

LMV1012

Integrated Circuits for High Performance Electret Microphones



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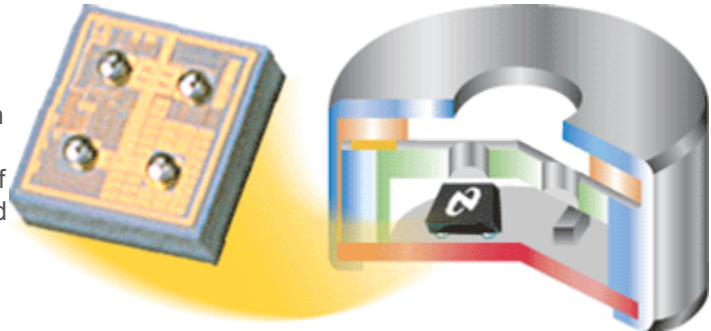
Technology Edge

Integrated Circuits for High Performance Electret Microphones

By Arie Van Rhijn

Introduction

Electret Condenser Microphones (ECM) are used in almost every consumer and communication audio application. The total yearly volume of all ECM's is well over one billion units. Over the years, innovation in ECM's has concentrated mainly on lower cost production and smaller sizes. Other improvements of sensitivity, Signal-to-Noise Ratio (SNR), linearity, and supply current have not been addressed.



In this white paper we introduce significant innovations to ECM's from National Semiconductor through new amplifier IC and package designs. First, a short description of current ECM's using Junction Field Effect Transistors (JFET), focusing on the advantages and drawbacks. After that, two analog amplifiers, replacing the JFET in an ECM, showing the performance improvements achieved. Finally, further innovation through complete Analog-to-digital conversion inside the ECM.

Current Electret Condenser Microphones

The most commonly used ECM's consist of a JFET inside an electret microphone canister, which acts as a buffer between the capacitive sensor and the output. JFET's are small, three-terminal devices that have been improved toward very small, low cost plastic packages. This enabled the main innovation of ECM, their increasingly smaller sizes. Currently, ECM's as small as 2mm in height are common. With a stack of condenser microphone plates and spacers, this requires packaged JFET's as small as 0.5mm in thickness. A cross sectional view of a typical ECM is shown in Fig 1.

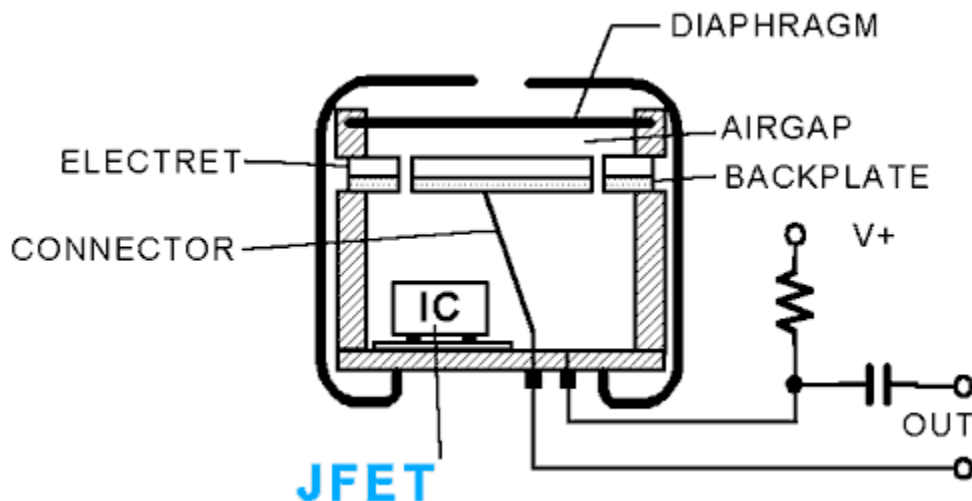


Fig 1. Typical cross section of an ECM with JFET buffer and Phantom Biasing

Biasing And Interfacing The ECM

An Electret microphone consists of a pre-charged, non-conductive membrane between 2 plates that form a capacitor. One of the plates is fixed and the other plate moves with sound pressure. Movement of the plate results in a capacitance change, which in turn results in a change in output voltage due to the non-conductive, pre-charged membrane. An electrical representation of such an acoustic sensor consists of a signal voltage source in series with a source capacitor. The most common method of interfacing this sensor has been a high impedance buffer/amplifier. A single JFET with its gate connected to the sensor plate and biased as shown in

Fig.1 provides the following properties:

- Signal Buffering.

The high input impedance of a JFET gate provides a good interface to the capacitive sensor, and the relatively low resistance connected to the drain provides sufficient output drive toward a signal-conditioning block such as an ADC.

- High Pass Filtering.

Audio microphones need high pass filtering with a cut-off frequency around 100Hz to attenuate large low frequency signals. The input impedance of a typical JFET is around a few 100W, which, with a typical source capacitance of an electret microphone, results in a high pass frequency of a few 100 Hz.

- Self-Biasing Of Active Component

The gate of a JFET is a reverse biased diode, which has some small leakage. This leakage current makes the DC gate voltage settle around 0V, which is the preferred bias condition for this device. Large overdriving signals are either clipped by the reverse leakage or the forward conduction of the gate diode.

- External Phantom Biasing

The method of biasing and interfacing the ECM, called "phantom biasing" through a load resistor of a few kW, and a series capacitor enables a very efficient ECM design with only 2 connections: GND and signal/bias (see also Fig 1.). This enables very low cost ECM's for high volume applications.

The main benefits of this type of ECM are its small size, low cost and relatively low noise. However, the combination of a single JFET and low load resistor results in a low gain (typically -3 dB) and therefore low sensitivity of the ECM. Also JFET's are inherently non-linear (THD of 1-10% typical) and have a large spread on their supply current, due to process spread in threshold voltage.

Having a low sensitivity of the ECM results in small output voltages of the sensor (on the order of 0.1-10mV average, 100mV peak). To make such a microphone work in a system (such as a mobile phone) requires careful board design, along with additional filtering components, to keep a reasonable signal-to-interference ratio. In systems such as wireless communication devices, significant interference is present due to RF transmission and high speed digital processing. Also, to supply the signal to an Analog-to-Digital (ADC) converter, significant pre-amplification is necessary.

Harmonic distortion makes it difficult to design complex audio systems, such as echo cancellation, or achieve Hi-Fi audio specifications.

A large and varying supply current affects battery life in handheld systems, resulting in lower audio performance or talk time in the case of mobile phones.

Analog Pre-Amplified Microphone

The above-described disadvantages of ECM's using a single JFET can be addressed through more complex amplifier circuitry. Until recently, the resulting packaged chip size did not allow these improved pre-amplifiers to fit into the increasingly smaller ECM's. Through a combination of innovative circuit design and packaging technology, significant improvements to properties, such as sensitivity, linearity and supply current, have yielded a small, low cost ECM with greatly improved performance. It is now possible to apply commonly used Amplifier circuit techniques to interface and amplify the signals from an ECM. For instance, applying an Operational Amplifier with feedback, such that a significant voltage gain results, can achieve improvements to sensitivity and linearity. Small packaging will allow this amplifier to still fit inside the microphone canister. Applying this new kind of ECM is therefore transparent to the customer.

Below are two descriptions of Microphone pre-amplifiers designed to fit in the smallest ECM's, both using the common two- and three-wire ECM standards.

Two-Wire, Direct Replacement JFET ECM

For the two-wire ECM application, the Amplifier design goal is to be 100% compatible with JFET ECM's: simply replacing the JFET for a pre-amp that works with a phantom biased interface can bring improvements in sensitivity, gain and THD. A simple voltage amplifier is cannot be used, since in a phantom biased connection, the output of the amplifier is also the supply voltage of the amplifier. Also, in an advanced BiCMOS technology, creating high input impedance, low input leakage as well as a 100Hz high pass filter and fast overdrive recovery is not easy. As opposed to a JFET, a CMOS transistor has extremely low leakage, resulting in near DC response. Using a BJT is difficult because the need for a bias current while the input impedance is greater than 150W. Special design techniques have overcome this problem.

The resulting product, LMV1012 has about an 18dB gain increase over the same ECM with a JFET inside. Output swing levels at the maximum Sound Pressure Levels (SPL) set this gain. For a close-talking microphone and a 2V supply voltage, higher gains (although easily implemented) will result in clipping of the audio signal. The THD is below 0.5% over the complete output range and the supply current is around 300mA. Figure 2 shows a block diagram of this I.C.

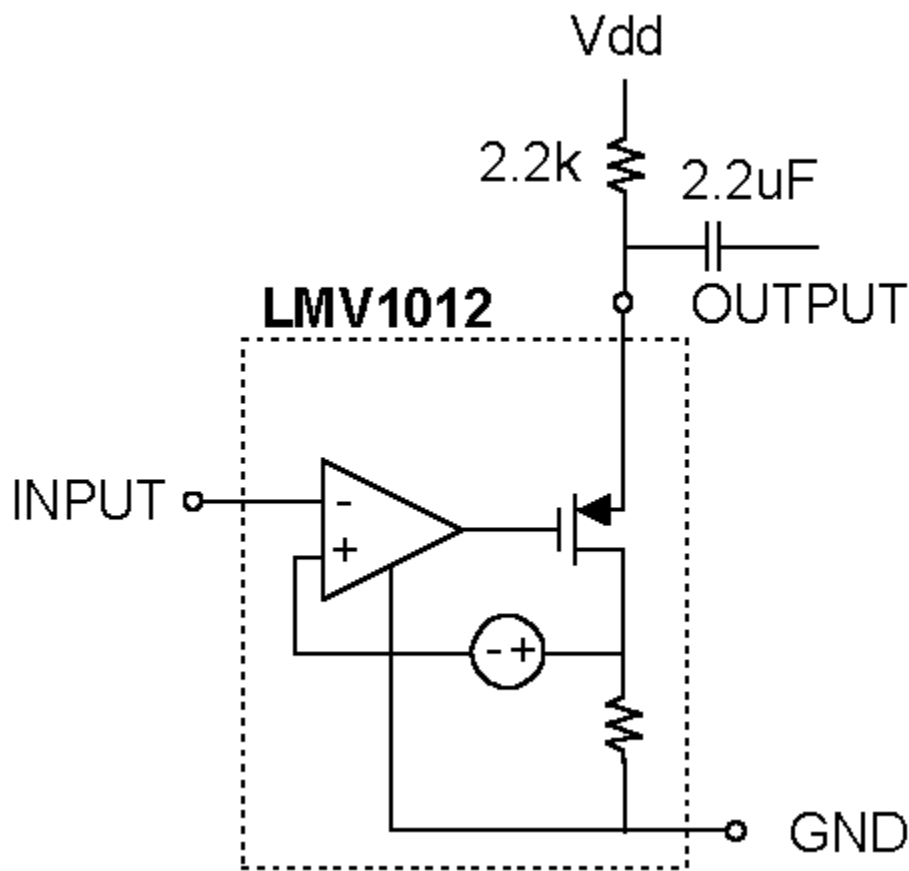


Fig 2. Block diagram of LMV1012

Applying an ECM with integrated pre-amplification results in a better signal-to-interference ratio and THD of the audio input. This reduces the design effort and external components of the audio input, thereby reducing development and production cost.

Because of the direct connection of output to supply voltage in a phantom biased configuration, careful design is needed to maintain a high RF immunity. Specifically in mobile phones, a large (pulsed) RF signal is present during transmit mode, when the audio signal is also sensed. This RF signal can cause interference when received by the ECM. The LMV1012 has similar RF immunity levels compared to a corresponding JFET ECM, which, factoring about a 20dB sensitivity improvement, results in better signal-to-interference ratio.

Three-Wire, High Performance ECM

AN ECM design with a separate supply signal is available, with significant improvements to the PSRR, can achieve output impedance and supply current.

Achieving a high PSRR with phantom biasing is limited because of the direct connection between Vdd and the output. Disconnecting this results in a more general amplifier configuration (see Fig 3.). Now the PSRR can be designed high without affecting the gain or output swing.

In this configuration it is also possible to create low output impedance, making the output signal less susceptible to interference signals.

Finally, because the supply current does not flow through the load resistor, a much lower supply current can be achieved for the same noise level.

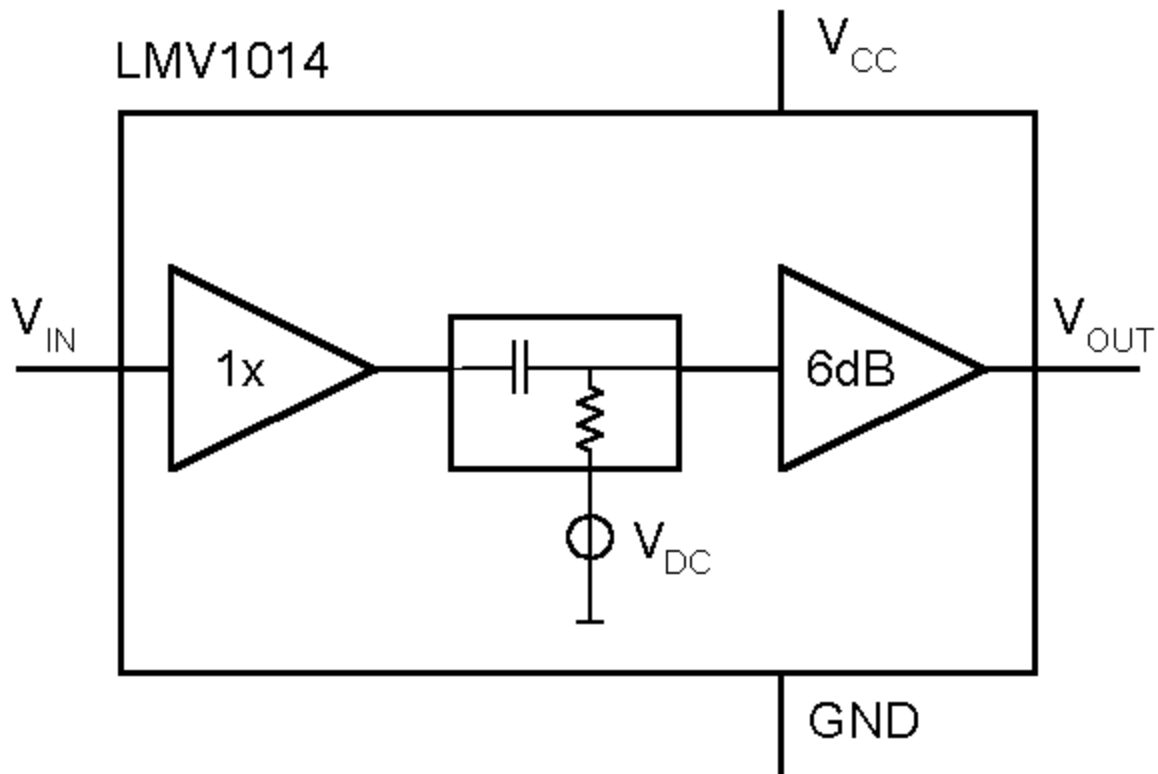


Fig 3. Block diagram of LMV1014

The LMV1014 has been designed for this application and has a low total supply current of 30mA while keeping an overall ECM SNR of >55dB. Furthermore, it has a very low output impedance of 200 Ω and high PSRR of >60dB. The minimum supply voltage is 1.7V. This makes an ECM with LMV1014 very suitable for low power applications.

Conclusion

Combining new Amplifier technologies and advanced miniaturized packaging has created new ECM's with significant performance improvements. These ECM's have new active components inside the ECM canister, making them transparent to the microphone user.

Starting from direct replacement of conventional JFET's in common two-wire microphones, higher sensitivity and lower THD is achieved. In high performance three-wire microphones, very low supply current and excellent PSRR and output impedance is achieved.

[Click here](#), for detailed information on the LMV1012/14 and for information on how to receive ECM samples.

[See related Article](#) Digital Microphones - Applications and System Partitioning, by Arie van Rhijn

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