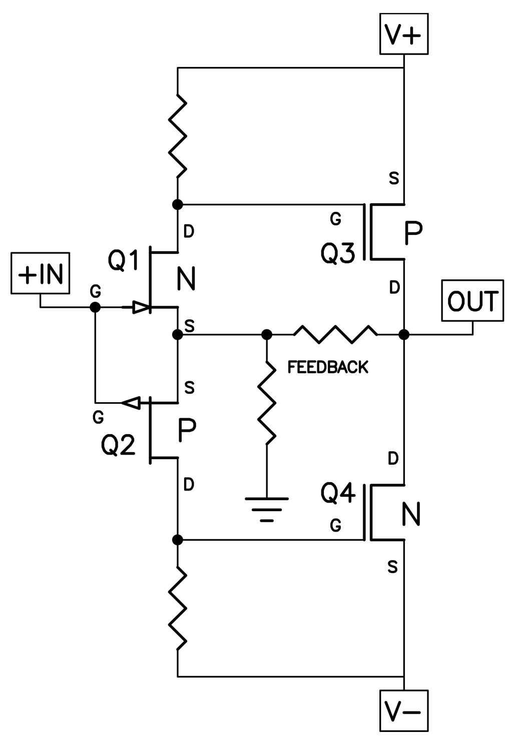
The DIY ACA mini Amplifier

by Nelson Pass

The first amp camp goes back almost ten years when a small group of people held the first and only event in Sebastopol California. I had the privilege of designing this little class A amplifier which has proven to be popular among audio DIYers and is currently available in the "store" at www.diyAudio.com. Over the years it has acquired a nice chassis and some minor improvements.

Another Amp Camp was planned but then delayed waiting for Covid to bugger off, but finally the organizers of the Burning Amp Festival decided to go online with it, and once again I have had the pleasure of doing the design, something a little different. My goal was to make a nice little class A amplifier that brings some interesting circuit design elements but at a much lower cost, while still appealing to more *sophisticated audiophiles*.

Here is the simplified schematic of the ACA mini:

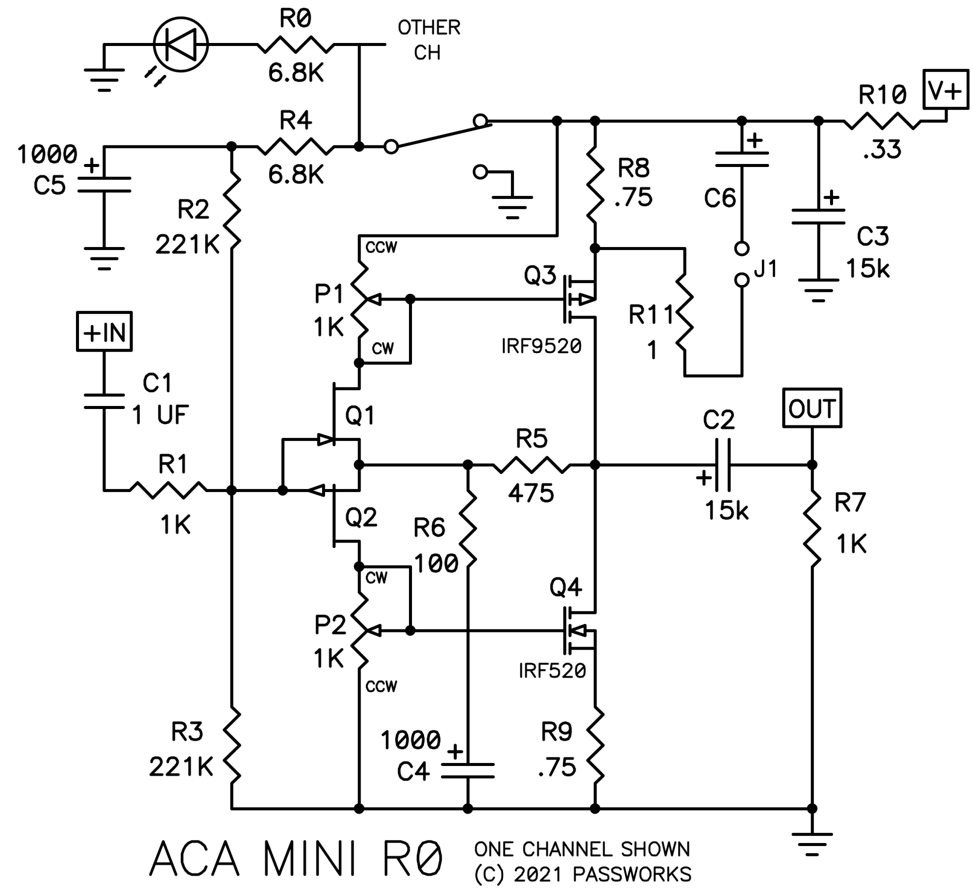


This would be described as a Class A two-stage complementary push-pull amplifier using Jfet input transistors (Q1, Q2) and Mosfet output transistors (Q3, Q4) operated in Common-Source mode. It uses a current feedback loop (CFA). The input transistors are undegenerated push-pull and the output transistors are degenerated via Source resistors.

Some will note the resemblance to the First Watt F7 and F5 amplifiers, but the basic circuit previously appeared in Plantefeve's Selectronics amplifier and probably earlier.

In this case there is an interesting twist that we will discuss later.

Here is the full schematic, showing one channel.



At the top, the switch, resistor R0 and the display LED occur only once and other parts are duplicated for the two channels on the circuit board, segregated as Left and Right.

This amplifier runs off a single supply, and is necessarily coupled at the input and output through capacitors C1 and C2. The feedback resistors R5 and R6 are also capacitively coupled to ground through C4. Resistors R2 and R3 provide a reference voltage that the amplifier output will settle into, slightly lower than halfway between Ground and the 24 V positive supply.

Resistors P1 and P2 are potentiometers that will be adjusted to set the idle current of the output Mosfets at about 0.4 Amps, which is about 5 watts dissipation for each output device.

Because the transistors will drift with temperature, we add resistors R8 and R9 to the Source pins of the output stage Mosfets. Known as degenerating resistors, they make the two devices more matched and provide ballast to stabilize the bias current.

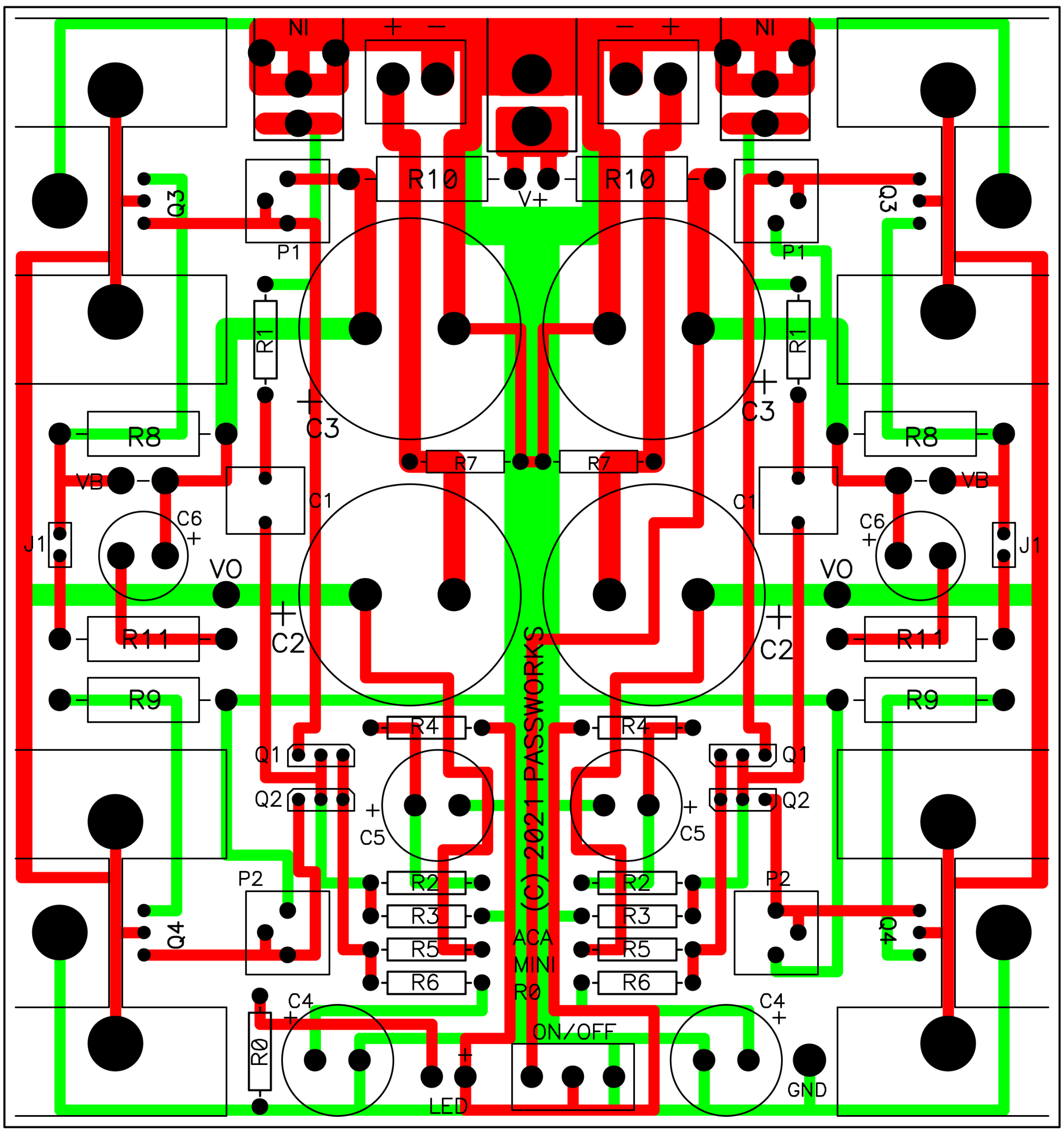
The amplifier will be powered by an external “desktop” switching supply at 24 volts. R10 and C3 are power supply filters that clean up the high frequency AC noise from the voltage seen at the positive supply rail. R4 and C5 are also power supply filters as well as a timing mechanism for slow turn-on and turn-off, avoiding thumps visited upon the loudspeaker.

R7 at the output is a “bleed” resistor so that there are no thump surprises if you connect a loudspeaker to an already running amplifier. You will see the power switch which puts the amplifier in a stand-by mode where the bias current is shut down so as to not waste power.

As you will see later from the pictures, the amplifier sits on a single circuit board roughly 5 by 5 inches which holds all the components except the external desktop switching supply. Everything is arranged as left and right, including channel parts and connectors. There are four board-mounted vertical heat sinks for the output transistors and capacitors for separate supply filters for each channel.

The amplifier can be operated as a stand-alone or can be mounted in a chassis.

Here is the artwork for the pc board, showing red as the top layer and green as the bottom.

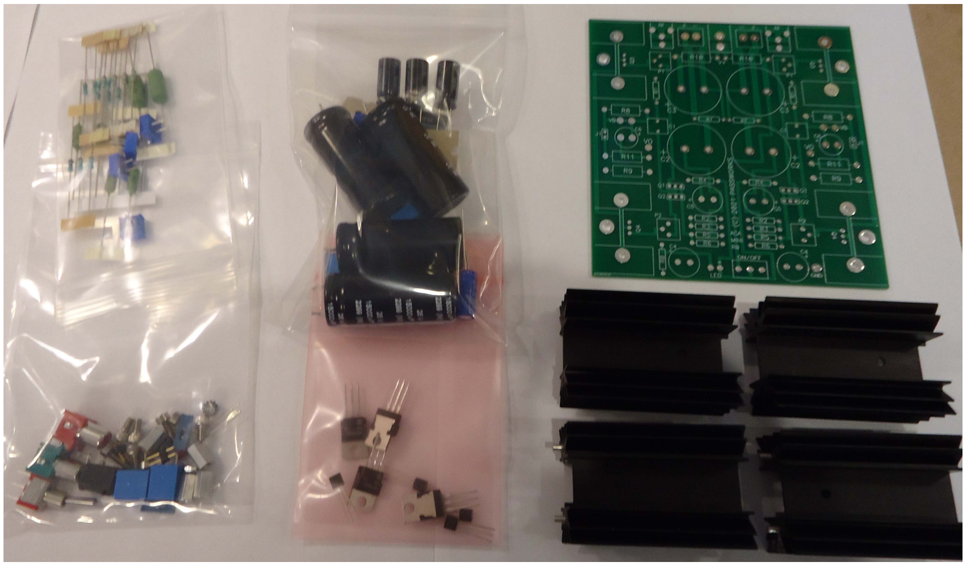


And here is the Bill of Materials:

ACA MINI R0 BILL OF MATERIALS 10/23/21

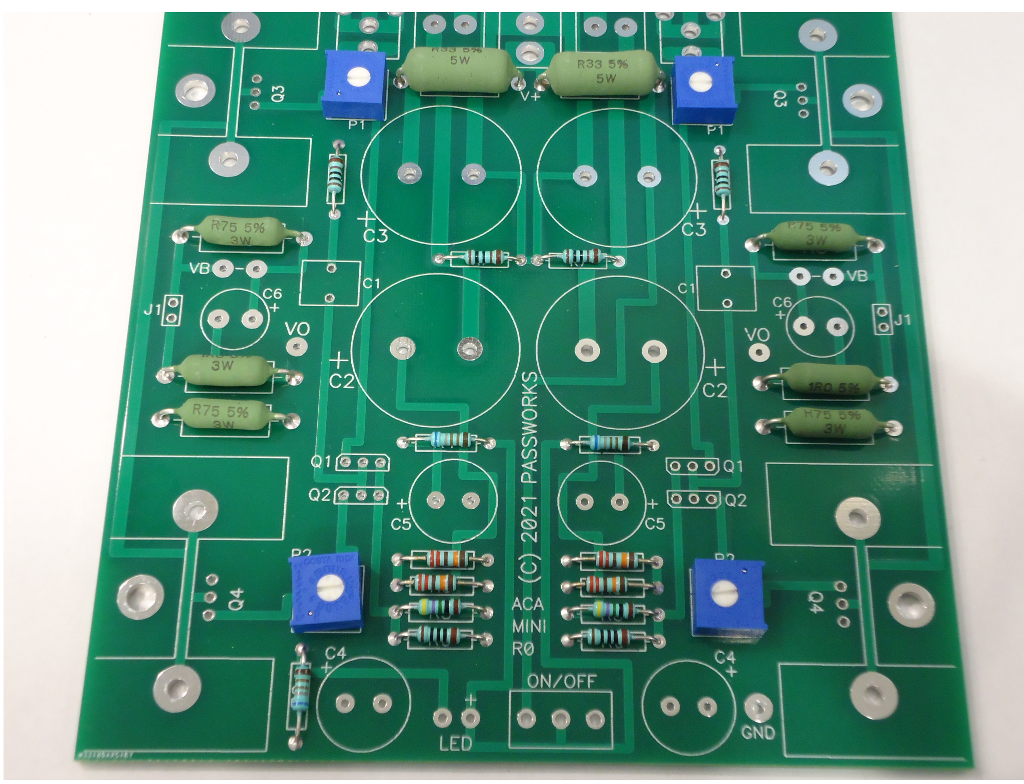
REFERENCE	QTY	ITEM	SOURCE	PART #
PC BOARD	1	2 CHANNEL PC BOARD		
R1, R7	4	1K	DIGIKEY	PPC1.00KYCT-ND
R2, R3	4	221K	DIGIKEY	PPC221KYCT-ND
R0, R4	3	6.8K	DIGIKEY	PPC6.81KYCT-ND
R5	2	475	DIGIKEY	PPC475YCT-ND
R6	2	100	DIGIKEY	PPC100YCT-ND
R8, R9	4	0.75 OHM 3W	DIGIKEY	PPC3W.75TB-ND
R10	2	0.33 OHM 3W	DIGIKEY	PPC3W.33CT-ND
R11	2	1.0 OHM 3W	DIGIKEY	PPC3W1.0TB-ND
P1, P2	4	1000 OHM PC MOUNT POT	DIGIKEY	3386P-102LF-ND
Q1	2	LSK170 JFET	LS	
Q2	2	LSJ74 JFET	LS	
Q3	2	IRF9520 (HARRIS)		
Q4	2	IRF520 (HARRIS)		
C1	2	1 UF FILM CAP - WIMA	MOUSER	505-MKS21/100/5
C2, C3	4	15K UF ELECTROLYTIC	DIGIKEY	495-77174-ND
C4, C5	3	1000 UF 25V ELECT	DIGIKEY	493-5913-1-ND
C6	2	3.3F 2.7V SUPERCAP	MOUSER	581-SCCR20B335PRBLE
INPUT CONN L	1	RCA INPUT PC MOUNT GRN	DIGIKEY	CP-1423-ND
INPUT CONN R	1	RCA INPUT PC MOUNT RED	DIGIKEY	CP-1419-ND
POWER CONN	1	PWR JACK 2.5X5.5MM	DIGIKEY	CP-037B-ND
OUTPUT CONN	2	TERM BLOCK 5MM 2 POS	DIGIKEY	ED-1609-ND
SWITCH	1	SPDT SWITCH	DIGIKEY	EG2355-ND
LED	1	LED	DIGIKEY	1080-1063-ND
SCREW #3 M	4	M3X8 SOCKET HEAD		
NUT #3 M	4	M3 KEPNUT		
SCREW 6-32	4	6-32 X 0.25”		
SPACER 6-32	4	6-32 X 0.5”		
HEAT SINK	4	AAVID TO-220 BOARD MNT	DIGIKEY	HS380-ND
POWER SUPP	1	MEANWELL GSM90B24-P1M	DIGIKEY	
PS CORD	1			

The kit arrives looking like this, plus the power supply and cord:

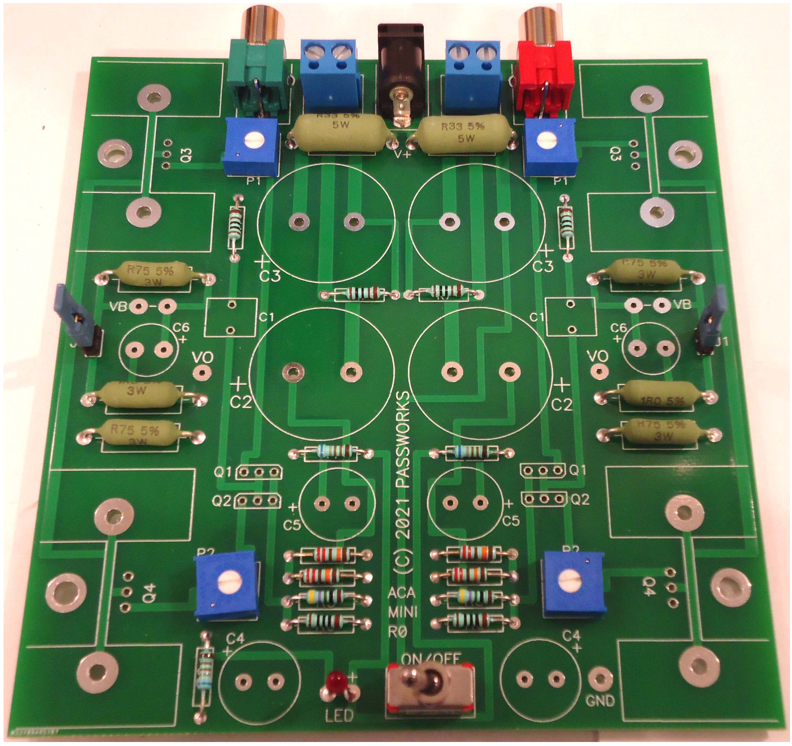


I suggest that you count out the parts, confirming that they match the BOM before you start.

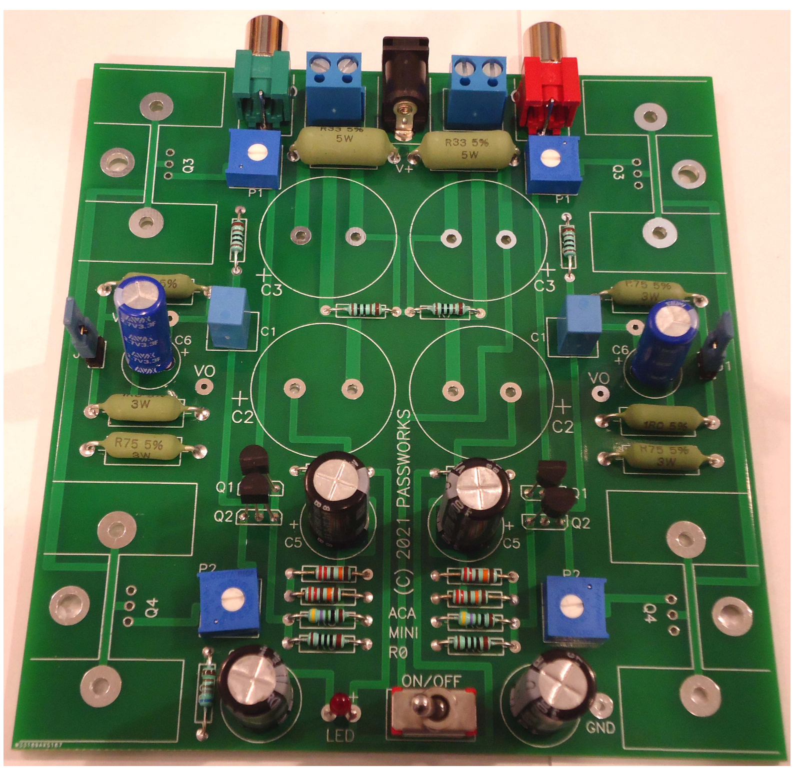
I further suggest that assembly starts with the resistors - first all the small 0.4 watt resistors mounted and soldered, then the larger resistors and the potentiometers. I recommend that you use a digital multimeter to check the resistance values of each before mounting, as the color codes on these can be confusing.



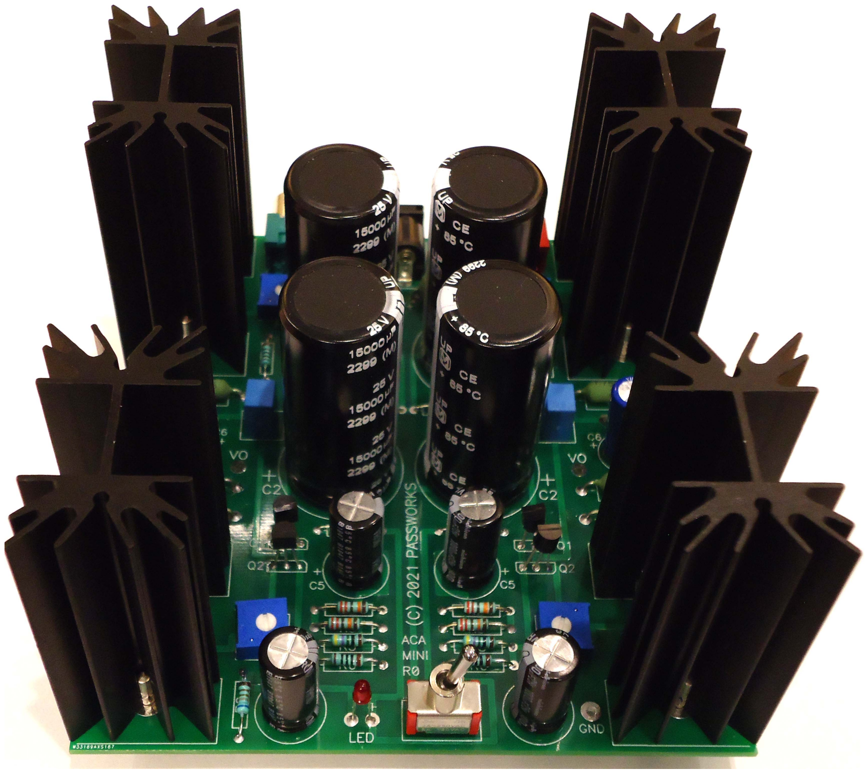
Next comes the connectors. You will note the jumpers on each side with the two longer pc pins joined to the blue shorting connector. The long lead on the LED is +

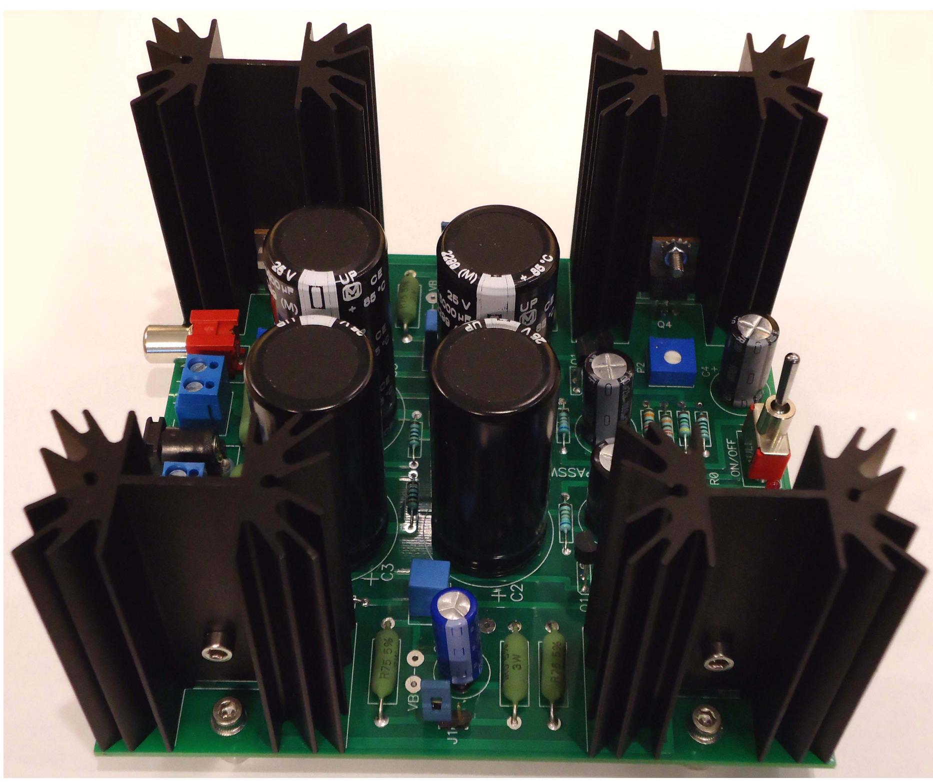


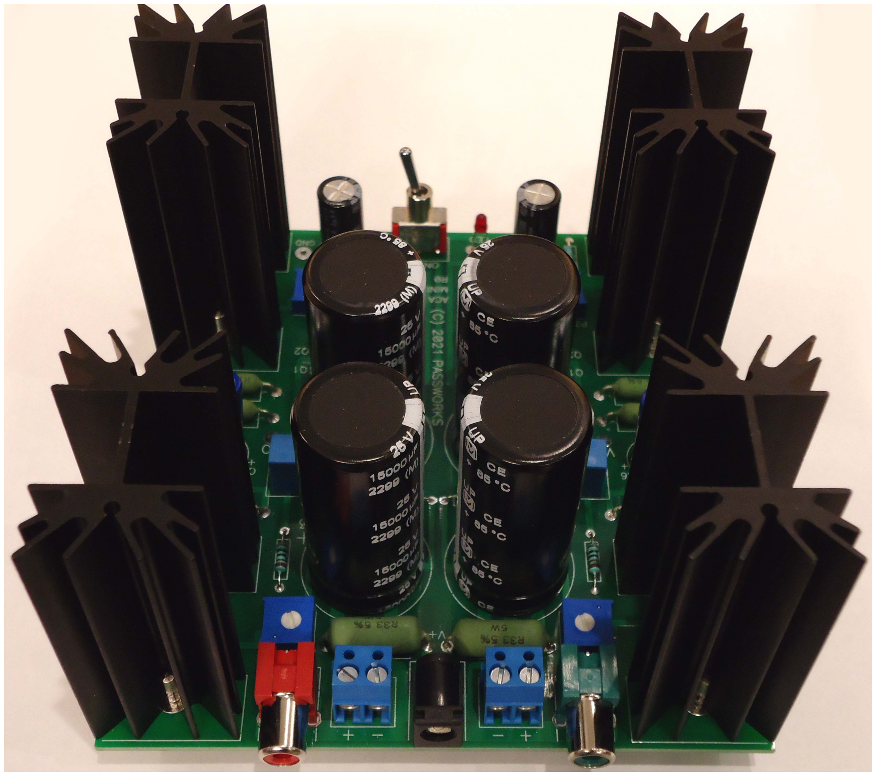
And below we have mounted up the small capacitors. Make note of the polarities, as it is easy to put them in backward.

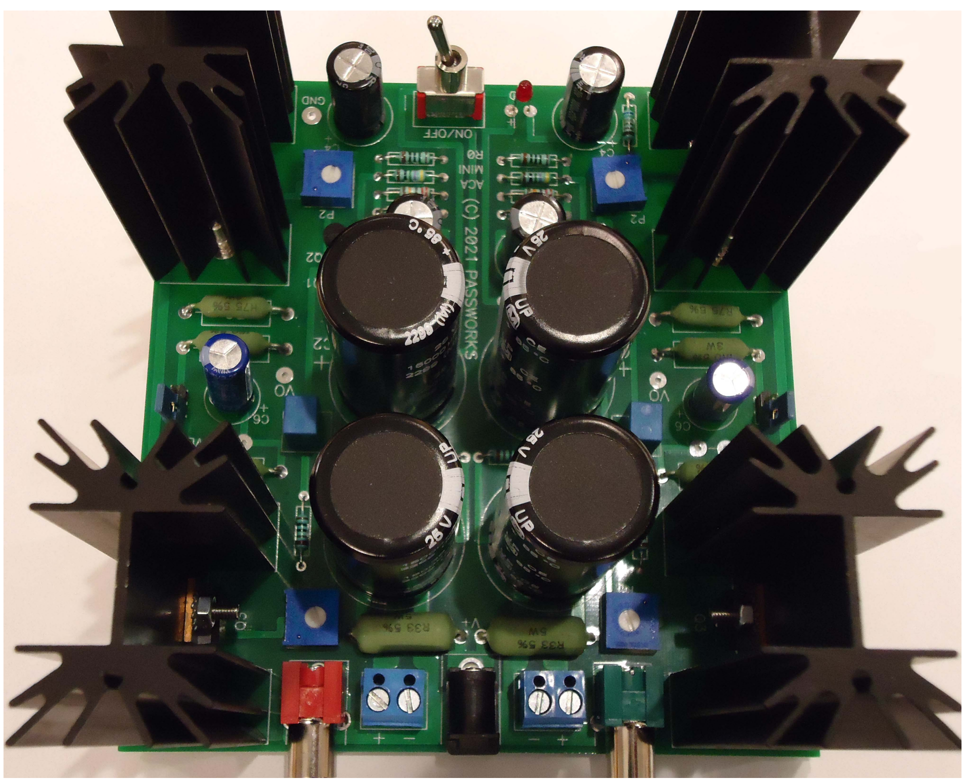


Pictures are cheap, so here are some more to assist you in assembly:






(C) 2021 PASSWORKS


ON/OFF
(C) 2021 PASSWORKS

Now let's talk about the other element in the design.

The most astute will have noticed in the schematic that there is an R11 in series with C6 and a jumper, all these in parallel with R8, the degenerating resistor for Q3.

As always, there is a story. When I evaluated the original prototypes I noticed that the amplifier has a strong “negative phase 2nd harmonic” character. Personally, I like this in my little amplifiers, as it has a charming single-ended tube-like character (although some SE tube amplifiers don't have it) that seems to go with efficient speakers played at reasonably low levels, particularly speakers of the full-range variety.

This effect is obviously an illusion, but then this is entertainment, not dialysis.

Nevertheless, it is interesting to check out the variations that can be had in a simple circuit.

We note that this 2nd harmonic character is the mostly result of the differences between Q3 and Q4, where the P channel Mosfet on top has lower gain than the N channel. That's fine if you like your negative-phase second, but maybe not so much if, like many audiophiles, you prefer lower distortion.

However, this is adjustable by varying the degeneration on the output devices. Slightly lowering the resistance on Q3 will raise the gain, improving the balanced between Q3 and Q4 and lowering the amount of 2nd harmonic. You could do this by simply using a lower value resistor, but we find that this results in greater bias drift with temperature.

However, you can parallel R8 with an RC network consisting of a power resistor in series with a capacitor to get the same effect for AC, leaving the DC character alone. Typical values for the resistor would be from zero to several ohms. In the case of this circuit, it works out that something from about .75 ohms to 1.5 ohms does the trick.

That leaves the decision as to the C value. We want the effect to operate down to below the lowest frequency of interest, maybe something like 10 Hz. For a 1 ohm resistor we would need something like 16,000 uF. A quick look a the offerings at Digikey and Mouser reveals that they start at around $3.

How about Super Capacitors? **3.3 Farads for 60 cents!** The RC time constant on these is come out to about .05 Hz. Looks good, sez I, but what's wrong with them?

After testing some, I came to the conclusion that for this purpose, nothing wrong at all, and so this kit comes with 3.3 F / 1 ohm degeneration. You can plug and unplug the jumper while the amp is running and observe the difference. Certainly you can substitute other resistance values in instead of 1 ohm, no problem if you own a soldering iron (and we have already established that you do).

Another item, the choice of power supply. The Meanwell supplies in the kit are quiet, they charge the big supply filter caps well, and they are isolated from AC ground, so no ground loops. You can use anything else you like, however I recommend that you keep the voltage to the 24 volt figure - many of the parts here are rated at 25 volts, which is fine as they are not worked hard, but exceeding that is not a good idea.

Lastly, you will have noticed that there is no chassis provided with this kit. This is where you are on your own. Beyond the aesthetic considerations, a chassis provides additional hazard safety. 24 volts is not a lot, and the heat sinks on top are at 12V, but you still would not want these exposed to toddlers or small animals.

Also there is a certain amount of heat coming off the fins on the sinks - at 5 watts each, the temperature rise is about 25 deg C. (5 deg C per watt), which is plenty warm but not dangerous. However, this is in open air, so your enclosure wants to be well ventilated, so you want a chassis which balances these considerations.

Some of you will just let it sit on the shelf without a chassis, which you can do, given that the connectors are all on the pc board. If you take that approach, then do so with some caution.

Looking at the project pictures posted on-line at diyAudio, I am confident you will find the creatively appropriate solution.

Construction Notes

This is a pretty straightforward deal, with a few details.

Before you solder anything:

Make sure the input jacks are fully snapped down into the board top.

Double check the polarity of all caps.

Double check the numbers on the transistors.

All transistors in the kit with the same numbers on them are matched, no worries.

As we did not end up with the complete quantity of Linear Systems Jfets in the desired matches, we substituted the same Toshiba matched parts in some of the kits. Don't worry, they are fine.

And the output devices are the Harris versions of the IRF520 and IRF9520.

The heat sinks expect to be soldered to the pc board. Don't worry, this does not require a big soldering iron, just a little patience.

Save installation of the transistors for last. The TO-220 output devices will slide right into their spots on the sinks and are fastened to the sinks with **modest torque** on the metric hardware provided.

I recommend old fashioned tin/lead solder - it melts at a lower temperature and is much easier to rework.

If you need a solder sucker, I recommend the Soldapullt. I have several, but I've only had to use one for 20 years or so - and I use it a lot.

Adjustment

Before you fire it up the first time, you want to have all four of the trim pots on the board set to counterclockwise position, which is minimum (zero) bias for the output stage.

You need a good multimeter, and ideally it will have pointy probes for looking at the DC voltages on little labeled pads/holes provided.

We will be measuring two voltages during the adjustment of each channel and adjusting the pots P1 and P2 to get these voltages where we want them. All adjustments should have halfway goals - if you want to go from 2 to 3 on something, then go to 2.5 first. Also, both P1 and P2 affect both the bias current and the output DC value, so adjustments will be made in an alternating fashion. One channel at a time is a good idea.

Also a good idea is to do this where the room temperature approximates actual usage, since the bias current does drift a bit with the ambient temperature.

Initially we bias the amplifier low and let the bias drift up as the temperature of the transistors rises. Most of the time the bias will drift up about 50% or so from cold to hot operation.

The two voltages on each channel are the bias current (measured as the DC voltage between the two pads labeled VB) which is the voltage divided by 0.75 ohms, and the DC output voltage, which is between the single pad labeled GND at the front of the board and the pads labeled VO (one for each channel).

Initially the values will be at or close to 0 volts. While keeping an eye on both the VB and VO, slowly alternately turn P1 and P2 clockwise. Eventually you will see some voltage appear (don't worry if it's a minus voltage). Oh yeah, remember to turn on the switch.

We are looking to have a VO of 11.5 volts and a VB of about 0.15 volts. Keep alternatively adjusting the pots clockwise until you get to these voltages. Sometimes you might have to back off one one pot to get both these numbers aligned.

It's a little tricky, but it doesn't have to be very accurate at this point - we will fine tune that after the amp has had a chance to warm up. When you get close to these voltages, just sit back and watch the drift, no hurry, no drama.

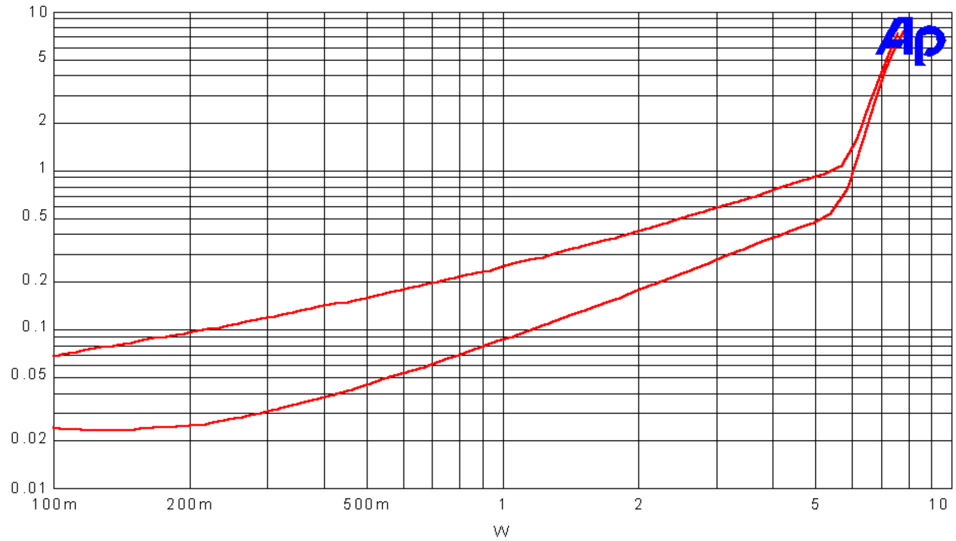
Ultimately you will want to be at VO of 11.5 VDC and VB of 0.30 V to 0.35 V (0.4 Amps to 0.46 Amps of current). If you have a cool room or lots of ventilation you can venture into the 0.35 V territory. If not, there is little performance penalty at 0.30 V and that's how I run them in my system. You will see some longer term temperature drift, so after you think it's stable on those voltages, keep an eye on it for an hour or so anyway.

The VO is not very critical, and the range of 11.4V to 11.6 volts is plenty good enough.

Performance

I went to the trouble of documenting the objective performance, so here it is -

The graph of the harmonic distortion at 1 kilohertz Into 8 ohms



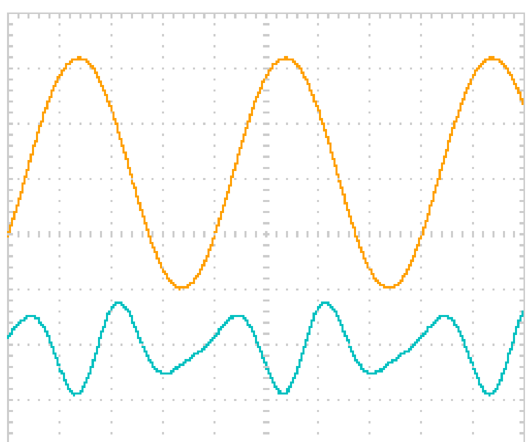
% THD VS OUTPUT POWER @ 8 OHMS

The lower curve is the distortion with the jumper in place.

Below we see an image of that distortion on an oscilloscope

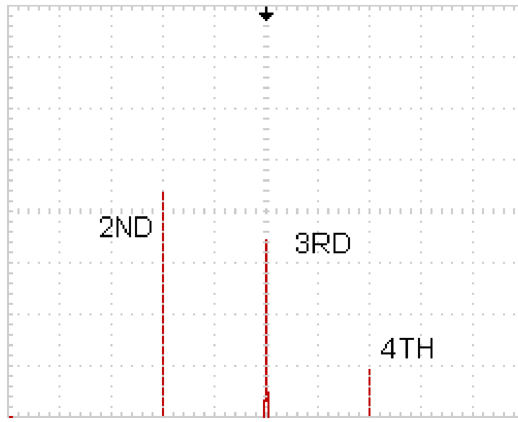
The top sine wave in orange is the fundamental 1 khz tone and the blue wave below is a magnified view of the distortion embedded In that fundamental.

It is largely second harmonic, time aligned in what i call negative phase second where the negative peaks of the distortion occur at both positive and negative peaks of the fundamental.



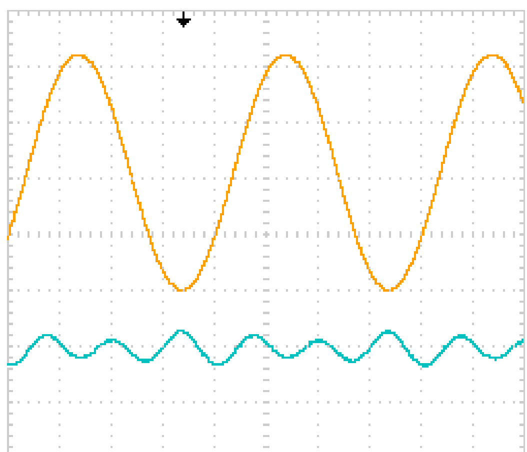
THD WAVE 1W 8 OHM W/0 JUMPER

And here you see the spectral content of that blue trace on a fast fourier transform:

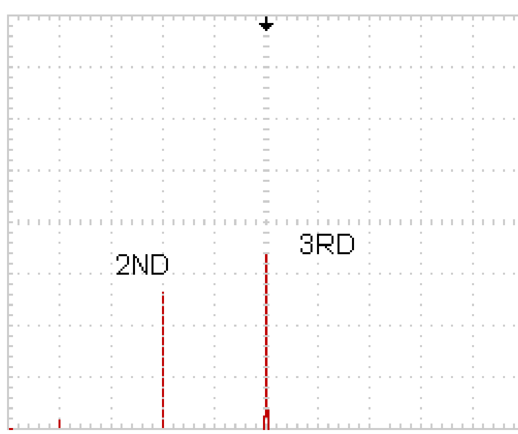


THD SPECTRUM W/O JUMPER
1 KHZ 1 WATT 8 OHM 10 DB/DIV

And now those same test images with the J1 jumper in place:

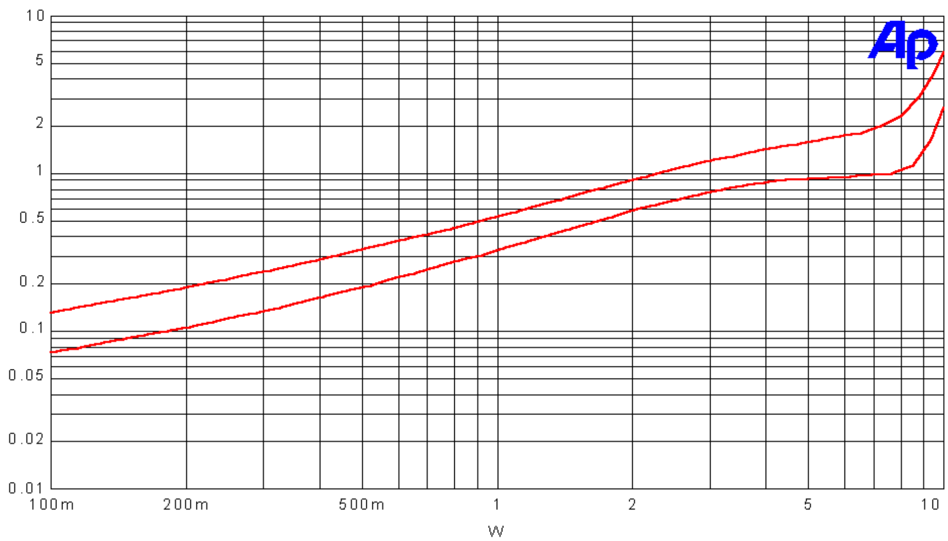


THD WAVE 1W 8 OHM W/ JUMPER

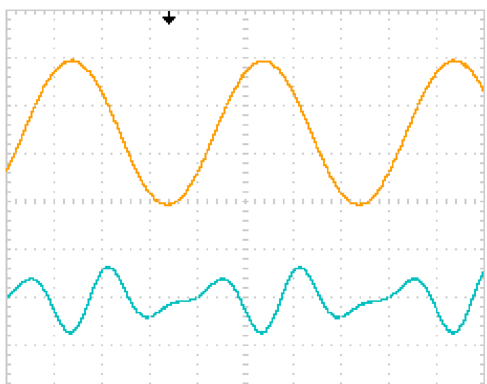


THD SPECTRUM W/ JUMPER
1 KHZ 1 WATT 8 OHM 10 DB/DIV

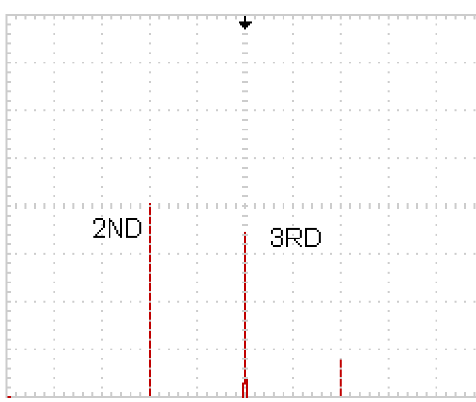
The distortion into 4 ohms:



% THD VS OUTPUT POWER @ 4 OHMS

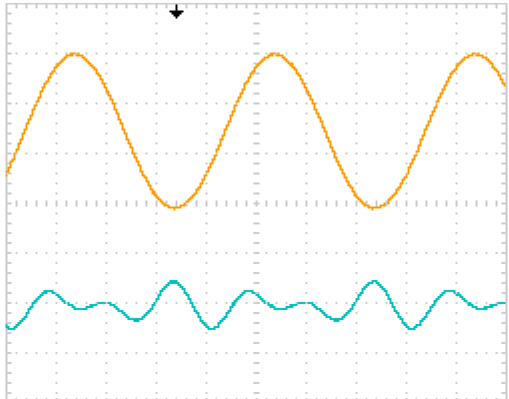


THD WAVE 1W 4 OHM W/O JUMPER

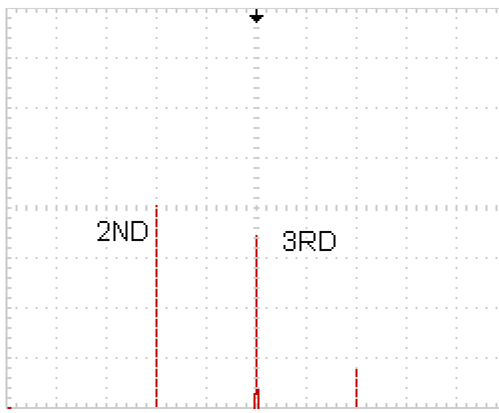


THD SPECTRUM W/O JUMPER
1 KHZ 1 WATT 4 OHM 10 DB/DIV

With 4 ohms and the jumper in place:

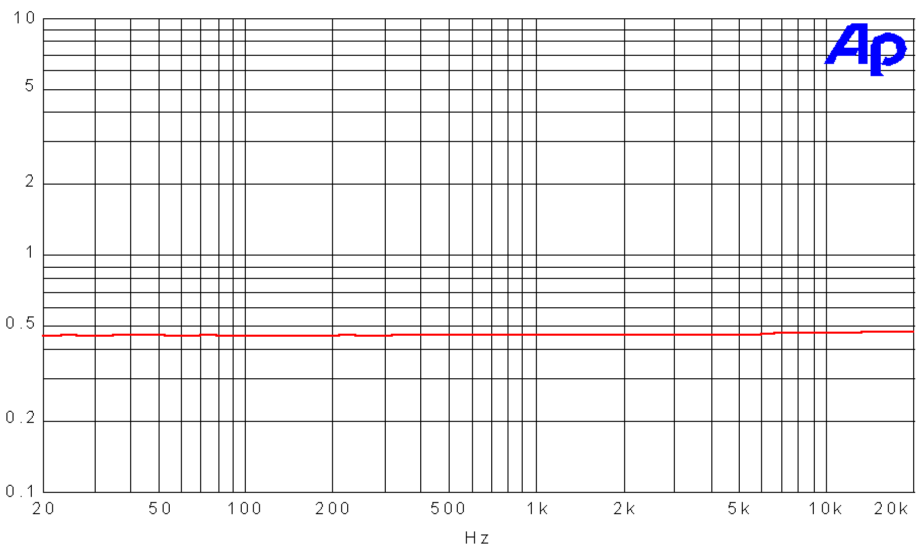


THD WAVE 1W 4 OHM W/ JUMPER



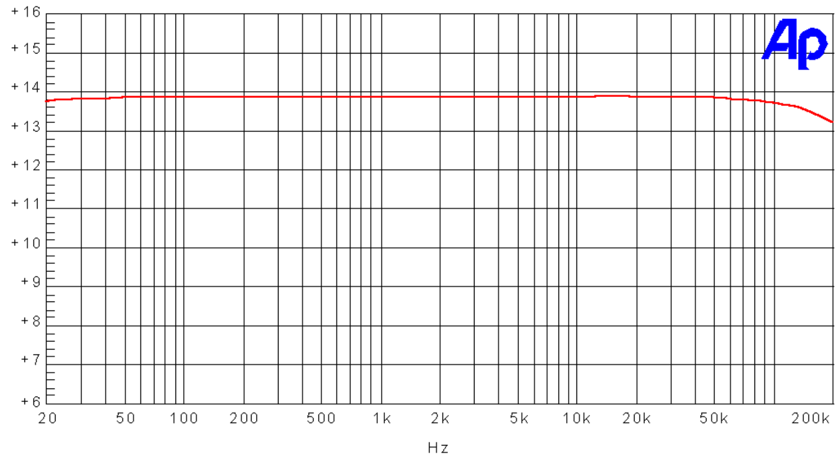
THD SPECTRUM W/O JUMPER
1 KHZ 1 WATT 4 OHM 10 DB/DIV

Here is the distortion versus frequency, which you can see is flat across the audio band.



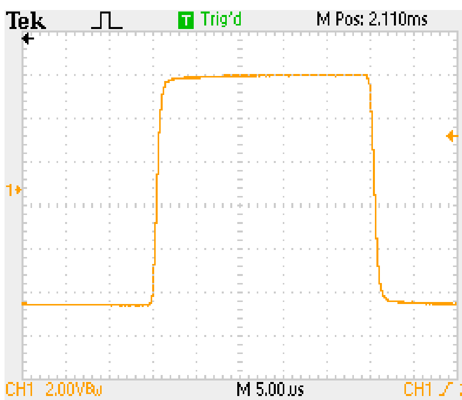
% DISTORTION VS FREQUENCY @ 1 WATT

And the frequency response:



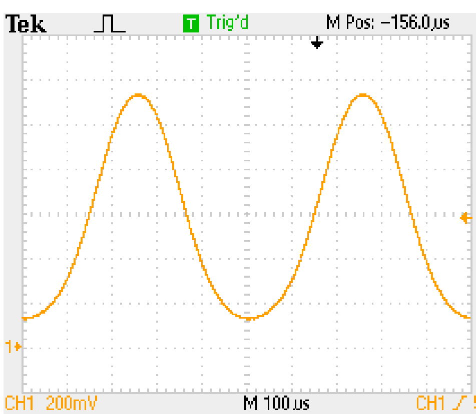
FREQUENCY RESPONSE

The wide bandwidth is further on display with this 20 kilohertz square wave at 2 watts



20 KHZ SQUARE WAVE

Lastly, here is scope image of the current through Q3 at an output of 5 watts into 8 ohms where the square-law character of the Fets delivers a generous margin for Class A operation.



BIAS CURRENT @ 5W 8 OHMS

Oh, and I forgot - the damping factor is about 10.

So there we have it.

As I write, kits have begun their travels through the postal system and then building starts.

Of course the first one went to esteemed diyAudio member 6L6 so that he can put together his reference build guide, always a huge help.

And also of course a thread devoted to this will be found in the Pass Labs forum.

Thanks to Linear Systems for providing the expensive and hard-to-get Jfets for this project.

And thanks to the Postal workers and Fedex and UPS guys for faithfully delivering all this stuff to and from my front porch. Couldn't have done it without you...

Lastly I hope that everyone has the same great experience with this project that I did.

More to come.