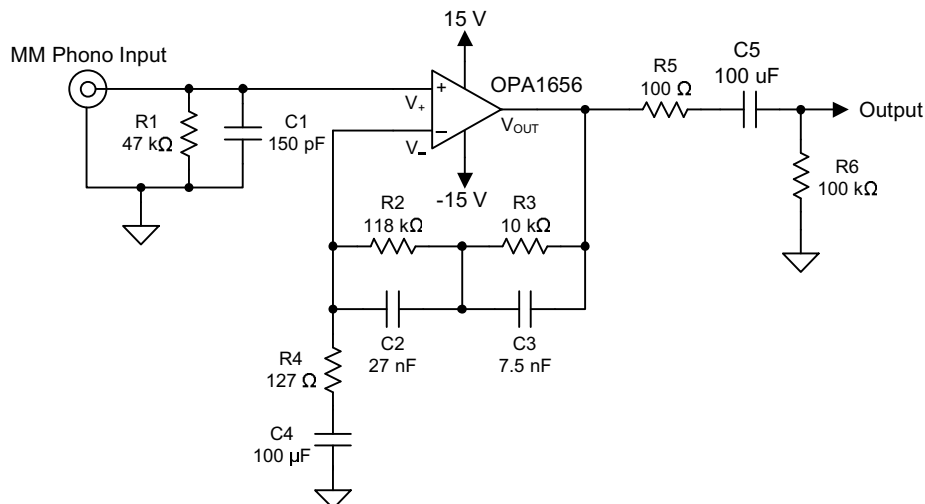


## 8.2 Typical Applications

### 8.2.1 Preamplifier Circuit for Vinyl Record Playback With Moving-Magnet Phono Cartridges

The noise and distortion performance of the OPA1656 is exceptional in applications with high source impedances, which makes these devices an excellent choice in preamplifier circuits for moving magnet phono cartridges. The high source impedance of the cartridge, and high gain required by the RIAA playback curve at low frequency, requires an amplifier with both low input current noise and low input voltage noise.



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**Figure 47. Preamplifier Circuit for Vinyl Record Playback With Moving-Magnet Phono Cartridges (Single Channel Shown)**

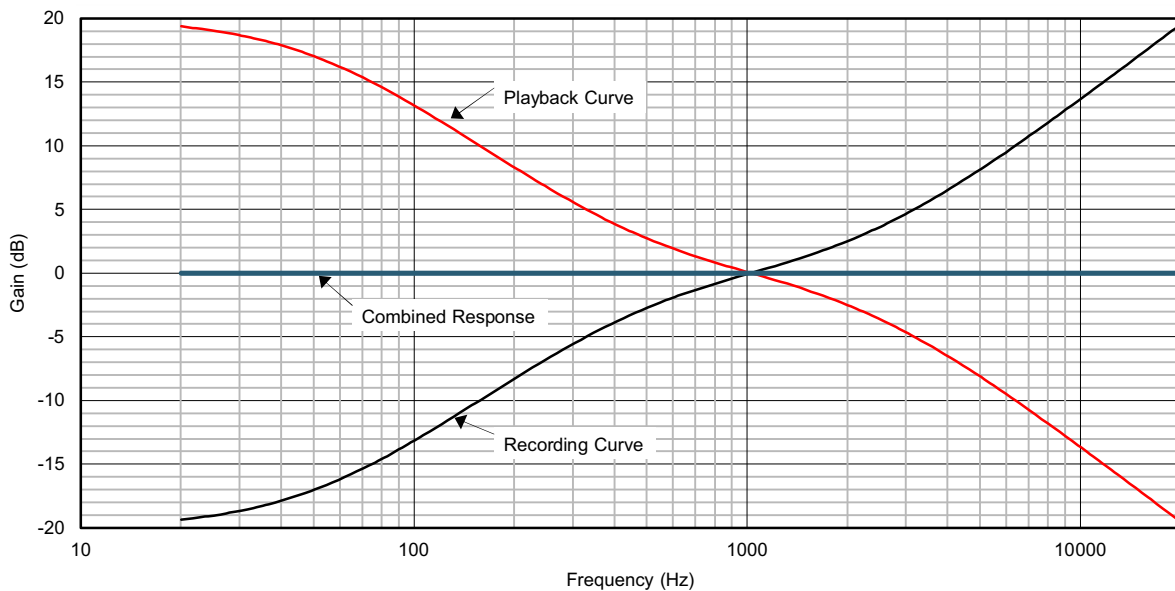
#### 8.2.1.1 Design Requirements

- “ Gain: 40 dB (1 kHz)
- “ RIAA Accuracy:  $\pm 0.5$  dB (100 Hz to 20 kHz)
- “ Power Supplies:  $\pm 15$  V

## Typical Applications (continued)

### 8.2.1.2 Detailed Design Procedure

Vinyl records are recorded using an equalization curve specified by the Recording Institute Association of America (RIAA). The purpose of this equalization curve is to decrease the amount of space occupied by a groove on the record and therefore maximize the amount of information able to be stored. Proper playback of music stored on the record requires a preamplifier circuit that applies the inverse transfer function of the recording equalization curve. The combination of the recording equalization and the playback equalization results in a flat frequency response over the audio range, as Figure 48 shows.



**Figure 48. RIAA Recording and Playback Curves Normalized at 1 kHz**

The basic RIAA playback curve implements three time constants: 75  $\mu$ s, 380  $\mu$ s, and 3180  $\mu$ s. An IEC amendment is later added to the playback curve and implements a pole in the curve at 20 Hz with the intent of protecting loudspeakers from excessive low frequency content. Rather than strictly adhering to the IEC amendment, this design moves this pole to a lower frequency to improve low frequency response and still providing protection for loudspeakers.

Resistor R1 and capacitor C1 are selected to provide the proper input impedance for the moving magnet cartridge. Cartridge loading is specified by the manufacturer in the cartridge datasheet and is absolutely crucial for proper response at high frequency. 47 k $\Omega$  is a common value for the input resistor, and the capacitive loading is usually specified to 200 pF to 300 pF per channel. This capacitive loading specification includes the capacitance of the cable connecting the turntable to the preamplifier, as well as any additional parasitic capacitances at the preamplifier input. Therefore, the value of C1 must be less than the loading specification to account for these additional capacitances.

The output network consisting of R5, R6, and C5 serves to ac couple the preamplifier circuit to any subsequent electronics in the signal path. The 100- $\Omega$  resistor R5 limits in-rush current into coupling capacitor C5 and prevents parasitic capacitance from cabling from causing instability. R6 prevents charge accumulation on C5. Capacitor C5 is chosen to be the same value as C4; for simplicity however, the value of C5 must be large enough to avoid attenuating low frequency information.

## Typical Applications (continued)

The feedback resistor elements must be selected to provide the correct response within the audio bandwidth. In order to achieve the correct frequency response, the passive components in [Figure 47](#) must satisfy [Equation 1](#), [Equation 2](#), and [Equation 3](#):

$$R_2 \times C_2 = 2200 \mu\text{s} \quad (1)$$

$$R_3 \times C_3 = 75 \mu\text{s} \quad (2)$$

$$(R_2 \parallel R_3) \times (C_2 + C_3) = 2200 \mu\text{s} \quad (3)$$

R2, R3, and R4 must also be selected to meet the design requirements for gain. The gain at 1 kHz is determined by subtracting 20 dB from gain of the circuit at very low frequency (near dc), as shown in [Equation 4](#):

$$A_{1\text{kHz}} = A_{\text{LF}} - 20\text{dB} \quad (4)$$

Therefore, the low frequency gain of the circuit must be 60 dB to meet the goal of 40 dB at 1 kHz and is determined by resistors R2, R3, and R4 as shown in [Equation 5](#):

$$A_{\text{LF}} = 1 + \frac{R_2 + R_3}{R_4} = 1000(60\text{dB}) \quad (5)$$

Because there are multiple combinations of passive components that satisfy these equations, a spreadsheet or other software calculation tool is the easiest method to examine resistor and capacitor combinations.

Capacitor C4 forces the gain of the circuit to unity at dc in order to limit the offset voltage at the output of the preamplifier circuit. The high-pass corner frequency created by this capacitor is calculated by [Equation 6](#):

$$F_{\text{HP}} = \frac{1}{2\pi R_4 C_4} \quad (6)$$

The circuit described in [Figure 47](#) is constructed with 1% tolerance resistors and 5% tolerance NP0, C0G ceramic capacitors without any additional hand sorting. The large value of C4 typically requires an electrolytic type to be used. However, electrolytic capacitors have the potential to introduce distortion into the signal path. This circuit is constructed using a bipolar electrolytic capacitor specifically intended for audio applications.

### 8.2.1.3 Application Curves

The deviation from the ideal RIAA transfer function curve is shown in [Figure 49](#) and normalized to an ideal gain of 40 dB at 1 kHz. The measured gain at 1 kHz is 0.05 dB less than the design goal, and the maximum deviation from 100 Hz to 20 kHz is 0.18 dB. The deviation from the ideal curve can be improved by hand-sorting resistor and capacitor values to their ideal values. The value of C4 can also be increased to reduce the deviation at low frequency.

A spectrum of the preamplifier output signal is shown in [Figure 50](#) for a 10 mV<sub>RMS</sub>, 1-kHz input signal (1-V<sub>RMS</sub> output). All distortion harmonics are below the preamplifier noise floor.

