# *Tektronix 49x/275x/279x-Series Spectrum Analyzer Service Notes*

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## *Errata and helpful notes on calibration/service procedures*

Page numbers refer to 494/P service volume 1, 070-4416-00, but in most cases there are equivalent pages/sections in all other 49x/275x manuals

**3. Deflection amplifier (gain and frequency response)**, p. 5-6

Step 3b: *Apply a 500-kHz signal...* In later editions (e.g. 494A/P volume 2, 070-5561-00), this was corrected to *500 Hz.*

Step 3b: *... and set Triggering to Int.* I've found that at least some models need to be left in *FREE RUN* mode to trigger on the specified video waveform.

The 49x/275x deflection amplifier underwent several revisions throughout production, including a complete redesign in 1988. Regardless of your instrument model, refer to the manual change information in the 494/A manual (070-5560-00) if your instrument has one of these newer subassemblies.

Don't forget to disable digital storage before adjusting the X/Y deflection gain. Recalibrate the digital storage subsystem immediately after any adjustments are made.

**5. Frequency Control System Calibration**, p. 5-9

Step e: When observing the markers, either turn digital storage off, or follow the procedure in **13. Digital storage calibration** first. I recommend calibrating digital storage immediately after the deflection amp gain, so you aren't confused in any subsequent steps by storage-registration errors. This is reflected in later manuals such as the 494A/P's.

Step e-3: *...apply 0.2 us time marks from the time mark generator to the RF input*. Any 5-MHz sinewave source is OK for this, especially if it's strong enough to create some additional harmonic distortion in the front end. Select 100 kHz RBW to yield narrower markers.

Step f: *Max Span Dot* Don't bother to change the resistor based on the response at the left end of the display, as the manual specifies. Change the resistor only if the dot marker is substantially out of alignment at higher-frequency markers, e.g. at 1.8 GHz in step f-3. (The 1.8 GHz marker may be too weak to see; neighboring markers are OK for this test as well.)

**Figure 5-10: Adjustment and test point locations for calibrating the frequency control system,** p. 5-11

TP1073 is located on the Span Attenuator circuit board, not the 1st LO Driver circuit board as shown in the 494/P and earlier manuals.

**8. Log Amplifier Calibration**, p. 5-14

This procedure involves various interacting control settings, ambiguous instructions, and printing errors. Don't adjust your logamp unless you actually need to. Symptoms such as excessive amplitude drift will not be corrected by calibration alone.

While Tektronix continually upgraded their instruments to use the latest modules in production, the same cannot be said of their service manuals. Calibration-procedure change notes were never issued in many cases, so it's best to follow the instructions in later 49x/275x instrument manuals whenever they apply to the modules in your instrument. When searching for the correct schematics and service information for your instrument, date codes on components are often a better clue than the model nomenclature on the front panel.

For example, you may not need to install your logamp on extenders and remove its covers, as recommended in step 8b on page 5-14 of the 494/P manual, if your logamp's control adjustments are easily accessible through the slots in the housing as they were in all later instruments.

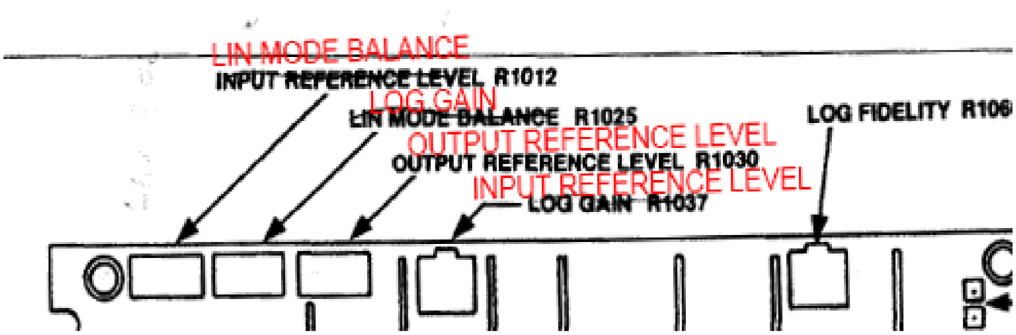
The first step in logamp calibration is to identify which of the three possible **Log and Video Amplifier test point and adjustment locations** figures (5-17 in 070-4416-00, or 5-13 in 070-5560-00 with two possible control layouts) applies to the module in your instrument. An analyzer with the older-style logamp uses figure 5-17 in the 494/P manual, while logamps in newer 492A/492B/494/495/497 analyzers and their 275x-series counterparts use the physical layout in figure 5-13 of the 494A/P manual.

The catch is that at least two different layouts were used for the controls in figure 5-13. At some point, probably around the time Tek redesigned the board using surface-mount components in the late 1980s-early 1990s, the trimmer functions were reordered *while their physical locations were left alone*. In earlier logamp assemblies, the order is as specified (left-to-right on the component side):

INPUT REFERENCE LEVEL R1012
LIN MODE BALANCE R1025
OUTPUT REFERENCE LEVEL R1030
LOG GAIN R1037
LOG FIDELITY R1060 (also called “log linearity” in some manuals)

In later assemblies, the correct control order is:

LIN MODE BALANCE R1025
LOG GAIN R1037
OUTPUT REFERENCE LEVEL R1030
INPUT REFERENCE LEVEL R1012
LOG FIDELITY R1060




Step h: *Return the step attenuator to 0 dB. Display should be full screen (+6 dBm); if not, readjust the signal generator output for +6 dBm*. This confusing step was modified in the later 494A/P manual (step i) but never actually "fixed." The overall goal is to achieve and maintain fullscreen (reference-level) response with +6 dBm at the input to the logamp. It's not clear what Tek's intention was when documenting this part of the calibration procedure, but it appears the intent is for the vertical position control to be adjusted to maintain a fullscreen indication with +6 dBm. If someone has a better interpretation, please email me and help keep this document up to date!

Note that the first-generation 492/496 logamp modules used 0 dBm as a reference level rather than +6 dBm.

If your signal generator has a calibrated attenuator (HP 8656/8657/8642/8662 etc.), you obviously don't need to bother with the step attenuators. Users of HP 8640s and other generators with vernier level controls will probably find it easier to use the outboard attenuators as specified.

When servicing your logamp module, watch out for corrosion from any surface-mount electrolytic capacitors that may be present. 494AP-era logamps were among the earlier surface-mount assemblies produced by Tektronix in the late 1980s. The quality of the surface-mount capacitors used at the time was terrible, as owners of other Tek instruments such as the early TDS-series DSOs can often attest. I've had to junk at least one logamp module due to instability and intermittents caused by this corrosion. See Symptom: Unstable amplitude response for more on this.

**8. Adjust Resolution Bandwidth and Shape Factor,** p. 5-14 of 494A/P manual (070-5560-00)

Step i: At the conclusion of this part of the procedure, reconnect J693.

**13. Digital Storage Calibration**, p. 5-22

The layout shown for the trimpots on the horizontal digital storage board in figure 5-24 is wrong. The correct order for these controls (from left to right) is:

OUTPUT OFFSET R1039
OUTPUT GAIN R1041
INPUT OFFSET R1046
INPUT GAIN R1048

Unlike the logamp controls above, I don't believe this control layout varies with the board revision.

As noted elsewhere, the digital storage controls should be aligned much earlier in the calibration process than the 494P manual recommends. Perform this procedure immediately after servicing or recalibrating the deflection amp.

**15. Preselector Driver Calibration**, p. 5-24

Follow the procedure **13. Adjust Preselector Driver**, p. 5-21 in the 494A/P service manual when aligning the preselector. It's normal for the 19- and 21-GHz response peaks to be rather broad, or to occur at the far extent of their respective shaper adjustments.

In most cases it will not be possible to achieve perfect preselector tracking in any one band, much less across all bands, and in any event, thermal factors will limit repeatability. You can spend hours tweaking the preselector response if you like, but as soon as you put the cover back on the analyzer, the effort will be wasted.

Ultimately the response with the PEAKING control centered may be 3-4 dB down at various frequencies in the different bands, but with correct alignment, it should be possible to peak the response at any given frequency between 1.7 and 21 GHz without leaving the shaded area. If your preselector response already meets this criterion, there is little benefit in adjusting the preselector driver assembly.

If the TM500-series time-mark generator and comb generator specified by Tek are not available, an HP 33002A SRD comb generator module driven by a +23 dBm, 100 MHz signal source makes a good substitute. You can also perform the procedure with a CW-capable sweep generator (e.g., HP 86290A-H08) or synthesizer (HP 8673B or equivalent), but it's more time-consuming. Absolute amplitude control is not needed for preselector calibration.

**Maintenance: Replacing the Crt**, p. 6-29

Like the logamp alignment instructions, this is an area of the manual where the engineers and technical writers at Tektronix never quite found themselves on the same page. **Personal injury or equipment damage can result from following Tektronix's CRT installation procedure.**

The key point is simple: before reinstalling the clear plastic implosion shield and metal bezel frame, you should loosen the four plastic mounting blocks around the perimeter of the new CRT's face. This will allow the CRT to rest as far back in the instrument as possible while the bezel is being tightened. The goal is to be able to tighten the **bezel**'s four Allen screws in a cross pattern without putting any pressure on the CRT face. **You should be able to slide the implosion shield around freely with one hand while you tighten each bezel screw.** If the plastic shield binds up as you tighten one of the bezel screws, the mounting-block screw at that corner is still too tight.

In particular, don't follow step 6 on page 6-30 of the 494P manual (070-4416-00) ("remove the bezel and tighten the mounting block screws..."), or any similar instructions that may be in your edition of the service manual. Instead, once the bezel screws are tight and you've verified that the plastic shield is still free to slide across the CRT face, tighten the mounting block screws evenly in a cross pattern to approximately 8 inch-pounds, **with the bezel still in place**. This procedure will bind the CRT with a safe amount of pressure, allowing it to undergo normal handling jolts without overstressing either the CRT face or the plastic implosion shield.

It's not necessary to follow any instructions in the manual regarding removal of the old CRT from its shield cladding. There's no reason to do this unless your replacement CRT didn't come with its own shield.

## *Troubleshooting topics*

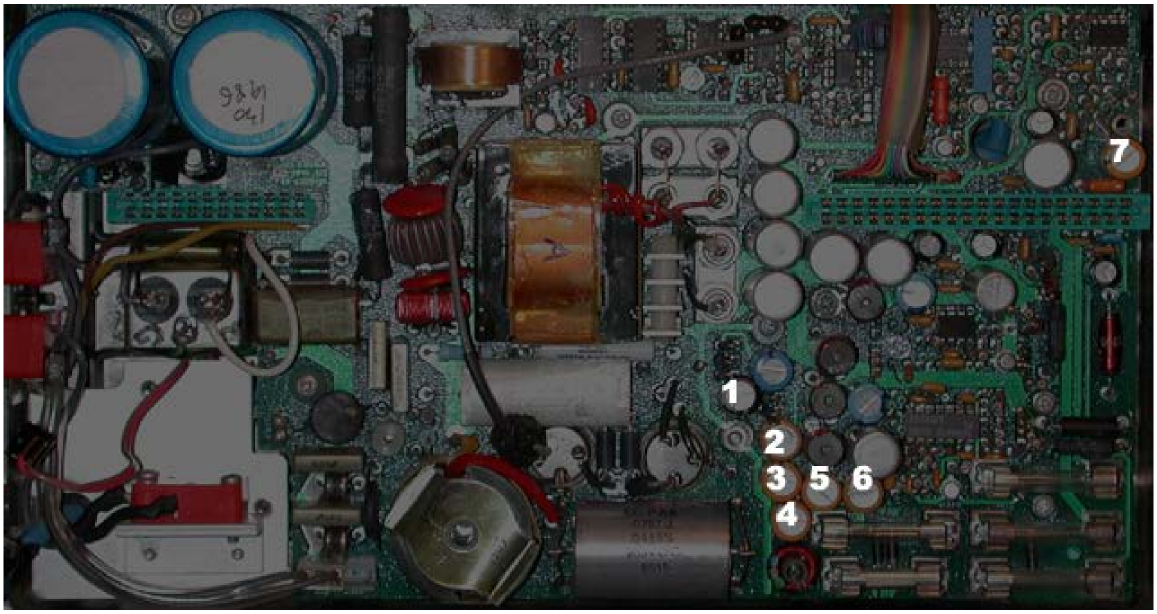
### General notes on power-supply service

Regulation tolerances for the low-voltage supply buses are specified in service volume 1, and are not usually a problem. However, the +100V and +300V supplies are frequently below their specified values. If any 66-kHz ripple or sagging is observed, all of the miniature 2.2 uF/200V axial-lead electrolytic capacitors in the power supply should be replaced. These are inexpensive high-failure-rate parts, so they should be replaced in any event if the power supply is otherwise disassembled for service.

I recommend checking the ESR on any replacement high-voltage electrolytics as well. Several "new" capacitors in this voltage range have proven defective when obtained from surplus sources.

High ESR in the filter capacitors on the lower-voltage rails (+17V, +5V) has been reported as a cause of excessive power-supply temperature, so when servicing the power supply, you should check ESR on *all* electrolytics as a matter of habit. Check heat-sink fasteners for tightness, and renew the heat-sink compound while you're at it. Avoid losing track of the mica washers and aluminum spacers that may fall out when you remove the PCB.

Use 105 degree C-rated electrolytics where possible, e.g., 3.3 uF 350V 105C, Digi-Key part # 493-2046-ND. These can replace all of the smaller high-voltage capacitors in the power supply (6x 2.2uF/200V, 1x 1uF/350V).



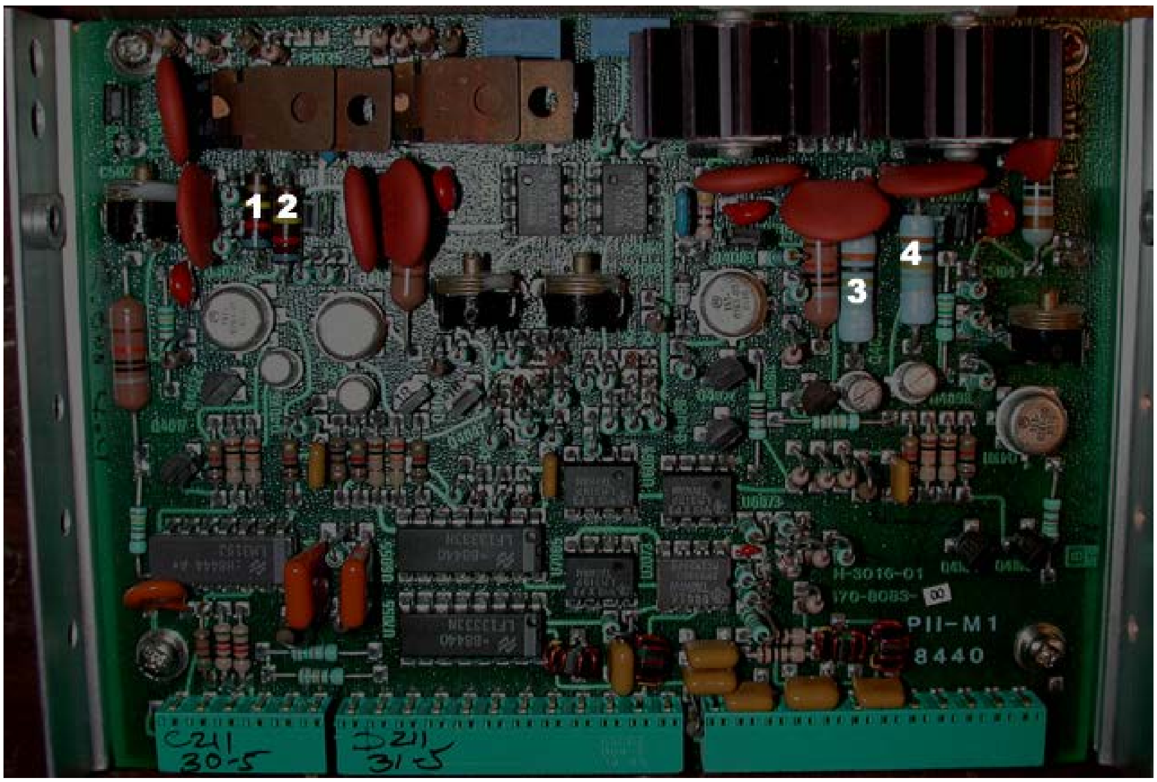

The two large filter electrolytics on the AC line side seldom cause trouble. They can be replaced if necessary with Panasonic EETED2E821DA (Digi-Key P11644-ND or Farnell 1198619).

According to a Usenet post (sci.electronics.equipment, 2-Sep-01), the large stud-mounted transistors with Tektronix part number 151-0703-00 cross-reference to the industry-standard part number 2N6586 (10A/450V, 12.5 MHz fT, TO61 package). With the appropriate mechanical modification, 2SC4237 transistors have also been successfully used.

## Symptom: Display noise/jitter

The 49x/275x CRT display subsystem is one of its weaker areas. You will not see HP-like levels of display stability and sharpness in these instruments, but there's often a lot of room for improvement.

When servicing instruments with the pre-1988 deflection amplifiers, it's a good idea to replace the 620K and 300K carbon-composition resistors in the negative-feedback paths. Many of these resistors have drifted upward over time, and/or become noisy. Typical replacement parts would be Digi-Key P620KBBCT-ND (two each) and BC300KW-2CT-ND (two each). Calibrate the deflection amplifier and digital storage subassemblies after replacing these resistors.




This particular board already had 300K metal film resistors (3,4) in place, so they were left alone. The 620K, 5% carbon-composition resistors (1,2) were measured at 580K and 980K, respectively.

It may be necessary to adjust the frequency-compensation trimmer caps for stable readout characters as well. Misalignment here causes instability as well as "tearing."

Ensure that the ribbon cables that go to the CRT's X and Y deflection plates are dressed away from the deflection amplifier PCB. If these cables are routed too close to the deflection-amplifier input components, they can cause feedback problems.

Check the +100V and +300V supplies under the aluminum cover on the Z-axis/RF interface board. Low voltage or excessive ripple indicates failure of the miniature high-voltage electrolytic filter capacitors in the main power supply. See notes on PSU service.

## Symptom: Baseline lift or instabilty when servicing VR#1 and VR#2 assemblies

The short wire pigtails from the various SMB connectors should be routed close to the assembly walls, away from the PCB and other components. Some possible layout-related issues near the 20-dB Gain Steps subassembly have been observed to cause baseline lift, at least in later (494A/P-era) instruments, and particularly with the VR assembly covers removed for servicing.

Final calibration of the VR assemblies should always be done with the covers in place, especially given the possibility of leakage from 10 MHz GPS clocks in many labs and ham shacks these days. If your analyzer doesn't meet its noise-floor specifications with a 50-ohm terminator at the input jack, this is a good thing to check.

## Symptom: Span/division does not match the value displayed on the CRT

Check the blue epoxy-encapsulated ceramic capacitors on the Span Attenuator board for DC resistance or shorts. These are used as RF bypasses across the TTL switch lines to help keep digital bus noise out of the LO control loop. If troubleshooting leads you to suspect either U1042 or its driver logic, be sure to rule out the capacitors first.

## Symptom: Noisy or defective cooling fan

Failure of the high-performance tubeaxial fan is common on higher-mileage 49x/275x analyzers. The OEM fan is an exotic part which is unobtainable today. Especially on the newer analyzers with 10 Hz resolution, avoid the temptation to hack in a cheap CPU fan as a substitute. Chances are, it won't put out enough air to cool the entire analyzer safely. Additionally, the fan is mounted in close proximity to sensitive IF circuitry, so both EMI and mechanical vibrations *will* appear as excessive composite noise or sidebands at close-in offsets. It's a good idea to run a phase-noise plot before and after replacing the fan to make sure you haven't degraded the instrument's performance, watching carefully for spurs.

When a conventional single-phase DC fan is installed, the multiphase driver board will be unused. Ideally, the new fan will use some combination of the supply voltages available to the existing driver board (+9V, +5V, -17V, and ground). A 12-volt fan can be used on the -17V bus with a suitable Zener diode, for instance.

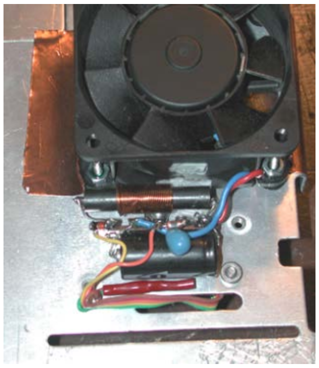
The original Buehler tubeaxial fan was rated for 31 CFM of airflow at 12 VDC, consuming 2.4 watts. Superficially, the EBM Papst 622HH model is a close substitute (33 CFM, 12 VDC, 3.5W), but its EMI characteristics are much worse than the original part, and also noticeably worse than the Papst 622H model (27.1 CFM, 12 VDC, 2.3 watts). This is most likely due to its higher current consumption. For most environments the 622H will be "good enough," although neither of these fans can be used without additional EMI filtering.

Some EMI advantages may be gained through the use of a higher-voltage fan such as the Papst 624H (18-28 volts, 27.1 CFM at 24 volts nominal) or 624HH (18-28 volts, 33 CFM at 24 volts nominal). A 624HH fan on the -17V bus is likely to work well. It should cause less EMI than the 12-volt 622HH, especially when run at a lower-than-specified supply voltage.

Various resellers for the EBM Papst fans can be located by entering part numbers such as "624HH" at http://www.octopart.com/ or http://www.findchips.com/ . Regardless of which replacement fan you select, it will be necessary to fabricate a mechanical shock mount with materials such as rubber/silicone grommets and/or gasket compound. Do not attempt to bolt the fan to the power-supply housing without a vibration-dampening mount unless you enjoy looking at noise sidebands.

Similarly, careful electrical isolation is needed to maintain the instrument's original performance. Twist the fan leads together and keep them as short as possible. Bypass the fan with a parallel combination of a large (470 to 1000 uF) electrolytic capacitor and smaller tantalum capacitor (~10 uF), and use a series choke with a value of 100 uH or more that's rated for the fan's supply current.

A more subtle consequence of using a replacement fan is extended warm-up time for the entire analyzer, assuming the fan is no longer temperature-controlled.



Another take on fan repair is excerpted here by permission from its originator on the Tektronix customer forum:

> *Noisy Fan Repair*
>
> *My fan was making a loud buzzing noise. When turned on the hub is pushed back into the fan assembly say 3/16th of an inch by air pressure. When off, the fan spins freely in its forward position but not so freely when it is pushed back 3/16th of an inch.*
>
> *If I place a small 1/4X1/16 Neodymium disk magnet to within 1/8th of an inch of the center hub of the fan then turned the fan on, the hub stays in its' forward position and no more buzz…*
>
> *I took a 2 inch by 1/8th inch diameter wire and bent a ring on one end and slipped two of these magnets into the ring and glued in place (two magnets to make one stronger magnet). At the other end of the wire I made another small loop for a securing screw that I ran through an unused screw hole on the side frame near the fan. The wire was then bent to center the magnets at the center of the hub, 1/8th inch off the face. I think the wire I used was actually a lead free solder for plumbing, very malleable but not as soft as lead.*
>
> *No more buzz… No obvious downside but certainly not tested to 21 GHz either.*
>
> *I'm not a RF guy so I can't say if a strong magnetic field located near the fan will cause a performance hit. For certain the fan vibration was a problem.*
>
> *-- posted by **cap** on Mon Jan 10, 2011 6:04 pm*

This is a pretty common way for the fans to fail, so **cap**'s suggestion could be quite helpful. A small stationary magnet should not cause any problems when mounted in that vicinity, assuming the fan continues to run OK in its presence. (Of course, strong magnets should be kept well away from the YIG-tuned devices on the RF deck.)

## Symptom: Failure of front-panel CENTER FREQUENCY control

The CENTER FREQUENCY control's optical encoder uses a 2mm incandescent bulb which can be replaced by a type 7153 lamp (5V, 115 mA, Mouser Electronics part number 606-CM7153).

## Symptom: Excessive phase noise

Check ESR on the two aluminum electrolytics on the YIG oscillator interface board. These capacitors are paralleled for low ESR, so one of them will need to be temporarily disconnected in order to measure them independently.

Check for dirty/intermittent operation of the loop-gain trimmer on the PLL assembly, and for noise in the 10-volt reference on the 1st LO Driver board. All electrolytics on these assemblies should be checked for ESR as well.

It is less common to see excess noise at narrowband (less than 10 kHz) offsets. See the graphs at the end of this document for an idea of what to expect from your analyzer.

Helpful hint: "listen" to the power supplies and voltage references with a crystal earphone. Use back-to-back 1N4148s across the earphone to avoid damaging the barium titanate crystal (or your eardrums), with a 1K series resistor to the supply being monitored.

## Symptom: Low or unstable amplitude response

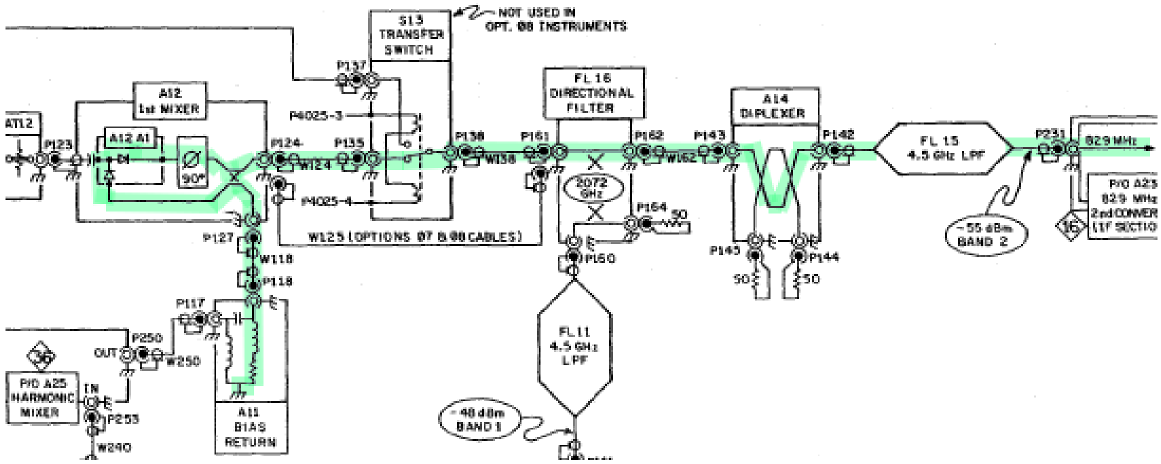
A wide variety of problems can cause this behavior. You'll need to troubleshoot the analyzer just as if it were any other multi-conversion superhet receiver.

One common issue is overtorqued SMA connectors in the front end. If someone has been too heavy-handed with a wrench, the ferrules at the hardline terminations have probably been crushed, and will no longer make good contact regardless of the amount of torque applied. Nothing can be done here except to search eBay for microwave-quality SMA jumpers. This is especially likely to be the problem if you're seeing a lot of FM, TV, or cellular/pager leakage into the analyzer with nothing connected to the input jack. From what I've seen this was a bigger issue with earlier 49x analyzers than with later ones, where more resilient ferrules were used.

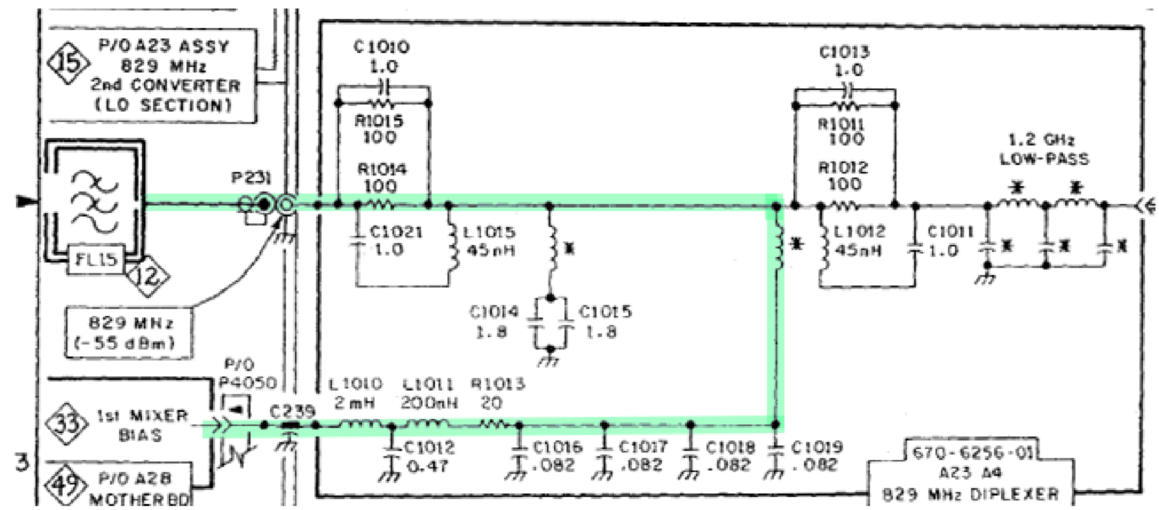
If your RF attenuator seems balky, check Q3028 on the Z-axis/RF interface board, and see the Manual Change Information page for reference M65465 (page 308 of the 494A/P volume 2 .PDF). A70CR3028 was added to protect Q3028 from reverse voltage induced by the attenuator coils.

49x/275x analyzers with the preselector and external-mixer features have several coax switches in the front end signal path, but the switches have been very reliable in my experience. Bias tees and diplexers are more likely to be faulty.

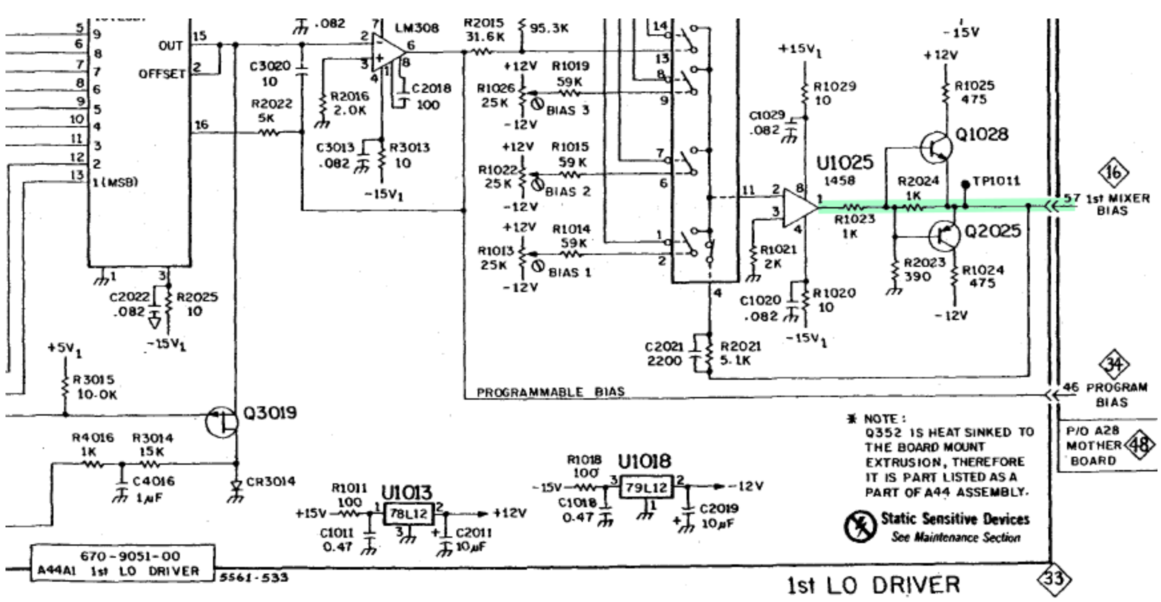
Before condemning the first mixer in the 21 GHz analyzers, for instance, make sure the DC bias path from the LO driver board to the mixer bias termination is OK. The front-end mixers in the 1.8 GHz analyzers were operated at zero bias, but the 21 GHz models used a circuitous bias path with several potential points of failure. Excerpts from the 494AP schematics appear below with the first mixer bias path highlighted in green.



NOT USED IN OPT. 08 INSTRUMENTS
S13 TRANSFER SWITCH
A12 1st MIXER
A12 A1
90°
FL 16 DIRECTIONAL FILTER
2072 GHz
A14 DIPLEXER
FL 15 4.5 GHz LPF
829 MHz
P/O A23 829 MHz 2nd CONVER (LO SECTIO
−55 dBm BAND 2
W125 (OPTIONS 07 & 08 CABLES)
FL11 4.5 GHz LPF
−48 dBm BAND 1
P/O A25 HARMONIC MIXER
A11 BIAS RETURN

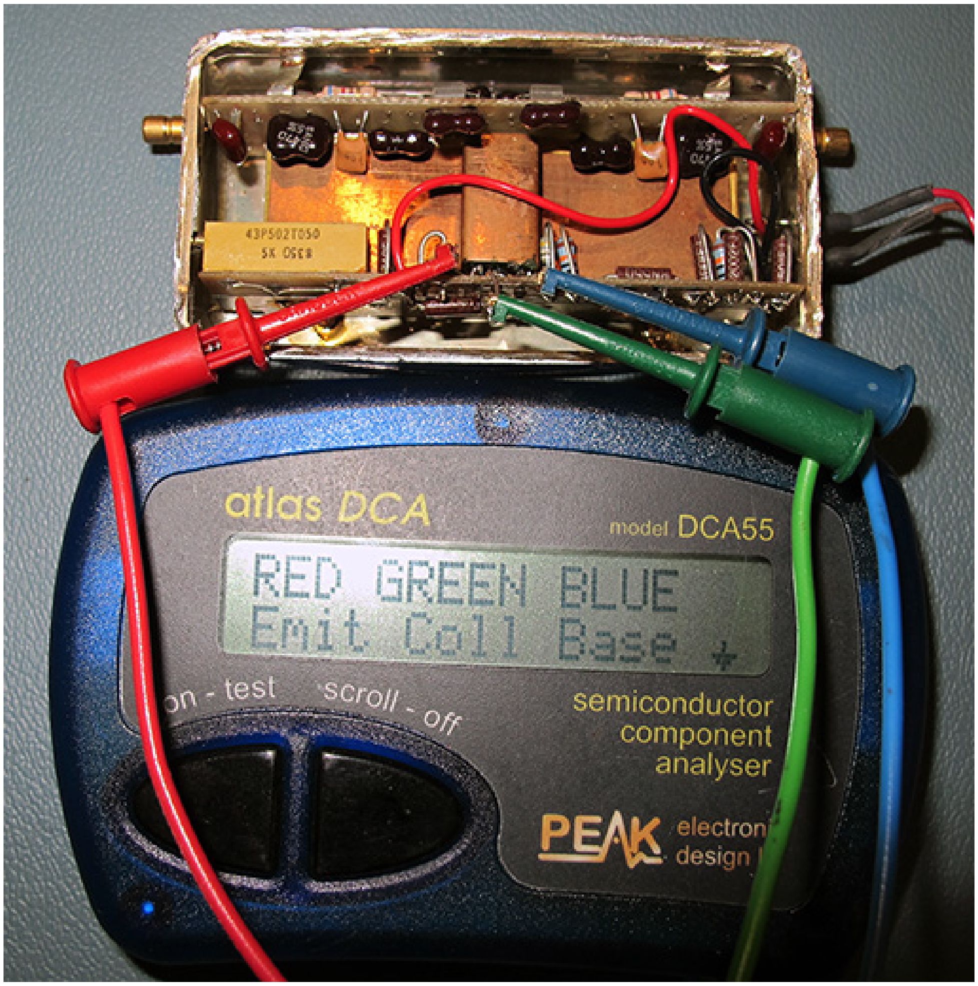
P/O A23 ASSY 829 MHz 2nd CONVERTER (LO SECTION)
829 MHz (−55 dBm)
1st MIXER BIAS
P/O A28 MOTHER BD
1.2 GHz LOW-PASS
670-6256-01 A23 A4 829 MHz DIPLEXER

LM308
U1025 1458
Q1028
Q2025
1st MIXER BIAS
PROGRAM BIAS
PROGRAMMABLE BIAS
Q3019
U1013 78L12
U1018 79L12
NOTE: Q352 IS HEAT SINKED TO THE BOARD MOUNT EXTRUSION, THEREFORE IT IS PART LISTED AS A PART OF A44 ASSEMBLY.
Static Sensitive Devices See Maintenance Section
P/O A28 MOTHER BOARD
670-9051-00 A44A1 1st LO DRIVER
5561-533
1st LO DRIVER

## Symptom: Self-calibration failure on 494P and 496P

The signal paths used for the 30 Hz and 100 Hz resolution bandwidths in these models used an ovenized crystal filter. This filter is mounted above the CRT. It can reach 60-70 degrees C in normal operation – too hot to touch for more than a few seconds. If the filter housing fails to warm up, the pass transistor in the oven control loop has probably failed.

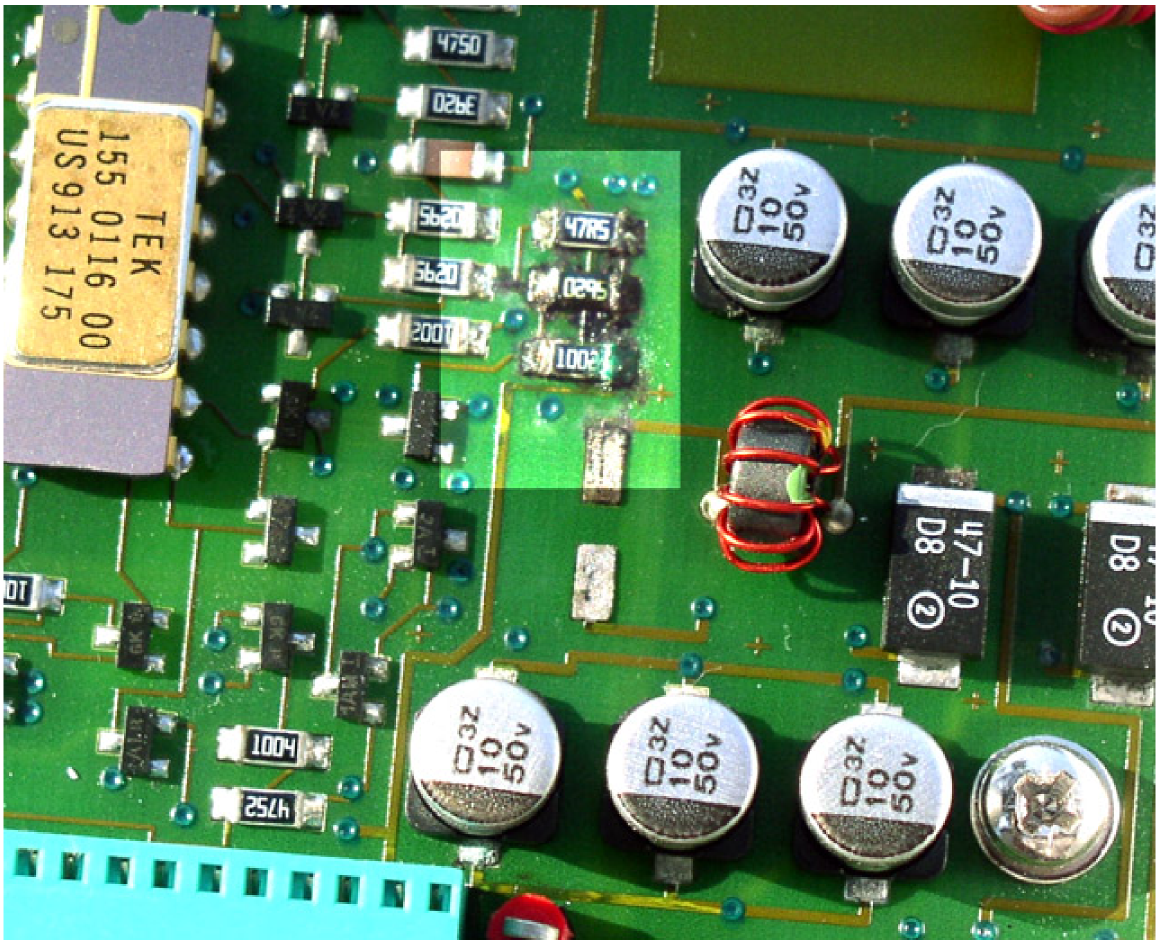



The pass transistor is bonded to a copper “heat sink” that’s in contact with the oven heating coil wrapped around the crystals. The intent may have been to use the transistor as part of the heating element to achieve faster warmup time. This practice is common in oscillator oven circuits, but in this case it seems to have contributed to reliability problems. By the time the analyzer has accumulated a few thousand operating hours many of these transistors will have failed.

In the photo above, one of the lucky ones is being characterized by a pocket semiconductor tester. The part was identified as an NPN silicon bipolar transistor with a beta of 110. I’ve used 2SC1847s to replace these transistors, but any similar part should be fine. I recommend bolting the replacement part to the side of the filter housing, rather than installing it in the original location under the copper strip.

## Symptom: Unstable amplitude response with slow/continuous variation

Amplitude instability in the newer units (e.g, later-production 494APs, as well as 495Ps with serial numbers after B030000) is becoming all too common, thanks to Tek's eagerness to adopt surface-mount technology at a time when component quality wasn't yet up to par with traditional through-hole tech. If you own one of these early-1990s vintage analyzers, chances are good that your logamp board (in particular) already looks like this:




The black "crud" in the highlighted area doesn't originate from the resistors or from the soldering or assembly process. Rather, it's caused by outgassing of corrosive vapors from one or more of the 10 uF/50V electrolytics nearby. Any corroded traces should be cleaned or bridged as soon as you spot the problem, and *all* of the aluminum-can electrolytics should be replaced.

50-volt capacitors aren't needed in most cases -- 35V is fine for supply buses up to +/-15 volt -- and their exact type (tantalum or aluminum) isn't important either. **Just get those old caps off the board!** Keep in mind that affected traces can be several inches away from the nearest capacitor. A careful inspection of the entire PCB is necessary when this failure occurs.

## Front-end mixer damage: causes and cures

Spectrum-analyzer front ends are vulnerable to damage due to a variety of causes:

- RF overload
  - Keying a transmitter into the input jack
  - Use of an efficient antenna near a high-powered transmitter
  - Connecting the analyzer to a oscillator or other source >> 100 mw
- Application of DC to an unprotected input
  - Failure to use a feedthrough capacitor or DC block
  - Failure of a feedthrough capacitor or DC block at the component level
  - Use of a feedthrough capacitor large enough to dump a substantial charge into the front end when power is applied to the unit under test
  - Failure to verify that no DC bias is present on an unfamiliar signal connection
- ESD
  - Setting RF ATTEN to 0 dB, then touching the center conductor of the input jack
  - Failure to use an external attenuator and/or preamp when working with an antenna, then touching the antenna or exposing it to high-potential sferics
  - Use of a long piece of coax that carries a leftover DC charge
  - Other bench practices associated with ESD hazards

In the 1.8 GHz analyzers (495P, 496P, and their 275x equivalents), it's easy to substitute an off-the-shelf mixer for the Tektronix front-end mixer. The Mini-Circuits ZX05-83LH+ is a good choice that will maintain or even exceed the original mixer's conversion-gain and IMD performance. It's necessary to reverse the RF and IF ports when installing an aftermarket DBM.

The mixers in most of the 21 GHz analyzers seem to use Tektronix part numbers in the 119-1017-xx family. Note that 492s with 8 GHz coverage (option WJ) use 119-1353-xx parts instead. One difference between 119-1017-xx and 119-1353-xx seems to be the presence of a DC block at the input to the former (21 GHz) mixer.

It's been reported by Luis Cupido, CT1DMK that the beam-lead diodes can be replaced with either BAT30 low-barrier parts from Infineon or MSKN709 medium-barrier diodes from Metelics. Low-barrier Metelics parts should also be usable, as may similar diodes from MA/COM. Luis has found that the better-known HCSC9101 diodes need more LO power than the analyzer has available.

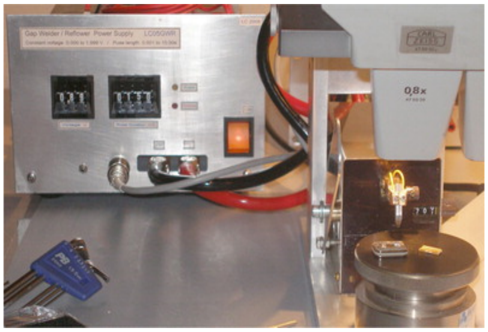
Although the mixer and its diode carrier are easy to work with on the bench, replacing the diodes on the carrier is another matter. Gap-welding capabilities are required for the gold ribbon-to-substrate attachment, while gap reflowing is used to attach the ribbons to the diode holder (although the latter operation may be performed with a small soldering iron). It may be difficult to preserve the original gold ribbons during dissembly; be prepared to replace them with new ribbon stock.

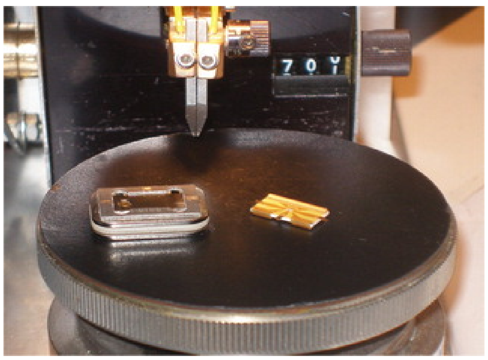
Amateur wire-bonding and gap-welding work is discussed on Luis's chip-hybrids Yahoo group.

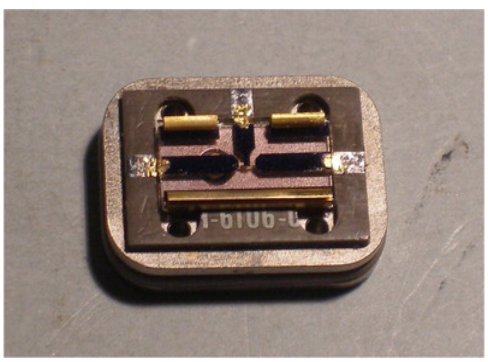
When replacing front-end components, use extreme care to avoid overtorquing the 0.141" hardline SMA interconnects. Don't use needle-nose or serrated pliers to work with gold-plated connectors -- use a 5/16" or 8mm wrench, ideally an SMA torque wrench.

## Inside the first mixer

Photos courtesy Luis Cupido, CT1DMK, of the chip-hybrids group, showing the diode carrier from the 21 GHz first mixer with its substrate removed, undergoing diode replacement.







The mixer diodes themselves are almost too small to see, even in the magnified view at bottom. Actual width of the entire substrate is approximately 15 mm.

## Parts / accessory sources

The TekScopes Yahoo group is a great resource for repair information for all Tektronix instruments, new and old. Watch for contributions from Tektronix veterans such as Stan Griffiths, whose work at the company included technical marketing for the spectrum-analyzer product line.

PC board extenders are needed for many 49x/275x service and calibration tasks. High-quality reproductions are frequently available from Norway Labs ; ask for Matt North when inquiring about them.

Extenders for the keyboard and power supply assemblies were also issued by Tektronix, but they are not included in Norway Labs's package, and appear only rarely on the surplus market. While nice to have, they are not as important as a full set of PCB extenders.

Quickar Electronics and Sphere Electronics are good sources for Tektronix-specific semiconductors and other components. You can also search for Tek part numbers at these sites:

http://www.american-milspec.com/
http://www.talonix.com/
http://qservice.tv/ (Greece)

Don't neglect eBay when searching for parts and documentation -- it should be your first resort. If you can afford a "parts mule" -- a junked instrument whose modules are compatible with yours -- by all means grab one!

## Module swaps and upgrade possibilities

Modules can typically be exchanged between instruments of similar vintage -- 492/496, 494/492A, 494A/492B, and so on. Early-model 495s are most compatible with the 494 and 492A models, while late-model 495s with the 10 Hz RBW feature (post-B030000) are essentially 494As without the 829 MHz IF strip.

That being said, Brian Henry has noted a few differences between the VR modules from his 494AP and a late-model 495P, after observing that he needed to maximize the 110 MHz IF gain to calibrate the latter properly:

> . . . I checked the input level to the (495P’s) VR module and it was at -25 dBm. In the 494AP manual, it is supposed to be -35 dBm at that point. In light of that, I decided to back down the IF gain to -35 dBm. After doing that, the output level from the VR module dropped by 10 dB. So, I then wondered where that 10 dB was going. It turned out that the levels were as specified in the manual until the output of the 10 dB gain steps amp. The manual says -3 dBm, but the best I could do with the Amp gain cranked wide open was - 5 dBm. Just to make sure that it wasn't a bad board, I swapped the one from my 494AP and got the same result. I noticed while I had the #1 VR module open, that the VR input on the 495P is much different than that of the 494AP. It has an additional gain adjust pot, and more circuitry. It appears to be for setting the -60 dB gain? For the 494AP, the Band 1 leveling adjustment is set fully CCW. With the 495P, things may be handled differently. I noticed that the Band 1 leveling had previously been set to about mid range. That is where I left it.
>
> The VR module in my 494AP is: 644-0645-02 (agrees with the 494AP manual)
> The VR module in my 495P is: 644-0776-01
>
> VR module #2 may be fully compatible, but there appear to be some differences with VR module #1. What is even more puzzling is that the 494AP manual references 644-0645-02 as being for the 495P. Somewhere down the line, it changed. This particular 495P (B031241, late 1993 production) probably has more in common with a 2795 than an early 495P.

Along the same lines, the later 497s (post-B020000) *are* relabeled 494As as far as I've been able to tell. They can be recalibrated for use up to 21 GHz.

When upgrading the VR assemblies to bring a 492AP or similar model up to 494AP-era standards, remember to install the 3 MHz filter (FL36) on the RF deck as well.

## Firmware

Firmware images and notes on DIP switch settings -- invaluable for upgrading as well as troubleshooting -- can be found in the Manuals/ROM Images section at http://www.ko4bb.com/.

Each set of 49x-series firmware images is shared across several models in the product line, with the DIP switches determining the instrument's actual 'personality.' For example, the v9.0 firmware stored at the "Tek - 495p_9_0" link is applicable to the 494A/P, 492A/P, 495/P, 2753/P, 2754/P, 2755/P, and 2756/P models, while the v9.7 firmware stored under "Tek – 494AP_497P_9_7" added support for the newer 492B/P, 2755A/P, and 497/P models. I'm not aware of any benefits to upgrading a 9.0 instrument to 9.7, so I don't recommend doing so in most circumstances.

There is also an earlier version, "Tek-492ap_6_0," which is suitable for use with the original 495/P and 492A/P ROM boards that have only eight EPROM sockets rather than the ten that are present on the later instruments. Search the various notes and spreadsheets in the ROM Images section carefully for the latest information applicable to your model.

Users of the original 492 should look for the Tek-492_1_6 link, which contains the original 1.6 firmware for the 492 plus a consolidated file suitable for writing to a single EPROM, with notes by Luis Cupido. I'm unsure if this file can be used to support a 496, 496P, or 492P.

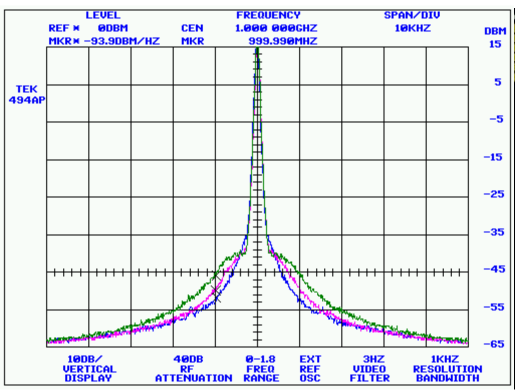
Use caution when toggling DIP switches found in these analyzers, especially the GPIB switch on the back panel. These switches sometimes fail when actuated for the first time in 20+ years, leading to difficult-to-diagnose problems.

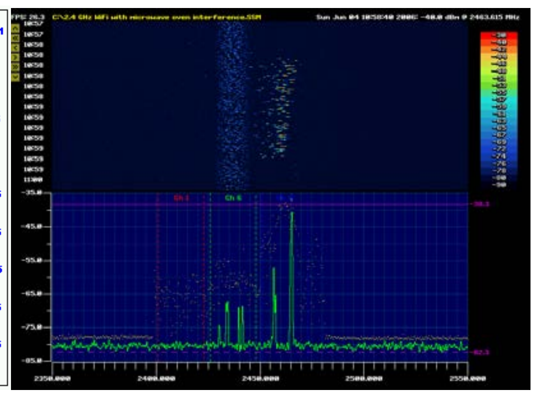
## *Software applications*

Several measurement applications were marketed by Tektronix for the -P suffix (GPIB programmable) analyzers in the 49x/275x line, allowing users to take screenshots, automate basic RF measurement tasks, and control equipment located at remote sites. Beginning with the 494P, the instruments' firmware could drive pen plotters directly. However, resurrecting obsolete Tektronix controllers and plotters is not usually worthwhile unless you're faced with the need to recreate or support a specific measurement system. Many commonly-used spectrum analysis applications have been recreated on modern PC operating systems.

Commercial applications that support the 49xP/275xP spectrum analyzers include PrintCapture from F&F SoftTools and various utilities from Aphena, including SoftPlot, RemoteControl, and Plottergeist.

On the freeware side, the KE5FX GPIB Toolkit (by the author of this document) provides a large collection of Windows applications for Tektronix, Advantest, and HP/Agilent spectrum analyzers, including full C/C++ source code. The GPIB Toolkit includes utilities for screen capture, elapsed-time spectrum recording with "waterfall" displays, phase noise measurement, and other applications.





In short, GPIB support is a *very* useful feature, one that often goes unappreciated by hobbyists. If you have a programmable spectrum analyzer that isn't connected to your PC, you're missing half the fun!

## *Recommended books and app notes*

*TekScope* volume 12, issue 1 (1980), available in .PDF format at the http://www.ko4bb.com/ manuals page, introduces the 492 with descriptions of various production advances and key design concepts.

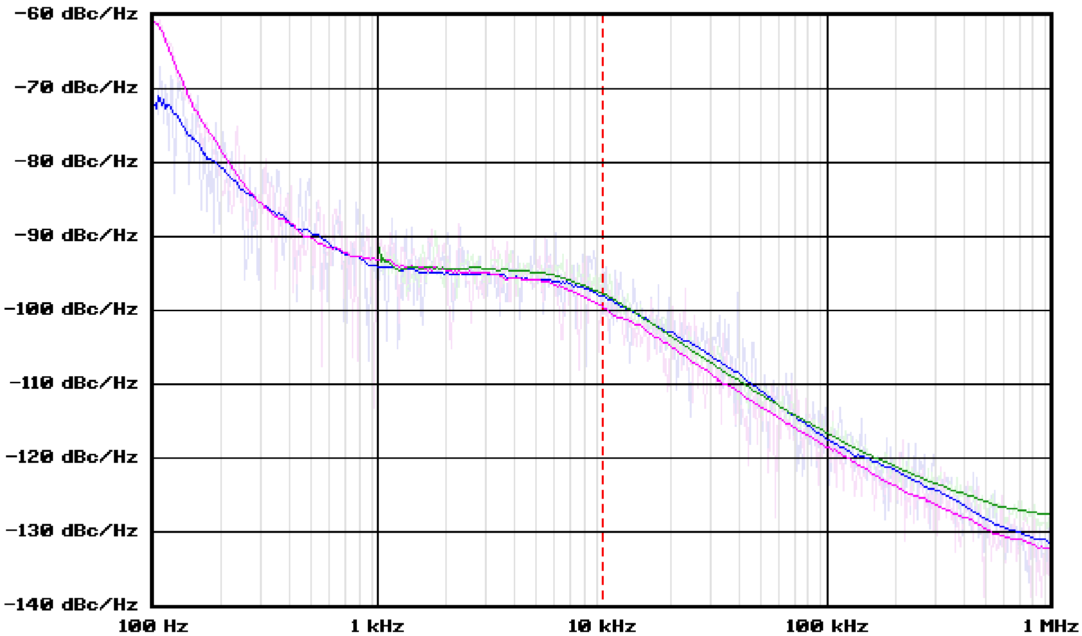
The Manuals / Tektronix 49x directories contain other useful application notes as well, including the well-regarded *Fundamentals of Spectrum Analysis*. As the directory layout on this site may be subject to change over time, it's not practical to include direct links. It's very worthwhile to explore the Manuals / Tektronix pages on your own.

*Spectrum and Network Measurements* by Bob Witte is a great tutorial on all facets of spectrum analysis. A more technically-oriented (and much harder to find) volume is ***Modern Spectrum** Analyzer Theory and Applications* (Artech House 2nd edition, 1984) by Tektronix's Morris Engelson. Neither of these books is oriented towards cutting-edge signal analysis technology, but they do an outstanding job of covering topics that are relevant to users of 1980s- to 1990s-vintage instruments.

Other Tektronix application notes describe the use of accessories such as waveguide mixers and tracking generators, as well as specific measurement techniques. Links to online copies of these will be added to future versions of this document as they become available.

## *Appendix: Typical phase-noise baseline plots*

The traces below were acquired with PN.EXE from the GPIB Toolkit, measuring the output of a Wenzel crystal oscillator whose phase noise is substantially lower than the analyzers' own. Typical examples of the 494AP, 494P, and 492P spectrum analyzers were compared. Minimum RF attenuation was set to 0 dB in all three cases, and 20 dB of carrier clipping was used.




| Trace | Carrier Hz | Carrier dBm | dBc/Hz at 10000 Hz | Clip dB | Instrument |
|---|---|---|---|---|---|
| S/N B010388 | 100 000 000 | 8.00 | -98.1 | 20 | TEK 494AP |
| S/N B010845 | 100 000 000 | 8.00 | -99.6 | 20 | TEK 494P |
| S/N B055692 | 100 000 000 | 8.00 | -97.8 | 20 | TEK 492P |

The 494P appears noisier close to the carrier, but this is actually a consequence of its broader 30-Hz RBW specification compared to the 494AP's 10-Hz minimum bandwidth. The 30-Hz filter skirt, and not the LO phase noise, is responsible for the observed performance at offsets below about 300 Hz.

At offsets of 10 kHz and beyond, all 49x/275x analyzers should generally perform within +/- 5 dB of these traces. All three analyzers meet Tektronix's rather-loose PN specifications easily.

## *Appendix: Calibration program for 494P and earlier analyzers*

For analyzers that don't have firmware procedures to assist with digital storage and 1st/2nd LO calibration, here's a C version of the BASIC code from the 492P service manual (070-3783-01). A GPIB adapter from Prologix or National Instruments will be required.

This code can be compiled with the MS Visual Studio Express package and linked with the gpiblib.lib library provided with the KE5FX GPIB Toolkit. Specifically, you can save the file in the Toolkit's installation directory as *cal_tek490.cpp* and compile it with *cl cal_tek490.cpp gpiblib.lib* , then run *cal_tek490 <addr>* from the command line to display the required calibration pattern. Replace *<addr>* with the analyzer's actual GPIB address.

A ready-to-run copy of this program is included in the GPIB Toolkit under the name **cal_tek490.exe.**

```
#include <stdio.h>
#include <conio.h>
#include <assert.h>
#include <stdlib.h>

#define WIN32_LEAN_AND_MEAN
#include <windows.h>

#include "gpiblib.h"

S32 addr;

void WINAPI GPIB_error(C8 *msg, S32 ibsta, S32 iberr, S32 ibcntl)
{
   printf("%s",msg);
   exit(1);
}

void connect(void)
{
   GPIB_connect(addr,
                GPIB_error);
}

void disconnect(void)
{
   GPIB_disconnect();
}

void ds_cal(void)
{
   GPIB_CTYPE type = GPIB_connection_type();

   if (type != GC_NI488)
      {
      printf("Error: This test requires a National Instruments GPIB interface -- it");
      printf("will not work with Prologix adapters\n");
      return;
      }

   C8 C[1024];
   C[0] = 64;

   S32 k = 125;
   S32 i1 = 0;

   for (S32 i=1; i <= 10; i++)
      {
      for (S32 j=1; j <= 100; j++)
         {
         C[i1+j] = k;
         }

      k-=25;
      i1+=100;

      if (!(k >= 25))
         {
```

```
            k = 225;
            }
         }

      GPIB_write("SIGSWP");
      GPIB_write(C, 1001);

      printf("\nPress any key when test complete... ");
      getch();
      printf("Done\n");
      GPIB_write("INIT");
   }

   void cf_cal(void)
   {
      printf("\nConnect calibrator, then press any key when test complete... ");

      GPIB_write("INIT; REF -20; SPAN 2M; SIG");

      while (!kbhit())
         {
         GPIB_write("FREQ 100M;DEG;SIG;WAIT;");
         GPIB_write("FREQ 1.8G;DEG;SIG;WAIT;");
         }

      getch();
      printf("Done\n");
   }

   void lo1_sens_cal(void)
   {
      GPIB_write("INIT; FREQ 10M; SPAN 100K");
      disconnect();

      printf("\nCenter marker on screen, then press any key to continue... ");
      getch();

      connect();
      printf("\nPress any key when test complete... ");

      while (!kbhit())
         {
         GPIB_write("TUNE 5M;SIG;WAIT;");
         GPIB_write("TUNE -5M;SIG;WAIT;");
         }

      getch();
      printf("Done\n");
   }

   void lo2_range_cal(void)
   {
      printf("\nPress any key when test complete... ");

      while (!kbhit())
         {
         GPIB_write("TUNE 2M;SIG;WAIT;");
         GPIB_write("TUNE -2M;SIG;WAIT;");
         }

      getch();
      printf("Done\n");
   }

   void lo2_sens_cal(void)
   {
      printf("\nPress any key when test complete... ");

      while (!kbhit())
         {
         GPIB_write("TUNE 2K;SIG;WAIT;");
         GPIB_write("TUNE -2K;SIG;WAIT;");
         }

      getch();
      printf("Done\n");
   }
```

```
void shutdown(void)
{
   GPIB_disconnect();
}

void main(S32 argc, C8 **argv)
{
   printf("\nThis program assists with calibration of Tektronix 49xP/275xP-series\n");
   printf("spectrum analyzers, using routines from volume 1 of the Tektronix 492P\n");
   printf("service manual (070-3783-01, FEB 1984 edition).\n");

   if (argc < 2)
      {
      printf("\nUsage: cal_tek490 <address>\n");
      exit(1);
      }

   addr = atoi(argv[1]);
   atexit(shutdown);

   for (;;)
      {
      printf("\n    1) Digital storage calibration (page 3-70)\n"
             "    2) 1st LO gain/offset (LO driver R1031, CF control R1032, page 3-51)\n"
             "    3) 0 MHz\n"
             "    4) 4.2 GHz (step 2c, page 3-52)\n"
             "    5) 4.278 GHz\n"
             "    6) 5.5 GHz (step 2c, page 3-52)\n"
             "    7) 1st LO tune sensitivity (CF control R1028, page 3-55)\n"
             "    8) 2nd LO tune range (CF control R4040, page 3-55)\n"
             "    9) 2nd LO tune sensitivity (CF control R3040, page 3-56)\n"
             "  ESC) Exit\n\n"
             "Choice: ");

      C8 ch = getch();

      if (ch == 27)
         {
         printf("Exit\n");
         exit(0);
         }

      printf("%c\n",ch);

      connect();

      switch (ch)
         {
         case '1':
            ds_cal();
            break;

         case '2':
            cf_cal();
            break;

         case '3':
            GPIB_write("FREQ 0M");
            break;

         case '4':
            GPIB_write("FREQ 4200M");
            break;

         case '5':
            GPIB_write("FREQ 4278M");
            break;

         case '6':
            GPIB_write("FREQ 5500M");
            break;

         case '7':
            lo1_sens_cal();
            break;

         case '8':
            lo2_range_cal();
            break;

         case '9':
```

```
            lo2_sens_cal();
            break;
         }

      disconnect();
      }
}
```

If you are following the calibration procedures in the 492P manual (070-3783-01), note that the roles of the 1st LO Offset (R1032) and 1st LO Sense (R1031) controls are reversed in steps 2(a) and 2(b). Use R1031 to bring the two signals to the same horizontal position, and R1032 to align the two signals at midscreen.

# *Appendix: Attenuator control firmware patch*

RF attenuator failures can be difficult to repair due to the lack of available replacement parts. It's possible to replace the attenuator with a three-section unit from any of several other spectrum analyzer models with similar frequency coverage, using appropriate circuitry to handle any differences in solenoid voltages or latching characteristics. But unless the replacement attenuator's switched elements correspond to the 10, 20, and 30 dB pads used in the 49x series, some 'glue logic' may be needed as well.

You can use almost anything from a few discrete transistors to an FPGA to modify the behavior of the Z-axis/RF Interface assembly, or you can take the easy way out and hack the firmware. Below, Luis Cupido offers some notes on modifying the V1.6 492 firmware to allow it to drive the 10/20/40-dB attenuators found in many analyzers from HP and other manufacturers:

```
The original table below contains the attenuator control bytes for each
attenuator setting:

addr - value - att settings
C1E2 - 45    -  0dB
C1EC - 44    - 10dB
C1F6 - 05    - 20dB
C200 - 41    - 30dB
C20A - 40    - 40dB
C215 - 01    - 50dB
C21E - 00    - 60dB

The bit meanings are as below:
bit:   7      6      5      4      3      2      1      0
is:   <x>   <20dB>  <x>    <x>    <x>   <30dB>  <x>   <10dB>

Original and modified byte values:

C1E2 - 45 - 0100 0101  0dB <unchanged>
C1EC - 44 - 0100 0100 10dB <unchanged>
C1F6 - 05 - 0000 0101 20dB <unchanged>
C200 - 41 - 0100 0001 30dB <30dB was 0+0+30, now become 10+20+0> 0000 0100 - 04
C20A - 40 - 0100 0000 40dB <40dB was 10+0+30, now become 0+0+40> 0100 0001 - 41
C215 - 01 - 0000 0001 50dB <50dB was 0+20+30, now become 10+0+40> 0100 0000 - 40
C21E - 00 - 0000 0000 60dB <60dB was 10+20+30, now become 0+20+40> 0000 0001 - 01

---

PATCH THE ROM WITH THIS

C1E2 - 45
C1EC - 44
C1F6 - 05
C200 - 04
C20A - 41
C215 - 40
C21E – 01
```

Image files for the 492 1.6 ROMs are available in both original and modified form at http://www.ko4bb.com in the **ROM Images and Drivers/Tek 49x firmware and notes** directory. The attenuator control table is likely to appear at a different offset in other firmware versions, including those for other instrument models, so you should verify the location of the original byte array before making any changes.

The firmware for models later than the original 492/496 is checksummed, so it will be necessary to update the checksum after applying any binary patches. See ***Firmware checksum calculation*** for more information.

## *Appendix: Firmware checksum calculation*

When modifying the firmware in instruments later than the original 492/496 models, it's necessary to calculate and store a new checksum word to avoid error messages at bootup time. The following program is a small Win32 console application that will display the current and new checksums for a given binary ROM image file and allow you to update the file if desired.

This program is also available at the http://www.ko4bb.com site in the **ROM Images and Drivers/Tek 49x firmware and notes/Tek – 497p_9_7** directory.

```
#include <stdio.h>
#include <conio.h>

int main(int argc, char **argv)
{
   printf("\n");
   printf("Tektronix 49x ROM checksum utility V1.00 of 20-May-04\n");
   printf("John Miles KE5FX (jmiles@pop.net)\n");
   printf("---------------------------------------------------------------------------\n");

   if ((argc < 3)
         ||
      ((argv[2][0] != '0') && (argv[2][0] != '1')))
      {
      printf("\nUsage: chksum filename.bin bank\n");
      printf("Bank = 0 for first 16K bank in image, 1 for second 16K bank\n\n");
      return 1;
      }

   static unsigned char image[32768];

   FILE *in = fopen(argv[1],"rb");

   if (in == NULL)
      {
      printf("Error: could not find %s\n",argv[1]);
      return 1;
      }

   if (fread(image, 32768, 1, in) != 1)
      {
      printf("Error: could not read %s\n",argv[1]);
      return 1;
      }

   fclose(in);

   int start = 0;
   int end   = 16383;

   if (argv[2][0] == '1')
      {
      start = 16384;
      end   = 32767;
      }

   unsigned short original = *(unsigned short *) &image[start];

   printf("Previous checksum: %X\n",original);

   //
   // Original 6802 checksum algorithm:
   //
   //          CLR A               ;Init sum = 0 (A=MSB, B=LSB)
   //          CLR B
   //
   // L_DBC4   ASL B               ;16-bit sum <<= 1
   //          ROL A               ;Shift MSB out to carry
   //          ADC B   $00,X       ;16-bit add of $00,x plus carry -> sum
   //          ADC A   #$00
   //          INX                 ;Loop from $C002 to FFFF inclusive
   //          CPX     #$0000
   //          BNE     L_DBC4
   //
```

```
   unsigned short sum = 0;

   for (int i=start+2; i <= end; i++)
      {
      unsigned short C = (sum & 0x8000) ? 1 : 0;
      sum <<= 1;

      sum = sum + C + image[i];
      }

   image[start  ] = (sum >> 8) & 0xff;
   image[start+1] =  sum       & 0xff;

   unsigned short updated = *(unsigned short *) &image[start];

   printf("     New checksum: %X\n\n",updated);

   if (updated == original)
      {
      printf("     Checksum is unchanged\n");
      return 0;
      }

   fflush(stdin);
   printf("Press 'y' to update %s, any other key to exit...\n",argv[1]);

   char ch = getch();
   if ((ch == 'y') || (ch == 'Y'))
      {
      FILE *out = fopen(argv[1], "wb");

      if (out == NULL)
         {
         printf("Error: could not open %s for writing\n",argv[1]);
         return 1;
         }

      if (fwrite(image, 32768, 1, in) != 1)
         {
         printf("Error: could not write to %s\n",argv[1]);
         return 1;
         }

      fclose(out);
      printf("OK\n");
      }

   return 0;
}
```

The source code above can be compiled under Windows by saving it as **chksum.cpp** and running **cl chksum.cpp** with your environment configured for access to the Visual Studio command-line tools. It can also be compiled under Linux, MS DOS, or MacOS with few if any changes.

The program operates on a specified 16KB bank within a 32 KB binary EPROM image (.bin) file. After modifying the .bin file as needed to alter the model name, attenuator-control table, or other properties, run the **chksum.exe** program and tell it which bank (0 or 1) to update. After updating the checksum, you can write the .bin file to a 27256-3 or faster EPROM and install it in the analyzer.

Again, this operation is not necessary (and will not work) with the base-model 492/496 ROM images.

-end-