

# Reducing Crosstalk in Directpath™ Headphone Amplifiers

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## ABSTRACT

Crosstalk is a common issue faced when using a stereo Directpath™ headphone amplifier. While using a simple headphone speaker this artifact may not be audible, but if an external amplifier with large gains is used, crosstalk might become audible. The crosstalk is measured using an audio analyzer and the connecting point where the measurement is taken is critical to get the correct reading. This application report talks about the design time considerations for reducing the cross talk. The measurement can be skewed if using the wrong headset during tests

### 1 What is Crosstalk in a Stereo or Multichannel Audio Amplifier?

An un-desired signal coupling between the channels of amplifier is called cross talk. Though the IC's are designed to have maximum separation between channels, external factors such as power supplies, designs, PCB layout, components, and so on, can affect the crosstalk.

### 2 What is a Directpath™ Amplifier?

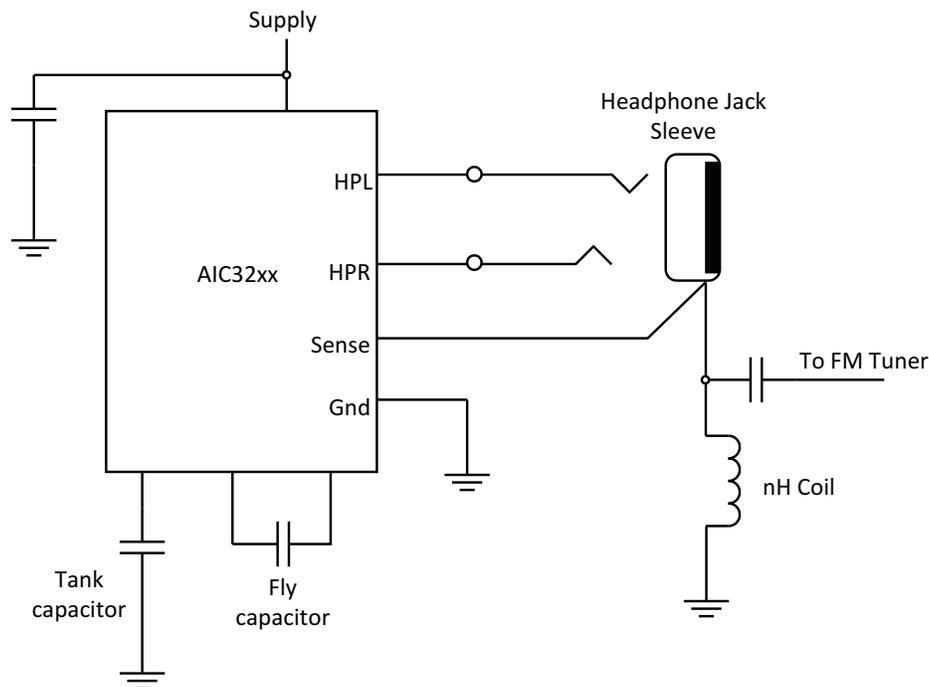
A Directpath™ amplifier is an amplifier where the signal is centered with respect to ground (Ground Centered Amplifier). Ground centering avoids the need for large DC Blocking output capacitors, saving board space and cost. This eliminates the High Pass Filter (HPF) that is formed while connecting the load and gives excellent low frequency response. The amplifier allows the output signal to swing -ve below the ground signal level. If the amplifier is operated using single supply, there is a charge pump based power supply generated to create the opposite polarity supply. These types of amplifiers can be known by different names by different semiconductor manufacturers.

To center the output close to the ground level, and to reduce the DC current flowing through the headphones (power wastage), and to increase the battery life in portable devices, most direct path amplifiers sense the ground potential using a separate pin. The point where the ground potential is sensed becomes important. Large variations in sensing this potential cause reduced performance of the amplifier, specifically noise, distortion and crosstalk. Some amplifiers are designed to accept up to few hundreds of millivolts at the sense pin by compromising the Power delivered and Distortion. See the device data sheet about this information.

### 3 What Causes Crosstalk in Directpath™ Amplifier?

Analyzing the two circuit configurations allows the user to know the impact of cross talk performance. The changes are minimal between them, yet a large variation in crosstalk is found.

### 3.1 Case 1- No or Minimal Crosstalk



**Figure 1. Typical Application Reference Diagram**

Figure 1 is commonly used in most mobile phones and tablets. The headphone cable is also used as an FM antenna.

The amplifier sets a bias output signal riding on the voltage sensed by the sense pin. With this technique and Kirchhoff's current law, Figure 1 is analyzed. Assume a sine wave signal is applied to only on the HP (Head Phone) left output. The current that returns to ground during positive sine wave cycle causes a voltage drop across the nH coil. Thus, the sense pin has some voltage sensed instead of clean ground potential of 0V. The HP amplifier right output contains this small signal. Thus, a right ear headphone load that is connected to the jack has both terminals swinging simultaneously causing the potential difference to be zero, and hence, no audible output - no crosstalk. The same is true when the signal is playing only on the HP right channel.

Using Equation 1, consider the impedance offered by the nH coil as  $z_H$  (frequency dependant). A signal at the left output causes the  $I_L$  current to flow. Thus, the voltage sensed by the sense pin on the ground sleeve is

$$v_T = I_L \times z_H \quad (1)$$

The output of the amplifier is:

$$v_T + A \times \sin(\omega t) \quad (2)$$

The right headphone speaker will see  $v_T$  on the jack common sleeve and the thus the signal to the load can be only  $A \times \sin(\omega t)$ . Therefore, there is no crosstalk.

### 3.2 Case2- Increased Crosstalk

Using Figure 2, add a 0Ω resistor intentionally, and the sense pin is connected after this resistor. Also this resistor, is assumed as a PCB routing resistance even if it is in mΩ.

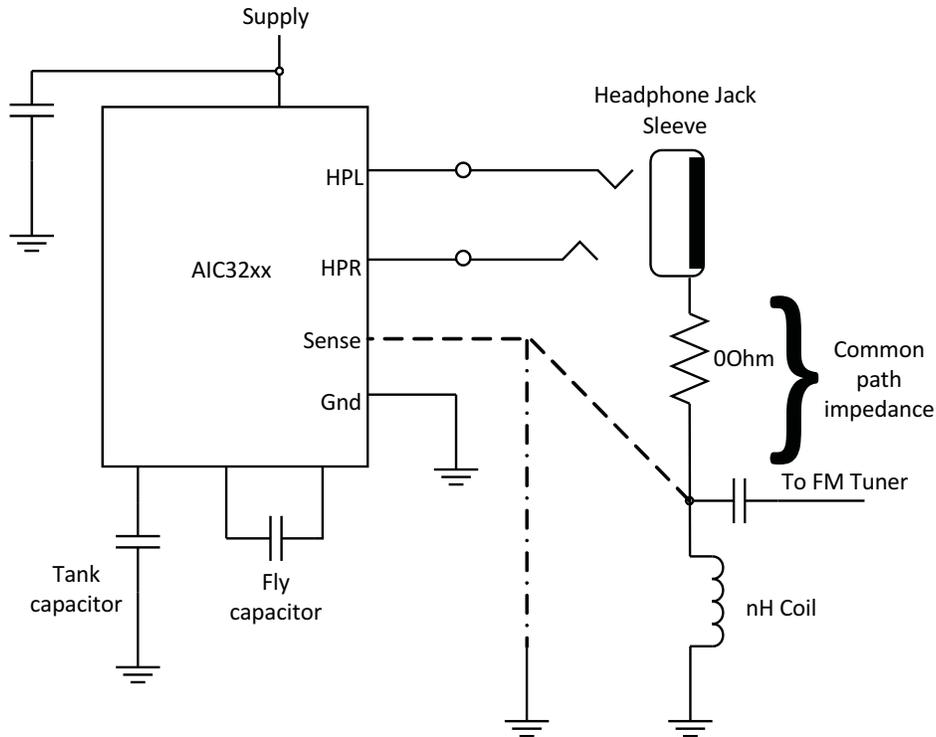


Figure 2.

Analyzing Figure 2, the voltage at the common sleeve  $v_T$ :

$$v_T = I_L \times (Z_H + Z_R) \tag{3}$$

But the voltage sensed by the sensing circuit is only:

$$v_S = I_L \times Z_H \tag{4}$$

Now, the output of the amplifier is  $v_S + A \times \sin(\omega t)$ . The right headphone speaker has  $v_T$  voltage at the common sleeve and  $v_S + A \times \sin(\omega t)$  at the signal. The difference is  $I_L \times Z_R$ , is the amount of crosstalk.

#### 4 How much is the Crosstalk?

If the amplifier is delivering 10mW power into 16Ω load per channel. This causes 25mA to flow through the common path and the voltage swinging would be 400mV at the output. Assume routing resistance of 1mΩ and the voltage is dropped across this resistor it is 25μV.

Crosstalk,  $20 \times \text{LOG}_{10}(25\mu\text{V}/400\text{mV}) = -84.08\text{dB}$ . With 5mΩ as routing resistance the crosstalk will increase to -70.1dB

This is worse if the sensing is done on a ground point with inductor in common path as shown in Figure 2.

## 5 **How or Where to Measure the Crosstalk in a System that has Directpath™ Amplifier?**

While taking a crosstalk measurement with an audio analyzer, the connections must be made at the jack terminals directly. This is what the headphones or an external amplifier will see and the human ears will hear. If the measurement is with respect to system ground it may be skewed from the correct value.

## 6 **Conclusion**

The PCB layout is critical in reducing the crosstalk between channels. Always connect the ground sense pin of the device to the jack common terminal. Reduce the common current paths as much as possible. If additional components are unavoidable, use layout techniques to reduce the common path resistance and connect sense as close to jack as possible.

Some headphone comes with cables that have single wire (common path) for return currents and performance measurements taken with such headphones will be skewed towards bad numbers. Bad soldering (increased contact resistance) on the sleeve also causes increased crosstalk. The layout techniques such as modifying the footprint for sleeve (kelvin connection for ground and sense) can resolve the contact resistance issue.

For further questions, contact TI through the E2E forum or your local sales representatives.

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