A Homebrew Transmitter from the 1960's, Updated for Today's AM

A 6DQ5 Sweep Tube modulated by Four 1625s

December 22, 2006, Bob Hansen, NA7RH

Here is my opportunity to tell about adventures with the homebrew 6DQ5 transmitter and companion 1625 × 4 plate modulator, and to discuss some of the changes made to these classic designs from *The Radio Amateur's Handbook.*

The 6DQ5 transmitter was pieced together during the fall/winter of 1962/63, using a copy of a 1960 ARRL Handbook that had been studied for years. The 6DQ5 design was the only Novice-class Handbook transmitter that promised 75 watt plate input power, 5-band coverage through band switching, switchable crystals and provisions for adding an external VFO and AM modulator. In the Handbook it had the most commercial looking front panel and layout. The 6DQ5 Beam Power Pentode, in addition to being a widely used TV horizontal sweep tube, was applied in commercial ham transmitters in the early 1960's including the Gonset G76, Hammarlund HX-50, Hallicrafters HT-40 and HT-44, and the early Swan transceivers.

The exterior of the transmitter is little changed from 1963 in this recent photo. There has been little inclination to alter the original labels or the controls; however, the multi-scale Simpson meter is a treasure from a recent swap meet.

When starting to build the transmitter at age 15, I didn't have much contact with other amateur radio builders for help and parts, or experience constructing gear from scratch. However, the prior years were filled with experiments using old radio chassis to build intercoms, phone patches, PA systems, a modulated light beam communicator, etc. And many hours were spent listening to discussions about radio on the ham bands using the trusty Knight R55 Receiver. That receiver kit was assembled in 1961, preceded by other small kits. When it came to building the transmitter, the metal work was new, but the Handbook design could be replicated with simple tools and patience. The magic RF circuit areas of the design were faithfully duplicated. Some liberties were taken in control circuits, RF tightness of TVI shielding and the power supply.

The Novice license arrived in January of 1963, thanks to a code and theory class offered by the El Paso (Texas) ARC. The 6DQ5 transmitter was far enough along for an initial CW contact two weeks after receiving the license. Novice contacts were made with the transmitter on the 80-, 40- and 15-meter bands from February through August of 1963. The old log book does not offer many details of that period, but many hours were spent making the station functional rather than accumulating operating time. Working with a very limited set of borrowed crystals and struggling with the mysteries of transmitter instabilities, the CW contacts tended to be nervous and infrequent. I was longing to move on to AM Phone as WA5FNJ in October. A transistorized screen modulator was put together from an article in some magazine and was ready for trial during the 1963 Christmas holidays. The first contact with the home brew AM transmitter (albeit solid state screen modulated) was on December 23. That modulator worked for many mostly local contacts, but it was never good for more than about 25 watts carrier input and 70% modulation.

The 1964 edition of the ARRL Handbook described a better companion modulator for the 6DQ5 transmitter, a 50-Watt Class-AB_1 Modulator that used economical tubes and power supply. Most parts (except the modulation transformer, cabinet and rectifiers) were on hand or freely offered by generous hams. The plate modulator and separate power supply were completed in the summer of 1964, and were used with the transmitter from the end of July through 1966. The Knight R55 was the receiver during that time. With a borrowed Hallicrafters HA-5 VFO which, with its 6AQ5 output tube could drive the transmitter better than other VFO types, AM contacts were regularly made from 80 through 10 meters.

That era of friendly local AM gatherings on 3828 kHz and 29.6 MHz came to an end when many of us were attracted to the newly affordable SSB rigs. The Heathkit SB100 was assembled in January, 1967. The power supply of the modulator was soon traded away and the 6DQ5 transmitter was off the air until March, 2004.

In the 1960’s, building and trouble shooting the AM transmitter, and being able to describe my experience helped open opportunities in a work-study program that made a better education affordable. The practical knowledge also provided a fine foundation for a 35-year career in space radio-electronics.
I cannot think of a time in the intervening years of more on-the-air enjoyment as I’m now having after updating this homebrew AM transmitter.

Details of Building the Original Transmitter

The ARRL Handbook descriptions, "A 75 Watt 6DQ5 Transmitter" and "A 50-Watt Class AB1 Modulator" appeared in the 1961 through 1964 editions (also, 1960 for the transmitter). The originally built transmitter and modulator differed in a number of ways from the models in the Handbook. Both are built in 7½ x 15 x 9-inch light blue hammer-tone painted steel cabinets. These enclosed cabinets, including 2⅜ x 13½ x 8-inch chassis, were available from World Radio Labs in the 1960's. The transmitter layout and control locations are about the same as in the Handbook, but parts are somewhat closer together since the WRL chassis has half the volume of the 3 x 17 x 10-inch chassis used for the Handbook transmitter. The biggest transmitter layout compromise, due to the 7½ inch cabinet height and tube height, was the 6DQ5 socket location on a sub-plate below the main chassis, instead of above the chassis as in the 8¾ inch high Handbook transmitter. There was room for only three of the octal sockets for FT-243 crystals, allowing front panel switching between 6 crystals rather than 11 in the ARRL design (But what young Novice could afford 11 crystals? My entire collection of 3 or 4 was borrowed).

Many of the RF parts including B&W inductor stock for the grid and plate tanks, Johnson plate choke, Centralab ceramic rotary switches and Hammarlund and Allied Radio plate tuning and loading capacitors are the original part numbers from the Handbook. Many RF parts were purchased locally in El Paso, TX. As available spending money allowed, Saturdays often included a bus trip to the supply houses for this or that part. Other items were mail order catalog specials, mostly from Burstein-Applebee, World Radio Labs and Allied Radio. The tool box was supplemented with a mail-order chassis punch set (5 sizes, ⅝″ to $1\frac{3}{32}$″).

**Shark (Japan)
Model 10.110-1
Chassis Punch Set**

The transmitter power transformer is a Stancor P4004 (175 ma DC rating) rather than the larger 200 ma rated Triad R-121-A. The P4004 was an old design in 1962 since it appears as XP-4004 in a 1937 Stancor catalog (for $8.50)[1]. Filter capacitors are the unusual 16 µF, 700 VDC electrolytic of the Handbook design. The power supply choke is a no-name 8-Henry part found in a catalog at a low price, instead of the Triad C-16A. The original power supply with 5U4-GB rectifier delivered about 385 volts to the final when loaded to 190 ma of plate current. Most of the difference from the 400 volts under load indicated for the Handbook transmitter was likely due to higher winding resistance in the Stancor power transformer. I

[1] http://www.amfone.net/stdcor2.htm

was happy to have a working transmitter and perhaps that soft supply prevented damage in the early years when the plate current meter was regularly against the 300 ma peg.

The transmitter control switching is a little different than the Handbook design. In order to be able to operate from either crystals or a VFO without inserting and removing plug P1 in the Handbook schematic, an additional section of the crystal selector switch S1 connects the 0.01 µF capacitor to the cathode of the 6AG7. In order to provide easy switching between CW and AM, additional SP3T sections of the Function Switch S2 in the Handbook schematic allow it to perform the equivalent of inserting P2 (CW), removing P2 (SPOT), or connecting the modulator cable at X2 (AM). Since the SPOT position removes plate and screen voltage from the final, the final cathode may be grounded with the key and grid current observed for casual final grid tuning and drive adjustment. From the beginning the EXT position in the Handbook design seemed a bit scary since it could allow the final to be keyed without drive. It was replaced by the AM position on S2. The front panel has one additional control not in the Handbook design. A front panel Transmit/Receive toggle switch controls AC power to a back panel socket for an external antenna relay. In the AM position of S2 the toggle switch also actuates a relay on the chassis that keys the transmitter, switches the modulator bias to the operating level and can mute a receiver.

Although the transmitter was usable on all bands (on 10 meters only with a high output VFO), on several bands there were problems with the neutralization or parasitic instability that I didn't know how or have equipment to solve. The adjustments of the neutralization and parasitic suppressor by normal procedures did not seem to provide the results expected per the various sections of the Handbook. Eventually a set of adjustments was found that avoided the tendency for instability on the bands. That set of adjustments was somewhat fragile since seemingly unrelated changes could upset the stability.
Resolution of these problems had to wait 40 years. To a large degree they were rooted in the original published design. The way the Handbook 6DQ5 neutralization was connected differently in the top view photo than in the schematic suggests that some instability was found in the ARRL working model. In spite of these difficulties the transmitter was usable and provided a great many hours of learning and operating enjoyment. The transmitter design proved sufficiently robust that the original 6DQ5 tube is working fine today.

Details of Building the Original Modulator

Thanks to my neighbor on the next block (WA5DJC, the Old Man in his 30’s with a BC610 and a truck) there were opportunities to learn about 80 meter transmitter hunts and to scrounge parts and old chassis at local swap meets and club events. The junk box quickly grew before the plate modulator was built during the summer of 1964. Hams in the El Paso club knew about the homebrew transmitter and had some good parts to use in the modulator, so only a few items needed to be purchased. I already had driver transformers, power supply components and tubes including the 1625s along with their ceramic tube sockets.

The Handbook modulator article discusses the range of output power from four 1625 tubes in Class AB_1 at various supply voltages, 140 watts of audio being available with a 750 volt supply. The Stancor A-3894 125-watt modulation transformer was about $36 in a catalog

while the A-3893 60-watt version was about $28. Most of the parts were on hand for a 750 volt power supply using a large TV transformer, so the modulator would be capable of much more than 60 watts. The decision to go for the larger modulation transformer was easy, but then there was the larger cash advance that needed to be negotiated with my providers.
The parts box had 12AX7s and 12AU7s and none of the similar 6AV6 or 6CG7, so the speech amplifier was more like that of other modulators in that 1964 Handbook. Two stages of 12AX7 audio amplification with a mic gain adjusting pot between them, drove the front panel modulation level control pot then the driver stage that used one half of a 12AU7. The available driver transformer was a Stancor A-4774 Universal Interstage Transformer (Single or P-P Plate to Single or P-P Grid). The primary was operated single ended at about 9 ma of plate current, while in the Handbook design the smaller Triad A-31X driver transformer operated with 3 to 4 ma in the primary with a reduced driver plate voltage.

There was no possibility of installing that 125-watt modulation transformer, four 1625s and the power supply components in the WRL cabinet that was purchased to match the transmitter. Due to the 1625 tube height, the sockets in the modulator were suspended about an inch below the chassis. The original modulator power supply with silicon diode bridge rectifier was built into an outboard chassis, and included the screen regulator tubes and bias supply. Instead of the voltage tripling -50 volt bias supply of the Handbook, a winding on the power transformer allowed a diode half-wave rectifier to develop -100 volts. That higher bias voltage allowed operate/standby control of the modulator without requiring an external bias supply or the switching of high voltage as in the Handbook design. When transmitting, the positive end of the 10K bias adjustment pot was shorted to ground by the T/R relay in the transmitter, providing -35 volt modulator operating bias. For standby, the open contact in series with the adjustment pot allowed the bias to increase to more than 90 volts negative.

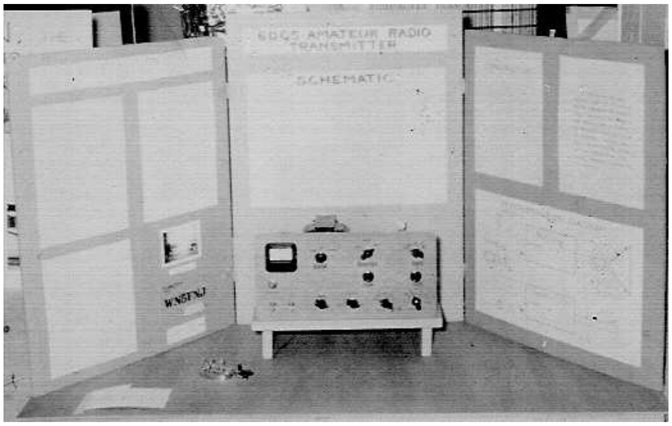
The modulator was usable back in 1964. Without any audio compression or clipping, and with excess available audio power and a low plate voltage on the transmitter final, it was always difficult to modulate at a good percentage without some audible distortion from negative peak over-modulation. In order to control the audio peaks back then I tried an audio AGC scheme and tried negative cycle loading using tube rectifiers. Some other approaches for limiting within the modulator that were never tried included reducing the modulator supply voltage, changing modulation transformer taps or adding a low level clipper.
The Handbook implementation of the modulator with its lower 1625 plate voltage and lower output power should have been a better match for the single 6DQ5 and could have presented less of a problem of transient over modulation.

The plate supply input capacitance presented by the Handbook transmitter final was too high to preserve the AM fidelity designed into the Handbook modulator. The original 6DQ5 plate coupling, plate choke bypass and screen bypass capacitors (all 0.01 µF in the Novice transmitter) were reduced considerably in the quest to obtain adequate response at higher audio frequencies. The 6DQ5 screen voltage was supplied by resistively dividing the modulated plate voltage rather than using an audio screen choke as shown in the Handbook modulator.

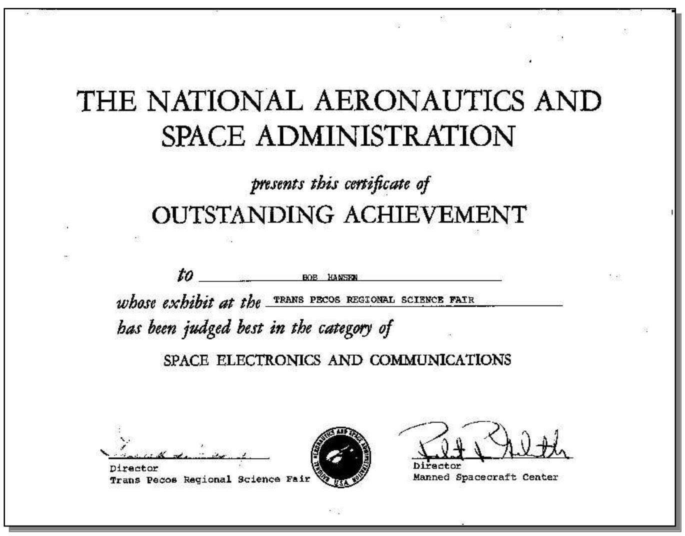
So that is how the transmitter and modulator remained for almost 40 years.

Other Novice Adventures

The 6DQ5 CW transmitter was entered in the regional Science Fair, April, 1963.



When the operator was in attendance, the exhibit had lit tubes, a grid current indication when keyed, and a beat note from the hidden receiver.



THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

presents this certificate of

OUTSTANDING ACHIEVEMENT

to BOB HANSEN

whose exhibit at the TRANS PECOS REGIONAL SCIENCE FAIR

has been judged best in the category of

SPACE ELECTRONICS AND COMMUNICATIONS

Director
Trans Pecos Regional Science Fair

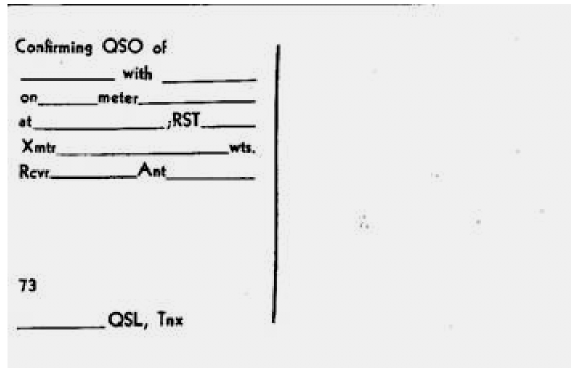
Director
Manned Spacecraft Center

NASA was recognizing the role of Amateur Radio in the early days of the Apollo program
(However, the entry wasn't exactly space electronics, and CW wasn't a comm. mode of choice for moon rockets.)

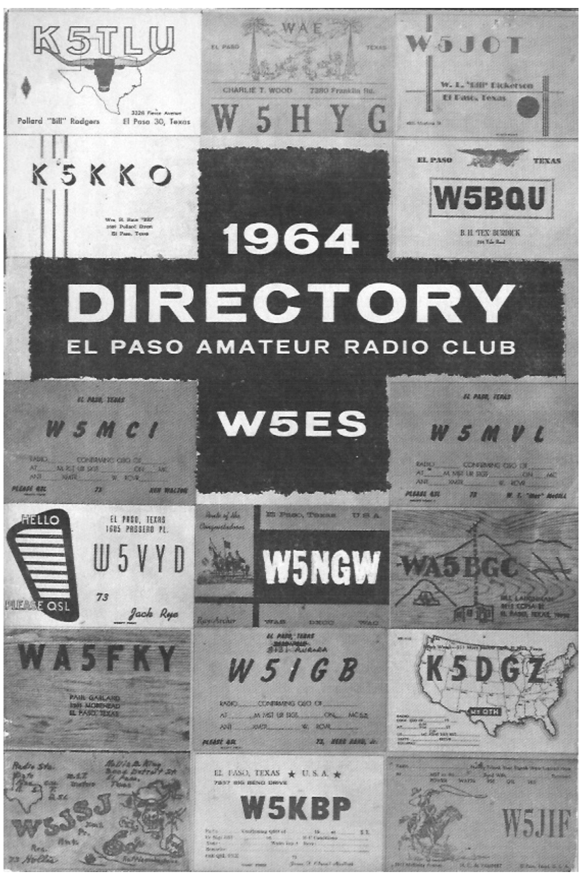
People from the NASA White Sands Test Facility lived in the El Paso area and could have done Science Fair duty at the request of the El Paso schools; however, the NASA signature on the certificate is Robert R Gilruth, Director of NASA Houston from 1961 to 1972. The other signature is that of the Science Fair Director, Frank Gary from the El Paso schools (who also happened to be the father of Bob Gary, WA5BFT).

Our QSL card Print Shop

Soon after the transmitter was built, a family friend who owned a small printing business loaned a hand operated printing press usable for QSL cards. Supplies had to be mail ordered[2] including card stock, movable lead type, ink and reconditioned rubber ink rollers.



Our multicolor QSL cards were printed using lead type and hand carved linoleum block call letters and figures.



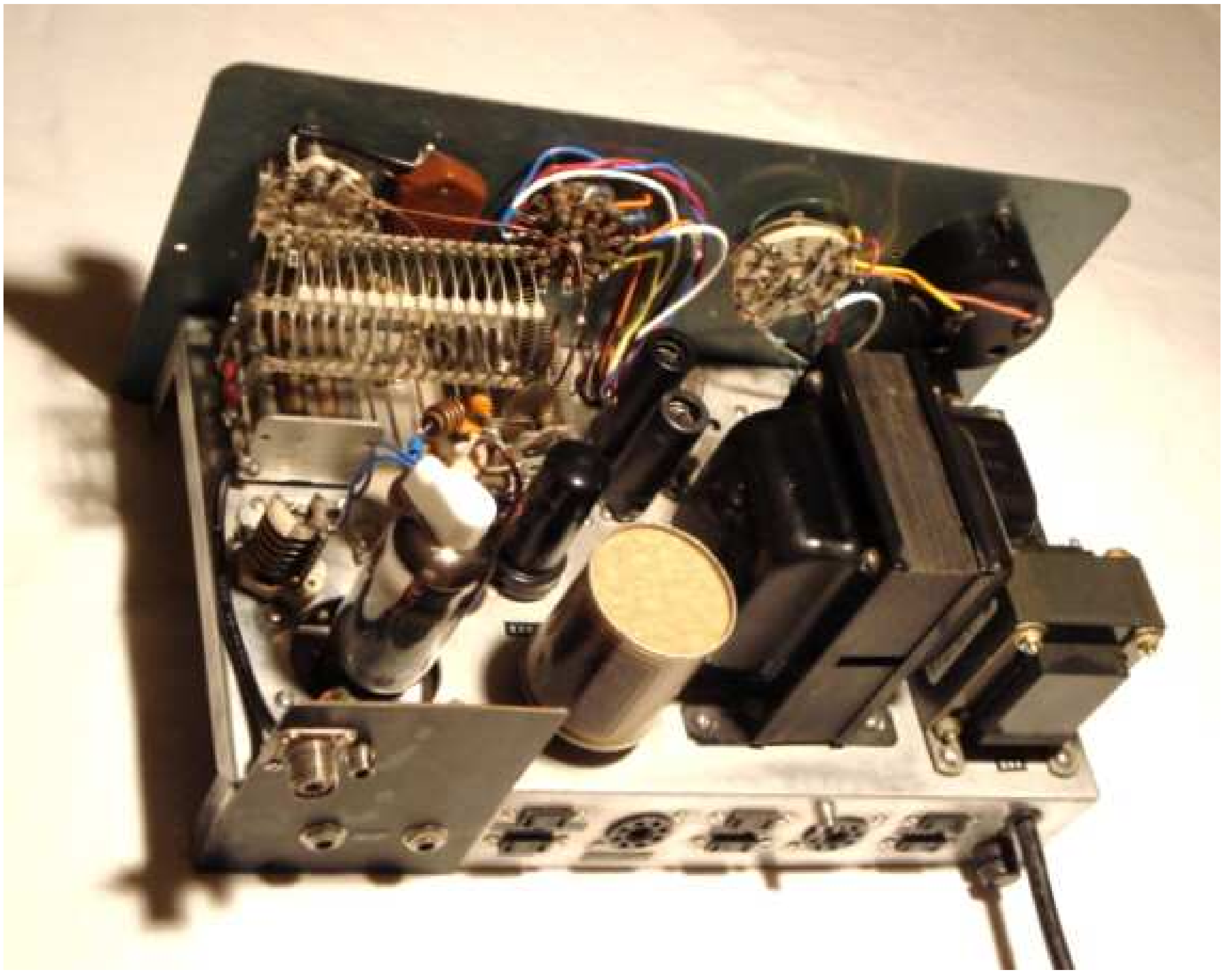
Ken (now WA7UIM) and I made cards for ourselves and a few local hams, including those of WA5FKY and WA5BGC on this cover.

[2] The Kelsey Company, Meriden, Connecticut, now see http://www.nagraph.com/storefront.html

Fortieth Anniversary Updates, October 2003 to Present

Listening to the AM activity on the bands a few years ago started the process of returning the homebrew transmitter to the air. The local roundtables were a strong reminder of 80-meter gatherings long ago. There was also a sense of a misdeed done in trading the original modulator power supply, leaving the transmitter unusable for AM. The capability to enjoy the quality of AM and the satisfaction of self-built gear had slipped away. While making the transmitter updates, there was also the thought that the RF stability deficiencies amounted to unfinished work for someone claiming to know a few things about RF design.
The recent changes are summarized as follows.

TRANSMITTER

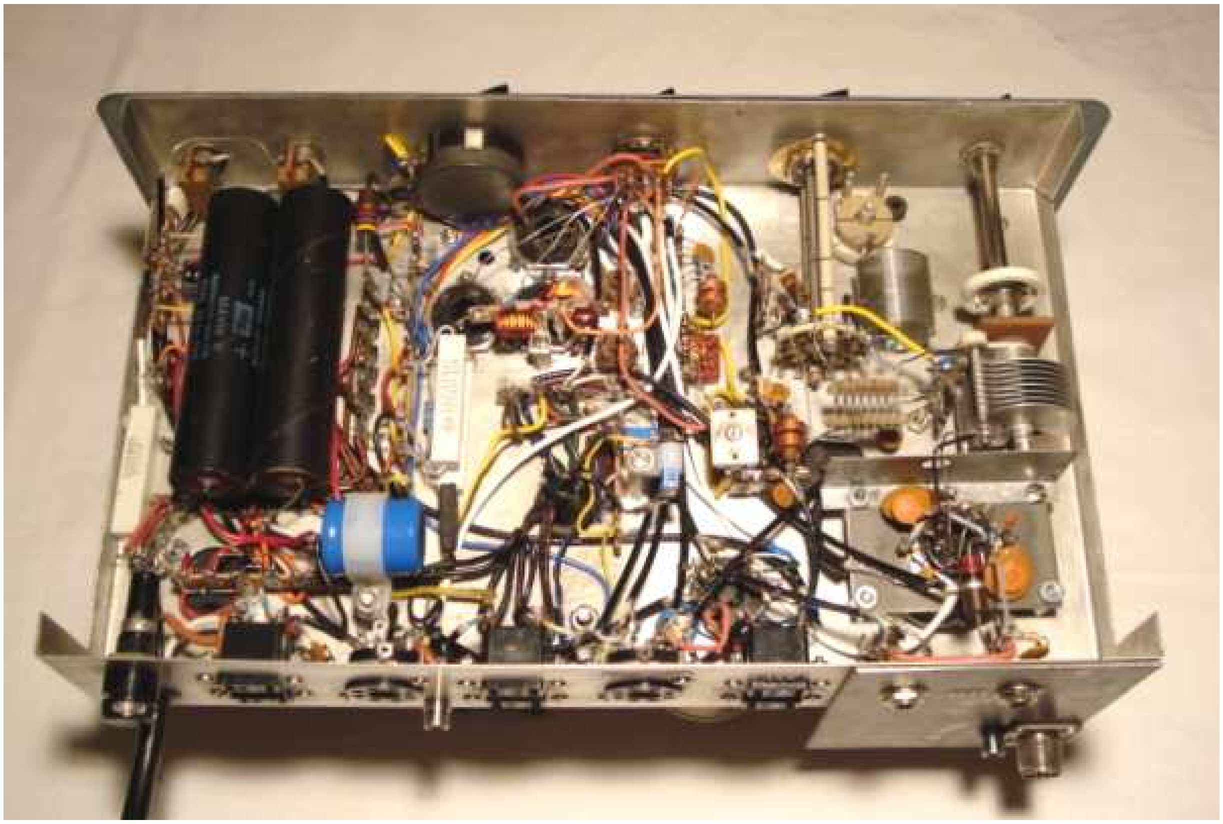


This view of the transmitter shows a number of the recent changes
Visible are the relocated neutralization capacitor, the added screen voltage regulator tubes for the 6AG7, and for the added 300 volt B+ supply, a transformer in place of the 5U4 rectifier. The round yellow can is the original 115 volt AC octal-plug relay (military surplus) for AM T/R control.

The 6DQ5 was more expensive than surplus transmitting tubes back in 1963 – the new 6DQ5 may have cost $9. After my AM transmitter was operational some hams were keen to tell me how they would have used something less costly / higher power such as a pair of 807s. But old stock 6DQ5s seem to be affordable today at swap meets and from old parts suppliers, while the other similar sweep tubes now command a high price. The industrial version of the tube, the 8236 with a carbon anode and 60 watt plate dissipation (used in the Hallicrafters SR-500) is now rare and expensive. The later vintage 6JE6A and 6LQ6 are very similar to the 6DQ5, except each has a 9-pin Novar base, grid 3 brought out to a pin and 30 watt plate dissipation. The 6DQ5 has some desirable qualities for application up to 30 MHz in plate modulated AM transmitters. The 24 watt plate dissipation rating in TV service lies somewhere between the 6146A and 6146B, assuming that the 6DQ5 data sheet rating is equivalent to CCS. The 6DQ5, with its 2.5 Amp filament and high cathode emission has considerably higher ratings than the 6146 for peak plate current (1.0 A), DC plate voltage (990 V) and peak plate voltage

(6500 V). This can provide great RF amplifier plate modulation linearity on positive transient audio peaks. The 6DQ5 also has twice the grid No. 1 input capacitance and plate to grid No.1 capacitance, and 30% more plate output capacitance than the 6146A. That means that it probably cannot approach the 175 MHz upper frequency limit of the 6146A. The Gonset G76 applied the 6DQ5 in the in the 6-meter band, but that required separate neutralization.

The recent modifications to the transmitter have primarily been aimed at improving stability against parasitic and grid-plate oscillations, improving the audio frequency response and linearity of the modulated final stage, protecting the oscillator and final when un-driven or mistuned, and reducing component stress to within ratings.



This bottom view of the transmitter shows some of the other changes
Visible are the -68v protective bias supply (terminal strip at upper left), 300v B+ supply components (at lower left), solid state plate supply rectifiers, push-to-talk reed relay and +8v relay supply (center, left of trimmer cap), and the interface circuit for the Heathkit HG-10 VFO (toroidal inductor tank - upper center).

Much of the transmitter wiring is original. The heavy black wires are high voltage, single conductor shielded lines for AC wiring as well as for modulated and un-modulated supply lines to the plate and screen.

Parasitic Stability

Parasitic Resonance in Neutralizing Circuit

There was a high-Q VHF parasitic resonance at a relatively low frequency in the original neutralizing circuit and the plate spacing of the neutralizing capacitor was too small for the applied peak voltage. The old difficulties with instability reappeared after the transmitter and updated modulator returned to the air in 2004. Modulation peaks were causing the 6DQ5 plate current to misbehave for a few seconds until the transmitter AC power line fuse opened. At first thought the blown fuse and an audible noise could have been from a poorly closing bias circuit relay contact inducing a large amount of noise in the modulator and modulation transformer. Then the sound seemed to be more like arcing, coming from the transmitter just as the fuse blew. This fuse blowing ended my transmissions several times while I was in a QSO. Once the fuse was replaced, everything seemed to be fine on the bench without the modulator. I did not have much of an idea of what was happening until I read several articles about parasitic suppression. The information on the web by Richard Lloyd Measures, AG6K[3] was most helpful. The grid dip meter revealed a sharp 140 MHz resonance in the line from the plate, down to the neutralizing capacitor beneath the chassis. (The old capacitor is visible but unused in the bottom view photo above.)

Several articles on stabilization[4] mention possible problems with too much inductance in the neutralizing circuit leads. The layout of the 6DQ5 transmitter shown in the Handbook requires a fairly long lead from the plate cap down to the neutralizing capacitor under the front of the chassis. In looking for a solution I noticed in the Handbook top view photo, that the lead to the neutralizing capacitor may actually be connected to the plate choke side of the parasitic suppressor, instead of to the plate cap side as shown in the Handbook schematic. There doesn't seem to be much written about whether that connection in the photo could help de-Q the VHF parasitic resonance involving the long neutralization lead. As I recall, that connection to the plate choke side was tried on this transmitter in the 1960's without an indication of improved stability, but there were other stability problems at the time.
There was room on the chassis to relocate the neutralizing capacitor and reduce neutralization circuit inductance greatly. That change was expected to move the resonant frequency high enough that the direct connection to the plate cap would work, as demonstrated by use of a direct connection with short neutralizing leads in many other transmitters of the period. The updated transmitter uses the direct connection to the plate cap, as in the original schematic. There was also the thought that the direct plate cap connection could allow the neutralization to work better over all bands with one capacitor setting (see additional discussion under Neutralization below).

The original APC style variable neutralizing capacitor was a no-name mail order special with 0.022 inch plate spacing, while the Handbook specified 0.025 inch spacing. Per a table[5] in the Handbook, 0.022 spacing can be used safely to about 1250 volts peak. The peak voltage on

---

[3] http://www.somis.org/D-amplifiers1.html

[4] RCA Electron Tube Division, "Circuit-Design Considerations, Parasitic Oscillations", *Transmitting Tubes, Manual TT-5*, 1962, p. 44.

[5] The Radio Amateur's Handbook, Forty-first Edition, 1964, Ch. 6, High Frequency Transmitters, Component Ratings, p. 167.

the neutralizing capacitor is higher than on any other capacitor in the transmitter since it includes the DC plate voltage plus the peak modulating audio voltage, with that amount multiplied x2 for the peak RF swing, plus the negative grid bias on the other capacitor plate. For CW with the Handbook 400 volt power supply, that sum would be less than 1000 volts. With 100 percent AM and the 400 volt power supply, the peak voltage can approach 1750 volts, which exceeds the recommended rating for a capacitor with the originally specified 0.025 inch spacing. And for the modified transmitter and modulator with a 480 volt 6DQ5 plate supply and negative peak limiting which allows positive modulation swings up to the point of modulator saturation (480 V + ~780 volts peak on secondary), the peak voltage on the capacitor can approach 2700 volts. It is no wonder that the neutralizing capacitor was breaking down. Once the breakdown occurred, it could be sustained by the parasitic resonance causing a lot of current to be drawn instantly by the 6DQ5. Usually the plate current meter did not react before the AC line fuse blew.

The solution was to replace the neutralizing capacitor with one that has a greater air gap, and to mount the capacitor upside down on the top side of the chassis next to the 6DQ5. This is the arrangement seen in “A 90 Watt All Purpose Amplifier” in the early 1960's Handbooks, and in Novice Transmitters of later Handbooks. There, the neutralizing capacitor could be connected to the plate cap through two short, low inductance leads, one to each rail of the stator. Also, the 390 pf mica capacitor from the grid tank to ground, across which the neutralizing voltage is developed, was relocated to a point beside the grid tuning capacitor (C1) beneath the chassis, connecting directly to chassis ground. The connection from that mica capacitor and the grid tuning capacitor rotor to the neutralizing capacitor, now on the chassis above, was made with a much shorter low inductance lead through a grommet hole.
Other solutions could have provided a low inductance, high voltage breakdown neutralizing circuit. A neutralizing stub near the tube, as seen in contemporary transmitters such as the DX-60, would not be susceptible to voltage breakdown (the 6DQ5 with higher grid-plate capacitance would more likely require a metal plate next to the tube rather than a thin stub). That approach would probably also require the 390 pf mica capacitor value to be reduced greatly (it is 120 pf in the DX-60) and would be less likely to provide fine, reproducible adjustment.

The replacement APC style variable neutralizing capacitor (center) started out with 18 rotor and 19 stator plates and about a 0.02 in. air gap

After carefully removing 12 rotor and 13 stator plates the minimum air gap was about 0.07 in. (good for 3 kV peak) and the capacitance range was about 4 to 10 pf.

No further signs of parasitic breakdown were seen after replacing and relocating the neutralizing capacitor and lowering the lead inductance in the neutralizing circuit. See additional comments under Plate Parasitic Resonance and Neutralization below.

Parasitic Resonance in Filament Leads

The transmitter schematic in the Handbook and the original homebrew transmitter had no bypass capacitor on the 6DQ5 filament. Most other transmitters of the era have bypass capacitors on the ungrounded side of the RF power stage filaments. The transmitter under some conditions of startup, tuning and drive had occasionally exhibited an instability in which the front panel 6.3 volt pilot light became extra bright and the plate current was abnormal. That pilot light was the only load other than the 6DQ5 filament on one 6.3 volt power transformer winding. Both loads of that winding were connected to the power transformer through separate shielded wires. What I assume was a VHF parasitic oscillation involving the lengths of shielded wire to the pilot light and 6DQ5, was eliminated by bypassing the 6DQ5 filament to ground at the tube socket with a 0.0047 µF ceramic capacitor.

Parasitic Resonance in Plate Lead to Tuning Capacitor

After revising the neutralizing circuit, the main plate parasitic resonance, involving the plate tuning capacitor and the original parasitic suppressor, varied between 75 MHz (plate tuning capacitor at maximum) and 89 MHz (15 meter plate tuning). The Handbook section on VHF Parasitic Oscillation indicates that this resonance with the parasitic suppressor inductance in place should be above 100 MHz to stay well away from TV Channel 6 at 88 MHz. Perhaps that is not so easily achieved using the 6DQ5, with its longer internal leads, 100% higher grid-plate capacitance and 30% higher plate capacitance than a 6146. With the parasitic suppressor choke shorted by a strap, the resonance measured by the grid dip meter varied between 88 and 97 MHz. This parasitic resonant circuit includes the inductance of the 6DQ5 screen grid leads to ground, the 6DQ5 plate capacitance, the 6DQ5 plate lead (internal & external) to the parasitic suppressor, the neutralizing capacitance to ground, the capacitance to ground of the plate choke, the plate blocking capacitor and the lead from the plate blocking cap to the plate tuning capacitor and the plate tuning capacitance to ground.

The following change raised the resonance to 97 MHz at maximum tuning capacitance with the parasitic suppressor shorted: The inductance from the plate choke to the tuning capacitor was reduced by replacing a long, thin leaded 2200 pf plate blocking capacitor with two #10 wires in parallel, in series with two paralleled short leaded Sprague Cera-Mite HV ceramic capacitors (1000 pf and 470 pf). The parallel wires run from the two tuning capacitor stator terminals, to the blocking capacitors at a point next to the top of the plate choke.

The resulting higher resonant frequency allows the suppressor to provide a greater part of the total parasitic circuit inductance and provide greater damping. With the parasitic suppressor un-shorted, the resonance dropped to a broad peak at ~84 MHz with the plate tuning set for 40 meters (90 MHz when set for 15 meters). This was a significant improvement in margin against parasitic instability, providing lower Q at a higher parasitic resonant frequency. However, when tuned for 20 and 15 meters the TVI prevention goal should be to have the resonance well above 86 MHz (the highest frequency where a harmonic lands in TV Channel 6), and when tuned to 10 meters well above 88 MHz. These goals are not met, particularly for 20 meters tuning. Why these changes did not result in a greater parasitic resonant frequency is somewhat of a mystery, based on the known capacitances and estimated circuit inductances. Perhaps the least known component, the plate choke, at 90 MHz is a greater capacitive load than expected.

The parasitic suppressor has four turns, 8 turns/in. close wound (0.44 in., OD) on a 100 ohm, 2 watt resistor. This inductance (about 0.090 μH) is high enough that the dissipation in the resistor will approach 2 watts on 10 meters. I tried to move the parasitic resonant frequency higher by increasing the suppressor coil spacing to 6 then 4 turns/in., but the sharpness of the dip increased significantly (for the same size dip, the grid dip meter probe distance from the plate lead increased ~40% then ~60%) and the resonant frequency increased only about 2 MHz.

As an additional measure to prevent harmonic energy at the plate parasitic resonance from coupling to the antenna, the transmitter output lead wire connecting the loading capacitor to the back panel antenna connector (~#14 AWG in the Handbook design) was replaced with coaxial cable.

Fortunately TV Channel 6 is not used in the immediate area and cable TV is well used. If Channel 6 emissions became a problem, an option would be to reduce the value of the 390 pf capacitor from grid tank to ground. At half that value, the neutralization could be achieved with about half as much neutralizing capacitance and the plate parasitic resonance frequency should increase about 8%.

Parasitic Resonance in Grid Tuning Circuit

After raising the plate parasitic resonant frequency and replacing the neutralizing capacitor, there arose a concern that the plate parasitic resonance was close to the grid parasitic resonance (the grid resonance varied from 108 to 125 MHz with tuning). Moving the 390 pf capacitor close to the grid tuning capacitor had helped by eliminating some of the inductance in the grid parasitic circuit path. The grid circuit parasitic resonant frequency was then further increased by connecting the 6DQ5 grid directly to the closest end of the grid tuning capacitor stator bar with two parallel wires. This lead shortening reduced the coupling between the grid circuit and the resonances in unused, switch shorted parts of the grid tuning coil, as well as raised the grid parasitic resonant frequency. The minimum grid circuit parasitic resonant frequency over the used range of the grid tuning capacitor became 122 MHz.

Neutralization

The parasitic stability and neutralization were both greatly improved by relocating the neutralizing capacitor for reduced lead inductance. In any case, the neutralizing capacitor needed to be replaced by one with a higher voltage rating. The result of these changes is that the same setting of the neutralizing capacitor now appears to provide nearly optimum neutralization on all bands (currently verified from 80- to 15-meters). The grid current varies symmetrically on either side of the plate tuning dip and the output power peaks at the bottom of the plate dip (into 50 ohms) on all bands. The value of the adjusted neutralizing capacitor, estimated from the plate position, agrees well with the value calculated using the formula in the Handbook[6]. This was a very satisfying improvement.

Although relocating the neutralizing capacitor should be the best way to obtain parasitic stability, I wondered how well that connection option in the Handbook photo would work with the original capacitor location. As discussed above under Parasitic Resonance, close examination of the Handbook top view photo indicated that, unlike the schematic, the neutralizing capacitor lead was connected to the plate choke end of the parasitic suppressor in the ARRL model. Some later Handbooks[7] and a transmitting tube manual[8] show schematics for other 80-10 meter transmitters with the neutralizing capacitor connected to the plate choke side of the parasitic suppressor. I did not have much luck with that connection long ago, but perhaps unrelated stability problems were being observed. One concern with that connection was that it might adversely affect neutralization on the various bands.

After some investigation, it seems that when the neutralizing circuit parasitic resonance is moved down into the VHF region by excessive lead inductance, the sharp resonance seen by the grid will not be significantly damped regardless of which connection is used. A computer model was generated for the components from the 6DQ5 plate to the transmitter output, including the neutralizing circuit. The response from the plate to the 390 pf capacitor showed the sharp series resonance in the neutralizing capacitor path. When the original long leads from the plate to the 390 pf mica capacitor ground connection were modeled as a 0.225 µH inductor (with a 5.5 pf neutralizing capacitor) the resonance was near140 MHz. The sharp resonance frequency appears to involve only those neutralizing components between the plate

---

[6] The Radio Amateur's Handbook, Forty-first Edition, 1964, Ch. 6, High Frequency Transmitters, Screen-Grid Tube Neutralizing Circuits, p. 158. A value of 5-6 pf was calculated for the 390 pf mica capacitor, depending on what is assumed for strays.
[7] The Radio Amateur's Handbook, Fifty-third Edition, 1976, Chapter 6
[8] RCA Electron Tube Division, "Five-Band 10-80 Meter Transmitter (90 watts)", *Transmitting Tubes, Manual TT-5,* 1962, p. 306-307.

and the capacitor ground connection, with little sensitivity to the 6DQ5 plate capacitance or the parasitic suppressor inductance. Another model with the same long leads, but with the connection moved to the plate choke, showed an even greater sharp resonant response at 140 MHz. In a third model with reduced lead inductance, as estimated for the new capacitor location and larger/parallel leads, the sharp response was reduced in level and at a frequency above 300 MHz. That should be a high enough frequency for the parasitic to be suppressed by the 6DQ5 self-neutralizing[9].

In order for the original parasitic resonant frequency involving the neutralizing capacitor to have been as low as 140 MHz, the neutralizing circuit lead inductance must have been more than 0.2 µH. That excessive inductance is something that will also cause the best neutralizing capacitor setting to be different from band to band. On the higher bands, that series inductive reactance cancels some of the neutralizing capacitor reactance, resulting in a greater voltage being fed back. The phase of the fed back neutralizing voltage is unaffected since the sharpness of the resonance demonstrates that these elements are nearly pure reactance. The feedback leg of the neutralizing circuit is still a high impedance capacitive divider regardless of whether one capacitor's effective value is altered by series inductance. With that much lead inductance, the correct neutralizing capacitance could decrease 5% from 80- to 10-meters. That variation can be avoided by greatly reducing the lead inductance, as was done by relocating the capacitor.

Something that should be considered in the future, or perhaps considered instead of relocating the neutralizing capacitor in a well behaved existing transmitter, would be to reduce the value of the 390 pf mica capacitor, to 330 pf or 270 pf. That would result in a proportional reduction in the neutralizing capacitance which would raise the parasitic resonance frequency in the neutralizing circuit. It could also reduce the band to band differences in the neutralizing capacitor setting and to a smaller degree increase the frequency of the main parasitic resonance in the plate lead to the tuning capacitor.

Final Amplifier Bias and Protection

Original Grid Leak Bias

The Handbook 6DQ5 transmitter design is unusual in that the grid leak resistance is 47k ohms, which with 3 ma of grid drive produces -141 volts of DC bias. The control grid rating of the 6DQ5 is -250 volts peak (for RCA and Tung-Sol, in TV service), and the similarly voltage rated Type 8236 in Class C service has a DC Grid voltage rating of -150 volts. At 3 ma grid drive the design applies -280 to -290 volts on the RF negative peaks, not an unreasonable stress for ICAS. At 2.5 ma grid drive, the voltage peaks would be within the TV service ratings.

A high control grid DC bias is required to maintain linearity on positive amplitude modulation peaks. According to an old QST article[10], when the cutoff bias is 50 volts (6DQ5 with 150 volts on screen, no modulation), twice cutoff bias or -100 volts would be required for +100% AM. The screen voltage from the original design resistive divider may have been closer to 162 volts requiring a grid current of 2.3 ma to provide a -108 volt bias for 100% AM. For the

[9] Eitel-McCullough , Inc. (Varian/Eimac), *Care and Feeding of Power Grid Tubes*, 1967, p. 109-113.
[10] Grammer, "Lop-Sided Speech and Modulation," *QST*, February, 1940, http://www.arrl.org/tis/info/am.html

current transmitter with a 6DQ5 screen voltage of 150 volts, the -140 volts of bias developed at 3 ma grid drive is enough to keep the Class-C stage linear (conduction angle below 180 degrees) for +180% modulation peaks[11]. The article points out that more RF drive power is required to maintain this higher bias voltage, but 3 ma of grid drive is generated by the 6AG7 on 15- to 80-meters. Generating +180% modulation peaks would require about 135 watts of audio from the modulator, a number close to the capability of the 4 x 1625 Class-AB_1 modulator with a 750 volt supply.

Use of Grid Leak and Fixed bias

Ordinarily a combination of fixed and grid leak bias will not protect a class-C amplifier when the drive is removed. Clamp tubes were widely used for that purpose and they can hold the dissipation of the protected tube to a low level. The relatively high grid leak bias voltage, along with the use of a voltage divider to develop the screen voltage, provided an opportunity to protect the 6DQ5 with a combination of fixed and grid leak bias. Several things (rising plate voltage, rising screen voltage) work against being able to hold the tube within dissipation ratings with an amount of fixed bias that is also usable once RF is applied. With the upgraded power supplies, adjusted screen voltage divider and no RF drive, more than 70 volts of negative bias would be required to stay within the 24 watt dissipation limit with 50 ma of DC plate current. Allowing a 10% higher than rated dissipation for the unusual circumstances of short periods with no RF drive, a -68 volt fixed bias should provide the desired protection.
As a possible added benefit, the ARRL Handbook and Eimac publications indicate that better modulation linearity will be achieved when the grid bias is developed by a combination of fixed and grid leak bias.

Adding the Protective Bias

The Stancor power transformer has an 80 volt bias tap on its 800 VCT secondary.
Half wave rectified and Zener diode regulated, the tap voltage provides the -68 volt DC protective bias for the Final.
One small terminal strip added to the transmitter (visible at the upper left in the chassis-bottom photo) supports the rectifier, Zener diode and filter capacitor.
The 47k ohm final grid leak resistor was paralleled with another 47k.
The grid current meter shunt resistor (100 ohms in original schematic) is lifted from ground and connected to the -68 volt bias supply. (That was easy in my case since the meter shunt is on the meter switch.)
At 3 ma grid current the combined fixed and grid leak bias is the same -140 volts as developed by the original 47k ohm grid leak resistor. At 2.5 ma grid current the combined bias is about -128 volts where it had previously been -118 volts. In this range of grid currents, the amount of drive available for a fixed setting of the 6AG7 screen voltage did not change noticeably when switching to the combination bias.
The only notable change in adding this fixed bias protection is when the grid circuit is miss-tuned or the grid drive adjustment is set too low. Then the grid current drops off more rapidly than with only grid leak bias.

---

[11] Calculating: ((140v / 50v) -1) *100% = 180%.

Oscillator Protection

Limiting Dissipation when Not Driven or Oscillating
In the original transmitter, the 6AG7 could exceed its dissipation rating if a crystal failed or had poor activity and stopped oscillating or the VFO was selected but not powered or connected. This stress was made worse by having 400 to 550 volts DC on the plate when the 6AG7 rating is 300 volts. A 100 ohm resistor was added in series with RFC1 in the 6AG7 cathode DC path. That resistance, along with 17 ohms in the RF choke, was just enough to limit the cathode current with no drive to about 25ma and limit plate dissipation to the 11 watt ICAS limit, but only with the excitation pot set for a screen voltage below about 130 volts. The reasoning was that RF drive was most likely to fail on 40 or 80 meters where the excitation is set low and the oscillator plate is tuned near the crystal frequency (see below). After the power supply upgrade with the new 300V B+ for the oscillator, the 6AG7 remains within dissipation limits with the excitation set for a screen voltage of up to 215V (~max adjustment, considering screen current). The added cathode resistor bias was partially compensated by reducing the grid leak resistor from 68K to 56k ohms.

The original Handbook article did not offer a lot of instruction for adjustment of the excitation trimmer capacitor of the crystal oscillator. In order to get a better understanding, a small resistor in series with the oscillator grid leak resistor allowed oscillator grid current to be monitored. When the 6AG7 plate is tuned to the same frequency as the crystal (not frequency multiplying), the oscillator grid current varies greatly with Final grid tuning as well as with the excitation trimmer setting and crystal activity. When the Final grid tuning is slightly on the low frequency side of the Final grid current peak, the oscillator grid current goes through a dip where oscillator startup is least reliable and keying can be degraded. There seemed to be only a small tuning range on the excitation trimmer where keying was best near that dip in oscillator grid current. One crystal that eventually failed was erratic in this keying test and showed lower oscillator grid current.

Key-up Cathode voltage
The heater to cathode voltage rating of the 6AG7 is 90 volts. With screen and plate voltage applied to the 6DQ5, the key up voltage appearing on the cathodes of both tubes can be 170 volts due to the key up 6DQ5 screen voltage being over 200 volts and the plate voltage well over 500 volts. By adding a 100k ohm resistor across the key jack, the key up voltage is reduced to less than 50 volts. The resulting key up dissipation in the 6DQ5 is about ¼ watt, and if neutralized and stable at parasitic resonances, the 6DQ5 should not oscillate or emit RF noise when biased slightly into conduction. For longer periods without transmitting, in this transmitter S2 can be returned to the SPOT position which removes the 6DQ5 plate and screen voltages, reducing the cathode emission and dissipation to zero (SPOT does not ground the oscillator cathode; the key is closed for that).

Operator Protection

The key click filter capacitor, C5, can pack a punch at the key when charged to 170 volts. The addition of the 100k ohm resistor across the key jack as discussed above also improved operator safety and reduced arcing and sparking at the key.

HG-10 VFO Interface

The Heathkit HG-10 is a nicely constructed VFO that is very stable and has a wide slide rule dial for each band. It was marketed specifically to drive the DX-60 at a relatively low level of 5 volts rms minimum into a 50k ohm load. That level directly from the VFO cathode follower is insufficient to produce a low conduction angle and perform well when driving the 6AG7 as a frequency multiplier. By adding a parallel tank circuit on the transmitter VFO input to resonate the capacitance of the interconnecting cable and the 6AG7 input, the voltage was increased enough to drive the 6AG7 as a doubler, but not as a tripler. The tank circuit across the VFO input resonates both on 40 and 80 meters without switching and allows VFO operation on 80, 40 and 20 meters. Apparently, for VFO operation on 10 meters, either an additional stage of gain or multiplication, or a different VFO will be required.

Transmitter Power Supply Upgrades

Rectifiers

The old (and perhaps tired) 5U4GB rectifier was replaced with 1960's style solid state rectifiers (1N4007) in order to eliminate a heat source, lessen the load on the power transformer and operate the final at a more efficient voltage. That change increased the plate voltage from 385 to about 438 volts keyed under load. With that change, the 5 volt rectifier filament winding was employed to buck the 120 volt AC line so the 115 volt power transformer would produce close to 6.3 volts for the filaments.

Separate 300 Volt B+ Supply

When the Heath HG-10 VFO was acquired, powering it from the Transmitter was the plan. However, the limitations of the single high voltage B+ supply of the transmitter became all too clear. On 15 meters the 6AG7 stage and its excitation control can draw more than 35 ma. The 50K ohm bleeder and 6DQ5 screen divider (key down) draw about 27 ma. The keep-alive regulator in the modulator draws transmitter B+ current on voice peaks. Then, at >185 ma of 6DQ5 plate current, the total intermittent supply load was exceeding the power transformer 175 ma continuous rating by more than 40%. The thought of adding another 20 ma of continuous load for the VFO was not comforting. Neither was the idea of heating up the transmitter by resistively dropping voltage from the 440-550 volt supply to the 102 volt level regulated in the VFO.

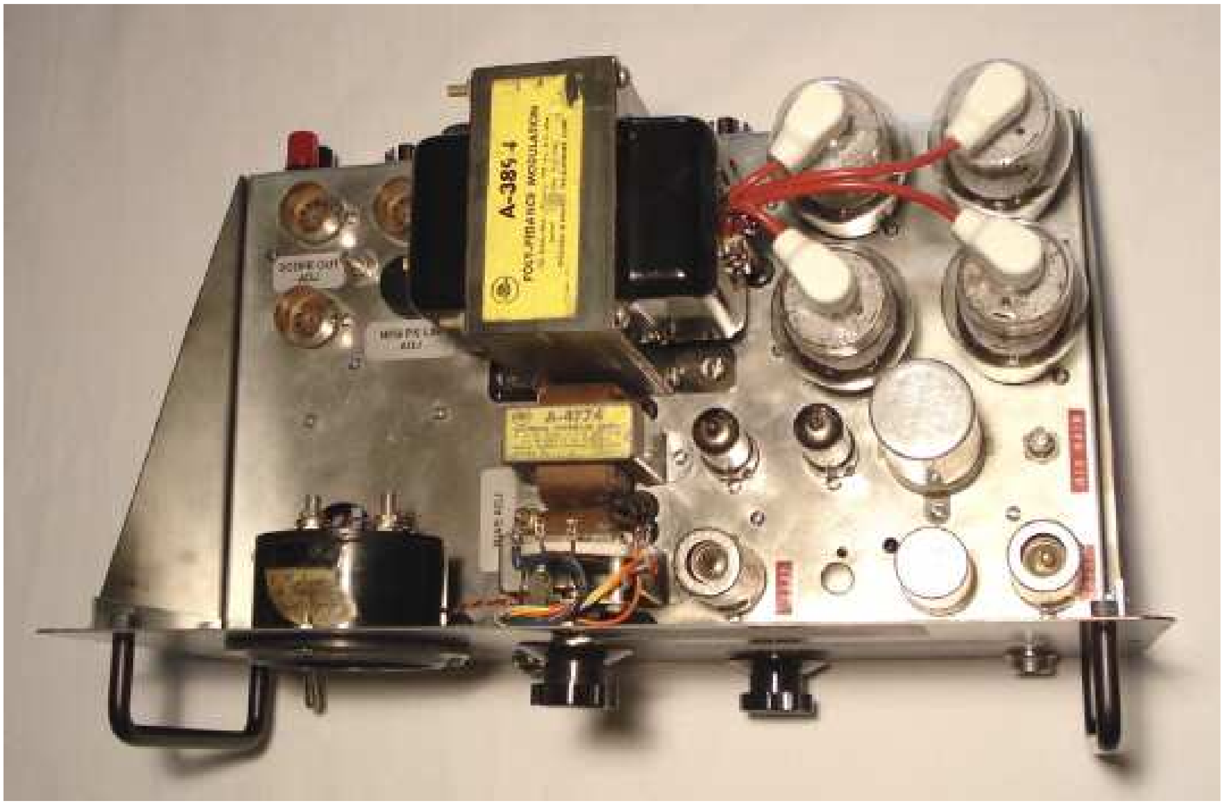
Another consideration was that the 6AG7 was already operating well above its 300 VDC plate voltage rating. It was probably the combination of the high plate voltage and lack of current limiting when oscillation stops or when the VFO is off, that caused one 6AG7 to degrade to the point that oscillation was unreliable. A separate lower voltage plate supply for the 6AG7 could also greatly reduce the change in oscillator plate and screen voltage during keying.

I collected a number of transformers at swap meets and looked for others on the web that would fit in the space on the chassis where the 5U4 had been. The older ones that would fit did not have enough output current to supply everything that could be powered from 300 to 350 volts. The newer globally specified 115V/230V transformers in the 80VA size have a small 2.5 x 2.37-inch chassis footprint and can be bridge rectified to conservatively deliver (at 120 volt AC line) more than 310 volts at 140 ma, per Hammond Mfg's formulas. I purchased the Hammond 185E230. Using a single modern 220 µF electrolytic capacitor[12] as a filter, ripple at 140 ma load current should be less than 0.5%.

The rectifier and filter capacitor were mounted neatly below the new transformer where the 5U4 socket used to be. Load regulation of the supply is good due to the large filter capacitance and the relatively low winding resistance (32 ohms) of the 230 volt secondary. The new transformer runs cooler than the older main power transformer. With the reduced high voltage supply current, the 6DQ5 plate voltage increased to 480 volts under load. 6DQ5 screen voltage divider values were adjusted for 150 volts at the screen, key down.

[12] 220uF @ 400v, CDE 380LQ221M400J022, 25mm x 30mm, $3.38 from Mouser

MODULATOR



The top view photo above shows the modulator after the updates. The meter, meter switch, ceramic plate caps and high voltage wiring are new. The screen voltage regulators (0A2s, unshielded at center) and bias adjust control were added to replace those in the original separate power supply. Also visible at the upper left are added controls for the negative peak limiter keep-alive voltage and the audio output level for the scope horizontal input.

This photo of the chassis wiring shows other additions. At the middle and upper right are the negative peak limiter and its MOSFET keep-alive supply regulator, and the tapped power resistor load of the limiter is on the far right. Also, at the middle far right is the resistor divider chain for developing line level and scope audio outputs and at the lower right is the screen voltage divider for use with the 6DQ5 on AM. The meter shunts and dividers are near the center of the chassis.

Speech Amplifier and Modulator Updates

Speech Amplifier

The speech amplifier changes were influenced by the article “The Competition Class Stock Eliminator Ranger”[13]. The mic input is now R-C low pass filtered for RF. Cathode resistor bias is applied to the first stage. The 12AX7 voltage amp stages were rebiased for maximum undistorted output voltage range per the GE 12AX7-A data sheet.

The mic input resistance at the first stage grid was increased to 10 megohms to preserve crystal microphone low frequency response (any benefit above 5 megohms is in doubt).

Inter-stage coupling capacitors are 0.022 µF, 630 volt polypropylene film.

Small mica RF bypass capacitors are distributed through the speech amp at each grid. The RF bypass at the first stage grid was reduced from 100 pf to 39 pf (This seemed to improve highs with crystal mic, but it could not have been a large effect since the mic also sees >100 pf of

[13] http://www.frn.net/tech/mods/vikingranger/

Miller effect parallel input capacitance at the 12AX7 grid). More recently, a 2-resistor, 2-capacitor audio response shaping network was added between the first stage plate coupling capacitor and the following gain control pot. The network currently attenuates the 300 to 600 Hz lower midrange by about 8 dB relative to highs above 2000 Hz and attenuates by about 2 dB relative to lows below 100 Hz.

A line-level audio input was added through an RCA connector on the rear of the chassis. It is resistively summed with the separately equalized and gain controlled mic signal at the grid of second 12AX7 stage. This is useful for measuring the frequency response and distortion of the modulator, and to sum in computer sound card and tape recorder output signals.

Driver

DC bias was removed from the driver transformer primary by going from single ended to push-pull drive. This extended the bass response and reduced the frequency at which low frequency distortion increases - both halves of the 12AU7 were used as a class-A long-tail-pair to drive the center tapped driver transformer primary. In going to push-pull drive, there are two plate resistances in series with the whole primary, so the transformer secondary sees a higher effective driver plate resistance. In order to further extend the low frequency response, the increased plate resistance was partially compensated by reducing the secondary load from 100k ohms to 75k ohms.

The Stancor A-4774[14] driver transformer with no DC bias was measured to have an inductance of at least 43 H for each secondary winding (secondary load sees >172 H with the two windings series connected). That transformer is the dominant source of low frequency roll-off in the modified speech amp/driver. Driven push-pull with the 75k ohm secondary load, the transformer attenuation is <1 dB at 100 Hz and <3 dB at 50 Hz. The Stancor A-4774 is almost identical, physically and electrically, to the Hammond 124E[15] (which is available from Antique Electronics, and is a favorite for upgrading Johnson AM rigs). The Hammond 124E has a lower primary resistance and its impedance and frequency response specs indicate an inductance of at least 35 Henrys per secondary winding.

Modulator Section

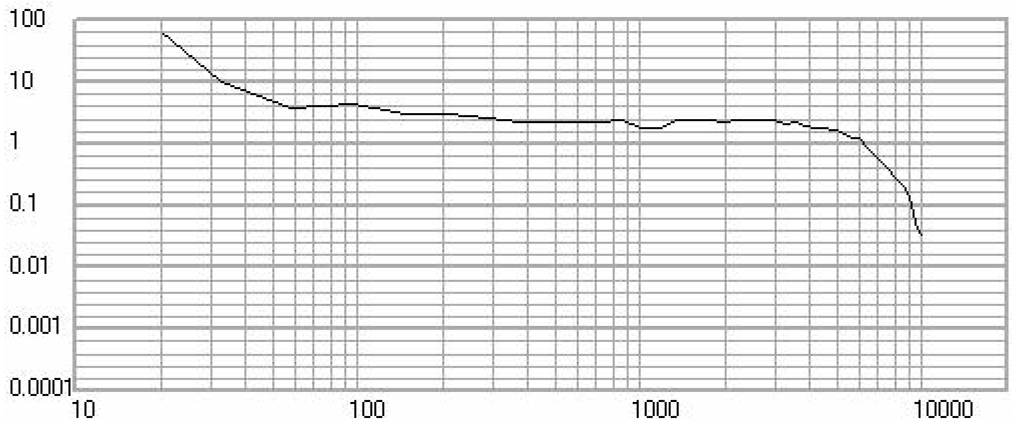
Sixty years after WWII, the 1625 is still widely available from old stock for $5. Large numbers of this 12 volt version of the 807 were produced for the war. Today it still represents the beam power bargain that made it attractive in the '60s.

The extensive RCA data sheet for the 807 Beam Power Tube[16], dated Nov. 5, 1954, shows typical operating conditions and distortion performance data applicable to the 1625. The class AB_1 operating conditions in the data sheet are about the same as in the Handbook modulator description: zero signal plate current levels are 28 ma per tube for 450 DC plate volts and 15 ma per tube for 750 volts. However, the 807 data sheet Class AB_1 distortion curves which show very good performance are not for those typical operating conditions, but for higher zero signal plate currents of 40-50 ma per plate. The achievable distortion performance at recommended operating conditions (with no negative feedback in this modulator design) remains unknown.

---

[14] http://www.clarisonus.com/Archives/Trans/Stancor61.pdf
[15] http://www.hammondmfg.com/124.htm
[16] Frank's Tubes, http://www.tubedata.org/

The total harmonic distortion at a 50 percent modulation level was measured on the updated modulator, from the line level input to modulated plate voltage output, through the speech amp, push-pull driver, modulator and negative peak limiter (see text below). While driving the operating transmitter, it was 1.8% at 1000 Hz, rising to 3% at 200 Hz and 4% from 60 to 100 Hz. Measurements were made using a computer sound card and the Tech-Systems-Labs TMS1 software[17].



Modulator THD: 3.9% at 60 Hz, 4.3% at 100 Hz, 2.9% at 200 Hz, 1.8% at 1000 Hz

The only changes to the original 1625 modulator section itself were to add current and voltage metering and to upgrade high voltage wiring and plate terminal caps.

Modulator Power Supply Replacement

The original separate homebrew supply was traded away.
This time a Heathkit HP-23 power supply, originally sold for transceivers such as the SB-100, was used unmodified for the modulator.
Two 0A2 tubes were added to the modulator chassis for the 300 volt 1625 screen regulation, using the HP23 low B+ output (340 to 370 volts loaded <45 ma). The two 12AX7 speech amp stages also operate from the regulated 300 volts. Using the smaller 0A2 regulators instead of the 0D3, there is an insufficient current range of regulation to also supply the 12AU7 driver plate when the 1625s draw the peak screen current at full output with a 750 volt supply. So the 12AU7 operates from the unregulated HP-23 340 to 370 volts using separate supply decoupling. Another circuit originally in the separate power supply that was added to the modulator chassis is a bias adjusting pot with the same type T/R bias control as used before, operating from the HP-23 -130 volt fixed bias. The HP-23 supply has a bias adjustment pot for -45 to -90 volt bias coming out on a separate pin, but without modification there is no access to the positive end of the pot for T/R bias control.

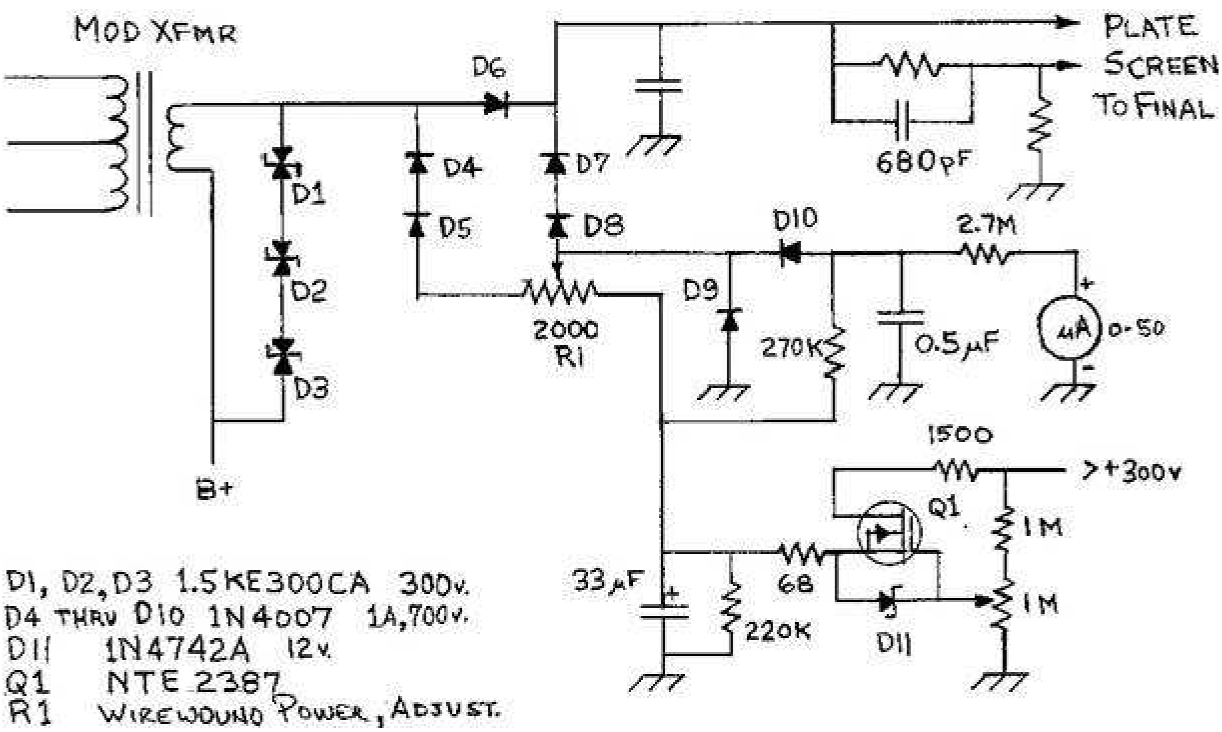
Also updated in the modulator were the HV wiring and 1625 plate terminal caps (Now HV test lead wire and ceramic caps; I no longer tolerate the thought of brushing against the old ARC-5-style plate terminal clips when operating with the chassis out of the cabinet).

[17] http://www.tech-systems-labs.com/test-software.htm

Added were a meter, meter switch and associated resistor networks in the modulator. The calibrated meter scales can monitor HV, cathode current, negative bias, or the keep-alive voltage/modulation level (more later).
The 12 VAC filament winding is not grounded in the HP-23 and is balanced with respect to ground in the modulator: capacitors and resistors to ground assure 6 VAC to ground on each leg. A shielded, twisted pair carries balanced 12.6 V to the speech amp filaments.

Secondary side of Modulation Transformer

High level negative peak limiting circuit
(Based on Three-diode configuration by Steve Cloutier, WA1QIX[18], modified per the Figure below)

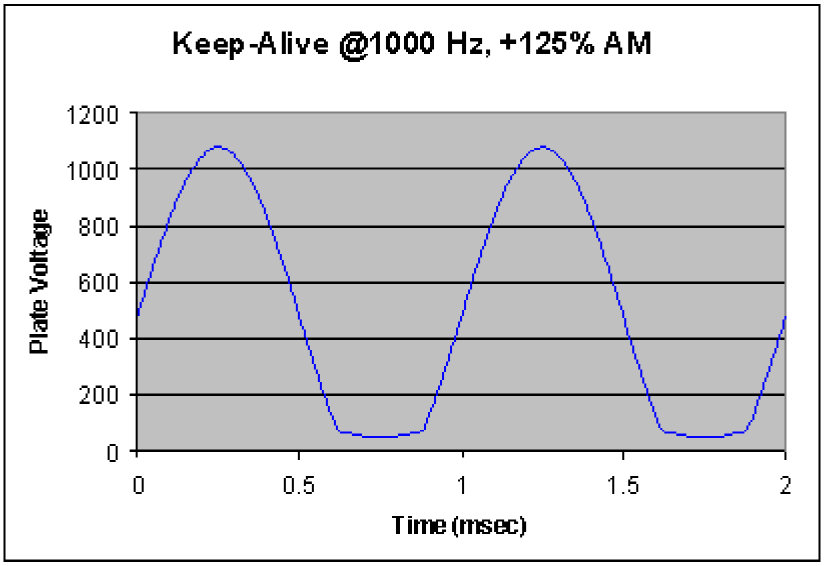


Negative Peak Limiter with Keep-Alive Supply

The three diode configuration with keep-alive supply introduces less distortion than full negative cycle loading schemes since during most of the cycle it is doing no clipping. When the microphone polarity is such that the high peaks of the voice waves are positive, the rounded portions of negative peaks carry little vocal energy and are transmitted at a low RF power level. Modifications to the WA1QIX scheme include use of an adjustable tap resistor. Instead of abruptly clipping negative peaks at a keep-alive voltage of 40 or 50 volts, the keep-alive voltage is nominally set to 75 volts. On negative peaks the final plate voltage continues downward toward 40 to 50 volts. Below the keep-alive voltage the waveform is rounded because in that region it is an amplitude reduced version of the negative going voltage peak at

[18] http:www.classeradio.com/3-diode.jpg

the modulation transformer output. The tap on R1 is set a few hundred ohms from the keep-alive supply end.



Modeled Sine Wave Response of the Limiter

A typical, asymmetric voice wave, properly phased, would show less negative peak rounding for +125% modulation peaks, than the sine wave above. If the ratio of positive to negative peaks is in the range of 1.25:1 to 2:1, as observed[10] for many people's voices and microphones, the limiter introduces very little distortion at all.

Keep-Alive Supply Regulator

The Keep-Alive supply uses a high voltage MOSFET (NTE2387[19]) as a series regulator. It charges the 33 uF capacitor as required to provide a regulated adjustable voltage for the negative peak limiter. Originally the regulator operated from the 6DQ5 plate supply, but now draws current from the new transmitter 325 volt supply. The NTE2387 was used because it has an 800 volt rating for margin with the unloaded plate supply. With the lower supply voltage, a 600 volt part such as the STP11NM60FDFP[20] might be a better choice; it has lower cost and an insulated thermal contact.

Limiter and Modulation Monitor

The meter switch has a keep-alive/modulation level position (150 volts full scale as shown in the schematic above). It reads the most negative of the keep-alive regulated voltage and the detected negative peak of the modulated 6DQ5 plate voltage. With no modulation the meter reads the keep-alive voltage, while modulation peaks momentarily drive the reading toward zero, the idea being to keep the 6DQ5 plate voltage above 40 to 50 volts on negative modulation peaks. The actual negative peak voltage from the modulation transformer can be several hundred volts negative with respect to ground, but the limiter diodes, tapped resistor and keep-alive supply assure that the plate and screen voltages remain positive. The tapped resistor provides a 2000 ohm load for the modulation transformer when the modulated B+ is negative with respect to the keep-alive voltage. As additional protection for the modulation

[19] http://www.nteinc.com/specs/2300to2399/pdf/nte2387.pdf
[20] http://www.st.com/stonline/products/literature/ds/7957/stp11nm60fd.htm

transformer, three 300 volt bi-directional transient suppressor diodes (Vishay 1.5KE300CA) in series are connected across the secondary.

Separate 6DQ5 screen voltage divider for AM

I was looking around for a screen choke as shown in the handbook so the screen voltage would not have to be divided from the modulated plate voltage. Then I read several ultra-modulation articles that indicated that the screen choke does not provide good modulation linearity with positive peaks in excess of 100 percent. In one article a 6146 screen divider was fine tuned for linearity by bringing some of its current from the unmodulated B+ and some from the modulated plate voltage. I have not tried that. All of the 6DQ5 screen divider current now comes from the modulated plate voltage. For the screen divider in the modulator, a small high voltage capacitor (680 pF) was connected across the upper resistor in order to form a capacitive divider with the 6DQ5 screen bypass (~1000 pF) and modulator-to-transmitter cable capacitance. With that capacitor in place the screen bypass capacitance does not roll off the high audio frequencies or contribute an audio phase delay at the screen. After that change, the retrace error (RF Final modulation distortion, mostly on negative going peaks) in the scope trapezoid pattern all but disappeared.

Line Level and Scope Monitor Points

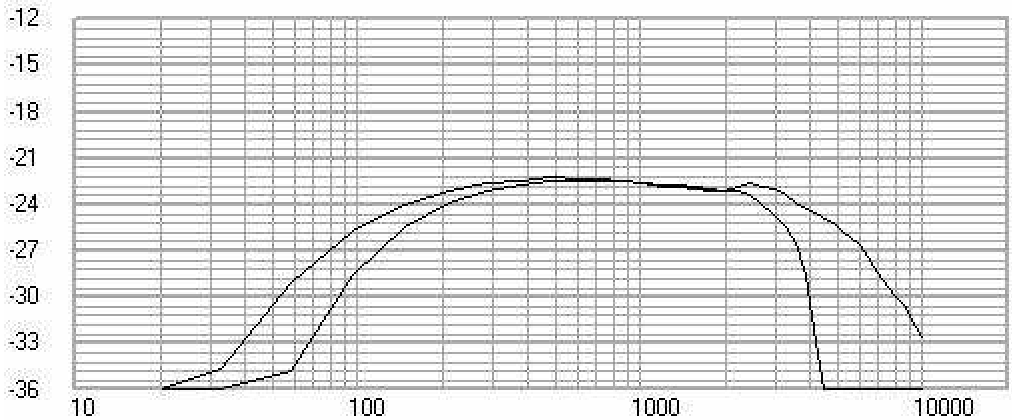
Also, not shown in the schematic above, an AC coupled high voltage divider chain was added to monitor the modulated, negative peak limited plate voltage. This divider is used to generate two adjustable audio test points; a line-level output for frequency response and distortion measurements, and a higher level scope output. This divider is per the old ARRL handbooks, as shown in the AM testing section (AC coupling and series resistor values give low phase shift).

Modulator Frequency Response

Transformer Shunting Capacitors

The capacitor across the modulation transformer secondary was reduced from the original 0.006 uF HV mica (0.004 was shown in handbook modulator article) to 1500 pf, then to a 680 pF HV ceramic on the transmitter side of the negative peak limiter. The total capacitance loading the modulator output is still about 5500 pf including the transmitter plate blocking capacitor, plate choke bypass capacitor, screen voltage divider and interconnecting multi-conductor shielded cable.

Also, the capacitor across the driver transformer secondary was changed to 180 pf (originally 330 pf, but Handbook called for 220 pf). These changes moved the upper -3dB point from 2900 Hz to about 5000 Hz. The response was measured from the speech amp line-level input (bypassing the mic preamp & response shaping), to the line-level output of the voltage divider that samples the modulated plate voltage (measured with modulator loaded by the operating transmitter).



Modulator Response at Final (top) and through Receiver (bottom)

Audio Response and Shaping
The lower -3 dB point, shown in the graph above as >100 Hz was measured prior to decreasing the driver transformer load resistance. After that change, the response improved slightly, but the -3 dB point is now no lower than 95 Hz.

On-the–air reports and voice recordings said that while this fairly flat response made pleasant enough listening under good conditions, additional emphasis at the high frequency (upper midrange) end, or perhaps a notch in the low midrange could improve the communication quality with my voice, particularly for distant stations or noisy conditions. After being informed on the air more than one time that this was true, once by WA1HLR, the Tim-Tron himself, I added a response shaping network after mic preamp in the speech amplifier.

Modulation Transformer Response
The modulation transformer response is the dominant factor in the overall low frequency response of the modulator chain. The modulator uses no negative feedback and the normally connected (as opposed to triode connected) 1625s present relatively high plate resistance. Then, the transformer low frequency response is established primarily by the inductance of the connected windings, by any reduction in that inductance due to the plate current DC bias in the transformer secondary, and by the audio load resistance presented by the 6DQ5 RF stage. The connections currently in use on the Stancor A-3894 Poly-Pedance Modulation Transformer are for 6000 ohms plate to plate on the primary when the secondary load is 2020 ohms[21] (according to the manufacturer's table[22]).
The impedance ratio of the connected taps was a better match for the original <400 volt supply voltage and 200 ma operation of the 6DQ5. The RF stage now presents a higher audio load resistance than before since the transmitter plate supply has increased to 480 volts, and DC plate current decreased to less than 180 ma when tuned for maximum RF output power. Considering that higher resistance RF stage load, the absence of negative feedback and that a driver roll-off of about a dB is included in the measurement, the measured low frequency response (-3 dB point is below 100 Hz) indicates that good performance is available from the

[21] Using the full primary windings in series, tabs 1 & 4 connect to the push-pull 1625 plates, and tabs 3 & 6 are connected to B+. The secondary consists of the full secondary windings in parallel - tab 7 connected to 12 and 9 to 10. Other transformers in the Stancor Poly-Pedance series provide the same impedances for these connections.
[22] http://www.amwindow.org/tech/htm/modtran/stancor/stancor1.htm

modulation transformer. The parallel connected modulation transformer secondary windings, rated >350 ma[23] total, are nowhere near saturation from the DC plate current bias, so there may be an opportunity to extend the response and reduce low frequency distortion further in the future, using taps for more secondary turns and a higher secondary inductance. A little negative feedback might do just as well.

[23] Each winding is rated 225 ma, but when paralleled and delivering 125 watts of audio to a 250 watt DC, 2020 ohm modulated stage load, total rated current would be at least 350 ma.

This write-up was started on September 9, 2005.
Bob

-----Original Message-----
From: Charlie Porter [mailto:kg6pro@cox.net]
Sent: Friday, June 24, 2005 8:55 PM
To: Robert Hansen
Subject: The 6DQ5 sweep tube special.

Hi Bob, This is from Charlie Porter in San Diego, the other 6DQ5 sister station. I am finally getting some time to contact and let you know I'm sending you via snail mail a long winded package about my adventures in re-storing my homebrew sweep tube special with a few pictures. I'm semi-retired now and busier than ever with many other hobbies and projects. So I'll keep this short and hope we can exchange any ideas that sound good! I will mail the package Saturday the 25th. Looking forward to hearing from you!

Charlie Porter
kg6pro@cox.net