A Practical Circlotron You Can Build

This project was originally published in the Volume 33, Issue 5 of AudioXpress magazine in May of 2002. It describes a high fidelity vacuum tube amplifier based the Circlotron from the 1950s. The circuit appears to be somewhat involved, but a closer look will reveal all. The primary object is to show what is possible with off the shelf parts & at reasonable cost.

If you should try this project, safety is important. Inside the chassis the circuit runs at more than 400 volts.

The photos show views of the finished amplifier. A complete parts list & set of performance data are included. Also you will find my note of response to a readers letter enquiring of the sound quality,

In its present form the amplifier is capable of more than 50 watts. The circuit is easily scalable for more power.

John L Stewart PEng   **March 2013**

A PRACTICAL CIRCLOTRON   John Stewart

Did you ever wonder what a Circlotron is? If you knew, did you wonder why anyone would use this relatively exotic topology to build an amplifier? In this article I hope to show you how this circuit works & provide enough information so that you can build your own. As well, you will be able to select from several versions of it. This circuit is probably not for beginners. If you are new to the hobby, best to try something simpler in order to gain some experience.

The Circlotron has been around for a long time, but not well understood. Nor has it been built often by amateurs. There are two important reasons why the Circlotron has not been popular. To begin with you will need two completely independent matching high voltage power supplies. The other problem is the requirement for an output transformer of one-quarter the impedance of those commonly available.

This second problem noted is the very reason someone took the time to develop the circuit in the first place. A low impedance audio output transformer is much easier to build than a similar device of high impedance. My amplifier is built on a 10 X 17 X 3 chassis from Hammond. When using 6L6GC's it is capable of 30 watts of clean audio. The version using 6550C's easily makes 50 watts.

Don't forget the potentials you will be working with are LETHAL!!

FEATURES OF THIS VERSION OF THE CIRCLOTRON

1)   Choice of Output Transformer configuration
            a) One custom built to low impedance or
            b) Use 2 off the shelf standard transformers or
            c) Use a transformer meant for Dyna, etc. but wired differently
2)   Uses two off the shelf transformers for the power supply.
3)   Allows Triode or Beam Tetrode operation.
4)   Runs with or without feedback.
5)   Choice of output tubes provided by wide range bias system.
6)   Standby & run modes.
7)   Outstanding performance
8)   Low cost.

AMPLIFIER CIRCUIT DESCRIPTION

The most important feature of the Circlotron is its output circuit in relation to the audio load.

In a common push-pull circuit, the power tubes appear to be in series as far as the audio signal is concerned. In the Circlotron the output tubes & load have been rearranged so that the tubes are able to drive the audio load in parallel. That will let us use an output transformer of ¼ the normal impedance. It has been shown that lowering the impedance of an audio transformer is a great way of improving it's performance.

Leakage inductance & winding capacity are much less of a problem in low impedance transformers.

So that you can follow the circuit easier I have separated the power supply from the amplifier.

The amplifier is completely balanced throughout & uses a two stage differential input circuit. The differential amplifier neatly sidesteps some of the problems associated with phase inversion. For this version of the diffamp the only drawback of note is the need for a negative power supply. In the days before low cost silicon rectifiers this created lots of circuit complication. As a result you will not see these circuits used often in amplifiers of the 50's. You will see in this power supply that a negative output is no longer a hindrance.

Voltages shown on the diagram are under no signal conditions. You will need to be careful while making voltages measurements while signals are present. At full output there will be about 250 volts peak signal on the wires marked A through F with reference to circuit ground. That could make a mess of a voltmeter set to measure low voltage DC on any of these locations.

The input signal is fed to one of the grids of a 6SL7GT (V1) on the left-hand side of the diagram. You could use a 12AX7 just as well. In many of my circuits I simply use the tubes I have on hand. Gain of the amplifier is set by the 100K Pot. RV1. If you intend to use full loop feedback, you can connect it to the other grid. Otherwise, simply connect that point to your circuit ground.

Power for the first stage comes through the 75K resistors R8 & R9. Later you will see that the double high voltage supply is driven by the full audio voltage on the primary of the output transformer. The voltages are equal & opposite so that the two resistors provide the average with very little audio modulation. Any residual is removed by the 22 µF capacitor C6.

Output of the 6SL7GT goes to a boot strapped 6SN7GTB (V2). Again, you could just as easily use a 12BH7 at this location. Reason for the boot strapping is to provide enough voltage swing for the output tubes (V5 & V6). The output tubes are connected into the output transformer as cathode followers, so they have no voltage gain. That means the 6SN7GTB driver plates must swing several hundred volts just to keep ahead of the output. Without bootstrapping, you would need a much higher voltage power supply for the driver to enable the circuit to provide full output. Coincidentally the bootstrapping increases the stage gain by about one db. Negative return for both the 6SL7GT & 6SN7GTB is to a regulated negative 150 volt supply. The 6SL7GT gets a little extra smoothing through the action of the 22 µF capacitor C7 & the 12K resistor R35.

You can see I have interposed 6J5 cathode followers (V3 & V4) between the driver 6SN7GTB & the output tubes in order to avoid capacity & resistance coupling. The 6J5's cathodes are direct coupled to their respective output grids through the 100 ohm resistors R23 & R24. That avoids a problem called blocking. Norman Crowhurst provides a good explanation of that condition in a reprint of one of his articles in Volume 5 of Audio Anthology. At this location you could use any of several SINGLE triodes, such as 6SF5 or 6C4.

You should not use dual triodes at this location since there is a good chance their heater to cathode insulation will fail the first time the gain control is turned up. In the power supply I have provided electrically separated heater supplies to avoid that problem. The 75K resistors R25 & R26 are connected to the respective heater windings on the power transformers so that they follow the cathodes.

The 220K resistors R27 & R28 are returned to the negative power supplies. That allows for fast negative going waveforms in this part of the signal path. Positive going signals are not a problem here since they are pulled up by V3 & V4. If the high voltage was on during warmup it would be possible for R27 & R28 to pull the power tube grids & the 6J5 cathodes all the way down & perhaps further since there would be no load on the power supply. That might cause some failures as well. That condition is prevented by the 120K resistors R29 & R30. During normal operation there is only a small signal difference between the grid & cathode of the output tubes so that there is negligible signal loss.

An important part of this amplifier are eight grid stopper resistors. The output tubes in particular have very high transconductance & the amplifier will likely oscillate at radio frequencies on it's own if given a chance. Grid stopper resistors lower the Q (Quality Factor) of the circuit according to the formula

$$Q = (1/R) * SQR (L/C)$$

As little as 100 ohms in a conductor interferes with the RF to the extent that it is eliminated. The audio is left intact. For the control grids any small non-inductive resistor from 1K to 10 K will do. You should use 100 ohms for R36 & R37 in the output screen grids in order to prevent power loss in the output stage.

The schematic shows the output tubes connected for beam tetrode operation. You can easily go to triode operation by changing the connections of the 100 ohm resistors R36 & R37. The screen grid return through R36 should be connected directly to the plate of the same tube. Do the same with R37.

AMPLIFIER ADJUSTMENT

The amplifier has three controls which will enable you to adjust the operating conditions.
The 10K Pot. P1 is used to set to minimum the even order (2nd, 4th, Etc.) harmonic distortion at the amplifier output. If the output tubes are not a matched pair there is a good possibility they will need unequal drive signals. You will need something to measure or observe the distortion. By using a distortion analyzer such as one of the HP 330 Series it is possible to use it as a rejection filter & observe the remaining waveform on an oscilloscope. The Pot. P1 is then adjusted for minimum signal on the scope. The HP 330 Series instruments measures Total Harmonic Distortion (THD).

Another method involves the use of one of the virtual measurement attachments connected to your PC. For all of the harmonic distortion measurement results in this article I used the system manufactured by Pico Technology. This system uses FFT to provide a measurement of each of the individual harmonics, on the fly. It allows the 2nd harmonic to be observed while P1 is adjusted for minimum.

If you don't have access to one of these measurement systems than it is best to invest in a matched pair of output tubes. If you do than the pot & the 22K resistor R16 should be replaced by a single 27K resistor. That way the output of the driver circuit will be balanced into your output tubes.

The 10K Pot. P2 along with 75K resistors R19 & R20 is used to balance the DC conditions in the output stage. First be sure to disconnect any input signal & then set the gain control to minimum.
Use a DC voltmeter set to a low range to measure the voltage difference between the test points TP1 & TP2. Then adjust P2 for zero volts. If the adjustment is properly made there will be no current in the output transformer caused by the output tubes. There is a small current remaining in the output transformer. It is primarily the diff amp return flow from the negative supply.

The 10K Pot. P3 & the 39K resistor R34 sets the bias for the output tubes by way of V3 & V4.
It is possible to set a wide range of operating points. You should monitor the output tube current by measuring the voltages across the 10 ohm sampling resistors R31 & R32 while setting the bias.
Take care not to exceed the plate dissipation ratings of the output tubes you have chosen. With no signal applied the voltage at these test points is quite low. However, if a signal were applied to the input, lethal audio voltages may be present.

Don't forget to buy some pot. locks for each of these controls. After set up you will want to be sure they don't inadvertently get changed.

THE POWER SUPPLY

You will be able to avoid an expensive & perhaps hard to find special power transformer for this unusual amplifier. It is possible to use a pair of identical off the shelf units. I used Hammond 272BX's in the final version of my amp. There is even a discount available when you buy two of them. The resulting two high voltage supplies are identical. Each consists of a full bridge of silicon power diodes, D1 to D4 & D5 to D8. For the positive voltages each feeds into a 100 μF capacitor, C101 & C106. That is smoothed by 100 ohm resistors R101 & R104 feeding into 100 μF capacitors C102 & C107. The resulting 395 volts will drop to about 380 volts under full load conditions. Some may be tempted to use choke filtering at this point. You will find it not needed since the remaining ripple on each of the power supplies is cancelled in the output transformer. There is one not so obvious advantage the RC filter has over the LC filter. It is not resonant, so will not give your program material some extra unwanted coloration. I have included the 330nF caps C103 & C108 as high frequency bypasses. They are connected electrically & physically as close as possible to the output tubes & transformer The 330K resistors R115 & R118 safely discharge the capacitors should the load become unhooked.

The negative voltages are derived in a similar fashion. You don't need as much current to be supplied by this part of the circuit. To avoid some heating in the transformers the 1K resistors R103 & R106 are used to limit the charging current into the 10 μF caps C105 & C110. They also prevent the negative supplies from exceeding the voltage rating (385 volts) of the electrolytics I used. If you like you could use 450 volt caps. I again used RC filtering through the networks formed by R102/C104 & R105/C109. A safety discharge path is provided by the one meg resistors R116 & R117. The negative supply is further smoothed & regulated by the 0D3/VR150 gas regulator tube & the 25K resistors R107 & R108. C111 the 6.8 nF cap forms a high frequency bypass across the VR tube to remove some of it's noise. R109 & R110 are not assigned.

I wanted the amplifier to be free as possible of potential problems. Because output of the Circlotron power stage comes from the cathodes there is a very good chance of heater to cathode insulation failure. Each transformer has a 6 volt winding so that they are used here to separately power their respective heaters. There is also a 5 volt winding on each transformer. I connected these in series & then used 12 ohm resistors R111 through R114 to supply the heaters of V1, V2 & the pilot light.

The 4 pole, single throw switch S2 provides the amplifier with a standby & warmup mode. Pins 3 & 7 of the 0D3/VR150 regulator are wired into the primary of the power supply. The amplifier will not power up unless the regulator is plugged in.

The one nF, 1KV caps C112 & C113 will reflect some of the crud coming off the line back into the wall. Be sure to use shielded cable at your input to prevent internal feedback & coupling to the power supply.

DETERMINATION OF OUTPUT STAGE LOAD IMPEDANCE

If you check your tube manuals you won't find much information regarding proper push-pull loading for the power tubes we would like to use in this circuit when the plate & screen are run at the same voltage. Fortunately the circuit lends itself to experimental determination of these conditions.

I had a relatively large output transformer of low DC resistance in my junk box. I connected it to the amplifier as shown in the diagram with no loading on it's secondary. Then I used several large power resistors in the 1K & 2K range in various combinations to load the amplifier at points C&D. From these

measurements I was able to determine the optimum loading for maximum power output. The curves relating output power & distortion for pentodes & beam tetrodes tell us that as load impedance is decreased the 2nd harmonic will increase but the 3rd harmonic decreases. The 2nd harmonic will be cancelled in a properly balanced push-pull amp. For that reason I chose a load impedance about 10% less than optimum in order to reduce the 3rd harmonic component.

THE OUTPUT TRANSFORMER

I tried three alternative hookups. The first & best of these is a custom wound unit from Hammond. It has four separate primary windings which allows matching 6L6GC's to 1400 ohms or 6550C's to 800 ohms. The Hammond part number is H300767. The 800 ohm connection could also be used with KT88's or EL34's. The 1400 ohm connection would be OK for KT66's. Secondary of the transformer is the normal Hammond configuration of two windings allowing 4, 8 & 16 ohm loading.

A very good 2nd alternative is that using a pair of Hammond 125E universal output transformers. It occurred to me that if you could parallel connect resistors, capacitors or inductors to reduce the impedance than why not transformers? The transformer primaries are connected in parallel so that they will reflect ½ the data sheet impedance if similar secondary's are used. Keep in mind they are rated for 15 watts of audio each. That would be OK for the 6L6GC version of the amp. If you connect the secondary taps 1 & 5 of each transformer in series to an 8 ohm load you will reflect a load of 1500 ohms to the output tubes which will make them very happy. The damping factor is not as good as when the H300767 transformer was used.

The 3rd transformer hookup allows you to use some of the commonly available push-pull output transformers. The key here is that the two halves of the primary must be electrically isolated. You will find these in old amplifiers as well as replacement units now on the market. If the two halves of the primary are paralleled the impedance will be ¼ of the normal hookup. For example, if you were lucky enough to have a transformer made for push-pull 6L6's with plate to plate impedance of 6600 ohms then the new connection would give you 1650 ohms. That is close enough to satisfy the 6L6GC's in this version of the Circlotron.

You will notice in the schematic for this alternative I have shown the transformer primaries connected to each others opposite connection, that is blue to brown & vice versa. As well, the transformer secondary's are also reversed, so that the output signals are still additive. In many lower cost audio transformers the secondary is wound around one end of the primary. This results in more stray capacity on one end of the primary then on the other end. For the Hammond 125 Series the secondary is wound around the brown end of the primary. This may cause problems unless you give it some consideration. In a pushpull amplifier, the high frequency balance of the output stage is disturbed. By paying attention to this simple relation, you can avoid that condition.

You will still need to provide a DC return for the negative power supply. That is possible by using a pair of resistors bridged across the transformer primary. See R38 & R39 in the diagram. The resistances used will need to be rather large in order to avoid audio signal power loss at this point, since they form a load across the transformer primary. That in itself is not a problem. However, DC return current in these same resistors adds too much to the output tube bias, tending to bias them off. For this reason I do not recommend this hookup.

Fortunately, most of the output transformers I referred to above come with Ultralinear (UL) taps. That will neatly step around the biasing problem I referred to. The taps are normally at 20% or 43% of each ½ of the primary. That means you can use a much smaller bridging resistance which will have much less effect on the output tube bias. Even still you will need to make a small adjustment in the bias network to bias the tubes properly.

As an example, I had set the idling current of each 6L6GC in the circuit to 42 ma in the circuit of the first output transformer alternative described above. When I connected this transformer alternative which has 43% UL taps the new biasing conditions had reset the idling current to 30 ma. Measuring the voltage drop across the bridging resistors I found that 5.72 volts had been added to the bias. The good news is that the audio signal voltage developed across the bridging resistors when the output was set to 12.5 watts was only 18.7 volts rather than 131 volts. That had allowed the bridging resistors to be reduced by 86%, a very worthwhile improvement in this part of the circuit.

PERFORMANCE

Summaries are given in Tables A & B so that you can compare the amplifier performance both with & without feedback. Having two kinds of output transformers, two kinds of tubes connected as triodes or tetrodes & then with & without feedback resulted in a dazzling array of test data. I managed to get 17 (not 16 as you would think) sets of test data to bewilder you with. However, out of all this you will be able to arrive at some interesting conclusions & select a combination which best suits your needs.

Feedback has been normalized at 10 db so that valid comparisons can be made. In each case the feedback resistor needed to connect to the 8 ohm tap is noted as R_{fb}. The amplifier AC Balance adjustment has been set for best results in each case at 10 watts output. This may not be the best setting for lower power outputs. The load resistor used in testing consisted of six 50 ohm & one 150 ohm resistor (all 10 watt) connected in parallel. The result measured 7.86 ohms & was connected to the 8 ohm output in each case.

No output matched pairs or special tube selections were used to get this performance. Cathode current for the 6550C's was set at 70 ma each for these tests. I set the cathode current for the 6L6GC tests at 53 ma each. You could set these higher & reduce the odd order (3rd, 5th, Etc.) distortion.
The line voltage measured 116.

Individual harmonic distortion & total harmonic distortion have been measured at several power levels. Damping Factor (DF) was calculated from the output voltage drop caused by connecting an extra 30 ohm load in parallel to the 8 ohm output connection at a one watt level. The columns marked "Input" contain the voltage needed to produce 10 watts at the output. Columns marked "Reference" are to keep me on track while sorting out this mass of data. The GW GAG-810 test signal generator distortion measured 0.03%.

While recording the amplifier response to the 100 HZ square wave I made an interesting observation. Low frequency phenomena on the scope doesn't photograph very well. That's because most scopes use a P31 phosphor which doesn't have a lot of afterglow. I recall selling many scopes with a longer persistence phosphor, the P7 to users who needed the longer yellow afterglow. This continued long after the advent of variable persistence scopes because the price & performance was good. For these measurements I used the storage capabilities of the Pico Technology Virtual Instrument. The response at one & 10 KHZ was photographed straight from the scope.

With no feedback there is no overshoot. With 10 db feedback there is a minor overshoot but no ringing. This could be eliminated with phase correction networks. Form of the correction network will depend on the output transformer you use. All of the square wave measurements where made at a level of 12 volts peak to peak.

In the photograph of the amplifier underside you may notice on the right hand side what looks like automotive trailer electrical connectors. These formed a convenient way for me to quickly change the various output transformer schemes I wanted to try. You won't need those in your finished amplifier.

DISCUSSION OF RESULTS TABLES

Even without full loop feedback, the Damping Factor (DF) for the tetrode connected examples is a very triode like 2 to 3. That will provide very good control of your loudspeaker. The triode connected cases are even better in the range of 3 & 4. Had the tetrodes been connected in the regular fashion such as used by common amplifiers such as the Williamsons, Dynas & Mullard 520's, damping factors would have been in the range 0.12 to 0.20 before feedback had been applied. That is a huge difference.

Using two of the Hammond 125E output transformers as an alternative to the large output transformer results in a small decrease in the DF. That is caused by more copper losses due to the higher winding resistance in the signal path. Distortion at high levels & low frequencies increases as well. This is a result of the limited amount of iron available in these transformers. Lets hope Hammond comes up with a 125F!! Still a very useable alternative.

Output tubes connected as triodes results in even better DF, with or without feedback then when tetrode connected. Distortion is marginally less at low levels but power output capability is limited.

Equipment used in the development of this amplifier-

> HP 200CD Oscillator
> GW GAG-810 Sine/Square Wave Generator
> HP 302A Wave Analyzer
> HP 334A Distortion Analyzer
> Rohde & Schwarz BOL 4 Trace 100 MHz Scope
> Radio Shack 22-168A DMM
> Sanwa AX 303-TR Analogue Multimeter
> PicoScope ADC-100 Virtual Instrument
>
> Electronic Workbench Software

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.

TABLE ONE　　　CIRCLOTRON PERFORMANCE SUMMARY
No feedback is connected.

Percent Harmonic Distortion at conditions noted in the left column.

CONDITION	WATTS	2 harm	3	4	5
2X 6L6GC	10	0.52	0.27	~	~
H300767	25	0.16	1.58	0.19	0.49
1000 HZ					

Damping Factor = 2.19

2X 6L6GC	1	0.33	~	~	~
2X 125E	10	0.48	0.32	~	~
1000 HZ	25	0.09	1.67	0.16	0.38

Damping Factor = 1.46

2X 6L6GC	1	0.22	0.12	~	~
2X 125E	10	0.37	0.29	~	~
100 HZ	25	0.09	0.95	0.11	O.16

2X 6L6GC	1	0.24	~	~	~
H300767	10	0.31	0.29	~	~
100 HZ	25	0.14	1.06	0.13	0.17

Damping Factor = 2.35

2X 6550C	1	0.16	0.12	~	~
H300767	10	0.11	0.14	~	~
1000 HZ	40	0.31	0.38	0.12	0.59

Damping Factor = 1.94

2X 6L6GC	1	0.37	0.10	~	~
TRIODES	10	0.17	1.38	0.27	0.24
H300767/1000 HZ					

Damping Factor = 3.25

2X 6550C	1	0.14	~	~	~
TRIODES	10	0.15	0.21	0.08	~
H300767/1000 HZ	20.77 max	1.01	2.33	0.29	0.64

Damping Factor = 2.83

file- Table One

TABLE TWO   CIRCLOTRON PERFORMANCE SUMMARY
                    10 db feedback is connected.

Percent Harmonic Distortion at conditions noted in the left column.

CONDITION	WATTS		2 harm	3	4	5
2X 6L6GC	1	0.17	0.11	~	~	
H300767	10	0.18	0.13	~	~	
1000 HZ	25	0.09	0.38	~	0.09	

   Damping Factor = 7.61

CONDITION	WATTS		2 harm	3	4	5
2X 6L6GC	1	0.19	~	~	0.14	
2X 125E	10	0.26	0.13	~	0.09	
1000 HZ	25	0.07	0.70	0.08	0.18	

   Damping Factor = 5.59

CONDITION	WATTS		2 harm	3	4	5
2X 6L6GC	1	0.14	~	~	~	
2X 125E	10	0.17	0.14	~	~	
100 HZ	25	~	0.39	0.06	O.07	

   Damping Factor = 5.48

CONDITION	WATTS		2 harm	3	4	5
2X 6L6GC	1	0.15	0.12	~	~	
H300767	10	0.63	0.41	~	~	
100 HZ	25	0.06	0.46	0.06	0.10	

   Damping Factor = 7.24

CONDITION	WATTS		2 harm	3	4	5
2X 6550C	1	0.12	0.10	~	0.12	
H300767	10	0.10	0.08	~	~	
1000 HZ	40	0.06	0.17	~	0.25	

   Damping Factor = 6.62

CONDITION	WATTS		2 harm	3	4	5
2X 6L6GC	1	0.19	0.10	~	0.15	
TRIODES	10	0.13	0.63	0.19	0.16	
H300767/1000 HZ						

   Damping Factor = 10.19

file- Table Two

PARTS LIST
THE CIRCLOTRON

AE indicates Antique Electronics
Some parts are available at Radio Shack
All Resistors are 2 watt unless noted otherwise

C1	1.0 μF	400 vdc
C2, C3	330 nF	600 vdc
C4, C5	100 nF	600 vdc
C6, C7	22 μF	450 vdc
C101, C102, C106, C107		
	100 μF	450 vdc
C103, C108		
	470 nF	600 vdc
C104, C105, C109, C110		
	10 μF	450 vdc
C111	6.8 nF	600 vdc
C112, C113		
	1 nF	1000 vdc

R1	not assigned
R2	1.2K
R3, R4	1.2K
R5, R6	100K
R7, R8, R9	75K
R10, R11	1.2K
R12, R13	330K
R14	27K
R15	33K
R16	22K
R17, R18	330K
R19, R20	75K
R21, R22	1.2K
R23, R24	100R
R25, R26	75K
R27, R28	220K
R29, R30	120K
R31, R32	10R
R33	not assigned
R34	39K
R35	12K
R36, R37	100R

R101, R104	100R
R102, R103	1K
R105, R106	1K
R107, R108	25K, 10 Watts
R109, R110	not used
R111, R112	12R
R113, R114	12R
R115, R118	330K
R116, R117	1M

RV1	**100K Pot. (Gain) & Knob**
P1, P2, P3	**10K, 2 Watt Pot. & Pot. Locks**
T1	**See Text**
T101, T102	**Hammond 272BX**
V1	**6SL7GT**
V2	**6SN7GTB**
V3, V4	**6J5**
V5, V6	**See Text**
V7	**0D3/VR150**
D1 thru D8	**FR107 fast recovery, AE p/n P-QFR107**
S1	**SPST Switch (On-Off)**
S2	**4PST Switch (Standby)**

Aluminum Chassis 10" X 17" X 3"
               Hammond 1444-32
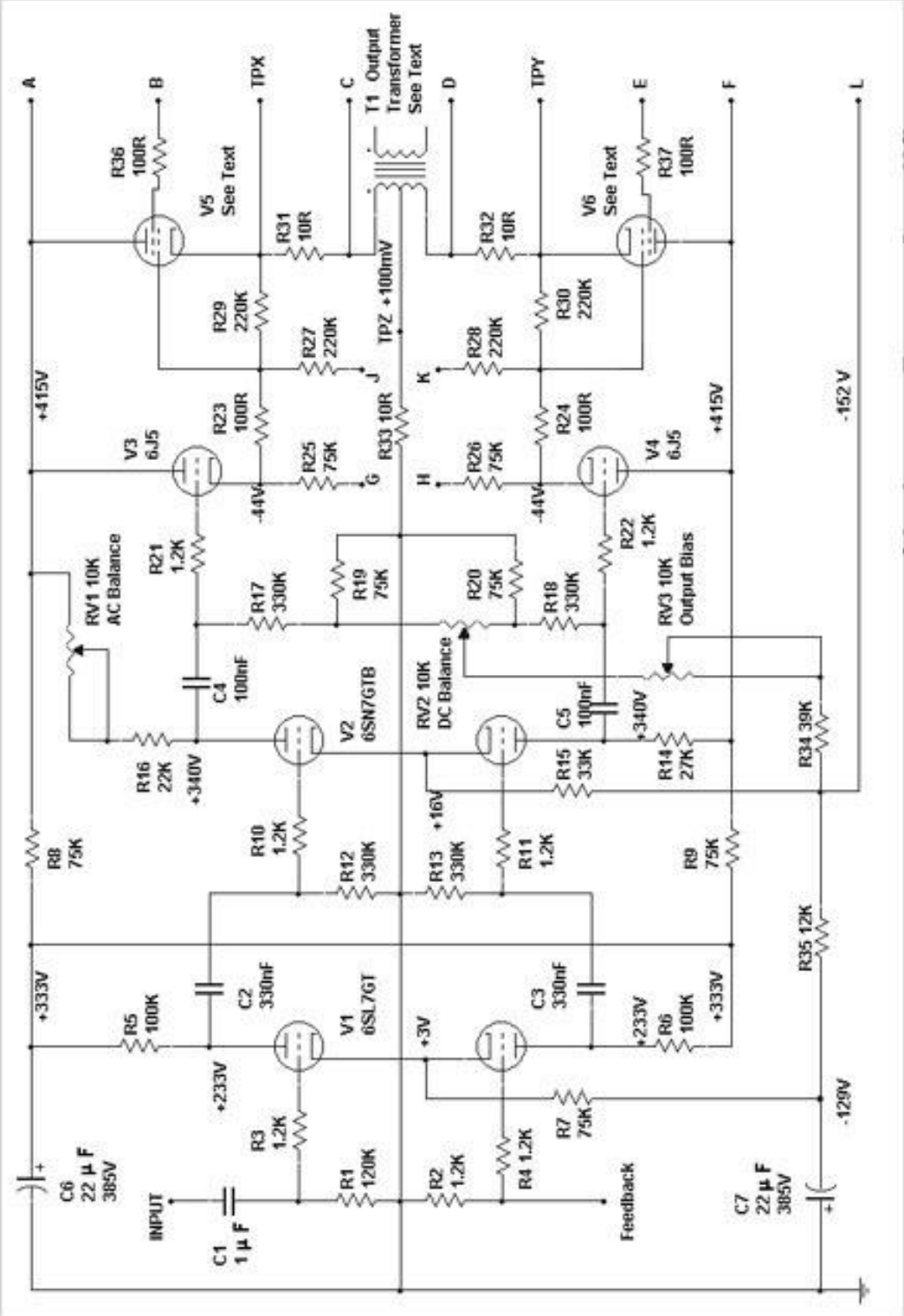**Aluminum Bottom Plate 8" X 16"**
               Hammond 1434-30

#1815 Pilot & Holder, AE p/n P-L114
Fuse 2Amp & Holder, AE p/n S-H258
Octal Sockets, AE p/n P-ST8-801, need 7

Terminal Strips

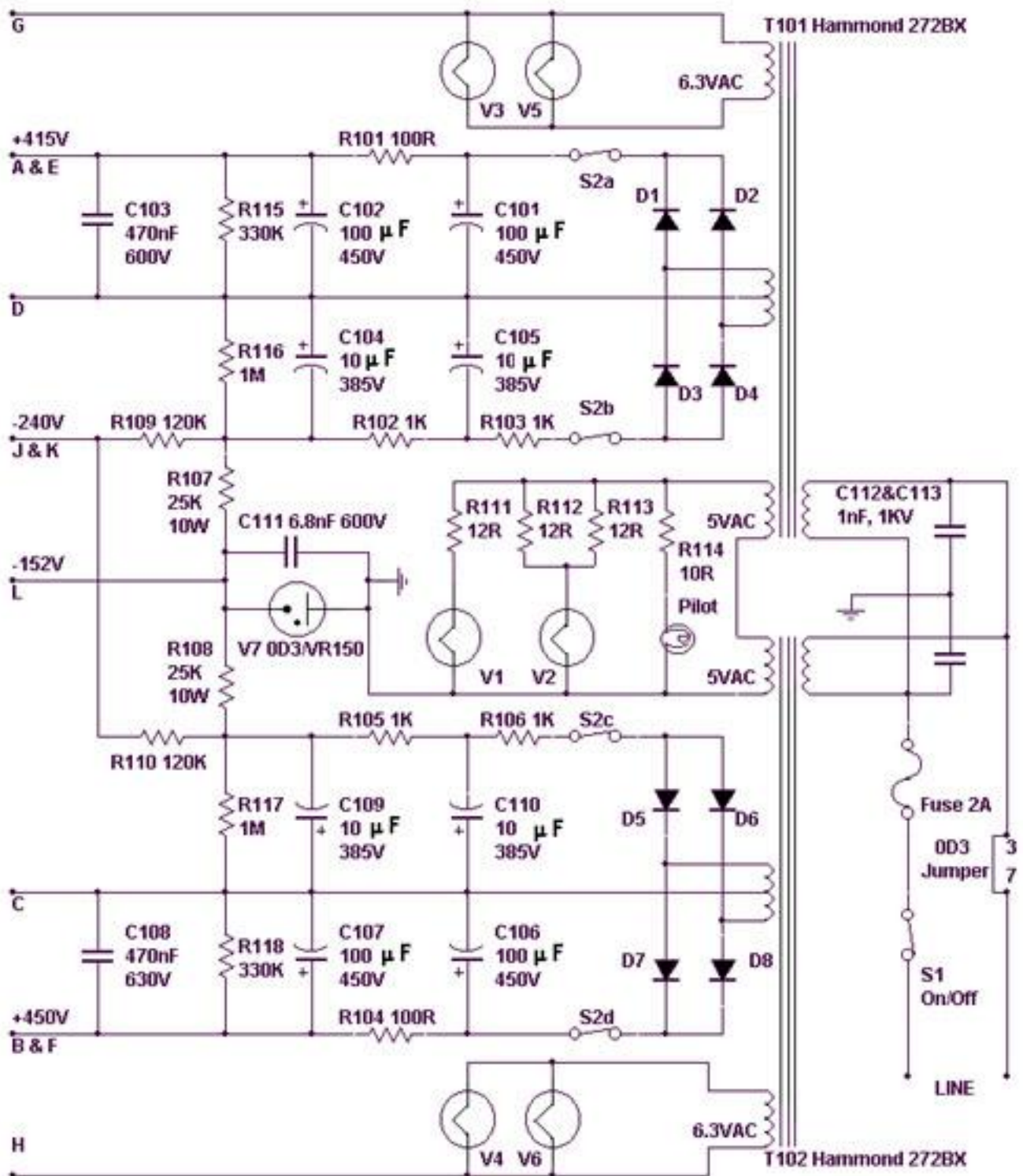| AE p/n	lugs	quan
P-0201H	**2**	**2**
P-0301H	**3**	**7**
P-0501H	**5**	**6**
P-0601H	**6**	**5**
P-0701H	**7**	**2**
P-0901H	**9**	**7**
S-H317	**6 screws**	**1**

Double Phono Jack AE p/n S-H310
6 ft. Line Cord AE p/n S-W105
Rubber Grommet AE p/n P-G005
Rubber Feet AE p/n P-H253, need 4
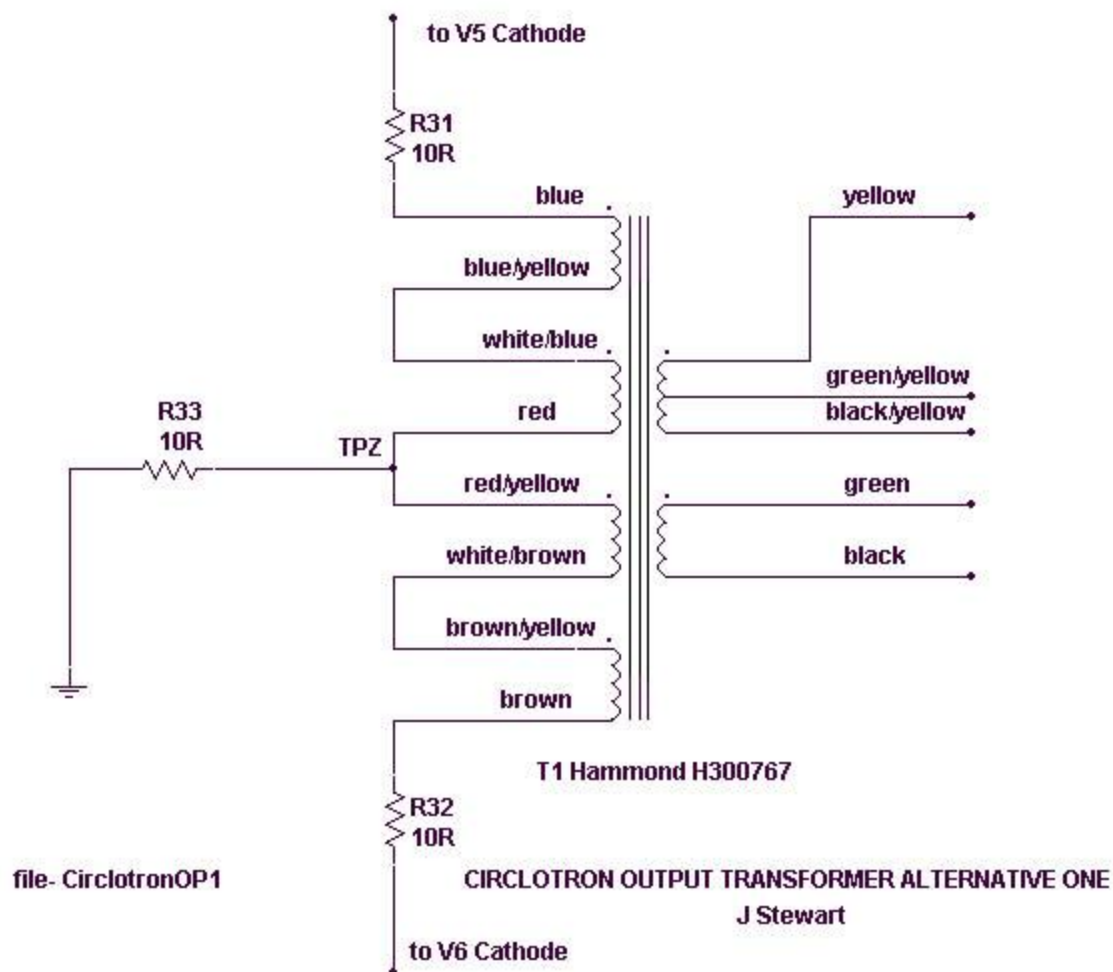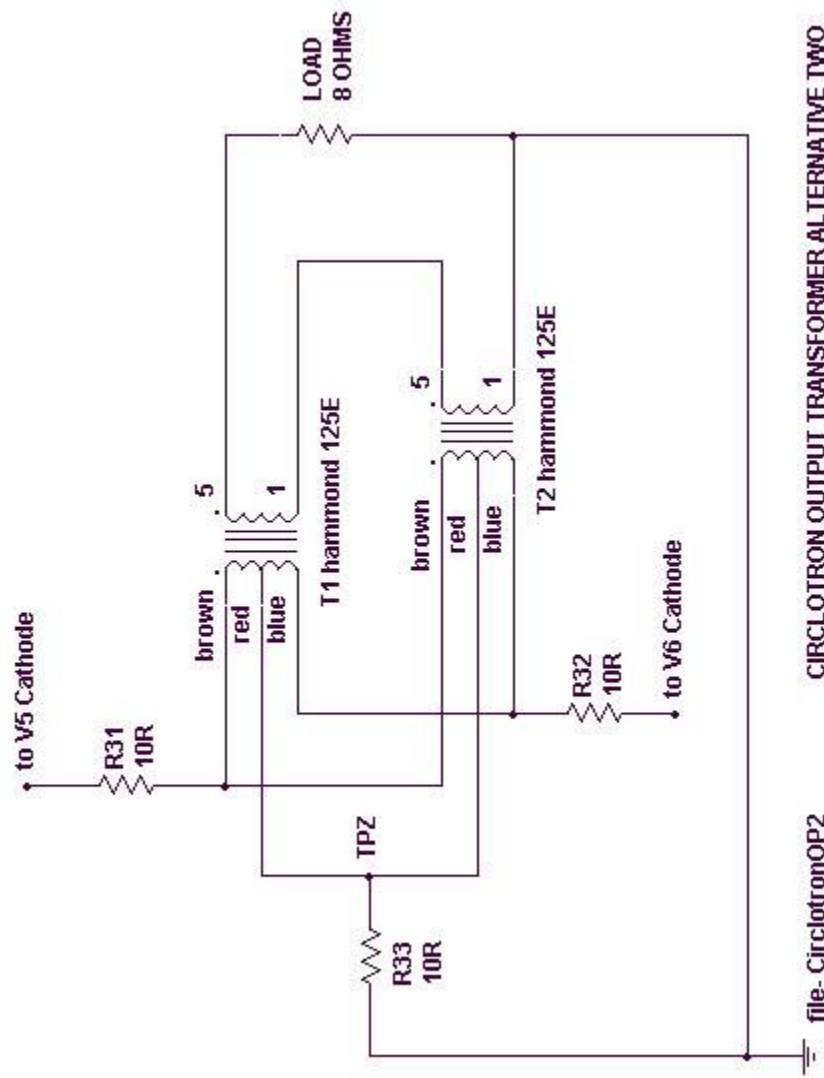**Assorted machine screws, nuts & washers**
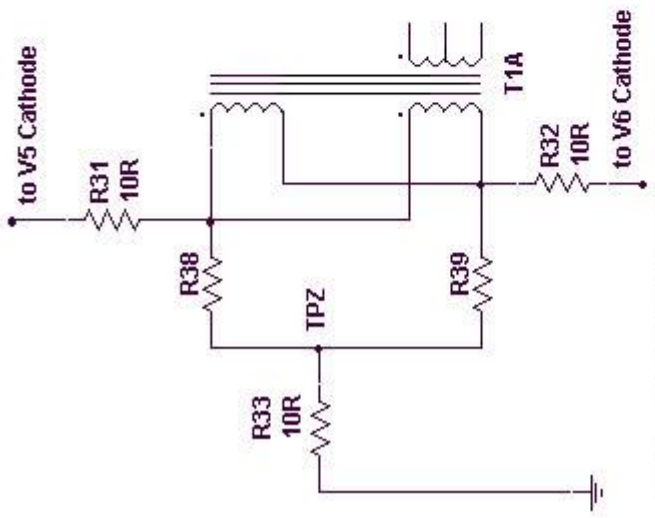
Circlotron Power Amplifier

J Stewart

file- Circlotron2

G

T101 Hammond 272BX

6.3VAC

V3 V5

+415V
A & E

R101 100R

S2a

D1   D2

C103
470nF
600V

R115
330K

C102
100 μF
450V

C101
100 μF
450V

D

R116
1M

C104
10 μF
385V

C105
10 μF
385V

D3   D4

S2b

-240V
J & K

R109 120K

R102 1K

R103 1K

R107
25K
10W

C111 6.8nF 600V

R111
12R

R112
12R

R113
12R

5VAC

R114
10R

C112&C113
1nF, 1KV

-152V
L

V7 0D3/VR150

Pilot

R108
25K
10W

V1   V2

5VAC

R105 1K

R106 1K

S2c

R110 120K

R117
1M

C109
10 μF
385V

C110
10 μF
385V

D5   D6

C

C108
470nF
630V

R118
330K

C107
100 μF
450V

C106
100 μF
450V

D7   D8

Fuse 2A

0D3
Jumper

3
7

S1
On/Off

+450V
B & F

R104 100R

S2d

LINE

H

6.3VAC

V4 V6

T102 Hammond 272BX

to V5 Cathode

R31
10R

blue

blue/yellow

white/blue

R33
10R

TPZ

red

red/yellow

white/brown

brown/yellow

brown

yellow

green/yellow
black/yellow

green

black

T1 Hammond H300767

file- CirclotronOP1

CIRCLOTRON OUTPUT TRANSFORMER ALTERNATIVE ONE
J Stewart

R32
10R

to V6 Cathode

LOAD
8 OHMS

.5

1

T1 hammond 125E

brown

red

blue

.5

1

T2 hammond 125E

brown

red

blue

to V5 Cathode

R31
10R

R32
10R

to V6 Cathode

TPZ

R33
10R

CIRCLOTRON OUTPUT TRANSFORMER ALTERNATIVE TWO

J Stewart

file- CirclotronOP2

to V5 Cathode
R31 10R
T1B
R32 10R
to V6 Cathode
R38 1.2K
TPZ
R39 1.2K
R33 10R

T1B is a Push-Pull Output Transformer with separate primary windings and has UL taps

CIRCLOTRON OUTPUT TRANSFORMER ALTERNATIVE THREE

J Stewart

to V5 Cathode
R31 10R
T1A
R32 10R
to V6 Cathode
R38
TPZ
R39
R33 10R

T1A is a Push-Pull Output Transformer with separate primary windings but no UL taps

file- CirclotronOP3

Reply Letter to a Reader

Thankyou for your response to my recent article covering a Circlotron Amplifier. Some of my comments in regard to your concerns may surprise you & others. I have some very strong feelings about the way this or that amplifier may "sound".

First of all let me preface my comments as follows. I don't think I am qualified to tell you how any of my amplifiers "sound". I would probably tend to be biased in a direction that might make them sound better than others would say. I don't have any friends or acquaintances that are professionals in the audio field who might pass judgment. However, for those who have listened the comments have been positive.

As well, I can think of at least three filters we often tend to ignore when evaluating the "sound" of an amplifier, even though they are with us at all times. Between the output terminals of every amplifier & our ears, whether it be Circlotron, McIntosh or our kitchen radios we have a loudspeaker, it's enclosure & the listening room.

Each of these has a profound effect on what we hear, in particular the speaker. At the present state of the art the loudspeaker appears to be the weakest link in the reproduction of sound.

For example, I have an old (50 years?) AC/DC, AM kitchen radio connected to a good 12-inch speaker, properly baffled in my garage. The radio has an RF stage & we are far away from electrical disturbances, so that the program material is reasonably good by the time it reaches the power stage.

The power stage has been "smiled upon". I have replaced the usual 35L6GT output tube which provides no speaker damping at all with a feedback pair consisting of a 12J5 & 50L6GT. The 12J5 plugs into the rewired socket where the 35Z5GT rectifier used to live. The silicon diode replacing that results in a higher B+ so that the output power is about doubled. I've done several of these in the past, all with considerable improvement in the sound, but only when connected to a good loudspeaker in a proper enclosure. To me these all sound good but I & my ears are getting old, so you can draw your own conclusions!

I built only one Circlotron amplifier, but in such a way that you could easily try many combinations of the various topologies & components available. I wanted to offer something to the experimenter that would allow a wide choice of tubes as well as connecting for triode or pentode operation. You can also operate with or without feedback. Choose which combination suits your taste best by referring to the comprehensive set of performance result tables.

Now, how did the Circlotron "sound"? Again, to me very good. It may sound even better to you but of course that will depend very much on your reproducing equipment & listening room. My speakers are by no means even close to the best, but nevertheless quite reasonable in my opinion. They are each about three feet high & about 1.5 feet square. Inside each is a twelve-inch woofer (with a large magnet), a four-inch midrange & a two-inch tweeter. The crossovers are adjustable. They are now about 25 years old, but soldiering on.

The listening room measures about 16 X 36 feet, so low frequencies are easily reproduced. I have a good music library to compare with (about 1000 vinyl discs & even some 78's). I also have four large wide range speakers outside aimed into the back "40" here. Luckily my closest neighbor in that direction is about one mile away.

There are probably a few out there who can actually hear the difference between this or that amplifier through all of the filters I've mentioned above. That would include professional musicians whose living depends upon detailed recognition of various sounds. Technicians & those in the business of manufacturing & repairing amplifiers as a living would have the opportunity to hear many amplifiers & be in a good position to make valid comparisons. My background is hitech, but not in the sound business.

Having said all of that, for me design of the various circuits involved is my primary interest. Many years ago I started out as a circuit designer in the realm of tubes & now find considerable satisfaction in pursuing that activity again. Several amplifiers have resulted from that activity, some of which you may have read about in past issues of these pages. What happens to the amplifiers when the article is finished? Sometimes they are cannibalized for the next project! Others are sitting here on shelves in the workshop.

There are many tradeoffs in any system. It is the designer's task to separate what is important from what is not. I would recommend to anyone putting together a sound system to pay special attention to the loudspeakers, their enclosures & the listening room. The reward will be a good performance whether they choose to use a Single Ended Triode, Ultralinear, McIntosh, Williamson or any of several other amplifier topologies.