Name/NetID: Teammate:

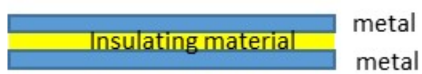
Module: Characterizing an Electret Microphone

Module Outline

In this module you will learn to use an electret microphone. There are many different technologies used to manufacture microphones – you have them in your phones, computers, cars… The microphones that you will be experimenting with here are small, decent quality microphones that the hobby community has embraced because they are relatively easy to use.

A microphone is a *transducer* – a device that converts energy from one form into another. In the case of a microphone the device is sensitive to the small fluctuations in air pressure that our ears interpret as 'sound'. These fluctuations are converted to, as with all devices used by electrical engineers, a voltage. The tricky part when using a microphone is that the voltage fluctuations need to be amplified if the signal is to be interfaced with other devices like a speaker or an Analog-to-Digital Converter (a device that digitizes analog signals) for speech recognition.

The sound is transformed into a voltage by using a very small capacitor. Remembering that the capacitance C=QV, how might this device be used to detect pressure variations and convert them into a voltage variation? To understand how this happens it helps to know how capacitors are configured and how that configuration determines the *capacitance*.



Capacitors are usually made from 2 closely spaced metal plates that sandwich an insulating material. The size of the plates and the measure of polarizability of the insulating material all contribute to the capacitance. A more complete explanation can be found in the 'Making a Capacitor' Module – for now let's go with the relationship $C = \varepsilon \frac{A}{d}$ which states that the capacitance depends upon how big the area of the metal layers are (A), how polarizable the atoms/molecules are in the insulating material, and how close the metal plates are. It is difficult to imagine how the area of the metal plates might change in response to differences in air pressure or the properties of the insulating material. But if the capacitor is built so that the metal plates can move easily in response to changes in the air pressure then the *distance between the plates* can change. So the change in voltage ΔV=ΔC/Q occurs as the capacitance changes assuming the charge can be maintained at a constant level.

Notes:

The specialness of the electret microphone lies in the fact that the capacitor is made from a special type of material whose molecules are all permanently polarized and aligned so that there is a permanent charge separation without any external circuitry – it is the electric equivalent of a permanent magnet. As the material is deformed by the sound a voltage is generated.

Pertinent Information

A portion of the datasheet is shown below. It was obtained from the Sparkfun website. To hook up the microphone several pieces of information are important. The most important of which is specified in the DESCRIPTION and the Loading Resistance section.

Omni-Directional Foil Electret Condenser Microphone

DESCRIPTION

Omni-Directional Foil Electret Microphone, 9.7 mm diameter and 4.5 mm high, Power Supply 5.0 V max, External Resistance Loading of 680 Ω, and sensitivity of -44 dB. Terminated with 2 solder points, Lead Free RoHS Compliant

SPECIFICATIONS:

Direction	Omni Directional Foil Electret	Minimum Direction sensitivity	
Operating Voltage Range	Vs= 1.0 Vdc ~ 10.0 Vdc	Power Supply (Vs)	1.5 V
Frequency Range	100 ~ 10,000 Hz.	Maximum Current	0.5 mA
Sensitivity	- 46 ± 2.0, (0 dB = 1V / Pa) at 1K Hz.	Minimum Sensitivity to Noise Ratio	58 dB
Sensitivity Reduction	3.0 V to 2.0 V -3 dB	Maximum input S.P.L.	110 dB at 1.0 KHz, THD <1%
Operating Temperature	-20ºC to + 60ºC	Storage Temperature	-40ºC to + 75ºC
Loading Resistance (R_L)	External, 680 Ω at Vs = 1.5 V, Max. 2,200 Ω	Built in Capacitors	None
Termination	PC Pins, 4.5 mm Long, 0.6 mm ø, 2.54 mm Spacing		

Dimensions	Length / Diameter	9.7 mm ø	Height	4.5 mm	Housing Material	Al-Mg Alloy.	Color	
Approximate Weight	0.7 grams	Options				Compliance	RoHS, Lead Free	

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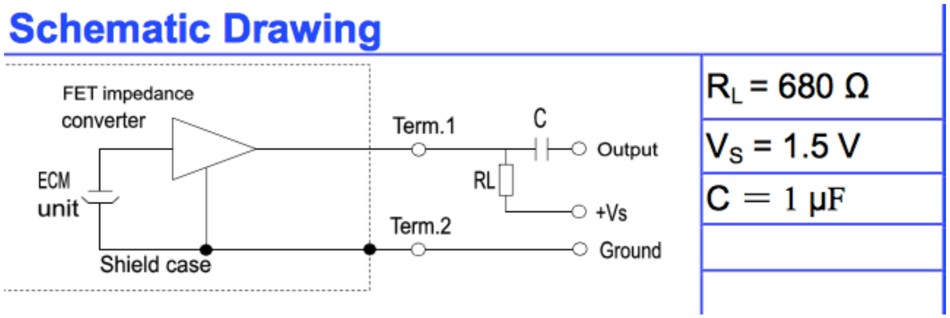
To make sense of this information a schematic of what is inside the microphone is included and is shown below. It includes, not only the sub-circuits inside the device but also the suggested external circuitry. Inside the device is the microphone (labeled ECM) and an FET that is used to buffer the electret microphone capacitor (ECM in the diagram) voltage so that the microphone can be connected to an amplifier circuit. The microphone itself needs no external power since it is permanently charged but the FET needs an external supply with a suggested value of 1.5 V in series with a resistor and a by-pass capacitor.



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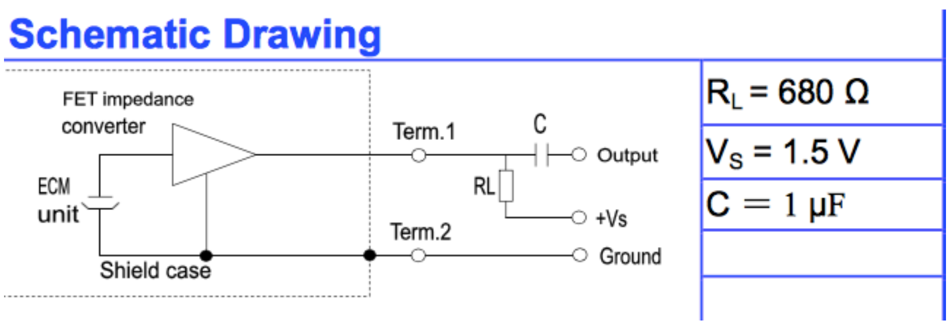
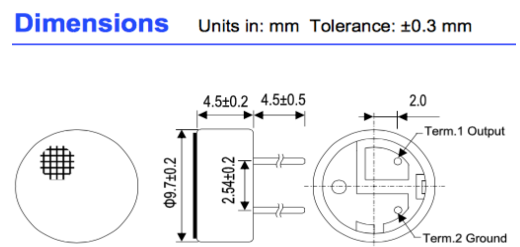
Procedures

Build and Experiment with parameters of External Circuit

To better understand how to interface the world of sound in the form of pressure waves to the world of electronics in the form of a voltage let's experiment with the circuit suggested in the datasheet.

- ✓ Build the circuit with the microphone unit, 680Ω resistor, using the power supply set to 1.5V. Note: the microphone has two terminals but each is different. One is labeled **Term. 1 Output** and **Term. 2 Ground**. It is a little hard to distinguish terminal 1 from 2 but you should be able to use the figure to the left help. DO NOT ADD the external capacitor yet.
- ✓ Probe the voltage across the terminals of the microphone with channel 1 of the oscilloscope with a vertical scale of 1V in high impedance mode.





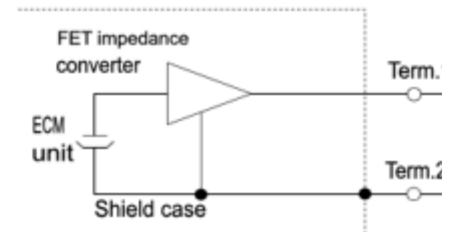
Question 1: Talk into the microphone or tap it with your finger. Once you get the parameters set correctly when you will see a dramatic response. But at first you should just see a constant 1.5V signal and maybe some wiggles around this voltage. To see the signal generated by the sound you need to remove the DC offset – remember the

Notes:

AC coupling mode of the oscilloscope? Turn AC Coupling on for channel 1. Now you should see a dramatic response. Capture a couple of screen shots of the oscilloscope and notate what you noise you were making (you may need to change the scale on channel 1). Try a single note, a song from your phone…

Powering the microphone –

The electret microphone does not actually need to be powered – it is the Field Effect Transistor included inside the device that needs to be turned on. The FET allows the microphone to be connected to external circuitry so that the device functions no matter (within reason) how you use it in a circuit. One constraint when using these microphones is the available source voltage – our batteries deliver 7-9V and the datasheet implies that the microphone can be used with up to 10V but the suggested voltage 1.5V is actually quite low so let's see how sensitive the microphone output is to the voltage driving it.



What happens to the signal if the voltage is increased?

Question 2: Using either the computer, or your phone output a single tone – the concert A at 440Hz (YOUTube has a video with hours of the same tone). The important parameter to note is the amplitude of the signal – you can use either the traditional definition of amplitude or you can be a signal generator and specify the peak-to-peak amplitude. Use the table supplied below to note the amplitude when the microphone is powered by the specified different voltage levels.

Voltage (V)	Amplitude (V)
1.5V	
3.3V	
5V	
9V	

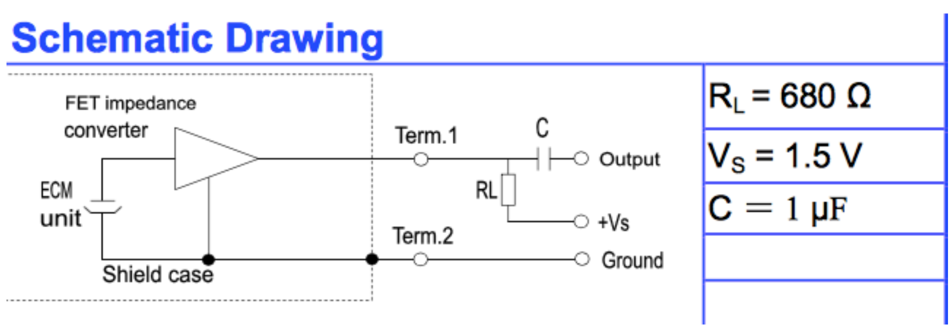
Question 3: Describe the effect, if any, of the variation in voltage on the output signal.

As it happens the behavior of the microphone is relatively insensitive to the voltage – 9V is actually larger than the recommended 5V max. This can come in handy if other components in your circuit – like an amplifier stage to increase the output voltage of the microphone – are powered by say 5 or 9V. Then the microphone can be powered without having to decrease the voltage using extra circuitry.

Exploring Output Impedance –

The datasheet recommends a value of 680Ω for the serial resistor labeled R_L in the figure below, but if you have been monitoring the current drawn from the power supply it has been negligibly small regardless of the voltage. The resistor value was chosen under the assumption that you will be using the device for a specific application – interfacing it with amplifiers and speakers with known electrical characteristics.

- ✓ Disconnect the microphone circuit from the power supply and connect it to the 5V coming out of the Arduino/Redboard as this is probably how you will be using the device.



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Question 4: Keep monitoring the same voltage across the microphone on channel 1 while playing the 440Hz tone. Using the table provided below change the resistor value sampling the range 100Ω - 100kΩ noting the amplitude of the signal as before.

Resistance (Ω)	Amplitude (V)
100	
680	
1k	
10k	
22k	
1M	

Question 5: How does the amplitude depend on the value of resistor R_L?

Adding the By-pass Capacitor –

- ✓ Put the capacitor into the circuit – any of the small orange capacitors in your kit will work fine – the exact value is not important for your applications.
- ✓ Keep monitoring the output of the microphone with channel 1.

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- ✓ Use channel 2 to monitor the voltage on the other side of the capacitor.
- ✓ Set the coupling mode of both channels of the oscilloscope to DC coupling.

Question 6: Using any sound describe the effect of the capacitor on the circuit by comparing what you see looking at channel 1 and channel 2.

Question 7: (Optional) Explain why this works – a capacitor used this way is call a by-pass capacitor.

Now what? You have a working microphone that you can drive with a voltage from 1.5 – 10V, in series with a resistor whose value depends upon what will be connected to the output, and a capacitor that you may or may not need again depending on what will be connected to the output. This is only the beginning of designing a microphone into an application. Luckily this device is very flexible working at voltages up to 10V (it gets a little toasty warm at higher voltages but is quite the trooper) and with a wide range of impedances. The microphone part of the circuit is the easy part.

Most designs go one of three ways: i) connect the output to an analog input on the Arduino/RedBoard, ii) connect the output to an amplifier using an op-amp circuit, iii) or connect the output to an amplifier using a transistor circuit.

As you saw the microphone only outputs at most a couple hundred mV which CAN be detected when the microphone is connected directly to the Arduino, but a change of 10 – 20, at most, in the digitized version of the analog signal out of 1024 is the best you can hope for.

The next step is usually to connect the microphone to an amplifier – depending on your choice you are now prepared to optimize the output performance of this little beauty for any application.