How to Construct a Q-Multiplier

by Ian Pogson

This simple little device is easy to build and get going and will be found very useful in stepping up the selectivity of short-wave and other receivers which may be somewhat lacking in this respect. The selectivity can be adjusted from the original broad characteristic of the receiver, to a point where it is very sharp indeed.

Although Q-multipliers have been around for 15 years or more, and there are many receivers which would be the better for the use of one of these devices, we have never described one in the pages of this magazine. We are about to make good this omission and describe a simple version.

What is a Q-multiplier, what does it do and how does it work? These are some questions which should be answered at least in part before we proceed with other aspects of the unit.

Basically, a Q-multiplier is an amplifier which is tunable to the frequency required and which has a positive feedback loop, but under conditions where the regeneration is under strict control at all times.

When the output of this amplifier or Q-multiplier is connected across a tuned circuit, such as an IF transformer, the regeneration makes up in a controllable manner, the intrinsic losses of the particular tuned circuit. This results in an apparent increase in the Q of the tuned circuit, with a consequent sharpening of its selectivity.

Alternatively, the arrangement may be looked upon as one tuned circuit in parallel with another. The original tuned circuit is broad but the Q-multiplier circuit is very sharp and consequently has a high dynamic impedance at the centre frequency so letting signal though at this precise frequency. However, as the skirts of the multiplier are very steep, the dynamic impedance falls off sharply and shunts the signals at either side of mid-frequency, so giving the effect of high selectivity.

The circuit of a Q-multiplier often takes the form of a slightly modified Colpitts oscillator. The feedback is obtained via a capacitive voltage divider in the usual way. However, in the case of a grounded cathode configuration, a variable resistor is placed in the cathode circuit. This is un-bypassed and so adds a certain amount of degeneration to the circuit. The amount of degeneration is controlled by varying the value of the resistor. This should be adjustable over the range from where little regeneration is evident, to the point where the amplifier goes gently into oscillation. It is just before this latter point where the maximum possible selectivity is obtainable.

As we have just implied, early Q-multipliers were designed around valves, quite often a 12AX7 or similar triode. More recently, valves have tended to give place to transistors, the design and circuitry being modified to accommodate the lower impedances and other characteristics of bipolar transistors. The unit which we are now presenting uses a FET (field effect transistor). As these devices have input and output impedances comparable with those of a valve, the circuit once again takes on the more familiar appearance which we knew earlier on.

There is one decided advantage which the field effect transistor has over the valve, namely that no heater supply is required. But, in common with other transistors, it is physically small and requires only a modest supply voltage.

However, while FETs hold excellent promise for the future, they, too, have their problems. As readers may be aware, there are various types of field transistor, some of them very delicate and needing special care in handling. The junction FET, one of which we are using in the Q-multiplier, is reasonably rugged, but often suffers from a wide spread in characteristics. Fortunately, the type which we are using is fairly good in this respect.

The actual shape of the selectivity curve which results from the use of a Q-multiplier must be considered. Due to the nature of the device, the curve is one which comes to a more or less sharp point—according to its adjustment—and resembles that of a single correctly phased crystal filter. At its sharpest, the selectivity and shape of the curve makes it ideally suited to Morse Code reception. On the other hand, these characteristics make it less suitable for AM reception. Also, for SSB reception, we need a pass-band shape which is ideally flat on top, with steep skirts on each side.

Although the ideal shapes are not obtained with the Q-multiplier for these modes, it is nevertheless still very worthwhile, particularly where improved selectivity is being sought at low cost. As was pointed out earlier, it is possible to control the degree of selectivity with a Q-multiplier. For AM work, adequate selectivity is likely to be obtained without even approaching the maximum limit. With SSB reception it would normally be possible to use a greater amount of the available selectivity, giving quite acceptable results, even though the pass-band shape will not be the best.

Although we have only discussed the possibility of stepping up the selectivity of a receiver with a Q-multiplier, it is actually possible to create quite a different effect. Instead of effectively making the selectivity shape very sharp, we can, by inversion, introduce a sharp, deep notch in the normal pass band of the receiver. This can be very useful, particularly when the notch can be tuned across the pass-band to attenuate an adjacent interfering heterodyne.

The effect is achieved by adding another stage to the system, the extra stage incorporating negative feedback. Instead of the output of the Q-multiplier having some characteristics of a parallel resonant circuit with a very high impedance, it now looks like a series resonant circuit, with a very low impedance and high Q. This cuts a very narrow slice or notch out of the passband.

This feature can be useful where AM reception is the general rule and where trouble is constantly being experienced with heterodynes from adjacent AM transmissions. We have not incorporated it in our unit in the interests of simplicity.

If you take a look at our circuit, you will notice that the Q-multiplier is intended to connect to the output of the mixer of the receiver, via a 15pF capacitor. Most Q-multipliers have a much larger capacitor, something like

.001uF, at the input. This can necessitate the addition of a large adjustable inductor, of the order of 1.5 to 3mH, to tune out the effect of the capacitance of the coaxial cable between the mixer stage in the receiver and the input to the Q-multiplier. In the interests of simplicity, we have used the value of 15pF; it may have a slight effect on the ultimate amount of selectivity attainable but there is adequate available for most purposes.

In fact, the circuit is about as simple as it can be; besides the 2N5459 field effect transistor and the coil, there are only four resistors and six capacitors. As mentioned earlier, the circuit is fundamentally a Colpitts oscillator, the ratio of the two feedback divider capacitors, across the coil, being about three to one. The values which we have chosen suit the inductance of the types of coil which we had in mind.

Suitable coils are either the tuned winding of an aerial or RF coil, as used in a broadcast receiver, originally with a 415pF tuning gang. The one which we used was an old aerial coil, made by Aegis. Resonated at 455KHz, the tuned winding had a Q of 120, which is quite good for coils of this type. However, in many articles describing Q multipliers in the past, the emphasis has been directed towards getting a coil with as high a Q as possible. Although the Q of 120 is satisfactory, it is possible to get much higher Qs by winding your own coil, either on a pot core or a toroidal core.

We wound a coil on a Ducon toroidal former, Q1 material, 23/32in OD x 15/32in ID x ¼in thick, with 57 turns of 24 gauge enamelled copper wire. Measured on the Q meter, this coil came up with a Q of 240, or double that of the other coil. If you wish to try this type of winding, the number of turns stated can only be a guide, as the inductance will vary with physical variations, such as the actual disposition of the turns on the former. Also, if you use a toroidal coil, make sure you mount it at least ¼in clear of any metal objects, otherwise the Q may suffer accordingly.

The 50pF variable capacitor, across the 820pF capacitor, may be used to set the tuned circuit precisely to the wanted frequency. In the case of the slug-tuned aerial coil which we used, the variable capacitor may be used in addition to the slug, to adjust to the intermediate frequency, under actual operating conditions. This is a debatable advantage, however, and, where simplicity is paramount, the capacitor may be dispensed with and the coil brought to the IF centre frequency with its own slug.

On the other hand, if you use a toroidal coil, it is difficult to adjust the inductance to a precise value. Under these conditions, the inductance should be brought as close as possible to the wanted value, with the 50pF variable capacitor in its mid-position. The tuned circuit can then be adjusted to the centre of the pass-band with the variable capacitor.

In the source circuit of the FET are a 470 ohm fixed resistor and a 1K potentiometer. The 470 ohm resistor is simply provided to limit the control range of the potentiometer and to give some vernier action to the selectivity adjustment. More will be said about this later on.

The complete prototype unit was housed in a diecast metal box made by Eddystone and measuring 4-5/8in x 3-5/8in x 2-3/16in. This box gives the finished job a professional appearance but a folded metal box may be substituted, if desired.

The layout of the components is not critical but we will detail how we went about it so you may follow it closely or use it as a guide. The variable capacitor, potentiometer and On-Off switch are mounted on the front panel. The coil assembly is more or less free and can be clamped conveniently at one end of the box and close to the potentiometer. If you use a different size and shape of coil, other methods of fixing will no doubt suggest themselves.

The rest of the components, including the field effect transistor, are mounted on a piece of tag board. The coded diagram of the board should make wiring and assembly an easy matter. As is always the case, care must be taken to make good soldered joints but, at the same time, the components should not be overheated. This applies particularly to the FET.

The completed tag board assembly is held to the front panel with two stand-off pillars, 1-1/4in long. As pillars of this length were not readily available, we used some 1in spacers which were tapped at each end and then made up the extra 1/4in with another spacer with a clearance hole through it.

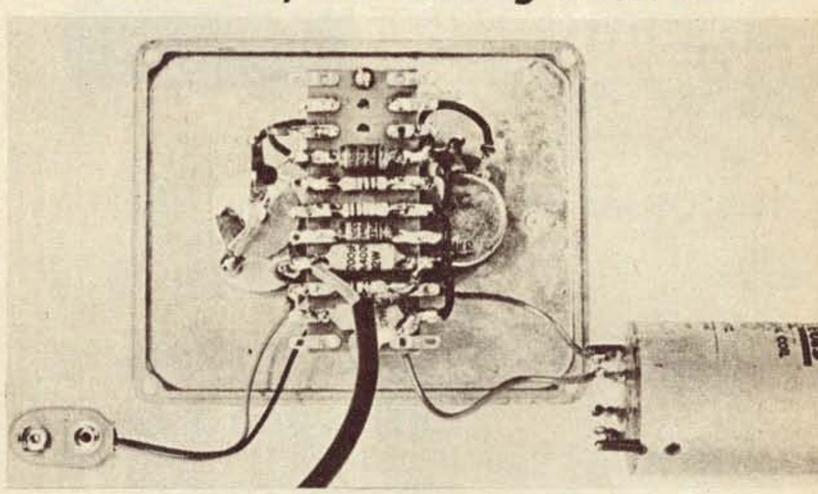
You will notice that the tag-board has a few spare tags. We made it a little longer than necessary, so that the spacers were located towards the edges of the panel. This allows more space under the tag-board and makes for a better location of the switch.

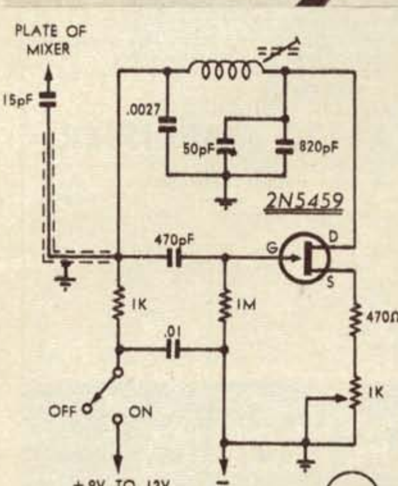
Having built the unit up to this point, all that remains is to connect it to the receiver. This is normally done via a short run of low capacitance coaxial cable. A grommeted hole is needed in the back of the case, to pass the cable through. A convenient point for connecting the cable is across the .0027uF capacitor.

Just how you connect the other end to the receiver will depend on circumstances. The cable could be taken through the skirt of the chassis, adjacent to the mixer valve or its equivalent. Alternatively, a coaxial socket could be installed at this point on the chassis, with a mating plug on the coaxial cable. In any case, the active conductor must be connected to the plate of the mixer, via the 15pF capacitor connected right at the socket, with a minimum of lead length between capacitor and socket.

We carried out our initial bench tests with the "1967 All Wave Seven"

More selectivity for existing receivers





Q MULTIPLIER

Above is an inside view, with an old aerial coil to the right and a battery connection to the left. At left is the simple circuit diagram. Note the FET connections.

receiver, with connection made to pin 5 of the 6BE6. The earth connection was made to the centre shield of the valve socket. It was found that the coaxial cable was not really necessary in this case and we were able to "get away" with a twisted pair of hookup wires. In most cases it would be wise to use a piece of coaxial cable, no longer than necessary. The piece which we finally used is about 14in long.

Having completed the unit and connected it to the receiver, the next task is to align and make adjustments. Firstly, and before the Q-multiplier is switched on, the IF trans-

PARTS LIST

- *1 Diecast box 4-5/8in x 3-5/8in x 2¼in.*
- *1 50pF miniature variable capacitor.*
- *1 Coil (see text).*
- *1 Power supply (see text).*
- *1 1K linear potentiometer.*
- *1 SPST toggle switch.*
- *1 Tag-board (11 pairs of tags).*
- *2 Spacers, 1in long, tapped 1/8in Whit. each end.*
- *2 Spacers, ¼in long, 1/8in clearance hole.*
- *1 2N5459 field effect transistor.*
- *1 470 ohm ½W resistor.*
- *1 1K ½W resistor.*
- *1 1M ½W resistor.*
- *1 15pF NPO ceramic capacitor.*
- *1 470pF plastic capacitor.*
- *1 820pF plastic capacitor.*
- *1 .0027uF plastic capacitor.*
- *1 .01uF plastic capacitor.*

Coaxial cable, hookup wire, screws, nuts, knobs, solder, grommet, etc.

former following the mixer stage will need to be realigned. If no signal generator is available it can be done by tuning accurately to, say, a broadcast station, which is not fading and which is not too strong. Peak the slugs in each winding of the IF transformer.

Set the potentiometer selectivity control so that the rotor is at the earthy end of the track. If you have wired in a variable capacitor, set it to the mid-point of its travel. Switch on the Q-multiplier and advance the potentiometer. If the tuned circuit is close to the intermediate frequency, a hollow sound will become evident. With further advancement of the potentiometer, a squeal will be heard, indicating that the Q-multiplier has gone into oscillation. Back off the potentiometer until oscillation just ceases. Now adjust the slug in the coil for maximum response. If the coil has no slug, the variable capacitor will be used for this purpose.

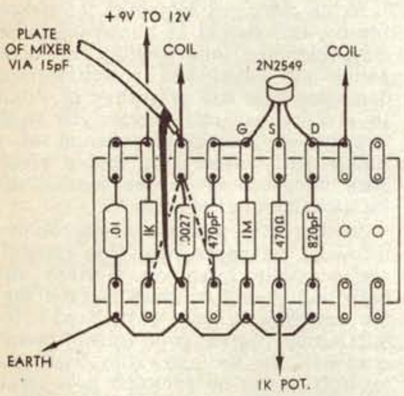
This exercise calls for a little juggling, practice and patience, until one gets to understand the nature of the device. You will find that, as the potentiometer selectivity peaking control is advanced, there will be a slight but noticeable shift in frequency. The coil slug or the variable capacitor should be so adjusted that it is correct at the point of maximum selectivity.

The behaviour of the potentiometer can be varied by altering the value of the 470 ohms resistor shown in series with it. If the Q-multiplier goes into oscillation at, say, the mid-point of its travel, the second half of the track is being wasted. Try increasing the 470 ohms resistor to say, 1K, or to that value which allows the multiplier to go into oscillation just before the end of the track is reached. This will give a much better vernier action and easier control. In some cases the control may be further improved by reducing the value of the potentiometer, such that when the rotor is at the earthy end, there is no further reduction in selectivity, compared with when the unit is switched off.

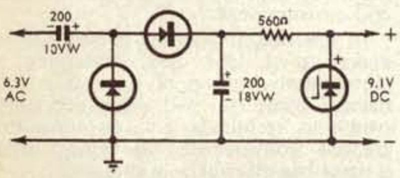
If you go to this bit of extra trouble, the ease of control will be worth the effort. The selectivity characteristic obtained with the Q-multiplier is continuously variable, a feature which is not usually available with other and often more complicated systems.

To sum up the worth of this simple Q-multiplier, we feel that it is a worthwhile addition to any short-wave receiver which is deficient in selectivity. If you desire to get the very best from it, we suggest that you go to the extra trouble of making up a special coil on a ferrite toroid. The Q-multiplier could of course be got going with a more conventional coil and then the toroid could be added later. However, the remarks relating to the potentiometer and its series resistor are important again, as the values will almost certainly have to be changed to suit the new coil.

So far, we have not touched on the subject of providing a power supply for the Q-multiplier. It will operate satisfactorily on voltages between 9 and 12. It is quite easy, of course, to supply it



This diagram shows clearly how the board is wired. The reason for the unused lugs is mentioned in the text.



Here is the circuit of a suggested power supply which makes use of a 6.3 volt heater supply, with one side grounded.

from a small 9-volt dry battery and this is what we did when the unit was being tested. There is no reason why this method should not be adopted permanently, except that it is not as economical as it might be. The FET can take anything between about 4 and 10 milliamps. At the higher figure, the battery is not likely to last very long, particularly if the receiver is used for lengthy periods.

Perhaps a more satisfactory idea, in the case of valve receivers, is to make use of the 6.3-volt heater supply. Almost certainly, one side of this supply will be earthed. This being so, we can feed the 6.3 volts into a half-wave doubler circuit. This will result in about 17 volts DC appearing at the output of the doubler. This can be fed through a dropping resistor to a 9-volt zener diode.

This is all shown on the circuit diagram. The series electrolytic capacitor is a 200uF rated at 10 volts working. The shunt electrolytic is also a 200uF but it is rated at 18 volts working, as it has the doubled voltage across it. At this point, there will be about 17 volts, depending upon the actual value of the nominal 6.3 volts fed into it.

We have to get this 17 volts down to, say, 9 volts nominal, although we could make it anything up to 12 volts if we wished. The 9 volts could be obtained simply by using a dropping resistor of the appropriate value. Herein lies a small problem, however. As mentioned before, the spread in field effect transistors is quite wide. The resistor would have to be calculated on the basis of the particular FET being used. A much better way out of this, although it costs a few cents more, is to instal a zener diode with a suitable dropping resistor.

Let us assume a total drain of 12 milliamps from the filter. This means that the series dropping resistor has to cope with 17 - 9 volts, which is a drop of 8 volts. Ohm's law tells us that a resistance of 530 ohms is required. The nearest preferred value is 560 ohms and this will do.

With no drain from the output of the power supply, as when the Q- multiplier is switched off, the total 15 milliamps will flow through the zener diode.

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This amounts to a dissipation of 135 milliwatts, which is well within the maximum permissible rating of 340 milliwatts. The result of this little design exercise is a regulated power supply of a nominal 9.1 volts and capable of accommodating the current spreads likely to be encountered with any FET likely to be used in the Q-multiplier.

If you should need a power supply like this one for some other purpose and where the current drain is likely to be up to 30 milliamps or so, it is possible to do this simply by reducing the 560-ohm resistor to one of 270 ohms. This will bring the zener diode close to its maximum permissible dissipation rating, when there is no current being drawn from the supply. Whatever current is drawn from the output is subtracted from the current flowing through the zener diode and the dissipation is reduced accordingly. ■