the junkbox mounted in nicely and gives me a little post to hang the scope probe onto.Returning to the guts of the 54112D, the first order was to dissect and clean the four input pods (each pod contains solenoid-controlled attenuators and preamp and trigger hybrid ICs). HP was proud of these custom input pods and has an article in the HP Journal dedicated to them. Working on these is not for the faint of heart as they contain microscopic little spring contacts. One wrong move and they will fly across the room never to be seen again. A few nerve-racking hours later, I had disassembled, cleaned and reassembled the four pods. That kept channels #1 and #2 working, and now channel #3 showed up correctly, except that the unit wouldn't trigger on channel #3. Channel #4 would occasionally show up depending on the V/div, impedance selection and offset value, but then would quickly disappear. And when the trace was there momentarily, it also wouldn't trigger on channel #4. The scope has four A/D boards for the four pods. By switching boards, I determined that the malfunction was most likely the fault of the boards, not my recently worked input pods. Well, good luck fixing the A/D boards with no schematic, no parts list, no detailed functional description, and of course, none of the HP hybrid ICs. As luck would have it, I spotted an eBay listing for parts from an HP 54111D (the seller said the parts came from a 54111D with a broken CRT). The parts included all nine circuit boards and four input pods (two signal pods and two external trigger pods). So, for $100 I bought that with the thought that I could gut the 54112D and turn it into a 54111D. The conversion took a few hours and when I was done, all I got was one channel working "correctly." The trace was fine, but the voltage measurement was about 15% high and would not calibrate correctly. The second channel showed a highly distorted waveform as though the thing was sampling three or four times (in retrospect, the 1 GHz sampling rate of the 54111D is accomplished via interleaving four 250 MHz converters and it was this interleaving that seemed screwed up). Tektronix TDS520: Two+ channel 500 MHz digital scope. It actually has 4 channels, but the last two are called Aux1 and Aux2 and have limited vertical sensitivity choices. Moreover, there are only two digitizers, so you can only do two channels out of the four at once. While the bandwidth is 500 MHz, the maximum sample rate is also 500 MHz, so you had better be looking at repetitive signals up there. Tektronix 466: 100 MHz storage oscilloscope. If you practiced electronics in the 1970s or 1980s, chances are you used one of the Tektronix 400 series oscilloscopes. I can't think of too many other pieces of test equipment as ubiquitous as these except perhaps the Simpson 260 VOM or the HP 8640B signal generator (if you did RF work). My particular scope is the storage version of the classic Tek 465. It's pretty much everything you would expect of a 100 MHz dual-channel analog scope, so no need to bore you with the details. (PDF) Grade: B+I bought this for $50 in condition unknown, other than the picture showing a trace on the CRT. When received, I turned it on and started exercising the controls to see what worked and what didn't. A few minutes later, the CRT went blank and I smelled something burning. A visual inspection revealed nothing, and when I powered it back up, the power supply voltages were OK and the scope ran fine - it's been running for days without anything burning. So if something popped, it must have popped open. Maybe I'll see the effect of that, perhaps not. The scope basically worked except there were three minor problems. First, the delay position 10-turn pot was extremely noisy, so it was removed, dissected, cleaned and reinstalled. Second, some previous owner must have set the scope on its front panel which put all of the weight on the two V/div variable knobs and the time/div variable knobs, which transferred the weight onto the potentiometers on the circuit board. In the case of the two V/div pots, all that did was to bend them slightly off the board - no big deal. But the time/div variable pot was nearly sheared off and when I removed it, the pot measured infinite resistance. The pot was one of those black, square, ganged job with the back portion containing two switches and the front portion a standard 50K. I managed to find a 20K pot in a spared Tek 7B53A plug-in, so I used that. There is about 50V across the pot, so I think the 20K will survive at about 1/8-

watt. The third problem was the channel #1 lost the signal input at 2, 0.2, and 0.02 V/div settings. This led me on a whole day wild goose chase on the attenuator board. At one point, with all components removed from the board, I was measuring 7 ohms resistance from an isolated trace to ground! Bottom line: when I finally pulled the now empty circuit board away from the aluminum mounting structure, out popped a tiny washer. Somehow, somewhere this "shorting" washer found its way onto the board and then hid itself under the mounting. Everything now seems to work fine, although I'm sure the 466 could benefit from a complete calibration. Not something I'm looking forward to given that it is also 50 pages long.Postscript: Did some minor tweaking of the adjustments in the attenuators and the sweep timings and the 466 is now pretty accurate. Adjusting the fast storage mode, however, is not for novices. I think I have it as good as it is going to get. All these Tek storage scopes are a huge pain in the ass to set up right and operate. Of course I have perfectly good digital scopes if I ever need to "store" a waveform. To make a long story short, I also found two defective ICs and a defective zener, once I wired around the middle layer defects. HP 8901A: HP's basic modulation analyzer. Produced in the mid 1960's to mid 1970's, the 419A must have been pretty impressive at the time. Some fifty years later, it still is pretty impressive. (PDF) Grade: A-The seller offered no description as to whether or not this piece worked and naturally I assumed the worst. And I wasn't disappointed as the NiCd batteries were completely toast and had corroded quite a few nearby connectors. I removed the batteries, cleaned up the corrosion and installed two 12V Zeners where the batteries had been (the 419A can run off of AC power). Powered the thing up and - absolutely nothing. There was +/-12V present on my Zeners but that was as far as the voltages went; the two circuit boards had zero power. The P/S voltages are actually distributed through the pushbutton switches and a quick check with an ohmmeter showed that almost all of the switches had infinite resistance when closed. I blasted the whole set with contact cleaner, worked the switches a few dozen times, and that did the trick. The 1.35V mercury battery tested fine, but the battery holder had cracked. I thought about gluing it all back together, but there was so much corrosion on the contacts, I simply cut the wires and soldered them directly to the battery. The only other obvious defect was the glass in front of the meter which had dislodged and was preventing the needle from swinging to the right. It wasn't too bad to pull the meter, take it apart and glue the glass back. But I had to pull it out a second time because when I first put it back, I didn't notice that I had dislodged the neon power-on light. AM and FM modulation. HP must have sold tens of thousands of these over the years. Every lab seems to have one. (PDF) Grade: A-This was one of the first signal generators I worked on. When I first turned it on, the P/S caught fire - literally. After I put the fire out, there were a few traces that had melted away. Jumpered them with heavy gauge wire. A couple of years later, the display intermittently showed the frequency as 0000.00. Turns out that they mounted the P/S pass transistors on the back panel and then put a metal screen over them. Metal screen gets pushed in, touches the TO-3 cans, shorts to ground, so you get the picture.Postscript: Preemptively replaced the Rifa 0.022 uF Y-capacitor hanging off the line filter with a non-Rifa 0.01 uF X-capacitor. The capacitor was across L-N, and the line filter internally had two Y-capacitors between L-G and N-G, so using an X-capacitor was fine. Keithley 179-20A: Pretty basic 4-1/2 digit DMM. I guess the -20A refers to the 20A option. Keithley always made very high-end stuff, much too expensive for my meager budget. So this was my chance to own one of their pieces as it was in a single buy with the Fluke 8050As and Fluke 8800A. The build quality is pretty average, but the thing seems really accurate. (PDF) Grade: B-Nothing was really wrong with this except dirty switches and a blown internal fuse. It was very easy to calibrate since the inner cover plate has the step number, the instrument setting, the calibration voltage and the expected reading all printed on it with arrows pointing to all the adjustment pots. Cheap Chinese knockoff, but useful for a quick survey or to check harmonics of signal generators and the like. Very limited selection of two resolution bandwidths plus a drift of 100 kHz in one hour. This really is a poor man's spectrum analyzer. It's one of the very few pieces that I bought new and I've been disappointed with it ever since. Typical Chinese construction using low grade parts, poor board layouts, poor mechanicals, etc. Those viewing this page may note that there are very few spectrum analyzers listed. For some inexplicable reason, the eBay prices on used spectrum analyzers are proportionally way out of line compared to just about any other class of equipment. (OM) Grade: C-Postscript: Not that I have any use for this piece given my other spectrum analyzers, but I recently turned it on after a few years of dormancy just to see if it still worked. It didn't. In fact, the CRT was dark (although the filament was glowing) and the display and controls were frozen at the upper frequency limit. I gave it the visual once-over, but everything looked fine. By some quirk, the service manual for the re-branded Hameg HM5011 was on the web and if it weren't for that, I would have given up. The immediate problem was that the 12V line was shorted. This serves as the reference for -12V and for the voltages that are developed to supply the CRT, so no wonder everything was hosed. I pulled the P/S output line and the short was confined to the P/S. The pass transistor output has two capacitors hung off the output and I was sure it had to be one of those, since nothing else had a clear path (without a resistor) to ground. But it turned out to be the thermal insulator for the pass transistor that had failed, shorting the case to ground. After that was fixed, all the controls/displays went back to normal, except that the CRT was still dark. The -2000V going into the CRT board from the P/S was fine, so I pulled the CRT board and took a look. There was a 4N35 photo-transistor in a socket and when I pulled that and put it on the component transistor, the diode was OK but the transistor was toast. I managed to find an MCT2E in the junkbox and threw that in. Whoopee, the CRT came up just fine. There is also an LED hung off the base of the photo-transistor which is unlit and my guess is that opened up as well when the photo-transistor blew. I'll test/replace it one of these days. Until then, back on the pile the 5011 goes for a few more years. I would have liked to paint over the 0, but I couldn't get a satisfactory look, so I simply added a small red decimal point between the 1 and 0. I guess I would call this innocuous little unit a "sleeper," because it just does what it's supposed to do. I stripped off the labels, which were unreadable anyway, and gave the case a new paint job.Postscript: The fact that all of the 0.001 ohm increments read about 0.0006 ohms has really been gnawing at me. When I pulled the cover off of the bottom board, I was met with an unbelievable stench. The 2005, and its follow-on 2005A, have achieved cult status among tinkerers because the ripple and stability specs are better than most supplies being built today. This was verified on five different high precision DMMs as well as the HP 4328A milli-ohmmeter. Boonton 8210: A weak version of the Boonton 82AD listed above. Responds to RF from 2 MHz to 1.5 GHz with FM deviations of up to 100 kHz and AM depths to 100%, both in 10 and 100 ranges. Pretty self-explanatory from the picture. The demodulator does its thing and a Z80A uP does its thing. (PDF) Grade: B+Advertised as display not working, I thought it would be a simple fix. I was wrong, and the culprit seemed to be the Z80A reset circuit on power-up that was not functioning correctly, so the processor would simply hang. Many pointless hours later, I still had not gotten to the bottom of it, even though the reset circuit basically consists of a resistor and a capacitor. It might have been due to the leaking AAA batteries inside that covered part of the processor board in green goo. Anyway, I'm not inclined to pursue it further. I simply lifted the reset pin of the Z80A out of the socket and attached a small pushbutton switch on the back panel that grounds the line (while being held high by a pull-up resistor). Turn it on, press the button for a second and let go. Works fine.Postscript: To show you all what kind of fool am I, I looked at a later version of the service manual and step 2 of the troubleshooting chart is to check the memory back-up batteries. I initially thought that the absence of batteries would simply cause the calibration constants to be lost, but the unit goes through self-cal for 30 seconds upon start-up anyway. Not so fast. The schematic shows the batteries running through a DS1210 memory controller/battery back-up chip that has the nasty habit of screwing around with the RAM chip enable line if it doesn't like what it sees. Bottom line: two new AAA batteries and the thing starts right up, without any extras like my reset switch, and once the cal was completed, subsequent power-ons omit the start-up cal procedure I've seen this kind of behavior before - see the Racal 5002 below - but what confused me with the Boonton 8210 was that the thing mostly did work with my reset switch. I guess there is some checking by the uP at startup and I was able to get past that somehow.Postscript^2: Replaced the two AAA batteries which had leaked pretty badly in their plastic enclosure (but surprisingly measured OK) and the front panel power LED (which was very dim). C : C&C, Chinese No-Name, Circuit Specialists, Clarke-Hess, Cushman C&C 150U: 150 MHz frequency counter. This is a basic, no frills two-channel counter, as vanilla as it gets. Will do frequency, period and interval or ratio between channels. Input selections include AC/DC coupling, 10:1 attenuation and a 150 kHz low-pass filter. The gate time is selectable and controls the number of digits displayed (maximum of 8). The counter is designed around a custom ASIC and it is clear that C&C had one set of firmware for multiple models because pressing the function buttons leaves a "no-op" condition between Freq B and Period A where there must have been a "C" channel function in another model. Being a 7-digit per second counter, it is a good two or three orders of magnitude worse than your "normal" counter. Designed (and perhaps manufactured) in Korea, the build quality is surprisingly good. That is, until you try and fix it - then you get the real surprise (see the repair notes below). (PDF) Grade: C-Advertised as not powering up, I couldn't really resist at $19. The unit powered up just fine once you set the internal/external oscillator switch on the back panel correctly (when set to external, the unit actually does power up - it just looks like it didn't since the processor has no clock and the front panel is dead). There is a trigger level control on the front panel which was doing nothing. When I traced the circuit, the pot was wired incorrectly, so I switched two wires and brought the control back to life. But on the "B" channel, things were really hosed. The low-pass filter didn't work right, nor did the AC/DC coupling switch. Again, I traced the circuit and much to my surprise discovered that the front panel labels were incorrect! The three switches for the "A" channel and the three switches for the "B" channel are marked (from left to right), Coupling, Attenuation, Filter. But the "B" channel was actually wired as Filter, Attenuation, Coupling. I went back and looked at a bunch of eBay pictures of this model up for sale and saw several that were marked on both channels Coupling, Attenuation, Filter, and several that were marked Filter, Attenuation, Coupling. Nowhere did I see Coupling, Attenuation, Filter on one channel and Filter, Attenuation, Coupling on another. Perhaps there was a board revision and my unit's board was repaired with the wrong rev. Remains a mystery to me. Finally, as the picture shows, the display window looks terrible. That's because my units plastic window was nearly opaque and when I went to clean it with alcohol, the window turned into a gooey mess. So I hacked it out and put a piece of acrylic in. I did a terrible job, but then again, when will I ever actually use this piece of junk? Chinese No-name TES200: This is an integrated circuit tester. I have no idea who the manufacturer is but it was less than $40 shipped to my door from China. This thing tests 7400 TTL and 4000 CMOS series chips, several hundred of the most popular numbers; just what I need for 1970's and 1980's vintage repairs (but pretty worthless for modern equipment). The operation couldn't be simpler: Use the mode button to switch between TTL and CMOS, then use the up/down buttons to select the chip number, insert the chip into the ZIF socket (pin 1 up) and press the test button. If it is a multi-gate chip like a quad NOR, the display will strobe out Gate 1 OK, Gate 2 OK, etc., until the end when a good/bad conclusion is presented. Obviously there is no connection to a computer and no hope of adding new chip data. In fact, the processor on the board has been sanded down to remove the markings. I guess the Chinese are afraid someone even cheaper than them will mass produce the thing. On the whole, however, very nifty and useful. (PDF) Grade: A-Postscript: Picked up another no-name Chinese IC tester for twenty bucks (picture not shown). This one is being sold as a "Multi-Function IC LED Optocoupler LM399 DIP Chip Tester." Operating off of a single AAA-cell, one inserts a 7400 or 4000 IC, presses the button, and a single alphanumeric LED strobes out the chip ID if good. It also can light up LEDs of all kinds and test about a dozen non-logic chips. Seems to work as advertised, but sometimes can give you the wrong ID (namely any other IC that has the same functional inputs and outputs). (PDF) Grade: A- Circuit Specialists CSI-3003X: 30V, 3A P/S. Desoldered the old one, put in the new one (socketed of course) and.... Hooked everything back up, threw the power switch and the display now read "Starting self-test," followed shortly thereafter by "Self-test passed." Then the display showed what looked like unsync-ed video gyrating all over the place. HP 5359A: Very, very expensive dual of the HP 5370 counter. So if I dial in 90 uF + 100 pF, my 100% error becomes miniscule since it is dominated by the 90 uF. The 30 MHz crystal had a big dent in it, like someone tried to "adjust" it with a pliers. The upper unit had a broken custom output amplifier IC and was replaced by a board designed by me. If you are looking for the ultimate time mark generator, this is it. If you just want to impress your friends by putting out a pulse exactly 13.456873 usec after a trigger, this is it. If you want to draw over 200 watts (a lot for an HP piece), this is it. Important note: The 5359A is a time synthesizer, not a pulse generator. Sure, you can set it to output a pulse train, but only the width of the pulses are what it cares about. The actual period of the pulse train can and does wander. So if you reach for this piece without thinking and hook it up to a frequency counter, the jittery readings might lead you to conclude the 5359A is faulty - it isn't. (PDF) Grade: AOne of the units worked fine. The other one produced funky output. The output amplifier is a custom HP hybrid which can't be replaced. So I built a board using an analog multiplier and some ECL glue chips to replace the hybrid. It doesn't give me quite as sharp rise/fall times as the other working unit, but it's good enough.Postscript: For checking/calibrating pieces like a time interval analyzer (5370A, 5371A, 53310A), one can set the 5359A, for instance, to a 100 nsec pulse width and then measure pulse width on the analyzer. However, the 5359A with the replacement amplifier has particularly long rise times that can influence the measurement. Fortunately, there's a better way. Simply use the 5359A's two auxiliary output jacks on the back panel that put out nice sharp pulses synchronized to the start and stop of the output pulse (these are ahead of the output amplifier). Then put the analyzer in time interval mode, not pulse width. Works like a champ.Postscript^2: A few years later, I traded a work buddy some spare Fluke 8502A boards for the 5359's A18 output board from his spare unit. I ripped out my hybrid replacement board and installed the new HP board with the functioning output amplifier. But even then, the unit threw error 9.1 and the output was all wrong. Turned out to be a faulty 2N3906 (A17Q4) on the next board over. Other than that, it should be fixable. HP 3324A: 21 MHz function generator. While the HP 3325A (and successor, HP 3325B) were perfectly good function generators, HP decided to build a more "modern" version. Why, I'm not quite sure, but perhaps they managed to get the cost (and retail price) down. The general specs are not really any better than the 3325 series, but the 3324A is a little more capable in the sweep department. Very strange build quality containing both surface-mount and through-hole construction. Shown here measuring a few billion ohms resistance of a piece of a Q-tip. I don't often need to measure the resistance of a Q-tip, but when I do, I've got the piece that will do it! Seriously, I have used this to measure some of the stupidly high resistors in the Simpson and Triplett VOMs. (PDF) Grade: A- HP 4332A: Analog LCR meter. The 4332A measures inductance, capacitance and resistance in 12 ranges on a 1-3-10 scale. The full-scale ranges are 3uH - 1H, 3pF - 1uF and 3 ohms - 1000 ohms. The series-parallel selection and AC measurement frequencies are pre-ordained by the unit (L-series, C-parallel, R-series at 1 kHz or 100 kHz). By the time you add up all the accuracy specs, the basic conclusion is about 2.5%. Measurements are done with a two-terminal arrangement, however there is a third guard terminal which really needs to be used, for instance, at high resistance measurements. Nowhere as good as the digital LCR meters (e.g., HP 4262A or HP 4274A), but the small size makes it very convenient for a quick measurement. ($CD) Grade: A- (see Postscript below)Postscript: I made up a set of test leads which makes the 4332A so much better at both extremes of the ranges. The High and Guard terminals go through a banana plug to BNC adapter. The other end of the BNC cable has the shield clipped at the end and the inner terminal to an alligator clip. The Low terminal uses a banana plug to a wire to another alligator clip, with the wire simply loosely wrapped around the High/Guard coax. I've now bumped up my previous grade of B+ to an A-.Upon receipt, the 4332A almost worked. Many of the ranges were spot on, but there were others where it was flaky. For instance, the meter is supposed to read zero for a C measurement with the input open (and there is a zero pot on the front panel for fine adjustment). But mine was reading about 40 pF and couldn't be zeroed. The upper R scales were also gyrating a bit. I bought the manual (the on-line free version was unreadable) and a few days later settled down for a nice troubleshooting session. While I was getting the scopes and voltmeters set up, the 4332A settled down and all the problems disappeared. I went through the calibration procedure and all the adjustments worked as expected. This may have been another instance of a dormant piece needing a few hours to reform the capacitors. All that was left was to replace the burned out neon bulb in the power switch. But HP used a strange switch where I have no idea how to remove the neon bulb without destroying the switch button. So I simply exchanged the entire switch with the more standard version found in my pile of defunct HP parts. HP 3570A: Narrowband network analyzer. Not very good with no solder; the ground of the IC was definitely not making contact (I didn't check some of the other pins, but who cares at that point). HP 419A: DC Null Voltmeter: Although the 419A will function as a standard DC voltmeter, its real utility is as a null meter; such a beast is used most often to compare two voltages, as in calibrating a voltage source to a standard. It is very similar both in circuit design and performance to my Fluke 845AR (see the description for that item) so I won't bore you with the specs. Although the Fluke 845AR has a 1uV full scale setting, the HP 419A only goes down to 3uV full scale. However, the meter is so much nicer (larger) on the HP, you really don't suffer too badly and can easily interpolate down to tens of nanovolts. One nice feature of the 419A, absent in the 845AR, is the ability to achieve basically infinite input impedance at the null. This is done through the use of a bucking voltage supply (1.35V battery) that is switched into the circuit to "cancel" out the input, and then reversed in polarity to produce the final voltage reading. Of course, the 1.35V mercury batteries are no longer available, but there are easy alternatives available. The photo of the 419A shows the reading against 1uV obtained from my Fluke 343A DC calibrator, set to 100uV, feeding my ESI RV622A divider, set to 0.01. So much for modern European design. When I opened it up, there was a QA sticker on the frame that said "This unit was built 100% right," signed by some Sencore technician. The basic specs are 0.1% accuracy making this thing at the top of the LCR heap. That can't be good. I remembered that I never bothered to reconnect all the good capacitors that I clipped, and after I did that, all was well. Wavetek 164: The 30 MHz version of the Wavetek 166. Soltec VP-6415S: This is an x-y plotter that can be used to make simple unannotated graphs. Many of my test equipment pieces have an output jack with a voltage proportional to what the equipment is measuring. Just hook that output up to the y-input of the Soltec, set the Soltec's internal time base to control the speed of the x-direction and plot away. For instance, use the Soltec in conjunction with a selective level receiver and plot signal power vs. Currently being fed with VHS tape. Everybody needs a 14 channel instrumentation recorder, right? This thing must have cost upwards of $50K when new. It works great providing you can find 1/2" instrumentation tape at a reasonable price. I couldn't. (OM) Grade: B+What a beast! Had to manufacture my own take-up reel and had to have the capstan re-rubberized. There were faulty CD4011 and CD4013s on channel 14's record board.Postscript: The tape transport mechanism uses two mechanical arms to measure tape tension and feeds back the imbalance to the spool motor drivers. These arms operate on oil-filled bearings to provide dampening. On my unit, the oil had leaked out of one of the arms and despite all efforts to fill it back up, the arm exhibited no dampening. This caused the tape transport to suddenly stop once in a while during rewind or fast-forward. About a year after I bought the 14DS, I saw a "parts unit" for sale on eBay. It was basically complete except for some of the cabinet parts. The price? A mere 99 cents (plus shipping). Now my tension arms operate like they should. Plus I now have three boxes full of spare motors, spare circuit boards and miscellaneous switches and other mechanical parts. Is this a great country, or what? In fact, it is pretty much unmeasurable on any of my AC voltmeters and can't be seen on any of my scopes. The unit appears to be in spec from the limited performance tests, but someday I might try the calibration as soon as I can come up with two 15 pin extender boards and one 10 pin extender board all the same height. Oh, there are well over 100 pots/caps to adjust and I estimate at least six hours to do it right.Postscript: One day, I entered 50 nsec for the A-channel pulse width and got 500 nsec out. Moreover, the pulse widths were all OK for values less than 50 nsec, but abruptly changed to 500 nsec the moment I entered 50 nsec. And it basically was flaky all over - for instance, a change in amplitude affected the pulse width. The B-channel, however was all good. I exchanged A- and B- channel width boards (the one of three that handles each channel's >50 nsec widths) and the problem moved with the exchange, so that narrowed it down to one board. Finally, I noticed that when I changed a B-channel parameter, that also affected the A-channel. All of this pointed to a problem with what HP called the "acceptor," on the A-channel width #3 board, which is just a fancy way of saying an address decoder. The acceptor is implemented with five CMOS 4000 chips and I had three out of five in my junkbox, so in they went. Turned it back on and everything works. Funny, but the little Chinese TES200 IC tester I have indicated all three of the pulls were OK. My guess is that the flip-flop was the faulty component and the tester isn't very good - the other two chips were simple combinatorial logic and it would be hard to fool the tester on those. Anyway, who cares - the 8160A works.Postscript^2: Turned the 8160A one day and I heard a few pops followed by a terrible stench emanating out the back all the while the unit seemed to work just fine. Indeed, one of the notorious Rifa 0.22 uF suppression caps exploded. I replaced it temporarily with a 0.1 uF cap, but since it is part of the snubber circuitry across the main transformer in the switching power supply, I ordered the correct value and in it will go.Postscript^3: I decided to replace all nine of the Rifa suppression caps in the P/S since if one exploded, others are sure to follow. Curiously, all nine caps read very high on the LCR meter - most by at least 50%. Now, the May 1979 HP Journal describes the 8160A's P/S this way: "accessibility and hence serviceability are good thanks to modular design with functionally separated plug-in boards." Yeah, right. The supply is crammed together with virtually no free space. It took me several hours to pull out the line filter board, A13, since it is directly soldered to the back of the AC receptacle and fuse holder that stick through the outside (non-removable) cover, and there is a riveted bracket in the way that has to be drilled out. And then when you try to lift the board out, there are several parts on the motherboard in the way that must be removed. "Serviceability?" I guess if you just want to probe parts of the boards, it is OK. "Accessibility?" Not a chance in hell. It's a bit of a shame because someone at HP must have given the designers a volume constraint on the P/S. The whole supply sticks out the back, but only about half of the back panel is interrupted. They might have made the supply a bit larger one would think. Wavetek 21: The Wavetek 21 is a 100 uHz to 11 MHz function generator producing sine, square, triangle, ramp up/down, haver-functions and DC with a maximum output voltage of 10 Vp-p into 50 ohms. It has the usual gated and trigger modes. The 3-1/2 digit LCD displays only frequency; you are on your own for amplitude and offset. Typical of many of the early Wavetek function generators, it is not particularly accurate nor is it low distortion. The thing generates signals in the usual analog fashion (charging/discharging a range capacitor from a current source) over 1.1 kHz and digitally (via a ROM-based wavetable) under 1.1 kHz. The ramp up/down and haver-functions only are generated digitally, hence they are restricted to 25W and it does it one transistor and resistor at a time. Solder was then used to bridge the connections between the two boards. The scope may go to >100 MHz, but it's only 6 bits! Nice touch screen. I'm sure HP impressed everybody with the nice color screen, but the thing is horrendously slow and extremely cumbersome to use. And who wants to fish out the floppy disks every time you turn it on? I'll use the HP 1630G, thank you. (OM) Grade: B-No electrical problems, but the front floppy drive didn't work. I dissected the drive and fixed the pawl and gear. Tektronix PS503A: Triple output power supply plug-in for my TM5006 mainframe. Will do a fixed 5V @ 1A and dual 20V @ 1A. This is one of Tek's better attempts since it has full current limiting controls plus a nifty tracking potentiometer that will adjust both 20V supplies to a proportion of their settings. (PDF) Grade: A-Nothing to do but replace one of the internal fuses and spritz the switches. Tektronix T912: Two channel, 10 MHz storage oscilloscope from the 1970s. Pretty useless nowadays except possibly to repair some vintage audio equipment or to teach a high school student how to use a scope. Does not use any custom Tek semiconductors, so is relatively easy to fix. Moreover, unlike most other Tek mechanical designs, this one seems well thought out and is a snap to disassemble (once you've read the manual). A bare bones piece but implemented very well for what it is. ($CD) Grade: B+The T912 was received in the advertised condition: fan runs when powered on, no other activity seen. A check of the internal fuse on the (unregulated) 120 VDC power supply output showed it blown. Moreover, an inspection of the P/S board revealed an electrolytic cap with a broken solder joint and a shorted diode nearby. After the fuse, cap and diode were replaced, the scope powered up fine but not all the P/S voltages were correct. Indeed, the regulated 120 VDC was about 12 V; the unregulated 120 V was fine. Rather than separating the P/S from the rest of the circuitry (I figured out an easy way to do this eventually), I removed the transistor in the 120 V regulator circuit responsible for foldbacking the supply in the event of over-current. That immediately let the smoke out on the board driving the CRT. One of the 120 V lines goes through a 470 ohm resistor into one of the CRT grids with a 0.033 uF cap to ground. The cap had shorted and now I had full current through the 470 ohm resistor - poof! Once the cap and burned resistor were replaced, all my P/S voltages were correct and the scope appeared to work. Shortly thereafter, however, the trace went to full brightness with little change from the intensity knob and was unable to focus sharply. Also, on certain time bases it looked like the scope was drawing a second waveform on top of the first one with about 1/10th the sweep time. And at low time bases (>1 msec), I was only getting about 1/4 of the horizontal waveform and the retrace time seemed way too long. This all pointed to something to do with the blanking circuit, but it wasn't clear what the intensity and/or focus problems had to do with the blanking. While I was trying to diagnose, the scope abruptly started to work flawlessly. Over the next few days, sometimes it would work and sometimes it would go into the weird behavior. When it did change and I happened to be watching, the change was instantaneous. Finally, the CRT went totally dark. The HV (~ -2700V) for the CRT cathode and grid are developed off two secondaries of a switching power supply transformer each having a 10 KV, 10 ma diode. When I tested these with my DMM, they were open. This led me on a wild goose chase debugging the HV circuit until I stumbled on a repair forum describing how to test these HV diodes. [Lesson #1: HV diodes are internally comprised of several lower voltage diodes in series. Hence, your normal DMM (either ohms or diode function) doesn't have enough output voltage to get the diode to conduct - they will read open in both directions]. So I hooked up my HP 6177C current source with a 50 V compliance and successfully pumped a few mA through the two diodes (with no current in the reverse direction) which proved the HV diodes were indeed OK. So back to the original problem - the unblanking signal. This signal actually is summed in with the intensity control voltage which explains why a malfunction in the unblanking could also effect the trace brightness. The unblanking signal is developed via two 7400 quad-nand chips on the horizontal board, so I pulled them both out and one tested bad. Socketed the two ICs, put the good one back and a new one for the bad chip. That seemed to fix my problems until I noticed that now the auto and normal triggers don't work correctly. [Lesson #2: When you desolder an IC, then socket the board, don't put the old IC back. It may not make good contact in the socket. Either put a new IC in the socket, or directly solder the old IC back in the board]. After I removed the sockets and soldered the chips back in the board, everything was fixed. Or was it? Now the vertical baseline on channel #1 was moving all over the place with the V/div knob. All my jostling around with the boards must have loosened some of the pins that are used as board interconnects, because there is one particular screw that helps hold the vertical board in which cured the vertical baseline problem as soon as I loosened it a half a turn! I simply left the screw out rather than putz around with it any more. Tektronix TDS350: Two channel, 200 MHz digital scope from the mid-1990s. Although the nameplate says 1 Gs/s sampling, Tektronix cheated a bit. Sure, the analog voltages are "stored" at that rate into an analog ASIC. Then they are digitized into memory at 25 MHz. While this preserves the 1 GHz effective rate and no information is lost, the impact is, of course, a much slower waveform update rate than one would truly get at full speed. Since the anti-alias pre-sample filter Tek used has a rather shallow roll-off, the 1 GHz sampling should support waveforms up to 500 MHz. And so it does - the scope has no problems at all triggering and capturing a 450 MHz sine wave (albeit at a lower amplitude). Tek made a slew of related scopes in this era, the TDS 400, 500, 600, 700 and 800 series, each getting progressively better (and more expensive). Mine is the upper end of the TDS300 series (TDS310 at 60 MHz, TDS320 at 100 MHz and TDS350 at 200 MHz). They only lasted a couple of years until Tek came out with the TDS340, 360 and 380. The TDS series all share the fantastic basic front panel buttonology which pretty much has been maintained to the present day. Minimal interaction and everything is to the point. I'm usually critical of Tektronix equipment (particularly their 1970's and 1980's stuff) because of their excessively complex mechanical designs. But I do have to admit: Tektronix really does know how to make an oscilloscope. And I find the clarity of the CRT superior to the HP scopes of that era. (PDF) Grade: AI spent a fair amount on this piece: $150 + shipping. Usually I don't, but even broken TDS350s go for $300 to $500 routinely. Mine was advertised as condition unknown and the listing photo showed the boot-up screen with a "Cal Initialization Failure." My guess was that the NVRAM (a Dallas 256K RAM with an integrated, non-replaceable 10 year battery) was toast and that the thing simply lost its cal constants. Turns out the NVRAM, dated 1995, wasn't toast. But I dutifully replaced it with a 2013 date code NVRAM and ran the cal procedures only to find that they failed. The scope seemed to work somewhat on channel #1, but without the cal constants in my new NVRAM, the baseline (ground) was all over the place and the trigger levels were also way off. Channel #2 worked similarly, but the trace vanished off the screen at