

# Omnidirectional Microphone with Bottom Port and Analog Output

## GENERAL DESCRIPTION

The INMP401\* is a high-quality, high-performance, low-power, analog-output bottom-ported omnidirectional MEMS microphone. The INMP401 consists of a MEMS microphone element, an impedance converter, and an output amplifier. The INMP401 sensitivity specification makes it an excellent choice for near-field applications. The INMP401 has a wideband frequency response, resulting in natural sound with high intelligibility. The specially designed low frequency cutoff reduces wind noise. Its low current consumption enables long battery life for portable applications.

The INMP401 complies with the TIA-920 *Telecommunications Telephone Terminal Equipment Transmission Requirements for Wideband Digital Wireline Telephones* standard.

The INMP401 is available in a 4.72 × 3.76 × 1.00 mm surface-mount package. It is reflow solder compatible with no sensitivity degradation. The INMP401 is halide free.

\*Protected by U.S. Patents 7,449,356; 7,825,484; 7,885,423; and 7,961,897. Other patents are pending.

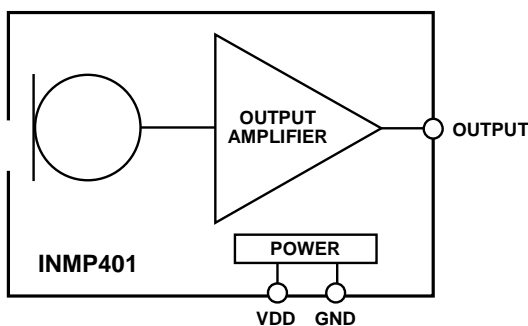
## APPLICATIONS

- Mobile Devices
- Teleconferencing Systems
- Headsets
- Security Panels
- Intercom Devices

## FEATURES

- 4.72 × 3.76 × 1.00 mm Surface-Mount Package
- SNR of 62 dBA
- Sensitivity of -42 dBV
- Flat Frequency Response from 60 Hz to 15 kHz
- Low Current Consumption: <250 μA
- Single-Ended Analog Output
- High PSR of 70 dB
- Compatible with Sn/Pb and Pb-Free Solder Processes
- RoHS/WEEE Compliant

## FUNCTIONAL BLOCK DIAGRAM



## ORDERING INFORMATION

| PART            | TEMP RANGE     |
|-----------------|----------------|
| INMP401ACEZ-R0* | -40°C to +85°C |
| INMP401ACEZ-R7† | -40°C to +85°C |
| EV_INMP401      | —              |
| EV_INMP401-FX   | —              |

\* – 13” Tape and Reel

† – 7” Tape and reel to be discontinued. Contact [sales@invensense.com](mailto:sales@invensense.com) for availability.

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**SPECIFICATIONS**

**TABLE 1. ELECTRICAL CHARACTERISTICS**

( $T_A = -40$  to  $85^\circ\text{C}$ ,  $V_{DD} = 1.5$  to  $3.3$  V, unless otherwise noted. All minimum and maximum specifications are guaranteed across temperature and voltage, and are specified in Table 1, unless otherwise noted. Typical specifications are not guaranteed.)

| PARAMETER                       | CONDITIONS  | MIN | TYP  | MAX | UNITS         | NOTES |
|---------------------------------|---|-----|------|-----|---------------|-------|
| <b>PERFORMANCE</b>              |   |     |      |     |               |       |
| Directionality                  |   |     | Omni |     |               |       |
| Sensitivity                     | 1 kHz, 94 dB SPL  | -45 | -42  | -39 | dBV           |       |
| Signal-to-Noise Ratio (SNR)     |   |     | 62   |     | dBA           |       |
| Equivalent Input Noise (EIN)    |   |     | 32   |     | dBA SPL       |       |
| Dynamic Range                   | Derived from EIN and maximum acoustic input               |     | 88   |     | dB            |       |
| Frequency Response              | Low frequency -3 dB point                                 |     | 60   |     | Hz            | 1     |
|                                 | High frequency -3 dB point                                |     | 15   |     | kHz           |       |
| Total Harmonic Distortion (THD) | 105 dB SPL  |     |      | 3   | %             |       |
| Power-Supply Rejection (PSR)    | 217 Hz, 100 mVp-p square wave superimposed on VDD = 1.8 V |     | -70  |     | dBV           |       |
| Maximum Acoustic Input          | Peak  |     | 120  |     | dB SPL        |       |
| <b>POWER SUPPLY</b>             |   |     |      |     |               |       |
| Supply Voltage ( $V_{DD}$ )     |   | 1.5 |      | 3.3 | V             |       |
| Supply Current ( $I_S$ )        |   |     |      | 250 | $\mu\text{A}$ |       |
| <b>OUTPUT CHARACTERISTICS</b>   |   |     |      |     |               |       |
| Output Impedance ( $Z_{OUT}$ )  |   |     | 200  |     | $\Omega$      |       |
| Output DC Offset                |   |     | 0.8  |     | V             |       |
| Output Current Limit            |   |     | 90   |     | $\mu\text{A}$ |       |

**Note 1:** See Figure 3 and Figure 4.

**ABSOLUTE MAXIMUM RATINGS**

Stress above those listed as Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to the absolute maximum ratings conditions for extended periods may affect device reliability.

**TABLE 2. ABSOLUTE MAXIMUM RATINGS**

| PARAMETER                  | RATING  |
|----------------------------|---|
| Supply Voltage (VDD)       | -0.3 V to +3.6 V                              |
| Sound Pressure Level (SPL) | 160 dB  |
| Mechanical Shock           | 10,000 g                                      |
| Vibration                  | Per MIL-STD-883 Method 2007, Test Condition B |
| Temperature Range          | -40°C to +85°C                                |

**ESD CAUTION**



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

SOLDERING PROFILE



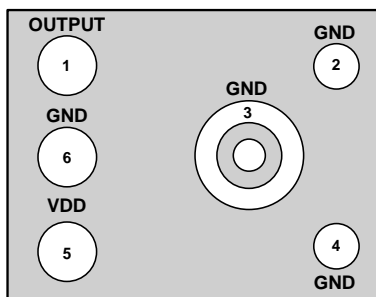
Figure 1. Recommended Soldering Profile Limits

TABLE 3. RECOMMENDED SOLDERING PROFILE\*

| PROFILE FEATURE                                       |  | Sn63/Pb37        | Pb-Free          |
|---|--|------------------|------------------|
| Average Ramp Rate ( $T_L$ to $T_P$ )                  |  | 1.25°C/sec max   | 1.25°C/sec max   |
| Preheat   | Minimum Temperature ( $T_{SMIN}$ )       | 100°C            | 100°C            |
|   | Minimum Temperature ( $T_{SMIN}$ )       | 150°C            | 200°C            |
|   | Time ( $T_{SMIN}$ to $T_{SMAX}$ ), $t_s$ | 60 sec to 75 sec | 60 sec to 75 sec |
| Ramp-Up Rate ( $T_{SMAX}$ to $T_L$ )                  |  | 1.25°C/sec       | 1.25°C/sec       |
| Time Maintained Above Liquidous ( $t_L$ )             |  | 45 sec to 75 sec | ~50 sec          |
| Liquidous Temperature ( $T_L$ )                       |  | 183°C            | 217°C            |
| Peak Temperature ( $T_P$ )                            |  | 215°C +3°C/-3°C  | 245°C +0°C/-5°C  |
| Time Within +5°C of Actual Peak Temperature ( $t_p$ ) |  | 20 sec to 30 sec | 20 sec to 30 sec |
| Ramp-Down Rate  |  | 3°C/sec max      | 3°C/sec max      |
| Time +25°C ( $t_{25°C}$ ) to Peak Temperature         |  | 5 min max        | 5 min max        |

**Note:** \*The reflow profile in Table 3 is recommended for board manufacturing with InvenSense MEMS microphones. All microphones are also compatible with the J-STD-020 profile.

**PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS**



**BOTTOM VIEW**  
Not to Scale

**Figure 2. Pin Configuration**

**TABLE 4. PIN FUNCTION DESCRIPTIONS**

| PIN | NAME   | FUNCTION             |
|-----|--------|----------------------|
| 1   | OUTPUT | Analog Output Signal |
| 2   | GND    | Ground               |
| 3   | GND    | Ground               |
| 4   | GND    | Ground               |
| 5   | VDD    | Power Supply         |
| 6   | GND    | Ground               |

**TYPICAL PERFORMANCE CHARACTERISTICS**



**Figure 3. Frequency Response Mask**



**Figure 4. Typical Frequency Response (Measured)**



**Figure 5. Typical Power Supply Rejection Ratio vs. Frequency**

**APPLICATIONS INFORMATION**

**CONNECTING TO AUDIO CODECS**

The INMP401 output can be connected to a dedicated codec microphone input (see Figure 6) or to a high input impedance gain stage (see Figure 7.) A 0.1 μF ceramic capacitor placed close to the INMP401 supply pin is used for testing and is recommended to adequately decouple the microphone from noise on the power supply. A DC-blocking capacitor is required at the output of the microphone. This capacitor creates a high-pass filter with a corner frequency at

$$f_c = 1/(2\pi \times C \times R)$$

where *R* is the input impedance of the codec.

A minimum value of 2.2 μF is recommended in Figure 6 because the input impedance of codecs can be as low as 2 kΩ at its highest PGA gain setting, which results in a high-pass filter corner frequency at about 37 Hz. Figure 7 shows the INMP401 connected to an op amp configured as a non-inverting preamplifier.



Figure 6. INMP401 Connected to a Codec

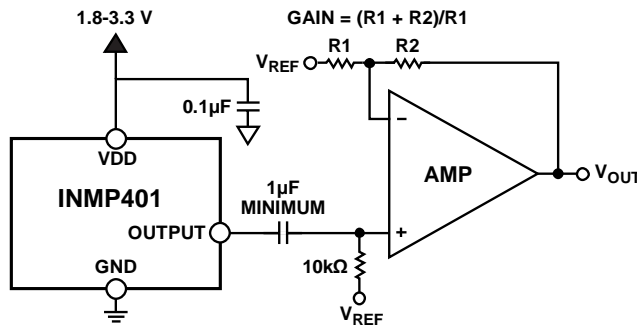


Figure 7. INMP401 Connected to an Op Amp



## **SUPPORTING DOCUMENTS**

For additional information, see the following documents.

### **EVALUATION BOARD USER GUIDE**

[UG-445](#) Analog Output MEMS Microphone Flex Evaluation Board

[UG-126](#) Analog Output MEMS Microphone Flex Evaluation Board

### **APPLICATION NOTES (PRODUCT SPECIFIC)**

[AN-0207](#) High Performance Analog MEMS Microphone's Simple Interface to SigmaDSP Audio Codec

[AN-0262](#) Low Noise Analog MEMS Microphone and Preamp with Compression and Noise Gating

### **APPLICATION NOTES (GENERAL)**

[AN-1003](#) Recommendations for Mounting and Connecting the Invensense Bottom-Ported MEMS Microphones

[AN-1068](#) Reflow Soldering of the MEMS Microphone

[AN-1112](#) Microphone Specifications Explained

[AN-1124](#) Recommendations for Sealing Invensense, Bottom-Port MEMS Microphones from Dust and Liquid Ingress

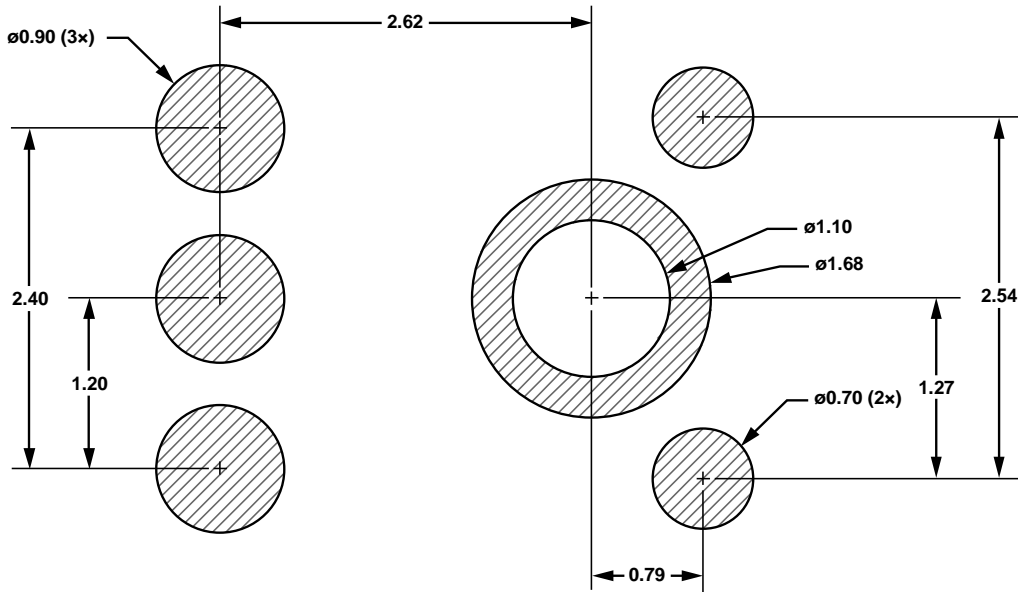
[AN-1140](#) Microphone Array Beamforming

[AN-1165](#) Op Amps for MEMS Microphone Preamp Circuits

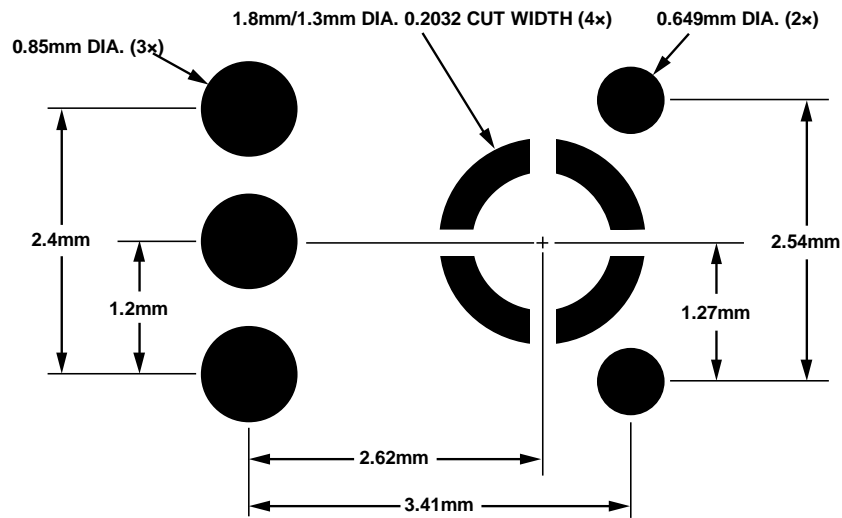
[AN-1181](#) Using a MEMS Microphone in a 2-Wire Microphone Circuit

**PCB DESIGN AND LAND PATTERN LAYOUT**

The recommended PCB land pattern for the INMP401 should be laid out to a 1:1 ratio to the solder pads on the microphone package, as shown in Figure 8. Take care to avoid applying solder paste to the sound hole in the PCB. A suggested solder paste stencil pattern layout is shown in Figure 9. The diameter of the sound hole in the PCB should be larger than the diameter of the sound port of the microphone. A minimum diameter of 0.5 mm is recommended.



**Figure 8. PCB Land Pattern Layout**  
Dimensions shown in millimeters



**Figure 9. Suggested Solder Paste Stencil Pattern Layout**  
Dimensions shown in millimeters

## **HANDLING INSTRUCTIONS**

### **PICK AND PLACE EQUIPMENT**

The MEMS microphone can be handled using standard pick-and-place and chip shooting equipment. Take care to avoid damage to the MEMS microphone structure as follows:

- Use a standard pickup tool to handle the microphone. Because the microphone hole is on the bottom of the package, the pickup tool can make contact with any part of the lid surface.
- Do not pick up the microphone with a vacuum tool that makes contact with the bottom side of the microphone. Do not pull air out of or blow air into the microphone port.
- Do not use excessive force to place the microphone on the PCB.

### **REFLOW SOLDER**

For best results, the soldering profile must be in accordance with the recommendations of the manufacturer of the solder paste used to attach the MEMS microphone to the PCB. It is recommended that the solder reflow profile not exceed the limit conditions specified in Figure 1 and Table 3.

### **BOARD WASH**

When washing the PCB, ensure that water does not make contact with the microphone port. Do not use blow-off procedures or ultrasonic cleaning.

OUTLINE DIMENSIONS

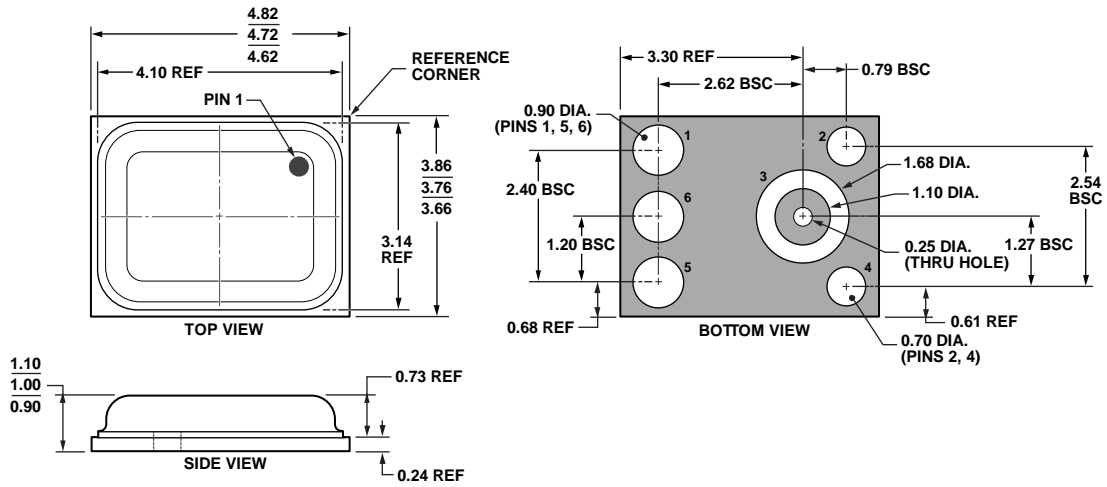


Figure 10. 3-Terminal Chip Array Small Outline No-Lead Cavity [LGA\_CAV]  
 4.72 × 3.76 × 1.00 mm Body  
 Dimensions shown in millimeters

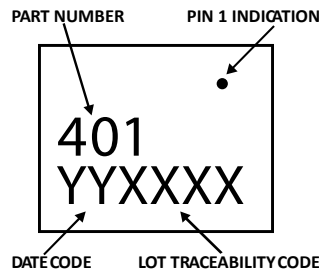


Figure 11. Package Marking Specification (Top View)

**ORDERING GUIDE**

| PART                         | TEMP RANGE     | PACKAGE               | QUANTITY |
|------------------------------|----------------|-----------------------|----------|
| INMP401ACEZ-R0 <sup>1*</sup> | -40°C to +85°C | 6-Terminal LGA_CAV    | 4,500    |
| INMP401ACEZ-R7 <sup>1†</sup> | -40°C to +85°C | 6-Terminal LGA_CAV    | 1,000    |
| EV_INMP401                   | —              | Evaluation Board      | —        |
| EV_INMP401-FX                | —              | Flex Evaluation Board | —        |

\* – 13" Tape and Reel

† – 7" Tape and reel to be discontinued. Check with [sales@invensense.com](mailto:sales@invensense.com) for availability.

<sup>1</sup>Z = RoHS-Compliant Part

**REVISION HISTORY**

| REVISION DATE | REVISION | DESCRIPTION                   |
|---------------|----------|-------------------------------|
| 02/06/2014    | 1.0      | Initial Release               |
| 05/21/2014    | 1.1      | Updated Compliance Disclaimer |

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Тел: +7 (812) 336 43 04 (многоканальный)

Email: [org@lifeelectronics.ru](mailto:org@lifeelectronics.ru)