Reading 17

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MICROPHONES

SOUND

Sound consists of small fluctuations in air pressure. We hear sound because these changes in air pressure produce fluctuating forces on our eardrum. You only have to place your hand in the front of your mouth while you are talking, or in front of a sound system to actually feel the fluctuating forces.

Similarly, microphones respond to the changing forces on their components and produce electric currents that are effectively proportional to those forces.

The best way of detecting sound is with a diaphragm ('dia'-'fram'). Our eardrums are in effect a diaphragm. Just like the skin or covering of a musical drum. When sound waves enter the ear, the force of the sound waves cause the eardrum to vibrate. Vibrations from the eardrum are transmitted by various structures in the ear to our brain for processing.

All microphones have a diaphragm, which usually consists of some type of taut material like plastic, paper, or even very thin aluminium. With all microphones, sound waves strike a diaphragm and cause it to vibrate. This vibration is then, by the mechanism of the microphone, made to make a voltage or current vary in sympathy with the sound waves. The voltage or current thus produced can be made to travel long distances (if necessary) along conductors and then we can recover the sound by converting current variations back into sound wave variations.

THE CARBON MICROPHONE

Carbon microphones are no longer used, as they are very poor quality. However a short discussion of the carbon microphone is a good introduction to all microphones. The carbon microphone was once the only type of microphone used in telephones and two-way radios.

The principle of operation was both simple and ingenious. Sound waves strike the diaphragm and move it. The movement of the diaphragm causes a plunger or piston to move with it.

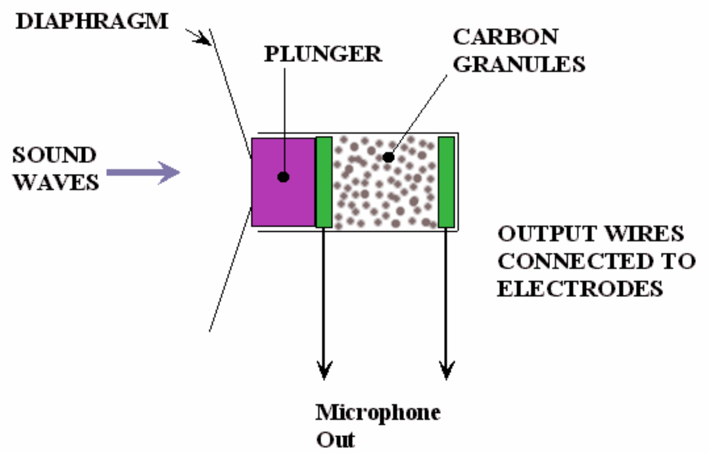

Figure 1 – Carbon microphone.

The plunger compresses and decompresses a chamber filled with carbon granules. Now, carbon granules will conduct electric current. If a battery is connected to the microphone terminals a current will flow. How much current flows will depend on the degree of compression of the carbon granules. If the sound wave forces the diaphragm inwards, then the granules are compressed, and their resistance decreases and the current increases. Similarly, if the sound amplitude (loudness) decreases, the tension of the diaphragm allows it to move outwards, which means the carbon granules are under less pressure, the resistance increases, and so the current decreases.

In other words, the resistance of the carbon microphone varies in sympathy with the sounds waves that strike the diaphragm, and this in turn causes a varying current in the circuit which is a good representation of the original sound wave.

Carbon microphones were used for many years. You may have seen people bang a telephone handset against something to get rid of noise. This is because the carbon granules would cling together a bit in older microphones and make a noise called 'frying' because the noise sounded like something frying in a pan.

THE DYNAMIC OR MOVING COIL MICROPHONE

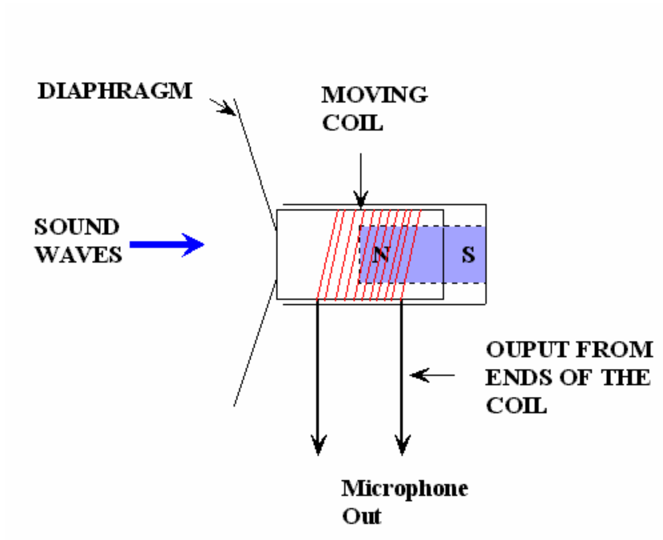

Figure 2 – Dynamic or moving coil microphone.

In the dynamic microphone the diaphragm is connected to a lightweight coil. Inside the coil is a permanent magnet. When sound strikes the diaphragm, the coil will move back and forth in the magnetic field of the permanent magnet. We have relative motion between a conductor and a magnetic field (Faradays Law), so an emf or voltage is induced into the coil. This induced emf is a very good electrical representation of the original sound wave. A dynamic microphone produces its own output voltage and does not need a battery like the carbon mic.

Dynamic microphones can be made in various impedances. (Impedance is the total opposition to current flow in an AC circuit). The dynamic microphone or some variation of it, is widely used in telephones, radiocommunications and quality sound recording.

IN REVERSE A SPEAKER!

The speaker is essentially the same as the dynamic microphone, except the current carrying the sound to be recovered is fed through the coil, which creates a moving magnetic field around the coil. The interaction between the magnetic field about the coil and the field of the permanent magnetic cause the diaphragm to move back and forth. The motion of the diaphragm recreates the original sound wave.

A SIMPLE TELEPHONE (FAR SOUND)

You do not need to know how a telephone works, however, looking at a simple telephone circuit will help to consolidate what you do need to know. In figure 3 we have a carbon microphone, a source of emf, and a speaker in series. A current will flow in the circuit without any sound. When sound hits the diaphragm of the microphone, its resistance will vary in accordance with the sound wave amplitude (loudness) and frequency. This causes corresponding current variations to flow through the entire circuit. This current contains all of the information present in the original sound wave (amplitude and frequency). Since the current flows through the moving coil of the speaker, the diaphragm (cone) of the speaker will move back and forth with the same frequency and amplitude of the original sound wave and therefore recreate it.

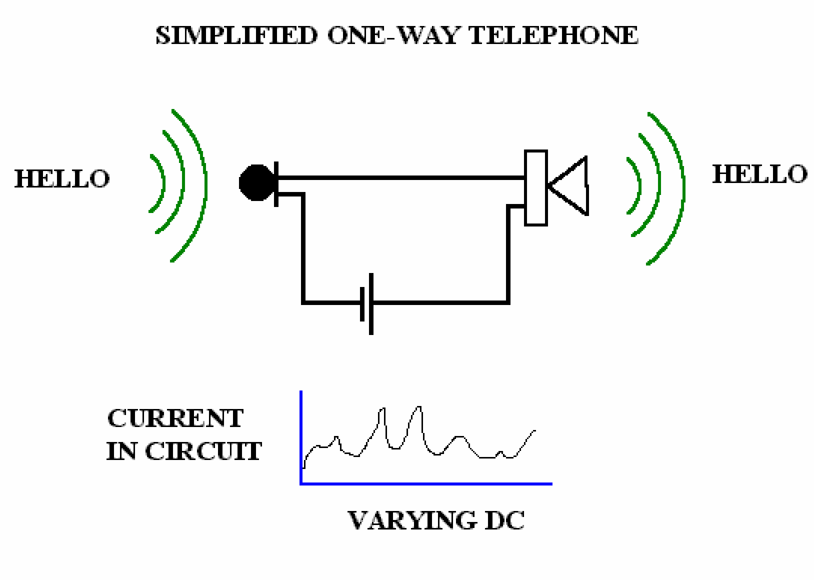

Figure 3.

The distance between the microphone and the speaker can be a long way apart enabling voice communications over a long distance through wires. Add another microphone and speaker and you would be able to have two-way communications. The modern telephone is really not much more than this in principle. The carbon microphone that was used in telephones for many decades, has been replaced by a variant of the moving coil type (rocking-armature). It does seem so simple does it not? Yet the impact of the telephone when it was first invented had a profound effect on the world. Of course the telegraph came first. However, imagine how mysterious and wonderful it must have been for the first telephone users to hear and talk to someone thousands of miles away.

The word telephone comes from the Greek roots tele ("far") and phone ("sound"). Alexander Graham Bell invented the telephone, though many others improved on the invention. The U.S. patent granted to Bell in March 1876 (No. 174,465) for the development of a device to transmit speech sounds over electric wires, is often said to be the most valuable ever issued.

CONDENSER (CAPACITOR) MICROPHONE

When we learned about capacitance, we found that the capacitance of a capacitor was determined by the area of the plates, the type of dielectric, and the distance between the plates.

Now, suppose a capacitor is connected to a source of emf and allowed to fully charge (at least 5 time constants). What would happen if we left the capacitor in the circuit and somehow altered its capacitance?

If we increased the capacitance of the capacitor in the circuit it would be able to hold more charge. So increasing the capacitance would cause the capacitor to charge further and current would flow in the circuit while the charging process was taking place. If we then decreased the capacitance, the capacitor would no longer be able to hold as much charge and it would discharge back into the source of the applied emf. While it is discharging, current would again flow in the circuit.

In the capacitor microphone this is exactly what happens. One of the plates of the capacitor is made of very light material and is the diaphragm of the microphone. Sound waves striking the diaphragm (one plate) will cause it to vibrate in sympathy with the sound waves. The moving diaphragm (plate) will cause the capacitance to change. As the diaphragm moves in, the capacitance will increase and a charge current will occur. As the diaphragm moves out, the capacitance decreases and a discharge current occurs. Since the motion of the diaphragm and the capacitance are in sympathy with the sound waves, the charge and discharge currents are once again an electrical representation of the original sound wave.

The diaphragm of the microphone can be one of the plates of the capacitor microphone, or a diaphragm can be connected mechanically to make a capacitor plate to move.

Like a carbon microphone, the capacitor microphone needs a source of emf, as it does not generate any of its own.

The term 'condenser' is an old term for capacitor. When you see these microphones referred to, the words 'condenser' and 'capacitor' are often used interchangeably. I prefer 'capacitor microphone' but it seems for many the term 'condenser' has stuck from tradition. Capacitor microphones have the advantage of being very small, which makes them attractive for use in small equipment, such as handheld two-way radios (transceivers) and small tape recorders, and the like.

The quality of the capacitor microphone, like the carbon microphone is not all that good. However, for voice communications they are more than adequate.

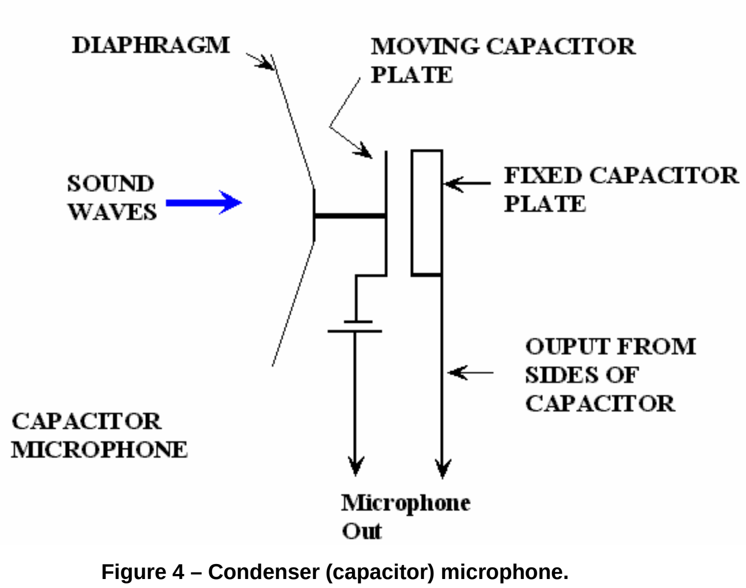

Figure 4 – Condenser (capacitor) microphone.

Since I just touched on quality in the last paragraph, I thought I might as well discuss a microphone's requirements for radio-communications. It has been found that the intelligence content of a human voice is mostly contained in the range of frequencies from 100Hz to 3000Hz (voice frequencies). For a microphone to operate over this range of audio frequencies is not asking much. Communications microphones then, are not to be compared in quality to sound recording or radio/television broadcast microphones.

There is a special type of capacitor microphone called the 'electret microphone'. The principle of operation of these microphones is identical to that of a capacitor microphone.

However, a special electret material is used as the dielectric in the capacitor. The electret microphone does not require a bias battery. An electret material is one that holds a charge for many years similar to the way a magnetic material can hold a magnetic field for a long time.

For exam purposes you need only remember that an electret is the same as an ordinary capacitor microphone, however it can be used without a bias voltage.

The dynamic and capacitor microphones are the most popular microphones for radiocommunications.

CRYSTAL MICROPHONE

The Piezoelectric Effect (pee-zo-electric)

If a piece of quartz crystal is held between two flat metal plates and the plates are pressed together, a small emf will be developed between the plates, as if the crystal became a small battery for an instant. How much emf is produced is pretty much proportional to the pressure applied. When the pressure on the plates is released the crystal springs back and an opposite polarity emf is produced on the plates. In this way mechanical energy is converted into electrical energy by the crystal.

If an emf is applied to the plates of a crystal, the physical shape of the crystal will distort. If an opposite polarity emf is applied, the crystal will reverse its physical distortion. In this way a quartz crystal converts electrical energy to mechanical energy.

Note: Some ceramic materials also exhibit a piezoelectric effect.

These two reciprocal effects of a crystal are known as the piezoelectric effect.

Well, if you are thinking ahead of me, here we have another way to make a microphone. After all, the function of a microphone is to convert mechanical energy (sound waves) into electrical energy and the piezoelectric effect does just this.

Sound waves striking the diaphragm cause varying pressure to be applied to the crystal, which in turn causes the microphone to produce an output voltage in sympathy with the sound waves. A crystal microphone does not require a battery. Like the dynamic microphone, it directly converts mechanical energy into electrical energy.

The crystal earpiece is the same principle used in reverse.

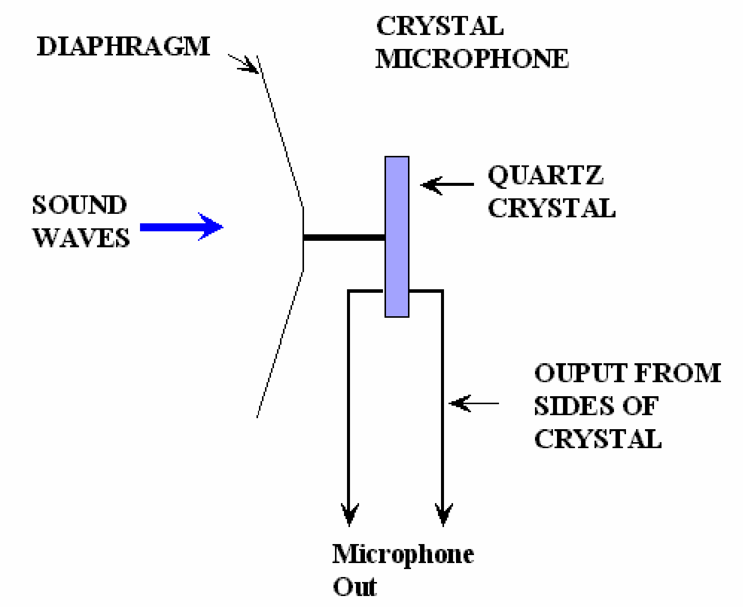

Figure 5 – Crystal microphone.

Crystal microphones are not high quality but they have the advantage of being very small and inexpensive. By the way, the quartz crystal is not used the way you have seen them in nature. They are cut into thin slices.

Well, that’s about it for microphones. Microphones used for radio communications are not high fidelity (high quality). Talk to a recording or sound engineer about microphones and they can go on about all of the different types used in their field. For example, special microphones that pick up sound from some directions and not others, etc. However, for us radio communication people, a simple dynamic or capacitor microphone does the job.

MICROPHONE AMPLIFICATION

Because the output of a microphone is very low in electrical terms, in almost all applications, an amplifier called a microphone amplifier or pre-amplifier, is connected to the microphone to increases the level of the output signal. Many microphones come with a built in amplifier in the microphone housing.

A common mistake

Many radio operators add microphone amplification to their transceiver. This is fine, however adding too much amplification causes distortion to the transmitted and received signal that does not sound good (though many think it does) and can cause interference to other radiocommunications users. We will be discussing this in depth later (called ‘overmodulation’)

WHAT'S IN A NAME

Alexander Graham Bell (born March 3, 1847, Edinburgh. Died, August 2, 1922, Beinn Bhreagh, Cape Breton Island, Nova Scotia, Canada). Scottish born American audiologist best known as the inventor of the telephone (1876). For two generations his family had been recognised as leading authorities in elocution and speech correction, with Alexander Melville Bell's Standard Elocutionist passing through nearly 200 editions in English. Young Bell and his two brothers were trained to continue the family profession. His early achievements on behalf of the deaf and his invention of the telephone before his 30th birthday, bear testimony to the thoroughness of his training. Biography source - Encyclopaedia Britannica.

Guess where the term decibel i.e. tenths of a Bel comes from!

End of Reading 17.
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