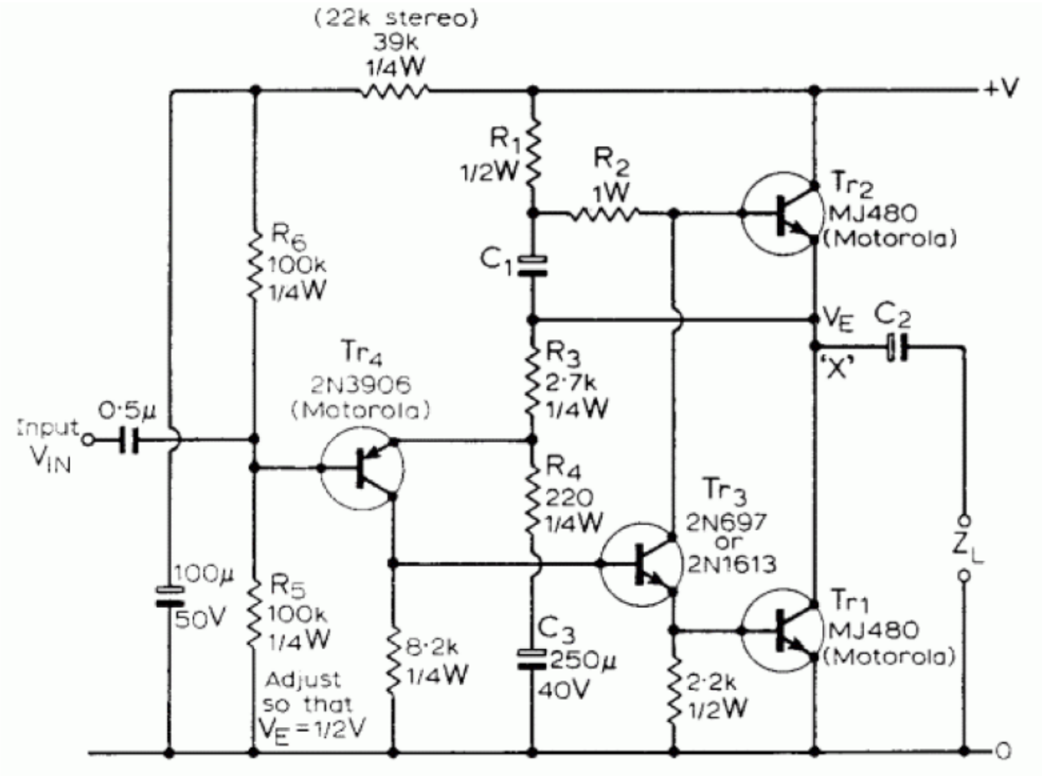
Nostalgia

A 25 W Class A power amplifier

In 1969 John Linsley Hood published a small Class A amplifier. The amplifier gained a good reputation for its performance despite the limited output power. The original article can be found here. The schematic is shown below.



I will not go into detail here, but Nostalgia is configured in the same manner. However, there are two main differences. Nostalgia is using only FET transistors, and it is also using a split supply. The latter avoids the output capacitor and the FET input makes it possible to avoid the capacitor on the input as well.

The FET part is inspired by Nelson Pass, who in 2005 had a new look at the original JLH amplifier shown above. He removed the input stage and replaced the other transistors with MOSFETs, resultating in the PLH amplifier, shown below. The article can be found here. Here Nelson Pass has introduced a potentiometer (P_2) that together with the bootstrap capacitor (C_2) can vary the amplifier from operating in push-pull to single ended. In the article you can also study the distortion figures for the various potentiometer settings and the preferences for Nelson Pass.

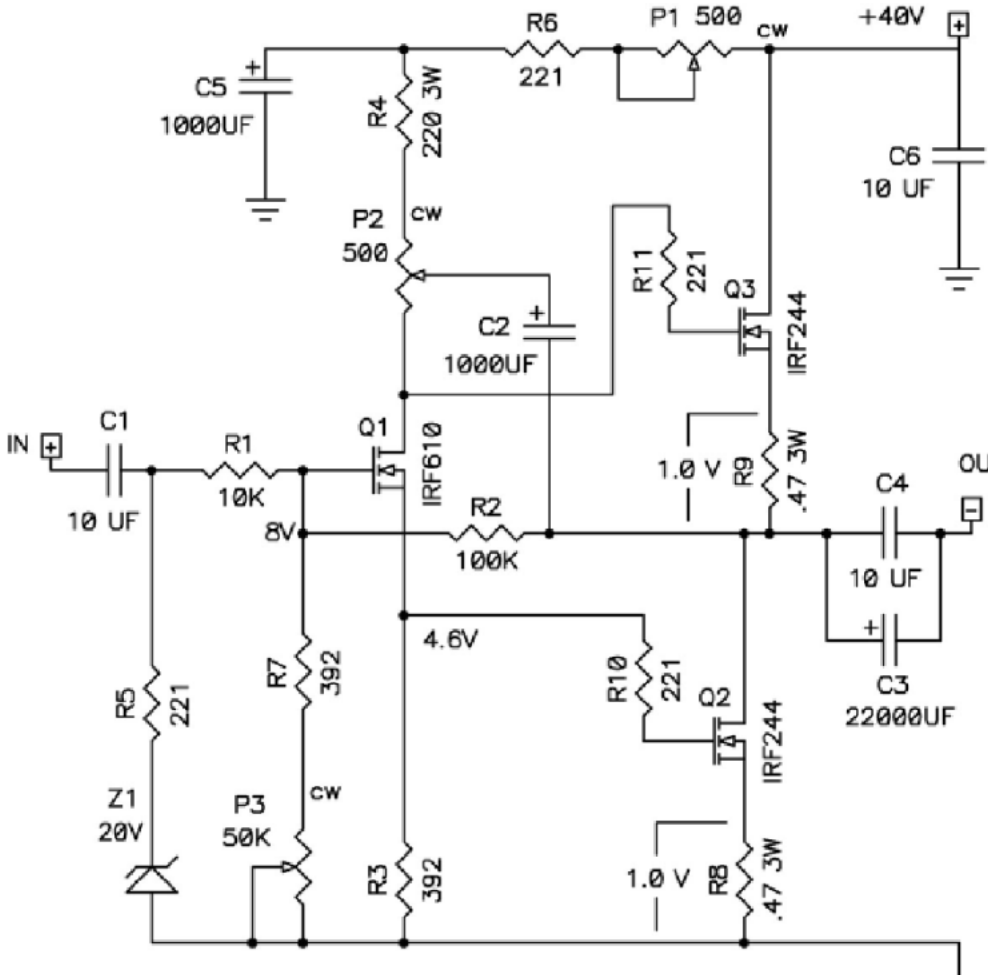
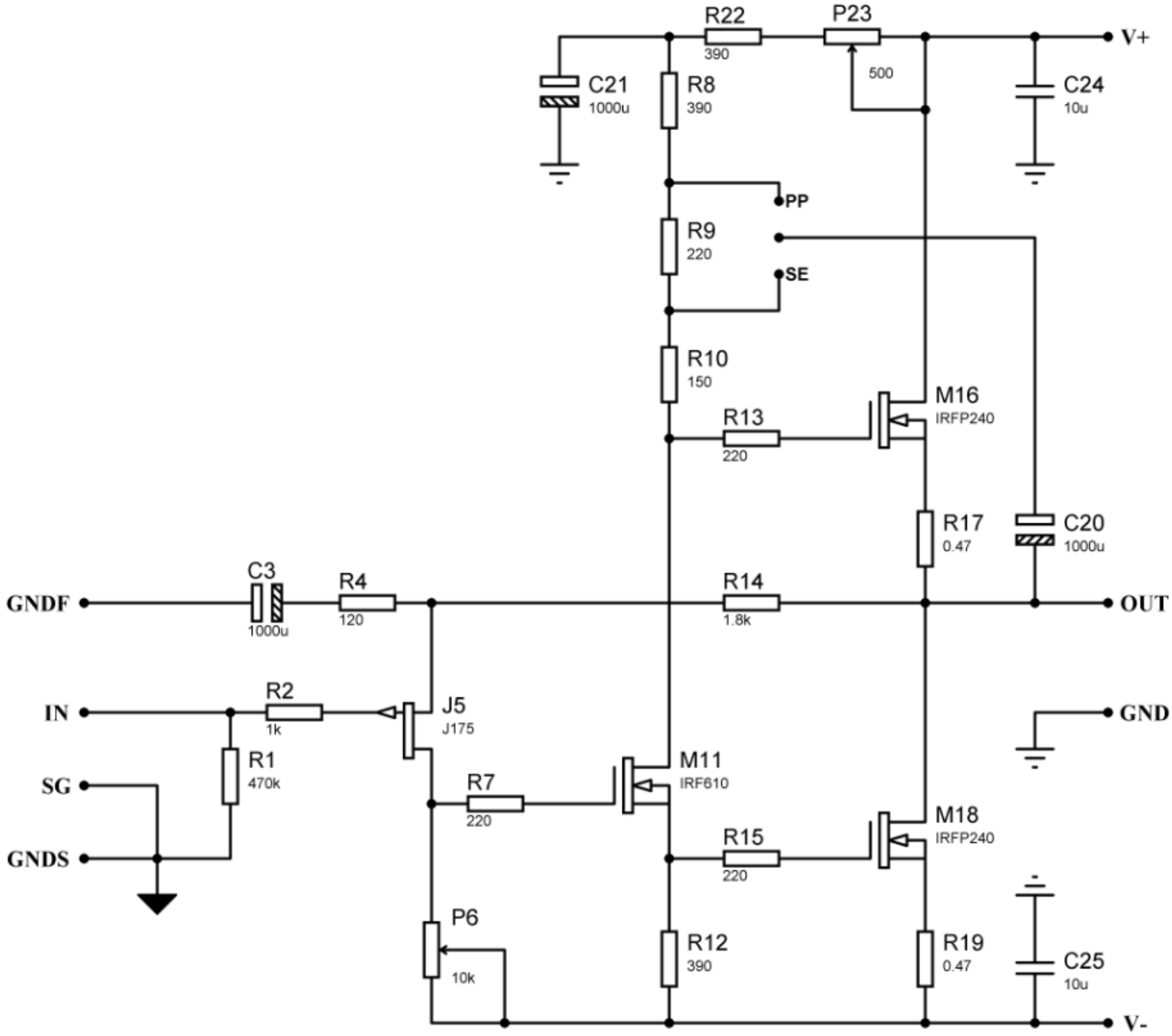


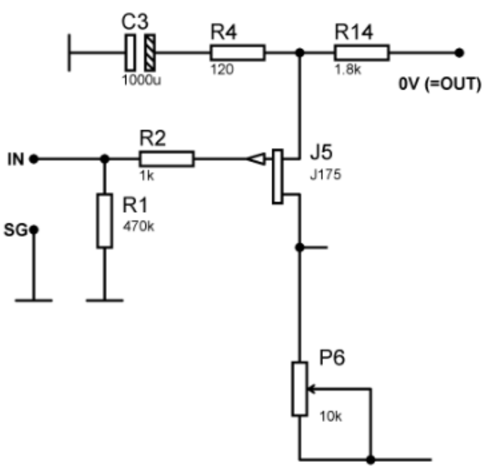
FIG 8 PLH POWER AMPLIFIER

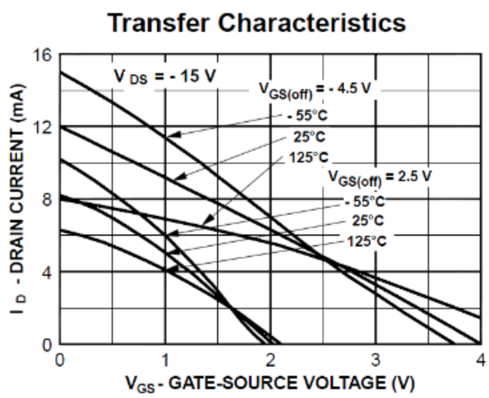
In the Nostalgia amplifier I have not used a potentiometer, but a switch to change between a Single ended and a Push-pull configuration. The schematic of Nostalgia is shown below.



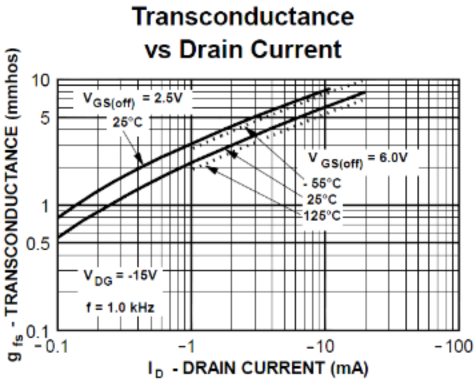
The input stage

The input stage is shown in the figure below. I am using the P-channel JFET J175 from Fairchild as the amplifying device. The I_{DSS}-variation is quite large. I have used transistors with an I_{DSS} of about





20 mA. From the characteristic below you can see that our 1.8kohm resistor (R_{14}) will give about I_D = 1.5 mA of drain current for VGS = 2.7 V as the quiescent point for J_5 (assuming that the output is at 0V DC), since $I_D = V_{GS}/R_{14}$. The potentiometer P_6 is used to set the working point for M_{18} (and M_{11}). The gain in the first stage is given by the transconductance of the JFET and the resistors R_4 and P_6. The transconductance as a function of the drain current is shown in the figure at left. The gain is given by

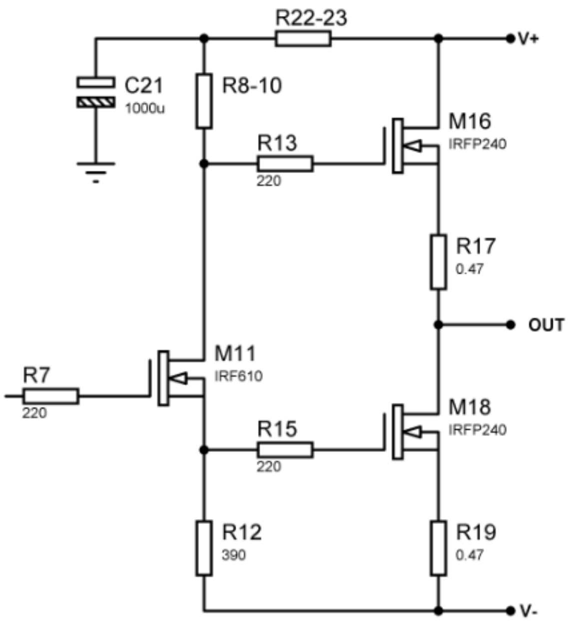


$$A_1 = \frac{g_{fs} \cdot P_6}{1 + g_{fs} \cdot R_4} \approx 20\ dB$$

Here we have used R_4 = 120 ohms. Please notice that J174 is an alternative to J175, but I have not tried this alternative.

Push-pull/single ended operation

The phase splitter is M_{11}, see the schematic below. The signal at the source of this MOSFET is in phase with the signal on the gate, and the signal at the drain of this MOSFET is phase inverted. This means that the power MOSFETs M_{16} and M_{18} will sink and source the output current. The coupling of C_{20} at the upper end of R_9 implies that the two transistors are operated in push pull mode, i.e. when the current in M_{16} increases, the current in M_{18} decreases, and vice versa. However, when C_{20} is connected to the lower end of R_9, M_{16} is almost coupled as a current generator and M_{18} must deliver most of the current variation, we can say that the output is operated single ended. The gain is lower for the single ended case. Neglecting the effect of C_{20} and R_{10}, this is about:



$$A_2 = \frac{g_m \cdot R_{Load}}{1 + g_m \cdot R_{19}} \approx 21\ dB$$

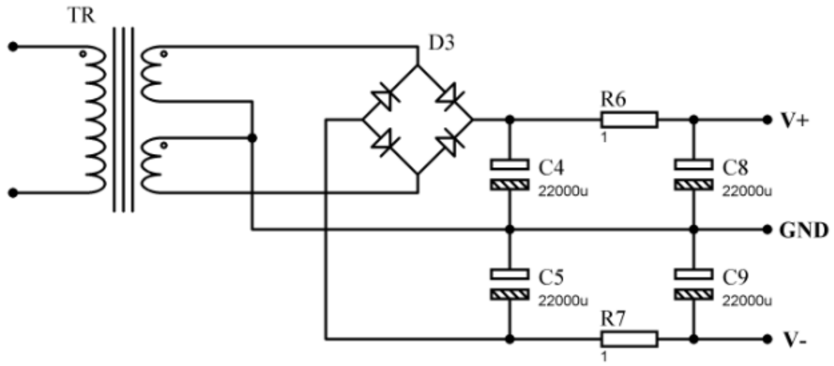
Here R_{Load} is the speaker load (assumed 8 ohms here) and g_m is the transconductance of M_{18} (about 5 S at an idle current of 1.5 A). In fact the gain A_2 is somewhat higher because of the bootstrapping (C_{20} and R_{10}): $A_2 \approx$ 23 dB. When operated in push-pull, the gain is about 3 dB higher: $A_2 \approx$ 26 dB. The resulting open loop gain is thus $A \approx$ 44 dB in Single ended mode and $A \approx$ 47 dB in Push-pull mode. The open loop bandwidth is about 40 kHz and 30 kHz for Single ended and Push-pull, respectively. The resulting closed loop gain with R_4 = 120 ohm is $G \approx$ 23 dB with a bandwidth extending 700 kHz.

The distortion is higher in Single ended operation with more second harmonic distortion, while in Push pull the distortion is lower, while the amplifier now can deliver more current to the load. The output impedance is also higher for the Single ended mode than for Push pull.

The operation between the Push pull and Single ended operation is done with a switch on the amplifier back plane (In the PLH amplifier this operation is done with the potentiometer P_2).

Power Supply

I started out with an ordinary unregulated power supply with additional RC-filtering, see the schematic below.



However, this was not sufficient for the negative leg (M_{11} and M_{18} is operating in common gate for signals on the negative leg), causing a ripple at the amplifier output that was annoying. So one more RC section was added at the negative rail with another one ohm resistor and 22000 μf capacitor. A better solution would probably be to use a capacitance multiplier instead of all the RC-filtering.

I have used a 2x18 V 500 VA transformer (TR in the figure above) common for the two channels. However the rectifier and filter capacitors are separate for the two channels. The voltage is about 24 V on the positive leg and about 23 V on the negative leg. This means that the amplifier can deliver a maximum of about 25 W to an 8 ohms load. The rectifier should withstand 35 A at least. The power resistors used are 5 W wirewounds types. The filter capacitors should be rated to more than 25 V.

Assembly

The printed circuit board (PCB) measures about 99x52 mm, see the component placement here. The layout is shown here. With the exception of the power resistors, 0.6 W metal film oxide resistors with 1 % tolerance is used. The power resistors R_{17} and R_{19} are ordinary wire wound 3 W types. If you want to change the gain, increase R_4 to reduce the gain, and vice versa.

The output transistors used for M_{16} and M_{18} is IRFP240 from International Rectifier (IR). If you are looking for a replacement for these, be sure they are vertical MOSFETs. These power transistors are mounted directly to the heat sink. The phase splitter is IRF 610, that also come from IR. This is also a vertical MOSFET, but this transistor is not mounted on the heat sink. I have not tried any substitution for this transistor. I have mounted the PCB directly to the heat sink.

The outputs from the transformer are carried to the rectifiers as shown in the power supply schematics. I have used the principle of star ground here; that is, I use a common connection between the filter capacitors (C_4, C_5, C_8, C_9) to the mid point from the transformer. This point is then connected to a star point where the loudspeaker minus also is connected. The GNDS terminal on the PCB is also connected to this star point. The same is the GND terminal on the PCB. I have also connected the GNDF terminal on the PCB to the GNDS terminal on the PCB itself. The signal ground (SG) on the PCB with the Input is connected to the phono socket on the back of the amplifier with a screened cable. I have used a chassis connection from the star ground. From the loudspeaker plus output I have used a single leader to the OUT on the PCB. You may try other grounding schemes, but if some sort of instability or noise should occur, the probability is high that the reason is bad wiring (e.g. earth loops).

The Final

I used a variable DC voltage generator first time the amplifier was started up. When the power supply voltage was increased, both the output-offset voltage and the idle current was adjusted by means of the potentiometer P6 and P23. The idle current was set to about 1.6 A. It is advisable to run this amplifier with a high idle current, the higher the better. However the heat sinks must be large, and heat sinks with a minimum capacity of 0.35K/W is recommended. The idle current and offset was readjusted when the ordinary power supply was connected. The quiescent current is quite stable when the heat sinks reach their working temperature.

Some measuring results		
	Single ended	Push pull
Sensitivity:	1.4 V	1.4 V
Input impedance:	470 kohm	470 kohm
Output power:	25 W	25 W
Output impedance:	0.50 ohm	0.35 ohm
Bandwidth (small signal)	700 kHz	700 kHz
THD at 10 V RMS 1 kHz:	2H:- 49, 3H: -58, 4H: -70, 5H: -79 dB	2H: -67, 3H: -68 dB

I have compared the sound between the Single ended and the Push pull mode. I must admit that the difference is very small, but I prefer the Push pull mode with my speakers: they are not to fond of the higher output impedance in the Single ended mode. But I must say, I think the sound from this amplifier is great, independent of which mode I am listening to.