Crystal Filter Design with Small Computers

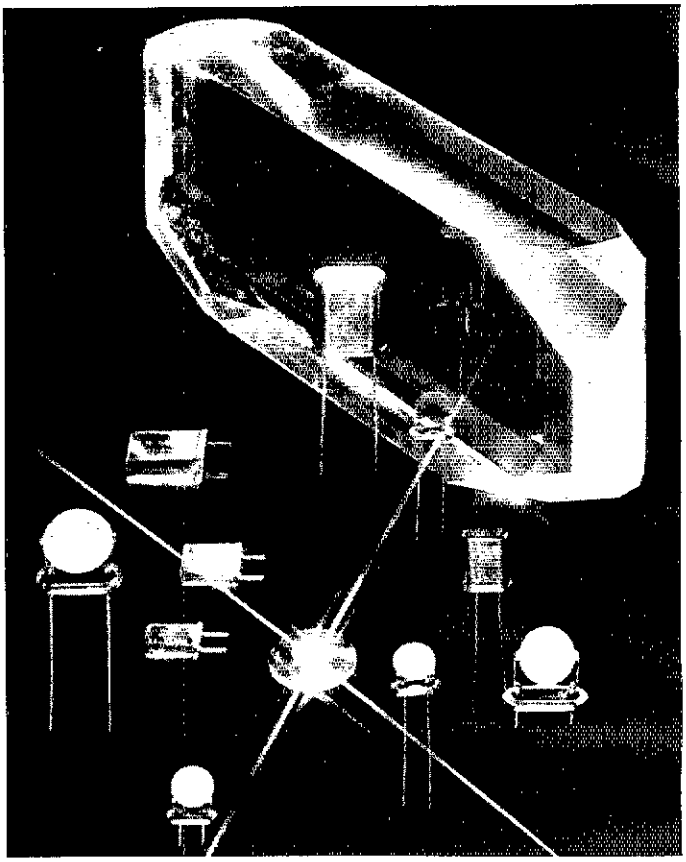

photo courtesy M-Tron Industries, Inc.

Thinking of making a crystal filter? This computer program will provide excellent results. It even allows calculations for filters that provide large bandwidths.

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Crystal filters are being used where superior selectivity is required and the specific bandwidth may be anywhere from a few hundred hertz up to 100 kHz. Crystal filters, as generally offered, are of the Chebyshev design. These filters, however, frequently exhibit bad ringing and group-delay distortion. A natural question at this point would be, "Is there an alternative and, if so, what is it? In answer, this article provides information on the use of a small BASIC computer to aid in building more suitable crystal filters. The actual program is shown, along with computer results. In addition, attenuation graphs are provided to illustrate the effects of additional filter poles. The program is written in such a way that it allows the calculations of large-bandwidth crystal filters. Such information has not been available previously.

Standard Filter Design

A half-lattice crystal filter with one crystal appears in Fig. 1. Filters of this type have been designed into receiver circuits, but with rather poor results. By tuning the neutralizing capacitor, C1, a pole can be moved in order to influence the bandwidth and the notch depth.

Fig. 2A presents the attenuation performance of a single-crystal 300-kHz filter. The notch at the right is set by the neutralizing capacitor. Attenuation in excess of 100 dB is possible.

The close-in performance of the single-crystal filter can be seen in Fig. 2B while Fig. 2C is a graph of the overall performance. If the pole is removed far enough, as in Fig. 2C, the selectivity improves greatly on the left side and the filter action becomes symmetrical. In reality, though, such filters do not offer outstanding performance. Consequently, they are seldom used today.

A typical ssb filter has a total of six crystals. How a filter of this type behaves is indicated by Fig. 2D. In practice, the ultimate rejection would be limited to 120 dB.

Crystal filters are found frequently in up-conversion receivers like the DJ2LR HF-1030. Fig. 2E shows the performance of a typical circuit of this nature. If the filter is improperly tuned, a performance similar to that in Fig. 2F can be expected. At times, such an adjustment may be useful to suppress a mixing product or an image if a 60-dB attenuation on the other side is sufficient.

In practice, we should evaluate those performances when we are working with a crystal filter design and then calculate the parameters of the particular crystal filter in which we are interested. This can be done with the aid of the program.

Table 1 contains a list of program information covering a wide variety of possible bandwidths for a universal crystal filter. The basic configuration for such a crystal filter appears in Fig. 3. It consists of three tuned transformers constructed with small pot cores suitable for high-frequency application. A pot core recommended for this application is Siemens' type 4.6 × 4.1 (mm), no. B65495-K0005-A017 for lower-frequency use. For the region around 10 MHz, the core material K65495-K00016-A001 is satisfactory.[1]

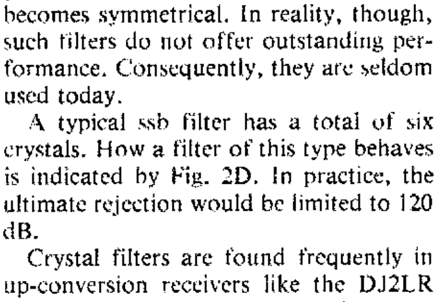

Fig. 1 — A half-lattice crystal filter circuit.

Computer-Aided Design of a Crystal Filter

Lines 1 through 20 in the program of

[1]Details on Siemens' pot cores are found in the Siemens book, *Ferrites Soft-Magnetic Material Data Book 1979/80*, p. 98. This book is available from the Siemens Corporation, 186 Wood Ave. S., Iselin, NJ 08830, tel. 201-494-1000.

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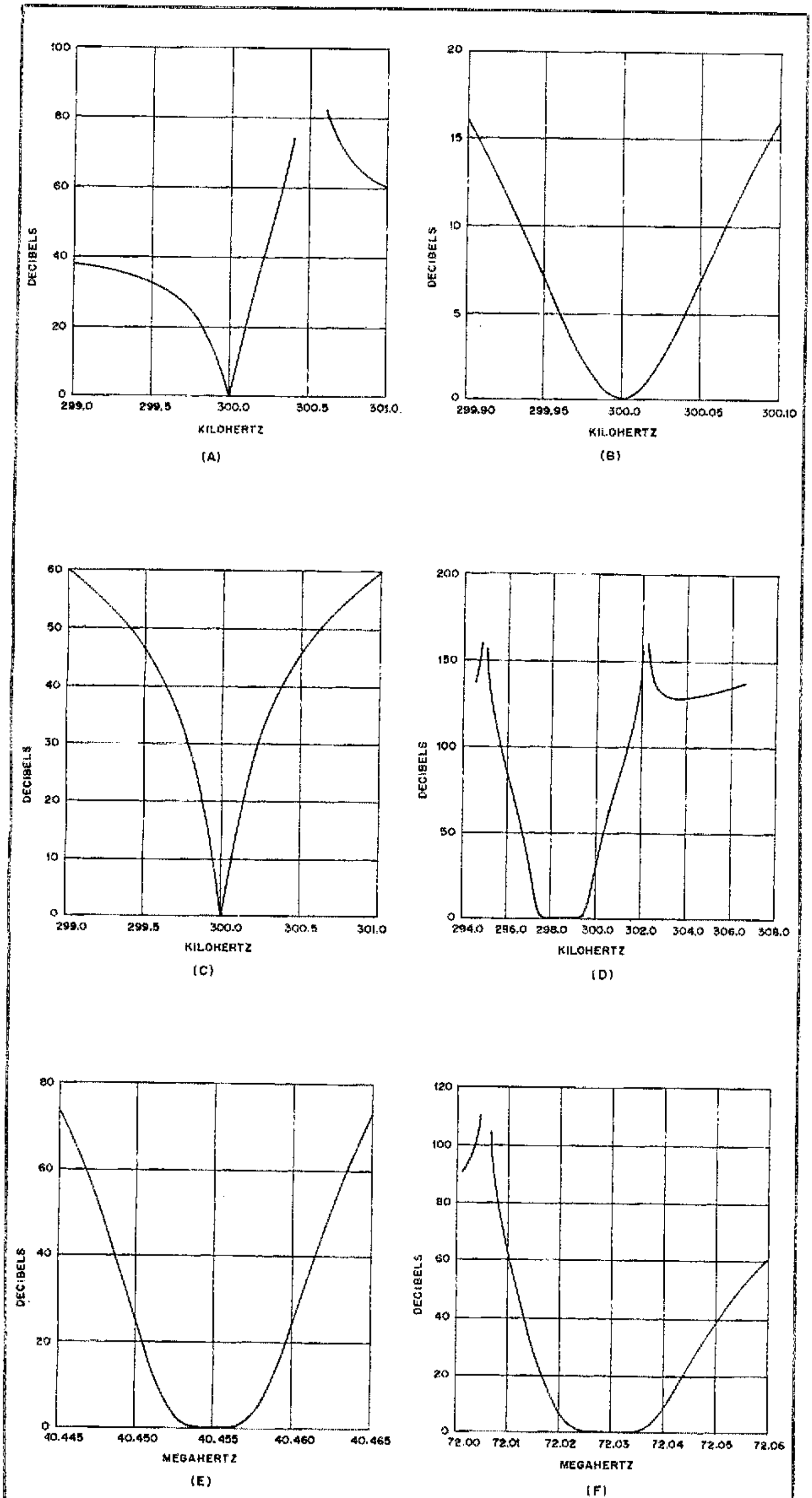

Fig. 2 — Crystal filter responses. The amplitude response of the crystal filter in Fig. 1 with C1 set to generate a pole 500-Hz above center frequency is shown at A. The close-in performance of this same filter is indicated at B, while the overall response is represented in C. In the latter case, the pole is tuned considerably away from the center frequency. At D the amplitude response of a six-crystal single-sideband filter at 300 kHz. A Chebyshev six-crystal filter at 40.455 MHz is represented by the curve at E. The curve at F is for the amplitude response of a 72.03-MHz crystal filter with an attenuation pole on the left side.

Table I activate the user-definable keys available on the Tektronix 4051/52 computers. After initiation of the program, it will start on line 100 and ask whether the results should be displayed on the screen or on the printer. Most of the hobby computers on which this program will run have printer-definable ports that have to be addressed. The address to which the information is routed is V5.

In line 200, the computer will ask the center frequency. In line 230, it will ask the bandwidth while in line 250 it will request the crystal inductance.

Fig. 4 shows the inductance in relation to a function of frequency for a crystal that can be manufactured. The highest possible inductance for L1 should always be selected without sacrificing performance in a manner that would lead to spurious response. A minimum Q of 80,000 (100,000 is better) for the crystal is desired for narrow bandwidths. If you start building a crystal filter and order the crystal from a company like Bliley, a firm experienced in crystal and filter manufacturing, you will do well to have them verify these two parameters.

At line 260, the computer will ask you for the capacitance of the holder. You can generally presume that the HC-18/U holder is rated at 1.5 pF, with the larger HC-6/U unit having a capacitance of 6 pF.

On line 280, you will finally be asked what filter response you desire. Various types of responses are available. If selectivity is the prime object, a Chebyshev filter should be chosen. Where constant group delay and therefore low fm distortion are required, a flat delay is important. For perfect pulse response, either the linear phase filter or the Gaussian response should be chosen.

Amateurs who desire additional general information on filter theory will find Zeverev's *Handbook of Filter Synthesis*, published by John Wiley and Sons, particularly useful. The "look-up" tables I refer to in this computer program are taken from his book. In this publication, Zeverev briefly elaborates on the difficulties in building crystal filters that have a large bandwidth in comparison to the center frequency. A typical problem, for instance, is one concerning a 10- to 20-kHz-bandwidth filter designed for 10 MHz. Because Zeverev seems to avoid giving clear design rules for such filter circuitry, additional guidelines are needed. This is where the computer program fills in, for it incorporates the necessary "spreading inductance" which will cure the problem.

Another good source of general filter information is the ITT book *Reference Data for Engineers*, fifth edition, chapters 7, 8 and 9. Inasmuch as many readers may be less interested in precise theory, preferring just to build some filters, none of the mathematics is repeated. Fig. 5 is a graph with the different response curves shown in comparison with each other.

Computerized Tuned-Circuit Information

After you have responded to the query in the filter program concerning the type of filter you wish to have, the computer will use the "look-up" table as provided by line 890 and 1290. The aim of this part of the program is to calculate the component values of lines 380 through 580. You can delete lines 140 and 590, a screen-erase command for the Tektronix computer. Lines 600 through 840 transfer the characteristic values to the printer or the screen. Lines 600 to 650 print, respectively, the header, the center frequency, the bandwidth, the inductance, the internal impedance and the external reference capacitance. Other information includes the input impedance that is printed in line 660 with the required inductance, the capacitance in line 700, and the output values in line 670 together with line 710.

Lines 680 and 690 determine the tuned circuit for the middle of the range. In order to obtain the right crystal from the manufacturer, the four frequencies required are printed on lines 720 through 750. A six-digit accuracy is desirable when these crystals are ordered. Line 800 gives the reference input voltage for a second computer program to determine the actual band-pass characteristic. Lines 820 through line 840 verify that all tuned circuits are on the center frequency.

When aligning the filters, do realize that any mistuning of the input stages will result in poles as shown in Figs. 2A, 2D and 2F. In order to get sharper skirts at times, it is desirable to use poles like these. They can always be determined experimentally. The procedure is to set all three tuned circuits precisely on the center frequency with the crystals inserted.

For those amateurs who do not have a computer, some calculations of interest also are shown in the tables. Table 2 shows the Butterworth, Chebyshev, flat-delay crystal filter, linear-phase crystal filter and Gaussian response filter for a 250-Hz bandwidth. The Chebyshev response should really be avoided because of ringing. The optimum choice probably is the flat-delay or linear-phase approach.

As we take a look at the filters of Table 2, we see that 9 MHz has been selected for the center frequency with a 250-Hz bandwidth. The present inductance is 200 mH. All other values are self-explanatory.

My calculations for single-sideband filters for both upper and lower sidebands are shown in Table 3. For perfect low distortion, the flat-delay versions should be preferred.

In cases where further selectivity is required, two of those crystal filters can be cascaded either directly with a 1-dB resistive matching pad in between or a transistor stage with 3 to 4 dB gain and heavy feedback. Finally, for those in-

Table 1

Wide Bandwidth Filter Design Program

```
1 GO TO 100
4 RUN 280
8 PAGE
9 GO TO 2ØØ
2Ø LIST 129Ø, 2ØØØ
1ØØ INIT
11Ø SET KEY
12Ø DIM C(13)
13Ø C$ = ""
14Ø PAGE
15Ø PRINT "*** CRYSTAL FILTER PROGRAM *** J__J__"
16Ø REM COPY-RIGHT RESERVED
17Ø REM ULRICH L. ROHDE, PH.D., SC.D.
18Ø PRINT "DO YOU WANT OUTPUT AT SCREEN (32) OR PRINTER (41)?"
19Ø INPUT V5
2ØØ PRINT "WHICH CENTER FREQUENCY DO YOU WANT?"
21Ø INPUT FØ
22Ø PRINT "WHICH BANDWIDTH DO YOU WANT?"
23Ø INPUT BØ
24Ø PRINT "WHICH INDUCTANCE DO YOU HAVE?"
25Ø INPUT L
26Ø PRINT "WHAT HOLDER CAPACITANCE DO YOU HAVE"
27Ø INPUT C(9)
28Ø PRINT "WHICH FILTER TYPE DO YOU WANT, BUTTERWORTH,"
29Ø PRINT "CHEBYSHEV, FLAT DELAY, LIN. PHASE, GAUSS RESP. (B,C,F,L,G)?"
300 INPUT A$
31Ø IF A$ = "" THEN 1290
32Ø IF A$ = "B" THEN 89Ø
33Ø IF A$ = "C" THEN 97Ø
34Ø IF A$ = "F" THEN 1Ø5Ø
35Ø IF A$ = "L" THEN 113Ø
36Ø IF A$ = "G" THEN 121Ø
37Ø RETURN
38Ø RØ = PI*L*BØ
39Ø CØ = 1/(2*BØ*PI↑2*FØ*L)
4ØØ QØ = 15ØØØØ*BØ/FØ
41Ø R1 = RØ*(K2↑2 + (1/Q1 - 1/QØ)↑2)/(1/Q1 - 1/QØ)
42Ø R2 = RØ*(K2↑2 + (1/Q4 - 1/QØ)↑2)/(1/Q4 - 1/QØ)
43Ø C(1) = CØ*K2/(K2↑2 + (1/Q1 - 1/QØ)↑2) - 2*C(9)
44Ø C(8) = C(1) + 2*C(9)
45Ø GO TO 13ØØ
46Ø C(2) = CØ*K2/(K2↑2 + (1/Q4 - 1/QØ)↑2) - 2*C(9)
47Ø C(1Ø) = C(2) + 2*C(9)
48Ø GO TO 134Ø
49Ø C(11) = CØ/K2 - 4*C(9)
5ØØ C(3) = 1/((2*PI*FØ)↑2*L1) + C(11)
51Ø F1 = FØ - BØ/2*(K2 + K1)
52Ø F2 = FØ - BØ/2*(K2 - K1)
53Ø F3 = FØ - BØ/2*(K2 + K3)
54Ø F4 = FØ - BØ/2*(K2 - K3)
55Ø C(4) = 1/(4*PI↑2*F1↑2*L)
56Ø C(5) = 1/(4*PI↑2*F2↑2*L)
57Ø C(6) = 1/(4*PI↑2*F3↑2*L)
58Ø C(7) = 1/(4*PI↑2*F4↑2*L)
59Ø PAGE
6ØØ PRINT @V5:F$;"J__"
61Ø PRINT @V5:"FØ =  ";FØ
62Ø PRINT @V5:"BØ =  ";BØ
63Ø PRINT @V5:"L =  ";L
64Ø PRINT @V5:"RØ =  ";RØ
65Ø PRINT @V5:"CØ =  ";CØ
66Ø PRINT @V5:"RIN =  ";R1
67Ø PRINT @V5:"ROUT =  ";R2
68Ø PRINT @V5:"CK =  ";C(3)
69Ø PRINT @V5:"LK =  ";L1
7ØØ PRINT @V5:C$;L1,"CIN =  ";C(12)
71Ø PRINT @V5:D$;L2,"COUT =  ";C(13)
72Ø PRINT @V5:"F1 =  ";F1
73Ø PRINT @V5:"F2 =  ";F2
74Ø PRINT  @V5:"F3 =  ";F3
75Ø PRINT @V5:"F4 =  ";F4
76Ø PRINT @V5:"CS1 =  ";C(4)
77Ø PRINT @V5:"CS2 =  ";C(5)
78Ø PRINT @V5:"CS3 =  ";C(6)
79Ø PRINT @V5:"CS4 =  ";C(7)
8ØØ VØ = (R1 + R2)/R1
81Ø PRINT @V5:"VØ =  ";VØ
82Ø WØ = 1/(2*PI*SQR(L1*(C(12) + C(1))))
83Ø W1 = 1/(2*PI*SQR(L2*(C(13) + C(2))))
84Ø PRINT @V5:"POLE FREQUENCIES ARE ";WØ;" ";W1
```

```
850Ø CALL "WAIT",1
860Ø PRINT @V5:"J_J_J_"
870Ø GO TO 28Ø
880Ø END
890Ø QØ = 1ØØ
900Ø F$ = "BUTTERWORTH RESPONSE 4TH ORDER CRYSTAL FILTERJ_"
910 Q1 = 1.0457
920 Q4 = 1.0457
930 K1 = 0.7369
940 K2 = Ø.5413
950 K3 = Ø.7369
960 GO TO 38Ø
970 QØ = 1ØØØ
980 F$ = "CHEBYSHEV RESPONSE 4TH ORDER CRYSTAL FILTER 0.01DB RIPPLEI_J_'
990 Q1 = 1.8258
1ØØØ Q4 = 1.8258
1Ø1Ø K1 = Ø.6482
1Ø2Ø K2 = Ø.5446
1Ø3Ø K3 = 0.6482
1Ø4Ø GO TO 38Ø
1Ø5Ø QØ = 1ØØØ
1Ø6Ø F$ = "MAXIMALLY FLAT DELAY 4TH ORDER CRYSTAL FILTERJ_"
1Ø7Ø Q1 = Ø.2334
1Ø8Ø Q4 = 2.2404
1Ø9Ø K1 = 2.5239
11ØØ K2 = 1.1725
111Ø K3 = Ø.6424
112Ø GO TO 38Ø
113Ø Q = 1ØØØ
114Ø F$ = "LINEAR PHASE 4TH ORDER CRYSTAL FILTER 0.05DEG PHASE ERRORJ_"
115Ø Q1 = Ø.4934
116Ø Q4 = Ø.7182
117Ø K1 = 1.632
118Ø K2 = Ø.7181
119Ø K3 = Ø.7391
12ØØ GO TO 38Ø
121Ø QØ = 1ØØØ
122Ø F$ = "GAUSSIAN RESPONSE 4TH ORDER CRYSTAL FILTERJ_"
123Ø Q1 = 0.2747
124Ø Q4 = Ø.4Ø83
125Ø K1 = 2.2792
126Ø K2 = Ø.7553
127Ø K3 = Ø.9896
128Ø GO TO 38Ø
129Ø END
13ØØ C$ = "TUNED INPUT L1 = "
131Ø C(12) = 1. ØE - 11*1. ØE + 8/FØ
132Ø L1 = 1/((2*PI*FØ)↑2*(C(12) + C(1)))
133Ø GO TO 46Ø
134Ø D$ = "TUNED INPUT L2 = "
135Ø C(13) = 1. 0E - 11*1. ØE + 8/FØ
136Ø L2 = 1/((2*PI*FØ)↑2*(C(13) + C(2)))
137Ø GO TO 49Ø
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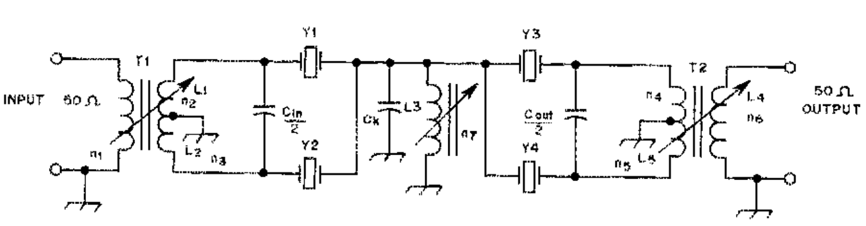

$n_2 = n_3$

n_2 is determined from L1 or L2
To obtain the required value for n_2 let

$$n_1 = \sqrt{\frac{R_{in}}{50\ \Omega}} \cdot n_2$$

$n_4 = n_5$

n_4 is determined from L4 or L5.
To obtain the value n_6 let

$$n_6 = \sqrt{\frac{R_{out}}{50\ \Omega}} \cdot n_4$$

For different impedance, n_2 and n_4 may be changed or the source on board changed from 50 ohms.

Fig. 3 — A four-crystal filter circuit. The input and output impedances are determined by the turns ratio of the input and output transformers. Also shown are the calculations for this filter.

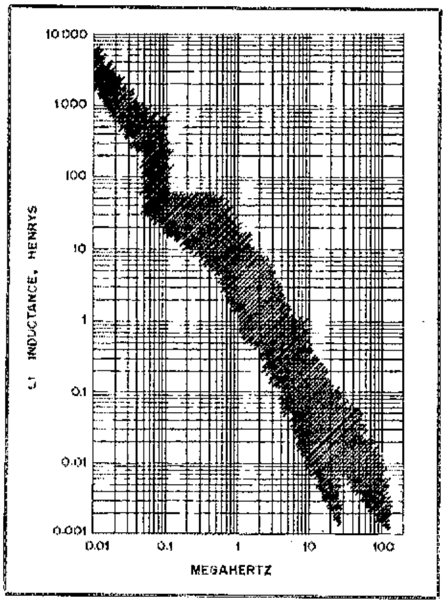

Fig. 4 — This graph shows the relationship of inductance and frequency for a particular crystal selected as a test example.

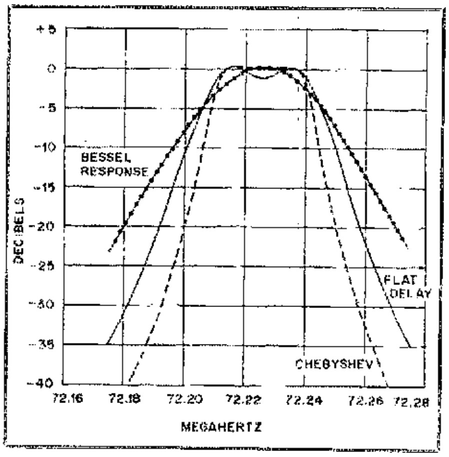

Fig. 5 — The Bessel, flat-delay and Chebyshev responses are represented by this composite graph. The Chebyshev response provides the steepest skirts, while the Bessel response has the poorest amplitude curve.

terested in constructing a double-conversion receiver, the parameters for a 41-MHz crystal filter are provided in Table 4. Table 5 is a Gaussian response filter designed for use in a radar receiver.

In Summary

This short presentation on how to design and build crystal filters with the aid of a small computer should encourage experimentation with various types of filters. In the past, wideband filters like the 72.225-MHz, 31-kHz bandwidth filter of Table 5 required special computer programs. Now this unique program can solve the design problem for an extremely wide bandwidth range.

Table 2

Calculations for Some Large-Bandwidth Filters

	BUTTERWORTH RESPONSE FOURTH ORDER CRYSTAL FILTER	*CHEBYSHEV-RESPONSE FOURTH ORDER CRYSTAL FILTER (Ø.Ø1dB RIPPLE)*	*MAXIMALLY FLAT DELAY FOURTH-ORDER FILTER*	*LINEAR PHASE FOURTH ORDER ORDER CRYSTAL (0.05° PHASE ERROR)*	*GAUSSIAN RESPONSE FOURTH ORDER CRYSTAL FILTER*
FØ =	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ
BØ =	25Ø	25Ø	25Ø	25Ø	25Ø
L =	0.2	0.2	0.2	0.2	0.2
RØ =	157.Ø79632679	157.Ø79632679	157.079632679	157.079632679	157.079632679
CØ =	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø	1.12579Ø929E-1Ø
RIN =	176.77ØØ73394	199.7392822Ø7	688.699716Ø17	325.996645717	560.476789ØØ7
ROUT =	176.77ØØ73394	199.7392822Ø7	1078.92346935	251.3Ø4525198	387.579899958
CK =	3.856888Ø33E-1Ø	4.655256668E-1Ø	2.0557123Ø9E-1Ø	2.8Ø686Ø945E-1Ø	2.581716487E-1Ø
LK =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	2.7Ø6242448E-6	2.4Ø7155723E-6	2.716479143E-6
TUNED INPUT					
L1 =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	2.7Ø6242448E-6	2.4Ø7155723E-6	2.716479143E-6
CIN =	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø
L2 =	1.7Ø2249344E-6	1.18Ø9353Ø2E-6	1.553941872E-6	2.Ø57891921E-6	2.527836771E-6
COUT =	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø	1.111111111E-1Ø
F1 =	899984Ø 225	899985Ø.9	8999537.95	89997Ø6.2375	899962Ø.6875
F2 =	9ØØØØ24.45	9ØØØØ12.95	9ØØØ168.925	9ØØØ114.2375	9ØØØ19Ø.4875
F3 =	8999840.225	8999850.9	8999773.1375	8999817.85	8999781.8875
F4 =	9ØØØØ24.45	9ØØØØ12.95	8999933.7375	9ØØØØØ2.625	9ØØØØ29 2875
CS1 =	1.563654Ø31E-15	1.563650322E-15	1.563759Ø72E-15	1.5637ØØ591E-15	1.56373Ø32E-15
CS2 =	1.56359ØØ17E-15	1.563594Ø13E-15	1.563539819E-15	1.56355882E-15	1.563532327E-15
CS3 =	1.563654Ø31E-15	1.563650322E-15	1.563677343E-15	1.5636618Ø6E-15	1.5636743Ø3E-15
CS4 =	1 56359ØØ17E-15	1.563594Ø13E-15	1.563621537E-15	1.5635976Ø1E-15	1.563588337E-15
VØ =	2	2	2.5666Ø94297	1.77Ø88Ø7Ø844	1.69151819943
POLE FREQUENCIES	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ
	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ	9ØØØØØØ

Table 3

Single-Sideband Filter Calculations

	UPPER SIDEBAND CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE	*UPPER SIDEBAND MAXIMALLY FLAT DELAY FOURTH ORDER CRYSTAL FILTER*	*LOWER SIDEBAND CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*	*LOWER SIDEBAND MAXIMALLY FLAT DELAY FOURTH ORDER CRYSTAL FILTER*
FØ =	9ØØ21.ØØ	9ØØ21ØØ	89979ØØ	89979ØØ
BØ =	21ØØ	21ØØ	21ØØ	21ØØ
L =	Ø.Ø3	Ø.Ø3	Ø.Ø3	Ø.Ø3
RØ =	197.92Ø337176	197.92Ø337176	197.92Ø337176	197 920337176
CØ =	8.932764334E-11	8.932764334E-11	8.93693393E-11	8.93693393E-11
RIN =	215.822217917	906.264311969	215.821952659	906.266750613
ROUT =	215.822217917	733.98Ø82547	215.821952659	733.962678696
CK =	3.52Ø472927E-1Ø	1.836453586E-1Ø	3.522137182E-1Ø	1.837352494E-1Ø
LK =	1.611Ø14457E-6	2.754931668E-6	1.611772269E-6	2.756184362E-6
TUNED INPUT				
L1 =	1.611014457E-6	2.754931668E-6	1.611772269E-6	2.756184362E-6
CIN =	1.11Ø851912E-1Ø	1.11Ø851912E-1Ø	1 11137Ø431E-1Ø	1.11137Ø431E-1Ø
L2 =	1.611Ø14457E-6	1.779138943E-6	1.611772269E-6	1.77996Ø146E-6
COUT =	1 11Ø851912E-1Ø	1.11Ø851912E-1Ø	1.11137Ø431E-1Ø	1.11137Ø431E-1Ø
F1 =	9ØØØ847.56	8998218.78	8996647.56	8994Ø18.78
F2 =	9ØØ22Ø8.78	9ØØ3518.97	8998ØØ8.78	8999318.97
F3 =	9ØØØ847.56	9ØØØ194.355	8996647.56	8995994.355
F4 =	9ØØ22Ø8.78	9ØØ1543.395	8998ØØ8.78	8997343.395
CS1 =	1.Ø422Ø27Ø4E-14	1.Ø42811741E-14	1.Ø43176Ø16E-14	1.Ø437859Ø6E-14
CS2 =	1.Ø41887546E-14	1.Ø41584337E-14	1.Ø4286Ø416E-14	1.Ø42556783E-14
CS3 =	1.Ø422Ø27Ø4E-14	1.Ø42353989E-14	1.Ø43176Ø16E-14	1.Ø43327513E-14
CS4 =	1.Ø41887546E-14	1.Ø42Ø41582E-14	1.Ø4286Ø416E-14	1.Ø43Ø14668E-14
VØ =	2	1.8Ø9897Ø86Ø7	2	1.8Ø987488308
POLE FREQUENCIES	9ØØ21ØØ	9ØØ21ØØ	89979ØØ	89979ØØ
	9ØØ21ØØ	9ØØ21ØØ	89979ØØ	89979ØØ

Table 4

Calculations for a Double-Conversion Receiver 41-MHz Crystal Filter

	CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE	*CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*	*CHEBYSHEV RESPONSE FOURTH ORDER CRYSTAL FILTER Ø.Ø1dB RIPPLE*
FØ =	4.Ø455E + 7	4.1E + 7	7.Ø455E + 7
BØ =	7ØØØ	7ØØØ	7ØØØ
L =	Ø.Ø1	Ø.Ø1	Ø.Ø1
RØ =	219.911485751	219.911485751	219.911485751
CØ =	1.78895746E-11	1.769177415E-11	1.Ø27212746E-11
RIN =	24Ø.Ø69542975	24Ø.Ø8611Ø77	241.4Ø15Ø5946
ROUT =	24Ø.Ø69542975	24Ø.Ø8611Ø77	241.4Ø15Ø5946
CK =	6.6Ø9534562E-11	6.511358Ø11E-11	3.465894436E-11
LK =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
TUNED INPUT			
L1 =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
CIN =	2.471882338E-11	2.439Ø2439E-11	1.419345682E-11
L2 =	3.943635932E-7	3.893569691E-7	2.341Ø824Ø9E-7
COUT =	2.471882338E-11	2.439Ø2439E-11	1.419345682E-11
F1 =	4.Ø45Ø8252E + 7	4.Ø9958252E + 7	7.Ø45Ø8252E + 7
F2 =	4.Ø4553626E + 7	4.1ØØØ3626E + 7	7.Ø4553626E + 7
F3 =	4.Ø45Ø8252E + 7	4.Ø9958252E + 7	7.Ø45Ø8252E + 7
F4 =	4.Ø4533626E + 7	4.1ØØØ3626E + 7	7 Ø4553626E + 7
CS1 =	1.548Ø51812E-15	1.5Ø7165686E-15	5.1Ø349971E-16
CS2 =	1.5477Ø4578E-15	1.5Ø6832117E-15	5.1Ø284239E-16
CS3 =	1.548Ø51812E-15	1.5Ø7165686E-15	5.1Ø349971E-16
CS4 =	1.5477Ø4578E-15	1.5Ø6832117E-15	5.1Ø284239E-16
VØ =	2	2	2
POLE FREQUENCIES	4.Ø455E + 7 4.Ø455E + 7	4.1E + 7 4.1E + 7	7.Ø455E + 7 7.Ø455E + 7

Table 5

Calculations for a 31-kHz Bandwidth Filter

GAUSSIAN RESPONSE FOURTH-ORDER CRYSTAL FILTER	
FØ =	7.2225E + 7
BØ =	31ØØØ
L =	Ø.Ø13
RØ =	1266.Ø618394
CØ =	1.74Ø514567E-12
RIN =	4788.47944845
ROUT =	3377.929Ø4618
CK =	7.245912256E-12
LK =	4.438ØØ5914E-7
TUNED INPUT	
L1 =	4.438ØØ5914E-7
CIN =	1.384562132E-11
L2 =	4.39519567E-7
COUT =	1.384562132E-11
F1 =	7.217796525E + 7
F2 =	7.224862Ø45E + 7
F3 =	7.2197954Ø5E + 7
F4 =	7.222863165E + 7
CS1 =	3.74Ø138126E-16
CS2 =	3.7328264Ø2E-16
CS3 =	3.738Ø67416E-16
CS4 =	3.734892759E-16
VØ =	1.7Ø5428327
POLE FREQUENCIES	7.2225E + 7 7.2225E + 7

Strays

John Schmale, K2IZ, N.Y.C./Long Island SCM, towers behind members of the Hall of Science Amateur Radio Club (Queens, New York) after presenting Public Service Commendations to many of them for their dedicated efforts during the recent Italian earthquake disaster. Club members received, relayed, answered or directed more than 1000 messages during the around-the-clock operation that lasted nearly two weeks. *(photo by Fred Kahn, WB2TBC)*

FIRE AT SEA

☐ Last October, the Dutch ship *Prinsendam* caught fire in the Gulf of Alaska, and 533 passengers and crew were forced to abandon ship. Through poor sea conditions, people were lifted by helicopter from their lifeboats to the rescue ships. Alaskan Amateur Radio operators monitoring the situation quickly realized that their services would be needed. Health-and-welfare nets were organized, and liaisons with the Red Cross, Alaska State Troopers and the Coast Guard were set up.

As the passengers and crew safely arrived on shore, the expected communications crunch developed. Shifting band conditions were a problem. Another obstacle was passing traffic to foreign countries with whom the U.S. had no third-party agreement. As a result of outstanding cooperation among amateurs and their good on-the-air conduct, over 300 pieces of traffic were successfully passed. Fortunately, there were no fatalities during the rescue; the ship, however, sank. — *Don Bush, KL7JFT*

From left to right stand Jack van der Zee, radio officer of the *Prinsendam*, Jim Pfister, N6CF, and David Ring, N1EA, radio officers aboard the *Williamsport*, one of the tankers involved in the rescue effort. Jack maintained vital communications in the smoke-filled radio room despite melting cables and dwindling emergency power. Providing an essential link in the communications, Jim and David relayed positions and estimated time of arrivals and kept the distress frequency clear. *(photo courtesy David J. Ring Sr.)*