

## LMV1089

# Dual Input, Far Field Noise Suppression Microphone Amplifier with Automatic Calibration Capability

## General Description

The LMV1089 is a fully analog dual differential input, differential output, microphone array amplifier designed to reduce background acoustic noise, while delivering superb speech clarity in voice communication applications.

The LMV1089 preserves near-field voice signals within 4cm of the microphones while rejecting far-field acoustic noise greater than 50cm from the microphones. Up to 20dB of far-field rejection is possible in a properly configured and calibrated system.

Part of the Powerwise™ family of energy efficient solutions, the LMV1089 consumes only 1.1mA of supply current providing superior performance over DSP solutions consuming greater than ten times the power.

A quick calibration during the manufacturing test process of the product containing the LMV1089 compensates the entire microphone system. This calibration compensates for mismatch in microphone gain and frequency response, as well as acoustical path variances. The LMV1089 stores the calibration coefficients in the on-chip EEPROM. The calibration is initiated by an I<sup>2</sup>C command or by a logic pin control.

The dual microphone inputs and the processed signal output are differential to provide excellent noise immunity. The microphones are biased with an internal low-noise bias supply.

## Key Specifications

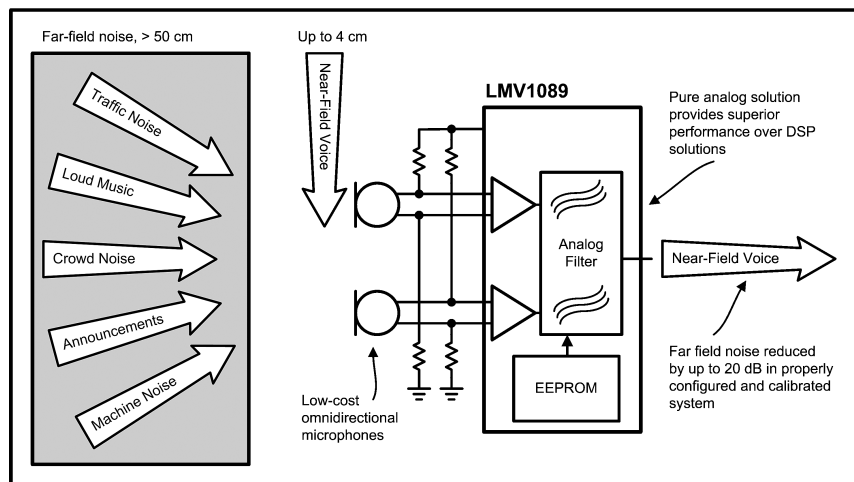
|                                                        |              |
|--------------------------------------------------------|--------------|
| ■ Far Field Noise Suppression (Electrical), (f = 1kHz) | 37dB         |
| ■ Supply Voltage                                       | 2.7V to 5.5V |
| ■ Supply Current                                       | 1.1mA (typ)  |
| ■ Standby Current                                      | 0.7μA (typ)  |
| ■ Signal-to-Noise Ratio (A-weighted)                   | 65dB (typ)   |
| ■ Total Harmonic Distortion + Noise                    | 0.1% (typ)   |
| ■ PSRR (217Hz)                                         | 96dB (typ)   |

## Features

- Low power consumption
- Shutdown function
- No added processing delay
- Differential inputs and outputs
- Automatic calibration
- Adjustable 6 - 48dB gain
- Excellent RF immunity
- Space-saving 36-bump micro SMD package

## Applications

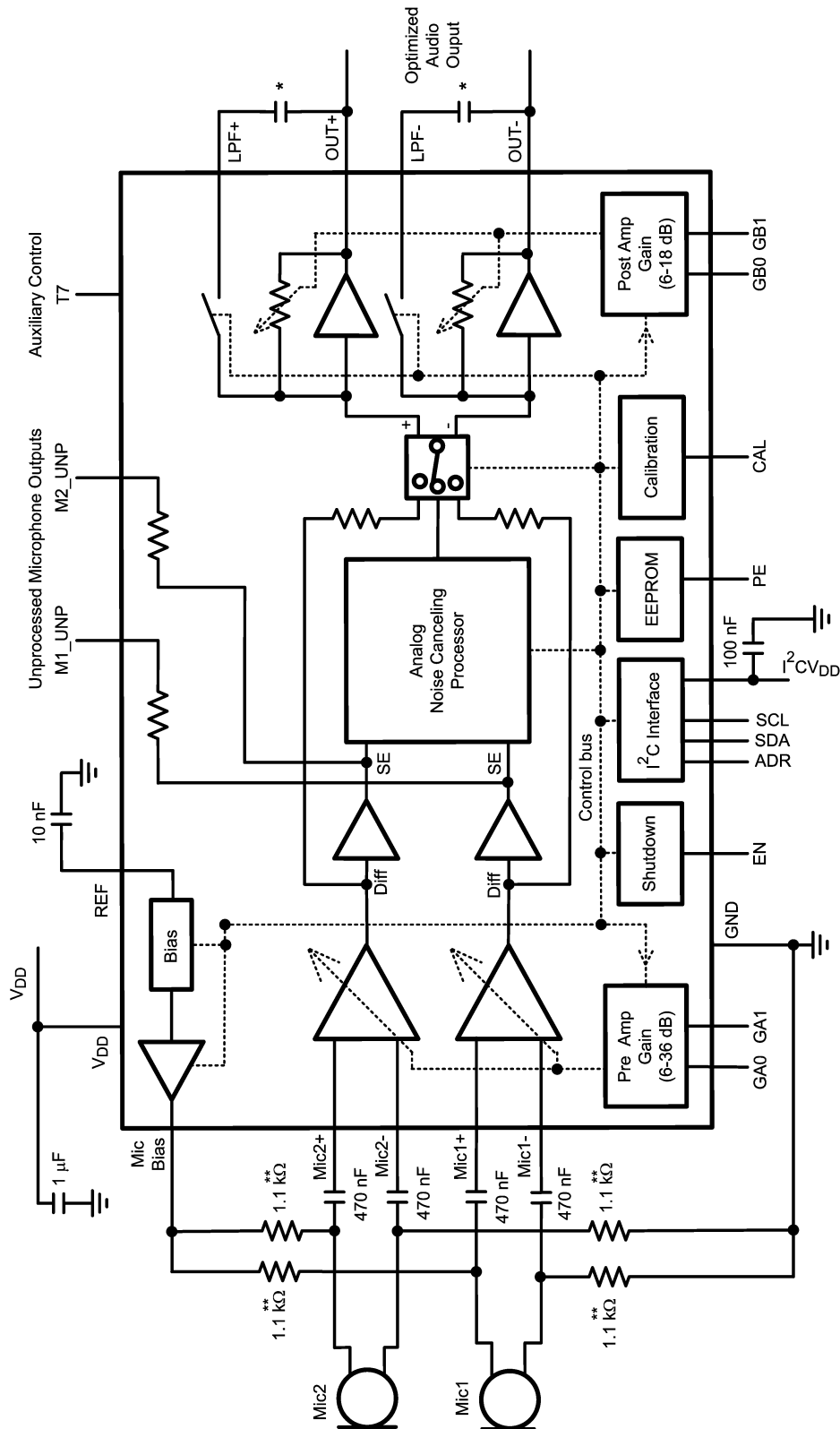
- Headset and Boom microphones
- Mobile handsets and two-way radios
- Bluetooth and other powered headsets
- Hand-held voice microphones
- Equalized stereo microphone preamplifier



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FIGURE 1.

## Typical Application



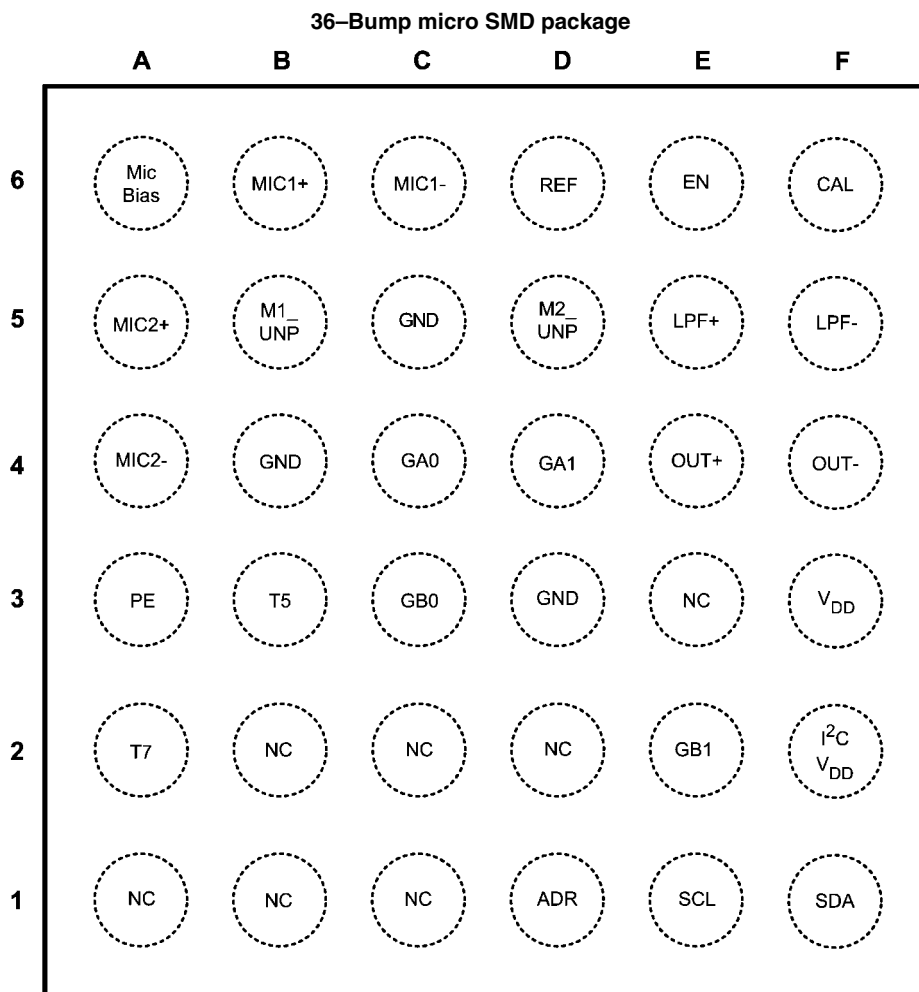
\* The value of the low-pass filter capacitor is application dependent, see the application section for additional information.

\*\* The value the microphone resistors is a standard value often used for electret microphones.

FIGURE 2. Typical Dual Microphone Far Field noise Cancelling Application

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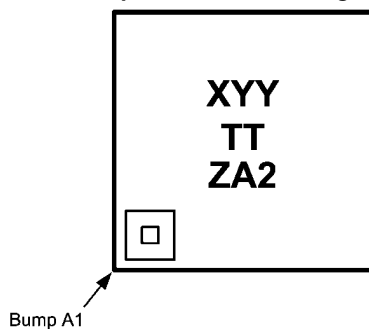
## Connection Diagrams



30047230

**Top View**  
**Order Number LMV1089RL**  
**See NS Package Number RLA36TTA**

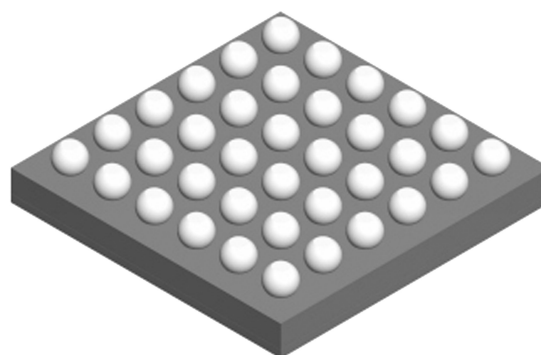
### 36-Bump micro SMD Marking



**Top View**  
**X = Plant Code**  
**YY = Date Code**  
**TT = Die Tracability**  
**ZA2 = LMV1089RL**

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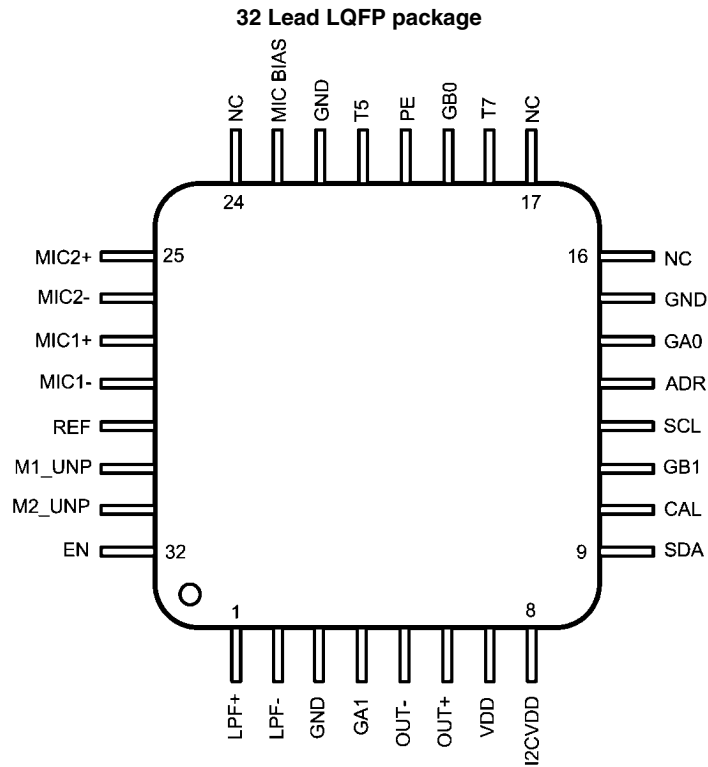
### micro SMD Package View



**Bottom View**

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Connection Diagrams



30047227

Top View  
Order Number LMV1089VY  
See NS Package Number NVBE0032

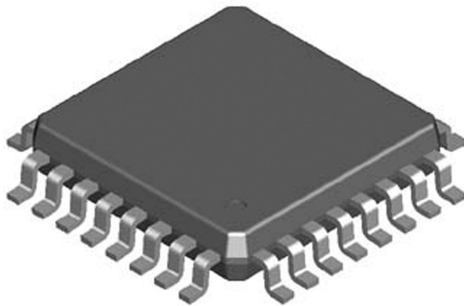
32 Lead LQFP Marking



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Top View  
U = Wafer Fab Code  
Z = Assembly Plant Code  
XY = 2 Digit Date Code  
TT = Die Traceability  
LMV1089 = LMV1089VY

LQFP Package View



30047228

Bottom View

Ordering Information

| Order Number | Package           | Package Drawing Number | Device Marking | Transport Media             |
|--------------|-------------------|------------------------|----------------|-----------------------------|
| LMV1089RL    | 36 Bump $\mu$ SMD | RLA36TTA               | XYTTZA2        | 250 units on tape and reel  |
| LMV1089RLX   | 36 Bump $\mu$ SMD | RLA36TTA               | XYTTZA2        | 1000 units on tape and reel |
| LMV1089VY    | 32 Lead LQFP      | NVBE0032               | UZXYTT         | 250 units on tape and reel  |
| LMV1089VYX   | 32 Lead LQFP      | NVBE0032               | UZXYTT         | 1000 units on tape and reel |

## Pin Descriptions

TABLE 1. Pin Name and Function

| Bump Number | Pin Name                        | Pin Function                                                           | Pin Type             |
|-------------|---------------------------------|------------------------------------------------------------------------|----------------------|
| A1          | NC                              | No connect                                                             | No Connect           |
| A2          | T7                              | Auxiliary Control Manual Calibration = $V_{DD}$ Auto Calibration = GND | Digital Input        |
| A3          | PE                              | Program Enable EEPROM                                                  | Digital Input        |
| A4          | MIC2–                           | microphone 2 negative input                                            | Analog Input         |
| A5          | MIC2+                           | microphone 2 positive input                                            | Analog Input         |
| A6          | Mic Bias                        | Microphone Bias                                                        | Analog Output        |
| B1          | NC                              | No Connect                                                             | No Connect           |
| B2          | NC                              | No Connect                                                             | No Connect           |
| B3          | T5                              | Float (do not connect to GND)                                          | Production Test      |
| B4          | GND                             | amplifier ground                                                       | Ground               |
| B5          | M1_UNP                          | microphone 1 unprocessed output                                        | Analog Output        |
| B6          | MIC1+                           | microphone 1 positive input                                            | Analog Input         |
| C1          | NC                              | No Connect                                                             | No Connect           |
| C2          | NC                              | No Connect                                                             | No Connect           |
| C3          | GB0                             | default Post Amp Gain 0                                                | Digital Input        |
| C4          | GA0                             | default Pre Amp Gain 0                                                 | Digital Input        |
| C5          | GND                             | amplifier ground                                                       | Ground               |
| C6          | MIC1–                           | amplifier ground                                                       | Analog Input         |
| D1          | ADR                             | I <sup>2</sup> C Address select                                        | Digital Input        |
| D2          | NC                              | No Connect                                                             | No Connect           |
| D3          | GND                             | amplifier ground                                                       | Ground               |
| D4          | GA1                             | default Pre Amp Gain 1                                                 | Digital Input        |
| D5          | M2_UNP                          | microphone 2 unprocessed output                                        | Analog Output        |
| D6          | REF                             | reference voltage de-coupling                                          | Analog Reference     |
| E1          | SCL                             | I <sup>2</sup> C clock                                                 | Digital Input        |
| E2          | GB1                             | default Post Amp Gain 1                                                | Digital Input        |
| E3          | NC                              | No Connect                                                             | No Connect           |
| E4          | OUT+                            | positive optimized audio output                                        | Analog Output        |
| E5          | LPF+                            | Low Pass Filter for positive output                                    | Analog Input         |
| E6          | EN                              | chip enable                                                            | Digital Input        |
| F1          | SDA                             | I <sup>2</sup> C data                                                  | Digital Input/Output |
| F2          | I <sup>2</sup> CV <sub>DD</sub> | I <sup>2</sup> C power supply                                          | Supply               |
| F3          | V <sub>DD</sub>                 | power supply                                                           | Supply               |
| F4          | OUT-                            | negative optimized audio output                                        | Analog Output        |
| F5          | LPF-                            | Low Pass Filter for negative output                                    | Analog Input         |
| F6          | CAL                             | calibration enable                                                     | Digital Input        |

## Absolute Maximum Ratings (Note 1)

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

|                                     |                    |
|-------------------------------------|--------------------|
| Supply Voltage                      | 6.0V               |
| Storage Temperature                 | -85°C to +150°C    |
| Power Dissipation (Note 3)          | Internally Limited |
| ESD Rating (Note 4)                 | 2000V              |
| ESD Rating (Note 5)                 | 200V               |
| Junction Temperature ( $T_{JMAX}$ ) | 150°C              |
| Mounting Temperature                | 235°C              |
| Infrared or Convection (20 sec.)    |                    |

Thermal Resistance

$$\theta_{JA} \text{ (microSMD)} \quad 70^{\circ}\text{C/W}$$

Soldering Information See AN-112 "microSMD Wafers Level Chip Scale Package."

## Operating Ratings (Note 2)

|                                 |                                                |
|---------------------------------|------------------------------------------------|
| Supply Voltage                  | $2.7\text{V} \leq V_{DD} \leq 5.5\text{V}$     |
| $I^2CV_{DD}$                    | $1.7\text{V} \leq I^2CV_{DD} \leq 5.5\text{V}$ |
| Supply Voltage (Note 8)         |                                                |
| Temperature Range               | -40°C to 85°C                                  |
| $T_{MIN} \leq T_A \leq T_{MAX}$ | -40°C $\leq T_A \leq$ +85°C                    |

## Electrical Characteristics 3.3V (Note 1)

Unless otherwise specified, all limits guaranteed for  $T_J = 25^{\circ}\text{C}$ ,  $V_{DD} = 3.3\text{V}$ ,  $V_{IN} = 18\text{mV}_{P-P}$ ,  $f = 1\text{kHz}$ ,  $EN = V_{DD}$ , pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB,  $R_L = 100\text{k}\Omega$ , and  $C_L = 4.7\text{pF}$ ,  $C_{REF} = 10\text{nF}$

| Symbol            | Parameter                                          | Conditions                                                                              | LMV1089          |                 | Units (Limits)          |
|-------------------|----------------------------------------------------|-----------------------------------------------------------------------------------------|------------------|-----------------|-------------------------|
|                   |                                                    |                                                                                         | Typical (Note 6) | Limits (Note 7) |                         |
| SNR               | Signal-to-Noise Ratio                              | $f = 1\text{kHz}$ , $V_{IN} = 18\text{mV}_{P-P}$                                        | 63               |                 | dB                      |
|                   |                                                    | $f = 1\text{kHz}$ , $V_{IN} = 18\text{mV}_{P-P}$ , A-Weighted voice band (300 – 3400Hz) | 65               |                 | dB                      |
| $e_N$             | Input Referred Noise level                         | A-weighted                                                                              | 5                |                 | $\mu\text{V}_{RMS}$     |
| $V_{IN}$          | Maximum Input Signal                               | THD+N < 1%, Pre Amp Gain = 6dB                                                          | 910              | 850             | $\text{mV}_{P-P}$ (min) |
| $V_{OUT}$         | Maximum AC Output Voltage                          | $f = 1\text{kHz}$ , Differential Out+, Out- THD+N < 1%                                  | 1.2              | 1.1             | $V_{RMS}$ (min)         |
|                   | DC Level at Outputs                                | Out+, Out-                                                                              | 800              |                 | mV                      |
| THD+N             | Total Harmonic Distortion + Noise                  | Differential Out+ and Out-                                                              | 0.1              | 0.2             | % (max)                 |
| $Z_{IN}$          | Input Impedance                                    |                                                                                         | 142              |                 | $\text{k}\Omega$        |
| $Z_{OUT}$         | Output Impedance                                   |                                                                                         | 300              |                 | $\Omega$                |
| $Z_{LOAD}$        | Load Impedance (Out+, Out-)                        | $R_{LOAD}$                                                                              |                  | 10              | $\text{k}\Omega$ (min)  |
|                   |                                                    | $C_{LOAD}$                                                                              |                  | 100             | pF (max)                |
| $A_M$             | Microphone Preamplifier Gain Range                 |                                                                                         | 6 – 36           |                 | dB                      |
| $A_{MR}$          | Microphone Preamplifier Gain Adjustment Resolution | $f = 1\text{kHz}$                                                                       | 2                | 1.7             | dB (min)                |
|                   |                                                    |                                                                                         |                  | 2.3             | dB (max)                |
| $A_P$             | Post Amplifier Gain Range                          | Pass Through Mode and Summing Mode                                                      | 6 – 18           |                 | dB                      |
| $A_{PR}$          | Post Amplifier Gain Resolution                     |                                                                                         | 3                | 2.6             | dB (min)                |
|                   |                                                    |                                                                                         |                  | 3.4             | dB (max)                |
| $A_{CR}$          | Gain Compensation Range                            |                                                                                         | $\pm 3$          |                 | dB                      |
| $A_{MD}$          | Maximum Gain Matching Difference After Calibration | $f = 300\text{Hz}$                                                                      | 0.5              |                 | dB                      |
|                   |                                                    | $f = 1\text{kHz}$                                                                       | 0.25             |                 | dB                      |
|                   |                                                    | $f = 3\text{kHz}$                                                                       | 0.5              |                 | dB                      |
| $X_{Talk}$        | Crosstalk Attenuation between Mic1 and Mic2        | Measured at M1_UNP and M2_UNP                                                           | 52               | 41              | dB (min)                |
| $T_{CAL}$         | Calibration Duration                               |                                                                                         |                  | 790             | ms (max)                |
| FFNS <sub>E</sub> | Far Field Noise Suppression Electrical             | $f = 1\text{kHz}$ (See Test Method)                                                     | 32               | 20              | dBV(min)                |
|                   |                                                    | $f = 300\text{Hz}$ (See Test Method)                                                    | 37               | 22              | dBV (min)               |
| SNRI <sub>E</sub> | Signal-to-Noise Ratio Improvement Electrical       | $f = 1\text{kHz}$ (See Test Method)                                                     | 24               | 14              | dBV (min)               |
|                   |                                                    | $f = 300\text{Hz}$ (See Test Method)                                                    | 28               | 15              | dBV (min)               |
| PSRR              | Power Supply Rejection Ratio                       | Input Referred, Input AC grounded                                                       |                  |                 |                         |
|                   |                                                    | $f_{RIPPLE} = 217\text{Hz}$ ( $V_{RIPPLE} = 100\text{mV}_{P-P}$ )                       | 96               | 85              | dB (min)                |
|                   |                                                    | $f_{RIPPLE} = 1\text{kHz}$ ( $V_{RIPPLE} = 100\text{mV}_{P-P}$ )                        | 91               | 80              | dB (min)                |
| CMRR              | Common Mode Rejection Ratio                        | $f = 1\text{kHz}$                                                                       | 60               |                 | dB                      |

|                 |                                                   |                                                                 |     |              |                     |
|-----------------|---------------------------------------------------|-----------------------------------------------------------------|-----|--------------|---------------------|
| $V_{BM}$        | Microphone Bias Supply Voltage                    | $I_{BIAS} = 1\text{mA}$                                         | 2.0 | 1.85<br>2.15 | V (min)<br>V (max)  |
| $e_{VBM}$       | Microphone Bias Noise Level                       | A-Weighted, 10nF cap at $V_{REF}$ pin                           | 10  |              | $\mu\text{V}_{RMS}$ |
| $I_{BM}$        | Total available Microphone Bias Current           |                                                                 |     | 1.2          | mA (min)            |
| $I_{DDQ}$       | Supply Quiescent Current                          | $V_{IN} = 0\text{V}$                                            | 1.1 | 1.5          | mA (max)            |
| $I_{DD}$        | Supply Current                                    | $V_{IN} = 25\text{mV}_{P-P}$ both inputs, Noise cancelling mode | 1.1 |              | mA                  |
| $I_{SD}$        | Shut Down Current                                 | EN pin = GND                                                    | 0.7 | 1            | $\mu\text{A}$ (max) |
| $I_{DDCP}$      | Supply Current during Calibration and Programming | Calibrating or Programming EEPROM                               | 30  | 45           | mA (max)            |
| $I_{DD}^{I^2C}$ | I <sup>2</sup> C supply current                   | I <sup>2</sup> C Idle Mode                                      | 25  | 100          | nA (max)            |
| $T_{ON}$        | Turn On Time                                      |                                                                 |     | 40           | ms (max)            |
| $T_{OFF}$       | Turn Off Time                                     |                                                                 |     | 60           | ms (max)            |

## Electrical Characteristics 5.0V (Note 1)

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $V_{DD} = 5\text{V}$ ,  $V_{IN} = 18\text{mV}_{P-P}$ ,  $EN = V_{DD}$ , pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB,  $R_L = 100\text{k}\Omega$ , and  $C_L = 4.7\text{pF}$ .

| Symbol            | Parameter                                          | Conditions                                                                              | LMV1089  |            | Units<br>(Limits)       |
|-------------------|----------------------------------------------------|-----------------------------------------------------------------------------------------|----------|------------|-------------------------|
|                   |                                                    |                                                                                         | Typical  | Limit      |                         |
|                   |                                                    |                                                                                         | (Note 6) | (Note 7)   |                         |
| SNR               | Signal-to-Noise Ratio                              | $f = 1\text{kHz}$ , $V_{IN} = 18\text{mV}_{P-P}$                                        | 63       |            | dB                      |
|                   |                                                    | $f = 1\text{kHz}$ , $V_{IN} = 18\text{mV}_{P-P}$ , A-Weighted voice band (300 – 3400Hz) | 65       |            | dB                      |
| $e_N$             | Input Referred Noise level                         | A-weighted                                                                              | 5        |            | $\mu\text{V}_{RMS}$     |
| $V_{IN}$          | Maximum Input Signal                               | $f = 1\text{kHz}$ , $\text{THD+N} < 1\%$                                                | 918      | 850        | $\text{mV}_{P-P}$ (min) |
| $V_{OUT}$         | Maximum AC Output Voltage                          | $f = 1\text{kHz}$ , $\text{THD+N} < 1\%$ between differential output                    | 1.2      | 1.1        | $V_{RMS}$ (min)         |
|                   | DC Output Voltage                                  |                                                                                         | 800      |            | mV                      |
| THD+N             | Total Harmonic Distortion + Noise                  | $f = 1\text{kHz}$ , $V_{IN} = 18\text{mV}_{P-P}$                                        | 0.1      | 0.2        | % (max)                 |
| $Z_{IN}$          | Input Impedance                                    |                                                                                         | 142      |            | $\text{k}\Omega$        |
| $Z_{OUT}$         | Output Impedance                                   |                                                                                         | 300      |            | $\Omega$                |
| $A_M$             | Microphone Preamplifier Gain Range                 | $f = 1\text{kHz}$                                                                       | 6 – 36   |            | dB                      |
| $A_{MR}$          | Microphone Preamplifier Gain Adjustment Resolution | $f = 1\text{kHz}$                                                                       | 2        | 1.7<br>2.3 | dB (min)<br>dB (max)    |
| $A_P$             | Post Amplifier Gain Range                          | $f = 1\text{kHz}$ Pass Through Mode and Summing Mode                                    | 6 – 18   |            | dB                      |
| $A_{PR}$          | Post Amplifier Gain Adjustment Resolution          | $f = 1\text{kHz}$                                                                       | 3        | 2.6<br>3.4 | dB (min)<br>dB (max)    |
| $A_{CR}$          | Gain Compensation Range                            | $f = 1\text{kHz}$                                                                       | $\pm 3$  |            | dB                      |
| $A_{MD}$          | Maximum Gain Matching Difference After Calibration | $f = 300\text{Hz}$                                                                      | 0.5      |            | dB                      |
|                   |                                                    | $f = 2\text{kHz}$                                                                       | 0.25     |            | dB                      |
|                   |                                                    | $f = 3\text{kHz}$                                                                       | 0.5      |            | dB                      |
| $T_{CAL}$         | Calibration Duration                               |                                                                                         |          | 790        | ms (max)                |
| FFNS <sub>E</sub> | Far Field Noise Suppression Electrical             | $f = 1\text{kHz}$ (See Test Method)                                                     | 32       | 20         | dBV                     |
|                   |                                                    | $f = 300\text{Hz}$ (See Test Method)                                                    | 37       | 22         | dBV                     |
| SNRI <sub>E</sub> | Signal-to-Noise Ratio Improvement Electrical       | $f = 1\text{kHz}$ (See Test Method)                                                     | 24       | 14         | dBV                     |
|                   |                                                    | $f = 300\text{Hz}$ (See Test Method)                                                    | 28       | 15         | dBV                     |
| PSRR              | Power Supply Rejection Ratio                       | Input Referred, Input AC grounded                                                       |          |            |                         |
|                   |                                                    | $f_{RIPPLE} = 217\text{Hz}$ ( $V_{RIPPLE} = 100\text{mV}_{P-P}$ )                       | 96       | 85         | dB (min)                |
|                   |                                                    | $f_{RIPPLE} = 1\text{kHz}$ ( $V_{RIPPLE} = 100\text{mV}_{P-P}$ )                        | 91       | 80         | dB (min)                |
| CMRR              | Common Mode Rejection Ratio                        | $f = 1\text{kHz}$                                                                       | 62       |            | dB                      |
| $V_{BM}$          | Microphone Bias Supply Voltage                     | $I_{BIAS} = 1\text{mA}$                                                                 | 2.0      |            | V                       |
| $e_{VBM}$         | Microphone Bias Noise Level                        | A-Weighted                                                                              | 10       |            | $\mu\text{V}_{RMS}$     |
| $I_{BM}$          | Total Available Microphone Bias Current            |                                                                                         |          | 1.2        | mA (min)                |
| $I_{DDQ}$         | Supply Quiescent Current                           | $V_{IN} = 0\text{V}$                                                                    | 1.1      | 1.5        | mA (max)                |
| $I_{DDCP}$        | Supply Current during Calibration and Programming  | Calibrating or Programming EEPROM                                                       | 30       |            | mA (max)                |
| $I_{DD}$          | Supply Current                                     | $V_{IN} = 25\text{mV}_{P-P}$ both inputs, Noise cancelling mode                         | 1.1      |            | mA (max)                |
| $I_{SD}$          | Shut Down Current                                  | EN pin = GND                                                                            | 1.6      |            | $\mu\text{A}$           |
| $T_{ON}$          | Turn On Time                                       |                                                                                         |          | 40         | ms (max)                |
| $T_{OFF}$         | Turn Off Time                                      |                                                                                         |          | 60         | ms (max)                |



## Digital Interface Characteristics (Note 1, Note 8)

Unless otherwise specified, all limits guaranteed for  $T_J = 25^\circ\text{C}$ ,  $I^2\text{CV}_{DD}$  within the Operating Rating (Note 8)

| Symbol        | Parameter                                   | Conditions                     | LMV1089             |                                 | Units<br>(Limits) |
|---------------|---------------------------------------------|--------------------------------|---------------------|---------------------------------|-------------------|
|               |                                             |                                | Typical<br>(Note 6) | Limit<br>(Note 7)               |                   |
| $V_{IH}$      | Logic High Input Level                      | EN, TM, SCL, SDA, ADR, CAL, PE |                     | $0.75 \times I^2\text{CV}_{DD}$ | V (min)           |
|               |                                             | GA0, GA1, GB0, GB1             |                     | $0.6 \times V_{DD}$             |                   |
| $V_{IL}$      | Logic Low Input Level                       | EN, TM, SCL, SDA, ADR, CAL, PE |                     | $0.25 \times I^2\text{CV}_{DD}$ | V (max)           |
|               |                                             | GA0, GA1, GB0                  |                     | $0.4 \times V_{DD}$             |                   |
| $t_{s_{CAL}}$ | CAL Setup Time                              |                                | 2                   |                                 | ms                |
| $t_{h_{CAL}}$ | CAL Hold time until calibration is finished |                                |                     | 790                             | ms (min)          |
| $t_{s_{PEC}}$ | PE Setup Time                               |                                | 2                   |                                 | ms                |
| $t_{h_{PEC}}$ | PE Hold until calibration is finished       |                                |                     | 790                             | ms (min)          |

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the Absolute Maximum Ratings or other conditions beyond those indicated in the 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.

**Note 2:** The Electrical Characteristics tables list guaranteed 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 guaranteed.

**Note 3:** The maximum power dissipation must be de-rated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JC}$ , 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. For the LMV1089,  $T_{JMAX} = 150^\circ\text{C}$  and the typical  $\theta_{JA}$  for this microSMD package is  $70^\circ\text{C/W}$  and for the LLP package  $\theta_{JA}$  is  $64^\circ\text{C/W}$ . Refer to the Thermal Considerations section for more information.

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

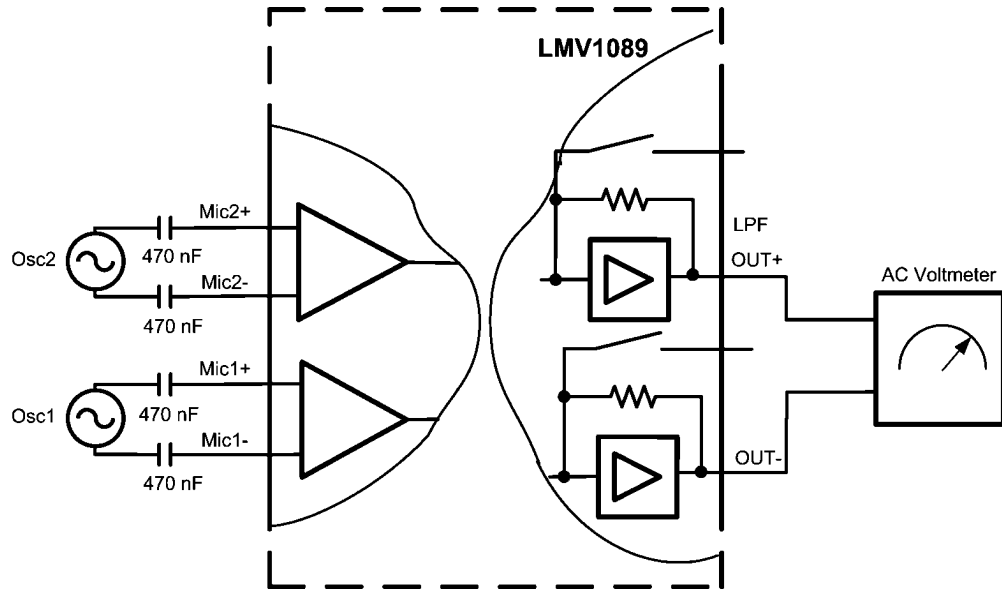
**Note 5:** Machine model, applicable std. JESD22-A115-A.

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

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

**Note 8:** The voltage at  $I^2\text{CV}_{DD}$  must not exceed the voltage on  $V_{DD}$ .

## Test Methods



30047212

FIGURE 3.  $FFNS_E$ ,  $NFSL_E$ ,  $SNRI_E$  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 15). 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 3 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  $1.1^\circ$  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 16). 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 3 is used with the following procedure to measure the  $NFSL_E$ .

1. A  $25mV_{P-P}$  and  $17.25mV_{P-P}$  ( $0.69 \times 25mV_{P-P}$ ) sine wave is applied to Mic1 and Mic2 respectively. Once again, a signal generator is used to delay the phase of Mic2 by  $15.9^\circ$  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 ( $SNRI_E$ )

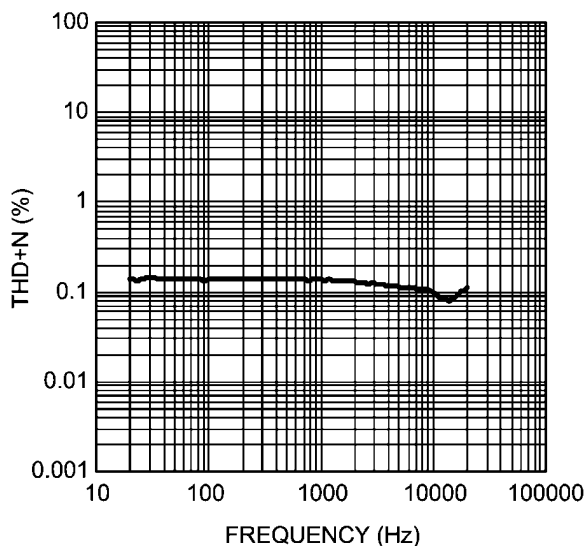
The  $SNRI_E$  is the ratio of  $FFNS_E$  to  $NFSL_E$  and is defined as:

$$SNRI_E = FFNS_E - NFSL_E$$

## Typical Performance Characteristics

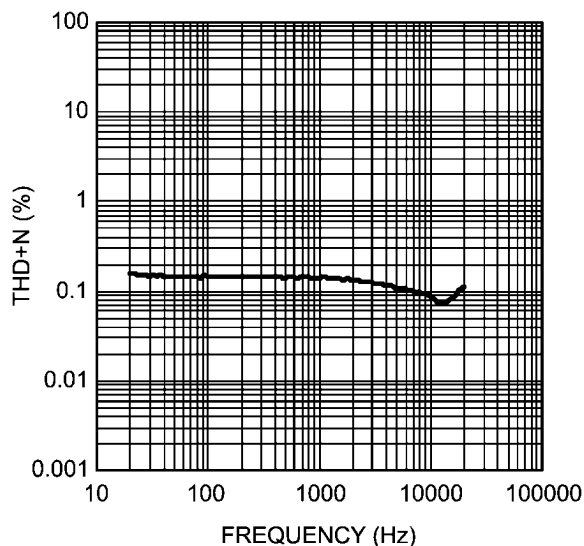
Unless otherwise specified,  $T_J = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{V}$ , Input Voltage =  $18\text{mV}_{\text{p-p}}$ ,  $f = 1\text{ kHz}$ , pass through mode (Note 8), Pre Amp gain = 20dB, Post Amp gain = 6dB,  $R_L = 100\text{k}\Omega$ , and  $C_L = 4.7\text{pF}$ .

**THD+N vs Frequency**  
Mic1 = AC GND, Mic2 =  $36\text{mV}_{\text{p-p}}$   
Noise Canceling Mode



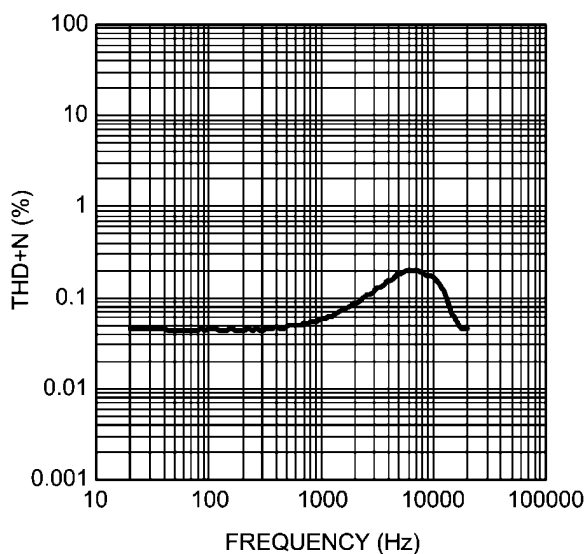
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**THD+N vs Frequency**  
Mic2 = AC GND, Mic1 =  $36\text{mV}_{\text{p-p}}$   
Noise Canceling Mode



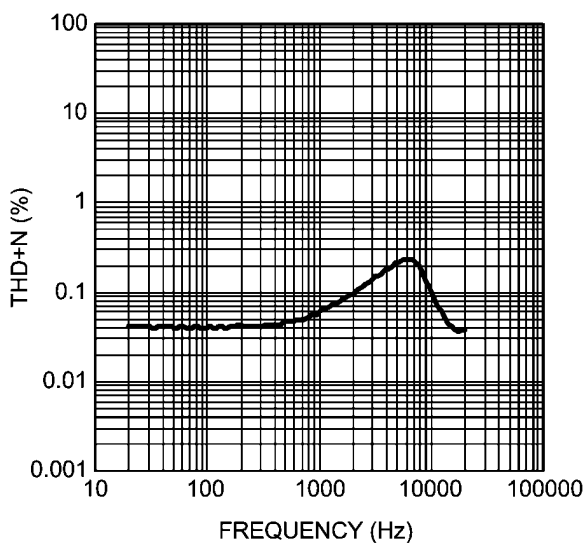
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**THD+N vs Frequency**  
Mic1 =  $36\text{mV}_{\text{p-p}}$   
Mic1 Pass Through Mode



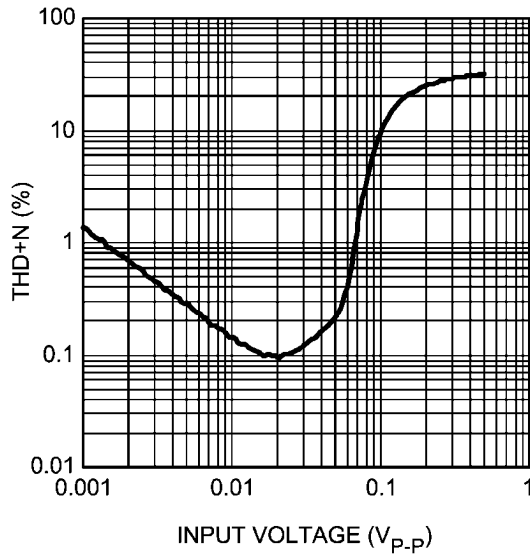
30047249

**THD+N vs Frequency**  
Mic2 =  $36\text{mV}_{\text{p-p}}$   
Mic2 Pass Through Mode



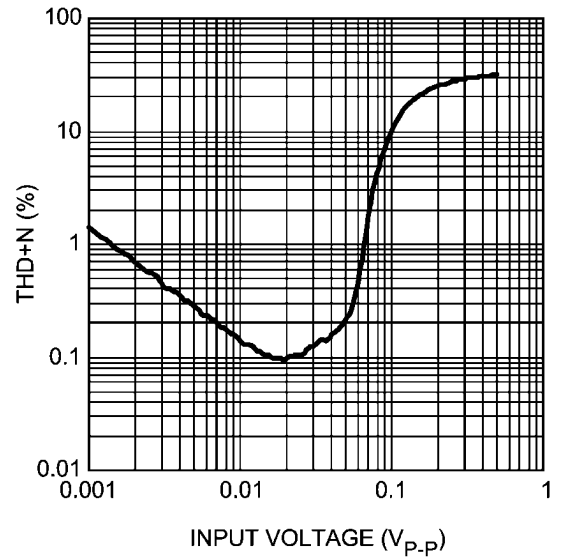
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**THD+N vs Input Voltage**  
**Mic1 = AC GND, f = 1kHz**  
**Mic2 Noise Canceling Mode**



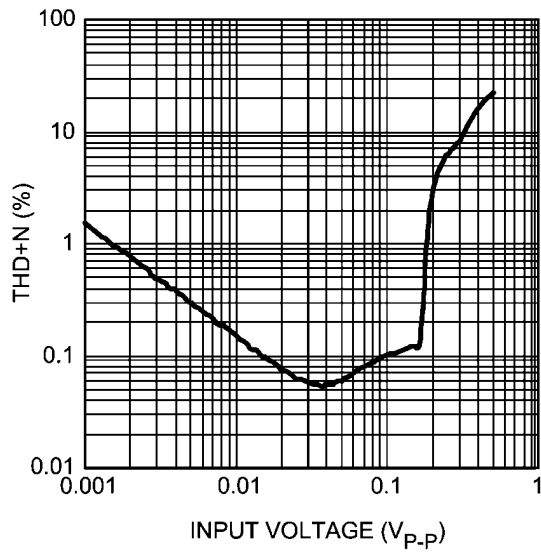
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**THD+N vs Input Voltage**  
**Mic2 = AC GND, f = 1kHz**  
**Mic1 Noise Canceling Mode**



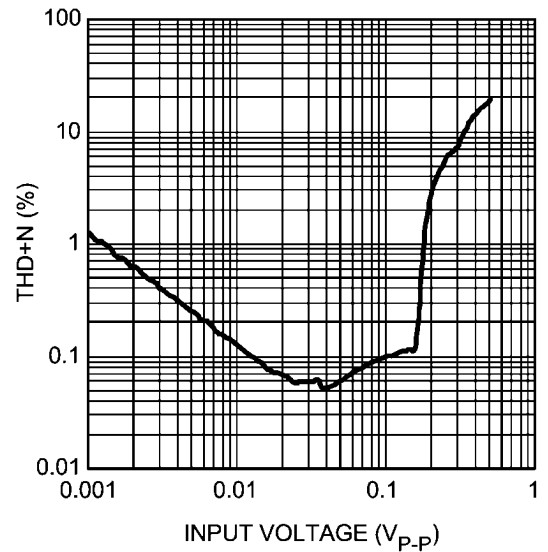
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**THD+N vs Input Voltage**  
**f = 1kHz**  
**Mic1 Pass Through Mode**



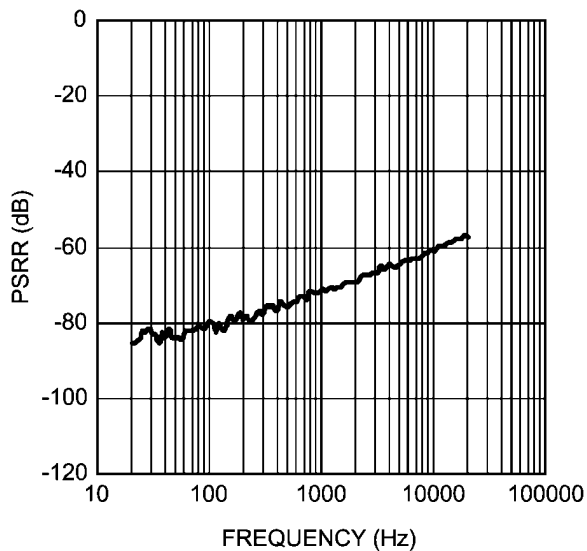
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**THD+N vs Input Voltage**  
**f = 1kHz**  
**Mic2 Pass Through Mode**



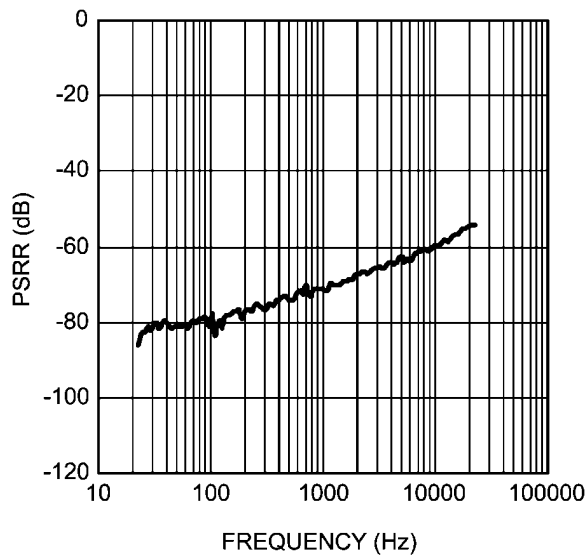
30047254

**PSRR vs Frequency**  
 Pre Amp Gain = 20dB, Post Amp Gain = 6dB  
 $V_{\text{RIPPLE}} = 100\text{mV}_{\text{p-p}}$ , Mic1 = Mic2 = AC GND  
 Mic1 Pass Through Mode



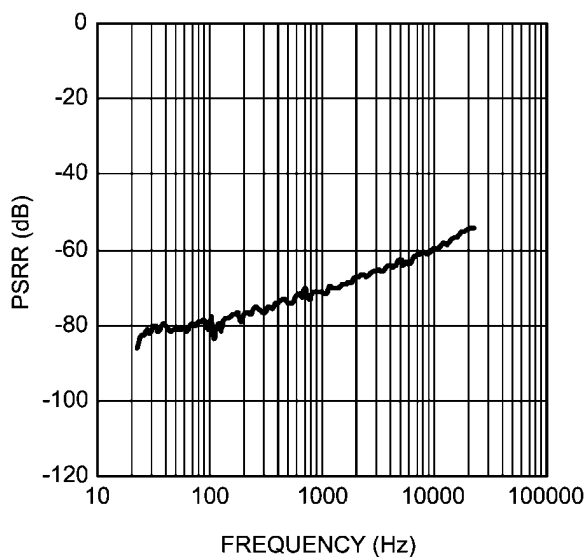
30047244

**PSRR vs Frequency**  
 Pre Amp Gain = 20dB, Post Amp Gain = 6dB  
 $V_{\text{RIPPLE}} = 100\text{mV}_{\text{p-p}}$ , Mic1 = Mic2 = AC GND  
 Mic2 Pass Through Mode



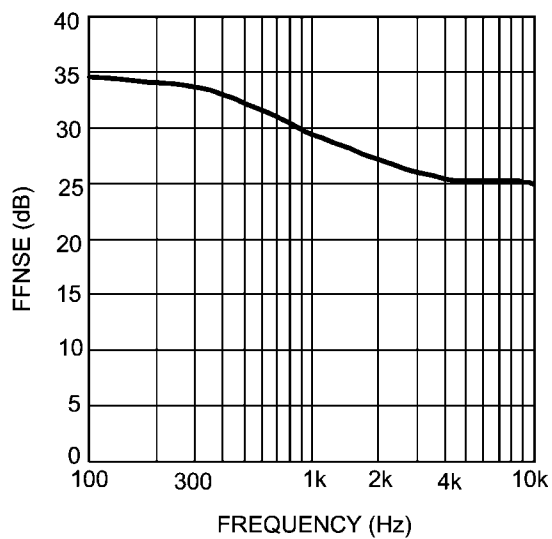
30047245

**PSRR vs Frequency**  
 Pre Amp Gain = 20dB, Post Amp Gain = 6dB  
 $V_{\text{RIPPLE}} = 100\text{mV}_{\text{p-p}}$ , Mic1 = Mic2 = AC GND  
 Noise Canceling Mode

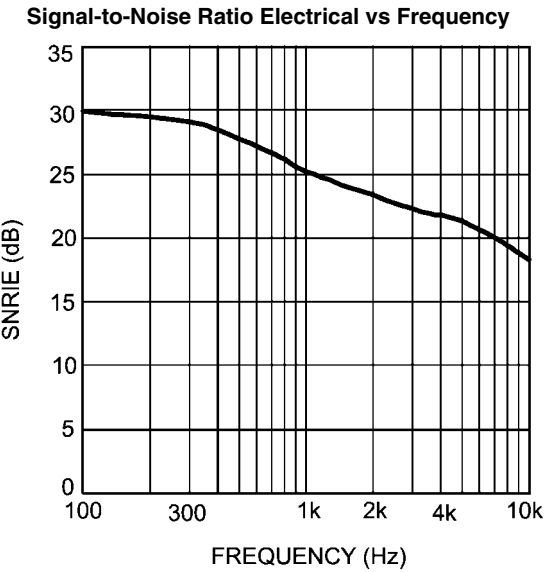


30047245

**Far Field Noise Suppression Electrical vs Frequency**



30047255



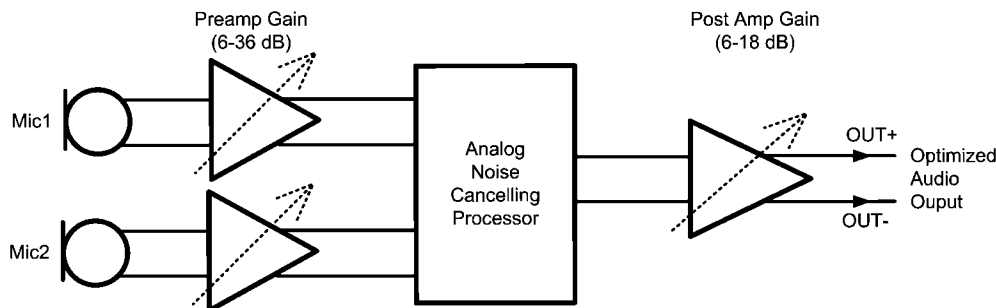
30047256

## Application Data

### INTRODUCTION

The LMV1089 is a fully analog single chip solution to reduce the far field noise picked up by microphones in a communi-

cation system. A simplified block diagram is provided in [Figure 4](#).



30047224

FIGURE 4. Simplified Block Diagram of the LMV1089

The output signal of the microphones is first amplified by a pre-amplifier stage with an adjustable gain of 6dB to 36dB. The signal is then processed by the noise cancelling processor. The noise cancelling processor matches the gain and frequency responses of the microphones and the acoustic characteristics of the enclosure using coefficients derived during the auto-calibration step and the stored in EEPROM. The resulting noise-suppressed signal is then amplified by the 6dB to 18dB gain-adjustable post-amplifier. For optimum noise and EMI immunity, the microphones have a differential connection to the LMV1089 and the output of the LMV1089 is also differential. The adjustable gain functions can be controlled via I<sup>2</sup>C and four control pins. Both methods are described later in the application section.

## Power Supply Circuits

A low drop-out (LDO) voltage regulator in the LMV1089 allows the device to be independent of supply voltage variations.

The Power On Reset (POR) circuitry in the LMV1089 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 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.

Most of the logic levels for the digital control interface are relative to I<sup>2</sup>CV<sub>DD</sub> voltage. This eases interfacing to the micro controller of the application containing the LMV1089. The supply voltage on the I<sup>2</sup>CV<sub>DD</sub> pin must never exceed the voltage on the  $V_{DD}$  pin.

Only the four pins that determine the default power up gain (as described in [SETTING ADJUSTABLE GAIN](#)) have logic levels relative to  $V_{DD}$ .

## Shutdown Function

As part of the Powerwise™ family, the LMV1089 consumes only 1.1mA 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 LMV1089 pro-

vides two individual microphone power down functions. When either one of the shutdown functions is activated the part will go into shutdown mode consuming only a few  $\mu$ A of supply current.

### 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.

### SHUTDOWN VIA I<sup>2</sup>C

The LMV1089 offers an additional shutdown function by reprogramming an I<sup>2</sup>C register (see [Table 6](#)). The LMV1089 will only consume power in a mode where it can perform its normal functions. So at least one of the microphone amplifier circuits must be enabled ('1'). Writing '0' to the both bit 4 and bit 5 of the I<sup>2</sup>C 'A' register (address 0x01h) of the LMV1089 will force the part into shutdown mode, even if the EN pin is 'High', the only part that remains active in this state is the I<sup>2</sup>C, which consumes neglectable power when compared to the standby current.

## Adjustable Gain

The LMV1089 has two gain stages where the gain can be adjusted to meet the requirements for the application. There is a preamplifier and a post amplifier that can be varied independent of each other. In most applications the gain will be set via the I<sup>2</sup>C interface, see [Table 6](#).

### SETTING ADJUSTABLE GAIN

The LMV1089 provides four pins to set the default gain settings during power up of the device, which is convenient for applications without a micro controller. The default gain of the preamplifier is controlled by the GA0 and GA1 pins and can be set by wiring those pins to either  $V_{DD}$  or GND. In this way, one of the four possible values in the 12dB to 36dB range (see [Table 2](#)) can be chosen. The default post amplifier gain is set in the same way by connecting the GB0 and GB1 pins to either  $V_{DD}$  or GND to select a gain between 6dB and 15dB (see [Table 3](#)). Setting the gain of the preamplifier and post amplifier

via the I<sup>2</sup>C interface (see [Table 6](#)) will override this default gain.

The default gain is only set during power up of the device. Toggling the logic level of the enable pin (EN) will not change the current gain setting of the part. Any gain setting done via the I<sup>2</sup>C interface will remain valid during activation of the function.

**TABLE 2. Default preamplifier gain**

| GA1 | GA0 | Gain                            |
|-----|-----|---------------------------------|
| 0   | 0   | 12dB                            |
| 0   | 1   | 20dB ( <a href="#">Note 9</a> ) |
| 1   | 0   | 28dB                            |
| 1   | 1   | 36dB                            |

**TABLE 3. Default post amplifier gain**

| GB1 | GB0 | Gain                           |
|-----|-----|--------------------------------|
| 0   | 0   | 6dB ( <a href="#">Note 9</a> ) |
| 0   | 1   | 9dB                            |
| 1   | 0   | 12dB                           |
| 1   | 1   | 15dB                           |

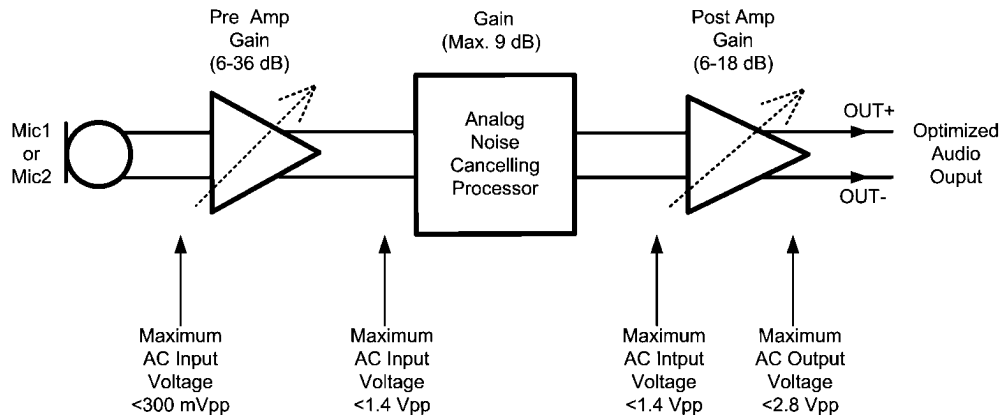
**Note 9:** Default value used for performance measurements

## 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 clipping and saturation in the noise cancelling processor and output stages.

The gain ranges and maximum signal levels for the different functional blocks are shown in [Figure 5](#). Two examples are given as a guideline on how to select proper gain settings.



30047241

**FIGURE 5. Maximum Signal Levels**

### Example 1

An application using microphones with 50mV<sub>P-P</sub> maximum output voltage, and a baseband chip after the LMV1089 with 1.5V<sub>P-P</sub> maximum input voltage.

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

1. 50mV<sub>P-P</sub> +36 dB = 3.1V<sub>P-P</sub>.
2. 3.1V<sub>P-P</sub> is higher than the maximum 1.4V<sub>P-P</sub> allowed for the Noise Cancelling Processor (NCP). This means a gain lower than 28.9dB should be selected.
3. Select the nearest lower gain from the gain settings shown in Table 2, 28dB is selected. This will prevent the NCP from being overloaded by the microphone. With this setting, the resulting output level of the Pre Amplifier will be 1.26V<sub>P-P</sub>.
4. The NCP can have a maximum processing gain of 9dB (depending on the calibration result) which will result in

3.5V<sub>P-P</sub> at the output of the LMV1089. This level is higher than maximum level that is allowed at the input of the post amp of the LMV1089. Therefore the preamp gain has to be reduced, to 1.4V<sub>P-P</sub> minus 9dB = 0.5V<sub>P-P</sub>. This limits the preamp gain to a maximum of 20dB.

5. The baseband chip limits the maximum output voltage to 1.5V<sub>P-P</sub> 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<sub>P-P</sub>. Now calculating this for a maximum NCP gain of 9dB the output of the preamp must be <266mV<sub>P-P</sub>.
6. Calculating the new gain for the preamp will result in <1.4dB gain.
7. The nearest lower gain will be 14dB.

So using preamp gain = 14dB and postamp gain = 6dB is the optimum for this application.



## Example 2

An application using microphones with  $10\text{mV}_{\text{P-P}}$  maximum output voltage, and a baseband chip after the LMV1089 with  $3.3\text{V}_{\text{P-P}}$  maximum input voltage.

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

1.  $10\text{mV}_{\text{P-P}} + 36\text{dB} = 631\text{mV}_{\text{P-P}}$ .
2. This is lower than the maximum  $1.4\text{V}_{\text{P-P}}$  so this is OK.
3. The NCP can have a maximum processing gain of 9dB (depending on the calibration result) which will result in  $3.5\text{V}_{\text{P-P}}$  at the output of the LMV1089. This level is higher than maximum level that is allowed at the input of the Post Amp of the LMV1089. Therefore the Pre Amp gain has to be reduced, to  $1.4\text{V}_{\text{P-P}}$  minus 9dB =  $0.5\text{V}_{\text{P-P}}$ . This limits the Pre Amp gain to a maximum of 34dB.
4. With a Post Amp gain setting of 6dB the output of the Post Amp will be  $2.8\text{V}_{\text{P-P}}$  which is OK for the baseband.
5. The nearest lower Post Amp gain will be 6dB.

So using preamp gain = 34dB and postamp gain = 6dB is optimum for this application.

## Unprocessed Output Pins

The LMV1089 provides two single ended output pins M1\_UNP and M2\_UNP. These pins provide the amplified output signal from the two differential microphone input amplifiers Mic1 and Mic2. When the application containing the LMV1089 is in a calibrated state the output level of the two microphone paths are matched. This makes these outputs suitable for stereo applications like video camera webcams and photo cameras. Low cost microphones with wider gain tolerance can be used because gain differences of the microphones will be compensated by the calibration system of the LMV1089. In this situation the default gain of the Pre Amplifiers is set by GA0 and GA1 as described in [Table 2](#). This gain can be changed via I<sup>2</sup>C by writing register A as described in the [I<sup>2</sup>C Compatible Interface](#) section.

## I<sup>2</sup>C Compatible Interface

### I<sup>2</sup>C SIGNALS

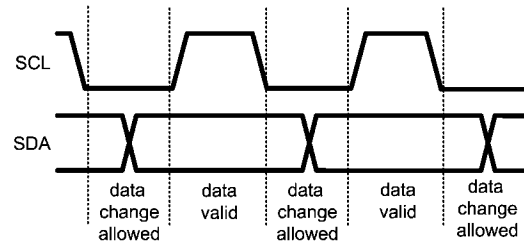
The LMV1089 pin Serial Clock (SCL) pin is used for the I<sup>2</sup>C clock and the Serial Data (SDA) pin is used for the I<sup>2</sup>C data. Both these signals need a pull-up resistor according to I<sup>2</sup>C specification. The LMV1089 can be controlled through two slave addresses. The digital I<sup>2</sup>C address pin selects the I<sup>2</sup>C address for LMV1089 as shown in [Table 4](#).

TABLE 4. Chip Address

|                                                              | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0                      |
|--------------------------------------------------------------|----|----|----|----|----|----|----|-------------------------|
| 1 <sup>st</sup> Chip Address<br>I <sup>2</sup> C Address='0' | 1  | 1  | 0  | 0  | 1  | 1  | 0  | $\overline{\text{W/R}}$ |
| 2 <sup>nd</sup> Chip Address<br>I <sup>2</sup> C Address='1' | 1  | 1  | 0  | 0  | 1  | 1  | 1  | $\overline{\text{W/R}}$ |

### I<sup>2</sup>C DATA VALIDITY

The data on SDA line must be stable during the HIGH period of the clock signal (SCL). In other words, the state of the data line can only be changed when SCL is LOW.

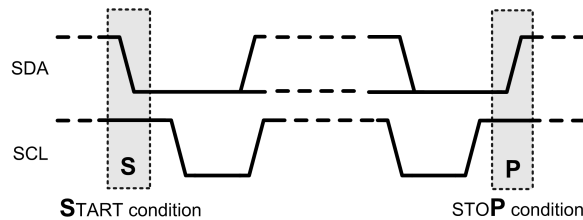


I<sup>2</sup>C Signals: Data Validity

300472q1

### I<sup>2</sup>C START AND STOP CONDITIONS

START and STOP bits classify the beginning and the end of the I<sup>2</sup>C data transmission session. START condition is defined as the SDA signal transitioning from HIGH to LOW while SCL line is HIGH. STOP condition is defined as the SDA transitioning from LOW to HIGH while SCL is HIGH. The I<sup>2</sup>C master always generates START and STOP bits. The I<sup>2</sup>C bus is considered to be busy after START condition and free after STOP condition. During data transmission, I<sup>2</sup>C master can generate repeated START conditions. First START and repeated START conditions are equivalent, function-wise. ([Note 10](#))



I<sup>2</sup>C Start Stop Conditions

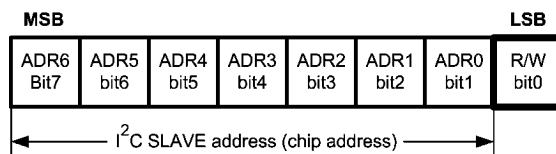
300472q2

**Note 10:** The master should issue STOP after no acknowledgment.

### TRANSFERRING DATA

Every byte put on the SDA line must be eight bits long, with the most significant bit (MSB) being transferred first. Each byte of data has to be followed by an acknowledge bit. The acknowledge related clock pulse is generated by the master. The transmitter releases the SDA line (HIGH) during the acknowledge clock pulse. The receiver must pull down the SDA line during the 9<sup>th</sup> clock pulse, signifying an acknowledge (ACK). A receiver which has been addressed must generate an acknowledge after each byte has been received.

After the START condition, the I<sup>2</sup>C master sends a chip address. This address is seven bits long followed by an eighth bit which is a data direction bit (R/W). The LMV1089 address is **11001100<sub>2</sub>** or **11001110<sub>2</sub>**. For the eighth bit, a "0" indicates a WRITE and a "1" indicates a READ. The second byte selects the register to which the data will be written. The third byte contains data to write to the selected register.

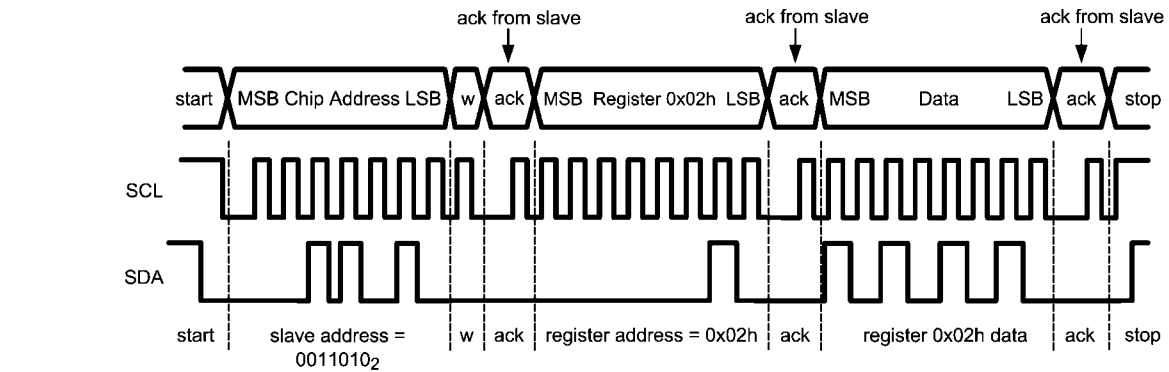


I<sup>2</sup>C Chip Address

300472q3

Register changes take effect at the SCL rising edge during the last ACK from slave.

In [Figure 6](#), a write example is shown, for a device with a randomly chosen address '00110100<sub>2</sub>'.



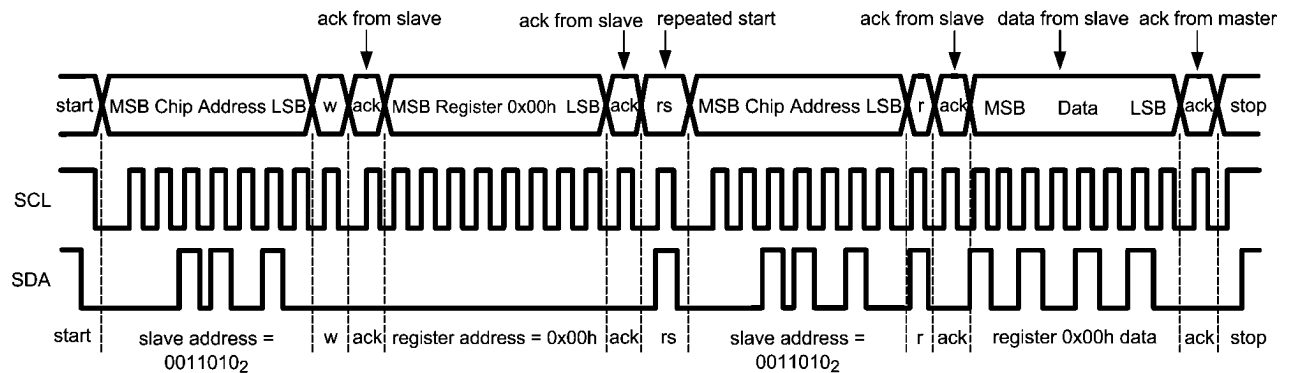
300472q5

w = write (SDA = "0")  
 r = read (SDA = "1")  
 ack = acknowledge (SDA pulled down by slave)  
 rs = repeated start

FIGURE 6. Example I²C Write Cycle

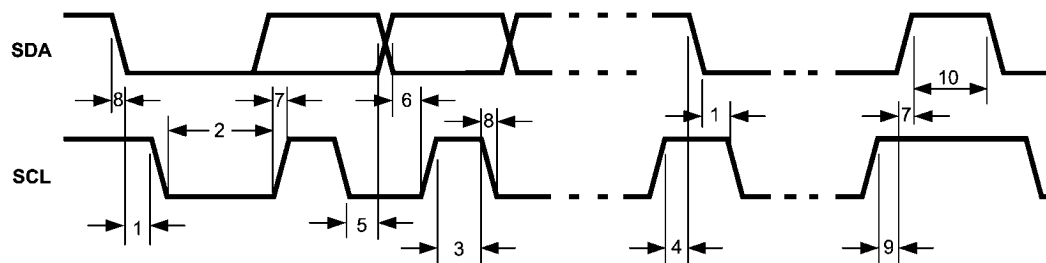
When a READ function is to be accomplished, a WRITE function must precede the READ function, as shown in the Read

Cycle waveform. [Figure 7](#) shows this read example for a randomly chosen address '00110101<sub>2</sub>'.



300472q6

FIGURE 7. Example I²C Read Cycle



300472q9

FIGURE 8. I²C Timing Diagram

TABLE 5. I<sup>2</sup>C Timing Parameters

| Symbol         | Parameter                                                       | Limit |      | Units |
|----------------|-----------------------------------------------------------------|-------|------|-------|
|                |                                                                 | Min   | Max  |       |
| 1              | Hold Time (repeated) START Condition                            | 0.6   |      | μs    |
| 2              | Clock Low Time                                                  | 1.3   |      | μs    |
| 3              | Clock High Time                                                 | 600   |      | ns    |
| 4              | Setup Time for a Repeated START Condition                       | 600   |      | ns    |
| 5              | Data Hold Time (Output direction, delay generated by LMV1089)   | 300   | 1100 | ns    |
| 5              | Data Hold Time (Input direction, delay generated by the Master) | 0     | 1100 | ns    |
| 6              | Data Setup Time                                                 | 300   |      | ns    |
| 7              | Rise Time of SDA and SCL                                        | 20    | 300  | ns    |
| 8              | Fall Time of SDA and SCL                                        | 15    | 300  | ns    |
| 9              | Set-up Time for STOP condition                                  | 600   |      | ns    |
| 10             | Bus Free Time between a STOP and a START Condition              | 1.3   |      | μs    |
| C <sub>b</sub> | Capacitive Load for Each Bus Line                               | 10    | 200  | pF    |

**NOTE:** Data guaranteed by design

TABLE 6. I<sup>2</sup>C Register Description

| Address | Reg. | Bits  | Description                                                                                                       | Default     |
|---------|------|-------|-------------------------------------------------------------------------------------------------------------------|-------------|
| 0x01h   | A    | [3:0] | Microphone preamplifier gain from 6dB up to 36dB in 2dB steps.                                                    | See Table 2 |
|         |      |       | 0000 6dB                                                                                                          |             |
|         |      |       | 0001 8dB                                                                                                          |             |
|         |      |       | 0010 10dB                                                                                                         |             |
|         |      |       | 0011 12dB                                                                                                         |             |
|         |      |       | 0100 14dB                                                                                                         |             |
|         |      |       | 0101 16dB                                                                                                         |             |
|         |      |       | 0110 18dB                                                                                                         |             |
|         |      |       | 0111 20dB                                                                                                         |             |
|         |      |       | 1000 22dB                                                                                                         |             |
|         |      |       | 1001 24dB                                                                                                         |             |
|         |      |       | 1010 26dB                                                                                                         |             |
|         |      |       | 1011 28dB                                                                                                         |             |
|         |      |       | 1100 30dB                                                                                                         |             |
|         |      |       | 1101 32dB                                                                                                         |             |
|         |      |       | 1110 34dB                                                                                                         |             |
|         |      |       | 1111 36dB                                                                                                         |             |
|         | A    | [5:4] | A4 = mute mic1 and A5 = mute mic2.<br>(0 = microphone on)                                                         | 00(on)      |
|         | A    | [7:6] | Mic enable bits, A6 = enable Mic1, A7 = enable Mic2<br>(1 = enable), A6 and A7 both 0 = Shutdown Mode             | 11(on)      |
| 0x02h   | B    | [2:0] | Gain setting for the post amplifier from (3dB steps)                                                              | See Table 3 |
|         |      |       | 000 6db                                                                                                           |             |
|         |      |       | 001 9dB                                                                                                           |             |
|         |      |       | 010 12dB                                                                                                          |             |
|         |      |       | 011 15dB                                                                                                          |             |
|         |      |       | 100 18dB                                                                                                          |             |
|         |      |       | 101 18dB                                                                                                          |             |
|         |      |       | 110 18dB                                                                                                          |             |
|         |      |       | 111 18dB                                                                                                          |             |
|         | B    | [4:3] | Mic select bits                                                                                                   | 00          |
|         |      |       | 0 0 Noise cancelling mode                                                                                         |             |
|         |      |       | 0 1 Only Mic1 enabled                                                                                             |             |
|         |      |       | 1 0 Only Mic2 enabled                                                                                             |             |
|         |      |       | 1 1 Mic1 + Mic2                                                                                                   |             |
|         | B    | [7:5] | Not Used                                                                                                          | 000         |
| 0x0Ch   | L    | [7:0] | reads the output of the EEPROM                                                                                    | read only   |
| 0x0Dh   | M    | [7:0] | reads the output of the EEPROM                                                                                    | read only   |
| 0x0Eh   | N    | [6:0] | reads the output of the EEPROM                                                                                    | read only   |
|         | N    | [7]   | Reads the "ready" signal. This give the status of the program cycle.<br>1 = ready ; 0 = program cycle in progress | read only   |

| Address | Reg. | Bits  | Description                                                 | Default |
|---------|------|-------|-------------------------------------------------------------|---------|
| 0x0Fh   | O    | [3:0] | Control the gain compensation between the two mics at 3kHz  |         |
|         |      |       | 0000 (0)                                                    | 0.0dB   |
|         |      |       | 0001 (1)                                                    | 0.5dB   |
|         |      |       | 0010 (2)                                                    | 1.0dB   |
|         |      |       | 0011 (3)                                                    | 1.5dB   |
|         |      |       | 0100 (4)                                                    | 2.0dB   |
|         |      |       | 0101 (5)                                                    | 2.5dB   |
|         |      |       | 0110 (6)                                                    | 3.0dB   |
|         |      |       | 0111 (7)                                                    | 3.0dB   |
|         |      |       | 1000 (8)                                                    | 0dB     |
|         |      |       | 1001 (9)                                                    | -0.5dB  |
|         |      |       | 1010 (A)                                                    | -1.0dB  |
|         |      |       | 1011 (B)                                                    | -1.5dB  |
|         |      |       | 1100 (C)                                                    | -2.0dB  |
|         |      |       | 1110 (D)                                                    | -2.5dB  |
|         |      |       | 1110 (E)                                                    | -3.0dB  |
|         |      |       | 1111 (F)                                                    | -3.0dB  |
|         |      | [7:4] | Control the gain compensation between the two mics at 300Hz |         |
|         |      |       | 0000 (0)                                                    | 0.0dB   |
|         |      |       | 0001 (1)                                                    | 0.5dB   |
|         |      |       | 0010 (2)                                                    | 0.0dB   |
|         |      |       | 0011 (3)                                                    | 1.5dB   |
|         |      |       | 0100 (4)                                                    | 2.0dB   |
|         |      |       | 0101 (5)                                                    | 2.5dB   |
|         |      |       | 0110 (6)                                                    | 3.0dB   |
|         |      |       | 0111 (7)                                                    | 3.0dB   |
|         |      |       | 1000 (8)                                                    | 0dB     |
|         |      |       | 1001 (9)                                                    | -0.5dB  |
|         |      |       | 1010 (A)                                                    | -1.0dB  |
|         |      |       | 1011 (B)                                                    | -1.5dB  |
|         |      |       | 1100 (C)                                                    | -2.0dB  |
|         |      |       | 1101 (D)                                                    | -2.5dB  |
|         |      |       | 1110 (E)                                                    | -3.0dB  |
|         |      |       | 1111 (F)                                                    | -3.0dBd |

| Address | Reg. | Bits     | Description                                                                                                 | Default |
|---------|------|----------|-------------------------------------------------------------------------------------------------------------|---------|
| 0x10h   | P    | [3:0]    | Control compensation gain for left channel at ALL frequencies                                               | 1111    |
|         |      | 0000 (0) | −3.0dB                                                                                                      |         |
|         |      | 0001 (1) | −3.0dB                                                                                                      |         |
|         |      | 0010 (2) | −2.5dB                                                                                                      |         |
|         |      | 0011 (3) | −2.0dB                                                                                                      |         |
|         |      | 0100 (4) | −1.5dB                                                                                                      |         |
|         |      | 0101 (5) | −1.0dB                                                                                                      |         |
|         |      | 0110 (6) | −0.5dB                                                                                                      |         |
|         |      | 0111 (7) | 0.0dB                                                                                                       |         |
|         |      | 1000 (8) | 0.0dB                                                                                                       |         |
|         |      | 1001 (9) | 0.5dB                                                                                                       |         |
|         |      | 1010 (A) | 1.0dB                                                                                                       |         |
|         |      | 1011 (B) | 1.5dB                                                                                                       |         |
|         |      | 1100 (C) | 2.0dB                                                                                                       |         |
|         |      | 1101 (D) | 2.5dB                                                                                                       |         |
|         |      | 1110 (E) | 3.0dB                                                                                                       |         |
|         |      | 1111 (F) | 3.0dB                                                                                                       |         |
|         |      | [7:4]    | Control compensation gain for right channel at ALL frequencies                                              | 1111    |
|         |      | 0000 (0) | −3.0dB                                                                                                      |         |
|         |      | 0001 (1) | −3.0dB                                                                                                      |         |
|         |      | 0010 (2) | −2.5dB                                                                                                      |         |
|         |      | 0011 (3) | −2.0dB                                                                                                      |         |
|         |      | 0100 (4) | −1.5dB                                                                                                      |         |
|         |      | 0101 (5) | −1.0dB                                                                                                      |         |
|         |      | 0110 (6) | −0.5dB                                                                                                      |         |
|         |      | 0111 (7) | 0.0dB                                                                                                       |         |
|         |      | 1000 (8) | 0.0dB                                                                                                       |         |
|         |      | 1001 (9) | 0.5dB                                                                                                       |         |
|         |      | 1010 (A) | 1.0dB                                                                                                       |         |
|         |      | 1011 (B) | 1.5dB                                                                                                       |         |
|         |      | 1100 (C) | 2.0dB                                                                                                       |         |
|         |      | 1101 (D) | 2.5dB                                                                                                       |         |
|         |      | 1110 (E) | 3.0dB                                                                                                       |         |
|         |      | 1111 (F) | 3.0dB                                                                                                       |         |
| 0x11h   | Q    | [6:0]    | Values are clocked into EEPROM registers once “newdata” pulse is generated                                  | 1       |
|         |      | [7]      | StoreBar signal<br>StoreBar = 0 enables EEPROM programming<br>StoreBar = 1 data clock into EEPROM registers |         |
| 0x12h   | R    | [0]      | Start Calibration via I2C ‘0’ to ‘1’ = start calibration (keep ‘1’ during calibration)                      | 0       |
|         |      | [7]      | Internal test                                                                                               | 0000000 |

## Calibration

Automatic calibration should only be required once, when the product containing the LMV1089 has completed manufacture, and prior to application packaging. The product containing the LMV1089 will be calibrated to the microphones, the microphone spacings, and the acoustical properties of the final design.

The compensation or calibration technology is achieved via memory stored coefficients when the FFNS circuitry activates the calibration sequence. The purpose of the calibration sequence is to choose the optimized coefficients for the FFNS circuitry for the given microphones, spacing, and acoustical design of the product containing the LMV1089.

A basic calibration can be performed with a single 1kHz tone, however to take full advantage of this calibration feature a three tone calibration (See [PERFORMING A THREE TONE CALIBRATION](#)) is preferred.

The automatic calibration process can be initiated from either a digital interface CALIBRATE pin (CAL) or via the I<sup>2</sup>C interface.

The logic level at the PROGRAM ENABLE (PE) pin determines if the result of the calibration is volatile or permanent.

To make the result of the calibration permanent (stored in the EEPROM) the PROGRAM ENABLE (PE) pin must be high during the automatic calibration process.

### AUTOMATIC CALIBRATION VIA CAL PIN

To initiate the automatic calibration via the CAL pin, the following procedure is required. See timing diagram Figure 11:

- From the initial condition where both PE and CAL are at 'low' level
- bring PE to a 'high' level (enable EEprom write)
- bring CAL to a 'high' level to start Calibration
- Apply Audio stimulus (single tone 1kHz or three tone sequence as described in [PERFORMING A THREE TONE CALIBRATION](#)) (see Figure 12).
- Hold CAL 'high' for at least 790ms
- Remove Audio stimulus
- bring CAL to a 'low' level to stop Calibration
- bring PE to a 'low' level (disable EEprom write)

A tone may be applied prior to the rising of CAL and PE. Signals applied to the microphone inputs before rising of CAL and PE are ignored by the calibration system.

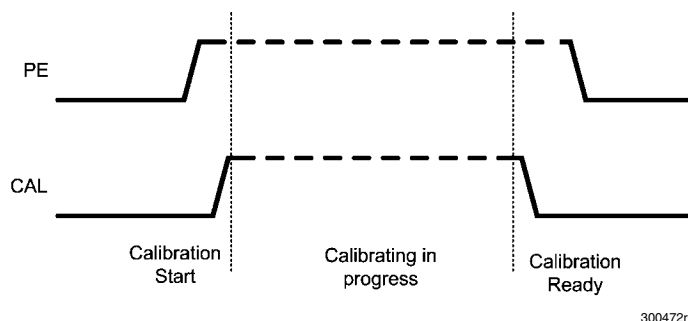


FIGURE 9. Automatic Calibration via CAL pin

Note: When the I<sup>2</sup>C is operated, make sure that register 'R' (address 0x12) bit 0 is '0' before operating the CAL pin (default value for this bit). When this bit is set '1' the calibration engine of the LMV1089 is started and will remain active with a higher supply

current than normal operation. The state of the calibration remains active until this bit is reset, '0'. With the bit set the 'low' to 'high' transfer of the CAL pin will be ignored.

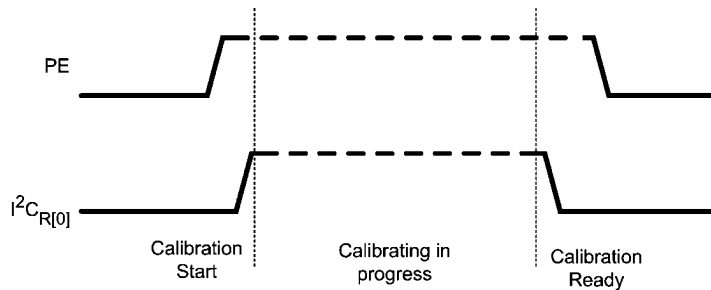
### AUTOMATIC CALIBRATION VIA I<sup>2</sup>C COMMAND

To initiate the automatic calibration via the I<sup>2</sup>C interface, the following procedure is required:

- From the initial condition where PE is 'low' level
- Bring PE to a 'high' level (enable EEPROM write)
- Write '1' into I<sup>2</sup>C register 'R' (address 0x12) bit 0 to start calibration
- Apply Audio stimulus (single tone 1kHz or three tone sequence as described in [PERFORMING A THREE TONE CALIBRATION](#))

- Wait at least 790ms
- Remove Audio stimulus
- Write '0' into I<sup>2</sup>C to finish calibration
- Bring PE to a 'low' level (disable EEPROM write)

A tone may be applied prior to the rising of PE or setting the I<sup>2</sup>C calibration bit. Signals applied to the microphone inputs before rising of PE or setting the I<sup>2</sup>C calibration bit are ignored by the calibration system.



300472r2

FIGURE 10.

### PERFORMING THE AUTOMATIC CALIBRATION

Automatic calibration can be performed as 'one tone' or as 'three tone' calibration. Three tone calibration is preferred because the three tone calibration not only compensates for differences in the gain between the two microphones, but this function also corrects for differences in the frequency response between in the two microphones and compensates for the acoustical effects of the enclosure.

The one tone calibration only compensates for the gain difference between the two microphones at 1kHz and can lead to less far field noise reduction when compared to three tone calibration.

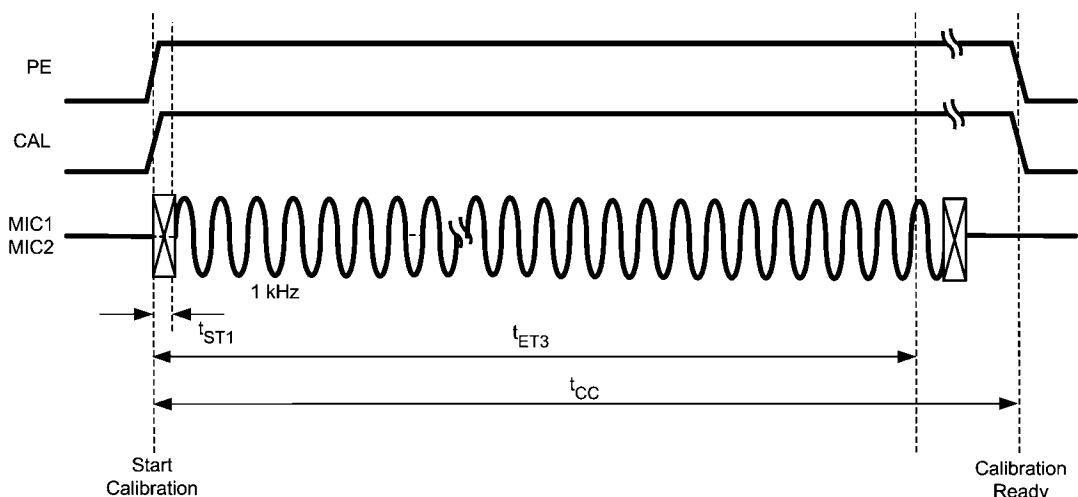
### PERFORMING A ONE TONE CALIBRATION

The easiest way to perform an automatic calibration with the LMV1089 uses a 1kHz tone. This tone can be a steady state

tone or a 1kHz tone that is switched on and off using the timing from [Figure 11](#).

To perform a one tone calibration, a 1kHz test tone is required right after the PE and CAL inputs are brought to a logic high level and that tone should be stable during the time as indicated in [Table 7](#). At the end of this sequence the calibration data is automatically stored in the internal EEPROM (see [Figure 12](#)).

A tone may be applied prior to the rising of CAL start signal and PE. Signals applied to the microphone outside the limits shown in [Figure 11](#) and [Table 7](#) are ignored by the calibration system.



300472r4

FIGURE 11. One Tone Calibration Timing



### PERFORMING A THREE TONE CALIBRATION

In a system with two microphones in an enclosure there will always be a difference in the transfer function in both gain and frequency response between the two channels. The LMV1089 has the capability to perform an automatic calibration function to minimize these differences. To perform this calibration, a test sequence of three tones is required right after the PE and CAL inputs are brought to a logic high level. At the end of this sequence the calibration data is automatically stored in the internal EEPROM.

The three tones have to be applied as follows (see Figure 12):

- A first tone with a frequency of 1kHz

- A second tone with a frequency of 300Hz
- A third tone with a frequency of 3kHz

A tone may be applied prior to the rising of CAL start signal and PE. Signals applied to the microphone outside the limits shown in [Figure 12](#) and [Table 7](#) are ignored by the calibration system.

Between each tone pair there is a small time, indicated by a cross, to change the frequency. During that time the input tone is ignored by the calibration system.

The total calibration sequence requires less than 790ms.

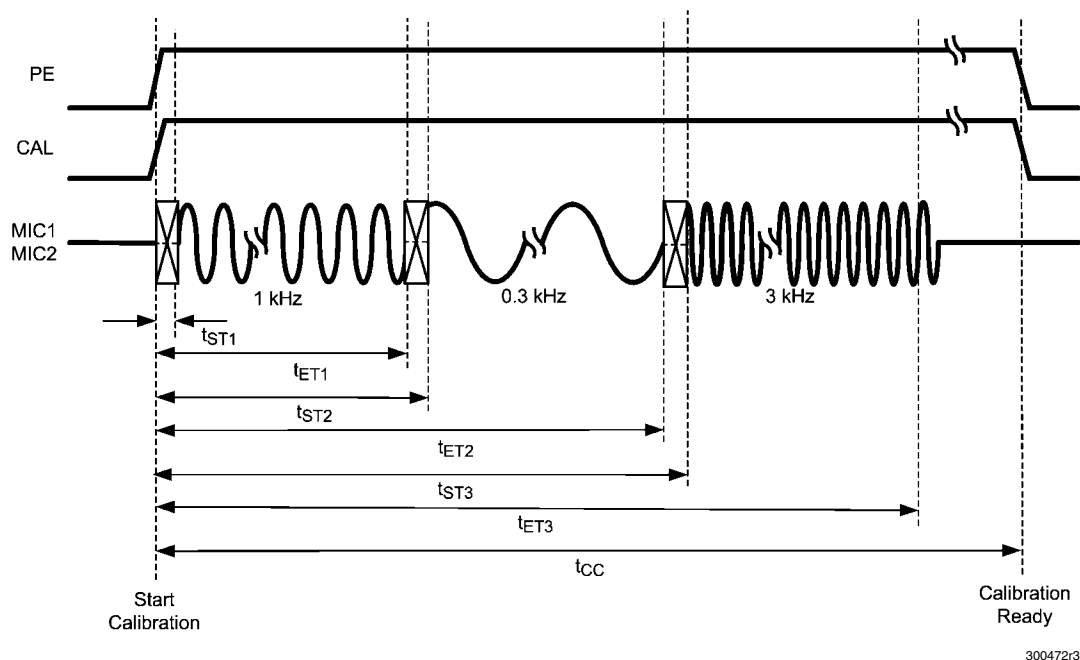


FIGURE 12. Calibration Timing

TABLE 7. Automatic Calibration Timing Parameters

| Symbol    | Parameter                | Limits |     | Units |
|-----------|--------------------------|--------|-----|-------|
|           |                          | Min    | Max |       |
| $t_{ST1}$ | Calibration Start Tone 1 |        | 10  | ms    |
| $t_{ET1}$ | Calibration End Tone 1   | 200    |     | ms    |
| $t_{ST2}$ | Calibration Start Tone 2 |        | 210 | ms    |
| $t_{ET2}$ | Calibration End Tone 2   | 400    |     | ms    |
| $t_{ST3}$ | Calibration Start Tone 3 |        | 410 | ms    |
| $t_{ET3}$ | Calibration End Tone 3   | 600    |     | ms    |
| $t_{CC}$  | Calibration Complete     | 790    |     | ms    |

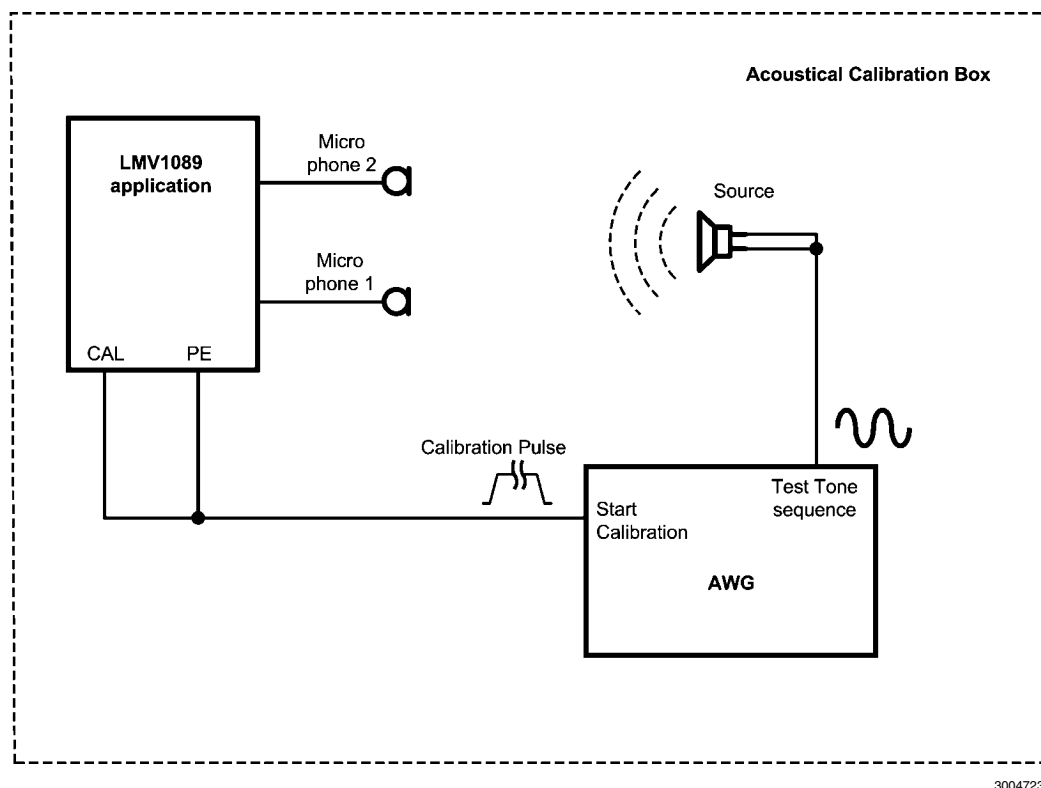
NOTE: Data guaranteed by design

### AUTOMATIC CALIBRATION SETUP

A calibration test setup consists of a test room (acoustical box) with a loudspeaker (acoustical source) driven with the test tone sequence from [Figure 12](#). The test setup is shown in [Figure 13](#). The distances between the source and microphone 1 and microphone 2 must be equal and the sound must travel without any obstacle from source to both microphones.

The sound will travel with the limited speed of 300m/s from the loudspeaker source to the microphones. When creating the calibration signals this time should not be ignored, 30cm distance will cause 1ms delay.

For an optimum automatic calibration the output level of the microphones and preamp gain must be set so that the resulting signal at the output of the preamplifier is  $100\text{mV}_{\text{P-P}} \pm 6\text{dB}$



30047235

FIGURE 13. Calibration Test setup

### MANUAL CALIBRATION

You can manually program the gain compensation of the two mic inputs on the LMV1089 using the I<sup>2</sup>C interface. [Table 5](#) shows the control bits for I<sup>2</sup>C Register O and P with the corresponding gains. This can be easily done by doing the following:

- 1) READ contents of the I<sup>2</sup>C register N immediately after powering up.
- 2) Set PE pin and T7 pin to Vdd.
- 3) WRITE to I<sup>2</sup>C register O and P to choose the calibration settings.

Bits O<7:4> control the two mics at 300Hz and bits O<3:0> control the two mics at 3kHz.

Bits P<7:4> control the right channel gain and bits P<3:0> control the left channel gain

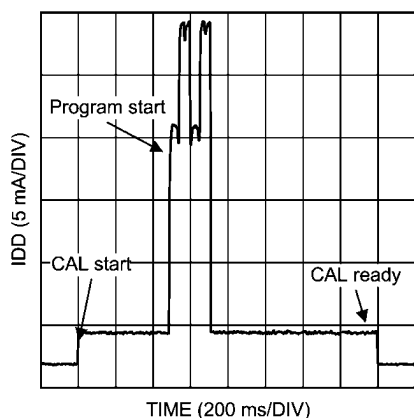
4) WRITE a '0' to I<sup>2</sup>C register Q<7> bit (storeBar) and the bits from I<sup>2</sup>C register N<6:0> to I<sup>2</sup>C register Q<6:0>

5) When I<sup>2</sup>C register N<7> (ready) goes high, then the EEPROM programming is complete. Now PE pin and T7 pin should be set to GND and I<sup>2</sup>C register Q<7> (storeBar) should be returned to '1'.

## SUPPLY CURRENT DURING CALIBRATION

The calibration function performs two main tasks in a sequence. First the AC characteristics of the microphones are matched. Then in the second stage, if the PE pin is high, the on-chip EEPROM is programmed.

During the first stage of this sequence the supply current on the LMV1089 will increase to about 2.5mA. During the writing of the EEPROM the supply current will rise for about 215 ms to about 30mA. This increased current is used for the on chip charge pump which generates the high voltages that are required for programming the EEPROM.



30047236

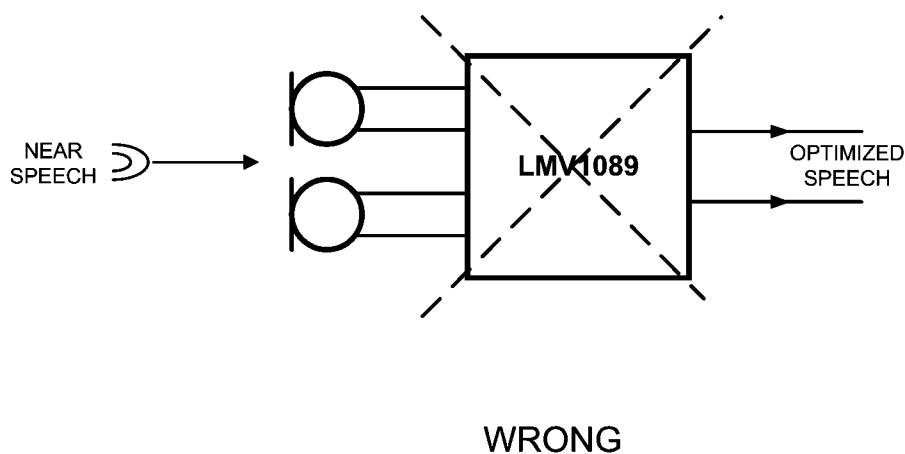
FIGURE 14. Supply current during calibration and programming

## Microphone Placement

Because the LMV1089 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

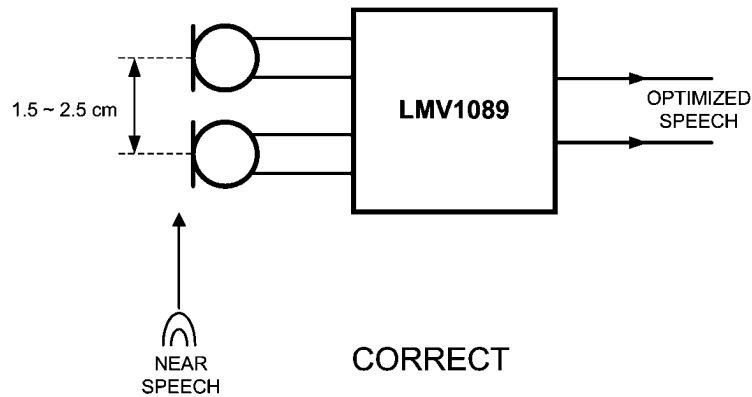
If the spacing between the two microphones is too small, near field speech will be canceled along with the far field noise. Conversely, if the spacing between the two microphones is large, the far field noise reduction performance will be degraded. The optimum spacing between Mic 1 and Mic 2 is 1.5-2.5cm. 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 16](#)) orientation from the sound source. If the 'near speech' (desired sound source) is equidistant to the source like a broadside array (see [Figure 15](#)) the result will be a great deal of near field speech loss.



30047243

FIGURE 15. Broadside Array (WRONG)



30047242

FIGURE 16. Endfire Array (CORRECT)

## Low-Pass Filter At The Output

At the output of the LMV1089 there is a provision to create a 1<sup>st</sup> 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:

$$H(s) = \frac{\text{Post Amplifier gain}}{sR_f C_f + 1}$$

This low-pass filter is created by connecting a capacitor between the LPF pin and the OUT pin of the LMV1089. 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](#).

TABLE 8. Low-Pass Filter Internal Impedance

| Post Amplifier Gain Setting (dB) in Pass Through mode | Feedback Resistance $R_f$ (k $\Omega$ ) |
|-------------------------------------------------------|-----------------------------------------|
| 6                                                     | 20                                      |
| 9                                                     | 29                                      |
| 12                                                    | 40                                      |
| 15                                                    | 57                                      |
| 18                                                    | 80                                      |

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

TABLE 9. Low-Pass Filter Capacitor For 2kHz

| Post Amplifier Gain Setting (dB) | $R_f$ (k $\Omega$ ) | $C_f$ (nF) |
|----------------------------------|---------------------|------------|
| 6                                | 20                  | 3.9        |
| 9                                | 29                  | 2.7        |
| 12                               | 40                  | 2.0        |
| 15                               | 57                  | 1.3        |
| 18                               | 80                  | 1.0        |

## Measurement Setup

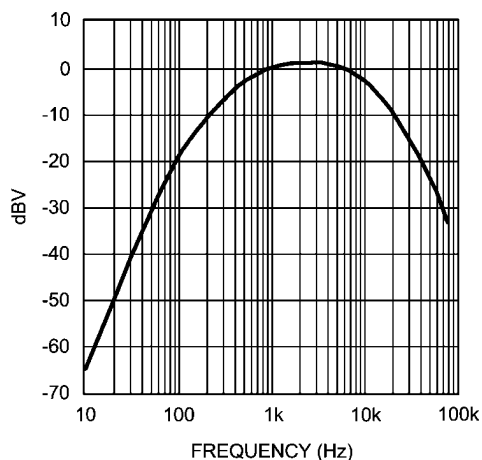
Because of the nature of the calibration system it is not possible to predict the absolute gain in the two microphone channels of the Far Field Noise Cancelling System. This is because, after the calibration function has been operated, the noise cancelling circuit will compensate for the difference in gain between the microphones. In Noise Cancelling mode, this can result in a final gain offset of max 3dB between the gain set in the registers (A[3:0] and B[2:0]) and the actual measured gain between input and output of the LMV1089. After performing a calibration the frequency characteristic of the microphone channels will be matched for the two microphones. As a result of this matching there can be a slight slope in the frequency characteristic in one or both amplifiers.

### 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.

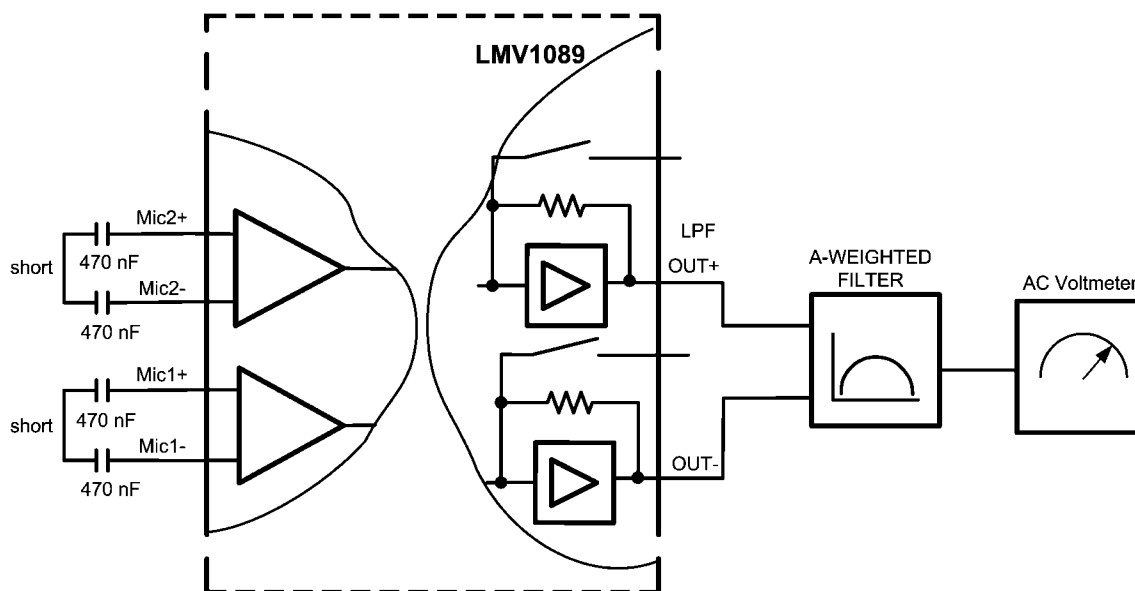
The A-weighted filter is used in signal to noise measurements, where the wanted audio signal is compared to device noise and distortion.

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



30047210

FIGURE 17. A-Weighted Filter



30047211

FIGURE 18. Noise Measurement Setup

For the signal to noise ratio (SNR) the signal level at the output is measured with a 1kHz input signal of  $18\text{mV}_{\text{P-P}}$  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 LMV1089 is programmed for 26dB of to-

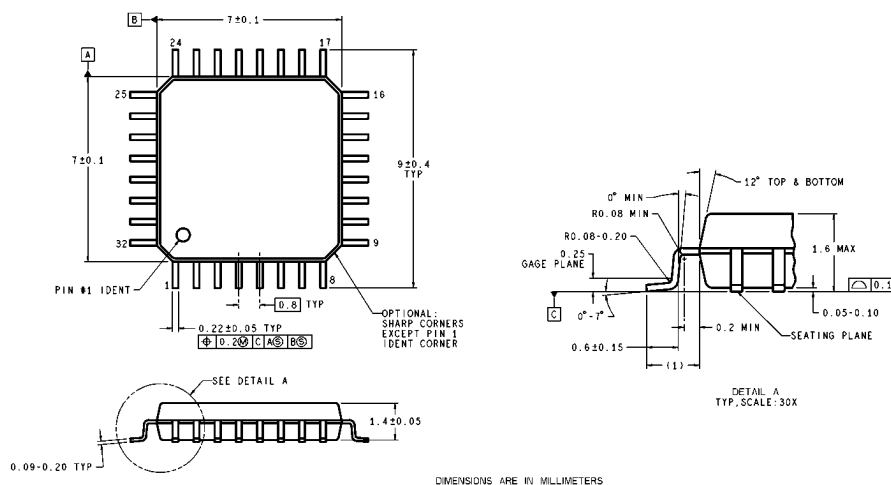
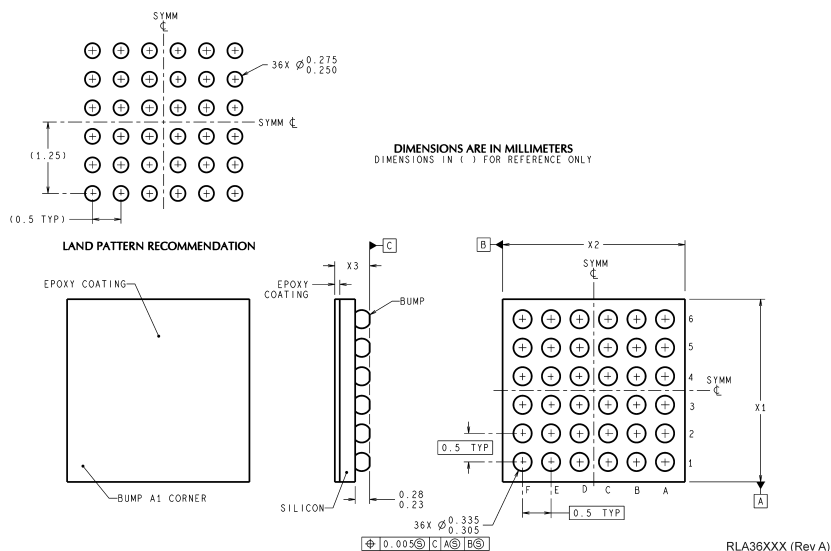
tal gain (20dB preamplifier and 6dB postamplifier) with only Mic1 or Mic2 used. (See also *I<sup>2</sup>C Compatible Interface*).

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 LMV1089 is disabled.

## Revision History

| Rev  | Date     | Description                                                               |
|------|----------|---------------------------------------------------------------------------|
| 1.0  | 09/24/08 | Initial release.                                                          |
| 1.01 | 09/30/08 | Text edits.                                                               |
| 1.02 | 10/14/08 | Text edits.                                                               |
| 1.03 | 10/24/08 | Text edits.                                                               |
| 1.04 | 10/28/08 | Added the LMV1089VY package .                                             |
| 1.05 | 12/11/08 | Text edits.                                                               |
| 1.06 | 12/17/08 | Text edits.                                                               |
| 1.07 | 01/13/09 | Edited graphic 30047227 (32-Lead LQFP package).                           |
| 1.08 | 02/23/09 | Text edits.                                                               |
| 1.09 | 02/27/09 | Deleted the “Clarisuond” label from the Typical Application ckt. diagram. |
| 1.10 | 06/17/09 | Text edits (A2 pin) in the Pin Name and Function table.                   |
| 1.11 | 07/06/09 | Updated the Typical and Limit values (Zin) in the EC tables.              |
| 1.12 | 05/19/10 | Fixed a minor typo in the front page.                                     |

## Physical Dimensions inches (millimeters) unless otherwise noted



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| Interface                      | <a href="http://www.national.com/interface">www.national.com/interface</a>     | Eval Boards                  | <a href="http://www.national.com/evalboards">www.national.com/evalboards</a>       |
| LVDS                           | <a href="http://www.national.com/lvds">www.national.com/lvds</a>               | Packaging                    | <a href="http://www.national.com/packaging">www.national.com/packaging</a>         |
| Power Management               | <a href="http://www.national.com/power">www.national.com/power</a>             | Green Compliance             | <a href="http://www.national.com/quality/green">www.national.com/quality/green</a> |
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| LDOs                           | <a href="http://www.national.com/ldo">www.national.com/ldo</a>                 | Quality and Reliability      | <a href="http://www.national.com/quality">www.national.com/quality</a>             |
| LED Lighting                   | <a href="http://www.national.com/led">www.national.com/led</a>                 | Feedback/Support             | <a href="http://www.national.com/feedback">www.national.com/feedback</a>           |
| Voltage References             | <a href="http://www.national.com/vref">www.national.com/vref</a>               | Design Made Easy             | <a href="http://www.national.com/easy">www.national.com/easy</a>                   |
| PowerWise® Solutions           | <a href="http://www.national.com/powerwise">www.national.com/powerwise</a>     | Applications & Markets       | <a href="http://www.national.com/solutions">www.national.com/solutions</a>         |
| Serial Digital Interface (SDI) | <a href="http://www.national.com/sdi">www.national.com/sdi</a>                 | Mil/Aero                     | <a href="http://www.national.com/milaero">www.national.com/milaero</a>             |
| Temperature Sensors            | <a href="http://www.national.com/tempsensors">www.national.com/tempsensors</a> | SolarMagic™                  | <a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>       |
| PLL/VCO                        | <a href="http://www.national.com/wireless">www.national.com/wireless</a>       | PowerWise® Design University | <a href="http://www.national.com/training">www.national.com/training</a>           |

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