The Hallicrafters HT-40 Transmitter

The “Atch-T-Fortee” (Hallicrafters HT-40) is probably one of the better Novice rigs to come out of the late 50's and early sixties venues. https://www.radiomuseum.org/r/hallicraft_ht_40_ht40.html and see schematic here;

https://bama.edebris.com/download/hallicra/ht40/094-902795D_Hallicrafters_HT-40_Mark_I_Operating_And_Service_Instructions_Apr1964.pdf as this will be our reference schematic.

I had upgraded and or restored 4 HT-40's before this one and currently have one in the shack, a highly modified HT-Turbo-40.

It is simple, reliable, and the transmit audio on AM was better right out of the box than the DX-60 and others' of the same vintage. It has four vacuum tubes and two solid state diodes with a voltage doubler power supply. The modulation system is *screen grid modulation* with a *controlled carrier* circuit. I had recently acquired this transmitter with its companion SX-140 receiver at a local hamfest.

However, I new I was in for the “long haul” when I removed the cover and saw four diodes strung across the two original Aerovox 40 uF electrolytics' at the bottom with date codes of 61XX. I always set the chassis on its left side for reference so by 'bottom' this means the Function Switch is to the left near the bench with the Power transformer touching the bench. Keeping a safe distance from the widowmaker web of diodes, I put it on a Variac and slowly brought the voltage up from 50Vac to 110Vac, and astonishingly, it output 10 Watts on 7.05 MHz, but the scope waveform showed it needed some serious upgrades. “Preferred” was simply the file name for this specific HT-40 rebuild.

Goals for this Modification:

1. I would use the original power transformer this time with its 205Vac secondary but increase the HV B+. I usually replace it with a 220Vac or higher secondary voltage transformer.

2. Increase audio quality, keep the controlled carrier circuitry, and raise the AM Modulation percentage to at least 100%. The percentage of modulation needed on AM cannot be tolerated by the anemic 80% of the stock transmitter.

3. Use my previously developed variable power circuit to control power output from 15 Watts to 35 Watts for feeding Linear Amps such as my AL-80A and Henry 2K-4.

The Power Supply.

Note: All capacitors are ceramic 1kV types unless otherwise noted. All resistors are metal film/metal oxide type unless otherwise noted. Voltages with a “*” represents the Keydown voltage. **It is a good idea at this time to place 5.1 Volt 1.3 Watt zener across the meter before ever powering this transmitter since these meters are almost unobtanium.**

As mentioned previously, it has a voltage-doubler power supply with choke filtering. I wanted to use 68 uF 350 volt *radial* types I had for the first two caps, but the leads weren't long enough. I had 80uF 500 Volt *axial* caps I had “over” ordered from A.E.S. for a previous project so I used them for C44 and C45 and they filled the space. Two 220k 1W resistor were added across them to equalize the voltages. I also had two 47uF 500 volt caps and used them for C46 and C47 and equalized them with 100k 3W resistors. Since these are post choke capacitors they need not be larger than 47uF. Voltage regulation is not great because of the transformer's secondary resistance and so the Keydown voltage was the main focus.

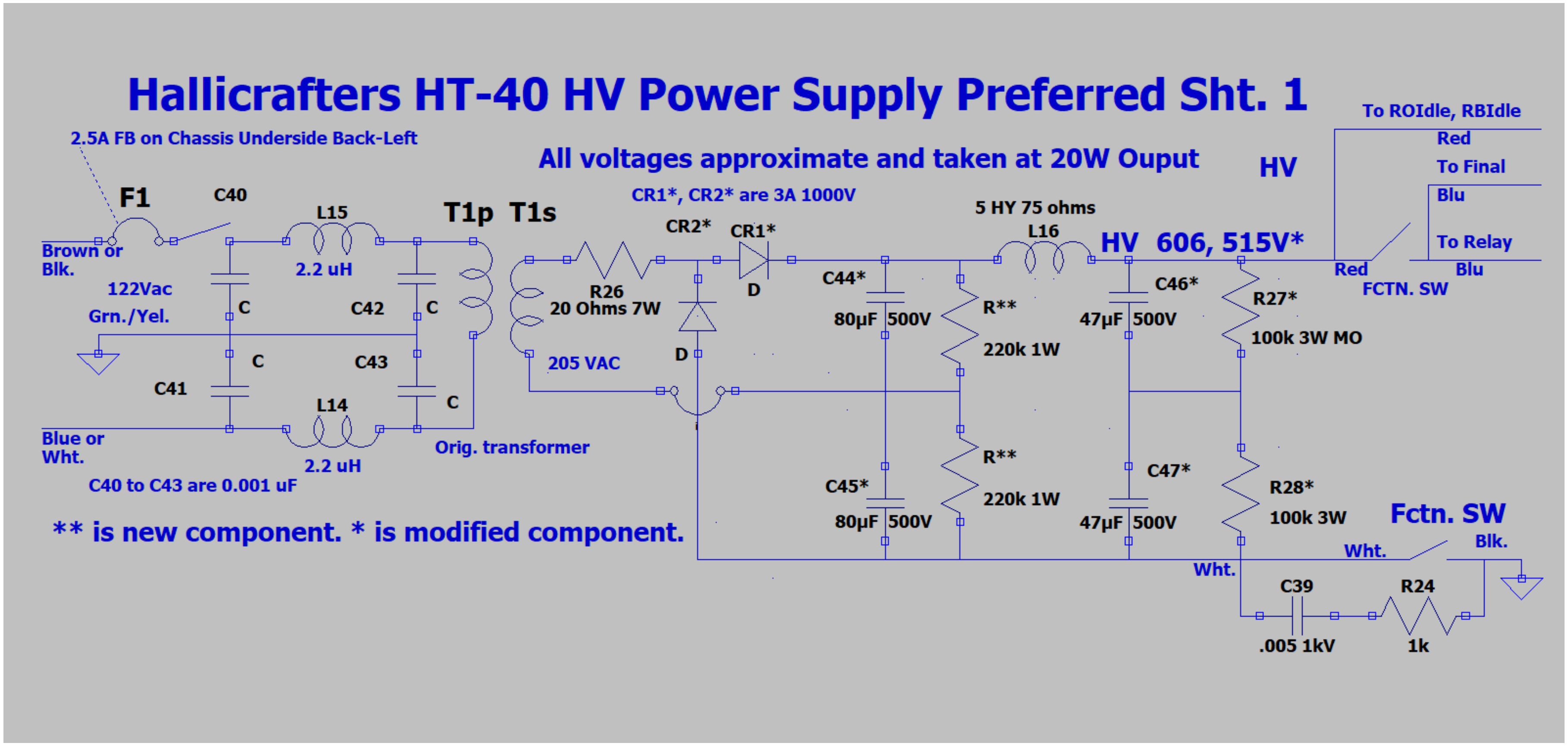
Being that this transmitter had been worked on before, I found many short and cut wires still in the terminal strip and tube base solder lugs that had to be cleaned out. More time was spent cleaning out solder lugs than any other exercise.

The stock voltages to the individual exciter tube (6CX8) stages were too high so provision was made to use voltage dividers and dropping resistors to establish Keydown plate voltages commensurate with extended tube life, but not so low as to sacrifice drive to the Final stage. I also wanted to insure that Keyup voltages were high enough to establish a bias to cut off the exciter's Pentode stage and the 6DQ5 Final (See, **The Cathode Bias Rail)**. To do this this I used a relay circuit that switched Keyup and Keydown voltages. The Oscillator cathode was grounded to keep the oscillator “alive” on Keyup, but with reduced output so as not to generate too much RF on receive that might leak out of the cabinet. So in essence, the oscillator is active all the time and this helps with frequency stability.

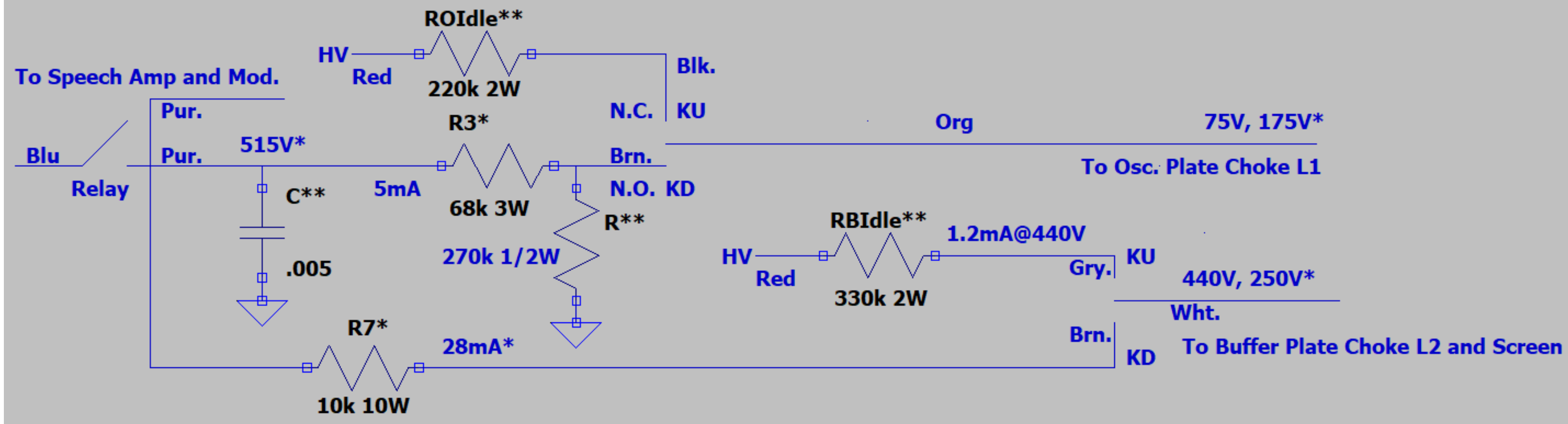
The relay also switches voltage to the the Speech Amplifier and the Modulator on Keydown and only when needed. The modulator circuit controls both AM and CW power output.

A half-wave bias supply was added to properly bias the 6DE7 Modulator's second stage and will be explained in the “Modulator' section.

Note: Upon Power-Up, the HV power supply is energized. Only in Tune, AM and CW is the power supply's Negative rail grounded. Don't think that because you are ***not*** in Tune, AM and CW mode there is no HV voltage present. Be careful!


Hallicrafters HT-40 HV Power Supply Preferred Sht. 1
2.5A FB on Chassis Underside Back-Left
All voltages approximate and taken at 20W Ouput
HV
To ROIdle, RBIdle
Red
To Final
Blu
To Relay
Red
Blu
FCTN. SW
F1
C40
L15
2.2 uH
T1p T1s
CR1*, CR2* are 3A 1000V
CR2*
CR1*
D
5 HY 75 ohms
L16
HV 606, 515V*
Brown or
Blk.
122Vac
Grn./Yel.
C
C42
C
R26
20 Ohms 7W
D
C44*
80µF 500V
R**
220k 1W
C46*
47µF 500V
R27*
100k 3W MO
C
C43
205 VAC
C41
L14
C
Blue or
Wht.
2.2 uH
Orig. transformer
C40 to C43 are 0.001 uF
C45*
80µF 500V
R**
220k 1W
C47*
47µF 500V
R28*
100k 3W
Fctn. SW
Wht.
Blk.
Wht.
C39
.005 1kV
R24
1k
** is new component. * is modified component.

Hallicrafters HT-40 HV Power Supply Preferred VD's Sht. 2



The Modulator Stage:

The 6DE7 V4A stage was converted to a resistance-capacitance coupled Class A audio stage to boost peak-to-peak audio voltages necessary for 100% modulation. Tube curves were consulted and simulation was done using MatLab to determine component values for biasing and plate load resistor values. Those 510k ohm resistors can be replaced with 470k ohm resistors without any degradation in audio quality. It was a case where I didn't have enough 470k's but a bunch of 510k's. (You never seem to have what you really need or want unless you order ahead of your project, which I didn't, thinking I had all of the necessary components). That's what I get for thinking.

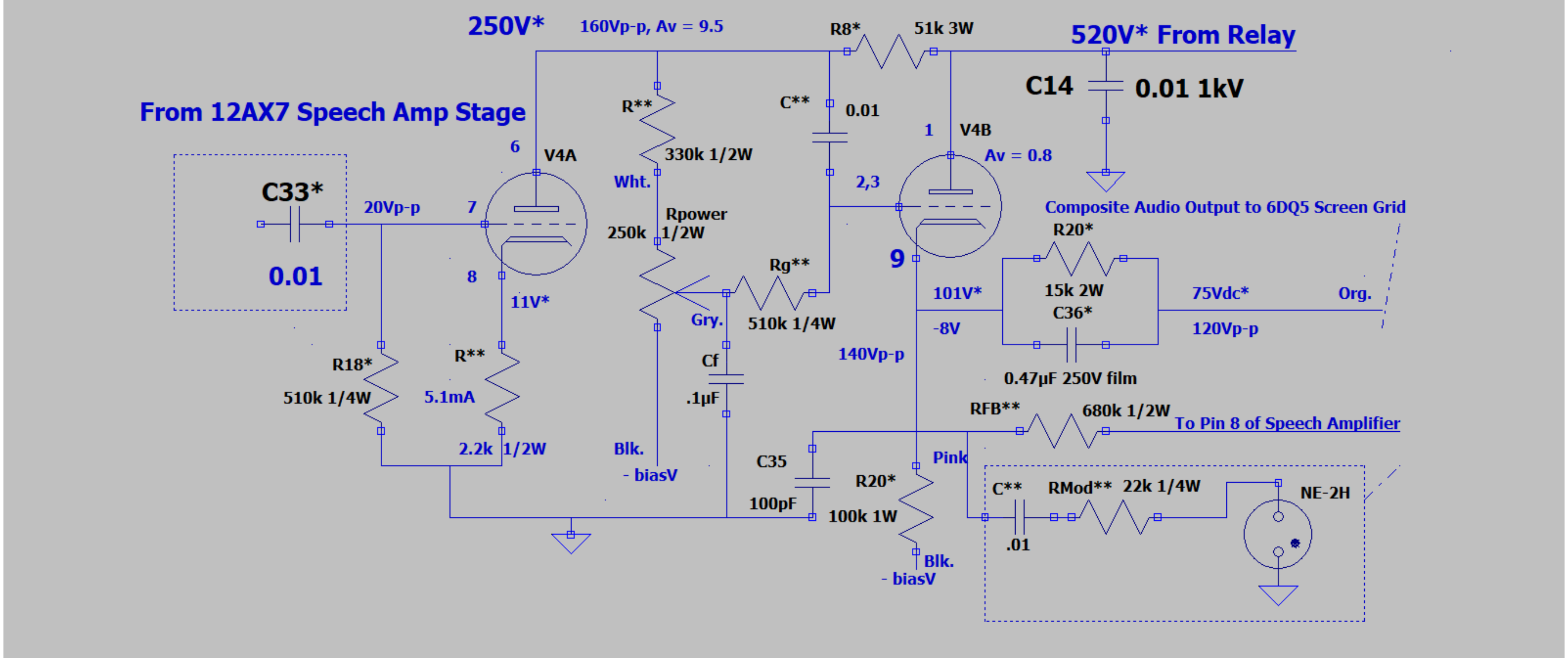
The V4B is a Cathode Follower stage which has a high input impedance and a low output impedance and was modified to control power output. A low impedance is necessary to properly control the Final's screen grid. The control carrier circuit was modified slightly to improve articulation. I also characterized the second 6DE7 stage to determine its operational values. An RFB** resistor was added to reduce overall distortion.

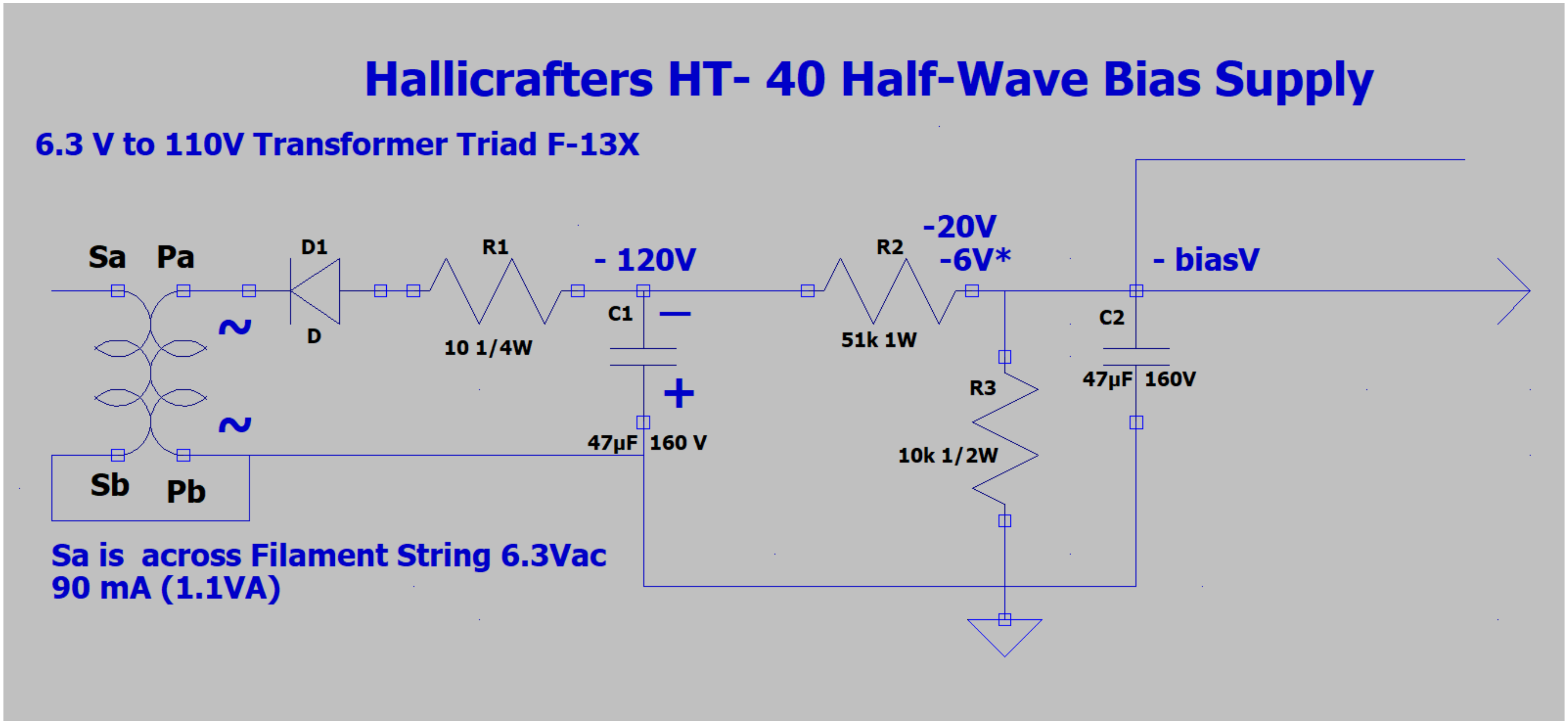
In the original referenced schematic there are two neon bulbs in series with a current limiting resistor R29 of 68k. This resistor and one neon bulb are located at the Function switch. So in stock configuration you have two flashing neon bulbs but only one is visible. The modulation indicator was difficult to simulate even though I had a subcircuit model for it. The reason is this is a NE-2H neon indicator and will glow on DC or AC, but I only wanted it to flash on modulation peaks. Since the modulator's output is essentially a composite signal consisting of DC with an AC component riding on it (actually a varying DC voltage), the DC is decoupled and a series resistance is used to limit the indicator's current to about 1.8 mA. A 3 lug with center grounded terminal strip, to accommodate the additional components, replaced the 2 lug strip behind the modulation indicator. Be very careful handling the Neon Bulb's leads. They are brittle and very stiff.

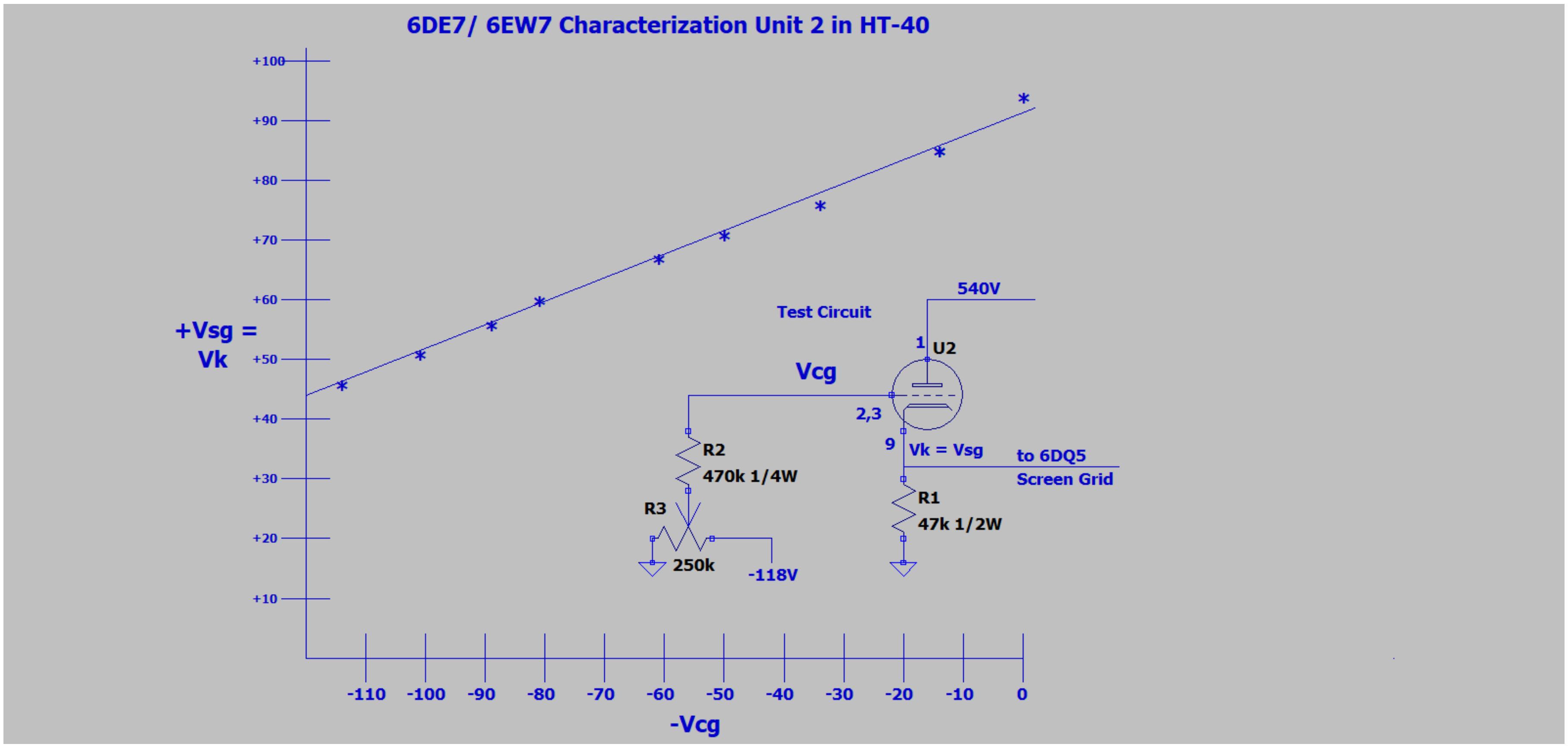
The power control circuit is a voltage divider situated between V4A's plate supply and the bias voltage. An additional resistor isolates the grid control voltage from the voltage divider and a capacitor couples the V4A audio to the V4B's grid. The 250k variable resistor is mounted between and just below the Plate Load control and the meter.

The bias supply is based on a reversed 6.3 Vac transformer. The bias voltage supply also used a voltage divider to “trim” the needed bias for power control. There is no detected 60 Hz ripple on the bias supply as it is way over-filtered.

Halli HT-40 6DE7 Modulator Circuit for Variable Power Preferred




Hallicrafters HT- 40 Half-Wave Bias Supply
6.3 V to 110V Transformer Triad F-13X
Sa
Pa
Sb
Pb
~
~
D1
D
R1
10 1/4W
- 120V
C1
—
+
47µF 160 V
R2
51k 1W
-20V
-6V*
R3
10k 1/2W
C2
47µF 160V
- biasV
Sa is across Filament String 6.3Vac
90 mA (1.1VA)


6DE7/ 6EW7 Characterization Unit 2 in HT-40
+Vsg =
Vk
+100
+90
+80
+70
+60
+50
+40
+30
+20
+10
-110
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
-Vcg
Test Circuit
540V
1
U2
Vcg
2,3
9
Vk = Vsg
to 6DQ5
Screen Grid
R2
470k 1/4W
R3
250k
-118V
R1
47k 1/2W

The Speech Amplifier:

The speech amplifier components were changed to improve each stage's linearity and general audio quality. A pre-emphasis circuit is at the V3A cathode to improve intelligibility during noisy band conditions. A rolloff circuit is at the output of V3B to limit the audio bandwidth and unwanted sonics' that may have passed through V3A and B.

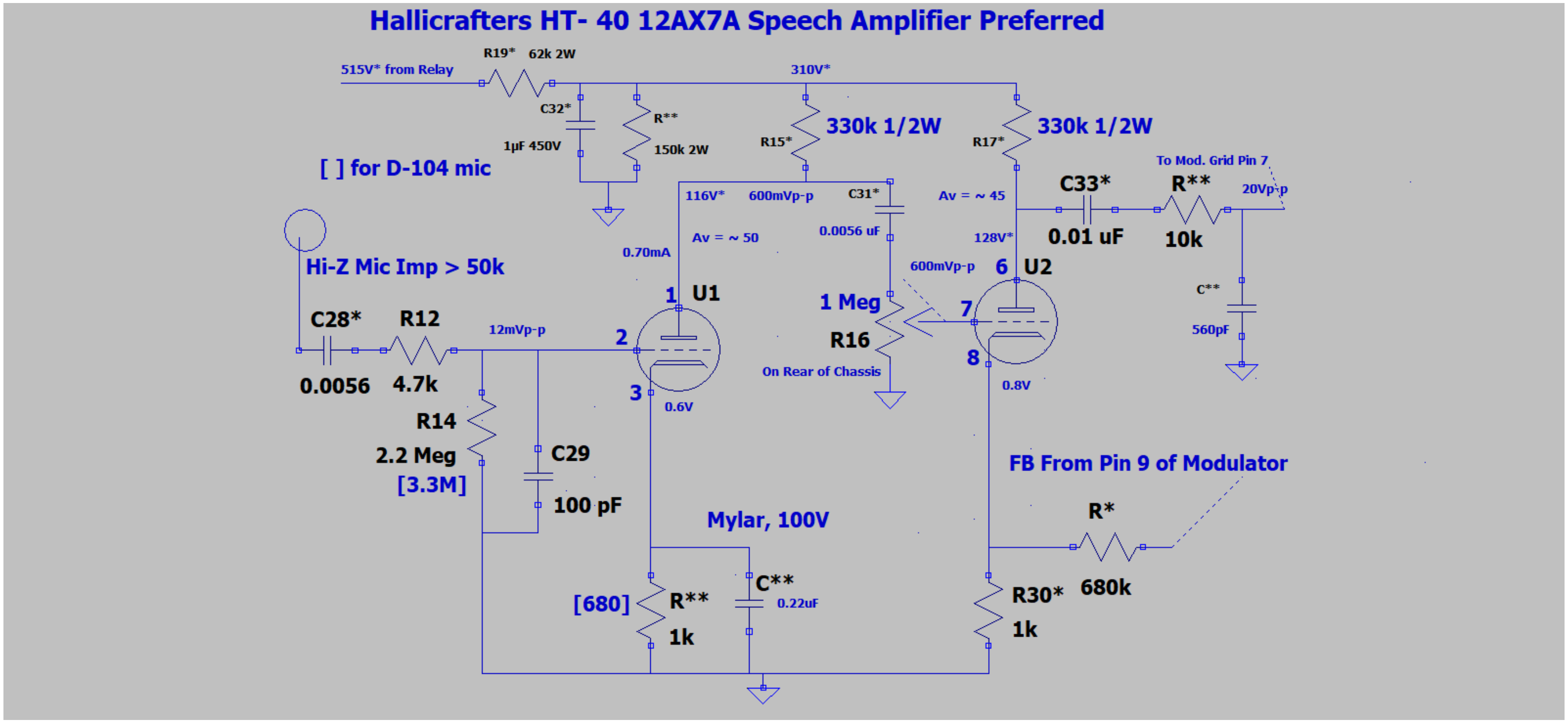
The values in brackets “[ ]” are to be used if you are using a D-104 microphone, otherwise your audio will sound “tinny.” Note that R13 has been *removed* for the same reason. A D-104 needs at least a 3.3 Megaohms load so as not to attenuate the low frequency audio components of the voice.

RFB** connects to R30* as feedback to reduce distortion.

Voltage divider R19* and R** establish the Speech Amplifier's source voltage fed from the relay. Can you tell I like Voltage Dividers? Voltage dividers establish predictable voltages and load currents.

C32* filters the DC voltage with a time constant of about 7.5X the 120Hz ripple. You want to reduce as much ripple as possible in low level audio stages so that any hum or buzz is not passed on to the modulator. Relay keying of the Speech Amplifier/ Modulator reduces tube heat and tends to extend the life of the tubes.

Just trying not to increase the cost of those expensive 12AX7A's that audio-phools tend to increase in price..


Hallicrafters HT- 40 12AX7A Speech Amplifier Preferred
515V* from Relay
R19* 62k 2W
310V*
C32*
1µF 450V
R**
150k 2W
R15*
330k 1/2W
R17*
330k 1/2W
[ ] for D-104 mic
116V*
600mVp-p
C31*
0.0056 uF
Av = ~ 50
0.70mA
Av = ~ 45
128V*
C33*
0.01 uF
R**
10k
To Mod. Grid Pin 7
20Vp-p
C**
560pF
Hi-Z Mic Imp > 50k
C28*
0.0056
R12
4.7k
12mVp-p
1 U1
2
3
0.6V
1 Meg
R16
On Rear of Chassis
600mVp-p
6 U2
7
8
0.8V
R14
2.2 Meg
[3.3M]
C29
100 pF
Mylar, 100V
FB From Pin 9 of Modulator
R*
680k
[680]
R**
1k
C**
0.22uF
R30*
1k

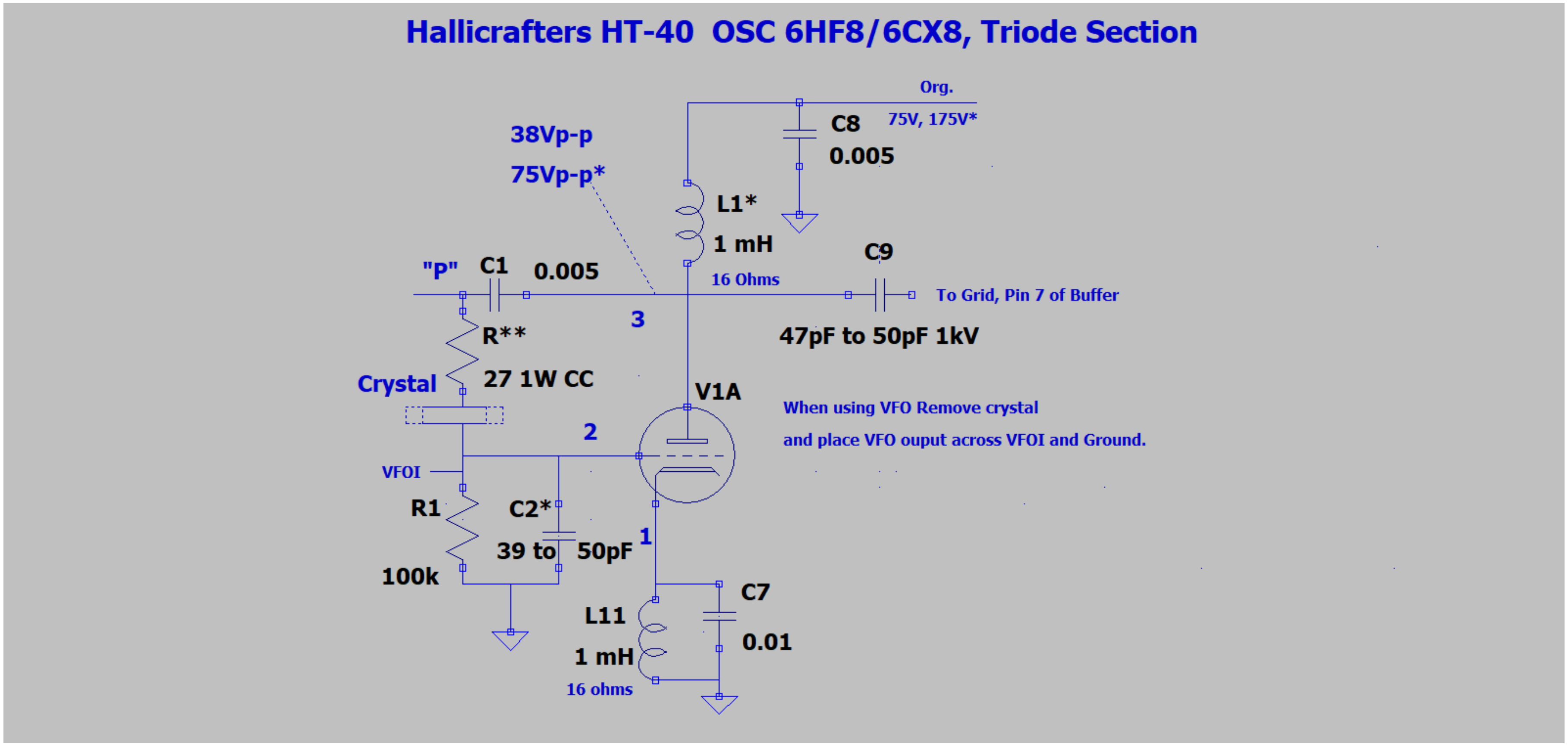
The Exciter's Oscillator:

The exciter is comprised of V1's multi-functional 6CX8 vacuum tube which has a triode and a pentode in one miniature glass bulb. The oscillator V1A uses the triode is the oscillator, a type called the *Modified Pierce* oscillator. A crystal or VFO can be used to provide excitation. A 6HF8 can also be used, a later version of the 6CX8 tube with slightly higher transconductance. RF performance is about the same among the two tubes.

A 27 ohm 1 Watt CC or CF resistor is placed in the plate feedback path to the crystal holder pin to reduce crystal current somewhat and to dampen any parasitics. Crystal currents can be as high as 90 mA so I wanted an operational “safe-space” for my FT-243 crystals. Besides, it looks really **retro!**

If you have an earlier HT-40 with .001uF coupling capacitors as C9 and C14 replace them with 47pF to 50pF coupling capacitors.
Those 0.001uF coupling capacitors cause stability problems and *over-couple* those stages,

L1* is now a 1mH inductor for the same reasons stated above.


Hallicrafters HT-40 OSC 6HF8/6CX8, Triode Section
Org.
75V, 175V*
C8
0.005
38Vp-p
75Vp-p*
L1*
1 mH
16 Ohms
C9
"P"
C1
0.005
To Grid, Pin 7 of Buffer
3
R**
27 1W CC
47pF to 50pF 1kV
Crystal
V1A
When using VFO Remove crystal
and place VFO ouput across VFOI and Ground.
2
VFOI
R1
C2*
39 to 50pF
1
100k
C7
L11
0.01
1 mH
16 ohms

The Buffer-Multiplier-Driver Stage

The Buffer-Multiplier-Driver stage V1B uses the same 6CX8/6HF8 as described above except the pentode section is used as the Buffer-Multiplier-Driver. It buffers the oscillator from the Final, multiplies the frequency when necessary, and also drives the grid of the 6DQ5 Final. See Page 2 of the manual for the frequency multiplication process.

Without the buffering function of this stage, impedance changes at the output of the transmitter would be reflected back to the oscillator, changing the crystal's oscillation frequency and V1A's stage gain.

Some *Turkey-Bird* owner had replaced R4 with a 1 Megaohm resistor. Undoubtedly this contributed to the demise of R5 since this stage was operating in saturation rather than in class C. Furthermore, with the 1 Megaohm resistor value, I doubt any frequency multiplication could occur. You know, if 100k is good, then 1 Megaohm has to be 10X better!

After the necessary component changes and power-on, there was no RF output even though the filament was lit. I checked this original tube once again in the tube checker and wolla, it was failing on all counts, most likely due to the R4 component change and subsequent suffering. So a NOS tube went in and power output was restored. Always measure the cathode resistor R5 and the screen resistor R6. I found R5 was 715 ohms so it was replaced with a metal film resistor of the stated value of 470 ohms. R6 was right on and miraculously, I have found this 12K resistor to be stable in most HT-40's. In this case, and due to the failure of the original V1B, I replaced both R6 and L2.

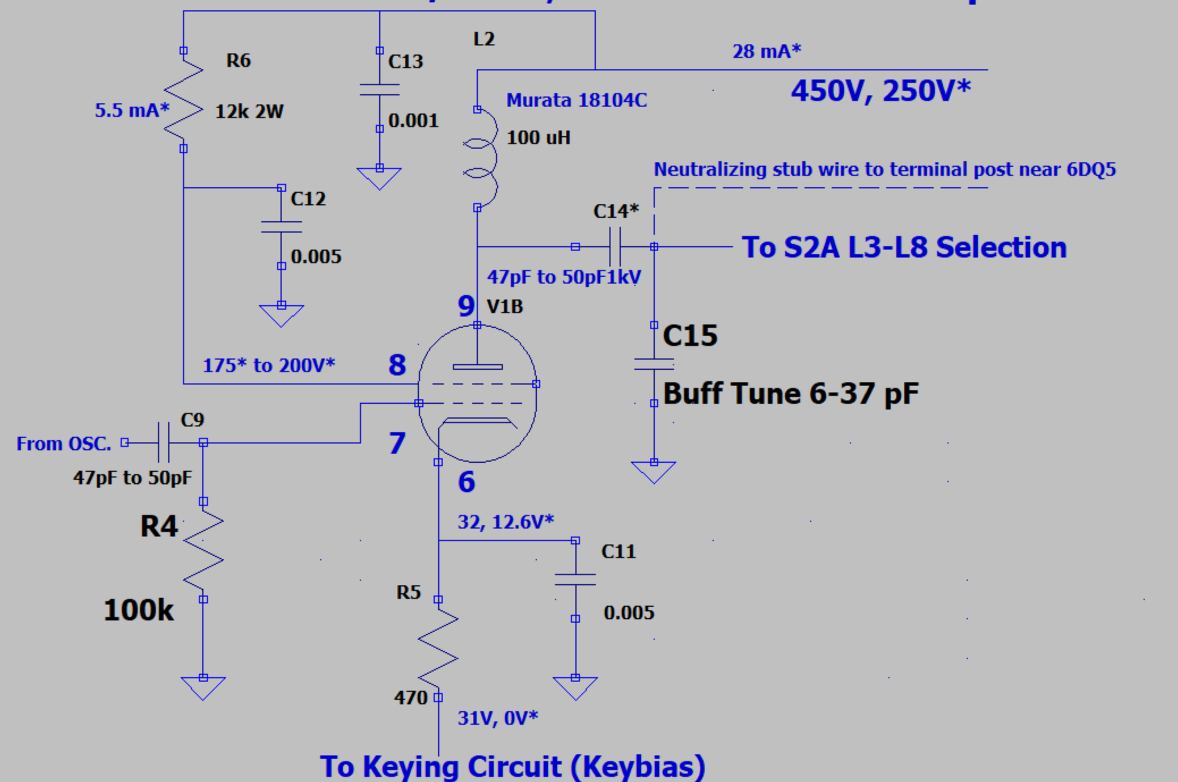
Another *Turkey-Bird* moment was found when the expected stage gain wasn't as high as it should be. If this was originally a Kit, then *Turkey-Bird* forgot to solder in C11 from the cathode Pin 6 and to ground. With C11 now in circuit the stage gain was higher, with less RF on the Keybias rail.

This stage feeds the 6DQ5 Final's grid via a pi-net input circuit. RF feedback from the Final is fed to the junction of C14 and C15 to curb any parasitic oscillations and is a Neutralizing circuit. I have never experienced any neutralization problems in an HT-40 with or without a stub at the 2 lug terminal strip next to the Final.

C15 and L3 through L8 tune this circuit. If frequency multiplication is to occur, specific coils are shorted out to resonate at the multiplied frequency. Again see Page 2 of the Manual for the multiplication scheme.

Since this transmitter uses point-to-point wiring there is RF all over the place and extra 0.005uF ceramic caps were added at Power Supply origination and termination points to reduce RF from getting into the audio and modulator circuits. The only shielded cables in here are the cable that connects the Keybias line to R31*, and the Mic Gain potentiometer in the Speech Amplifier circuit.

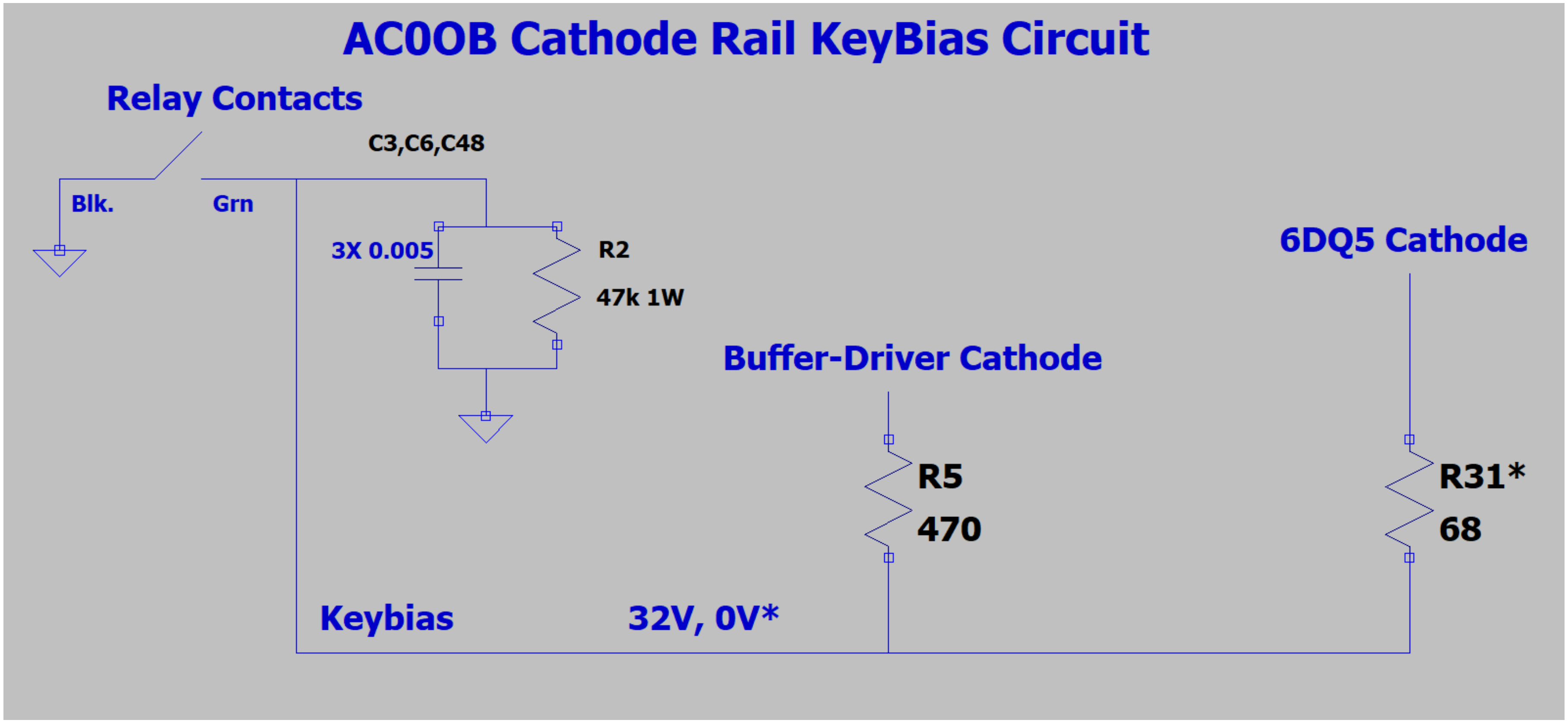
Hallicrafters HT- 40 6HF8/6CX8, Pentode Buffer-Multipler-Driver



The Cathode Bias Rail:

This transmitter uses cathode bias to shut off the buffer-multiplier-driver and Final tubes on Keyup. In Keyup a high voltage is on the V1B and V2 plates but very little current is flowing through the tubes, but it is enough current (0.7 mA) to pull the cathodes up to a voltage of 32V across R2. This voltage reverse biases the tubes and keeps them from amplifying RF.

On Keydown, the “Keybias” voltage goes to zero allowing the V1B and V2 tubes to conduct.


AC0OB Cathode Rail KeyBias Circuit
Relay Contacts
C3,C6,C48
Blk.
Grn
3X 0.005
R2
47k 1W
6DQ5 Cathode
Buffer-Driver Cathode
R5
470
R31*
68
Keybias
32V, 0V*

The V2 Final Stage and the Metering Switch:

The final's cathode resistor R31* was lowered to increase tube current for a little more power output.

When cathode current is increased for more power output, the cathode bias resistor will have a greater voltage drop across it resulting in more grid bias, thus reducing the current and subsequent power output. The resistance was lowered from 100 ohms to 68 ohms. This reduced the bias across it in Keydown, but still produced enough bias in case RF drive from V1B is lost, a tube protection scheme.

The relative output power is sampled from the SO-239 connector, rectified, and displayed on the meter. However, this is relatively useless as one cannot determine cathode or plate current in order to dip it for minimum current when tuning.

The meter rectifier board was modified as shown to sample the cathode current. The cathode current is a sum of control grid current, screen grid current, and plate current. With the values shown, when the cathode current is about 105 mA, you simply divide by 2 and then you have the actual plate current. We know this because the grid current is 0.5 mA and the screen grid current is about 5 mA, so the plate current is 100 mA. You can now visually dip the plate current. So a 2.25 meter reading is 100 mA of plate current.

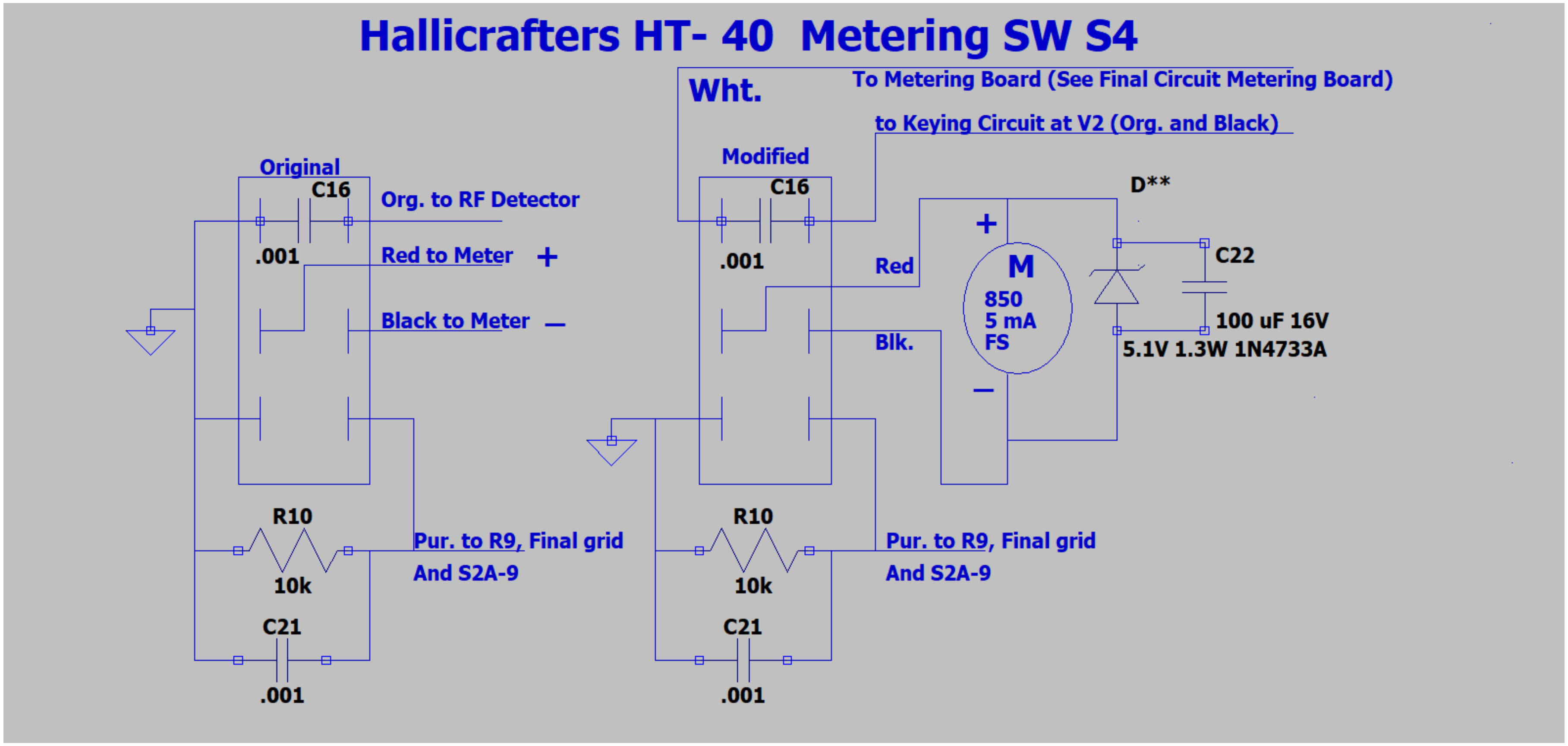
The control grid current is determined by sampling the voltage across the grid metering resistor (grid shunt for metering) R10 which averages 5 Volts (with the S4 switch in the “Power” position) so the control grid current with RF excitation is approximately 0.5 mA. This is low for power tubes, but shows the power sensitivity of the 6DQ5. This is equivalent to a grid driving power of only 250 milliwatts!

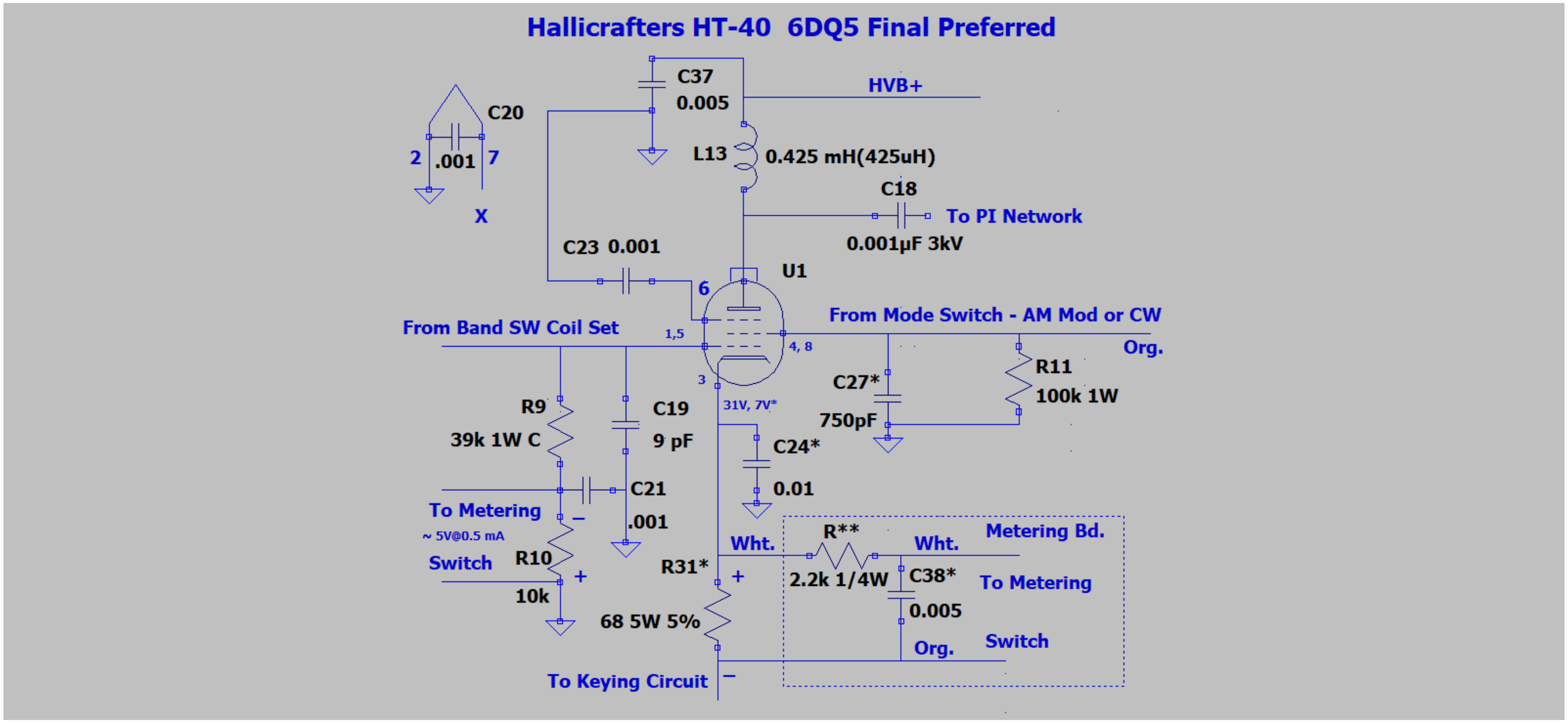
Since we sample only the cathode current, the Grid Current/Power slide switch S4 had to be modified. It was a simple modification to this switch as shown in the schematic. A new wire was run from the modified metering board to the S4 switch as shown, and the original cotton-covered orange wire was connected to the V2 shielded cable center conductor that is the Keybias line to the V2 stage.

C24 was increased to a 0.01uF cap since the cathode resistor R31 was lowered in value. This reduces the RF noise on the Keybias line and increases the gain of V2 slightly.

Screen capacitor C27 was lowered to 750pF from 0.001uF to improve the high frequency audio response, but still high enough in value yo keep RF from traveling back to V4B's cathode.

R9, the Final's grid-leak resistor is located underneath the Bandswitch coil turret. It is a good idea to measure the resistance from ground to Pin 1 or 5 at the Final's socket. Resistance should yield about 43k to 49k because, in some cases, R9 has a 33k value that is not reflected on the schematic. R11 was raised from 22k to 100k so the R20* and C36* CC time constant circuit could see the same approximate impedance during its oscillatory cycle.

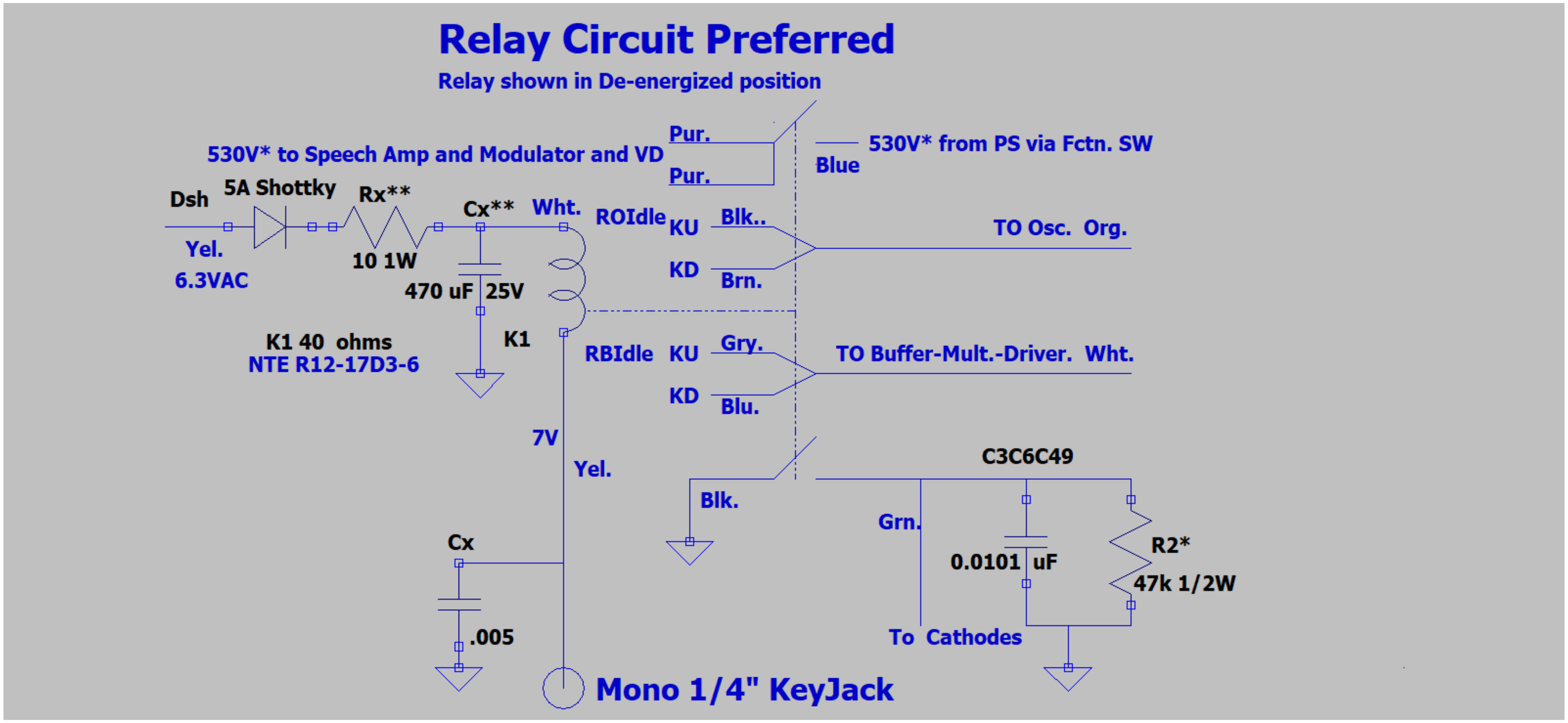

Hallicrafters HT- 40 Metering SW S4
Wht.
To Metering Board (See Final Circuit Metering Board)
to Keying Circuit at V2 (Org. and Black)
Original
C16
Org. to RF Detector
.001
Red to Meter +
Black to Meter —
R10
Pur. to R9, Final grid
And S2A-9
10k
C21
.001
Modified
C16
.001
Red
Blk.
+
M
850
5 mA
FS
—
D**
C22
100 uF 16V
5.1V 1.3W 1N4733A
R10
Pur. to R9, Final grid
And S2A-9
10k
C21
.001


Hallicrafters HT-40 6DQ5 Final Preferred
C37
0.005
HVB+
C20
2
.001
7
X
L13
0.425 mH(425uH)
C18
To PI Network
0.001µF 3kV
C23 0.001
U1
6
From Band SW Coil Set
1,5
From Mode Switch - AM Mod or CW
4, 8
Org.
R11
100k 1W
C27*
750pF
3
31V, 7V*
R9
39k 1W C
C19
9 pF
C24*
0.01
C21
.001
To Metering
~ 5V@0.5 mA
Switch
R10
10k
R**
Wht.
Wht.
Metering Bd.
R31*
2.2k 1/4W
C38*
To Metering
0.005
68 5W 5%
Org.
Switch
To Keying Circuit

The Relay Circuit:

The relay circuit is shown below and contains a power supply to supply the needed coil current. Components are mounted on a 4 lug terminal strip with ground. The 6.3Vac for the relay supply comes directly off the Finals filament Pin 7.

All connections are made with 22 gauge solid wire of various colors.


Relay Circuit Preferred
Relay shown in De-energized position
Pur.
Pur.
530V* to Speech Amp and Modulator and VD
530V* from PS via Fctn. SW
Blue
Dsh
5A Shottky
Rx**
Cx**
Wht.
ROIdle
KU
Blk..
TO Osc. Org.
Yel.
6.3VAC
10 1W
470 uF 25V
KD
Brn.
K1 40 ohms
NTE R12-17D3-6
K1
RBIdle
KU
Gry.
TO Buffer-Mult.-Driver. Wht.
KD
Blu.
7V
Yel.
C3C6C49
Blk.
Grn.
Cx
0.0101 uF
R2*
47k 1/2W
.005
To Cathodes
Mono 1/4" KeyJack

Concluding Remarks: The goals set forth were achieved as the power output can now be varied from less than 15 Watts to over 35 Watts. All voltages shown in the schematics were taken with the Power Potentiometer adjusted for 20W RF output at 7.160 MHz. Plate current is dipped and loading set for a maximum output of 20W. Buffer Tune is also adjusted for max output.

The output pi-network tuning was fairly sufficient in terms of needed inductance and capacitance for all bands. I did add a 22pF 2kV capacitor across C26 in order to boost power when using a 3.705 MHz crystal on the 80 meter band. Interestingly, this chassis had a 20 turn L10 coil, whereas previous chassis' had 19 turns. Possibly a later factory improvement? If your chassis has a 19 turn L10, you will probably want to add an additional 33pF across C25 as well to improve 80 meter operation.

The mic gain was set to full ClockWise for peak-to-peak audio voltage measurements. The peak-to-peak audio voltages indicated are for 100% Modulation, so each audio stage's Peak-to-peak voltage is shown for 100% Modulation.

The modulation percentage that can be achieved in the AM mode can exceed 100% modulation, although I try not to exceed 105% with my Shure 450 Series II in the high impedance configuration. No flat-topping or any other distortion artifacts were seen in the audio chain up to the Final's screen port. If using an un-amplified D-104, then the "[ ]" values of R14 and R** in the speech amp should be used.

Modulation percentage is best viewed on a 30 MHz or higher frequency scope in order to set the mic gain for your specific microphone with a 1-2" separation between the face of the mic and your mouth. I sample directly across the wire going to the SO-239 connector with a X10 probe with about a 0.5 millisecond sweep rate.

If you get bored, the HT-40 chassis can be used for both prototyping and experimentation because of its open chassis and because it is difficult to kill it.

Selected References for Vintage Amateur Radio Equipment:

1. Grayson Evans, ***Hollow State Design***, 2014.
2. Phil Legate, ***Electric Radio Magazine***, Issues #309-315, 324, 327, 334, 341, 350, 351, 353, 354, 357, 359, 360-362.
3. Fred Osterman, ***Receivers, Past and Present***, 2014.
4. Igor Popovitch, **Vacuum Tube Testers**, 2017.
5. Eugene Rippen, ***Tube Type Transmitters**, 1930 to 1980;* Hallicrafters Section: Pages 109 – 119, 2nd Edition, 2011.
6. Ludwell Sibley, ***Tube Lore II***, 2019.