Headphone Jack Detection in Personal Electronics Using Comparators

Electronic devices from cell phones to laptop computers usually include a stereo headphone jack. When an external headphone is plugged in, the built-in speaker must be disconnected and the audio output switched to the external device. The switching process must be free of any clicking noise and may also provide additional user experience features such as audio volume fading in and out, pausing the music player, and so forth.

The output switching process is commonly accomplished through dedicated control circuitry. It may require constant power even after the host device is in sleep mode because these device would still register and respond to the user's actions while in this state. In this case, low quiescent current (I_Q) becomes a key requirement.

The control circuitry is commonly built with comparators at its core. The newly introduced nano-power and small size open-drain TLV7041 comparator is designed for these applications.

The TLV7041 comparator includes the following benefits:

1. 335-nA typical quiescent supply current
2. 3-pA typical input bias current
3. Input protection and flexible output pullup options (1.6 V to 6.5 V)
4. Small package dimensions (0.8 mm × 0.8 mm × 0.4 mm)

To meet these requirements, the audio output must be switched to the external device only when the headphone jack is fully seated. This is normally accomplished by the confirmation that both the tip and ground (G) of the headphone plug are connected.

Figure 1 shows the connection terminals of a typical headphone plug (left) and its matching socket (right). In this configuration, two dedicated terminals GND_detect and L_detect are responsible for the state detection. When the headphone jack is fully engaged, GND_detect is connected to GND and the L_detect to L (left audio channel) through the conductor segments of the headphone plug (left). When L_detect is connected, the headphone jack is considered fully seated based on the fact that the L_detect terminal and plug tip L are situated at the far end of the headphone plug.

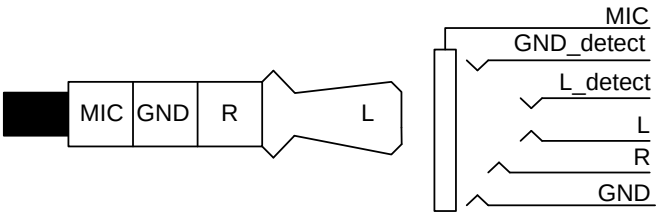

Figure 1. Headphone plug (Left) and Socket

The control circuit uses GND_detect and L_detect terminals to determine the plugged-in state, and the circuit sets the output headset_on_n (active low) accordingly. Figure 2 shows a complete schematic of the circuit based on a single TLV7041.

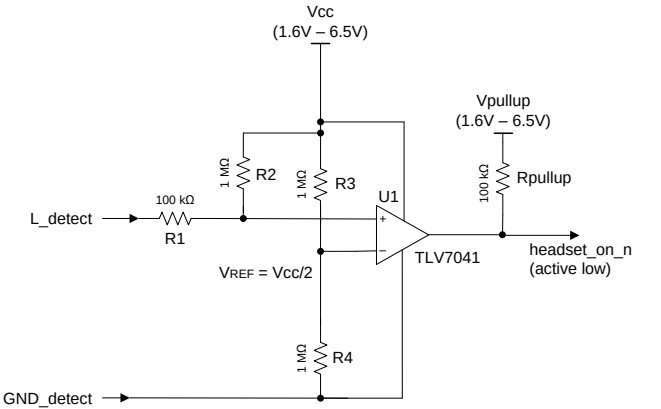

Figure 2. Headphone Detection Circuit

The resistor network (R3 and R4) establishes a reference V_{REF} at $V_{CC}/2$ which feeds to the inverting input of TLV7041. R2 pulls the noninverting input to V_{CC} when the headphone jack is not engaged, causing the open-drain output pulled high to V_{pullup}. Thanks to TLV7041's low input bias current (typically at 3 pA), larger resistance values can be used for R2, R3, and R4 (all three resistors are 1 MΩ) without compromising accuracy, which helps reduce total power consumption.

Notice that the V_{EE} of the comparator is connected to the GND_detect instead of to GND. When the headphone jack is not engaged, V_{EE} is pulled to the same level as V_{CC} through R3 and R4 and consequently the comparator is not powered. This causes the output headset_on_n pulled high to V_{pullup}, which indicates an inactive state.

When a user plugs in the headphone jack, the V_{EE} of the comparator is first connected to GND through the GND_detect to power the comparator. This *floating ground* design technique is made possible thanks to the TLV7041 robust input and output protection and design features. For further details, refer to the *Application and Implementation* section of the TLV7041 data sheet.

When the headphone jack is fully seated, the L_detect terminal is connected to L by the conductor tip of the headphone plug. Consequently, the lower impedance of the headphone coil (through R1) pulls the noninverting input below V_{REF}, which brings the output (headset_on_n) to low (active state) to indicate the headphone has been plugged in.

R1 is used to limit the maximum current fed into the TLV7041 input. Before GND_detect is robustly connected to GND, the device's V_{EE} is pulled to V_{CC}. During which, if L_detect is momentarily pulled low, the input level could potentially be below V_{EE}. In this case, R1 limits the current flowing though the input ESD diode (now turned on).

The example uses a separate V_{pullup} to support a load that is powered with a different supply. If that is not the case, a common supply can be used for both V_{CC} and V_{pullup}, and the sister push-pull output feature of the TLV7031 may also be an option.

If you have questions on comparator application, please visit the E2E forum on ti.com.

Table 1 shows the truth table of the circuit.

Table 1. Headphone Jack Detection Truth Table

INPUT		OUTPUT	HEADPHONE JACK STATE
GND_detect	*L_detect*	*headset_on_n*	
Open	Open	high	not plugged in
GND	Open	high	not plugged in
Open	L	high	not plugged in
GND	L	low	plugged in

In summary, the TLV7041 comparator provides several benefits such as low quiescent current, virtually negligible input bias current, small package size, and robust input and output protection engineers can use in power-conscious potable applications.

Table 2. Alternative Open-Drain Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
TLV7081	I_Q = 370 nA, 4-pin WCSP (0.7 × 0.7 mm^2) Package	Prop Delay = 4 µs
TLV7021	Prop Delay = 260 ns, 5-pin X2SON (0.8 × 0.8 mm^2) Package	I_Q=5 µA
TLV3691	I_Q = 75 nA, 4-pin X2SON (1 × 1 mm^2) Package	Prop Delay = 24 µs

Table 3. Adjacent Tech Notes

SNOA981	Nano-Power Battery Monitoring in Personal Electronics
SNVA808	Low Power Comparator for Signal Processing and Wake-Up Circuit in Smart Meters
SCEA055	Designing and Manufacturing with TI's X2SON Packages

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