**FEATURES**

- 3-Wire Serial Interface
- Daisy-Chain Capability
- 104dB Mute Attenuation
- Pop and Click Free Attenuation Changes

**APPLICATIONS**

- Automated Studio Mixing Consoles
- Music Reproduction Systems
- Sound Reinforcement Systems
- Electronic Music (MIDI)
- Personal Computer Audio Control

**KEY SPECIFICATIONS**

- Total Harmonic Distortion + Noise: 0.003 % (max)
- Frequency response: 100 kHz (~3dB) (min)
- Attenuation range (excluding mute): 76 dB (typ)
- Differential attenuation: ±0.25 dB (max)
- Signal-to-noise ratio (ref. 4 Vrms): 110 dB (min)
- Channel separation: 110 dB (typ)

**DESCRIPTION**

The LM1973 is a digitally controlled 3-channel 76dB audio attenuator fabricated on a CMOS process. Each channel has attenuation steps of 0.5dB from 0dB–15.5dB, 1.0dB steps from 16dB–47dB, and 2.0dB steps from 48dB–76dB, with a mute function attenuating 104dB. Its logarithmic attenuation curve can be customized through software to fit the desired application.

The performance of a µPot is demonstrated through its excellent Signal-to-Noise Ratio, extremely low (THD+N), and high channel separation. Each µPot contains a mute function that disconnects the input signal from the output, providing a minimum attenuation of 96dB. Transitions between any attenuation settings are pop free.

The LM1973’s 3-wire serial digital interface is TTL and CMOS compatible; receiving data that selects a channel and the desired attenuation level. The Data-Out pin of the LM1973 allows multiple µPots to be daisy-chained together, reducing the number of enable and data lines to be routed for a given application.

**TYPICAL APPLICATION**

![Figure 1. Typical Audio Attenuator Application Circuit](image)

**CONNECTION DIAGRAM**

![Figure 2. PDIP and SOIC Packages](image)

See Package Numbers NFH0020A and DW0020B

---

**Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.**

All trademarks are the property of their respective owners.
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### ABSOLUTE MAXIMUM RATINGS (1)(2)(3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage (V&lt;sub&gt;DD&lt;/sub&gt;−V&lt;sub&gt;SS&lt;/sub&gt;)</td>
<td>15V</td>
</tr>
<tr>
<td>Voltage at Any Pin</td>
<td>V&lt;sub&gt;SS&lt;/sub&gt; − 0.2V to V&lt;sub&gt;DD&lt;/sub&gt; + 0.2V</td>
</tr>
<tr>
<td>Power Dissipation (4)</td>
<td>150 mW</td>
</tr>
<tr>
<td>ESD Susceptibility (5)</td>
<td>1800V</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>150°C</td>
</tr>
<tr>
<td>Soldering Information</td>
<td>NFH0020A Package (10 sec.)</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>−65°C to +150°C</td>
</tr>
</tbody>
</table>

1. All voltages are measured with respect to GND (pins 1, 3, 5, 14, 17), unless otherwise specified.
2. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional. Electrical Characteristics state DC and AC electrical specifications under particular test conditions and specific performance limits. This assumes that the device is within the Operating Ratings. The typical value is a good indication of device performance.
3. If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
4. The maximum power dissipation must be derated at elevated temperatures and is dictated by T<sub>MAX</sub>, θ<sub>JA</sub>, and the ambient temperature T<sub>A</sub>. The maximum allowable power dissipation is PD = (T<sub>MAX</sub> − T<sub>A</sub>)θ<sub>JA</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM1973N, T<sub>MAX</sub> = +150°C, and the typical junction-to-ambient thermal resistance, when board mounted, is 65°C/W.
5. Human body model, 100 pF discharged through a 1.5 kΩ resistor.

### OPERATING RATINGS (1)(2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Range</td>
<td>T&lt;sub&gt;MIN&lt;/sub&gt; ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ T&lt;sub&gt;MAX&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>0°C ≤ T&lt;sub&gt;A&lt;/sub&gt; ≤ +70°C</td>
</tr>
<tr>
<td>Supply Voltage (V&lt;sub&gt;DD&lt;/sub&gt; − V&lt;sub&gt;SS&lt;/sub&gt;)</td>
<td>4.5V to 12V</td>
</tr>
</tbody>
</table>

1. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional. Electrical Characteristics state DC and AC electrical specifications under particular test conditions and specific performance limits. This assumes that the device is within the Operating Ratings. The typical value is a good indication of device performance.
2. All voltages are measured with respect to GND (pins 1, 3, 5, 14, 17), unless otherwise specified.
**ELECTRICAL CHARACTERISTICS** *(1)(2)*

The following specifications apply for all channels with \( V_{DD} = +6\text{V}, \ V_{SS} = -6\text{V}, \ V_{IN} = 5.5 \ \text{Vpk}, \) and \( f = 1 \ \text{kHz}, \) unless otherwise specified. Limits apply for \( T_A = 25^\circ \text{C}. \) Digital inputs are TTL and CMOS compatible.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_S )</td>
<td>Supply Current</td>
<td>Inputs are AC Grounded</td>
<td>3</td>
<td>5</td>
<td>mA (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THD+N</td>
<td>Total Harmonic Distortion plus Noise</td>
<td>( V_{IN} = 0.5 \ \text{Vpk at 0dB Attenuation} )</td>
<td>0.0008</td>
<td>0.003</td>
<td>% (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XTalk</td>
<td>Crosstalk (Channel Separation)</td>
<td>0dB Attenuation for ( V_{IN} )</td>
<td>110</td>
<td>dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{CH} ) measured at −76dB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-Noise Ratio</td>
<td>Inputs are AC Grounded at −12dB Attenuation</td>
<td>120</td>
<td>110</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-Weighted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( A_M )</td>
<td>Mute Attenuation</td>
<td>104</td>
<td>96</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attenuation Step Size Error</td>
<td>0dB to −16dB</td>
<td>±0.05</td>
<td>dB (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>−17dB to −48dB</td>
<td>±0.1</td>
<td>dB (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>−49dB to −76dB</td>
<td>±0.25</td>
<td>dB (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absolute Attenuation Error</td>
<td>Attenuation at 0dB</td>
<td>0.01</td>
<td>0.5</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attenuation at −20dB</td>
<td>19.8</td>
<td>19.0</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attenuation at −40dB</td>
<td>39.5</td>
<td>38.5</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attenuation at −60dB</td>
<td>59.3</td>
<td>58.0</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attenuation at −76dB</td>
<td>74.5</td>
<td>73.0</td>
<td>dB (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Channel-to-Channel Attenuation</td>
<td>Attenuation at 0dB, −20dB, −40dB, −60dB</td>
<td>±0.5</td>
<td>dB (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tracking Error</td>
<td>Attenuation at −76dB</td>
<td>±0.75</td>
<td>dB (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{LEAK} )</td>
<td>Analog Input Leakage Current</td>
<td>Inputs are AC Grounded</td>
<td>10.0</td>
<td>100</td>
<td>nA (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{IN} )</td>
<td>AC Input Impedance</td>
<td>Pins 2, 4, 18, ( V_{IN} = 1.0 \ \text{Vpk}, \ f = 1 \ \text{kHz} )</td>
<td>40</td>
<td>20</td>
<td>k( \Omega ) (min)</td>
<td>60</td>
<td>k( \Omega ) (max)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{IN} )</td>
<td>Input Current</td>
<td>at Pins 9, 10, 11 at 0V &lt; ( V_{IN} &lt; 5V )</td>
<td>1.0</td>
<td>±100</td>
<td>nA (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{CLK} )</td>
<td>Clock Frequency</td>
<td></td>
<td>3</td>
<td>2</td>
<td>MHz (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{IH} )</td>
<td>High-Level Input Voltage</td>
<td>at Pins 9, 10, 11</td>
<td></td>
<td></td>
<td>2.0</td>
<td>V (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{IL} )</td>
<td>Low-Level Input Voltage</td>
<td>at Pins 9, 10, 11</td>
<td></td>
<td></td>
<td>0.8</td>
<td>V (max)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Data-Out Levels (Pin 12)</td>
<td>( V_{DD} = 6\text{V}, \ V_{SS} = 0\text{V} )</td>
<td></td>
<td></td>
<td>0.1</td>
<td>V (max)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.9</td>
<td>V (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions and specific performance limits. This assumes that the device is within the Operating Ratings. The typical value is a good indication of device performance.

(2) All voltages are measured with respect to GND (pins 1, 3, 5, 14, 17), unless otherwise specified.

(3) Typicals are measured at 25°C and represent the parametric norm.

(4) Limits are specified to TI’s AOQL (Average Output Quality Level).

(5) At the present time the Crosstalk measurement is specified as a typical only, which is due to a hardware limitation of the automated test equipment.
PIN DESCRIPTIONS

**Signal Ground (1, 5, 17):** Each input has its own independent ground, GND1, GND2, and GND3.

**Signal Input (2, 4, 18):** There are 3 independent signal inputs, IN1, IN2, and IN3.

**Signal Output (6, 16, 20):** There are 3 independent signal outputs, OUT1, OUT2, and OUT3.

**Voltage Supply (13, 15):**

**Voltage Supply (7, 19):** Negative voltage supply pins, $V_{SS1}$ and $V_{SS2}$. To be tied to ground in a single supply configuration.

**AC Ground (3, 14):** These two pins are not physically connected to the die in any way (i.e., No bondwires). These pins must be AC grounded to prevent signal coupling between any of the pins nearby. Pin 14 should be connected to pins 13 and 15 for ease of wiring and the best isolation.

**Logic Ground (8):** Digital signal ground for the interface lines; CLOCK, LOAD/SHIFT, DATA-IN and DATA-OUT.

**Clock (9):** The clock input accepts a TTL or CMOS level signal. The clock input is used to load data into the internal shift register on the rising edge of the input clock waveform.

**Load/Shift (10):** The load/shift input accepts a TTL or CMOS level signal. This is the enable pin of the device, allowing data to be clocked in while this input is low (0V).

**Data-In (11):** The data-in input accepts a TTL or CMOS level signal. This pin is used to accept serial data from a microcontroller that will be latched and decoded to change a channel's attenuation level.

**Data-Out (12):** This pin is used in daisy-chain mode where more than one μPot is controlled via the same data line. As the data is clocked into the chain from the μC, the preceding data in the shift register is shifted out the DATA-OUT pin to the next μPot in the chain or to ground if it is the last μPot in the chain. The LOAD/SHIFT line goes high once all of the new data has been shifted into each of its respective registers.
**TYPICAL PERFORMANCE CHARACTERISTICS**

**Figure 4.** Supply Current vs Supply Voltage

**Figure 5.** Supply Current vs Temperature

**Figure 6.** Noise Floor Spectrum by FFT

**Figure 7.** THD vs Frequency

**Figure 8.** THD vs Output Voltage

**Figure 9.** Crosstalk Test

Copyright © 1994–2013, Texas Instruments Incorporated

Product Folder Links: LM1973
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

**THD + N vs Frequency and Amplitude**

![Figure 10.](image1)

**FFT of 1 kHz THD**

![Figure 11.](image2)

**THD + N vs Amplitude**

- **f = 1 kHz, V_{DD} = ±6V**
- **V_{DD} = ±6V, V_{DPAMP} = ±15V**

![Figure 12.](image3)

**FFT of 20 kHz THD**

![Figure 13.](image4)

**THD + N vs Amplitude**

- **f = 20 kHz, V_{DD} = ±6V**
- **V_{IN} into CH1 at 0 dB**

![Figure 14.](image5)

**THD + N vs Amplitude**

- **f = 20 kHz, V_{DD} = ±6V**
- **V_{IN} into CH1 at 0 dB**

![Figure 15.](image6)
APPLICATION INFORMATION

ATTENUATION STEP SCHEME

The fundamental attenuation step scheme for the LM1973 μPot is shown in Figure 16. This attenuation step scheme, however, can be changed through programming techniques to fit different application requirements. One such example would be a constant logarithmic attenuation scheme of 2dB steps for a panning function as shown in Figure 18. The only restriction to the customization of attenuation schemes are the given attenuation levels and their corresponding data bits shown in Table 1. The device will change attenuation levels only when a channel address is recognized. When recognized, the attenuation level will be changed corresponding to the data bits shown in Table 1. As shown in Figure 19, an LM1973 can be configured with a mono audio signal level control and with a panning control which separates the mono signal into left and right channels. This circuit may utilize the fundamental attenuation scheme of the LM1973 for the level control, but also possess a constant 2dB panning control for the left and right channels as stated earlier.

![LM1973 Channel Attenuation vs Digital Step Value](image1)

**Figure 16.**

![LM1973 1.0dB and 2.0dB Attenuation Step Scheme](image2)

**Figure 17.**
INPUT IMPEDANCE

The input impedance of a μPot is constant at a nominal 40 kΩ. To eliminate any unwanted DC components from propagating through the device it is common to use 1 μF input coupling caps. This is not necessary, however, if the dc offset from the previous stage is negligible. For higher performance systems, input coupling caps are preferred.

OUTPUT IMPEDANCE

The output of a μPot varies typically between 25 kΩ and 35 kΩ and changes nonlinearly with step changes. Since a μPot is made up of a resistor ladder network with a logarithmic attenuation, the output impedance is nonlinear. Due to this configuration, a μPot cannot be considered as a linear potentiometer, but can be considered only as a logarithmic attenuator.

It should be noted that the linearity of a μPot cannot be measured directly without a buffer because the input impedance of most measurement systems is not high enough to provide the required accuracy. Due to the low impedance of the measurement system, the output of the μPot would be loaded down and an incorrect reading will result. To prevent loading from occurring, a JFET input op amp should be used as the buffer/amplifier. The performance of a μPot is limited only by the performance of the external buffer/amplifier.

MUTE FUNCTION

One major feature of a μPot is its ability to mute the input signal to an attenuation level of 104dB as shown in Figure 16. This is accomplished internally by physically isolating the output from the input while also grounding the output pin through approximately 2 kΩ.
The mute function is obtained during power-up of the device or by sending any binary data of 01001111 and above (to 11111111) serially to the device. The device may be placed into mute from a previous attenuation setting by sending any of the above data. This allows the designer to place a mute button onto his system which could cause a microcontroller to send the appropriate data to a μPot and thus mute any or all channels. Since this function is achieved through software, the designer has a great amount of flexibility in configuring the system.

**DC INPUTS**

Although the μPot was designed to be used as an attenuator for signals within the audio spectrum, the device is capable of tracking an input DC voltage. The device will track DC voltages to a diode drop above each supply rail.

One point to remember about DC tracking is that with a buffer at the output of the μPot, the resolution of DC tracking will depend upon the gain configuration of that output buffer and its supply voltage. It should also be remembered that the output buffer’s supply voltage does not have to be the same as the μPot’s supply voltage. This could allow for more resolution when DC tracking.

**SERIAL DATA FORMAT**

The LM1973 uses a 3-wire serial communication format that is easily controlled by a microcontroller. The timing for the 3-wire set, comprised of DATA-IN, CLOCK, and LOAD/SHIFT is shown in Figure 3. Figure 22 exhibits in block diagram form how the digital interface controls the tap switches which select the appropriate attenuation level. As depicted in Figure 3, the LOAD/SHIFT line is to go low at least 150 ns before the rising edge of the first clock pulse and is to remain low throughout the transmission of each set of 16 data bits. The serial data is comprised of 8 bits for channel selection and 8 bits for attenuation setting. For both address data and attenuation setting data, the MSB is sent first and the 8 bits of address data are to be sent before the 8 bits of attenuation data. Please refer to Figure 20 to confirm the serial data format transfer process.

**Table 1. LM1973 Micropot Attenuator Register Set Description**

<table>
<thead>
<tr>
<th>MSB: LSB</th>
<th>Address Register (Byte 0)</th>
<th>Data Register (Byte 1)</th>
<th>Attenuation Level dB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Channel 1</td>
<td>Contents</td>
<td></td>
</tr>
<tr>
<td>0000 0000</td>
<td>Channel 2</td>
<td>0000 0000</td>
<td>0.0</td>
</tr>
<tr>
<td>0000 0001</td>
<td>Channel 3</td>
<td>0000 001</td>
<td>0.5</td>
</tr>
<tr>
<td>0000 0010</td>
<td></td>
<td>0000 0010</td>
<td>1.0</td>
</tr>
<tr>
<td>0000 0011</td>
<td></td>
<td>0000 0011</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0001 1110</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0001 1111</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0010 0000</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0010 0001</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0010 0010</td>
<td>18.0</td>
</tr>
</tbody>
</table>
Table 1. LM1973 Micropot Attenuator Register Set Description (continued)

<table>
<thead>
<tr>
<th>MSB:</th>
<th>LSB</th>
<th>Address Register (Byte 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>: :</td>
<td>0011 1110</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0011 1111</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 0000</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 0001</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 0010</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 1100</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 1101</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 1110</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0100 1111</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>0101 0000</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>1111 1110</td>
</tr>
<tr>
<td></td>
<td>: :</td>
<td>1111 1111</td>
</tr>
</tbody>
</table>

μPot SYSTEM ARCHITECTURE

The μPot's digital interface is essentially a shift register, where serial data is shifted in, latched, and then decoded. As new data is shifted into the DATA-IN pin, the previously latched data is shifted out the DATA-OUT pin. Once the data is shifted in, the LOAD/SHIFT line goes high, latching in the new data. The data is then decoded and the appropriate switch is activated to set the desired attenuation level for the selected channel. This process is continued each and every time an attenuation change is made. Each channel is updated, only, when that channel is selected for an attenuator change or the system is powered down and then back up again. When the μPot is powered up, each channel is placed into the muted mode.

μPot LADDER ARCHITECTURE

Each channel of a μPot has its own independent resistor ladder network. As shown in Figure 21, the ladder consists of multiple R1/R2 elements which make up the attenuation scheme. Within each element there are tap switches that select the appropriate attenuation level corresponding to the data bits in Table 1. It can be seen in Figure 21 that the input impedance for the channel is a constant value regardless of which tap switch is selected, while the output impedance varies according to the tap switch selected.

![Figure 21. μPot Ladder Architecture](image)

DIGITAL LINE COMPATIBILITY

The μPot's digital interface section is compatible with either TTL or CMOS logic due to the shift register inputs acting upon a threshold voltage of 2 diode drops or approximately 1.4V.
DIGITAL DATA-OUT PIN

The DATA-OUT pin is available for daisy-chain system configurations where multiple μPots will be used. The use of the daisy-chain configuration allows the system designer to use only one DATA and one LOAD/SHIFT line per chain, thus simplifying PCB trace layouts.

In order to provide the highest level of channel separation and isolate any of the signal lines from digital noise, the DATA-OUT pin should be terminated through a 2 kΩ resistor if not used. The pin may be left floating, however, any signal noise on that line may couple to adjacent lines creating higher noise specs.

![Figure 22. μPot System Architecture](image)

DAISY-CHAIN CAPABILITY

Since the μPot's digital interface is essentially a shift register, multiple μPots can be programmed utilizing the same data and load/shift lines. As shown in Figure 24, for an n-μPot daisy-chain, there are 16n bits to be shifted and loaded for the chain. The data loading sequence is the same for n-μPots as it is for one μPot. First the LOAD/SHIFT line goes low, then the data is clocked in sequentially while the preceding data in each μPot is shifted out the DATA-OUT pin to the next μPot in the chain or to ground if it is the last μPot in the chain. Then the LOAD/SHIFT line goes high; latching the data into each of their corresponding μPots. The data is then decoded according to the address (channel selection) and the appropriate tap switch controlling the attenuation level is selected.

CROSSTALK MEASUREMENTS

The crosstalk of a μPot as shown in Figure 9 in the TYPICAL PERFORMANCE CHARACTERISTICS was obtained by placing a signal on one channel and measuring the level at the output of another channel of the same frequency. It is important to be sure that the signal level being measured is of the same frequency such that a true indication of crosstalk may be obtained. Also, to ensure an accurate measurement, the measured channel's input should be AC grounded through a 1 μF capacitor.

CLICKS AND POPS

So, why is that output buffer needed anyway? There are three answers to this question, all of which are important from a system point of view.

1. The first reason to utilize a buffer/amplifier at the output of a μPot is to ensure that there are no audible clicks or pops due to attenuation step changes in the device. If an on-board bipolar op amp had been used for the output stage, its requirement of a finite amount of DC bias current for operation would cause a DC voltage “pop” when the output impedance of the μPot changes. Again, this phenomenon is due to the fact that the output impedance of the μPot is changing with step changes and a bipolar amplifier requires a finite amount...
of DC bias current for its operation. As the impedance changes, so does the DC bias current and thus there is a DC voltage “pop”.

2. Secondly, the μPot has no drive capability, so any desired gain needs to be accomplished through a buffer/non-inverting amplifier.

3. Third, the output of a μPot needs to see a high impedance to prevent loading and subsequent linearity errors from occurring. A JFET input buffer provides a high input impedance to the output of the μPot so that this does not occur.

Clicks and pops can be avoided by using a JFET input buffer/amplifier such as an LF412ACN. The LF412 has a high input impedance and exhibits both a low noise floor and low THD+N throughout the audio spectrum which maintains signal integrity and linearity for the system. The performance of the system solution is entirely dependent upon the quality and performance of the JFET input buffer/amplifier.

LOGARITHMIC GAIN AMPLIFIER

The μPot is capable of being used in the feedback loop of an amplifier, however, as stated previously, the output of the μPot needs to see a high impedance in order to maintain its high performance and linearity. Again, loading the output will change the values of attenuation for the device. As shown in Figure 23, a μPot used in the feedback loop creates a logarithmic gain amplifier. In this configuration the attenuation levels from Table 1, now become gain levels with the largest possible gain value being 76dB. For most applications 76dB of gain will cause signal clipping to occur, however, because of the μPot’s versatility the gain can be controlled through programming such that the clipping level of the system is never obtained. An important point to remember is that when in mute mode the input is disconnected from the output. In this configuration this will place the amplifier in its open loop gain state, thus resulting in severe comparator action. Care should be taken with the programming and design of this type of circuit. To provide the best performance, a JFET input amplifier should be used.

![Figure 23. Digitally-Controlled Logarithmic Gain Amplifier Circuit](image)

![Figure 24. n-μPot Daisy-Chained Circuit](image)
REVISION HISTORY

Changes from Revision A (March 2013) to Revision B

- Changed layout of National Data Sheet to TI format .......................................................... 12
<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM1973M/NOPB</td>
<td>LIFEBUY</td>
<td>SOIC</td>
<td>DW</td>
<td>20</td>
<td>36</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU SN</td>
<td>Level-3-260C-168 HR</td>
<td>0 to 70</td>
<td>LM1973M</td>
<td></td>
</tr>
<tr>
<td>LM1973MX/NOPB</td>
<td>LIFEBUY</td>
<td>SOIC</td>
<td>DW</td>
<td>20</td>
<td>1000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU SN</td>
<td>Level-3-260C-168 HR</td>
<td>0 to 70</td>
<td>LM1973M</td>
<td></td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) **Lead/Ball Finish** - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
TAPE AND REEL INFORMATION

**Device** | **Package Type** | **Package Drawing** | **Pins** | **SPQ** | **Reel Diameter** | **Reel Width W1** | **A0** | **B0** | **K0** | **P1** | **W** | **Pin1 Quadrant**
---|---|---|---|---|---|---|---|---|---|---|---|---
LM1973MX/NOPB | SOIC | DW | 20 | 1000 | 330.0 | 24.4 | 10.9 | 13.3 | 3.25 | 12.0 | 24.0 | Q1

*All dimensions are nominal.*

**Definitions:**
- **A0**: Dimension designed to accommodate the component width
- **B0**: Dimension designed to accommodate the component length
- **K0**: Dimension designed to accommodate the component thickness
- **W**: Overall width of the carrier tape
- **P1**: Pitch between successive cavity centers

*www.ti.com 8-Apr-2013*
**TAPE AND REEL BOX DIMENSIONS**

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM1973MX/NOPB</td>
<td>SOIC</td>
<td>DW</td>
<td>20</td>
<td>1000</td>
<td>367.0</td>
<td>367.0</td>
<td>45.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
NOTES:
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm per side.
5. Reference JEDEC registration MS-013.
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.
Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and implied warranties the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, “Designers”) understand and agree that Designers remain responsible for using their own independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers’ applications and compliance of their applications (and of all TI products used in or for Designers’ applications) with all applicable regulations, laws and other applicable requirements. Designers represent that, with respect to their applications, Designers have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designers agree that prior to using or distributing any applications that include TI products, Designers will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, “TI Resources”) are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designers (individually or, if Designers is acting on behalf of a company, Designers’ company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designers are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY TECHNOLOGY, PATENT RIGHT OR ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILTY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designers may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers’ own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designers will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer’s non-compliance with the terms and provisions of this Notice.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated