MEMS Microphones

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Agenda

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04 MEMS Microphone Arrays
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01 Microphone Overview
Introduction

Purpose
• Provide an overview of MEMS microphone technology
  - Working principles, key specifications, applications

Objectives
• Introduce common microphone technologies
  - CUI offers both ECM and MEMS microphones
• Outline key specifications for MEMS microphones
• Discuss MEMS microphone arrays and other potential applications
• Highlight CUI’s range of MEMS microphone products
What is a microphone?

Microphones are electromechanical products used to detect sound and produce electrical signals

MEMS Microphone Features
- Compact package sizes (*Smaller than 2 x 3 x 1 mm*)
- Improved signal quality
- Durable, stable performance

Electret Condenser Microphones (ECM)
- Flexible mounting configurations (*SMT and THM*)
- Unidirectional and noise canceling directivity
- Wide operating voltage ranges
Why use a microphone?

Use Cases
- Audio recording and voice capture
- Detection sensors
- Activity monitoring
- Machinery failures

Industry Applications
- Consumer
- Scientific
- Industrial
- Medical
ECM Microphone Review

Typical ECM construction

Typical ECM application
MEMS Microphone Overview

Typical MEMS microphone construction
MEMS Microphone Advantages

- Smaller package sizes
- Analog or digital output signal
- Choice of top or bottom sound port
  - Product packaging options
- Internal IC pre-amp
  - Signal stability over time and temperature
- Low output impedance
  - Greater immunity to electrical noise
- Tight sensitivity tolerances
  - Higher performance arrays
- Low current consumption
  - Energy harvesting, battery powered and IoT applications
MEMS Microphone Outputs
Analog MEMS Microphones

Analog Output Construction
• Microphone element and preamplifier
• Two co-packaged die

Analog Output Features
• No digital processing required
• Application circuits easy to design
• Low output impedance
  - Reduces susceptibility to electrical noise

Analog, 2-pin Configuration

Analog, 3-pin Configuration
Digital MEMS Microphones

Digital Output Construction

- Microphone element, preamplifier and ADC
- Two co-packaged die

Digital Output Features

- Simple interface to digital circuits
- Strongly immune to electrical noise
  - Large signal levels

Typical Digital Configuration
Pulse Density Modulation

- Requires clock and one data line
  - 1 bit wide data word
- Clock rate > 100X analog bandwidth
- Fixed pulse width
  - Encoding by presence or absence of pulses
- Stereo encoding with shared clock and data lines
  - First channel drives data on HIGH clock
  - Second channel drives data on LOW clock
  - Data line is ‘wired AND’ driven
03 Key Specifications
Top and Bottom Ports

Top port configuration  Bottom port configuration
Anechoic Chamber, A-Weighting & dB

Anechoic Chamber
• A chamber with walls that absorb sound energy and do not reflect it back
  (Enables accurate measurement of the direct sound path)

A-weighting
• A standard for specifying a sound energy distribution over the audio range
  (Enables specifications to relate to human hearing sensitivity)

dB
• A method used to easily express ratios of pressure levels over a wide range
  • $\text{dB} = 20 \times \log_{10}(P_1/P_2)$
  • $2:1 = 3 \text{ dB}$, $10:1 = 20 \text{ dB}$, $1,000:1 = 60 \text{ dB}$, $1:100,000 = -100 \text{ dB}$
**Sound Pressure (in air) & SPL**

**Sound Pressure (in air)**
- Loudness (volume) of sound is related to the magnitude of air pressure change
- Sound pressure is specified in units of Pascal (Pa)

**SPL (Sound Pressure Level, specified in units of dB)**
- Ratio of measured sound pressure relative to 20 µPa of pressure
  - 20 µPa is the threshold of hearing (0 dB SPL)
  - 1 Pa is equal to 94 dB SPL
Sensitivity & Sensitivity Tolerance

Sensitivity

- Measured in dBV for analog and dBFS for digital
- Ratio of microphone output voltage from 1 Pa excitation at 1 kHz
  - Analog; Sensitivity (dBV) = 20 \times \log_{10}(\text{SmV/Pa} \div \text{Ref}); \text{Ref} = 1000 \text{ mV/Pa}
  - Digital; Sensitivity (dBFS) = 20 \times \log_{10}(\text{S\%FS} \div \text{Ref}); \text{Ref} = 1.0
- A larger value of sensitivity is better than a smaller value of sensitivity
  - -23 dB is better than -36 dB

Sensitivity Tolerance

- Typical MEMS microphones exhibit tolerances from ±3 dB down to ±1 dB
- Relates to both initial and long term matching of sensitivity between microphones
  - Important for phased array applications
Signal to Noise Ratio (SNR)

Ratio of Desired Signal to Undesired Noise

- Measured with standardized excitation
- Specified in dB
- Larger SNR values are good
  - 53 dB is better than 48 dB

$$SNR = 20 \log(PS/PN)$$

- PS – Output signal power level
  - Measured at 1 Pa (94 dB SPL) at 1 kHz
- PN – Noise signal power level
  - Measured at 20 kHz bandwidth
  - A-weighted
  - Characterized in an anechoic chamber
AOP & Dynamic Range

Acoustic Overload Point (AOP)
- Excitation sound level where distortion rises rapidly
  - Defined at a 10% distortion level

Dynamic Range
- Ratio of maximum to minimum sound pressure microphone can handle
  - Maximum sound pressure
    - Sound pressure which creates 10% distortion in output waveform
  - Minimum sound pressure
    - Equivalent sound pressure to create microphone background noise level
- A larger value of dynamic range is better than a smaller value of dynamic range
04 MEMS Microphone Arrays
**MEMS Microphone Arrays**

- Placing MEMS microphones in arrays can be used for signal enhancement (beamforming)
- Increase sensitivity
  - Listening to sounds at a distance
- Noise cancelation
  - Listening to sounds in a loud environment
- Sound direction detection
  - Determining the direction of the source of a sound
- Tight sensitivity tolerances required between microphones

- Digital signal processing (DSP) capability required in host system
  - Calculations on microphone signals
- Tight sensitivity matching and digital signal outputs are best for array applications
  - CUI Devices MEMS microphones CMM4030DT-26154-TR, CMM4030DB-26154-TR, CMM4737DT-26186-TR
Broadside Microphone Arrays

Broadside arrays utilize amplitude and phase information from each microphone

- Used in products where sound arrives perpendicular to the array
- Conference room phone systems
- Interactive game voice commands
- Car audio interfaces
Endfire Microphone Arrays

Endfire arrays emphasize time delay (phase) information from each microphone

- Useful when sound arrives in-line with the array
- Hand-held microphones
- Manually or mechanically pointed directional microphones
Sound Location Detection Arrays

Location arrays utilize amplitude and phase information from each microphone:

- More complex (expensive) than broadside or endfire arrays
- Useful when the location of the sound is unknown
- Security (Intruder detection, drone detection)
- Military and law enforcement (Gun-fire detection)
Available Products
Available Products

Features

- Analog or digital (PDM) outputs
- Compact, low profile footprints
- Top or bottom sound port
- Low current consumption down to 80 µA
- -44 up to -26 dB sensitivity ratings
- 57 up to 65 dB signal-to-noise ratios
- Tight sensitivity tolerances for array applications
- Reflow solder compatible
- Rectangular or round form factors
- -40 up to 105°C operating temperature ranges
Available Products | Evaluation Boards

Features

• 4 MEMS models available
  - Decoupling and output coupling capacitors included

• Compact PCB size
  - Approximately 15 x 15 mm

• External connections with wires or 0.1” square pins
  - Convenient connections for evaluation and pro-typing
CUI Devices' library of ready-made 3D models helps to streamline the design process, saving you time and resources. Users are able to view and download MEMS microphone 3D models in all major mechanical CAD formats free of charge.

- AutoCAD®
- Autodesk Inventor™
- CADKEY®
- CATIA®
- I-DEAS/Master Series™
- Anvil™
- Mechanical Desktop ©
- Pro/ENGINEER ©
- SolidWorks ©
- Unigraphics ©
- IGES Step
- Iron CAD™
- ACIS
- DXF
- eDrawings
- Solid Edge™
With CUI Devices’ catalog of verified PCB footprints and schematics, users are able to prevent footprint errors and shorten the time-consuming process of circuit board design with free-to-download files available in the following formats:

- Altium
- Eagle
- KiCad
- OrCAD/Allegro
- PADS/DxDesigner
- PCB123
- Pulsonix
Online Resources | Parametric Search

Use our advanced Parametric Search to quickly find and compare MEMS microphone models based on key specification criteria, including:

- Output Type
- Port Location
- Sensitivity (dB)
- Operating Voltage
- Operating Frequency
- SNR (dBA)
- Current Consumption
- Shape
- Package Size
Get helpful information and tips with 3 of our top MEMS microphone resources:

- Comparing MEMS and Electret Condenser Microphones
- Analog or Digital: How to Choose the Right MEMS Microphone Interface
- An Introduction to MEMS Microphone Arrays

Download the resource kit now!
Summary

• MEMS microphones are used in many products
• Hold distinct advantages over electret condenser mics
  - Smaller size
  - Improved performance
  - Tight sensitivity matching
• Applications
  - Consumer, industrial, scientific, medical
  - Voice capture and recording
  - Arrays and beam forming
• CUI Devices offers a range of MEMS microphone products

All CUI Devices MEMS products are registerable!
Thank You

For any questions, please contact:
https://futureelec.wufoo.com/forms/cui-webinar-inquiries/