

# Mono, Bridge-Tied Load, Ceramic Speaker Driver with I<sup>2</sup>C Volume Control and Reset

## General Description

The LM48557 is a single supply, mono, ceramic speaker driver with an integrated charge-pump, designed for portable devices, such as cell phones and portable media players, where board space is at a premium. The LM48557 charge pump allows the device to deliver 5.8V<sub>RMS</sub> from a single 4.2V supply.

The LM48557 features high power supply rejection ratio (PSRR), 80dB at 217Hz, allowing the device to operate in noisy environments without additional power supply conditioning. Flexible power supply requirements allow operation from 2.7V to 4.5V. The LM48557 features an active low reset input that reverts the device to its default state. Additionally, the LM48557 features a 36-step I<sup>2</sup>C volume control and mute function. The low power Shutdown mode reduces supply current consumption to 0.01μA.

The LM48557's superior click and pop suppression eliminates audible transients on power-up/down and during shutdown. The LM48557 is available in an ultra-small 16-bump micro SMD package (1.965mmx1.965mm).

## Key Specifications

■ Output Voltage at V <sub>DD</sub> = 4.2V R <sub>L</sub> = 1μF +22Ω, THD+N ≤ 1%	5.8V <sub>RMS</sub> (typ)
■ Quiescent Power Supply Current at 4.2V	5mA (typ)
■ PSRR at 217Hz	80dB (typ)
■ Shutdown current	0.01μA (typ)

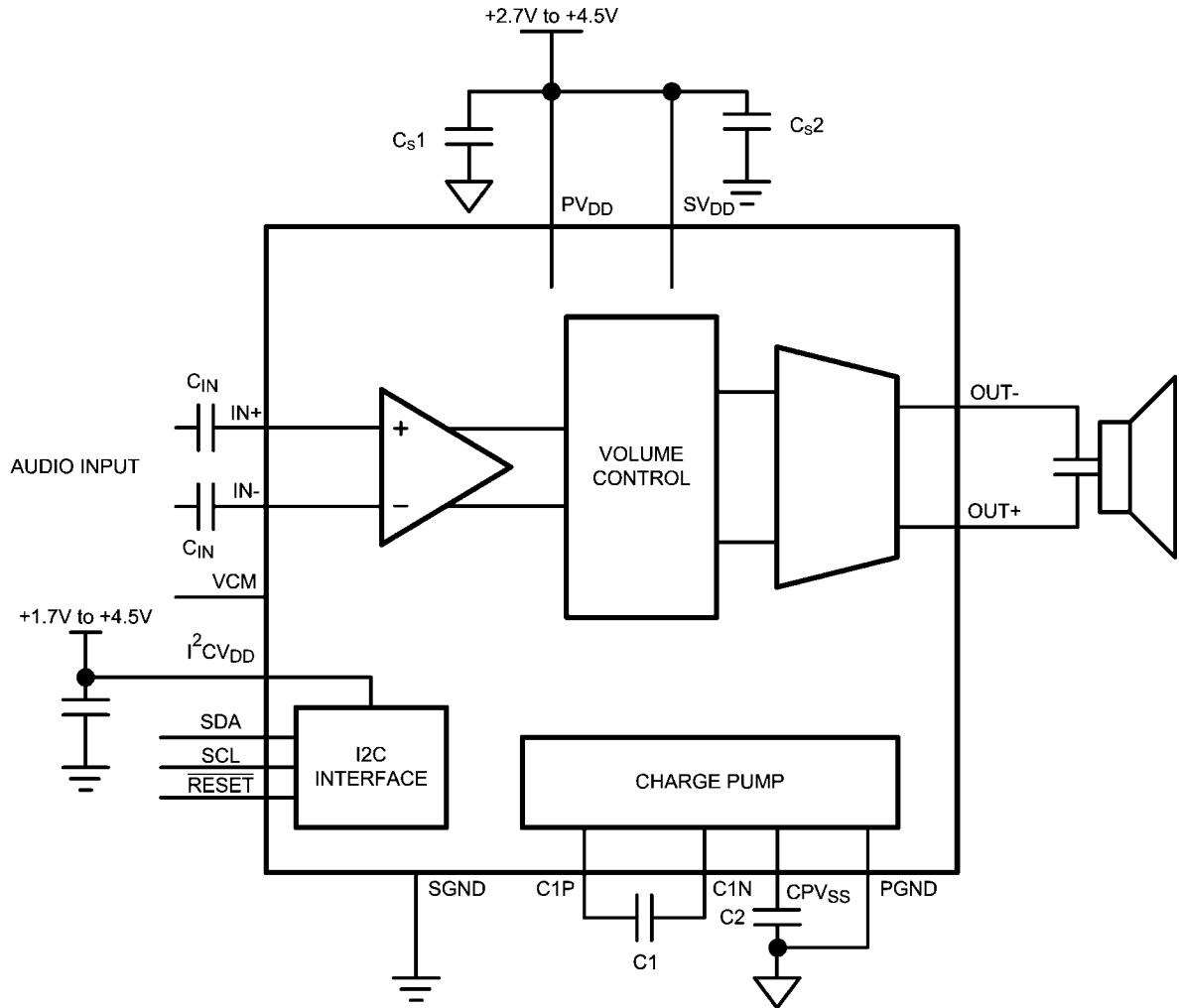
## Features

- Integrated Charge Pump
- Bridge-tied Load Output
- Differential Input
- High PSRR
- I<sup>2</sup>C Volume and Mode Control
- Reset Input
- Advanced Click-and-Pop Suppression
- Low Supply Current
- Minimum external components
- Micro-power shutdown
- Available in space-saving 16-bump micro SMD package

## Applications

- Mobile phones
- PDAs
- Notebook Electronic Devices
- MP3 Players

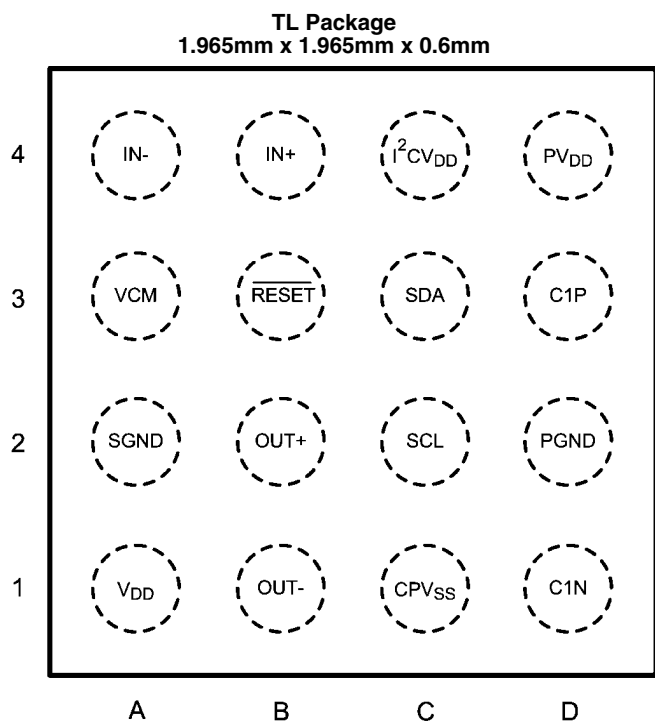
## Typical Application



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

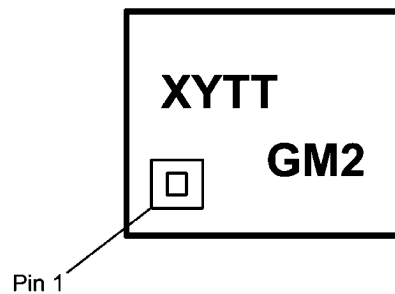
## Connection Diagrams



**Top View**  
Order Number LM48557TL  
See NS Package Number TLA1611A

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**16-Bump micro SMD Marking**



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**Top View**  
XY – Date Code  
TT – Lot Traceability  
G – Boomer Family  
M2 – LM48557TL

## Ordering Information

Order Number	Package	Package DWG #	Transport Media	MSL Level	Green Status
LM48557TL	16-Bump micro SMD	TLA1611A	250 units on tape and reel	1	RoHS & no Sb/Br
LM48557TLX	16-Bump micro SMD	TLA1611A	3000 units on tape and reel	1	RoHS & no Sb/Br

## Bump Descriptions

Bump	Name	Description
A1	$SV_{DD}$	Signal Power Supply
A2	SGND	Signal Ground
A3	VCM	Common Mode Sense Input
A4	IN-	Amplifier Inverting input
B1	OUT-	Amplifier Inverting output
B2	OUT+	Amplifier Non-Inverting Output
B3	$\overline{\text{RESET}}$	Active Low Reset Input. Connect to $V_{DD}$ for normal operation. Toggle between $V_{DD}$ and GND to reset the device.
B4	IN+	Amplifier Non-Inverting Input
C1	$CPV_{SS}$	Charge Pump Output
C2	SCL	I <sup>2</sup> C Serial Clock Input
C3	SDA	I <sup>2</sup> C Serial Data Input
C4	I <sup>2</sup> C $V_{DD}$	I <sup>2</sup> C Supply Voltage
D1	C1N	Charge Pump Flying Capacitor Negative Terminal
D2	PGND	Power Ground
D3	C1P	Charge Pump Flying Capacitor Positive Terminal
D4	$PV_{DD}$	Power Supply

## Absolute Maximum Ratings (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (Note 1)	5.25V
Storage Temperature	-65°C to +150°C
Input Voltage	-0.3V to $V_{DD} + 0.3V$
Power Dissipation (Note 3)	Internally Limited
ESD Rating-Human Body Model (Note 4)	2kV
ESD Rating-Machine Model (Note 5)	150V
Junction Temperature	150°C

Thermal Resistance

$$\theta_{JA} \text{ (typ) - (TLA1611A)}$$

63°C/W

Soldering Information

See AN-1112 "Micro SMD Wafer Level Chip Scale Package."

## Operating Ratings

Temperature Range

$$T_{MIN} \leq T_A \leq T_{MAX}$$

$$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$$

Supply Voltage

$$PV_{DD} \text{ and } SV_{DD}$$

$$2.7V \leq V_{DD} \leq 4.5V$$

$$I^2CV_{DD}$$

$$1.7V \leq I^2CV_{DD} \leq 4.5V$$

## Electrical Characteristics $V_{DD} = 4.2V$ (Notes 1, 2)

The following specifications apply for  $A_V = 6dB$ ,  $R_L = 1\mu F + 22\Omega$ ,  $C_1 = 2.2\mu F$ ,  $C_2 = 2.2\mu F$ ,  $f = 1kHz$ , unless otherwise specified. Limits apply for  $T_A = 25^\circ\text{C}$ .

Symbol	Parameter	Conditions	LM48557			Units
			Min	Typ	Max	
			(Note 7)	(Note 6)	(Note 7)	
$V_{DD}$	Supply Voltage Range		2.7		4.5	V
$I^2CV_{DD}$	I <sup>2</sup> C Supply Voltage Range		1.7		4.5	V
$I_{DD}$	Quiescent Power Supply Current	$V_{IN} = 0V$ , $R_L = \infty$		5	8	mA
$I_{SD}$	Shutdown Current	Shutdown Enabled		0.01	1	$\mu A$
$ V_{OS} $	Differential Output Offset Voltage	$V_{IN} = 0V$ , $A_V = 0dB$		3	12	mV
		$V_{IN} = 0V$ , $A_V = 48dB$		40	160	mV
$V_{IH}$	Logic High Input Threshold	$\overline{RESET}$ , $V_{DD} = 2.7V$ to $4.5V$	1.4			V
$V_{IL}$	Logic Low Input Threshold	$\overline{RESET}$ , $V_{DD} = 2.7V$ to $4.5V$			0.4	V
$A_V$	Gain	Minimum Gain Setting Volume Control = 000001	-25.5	-25	-24.5	dB
		Maximum Gain Setting Volume Control = 111111	47	48	49	dB
$A_{V(MUTE)}$	Mute Attenuation	Volume Control = 000000		-90		dB
$R_{IN}$	Input Resistance		1	3		M $\Omega$
$V_{IN}$	Common Mode Input Voltage Range		-1		1	$V_{P-P}$
$V_O$	Output Voltage	$R_L = 1\mu F + 22\Omega$ , THD+N = 1%				
		$f = 1kHz$	5.5	5.8		$V_{RMS}$
			15.6	16.4		$V_{P-P}$
		$f = 5kHz$		4.0		$V_{RMS}$
		$R_L = 2.2\mu F + 10\Omega$ , THD+N = 1%				
		$f = 1kHz$		5.6		$V_{RMS}$
		$f = 5kHz$		2.9		$V_{RMS}$
THD+N	Total Harmonic Distortion + Noise	$V_O = 4V_{RMS}$ , $f = 1kHz$ , $A_V = 48dB$		0.05		%

Symbol	Parameter	Conditions	LM48557			Units
			Min	Typ	Max	
			(Note 7)	(Note 6)	(Note 7)	
PSRR	Power Supply Rejection Ratio (Figure 2)	$V_{DD} = 4.2V + 200mV_{P-P}$ (sine), Inputs AC GND, $C_{IN} = 0.1\mu F$ , $A_V = 0dB$				
		$f_{RIPPLE} = 217Hz$		80		dB
		$f_{RIPPLE} = 1kHz$		80		dB
		$V_{DD} = 4.2V + 200mV_{P-P}$ (sine), Inputs AC GND, $C_{IN} = 0.1\mu F$ , $A_V = 48dB$				
		$f = 1kHz$	15	40		dB
		$f = 5kHz$		40		dB
CMRR	Common Mode Rejection Ratio (Figure 3)	$V_{CM} = 200mV_{P-P}$ (sine), $C_{IN} = 0.1\mu F$ , $A_V = 48dB$				
		$f_{RIPPLE} = 500Hz$	16	36		dB
		$f_{RIPPLE} = 1kHz$		37		dB
$f_{SW}$	Charge Pump Switching Frequency		230	300	370	kHz
SNR	Signal To Noise Ratio	$V_{OUT} = 5V_{RMS}$ , $f = 1kHz$ $A_V = 48dB$		74		dB
$\epsilon_{OS}$	Output Noise	$A_V = 0dB$ , A-Weighted Filter		20	30	$\mu V$
		$A_V = 48dB$ , A-weighted Filter		1		mV
$T_{WU}$	Wake Up Time	From shutdown		5		ms

### I<sup>2</sup>C Interface Characteristics $1.7V \leq I^2CV_{DD} \leq 4.5V$ (Notes 1, 2)

The following specifications apply for  $R_{PU} = 1k\Omega$  to  $I^2CV_{DD}$ , unless otherwise specified. Limits apply for  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	LM48557			Units
			Min	Typ	Max	
			(Note 7)	(Note 6)	(Note 7)	
$V_{IH}$	Logic Input High Threshold	SDA, SCL	$0.7 \times I^2CV_{DD}$			V
$V_{IL}$	Logic Input Low Threshold	SDA, SCL			$0.3 \times I^2CV_{DD}$	V
$V_{OL}$	Logic Output Low Threshold	SDA, $I_{SDA} = 3.6mA$			0.35	V
$I_{OH}$	Logic Output High Current	SDA, SCL, $I^2CV_{DD} = 4.5V$			2	$\mu A$
	SCL Frequency				400	kHz
6	SDA Setup Time		100			ns
5	SDA Stable Time		0	250	900	ns
1	Start Condition Time		100			ns
7	Stop Condition Time		100			ns

**Note 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 *Operating Ratings* is not implied. The *Operating Ratings* 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.

**Note 2:** The *Electrical Characteristics* tables list guaranteed specifications under the listed *Operating Ratings* except as otherwise modified or specified by the *Electrical Characteristics Conditions* and/or Notes. Typical specifications are estimations only and are not guaranteed.

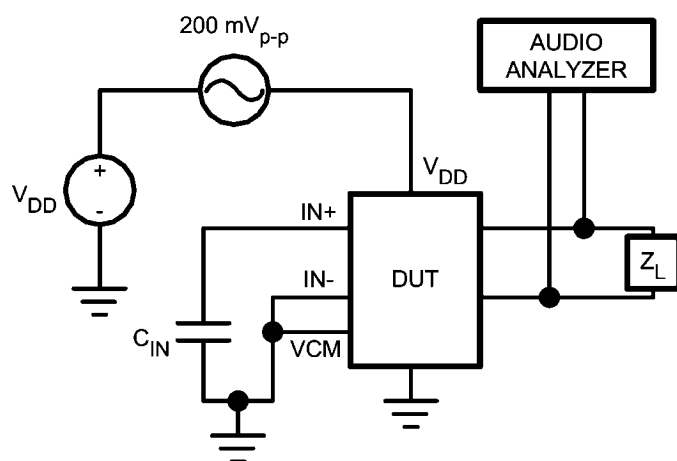
**Note 3:** The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$  or the number given in *Absolute Maximum Ratings*, whichever is lower.

**Note 4:** Human body model, applicable std. JESD22-A114C.

**Note 5:** Machine model, applicable std. JESD22-A115-A.

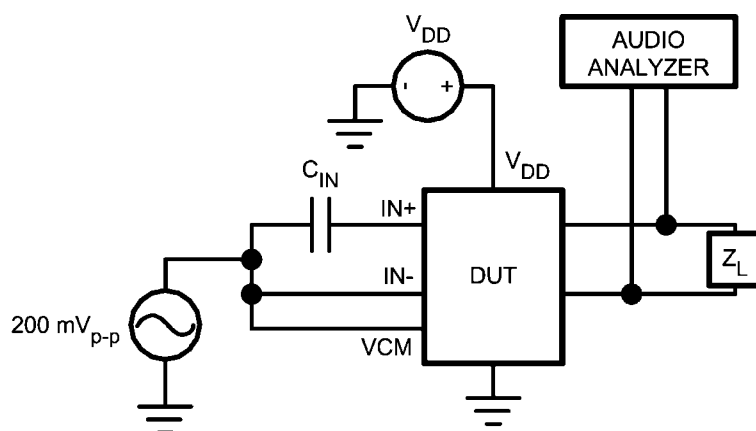
**Note 6:** Typical values represent most likely parametric norms at  $T_A = +25^\circ\text{C}$ , and at the *Operation Rating* at the time of product characterization and are not guaranteed.

**Note 7:** Datasheet min/max specification limits are guaranteed by test or statistical analysis.



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FIGURE 2. PSRR Test Circuit

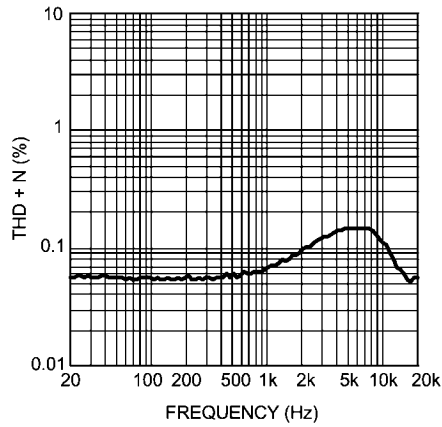


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FIGURE 3. CMRR Test Circuit

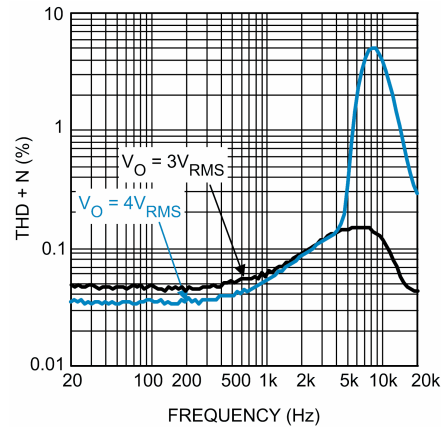
## Typical Performance Characteristics

**THD+N vs Frequency**  
 $V_{DD} = 3.6V$ ,  $Z_L = 1\mu F + 22\Omega$   
 $A_V = 48dB$ ,  $V_O = 2.5V$



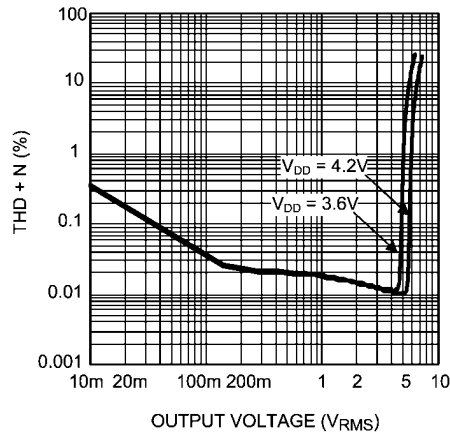
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**THD+N vs Frequency**  
 $V_{DD} = 4.2V$ ,  $Z_L = 1\mu F + 22\Omega$   
 $A_V = 48dB$



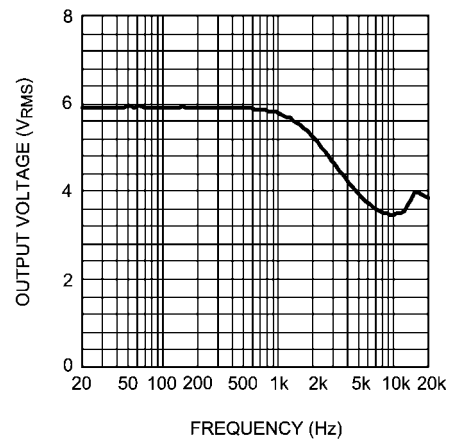
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**THD+N vs Output Voltage**  
 $Z_L = 1\mu F + 22\Omega$ ,  $A_V = 0dB$



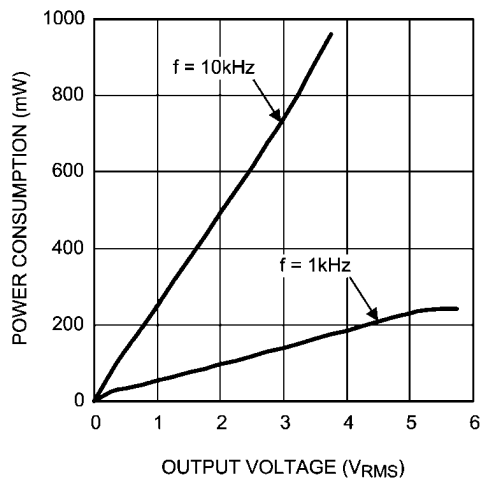
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**Output Voltage vs Frequency**  
 $V_{DD} = 4.2V$ ,  $Z_L = 1\mu F + 22\Omega$   
 $THD+N = 1\%$



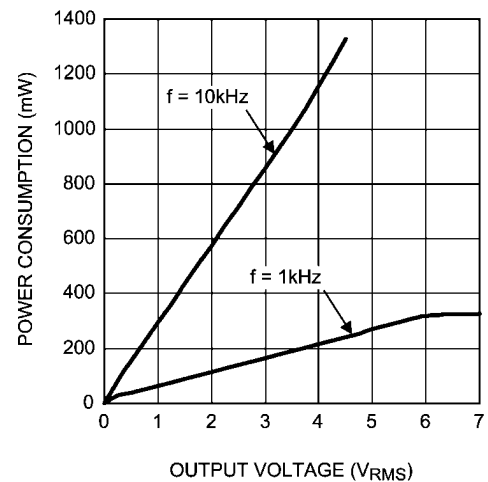
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**Power Consumption vs Output Voltage**  
 $V_{DD} = 3.6V$ ,  $Z_L = 1\mu F + 22\Omega$



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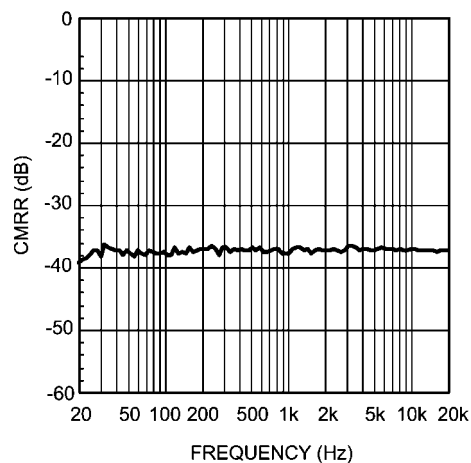
**Power Consumption vs Output Voltage**  
 $V_{DD} = 4.2V$ ,  $Z_L = 1\mu F + 22\Omega$



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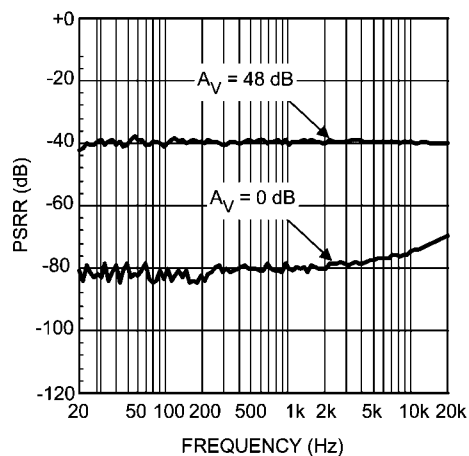


**CMRR vs Frequency**  
 $V_{DD} = 4.2V$ ,  $V_{RIPPLE} = 200mV_{P-P}$ ,  $A_V = 48dB$



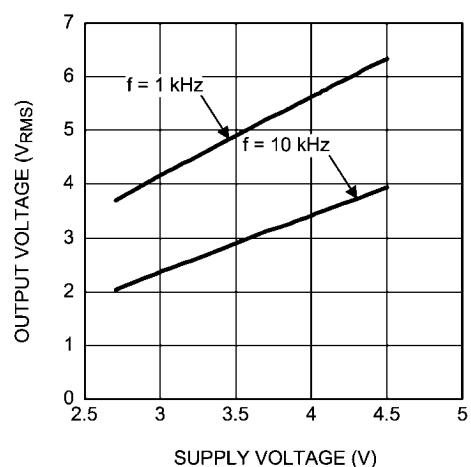
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**PSRR vs Frequency**  
 $V_{DD} = 4.2V$ ,  $V_{RIPPLE} = 200mV_{P-P}$



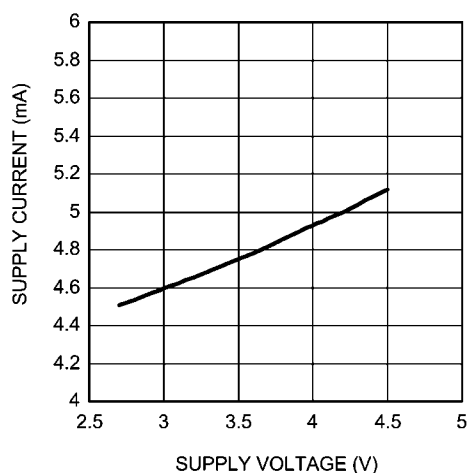
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**Output Voltage vs Supply Voltage**  
 $Z_L = 1\mu F + 22\Omega$ ,  $THD+N = 1\%$



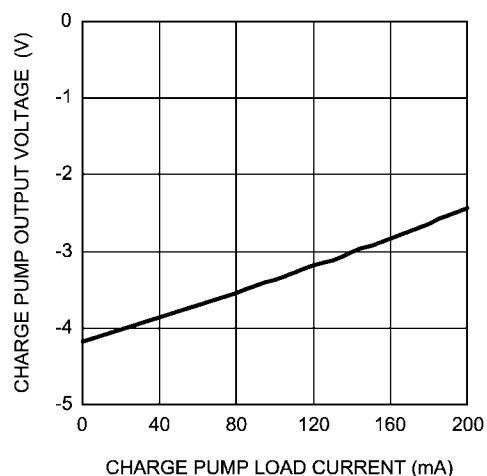
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**Supply Current vs Supply Voltage**  
 No Load



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**Charge Pump Output Voltage vs Load Current**  
 $V_{DD} = 4.2V$



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## Application Information

### I<sup>2</sup>C COMPATIBLE INTERFACE

The LM48557 is controlled through an I<sup>2</sup>C 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 LM48557 and the master can communicate at clock rates up to 400kHz. Figure 4 shows the I<sup>2</sup>C interface timing diagram. Data on the SDA line must be stable during the HIGH period of SCL. The LM48557 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 5). Each data word, device address and data, transmitted over the bus is 8 bits long and is always followed by an acknowledge pulse (Figure 6). The LM48557 device address is 11011110

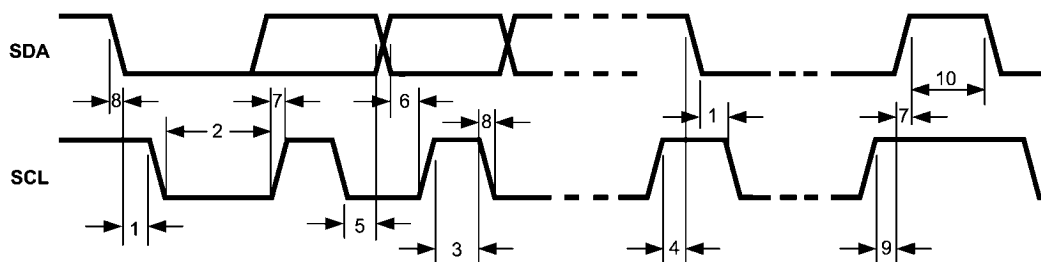
### I<sup>2</sup>C BUS FORMAT

The I<sup>2</sup>C bus format is shown in Figure 6. 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/W bit. Set  $R/\overline{W} = 0$ ; the LM48557 is a WRITE-ONLY device and will not respond to

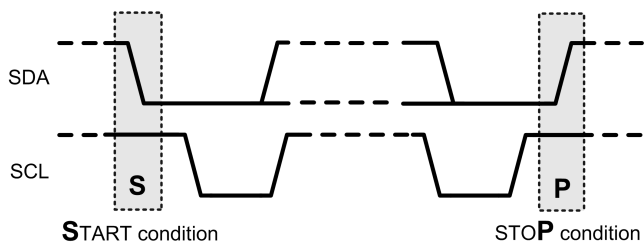
$R/\overline{W} = 1$ . In other words, the LM48557 will not issue an ACK when  $R/\overline{W} = 1$ . Each address bit is latched in on the rising edge of the clock. Each address bit must be stable while SCL is HIGH. After the last address bit is transmitted, the master device releases SDA, during which time, an acknowledge clock pulse is generated by the LM48557. If the LM48557 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. The LM48557 has two registers, Mode Control and Volume Control. The register address and register data are combined into a single byte, the most significant bit (MSB) indicates which register is being addressed. To address the Mode Control register, set the MSB of the data byte to 0, followed by seven bits of register data. To address the Volume Control register, set the MSB of the data byte to 1, followed by seven bits of register data. After the 8-bit register data word is sent, the LM48557 sends another ACK bit. The LM48557 supports single and multi-byte write operations, any number of data bytes can be transmitted to the device between START and STOP conditions. Following the acknowledgement of the last register data word, the master issues a STOP bit, allowing SDA to go high while SCL is high.



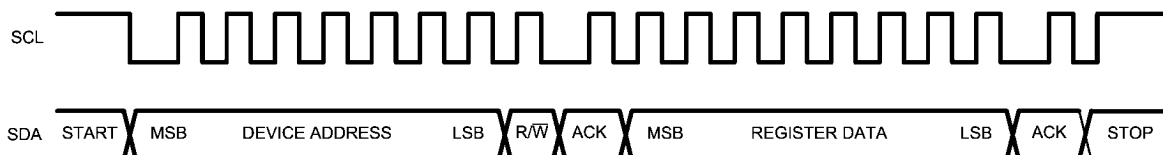
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FIGURE 4. I<sup>2</sup>C Timing Diagram



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FIGURE 5. Start and Stop Diagram



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FIGURE 6. Example Write Sequence

TABLE 1. Device Address

	B7	B6	B5	B4	B3	B2	B1	B0 R/W
Device Address	1	1	0	1	1	1	1	0

TABLE 2. Control Registers

Register Name	B7	B6	B5	B4	B3	B2	B1	B0
Mode Control	0	0	0	0	0	0	MUTE	$\overline{\text{SHDN}}$
Volume Control	1	0	VOL5	VOL4	VOL3	VOL2	VOL1	VOL0

TABLE 3. Mode Control Registers

BIT	NAME	VALUE	DESCRIPTION	DEFAULT SETTING
B0	$\overline{\text{SHDN}}$	0	Shutdown mode	0
		1	Normal operation	
B1	MUTE	0	Normal operation	0
		1	Device mute, $A_V = -90\text{dB}$ .	
B2	RESERVED*	X	Unused, Set to 0	0
B3	RESERVED*	X	Unused, Set to 0	0
B4	TESTMODE	0	Set B4 to 0. B4 = 1 enables TESTMODE. See TESTMODE section.	0
B5	RESERVED*	X	Unused, Set to 0	0
B6	RESERVED*	X	Unused, Set to 0	0
B7	REGISTER ADDRESS	0	Set to 0 to access Mode Control register	0

\*RESERVED bits are Don't Cares and are ignored by the device. The state of the RESERVED bits does not affect device operation.

TABLE 4. Volume Control Registers

BIT	NAME	VALUE	DESCRIPTION	DEFAULT SETTING
B0:B5	VOL0:VOL5	See Volume Control Table	Controls amplifier gain/attenuation	0
B6	RESERVED*	X	Unused, Set to 0	0
B7	REGISTER ADDRESS	1	Set to 1 to access Volume Control register	1

\*RESERVED bits are Don't Cares and are ignored by the device. The state of the RESERVED bits does not affect device operation.

### SINGLE AND MULTI-BYTE WRITE OPERATION

The LM48557 supports both single-byte and multi-byte write operations. A single-byte write operation begins with the master device transmitting a START condition followed by the device address (Figure 7). After receiving the correct device address, the LM48557 generates an ACK bit. The master device transmits the register data byte, after which the LM48557 generates an ACK bit. Following the ACK, the master issues a STOP condition, completing the single-byte data transfer.

A multi-byte write operation is similar to a single-byte operation, the master device issues a START condition and device

address, and the LM48557 responds with an ACK (Figure 8). The master device then transmits the first data byte. Following the LM48557's ACK, the master device does not issue a STOP condition, transmitting a second data byte instead. The LM48557 responds with an ACK bit. The master device can continue to issue data bytes, and the LM48557 will respond with an ACK, until a STOP condition is issued. Once a STOP condition is issued, the LM48557 ignores the I<sup>2</sup>C bus until the master issues the LM48557's device address.

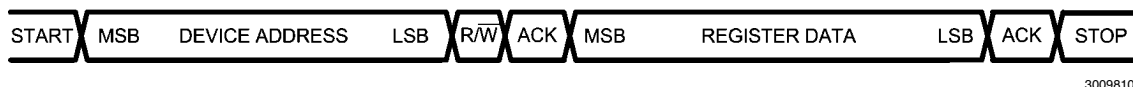


FIGURE 7. Single-Byte Write Example



FIGURE 8. Multi-Byte Write Example

### GENERAL AMPLIFIER FUNCTION

The LM48557 is a fully differential ceramic speaker driver that utilizes National's inverting charge pump technology to deliver over  $5.8V_{RMS}$  to a  $1\mu F$  ceramic speaker while operating from a single 4.2V supply. The low noise, inverting charge pump generates a negative supply voltage ( $CPV_{SS}$ ) from the

positive supply voltage ( $PV_{DD}$ ). The LM48557 takes advantage of the increased head room created by the charge pump and the bridge-tied load (BTL) architecture, delivering significantly more voltage than a single-ended, single-supply amplifier to the speaker.

TABLE 5. Volume Control Table

VOLUME STEP	VOL5	VOL4	VOL3	VOL2	VOL1	VOL0	GAIN (dB)
1 (MUTE)	0	0	0	0	0	0	-90
2	0	0	0	0	0	1	-25
3	0	0	0	0	1	0	-22
4	0	0	0	0	1	1	-19
5	0	0	0	1	0	0	-16
6	0	0	0	1	0	1	-13
7	0	0	0	1	1	0	-10
8	0	0	0	1	1	1	-8
9	0	0	1	0	0	0	-6
10	0	0	1	0	0	1	-4
11	0	0	1	0	1	0	-2
12	0	0	1	0	1	1	0
13	0	0	1	1	0	0	2
14	0	0	1	1	0	1	4
15	0	0	1	1	1	0	6
16	0	0	1	1	1	1	8
17	0	1	0	0	0	0	10
18	0	1	0	0	0	1	12
19	0	1	0	0	1	0	14
20	0	1	0	0	1	1	16
21	0	1	0	1	0	0	18
22	0	1	0	1	0	1	20
23	0	1	0	1	1	0	22
24	0	1	0	1	1	1	24
25	0	1	1	0	0	0	26
26	0	1	1	0	0	1	28
27	0	1	1	0	1	0	30
28	0	1	1	0	1	1	32
29	0	1	1	1	0	0	34
30	0	1	1	1	0	1	36
31	0	1	1	1	1	0	38
32	0	1	1	1	1	1	40
Do Not Use Volume Steps 33-60 See Table 6							
61	1	1	1	1	0	0	42
62	1	1	1	1	0	1	44
63	1	1	1	1	1	0	46
64	1	1	1	1	1	1	48

TABLE 6. Unused Volume Steps

VOLUME STEP	VOL5	VOL4	VOL3	VOL2	VOL1	VOL0	GAIN (dB)
33	1	0	0	0	0	0	-90
34	1	0	0	0	0	1	-25
35	1	0	0	0	1	0	-22
36	1	0	0	0	1	1	-19
37	1	0	0	1	0	0	-16
38	1	0	0	1	0	1	-13
39	1	0	0	1	1	0	-10
40	1	0	0	1	1	1	-8
41	1	0	1	0	0	0	-6
42	1	0	1	0	0	1	-4
43	1	0	1	0	1	0	0
44	1	0	1	0	1	1	4
45	1	0	1	1	0	0	8
46	1	0	1	1	0	1	12
47	1	0	1	1	1	0	14
48	1	0	1	1	1	1	16
49	1	1	0	0	0	0	18
50	1	1	0	0	0	1	20
51	1	1	0	0	1	0	22
52	1	1	0	0	1	1	24
53	1	1	0	1	0	0	26
54	1	1	0	1	0	1	28
55	1	1	0	1	1	0	30
56	1	1	0	1	1	1	32
57	1	1	1	0	0	0	34
58	1	1	1	0	0	1	36
59	1	1	1	0	1	0	38
60	1	1	1	0	1	1	40

## VOLUME CONTROL

The LM48557 has a 64 step volume control, but only 36 steps are recommended for use. Use steps 1 through 32 and steps 61 through 64 to set the gain of the device. Accessing steps 33 through 60 results in the repeated gain conditions shown in Table 6. Steps 33 through 60 are not tested and should not be used.

## SHUTDOWN FUNCTION

The LM48557 features a low-power shutdown mode that disables the device lowers the quiescent current to 0.01µA. Set bit B0 ( $\overline{\text{SHDN}}$ ) of the Mode Control register to 0 to disable the amplifier and charge pump. Set  $\overline{\text{SHDN}}$  to 1 for normal operation. Shutdown mode does not clear the I<sup>2</sup>C register. When re-enabled, the device returns to its previous volume setting. To clear the I<sup>2</sup>C register, either remove power from the device, or toggle RESET (see RESET section).

## RESET

The LM48557 features an active low reset input. Driving  $\overline{\text{RESET}}$  low clears the I<sup>2</sup>C register. Volume control is set to 000000 (-90dB) and  $\overline{\text{SHDN}}$  is set to 0, disabling the device. While RESET is low, the LM48557 ignores any I<sup>2</sup>C data. After the device is reset, and RESET is driven high, the LM48557 remains in shutdown mode with the volume set to -90dB. Re-enable the device by writing to the I<sup>2</sup>C register.

## MUTE

The LM48557 features a mute mode. Set bit B1 (MUTE) of the Mode Control register to 1 to mute the device. In mute mode, the gain is set to -90dB, equivalent to the volume step 1. Set MUTE = 0 to unmute the device. Once unmuted, the device returns to its previous volume step.

## TEST MODE

If enabled, TESTMODE does not affect device performance under normal operating conditions. Operating above the recommended supply voltage range with TESTMODE enabled can result in damage to the device.

## PROPER SELECTION OF EXTERNAL COMPONENTS

### Power Supply Bypassing/Filtering

Proper power supply bypassing is critical for low noise performance and high PSRR. Place the supply bypass capacitors as close to the device as possible. Place a 1µF ceramic capacitor from V<sub>DD</sub> to GND. Additional bulk capacitance may be added as required.

### 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<sub>DS(ON)</sub> 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 where 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<sub>SS</sub>. 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 where low maximum output power requirements.

### Input Capacitor Selection

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 LM48557. The input capacitors create a high-pass filter with the input resistors R<sub>IN</sub>. The -3dB point of the high pass filter is found using Equation (1) below.

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

Where the value of R<sub>IN</sub> is given in the Electrical Characteristics Table.

High pass filtering the audio signal helps protect the speakers. When the LM48557 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.

### COMMON MODE SENSE

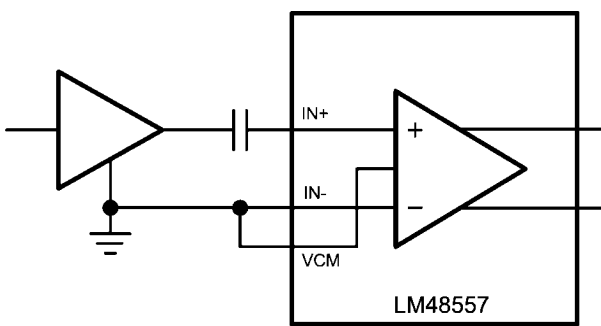
The LM48557 features a common mode sense pin (VCM, pin A3) that includes additional common mode cancelling circuitry that improves the CMRR. When the volume control is set at a high gain step such as 48dB, any mismatch in the input capacitors would degrade CMRR performance significantly. With the VCM pin connected to the ground of the input source, it takes the input capacitor mismatches out of the equation and therefore improves the CMRR. Another advantage with this feature is that only one input capacitor is needed in the single-ended configuration as opposed to two well matched capacitors. See next section for details of different configurations of the LM48857.

## SINGLE-ENDED INPUT CONFIGURATION

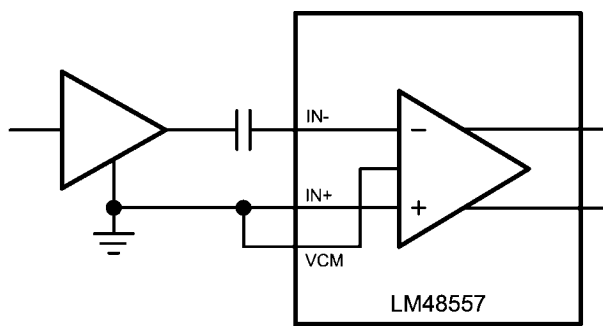
### Ground-Referenced Audio Source

The LM48557 input stage is compatible with ground-referenced input sources, such as CODECs with an integrated headphone amplifier. Connect either input, IN+ or IN- to the

CODEC output, and connect the unused input and VCM to the CODEC output ground (Figure 9). An input coupling capacitor in series with the source and device input is recommended to block the CODEC output offset voltage, minimizing click and pop and zipper noise during volume transitions.



Non-Inverting Configuration



Inverting Configuration

30098107

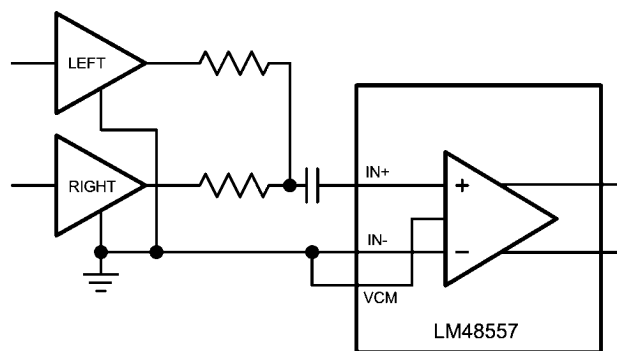
FIGURE 9. Single-Ended Input Configuration with a Ground-Referenced Source

## NON-GROUND REFERENCED AUDIO SOURCE

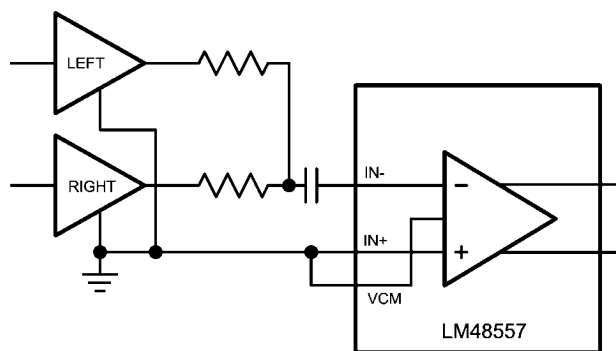
### Stereo-to-Mono Conversion

The LM48557 can convert a single-ended stereo signal to a mono BTL signal (Figure 10). Connect the left and right

CODEC outputs in parallel through two equal value resistors to either IN+ or IN-, and connect the unused input and VCM to the CODEC ground. Select the value of the resistors based on the desired frequency response created by the combination of the input resistor and the input coupling capacitor.



Non-Inverting Configuration



Inverting Configuration

30098108

FIGURE 10. Single-Ended Stereo-to-Mono BTL Conversion



## PCB Layout Guidelines

Minimize trace impedance of the power, ground and all output traces for optimum performance. Voltage loss due to trace resistance between the LM48557 and the load results in decreased output power and efficiency. Trace resistance between the power supply and ground has the same effect as a poorly regulated supply, increased ripple and reduced peak output power. Use wide traces for power supply inputs and amplifier outputs to minimize losses due to trace resistance, as well as route heat away from the device. Proper grounding

improves audio performance, minimizes crosstalk between channels and prevents switching noise from interfering with the audio signal. Use of power and ground planes is recommended.

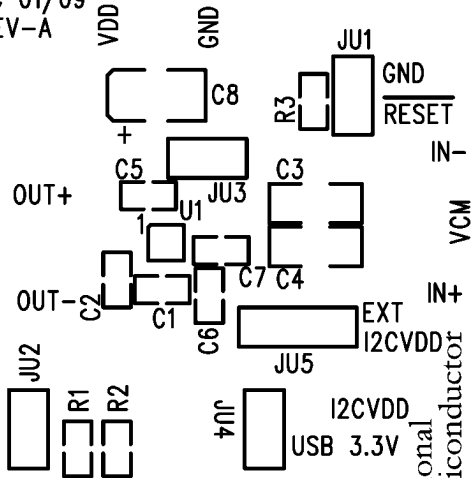
Place all digital components and route digital signal traces as far as possible from analog components and traces. Do not run digital and analog traces in parallel on the same PCB layer. If digital and analog signal lines must cross either over or under each other, ensure that they cross in a perpendicular fashion.

## LM48557TL Demoboard Bill of Materials

Designator	Quantity	Description
U1	1	LM48557TL Differential, Mono, Ceramic Speaker Driver with I <sup>2</sup> C Volume Control, and Reset
C1, C2, C5, C6, C7	5	CAP CERAMIC 2.2 $\mu$ F 10V X5R 10% 0603
C3, C4	2	CAP .1 $\mu$ F 16V CERAMIC X7R 10% 1206
C8	1	CAP TANT LOESR 10 $\mu$ F 16V 10% SMD
J2	1	CONN SOCKET PCB VERT 16POS .1"
JU1, JU2, JU3, JU4, VCM, VDD, GND, I <sup>2</sup> CV <sub>DD</sub> , IN+, IN-, OUT+, OUT-	12	CONN HEADER VERT .100 2POS 30Au
JU5	1	CONN HEADER VERT .100 3POS 30Au
R1, R2	2	RES 5.1K OHM 1/10W 5% 0603 SMD
R3	1	RES 20K OHM 1/10W 5% 0603 SMD
JU1_SH, JU2_SH, JU3_SH, JU5_SH	4	Jumper Shunt w/handle, 30uin gold plated, 0.100" pitch

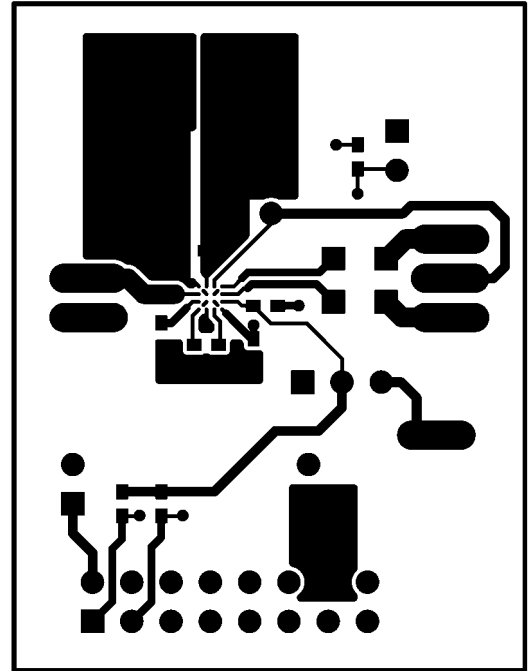
## PC Board Layout

LM48557 DEMO BOARD  
JC 01/09  
REV-A



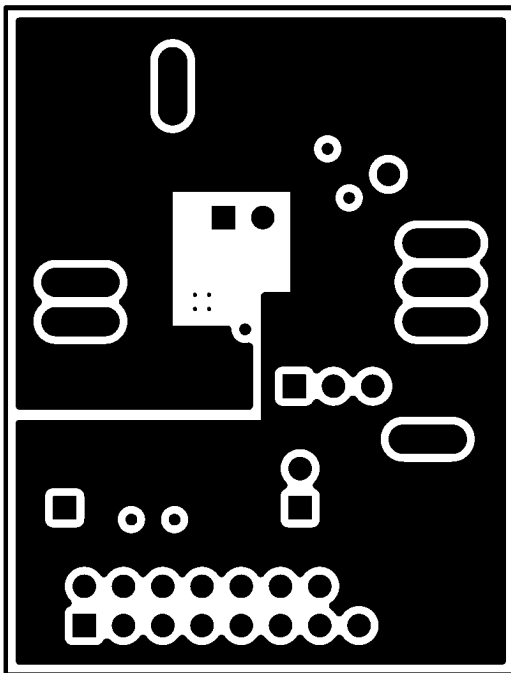
Silk Screen

30098125



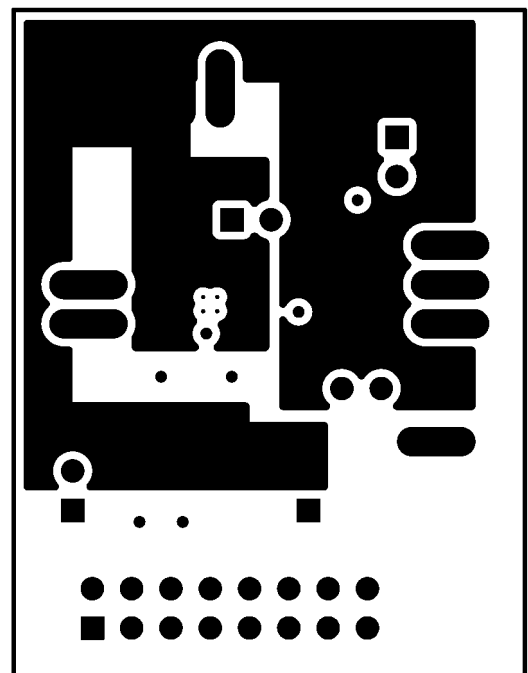
Top Layer

30098124



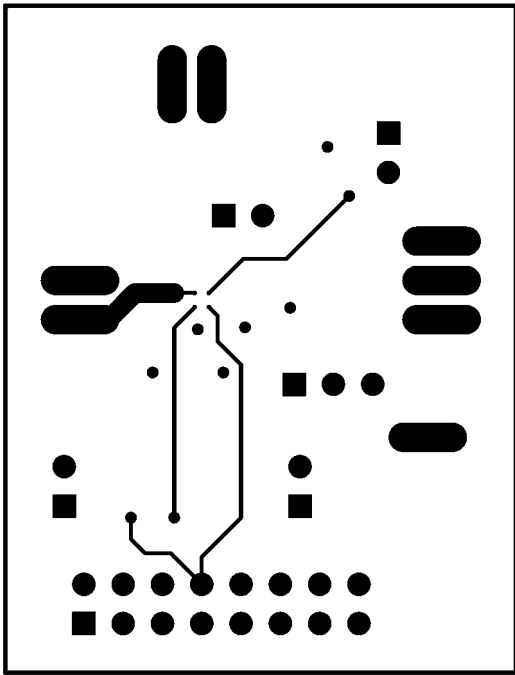
Layer 2

30098122



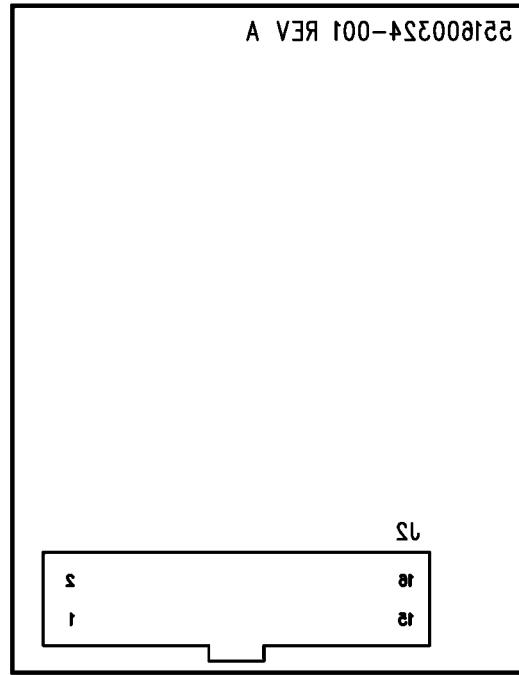
Layer 3

30098123



Bottom Layer

30098120



Bottom Silkscreen

30098121

## Demo Board Schematic

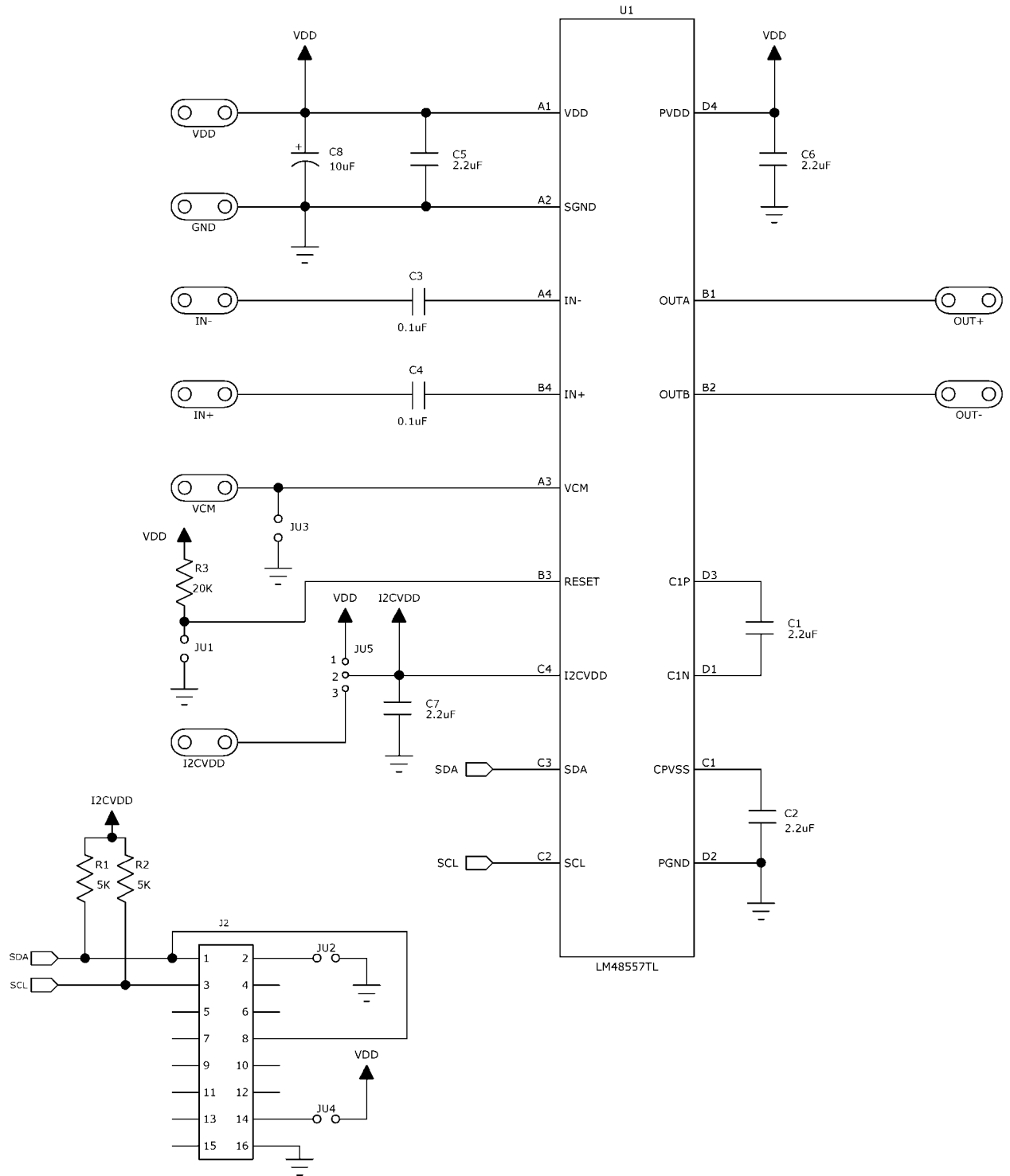
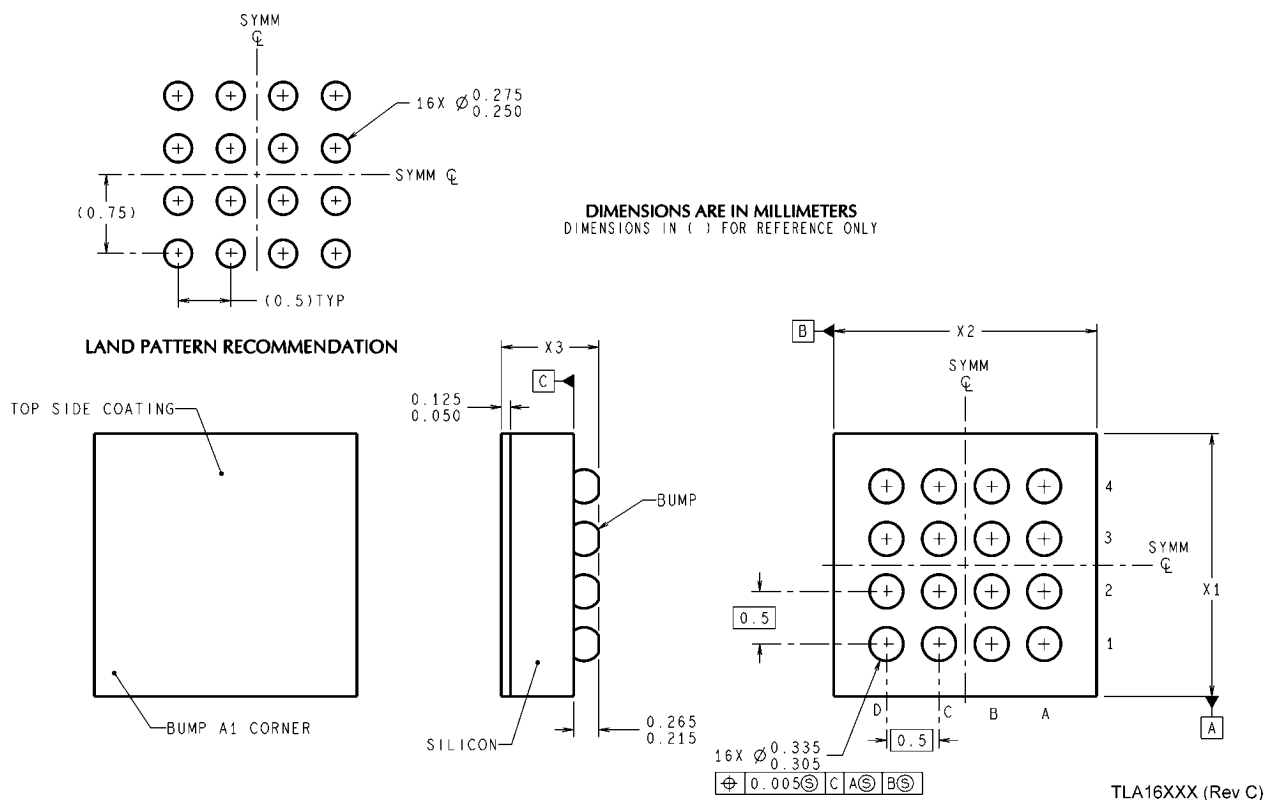


FIGURE 11. LM48557 Demo Board Schematic

30098119

## Revision History

Rev	Date	Description
1.0	07/08/09	Initial released.
1.01	07/15/09	Deleted the “Tru-GND...” trademark on the cover page.
1.02	08/05/09	Text edits.
1.03	08/06/09	Fixed a typo error.

**Physical Dimensions** inches (millimeters) unless otherwise noted

16-Bump micro SMD  
Order Number LM48557TL  
NS Package Number TLA1611A  
 $X_1 = 1.965 \pm 0.03$   $X_2 = 1.965 \pm 0.03$   $X_3 = 0.6 \pm 0.075$

## Notes

## Notes

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Clock and Timing	<a href="http://www.national.com/timing">www.national.com/timing</a>	Reference Designs	<a href="http://www.national.com/refdesigns">www.national.com/refdesigns</a>
Data Converters	<a href="http://www.national.com/adc">www.national.com/adc</a>	Samples	<a href="http://www.national.com/samples">www.national.com/samples</a>
Interface	<a href="http://www.national.com/interface">www.national.com/interface</a>	Eval Boards	<a href="http://www.national.com/evalboards">www.national.com/evalboards</a>
LVDS	<a href="http://www.national.com/lvds">www.national.com/lvds</a>	Packaging	<a href="http://www.national.com/packaging">www.national.com/packaging</a>
Power Management	<a href="http://www.national.com/power">www.national.com/power</a>	Green Compliance	<a href="http://www.national.com/quality/green">www.national.com/quality/green</a>
Switching Regulators	<a href="http://www.national.com/switchers">www.national.com/switchers</a>	Distributors	<a href="http://www.national.com/contacts">www.national.com/contacts</a>
LDOs	<a href="http://www.national.com/ldo">www.national.com/ldo</a>	Quality and Reliability	<a href="http://www.national.com/quality">www.national.com/quality</a>
LED Lighting	<a href="http://www.national.com/led">www.national.com/led</a>	Feedback/Support	<a href="http://www.national.com/feedback">www.national.com/feedback</a>
Voltage Reference	<a href="http://www.national.com/vref">www.national.com/vref</a>	Design Made Easy	<a href="http://www.national.com/easy">www.national.com/easy</a>
PowerWise® Solutions	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>	Solutions	<a href="http://www.national.com/solutions">www.national.com/solutions</a>
Serial Digital Interface (SDI)	<a href="http://www.national.com/sdi">www.national.com/sdi</a>	Mil/Aero	<a href="http://www.national.com/milaero">www.national.com/milaero</a>
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