# LM49153 Boomer™ Mono Audio Subsystem with Class G Headphone Amplifier, Class D Speaker Amplifier, Noise Gate and Speaker Protection

**Check for Samples: LM49153**

## FEATURES

- **Class G Ground Referenced Headphone Outputs**
- **High Efficiency Class D Amplifier with Spread Spectrum**
- **No Clip**
- **Speaker Protection**
- **Noise Gate**
- **$I^2C$ Volume and Mode Control**
- **Advanced Click-and-Pop Suppression**
- **Micro-Power Shutdown**

## APPLICATIONS

- **Feature Phones**
- **Smart Phones**

## KEY SPECIFICATIONS

- **Class G Headphone Amplifier, $HPV_{DD}$ = 1.8V, $R_L$ = 32Ω**
  - **$IDDQ_{HP}$, 1.2mA (Typ)**
  - **$P_{OUT}$, THD+N ≤ 1%, 25mW (Typ)**
  - **HP $V_{OS}$, 0.5mV (Typ)**
- **Mono Class D Speaker Amplifier, $R_L$ = 8Ω, THD+N < 1%**
  - **$P_{OUT}$, $LSV_{DD}$ = 5.0V, 1.35W (Typ)**
  - **$P_{OUT}$, $LSV_{DD}$ = 3.6V, 680mW (Typ)**
  - **Efficiency 88% (Typ)**

## DESCRIPTION

The LM49153 is a fully integrated audio subsystem designed for portable handheld applications such as cellular phones. Part of Texas Instruments' PowerWise family of products, the LM49153 combines an earpiece switch, a high efficiency 25mW class G headphone amplifier, and a high efficiency 1.35W class D loudspeaker into a single device.

The headphone amplifiers feature Texas Instruments' class G ground referenced architecture that creates a ground-referenced output with dynamic supply rails for optimum efficiency. The class D amplifier features an ALC (Automatic Level Control) with a noise gate that provides both no-clip and speaker protection.

Mode selection, shutdown control, and volume are controlled through an $I^2C$ compatible interface.

Click and pop suppression eliminates audible transients on power-up/down and during shutdown. The LM49153 is available in an ultra-small 25-bump 0.4mm pitch DSBGA package (2.30mm x 2.42mm).

## Typical Application

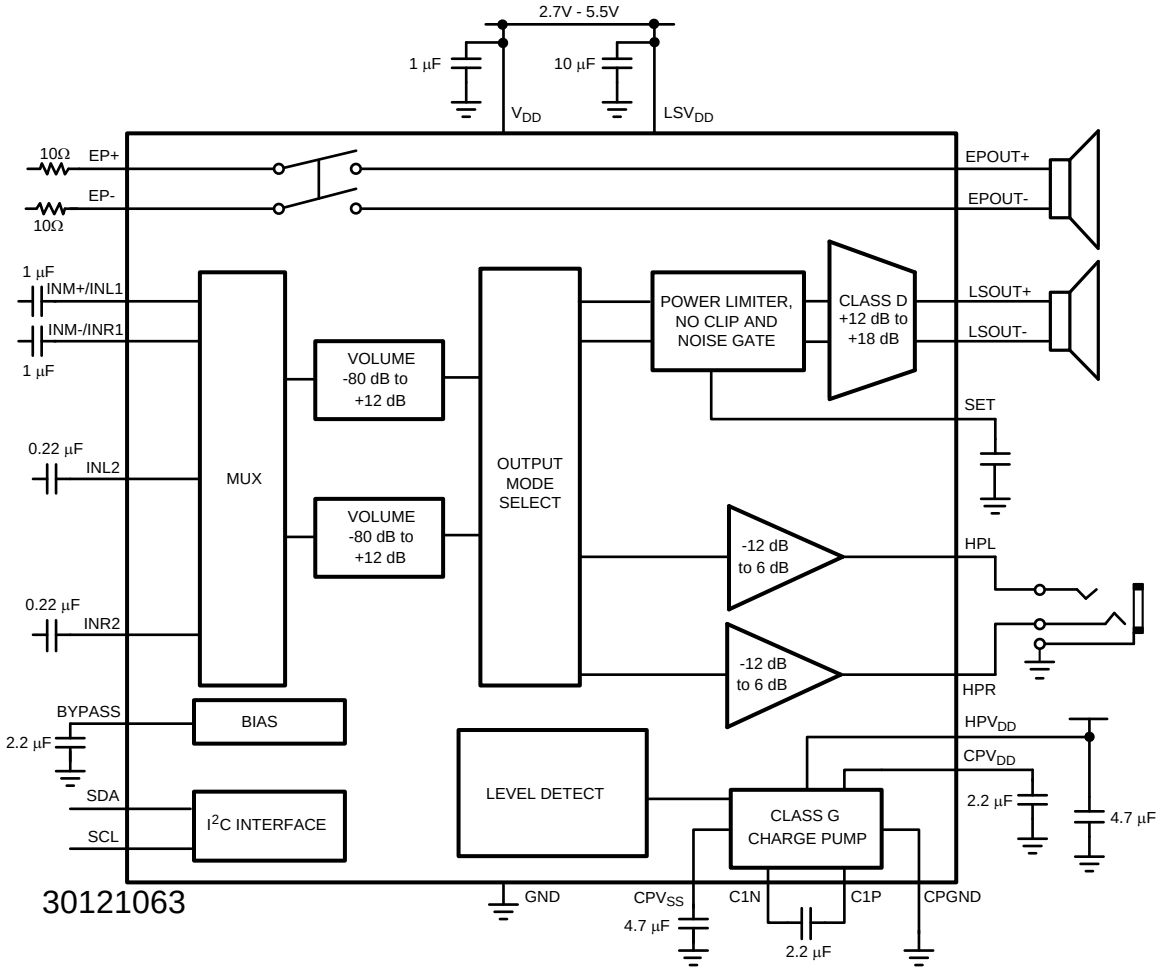


**Figure 1. Typical Audio Amplifier Application Circuit**

## Connection Diagram

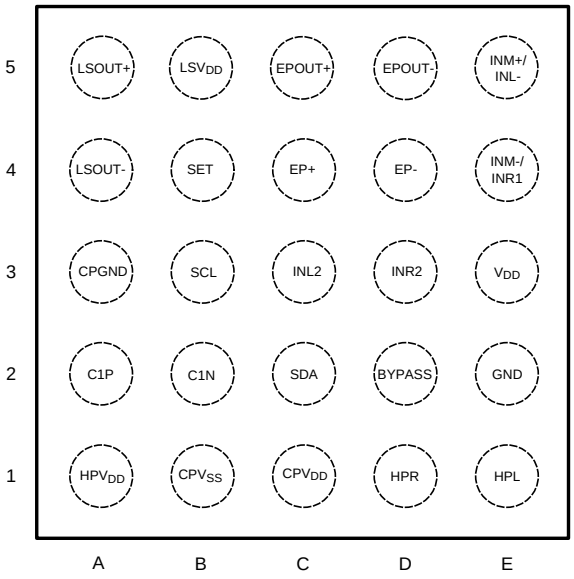


**Figure 2. 25 Bump DSBGA Package**
**Top View**
**See Package Number YFQ0025**

### BUMP DESCRIPTION

| Bump | Name | Description |
|---|---|---|
| A1 | $HPV_{DD}$ | Headphone Power Supply |
| A2 | C1P | Charge Pump Flying Capacitor Positive Terminal |
| A3 | CPGND | Charge Pump Ground |
| A4 | LSOUT- | Loudspeaker Inverting Output |
| A5 | LSOUT+ | Loudspeaker Non-Inverting Output |
| B1 | $CPV_{SS}$ | Charge Pump Output |
| B2 | C1N | Charge Pump Flying Capacitor Negative Terminal |
| B3 | SCL | $I^2C$ Serial Clock Input |
| B4 | SET | ALC Timing Set |
| B5 | $LSV_{DD}$ | Loudspeaker Power Supply |
| C1 | $CPV_{DD}$ | Charge Pump Power Supply |
| C2 | SDA | $I^2C$ Serial Data Input |
| C3 | INL2 | Left Channel Input 2 |
| C4 | EP+ | Earpiece Non-Inverting Input |
| C5 | EPOUT+ | Earpiece Non-Inverting Output |
| D1 | HPR | Right Channel Headphone Output |
| D2 | BYPASS | Mid-Rail Bias Bypass Node |
| D3 | INR2 | Right Channel Input 2 |
| D4 | EP- | Earpiece Inverting Input |
| D5 | EPOUT- | Earpiece Inverting Output |
| E1 | HPL | Left Channel Headphone Output |
| E2 | GND | Ground |
| E3 | $V_{DD}$ | Power Supply |
| E4 | INM-/INR1 | Mono Channel Inverting Input/Right Channel Input 1 |
| E5 | INM+/INL1 | Mono Channel Non-Inverting Input/Left Channel Input 1 |

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)

| | | |
|---|---|---|
| Supply Voltage ($V_{DD}$, $LSV_{DD}$)(1) | | 6V |
| Supply Voltage ($HPV_{DD}$)(1) | | 3V |
| Storage Temperature | | −635°C to +150°C |
| Input Voltage | | −0.3 to $V_{DD}$ +0.3 |
| Power Dissipation(4) | | Internally Limited |
| ESD Rating(5) | | 2.0kV |
| ESD Rating(6) | | 200V |
| Junction Temperature | | 150°C |
| Thermal Resistance | $\theta_{JA}$ (YFQ0025) | 46°C/W |
| Soldering Information | See AN-1112 (SNVA009) “DSBGA Wafer Level Chip Scale Package” | |

(1) *“Absolute Maximum Ratings”* indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the *Absolute Maximum Ratings* or other conditions beyond those indicated in the *Recommended Operating Conditions* is not implied. The *Recommended Operating Conditions* indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified

(2) The *Electrical Characteristics* tables list ensured specifications under the listed *Recommended Operating Conditions* except as otherwise modified or specified by the *Electrical Characteristics Conditions* and/or Notes. Typical specifications are estimations only and are not ensured.

(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 $T_{JMAX}$, $\theta_{JA}$, and the ambient temperature, $T_A$. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the number given in *Absolute Maximum Ratings*, whichever is lower.

(5) Human body model, applicable std. JESD22-A114C.

(6) Machine model, applicable std. JESD22-A115-A.

## Operating Ratings

| | | |
|---|---|---|
| Temperature Range | $T_{MIN} \le T_A \le T_{MAX}$ | $-40°C \le T_A \le +85°C$ |
| | Supply Voltage ($V_{DD}$, $LSV_{DD}$) | $2.7V \le V_{DD} \le 5.5V$ |
| | Supply Voltage ($HPV_{DD}$) | $1.7V \le HPV_{DD} \le 2.0V$ |

## Electrical Characteristics $V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V[1][2]

The following specifications apply for $V_{DD}$ = $LSV_{DD}$, $A_V$ = 0dB, $R_L$ = 15µH+8Ω+15µH (Loudspeaker), $R_L$ = 32Ω (Headphone), $C_{SET}$ = 0.1µF, f = 1kHz, ALC off, unless otherwise specified. Limits apply for $T_A$ = 25°C.[3].

| Symbol | Parameter | Conditions | LM49153 | | Units (Limits) |
|---|---|---|---|---|---|
| | | | Typical[4] | Limits[5] | |
| $I_{DD}$ | Supply Current | $V_{IN}$ = 0, No Load | | | |
| | | EP Receiver (Output Mode Bit EP Bypass = 1) | 0.3 | 2.5 | µA (max) |
| | | LS only (Mode 2)<br>$V_{DD}$, $LSV_{DD}$<br>$HPV_{DD}$ | <br>3.0<br>0 | <br>4.3 | <br>mA (max)<br>mA |
| | | HP only (Mode 1)<br>$V_{DD}$ + $LSV_{DD}$<br>$HPV_{DD}$ | <br>1.8<br>1.2 | <br>2.5<br>1.6 | <br>mA (max)<br>mA (max) |
| | | LS + HP (Mode 6)<br>$V_{DD}$ + $LSV_{DD}$<br>$HPV_{DD}$ | <br>4.3<br>1.2 | <br>5.5<br>1.6 | <br>mA (max)<br>mA (max) |
| $I_{SD}$ | Shutdown Current | $V_{SCL}$ = $V_{SDA}$ = 3.6V | 0.3 | 2.5 | µA (max) |
| $V_{OS}$ | Output Offset Voltage | $V_{IN}$ = 0, Mode 3, 6, 9 | | | |
| | | LS Output, $R_L$ = 8Ω, $A_V$ = 12dB | 9 | | mV |
| | | HP Output, $R_L$ = 32Ω, $A_V$ = 0dB | 0.5 | | mV |
| $t_{WU}$ | Wake Up Time | HP Mode, $C_{BYPASS}$ = 2.2µF<br>Normal turn on time<br>Fast turn on time | <br>32<br>18 | | <br>ms<br>ms |
| $A_{VOL}$ | Volume Control | Mute | –86 | | dB |
| | | Minimum Gain Setting (mono input) | –52.5 | –51<br>–54 | dB (max)<br>dB (min) |
| | | Maximum Gain Setting (mono input) | 12 | 12.5<br>11.5 | dB (max)<br>dB (min) |
| | | Minimum Gain Setting (stereo input) | –80 | | dB (max)<br>dB (min) |
| | | Maximum Gain Setting (stereo input) | 18 | | dB (max)<br>dB (min) |

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(2) The *Electrical Characteristics* tables list ensured specifications under the listed *Recommended Operating Conditions* except as otherwise modified or specified by the *Electrical Characteristics Conditions* and/or Notes. Typical specifications are estimations only and are not ensured.

(3) Loudspeaker $R_L$ is a resistive load in series with two inductors to simulate an actual speaker load. For $R_L$ = 8Ω, the load is 15µH + 8Ω, +15µH. For $R_L$ = 4Ω, the load is 15µH + 4Ω + 15µH.

(4) Typical values represent most likely parametric norms at $T_A$ = +25ºC, and at the *Recommended Operation Conditions* at the time of product characterization and are not specified.

(5) Datasheet min/max specification limits are specified by test or statistical analysis.

## Electrical Characteristics $V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V[1][2] (continued)

The following specifications apply for $V_{DD}$ = $LSV_{DD}$, $A_V$ = 0dB, $R_L$ = 15µH+8Ω+15µH (Loudspeaker), $R_L$ = 32Ω (Headphone), $C_{SET}$ = 0.1µF, f = 1kHz, ALC off, unless otherwise specified. Limits apply for $T_A$ = 25°C.[3].

| Symbol | Parameter | Conditions | LM49153 | | Units (Limits) |
|---|---|---|---|---|---|
| | | | Typical[4] | Limits[5] | |
| $A_V$ | Gain | LS Mode | | | |
| | | Gain 0 | 12 | | dB |
| | | Gain 1 | 18 | | dB |
| | | HP Mode | | | |
| | | Gain 0 | 6 | 5<br>7 | dB (min)<br>dB (max) |
| | | Gain 1 | 3 | | dB |
| | | Gain 2 | 0 | | dB |
| | | Gain 3 | –1.5 | | dB |
| | | Gain 4 | –3 | | dB |
| | | Gain 5 | –6 | | dB |
| | | Gain 6 | –9 | | dB |
| | | Gain 7 | –12 | –13<br>–11 | dB (min)<br>dB (max) |
| $A_{VMUTE}$ | Mute Attention | LS Output | –80 | | dB |
| | | HP Output | –98 | | dB |
| $R_{IN}$ | Input Resistance | Analog Switch | 4.5 | 6 | Ω (max) |
| | | MONO, RIN, LIN, Inputs | | | |
| | | Maximum Gain Setting | 13 | 11<br>15.5 | kΩ (min)<br>kΩ (max) |
| | | Minimum Gain Setting | 110 | 90<br>130 | kΩ (min)<br>kΩ (max) |
| $P_O$ | Output Power | LS Mode, $A_V$ = 18dB, $R_L$ = 8Ω | | | |
| | | $LSV_{DD}$ = 3.3V | 570 | | mW |
| | | $LSV_{DD}$ = 3.6V | 680 | 620 | mW (min) |
| | | $LSV_{DD}$ = 4.2V | 935 | | mW |
| | | $LSV_{DD}$ = 5.0V | 1350 | | mW |
| | | HP Mode, $A_V$ = 6dB | | | |
| | | $R_L$ = 16Ω | 25 | | mW |
| | | $R_L$ = 32Ω | 25 | 22 | mW (min) |
| THD+N | Total Harmonic Distortion + Noise | f = 1kHz | | | |
| | | LS Mode, $P_O$ = 250mW, mono input | 0.02 | | % |
| | | HP Mode, $P_O$ = 12mW, Stereo input | 0.02 | | % |
| | | EP Bypass Mode, $R_L$ = 32Ω | 0.05 | | % |
| PSRR | Power Supply Rejection Ratio (Output referred) | f = 217Hz, $V_{RIPPLE}$ = 200$mV_{PP}$, $C_B$ = 2.2µF, Inputs AC GND | | | |
| | | LS Mode, mono input, $A_V$ = 12dB | 72 | | dB |
| | | LS Mode, stereo input, $A_V$ = 12dB | 64 | | dB |
| | | HP Mode, mono input, ripple on $V_{DD}$ | 94 | | dB |
| | | HP Mode, mono input, ripple on $HPV_{DD}$ | 81 | | dB |
| | | HP Mode, stereo input, ripple on $V_{DD}$ | 80 | | dB |
| CMRR | Common Mode Rejection Ratio | $V_{RIPPLE}$ = $1V_{P-P}$, $f_{RIPPLE}$ = 217Hz, mono input, $A_V$ = 0dB | | | |
| | | LS Mode 2 | 38 | | dB |
| | | HP Mode 1 | 51 | | dB |
| η | Efficiency | LS Mode, THD+N = 1% | 88 | | % |
| $X_{TALK}$ | Crosstalk | $P_O$ = 12mW, f = 1kHz | 80 | | dB |

## Electrical Characteristics $V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V[1][2] (continued)

The following specifications apply for $V_{DD}$ = $LSV_{DD}$, $A_V$ = 0dB, $R_L$ = 15µH+8Ω+15µH (Loudspeaker), $R_L$ = 32Ω (Headphone), $C_{SET}$ = 0.1µF, f = 1kHz, ALC off, unless otherwise specified. Limits apply for $T_A$ = 25°C.[3].

| Symbol | Parameter | Conditions | LM49153 | | Units (Limits) |
|---|---|---|---|---|---|
| | | | Typical[4] | Limits[5] | |
| $\varepsilon_{OS}$ | Output Noise | A-weighted, Inputs AC GND | | | |
| | | LS Mode, mono input | 46 | | µV |
| | | LS Mode, stereo input | 52 | | µV |
| | | HP Mode, mono input | 11 | | µV |
| | | HP Mode, stereo input | 11 | | µV |
| SNR | Signal to Noise Ratio | LS Mode, $P_O$ = 680mW, A-weighted, Mono<br>HP Mode, $P_O$ = 25mW, A-weighted | 94<br>98 | | dB<br>dB |
| $t_A$ | Noise Gate Attack Time | $I^2C$ = 1<br>$I^2C$ = 0 | 0.1<br>0.9 | | ms<br>ms |
| $t_R$ | Noise Gate Release Time | $I^2C$ = 0<br>$I^2C$ = 1 | 1.2<br>2.1 | | s<br>s |
| CC | Clip Control | Low 010<br>Medium 011<br>High 100 | 7.3<br>7.8<br>8.1 | | $V_{P-P}$<br>$V_{P-P}$<br>$V_{P-P}$ |
| $P_{LIMIT}$ | Output Power Limit | LS Mode 1, THD+N ≤ 1%, Voltage Level[6]<br>001<br>010<br>011<br>100<br>101<br>110 | <br>4<br>4.8<br>5.6<br>6.4<br>7.2<br>8.0 | | <br>$V_{P-P}$<br>$V_{P-P}$<br>$V_{P-P}$<br>$V_{P-P}$<br>$V_{P-P}$<br>$V_{P-P}$ |
| $t_A$ | ALC Attack Time | | 0.5 | | ms |
| $t_R$ | ALC Release Time | | 200 | | ms |

(6) The LM49153 ALC limits the output power to which ever is lower, the supply voltage or output power limit.

## $I^2C$ Interface Characteristics $V_{DD}$ = 3.6V[1][2]

The following specifications apply for $A_V$ = 0dB, $R_L$ = 8Ω, f = 1kHz, unless otherwise specified. Limits apply for $T_A$ = 25°C.

| Symbol | Parameter | Conditions | LM49153 | | Units (Limits) |
|---|---|---|---|---|---|
| | | | Typical (3) | Limits (4) | |
| $t_1$ | SCL Period | | | 2.5 | µs (min) |
| $t_2$ | SDA Setup Time | | | 250 | ns (min) |
| $t_3$ | SDA Stable Time | | | 0 | ns (min) |
| $t_4$ | Start Condition Time | | | 250 | ns (min) |
| $t_5$ | Stop Condition Time | | | 250 | ns (min) |
| $V_{IH}$ | Input High Voltage | | | 1.2 | V (min) |
| $V_{IL}$ | Input Low Voltage | | | 0.6 | V (max) |

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(4) Datasheet min/max specification limits are specified by test or statistical analysis.

## Typical Performance Characteristics(1)

THD+N vs Output Power
$V_{DD}$ = 3.6V, $R_L$ = 8Ω, f = 1kHz
$A_V$ = 18dB, Mode 2

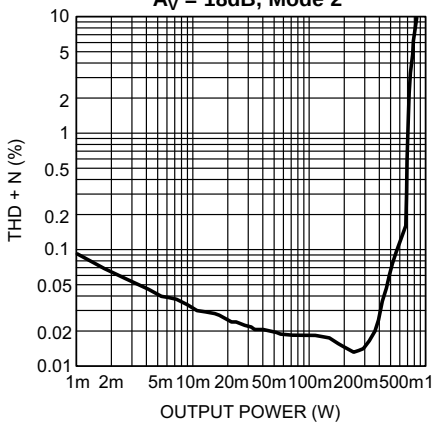



Figure 3.

THD+N vs Output Power
$V_{DD}$ = 4.2V, $R_L$ = 8Ω, f = 1kHz
$A_V$ = 18dB, Mode 2

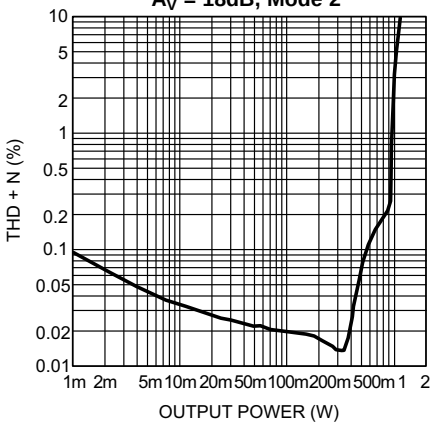



Figure 4.

THD+N vs Output Power
$V_{DD}$ = 5.0V, $R_L$ = 8Ω, f = 1kHz
$A_V$ = 18dB, Mode 2

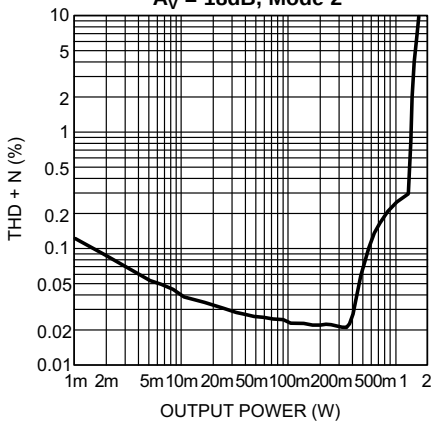



Figure 5.

THD+N vs Output Power
$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $R_L$ = 16Ω, f = 1kHz
$A_V$ = 6dB, Mode 4

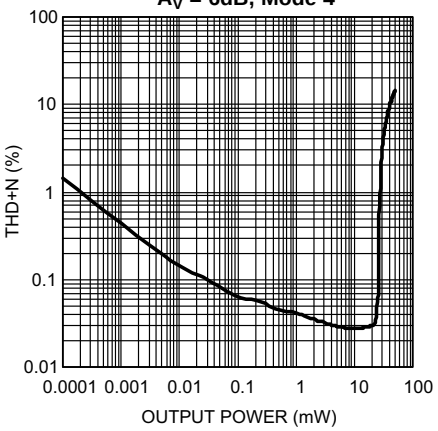



Figure 6.

THD+N vs Output Power
$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $R_L$ = 32Ω, f = 1kHz
$A_V$ = 6dB, Mode 4

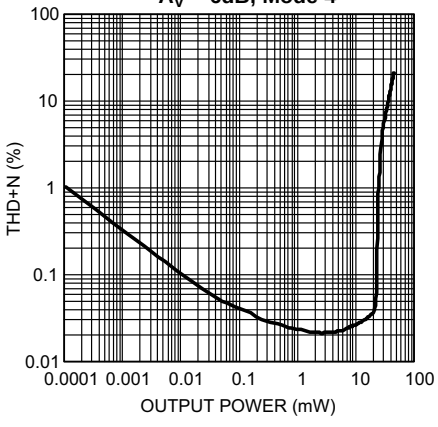



Figure 7.

THD+N vs Output Power
$R_L$ = 32Ω, f = 1kHz, Earpiece Mode

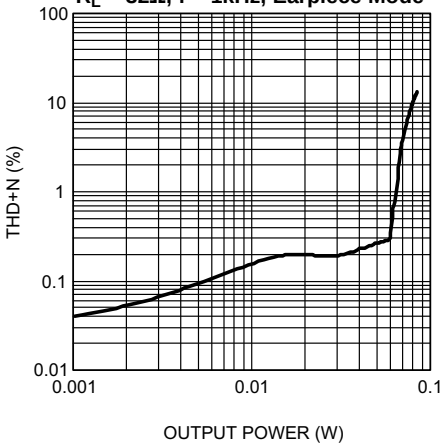



Figure 8.

(1) Loudspeaker $R_L$ is a resistive load in series with two inductors to simulate an actual speaker load. For $R_L$ = 8Ω, the load is 15µH + 8Ω, +15µH. For $R_L$ = 4Ω, the load is 15µH + 4Ω + 15µH.

## Typical Performance Characteristics[1] (continued)

**PSRR vs FREQUENCY**
**$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $V_{DD-RIPPLE}$ = 200m$V_{P-P}$**
**$R_L$ = 8Ω, Mono Input, LS Mode**

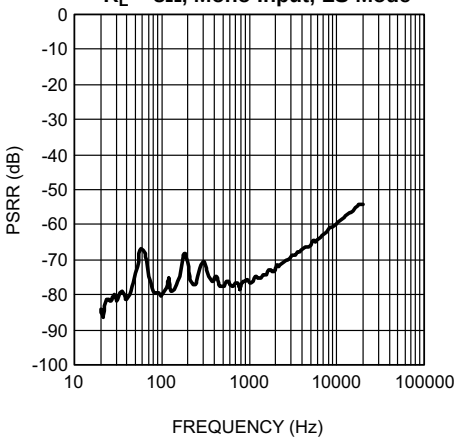



**Figure 9.**

**PSRR vs FREQUENCY**
**$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $V_{DD-RIPPLE}$ = 200m$V_{P-P}$**
**$R_L$ = 8Ω, Stereo Input, LS Mode**

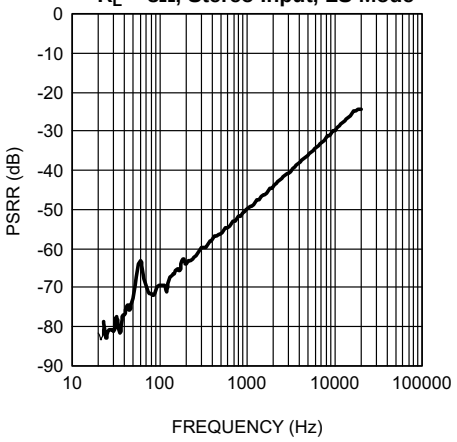



**Figure 10.**

**PSRR vs FREQUENCY**
**$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $V_{DD-RIPPLE}$ = 200m$V_{P-P}$**
**$R_L$ = 32Ω, Mono Input, HP Mode**

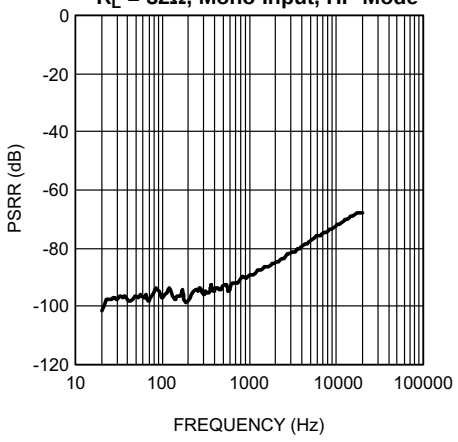



**Figure 11.**

**PSRR vs FREQUENCY**
**$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $HPV_{DD-RIPPLE}$ = 200m$V_{P-P}$**
**$R_L$ = 32Ω, Mono Input, HP Mode**

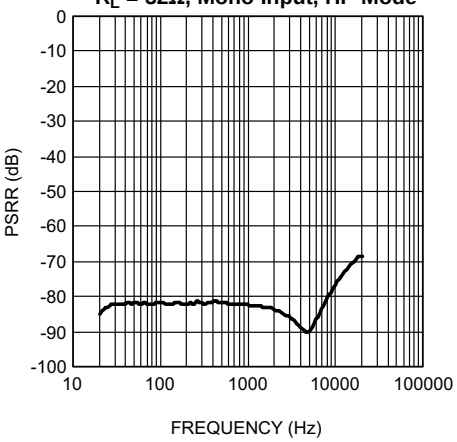



**Figure 12.**

**SUPPLY CURRENT vs SUPPLY VOLTAGE**
**No Load, Loudspeaker Mode 2**

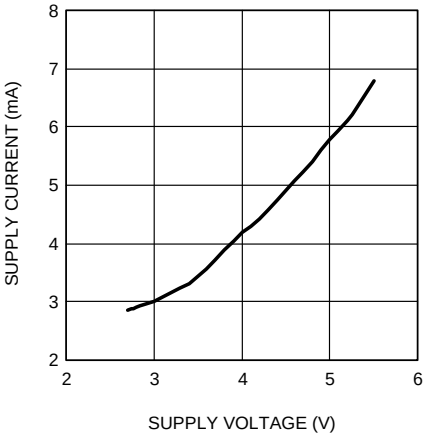



**Figure 13.**

**SUPPLY CURRENT vs SUPPLY VOLTAGE**
**No Load, Loudspeaker Mode 4**

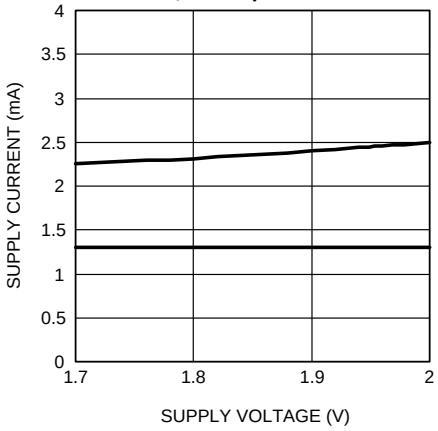



**Figure 14.**

## Typical Performance Characteristics(1) (continued)

**EFFICIENCY vs OUTPUT POWER**
**$R_L$ = 8Ω, f = 1kHz, Loudspeaker Mode 2**

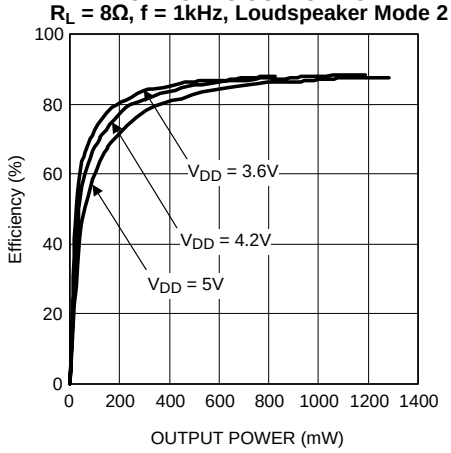



**Figure 15.**

**POWER DISSIPATION vs OUTPUT POWER**
**$V_{DD}$ = 3.6V, $HPV_{DD}$ = 1.8V, $R_L$ = 32Ω, f = 1kHz**
**Loudspeaker Mode 2**

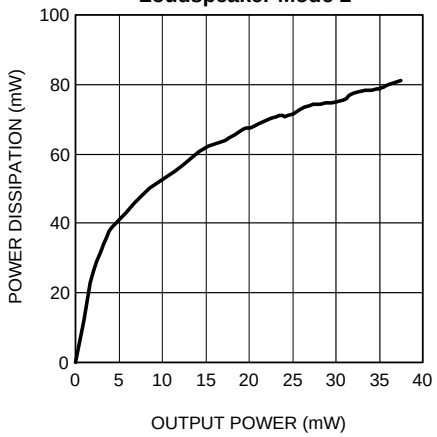



**Figure 16.**

**POWER DISSIPATION vs OUTPUT POWER**
**$R_L$ = 32Ω, f = 1kHz**
**Loudspeaker Mode 2**

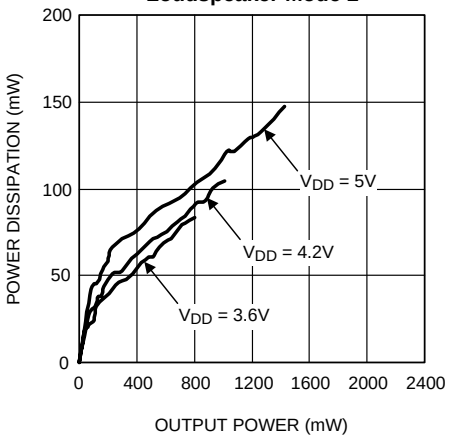



**Figure 17.**

**OUTPUT POWER vs SUPPLY VOLTAGE**
**$R_L$ = 8Ω, f = 1kHz**

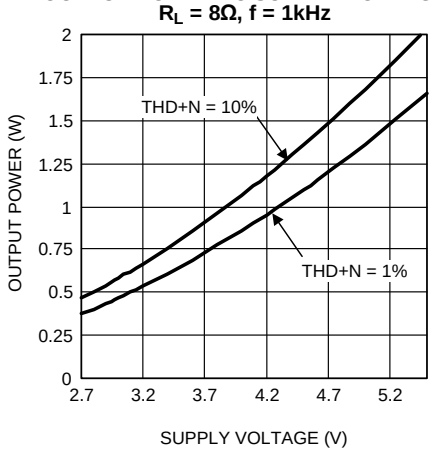



**Figure 18.**

**OUTPUT POWER vs SUPPLY VOLTAGE**
**$R_L$ = 32Ω, f = 1kHz**

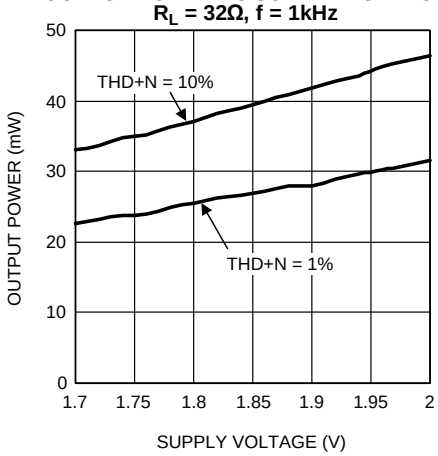



**Figure 19.**

# APPLICATION INFORMATION

## WRITE-ONLY I²C COMPATIBLE INTERFACE

The LM49153 is controlled through an I²C compatible serial interface that consists of a serial data line (SDA) and a serial clock (SCL). The clock line is uni-directional. The data line is bi-directional (open drain). The LM49153 and the master can communicate at clock rates up to 400kHz. Figure 20 shows the I²C interface timing diagram. Data on the SDA line must be stable during the HIGH period of SCL. The LM49153 is a transmit/receive slave-only device, reliant upon the master to generate the SCL signal. Each transmission sequence is framed by a START condition and a STOP condition (Figure 21). Each data word, device address and data, transmitted over the bus is 8 bits long and is always followed by an acknowledge pulse. The LM49153 device address is 1100000.

## I²C BUS FORMAT

The I²C bus format is shown in Figure 21. The START signal, the transition of SDA from HIGH to LOW while SCL is HIGH, is generated, alerting all devices on the bus that a device address is being written to the bus.

The 7-bit device address is written to the bus, most significant bit (MSB) first, followed by the R/$\overline{W}$ bit. R/$\overline{W}$ = 0 indicates the master is writing to the slave device, R/$\overline{W}$ = 1 indicates the master wants to read data from the slave device. Set R/$\overline{W}$ = 0; the LM49153 is a WRITE-ONLY device and will not respond the R/ $\overline{W}$ = 1. The data is latched in on the rising edge of the clock. Each address bit must be stable while SCL is HIGH. After the last address bit is transmitted, the master device releases SDA, during which time, an acknowledge clock pulse is generated by the slave device. If the LM49153 receives the correct address, the device pulls the SDA line low, generating an acknowledge bit (ACK).

Once the master device registers the ACK bit, the 8-bit register data word is sent. Each data bit should be stable while SCL is HIGH. After the 8-bit register data word is sent, the LM49153 sends another ACK bit. Following the acknowledgement of the register data word, the master issues a STOP bit, allowing SDA to go high.

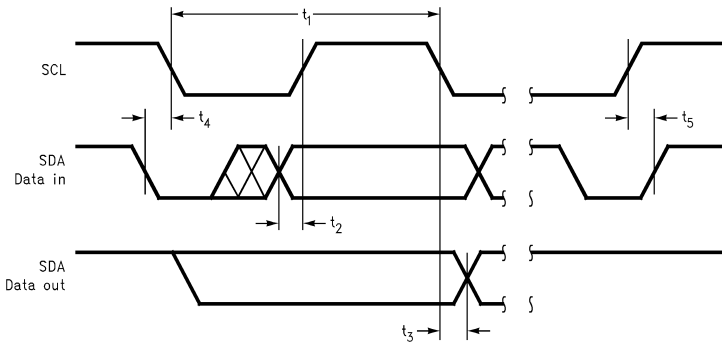



**Figure 20. I²C Timing Diagram**

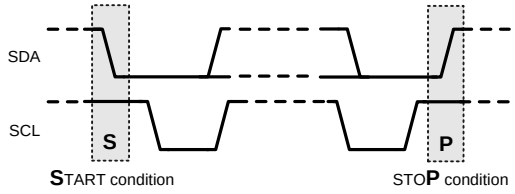



**Figure 21. Example I²C Write Cycle**

## DEVICE ADDRESS REGISTER

**Table 1. Device Address**

| | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 ($\overline{W}$) |
|---|---|---|---|---|---|---|---|---|
| Device Address | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |

## I²C CONTROL REGISTER

**Table 2. I²C Control**

| Register Name | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 |
|---|---|---|---|---|---|---|---|---|
| Shutdown control | 0 | 0 | 0 | 1 | GAMP_ON | HPR_SD | ClassG_SD | PWR_ON |
| Mode control | 0 | 0 | 1 | EP | MODE_CONTROL | | | |
| Power limiter control | 0 | 1 | 0 | ATTACK_TIME | | POWER_LEVEL | | |
| No clip control | 0 | 1 | 1 | RELEASE_TIME | | OUTPUT_CLIP_CONTROL | | |
| Gain control | 1 | 0 | 0 | 0 | LSGAIN | HP_GAIN | | |
| Volume control | 1 | 0 | 1 | LS_VOLUME/HP_VOLUME | | | | |
| LS control | 1 | 1 | 0 | 0 | NOISE_GATE_LEVEL | | NOISE_GATE_TIME | |
| Other control | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Class-G control | 1 | 1 | 1 | 0 | 1 | 0 | CLASS_G_TRIP_LEVEL | |
| Other control | 1 | 1 | 1 | 1 | 0 | 0 | SS_EN | TURN_ON TIME |

## SHUTDOWN CONTROL REGISTER

**Table 3. Shutdown Control**

| Bit | Name | Value | Description |
|---|---|---|---|
| B0 | PWR_ON | This enables or disables the device. | |
| | | 0 | Device disabled |
| | | 1 | Device enabled |
| B1 | Class G_SD | This enables or disables the Class G of the headphone. | |
| | | 0 | Class G enabled |
| | | 1 | Class G disabled |
| B2 | HPR_SD | This disables the right headphone output. | |
| | | 0 | Normal Operation |
| | | 1 | Right headphone disabled |
| B3 | GAMP_ON | This disables the gain amplifiers that are not in use to minimize $I_{DD}$. | |
| | | 0 | Normal Operation |
| | | 1 | Disable unused gain amplifiers |

## MODE CONTROL REGISTER

**Table 4. Mode Control**

| Bits | Field | Description | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| B3:B0 | MODE_ CONTROL | This set the different mixer output modes. | | | | | | | |
| | | Mode | Input (Diff/SE)(1) | Input(2) | SPK | HP | LS | HP(L) | HP ( R ) |
| | | 0 | 0 | X | 0 | 0 | SD | SD | SD |
| | | 1 | 0 | X | 0 | 1 | SD | GM X M | GM X M |
| | | 2 | 0 | X | 0 | 1 | GM(3) X M(4) | SD | SD |
| | | 3 | 0 | X | 1 | 1 | GM X M | GM X M | GM X M |
| | | 4 | 1 | 0 | 0 | 1 | SD | GST X L1 | GST X R1 |
| | | 5 | 1 | 0 | 1 | 0 | GST(5) X (L1 + R1)(6)(7) | SD | SD |
| | | 6 | 1 | 0 | 1 | 1 | GST X (L1 + R1) | GST X L1 | GST X R1 |
| | | 7 | 1 | 1 | 0 | 1 | SD(8) | GST X L2 | GST X R2 |
| | | 8 | 1 | 1 | 1 | 0 | GST X (L2 + R2)(6)(7) | SD | SD |
| | | 9 | 1 | 1 | 1 | 1 | GST X (L2 + R2) | GST X L2 | GST X R2 |
| B4 | EP | This enables the receiver bypass path. | | | | | | | |
| | | 0 | Normal output mode operation | | | | | | |
| | | 1 | Enable the receiver bypass path | | | | | | |

(1) 0: Differential, 1: Single-Ended
(2) 0: Stereo 1CH, 1: Stereo 2CH
(3) $G_M$: Differential input gain path
(4) M: Mono differential input
(5) $G_{ST}$: Single-Ended input path
(6) R1/R2: Right channel stereo input
(7) L1/L2: Left channel stereo input
(8) SD: Shutdown

## VOLTAGE LIMIT CONTROL REGISTER

**Table 5. Shutdown Control**

| Bits | Field | Description | |
|---|---|---|---|
| B2:B0 | VOLTAGE LEVEL | This sets the output voltage limit level. | |
| | | 000 | Voltage limit disabled |
| | | 001 | $V_{TH(VLIM)} = 4.0V_{P-P}$ |
| | | 010 | $V_{TH(VLIM)} = 4.8V_{P-P}$ |
| | | 011 | $V_{TH(VLIM)} = 5.6V_{P-P}$ |
| | | 100 | $V_{TH(VLIM)} = 6.4V_{P-P}$ |
| | | 101 | $V_{TH(VLIM)} = 7.2V_{P-P}$ |
| | | 110 | $V_{TH(VLIM)} = 8.0V_{P-P}$ |
| | | 111 | Voltage limit disabled |
| B4:B3 | ATTACK_ TIME | This sets the attack time of the automatic limiter control circuit based on $C_{SET}$ = 0.1µF. | |
| | | 00 | 0.7ms |
| | | 01 | 0.975ms |
| | | 10 | 1.5ms |
| | | 11 | 2.025ms |

## NO CLIP CONTROL REGISTER

**Table 6. No Clip Control**

| Bits | Field | Description | |
|---|---|---|---|
| B2:B0 | OUTPUT_CLIP_ CONTROL | This sets the output voltage limit level. | |
| | | 000 | No Clip disabled, output clip control disabled |
| | | 010 | No Clip enabled, output clip control disabled |
| | | 011 | Low |
| | | 100 | Med |
| | | 101 | High |
| B4:B3 | RELEASE_TIME | This sets the release time of the automatic limiter control circuit. | |
| | | 00 | 1s |
| | | 01 | 0.8s |
| | | 10 | 0.65s |
| | | 11 | 0.4s |

## GAIN CONTROL REGISTER

**Table 7. Gain Control**

| Bits | Field | Description | |
|---|---|---|---|
| B2:B0 | HP_GAIN | This sets the headphone output gain level. | |
| | | 000 | 0dB |
| | | 001 | -1.5dB |
| | | 010 | -3dB |
| | | 011 | -6dB |
| | | 100 | -9dB |
| | | 101 | -12dB |
| | | 110 | -15dB |
| | | 111 | -18dB |
| B3 | LS_GAIN | This sets the loudspeaker output gain level. | |
| | | 0 | 12dB |
| | | 1 | 18dB |

## VOLUME CONTROL REGISTER

**Table 8. Volume Control**

| VOLUME STEP | _G4 | _G3 | _G2 | _G1 | _G0 | Stereo GAIN (dB) | Mono GAIN (dB) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | -109 | -115 |
| 2 | 0 | 0 | 0 | 0 | 1 | -46.5 | -52.5 |
| 3 | 0 | 0 | 0 | 1 | 0 | -40.5 | -46.5 |
| 4 | 0 | 0 | 0 | 1 | 1 | -34.5 | -40.5 |
| 5 | 0 | 0 | 1 | 0 | 0 | -30 | -36 |
| 6 | 0 | 0 | 1 | 0 | 1 | -27 | -33 |
| 7 | 0 | 0 | 1 | 1 | 0 | -24 | -30 |
| 8 | 0 | 0 | 1 | 1 | 1 | -21 | -27 |
| 9 | 0 | 1 | 0 | 0 | 0 | -18 | -24 |
| 10 | 0 | 1 | 0 | 0 | 1 | -15 | -21 |
| 11 | 0 | 1 | 0 | 1 | 0 | -13.5 | -19.5 |
| 12 | 0 | 1 | 0 | 1 | 1 | -12 | -18 |

**Table 8. Volume Control (continued)**

| VOLUME STEP | _G4 | _G3 | _G2 | _G1 | _G0 | Stereo GAIN (dB) | Mono GAIN (dB) |
|---|---|---|---|---|---|---|---|
| 13 | 0 | 1 | 1 | 0 | 0 | -10.5 | -16.5 |
| 14 | 0 | 1 | 1 | 0 | 1 | -9 | -15 |
| 15 | 0 | 1 | 1 | 1 | 0 | -7.5 | -13.5 |
| 16 | 0 | 1 | 1 | 1 | 1 | -6 | -12 |
| 17 | 1 | 0 | 0 | 0 | 0 | -4.5 | -10.5 |
| 18 | 1 | 0 | 0 | 0 | 1 | -3 | -9 |
| 19 | 1 | 0 | 0 | 1 | 0 | -1.5 | -7.5 |
| 20 | 1 | 0 | 0 | 1 | 1 | 0 | -6 |
| 21 | 1 | 0 | 1 | 0 | 0 | 1.5 | -4.5 |
| 22 | 1 | 0 | 1 | 0 | 1 | 3 | -3 |
| 23 | 1 | 0 | 1 | 1 | 0 | 4.5 | -1.5 |
| 24 | 1 | 0 | 1 | 1 | 1 | 6 | 0 |
| 25 | 1 | 1 | 0 | 0 | 0 | 7.5 | 1.5 |
| 26 | 1 | 1 | 0 | 0 | 1 | 9 | 3 |
| 27 | 1 | 1 | 0 | 1 | 0 | 10.5 | 4.5 |
| 28 | 1 | 1 | 0 | 1 | 1 | 12 | 6 |
| 29 | 1 | 1 | 1 | 0 | 0 | 13.5 | 7.5 |
| 30 | 1 | 1 | 1 | 0 | 1 | 15 | 9 |
| 31 | 1 | 1 | 1 | 1 | 0 | 16.5 | 10.5 |
| 32 | 1 | 1 | 1 | 1 | 1 | 18 | 12 |

## NOISE GATE CONTROL REGISTER

**Table 9. Noise Gate Control**

| Bits | Field | Description | | |
|---|---|---|---|---|
| B1:B0 | NOISE_GATE_ TIME | This sets the noise gate attack and release time. | | |
| | | 00 | 0.9ms | 1.2s |
| | | 01 | 0.9ms | 2.1s |
| | | 10 | 0.1ms | 1.2s |
| | | 11 | 0.1ms | 2.1s |
| B4:B3 | NOISE_GATE_ LEVEL | This sets the noise gate trip level * | | |
| | | 000 | Noise gate disabled | |
| | | 010 | Low — 26mV$_{RMS}$ | |
| | | 011 | Medium — 40mV$_{RMS}$ | |
| | | 100 | High — 60mV$_{RMS}$ | |

## CLASS-G CONTROL REGISTER

**Table 10. Class-G Control**

| | | | |
|---|---|---|---|
| B4:B3 | CLASS_G_TRIP_ LEVEL | This sets the Class G trip level and determines when the headphone rails switches. | |
| | | 00 | Highest Level Trip Point (Default) |
| | | 01 | High Level Trip Point |
| | | 10 | Medium Level Trip Point |
| | | 11 | Low Level Trip Point |

## OTHER CONTROL REGISTER

**Table 11. Other Control**

| | | | |
|---|---|---|---|
| B0 | TURN_ON_TIME | This sets the turn on time. | |
| | | 0 | Normal Turn On Time |
| | | 1 | Fast Turn On Time |
| B1 | SS_EN | This enables Spread Spectrum. | |
| | | 0 | Spread Spectrum Disabled |
| | | 1 | Spread Spectrum Enabled |

## DIFFERENTIAL AMPLIFIER EXPLANATION

The LM49153 features a differential input stage for the mono inputs, which offers improved noise rejection compared to a single-ended input amplifier. Because a differential input amplifier amplifies the difference between the two input signals, any component common to both signals is cancelled. An additional benefit of the differential input structure is the possible elimination of the DC input blocking capacitors. Since the DC component is common to both inputs, and thus cancelled by the amplifier, the LM49153 can be used without input coupling capacitors when configured with a differential input signal.

## INPUT MIXER/MULTIPLEXER

The LM49153 includes a comprehensive mixer multiplexer controlled through the $I^2C$ interface. The mixer/multiplexer allows any input combination to appear on any output of LM49153. Multiple input paths can be selected simultaneously. Under these conditions, the selected inputs are mixed together and output on the selected channel. Table 4 (MODE CONTROL) shows how the input signals are mixed together for each possible input selection.

## SHUTDOWN FUNCTION

The LM49153 features the following shutdown controls: Bit B4 (GAMP_ON) of the SHUTDOWN CONTROL register controls the gain amplifiers. When GAMP_SD = 1, it disables the gain amplifiers that are not in use. For example, in Modes 1, 4 and 5, the Mono inputs are in use, so the Left and Right input gain amplifiers are disabled, causing the $I_{DD}$ to be minimized. Bit B0 (PWR_ON) of the SHUTDOWN CONTROL register is the global shutdown control for the entire device. Set PWR_ON = 0 for normal operation. PWR_ON = 1 overrides any other shutdown control bit.

## CLASS D AMPLIFIER

he LM49153 features a mono class D audio power amplifier with a filterless modulation scheme that reduces external component count, conserving board space and reducing system cost. With no signal applied, the outputs (LSOUT+ and LSOUT-) switch between VDD and GND with 50% duty cycle, in phase, causing the two outputs to cancel. This cancellation results in no net voltage across the speaker, thus there is no current to the load in the idle state.

With an input signal applied, the duty cycle (pulse width) of the class D output changes. For increasing output voltage, the duty cycle of LSOUT+ increases, while the duty cycle of LSOUT- decreases. For decreasing output voltages, the converse occurs. The difference between the two pulse widths yields the differential output voltage.

## ENHANCED EMISSION SUPPRESSION ($E^2S$)

The LM49153 class D amplifier features Texas Instruments' patent-pending $E^2S$ system that reduces EMI, while maintaining high quality audio reproduction and efficiency. The $E^2S$ system features selectable spread spectrum and advanced edge rate control (ERC). The LM49153 class D ERC greatly reduces the high frequency components of the output square waves by controlling the output rise and fall times, slowing the transitions to reduces RF emissions, while maximizing THD+N and efficiency performance.

## SPREAD SPECTRUM

The selectable spread spectrum mode minimizes the need for output filters, ferrite beads or chokes. In spread spectrum mode, the switching frequency varies randomly by 30% about a 300kHz center frequency, reducing the wideband spectral content, improving EMI emission radiated by the speaker and associated cables and traces. Where a fixed frequency class D exhibits large amounts of spectral energy at multiples of the switching frequency, the spread spectrum architecture spreads that energy over a larger bandwidth. The cycle-to-cycle variation of the switching period does not affect the audio reproduction, efficiency, or PSRR. Set bit B0 (SS_EN) of the SS CONTROL register to 1 to enable spread spectrum mode.

## GROUND REFERENCE HEADPHONE AMPLIFIER

The LM49153 features a low noise inverting charge pump that generates an internal negative supply voltage. This allows the headphone outputs to be biased about GND instead of a nominal DC voltage, like traditional headphone amplifiers. Because there is no DC component, the large DC blocking capacitors (typically 220µF) are not necessary. The coupling capacitors are replaced by two small ceramic charge pump capacitors, saving board space and cost. Eliminating the output coupling capacitors also improves low frequency response. In traditional headphone amplifiers, the headphone impedance and the output capacitor from a high-pass filter that not only blocks the DC component of the output, but also attenuates low frequencies, impacting the bass response. Because the LM49153 does not require the output coupling capacitors, the low frequency response of the device is not degraded by external components. In addition to eliminating the output coupling capacitors, the ground referenced output nearly doubles the available dynamic range of the LM49153 headphone amplifiers when compared to a traditional headphone amplifier operating from the same supply voltage.

## EARPIECE (EP) BYPASS

When B4 of MODE_CONTROL register is set to 1, earpiece amplifier is enabled and differential inputs are passed down to speaker outputs. This in turn disables the class D amplifier.

## AUTOMATIC LIMITER CONTROL (ALC)

When enabled, the ALC continuously monitors and adjusts the gain of the loudspeaker amplifier signal path if necessary. The ALC serves two functions: voltage limiter/speaker protection and output clip prevention (No-Clip) with three clip controls levels. The voltage limiter/speaker protection prevents an output overload condition by maintaining the loudspeaker output signal below a preset amplitude (See VOLTAGE LIMITER section). The No Clip feature monitors the output signal and maintains audio quality by preventing the loudspeaker output from exceeding the amplifier's headroom (see NO CLIP/OUTPUT CLIP CONTROL section). The voltage limiter thresholds, clip control levels, attack and release times are configured through the $I^2C$ interface.

## VOLTAGE LIMITER

The voltage limiter function of the ALC monitors and prevents the audio signal from exceeding the voltage limit threshold (Figure 22). The voltage limit threshold ($V_{TH(VLIM)}$) is set by bits B2:B0 in the Voltage Limit Threshold Register (see Table 5). Although the ALC reduces the gain of the speaker path to maintain the audio signal below the voltage limit threshold, it is still possible to overdrive the speaker output in which case loudspeaker output will exceed the voltage limit threshold and cause clipping on the output, and speaker damage is possible. Please see the ALC HEADROOM section for further details.

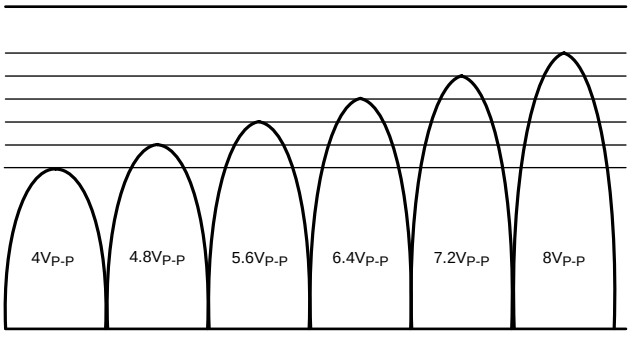



**Figure 22. Voltage Limit Output Level**

## NO CLIP/OUTPUT CLIP CONTROL

The LM49153 No Clip circuitry detects when the loudspeaker output is near clipping and reduces the signal gain to prevent output clipping and preserve audio quality (Figure 23). Although the ALC reduces the gain of the speaker path to prevent output clipping, it is still possible to overdrive the speaker output. Please see the ALC HEADROOM section for further details.

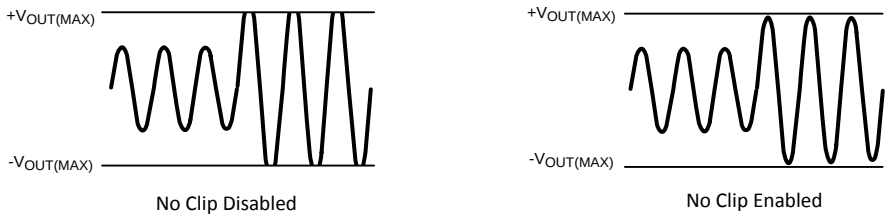



**Figure 23. No Clip Function**

The LM49153 also features an output clip control that allows a certain amount of clipping at the output in order to increase the loudspeaker output power. The clip level is set by B2:B0 in the No Clip Control Register (see Table 6). The clip control works by allowing the output to enter clipping before the ALC turns on and maintains the output level. The clip control has three levels: low, medium, and high. The low and high clip level control settings give the lowest distortion and highest distortion respectively on the output (see SHUTDOWN FUNCTION). The actual output level of the device will depend upon the supply voltage, and the output power will depend upon the load impedance.

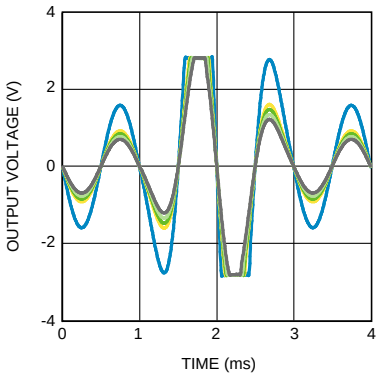



**Figure 24. Clip Control Levels**

## ALC HEADROOM

When either voltage limiter or no clip is enabled, it is still possible to drive LM49153 into clipping by overdriving the input volume stage of the signal path beyond its output dynamic range. In this case, clipping occurs at the input volume stage, and although ALC is active, the gain reduction will have no effect on the output clipping. The maximum input that can safely pass through the input volume stage can be calculated by following formula:

$$V_{IN} \leq \frac{V_{DD}}{\text{Av (volume gain)}} \quad (1)$$

So in the case of 0 dB volume gain, audio input has to be less than $V_{DD}$ for both voltage limiter or No clip settings.

When voltage limiter is enabled, ALC can reach its max attenuation for lower voltage limit levels as shown in the Figure 26. Typically, after the ALC started working, with 6dB of audio input change ALC is well within its regulation. Voltage limiter Input headroom can be increased by switching to the LS_GAIN to 18dB in the Gain Control Register (see Table 7).

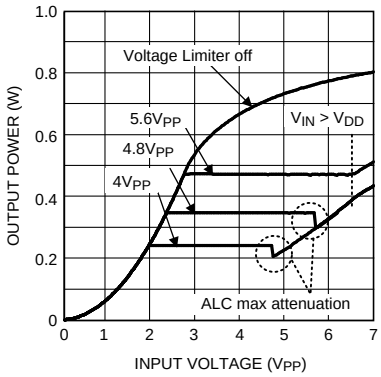



**Figure 25. Voltage Limiter Function**
**$V_{DD}$ = 3.3V, $R_L$ = 8Ω+30µH**
**$f_{IN}$ = 1kHz, LS_GAIN = 0**

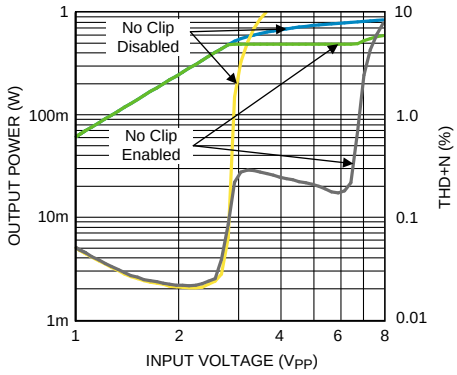



**Figure 26. No Clip Function**
**$V_{DD}$ = 3.3V, $R_L$ = 8Ω+30µH**
**$f_{IN}$ = 1kHz, LS_GAIN = 0**
**Gray, Yellow = THD+N vs Input Voltage**

When No Clip is enabled, class D speaker output reduces when it's about to enter clipping region and power stay constant as long as $V_{IN}$ is less than $V_{DD}$ for 0dB volume gain (see Figure 26). For example, in the case of $V_{DD}$ = 3.3V, there is a 6dB of headroom for the change in input. Please see the ALC typical performance curves for additional plots relating to different supply voltages and LS_GAIN settings for specific application parameters.

## ATTACK TIME

Attack time ($t_{ATK}$) is the time it takes for the gain to be reduced by 6dB (LS_GAIN = 0) once the audio signal exceeds the ALC threshold. Fast attack times allow the ALC to react quickly and prevent transients such as symbol crashes from being distorted. However, fast attack times can lead to volume pumping, where the gain reduction and release becomes noticeable, as the ALC cycles quickly. Slower attack times cause the ALC to ignore the fast transients, and instead act upon longer, louder passages. Selecting an attack time that is too slow can lead to increased distortion in the case of the No Clip function, and possible output overload conditions in the case of the Voltage limiter. The attack time is set by a combination of the value of $C_{SET}$ and the attack time coefficient as given by Equation 2:

$$t_{ATK} = 20k\Omega C_{SET} / \alpha_{ATK} \quad (2)$$

Where $\alpha_{ATK}$ is the attack time coefficient (Table 12) set by bits B4:B3 in the Voltage Limit Control Register (see Table 5). The attack time coefficient allows the user to set a nominal attack time. The internal 20kΩ resistor is subject to temperature change, and it has tolerance between -11% to +20%.

**Table 12. Attack Time Coefficient**

| B5 | B4 | $\alpha_{ATK}$ |
|---|---|---|
| 0 | 0 | 2.667 |
| 0 | 1 | 2 |
| 1 | 0 | 1.333 |
| 1 | 1 | 1 |

## RELEASE TIME

Release time ($t_{RL}$) is the time it takes for the gain to return from 6dB (LS_GAIN = 0) to its normal level once the audio signal returns below the ALC threshold. A fast release time allows the ALC to react quickly to transients, preserving the original dynamics of the audio source. However, similar to a fast attack time, a fast release time contributes to volume pumping. A slow release time reduces the effect of volume pumping. The release time is set by a combination of the value of $C_{SET}$ and release time coefficient as given by Equation 3:

$$t_{RL} = 20M\Omega C_{SET} / \alpha_{RL} \quad (s) \tag{3}$$

where $\alpha_{RL}$ is the release time coefficient (Table 13) set by bits B4:B3 in the No Clip Control Register. The release time coefficient allows the user to set a nominal release time. The internal 20MΩ is subject to temperature change, and it has tolerance between -11% to +20%.

**Table 13. Release Time Coefficient**

| B5 | B4 | $\alpha_{RL}$ |
|---|---|---|
| 0 | 0 | 2 |
| 0 | 1 | 2.5 |
| 1 | 0 | 3 |
| 1 | 1 | 5 |

## PROPER SELECTION OF EXTERNAL COMPONENTS

### ALC Timing ($C_{SET}$) Capacitor Selection

The recommended range value of $C_{SET}$ is between .01µF to 1µF. Lowering the value below .01µF can increase the attack time but LM49153 ALC ability to regulate its output can be disrupted and approaches the hard limiter circuit. This in turn increases the THD+N and audio quality will be severely affected.

### Charge Pump Capacitor Selection

Use low ESR ceramic capacitors (less than 100mΩ) for optimum performance.

### Charge Pump Flying Capacitor (C1)

The flying capacitor (C1) affects the load regulation and output impedance of the charge pump. A C1 value that is too low results in a loss of current drive, leading to a loss of amplifier headroom. A higher valued C1 improves load regulation and lowers charge pump output impedance to an extent. Above 2.2µF, the $R_{DS(ON)}$ of the charge pump switches and the ESR of C1 and C2 dominate the output impedance. A lower value capacitor can be used in systems with low maximum output power requirements.

### Charge Pump Hold Capacitor (C2)

The value and ESR of the hold capacitor (C2) directly affects the ripple on $CPV_{SS}$. Increasing the value of C2 reduces output ripple. Decreasing the ESR of C2 reduces both output ripple and charge pump output impedance. A lower value capacitor can be used in systems with low maximum output power requirements.

### Input Capacitor Selection

Input capacitors may be required for some applications, or when the audio source is single-ended. Input capacitors block the DC component of the audio signal, eliminating any conflict between the DC component of the audio source and the bias voltage of the LM49153. The input capacitors create a high-pass filter with the input resistors $R_{IN}$. The -3dB point of the high-pass filter is found using Equation 4 below.

$$f = 1 / 2\pi R_{IN} C_{IN} \quad (Hz) \tag{4}$$

Where the value of $R_{IN}$ is given in the Electrical Characteristics Table.

High-pass filtering the audio signal helps protect the speakers. When the LM49153 is using a single-ended source, power supply noise on the ground is seen as an input signal. Setting the high-pass filter point above the power supply noise frequencies, 217Hz in a GSM phone, for example, filters out the noise such that it is not amplified and heard on the output. Capacitors with a tolerance of 10% or better are recommended for impedance matching and improved CMRR and PSRR.

## DEMO BOARD GUIDELINES

### Introduction

The LM49153 demoboard is shown in Figure TBD.

### Quick Start Guide:

1. Connect the one end of the USB cable to the PC that will be used to control the demo board and the other end to J1 of the LM49153 demo board.
2. Install the LM49153 $I^2C$ interface software.
3. Apply 2.7V to 5.5V to the header labeled $V_{DD}$ and apply a ground connection to the header labeled GND above C5.
4. Apply 1.7V to 2.0V to the header labeled $HPV_{DD}$ and apply a ground connection to the header labeled GND7.
5. Apply a mono differential signal or two single-ended signal to headers labeled INM-/INR1 and INM+/INL1. Then, apply a single-ended signal to headers labeled INL2 and INR2.
6. 
   (a) For class D speaker output, connect a speaker or load (≥4Ω) to LSOUT- and LSOUT+ header pins (a low pass filter may be required for measurements).
   (b) For headphone output, connect either through headphone output jack or HPR and HPL header pins.
7. Run the LM49153 $I^2C$ interface software, select desired mode, set 0dB volume gain, and Power on options from the GUI.

### Board Features

The LM49153 demonstration board has all of the necessary connections, using 100mil headers, to apply the power supply voltage and the audio input signals. The Class D amplifier's output is available on 100mil headers. The Class AB headphone's amplified audio signal is available on both a stereo headphone jack and 100 mil headers. The input and output of the earpiece analog switch are also available on 100mil headers. On-board $I^2C$ signal generation microcontroller allows for a convenient connection via USB jack.

### Connections

| Headers/Jumpers Description | Function/Use |
|---|---|
| $V_{DD}$ and GND | Power supply connection. Connect an external power supply's positive voltage source to $V_{DD}$ and the supply's ground source to GND header pins respectively. |
| $HPV_{DD}$ and GND7 | Headphone power supply connection. Connect an external power supply's positive voltage source to $HPV_{DD}$ and the supply's ground source to GND7 header pins respectively. |
| INM+/INL1 and INM-/INR1 | These header pins provide a connection to a mono differential or stereo left and right single-ended input. |
| INL2 and INR2 | These header pins provide a connection to stereo left and right single-ended input. |
| EP+ and EP- | These header pins provide a connection to the input of the earpiece bypass switch. |
| LSOUT- and LSOUT+ | These header pins provide a connection to Class D loudspeaker outputs. Apply a load greater than 4Ω. A low pass filter may be required for measurements. |
| HPL and HPR | These header pins provide a connection to headphone outputs. Apply a load greater than 16Ω. |
| J1 | J1 provides a USB connection to control the LM49153. |
| JU1 | Stereo headphone jack |

### Power Supply Sequencing

The LM49153 uses two power supply voltages, $V_{DD}$ for the Class D and $HPV_{DD}$ for the Headphones. If using two separate power supplies, apply $V_{DD}$ first before applying $HPV_{DD}$ to ensure proper operation.

### I²C Interface GUI Software

The LM49153 demo board has the I²C signal generation microcontroller integrated and will generate the address byte and the data byte when used with the LM49153 GUI software (see Figure 27).

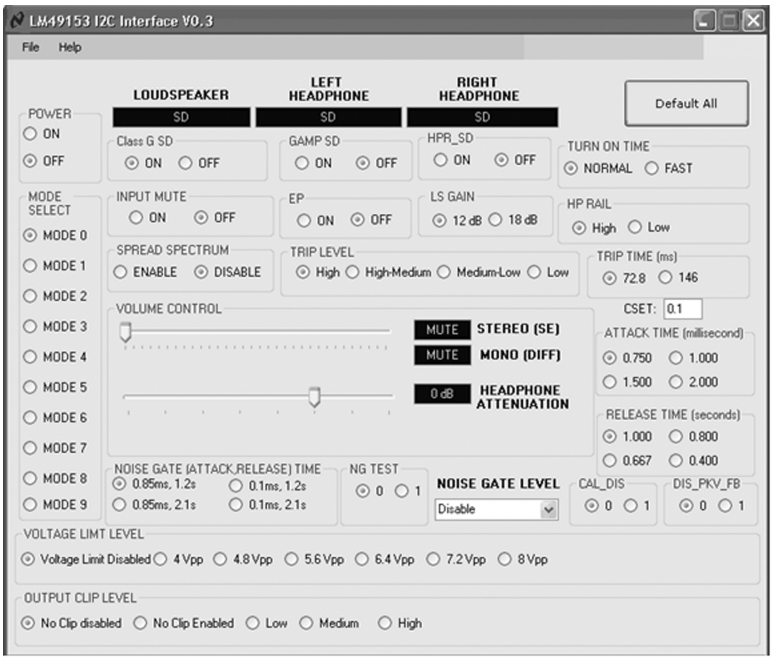



**Figure 27. GUI Software**

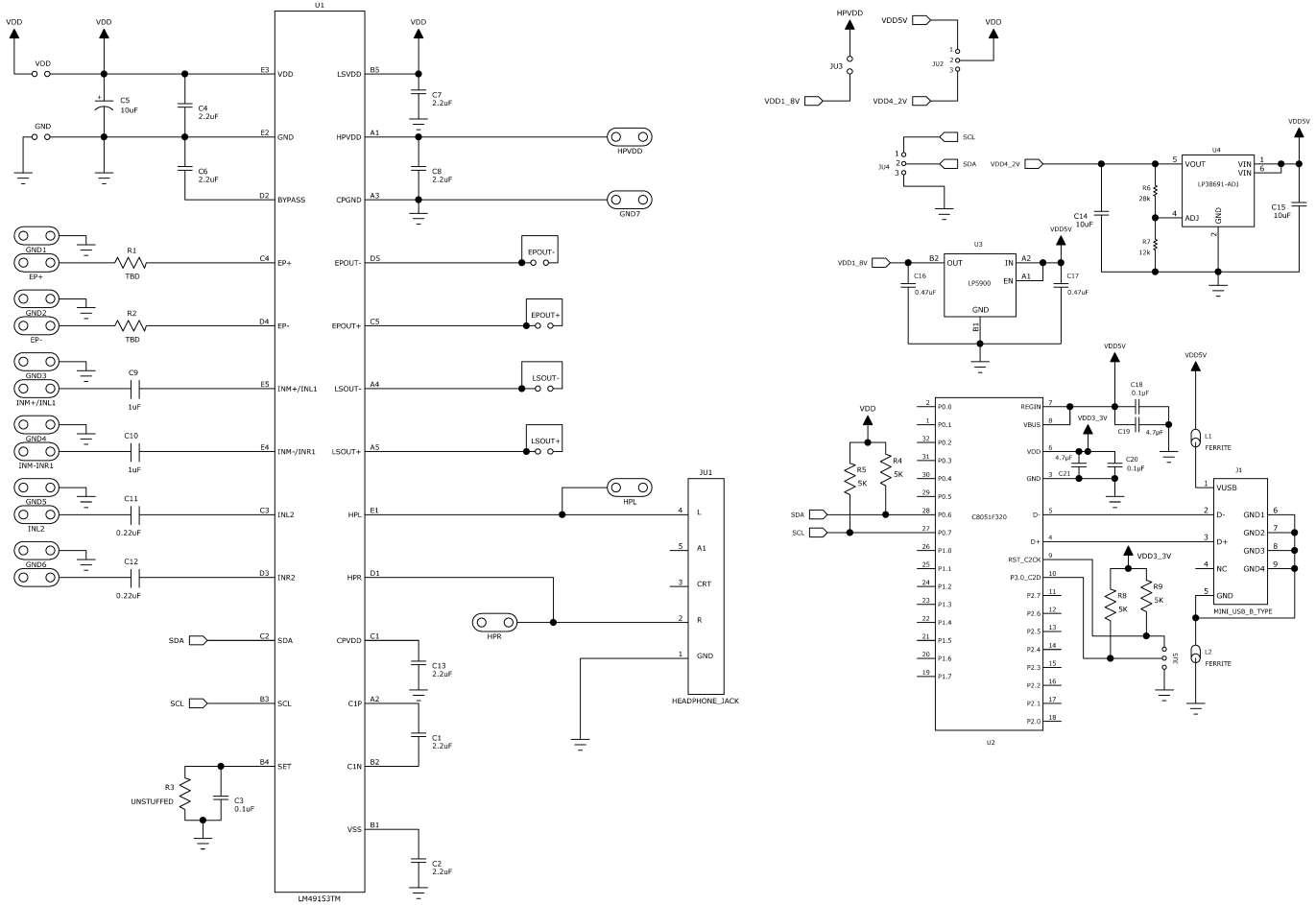
### Software Installation Instructions

1. Unzip the LM49153 setup.zip file to a specified folder.
2. Run “LM49153 setup.msi” from the specified folder. If prompted to install Microsoft framework 2.0, please proceed to do so, internet connection may be required)
3. The LM49153 Control Software installation will begin.

## Bill Of Materials

| Item | Ref Designator | Part Description | Manufacturer | Part Number | Value | Footprint | Qty |
|---|---|---|---|---|---|---|---|
| 1 | PCB | LM49153EVAL PCB | Texas Instruments | 551600453-001 RevA | | | 1 |
| 2 | U1 | LM49153TMEVAL IC | Texas instruments | LM49153TM | | | 1 |
| 3 | U2 | C8051F320 | Silicon Labs | C8051F320 | | LQFP-32 | 1 |
| 4 | U3 | LP5900 | Texas instruments | LP5900TL-1.8 | | uSMD-4 | 1 |
| 5 | U4 | LP38691-ADJ | Texas instruments | LP38691SD-ADJ | | LLP-6 | |
| 6 | C1, C4, C6, C7, C13 | Ceramic Capacitor | Panasonic | ECJ-1VB1A225K | 2.2uF | 603 | 7 |
| 7 | C5 | Tantalum capacitor | AVX | TPSB106K016R0800 | 10uF | B Case | 1 |
| 8 | C9, C10 | Ceramic Capacitor | Taiyo Yuden | EMK316B7105KF-T | 1uF | 1206 | 2 |
| 9 | C11, C12 | Ceramic Capacitor | Panasonic | ECJ-3VB1C224K | 0.22uF | 1206 | 2 |
| 10 | C14, C15 | Ceramic Capacitor | Taiyo Yuden | JMK107BJ106MA-T | 10uF | 603 | 2 |
| 11 | C16, C17 | Ceramic Capacitor | Kemet | C0603C474K4RACTU | 0.47uF | 603 | 2 |
| 12 | C3, C18, C20 | Ceramic Capacitor | Kemet | C0603C104J3RACTU | 0.1uF | 603 | 2 |
| 13 | C2, C8, C19, C21 | Ceramic Capacitor | Taiyo Yuden | LMK107BJ475KA-T | 4.7uF | 603 | 2 |
| 14 | J1 | Mini USB B Type | Hirose | UX60-MB-5ST | | | 1 |
| 15 | JU1 | 5-pole Headphone Jack | Switch Craft | 35RAPC4BH3 | | | 1 |
| 16 | L1, L2 | FERRITE | Murata | BLM21PG300SN1D | FERRITE CHIP 30 OHM 3000MA 0805 | 805 | 2 |
| 17 | R1, R2 | 0603 Resistor | Panasonic | ERJ-3EKF10R0V | 10ohm | 603 | 2 |
| 18 | R4, R5, R8, R9 | 0603 Resistor | Vishay/Dale | | | 603 | 4 |
| 19 | R6 | 0603 Resistor | Vishay/Dale | | | 603 | 1 |
| 20 | R7 | 0603 Resistor | Vishay/Dale | | | 603 | 1 |
| 21 | EP+, EP-, EPOUT+, EPOUT-, GND, GND1, GND2, GND3, GND4, GND5, GND6, GND7, GND8, HPL, HPR, HPVDD, INL2, INM+/INL1, INM-/INR1, INR2, VDD, LSOUT+, LSOUT-, JU3 | 2–pin 100 mil Jumper | AMP | 87220–2 | | | 24 |
| 22 | JU2, JU4, JU5 | CONN HEADR BRKWAY. 10003POS STR | TYCO | 9–146285–0–03 | | | |
| 23 | R3 | | | | | | |

## Demo Board Schematic Diagram



## Demo Board Layout

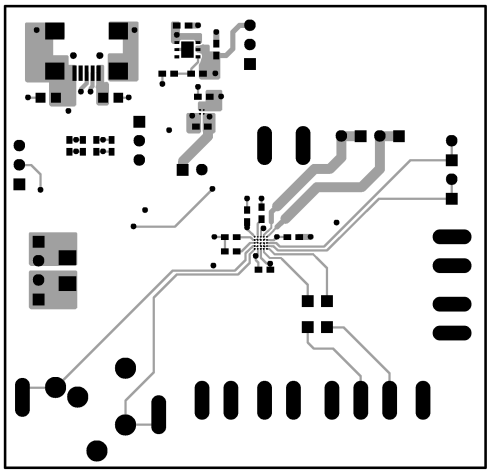


Figure 28. Top Layer

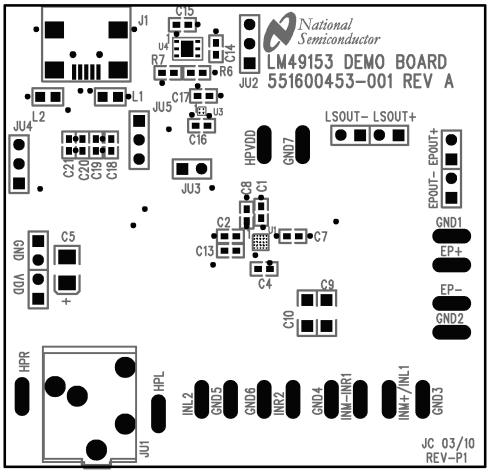



Figure 29. Top Silkscreen

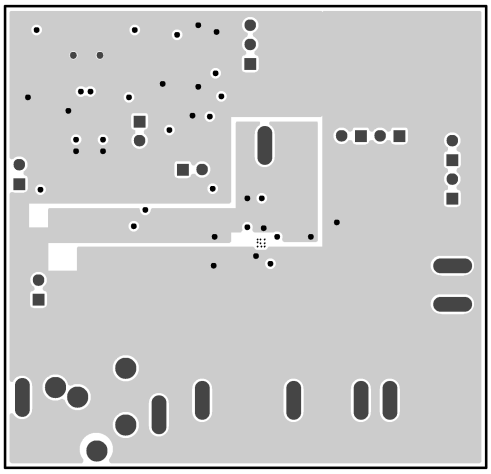


Figure 30. Layer 2

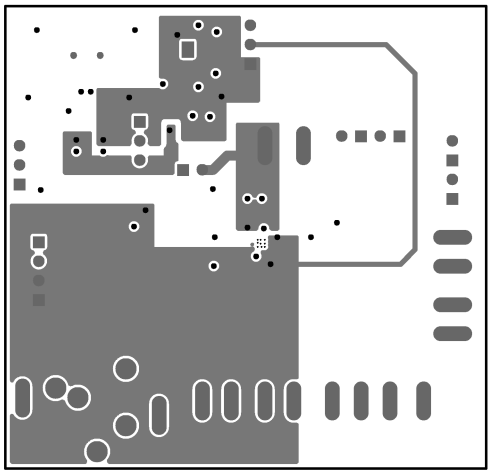


Figure 31. Layer 3

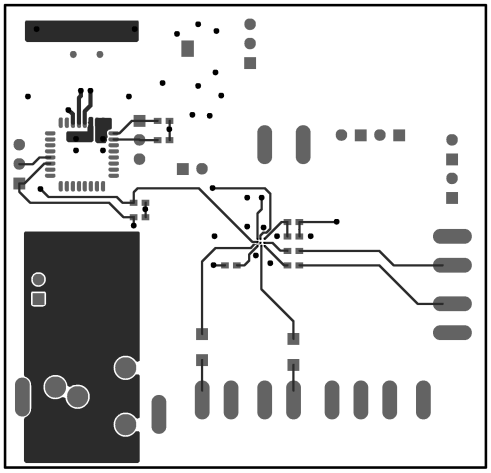


Figure 32. Bottom Layer

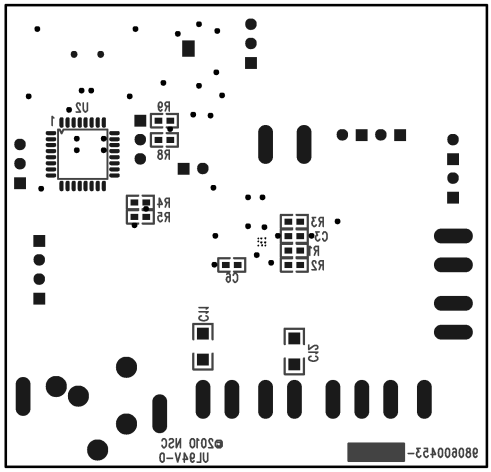


Figure 33. Bottom Silkscreen

## Revision History

| Rev | Date | Description |
|---|---|---|
| 1.0 | 12/02/10 | Initial WEB released. |
| 1.01 | 12/08/10 | Text edits. |
| 1.02 | 03/31/11 | Changed the Typical value on Xtalk from 68 to 78 (EC table). |
| 1.03 | 04/01/11 | Changed the Typical value on Xtalk from 78 to 80 (EC table). |
| C | 05/03/13 | Changed layout of National Data Sheet to TI format. |

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LM49153TME/NOPB | ACTIVE | DSBGA | YFQ | 25 | 250 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | GO1 | Samples |
| LM49153TMX/NOPB | ACTIVE | DSBGA | YFQ | 25 | 3000 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | GO1 | Samples |

(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.

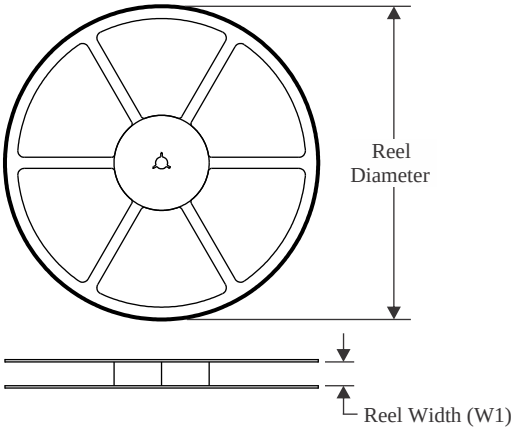
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

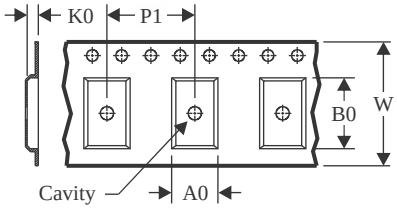
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

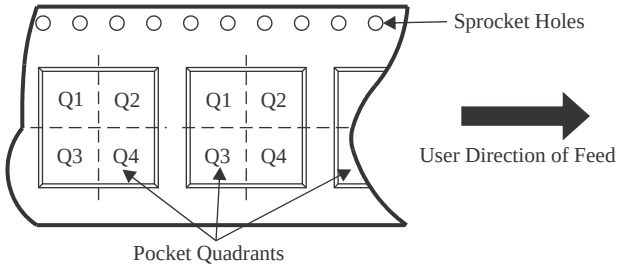



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

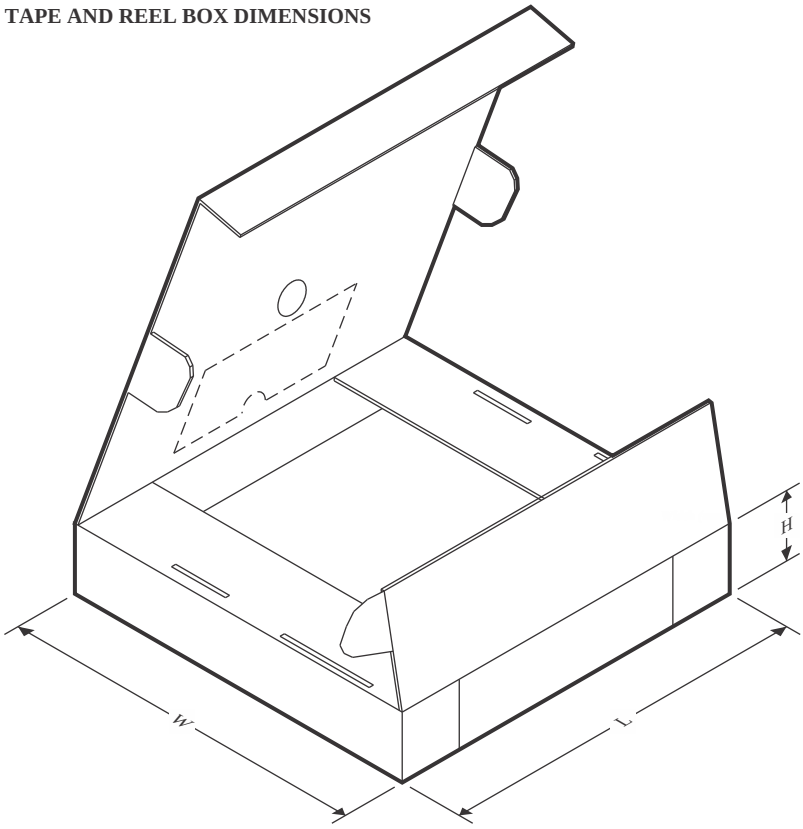
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM49153TME/NOPB | DSBGA | YFQ | 25 | 250 | 178.0 | 8.4 | 2.39 | 2.64 | 0.76 | 4.0 | 8.0 | Q1 |
| LM49153TMX/NOPB | DSBGA | YFQ | 25 | 3000 | 178.0 | 8.4 | 2.39 | 2.64 | 0.76 | 4.0 | 8.0 | Q1 |

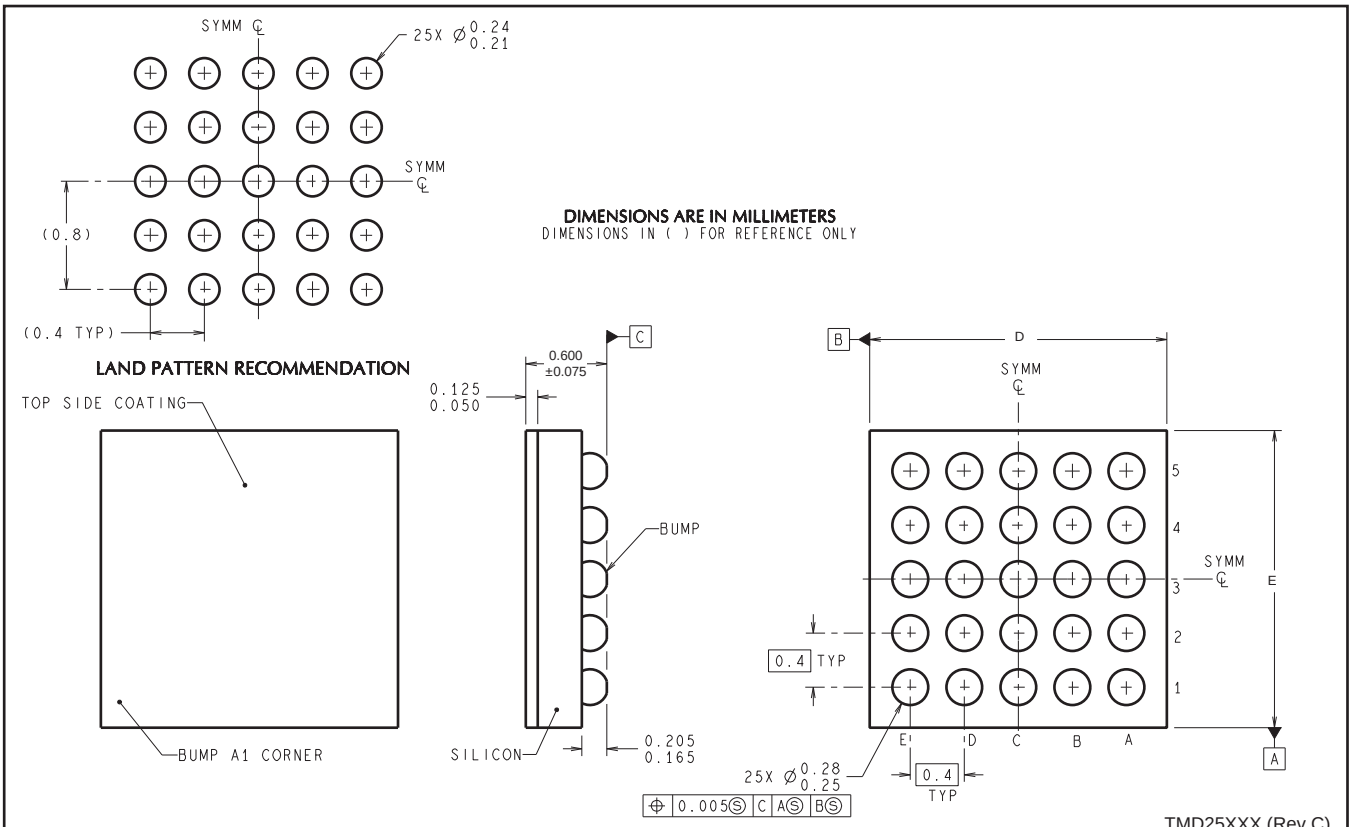
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM49153TME/NOPB | DSBGA | YFQ | 25 | 250 | 208.0 | 191.0 | 35.0 |
| LM49153TMX/NOPB | DSBGA | YFQ | 25 | 3000 | 208.0 | 191.0 | 35.0 |

# YFQ0025




D: Max = 2.446 mm, Min =2.386 mm

E: Max = 2.329 mm, Min =2.269 mm

4215084/A 12/12

NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.

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