Using LME49810 to Build a High-Performance Power Amplifier – Part I

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Introduction

Although switching or Class-D amplifiers are gaining acceptance to audiophile community, linear amplification is still the preferred choice in the DIY world. For novices, the simplest form of power amplifier would be an op-amp followed by a current booster output stage. However, an op-amp capable of operating at high voltage, e.g. > +/- 30 V, is not common. Hence, a discrete voltage amplification stage is needed which leads to a complex circuit configuration.

LME49810 is the newest power op-amp from National Semiconductor. Similar to its predecessor, LM4702, it is a high-voltage power driver but in mono design. With this chip, constructing a high-performance power amplifier is rather simple. Compared to LM4702, the new chip has higher drive current, higher slew rate and Baker clamp. This is a good chip not only for beginners, but also for elites.

A high-performance mono-block power amplifier is built with this chip. BJT is employed in driver and output stage. ThermalTrak complementary BJT from ON Semiconductor are selected for the emitter follower output stage. It has a thermally matched bias diode in the same package which eliminates thermal tracking lag. The bias generation circuit can also be simplified which results in a lower THD of the amplifier, as claimed in an ON's App Note.

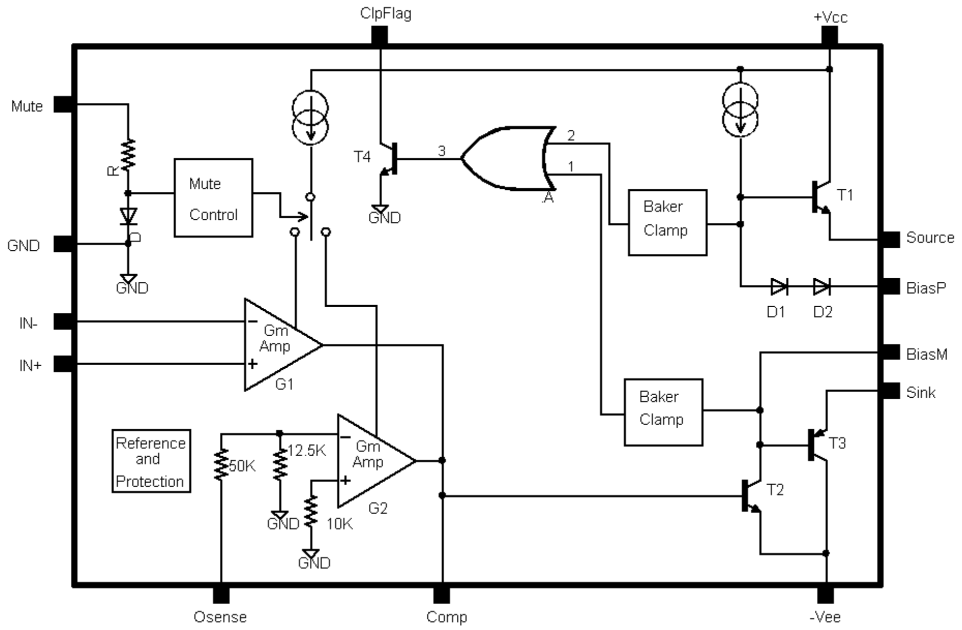


Figure 1 LME49810 Simplified Block Diagram

About The Chip

The block diagram of LME49810 is depicted in Figure 1. The chip is encapsulated in a plastic TO-264 package. The first stage, G1, is differential transconductance amplifier similar to that of most discrete amplifiers. It amplifies input differential voltage to current output. The second stage T2 forms a voltage amplifier. An external compensation capacitor (Miller capacitor) is connected via pins Comp and BiasM. G2 block is responsible for output level monitoring. There two diodes, D1 and D2, that can be used to bias the output transistors, T1 and T2, by shorting BiasP and BiasM. With emitter resistor connected to T1 and T2, LME49810 alone could be used as a headphone amplifier. Or a pre-amp has high output current capability?

From the data sheet, is it seen that the chip has outstanding performance. However, the THD performance curves are measured with no load. We will investigate its performance when the output of the test circuit has a load connected.

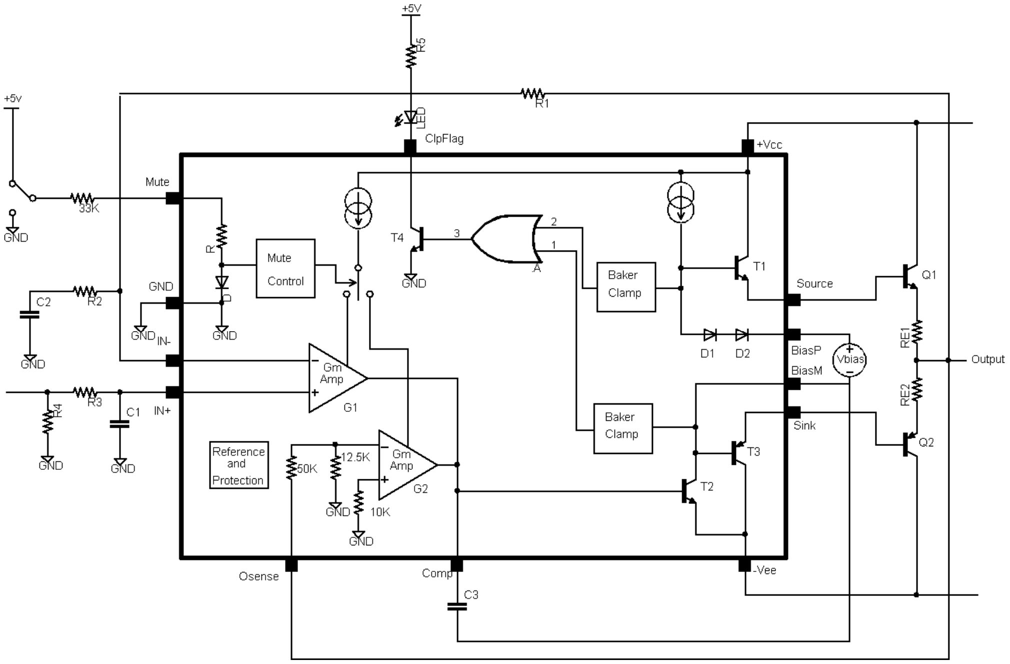
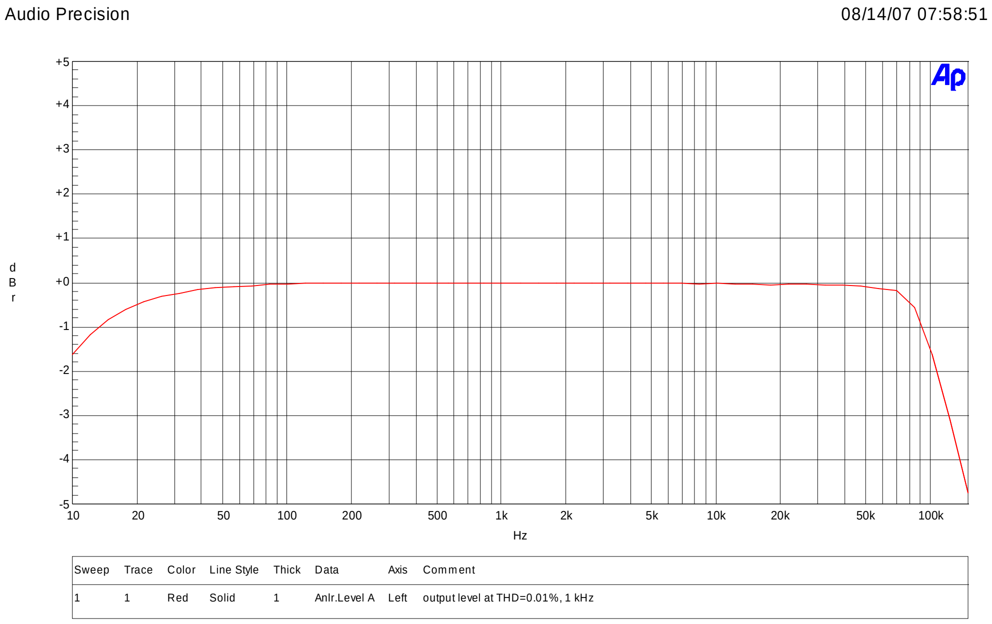


Figure 2 A typical amplifier with LME49810 and discrete output devices.

A typical amplifier based on LME49810 is shown in Figure 2. A bias generator is connected between BiasP and BiasM. In general, it will be a so-called V_{be} multiplier. The transistor employed for generating bias voltage is typically mounted on the heat sink to track the output devices temperature for thermal compensation. New generation BJT’s from Sanken and ON Semiconductor have biasing diodes embedded in the same package. Hence, bias generation circuit can be simplified and thermal tracking accuracy is improved. We will use NJL3281 and NJL1302 complementary BJT pair from ON to form the emitter follower output stage.

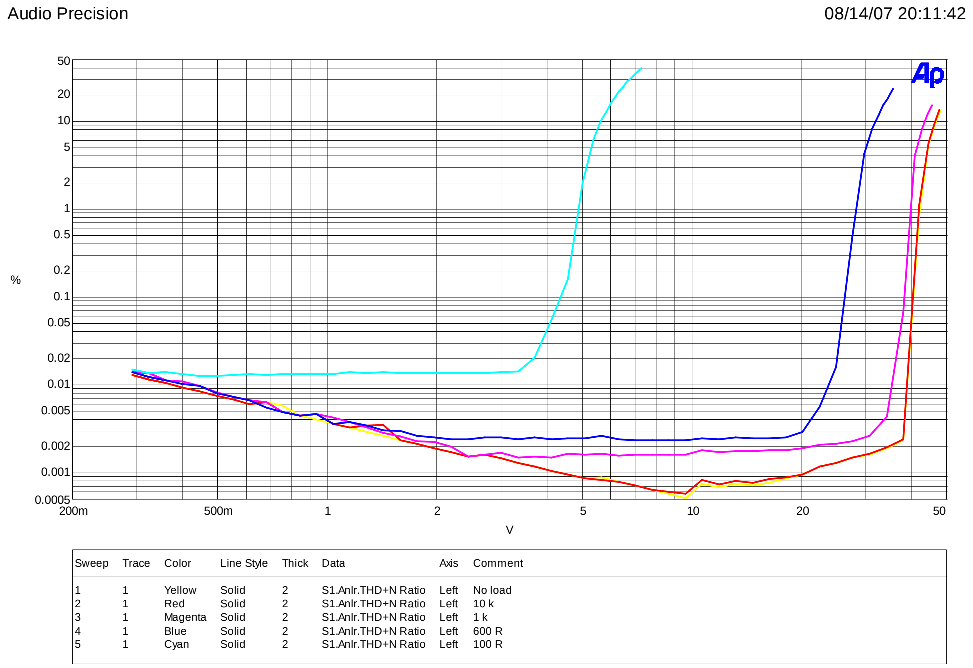
Figure 3 Test circuit for measuring loaded performance.

Figure 4 System One audio analyzer



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Red	Solid	1	Anlr.Level A	Left	output level at THD=0.01%, 1 kHz

Figure 5 Frequency response for no load.

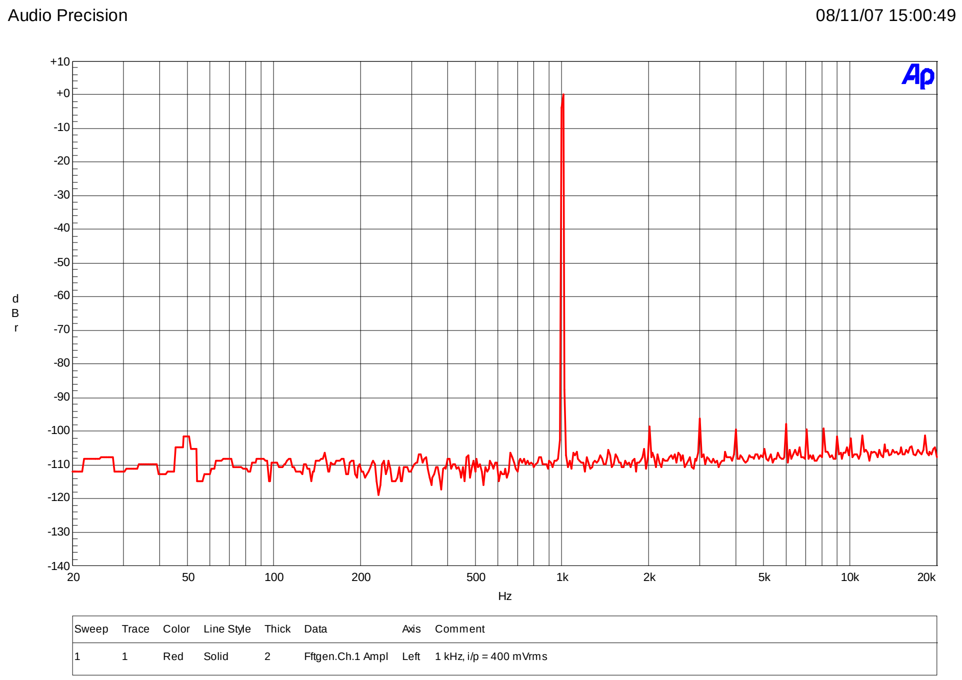


Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Yellow	Solid	2	S1.Anlr.THD+N Ratio	Left	No load
2	1	Red	Solid	2	S1.Anlr.THD+N Ratio	Left	10 k
3	1	Magenta	Solid	2	S1.Anlr.THD+N Ratio	Left	1 k
4	1	Blue	Solid	2	S1.Anlr.THD+N Ratio	Left	600 R
5	1	Cyan	Solid	2	S1.Anlr.THD+N Ratio	Left	100 R

Figure 6 1 kHz THD with different output loads.

Here we spend some time on evaluating LME49810 performance when it is loaded. Resistor values of 10 kΩ, 1 kΩ, 600 Ω and 100 Ω were used in the measurement. The test circuit shown in Figure 3 of the data sheet was built on a prototyping board as shown in Figure 3. DC supply voltage of +/- 63 V was applied. Audio Precision System One audio analyzer in Figure 4 carried out measurements in the following. The no load full-scale frequency response is depicted in Figure 5. The rather significant low-frequency roll-off is probably due to the electrolytic capacitor on the feedback path. Two 220 uF cap are in series for having bipolar characteristic.

Hence, the cap value becomes 110 uF. This capacitor can be eliminated by using DC servo circuit to achieve zero out DC offset. It will be investigated later.



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Red	Solid	2	Fftgen.Ch.1 Ampl	Left	1 kHz, i/p = 400 mVrms

Figure 7 FFT of 1 kHz sine wave with no load

Figure 6 shows the total harmonic distortion (THD) performance versus output level for a 1 kHz sine wave. The analyzer upper bandwidth was set to 22 kHz. We can see the loading effect of 10 kΩ is negligible. When the load resistor value drops to 1 kΩ, the THD jumps to 0.002 % before clip. Small increment on THD is seen when the load becomes 600 Ω. We can also see the output clipping level dropping while loading is increasing. The performance for a load of 100 Ω is degraded substantially. There is about an order of magnitude increment on THD before clip. For 1 kΩ and 100 Ω loads, the output currents associated with the clipping voltage are near the typical value, 60 mA, specified in the data sheet. This output clipping value implies that a driver is essential for any design of output 200W/8 Ω and up. High-power BJT’s tend to have lower current gain β value. Moreover, β value is dropping when the collector current I_c increases. This is commonly referred to as beta drop. Fortunately, most recent power BJT’s have a rather flat beta versus I_c till a threshold. It can be seen from NJL3281/1302 data sheet that the current gain is essentially flat for I_c less than 5 A. Since the typical value of beta of NJL3281/1302 is about 100, a driver stage is necessary output current higher than 5 A.

The harmonic contents of the output are available via FFT analysis. The no load harmonics are shown in Figure 7. Second, third and higher harmonics are at least 95 dB down compared to the fundamental.

The SPICE model of NJL3281/1302 is available from ON's web site. It was simulated in LTspice (Figure 8 and 9) for beta drop effect. Indeed, the driver and output stage can be simulated in LTspice to estimate how much current is needed from LEM49810.

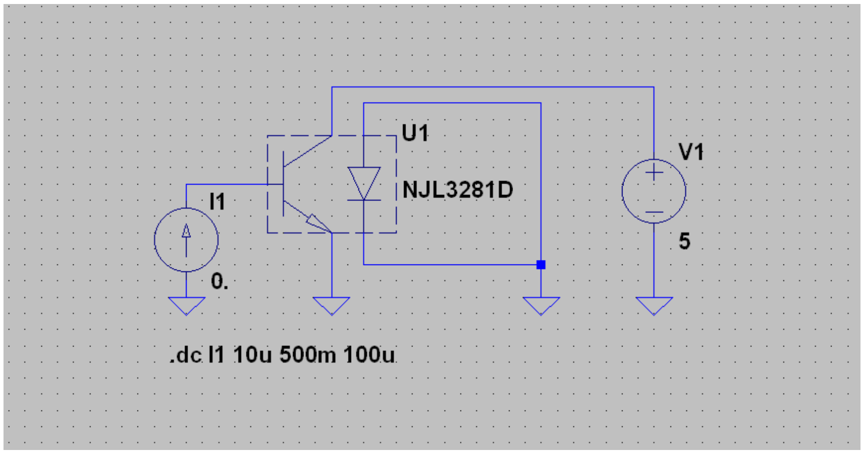


Figure 8 Simulation for beta drop of NJL3281

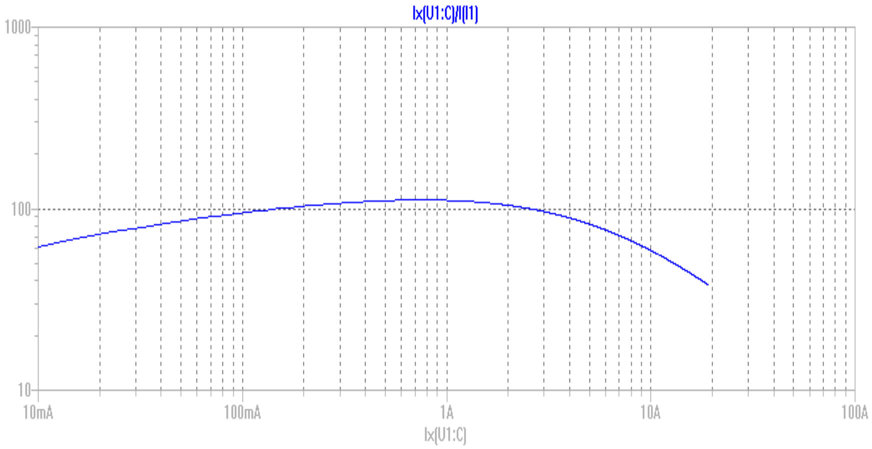


Figure 9 Simulated beta versus Ic

About the Circuit

From the above measurement data, the final amplifier circuit is shown in Figure 10. Input impedance is set by R_{13}. R_{14} and C_7 form a low-pass filter to suppress RF interference. C_2 is a DC blocking capacitor. The driver stage consists of Q_1 and Q_2. According to Self's book, a speed-up capacitor C_4 in parallel with R_8 is added. Resistors R_6 and R_7 at drivers' base are inserted to work with protection circuit preventing Source and Sink pins of LME49810 directly shorted to ground during output short-circuit. These two resistors can be omitted if a current mechanism is provided to limit the current from/to those pins. We will cover this topic in the next article.

Two pairs of NJL3281/1302 are employed in the output stage to provide enough driving capability for 4 Ω or even impedance lower speakers. R_{19}, R_{20}, R_{22} and R_{23} resistors are used to suppress parasitic oscillation from the output stage. A resistance of 10 Ω is a good value to start with. Diodes D_1 and D_2 are added to protect output transistors from voltage transients due to inductive loads. T_1 forms the traditional Vbe multiplier bias circuit such that BJT's without biasing components can also be used in the output stage. If this is the case, T_1 should also be mounted on the heat sink with output transistors. With NJL3281/1302 employed, the bias circuit can be simplified as shown in Figure 10. We can adjust potentiometer R_1 to set the bias current. The current pass through R_1 is 2.8 mA. The circuit consists of a feedback network that is employed in the famous LEACH Amp. At audio frequencies, feedback signal is taken from the output stage and the amplifier gain is equal to $\left(1+\frac{R_{11}+R_{20}}{R_{12}}\right)$. At higher frequencies, C_{11} and C_{12} becomes short circuit. Hence, feedback is from the driver stage instead of the output stage. This feedback approach improves amplifier's stability when driving capacitive loads. Reader can simply omit C_{11}, C_{12}, R_{29} and R_{30} if a pure resistive feedback network is considered. The amplifier gain is then solely determined by $\left(1+\frac{R_{11}}{R_{12}}\right)$. We can see that the circuit is designed for ease of making various experiments.

We mainly present the overall amplifier architecture in this article. Output stage protection and DC servo circuits are not shown in the schematic. They will be on a separate board and discussed in the next article. Solder posts are provided on the main board for wiring them together. All component values will also be given in the coming article. Readers can indeed have their own values to suit different operating conditions and output power.

A layout example is given in Figure 12. Driver stage transistors are expected in either TO-126 or TO-220 package. Area for heat sink is reserved. The feedback take-off point follows the idea presented in Self's book. In practice, PCB traces have non-zero resistance. There is voltage difference between point A and point B in Figure 13. Point B is the correct feedback take-off point where point A is not. Hence, the take-off point in the layout example is at pad O1.

In the next article, output-stage protection circuit, DC servo, all component values will be given for no less than 120 W/8 Ω output power. Measurement results of a finished amplifier will be presented.

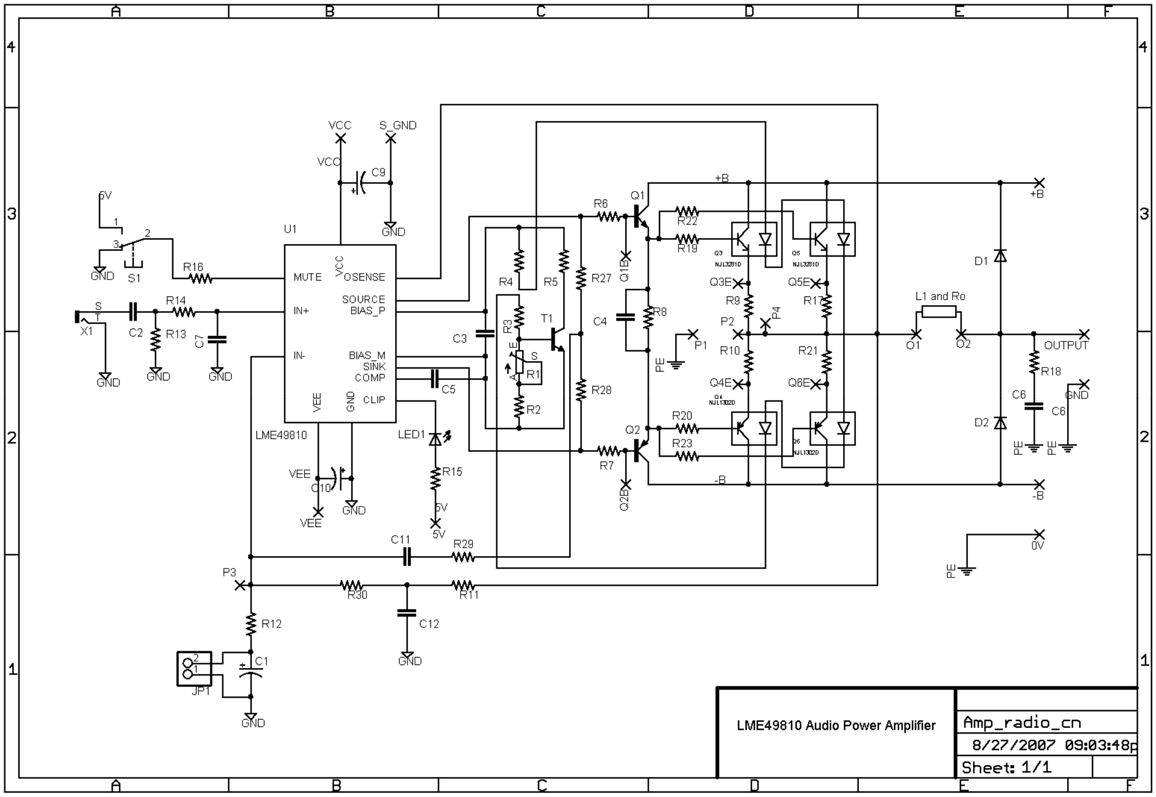


Figure 10 The amplifier circuit

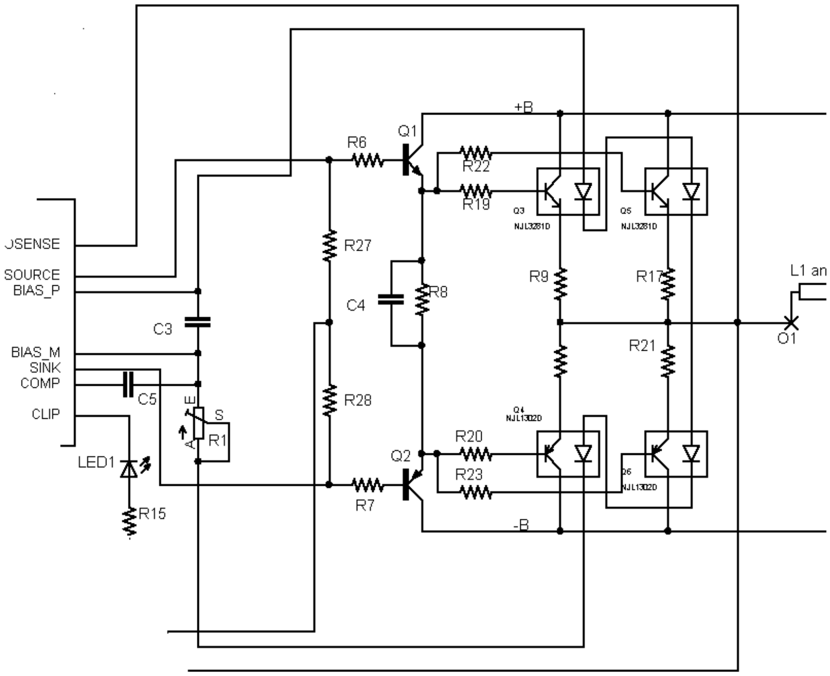


Figure 11 Simple bias circuit for NJL3281/1302 output BJT pair

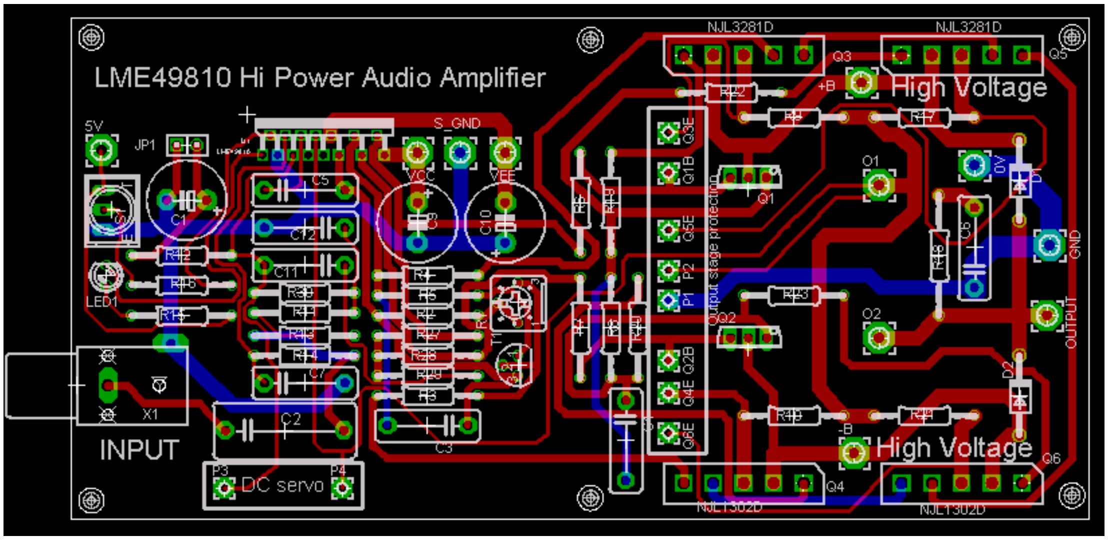


Figure 12 The amplifier board layout

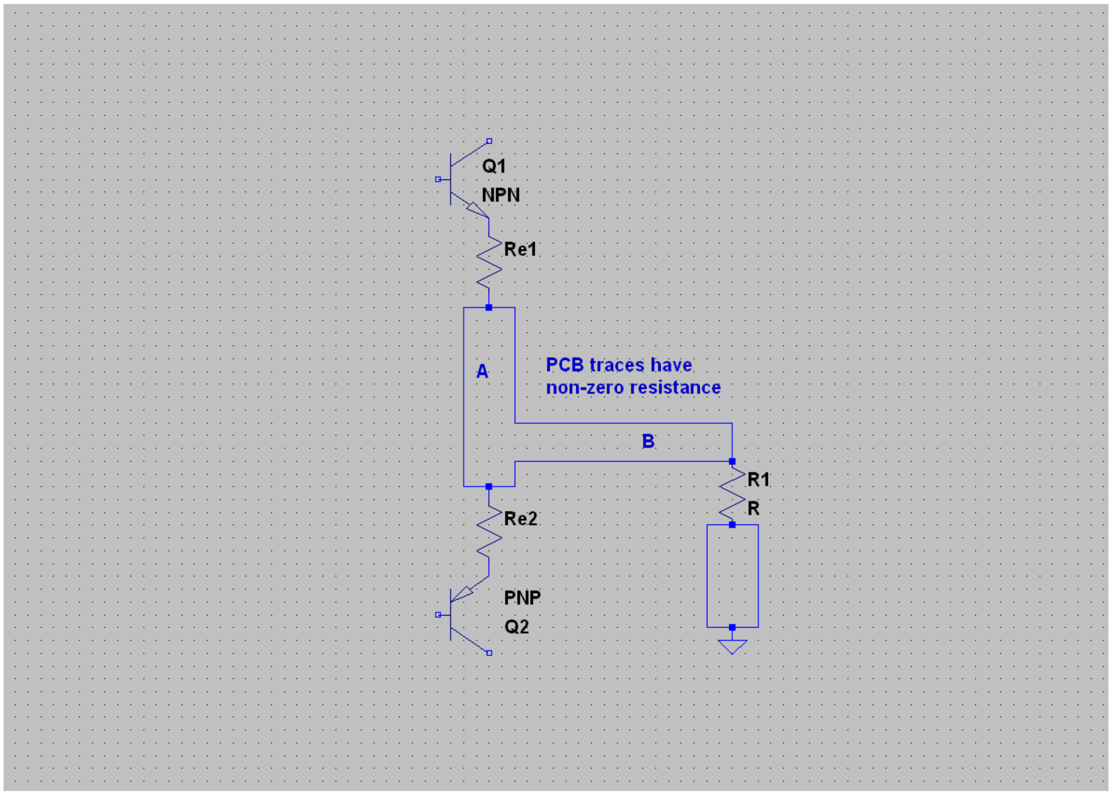


Figure 13 Feedback take-off point A – wrong, B – correct.

References

1. ThermalTrak Audio Output Transistors, AND8196/D, ON Semiconductor, 2005.
2. Douglas Self, Audio Power Amplifier Design Handbook, 4th edition, Newnes, 2006.
3. LEACH Amp web site, http://users.ece.gatech.edu/~mleach/lowtim/