Vacuum Tube Gain Controlled Amplifier

All Triode Design

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Citation
Paper presented to the Convention of the Audio Engineering Society, New York on the subject of difference in the harmonic distortion components of the amplified signal, with tubes, transistors and operational amplifiers separating into distinct groups.
(Hamm, 1972)

PREFACE

This paper describes the design of an all triode vacuum tube gain controlled amplifier. Although the original prototype performed well some variations in circuit operation may require experimentation. This is a project for the experienced builder.

A gain controlled amplifier is an amplifier that maintains an average output level over a larger input level range. This type of amplifier is used to prevent overdriving audio systems, playback or record, and keep levels in a more comfortable listening range. This particular design uses all triode vacuum tubes including a triode gain control stage, all stages are built around the popular 12AX7 tube.

Most of the circuits use common available parts. There is a specific type VTL5C2 LDR optical isolator that must be used. As of 6/2016 the VTL5C2 is discontinued, but available as surplus requiring a little searching to find suppliers. Two 6AL5 dual diode tubes are used in AGC DC control circuits. The 6AL5 tubes are no longer manufactured, but are easily obtained as new old stock (NOS). A 1MA DC meter is required with a removable meter face so a custom scale can be made to indicate gain reduction. The meter must be made so it can be easily opened to access the face plate. Using a standard VU meter is also an option if you are not up to the task of modifying a meter and making a meter face plate.

All circuits are provided; stage circuits are individually drawn and functional descriptions provided. Interconnecting points between the stages are labeled, a block diagram with labeled interconnecting points illustrates how the stages all connect together.

The original prototype amplifier built from this design was used in radio broadcasting and operated 24 hours a day 7 days a week for well over a year. During this period the unit never drifted and never required any service, it operated flawlessly. When the vacuum tubes were tested after this period they all tested good, an indication that the tubes were operating well within safe limits.

The basic design concept is simple, an input stage followed by a gain controlled stage, then followed by an output stage. All the stages that audio pass through, including the gain control stage, should be triode vacuum tubes. Triodes are desired because of their predominant second harmonic distortion characteristic. Additional stages would be used to amplify the audio signal high enough to convert audio to DC control voltages for the AGC circuits.

COMPRESSION RATIO

The amount of gain control is usually stated in terms of compression ratio of the input to output signal levels (input:output). At a 1:1 (1 to 1) ratio the audio level out follows the input level, with a 2:1 ratio the increase of output level is about half the increase of input level.

This processor has a variable compression ratio; the ratio becomes tighter as the input level increases past the compression threshold. This allows soft passages to retain high dynamics while imposing more control on loud passages.

The term AGC is short for Automatic Gain Control.

MEASURED VARIABLE COMPRESSION RATIO

INPUT LEVEL TO OUTPUT LEVEL RATIO

AT THRESHOLD = 1 : 1
5DB PAST THRESHOLD = 1.3 : 1
10DB PAST THRESHOLD = 1.7 : 1
15DB PAST THRESHOLD = 1.9 : 1
20DB PAST THRESHOLD = 2 : 1
30DB PAST THRESHOLD = 2.3 : 1

A 2 to 1 ratio is a happy medium; levels are somewhat restricted to a specific range but not so much as to destroy dynamics. Compression ratios of 5 to 1 or higher destroy dynamics and can be classified as brick wall processors, it's like the audio is hitting a brick wall.

This amplifier is not designed to be a brick wall processor. In fact, during listening test it seemed as if the processor was not having any effect on controlling levels until the test/operate switch was switched into test mode and the output level began to rise significantly. Also, the sound quality remained the same in operate or test mode.

The following are performance measurements made to the finished prototype amplifier. Since the amplifier was to be used interfaced with professional equipment, measurements were taken in the 0DB to +4DB output level range.

TEST MODE MEASUREMENTS

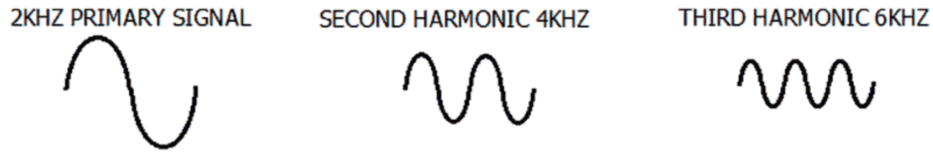
FREQUENCY RESPONSE = ±2DB 30HZ – 70KHZ
HARMONIC DISTORTION LESS THAN 1% 30HZ – 30KHZ
HUM AND NOISE 65DB BELOW 0DB OUTPUT REFERENCE
MAXIMUM OUTPUT LEVEL +18DB

OPERATE MODE MEASUREMENTS

AVERAGE OUTPUT LEVEL – 0DB TO +4DB
HARMONIC DISTORTION
100 – 30KHZ
25DB GAIN REDUCTION – 1%
30DB GAIN REDUCTION – 3%
DISTORTION SECOND HARMONIC DOMINATE

HARMONICS

Audio is composed of complex primary frequencies plus harmonic frequencies. For example, a frequency of 2KHZ will have a second harmonic of 4KHZ and a third harmonic of 6KHZ.



Generally speaking, the higher harmonic frequencies are lower in amplitude. By the time you get to the eighth or ninth harmonic the harmonics may be too low to measure. This only applies to sine waves; square wave harmonics are significantly higher.

Harmonic distortion is the presence of extra harmonics that are not in the original signal usually caused by non-linear amplification. Although it varies from person to person, harmonic distortion does not become noticeable until it reaches about .25%. As the amount of distortion increases it becomes more apparent although depending on the harmonics, second, third, fourth, etc, the actual effect to the sound varies.

The following is an excerpt from a study by Russell O. Hamm in 1972 presented to the Convention of the Audio Engineering Society.

In the simplest classification, the lower harmonics are divided into two tonal groups. The odd harmonics (third and fifth) produce a "stopped" or "covered" sound. The even harmonics (second, fourth and sixth) produce "choral" or "singing" sounds.

The second and third harmonics are the most important from the viewpoint of the electronic distortion graphs. Musically the second is an octave above the fundamental and is almost inaudible; yet it adds body to the sound, making it sound fuller.

The third is termed a quint or musical twelfth. It produces a sound many musicians refer to as "blanketed". Instead of making the tone fuller, a strong third actually makes the tone softer. Adding a fifth to a strong third gives the sound a metallic quality that gets annoying in character as its amplitude increases.

As might be suggested by the O Hamm study, the effect of added second harmonic distortion can be used to an advantage. Added second harmonic content can be used as enhancement. Triodes operating Class A produce predominantly second harmonic distortion.

FUNCTIONAL DESCRIPTION

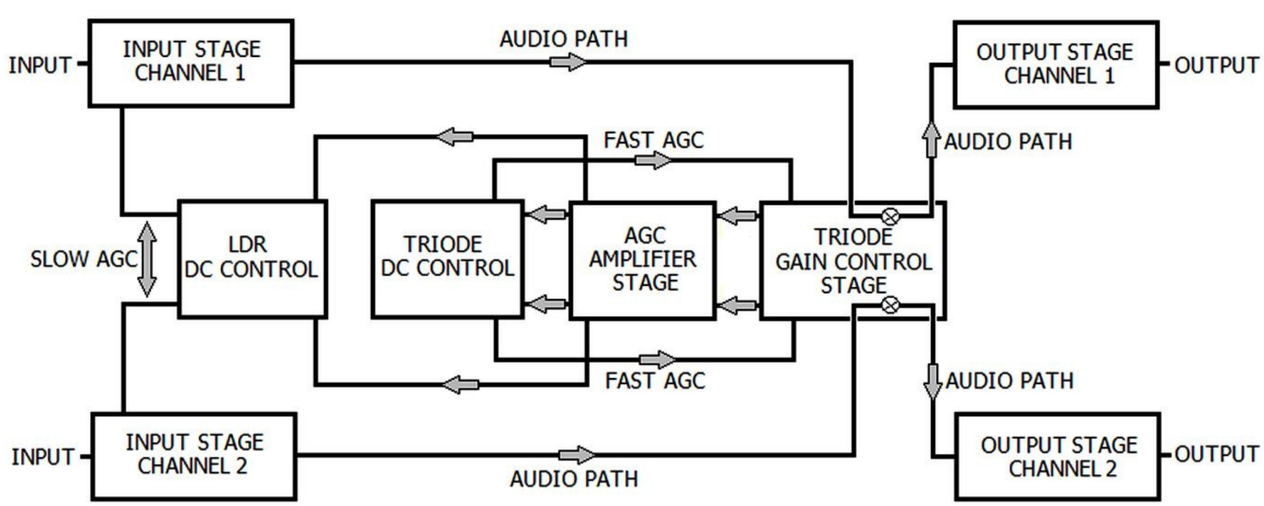
The following is a functional description of the all triode vacuum tube gain controlled amplifier.

Audio passes through a 12AX7 input consisting of a low impedance cathode follower input stage followed by a voltage amplifier stage. From the input stages audio passes through a 12AX7 gain control stage then to a 12AX7 output consisting of a voltage amplifier stage and a cathode follower output stage.

There are two points of gain control. The first point is at the input using an LDR (light driven resistor) optical isolator for slow AGC connected as a variable shunt to ground, audio does not actually pass through the LDR. The second point of gain control is the 12AX7 triode in the audio path between the input and output stages for fast AGC. The LDR slow gain control at the input keeps an average level plus helps to prevent the triode gain controlled stage from being over-driven. The result is a fast AGC riding on a slow AGC. The slow AGC maintains a moderate fast AGC action. Both the slow AGC and fast AGC have attack/release adjustment controls.

An AGC amplifier stage is used to provide a high level audio signal suitable for rectification into DC control voltages; the AGC amplifier feeds both the LDR and triode DC control stages. The signal input to the AGC amplifier stage is supplied from the output of the triode gain controlled stage; this is a feed-back system where the reference for gain control is after processing.
The AGC amplifier stage drives the LDR DC control stage and the triode DC control stage where audio signals are rectified to a DC control voltage, the DC control voltages are filtered through resistor/capacitor networks for the appropriate time constants.

ALL TRIODE PROCESSOR FUNCTIONAL DIAGRAM



TRIODE GAIN CONTROL

As pointed out in the Russell O. Hamm study, *musically the second (harmonic) is an octave above the fundamental and is almost inaudible; yet it adds body to the sound, making it sound fuller.*

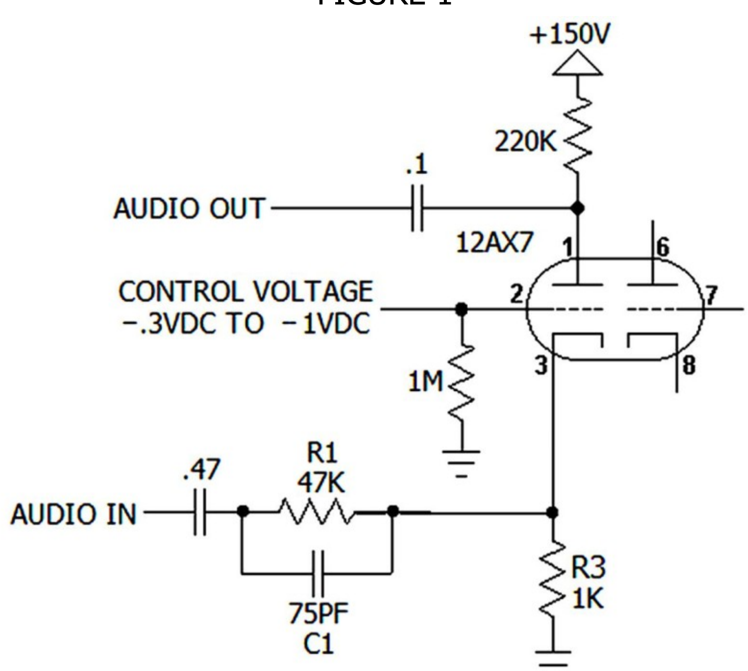
With this in mind, adding some second harmonic content can enhance audio. The distortion produced by triode vacuum tubes when operated class A is predominantly second harmonic, this make a triode a desirable choice for a gain controlling stage in an audio leveling amplifier.

Since a gain controlling stage usually requires an extra grid to control the gain of the tube, the signal must be inputted into the triode through the cathode allowing the grid to be used to control gain by grid bias voltage.

As the triode grid is made more negative the gain of the tube is reduced. Besides reducing gain the tube starts to be offset from its linear operating point and distortion increases. Although this may seem undesirable the result is an enhancement because the triode distortion is predominantly second harmonic; the more the stage is biased into gain reduction the more second harmonic content is added to the audio. It is best to supply critical AGC circuits with a regulated B+ voltage to reduce the chance of gain drift. A small change in grid bias makes a significant change in tube gain,

Input is supplied to the cathode; the grid is only used as a gain control. The grid control voltage does not supply much current so it is necessary to use a high value grid resistor to keep loading low. The high grid resistance results in higher grid capacitance and some high frequency compensation is needed. This is best done at the cathode input with a high frequency boost network of a capacitor (C1) across a resistor (R1), see Figure 1. In order to keep the stage operating as close to its linear operating curve as possible the input signal needs to be low. R1 and R3 form a pad and reduce the input level to the tube by about 34db. R1 also increases the input impedance (resistance) to reduce loading on the preceding stage.

FIGURE 1



CUSTOM METER FACE

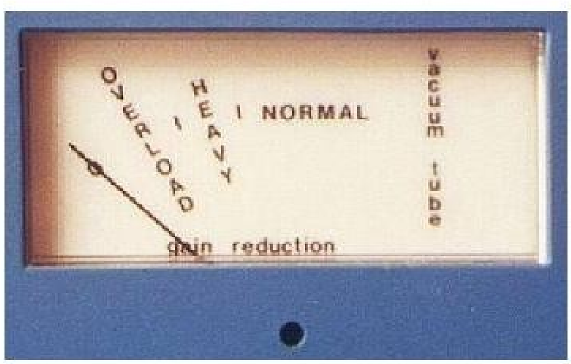
The next picture shows the custom meter face used on the prototype amplifier, the meter used was available special order with a blank face plate. The plate was lettered using press-on letter transfers then given a light coat of Krylon™ Crystal Clear Acrylic spray paint just enough to slightly coat the lettering. Note that the face plate was first lettered and sprayed with the clear acrylic then installed into the meter after drying. Do not attempt to letter or paint the face plate while installed in the meter.

With the amplifier powered on and no audio input, the meter will read almost full scale. As input levels increase and reach the compression threshold the meter will start deflecting to the left down scale, the more compression (gain reduction) there is the farther down scale the meter will deflect. This is a classic gain reduction meter indication.

During operation gain reduction in the normal area is the first 10DB of compression past threshold. As it gets deeper into compression and the compression ratio increases the meter indicates in the heavy region. When compression reaches 30DB past threshold the meter should start entering the overload region.

You could approximate and duplicate the scale in the picture and be close to the correct indications. Otherwise, after the unit is completely built and operational, use test tones while monitoring the input and output levels, mark off the points on the meter face at the correct input/output ratio points, then letter the meter face.

If you are not up to lettering a meter face and you are only interested in a relative indication of gain reduction, you could use a standard VU meter. VU meters are built to operate off audio (AC), but will also work with DC. If you cannot calibrate the VU meter to zero with R8, you may need to adjust the meter circuit values, in particular R9 of the Triode DC Control stage



STAGE CIRCUITS AND DESCRIPTION

INPUT
A 12AX7 is used for each channel input as a low impedance input and voltage amplifier. The input stage has slow AGC gain reduction through the use of a LDR and input resistor forming a variable input pad, the LDR being the shunt leg of the pad.

TRIODE GAIN CONTROL
This stage is used for faster gain control, a single 12AX7 is used with each section controlling a channel.

OUTPUT
Each channel uses a 12AX7 output stage as a voltage amplifier and low impedance output.

AGC AMPLIFIER
Output from the 12AX7 gain control stage is fed to both the output stage and the AGC amplifier stage, the AGC amplifier amplifiers the audio signal to a high level suitable to drive DC control circuits that rectify and filter producing DC gain control voltages.

LDR DC CONTROL
Driven by the AGC amplifier, this stage rectifies and filters a DC control voltage to control the LDR gain reduction.

TRIODE DC CONTROL
Also driven by the AGC amplifier, this stage rectifies and filters a DC control voltage to control the triode gain control stage by varying the 12AX7 grid bias. This stage also drives the gain reduction meter.

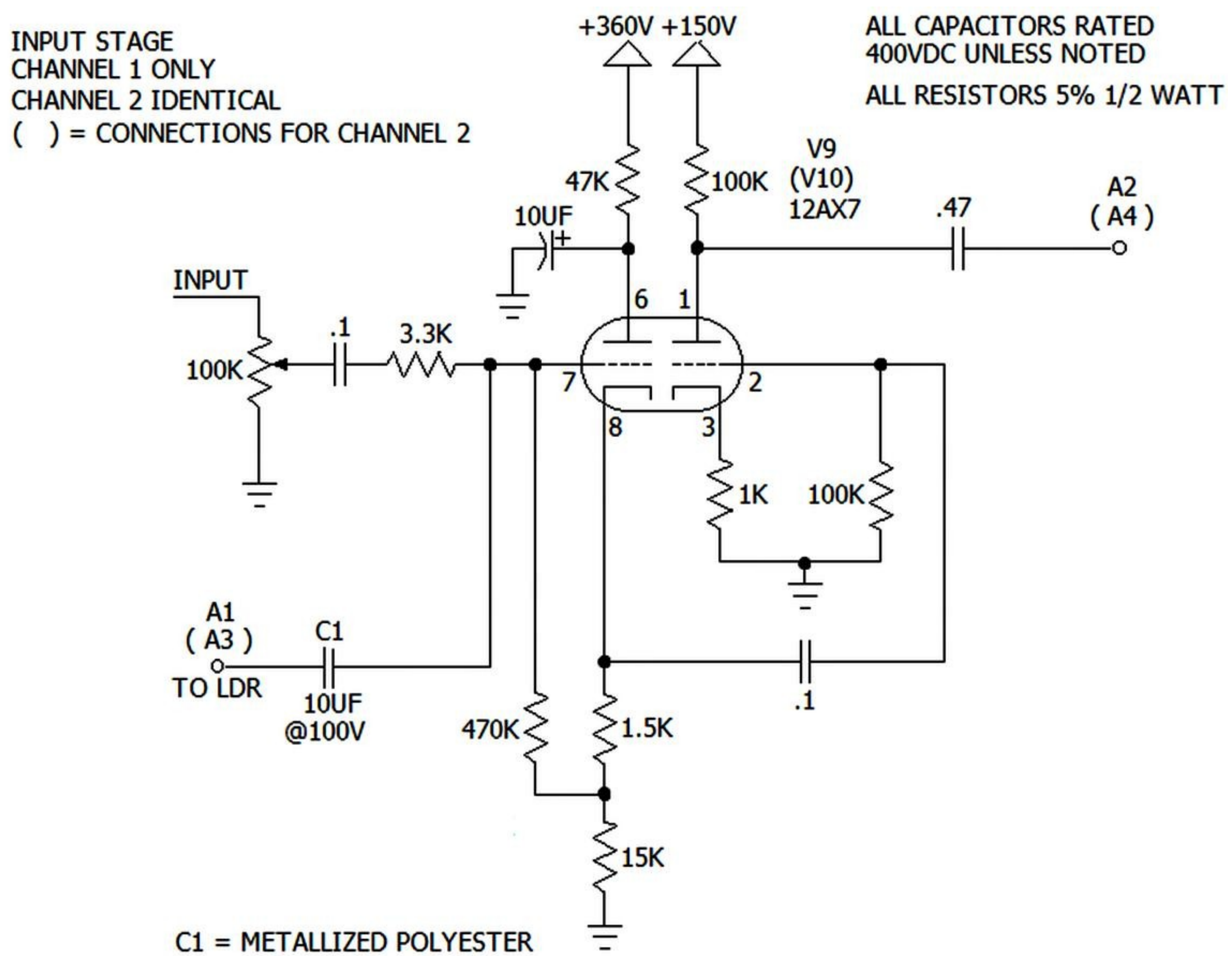
BLOCK DIAGRAM
All of the circuit diagrams have interconnecting point designations; the block diagram shows how all the stages connect together.

INPUT

Figure 2 is the Input stage. The input is a low impedance cathode follower coupled to a voltage amplifier. The input connects to a LDR for input AGC gain control. Capacitor C1 is used to prevent the LDR resistance change from affecting input grid resistance or grid bias of the 12AX7. C1 should be a metallized polyester or similar type capacitor, do not use an electrolytic.

Although the 100K input level adjust potentiometer could be an audio taper, a linear taper pot might be better. Since the input level adjusts the amount of compression drive, using a linear control would make fine adjustments easier.

FIGURE 2



INPUT PARTS LIST

For one channel only, double quantities for two channel stereo

1 – 12AX7
1 – 9 PIN miniature tube socket
1 – 1K ½ WATT resistor carbon composition
1 – 1.5K ½ WATT resistor carbon composition
1 – 3.3K ½ WATT resistor metal film
1 – 15K ½ WATT resistor carbon composition
1 – 47K ½ WATT resistor carbon composition
1 – 100K ½ WATT resistor (plate) carbon composition
1 – 100K ½ WATT resistor (grid) metal film
1 – 470K ½ WATT resistor (grid) metal film
1 – 100K ½ WATT potentiometer linear taper
2 – .1UF 400V capacitor
1 – .47UF 400V capacitor
1 – 10UF 100V capacitor metallized polyester
1 – 10UF 450V capacitor electrolytic

Metal film resistors should be low noise.

TRIODE GAIN CONTROL

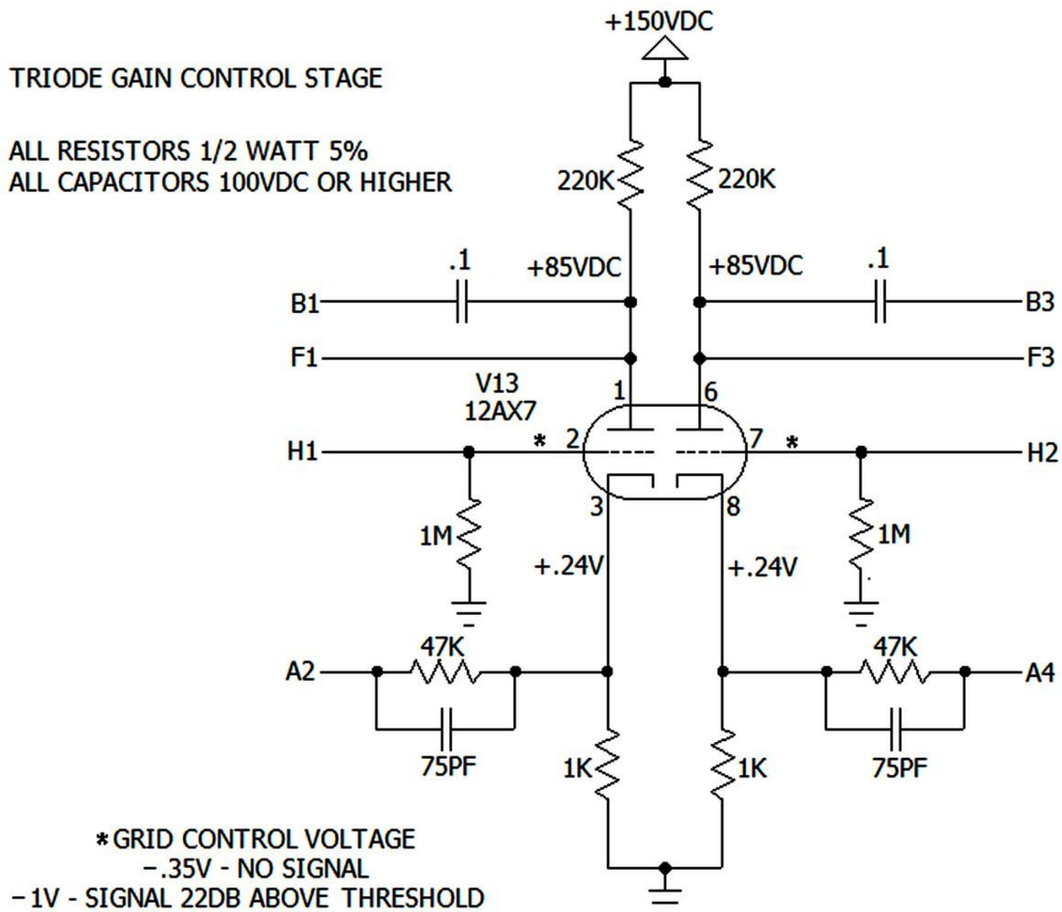
Figure 3 is the Triode Gain Control stage. The output of the input stages connect to A2 and A4. The 1K cathode resistors and 47K input resistors form a L pad reducing the input to the 12AX7 by about 34 DB. The 47K input resistor also increases the input impedance to the cathode reducing the load on the preceding stage. The reduced input level is required to keep the input signal in the linear operating curve of the tube as grid bias varies the tube operating point while controlling gain. The DC grid bias voltage to H1 and H2 is supplied from the Triode DC Control stage.

Outputs F1 and F3 connect to the AGC Amplifier input, outputs B1 and B3 connect to the output stage inputs.

To reduce circuit operation drift the +150VDC supply should be regulated.

Because the input level to this stage is reduced by about 34DB it is more susceptible to filament induced hum pickup. Filaments for this stage are best supplied with a well filtered DC voltage.

FIGURE 3



TRIODE GAIN CONTROL PARTS LIST

1 – 12AX7
1 – 9 pin miniature tube socket
2 – 1K ½ WATT resistor metal film
2 – 47K ½ WATT resistor metal film
2 – 220K ½ WATT resistor carbon composition
2 – 1M ½ WATT resistor metal film
2 – 75PF capacitor mica
2 – .1UF 400V capacitor

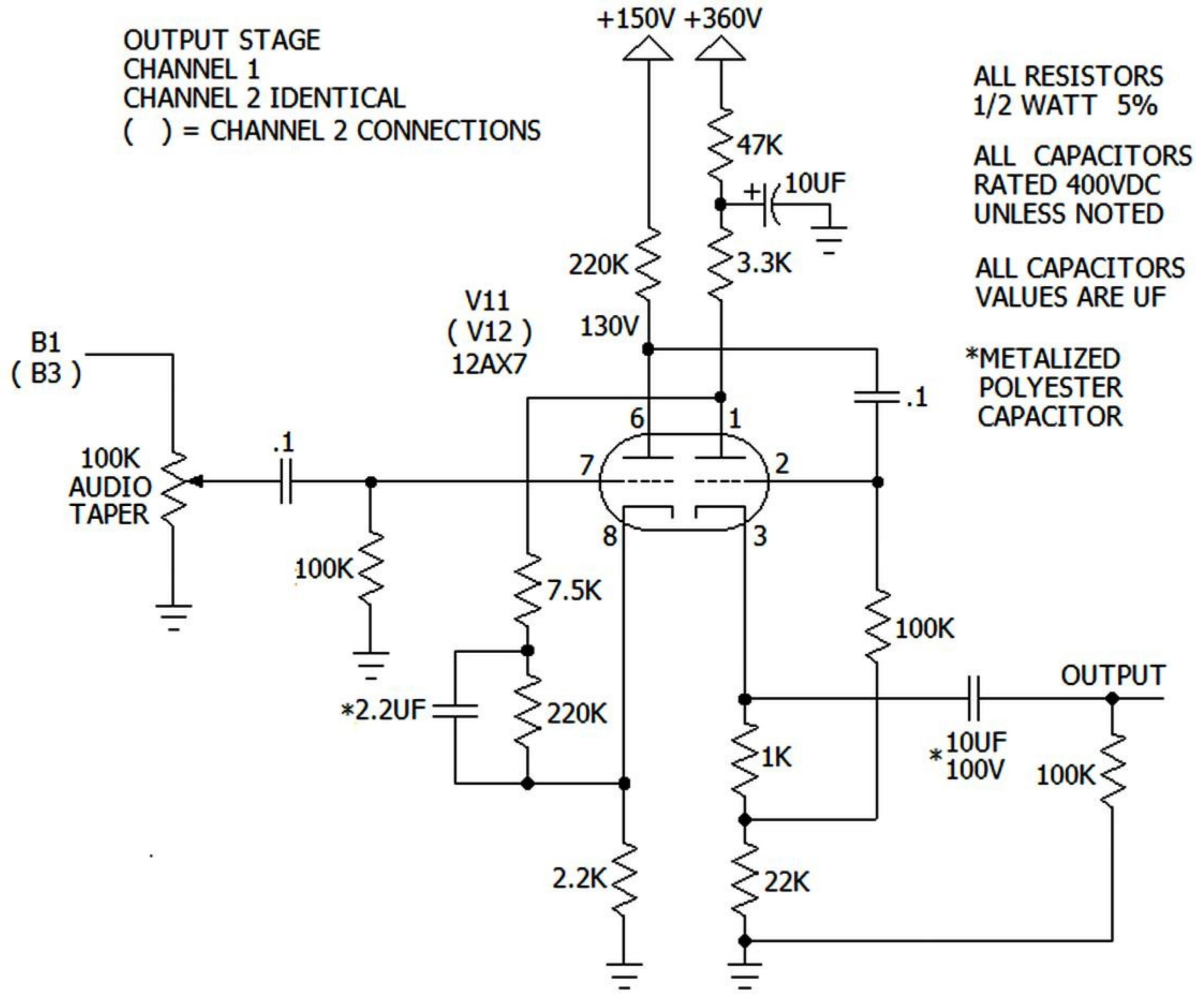
Metal film resistors should be low noise.

OUTPUT

Figure 4 is the Output stage. The output stage consists of a voltage amplifier and cathode follower output. The input point B1 (B3 for channel 2) comes from the Triode Gain Control stage.
The 2.2UF feedback capacitor and 10UF output capacitor should be metallized polyester or similar type capacitors, do not use electrolytic capacitors. The 10UF output capacitor value is large to allow connecting to either high impedance vacuum tube inputs or low impedance solid state equipment without loss of low end response.

The output level is adjusted using the 100K potentiometer.

FIGURE 4



OUTPUT PARTS LIST

For one channel only, double quantities for two channel stereo

1 – 12AX7
1 – 9 PIN miniature tube socket
1 – 1K ½ WATT resistor carbon composition
1 – 2.2K ½ WATT resistor carbon composition
1 – 3.3K ½ WATT resistor carbon composition
1 – 7.5K ½ WATT resistor carbon composition
1 – 22K ½ WATT resistor carbon composition
1 – 47K ½ WATT resistor carbon composition
3 – 100K ½ WATT resistor carbon composition
2 – 220K ½ WATT resistor carbon composition
1 – 100K ½ WATT potentiometer audio taper
2 – .1UF 400V capacitor
1 – 2.2UF 400V capacitor metallized polyester
1 – 10UF 100V capacitor metallized polyester
1 – 10UF 450V capacitor electrolytic

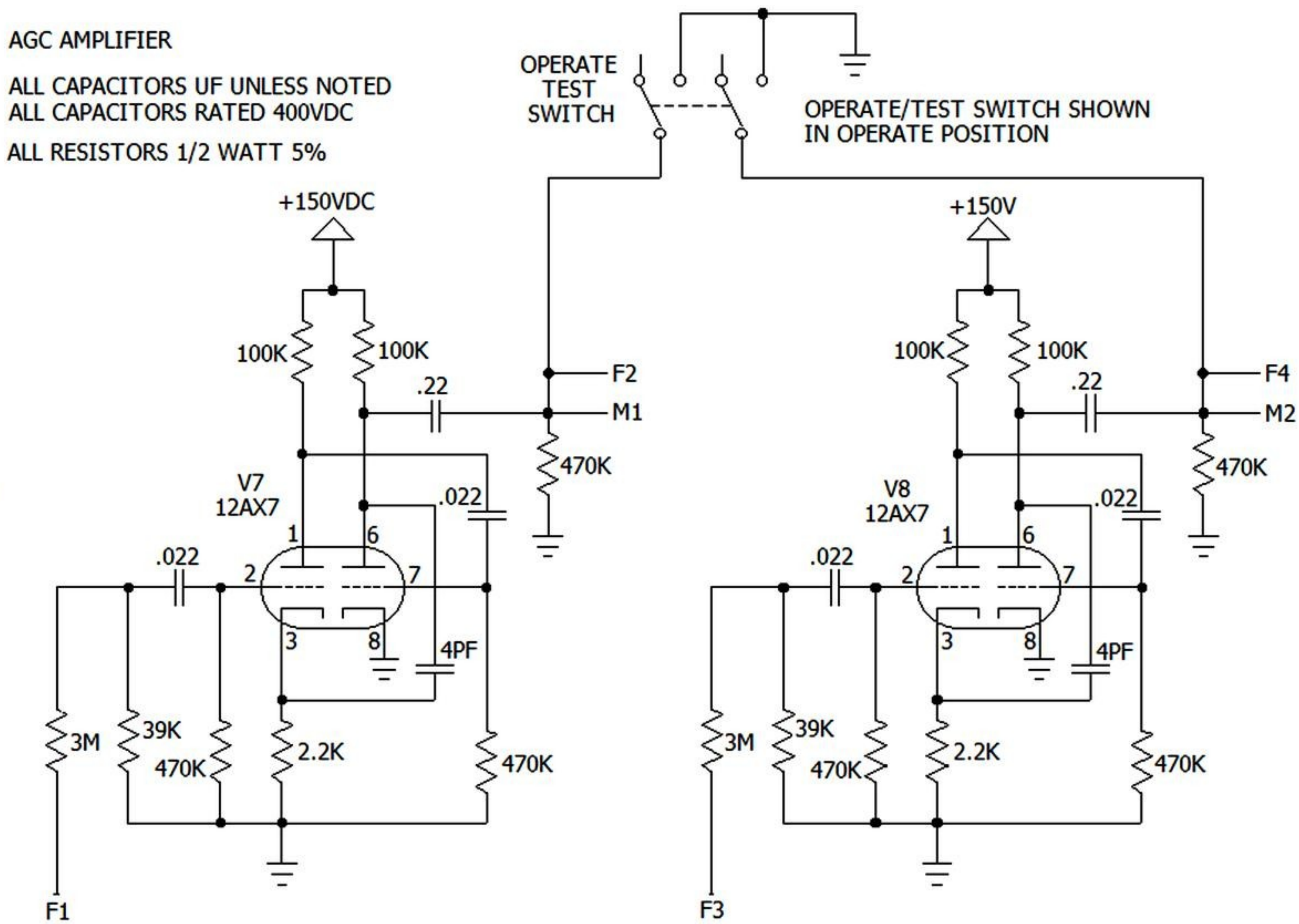
AGC AMPLIFIER

Figure 5 is the AGC Amplifier stage. Inputs F1 and F2 of the 12AX7's connect to the Triode Gain Control stage outputs. The AGC Amplifiers are two stages of voltage amplification used to amplify audio signals high enough to drive the DC Control stages, points M1 and M2 connect to the LDR DC Control stages, F2 and F4 connect to the Triode DC Control stages. The second stage voltage amplifier has a grounded cathode and operates saturated.

The Operate/Test switch grounds the output of both amplifiers when in the test position. Grounding the outputs kills the drive to the DC Control stages and allows the amplifier to operate without any gain reduction.

The 4PF feedback capacitor helps neutralize oscillations that might occur due to the high gain of the stage.

FIGURE 5



AGC AMPLIFIER PARTS LIST

2 – 12AX7
2 – 9 PIN miniature tube socket
2 – 2.2K ½ WATT resistor carbon composition
2 – 39K ½ WATT resistor carbon composition
4 – 100K ½ WATT resistor carbon composition
6 – 470K ½ WATT resistor carbon composition
2 – 3M ½ WATT resistor carbon composition
2 – 4PF capacitor mica
4 – .022UF 400V capacitor
2 – .22UF 400V capacitor
1 – DPDT switch

A carbon film or metal film resistor may be substituted for the 3M resistor depending on availability.

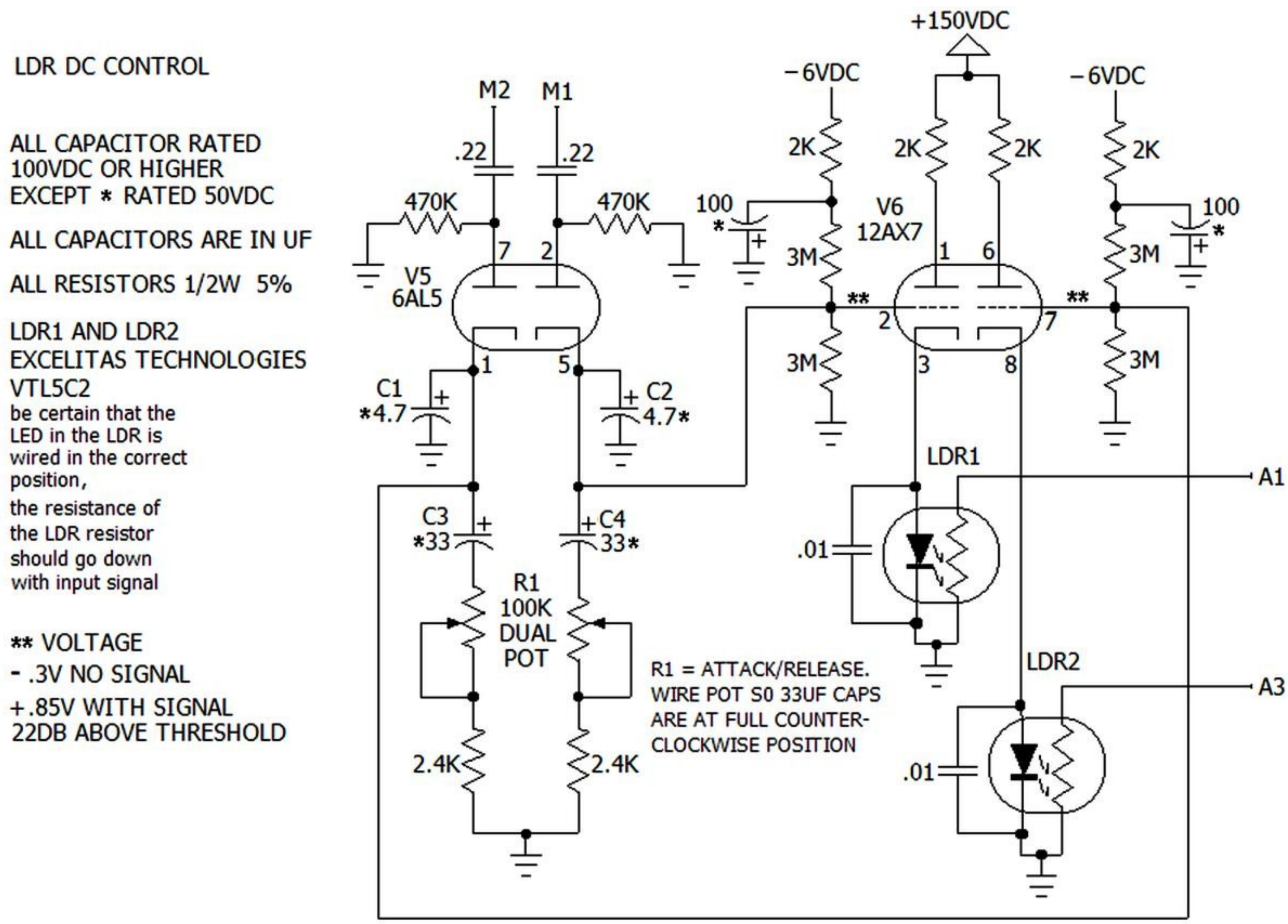
LDR DC CONTROL

Figure 6 is the LDR DC Control stage. The LDR DC Control stage uses a 6AL5 to rectify the amplified AGC audio into DC. C1, C2, C3, and C4 determine the time constant filtering for the LDR gain control action; this design uses an adjustable slow input time constant. The attack/release time is adjustable with R1 allowing some control over the input AGC action.

There is a −6VDC bias voltage applied to the V6 grids, two 3M ohm (3,000,000) resistors set a stable bias voltage at the grids. As the audio level increases into the amplifier, the amplified AGC audio driving the 6AL5 also increases and produces a positive voltage off each cathode. This positive voltage is applied to the V6 grids causing the grids to go more positive and increase current flow in V6.

The LDR LED's are in the cathode circuits of V6, current flow through V6 also flows through the LED in the LDR. As current flows through V6 the LED in each LDR illuminates the photocell resistors inside the LDR and lowers the resistance at points A1 and A3. The lower resistance of the LDR photocell shunts the input to the amplifier input stage reducing gain. The +150VDC supply voltage should be regulated to help reduce AGC drift.

FIGURE 6



LDR DC CONTROL PARTS LIST

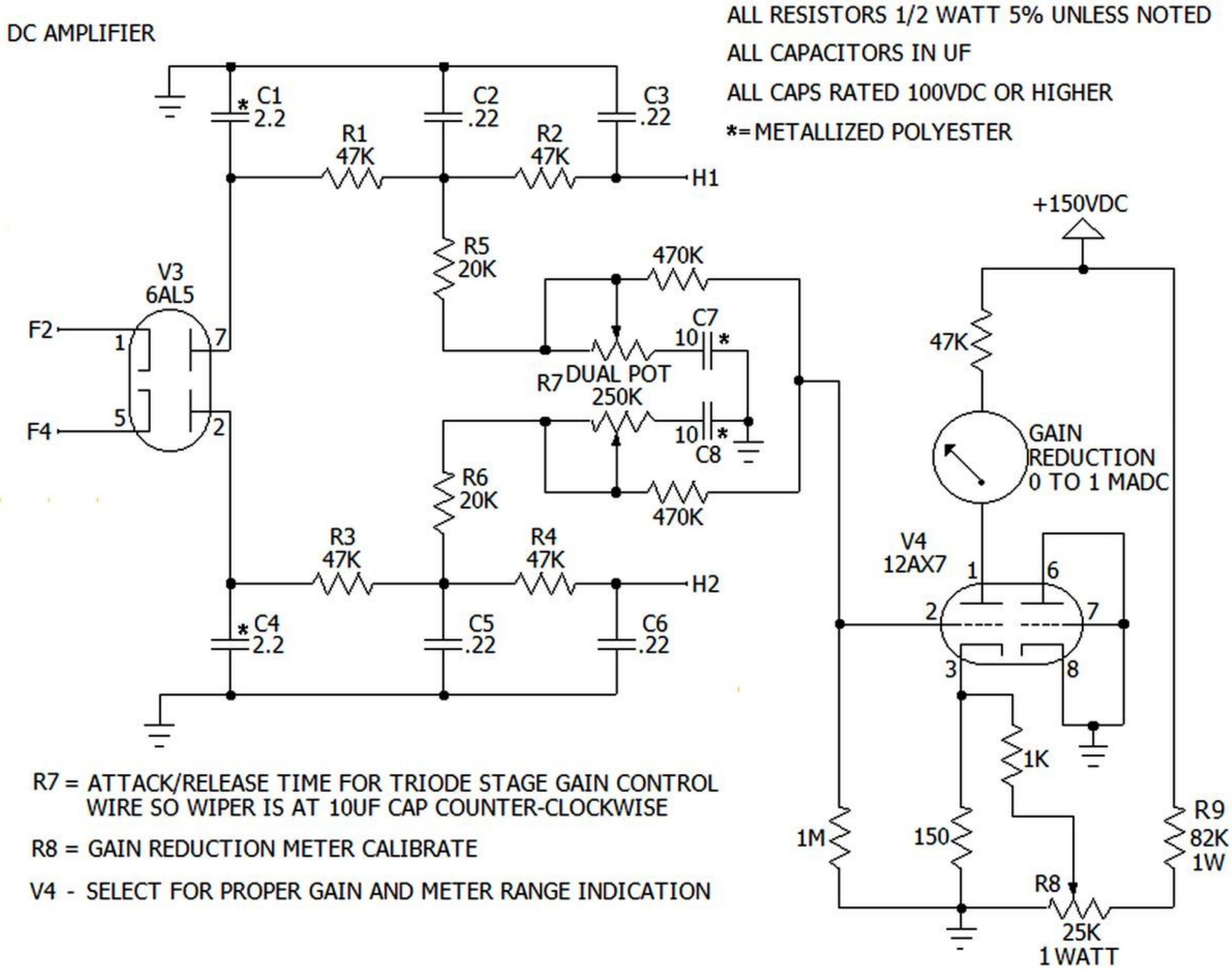
1 – 6AL5
1 – 7 PIN miniature tube socket
1 – 12AX7
1 – 9 PIN miniature tube socket
4 – 2K ½ WATT resistor carbon composition
2 – 2.4K ½ WATT resistor carbon composition
2 – 470K ½ WATT resistor carbon composition
4 – 3M ½ WATT resistor carbon composition
1 – 100K dual potentiometer linear taper
2 – .01UF 400V capacitor
2 – .22UF 400V capacitor
2 – 4.7UF 50V capacitor electrolytic
2 – 33UF 50V capacitor electrolytic
2 – 100UF 50V capacitor electrolytic
2 – LDR VTL5C2 Excelitas Technologies

TRIODE DC CONTROL

Figure 7 is the Triode DC Control stage. The Triode DC Control stage uses a 6AL5 to rectify the amplified AGC audio into DC. C1, C2, C3, C4, C5, C6, R1, R2, R3, and R4 determine the time constant filtering for the fast AGC gain control action. C7, C8, R5, R6 and R7 form an adjustable slow AGC DC reference time constant. This design uses a fast AGC action riding a slower AGC action, the slow AGC DC reference attack/release time is adjustable with R7 allowing control of the fast to slow AGC ratio.

The purpose of having a fast AGC riding a slow AGC is to reduce pumping of the audio, the slower AGC reference keeps the gain in an average level range while the faster AGC is processing.
The AGC metering DC control voltage is sampled through two 470K resistors, one for each channel, the sample drives V4 and the gain reduction meter. Also, the two 470K resistors link both channel AGC control voltages to keep the channels tracking together sufficiently to preserve channel imaging.

FIGURE 7



TRIODE DC CONTROL PARTS LIST

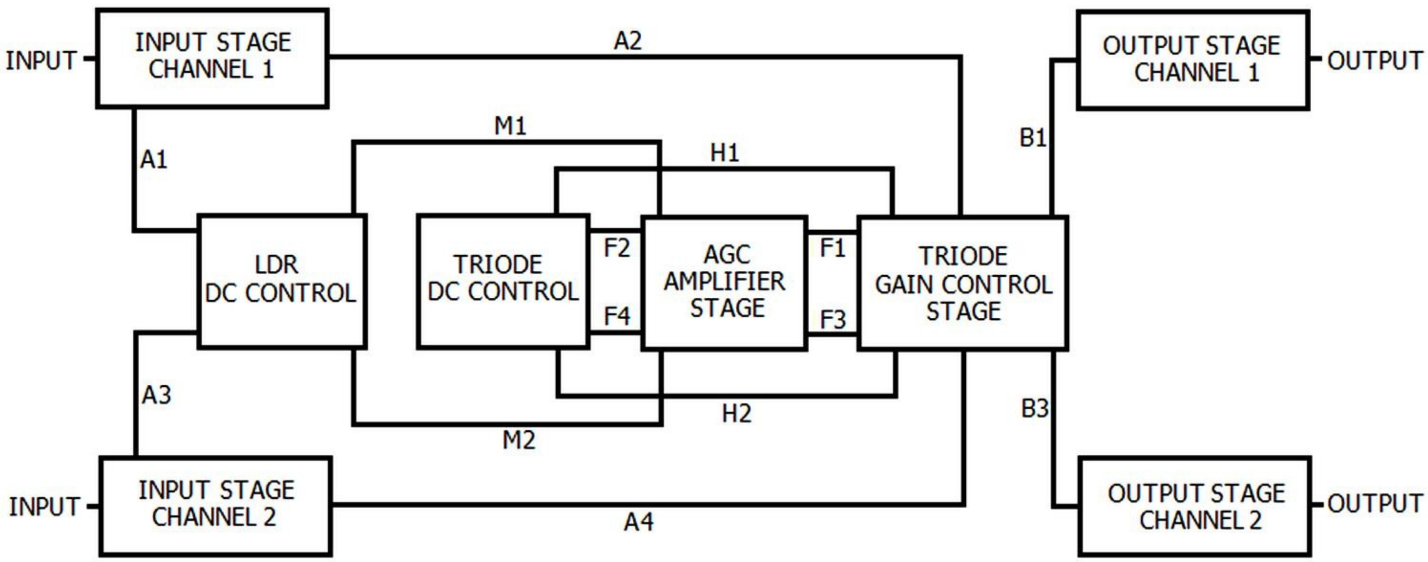
1 – 6AL5
1 – 7 PIN miniature tube socket
1 – 12AX7
1 – 9 PIN miniature tube socket
1 – 150 ½ WATT resistor carbon composition
1 – 1K ½ WATT resistor carbon composition
2 – 20K ½ WATT resistor carbon composition
5 – 47K ½ WATT resistor carbon composition
1 – 82K 1 or 2 WATT resistor metal film
2 – 470K ½ WATT resistor carbon composition
1 – 1M ½ WATT resistor carbon composition
1 – 25K 1 or 2 WATT potentiometer linear taper
1 – 250K ½ WATT dual potentiometer linear taper
4 – .22UF 100V capacitor
2 – 2.2UF 100V capacitor metallized polyester
2 – 10UF 100V capacitor metallized polyester

BLOCK DIAGRAM

Figure 8 is a block diagram of how everything connects together. All of the interconnecting line designations match the same designations on the circuit diagrams.

FIGURE 8

ALL TRIODE PROCESSOR BLOCK DIAGRAM



POWER SUPPLY

Supply loads,

AC FILAMENT SUPPLY = 6.3V @ 3.0 AMPS
DC FILAMENT SUPPLY = 6.3V @ .3 AMPS
+150VDC REGULATED @ 14MA
+360VDC UNREGULATED @ 18MA
LDR DC CONTROL BIAS = −6VDC @ .01MA

The regulated +150VDC voltage can be tapped off the 360VDC supply so then you would need a high voltage winding rated at least 32MA. The DC filament voltage is for the gain controlled triode stage filaments (V13).

Figure 9 is a power supply circuit. The specified EDCOR transformer high voltage winding is rated at 500VCT instead of 520VCT as shown on the circuit drawing. However, the transformer high voltage winding is rated at 130MA and since the actual load will be only 32MA the lightly loaded transformer winding will actually be higher closer to 520VCT.

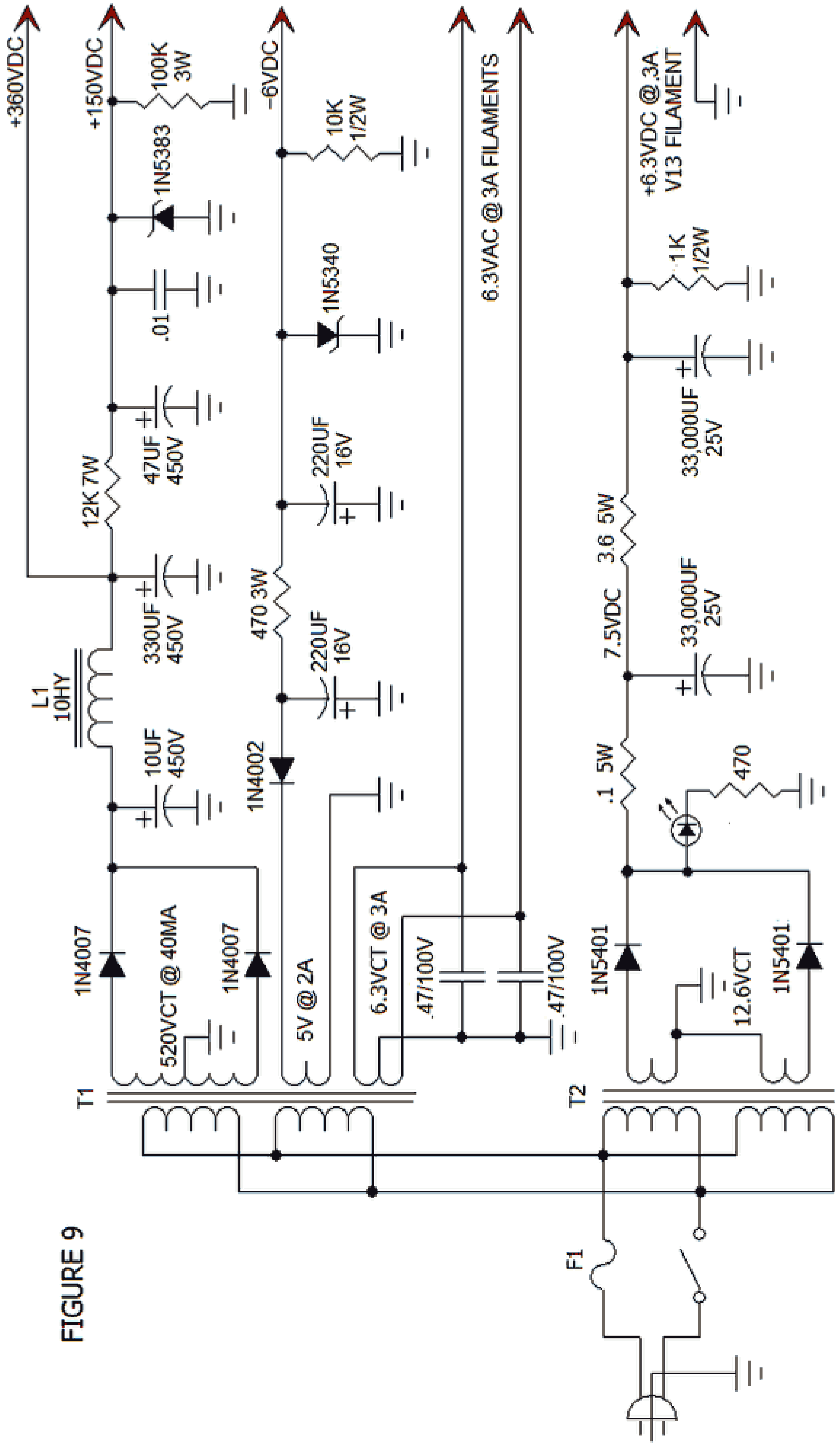
Tapped off the 360VDC supply voltage, a current limiting 12K ohm 7 watt resistor and a 1N5383 zener diode provide the regulated 150VDC supply.

The 5V filament winding is used for the −6VDC bias supply; the supply is regulated using a 470 ohm current limiting resistor and a 1N5340 zener diode.

The 6.3VCT filament winding is rated at the exact AC filament load of 3 AMPS. The 6.3VDC .3AMP filament supply is for V13 filament only.

The primaries of both power transformers specified can be wired for either 115/120 or 230/240 AC primary voltage. Figure 9 shows the primaries wires for 115/120 operation.
The value of the F1 primary fuse depends on the primary voltage. For 115/120V operation a 1 AMP slow-blow delayed type fuse should be sufficient. For 230/240V operation use a ½ AMP slow-blow delayed type fuse.

FIGURE 9



+360VDC
+150VDC
100K
3W
1N5383
.01
47UF
450V
12K 7W
330UF
450V
L1
10HY
10UF
450V
1N4007
520VCT @ 40MA
1N4007
T1
-6VDC
10K
1/2W
1N5340
220UF
16V
470 3W
220UF
16V
1N4002
5V @ 2A
6.3VCT @ 3A
.47/100V
.47/100V
6.3VAC @ 3A FILAMENTS
+6.3VDC @ .3A
V13 FILAMENT
1K
1/2W
33,000UF
25V
3.6 5W
7.5VDC
33,000UF
25V
.1 5W
470
1N5401
12.6VCT
1N5401
T2
F1

POWER SUPPLY PARTS LISTS

1 – T1 EDCOR XPWR221-120/240
1 – T2 TRIAD VPL12-800, secondary wired as 12.6VCT
1 – L1 TRIAD C-7X CHOKE 10HY @ 90MA
1 – AC cord or inlet connector for removable AC cord
1 – Fuse holder and fuse
1 – Power switch
2 – 1N4007 high voltage rectifier
1 – 1N4002 low voltage bias rectifier
2 – 1N5401 low voltage filament DC rectifier
1 – LED rated 20 – 30MA current
1 – 1N5340 6V zener
1 – 1N5383 150V zener
1 – .1 ohm 5 WATT resistor wirewound
1 – 3.6 ohm 5 WATT resistor wirewound
1 = 470 ½ WATT resistor carbon composition
1 – 470 3 WATT resistor metal film
1 – 1K ½ WATT resistor carbon composition
1 – 10K ½ WATT resistor carbon composition
1 – 12K 7 WATT resistor wirewound
1 – 12K 3 WATT resistor metal film
1 – .01UF 1000V capacitor ceramic disc
2 – .47UF 100V capacitor ceramic
1 – 10UF 450V capacitor electrolytic
1 – 47UF 450V capacitor electrolytic
2 – 220UF 16V capacitor electrolytic
1 – 330UF 450V capacitor electrolytic
2 – 33,000UF 25V capacitor electrolytic

CONSTRUCTION NOTES

Use a chassis large enough so that parts are spaced out neatly and not crammed together. The original prototype amplifier used a chassis 17 inch wide by 10 inches deep and was pretty well filled up. Chassis depth can be either 2 or 3 inches. Be sure to use a bottom panel on the chassis for shielding.

Resistors 5 watt or higher should be wirewound type. Resistors used in tube circuits, plate, grid, or cathode, should be 5% tolerance or better.
Metal Oxide resistors may be used in place of metal film resistors depending on the availability of values. Carbon composition resistors can be replaced with Metal Oxide resistors.

T2 and L1 are small enough they could mount inside the chassis if desired.

The +150VDC and −6VDC bias supply voltages need to be close to value. The +360VDC and filament voltages can be up to 5% off value.

The .01UF capacitor in the +150VDC supply is a high frequency noise bypass and should be a ceramic type capacitor.

The two .47UF @ 100V capacitors on the 6.3VAC filament supply are also noise bypass caps and should be ceramic type capacitors.

The 330UF @ 450V high voltage filter capacitor and the two 33,000UF @ 25V filament DC supply filter capacitors can be mounted on the top side of the chassis if 35MM diameter snap-in terminal type capacitors are used. A Cornell Dubilier VR3A mounting clamp will fit around 35MM diameter capacitors.

A 19 inch wide rack panel can used for a front panel, make sure you use a front panel high enough so components on the chassis will clear going into a cabinet.

Although an OA2 regulator tube could have been used instead of the 1N5383 zener diode, regulator tubes may become hard to find.

1MA DC METER

When marking off the meter face input/output compression ratio points while feeding in tones, you need to feed tone into both channels. This is important as the meter does not indicate properly if signal is fed only into one channel. Under normal operation there is audio present on both channels and you get an accurate indication of average gain reduction. Usually moments are brief when audio is on one channel only.

When calibrating the meter face, use a 1000HZ tone. There is no need to check the calibration at different frequencies; the gain reduction indication is just an average.

VU METER

Although DC current meters are readily available you may decide you want to use a VU meter for indicating gain reduction. There are a number of low cost VU meters available from China with reasonable shipping cost. Since a VU meter only gives you an approximate indication of gain reduction there is no need to do any calibrating by feeding tones. The only concern is being able to set the VU meter to 0 with no input using R8 in the Triode DC Control stage. If R8 is out of range such that you cannot set the meter to 0, then you need to adjust the value of R9.

MODIFICATIONS

As a project builder you are free to make circuit modifications. It may be wise to first try the time constant capacitor and resistor values used in the figure 6 LDR DC Control and figure 7 DC Amplifier circuits.