



As seen in *Planet Analog*

Digital microphone technologies improve the mobile user experience

Yongjin Luo, Fairchild Semiconductor

3/6/2011 8:15 PM EST

Understand the operation and key parameters of electret condenser microphones

Abstract

Because of advancements in microphone technologies and small-signal A/D (analog/digital) integrated circuits, Electret Condenser Microphones (ECM) are now able to deliver digital audio output, which opens a new horizon for microphone applications. For years, manufacturers have been striving to improve the performance of ECMs, such as sensitivity, SNR, reflow solderability, and A/D converter performance.

Not only have A/D converter ICs improved substantially allowing for high performance digital microphones (mics) are now being made using MEMS techniques and those two advancements are converging. This article will illustrate some of the key market and technical perspectives regarding modern mobile microphones.

Background

Because of advancements in microphone technologies and small-signal A/D integrated circuits, ECMs are now able to deliver digital audio output, which opens a new horizon for microphone applications especially in mobile handsets, tablets, and PCs such as echo cancelling, wind noise filtering and other advanced audio processing. Digital microphones are more immune to picking-up noise within the system, which is increasingly important due to the numerous noise sources all packed into a tight space, such as cellular radio ICs, Bluetooth and WiFi ICs, extremely fast application processors and many others.

For years, manufacturers have been striving to improve the performance of ECMs in the areas of sensitivity, signal to noise ratio (SNR), reflow solderability, and A to D converter performance. Not only have A to D converter ICs improved substantially allowing for high performance digital mics, but MEMS techniques are being employed to make mics. Furthermore, those two advancements are merging.

Market status

ECM and MEMS A/D converters are emerging on the scene and are challenging the hegemony of traditional junction field effect transistors (JFET) that have been used in mics for decades. Digital audio output from a mic is now available at a cost-effective price, which allows mics to be placed almost anywhere in a handset, tablet, or PC, which is not the case with analog output mics.

A MEMS microphone uses a silicon diaphragm implemented by etching a pressure sensing membrane into silicon via micro-electromechanical technology.

Advantages of MEMS (relative to ECM)

- Naturally flat temperature coefficient (no need for temperature compensation)
- MEMS is easier to assemble
- More heat tolerance for reflow soldering (performance does not change due to heat stress)

Disadvantages of MEMS (relative to ECM)

- Narrower bandwidth
- MEMS diaphragm is more fragile
- Slightly more expensive (today)

The market size for mics significantly exceeds the number of systems they are used in, for the simple reason that advanced audio processing--such as 3D sound, echo and noise cancelling and similar-- requires more than one mic. This multiplier effect is propelling the growth of all segments of the mic market. The digital ECM segment is starting to grow now and that will be followed by the digital and analog MEMS segment [*Editor's note*: this is a post-publication correction from "digital MEMS" alone], which is expected to reach over 850 Million units by 2014, **Figure 1** (based on internal marketing data).

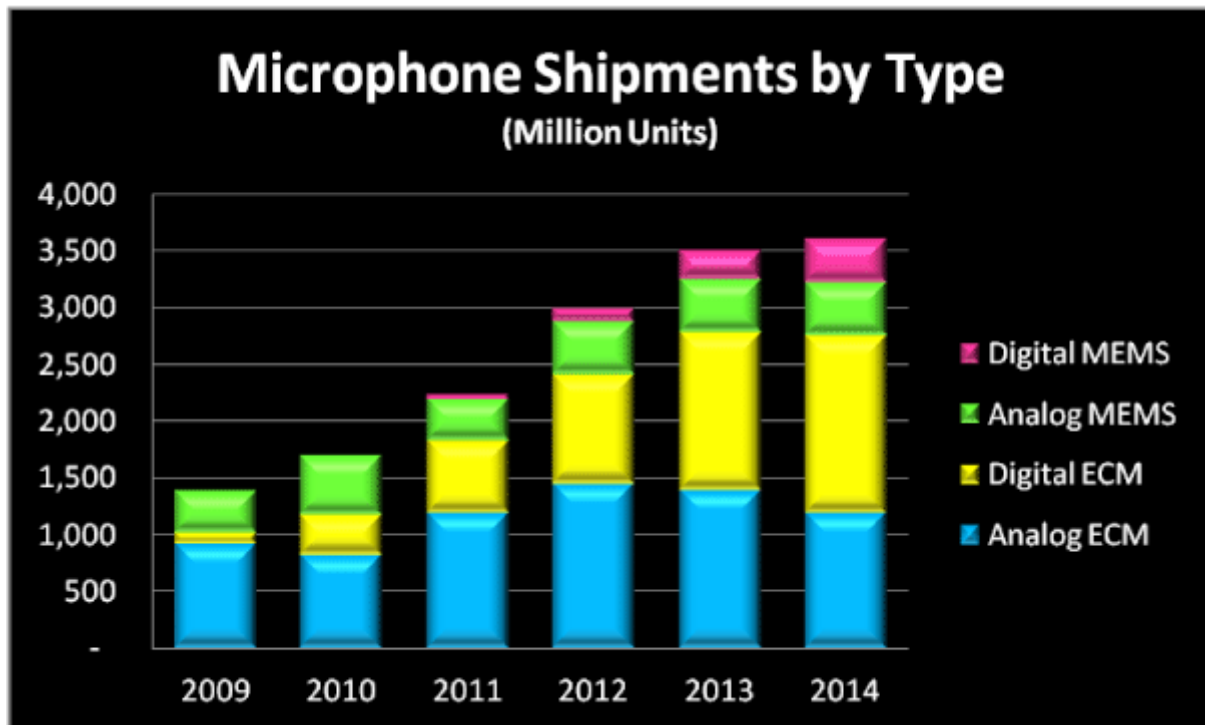


Figure 1: Microphone Market Size

In response to the digital trend, Fairchild is now developing high performance preamp plus A /D mic ICs, using fourth-order sigma delta techniques for use in ECM mics.

Technology

Figure 2 shows the basic structure of a digital ECM microphone. An electret membrane (typically a charged polymer material) or silicon MEMS membrane is used to transduce sound pressure into voltage. The mic IC is comprised of an

operational amplifier with extremely low noise, a high-performance sigma-delta ($\Sigma \Delta$) A/D converter (**Figure 3**), and a PDM digital interface that enables stereo audio or time division multiplexed audio.

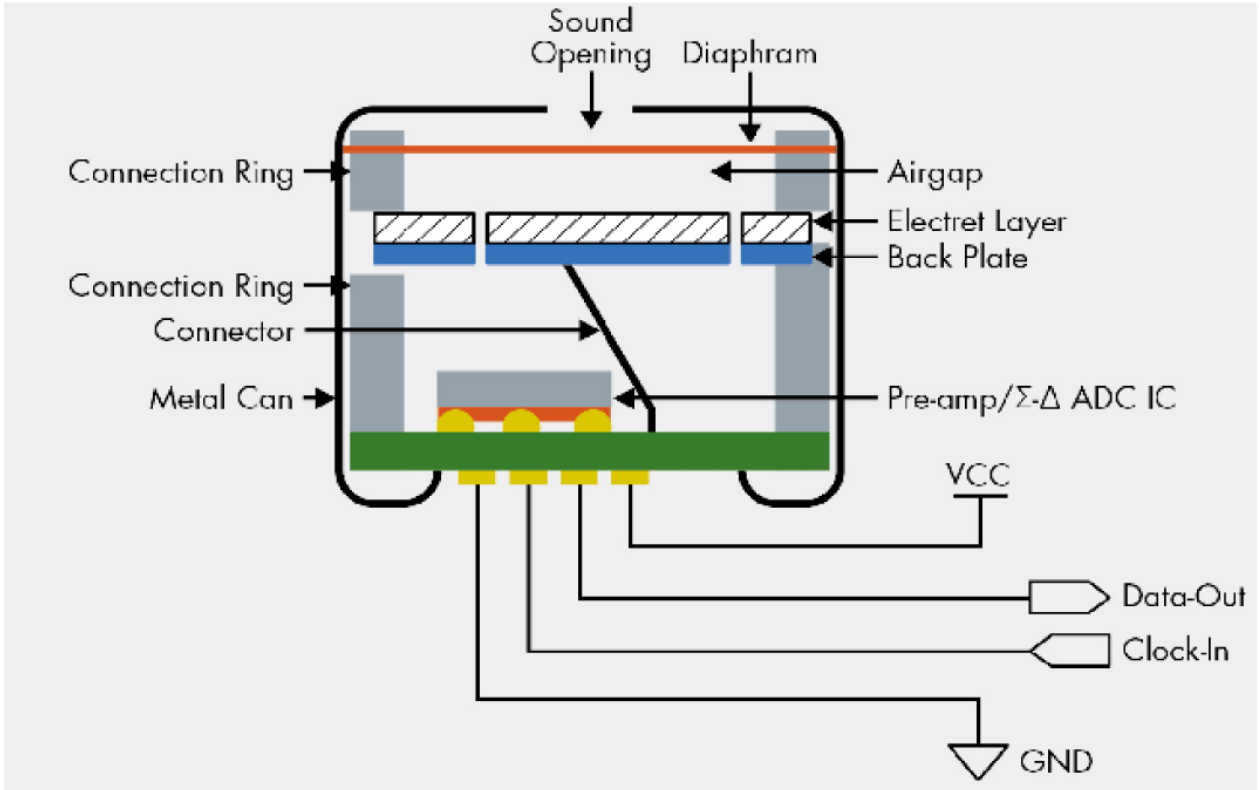


Figure 2: Basic structure of digital microphone

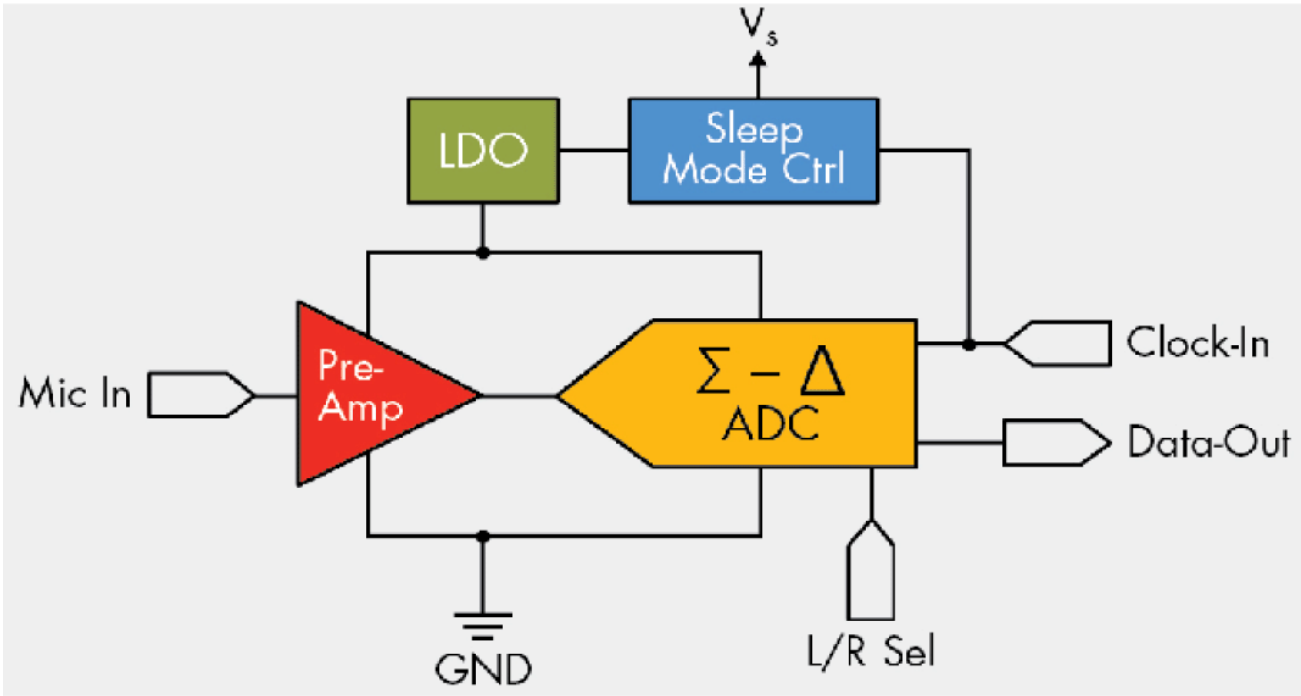


Figure 3: Block diagram of an A-D converter IC

Modern, high-performance digital ECM mic ICs with the construction noted can have the following features, **Table 1:**

<i>Parameter</i>	<i>Value</i>
SNR:	60-62dBc(A)@ 94dB SPL (– 26dBFS)
PGA + ADC Input Referred Noise	6.3 μV_{RMS}
PGA Input Referred Noise	3.2 μV_{RMS}
THD:	<0.02%@ 94dB SPL (– 26dBFS)
MAX signal input:	710 mV _{p-p} without THD compromises
Gain Example:	19dB gain for -42 dBV/Pa microphone with insertion loss compensation.
IC operation current:	$\leq 450 \mu\text{A}$

Table 1: ECM Microphone IC Specifications

Microphone Sensitivity

International standards have established 1 Pascal (Pa) as 94dB(SPL). This reference point is now accepted for specifying the sensitivity of microphones.

$$\text{Sound Pressure Level (SPL)} = 20 \log_{10} 10 (P/P_0)$$

$$= 10 \log_{10} (P/P_0)^2$$

Where P is the sound pressure value and the reference value

$$P_0 = 2 \times 10^{-5} \text{ N/m}^2, \text{ which is the "Threshold of Audibility"}$$

The sensitivity of a typical ECM ranges from -44 dBV/Pa to -38dBV/Pa, which means that when a typical ECM receives a pressure level of 1 Pascal, an average voltage fluctuation ranging from -44 dBV to -38dBV on the amplifier input will be applied to the front end of the amplifier. Here, 1 dBV corresponds to 1 V_{rms}, which is used as the measurement unit for the ECM's output voltage. So, we have the following equivalence relationships:

$$-42\text{dBV} = 7.9\text{mV}_{\text{RMS}} = 22.5\text{mV}_{\text{P-P}}$$

An ECM receiving a sound pressure of 120dB SPL will create a voltage equivalent to:

$$120\text{dB SPL} - 94\text{dB Pa/SPL} - 42\text{dBV/Pa}$$

$$= -16\text{dBV or } 158.4\text{mV}_{\text{RMS}}.$$

The dBFS (dB Full Scale) used in the above listed ECM specifications is the logarithm of the ratio of the ADC input voltage over the ADC reference voltage, which is:

$$20 \times \log_{10}(\text{VIN} \times \text{AV} / \text{VREF}) = \text{dBFS}$$

Usually, A_v (amplifier gain) and V_{REF} (ADC reference voltage) is set so that when the input sound pressure is 120dB SPL, the $V_{IN} \times A_v / V_{REF} = 1$. These settings are already configured in the mic's converter IC, with 0 dBFS corresponding to:

120dB SPL, -26dBFS

corresponding to 94dB SPL.

Table 2 helps make the numbers easier to relate to.

<i>SOUND</i>	<i>dB(SPL)</i>
Jet Engine at 3m	140
Threshold of Pain	130
Rock Concert	120
Accelerating Motorcycle at 5m	110
Pneumatic Hammer at 2m	100
Noisy Factory	90
Vacuum Cleaner	80
Busy Traffic	70
Quiet Restaurant	50
Residential Area at Night	40
Empty Movie House	30
Rustling of Leaves	20
Human Breathing at 3m	10
Threshold of Audibility (for Good Ears)	0

Table 2: Approximate dB (SPL) level of common sounds

(From S.S. Stevens, F. Warshofsky, Sound and Hearing,

Time-Life Books, 1965)

As for SNR and noise calculations, SNR is usually represented in dBc (where "c" stands for carrier) or dB. Usually, dBc is used to represent the signal intensity logarithm based upon noise as the reference.

So, in the specifications listed above, SNR is represented as 62dBc(A-weighted) at 94dB SPL (or equivalently, -26dBFS). In other words, the SNR could also be represented as the following:

62dBc(A) at 94dB SPL(-26dBFS), calculated at -26 dBFS/Pa sensitivity,

SNR = (sensitivity – noise floor), or 0dBc(A) at 32dB SPL(-88dBFS)

SNR = 0dBc means the effective signal intensity is equal to the noise intensity, and the corresponding noise floor created is 32dB (SPL), and the corresponding noise voltage is:

$32\text{dB SPL} - 94\text{dB PA/SPL} - 42\text{dBV/Pa} = -104\text{ dBV} = 6.3\text{ }\mu\text{VRMS}$.

It follows from these figures that the dynamic input pressure range for the ECM Digital Microphone Chip is 32 to 120dB(SPL).

Summary

High-performance digital microphone technology is vital to improving the audio quality of mobile devices and providing a more enriching user experience. Digital technology can deliver increased functionality, such as noise cancellation and filtering, or enable the coordination of several digital microphones to achieve better noise elimination and better pick-up orientation.

With portable devices being widely used in noisy environments and the increasing demands for better sound quality of mobile phones and multi-party communication services, the requirement for improved digital microphone technology will certainly prevail.

About the author



Roger (Yongjin) Luo is a Senior Technical Manager at Fairchild Semiconductor for the Asia Pacific region focusing on Mobile Solutions and Low Voltage products. Prior to working at Fairchild, he served as a smart phone project design leader at Inventec Shanghai. Roger got his Bachelors degree in Mechanical and Electronic Engineering from Huazhong University of Science and Technology. He received his Masters degree in Control Theory and Control Engineering from Shanghai Jiaotong University.