By Bill Christie (United States)

Build an External Phonograph Preamplifier

Design modifies modern equipment to play vinyl records

Many of today's receivers and preamplifier processors do not have phonograph inputs, so anyone with a vinyl collection will need an external phono preamplifier. My friend found himself in this predicament and asked me if I could build him one (see **Photo 1**). As an aside, my Outlaw Audio Model 950 preamplifier processor doesn't have a phono input either.

CHOOSING A DESIGN

Texas Instruments (TI) has a series of high-performance op-amps specifically designed for high-fidelity applications. The datasheets include the schematic for a phono preamplifier, the LME49740, which looked like a good candidate. The LME49740 is a 14-pin integrated circuit (IC) containing four op-amps, which is just the right number for the preamplifier. I've had excellent experience with this series and decided to use it.

The first thing I did was design a power supply worthy of the job. I started with a toroidal transformer to minimize the stray magnetic field. Then I used a bridge rectifier with large capacitors to form the raw supply. I regulated the raw supply down to ±14 V. I used adjustable regulators (the LM317 and the LM337) because they are said to have less noise than fixed regulators. The formula for the regulated voltages is as follows:

$$V_{OUT} = 1.25 \times \left(1 + \frac{R210}{R208}\right) + 0.00005 \times R208$$

Values of 470 Ω or R210 and 470 Ω for R208 provide a 13.985-V output.

The raw supply provides power to a relay driver circuit with about a 0.5 s turn on delay and almost instantaneous off delay. The relay shorts

Photo 1: The passively equalized phono preamplifier contains moving coil capability.

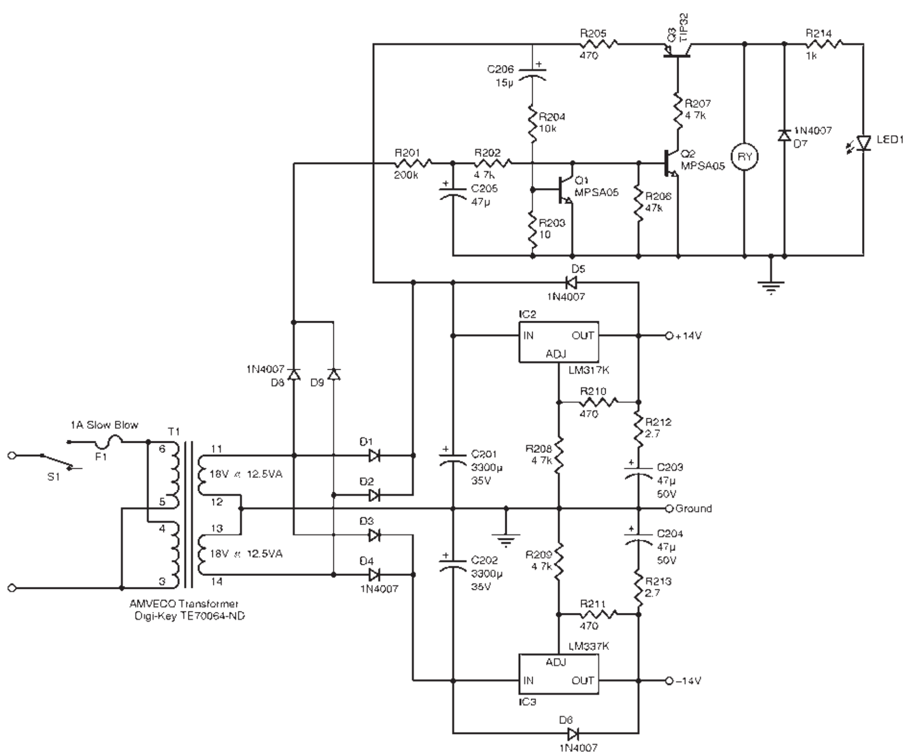

Figure 1: This schematic details the power supply and the relay driver circuits.

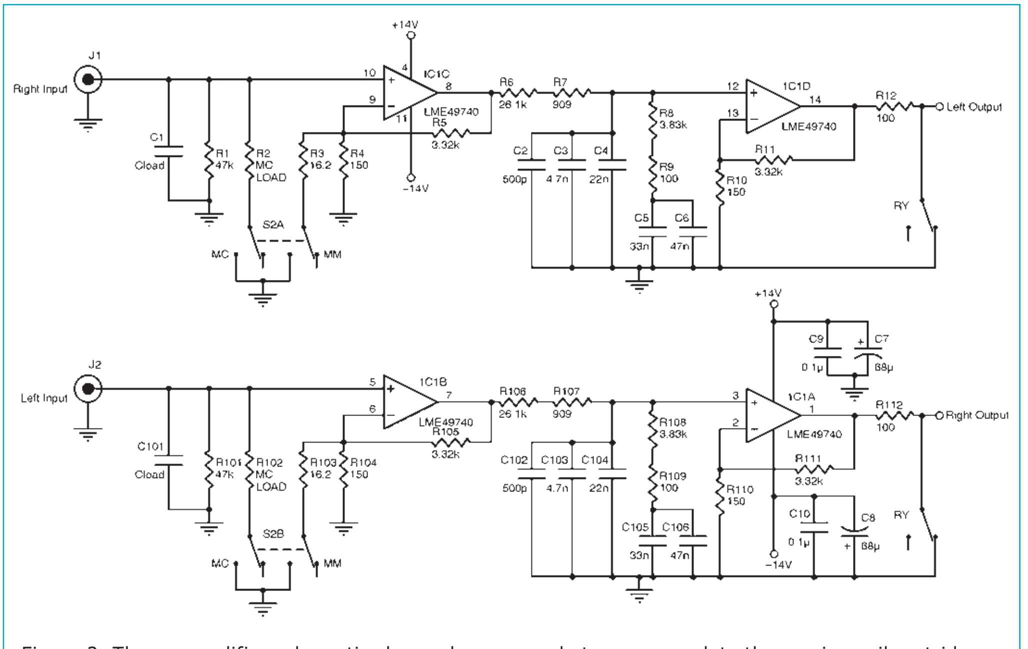

Figure 2: The preamplifier schematic shows changes made to accommodate the moving coil cartridges, cartridge loading, and output muting.

the op-amps' outputs while the power supply stabilizes after power up and at power down before the power supply bleeds off. This mutes the outputs to eliminate turn on and turn off pops. **Figure 1** shows the power supply and relay driver circuits. (The relay plugs into a standard 16-pin dip socket.)

PREAMPLIFIER CIRCUIT

The circuit for the preamplifier itself is essentially the TI-supplied circuit. I've made a few minor changes to accommodate the moving coil cartridges, cartridge loading, and output muting.

Figure 2 shows the modified circuit. The topology is simple. There is a linear gain stage at the input, followed by a passive Recording Industry Association of America (RIAA) filter, followed by a linear output gain stage. The passive filter consists of resistors in series and capacitors in parallel to closely achieve the proper component values. I used the values specified in the datasheet with excellent results. (The TI LME49740 datasheet is available at www.ti.com/lit/ds/symlink/lme49740.pdf.) It includes the phono preamplifier schematic with specified values. Other combinations are valid. A comprehensive explanation of passive RIAA filters can be found on Wayne Stegall's website (http://waynestegall.com/audio/riaa.htm).

CARTRIDGES

Moving coil (MC) cartridges typically have only one-tenth the output of moving magnet (MM) cartridges. Also, the recommended resistive loading is significantly lower. MM cartridges almost exclusively have a 47-kΩ recommended load while MC cartridges have a variety of recommended loads that go as low as 3 Ω. Switch S2 will not only select the proper loading but it will change the gain. The input stage's gain in the MM position can be calculated by the simple equation:

$$\text{Gain} = \frac{(R4 + R5)}{R4}$$

This calculates to 23.13. In the MC position of switch S2, a 15.8-Ω resistor, R3, is placed in parallel with the 150-Ω resistor, R4. The parallel resistance is 14.29. This causes the gain for the input stage to increase by approximately a factor of 10, or to 233.13. A gain that high would be problematic for general-purpose op-amps. But with the LME49740 noise is not measurable with my equipment. The same outcome can be achieved with 10:1 step-up transformers, but they are expensive and I don't think they would be any better.

The recommended loading capacitors for MM cartridges vary greatly. Data for an extensive list of cartridges (MM and MC) is available at www.vinylengine.com/cartridge_database.php.

Figure 3 shows a printed circuit board (PCB) layout that includes the power supply and the preamplifier. I provided component carriers for the cartridge loading components. These plug into dip sockets, so the components can be changed without soldering to the PC board. Since the 47-kΩ load is pretty standard for MM cartridges, I soldered it directly to the PCB. I repeated the same procedure for the gain resistor for the MC cartridges. (If a "high-output" MC cartridge is used, the gain-changing resistor would need to change. However, I didn't include a plug-in provision for that.)

The capacitors specified in the parts list are available from Digi-Key with

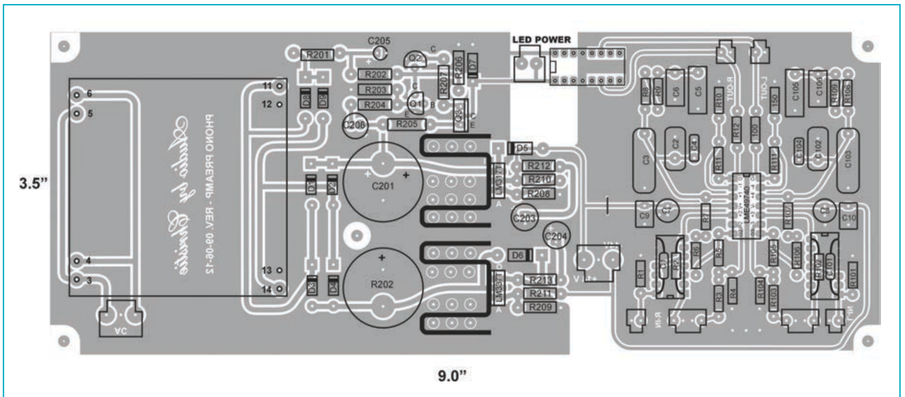

Figure 3: The PCB's component layout includes the power supply and the preamplifer.

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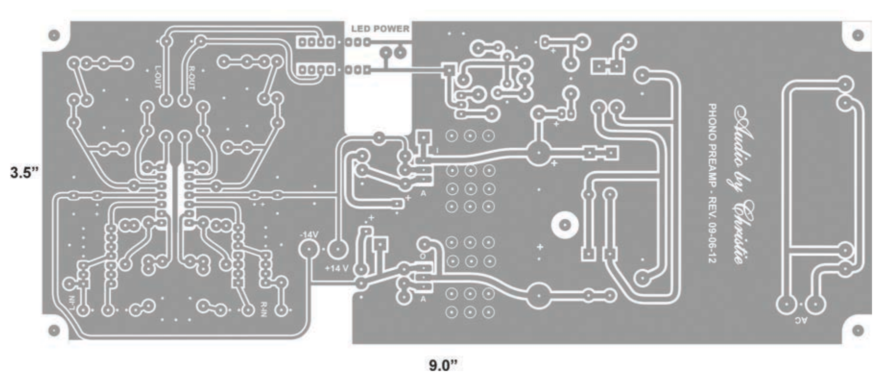

Figure 4: The PCB foil side shows the Molex connectors, which are optional.

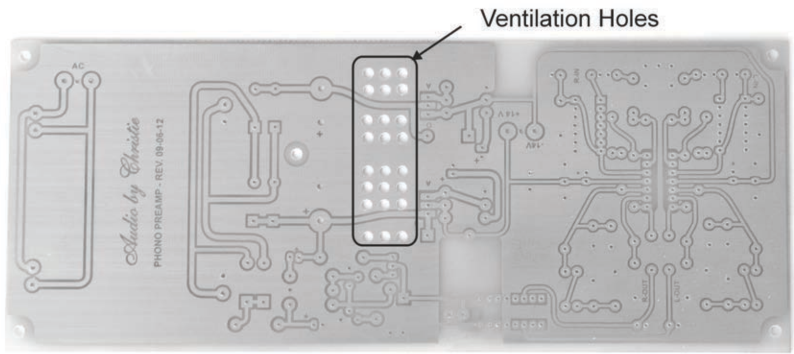

Photo 2: I drilled 24 holes in the PCB to ensure the components are well ventilated.

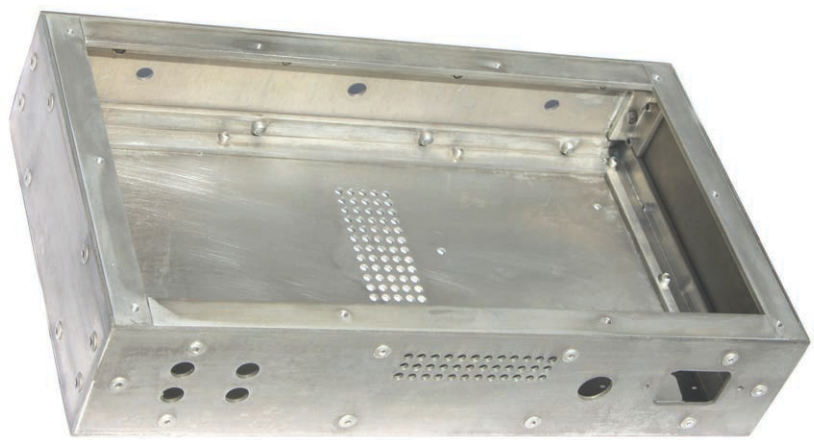

Photo 3: The chassis was a blank slate prior to painting.

lead spacings that fit the board layout. Molex connectors are optional. If used, they will eliminate the need to solder external wiring to the board. I used 0.156” headers for power connections and 0.1” headers for the signal. I provided a header to power auxiliary equipment, if desired. (I am thinking of incorporating this design into a complete preamplifier with input selection, tone, balance, and volume controls.)

Although the preamplifier's power consumption is quite low and heat should not be a problem, I decided to provide significant ventilation. I drilled 24 holes in the PCB under the heatsinks for the voltage regulators and array of holes in the bottom and back of the chassis (see **Photo 2**).

THE CHASSIS

I made the chassis out of 0.0625” thick aluminum plates fastened together with 0.5” aluminum angle and pop rivets. The front panel was made

Frequency	Measured	Ideal	Error
20 Hz	19.24 dB	19.25 dB	−0.01 dB
40 Hz	17.79 dB	17.79 dB	0 dB
100 Hz	13.1 dB	13.08 dB	0.02 dB
200 Hz	8.29 dB	8.22 dB	0.07 dB
400 Hz	3.86 dB	3.78 dB	0.08 dB
1,000 Hz	0 dB	0 dB	0 dB
2,000 Hz	−2.55 dB	−2.5 dB	−0.05 dB
4,000 Hz	−6.54 dB	−6.52 dB	−0.02 dB
10,000 Hz	−13.96 dB	−13.73 dB	−0.23 dB
20,000 Hz	−20.15 dB	−19.62 dB	−0.53 dB

Table 1: I tested the preamplifier's response at several frequencies and compared them to published response results.

from a 0.125" thick aluminum plate held to the chassis by the switches. **Photo 3** shows the bare chassis before painting.

Labeling the front panel was frustrating. I tried silk screening but after three attempts I was not satisfied with the results. I finally used a company that specializes in custom graphic items (Enlarging Arts in Akron,

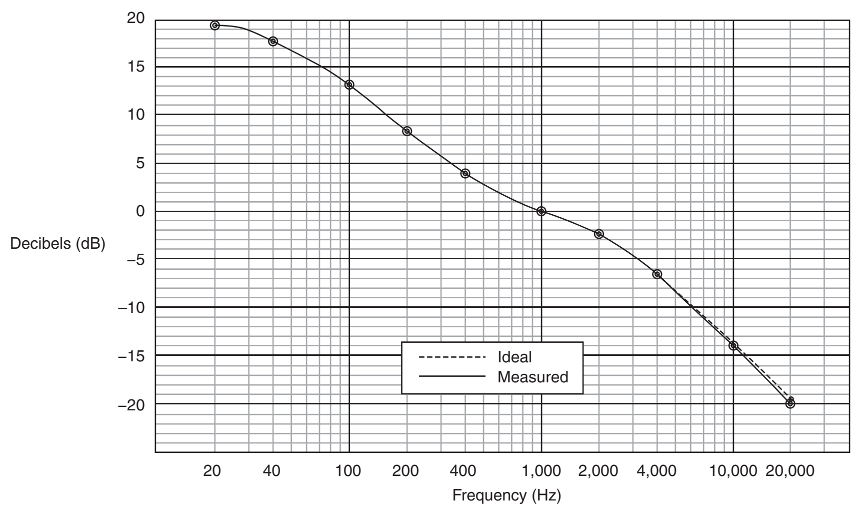

Figure 5: Here is a graphical representation of my test results.

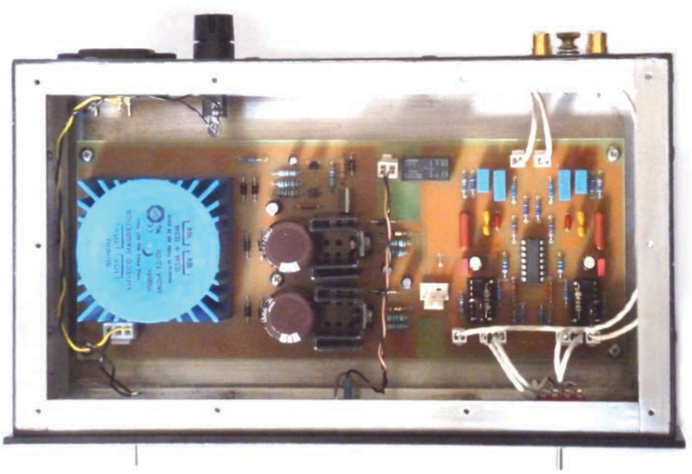

Photo 4: This is an inside view of the completed preamplifier.

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Phono Preamplifier Parts List

Capacitors

• C1, C101 = MM Load	Value dependent on cartridge
• C2, C102 = 500 pF, 5%	Digi-Key Part # 338-1069
• C3, C103 = 4.7 nF, 5%	Digi-Key Part # P15431
• C4, C104 = 22 nF, 5%	Digi-Key Part # P4517
• C5, C105 = 33 nF, 5%	Digi-Key Part # 495-1307
• C6, C106 = 47 nF, 5%	Digi-Key Part # 495-1290
• C7, C8 = 68 µF, 35 V	Digi-Key Part # P12926
• C9, C10 = 0.1 µF	Digi-Key Part # 445-4756
• C201, C202 = 3,300 µF, 35 V	Digi-Key Part # 565-2864
• C203, C204 = 47 µF, 35 V	Digi-Key Part # P5164
• C205 = 4.7 µF, 35 V	Digi-Key Part # P817
• C206 = 15 µF, 35 V	Digi-Key Part # P14495

Electrical Mechanical

• RY = DPDT 24-V relay	Digi-Key Part # Z769
• S1 = SPDP Toggle switch	Digi-Key Part # EG2350
• S2 = 4PDP Toggle switch	Digi-Key Part # EG2428
• T1 = Power transformer	Digi-Key Part # TE70064

Miscellaneous

- Molex connectors
- Insulators
- Power cord
- Screws
- Standoffs

Resistors

• R1, R101, R206 = 47 kΩ	
• R2, R102 = MC load	Value dependent on cartridge
• R3, R103 = 18 Ω	
• R4, R10, R104, R110 = 150 Ω	All resistors are 0.25 W 1% metal
• R5, R11, R105, R111 = 3.32 kΩ	film unless otherwise specified
• R6, R106 = 26.1 kΩ	
• R7, R107 = 909 Ω	
• R8, R108 = 3.83 kΩ	
• R9, R12, R109, R102 = 100 Ω	
• R201 = 200 kΩ	
• R202, R207 = 4.7 kΩ	
• R203, R204 = 10 kΩ	
• R205 = 470 Ω, 0.05 W	
• R210, R211 = 470 Ω	
• R212, R213 = 2.7 Ω	
• R214 = 1 kΩ (higher if LED is too bright)	

Semiconductors

• D1–D7 = 1N4007	Silicon diode
• IC1 = LME49740	Digi-Key Part # LME49740
• IC2 = LM317K	Positive adjustable regulator
• IC3 = LM337K	Negative adjustable regulator
• Q1, Q2 = MPSA05	NPN transistor
• Q3 = TIP32	PNP transistor

Ohio). The company made an adhesive-backed decal for the chassis. A durable vinyl film laminated to the front protects the lettering and looks as good as any commercial product I have seen. The cost was reasonable and I would recommend this company to anyone who has a custom-labeling requirement.

In order to test the completed unit, I measured the response at several frequencies and compared the results to published tables. The results for a limited amount of data points are listed in **Table 1**.

The sampling shows a remarkable fit preamplifier, except for a slight drop above 10,000 Hz (see **Figure 5**). The left and right channels tracked almost perfectly. As mentioned earlier, I could not measure any noise.

TESTING THE DESIGN

Having completed the bench testing, a few audiophile friends and I auditioned the preamplifier using a few different phono cartridges. Two of them were MM catridges, the Audio Technica AT-150MLX with a 100-pF capacitive load and the Shure V15 III with a 400-pF capacitive load. (I chose the low end of the recommended values to allow for the capacitance of the input cables.) I also tested a Benz Micro Gold MC cartridge with a 510-Ω resistive load.

The preamplifier sounded great with all three cartridges, actually better than a highly rated commercial preamplifier. I made two preamplifiers, one for me and one for my friend (see **Photo 4**). *aX*