

## LM4985 Boomer® Audio Power Amplifier Series

# Stereo 135mW Low Noise Headphone Amplifier with Selectable Capacitively Coupled or Output Capacitor-less (OCL) Output and Digitally Controlled (I<sup>2</sup>C) Volume Control

### General Description

The LM4985 is a stereo audio power amplifier with internal digitally controlled volume control. This amplifier is capable of delivering 68mW<sub>RMS</sub> per channel into a 16Ω load or 38mW<sub>RMS</sub> per channel into a 32Ω load at 1% THD when powered by a 3.6V power supply and operating in the OCL mode.

Boomer audio power amplifiers were designed specifically to provide high quality output power with a minimal amount of external components. To that end, the LM4985 features two functions that optimize system cost and minimize PCB area: an integrated, digitally controlled (I<sup>2</sup>C bus) volume control and an operational mode that eliminates output signal coupling capacitors (OCL mode). Since the LM4985 does not require bootstrap capacitors, snubber networks, or output coupling capacitors, it is optimally suited for low-power, battery powered portable systems. For added design flexibility, the LM4985 can also be configured for single-ended capacitively coupled outputs.

The LM4985 features a current shutdown mode for micropower dissipation and thermal shutdown protection.

### Key Specifications (V<sub>DD</sub> = 3.6V)

■ PSRR: 217Hz and 1kHz	
Output Capacitor-less (OCL)	
$f_{\text{RIPPLE}} = 217\text{Hz}$	77dB (typ)
$f_{\text{RIPPLE}} = 1\text{kHz}$	76dB (typ)
Capacitor Coupled (C-CUPL)	
$f_{\text{RIPPLE}} = 217\text{Hz}$	63dB (typ)
$f_{\text{RIPPLE}} = 1\text{kHz}$	62dB (typ)
■ Output Power per channel ( $f_{\text{IN}} = 1\text{kHz}$ , THD+N = 1%), $R_L = 16\Omega$ , OCL	
$V_{\text{DD}} = 2.5\text{V}$	31mW (typ)
$V_{\text{DD}} = 3.6\text{V}$	68mW (typ)
$V_{\text{DD}} = 5.0\text{V}$	135mW (typ)
■ THD+N ( $f = 1\text{kHz}$ )	
$R_{\text{LOAD}} = 16\Omega$ , OCL, $P_{\text{OUT}} = 60\text{mW}$	0.60
$R_{\text{LOAD}} = 32\Omega$ , OCL, $P_{\text{OUT}} = 33\text{mW}$	0.031
■ Shutdown Current	0.1μA (typ)

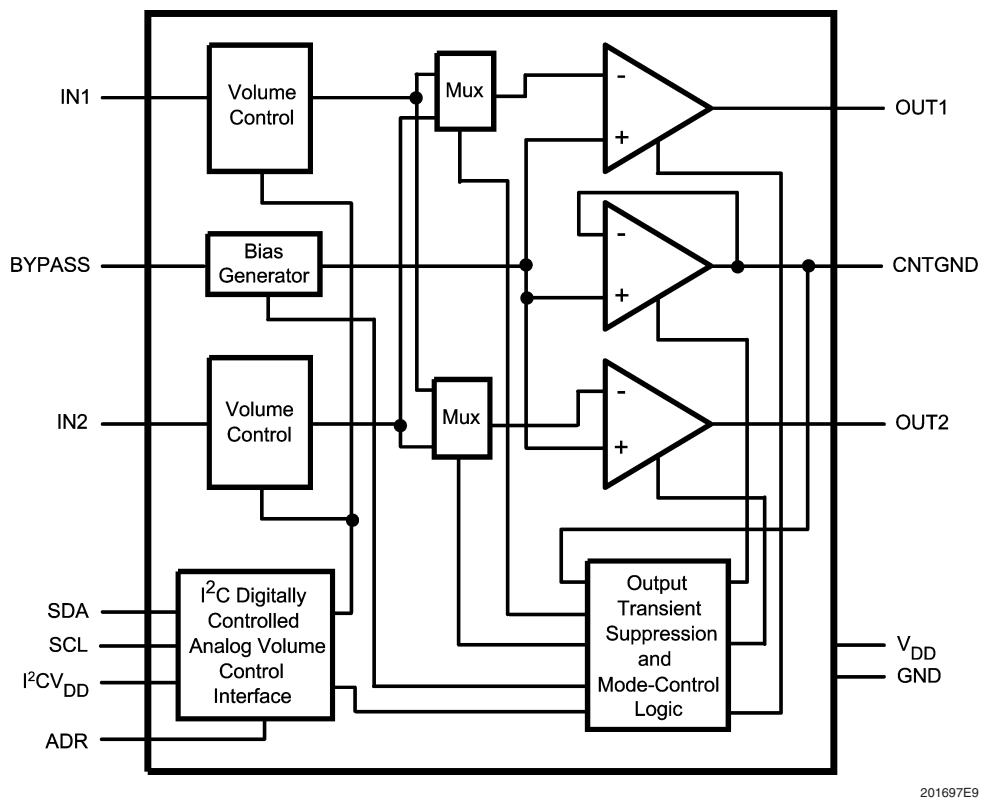
### Features

- OCL or capacitively coupled outputs (patent pending)
- I<sup>2</sup>C Digitally Controlled Volume Control
- Available in space-saving 0.4mm lead-pitch micro SMD package
- Volume control range: -76dB to +18dB
- Ultra low current shutdown mode
- 2.3V - 5.5V operation
- Ultra low noise

### Applications

- Mobile Phones
- PDAs
- Portable electronics devices
- MP3 Players

## Block Diagram



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FIGURE 1. Block Diagram

## Typical Application

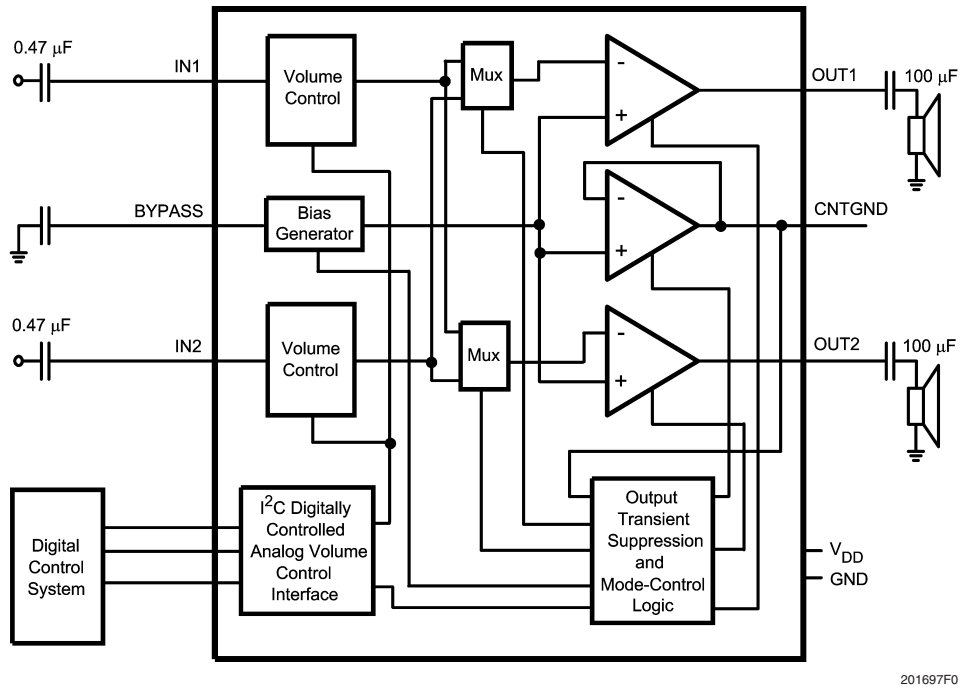


FIGURE 2. Typical Capacitively Coupled Output Configuration Circuit

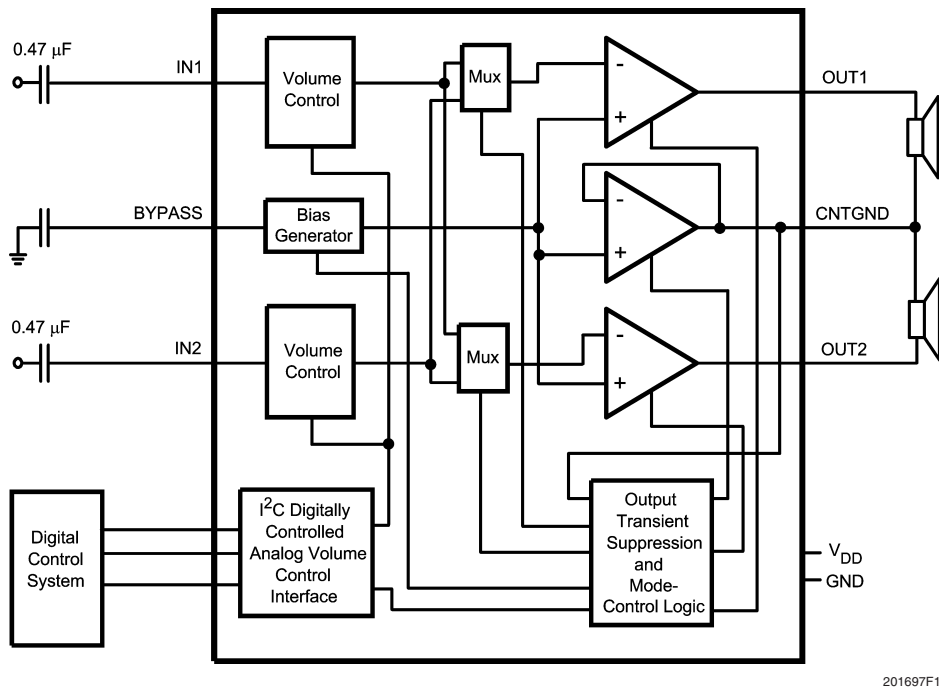
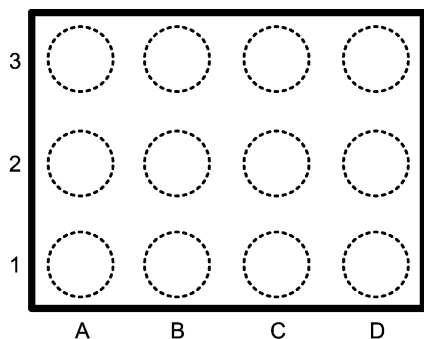


FIGURE 3. Typical OCL Output Configuration Circuit

## Connection Diagrams

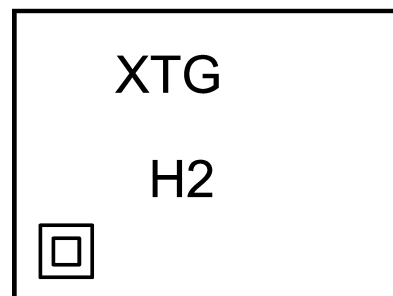
micro SMD Package



20169715

**Top View**  
**Order Number LM4985TM**  
**See NS Package Number TMD12AAA**

micro SMD Marking



20169730

**Top View**  
**X – Date Code**  
**T – Die Traceability**  
**G – Boomer Family**  
**H2 – LM4985TM**

Pin Reference, Name, and Function

Reference	Name	Function
A1	ADR	I <sup>2</sup> C serial interface address input.
A2	IN2	Analog signal input two.
A3	OUT2	Power amplifier two output.
B1	SDA	I <sup>2</sup> C serial interface data input.
B2	BYPASS	The internal $V_{DD}/2$ ac bypass node.
B3	CNTGND	In OCL mode, this is the ac ground return. It is biased to $V_{DD}/2$ . Leave unconnected for C-CUPL mode.
C1	SCL	I <sup>2</sup> C serial interface clock input.
C2	GND	The LM4985's power supply ground input.
C3	$V_{DD}$	The LM4985's power supply voltage input.
D1	I <sup>2</sup> CV <sub>DD</sub>	I <sup>2</sup> C serial interface power supply input. Can be connected to the same supply that is connected to the $V_{DD}$ pin.
D2	IN1	Analog signal input one.
D3	OUT1	Power amplifier one output.

**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 ( $V_{DD}$ , $I^2CV_{DD}$ )	6.0V
Storage Temperature	-65°C to +150°C
Input Voltage (IN1, IN2, OUT1, OUT2, BYPASS, CNTGND, GND pins relative to the $V_{DD}$ pin)	-0.3V to $V_{DD} + 0.3V$
Input Voltage (ADR, SDA, SCL pins, relative to the $I^2CV_{DD}$ pin)	-0.3V to $I^2CV_{DD} + 0.3V$
Power Dissipation (Note 3)	Internally Limited
ESD Susceptibility (Note 4)	2000V

ESD Susceptibility (Note 5)

200V

Junction Temperature

150°C

Thermal Resistance

 $\theta_{JA}$ 

109°C/W

**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

 $V_{DD}$  $2.3V \leq V_{CC} \leq 5.5V$  $I^2CV_{DD}$  $1.7V \leq I^2CV_{DD} \leq 5.5V$ **Electrical Characteristics  $V_{DD} = 5V$**  (Notes 1, 2)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$ , and  $C_B = 4.7\mu\text{F}$  unless otherwise specified. Limits apply to  $T_A = 25^\circ\text{C}$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
$I_{DD}$	Quiescent Power Supply Current	$V_{IN} = 0V$ , $I_{OUT} = 0A$			
		Single-Channel no load OCL	2		
		Single-Channel no load C-CUPL	1.5		
		Dual-Channel no load OCL	3	4.9	
		Dual-Channel no load C-CUPL	2.3	3.8	
$I_{SD}$	Shutdown Current	$V_{SHUTDOWN} = GND$	0.1	1.0	$\mu A$ (max)
$V_{SDIH}$	Logic Voltage Input High			3.5	V (min)
$V_{SDIL}$	Logic Voltage Input Low			1.5	V (max)
$P_O$	Output Power	$THD \leq 1\%$ ; $f_{IN} = 1\text{kHz}$			
		$R_{LOAD} = 16\Omega$ OCL	135	115	
		$R_{LOAD} = 16\Omega$ C-CUPL	135		
		$R_{LOAD} = 32\Omega$ OCL	79	70	
		$R_{LOAD} = 32\Omega$ C-CUPL	80		
THD+N	Total Harmonic Distortion + Noise	$R_{LOAD} = 16\Omega$ OCL, $P_O = 100\text{mW}$	0.08		
		$R_{LOAD} = 16\Omega$ C-CUPL, $P_O = 100\text{mW}$	0.02		
		$R_{LOAD} = 32\Omega$ OCL, $P_O = 60\text{mW}$	0.04		
		$R_{LOAD} = 32\Omega$ C-CUPL, $P_O = 70\text{mW}$	0.01		
$V_{ON}$	Output Noise Voltage	$V_{IN} = AC$ GND, $A_v = 0\text{dB}$ , A-weighted	15		$\mu V$
PSRR	Power Supply Rejection Ratio	$V_{RIPPLE} = 200\text{mVp-p}$ (Note 9)			
		$f_{IN} = 217\text{Hz}$ sinewave			
		OCL	77	57	
		C-CUPL	65		
Xtalk	Channel-to-channel Crosstalk	$f_{IN} = 1\text{kHz}$ sinewave			
		OCL	77	60	
		C-CUPL	65		
		$P_{out} = 40\text{mW}$ . OCL			
		$R_{LOAD} = 16\Omega$	51		
		$R_{LOAD} = 32\Omega$	56		
		$P_{out} = 50\text{mW}$ . C-CUPL			
		$R_{LOAD} = 16\Omega$	58		
		$R_{LOAD} = 32\Omega$	68		

**Electrical Characteristics  $V_{DD} = 5V$**  (Notes 1, 2) (Continued)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$ , and  $C_B = 4.7\mu\text{F}$  unless otherwise specified. Limits apply to  $T_A = 25^\circ\text{C}$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
$T_{WU}$	Wake Up Time form Shutdown	$C_{BYPASS} = 4.7\mu\text{F}$ (Note 11)			msec
		WT1 = 0, WT0 = 0			
		OCL	75		
		C-CUPL	285		
		WT1 = 0, WT0 = 1			
		OCL	110		
		C-CUPL	530		
		WT1 = 1, WT0 = 0			
		OCL	180		
		C-CUPL	1030		
$R_{IN}$	Input Resistance	Stereo mode	20		$k\Omega$
		Mono mode	10		
$A_{VMIN}$	Minimum Gain	Code = 00000	-76		dB (min)
$A_{VMAX}$	Maximum Gain	Code = 11111	18		dB (min)
$\Delta A_V$	Gain Accuracy per Step	$18\text{dB} \geq A_V \geq -44\text{dB}$ $-44\text{dB} \geq A_V > -76\text{dB}$	$\pm 0.5$ $\pm 1.0$		dB
$V_{OS}$	Output Offset Voltage	OCL $R_{LOAD} = 32\Omega$ $V_{IN} = \text{AC GND}$	2.0	20	mV (max)

**Electrical Characteristics  $V_{DD} = 3.6V$**  (Notes 1, 2)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1\text{kHz}$ , and  $C_B = 4.7\mu\text{F}$  unless otherwise specified. Limits apply to  $T_A = 25^\circ\text{C}$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
$I_{DD}$	Quiescent Power Supply Current	$V_{IN} = 0V$ , $I_{OUT} = 0A$			mA (max)
		Single-Channel no load OCL	1.8	3.1	
		Single-Channel no load C-CUPL	1.0		
		Dual-Channel no load OCL	2.1	4	
		Dual-Channel no load C-CUPL	2.3	3	
$I_{SD}$	Shutdown Current	$V_{SHUTDOWN} = \text{GND}$	0.1	1.0	$\mu\text{A}$ (max)
$V_{SDIH}$	Logic Voltage Input High			2.52	V (min)
$V_{SDIL}$	Logic Voltage Input Low			1.08	V (max)
$P_O$	Output Power	THD+N < 1%, $f_{IN} = 1\text{kHz}$			mW (min)
		$R_{LOAD} = 16\Omega$ OCL	68	60	
		$R_{LOAD} = 16\Omega$ C-CUPL	70		
		$R_{LOAD} = 32\Omega$ OCL	38	34	
		$R_{LOAD} = 32\Omega$ C-CUPL	41		

**Electrical Characteristics  $V_{DD} = 3.6V$**  (Notes 1, 2) (Continued)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1kHz$ , and  $C_B = 4.7\mu F$  unless otherwise specified. Limits apply to  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
THD+N	Total Harmonic Distortion + Noise	$R_{LOAD} = 16\Omega$ OCL, $P_O = 60mW$ $R_{LOAD} = 16\Omega$ C-CUPL, $P_O = 60mW$ $R_{LOAD} = 32\Omega$ OCL, $P_O = 33mW$ $R_{LOAD} = 32\Omega$ C-CUPL, $P_O = 38mW$	0.06 0.03 0.03 0.03		%
$V_{ON}$	Output Noise Voltage	$V_{IN} = AC$ GND, $A_V = 0dB$ , A-weighted	15		$\mu V$
PSRR	Power Supply Rejection Ratio	$V_{RIPPLE} = 200mVp-p$ (Note 9) $f_{IN} = 217Hz$ sinewave OCL C-CUPL $f_{IN} = 1kHz$ sinewave OCL C-CUPL	77 63 76 62	55 57	dB (min)
Xtalk	Channel-to-Channel Crosstalk	$P_{out} = 40mW$ . OCL $R_{LOAD} = 16\Omega$ $R_{LOAD} = 32\Omega$ $P_{out} = 50mW$ . C-CUPL $R_{LOAD} = 16\Omega$ $R_{LOAD} = 32\Omega$	51 56 58 69		dB dB
$T_{WU}$	Wake Up Time from Shutdown	$C_{BYPASS} = 4.7\mu F$ (Note 11)			
		WT1 = 0, WT0 = 0			
		OCL	66	93	
		C-CUPL	222		
		WT1 = 0, WT0 = 1			
		OCL	92		
		C-CUPL	405		
		WT1 = 1, WT0 = 0			
		OCL	143		
		C-CUPL	774		
		WT1 = 1, WT0 = 1			
		OCL	246		
		C-CUPL	1532		
$R_{IN}$	Input Resistance	Stereo mode Mono mode	20 10		k $\Omega$
$A_{VMIN}$	Minimum Gain	Code = 00000	-76	-72	dB (max)
$A_{VMAX}$	Maximum Gain	Code = 11111	18	17	dB (min)
$\Delta A_V$	Gain Accuracy per Step	$18dB \geq A_V \geq -44dB$ $-44dB \geq A_V > -76dB$	$\pm 0.5$ $\pm 1.0$	$\pm 1.0$ $\pm 2.0$	dB
$V_{OS}$	Output Offset Voltage	OCL $R_{LOAD} = 32\Omega$ $V_{IN} = AC$ GND	2.0	20	mV (max)

# Electrical Characteristics $V_{DD} = 2.5V$ (Notes 1, 2)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1kHz$ , and  $C_B = 4.7\mu F$  unless otherwise specified. Limits apply to  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
$I_{DD}$	Quiescent Power Supply Current	$V_{IN} = 0V$ , $I_{OUT} = 0A$ Single-Channel no load OCL Single-Channel no load C-CUPL Dual-Channel no load OCL Dual-Channel no load C-CUPL	1.6 1 2.1 1.6		mA
$I_{SD}$	Shutdown Current	$V_{SHUTDOWN} = GND$	0.1		$\mu A$
$V_{SDIH}$	Logic Voltage Input High			1.75	V (min)
$V_{SDIL}$	Logic Voltage Input Low			0.75	V (max)
$P_O$	Output Power	$THD+N < 1\%$ , $f_{IN} = 1kHz$ $R_{LOAD} = 16\Omega$ OCL $R_{LOAD} = 16\Omega$ C-CUPL $R_{LOAD} = 32\Omega$ OCL $R_{LOAD} = 32\Omega$ C-CUPL	31 33 19 19		mW
THD+N	Total Harmonic Distortion + Noise	$R_{LOAD} = 16\Omega$ OCL, $P_O = 26mW$ $R_{LOAD} = 16\Omega$ C-CUPL, $P_O = 20mW$ $R_{LOAD} = 32\Omega$ OCL, $P_O = 16mW$ $R_{LOAD} = 32\Omega$ C-CUPL, $P_O = 15mW$	0.07 0.05 0.06 0.04		%
$V_{ON}$	Output Noise Voltage	$V_{IN} = AC$ GND, $A_v = 0dB$ , A-weighted	10		$\mu V$
PSRR	Power Supply Rejection Ratio	$V_{RIPPLE} = 200mVp-p$ (Note 9) $f_{IN} = 217Hz$ sinewave OCL C-CUPL $f_{IN} = 1kHz$ sinewave OCL C-CUPL	75 59 75 59		dB
Xtalk	Channel-to-Channel Crosstalk	$P_{out} = 20mW$ , OCL $R_{LOAD} = 16\Omega$ $R_{LOAD} = 32\Omega$ $P_{out} = 20mW$ , C-CUPL $R_{LOAD} = 16\Omega$ $R_{LOAD} = 32\Omega$	50 55 58 67		dB dB
$T_{WU}$	Wake Up Time from Shutdown	$C_{BYPASS} = 4.7\mu F$ (Note 11) WT1 = 0, WT0 = 0 OCL C-CUPL WT1 = 0, WT0 = 1 OCL C-CUPL WT1 = 1, WT0 = 0 OCL C-CUPL WT1 = 1, WT0 = 1 OCL C-CUPL	66 214 92 544 145 1053 250 2098		msec
$R_{IN}$	Input Resistance	Stereo mode Mono mode	20 10		k $\Omega$
$A_{VMIN}$	Minimum Gain	Code = 00000	-76		dB



## Electrical Characteristics $V_{DD} = 2.5V$ (Notes 1, 2) (Continued)

The following specifications apply for  $R_L = 16\Omega$ ,  $f = 1kHz$ , and  $C_B = 4.7\mu F$  unless otherwise specified. Limits apply to  $T_A = 25^\circ C$ .

Symbol	Parameter	Conditions	LM4985		Units (Limits)
			Typ (Note 6)	Limit (Notes 7, 8)	
$A_{VMAX}$	Maximum Gain	Code = 11111	18		dB
$\Delta A_V$	Gain Accuracy per Step	$18dB \geq A_V \geq -44dB$ $-44dB \geq A_V > -76dB$	$\pm 0.5$ $\pm 1.0$		dB
$V_{OS}$	Output Offset Voltage	OCL $R_{LOAD} = 32\Omega$ $V_{IN} = AC\ GND$	2.0		mV

**Note 1:** All voltages are measured with respect to the GND pin unless otherwise specified.

**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**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. For the LM4985, see power derating currents for more information.

**Note 4:** Human Body Model: 100pF discharged through a 1.5k $\Omega$  resistor.

**Note 5:** Machine Model: 200pF  $\leq C_{mm} \leq 220pF$  discharged through all pins.

**Note 6:** Typicals are measured at 25°C and represent the parametric norm.

**Note 7:** Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

**Note 8:** Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

**Note 9:** 10 $\Omega$  terminated input.

**Note 10:** The LDA10A package has its exposed-DAP soldered to an exposed 1.2in<sup>2</sup> area of 1oz. Printed circuit board copper.

**Note 11:** The wake-up time ( $T_{WU}$ ) is calculated using the following formula;  $T_{WU} = [C_{BYPASS} (VDD) / 2 (I_{BYPASS})] + 40ms$ .

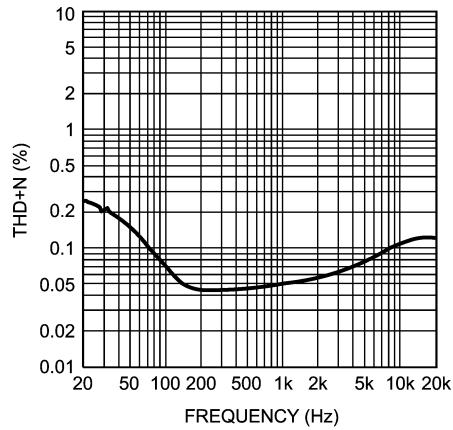
## External Components Description (Figure 2)

Components		Functional Description
1.	$C_i$	Input coupling capacitor which blocks the DC voltage at the amplifier's input terminals. Also creates a high-pass filter with $R_i$ at $f_c = 1/(2\pi R_i C_i)$ . Refer to the section <b>Proper Selection of External Components</b> , for an explanation of how to determine the value of $C_i$ .
2.	$C_S$	Supply bypass capacitor which provides power supply filtering. Refer to the <b>Power Supply Bypassing</b> section for information concerning proper placement and selection of the supply bypass capacitor.
3.	$C_B$	Bypass pin capacitor which provides half-supply filtering. Refer to the section, <b>Proper Selection of Proper Components</b> , for information concerning proper placement and selection of $C_B$ .
6.	$C_o$	Output coupling capacitor which blocks the DC voltage at the amplifier's output. Forms a high pass filter with $R_L$ at $f_o = 1/(2\pi R_L C_o)$ .

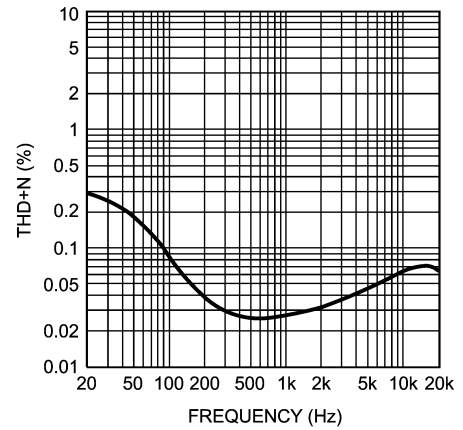
## Typical Performance Characteristics

$T_A = 25^\circ\text{C}$ ,  $A_V = 0\text{dB}$ ,  $f_{IN} = 1\text{kHz}$  unless otherwise stated.

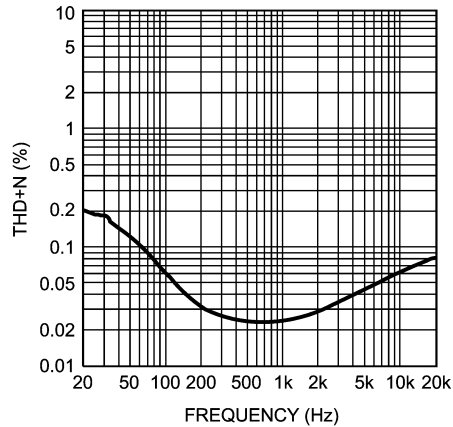
**THD+N vs Frequency**  
 $V_{DD} = 2.5\text{V}$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 20\text{mW}$ , C-CUPL



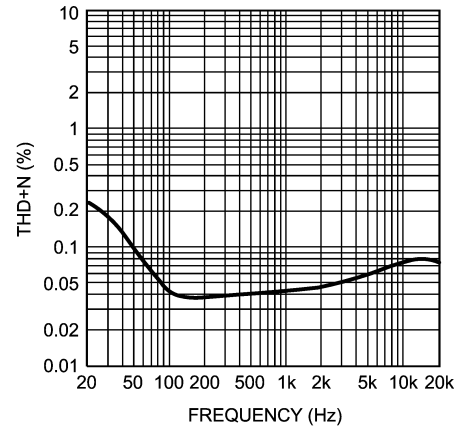
**THD+N vs Frequency**  
 $V_{DD} = 3.6\text{V}$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 50\text{mW}$ , C-CUPL



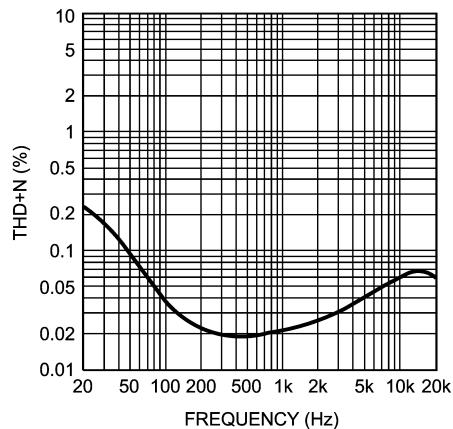
**THD+N vs Frequency**  
 $V_{DD} = 5\text{V}$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 50\text{mW}$ , C-CUPL



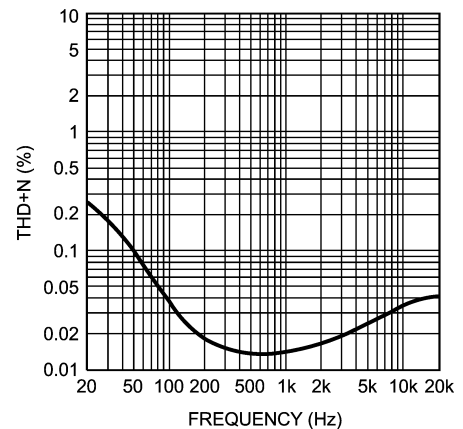
**THD+N vs Frequency**  
 $V_{DD} = 2.5\text{V}$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 15\text{mW}$ , C-CUPL



**THD+N vs Frequency**  
 $V_{DD} = 3.6\text{V}$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 35\text{mW}$ , C-CUPL



**THD+N vs Frequency**  
 $V_{DD} = 5.0\text{V}$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 60\text{mW}$ , C-CUPL

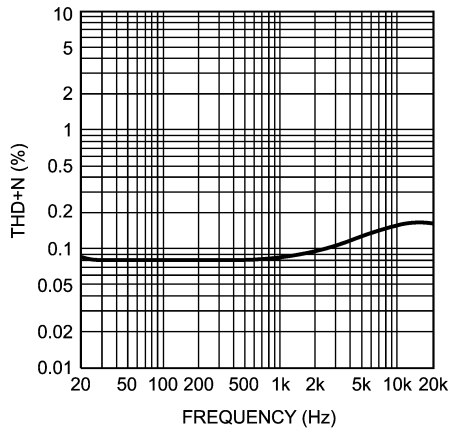


# Typical Performance Characteristics (Continued)

## THD+N vs Frequency

$V_{DD} = 2.5V$ ,  $R_L = 16\Omega$

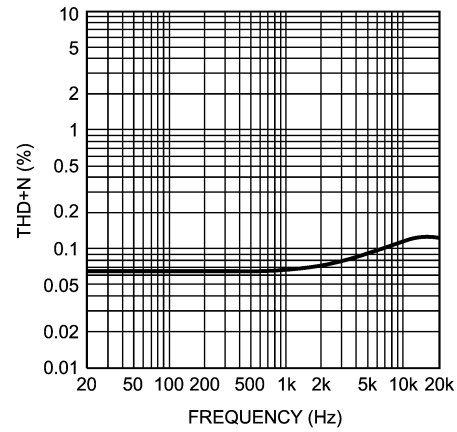
$P_{OUT} = 20mW$ , OCL



## THD+N vs Frequency

$V_{DD} = 3.6V$ ,  $R_L = 16\Omega$

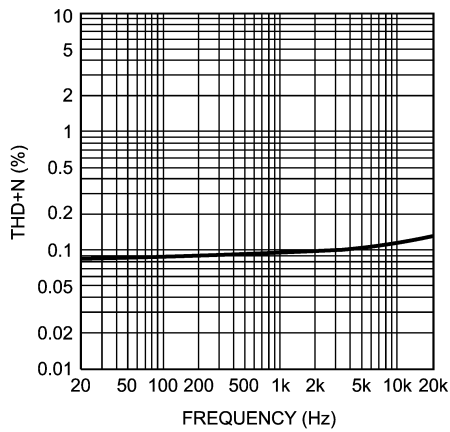
$P_{OUT} = 50mW$ , OCL



## THD+N vs Frequency

$V_{DD} = 5.0V$ ,  $R_L = 16\Omega$

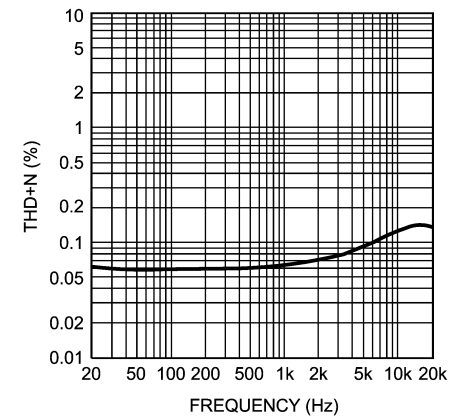
$P_{OUT} = 50mW$ , OCL



## THD+N vs Frequency

$V_{DD} = 2.5V$ ,  $R_L = 32\Omega$

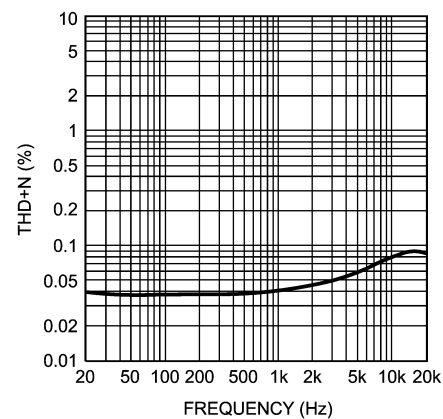
$P_{OUT} = 15mW$ , OCL



## THD+N vs Frequency

$V_{DD} = 3.6V$ ,  $R_L = 32\Omega$

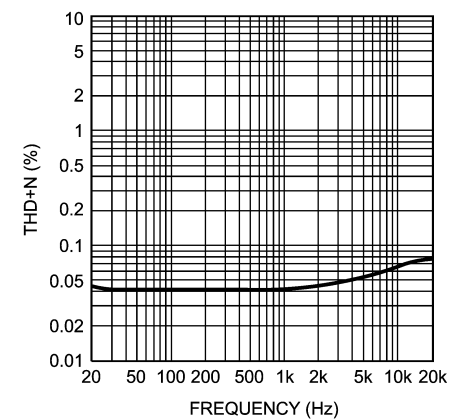
$P_{OUT} = 35mW$ , OCL



## THD+N vs Frequency

$V_{DD} = 5.0V$ ,  $R_L = 32\Omega$

$P_{OUT} = 60mW$ , OCL

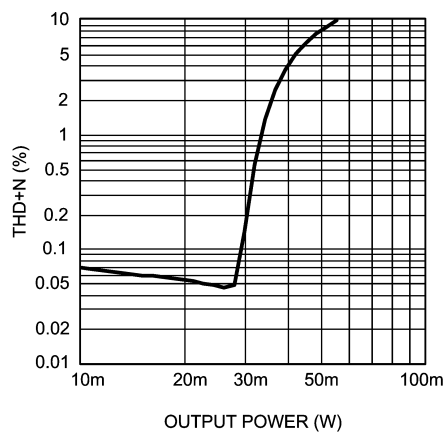


# Typical Performance Characteristics (Continued)

## THD+N vs Output Power

$V_{DD} = 2.5V$ ,  $R_L = 16\Omega$

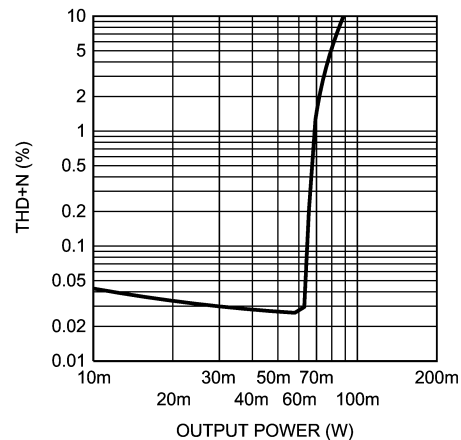
C-CUPL



## THD+N vs Output Power

$V_{DD} = 3.6V$ ,  $R_L = 16\Omega$

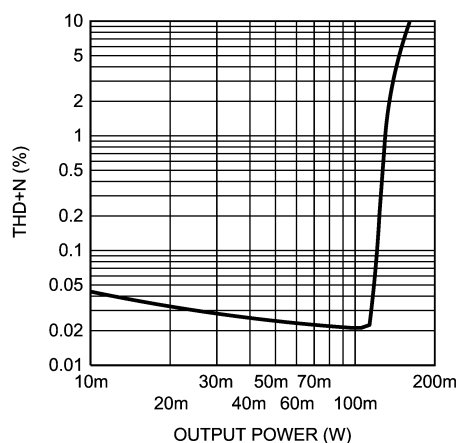
C-CUPL



## THD+N vs Output Power

$V_{DD} = 5.0V$ ,  $R_L = 16\Omega$

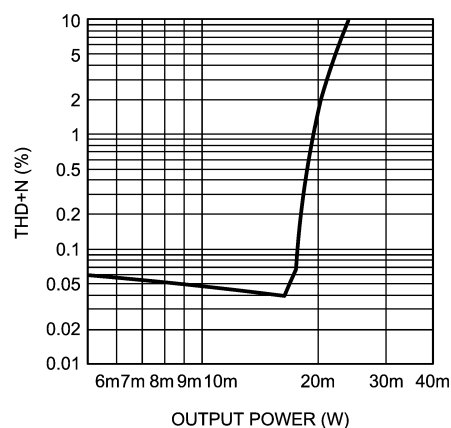
C-CUPL



## THD+N vs Output Power

$V_{DD} = 2.5V$ ,  $R_L = 32\Omega$

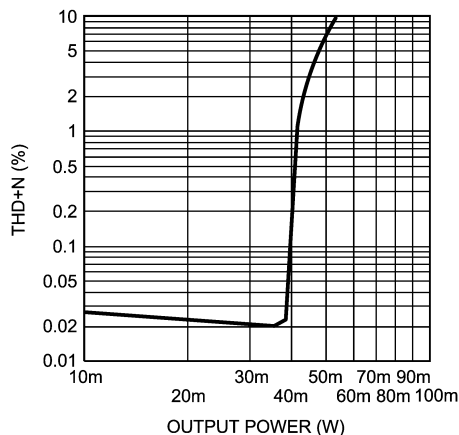
C-CUPL



## THD+N vs Output Power

$V_{DD} = 3.6V$ ,  $R_L = 32\Omega$

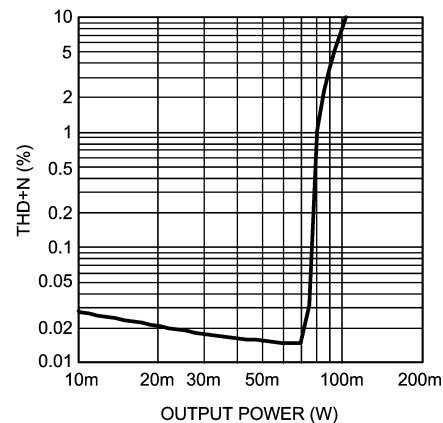
C-CUPL



## THD+N vs Output Power

$V_{DD} = 5.0V$ ,  $R_L = 32\Omega$

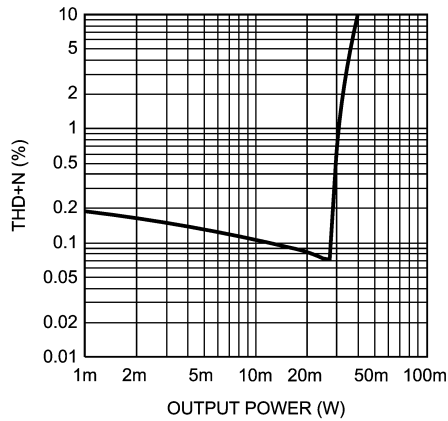
C-CUPL



# Typical Performance Characteristics (Continued)

## THD+N vs Output Power

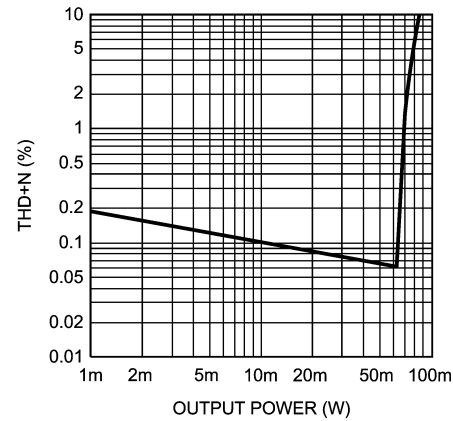
$V_{DD} = 2.5V$ ,  $R_L = 16\Omega$   
OCL



20169758

## THD+N vs Output Power

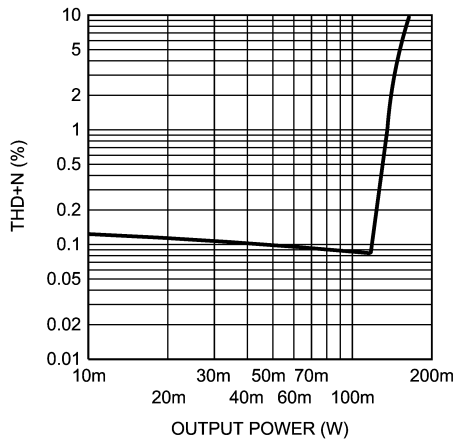
$V_{DD} = 3.6V$ ,  $R_L = 16\Omega$   
OCL



20169759

## THD+N vs Output Power

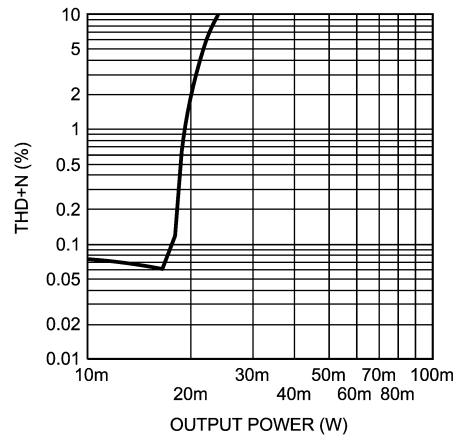
$V_{DD} = 5.0V$ ,  $R_L = 16\Omega$   
OCL



20169760

## THD+N vs Output Power

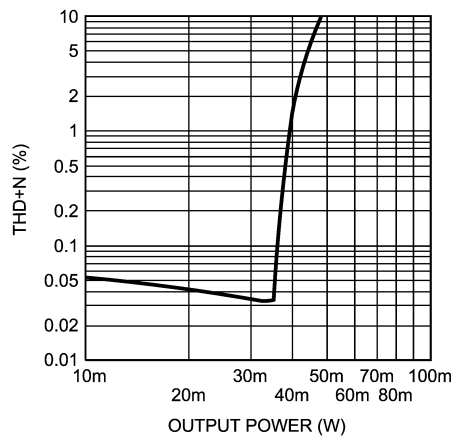
$V_{DD} = 2.5V$ ,  $R_L = 32\Omega$   
OCL



20169761

## THD+N vs Output Power

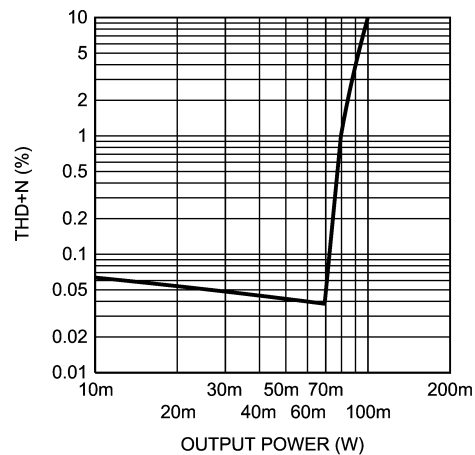
$V_{DD} = 3.6V$ ,  $R_L = 32\Omega$   
OCL



20169762

## THD+N vs Output Power

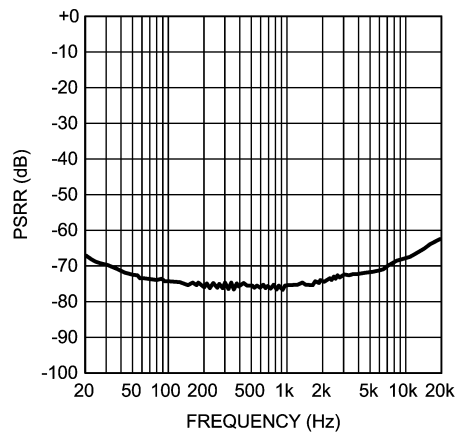
$V_{DD} = 5.0V$ ,  $R_L = 32\Omega$   
OCL



20169763

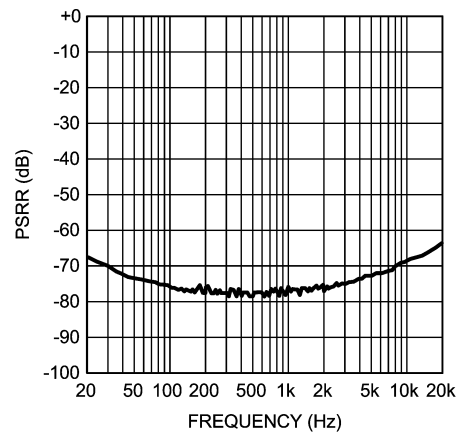
# Typical Performance Characteristics (Continued)

**PSRR vs Frequency**  
 $V_{DD} = 2.5V$ ,  $R_L = 16\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL



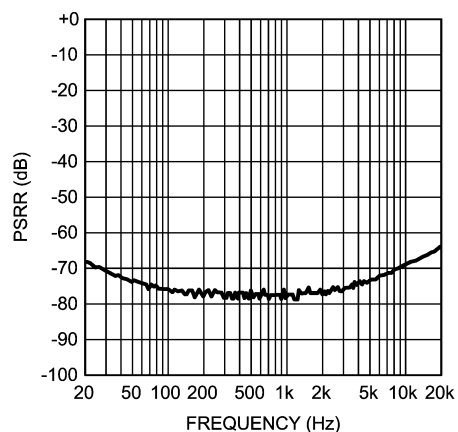
20169776

**PSRR vs Frequency**  
 $V_{DD} = 3.6V$ ,  $R_L = 16\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL



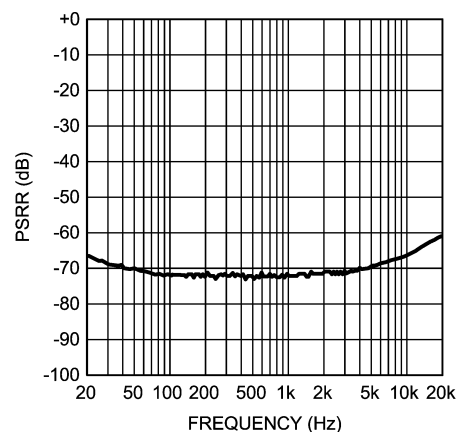
201697H5

**PSRR vs Frequency**  
 $V_{DD} = 5.0V$ ,  $R_L = 16\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL



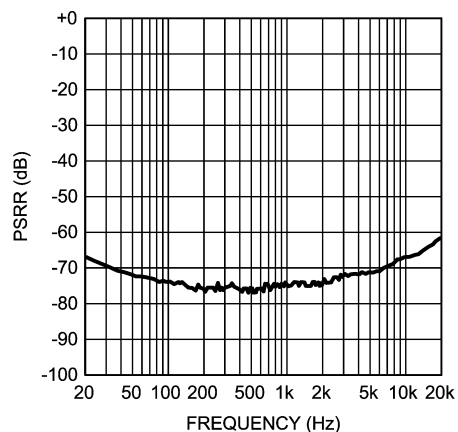
201697H6

**PSRR vs Frequency**  
 $V_{DD} = 2.5V$ ,  $R_L = 32\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL



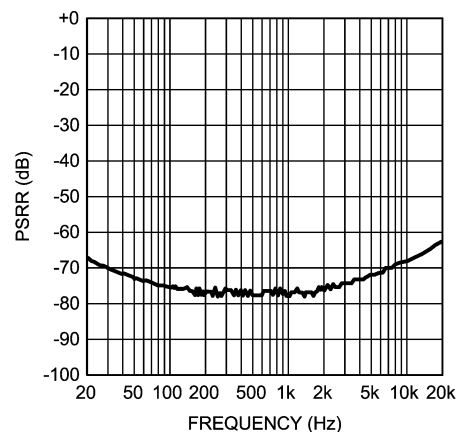
201697H7

**PSRR vs Frequency**  
 $V_{DD} = 3.6V$ ,  $R_L = 32\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL



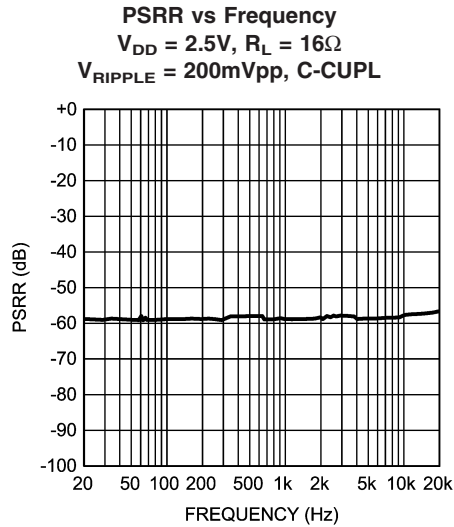
201697H8

**PSRR vs Frequency**  
 $V_{DD} = 5.0V$ ,  $R_L = 32\Omega$   
 $V_{RIPPLE} = 200mV_{pp}$ , OCL

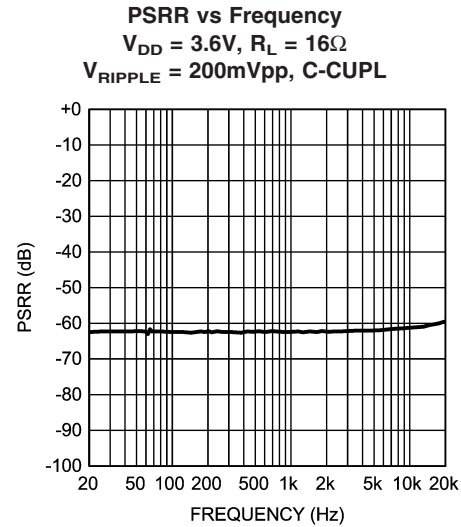


201697H9

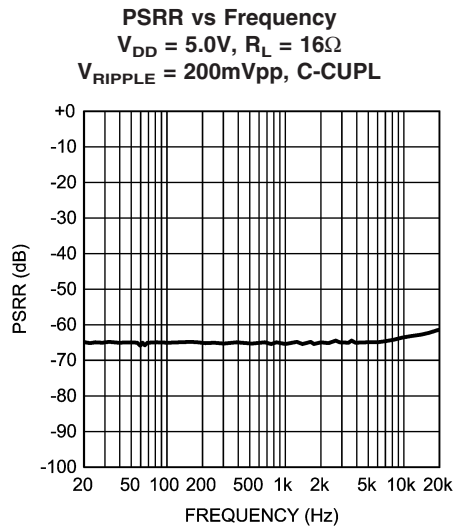
# Typical Performance Characteristics (Continued)



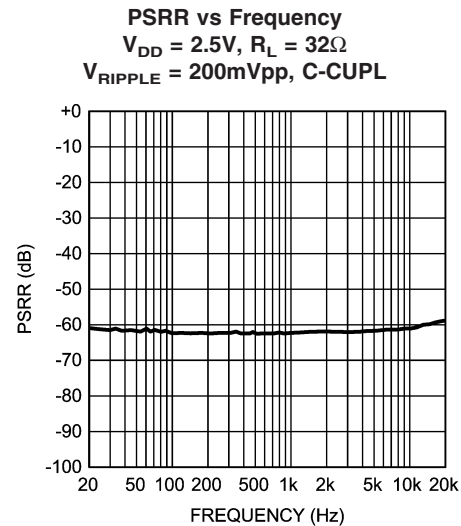
20169710



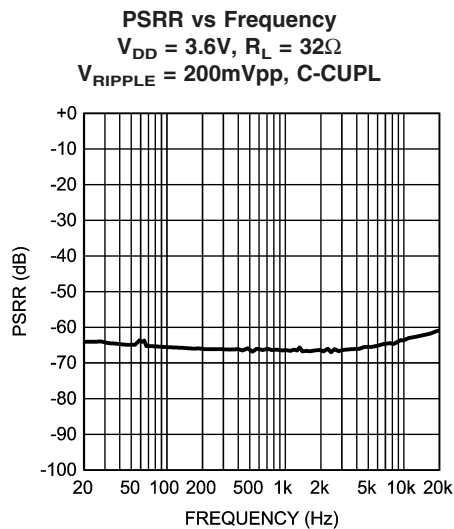
20169711



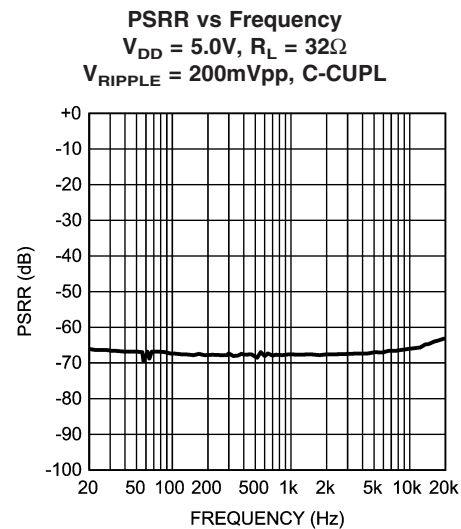
20169712



20169713



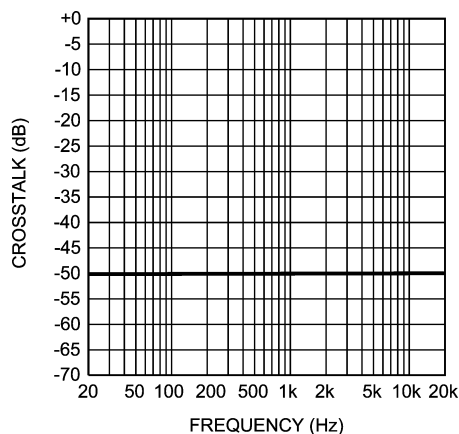
20169714



20169715

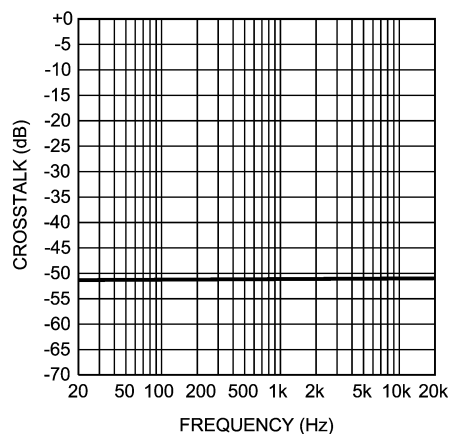
# Typical Performance Characteristics (Continued)

## Crosstalk vs Frequency

 $V_{DD} = 2.5V, R_L = 16\Omega$ 
 $P_{OUT} = 20mW, OCL$ 


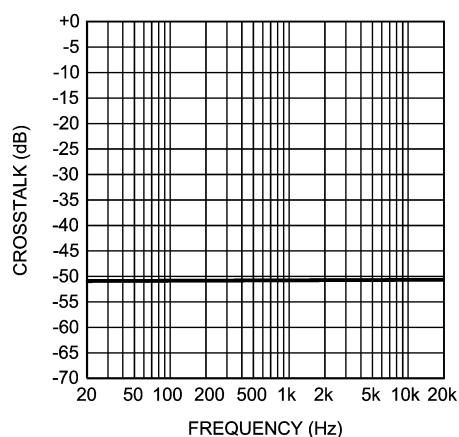
201697I6

## Crosstalk vs Frequency

 $V_{DD} = 3.6V, R_L = 16\Omega$ 
 $P_{OUT} = 40mW, OCL$ 


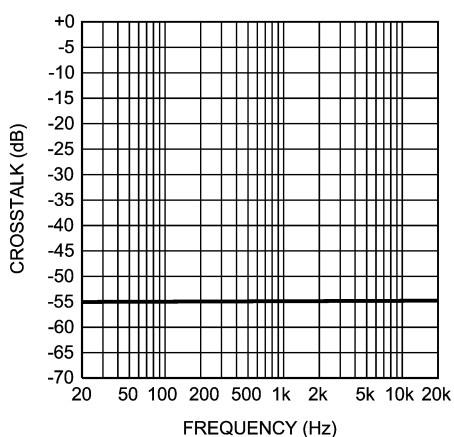
201697G8

## Crosstalk vs Frequency

 $V_{DD} = 5.0V, R_L = 16\Omega$ 
 $P_{OUT} = 40mW, OCL$ 


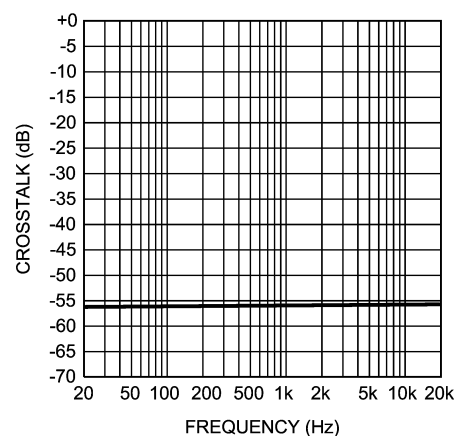
201697G9

## Crosstalk vs Frequency

 $V_{DD} = 2.5V, R_L = 32\Omega$ 
 $P_{OUT} = 20mW, OCL$ 


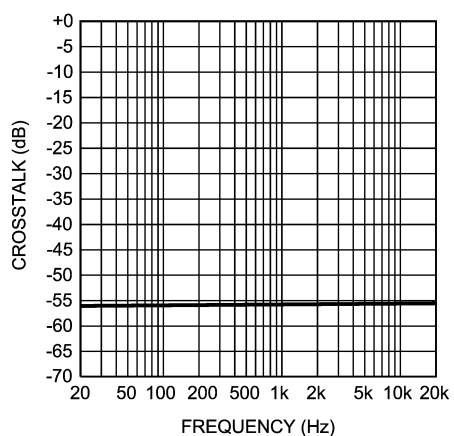
201697H0

## Crosstalk vs Frequency

 $V_{DD} = 3.6V, R_L = 32\Omega$ 
 $P_{OUT} = 40mW, OCL$ 


201697H1

## Crosstalk vs Frequency

 $V_{DD} = 5.0V, R_L = 32\Omega$ 
 $P_{OUT} = 50mW, OCL$ 


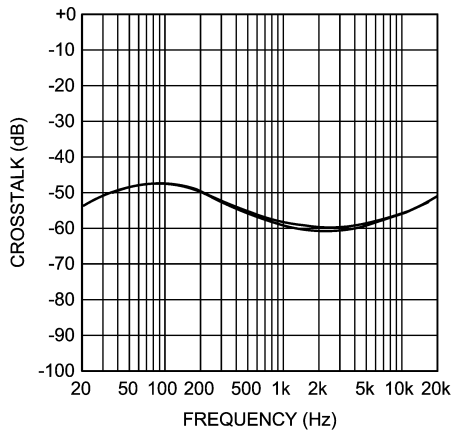
201697H2



# Typical Performance Characteristics (Continued)

## Crosstalk vs Frequency

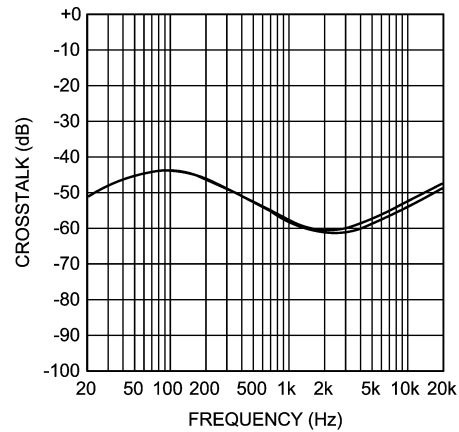
$V_{DD} = 2.5V$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 20mW$ , C-CUPL



201697D7

## Crosstalk vs Frequency

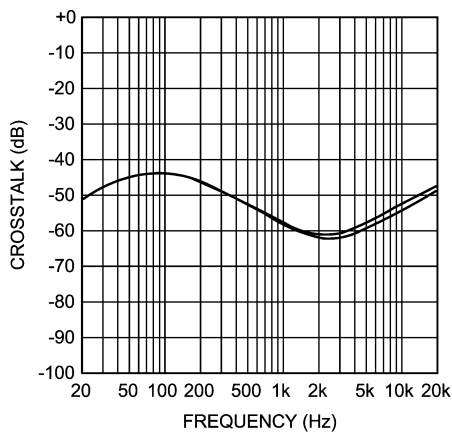
$V_{DD} = 3.6V$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 50mW$ , C-CUPL



201697D8

## Crosstalk vs Frequency

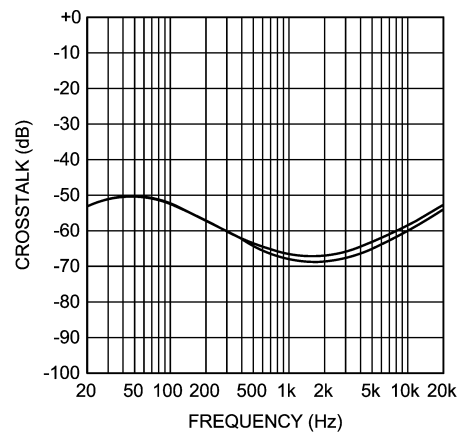
$V_{DD} = 5.0V$ ,  $R_L = 16\Omega$   
 $P_{OUT} = 50mW$ , C-CUPL



201697D9

## Crosstalk vs Frequency

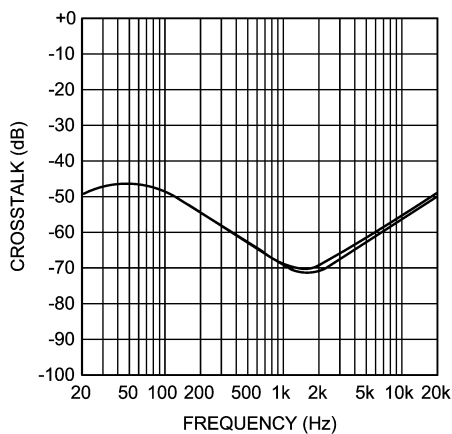
$V_{DD} = 2.5V$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 20mW$ , C-CUPL



201697E0

## Crosstalk vs Frequency

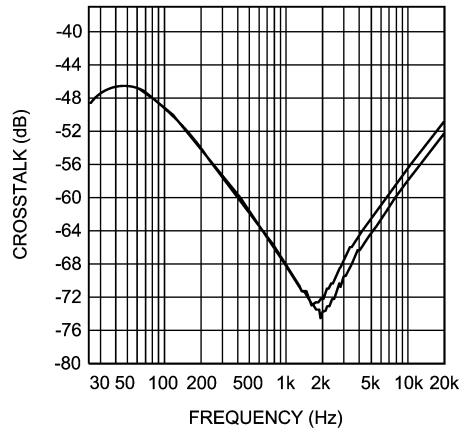
$V_{DD} = 3.6V$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 50mW$ , C-CUPL



201697E1

## Crosstalk vs Frequency

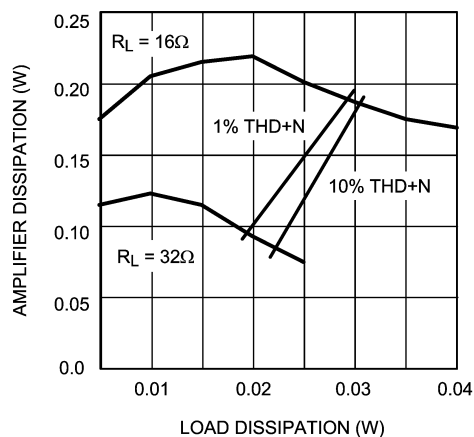
$V_{DD} = 5.0V$ ,  $R_L = 32\Omega$   
 $P_{OUT} = 50mW$ , C-CUPL



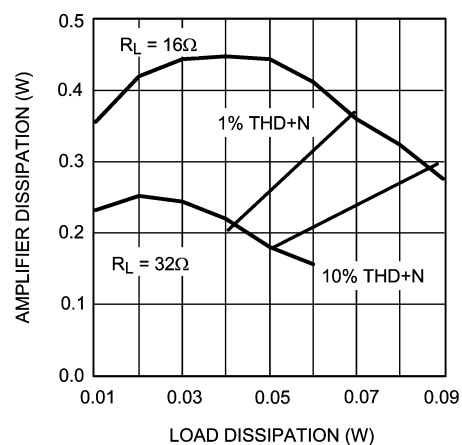
201697E2

# Typical Performance Characteristics (Continued)

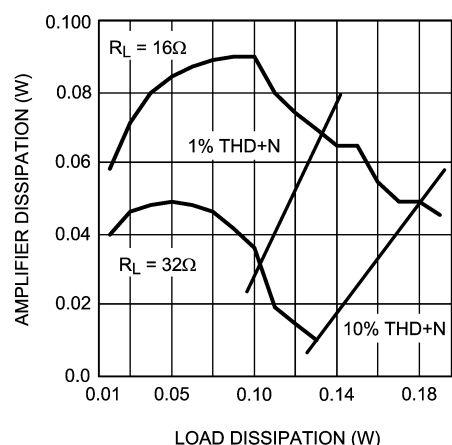
Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 2.5V$ , C-CUPL



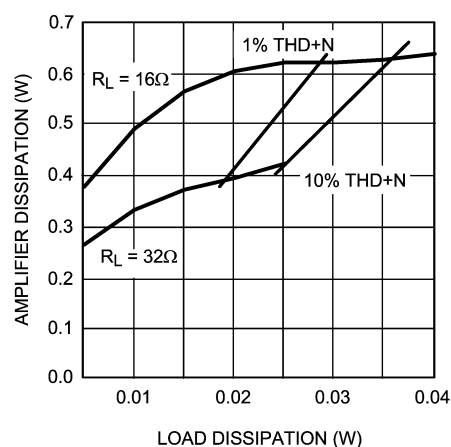
Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 3.6V$ , C-CUPL



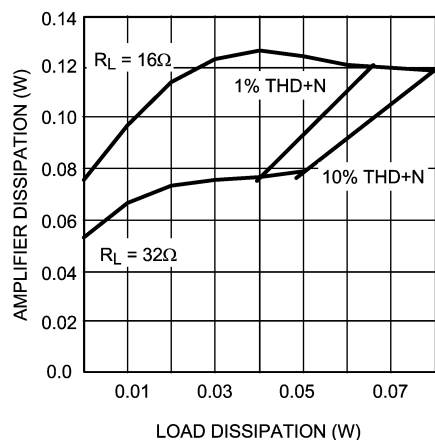
Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 5.0V$ , C-CUPL



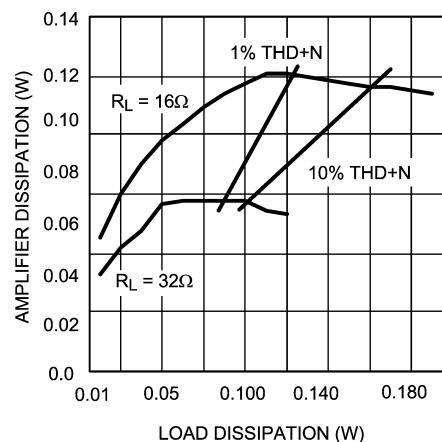
Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 2.5V$ , OCL



Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 3.6V$ , OCL

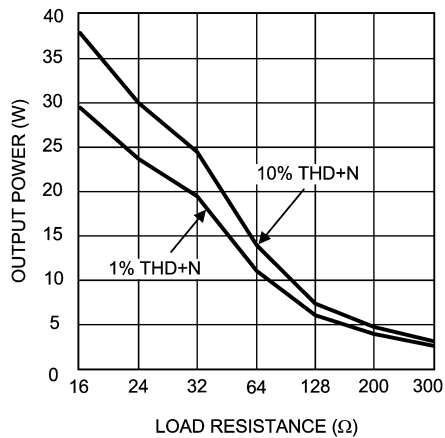


Load Dissipation vs Amplifier Dissipation  
 $V_{DD} = 5.0V$ , OCL



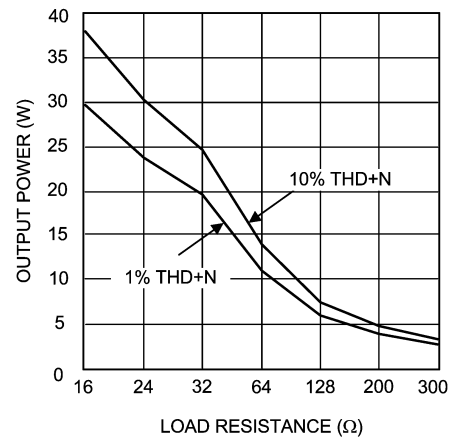
# Typical Performance Characteristics (Continued)

**Output Power vs Load Resistance**  
 $V_{DD} = 2.5V$ , C-CUPL



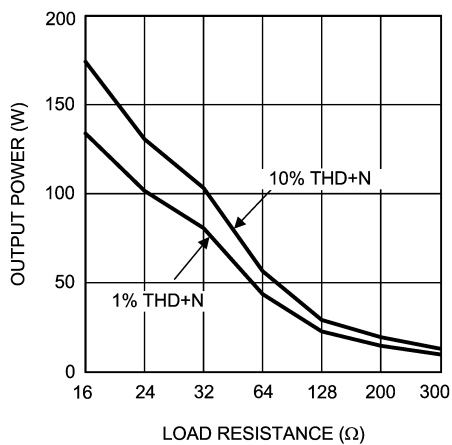
20169741

**Output Power vs Load Resistance**  
 $V_{DD} = 3.6V$ , C-CUPL



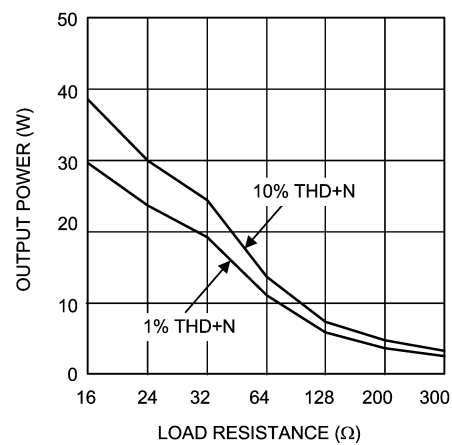
20169742

**Output Power vs Load Resistance**  
 $V_{DD} = 5.0V$ , C-CUPL



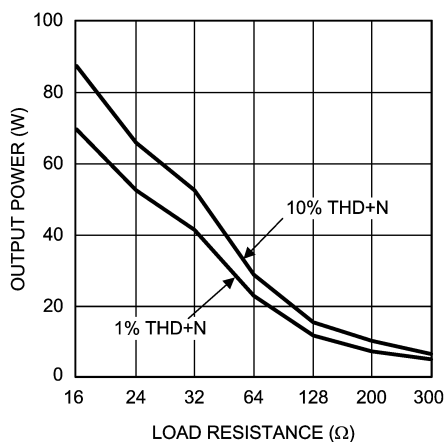
20169743

**Output Power vs Load Resistance**  
 $V_{DD} = 2.5V$ , OCL



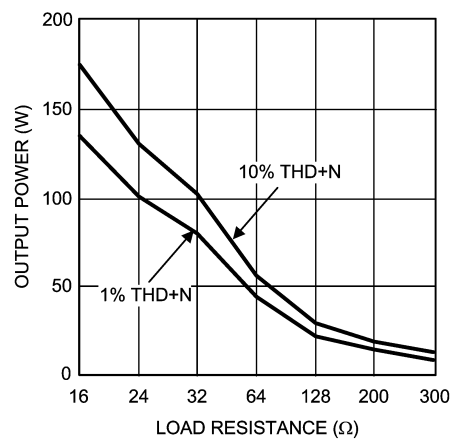
20169744

**Output Power vs Load Resistance**  
 $V_{DD} = 3.6V$ , OCL



20169745

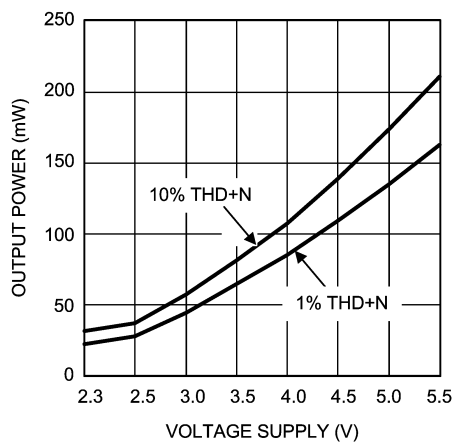
**Output Power vs Load Resistance**  
 $V_{DD} = 5.0V$ , OCL



20169746

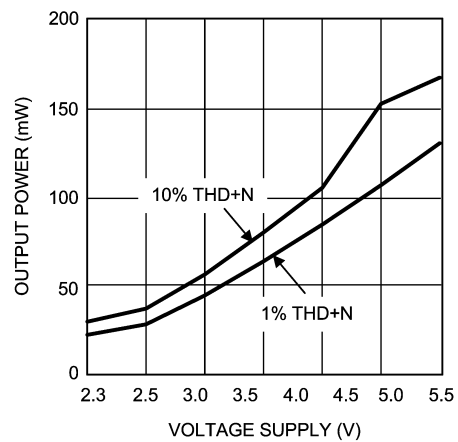
# Typical Performance Characteristics (Continued)

**Output Power vs Supply Voltage**  
 $R_L = 16\Omega$ , C-CUPL



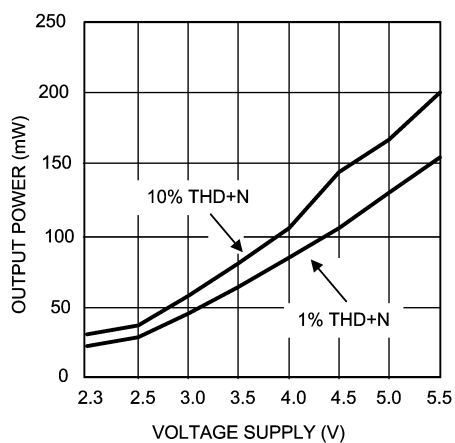
20169747

**Output Power vs Supply Voltage**  
 $R_L = 32\Omega$ , C-CUPL



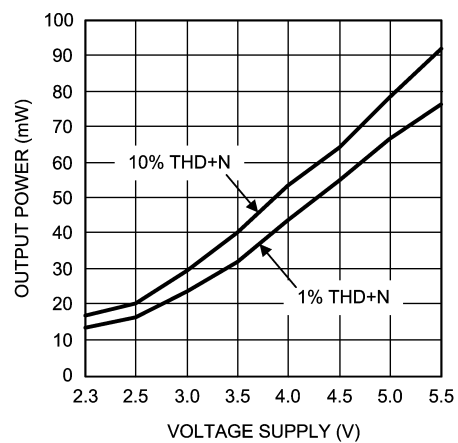
20169748

**Output Power vs Supply Voltage**  
 $R_L = 16\Omega$ , OCL



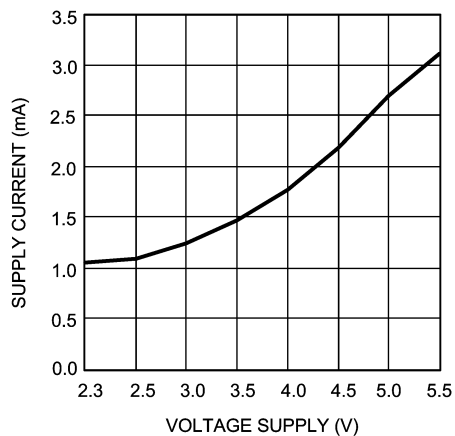
20169749

**Output Power vs Supply Voltage**  
 $R_L = 32\Omega$ , OCL



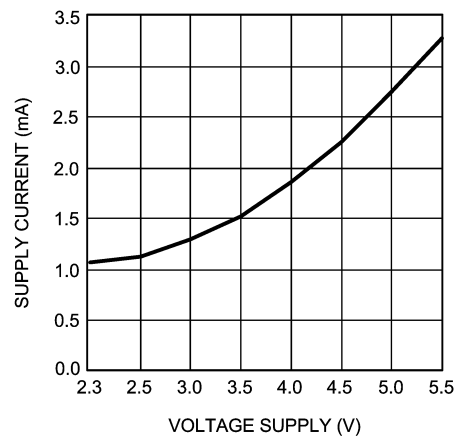
20169750

**Supply Current vs Supply Voltage**  
 $R_L = 16\Omega$ , C-CUPL



20169751

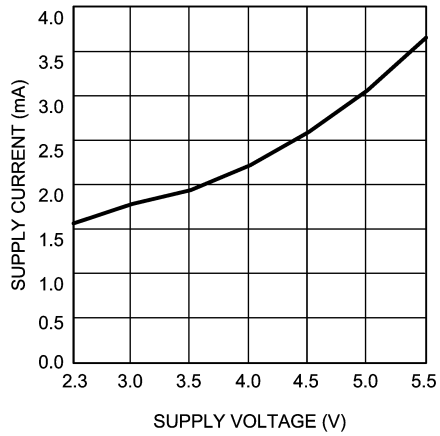
**Supply Current vs Supply Voltage**  
 $R_L = 32\Omega$ , C-CUPL



20169752

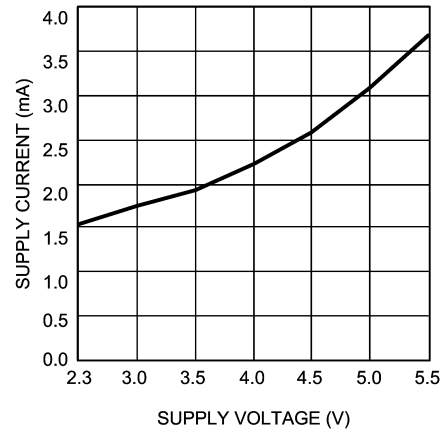
# Typical Performance Characteristics (Continued)

**Supply Current vs Supply Voltage**  
 $R_L = 16\Omega$ , OCL



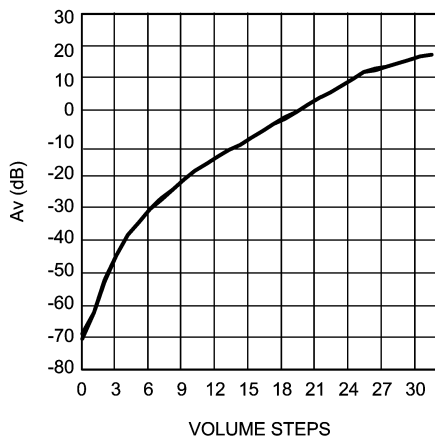
20169753

**Supply Current vs Supply Voltage**  
 $R_L = 32\Omega$ , OCL



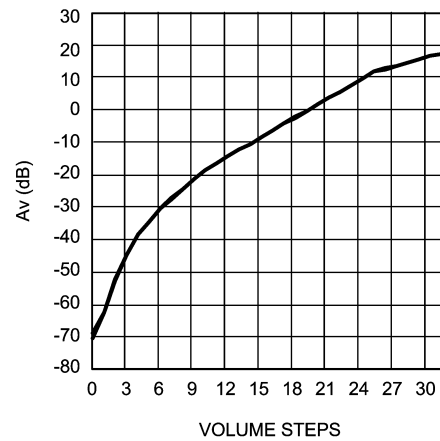
20169754

**Gain vs Volume Steps**  
 $V_{CC} = 2.5V$ ,  $R_L = 16\Omega$ , OCL



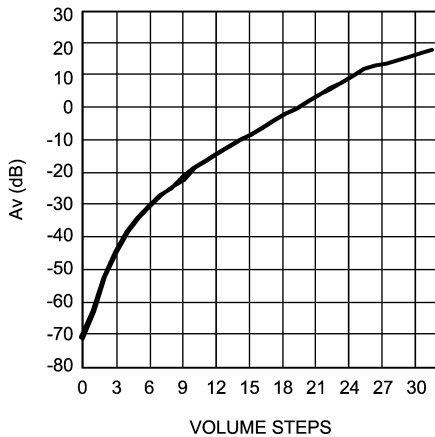
201697F7

**Gain vs Volume Steps**  
 $V_{CC} = 3.6V$ ,  $R_L = 16\Omega$ , OCL



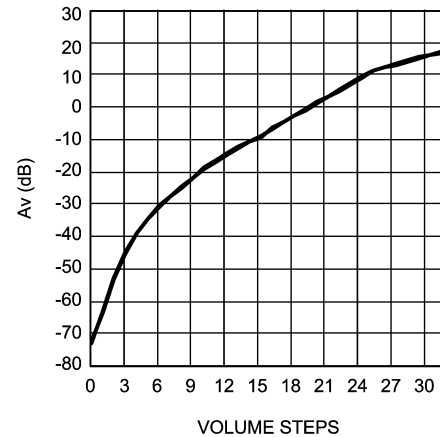
201697F5

**Gain vs Volume Steps**  
 $V_{CC} = 5V$ ,  $R_L = 16\Omega$ , OCL



201697G4

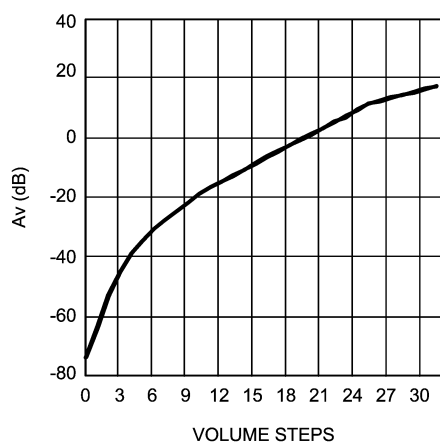
**Gain vs Volume Steps**  
 $V_{CC} = 2.5V$ ,  $R_L = 16\Omega$ , C-CUPL



201697F6

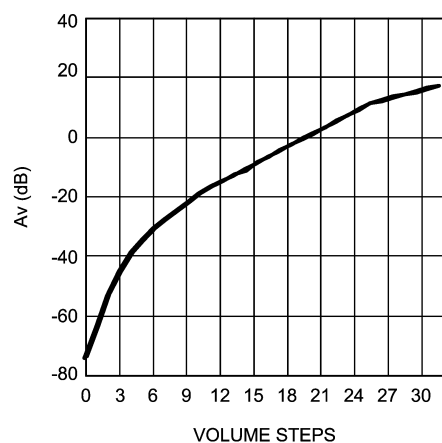
# Typical Performance Characteristics (Continued)

**Gain vs Volume Steps**  
 $V_{CC} = 3.6V$ ,  $R_L = 16\Omega$ , C-CUPL



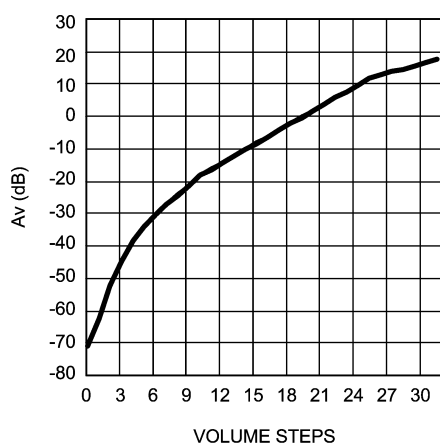
201697G0

**Gain vs Volume Steps**  
 $V_{CC} = 5V$ ,  $R_L = 16\Omega$ , C-CUPL



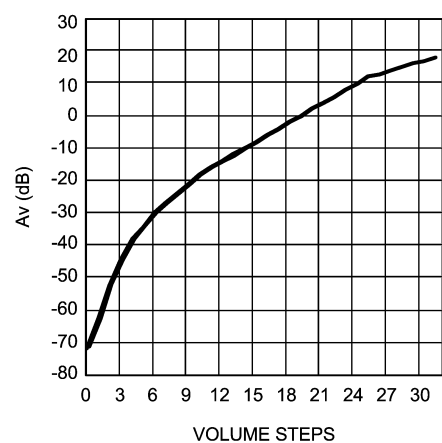
201697G3

**Gain vs Volume Steps**  
 $V_{CC} = 2.5V$ ,  $R_L = 32\Omega$ , OCL



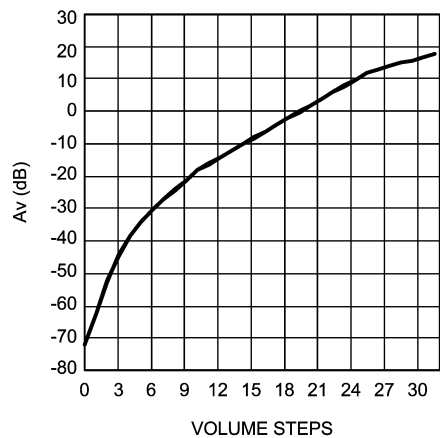
201697F9

**Gain vs Volume Steps**  
 $V_{CC} = 3.6V$ ,  $R_L = 32\Omega$ , OCL



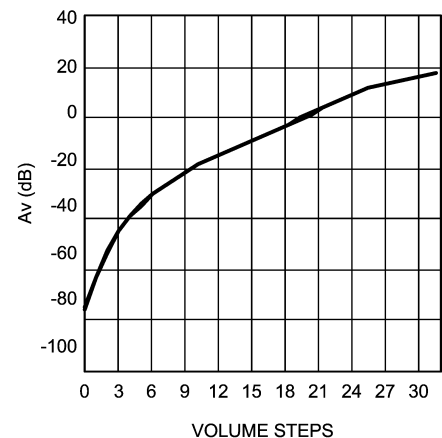
201697G2

**Gain vs Volume Steps**  
 $V_{CC} = 5V$ ,  $R_L = 32\Omega$ , OCL



201697G6

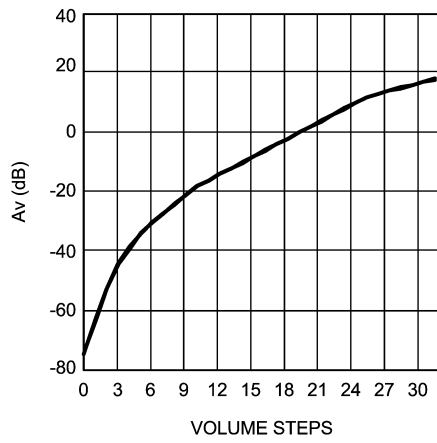
**Gain vs Volume Steps**  
 $V_{CC} = 2.5V$ ,  $R_L = 32\Omega$ , C-CUPL



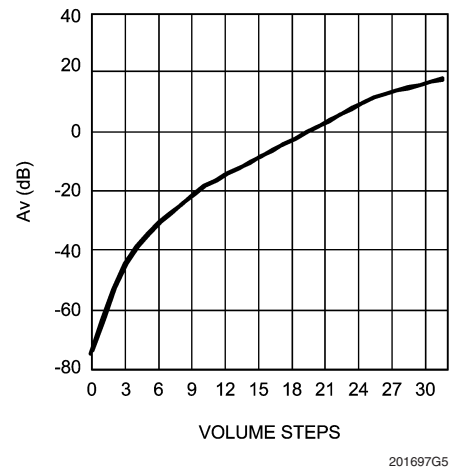
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## Typical Performance Characteristics (Continued)

Gain vs Volume Steps  
 $V_{CC} = 3.6V$ ,  $R_L = 32\Omega$ , C-CUPL



Gain vs Volume Steps  
 $V_{CC} = 5V$ ,  $R_L = 32\Omega$ , C-CUPL



## Application Information

### AMPLIFIER CONFIGURATION EXPLANATION

As shown in Figure 1, the LM4985 has three internal power amplifiers. Two of the amplifiers which amplify signals applied to their inputs, have internally configurable gain. The remaining third amplifier provides both half-supply output bias and AC ground return.

Loads, such as a headphone speaker, are connected between OUT1 and CNTGND or OUT2 and CNTGND. This configuration does not require an output coupling capacitor. The classical single-ended amplifier configuration, where one side of the load is connected to ground, requires large, expensive output coupling capacitors.

A configuration such as the one used in the LM4985 has a major advantage over single supply, single-ended amplifiers. Since the outputs OUT1, OUT2, and CNTGND are all biased at  $1/2 V_{DD}$ , no net DC voltage exists across each load. This eliminates the need for output coupling capacitors which are required in a single-supply, single-ended amplifier configuration. Without output coupling capacitors in a typical single-supply, single-ended amplifier, the bias voltage is placed across the load resulting in both increased internal IC power dissipation and possible loudspeaker damage.

The LM4985 eliminates these output coupling capacitors when operating in Output Capacitor-less (OCL) mode. Unless shorted to ground, VoC is internally configured to apply a  $1/2 V_{DD}$  bias voltage to a stereo headphone jack's sleeve. This voltage matches the bias voltage present on VoA and VoB outputs that drive the headphones. The headphones operate in a manner similar to a bridge-tied load (BTL). Because the same DC voltage is applied to both headphone speaker terminals this results in no net DC current flow through the speaker. AC current flows through a headphone speaker as an audio signal's output amplitude increases on the speaker's terminal.

The headphone jack's sleeve is not connected to circuit ground when used in OCL mode. Using the headphone output jack as a line-level output will place the LM4985's  $1/2 V_{DD}$  bias voltage on a plug's sleeve connection. This presents no difficulty when the external equipment uses capacitively coupled inputs. For the very small minority of equipment that is DC coupled, the LM4985 monitors the current supplied by the amplifier that drives the headphone jack's sleeve. If this current exceeds  $500\text{mA}_{PEAK}$ , the amplifier is shutdown, protecting the LM4985 and the external equipment.

### POWER DISSIPATION

Power dissipation is a major concern when using any power amplifier. When operating in capacitor-coupled mode (C-CUPL), Equation 1 states the maximum power dissipation point for a single-ended amplifier operating at a given supply voltage and driving a specified output load.

$$P_{\text{DMAX}} = 2(V_{\text{DD}})^2 / (2\pi^2 R_L) \quad (1)$$

When operating in the OCL mode, the LM4985's three operational amplifiers produce a maximum power dissipation given in Equation 2:

$$P_{\text{DMAX}} = [2(V_{\text{DD}})^2 / (2\pi^2 R_L)] + [V_{\text{DD}}^2 / (4\pi R_L)] \quad (2)$$

The maximum power dissipation point obtained from Equation 1 or Equation 2 must not be greater than the power dissipation that results from Equation 3:

$$P_{\text{DMAX}} = (T_{\text{JMAX}} - T_A) / \theta_{\text{JA}} \quad (3)$$

For package TMD12AAA,  $\theta_{\text{JA}} = 190^\circ\text{C/W}$ .  $T_{\text{JMAX}} = 150^\circ\text{C}$  for the LM4985. Depending on the ambient temperature,  $T_A$ , of the system surroundings, Equation 3 can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of Equation 2 is greater than that of Equation 3, then either the supply voltage must be decreased, the load impedance increased or  $T_A$  reduced.

For a typical application using a 3.6V power supply, with a  $32\Omega$  load, the maximum ambient temperature possible without violating the maximum junction temperature is approximately  $144^\circ\text{C}$  provided that device operation is around the maximum power dissipation point. Thus, for typical applications, power dissipation is not an issue. Power dissipation is a function of output power and thus, if typical operation is not around the maximum power dissipation point, the ambient temperature may be increased accordingly. Refer to the Typical Performance Characteristics curves for power dissipation information for lower output powers.

### POWER SUPPLY BYPASSING

As with any amplifier, proper supply bypassing is important for low noise performance and high power supply rejection. The capacitor location on the power supply pins should be as close to the device as possible.

Typical applications employ a regulator with  $10\mu\text{F}$  tantalum or electrolytic capacitor and a ceramic bypass capacitor which aid in supply stability. This does not eliminate the need for bypassing the supply nodes of the LM4985. A bypass capacitor value in the range of  $0.1\mu\text{F}$  to  $1\mu\text{F}$  is recommended for  $C_S$ .

### MICRO POWER SHUTDOWN

The LM4985's micropower shutdown is activated or deactivated through its I<sup>2</sup>C digital interface. Please refer to Table 1 for the I<sup>2</sup>C Address, Register Select, and Mode Control registers. Each amplifier within the LM4985 can be shutdown individually.

Please observe the following protocol when placing an individual amplifier channel in shutdown while the other channel remains active. The protocol requires activating both channels' shutdown simultaneously, then deactivating the shutdown of the channel whose output is desired (or leaving the desired channel in shutdown mode). Also, when operating in the C-CUPL mode, a short delay time is required between activating one channel after placing both channels in shutdown. If the user finds that both channels activate when only one was chosen, increase the delay.

### SELECTION OF INPUT CAPACITOR SIZE

Amplifying the lowest audio frequencies requires a high value input coupling capacitor,  $C_i$ . A high value capacitor can be expensive and may compromise space efficiency in portable designs. In many cases, however, the headphones used in portable systems have little ability to reproduce signals below 60Hz. Applications using headphones with this limited frequency response reap little improvement by using a high value input capacitor.

In addition to system cost and size, turn on time is affected by the size of the input coupling capacitor  $C_i$ . A larger input



## Application Information (Continued)

coupling capacitor requires more charge to reach its quiescent DC voltage. This charge comes from the output via the feedback. Thus, by minimizing the capacitor size based on necessary low frequency response, turn-on time can be minimized. A small value of  $C_i$  (in the range of 0.22 $\mu$ F to 0.68 $\mu$ F), is recommended.

### MAXIMIZING OCL MODE CHANNEL-to-CHANNEL SEPARATION

The OCL mode AC ground return (CNT\_GND pin) is shared by both amplifiers. As such, any resistance between the CNT\_GND pin and the load will create a voltage divider with respect to the load resistance. In a typical circuit, the amount of CNT\_GND resistance can be very small, but still significant. It is significant because of the relatively low load impedances for which the LM4985 was designed to drive: 16 $\Omega$

to 32 $\Omega$ . The ratio of this voltage divider will determine the magnitude of any residual signal present at the CNT\_GND pin. It is this residual signal that leads to channel-to-channel separation (crosstalk) degradation.

For example, for a 60dB channel-to-channel separation while driving a 16 $\Omega$  load, the resistance between the LM4985's CNT\_GND pin and the load must be less than 16m $\Omega$ . This is achieved by ensuring that the trace that connects the CNT\_GND pin to the headphone jack sleeve should be as short and massive as possible, given the physical constraints of any specific printed circuit board layout and design.

### DEMONSTRATION BOARD AND PCB LAYOUT

Information concerning PCB layout considerations and demonstration board use and performance is found in Application Note AN-1452.

## I<sup>2</sup>C Control Register

Table 1 shows the actions that are implemented by manipulating the bits within the two internal I<sup>2</sup>C control registers.

**Table 1. LM4985 I<sup>2</sup>C Control Register Addressing and Data Format Chart**

LM4985 I2C Control Register Addressing and Data Chart										
I2C Address		A6	A5	A4	A3	A2	A1	A0	Function	
		1	1	0	0	1	1	A0		
Register Select	D7	D6	D5	D4	D3	D2	RS1	RS0		
	0	0	0	0	0	0	0	0	Read and write the mode control register	
	0	0	0	0	0	0	0	1	Read and write the volume control register	
Mode Control Register	D7	D6	D5	D4	D3	D2	D1	D0		
		WT1	WT0	PHG	SDCH1	SDCH2	CHSEL1	CHSEL2		
	0	X	X	X	X	X	X	X	D7 must always be set to 0	
	–	0	0	X	X	X	X	X	Wake-up time: 80ms (OCL), 250ms (C-CUPL)	
	–	0	1	X	X	X	X	X	Wake-up time: 110ms (OCL), 450ms (C-CUPL)	
	–	1	0	X	X	X	X	X	Wake-up time: 170ms (OCL), 850ms (C-CUPL)	
	–	1	1	X	X	X	X	X	Wake-up time: 290ms (OCL), 1650ms (C-CUPL)	
	–	X	X	1	X	X	X	X	Output capacitor-less mode <b>active</b>	
	–	X	X	0	X	X	X	X	Output capacitor-less mode <b>inactive</b>	
	–	X	X	X	0	0	X	X	Amplifier's SHUTDOWN mode <b>active</b>	
	–	X	X	X	0	1	X	X	Illegal mode	
	–	X	X	X	1	0	X	X	Illegal mode	
	–	X	X	X	1	1	X	X	Amplifier's SHUTDOWN mode <b>inactive</b>	
	–	X	X	X	X	X	X	0	02	Amplifier's Chan. 1 is <b>Input 1</b> , Chan 2. is <b>Input 2</b>
	–	X	X	X	X	X	X	0	1	Amplifier's Chan. 1 is <b>Input 1</b> , Chan 2. is <b>Input 1</b>
	–	X	X	X	X	X	X	1	0	Amplifier's Chan. 1 is <b>Input 2</b> , Chan 2. is <b>Input 2</b>
	–	X	X	X	X	X	X	1	1	Amplifier's Chan. 1 is <b>Input 2</b> , Chan 2. is <b>Input 1</b>

## Volume Control Settings Binary Values

The minimum volume setting is set to  $-76\text{dB}$  when 00000 is loaded into the volume control register. Incrementing the volume control register in binary fashion increases the volume control setting, reaching full scale at 11111. Table C1 shows the value of the gain for each of the 32 binary volume control settings.

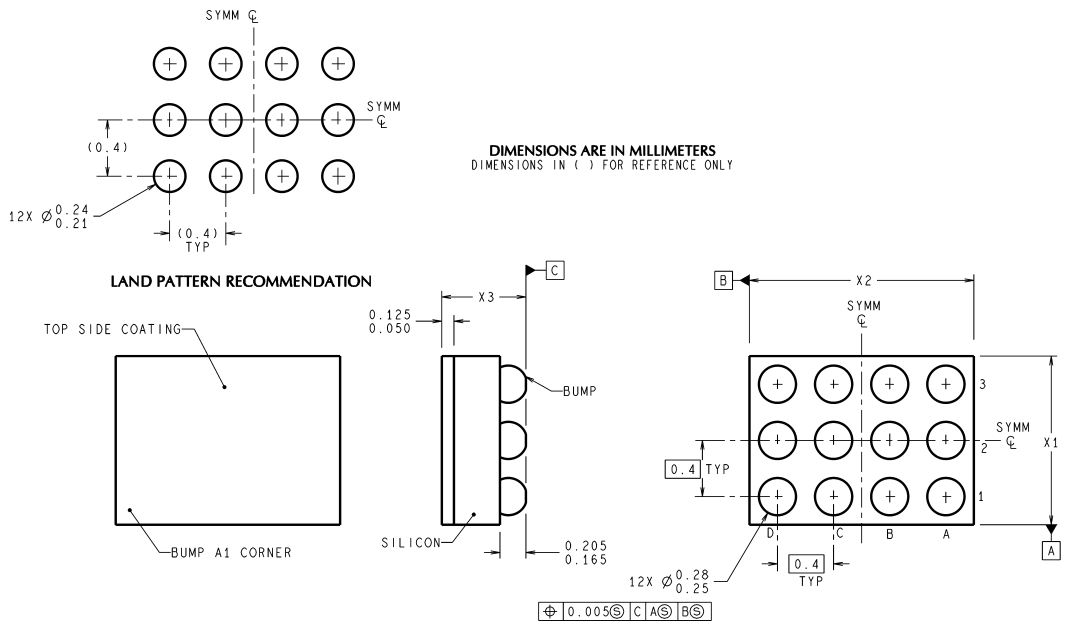
**Table C1. Binary Values for the Different Volume Control Gain Settings**

Gain	B4	B3	B2	B1	B0
18	1	1	1	1	1
17	1	1	1	1	0
16	1	1	1	0	1
15	1	1	1	0	0
14	1	1	0	1	1
13	1	1	0	1	0
12	1	1	0	0	1
10	1	1	0	0	0
8	1	0	1	1	1
6	1	0	1	1	0
4	1	0	1	0	1
2	1	0	1	0	0
0	1	0	0	1	1
-2	1	0	0	1	0
-4	1	0	0	0	1
-6	1	0	0	0	0
-8	0	1	1	1	1
-10	0	1	1	1	0
-12	0	1	1	0	1
-14	0	1	1	0	0
-16	0	1	0	1	1
-18	0	1	0	1	0
-21	0	1	0	0	1
-24	0	1	0	0	0
-27	0	0	1	1	1
-30	0	0	1	1	0
-34	0	0	1	0	1
-38	0	0	1	0	0
-44	0	0	0	1	1
-52	0	0	0	1	0
-62	0	0	0	0	1
-76	0	0	0	0	0

## Revision History

Rev	Date	Description
1.0	05/17/06	Initial WEB release.

## Physical Dimensions inches (millimeters) unless otherwise noted



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