A Different Kind Of Triode Audio Amplifier

John L Stewart PEng May 2012

Part One of this project was published in the Volume 11, Number 2 Issue of Glass Audio magazine in May 1999. It describes a simple method of providing the very large grid drive voltage required by low mu vacuum power tubes such as the 6080/6AS7G family. The circuit appears to be fairly obvious but it seems no one has previously published anything like it.

Part Two appeared a month later in Volume 11, Number 3 Issue of Glass Audio magazine. Circuit modifications are suggested so that other power triodes such as the 2A3 & 300B could utilize the basic circuit. A circuit simplification which avoids the use of the Ultra Linear Output Transformer in the first article is covered.

The circuit also appeared in short form in the July 1998 issue of Electronics World.

If you should try this project safety is important. The circuit runs around 400 volts.
The photo shows the amplifier in 'Proof of Concept' form. I used a separate power supply during the development.

A Different Kind Of Triode Amplifier, Part One

Designers of audio power amplifiers have long recognized the benefits of using triodes as the final stage. However, some of the best of these tubes are found to be difficult to drive. Others require large & dangerous high voltage power supplies. Many need special interstage transformers. Some even need a DC power source to run a directly heated cathode.

The circuit described here overcomes all of these shortcomings. It uses readily available, standard parts. Most can probably be found in the average experimenters junk box & are otherwise easily available commercially.

For this circuit I wanted to use an audio power tube or tubes which are readily available at low cost on the NOS market. Many of the tubes built recently offshore have been found to come up short for one reason or another. To demonstrate the principle used here I chose the 6080/6AS7G family. However, these same ideas may be applied to several other low mu triodes.

A form of boot strapping or positive feedback is used here to overcome the large drive requirements of the low mu triodes used. Some purists will object to the use of positive feedback. A similar fix is used in all of the very famous & outstanding McIntosh amplifiers. Add to that Electrovoice & Circlotron. Norman Crowhurst also used the technique in his "twin coupled amplifier".

The bootstrapping is provided by the ultra linear taps found on many output transformers, both old & new. It is applied to the ends of the driver stage load resistors, such that the signal voltages at these points in the circuit are series aiding. That way, the driver stage does not have to provide the enormous drive signal normally required by a low mu triode such as a 6080. There are similarities here to the McIntosh. However, I have never seen the principle applied to triodes.

If the circuit were to be redrawn with the output triodes side by side it would take on the appearance of a multivibrator. One may think that instability would occur. This does not happen since the gain of this part of the circuit is less than one. Tap on the output transformer is at 43%. This when coupled to the

6080 with a mu of 2 produces a gain of no more than 0.86 & stability results. Many experimenters may have on hand ultralinear transformers with 20% taps. This would allow them to use triodes whose mu is up to 4.5.

For the development work I had on hand output transformers with both 20% & 43% taps. The transformer with 20% taps is a special wound by Hammond, which I acquired around 1960 for some experimentation but never used. The performance in the circuit was OK, but not nearly as good as that with the 43% taps. It could be used to advantage with output tubes such as the 2A3, the 45, the 300B & perhaps some of the transmitting triodes.

A transformer with the 43% taps is a Hammond 1650N, readily available thru many vendors. It has a primary impedance of 4300 ohms & is a good match for a single 6080 connected in push pull. Using a single 6080 with the Hammond 1650N & a power supply of only 350 volts, this circuit produced 10 watts of very clean audio. This is all in sharp contrast to other topologies using expensive output tubes such as the 300B, complicated drive circuits both with & without transformers & sometimes dangerous high voltage power supplies needed to wake up the output tube.

The driving circuit as can be seen is quite ordinary other then the connection to the output transformer primary. It consists only of two double triodes. The choice of driver tubes has nothing to do whatever with what this or that tube might sound like. Selection was based upon the ease with which component changes could be implemented on the octal sockets. The primary objective here was to illustrate the drive circuit principle.

Since the development circuit was a success I decided to go for more power. The final circuit used the original driver but has a pair of 6080's in the output stage. This required an output transformer of 1/2 the original primary impedance. For this Hammond was able to provide a transformer whose primary impedance is 2150 ohms. It uses the same core as their 1650N which is rated at 60 watts audio. Hammond part number is H300429. With a power supply of 400 volts this version produced an easy 30 watts of triode audio power.

In both versions of the amplifier care must be taken with the biasing of the output tubes. Unlike most other output stages these absolutely must each have a separate cathode biasing resistor. Otherwise, a condition of thermal instability not unlike that seen in power junction transistors rapidly destroys the tube. As well, since a full 1/3 of the output stage HV power supply is dissipated in the biasing resistors they will need good ventilation. In the development unit they are under the chassis, but it will not be used for entertainment & is not needed to run continuously.

The output stage cathode resistors are 25 watt rated. I had earlier tried 10 watt resistors but found them not adequate for this application. There was too much change of resistance as they heated up.

The signal input capacitor is calculated for a 3 db rolloff at 32 hz. However it could be set to anything considered practical by the user.

Spectral test results were obtained using a Pico-Scope ADC100 connected to the printer port of a 486dx2/66. It is a 12 bit a-d converter. Predicted dynamic range is 72 db. When used in the DOS mode it manages about 70 db. Signal source was an HP200CD audio oscillator.

For the measurements taken with 13 db feedback a resistor of 4.7 k was used. Why 13 db ? Just a moderate feedback. This circuit doesn't need much. The feedback was connected from the 8 ohm tap of the output transformer to the 6SL7 grid opposite the input connection (x). If this causes oscillation then the transformer primary or secondary (not both) hookup needs to be reversed.

Damping factor is 3 without feedback & rises to 15 with this feedback. Input sensitivity drops from 0.64 volts to 3.1 volts for 25 watts out. The basic circuit is shown in the first schematic following. The fedback version has less than one percent distortion at 25 Watts. No significant higher order harmonics above the 3rd, unlike pentode amplifiers.

The power supply uses an octal replacement rectifier available from New Sensor Corp. The transformer & filter choke are dependant on which version of the amplifier is built. The single 6080 version could use a Hammond 272DX transformer & 156R choke. For the amplifier using two 6080's then try the Hammond 272JX & 158S. These combinations will result in a HV of about 380 volts. The 400 V PS I used is a bit on the high side. The 6080 dissipation ratings are slightly exceeded.

The negative 150v supply uses a gas regulator, the 0D3/VR150. The small cap in parallel removes some of the grass produced by the 0D3. Don't try large caps here. At this position a large cap often results in a very good relaxation oscillator.

Some improvements for those who would like to push the circuit further are as follows-

1) Rather than using cathode biasing which wastes a large part of power provided by the DC power supply a bias servo could be used. Examples are described in Valve Amplifiers by Morgan Jones (page 227) & Principles of Power by Kevin O'Conner (page 6-3). The high voltage power supply could then be reduced to 270 volts.

2) Gain of this version is somewhat low such that when full loop feedback is applied the input drive signal requirement may be high. Another gain stage could be added (carefully) to the front end to restore sensitivity. Even McIntosh found this to be the case in their amplifier.

References

Norman H crowhurst- "Realistic Audio Engineering Philosophy"
reprinted in Audio Anthology volume 5

Norman H crowhurst- "High fidelity at low cost with Twin Coupled Amplifier"
Radio Electronics November 1957

Norman H crowhurst- "Updating the RE Twin Coupled Amplifier"
Radio Electronics June 1960

Norman H crowhurst- "High Power Twin Coupled Amplifier"
Radio Electronics October 1960

Aspen Pittman- "The Tube Amp Book / 4th edition"
several examples of McIntosh amplifier circuits

C.G. McProud - "high quality amplifier with 6AS7G"
reprinted in Audio Anthology Volume One
lists characteristics of 6AS7G, Etc

RCA RC-16 Tube Manual
6AS7G characteristics & power amp circuit

Local Positive Feedback

There has been quite a debate on how much local feedback results from this connexion. In 2000 I measured that to be 1.38 db in the first version of the amplifier in this article.

Determination of Maximum Positive Feedback in Bootstrapped Driver

First of all, calculate the driver gain in grounded cathode mode from published specs-

For the 6SN7 family at 250 volts supply, Mu = 20
Rp = 7.7 K while grid volts is –8

Let A1 be the gain with these conditions,
Then A1 = (mu*Rl) / (rp + Rl)
= (20* 27) / (7.7 + 27)
= 15.56

Then find the maximum gain possible for any non-feedback triode stage-

Then A2 = mu
= 20

Gain change is A2/A1
= 20 /15.56

In DB becomes 20 log A2/A1
= 2.18 db

The feed back in the case of the bootstrapped driver is to the triodes anode, so no gain above mu is possible. There is no gain thru the triode being plate driven.

NTL, some experimenters have actually built working amplifiers this way using many triodes such as the 6S4 & 12B4. Starting digging, you will find them. Commonly referred to as the 'Inverted Triode'.

The equations can be further reduced as follows-

A1 = (mu*Rl) / (rp + Rl) and

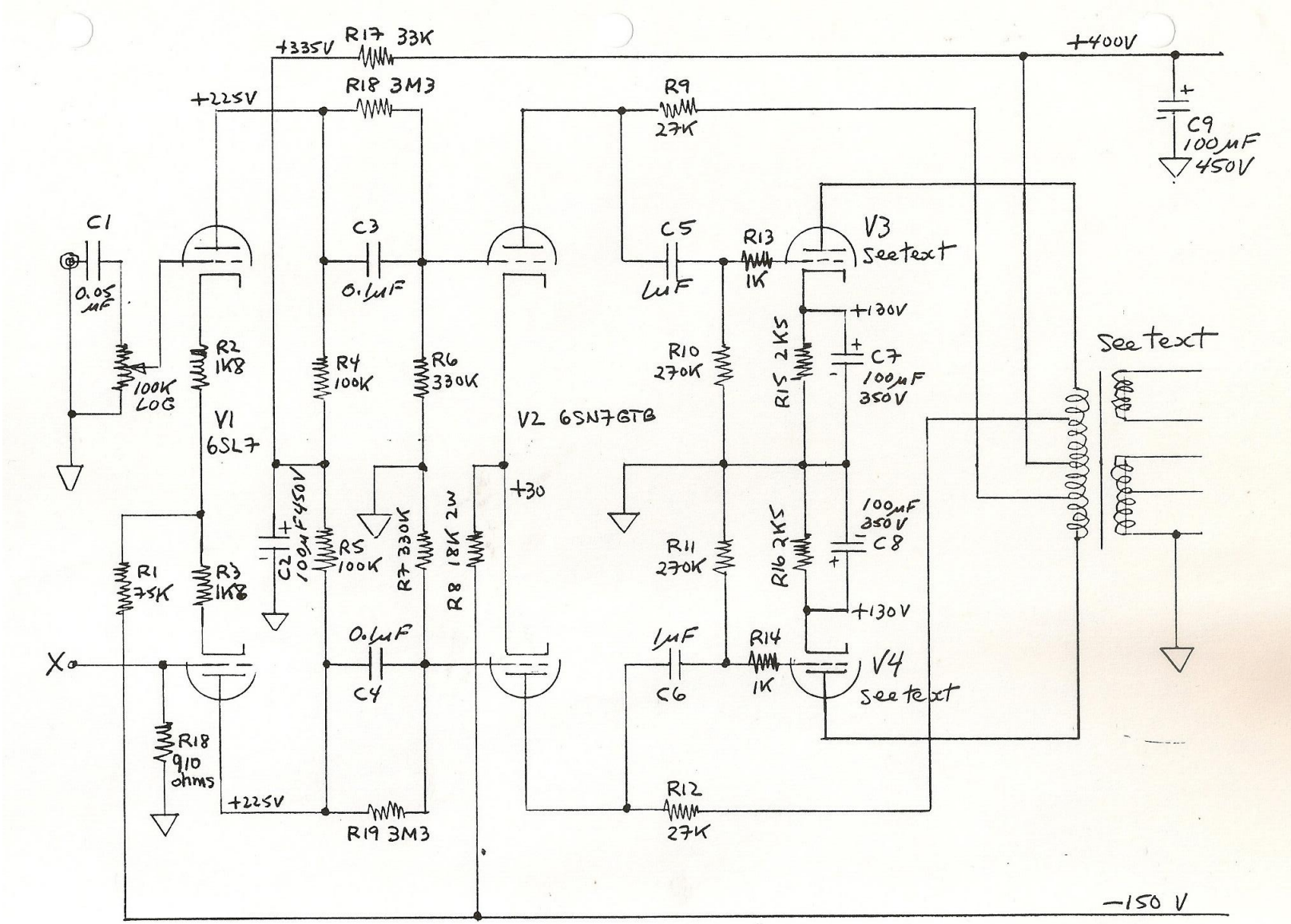
A2 = mu

Gain change is A2 / A1

So Gain change becomes (mu) / (mu*Rl) / (rp + Rl)

That reduces to Gain Change

A2 /A1 = (rp + Rl) / Rl


+335V
R17 33K
+400V
+225V
R18 3M3
R9
27K
C9
100μF
450V
C1
0.05μF
C3
0.1μF
C5
1μF
R13
1K
V3
see text
100K LOG
R2
1K8
R4
100K
R6
330K
V1
6SL7
V2 6SN7GTB
+130V
R10
270K
R15 2K5
C7
100μF
350V
see text
+30
C2
100μF 450V
R5
100K
R7 330K
R8 18K 2W
100μF
350V
C8
R16 2K5
R11
270K
+130V
R1
75K
R3
1K8
0.1μF
C4
1μF
C6
R14
1K
V4
see text
X
R18
910
ohms
+225V
R19 3M3
R12
27K
-150 V

6080/6AS7G Specs

TABLE 1

AUDIO AMPLIFIER SERVICE
Values are for each unit

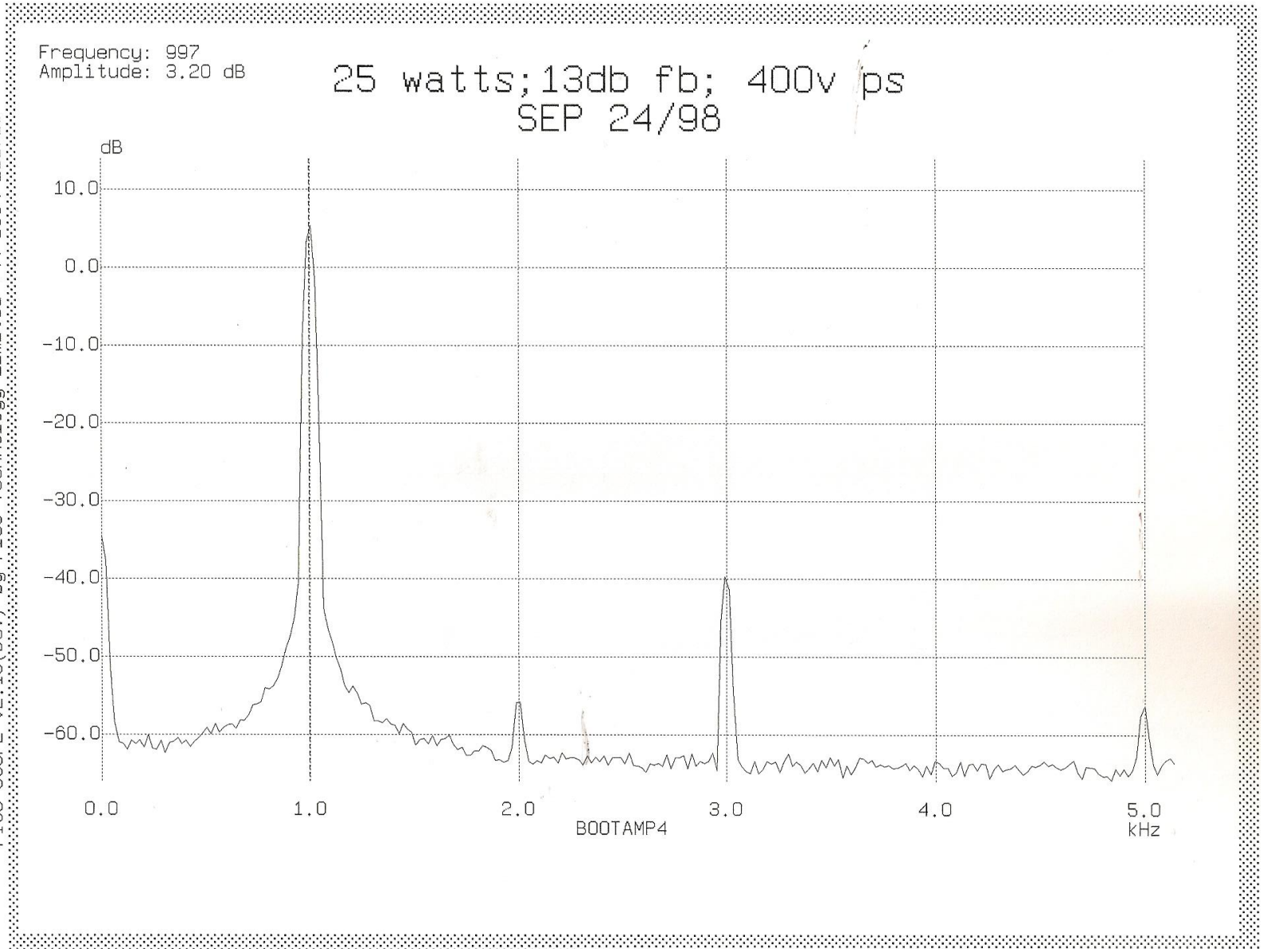
Maximum Ratings, Design Center Values:

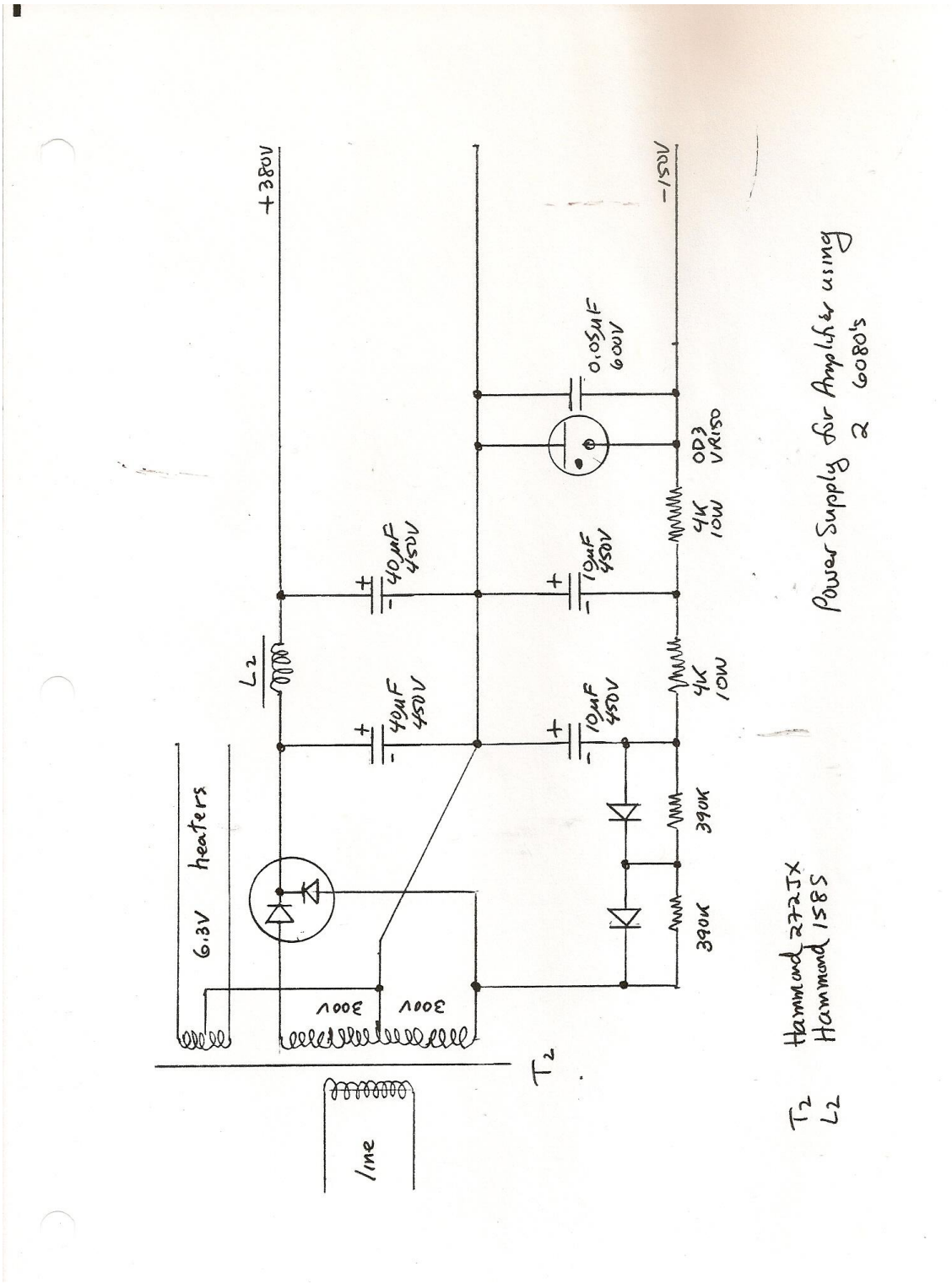
PLATE VOLTAGE	250 max.	volts
PLATE CURRENT	125 max.	ma
PLATE DISSIPATION	13 max.	watts
PEAK HEATER-CATHODE VOLTAGE		
Heater negative with respect to cathode	300 max.	volts
Heater positive with respect to cathode	300 max.	volts

Typical operation, Class A_1 push-pull amplifier. Unless otherwise specified, values are for both units.

Plate	200	250	volts
Grid	−90	−125	volts
Cathode Resistor (per unit)	1500	2500	ohms
Peak AF grid to grid voltage	180	250	volts
Zero signal plate current	120	100	ma
Max. signal plate current	128	106	ma
Effective load resistance (plate to plate)	4000	6000	ohms
Total harmonic distortion (less than)	4	4	per cent
Max. signal power output	11	13	watts
Amplification Factor (per unit)	2.0	2.0	

*It is essential that precaution be taken in equipment design to prevent subjecting the tube to full load current of 250 ma before its cathodes have reached normal operating temperature. The cathodes require approximately 15 seconds to attain normal operating temperature. Unless this precaution is observed, the cathodes will be seriously damaged, if not completely ruined. In speech amplifier service, as indicated under typical operating conditions, the plate voltage may be applied simultaneously with the filament voltage.


Frequency: 997
Amplitude: 3.20 dB
25 watts;13db fb; 400v ps
SEP 24/98
dB
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
0.0
1.0
2.0
3.0
4.0
5.0
kHz
BOOTAMP4
PICO-SCOPE V2.13(Dev) by Pico Technology Limited +44-1954-211716



John Stewart is a Professional Engineer (Electrical) with experience in both power & communication systems. He developed his experience with vacuum tubes while working on various research projects at Ferranti Packard & U of T Physics from 1957 to 1965. Then began many years of hitech sales of test equipment, semiconductors & land survey equipment with Hewlett Packard, Rohde & Schwarz, Etc.