Homebrew

The microphone: your voice transmission starts here...

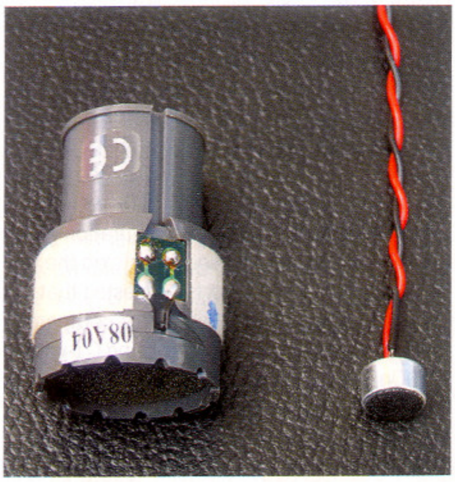


PHOTO 1: Typical dynamic microphone (left) and electret condenser mic (right). The electret mic is 9.8mm diameter.

ESSENTIAL ITEM. The microphone is one of the most important components of a telephony transmitter. As the microphone is the very first stage in a phone transmitter, any distortion or noise from the microphone or its amplifier is sure to degrade the quality of the transmitted signal. The amateur radio shack can be a harsh environment for a microphone. RF signals at high field strength and strong magnetic fields from power supply transformers are easily picked up by the mic. Acoustic noise from cooling fans is another source of unwanted noise.

A microphone is a transducer that converts sound (vibrations in air) into a varying electrical voltage or current. This electrical signal can be amplified and used to modulate a speech transmitter. 'Dynamic Mike' is not necessarily the name of a particularly lively radio amateur; the word 'microphone' is often abbreviated to 'mike' or 'mic'. There are many different types of microphone in common use.

- Some older military equipment used carbon microphones of the type that used to be found in telephones. The carbon microphone uses a loosely packed capsule of carbon granules that are in close contact with the diaphragm. Vibration of the diaphragm causes small changes in resistance of the carbon granules.
- Crystal microphones have a piezoelectric material in contact with the diaphragm. Stresses caused by the vibrating diaphragm generate a voltage across the piezoelectric material.
- Condenser (capacitor) microphones use one plate of a capacitor as the diaphragm. The second plate is fixed in position. A polarising bias voltage is applied across the two plates. Movement of the diaphragm plate relative to the fixed plate causes the capacitance to vary. This produces a changing output voltage.
- The dynamic microphone is an electromagnetic device that works in the same manner as a moving coil loudspeaker. The diaphragm is connected to a coil that is suspended in a magnetic field. Movement of the diaphragm will produce an electric current in the coil.

Carbon microphones are rarely used today because they tend to suffer from higher levels of distortion than other microphone types. The carbon mic is also very sensitive to humidity. Crystal microphones are not as popular as they used to be, but you will still hear many older examples on the amateur bands today. The two most popular types of microphone in use today are the dynamic mic and one particular type of condenser microphone known as the electret condenser mic. Both types are inexpensive, readily available and capable of producing high quality audio.

CONDENSER MICROPHONE. **Figure 1** shows the configuration of a condenser microphone. The two capacitor plates are on the left of the schematic. The fixed plate is connected to ground; the diaphragm plate is connected to a polarising voltage supply. Movement of the diaphragm varies the capacitance by changing the spacing between the plates. As the capacitor has a fixed charge provided by the polarising voltage, variations in capacitance will cause voltage changes at the input of the high impedance source-follower buffer amplifier. Regular readers will remember how I accidentally made a condenser microphone when I was testing an audio amplifier in the February 2010 Homebrew.

The electret type of condenser microphone doesn't need a polarising supply across the capacitor plates because the capacitor is made from a special, permanently charged material called an electret. Modern electret microphones are small, light, inexpensive and capable of producing very high quality audio. Electret mics are used in mobile phones, camcorders, telephony headsets and anywhere else that a small high quality microphone is required. Electret microphones usually have a built-in FET (field effect transistor) buffer amplifier with a very high input impedance. The buffer amplifier requires a DC supply, typically in the range 1.5 to 12V at a current of less than 1mA.

DYNAMIC MICROPHONES. **Figure 2** shows the configuration of a moving coil dynamic microphone. This type of microphone has a lightweight coil that is attached to the centre of the diaphragm. The coil is suspended in a magnetic field that is usually provided by a permanent magnet. Air pressure acting on the diaphragm causes the coil to move through the magnetic field, which induces a small electric current in the coil. The dynamic mic acts like a loudspeaker in reverse. Some small loudspeakers can make reasonably good microphones.

Photo 1 shows a typical dynamic mic insert (left) and an electret condenser mic. The dynamic insert is a DM-9 type (Maplin QN39N), the electret is a type EM-60B (Maplin FS43W). SSB is not very demanding in terms of microphone frequency response. The bandwidth of an SSB transmission is usually less than 3kHz. A typical SSB exciter will require a reasonably flat response from about 200-300Hz at the LF end up to 3kHz at the HF end. Both of these microphones have a specified frequency response from 50Hz to more than 12kHz. Dynamic microphones have a specified load impedance, which is usually in the 200-600Ω range. The DM-9 specifies an optimum load impedance of 600Ω. It is usually acceptable to use a load impedance that is a bit higher than the specified value. Many microphone amplifier inputs have an impedance somewhere between 1kΩ and 50kΩ. Using a load impedance that is much lower than the specified optimum impedance may lead to low output, excessive distortion and poor frequency response.

Electret microphone elements require a very high load impedance, in the order of

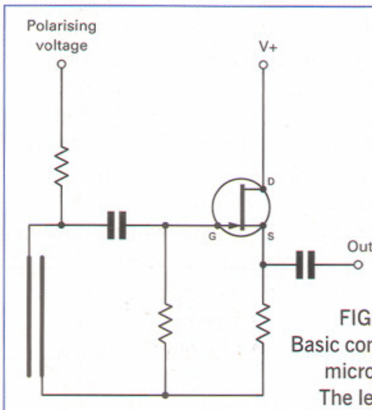


FIGURE 1: Basic condenser microphone. The left hand 'plate' is the diaphragm, which is moved in relation to the grounded plate by sound waves. This results in a voltage output that is impedance matched and buffered by the FET.

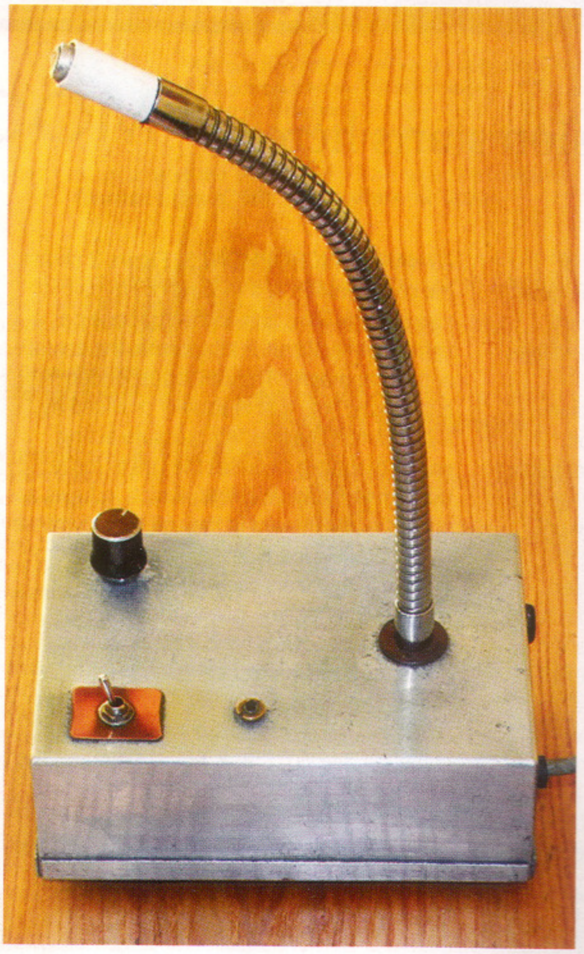


PHOTO 2: My original desk microphone, which has given more than 20 years' good service.

several megohms. Most if not all electret capsules (as in the photo) have a built-in FET amplifier that meets this requirement. The optimum load impedance for the output of the FET amplifier will be a more reasonable value ranging from 1kΩ to about 10kΩ.

As most dynamic microphones don't have a built in amplifier, no DC supply will be required. Take care to ensure that DC is not accidentally applied across the terminals of a dynamic mic. This could easily burn out the coil or damage the diaphragm. A coupling capacitor of about 10μF between the mic insert and the amplifier input will isolate the mic coil from the DC bias of the amplifier. Dynamic inserts with plastic bodies are usually symmetrical so that they can be used with either balanced or unbalanced amplifier inputs. Some metal-bodied inserts may have one end of the coil attached to the case ground. Electret inserts have the negative supply/mic ground terminal attached directly to the metal outer shell of the capsule.

There are two types of electret capsule in common use. One type has just two connection terminals, the other has three. **Figure 3** shows typical connections for both types, **Figure 4** shows the electrical configuration of both types. The three-terminal capsules (a) have a built-in load resistor for the FET amplifier. The DC supply is fed to one end of this resistor and the amplifier AF

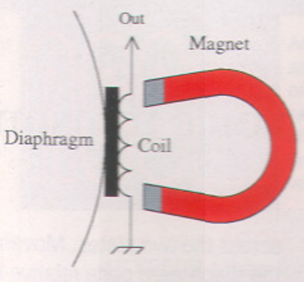


FIGURE 2: Basic principles of a dynamic microphone. A coil attached to the diaphragm moves in sympathy with sound waves and directly generates an electrical signal by induction.

output is taken from the other end at the junction with the drain of the FET amplifier. The two-terminal capsules (b) don't have this resistor built in, so it is necessary to use an external resistor connected to the DC supply. The external resistor is typically about 2.2kΩ for a 5-12V supply and about 1kΩ for a 1.5V supply. The external coupling capacitor is typically about 1μF. A close inspection of the back of the capsule will show that it is very easy to identify the negative/gnd terminal because it is always connected directly to the metal case. Note that a three terminal electret can usually be used to replace a two terminal type by simply leaving the V+ terminal unconnected.

MICROPHONE AMPLIFIER. The output from a typical dynamic microphone is just a few millivolts (mV) when the operator is speaking directly into the mic and even less when the mouth is more than a few centimetres away from the diaphragm. Electret mics produce slightly more output: I measured about 20mV p-p at normal speaking levels. This may be enough to fully modulate some transmitters, but my homebrew rig and some commercially made rigs will require a higher level for proper operation. The microphone amplifier in this month's construction project is based on my standard design as used in several previous projects [1]. I used the surface mount version of this amplifier as shown on p59 of the October 2009 *RadCom*. You can, if you prefer, use a DIL dual op-amp instead of the SMT components. The choice of op-amp is not too critical. I got good results using the LF353 dual op-amp. Even standard types like the humble LM4558 can be expected to perform well in this circuit. The schematic of this amplifier is shown in **Figure 5**. Some slight changes must be made to the circuit depending on whether it is to be used with the electret insert or the dynamic insert. For use with the electret insert, a 2k2 resistor was connected from the mic input to the DC supply rail. A 1μF capacitor was initially used for C1. The original R1/R2 values of 10k/100k were used. On-air testing of this configuration resulted in reasonably good reports on the audio quality. Some reports suggested that the audio was a little bit too 'bassy' compared to my usual microphone. Replacing C1 with a 100nF capacitor gives a slight bass cut at frequencies below 200Hz. On-air reports on this configuration were universally good.

For use with a dynamic microphone, the 2k2 resistor should be removed from the microphone amplifier input and C1 should be replaced by a capacitor with a much larger value: about 10μF works well with the DM-9 insert. If you use an electrolytic capacitor for C1, connect the positive side to the amplifier input and the negative side to the dynamic mic. To compensate for the low output of the dynamic mic, I changed R1 to 3k3 and replaced R2 with a 220kΩ pot so that I could set the amplifier gain to the required level.

DESK MICROPHONE. This month's construction project is a desk microphone that can be used with your home made or commercial transmitter. The design is based on my original desk microphone that has, so far, given more than 20 years of service,

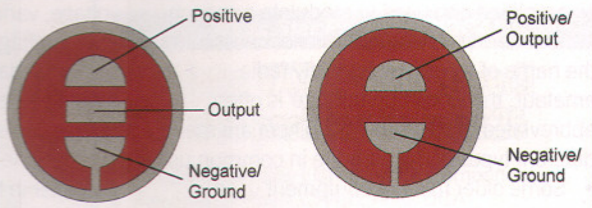


FIGURE 3: Typical electret mic connections: (left) three-terminal type (see Figure 4a) and (right) two-terminal type (see Figure 4b).

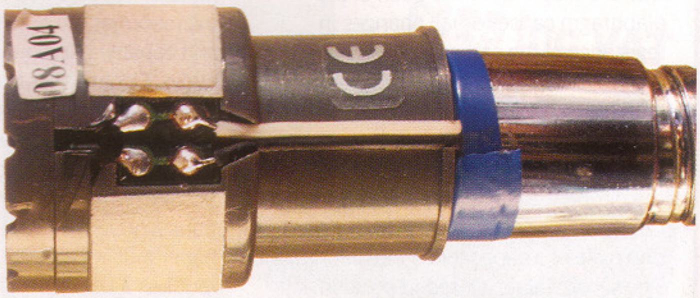


PHOTO 3: Detailed view of how the mic insert is mounted.

although I have had to replace the electret insert twice during this period. This microphone was built in an aluminium box, which gives good RF screening. The electret insert is mounted on a flexible metal 'gooseneck' removed from a cheap table lamp. A short length of plastic tubing was used to secure the electret mic on the end of the gooseneck. This microphone is shown in **Photo 2**. The Tx/Rx switch and mic gain controls are on the top of the box. The small push button was used to operate a 1750Hz tone burst oscillator for VHF repeater operation.

A similar method of construction was used for the new microphone. An aluminium box (Maplin AB10 or similar) was used as the base. Unfortunately, a desk lamp with a suitable gooseneck was not available on this occasion. After checking out some of the local electrical and DIY stores, I found that the only desk lamps with a suitable gooseneck actually cost considerably more than a 'proper' microphone gooseneck. There are a few possible alternatives like the flexible map reading lights available from car accessory shops or flexible lamp goosenecks that are designed to plug directly into a USB socket. One very practical approach as used by EI2EUB is to use a length of co-ax cable (Westflex 103 is ideal) as the gooseneck with standard PL259 and SO239 connectors for mounting it on the base. I eventually bought a 6in gooseneck (Maplin YW72P), a DM-9 dynamic insert (Maplin QN39N) and, to make a really posh job of it, a mic windshield (Maplin LB35Q). The SMT microphone amplifier/LPF PCB described earlier was used to amplify the signal from the dynamic mic up to the 50-100mV level required by my transceiver. The PTT switch (although push-to-talk isn't really an accurate description of this type of switch) is a standard DPDT single hole mounting type.

The DM-9 insert is a slightly loose fit on the end of a standard mic gooseneck. I used a thin layer of PVC tape to fill the gap. **Photo 3** shows close-up details of how the microphone insert is mounted. It doesn't look very pretty, but the windshield does a good job of concealing the ugly bits. **Photo 4** shows the finished project.

POWER SUPPLY. The obvious choice of power supply for a microphone amplifier is a small 9V battery, but there are some disadvantages to this approach. If you do decide to use a battery, you will need to fit a switch so that the amplifier can be turned off when the mic is not in use. It would be possible to use a spare pole on the PTT switch so that the amplifier is only powered up while you are transmitting. This approach can be problematic as it is likely to lead to audible pops and clicks on the transmitted signal. A separate power on/off switch is probably a better option, but if the switch is accidentally left on, the battery will run flat after a couple of days. You could fit a LED power indicator but, since it would draw more current than the mic amp, it might do more harm than good. In my experience, the best way to provide power for the microphone is to steal it from the radio. This is very easy to do if you use a home-made rig and you have a spare pin on the mic connector. Be careful about taking power from the mic socket of a commercially made rig. Many transceivers have a DC supply of about 8V

PHOTO 4: The finished microphone.

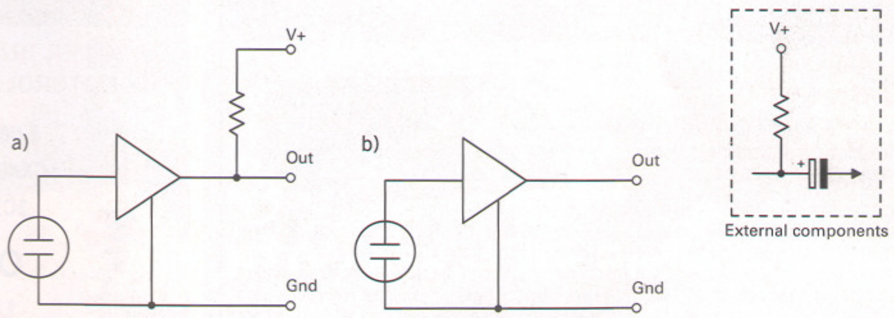


FIGURE 4: Representative circuit diagrams of the (a) three - and (b) two-terminal electret mic types shown in Figure 3.

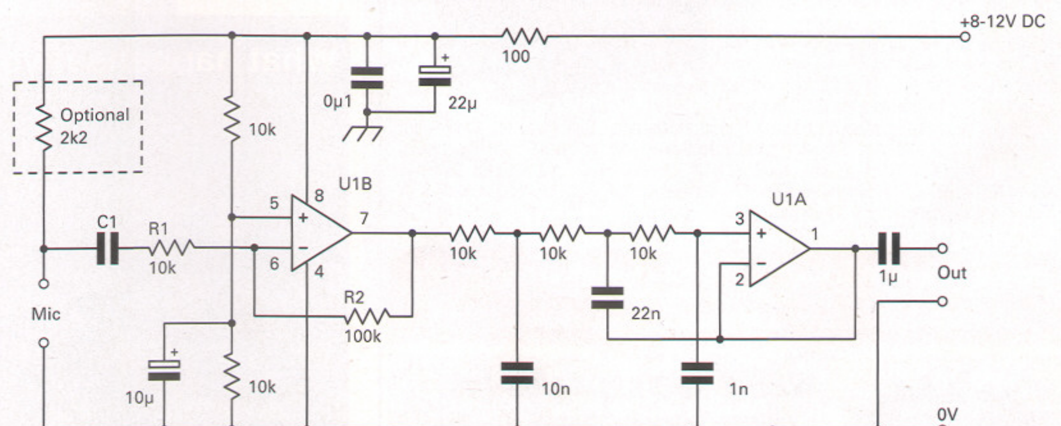
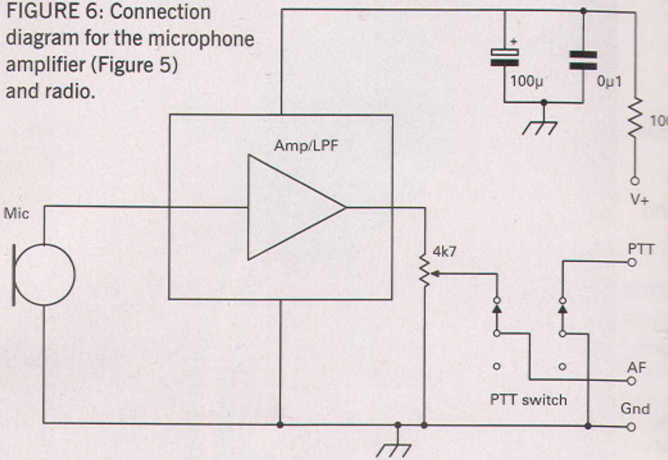


FIGURE 5: The standard microphone preamplifier circuit. See text for C1, R1 and R2 values for electret and dynamic mics.

FIGURE 6: Connection diagram for the microphone amplifier (Figure 5) and radio.



available from the mic socket. It is possible to damage some transceivers by shorting this DC output to ground. Accidental short circuits can lead to blown voltage regulators and damaged wiring. You have been warned!

Figure 6 shows the configuration of the microphone, amp/LPF module and PTT switch. Note that I have included the mic gain pot shown in the photographs.

I used a spare pin in the mic socket to provide power for the microphone amplifier. To eliminate the possibility of clicking/popping when changing from receive to transmit, the amplifier is always powered up, regardless of whether I am transmitting or receiving. Even in these environmentally aware times, the 3-4mA drawn by the mic amplifier can be regarded as insignificant.

I used the microphone for a few days without telling anyone that I had a new microphone. During this period, nobody noticed any change in my audio quality. Comparison tests have shown that the dynamic mic compares quite well with my old electret mic.

There is plenty of room in the base on the mic for additional circuits, such as oscillators for Morse code generation, two-tone testing, subaudible tone, DTMF generators etc... Other possible additions include level indicators, tone controls, equalisers, digital speech record/playback, AF or RF clippers/compressors – but please don't install a roger beep!

The microphone should be connected to the rig using screened cable that is grounded to the rig ground/chassis at one end and the metal case of the mic at the other. Special microphone cable has several wires with separate screening for the audio wire only. This guarantees good isolation between the audio wire and the other wires used for PTT and power. As this type of cable is not readily available, I use ordinary multi-core screened cable which has a single screen enclosing all wires in the cable. Old computer keyboard cables and some types of network cables are a good source of high quality screened wire. I have been chopping up old AppleTalk RS-422 cables to make my microphone leads. RF signals on the PTT and/or power wires could easily leak into the audio wire via capacitive coupling. To keep RF signals out of the microphone cable, it is a good idea to solder 10nF capacitors from the PTT and power pins directly to ground at the back of the microphone socket of a home made rig.

Next month: A VHF DDS/PLL frequency synthesiser.

REFERENCES:

[1] Homebrew August 2006, May 2009, October 2009.