LMV1099 Uplink Far Field Noise Suppression and Downlink SNR Enhancing Microphone Amplifier with Earpiece Driver

Check for Samples: LMV1099

FEATURES

- **Noise Reduction Without DSP-Type Artifacts**
- **Adapting AGC (Automatic Gain Control) on Ambient Noise Level and Downlink Signal Strength**
- **Downlink Adjustable Noise-reducing High Pass Filter**
- **Separate Uplink and Downlink Enable Functions**
- **No Added Process Delays**
- **Low Power Consumption**
- **Shutdown Function**
- **Maximum AGC Limiter**
- **Differential Inputs and Outputs for Noise Immunity**
- **Earpiece Amplifier**
- **Available in a 25-Bump DSBGA Package**

APPLICATIONS

- **Mobile Handsets**
- **Mobile and Handheld Two-Way Radios**
- **Bluetooth and Other Power Headsets**

KEY SPECIFICATIONS

- **Uplink Far Field Noise Suppression (Electrical $FFNS_E$ at f = 1kHz) 33dB (typ)**
- **Near-Field SNR Enhancement 6 to 18dB (typ)**
- **Downlink $SNRI_E$ 16dB (typ)**
- **Supply Voltage Range 2.7V to 5.5V**
- **Supply Current (V_{DD} = 3.6V) 3.8mA (typ)**
- **Shutdown Current 0.06µA (typ)**
- **Uplink PSRR (f = 217Hz) 106dB (typ)**
- **Downlink SNR (A-weighted) 102dB (typ)**
- **Downlink THD+N 0.03% (typ)**
- **Earpiece Output Power (R_L = 32Ω) 83mW (typ)**

DESCRIPTION

The LMV1099 is an uplink and downlink voice intelligibility enhancing analog IC, ideally suited for mobile handsets. Uplink voice intelligibility is improved by rejecting far-field noise through a unique two-microphone solution. Downlink voice intelligibility is improved by enhancing the SNR (Signal-to-Noise Ratio) between the downlink voice and the ambient noise environment at the user's earpiece.

The LMV1099 preserves uplink near-field voice signals within close range of the microphones while rejecting far-field acoustic noise greater than 0.5m from the microphones.

The LMV1099 also enhances downlink voice intelligibility by improving near-field SNR based on the user's environment. The analog circuitry adapts dynamically to both the user's ambient noise environment as well as the downlink signal amplitude to ensure optimum SNRI (signal-to-noise ratio improvement). The downlink path also provides uplink noise attenuation through an adjustable high pass filter before the SNR enhanced downlink voice reaches the user's earpiece.

Unlike digital-based noise reduction solutions, the all-analog low power consuming LMV1099 increases both uplink and downlink voice intelligibility without DSP-type artifacts, distortions or processing delays.

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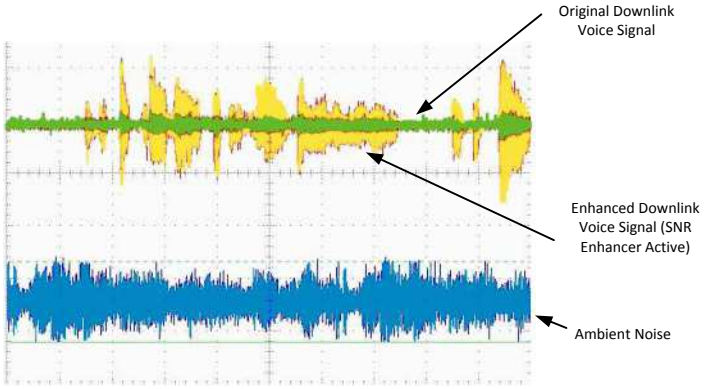
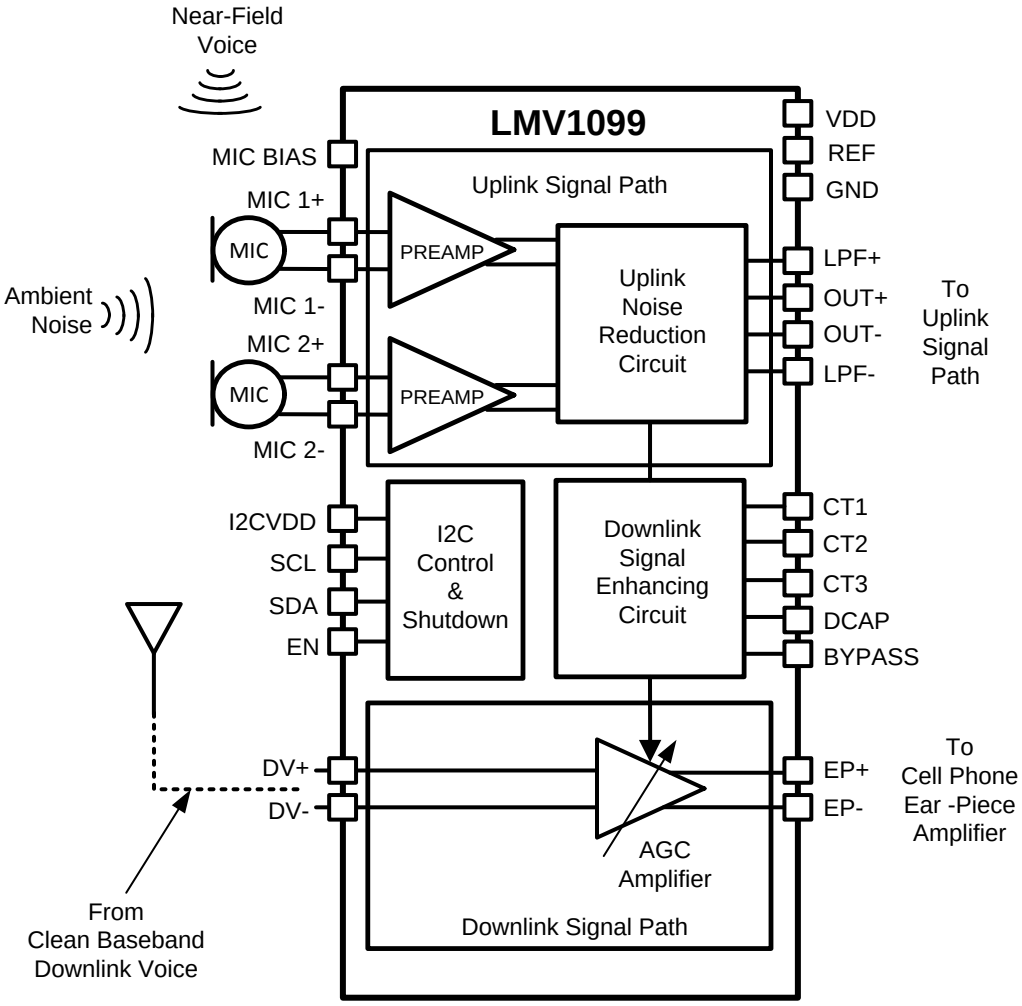


Figure 1. Voice Enhanced Signal

Block Diagram



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Typical Application

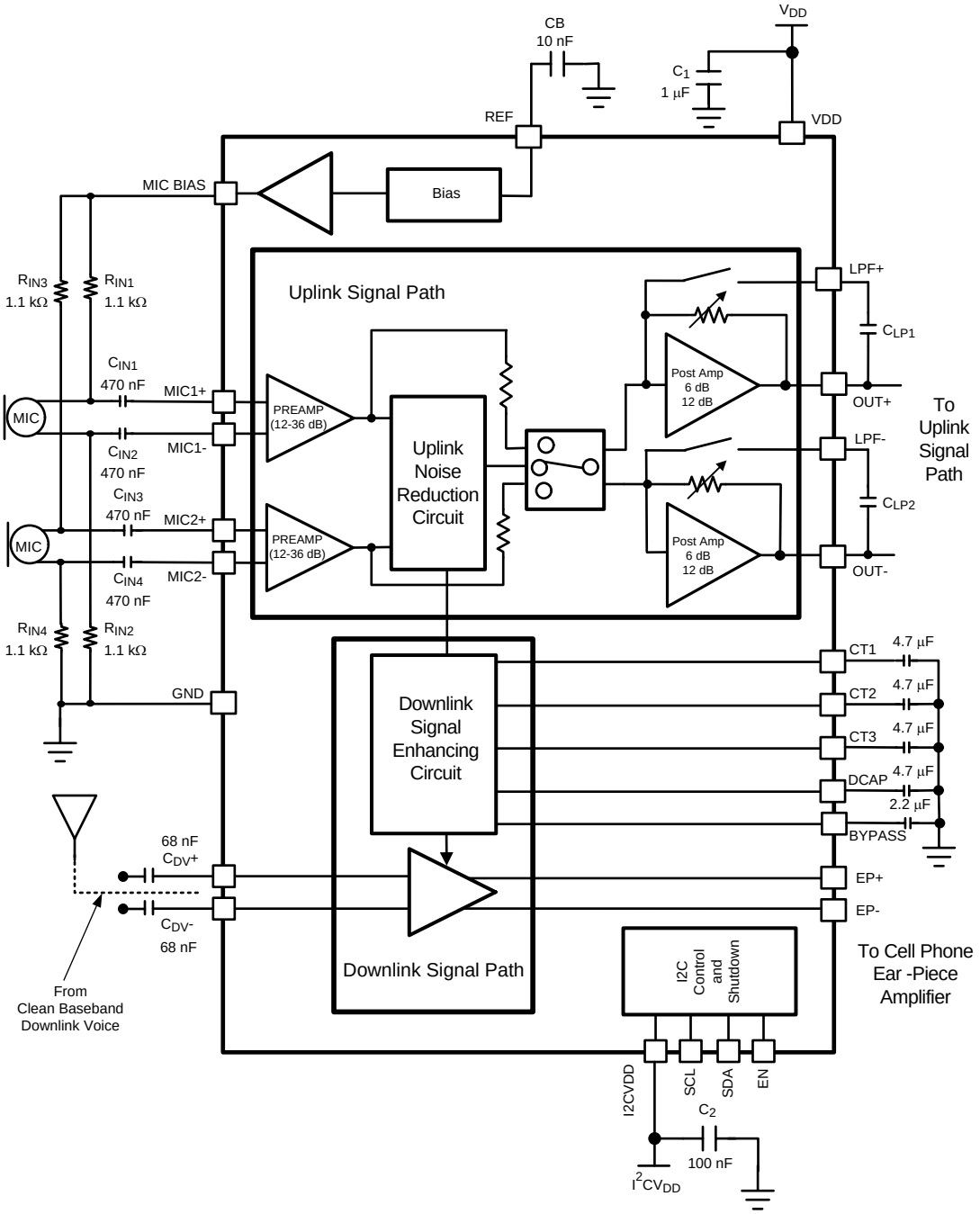


Figure 2. Typical Application Circuit Diagram

Connection Diagram

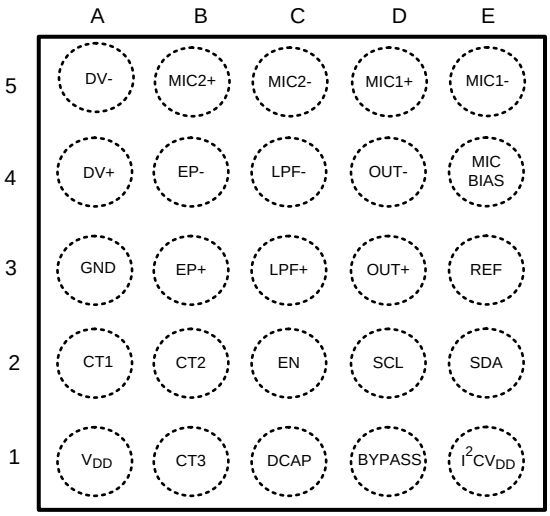


Figure 3. 25-Bump DSBGA (Top View)
See YZR0025 Package

PIN NAME AND FUNCTION (1)

PIN	NAME	TYPE	UPLINK PIN DESCRIPTIONS
D5	MIC1+	Analog Input	Uplink Voice Positive Microphone #1 Input
E5	MIC1-	Analog Input	Uplink Voice Negative Microphone #1 Input
B5	MIC2+	Analog Input	Uplink Voice Positive Microphone #2 Input
C5	MIC2-	Analog Input	Uplink Voice Negative Microphone #2 Input
E4	MIC BIAS	Analog Output	Microphone DC Bias Voltage Output
E3	REF	Analog Ref	Microphone Reference Bypass Pin
D3	OUT+	Analog Output	Uplink Positive Output (To Baseband Chipset)
C3	LPF+	Analog Input	Uplink-Output Low Pass Filter Positive Feedback Input
D4	OUT-	Analog Output	Uplink Negative Output (To Baseband Chipset)
C4	LPF-	Analog Input	Uplink-Output Low Pass Filter Negative Feedback Input
PIN	**NAME**	**TYPE**	**DOWNLINK PIN DESCRIPTIONS**
A4	DV+	Analog Input	Downlink Voice Positive Input
A5	DV-	Analog Input	Downlink Voice Negative Input
A2	CT1	Analog Ref	Control Signal Timing Capacitor
B2	CT2	Analog Ref	Control Signal Timing Capacitor
B1	CT3	Analog Ref	Control Signal Timing Capacitor
A3	GND	Ground	Power Supply Ground Pin
D1	Bypass	Analog Ref	Earpiece Reference Bypass Pin
B3	EP+	Analog Output	Ear Speaker Positive Output (To Ear Piece Speaker)
B4	EP-	Analog Output	Ear Speaker Negative Output (To Ear Piece Speaker)
PIN	**NAME**	**TYPE**	**DIGITAL INTERFACE & SUPPLY PIN DESCRIPTIONS**
D2	SCL	Digital Input	I^2C Serial Clock Digital Input
C2	EN	Digital Input	I^2C Chip Enable Digital Input

(1) Note: Pin assignment subject to change.

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PIN NAME AND FUNCTION (1) (continued)

PIN	NAME	TYPE	UPLINK PIN DESCRIPTIONS
E2	SDA	Digital I/O	I^2C Serial Data Address Digital Input/Output Pin
E1	I^2CV_{DD}	Digital Supply	I^2C Digital Supply Voltage Pin
A1	V_{DD}	Supply	Power Supply Voltage Pin
C1	DCAP	Analog Ref	Voice Signal Detection Capacitor

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.

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Absolute Maximum Ratings[1][2]

Supply Voltage		6.0V
Storage Temperature		-85°C to +150°C
ESD Rating (HBM)[3]		2000V
ESD Rating (MM)[4]		200V
ESD Rating (CDM)[5]		750V
Junction Temperature (T_{JMAX})		150°C
Mounting Temperature	Infrared or Convection (20 sec.)	235°C
Thermal Resistance	θ_{JA} (DSBGA)[6]	70°C/W
Soldering Information		See AN-1112 "microSMD Wafers 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) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(3) Human body model, applicable std. JESD22-A114C.
(4) Machine model, applicable std. JESD22-A115-A.
(5) Charge device model, applicable std. JESD22-C101D.
(6) The maximum power dissipation must be de-rated at elevated temperatures and is dictated by T_{JMAX}, θ_{JC}, 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 the *Absolute Maximum Ratings*, whichever is lower.

Operating Ratings[1]

Supply Voltage	$2.7V \le V_{DD} \le 5.5V$
I^2CV_{DD}	$1.7V \le I^2CV_{DD} \le 5.5V$
	$I^2CV_{DD} \le V_{DD}$
$T_{MIN} \le T_A \le T_{MAX}$	$-40°C \le T_A \le +85°C$

(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.

Electrical Characteristics V_{DD} = 3.6V[1]

Unless otherwise specified, all limits specified for T_A = 25°C, V_{DD} = 3.6V, EN = V_{DD}. For Uplink tests, unless otherwise specified, preamplifier gain = 20dB, post amplifier gain = 6dB, V_{IN} = 18mV_{P-P}, f = 1kHz, R_L = 100kΩ, C_L = 4.7pF and in pass-through mode. For Downlink tests, unless otherwise specified, f = 1kHz, R_L = 32Ω, AGC_{AV} = 0dB.

Symbol	Parameter	Conditions	LMV1099		Units (Limits)
			Typical[2]	Limit[3]	
GENERAL SPECIFICATIONS					
I_{DDQ}	Supply Quiescent Current	V_{IN} = 0V	3.8	4.5	mA (max)
I_{SD}	Shutdown Current	EN pin is Low	0.06	1	µA (max)
T_{ON}	IC Wake-up Time		27	40	ms (max)
V_{IH}	Logic High Input Threshold	EN, SCL, SDA		0.7xI^2CV_{DD}	V (min)
V_{IL}	Logic Low Input Threshold	EN, SCL, SDA		0.3xI^2CV_{DD}	V (max)
UPLINK SPECIFICATIONS					
$FFNS_E$	Far Field Noise Suppression (Electrical)	f = 1kHz (See Test Methods) f = 300Hz (See Test Methods)	33 42	27.5	dB (min) dB (min)

(1) *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.
(2) 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 ensured.
(3) Datasheet min/max specification limits are specified by test or statistical analysis.

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Electrical Characteristics V_{DD} = 3.6V[1] (continued)

Unless otherwise specified, all limits specified for T_A = 25°C, V_{DD} = 3.6V, EN = V_{DD}. For Uplink tests, unless otherwise specified, preamplifier gain = 20dB, post amplifier gain = 6dB, V_{IN} = 18mV_{P-P}, f = 1kHz, R_L = 100kΩ, C_L = 4.7pF and in pass-through mode. For Downlink tests, unless otherwise specified, f = 1kHz, R_L = 32Ω, AGC_{AV} = 0dB.

Symbol	Parameter	Conditions	LMV1099		Units (Limits)
			Typical[2]	Limit[3]	
$SNRI_E$	Signal-to-Noise Ratio Improvement (Electrical)	f = 1khz (See Test Methods) f = 300Hz (See Test Methods)	25 33	19.5	dB (min) dB (min)
V_{IN}	Maximum Input Signal	THD+N < 1%, Pre Amp Gain = 12dB	435	395	mV_{PP} (min)
V_{OUT}	Maximum AC Output Voltage	Differential Output, f = 1kHz THD+N < 1%	1.25	1.10	V_{RMS} (min)
	DC Level at Outputs	V_{IN} = GND	825		mV
V_{OS}	Output Offset Voltage	$V_{IN(Mic1/Mic2)}$ = 0V, Input Referred	0.7	5.0	mV (max)
THD+N	Total Harmonic Distortion + Noise	Differential Output	0.1	0.3	% (max)
FR	Frequency Response	30Hz – 12kHz (without Filter)	±0.5		dB
SNR	Signal-to-Noise Ratio	V_{IN} = 18mV_{P-P}, A-Weighted, audio band	65		dB
e_N	Input Referred Noise level	A-Weighted	7		μV_{RMS}
Z_{IN}	Input Impedance		150	127 173	kΩ (min) kΩ max)
Z_{OUT}	Output Impedance		235		Ω
Z_{LOAD}	Allowable Load Impedance	R_{LOAD} C_{LOAD}		10 100	kΩ (min) pF (max)
A_M	Microphone Pre Amplifier Gain Range	Minimum setting Maximum setting	12 36		dB
A_{MR}	Microphone Pre Amplifier Gain Resolution		2	1.7 2.3	dB (min) dB (max)
A_P	Post Amplifier Gain Range	Minimum setting Maximum setting	6 12		dB
A_{PR}	Post Amplifier Gain Resolution		6.0	5.8 6.2	dB (min) dB (max)
PSRR	Power Supply Rejection Ratio	Input Referred, Input AC Grounded (470nF)			
		f = 217Hz, V_{RIPPLE} = 200mV_{PP}	106	92	dB (min)
		f = 1kHz, V_{RIPPLE} = 200mV_{PP}	102	91	dB (min)
CMRR	Common Mode Rejection Ratio	Input referred	60		dB
V_{BM}	Microphone Bias Supply Voltage	I_{BM} = 1mA	2.0	1.85 2.15	V (max) V (min)
e_{VBM}	Microphone Bias Supply Noise	A-Weighted, C_B = 10nF	5.5		μV_{RMS}
I_{BMAX}	Maximum Microphone Reference Output Current			1.2	mA (max)
DOWNLINK SPECIFICATIONS					
$V_{IN(DV)}$	Maximum Input Signal (Differential)	THD+N < 1%, AGC_{AV} = 0dB	4.7	4.1	$V_{PP(DIFF)}$ (min)
V_{OS}	Output Offset Voltage	$V_{IN(DV)}$ = 0V, R_L = 32Ω, Input Referred	0.7	5.0	mV (max)
e_N	Output Noise level	A-Weighted, $V_{IN(DV)}$ = 0V, AGC_{AV} = 0dB	8.9		μV_{RMS}
SNR	Downlink Signal-to-Noise Ratio	P_O = 35mW, A-Weighted	102		dB
P_{OUT}	Output Power	THD+N<1%, f = 1kHz, R_L = 32Ω	83	65	mW (min)
V_{LIMIT}	Output Voltage Limit	PLEV = 0	3.6		V_{P-P}
		PLEV = 1	4.1		V_{P-P}
THD+N	Total Harmonic Distortion + Noise	f = 1kHz, P_O = 35mW, R_L = 32Ω	0.03	0.05	% (max)
FR	Frequency Response	30Hz – 17kHz (without Filter)	±0.5		dB

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Electrical Characteristics V_{DD} = 3.6V(1) (continued)

Unless otherwise specified, all limits specified for T_A = 25°C, V_{DD} = 3.6V, EN = V_{DD}. For Uplink tests, unless otherwise specified, preamplifier gain = 20dB, post amplifier gain = 6dB, V_{IN} = 18mV_{P-P}, f = 1kHz, R_L = 100kΩ, C_L = 4.7pF and in pass-through mode. For Downlink tests, unless otherwise specified, f = 1kHz, R_L = 32Ω, AGC_{AV} = 0dB.

Symbol	Parameter	Conditions	LMV1099		Units (Limits)
			Typical(2)	Limit(3)	
PSRR	Power Supply Rejection Ratio	Input AC Grounded (68nF)			
		f = 217Hz, V_{RIPPLE} = 200mV_{P-P}, R_L = 32Ω	93	82	dB (min)
		f = 1kHz, V_{RIPPLE} = 200mV_{P-P}, R_L = 32Ω	92	81	dB (min)
CMRR	Common Mode Rejection Ratio	V_{IN} = 200mV_{P-P}, f = 217Hz, R_L = 32Ω	50		dB
		V_{IN} = 200mV_{P-P}, f = 1kHz, R_L = 32Ω	60		dB
ZIN(DL)	Downlink Input Impedance	(See Table 6)	6.5 9.5 57		kΩ kΩ kΩ
SNR ENHANCEMENT SPECIFICATIONS					
AGC_{AV}	Automatic Gain Control Range	Minimum setting Maximum setting	0 18		dB
ΔAGC_{AV}	0dB Gain Accuracy	AGC_{AV} = 0dB, f = 1kHz, V_{DV} = 1V, V_{AN}= 0V	±0.05		dB
$SNRI_E$	Signal-To-Noise Ratio Improvement (Electrical)(4)	f_{DV} = f_{AN} = 300Hz			
		V_{DV} = 100mV_{P-P}, V_{AN}= 0.8mV_{P-P}	6		dB
		V_{DV} = 100mV_{P-P}, V_{AN} = 2mV_{P-P}	16		dB
		f_{DV} = f_{AN} = 1kHz			
		V_{DV} = 100mV_{P-P}, V_{AN} = 1.4mV_{P-P}	12		dB (min)
		V_{DV} = 100mV_{P-P}, V_{AN} = 2mV_{P-P}	16		dB (min)

(4) f_{DV} = Frequency of Downlink signal
f_{AN} = Frequency of Ambient Noise signal
V_{DV} = Voltage swing of Downlink signal
V_{AN} = Voltage swing of Ambient signal

I^2C Interface Characteristics V_{DD} = 3.3V, 1.8V ≤ $I^2C V_{DD}$ ≤ 5.5V(1)(2)

The following specifications apply for LS and HP VOLUMEGAIN = 0dB LSGAIN = 12B, HPGAIN = 0dB, EPGAIN = 0dB, R_L = 8Ω+30µH (Loudspeaker), R_L = 32Ω (Headphone), R_L = 32Ω (Earpiece), CSET = 0.1µF, ALC disabled, f = 1kHz, unless otherwise specified. Limits apply for T_A = 25°C. (Note 7).

Symbol	Parameter	Conditions	LMV1099		Units (Limits)
			Typical	Limits(3)	
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)
t_6	SDA Data Hold Time			250	ns (min)
V_{IH}	Input High Voltage			0.7x$I^2C V_{DD}$	V (min)
V_{IL}	Input Low Voltage			0.3x$I^2C V_{DD}$	V (max)

(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.

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(3) 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 ensured.

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Test Methods

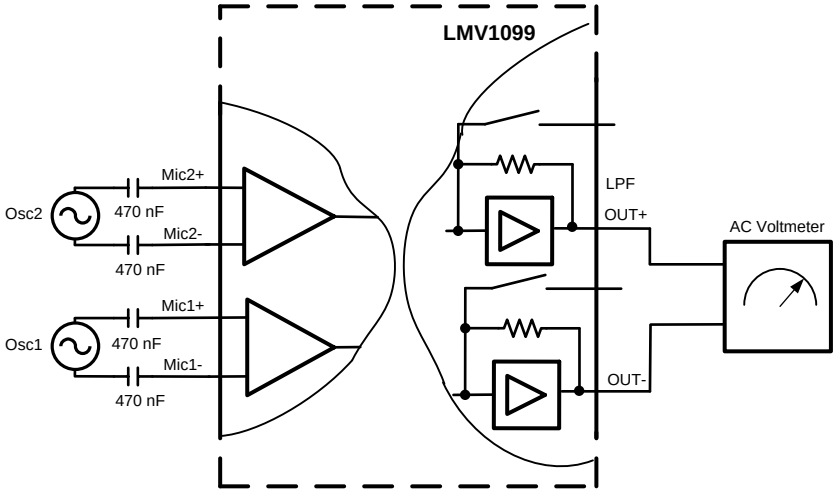


Figure 4. $FFNS_E$, $NFSL_E$, $SNRI_E$ Test Circuit

FAR FIELD NOISE SUPPRESSION ($FFNS_E$)

For optimum noise suppression the far field noise should be in a broadside array configuration from the two microphones, see Figure 26. Which means the far field sound source is equidistance from the two microphones. This configuration allows the amplitude of the far field signal to be equal at the two microphone inputs, however a slight phase difference may still exist. To simulate a real world application a slight phase delay was added to the $FFNS_E$ test. The block diagram from Figure 4 is used with the following procedure to measure the $FFNS_E$.

1. A sine wave with equal frequency and amplitude ($25mV_{P-P}$) is applied to Mic1 and Mic2. Using a signal generator, the phase of Mic 2 is delayed by 1.1° for 1kHz, or 0.33° for 300Hz, when compared with Mic1.
2. Measure the output level in dBV (X)
3. Mute the signal from Mic2
4. Measure the output level in dBV (Y)
5. $FFNS_E$ = Y - X dB

NEAR FIELD SPEECH LOSS ($NFSL_E$)

For optimum near field speech preservation, the sound source should be in an endfire array configuration from the two microphones (see Figure 27). In this configuration the speech signal at the microphone closest to the sound source will have greater amplitude than the microphone further away. Additionally the signal at microphone further away will experience a phase lag when compared with the closer microphone. To simulate this, phase delay as well as amplitude shift was added to the $NFSL_E$ test. The schematic from Figure 4 is used with the following procedure to measure the $NFSL_E$.

1. A $25mV_{P-P}$ and $17.25mV_{P-P}$ ($0.69*25mV_{P-P}$) sine wave is applied to Mic1 and Mic2 respectively. Once again, a signal generator is used to delay the phase of Mic2 by 15.9° for 1Khz, or 4.8° for 300Hz, when compared with Mic1.
2. Measure the output level in dBV (X)
3. Mute the signal from Mic2
4. Measure the output level in dBV (Y)
5. $NFSL_E$ = Y - X dB

SINGLE TO NOISE RATIO IMPROVEMENT ELECTRICAL ($SNRI_E$)

The $SNRI_E$ is the ratio of $FFNS_E$ to $NFSL_E$ and is defined as:

$$SNRI_E = FFNS_E - NFSL_E$$

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Typical Performance Characteristics

Unless otherwise specified, T_J = 25°C, V_{DD} = 3.6V. Uplink Path: Input Voltage = 18mV_{P-P}, f =1 kHz, pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB, R_L = 100kΩ, and C_L = 4.7pf. Downlink Path: R_L = 32Ω, f = 1kHz, SNR Enhancer disabled.

THD+N vs Frequency
V_{DD} = 3.6V, P_{OUT} = 50mW
Downlink Path

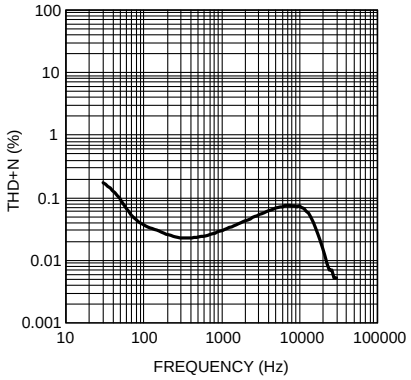


Figure 5.

THD+N vs Frequency
V_{DD} = 5V, P_{OUT} = 150mW
Downlink Path

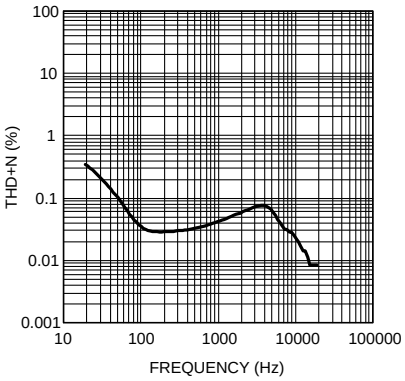


Figure 6.

THD+N vs Frequency
Mic1 = 36mV_{P-P}, Mic2 = AC GND
Noise Cancelling Mode, Uplink Path

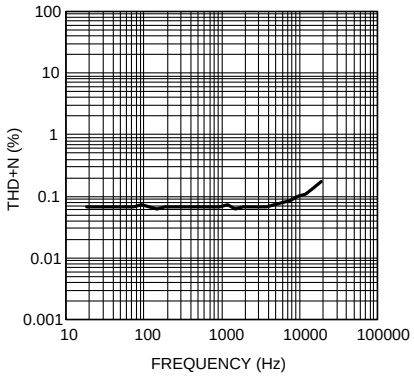


Figure 7.

THD+N vs Frequency
Mic1 = 36mV_{P-P}, Mic2 = AC GND
Noise Cancelling Mode, Uplink Path

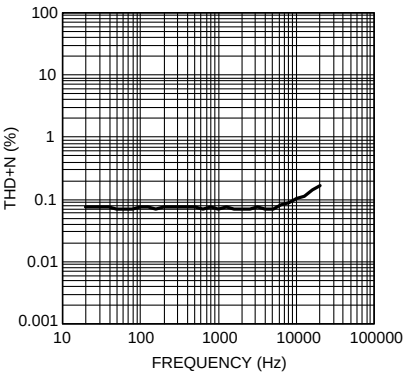


Figure 8.

THD+N vs Frequency
Mic1 = 36mV, Pass Through Mode Mic1
Uplink Path

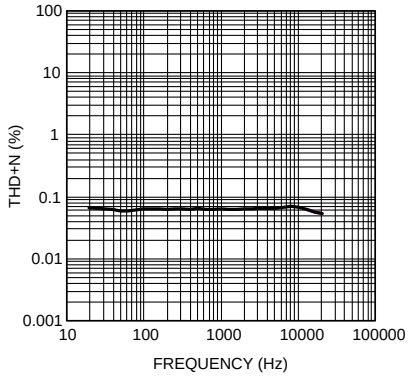


Figure 9.

THD+N vs Frequency
Mic2 = 36mV, Pass Through Mode Mic2
Uplink Path

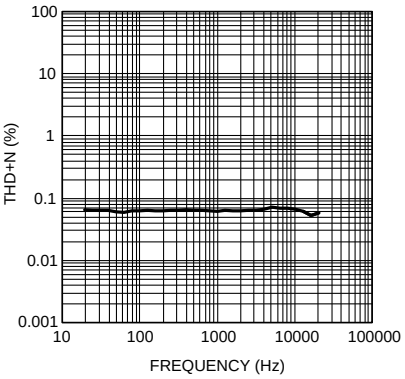


Figure 10.

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Typical Performance Characteristics (continued)

Unless otherwise specified, T_J = 25°C, V_{DD} = 3.6V. Uplink Path: Input Voltage = 18mV_{P-P}, f =1 kHz, pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB, R_L = 100kΩ, and C_L = 4.7pf. Downlink Path: R_L = 32Ω, f = 1kHz, SNR Enhancer disabled.

THD+N vs Output Power
V_{DD} = 3.6V, Downlink Path

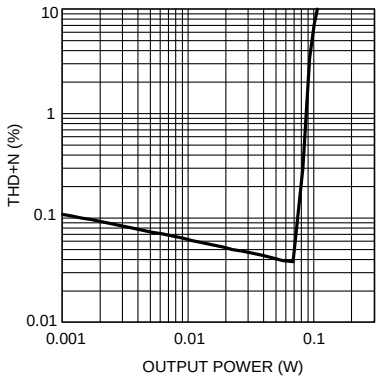


Figure 11.

THD+N vs Output Power
V_{DD} = 5V, Downlink Path

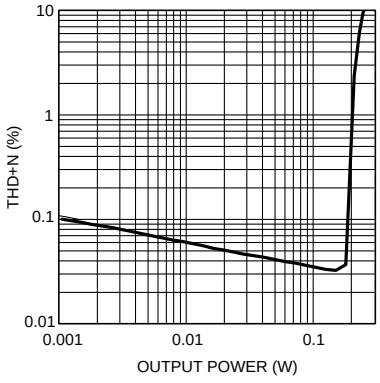


Figure 12.

THD+N vs Input Voltage
Mic1 Noise Cancelling Mode
Mic2 = AC GND, Uplink Path

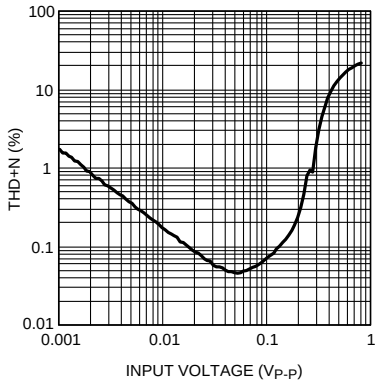


Figure 13.

THD+N vs Input Voltage
Mic2 Noise Cancelling Mode
Mic1 = AC GND, Uplink Path

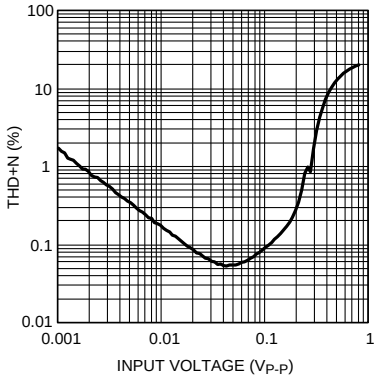


Figure 14.

Output Power vs Power Dissipation
V_{DD} = 3.6V, Downlink Path

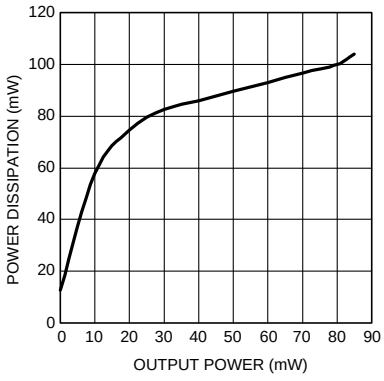


Figure 15.

Output Power vs Power Dissipation
V_{DD} = 5V, Downlink Path

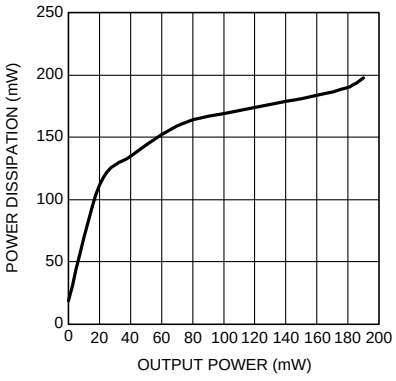


Figure 16.

Typical Performance Characteristics (continued)

Unless otherwise specified, T_J = 25°C, V_{DD} = 3.6V. Uplink Path: Input Voltage = 18mV_{P-P}, f =1 kHz, pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB, R_L = 100kΩ, and C_L = 4.7pf. Downlink Path: R_L = 32Ω, f = 1kHz, SNR Enhancer disabled.

PSRR vs Frequency
V_{DD} = 3.6V, V_{RIPPLE} = 200mV_{P-P}
Input Referred, Input = AC Ground
Downlink Path

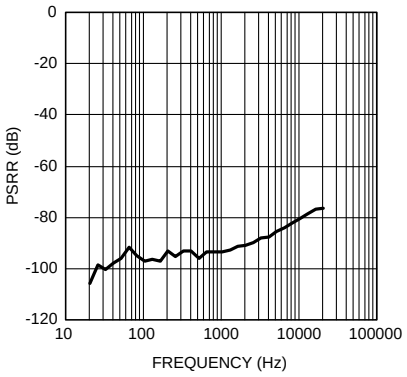


Figure 17.

PSRR vs Frequency
Input Referred, V_{RIPPLE} = 200mV_{P-P}
Passthrough Mode, Input = AC Ground
Uplink Path

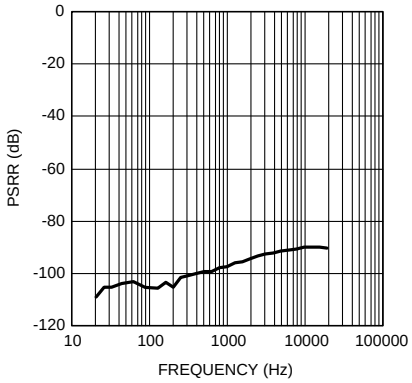


Figure 18.

PSRR vs Frequency
V_{DD} = 5V
Input Referred, V_{RIPPLE} = 200mV_{P-P}
Input = AC Ground, Downlink Path

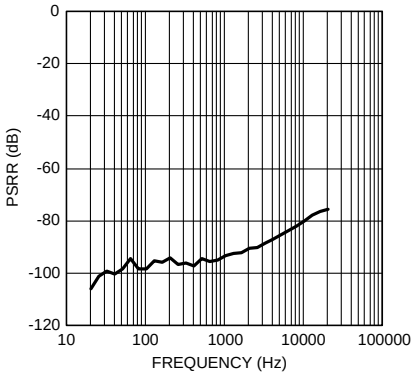


Figure 19.

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APPLICATION DATA

UPLINK FAR-FIELD NOISE REDUCTION OVERVIEW

The uplink portion of the LMV1099 is a fully analog solution to reduce the far field noise picked up by microphones in a communication system. A simplified block diagram is provided in Figure 20.

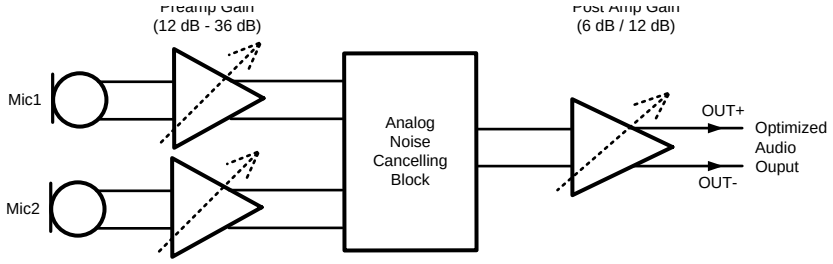


Figure 20. Simplified Block Diagram of the LMV1099 Uplink path

The output signal of the microphones is amplified by a pre-amplifier with adjustable gain between 12dB and 36dB. The matched signals are then routed through the Analog Noise Cancelling block which suppresses the far-field signal. The output of the analog noise cancelling processor is amplified in the post amplifier with selectable gain, 6dB or 12dB. For optimum noise and EMI immunity, the microphones have a differential connection to the LMV1099 and the uplink output is also differential. The adjustable gain functions can be controlled via I^2C.

POWER SUPPLY CIRCUITS

A low drop-out (LDO) voltage regulator in the LMV1099 allows the device to be independent of supply voltage variations.

The Power On Reset (POR) circuitry in the LMV1099 requires the supply voltage to rise from 0V to V_{DD} in less than 100ms.

The Mic Bias output is provided as a low noise supply source for the electret microphones. The noise voltage on the Mic Bias microphone supply output pin depends on the noise voltage on the internal the reference node. The de-coupling capacitor on the V_{REF} pin determines the noise voltage on this internal reference. This capacitor should be larger than 1nF; having a larger capacitor value will result in a lower noise voltage on the Mic Bias output.

GAIN BALANCE AND GAIN BUDGET

In systems where input signals have a high dynamic range, critical noise levels or where the dynamic range of the output voltage is also limited, careful gain balancing is essential for the best performance. Too low of a gain setting in the preamplifier can result in higher noise levels, while too high of a gain setting in the preamplifier will result in saturation of the noise cancelling processor and output stages.

The gain ranges and maximum signal levels for the different functional blocks are shown in Figure 21. Two examples are given as a guideline on how to select proper gain settings.

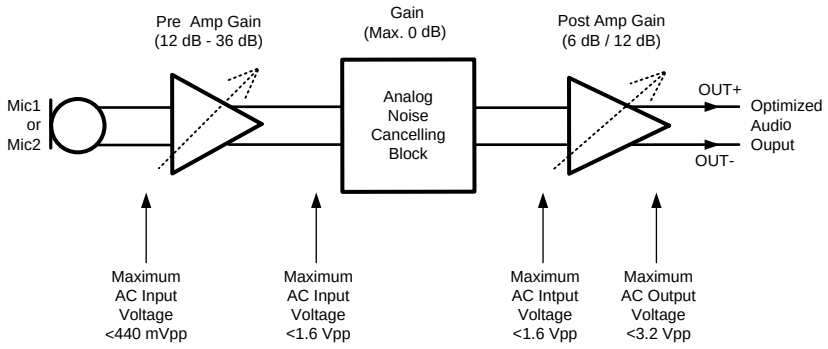


Figure 21. Maximum Signal Levels

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Example 1:

An application using microphones with 50mV$_{P-P}$ maximum output voltage, and a baseband chip after the LMV1099 with 1.5V$_{P-P}$ maximum input voltage.

For optimum noise performance, the gain of the input stage should be set to the maximum.

1. 50mV$_{P-P}$ + 36dB = 3.1V$_{P-P}$.
2. 3.1V$_{P-P}$ is higher than the maximum 1.5V$_{P-P}$ allowed for the Noise Cancelling Block (NCB). This means a gain lower than 29.5dB should be selected.
3. Select the nearest lower gain from the gain settings shown in Table 5, 28dB is selected. This will prevent the NCB from being overloaded by the microphone. With this setting, the resulting output level of the Pre Amplifier will be 1.26V$_{P-P}$.
4. The NCB has a gain of 0dB which will result in 1.26V$_{P-P}$ at the output of the LMV1099. This level is less than the maximum level that is allowed at the input of the post amp of the LMV1099.
5. The baseband chip limits the maximum output voltage to 1.5V$_{P-P}$ with the minimum of 6dB post amp gain, this results in requiring a lower level at the input of the post amp of 0.75V$_{P-P}$. Now calculating this for a maximum preamp gain, the output of the preamp must be no more than 0.75mV$_{P-P}$.
6. Calculating the new gain for the preamp will result in <23.5dB gain.
7. The nearest lower gain will be 22dB.

So using preamp gain = 22dB and postamp gain = 6dB is the optimum for this application.

Example 2:

An application using microphones with 10mV$_{P-P}$ maximum output voltage, and a baseband chip after the LMV1099 with 3.3V$_{P-P}$ maximum input voltage.

For optimum noise performance we would like to have the maximum gain at the input stage.

1. 10mV$_{P-P}$ + 36dB = 631mV$_{P-P}$.
2. This is lower than the maximum 1.5V$_{P-P}$, so this is OK.
3. The NCB has a gain of 0dB which will result in 1.5V$_{P-P}$ at the output of the LMV1099. This level is lower than the maximum level that is allowed at the input of the Post Amp of the LMV1099.
4. With a Post Amp gain setting of 6dB the output of the Post Amp will be 3V$_{P-P}$ which is OK for the baseband.
5. The nearest lower Post Amp gain will be 6dB.

So using preamp gain = 36dB and postamp gain = 6dB is optimum for this application.

I^{2}C Compatible Interface

The LMV1099 is controlled through an I^{2}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-collector) although the LMV1099 does not write to the I^{2}C bus. The LMV1099 and the master can communicate at clock rates up to 400kHz. Figure 22 shows the I^{2}C Interface timing diagram. Data on the SDA line must be stable during the HIGH period of SCL. The LMV1099 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 23). The data line is 8 bits long and is always followed by an acknowledge pulse (Figure 24).

I^{2}C Compatible Interface Power Supply Pin (I^{2}CV$_{DD}$)

The LMV1099 I^{2}C interface is powered up through the I^{2}CV$_{DD}$ pin. The LMV1099 I^{2}C interface operates at a voltage level set by the I^{2}CV$_{DD}$ pin which can be set independent to that of the main power supply pin V$_{DD}$. This is ideal whenever logic levels for the I^{2}C Interface are dictated by a microcontroller or microprocessor that is operating at a lower supply voltage than the main battery of a portable system.

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I²C Bus Format

The I²C bus format is shown in Figure 24. 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, R/W = 0 indicates the master is writing to the slave device, R/W = 1 indicates the master wants to read data from the slave device. Set R/W = 0; the LMV1099 is a WRITE-ONLY device and will not respond to the R/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 mater device release SDA, during which time, an acknowledge clock pulse is generated by the slave device. If the LMV1099 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 LMV1099 sends another ACK bit. Following the acknowledgement of the last register data word, the master issues a STOP bit, allowing SDA to go high while SCL is high.

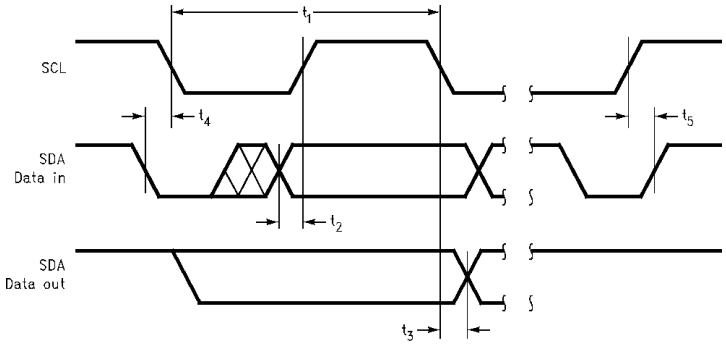


Figure 22. I²C Timing Diagram

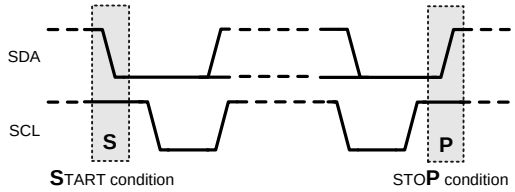


Figure 23. I²C Start Stop Conditions

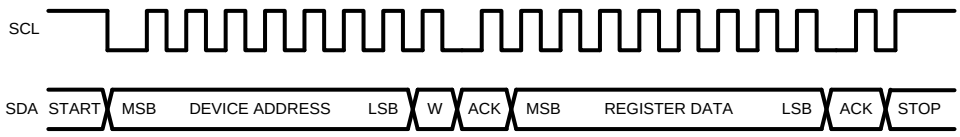


Figure 24. Start and Stop Diagram

I²C RESET PIN

When the I²C RESET pin is pulled low, the device will go into shutdown and the Power_on bit (seeTable 2) in the shutdown control register will reset. The device will remain in shutdown until an I²C command brings the device out of shutdown (see timing diagram in Figure 25). This pin can be connected to the I²CV_{DD} pin to prevent undefined and unwanted state changes that may occur when the I²C supply voltage is cycled.

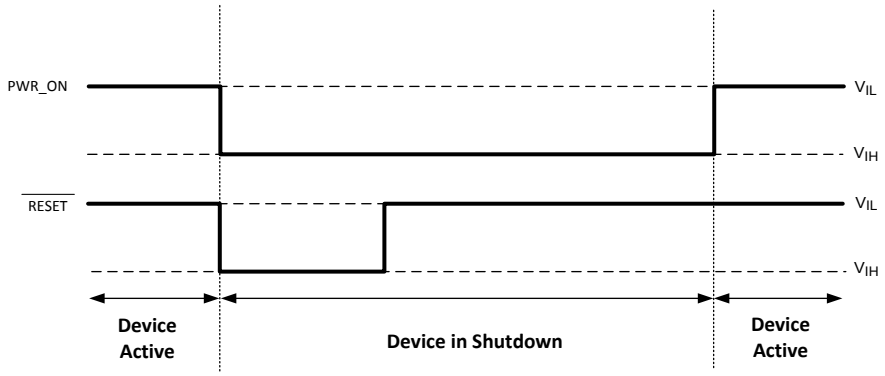


Figure 25.

Table 1. Chip Address

	B7 (1)	B6	B5	B4	B3	B2	B1	B0/$\overline{W}$
Chip Address	1	1	0	0	1	1	1	0

(1) The 7th Bit (B7) of the Register Data determines whether it will activate Register A or Register B.

Table 2. Control Registers

Register Name	Register Address B<6:5>	B<4>	B<3>	B<2>	B<1>	B<0>
Shutdown control	00	x	x	enable_ep	I^2CV_{DD}_sd	power_on
Mic mode control	01	mic_sel1	mic_sel0	agc_mic_mute	mute_mic2	mute_mic1
Mic Gain control	10	mic_post_gain	mic_pre_gain3	mic_pre_gain2	mic_pre_gain1	mic_pre_gain0
EP	11	ep_mute	plev	ep_bypass_agc	ep_ri1	ep_ri0

Table 3. Shutdown Control Register

BIT	NAME	DESCRIPTION	
B2	enable_ep	0	Disable earpiece
		1	Enable earpiece
B1	I^2CV_{DD}_SD	0	I^2CV_{DD} is an active low RESET input. If I^2CV_{DD} drops below 1.1V the device resets and the I^2C registers are restored to their default state
		1	Normal operation. I^2CV_{DD} voltage does not reset the device
B0	power_on	0	Device disable
		1	Device enable

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Table 4. LMV1099 Microphone Mode Control Register

BIT	NAME	DESCRIPTION		
B4:B3	mic_sel<4> mic_sel<3>	B4	B3	
		0	0	Noise canceling mode
		0	1	Only mic1 enabled (pass through)
		1	0	Only mic2 enabled (pass through)
		1	1	(mic1+mic2)/2
B2	agc_mic_mute	0		mic1 & mic2 mute not allowed
		1		mic1 & mic2 mute allowed
B1	mute_mic2 (1)	0		mic2 on
		1		mic2 mute
B0	mute_mic1 (1)	0		mic1 on
		1		mic1 mute

(1) agc_mic_mute overrides mute_mic1 and mute_mic2

Table 5. LMV1099 Microphone Gain Control Register

BIT	NAME	DESCRIPTION				
B4	mic_post_gain	0				6dB
		1				12dB
B3:B0	mic_pre_gain<3> mic_pre_gain<2> mic_pre_gain<1> mic_pre_gain<0>	B3	B2	B1	B0	
		0	0	0	0	12dB
		0	0	0	1	12dB
		0	0	1	0	12dB
		0	0	1	1	12dB
		0	1	0	0	14dB
		0	1	0	1	16dB
		0	1	1	0	18dB
		0	1	1	1	20dB
		1	0	0	0	22dB
		1	0	0	1	24dB
		1	0	1	0	26dB
		1	0	1	1	28dB
		1	1	0	0	30dB
		1	1	0	1	32dB
		1	1	1	0	34dB
		1	1	1	1	36dB

Table 6. LMV1099 Earpiece Control Register

BIT	NAME	DESCRIPTION	
B4	ep_mute	0	EP on
		1	EP mute
B3	plev	0	$3.6V_{P-P}$ Earpiece Output Level (50mW with 32Ω load)
		1	$4.1V_{P-P}$ Earpiece Output Level (70mW with 32Ω load)
B2	ep_bypass_agc	0	Normal operation
		1	Downlink SNR Enhancer Circuit bypassed (earpiece is still active)

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Table 6. LMV1099 Earpiece Control Register (continued)

BIT	NAME	DESCRIPTION		
B1:B0	ep_ri<1> ep_ri<0>	B1	B0	
		0	0	60kΩ input impedance
		0	1	9kΩ input impedance
		1	0	6kΩ input impedance
		1	1	6kΩ input impedance

Shutdown Function

As part of the Powerwise™ family, the LMV1099 consumes only 0.50mA of current. In many applications the part does not need to be continuously operational. To further reduce the power consumption in the inactive period, the LMV1099 provides two individual microphone power down functions (controlled through the mode control registers B3:B4). When either one of the shutdown functions is activated the part will go into shutdown mode consuming only a few µA of supply current. Shutdown functions can be controlled via the I^2C interface or a hardware pin.

SHUTDOWN VIA HARDWARE PIN

The hardware shutdown function is operated via the EN pin. In normal operation the EN pin must be at a 'high' level (V_{DD}). Whenever a 'low' level (GND) is applied to the EN pin the part will go into shutdown mode disabling all internal circuits.

Microphone Mode Control

The LMV1099 features four Microphone modes, Noise Cancellation Mode, Mic 1 pass through, Mic 2 pass through, and (Mic1+Mic2)/2. When in Noise Cancellation mode, it is imperative that Mic 1 and Mic 2 are NOT muted. If the mute function for either microphone path is enabled, the noise cancellation circuitry will be disabled. In mic1/mic2 pass through mode the noise canceling block is bypassed, and the LMV1099 is simply used as a microphone amplifier where the microphone signal passes through the pre and post amplifier gain stages. The last mode provides an average of the two microphone pass through signals (noise cancelling block is bypassed).

The microphone input paths can be muted individually via I^2C (Mic mode control register B1:B0). To enable the mute function, set bit B2 of the microphone mode control register to 1. If B2 is set to 0, the mute function will not activate.

Signal-to-Noise Ratio Enhancer (SNR Enhancer)

The SNR Enhancer in the LMV1099 is designed to provide excellent voice intelligibility in noisy environments. The control signal for the output gain adjustment is dependent on both the level and the type of ambient noise, compared with the signal energy of the downlink voice. The system was designed to operate transparently to the user, such that the gain changes are not evident but provide excellent voice intelligibility.

TI has invested considerable amount of time evaluating the acoustic effects of different ambient noise source types along with their practical SPL levels to determine optimum timing capacitor values for the proprietary downlink solution. These timing capacitor values should not be changed. We recommend using standard ceramic chip type capacitors with a low leakage rating. Electrolytic capacitors should not be used.

The SNR enhancing circuit will analyze the various energy levels for different frequency ranges and weight the AGC's gain change accordingly such that the downlink voice will remain intelligent. The overall intent of the circuit is for the gain changes to be transparent. Great care has gone into ensuring that gain changes won't be too perceptible or obnoxious. The system with have more dynamic gain change capability at low ambient noise levels in order to respond to fast changing noise sources. At the other extreme the system will have less dynamic gain change at high ambient noise levels since the environment will constantly be affecting intelligibility.

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Earpiece Control Registers

OUTPUT POWER LIMIT (PLEV)

While TI has done extensive ambient SPL analysis, there will always be unusual circumstances that may cause the amplifier to be at its maximum 18dB setting. LMV1099 features an Output Voltage Limit function to limit the output power delivered to a speaker. When the SNR enhancer is active, the Output Voltage Limit works to protect the loudspeaker in conditions where a large downlink input signal is present. The Output Voltage Limit can be set to a selectable ($3.6V_{P-P}$ or $4.1V_{P-P}$) output level to avoid violating the maximum power limitation of the transducer.

SNR ENHANCER BYPASS (EP_BYPASS_AGC)

The SNR enhancer can be bypassed by setting B4 of the Earpiece Control Register to 1. When the SNR enhancer is bypassed, the earpiece amplifier has a fixed 0dB gain.

EP_RI (INPUT IMPEDANCE)

The earpiece input of the LMV1099 features three input impedance options, this impedance in conjunction with the input capacitor creates a high-pass filter. The three options provide various cutoff frequencies for the high-pass filter. Table 7 shows the respective cutoff frequencies for each of the input impedance options when using a 68nF input capacitor.

Table 7. Input Impedance options

Input Impedance	f_C
60kΩ	40Hz
9kΩ	260Hz
6kΩ	390Hz

Changing the input coupling capacitor will affect the filters –3dB point through the simple RC equation shown below:

$$f = 1 / 2\pi RC \quad (1)$$

Microphone Placement

Because the LMV1099 is a microphone array Far Field Noise Reduction solution, proper microphone placement is critical for optimum performance. Two things need to be considered: The spacing between the two microphones and the position of the two microphones relative to near field source.

If the spacing between the two microphones is too small near field speech will be canceled along with the far field noise. Conversely, if the spacing between the two microphones is large, the far field noise reduction performance will be degraded. The optimum spacing between mic1 and mic2 is 1.5-2.5cm. This range provides a balance of minimal near field speech loss and maximum far field noise reduction. The microphones should be in line with the desired sound source 'near speech' and configured in an endfire array (see Figure 27) orientation from the sound source. If the 'near speech' (desired sound source) is equidistant to the source like a broadside array (see Figure 26) the result will be a great deal of near field speech loss.

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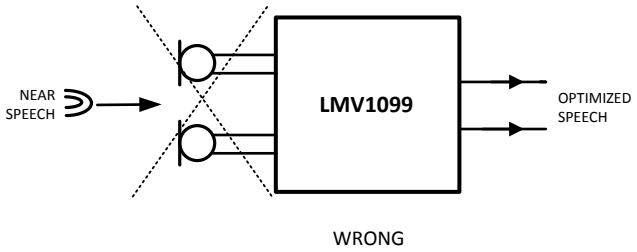


Figure 26. Broadside Array (WRONG)

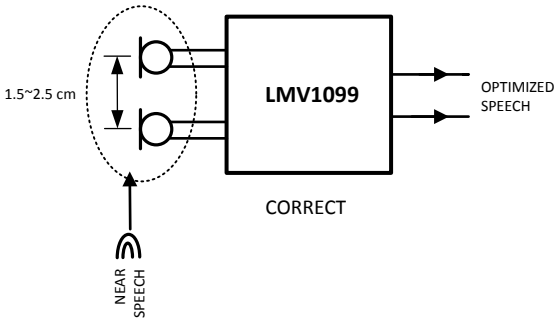


Figure 27. Endfire Array (CORRECT)

Low-Pass Filter At The Output

At the output of the LMV1099 there is a provision to create a 1st order low-pass filter (only enabled in 'Noise Cancelling' mode). This low-pass filter can be used to compensate for the change in frequency response that results from the noise cancellation process. The change in frequency response resembles a first-order high-pass filter, and for many of the applications it can be compensated by a first-order low-pass filter with cutoff frequency between 1.5kHz and 2.5kHz.

The transfer function of the low-pass filter is derived as:

$$H(s) = \frac{\text{Post Amplifier gain}}{sR_fC_f+1} \quad (2)$$

This low-pass filter is created by connecting a capacitor between the LPF pin and the OUT pin of the LMV1099. The value of this capacitor also depends on the selected output gain. For different gains the feedback resistance in the low-pass filter network changes as shown in Table 8.

This will result in the following values for a cutoff frequency of 2000 Hz:

Table 8. Low-Pass Filter Capacitor For 2kHz

Post Amplifier Gain Setting (dB)	R_f (kΩ)	C_f (nF)
6	20	3.9
12	40	2.0

A-Weighted Filter

The human ear is sensitive for acoustic signals within a frequency range from about 20Hz to 20kHz. Within this range the sensitivity of the human ear is not equal for each frequency. To approach the hearing response, weighting filters are introduced. One of those filters is the A-weighted filter.

The A-weighted filter is used in signal to noise measurements, where the wanted audio signal is compared to device noise and distortion.

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The use of this filter improves the correlation of the measured values to the way these ratios are perceived by the human ear.

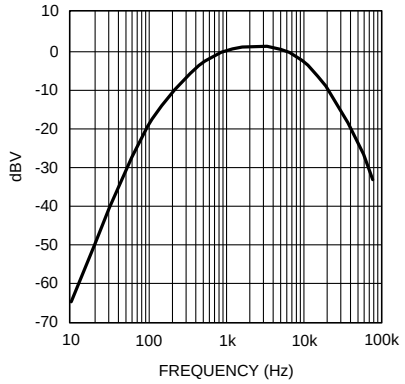


Figure 28. A-Weighted Filter

Measuring Uplink Noise and SNR

The overall noise of the LMV1099 is measured within the frequency band from 10Hz to 22kHz using an A-weighted filter. The Mic+ and Mic- inputs of the LMV1099 are AC shorted between the input capacitors, see Figure 29.

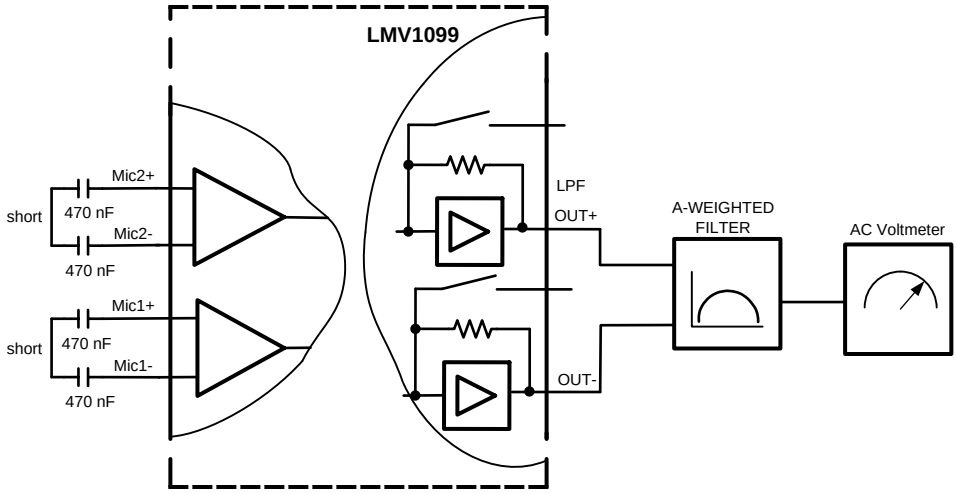


Figure 29. Noise Measurement Setup

For the signal to noise ratio (SNR) the signal level at the output is measured with a 1kHz input signal of $18mV_{P-P}$ using an A-weighted filter. This voltage represents the output voltage of a typical electret condenser microphone at a sound pressure level of 94dB SPL, which is the standard level for these measurements. The LMV1099 is programmed for 26dB of total gain (20dB preamplifier and 6dB postamplifier) with only mic1 or mic2 used. (See also I^2C Compatible Interface).

The input signal is applied differentially between the Mic+ and Mic-. Because the part is in Pass Through mode the low-pass filter at the output of the LMV1099 is disabled.

Table 9. Revision History

Rev	Date	Description
1.0	08/12/10	Initial release.
1.01	12/10/10	Added the X1, X2, and X3 values of the mktg outline.
1.02	03/30/11	Edited Table 3 (Control Registers).

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Table 9. Revision History (continued)

Rev	Date	Description
D	05/02/13	Changed layout of National Data Sheet to TI format

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LMV1099TL/NOPB	NRND	Production	DSBGA (YZR) | 25	250 | SMALL T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	ZA5
LMV1099TL/NOPB.A	NRND	Production	DSBGA (YZR) | 25	250 | SMALL T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	ZA5
LMV1099TLX/NOPB	NRND	Production	DSBGA (YZR) | 25	3000 | LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	ZA5
LMV1099TLX/NOPB.A	NRND	Production	DSBGA (YZR) | 25	3000 | LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 85	ZA5

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

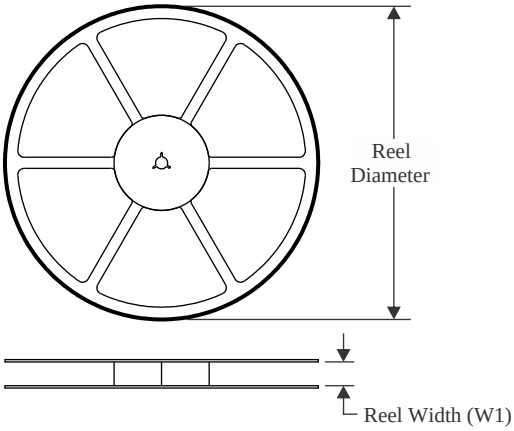
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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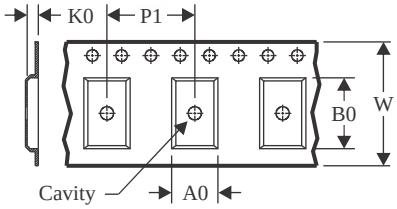
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

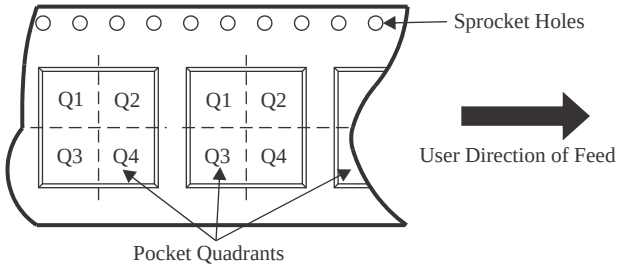


TAPE DIMENSIONS



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

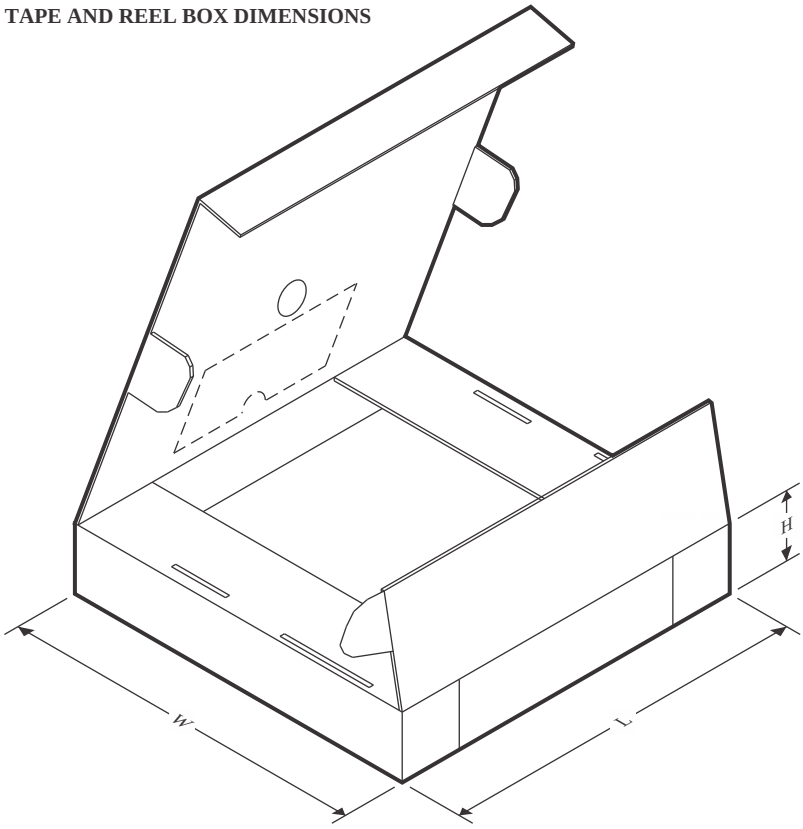
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LMV1099TL/NOPB	DSBGA	YZR	25	250	178.0	8.4	2.69	2.69	0.76	4.0	8.0	Q1
LMV1099TLX/NOPB	DSBGA	YZR	25	3000	178.0	8.4	2.69	2.69	0.76	4.0	8.0	Q1

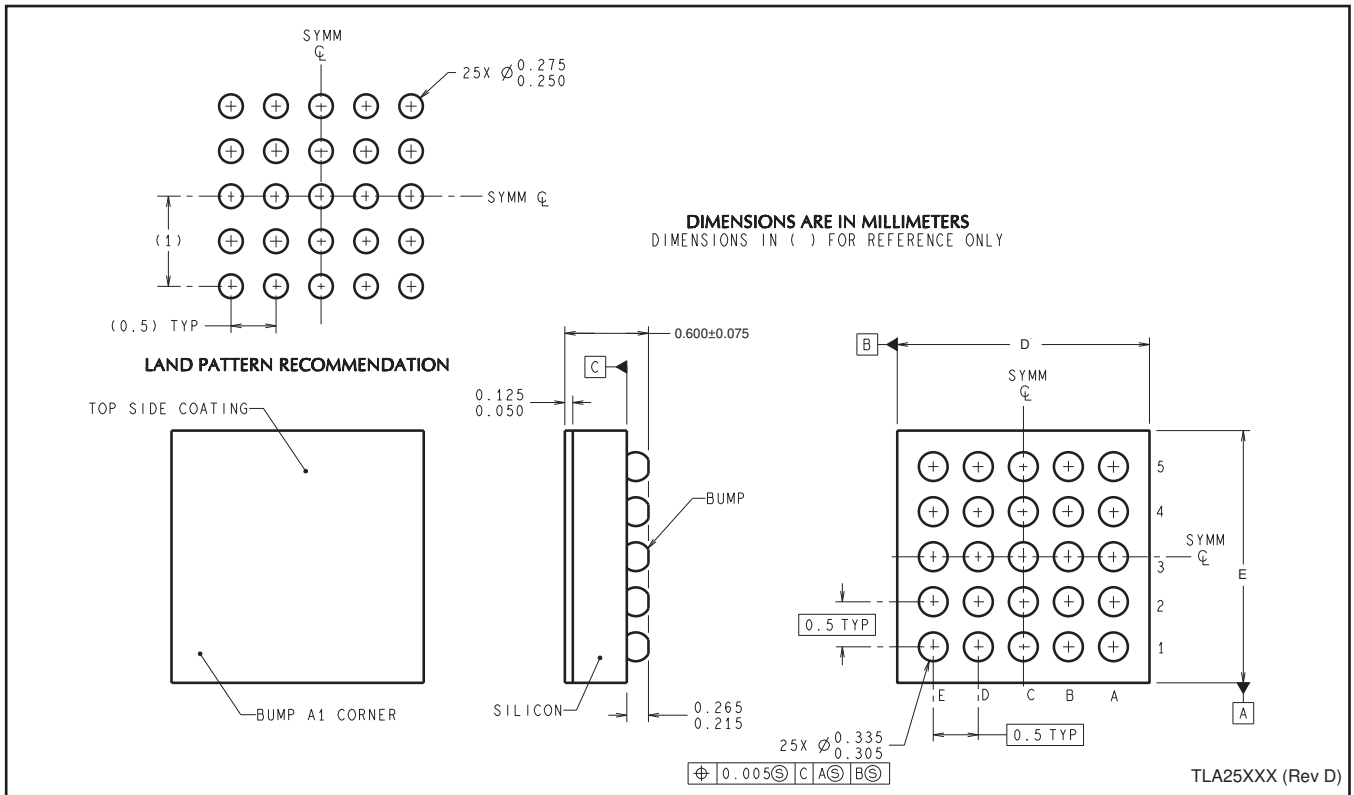
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMV1099TL/NOPB	DSBGA	YZR	25	250	208.0	191.0	35.0
LMV1099TLX/NOPB	DSBGA	YZR	25	3000	208.0	191.0	35.0

YZR0025



D: Max = 2.795 mm, Min =2.734 mm

E: Max = 2.67 mm, Min = 2.61 mm

4215055/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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