CERAMIC RESONATORS as IF filters and oscillators  

This discussion on the characteristics of ceramic filters on a nominal frequency of 455KHz, shows that they have a very wide potential for applications in receivers and transmitters, etc., and opens up a new field which has interesting and exciting possibilities.

By Ian Pogson

Concurrently, with the rapid development of solid-state devices, there has been a parallel development of ceramic products. These include ceramic capacitors of various types, and expansion of the piezoelectric properties of certain ceramics. It is the latter in which we are currently interested.

Although the piezoelectric properties of ceramic materials have been known for some time, the earlier ceramics were not a practical proposition, due to lack of stability in terms of time, and an unsatisfactory temperature characteristic. Recently, lead-zirconate-titanate ceramics have been brought to a state of development where aging and temperature characteristics have been stabilised satisfactorily.

This has resulted in a number of components being brought on the market, generally in the form of small units for use as filters in IF applications, particularly at 455KHz. The manufacture of ceramic filters is not as widespread as many other components, but we have seen samples from the United States, England and Japan. If it is the latter type of filters we are mainly concerned at present.

From Japan, two makers have come to our notice, Murata and National. Of the two, Murata appear to make the wider range and, from our experience, the Murata units seem to offer the greater scope for investigation.

Another important point is the fact that the Australian distributors for Murata filters, I.R.H. Components Pty. Ltd., are active in the field and keep good stocks on hand.

The writer has already made use of ceramic filters, both Murata and National, in tuners for the broadcast band, described in May, August and October, 1968. Such filters are attractive in that they are small in size, they do not need to be aligned and the ones most likely to be used in simple applications, are cheaper than IF transformers. On the other hand, there are some multiple ladder types offered, which have excellent characteristics, particularly skirt selectivity, and which are quite expensive.

Regarding the more expensive devices, Murata and we understand, others, have produced units which rival and often can take the place of crystal lattice and mechanical filters, so often used for SSB applications. In fact, Murata catalogues two grades of such filters, differing in the skirt shape and thus the adjacent channel rejection. The higher grade lists no less than 10 items, ranging from a nominal bandwidth of ±17.5KHz to ±1.5KHz; the other grade lists eight items, ranging from ±17.5KHz to ±3KHz. It was one of the latter group that we used in the Wide Band Tuner, with a nominal pass band of ±9KHz at the 3dB points.

From the experience thus gained, limited though it was at this stage, the idea naturally followed of using such filters in solid-state communications receivers. In such a receiver, we would otherwise use conventional IF transformers, backed up by either a mechanical or a crystal lattice filter, for the reception of SSB signals.

But each time we considered using the ceramic filters, obstacles seemed to appear. In the case of the expensive ceramic filter to take the place of the mechanical or crystal lattice filter, the unfortunate fact emerged that the narrowest unit offering was ±1.5KHz minimum, at the 6dB points. In fact, one of these units which became available, turned out to be a little over ±2KHz or more than 4KHz wide between the 6dB points. As a figure of 2KHz to 2.5KHz is the widely preferred choice for SSB, it is obvious that the narrowest ceramic filter would not be adequate.

When we turned our attention to the low-cost versions of the ceramic filters, for applications where they would be cascaded in an IF strip, the problem arose of tolerances on the centre frequency. The quoted tolerance is ±2KHz on the nominal centre frequency of 455KHz. This means that, in the extreme case and where we wished to use say four units in an IF strip, the centre frequencies of the individual units could be separated by as much as 4KHz. Where we are likely

![The SFD-455B resonator consists of two "ring-dor" elements connected as shown right. The capacitor size determines the bandwidth.](image)

### TABLE 1

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Frequency</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>10K, pin 1 to E:</td>
<td>fc = 454.30KHz</td>
<td>Approximately 10dB loss</td>
</tr>
<tr>
<td>10K, pin 2 to E:</td>
<td>fc = 454.55KHz</td>
<td>Approximately 3dB loss</td>
</tr>
<tr>
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<td>fc = 454.15KHz</td>
<td>Approximately 20dB loss</td>
</tr>
<tr>
<td>4.7K, pin 2 to E:</td>
<td>fc = 454.51KHz</td>
<td>Approximately 5dB loss</td>
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<tr>
<td>27pF, pin 1 to E:</td>
<td>fc = 453.76KHz</td>
<td>Practically no loss</td>
</tr>
<tr>
<td>27pF, pin 2 to E:</td>
<td>fc = 454.86KHz</td>
<td>Practically no loss</td>
</tr>
<tr>
<td>82pF, pin 1 to E:</td>
<td>fc = 452.63KHz</td>
<td>Practically no loss</td>
</tr>
<tr>
<td>82pF, pin 2 to E:</td>
<td>fc = 454.87KHz</td>
<td>Practically no loss</td>
</tr>
</tbody>
</table>

**Figure 1**

**Here is a group of the resonators about which we are writing. The case measures about 5/16in x 9/32in x 7/32in.**

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to be looking for a band width of 4 or 5 KHz, or even less, it is obvious that such tolerances would be unacceptable.

Still looking for an answer to the filter problem for SSB reception, we investigated the availability of mechanical filters (FT-241, etc.). We found that mechanical filters were not as readily available as we had hoped. Also, while FT241 crystals are still available in the United States, they are not readily available here. So we turned our thoughts to the low-cost ceramic filters again. Would it be possible to make use of them, in spite of the spread in tolerances?

With nothing to lose, and the possibility of something to gain, we decided to concentrate our efforts on the Murata type SFD-455B, a 5-terminal device. Its bandwidth can be adjusted by different values of top capacitive loads between the two elements, which go to make up the complete unit.

Figure 1 illustrates the "works" of an SFD-455B assembly. It consists of two elements, each a ceramic slab about 3.16n in size and about .015 in thickness. The slab is silver-plated on opposite faces. An oxide layer covers the complete part. On the other side, the plating is such that two separate areas are formed, as shown. When two of these matched elements are placed back-to-back, we have the five terminal device, type SFD-455B. In the actual package, the two elements are held in small clips, making the appropriate contacts and bringing out as small flat flexible lead.

To study the behavior of the ceramic resonators under various conditions, we set up a sweep generator on the Murata 455kHz oscillator, and the one described in December, 1963. A standard signal generator was used as a marker, monitored by an Advanced sweep meter, connected to the vertical input of the CRO.

Our first test was to determine the center frequency of each of a number of randomly selected SFD-455B units. Of five units checked, the centre frequencies turned out to be: 456.15KHz, 455.08KHz, 455.63KHz, 456.06KHz and 456.63KHz. The units all come well within the maker's tolerance of ±2 KHz. The greatest separation is represented by one on 455.08KHz and another on 456.63KHz; this amounts to 1.55KHz and looks promising, but we must face the reality that other samples could be much wider apart than these tested.

Our next test was a check of the band width at the 3dB points, of the same units and with the coupling of 47pF as shown in figure 2. The bandwidth turned out to be: 1.95KHz, 2.17KHz, 2.23KHz, 2.37KHz and 2.34KHz. Although there is little difference, they are well within the maker's tolerances.

At this point, the vital question arose. Could we do something to bring all units to the same center frequency, or otherwise control them so that a number of them could be used in cascade? If we could do this, then the selectivity characteristics of each unit in the setup would be additive, possibly resulting in a good shape factor. Also, could the bandwidth be controlled?

Our next test consisted of placing a random selection of SFD-455B units in the same test circuit, figure 1, as before. Arbitrary tests were carried out by connecting resistors and capacitors of various values across different terminals of the device. The results of this test are shown in Table 1.

A perusal of Table can be very enlightening and indeed, very promising. It will be noted that a resistor or a capacitor across certain terminals changes the centre frequency quite appreciably. The frequency shift is to the low side in most cases, except where a capacitor is connected from pin 2 to earth, which results in a small shift in the high direction. It will also be noted that while resistors shift the frequency, they introduce a considerable insertion loss, whereas a capacitor introduces no significant loss. It would seem from the above that resistors should be avoided and only capacitors used to modify characteristics, but this has turned out to be a premature assumption. In cases where elements in a complete system vary to a significant extent in Q, a suitable value of resistor can be used to advantages.

This is the circuit which we used to make tests on individual resonators. The circuit is straightforward and representative of current practice.

An extension of the one above, this circuit was set up to test a full set of resonators, as they may be expected to be used under IF conditions of a short-wave or communications receiver. The switching would be more elaborate on an actual strip, compared with the token switching shown.
stage to correct this. More will be said about this later on.

Further study of Table 1 shows up other points of interest. The higher the value of capacitor used, the greater is the frequency change. Alternately, the lower the value of resistor used, the greater the frequency change. Also, the amount of frequency change, all other things being equal, is different when different terminal connections are used.

A further point worth mentioning, and which is not shown in Table 1, is the fact that frequency changes can be achieved by connecting external components between terminals 3 and 4, and earth but the changes are not so great. Also, it is possible to effect changes by connecting between terminals 2 and 3, or 1 and 4. Again, the changes are not so marked.

The next series of tests were more ambitious, having been prompted by the results given in Table 1. Another test circuit was set up, so that a series of tests could be made which simulated actual application in an IF strip. The circuit is shown in figure 3.

This circuit consists of a BF115 transistor in the first stage, which could be the mixer in an actual application of the full system. Following this stage is provision for checks to be made on one or more SFD-455B filters. Then follows an amplifier stage in which we are using a 2N5459 field effect transistor. Between this and the next and similar stage is an SFD-455B filter as the coupling medium. Another SFD-455B is used to couple from the second FET, to the third IF amplifier stage, using a BF115 transistor.

Field effect transistors were selected for the first two amplifiers, as they could be controlled by an easily generated 10V DC voltage. The final stage uses a PNP, because it will not be controlled and it gives somewhat more gain than the FETs.

It will be noticed that the two FET's have a 250mH RF choke as the load, instead of the more conventional 3.3K resistor, which is associated with ceramic filters. The reason for this is that a much lower current is passed through a field effect transistor than bipolar transistors, something between 5 and 10 milliamperes. This means excessive voltage drop through the SFD-455B resistor. An SFD-455B supply voltage of 12V, the proposition would not be practical. The use of an RF choke solves the voltage drop problem and at the same time presents about the right source impedance for the filter.

An important point which should be mentioned in this circuit is the top coupling capacitor used for the SFD-455B filters, already installed. The coupling capacitor used is 100pF. This results in some overcoupling, with a slight double hump. The thinking behind this approach is that, if we make these circuits somewhat wider than the widest pass band required, most of the selectivity can be determined in the first stage and the two acting only in a supplementary capacity.

With figure 3 read to go, we connect our PNP SFD-455B unit between the first BF115 and the following FET. The top coupling capacitor used on this occasion was 47pF, the pattern on the CRO appearing substantially as shown in figure 4A. Although not by any means perfect, it could be more or less acceptable. By connecting a 6.8K resistor from terminal 2 to earth, the pass band shape as shown in figure 4B.

The single SFD-455B was then removed to make way for a more ambitious test. It was considered that we may be able to connect a number of these units in cascade, to improve the overall pass band. Normally, terminals 3 and 5 are the input, with terminals 4 and 5 for the output. As the units are symmetrical, i.e., the input and output impedances are equal, it should be possible simply to connect a number of units in series, pin 4 to 3, etc., and pins 5 to earth.

On this assumption, we connected three units together in this way. The 27pF capacitors were chosen for the top coupling for each unit and the whole assembly was then connected into the same position as previously. A reasonable shape was obtained, but attempts were then made to improve it. In this case, by connecting a 3.9K resistor from the first pin 2 to earth and a 3.3K resistor from the second pin 1 to earth, we obtained a very satisfactory shape.

Pursuing this approach a little further, we connected together another group of four and put them into the test circuit. Once again, our experience was much the same. By connecting a 5.6K resistor from the third pin 1 to earth, an excellent shape was again obtained.

The connections for the three tests just given are summarised in figures 5A, 5B and 5C respectively. At this point, quite a number of important observations can be made. Firstly, it would appear that the investigations are reasonably successful so far. The next question is, just how successful? This can be answered at least in part by referring to the three photographs on the screen of the CRO and in somewhat more detail from the curves shown in figure 6.

The photographs look encouraging, but they tell only part of the story. Just how good is the skin selectivity? The answer to this is given in curves of figure 6. Curve "A" is 5KHz wide at —6dB and 12.5KHz at —90dB. This gives a shape factor of 2.46. Curve "B" is 3.3KHz wide at —6dB and 9KHz wide at —60dB, a shape factor of 2.73. Curve "C" is 2.2 and 6.5 at the —6 and —60dB points, giving a shape factor of 2.9.2.

These figures for the shape factors could be considered as very satisfactory. It may be possible to improve upon these figures further by taking

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**Figure 3**

**Figure 4**

**Figure 5**

**Figure 6**
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a little more care in adjustment, or by adding an extra unit or two, to those already existing. At this stage, we have not tried to improve upon these figures.

It will be noticed that we have taken the curves down to the —80dB points. While we can vouch for the accuracy of the curves, within reasonably small limits, down to —60dB, there may be some greater errors at the higher attenuations. Suffice to say, that the overall adjacent channel attenuation is little short of excellent.

In cases where more than one degree of selectivity is required, blocks of filters with selected characteristics would be fitted between the mixer and the first IF amplifier, with facilities to switch from one position to the other. As the insertion loss of these filters increases with additional units added in cascade, it may be necessary to introduce some attenuation to the filter with the lower insertion loss, so that there will be no change in signal level, when switching from one position to the other. This is the reason for the voltage divider shown at the output of the filter in figure 5A.

By now, readers will be asking how the band-width of these assemblies can be controlled to give the wanted characteristics. Fortunately, the answer is simple. The overall band-width is controlled simply by changing the value of the top coupling capacitance for each unit. This, of course, has to be determined for the particular assembly together with any other measures such as the use of shunt capacitors or resistors, as mentioned previously. It is doubtful if the band-width could be changed, of a realistic assembly, after it has been finally adjusted, simply by altering the top coupling capacitors.

To sum up on the question of obtaining a certain band width, it is kept to a minimum by using a small coupling capacitance, such as 27pF. Progressively wider pass bands are achieved, within reasonable limits, by increasing the top coupling to something of the order of 100pF.

Figure 4

These curves are typical of "before" and "after" corrective measures are-taken.

So far, the whole idea looks very promising. However, in spite of all the investigations up to this point, the question of maker’s tolerances on centre frequency has not been fully resolved. As a further check, we picked at random another four new SFD-453B units and connected them up in a similar manner to those of figure 6C without any corrective measures.

A check on the sweep equipment showed that although the pass band shape was anything but correct, it would be reasonably satisfactory if nothing more was done about it. However, as it did leave quite a bit to be desired, we set about taking corrective measures. It transpired, after a few minutes’ investigation, that a 3.3K resistor from the first pin 1 to
This photograph from the CRO corresponds with the curve of figure 6C.

This photograph of the 3-unit filter corresponds to the curve of figure 6B.

A broad curve, with one unit and suitable for AM, corresponds to the curve of figure 6A.

earth, was sufficient to give a good shape. In short, and considering the foregoing, it would seem that there is no reason why these results could not be closely and satisfactorily approximated.

Clearly, a case has been established for the application of type SFD-455B ceramic resonator units in IF circuits where a high performance filter is required. It now becomes of interest to compare this potential, with the more firmly established mechanical filter and crystal lattice filter.

Although it is not easy to be too specific in a short space, we can at least make some general observations. The ceramic filters just described, compare favourably with either the more commonly used mechanical or crystal filters, in available bandwidths and shape factor. In size, the ceramic units would normally be smaller than equivalent mechanical or crystal filters. Perhaps one of the greatest advantages offered by the ceramic filters is that of cost. For a given performance, we suggest that a ceramic filter could be installed for about 20 per cent of the cost of a mechanical filter. It would also be much less than a crystal filter, depending on the source of the crystals.

We have already referred to the apparent reduction in supplies of mechanical filters and suitable crystals in this country, whereas stocks of SFD-455B ceramic resonators are readily available at a modest price.

So much for the advantages which ceramic filters have to offer. The question may be raised as to whether there are any disadvantages or, what is the catch? There are indeed, a couple of minor disadvantages but these can be readily overcome in most cases. We refer to the problem of alignment, where a builder has only limited test equipment in one instance and the insertion loss where several units are used for high performance.

The problem of insertion loss can be immediately overcome simply by adding an extra stage to the IF strip. The answer to the alignment problem with limited equipment, is not quite so easy. It may be possible to use an ordinary signal generator and a vacuum tube voltmeter, with a detector probe. However, we have not looked too closely into this one but we hope to have more to say about it later on, in a subsequent article.

Although we have spent some time on this investigation and we have come up with enough information to answer a lot of questions and to give much food for further thought, we feel that there is so much to be learned about these devices and the surface has only been scratched. Suffice to say that the findings so far are most exciting and the application potential could be far-reaching. (To be continued).

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<tbody>
<tr>
<td>HTV-R106</td>
<td>1,600 to 6,500°A</td>
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<tr>
<td>HTV-R136</td>
<td>1,600 to 8,000°A</td>
</tr>
<tr>
<td>HTV-R166</td>
<td>1,600 to 3,200°A</td>
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<tr>
<td>HTV-R196</td>
<td>4,000 to 12,000°A</td>
</tr>
<tr>
<td>HTV-R213</td>
<td>1,850 to 8,000°A</td>
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CERAMIC RESONATORS
as oscillator control elements...

Last month, in the first part of this article, we discussed the possibilities of 455KHz ceramic resonators for use in high-performance band-pass filter systems for short-wave and communications receivers. This month, we have a look at the possibilities of using the same resonators as the controlling unit for beat frequency oscillators.

By Ian Pogson

Facing up to the proposition, we referred to the Murata Technical Report on Ceramic resonators and studied the frequency versus impedance curve, reproduced here as figure 7. It will be seen that the series resonance point is nominally at 455KHz, the impedance (resistance) being of the order of 20 ohms or less. On this basis, we reasoned that the device should oscillate in the series mode. On studying the curve further, we noted that the parallel or antiresonance point occurred at about 495KHz. Clearly, this point would be of little value.

In some respects the curve is similar to that of a quartz crystal, but the series and parallel resonant frequencies are much further apart. Also, the resistance at series resonance is generally higher with a quartz crystal which emphasises the possibility of using the ceramic resonator in a series configuration.

The first test was with a single element unit, type SF455B, in the circuit as shown in figure 8. This setup was successful in that the resonator did oscillate. A further check showed that the frequency in this case could be changed from 450KHz with the series trimmer shorted to 456.8KHz, with the trimmer adjusted to the point where any further reduction resulted in unreliable oscillation. This was very encouraging. The possible change in frequency of 6KHz could be very useful, although the actual range covered did not straddle the likely pass band of a practical IF strip, using the same type of filter.

In further evaluating the circuit, we were influenced by a report that this particular resonator is no longer being made.

These facts led us to consider the use of the double units with which we had previously conducted the filter experiments. We turned our attention to the successful crystal oscillator, which had been developed some time ago in our laboratory and which we have since used in several projects. The type of circuit which evolved is shown in figure 9; initially, we did not have the coil and capacitors in the bypass of the first transistor.

Overall, results were so encouraging that we decided to investigate means of shifting the resonant frequency, at least by a sufficient amount so that it could be adjusted to one side of the pass band of the IF filter, when this oscillator was to be used as a BFO.

During the investigation, several important points emerged. It was found that quite a large frequency shift could be achieved, ±1KHz or so, by adding inductance and capacitance in suitable proportions, in the base circuit of the first transistor. Rather fortuitously, the optimum value of inductance turned out to be about 1mH, near enough to the inductance of an ordinary IF transformer winding. Even with the 100pF shunt capacitor still across the winding, a significant upward frequency could be achieved. By adding extra capacitance across the combination, the frequency could be shifted by about the same amount in the opposite direction.

Although this could be described as most encouraging, we felt that the amount of shift so far obtained, although useful, still left something to be desired. Subsequently, it was found that if the functions of terminals 1-2 and 3-4 were reversed, a considerable increase in frequency shift could be obtained. Coupled with this, it was also found necessary to increase the top capacitive coupling to 180pF. Under these conditions, as actually depicted in figure 9, we were able to achieve quite readily a frequency coverage from 452 to 458KHz.

ELECTRONICS Australia, October, 1969
One vital question still had to be answered: How would the stability of such an oscillator compare with a crystal oscillator, or even a good self-excited oscillator? Obviously the next task was to find out.

To make the test as realistic as possible, we decided to check, not at 455KHz, but at 453KHz, where the frequency had to be "pulled" by an amount likely to be met in practice. Measurements were taken over a period of one hour, against the frequency counter. From the moment of switching on, there was no significant drift. Indeed, the frequency stayed within a couple of Hz of the initial reading, for the whole hour. The resultant curve is shown in figure 12.

By way of interest, and to make the test more complete, we decided to make comparisons with a typical crystal locked BFO and a self-excited BFO. The circuits of the test oscillators are shown in figures 10 and 11, respectively. The results of these two checks are shown also in figure 12.

Close scrutiny of the curves for the ceramic resonator and the FT241 crystal shows that there is a slight negative drift with the ceramic resonator and a slight positive drift with the crystal. However, the drift in each case is so small that it would be of little consequence in practice. It is also interesting to note the performance of the self-excited oscillator, particularly after a warm-up period of 20 minutes. After this time, this oscillator is almost as stable as the other two. At the same time, it must generally be conceded that the self-excited oscillator is more likely to be upset by environmental conditions.

Before leaving our comparisons between the ceramic oscillator and the crystal counter, it may be worth looking at the temperature coefficients of the two elements. Here again, we refer to the Murata Technical Report, which gives the temperature coefficient of the ceramic unit as less than 50 parts per million, per degree Celsius; it also gives a figure of less than 10 parts per million, per degree Celsius, for a crystal. In round figures, therefore, we could expect a long-term stability with temperature, for the ceramic oscillator, to be about one-fifth that of a typical crystal — which should still be very satisfactory.

The point which emerges is that a stable BFO, perhaps not quite as good as a crystal controlled BFO, is possible at a very moderate cost. Furthermore, where two crystals would normally be required for upper and lower sideband reception, the same two functions can be performed by only one ceramic unit, thus making the cost factor even more attractive. In addition, it should also be possible to make the ceramic BFO continuously adjustable in frequency over its full range with a suitable variable capacitor.

These considerations hold good promise for the development of low cost, high performance short wave and communications receivers. We expect to make immediate use of this information for the development of receiver IF strips and BFOs. In addition, the possibility of using a ceramic filter assembly and ceramic oscillator for the carrier for an SSB generator is too promising to be overlooked.
CERAMIC RESONATORS
in practical applications . . . . 3

A description of a practical IF strip, featuring sharp and narrow response curves, a BFO, an AGC system suited to AM or SSB-CW, and using ceramic resonators throughout. Built as part of a communications receiver now under development, the details are given for the benefit of those readers who would care to experiment.

By Ian Pogson

In a previous article, we looked at the characteristics of some ceramic resonators, normally intended for applications in simple broadcast receiver IF systems. Until then, it had generally been accepted that these resonators had fixed characteristics, particularly with respect to their centre frequency. Also, any deviations from this centre frequency, from one unit to another, due to maker’s tolerances, had to be accepted. This presented problems when a designer desired to combine two or more of these devices, to achieve a certain performance characteristic.

It was shown that the concept of a fixed centre frequency was not valid and that, within very useful limits, the centre frequency and other relevant characteristics could be controlled quite readily. This opened up the possibility of combining two or more of these devices to achieve desired band widths and shape factors. Indeed, it was also shown that these factors could be readily controlled and that filters rivaling mechanical and crystal lattices could be produced. And all at a very attractive cost and with minimum space requirements.

In addition, it was demonstrated that these resonators could be used as an oscillator at (a nominal) 455KHz, thus suggesting its possible application in a receiver BFO. Such oscillators subsequently turned out to be very stable, while the frequency could be shifted by at least ±3KHz from the centre frequency of 455KHz. This gives the ceramic oscillator the advantages of both the crystal and self-excited BFOs. Once again, all at a very attractive cost.

This article will investigate the possible applications of this type resonator in the roles of IF filters of various characteristics, and as a BFO. Some of the information describes actual units which could be applied to solid state receivers. Circuits are based on our developments up to this point and are offered as suggestions and a place from which to carry on development.

We have pursued our recent findings with an eye to incorporating them into short-wave and communications receivers, which we hope to produce later on. Although the circuits shown may be subject to subsequent changes and modifications, they should be of interest to readers who may wish to use them as they are, or for experimental purposes.

We have already developed a complete IF system, using all solid state devices and without any conventional IF transformers. This has resulted in a compact module, capable of high performance at an attractive price.

The system to be described starts after the mixer. It includes a dual-selectivity ceramic filter assembly, followed by three IF amplifier stages. The AGC system, although relatively simple, is amplified, provides for long and short time constants, and is capable of quite a good performance. The detector, again a very simple arrangement, provides for AM, CW and SSB reception and is highly effective. The BFO used with this detector is that which was described earlier using a ceramic resonator. It is capable of being switched for upper and lower sideband reception. Checks made so far indicate that the system, as a whole, will give every satisfaction at a moderate cost.

Let us look at the circuit diagram and discuss the various parts and func-

Figure 1

This block diagram shows the arrangement of the resonators and other components on the wiring board assembly. Note the 3.3K resistor, part of the output divider. At right is a typical set of curves from this system.

Figure 2

[Graph showing frequency response]

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tions. For convenience, we have shown a mixer stage using a FET, but more will be said about mixers later on. There are two degrees of selectivity provided for — "wide," about 5KHz at the 6dB points, and "narrow" about 2.5KHz at the 6dB points. The complete filter assembly is made up on a compact wiring board measuring only 2in x 1 1/2in. By the time this appears in print, or shortly afterwards, we expect that boards should be available.

Figure 1 shows details of the components on the wiring board. Note the 3.3k resistor in series with the output of the wide filter section. This resistor forms part of a voltage divider which is necessary to bring the output of each filter section to the same level. The insertion loss of the multi-section narrow filter is much higher than the single-section wide filter. With the voltage divider, the sensitivity and signal strength meter readings will remain the same for both positions.

In order to adjust these two levels it is necessary, after the system is operative, to adjust the value of the resistor at the input of the following stage. The value will lie somewhere between 100 and 390 ohms, from our experience.

The circuit of figure 1 is shown in practical form in the accompanying photograph, built on a printed wiring board. In this particular unit there are four shape-correcting resistors on the narrow filter and one on the wide filter. This is more than is generally necessary and simply indicates the variable nature of individual filters. Representative curves of the two selectivity positions is given in figure 2.

Selection of the narrow or wide filter is by DC biased diodes in series with both input and output signal circuits. This method has been used by the writer in the past, with complete success. It offers the advantage that there are no long leads involved in the signal path and that the switch can be located at any convenient position on the front panel.

The operation of the diode switching as follows: Consider the input side first. There are two diodes, one in each filter line, both cathodes being connected to the FET drain. On each side of the diodes is a 2.5MH RF choke, which becomes the drain lead when required. The other end of each RF choke is terminated at a tuning or other suitable switch. This switch connects one RF choke to the positive 12-volt supply line and the other to earth. The circuit connected to the supply line has its diode connected such that it conducts and feeds the FET drain. This also allows the diode to conduct signal from the drain to the appropriate filter. The other RF choke is connected to earth and completes the circuit where-

This circuit diagram shows how the ceramic resonators may be applied to a practical IF amplifier strip, together with the additional application of the same resonators as an oscillator for the BFO. This oscillator is highly stable and may be shifted in frequency for upper and lower sideband reception.
by the associated diode is reverse biased. This results in the diode presenting a high resistance between the FET drain and the other filter. By converting the connections at the switch to the opposite condition will prevail.

The foregoing looks after the input side of the filters. However, the output also have to be switched. This is done in a similar manner but it is somewhat more complex. The output is fed into two different sets of conditions. Resistors are used from the switch to the individual diodes in this case, one being the required DC return. The other is not required to equalise the gain, as mentioned previously. The two cathodes of the diodes are connected together as before. However, as there is no wanted DC circuit return, this is created by adding a 6.8K resistor from the cathodes to earth. Switching is then effected in the same way as at the input.

The resistors used in the output circuits of the two filters are so selected that they provide about the right terminating value required. As this circuit is isolated from the following FET IF amplifier gate, a blocking capacitor is introduced.

Before leaving the filter, a question may arise and is answered in anticipation. Two RF chokes are used on the input side and the economy of the system may be questioned. Because of the relatively high current drawn by the FET, compared with a bipolar transistor, a drain feed of low DC resistance is necessary. The switching arrangement could be modified so that only one RF choke is necessary, but this involves complications and reduced gain. In any case, in the final application, the mixer may be so changed that this question may not arise.

The next stage uses a 2N5459 FET. The drain load is 2.5M RF choke, the reasons for its use being the same as for the mixer. Coupling between this and the following identical stage is by means of a slightly over-coupled ceramic filter used. The phase of this filter is controlled by the stage coupled to a third and uncontrolled IF amplifier, using a bipolar transistor. This may be a 2N5115 or any similar type.

There are two further points concerning this stage. A small amount of degeneration is introduced into the emitter circuit, with an un-bypassed 100 ohm resistor, so that the stage may handle a larger signal without over-load. The collector load is a 2.5M RF choke. This is used so that extra gain may be obtained from the stage.

Before leaving the IF strip, a brief comment about the reasons for using FETs in the first two stages and a bipolar transistor in the third stage. It had already been decided that, in a complete receiver design, we would be using a FET in the RF amplifier stage. This means that a negative AGC voltage would be needed. As it would introduce complications to provide control for this stage and nothing different for the IF stages, we decided that it would be the simplest way out to use FETs where AGC is to be applied. In the third stage, where no AGC is applied, a bipolar transistor offers the advantages of lower cost and higher gain.

Signal for AGC is taken from collector of the third IF amplifier. T is fed into a AGC amplifier, using BP115 or similar transistor. The gain of this stage is limited by the low value of coupling capacitor about 22pF, and an un-bypassed 2 ohm emitter resistor. The full gain of the amplifier provides more control than necessary, and introduces a problem of BFO signal breakthrough. T gives an unwanted AGC voltage and CW-SSB reception conditions.

The AGC amplifier collector circuit provides a low source impedance of the signal, which is then rectified and gated with two silicon diodes, type BA100, or similar. Silicon diodes were selected in preference to germanium types, to provide a small amount of voltage delay, which is a worthwhile improvement. Two time constants are provided, to cope with AM and CW-SSB reception. We used tantalum 2u and 10uF capacitors but ordinary electrolytes are satisfactory.

The detector is one which we originally described by Frederick W. Brown, in CQ for March, 1965. After checking this combined AM and CW-SSB detector, one wonders why other more complex devices are used so commonly. As can be seen, it is about
as simple as it could be. It uses two diode detectors, as for AM reception, but with the diodes connected in opposite polarities. When the switch is open, only the top circuit is operative and the circuit operates as a conventional diode detector. However, with the switch closed, and no BFO injection the signals from the two diodes cancel, providing the circuit is balanced.

Under such balanced conditions no audio output will be available; the network thus exhibiting a characteristic of a product detector. When injection is introduced from the BFO, the circuit functions as a mixer, thus giving output from CW and SSB signals.

Although it may not be essential, we used a matched pair of AA119 diodes and we suggest that their inclusion would be worthwhile. Apart from the other desirable features of this detector, the switching is the simplest possible. Reasonably long leads can be run to the switch on the front panel without any problems.

The BFO is the same as described in a previous article on the subject, (October, 1969, page 49). This is among the new and exciting circuits which are emerging from our investigations into ceramic resonators. The first transistor in the oscillator may be a BF115 or any one of a number of similar types. However, the second stage must be a PNP type, connected as shown. It may be a silicon type 2N3658 or similar, but there are many PNP germanium types which can be used successfully, such as OC44N, OC170, etc. The third transistor is simply a phase splitter and such types as BF115 or similar may be used.

Although we have used a transistor in the role of phase splitter, we are looking into the possibility of using a small transformer, wound on a "balun" type of ferrite core. So far we have not concluded these investigations.

The SFD-455B ceramic resonator is situated in series with the feedback loop of the oscillator. Note that the connections to the resonator are "upside down," compared with the normal interstage coupling connections. In other words, the coupling capacitor is connected between pins 3 and 4, and the input and output are via pins 1 and 2. Also, the top coupling capacitor is larger than usual, being 180pF. These changes allow a greater frequency shift to be achieved more readily.

Frequency shift is achieved by introducing inductance and capacitance, in the right proportions, in the base circuit of the first transistor. The inductance is a standard 1mH RF choke (C.5mH will not do). Two capacitors are selected to give the required frequencies for upper and lower sideband resolution, after the system is put into operation. The two values fitted to this prototype are 65pF and 100pF. For the low frequency operation, the 100pF capacitor is switched in parallel with the 65pF unit.

At this point, we draw readers' attention to the power supply described in August, 1969. This supply could be used as a supply for this new IF system.

It is important that the BFO be fed from a well-stabilised supply. The most convenient source is the 9V double regulated outlet from the above power supply, which has excellent stability. However, the BFO requires no more than six volts. This gives sufficient output for the product detector, whereas higher output, as from a higher supply voltage, causes BFO breakthrough into the AGC system, which must be avoided. We used a dropping resistor to reduce the supply voltage, but the value shown may need to be modified on an experimental basis, or if a different supply voltage is used.

When switching from AM to CW-SSB reception, a simple double pole single throw toggle switch is all that is necessary. For AM reception, both poles are open; for CW-SSB, both are closed. To simplify this function still further, a three-pole switch could be used, the extra pole being used to switch the AGC time constant.

As a matter of interest, we are reproducing drift curves, comparing a self-excited and a crystal-controlled BFO, with the ceramic resonator BFO. (Figure 3.) Although the new BFO uses three transistors, it is still economical, when compared with other types.

Although this article is not intended to be a constructional project in the normal sense, it may stimulate investigation into the possibilities of ceramic resonator application. For this reason, we will go into some of the more important constructional aspects, so that readers who wish may duplicate our original prototype.

From a constructional point of view, the printed board incorporating...
The smaller values of capacitors may be Styrosole, or similar. The 0.02µf and 0.01µf by-pass capacitors may be low voltage ceramics, such as the Redcaps, or mylar types, rated at 150 volts or less. The 0.1µf AGC capacitors must be low leakage types such as Styrosole or mylar.

As mentioned earlier, we have a few comments on mixers which may be used to precede the filter. Originally, we tried a 2N5439 FET, as it is perhaps one of the simplest approaches to this problem. However, for our particular application, this arrangement left something to be desired. Yet it is a characteristic of this type but, although the gain was satisfactory at the broadcast frequencies, it fell off rapidly at the higher frequencies. Quite a lot of local oscillator component appeared at the mixer drain. This is of no consequence in the circuit as it stands but we have a noise slinger in mind for this position and the oscillator component seriously affected the slinder operation.

For some time we have had a healthy respect for the "magic mixer". This consists of four diodes in a balanced circuit and has certain desirable characteristics. The gain (or loss) is varied over a constant frequency range and, as it is balanced, local oscillator components do not appear at the IF output. It would seem then, this circuit would not get the need at hand, except that it has no gain of its own. To counter this the mixer could be followed by a simple bipolar transistor amplifier. At this point of our experiments, his circuit looks promising.

So much for construction, mixers, etc. Having built the IF system, we have to make sure that it functions correctly, then set the pass bands of the two filters to the desired shape. At this stage, we feel that the most satisfactory way of doing this is to use a 455KHz sweep generator and a CRO. We are hopeful that a simple way may be found, but time has not allowed us to make a thorough investigation.

Equipment needed is a sweep generator which sweeps 455KHz, and a CRO. These are set up in the usual way. A marker generator is not really necessary, the object being to get the pass bands of the correct shape and bandwidth. Any deviation from the nominal frequency of 455KHz has to be accepted. This will not amount to more than a KHz or so anyway.

A peak-to-peak detector probe may be used, taking the output from the collector of the third IF amplifier or the output from the probe being fed into the vertical amplifier of the CRO. Alternatively, the built-in AM detector may be used, feeding the audio output to the CRO via a shielded lead.

After the alignment process nothing must be done to the circuitry of the complete IF strip which will in any way affect the final pass band shape. This applies in particular to components associated with the two coupling ceramic resonators, between the first and third IF amplifiers. Any change in component values can change the overall result. As an example, the 100 ohm resistor in the emitter of the third IF amplifier should not be removed, by-passed, or altered.
in value. If any such change must be made, then the alignment must be checked and adjusted if necessary.

Assuming you have set up for allignment, we suggest that you dispose of the broad position first, as being the simplest. Adjust the level of the display on the screen to conventional size. There is no requirement that there must be no signal being fed into the system as to cause overload anywhere along the line. This could look like an ideal curve but it would be incorrect.

Unless you are extremely lucky, the display on the screen will look "lopsided." The technique is to use resistors and capacitors of various sizes to make exactly that. The resistor values will normally range between about 10K and 1K, with the capacitors from about 22pF to 100pF or more. Start with either a capacitor or a resistor, of any value in the above range. Connect it between earth and pin 1 or 2 of the resonator and note the effect on the screen. Careful observation, together with a few tests, will soon give you the idea. Before long you will have decided on the correct value of resistor or capacitor. Connect the terminals to which it must be connected, to give the best pass-band shape.

More than likely, a resistor will give the best result. In some cases it may be necessary to connect a resistor or capacitor to both pins. We had one case where it was necessary to connect a 6.8K resistor and a 100pF capacitor, in parallel, from one pin to earth, with a second resistor of 12K from the other pin to earth. This was an extreme case.

Now switch to the sharp filter position. It may be necessary to readjust the gain of the CRO vertical amplifier. The same principles apply as before, but the procedure is somewhat more involved in that there are many more combinations possible. However, this may sound worse than it really is in practice. Proceed as before, with a resistor or capacitor from each of the pins 1 and 2 to earth, and note the effect. At this point, a certain amount of guesswork as well as judgment must be involved in the decision as to which looks most promising, in that it will have resulted in an improved, if not a correct, pass band shape. If improvement, proceed as before. More than likely, a component will be soon found which gives the final correction. If only an improvement is obtained, then it is necessary to connect it into circuit and proceed along the same lines. When the final pass band is achieved, all the corrective components are connected permanently to the copper side of the board.

This description may give the impression that this task is a tedious one. This is not the case and the correct shape can normally be obtained in a shorter time than it has taken to write the detailed instructions!

There is still one adjustment to make. This involves the introduction of the sweep. The trigger level can be adjusted to give the desired output of the broad filter, so that when switching from broad to sharp, there is no change in gain. This can be done most readily by connecting just the low value resistor (shown as 220 ohms) to the value to equalise the gain.

Using the sweep setup, the BFO can be set at, least approximately, to the correct frequencies on each side of the pass band of the sharp position. Assuming a capacitor of 68pF or so across the 1mH inductor, switch on the BFO and tune the BFO control to the centre frequency lies. It should be at about the centre of the bend at the bottom of the pass band. Adjust the capacitor in its holder until you have the point. Provide another capacitor, 100pF or so, across the capacitor just described. The new value should shift the BFO centre frequency to the corresponding bend on the other side. These positions may be subject to slight change under listening conditions.

If facilities for sweep alignment are not available it may be possible to see an ordinary signal generator, though we imagine that the process will be very tedious. The technique is to sweep the generator slowly across the pass band by hand, noting the readings on an output meter. The output meter may take two forms. It may be a conventional type, measuring recovered audio in conjunction with a modulated signal from the generator, or the signal may be unmodulated and the AGC voltage monitored with a VTM.

So far, over the past few months, we have described a power supply, an audio amplifier and now a complete IF strip and filters. These, it is hoped, will form the basis of a complete high stability, full coverage, solid state receiver, in the foreseeable future.

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The pattern of the printed wiring board for the filter illustrated on page 81. It is reproduced exact size.