National Semiconductor

The Sight & Sound of Information

Next-Generation Microphones

Some Jobs Are Better Than Others

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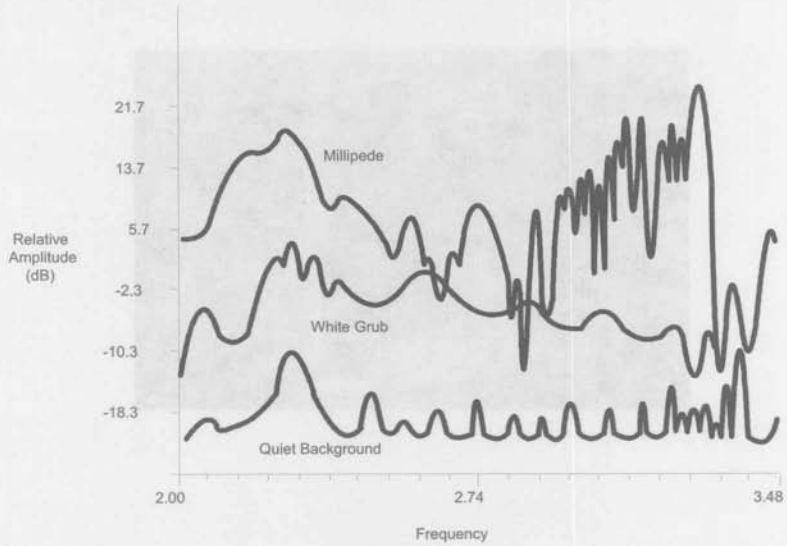
The Art of Analog 73

What are these men doing? They are orchard workers sifting through piles of dirt while sitting under the hot Florida sun. Why? They are listing and counting the insects present in the soil around their fruit trees to determine the level of pest damage that is likely. From this they can decide the amount and severity of the pesticides needed to protect the trees.

Bugging the Bugs



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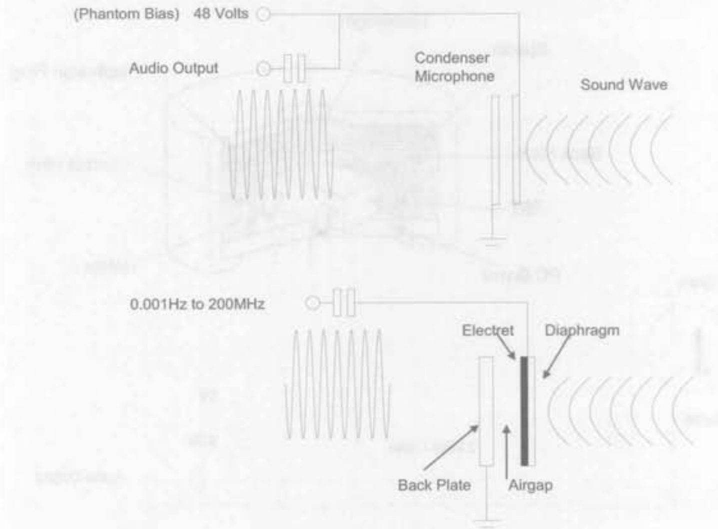
Researchers for the USDA Agricultural Research Service have found that electret microphone elements can provide acoustic signatures for various pests, such as the wheat stem sawfly and weevils, that attack the roots of orange trees. Under reasonably quiet conditions these pests have been detected within a few seconds at distances up to 30cm with 100% accuracy. Even under adverse conditions (high winds or local vehicular traffic) the accuracy is still at least 74%. Other researchers have recorded the Lemon tree borer larva (Oema herta), giving a non-destructive method of detecting borers prior to treatments for infestation.

Electret microphones, the name is said to come from the words *electric magnet*, are the most widely used type of microphones today and it has been estimated that current production is over a billion units a year. Apart from eavesdropping on insects, electrets are used in cell phones, hearing aids, cameras, computers, bat detectors, echo locators and even in high end studio audio. It is unlikely that a day will go by without you coming into contact with, or using, an electret microphone.

Electrets are inexpensive to manufacture, can be made physically very small, yet are rugged and can offer extremely high fidelity.

Condenser and Electret Microphones



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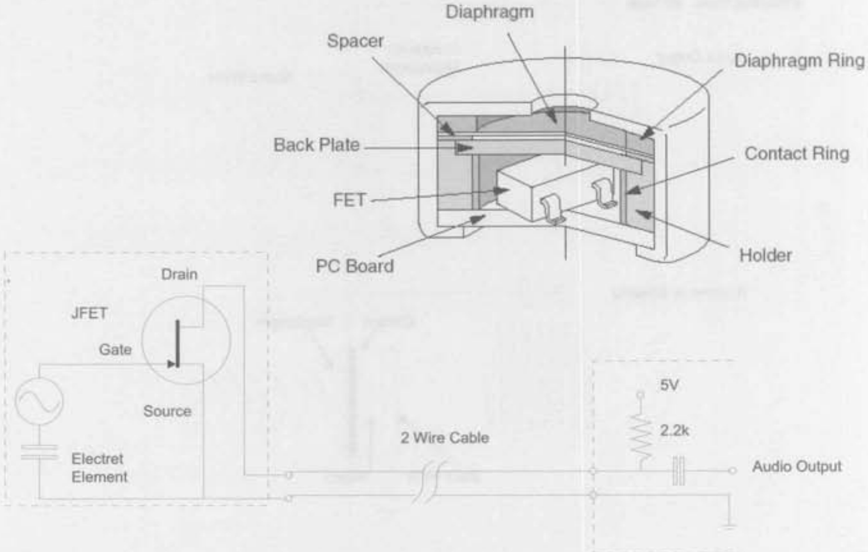
Electret microphones are similar in operation to condenser microphones (and are commonly known as ECMs, or Electret Condenser Microphones) where two parallel plates of thin metal are mounted close to each other. A high dc voltage (c. 50V) is applied across the plates to polarise them with a constant charge. When sound waves impact the plates they flex slightly causing a change in capacitance. This change in capacitance produces an ac voltage with a frequency and amplitude proportional to the sound wave. The electret differs from the condenser microphone in that it does not require the high phantom bias voltage to establish the charge on the plates.

In the late thirties and early forties researchers found that a thick layer of wax material uniformly spread over a thin flexible diaphragm could hold a more or less permanent charge. This electret meant that high bias voltages were not required during use of the microphone elements. Modern electrets are based on the work done by West and Sessler of Bell Labs in the 1960's. They found that a thin foil of teflon dielectric material would hold a permanent charge which, when applied to a diaphragm, established an electric field in the small air gap between the diaphragm and a closely mounted back-plate. Microphones with the electret attached to the diaphragm are known as front electrets. More recently, the electret is applied to the back-plate, (back electrets), allowing thinner (and more flexible) diaphragms to be used. Thin polymer electrets have extended the frequency range from 10^{-3} Hz to over $2x10^{8}$ Hz.

The FET Buffer



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The Art of Analog 76

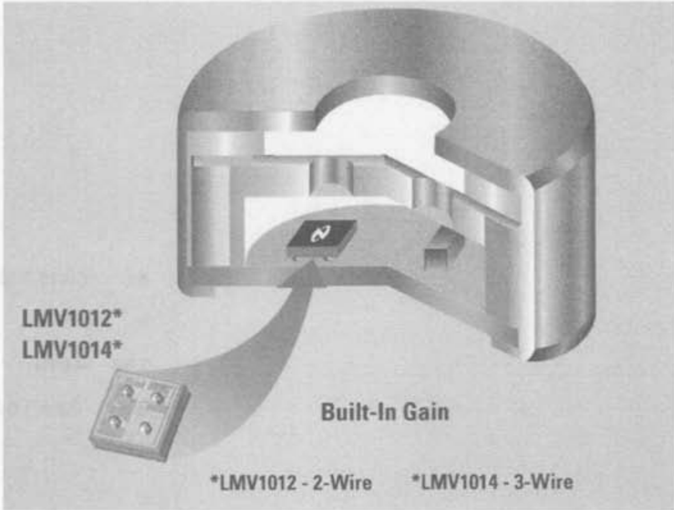
The electret element has a very high impedance and this presents problems in coupling the microphone output to subsequent amplifier stages, particularly if these amplifiers are at the other end of a cable. To a large measure this has been solved by using JFETs to buffer the element and present a relatively low impedance to the cable, as shown above. Although the JFET requires a dc bias voltage, the standard two wire cable is still used, with the bias source at the other end of the wire carrying the signal output. This is not phantom power in the sense applied to condenser microphones, and is usually a much lower voltage, from 1V to around 9V. The microphone impedance is related to the size of the bias resistor and is most often in the range of 2 kΩ to 5 kΩ.

An important factor in the development of electret microphones is decreased size. Early JFET ECMs were quite large in order to accommodate the JFET packages, but now JFET packages as thin as 0.5mm are commonly available and the total ECM thickness is as small as 2mm.

Along with small size the JFET confers additional benefits, particularly in telephony applications. The gate impedance of the JFET, along with the capacitance of the microphone element forms a low pass filter with a cut-off frequency around 100Hz. This helps to attenuate large low-frequency signals such as wind noise or breath noise with close-in speakers. The gate is a reversed-biassed diode connected across the capacitive signal source. Leakage current in the gate diode ensures that the gate voltage is close to 0V. Very large overdriving signals are clipped by forward conduction of the diode and the reverse leakage current.

While the JFET buffer has benefits, it also has disadvantages. The output signal is developed across the load resistor that is also supplying the current to the JFET. This means that the JFET will have low gain and the ECM will have low sensitivity. The spread in gate threshold voltage means that there will be a large variation in the supply current drawn by the ECM, from 200uA to over 800uA, and the THD will be in the range of 1 to 10%.

Next-Generation Electret Condenser Microphone



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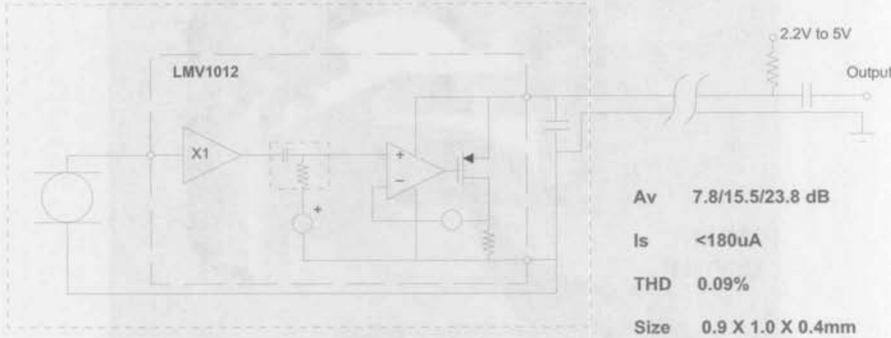
The Art of Analog 77

While JFET packaging developments have made it possible to produce ECMs with very small form factors, very little has been done to improve the sensitivity and lower the THD of the buffer amplifier. Efforts to replace the JFET have met with limited success….until now.

Utilizing experience in designing and manufacturing small, low power consumption operational amplifiers, National is introducing a new range of pre-amplifiers intended for use with electret microphones, both 2-Wire and 3-Wire, with improved performance over their JFET equivalents.

Integrated 2 Wire ECM



Av	7.8/15.5/23.8 dB
Is	<180uA
THD	0.09%
Size	0.9 X 1.0 X 0.4mm

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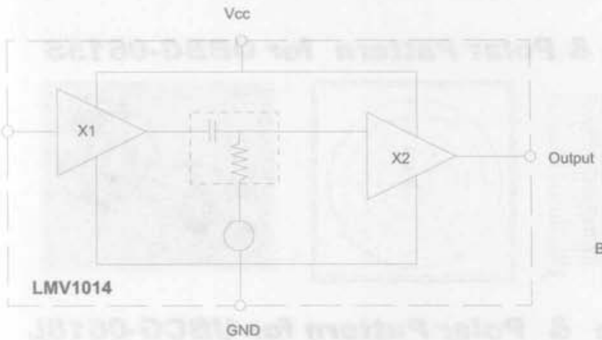
Overcoming the JFET's disadvantages with an integrated pre-amplifier while retaining the benefits and still remaining low cost can be quite challenging. High-input-impedance amplifiers are readily available but the smallest of these are typically in five lead packages with a package thickness of 1.1mm.

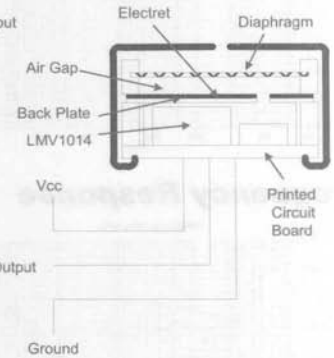
In 1999 National introduced the chip scale package, known as micro SMD, which is now available with dimensions of 0.93 X 1.0 X 0.4mm. Since the introduction of the micro SMD package, we have designed and manufactured a number of low-voltage, low-power amplifiers using a BiCMOS process. CMOS devices have near ideal high input impedances (>1000GΩ) but, unlike a JFET, the input stage requires biassing for linear operation and help with recovery from input overloads. In the LMV1012 this bias is provided by back to back diodes which also make a fast recovery circuit for the input MOS follower. Large, low frequency signals are attenuated by an internal high pass filter before the signal is passed on to the high-gain output stage. The filter also provides a convenient point to dc bias the output stage to approximately half the nominal supply voltage for maximum output dynamic range. To replicate the two wire output of the JFET ECM, a transconductance stage sets a current flowing through the load resistance. Since the output node is the supply rail, RF signals on the supply rail can be coupled into the circuit. Most ECM manufacturers add small by-pass capacitors (20-30pF), but careful layout of leads from the microphone are still required.

Signal voltages from the electret* are of the order of 100uV to 10mV on average, with 100-130mV peaks. The LMV1012-15 has a set gain of 15.5dB to avoid clipping on high signal swings. Higher (23.8dB) or lower (7.8dB) gains are available with the LMV1012-25 and the LMV1012-07 respectively. All three devices feature THDs of 0.1% and SNRs of 60dB.

*OBBG 0615S/0622S from BSE (www.bsecm.com)
Best Sound Electronics
#869-3, Jacjun-1dong
Keiyang-ku, Inchon-si, South Korea.

3-Wire ECM





Is	38uA
PSRR	88dB
Zo	<200Ω
Vcc	1.7V to 5V

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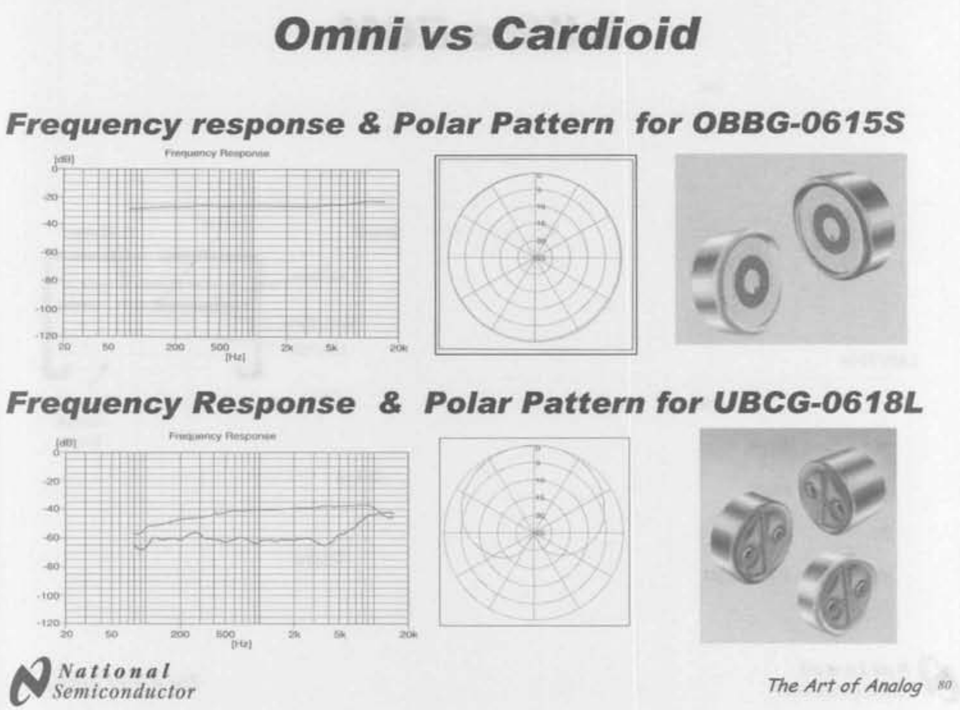
The Art of Analog 79

The LMV1012 is designed as a direct replacement for the conventional JFET ECM. With the same form factor, replacement involves simply substituting the microphone elements. Immediate benefits are improved sensitivity, lower distortion and lower supply currents (total supply current with 2.2KΩ loads are 160uA for the LMV1012-07 and LMV1012-25, and 200uA for the LMV1012-15).
Some battery-powered applications (Bluetooth™ technology) need even lower supply current levels, and if a 3 wire interconnect to the ECM is permissible, a more conventional output stage, such as that used by the LM1014 can be employed. Separating the output lead from the supply current lead means that high PSRRs can be readily achieved (88dB) with a much lower total supply current (38uA) for comparable noise levels. Although the PSRR falls off above 1kHz, it is still good enough to handle the GSM modulation rate of 216 Hz and its harmonics. RF decoupling capacitors may still be required on the supply line, but the lower output impedance of the LMV1014 (<200Ω) makes the signal output less susceptible to noise pick-up.



An omnidirectional microphone has an equal response to sound waves coming from all directions. A cardioid microphone, sometimes called a noise-reducing microphone, has reduced response to sound waves that are off-axis. Note that this is a decreased response, not an enhanced response to on-axis signals.. Because the off-axis response to ambient noise is less than that for an omnidirectional microphone, the cardiod is said to have a distance factor. For example, a distance factor of 1.8 means that the cardioid will have the same signal to ambient noise ratio at 18 inches as will the omnidirectional at 10 inches. Cardioids will also exhibit a proximity effect. When the speaker is close in to the microphone, frequencies below 500Hz get boosted compared to frequencies above 500Hz. This means that a voice can sound richer and deeper close to the microphone, but thinner and reedy further away from the microphone.

References

0dB SPL smallest sound normally detectable (20μPascals)

60dB SPLNormal speech at 3 feet distant

70dB SPLBusy Traffic

74dB SPLNormal speech at 1foot distant

94db SPL Normal speech at 1 inch distant (1 Pascal=10μbars=10dynes/cm^2)

Electret Microphone Sensitivity	*= -44dB SPL*	*= 6.3mV*
Amplified by the LMV1012		*= 38mV*
		= -28.5dB SPL

On the previous page, the frequency response for each microphone element was plotted with respect to relative amplitude …….. relative to what? Unfortunately, microphone manufacturers and the makers of electronic amplifiers have their own favourite reference levels and you need to know the relationship in order to make comparisons of specifications between different microphones. For the amplifier it is useful to know the microphone sensitivity in dB relative to 1 Volt (dBV), or for professional audio equipment in dB relative to 0.775 Volt (dBu), in order to determine if the amplifier noise floor will affect the overall S/N ratio. For the microphone manufacturer it is more useful (for comparative purposes) to know the sensitivity relative to sound pressure level (SPL).

0dB SPL (20μPa) is considered to be the smallest detectable sound level but this is not the reference level used for the microphone sensitivity specification. Instead either 74dB SPL or 94dB SPL are used as references. 74dB SPL is the sound pressure generated by normal speech at 1ft from the microphone. 94dB SPL is the sound pressure for normal speech within 1in of the microphone and corresponds to 1 Pascal = 10 μbars = 10 dynes/cm2. The reference voltage level is 1V/Pa. For example a microphone element with a sensitivity of -44dB SPL relative to 1V/Pa will generate a voltage of 6.3mV. Amplified by an LMV1012-15 this will give a microphone output level of 37.8mV or –28.5dB SPL.

Microphone noise measurements are given either as a SNR (dB) ratio or as a voltage referenced to 1V (dBV). It is not always clear which one is being used and the measurements are invariably A-weighted. This comes from the early days of telephony where measurements were made through a band-pass filter centered at 2-3kHz with a sharp rolloff on either side, -10dB at 20kHz and –20dB at 100Hz. A-weighting usually improves the measured S/N by 3dB to 6dB over an unweighted measurement.