

[54] **BANDPASS FILTER INCLUDING
MONOLITHIC CRYSTAL ELEMENTS
AND RESISTIVE ELEMENTS**

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[22] Filed: Dec. 16, 1970

[21] Appl. No.: 98,722

[52] U.S. Cl. 333/72, 310/9.8, 330/174

[51] Int. Cl. H03h 7/06, H03h 7/08, H03h 9/00

[58] Field of Search 333/72, 70; 330/174;
334/40; 310/9.8

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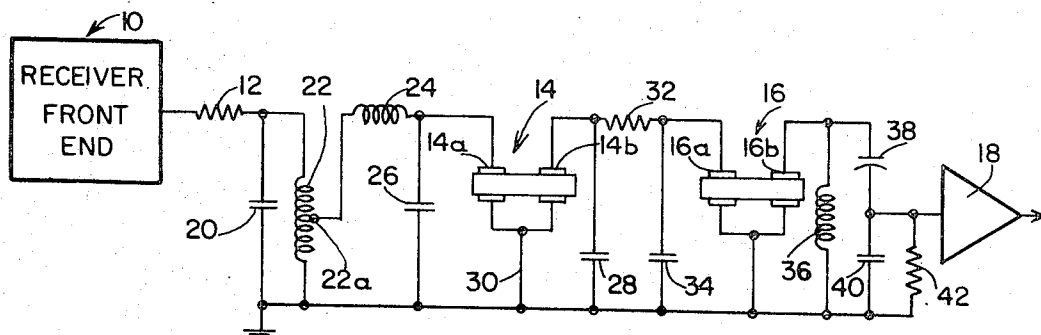
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[57] **ABSTRACT**

A bandpass filter circuit includes a pair of monolithic crystal filter elements and a resistance-capacitance network, which may be a lattice network, connected between the crystal filter elements. The crystal filter elements are dual-coupled resonators which have a pair of resonator spots formed on a quartz wafer, and the resonators have relatively well defined bandpass characteristics extending above and below their resonant frequencies and provide an abrupt change in attenuation at the limits of the bandpass frequencies. The resistance-capacitance network used with the crystal filter elements acts to relocate the pole frequencies so that the characteristic curve of the complete filter closely approximates a Gaussian shape in the vicinity of the bandpass. The bandpass filter circuit thus formed is particularly adapted for use in a mobile receiver where extraneous undesired signals may occur in the crystal filter elements resulting from impulse type signals, such as that produced by spark discharge of the ignition system, and these undesired signals are greatly reduced or eliminated.

12 Claims, 8 Drawing Figures



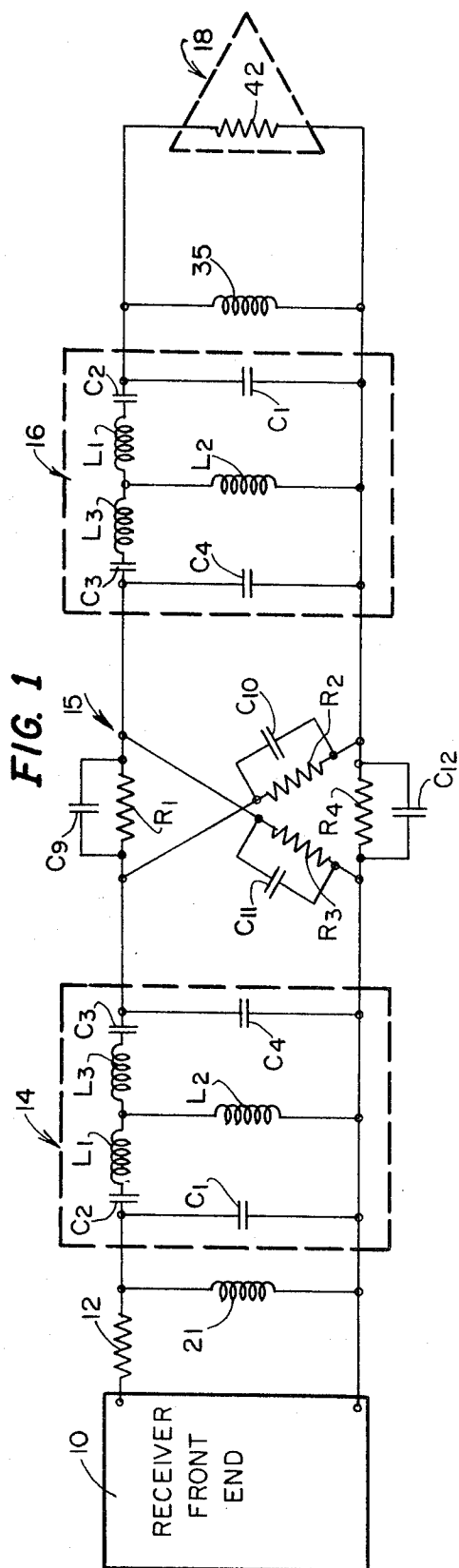


FIG. 3

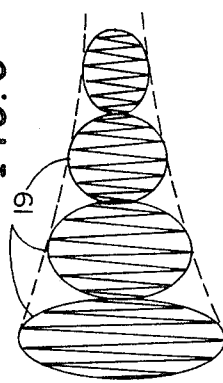


FIG. 4

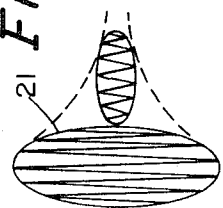
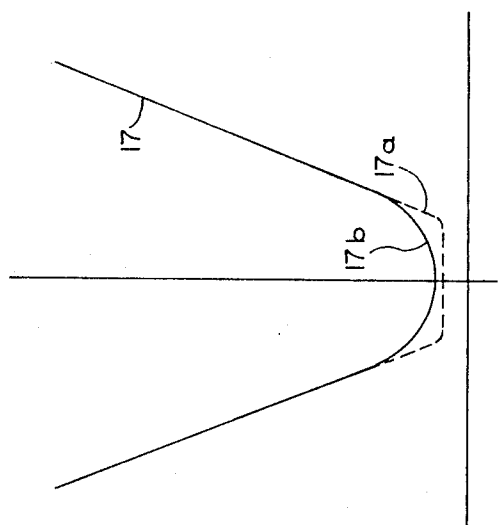
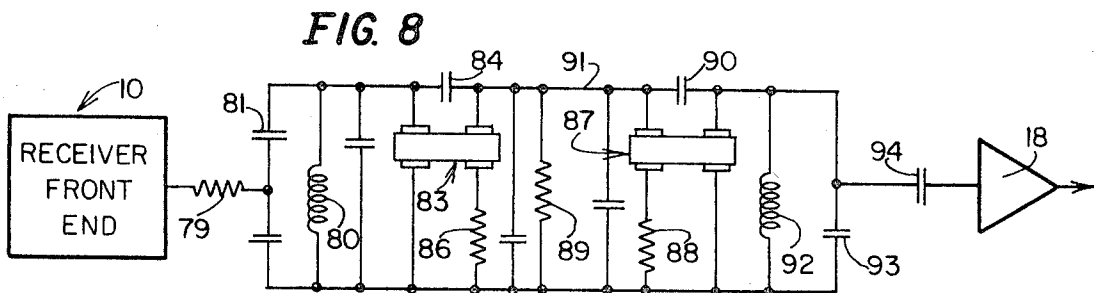
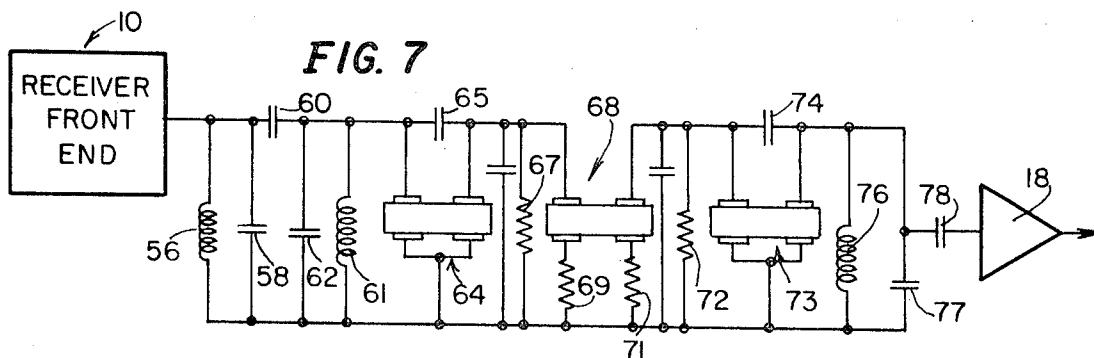
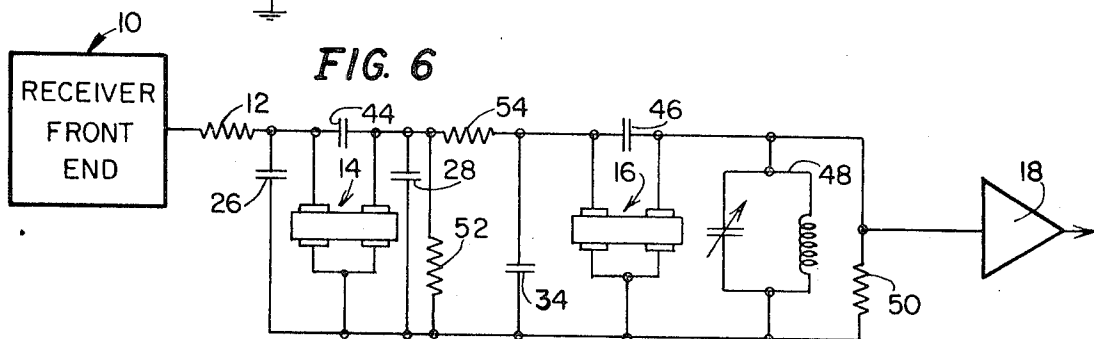
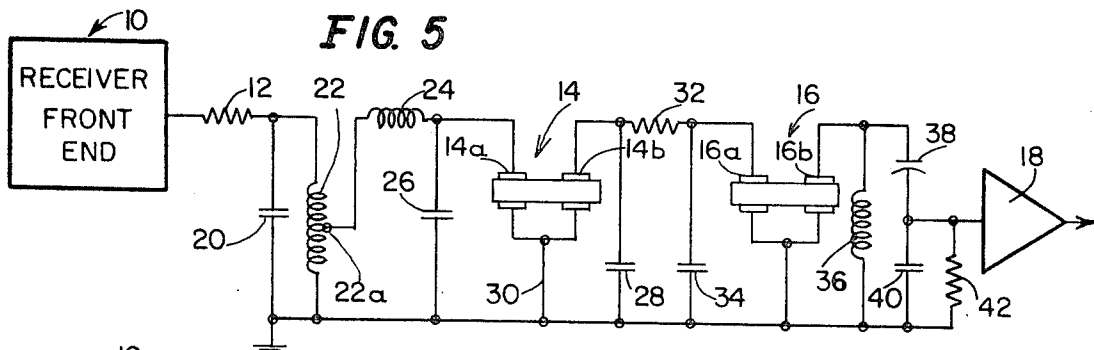


FIG. 2



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BANDPASS FILTER INCLUDING MONOLITHIC CRYSTAL ELEMENTS AND RESISTIVE ELEMENTS

BACKGROUND OF THE INVENTION

Reference is made to U.S. Pat. No. 3,633,134, issued Jan. 4, 1972 to Richard G. Barrows and William G. Ahillen, which discloses and claims a crystal bandpass filter circuit related to the bandpass filter circuit of the present invention.

This invention relates generally to crystal filter circuits, and more particularly, to bandpass filter circuits having dual-coupled resonators which are used as inter-coupling stages between IF amplifiers, or the like.

In providing bandpass filter circuits using monolithic crystal filters, it is very difficult to eliminate the objectionable affects of ringing caused by undesired pulse signals. Although crystal filter elements provide a well defined passband, which may be of the order of 4 to 30 kHz for a crystal element having a resonant frequency of about 5 to 30 MHz, the steep or sharp sides of the response curve near the nose of the curve, and the abrupt change therein, have been found to result in undesired ringing effects. This is a particularly important problem in connection with radio communication equipment for use in automobiles where ignition spark discharge is a major cause of extraneous signals, which can cause ringing in the filter and be heard in the speaker of the radio receiver. Such signals can also result in false operation when the receiver is used with coded signals.

Summary of the Invention

An object of this invention is to provide an improved crystal filter circuit wherein the affects of extraneous impulses applied to the crystal filter elements are substantially minimized.

Another object of this invention is to provide an improved crystal filter circuit which allows for shaping of the passband of any chosen filter characteristic (Butterworth, Chebyshev, Legendre, Image Parameter, etc.) to a shape approaching the desired Gaussian curve in the passband while maintaining the original frequency attenuation characteristics outside the passband.

A further object of the invention is to provide an improved bandpass filter circuit including monolithic crystal elements for sharp selectivity and one or more resistive-capacitive networks to change the filter characteristic in the vicinity of the passband so that the desired Gaussian characteristic is provided.

A feature of this invention is the provision of a bandpass filter including a lattice resistance-capacitance network or its derivative coupled between monolithic dual-coupled crystal filter elements with the network acting as part of the filter circuit and, as such, modifying the characteristic curve of the crystal filter elements to the desired essentially Gaussian curve in the passband.

Briefly, the bandpass filter circuit of this invention is adapted to receive an intermediate frequency (IF) signal, such as that produced at the output of a radio receiver front end. The IF signal is applied to a first dual-coupled resonator which may be formed on a single quartz crystal wafer and forms part of the bandpass crystal filter circuit. The signal is coupled through a re-

sistance-capacitance network to a second and similar dual-coupled resonator which provides the filter output. The resonating portions of each dual-coupled resonators can be at the same or a slightly different frequency, depending upon the design selected, but in either case the frequency of the mesh in which each resonating portion is connected is the same, thereby providing the desired relatively narrow and well defined passband. Although each resonating device is here illustrated as being a dual-coupled resonator on a single quartz wafer, which may be flat or contoured, it will be understood that each device may have three or more resonating areas formed on a single wafer, if desired, and that more than two resonating devices can be used in a filter circuit.

In accordance with this invention, the output of the first dual-coupled resonator is coupled to the input of the second dual-coupled resonator through a resistance-capacitance network which is selected to modify the characteristic curve of the crystal filter circuit. By so changing the characteristic curve in the vicinity of the passband to a Gaussian curve, undesired transient pulse-type responses caused by extraneous signals are greatly reduced or eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating the equivalent circuit arrangement of a crystal filter circuit constructed in accordance with this invention;

FIG. 2 illustrates the bandpass curve of the filter of FIG. 1;

FIGS. 3 and 4 illustrate the impulse response characteristic of filters before and after, respectively, the bandpass characteristic curve is changed to a Gaussian shape in the passband; and

FIGS. 5, 6, 7 and 8 illustrate various forms of crystal filter circuits which can be constructed in accordance with this invention.

DESCRIPTION OF THE INVENTION AS ILLUSTRATED IN THE DRAWINGS

Throughout the several views of the drawings, like reference numerals indicate similar or like components. Also, the components of the several embodiments are shown queued from an output circuit of a receiver front end to the input of an amplifier, but it will be understood that any component arrangement may be used.

Seen in FIG. 1 is a schematic diagram illustrating the equivalent circuit construction of a bandpass filter circuit including dual-coupled resonators and a resistance lattice network interconnected with the resonators in accordance with this invention. Here the front end 10 of an FM receiver, which may include an RF amplifier, local oscillator and mixer, produces an IF frequency at its output which will be translated through the crystal filter circuit of the invention. The FM receiver may be of any desired frequency range suitable for mobile use. The signal which is developed at the output of the receiver front end 10 is impressed across a resistor 12 and an inductance element 21. This IF signal from the receiver front end 10 includes desired signals within a range of frequencies and undesired signals above and below this range of frequencies. It is the desired signals within the range of frequencies which are to be selected

by the crystal filter circuit of this invention. To this end, a pair of resonators 14 and 16, with a resistive-capacitive network 15 therebetween, are interposed in the signal path from the receiver front end 10 to an amplifier circuit 18. The resonators 14 and 16 may include quartz crystal wafers or wafers of other piezoelectric material such as ceramic. The resonators are here shown by their equivalent circuit components and they preferably take the form of dual-coupled monolithic crystal filter elements.

The equivalent components of the crystal filter element 14 include an input capacitance C_1 , which may include the electrode capacitance, and which is shunted by the external inductance 21 which may have a value that will effectively tune out the input capacitance C_1 . Series capacitors C_2 and C_3 and series inductors L_1 and L_3 provide a signal path through the filter element, and inductor L_2 is the effective shunt inductance element. An output capacitance C_4 also includes electrode capacitance. Similarly, the equivalent circuit of the crystal filter element 16 is shown with a plurality of inductors and capacitors in substantially the same manner and designated by the same reference numbers as element 14. The elements are reversed for a symmetrical configuration. The output of the crystal filter element 16 is shunted by an external inductor 35, which tunes out the capacitance C_1 . The signal translated through the crystal filter circuit so formed is applied to load 42, which may be the input impedance of the amplifier 18.

In accordance with the broad aspects of this invention, the resistance network 15 is here illustrated as a lattice network coupled between the output of the crystal filter element 14 and the input of the crystal filter element 16. This lattice network includes resistors R_1 , R_2 , R_3 and R_4 , each illustrated as being shunted by an associated capacitor C_9 , C_{10} , C_{11} and C_{12} , respectively. From this lattice network, any one of the many possible resistance-capacitance coupling arrangements can be formed by changing the values or eliminating certain ones of the respective resistors and/or capacitors. That is, a series resistance coupling network, a pi network, or an L network, or any combination thereof, can be formed merely by changing the relative values of the components forming the lattice network 15. Also, networks of other configurations can be derived from the lattice network.

In accordance with one aspect of this invention, the resistance values, regardless of the type of network ultimately formed by the lattice network 15, are selected to change the shape of the characteristic curve of the bandpass filter circuit from what it would be to closely approximate a Gaussian shape in the passband. For example, a pair of monolithic crystal filters of the type illustrated, when connected directly in series, would have a natural characteristic curve as illustrated by the broken line portion 17a of the curve 17 of FIG. 2. The relatively sharp or abrupt corners at the lower end of the curve illustrate a substantially uniform minimum attenuation for the frequencies in the band extending below and above the center frequency, and then maximum attenuation for all frequencies beyond these values. However, this particular characteristic tends to cause substantial ringing to occur at the output of the filters as a result of impulse type signals. This is illus-

trated in FIG. 3 by the pulse including a series of lobes designed generally by reference numeral 19, which diminish in amplitude with increasing time, and the ringing within each lobe is at or near the center frequency of the crystal filter. Because of the repetition of such pulses and the consequent transient response, unwanted signals can be heard in the audio output of the receiver and may constitute a major noise disturbance in the receiver output.

However, it has been found that by proper selection of the resistance network between the crystal filter elements 14 and 16, the characteristic curve (FIG. 2) of the filter circuit can be changed, as indicated by reference numeral 17b, to a Gaussian curve which is symmetrical on either side of the vertical axis. By so changing the shape of the characteristic curve of the filter circuit, the subsequent lobes of each pulse will have substantially reduced amplitude, as shown in FIG.

4. Thus, the audible noise at the receiver output is reduced. This is shown diagrammatically by a single lobe 21 of ringing which is immediately followed by a sharply damped lobe and thereafter substantially no response at all. This single pulse 21 has a relatively short time duration and is substantially inaudible, at least as compared to the previous pulses 19 as shown in FIG. 3.

When the crystal filter elements 14 and 16 are dual-coupled monolithic crystal devices, the resonating areas on the quartz crystal may be formed to be resonant at slightly different frequencies to compensate for variations in input capacitance or inductance values of the circuitry connected thereto. Although there can be a slight difference in resonant frequency of the resonating areas due to the filter design chosen, the resonant frequencies of the meshes of the circuit in which they are connected is the same.

FIG. 5 illustrates one specific form of this invention and again shows the front end 10 of an FM receiver which provides an IF signal generally within a range of frequencies defined by the passband of the filter circuit involved. As previously stated, the IF signal may include signals above and below the desired passband frequency. To eliminate all frequencies which fall outside the particular passband involved, the bandpass filter, including the pair of monolithic crystal filter elements 14 and 16 and the single resistor 32, is provided for selecting the signal prior to amplification by amplifier circuit 18.

In the embodiment illustrated in FIG. 5, the IF signal is applied by resistor 12 to a capacitor 20 and an inductance element 22 which form a tuned circuit. The inductance element 22 has a tap 22a thereof coupled through a second inductance element 24 to the first crystal filter element 14, here shown diagrammatically as a quartz body with electrodes formed thereon. Shunt capacitors 26 and 28 may be discrete components, but may be the internal interelectrode capacitance of the crystal filter element 14, such as shown by capacitance C_1 of FIG. 1, and in this case the value of such capacitance is determined by the characteristics of the particular crystal filter element involved. The crystal filter element 14 is preferably formed of a single flat, or contoured, crystal body with electrodes diffused or deposited thereon to form a pair of resonating portions within the crystal body. Two pairs of electrodes or ter-

minals are provided on the crystal body so that the resonating portion of each resonator, i.e. crystal filter element, is that portion between the diametrically opposed terminals. For example, the crystal filter element 14 has an input terminal 14a for receiving signals and an output terminal 14b for passing signals of the desired IF frequency. The terminals on the opposite side of the crystal body are tied together and through a line 30 to a reference potential, such as ground. Signals are coupled through the crystal body or wafer from one resonating portion to the other by the interaction of the equivalent inductance and capacitance, as shown in FIG. 1.

A resistor 32 is coupled between the output of the filter element 14 and the input of the filter element 16, with the ends of the resistor 32 connected to shunt capacitors 28 and 34. The capacitors 28 and 34 provide the proper signal coupling between resonators 14 and 16. The signal is then applied to the input terminal 16a of the filter element 16 and received at the output terminal 16b in the same manner as described above with regard to filter element 14. It will be noted that the single resistor 32 is a derivative circuit formed from the lattice network 15 shown in FIG. 1.

The signal translated through this passband circuit is then developed across an inductance element 36 and a pair of series connected capacitors 38 and 40, and across a resistor 42 which is connected only across the capacitor 40. The signal is then applied to the amplifier 18 and therefrom to a detector or discriminator circuit, not shown. Here also the capacitor 34 may be the inherent capacitance of the input terminals of the crystal element 16.

The crystal filter circuit of this invention minimizes the response of the crystal filter elements 14 and 16 to extraneous impulse type signals, while maintaining proper frequency attenuation. Basically, the crystal filter circuit disclosed provides means for shaping a passband characteristic curve of any chosen filter design (Butterworth, Chebyshev, Legendre, Image Parameter, etc.) to a Gaussian curve characteristic to any normally desired passband attenuation level. This feature is accomplished by the resistance network, which is a modifying circuit, connected between the filter elements 14 and 16 while simultaneously maintaining the original frequency attenuation characteristics in the reject band, also maintaining symmetry of frequency attenuation about the center frequency, and maintaining the original design mesh frequencies.

The crystal filter circuit design is chosen to approximate the frequency bandpass characteristics desired, and this may or may not have passband ripple, and may or may not have staggered crystal frequencies. The bandpass width is initially designed wider than the desired bandpass width, since the shaping of the nose of the characteristic curve necessary to minimize the impulse response will cause a corresponding decrease in bandpass width, so that the ultimate bandwidth is achieved. The indiscriminate introduction of the resistance network between the appropriate crystal filter elements 14 and 16 will result in a shifting of some of the pole frequencies and/or a non-symmetry in the frequency attenuation characteristics from the originally designed crystal filter elements. This action will cause a strong discriminator output when the filter-

discriminator combination is subjected to impulse type input signals, which is an undesired result. Therefore, the resistance coupling network must be designed to minimize these effects, i.e. to have a symmetrical Gaussian curve characteristic.

In addition, resistor 32, or another form of the resistance network 15 of FIG. 1, will decrease the quality factor "Q" (de-Qing) of the associated crystal elements 14 and 16, thus resulting in a more tolerable filter arrangement since it is less susceptible to load impedance variations. That is, approximately plus or minus 50 percent variation from the normal design impedance value can be tolerated without any marked passband ripple changes, or any marked non-symmetry in frequency attenuation characteristics which would otherwise manifest itself if the quality factor Q of the elements 14 and 16 were maintained at their natural high level, as for example, in the order of 20,000.

The resistive-capacitive network is an integral part of the crystal filter design and may be external to the crystal elements or incorporated on a crystal chip design as an integral unit. Furthermore, the network may be provided in the form either of a thin film or thick film deposited on a quartz substrate. The techniques of crystal filter circuit construction can be applied to coupled crystal resonators having more than two coupled resonators on a single quartz wafer.

FIG. 6 illustrates an alternate circuit arrangement wherein several modifications have been made. Here the crystal filter element 14 is shunted with a capacitor 44 and the crystal filter element 16 is shunted with a capacitor 46. The use of these capacitors acts to steepen the sides of the response curve. A tank circuit 48 is connected at the output of crystal filter element 16 and is shunted by a fixed resistor 50. In this embodiment the resistance network between the two crystal filter elements 14 and 16 is provided by a resistance L-pad circuit comprising a first resistor 52 and a second resistor 54 which have their values selected to produce the desired change in the passband characteristic curve.

Referring now to FIG. 7, there is illustrated still another alternate form of this invention. Here the output from the receiver front end 10 is applied across an inductance-capacitance network including an inductor 56 and a capacitor 58. The signal is then coupled through a capacitor 60 to a second inductance-capacitance network including an inductor 61 and a capacitor 62. Crystal filtering action is then achieved by a crystal filter element 64 which is provided with a shunting capacitor 65 between the separate resonating portions formed within the body thereof. The output terminal side of the crystal filter element 64 is shunted by a resistor 67 to provide for part of the Gaussian curve characteristic to be formed. In this embodiment, a second crystal filter element 68 has the input terminal side thereof connected in series with a fixed resistor 69 which also serves to provide for another part of the Gaussian curve characteristic. A second fixed resistor 71 is connected in series with the output side of the filter element 68 and in this instance, the bottom terminals of the filter element are not tied together. The IF signal is coupled through the crystal filter element 68 and then applied across a resistor 72 and thence to a third crystal filter element 73, which is shunted by

capacitor 74. The signal is then coupled to an inductance-capacitance network including an inductor 76 and a capacitor 77 at the output of the crystal filter circuit. The IF signal so developed is then applied to the integrated circuit amplifier 18 through a coupling capacitor 78. In this embodiment, the resistance network which forms the Gaussian curve includes resistors 67, 69, 71 and 72 associated with the crystal filter elements 64, 68 and 73. Also, each crystal filter element is a dual-coupled resonator similar to those described in FIGS. 5 and 6.

Referring now to FIG. 8, there is seen still another alternate embodiment of this invention. Here the receiver front end 10 applies the IF signal to an inductance-capacitance network including an inductor 80 and a pair of capacitors 81 and 82 connected in parallel therewith, this signal coupling being made through a resistor 79. A first crystal filter element 83 passes the desired IF frequency signal and is shunted by a capacitor 84. The output terminal of the element 83 has a resistor 86 connected in series therewith. A second crystal filter element 87 receives the IF frequency signals, and this crystal filter element has a fixed resistor 88 connected in series with the input portion thereof. In this embodiment a resistor 89 is connected in parallel relation with the two resonating portions and their associated series connected resistors 86 and 88 respectively. To make this parallel connection, resistor 89 is connected to a common line 91 between the crystal filter elements 83 and 87, and together with the series connected resistors 86 and 88 serve to form the desired Gaussian curve. The signal is also coupled through a shunt capacitor 90 to an inductor 92 and a capacitor 93. The IF signal is ultimately delivered to the wide band integrated circuit amplifier 18 through a coupling capacitor 94.

The center frequency of the bandpass filter circuit disclosed herein may be at any desired frequency, and filters have been successfully constructed for frequencies of 5.26 MHz and 11.7 MHz. In the case of the 11.7 MHz filter, the characteristic curve portion 17b of FIG. 2 will be about 6 DB down at about 5.5 to 6 kHz above and below the center frequency, and about 110 DB down at 26 kHz above and below the center frequency.

By way of example, in the crystal filter circuit designed for 5.26 MHz, the pair of resonating portions may be of different frequencies. In the crystal filter circuit designed to pass 11.7 MHz, the pair of resonating portions may be resonant at the same frequency. However, in either case the characteristic curve is changed to approximate a Gaussian shape in the passband by the proper value of the resistance coupling network.

The following values are given by way of example and are typical for the equivalent circuit shown in FIG. 1 with regard to the two frequencies which have been discussed:

Reference No.	Values for 5.26MHz	Values for 11.7MHz
Inductor L ₁	0.66H	0.25H
Inductor L ₂	130uH	50uH
Inductor L ₃	.066H	.025H
Inductor 21	200uH	60uH
Inductor 35	200uH	60uH
Capacitor C ₁	4.0pf	3.0pf
Capacitor C ₂	.014pf	.007pf
Capacitor C ₃	0.014pf	.007pf
Capacitor C ₄	4.0pf	3.0pf
Capacitor C ₅	1.0pf	1.0pf
Capacitor C ₁₀	1.0pf	1.0pf

Capacitor C ₁₁	1.0pf	1.0pf
Capacitor C ₁₂	1.0pf	1.0pf
Resistor R ₁	1.5K ohms	330 ohms
Resistor R ₂	33.0K ohms	18.0K ohms
Resistor R ₃	33.0K ohms	18.0K ohms
Resistor R ₄	1.5K ohms	330 ohms
Resistor 12	1.0K ohms	1.0K ohms
Resistor 42	5.6K ohms	3.3K ohms

It may be desired to eliminate the resistance R₄ and the capacitor C₁₀ so that all of the shunt elements can be connected to a single reference or ground potential. In such case, the value of resistor R₁ should be doubled in value.

What has been described is a simple and effective crystal filter circuit arrangement with a resistive-capacitive network coupled between monolithic crystal filter elements acting as an integral part of the filter circuit and the component values are selected to provide the proper Gaussian curve and passband characteristics to reduce the time response with regard to extraneous signals and thereby reduce the effect of undesired ringing or other response at the output of the crystal filter.

We claim:

1. A bandpass filter circuit for passing frequencies within a predetermined passband, including in combination, first and second resonators each including a single crystal wafer and electrode means cooperating therewith to form at least two separate resonating portions each including a pair of electrodes on opposite sides of said wafer, input signal means coupled to said pair of electrodes of the first resonating portion of said first resonator for applying therebetween signals including signals which fall within said predetermined passband of the filter circuit, each of said first and second resonators acting to couple signals through said wafer thereof from said first resonating portion to said second resonating portion thereof, a coupling circuit connected from said pair of electrodes of said second resonating portion of said first resonator to said pair of electrodes of said first resonating portion of said second resonator for coupling signals from said second resonating portion of said first resonator to said first resonating portion of said second resonator, said coupling circuit including resistance means connected in series circuit with said pair of electrodes of said second resonating portion of said first resonator and said pair of electrodes of said first resonating portion of said second resonator, said resistance means having a value such that the characteristic curve of the filter circuit in the passband is substantially of symmetrical Gaussian shape to reduce undesired impulse-type signal transients, and means coupled to said pair of electrodes of said second resonating portion of said second resonator for receiving the signal translated through the bandpass filter circuit.

2. The bandpass filter circuit of claim 1 wherein said crystal wafers of said first and second resonators are made of quartz, and said resistance means is a single resistor connected in series between one electrode of said second resonating portion of said first resonator and one electrode of said first resonating portion of said second resonator.

3. The bandpass filter circuit of claim 1 wherein said resistance means is formed of first and second resistors connected in an L-pad configuration, with said first resistor connected in series between one electrode of said second resonating portion of said first resonator and

one electrode of said first resonating portion of said second resonator, and with said second resistor connected in shunt relation with said electrodes of said second resonating portion of said first resonator.

4. The bandpass filter circuit of claim 1 wherein said resistance means includes a resistor connected in series with said electrodes of said second resonating portion of said first resonator.

5. The bandpass filter circuit of claim 1 wherein said resistance means includes a resistor connected in series with said electrodes of said first resonating portion of said second resonator.

6. The bandpass filter circuit of claim 1 wherein said resistance means includes a first resistor connected in series with said electrodes of said second resonating portion of said first resonator, and a second resistor connected in series with said electrodes of said first resonating portion of said second resonator.

7. The bandpass filter circuit of claim 1 wherein said resistance means includes a first resistor connected in series with said electrodes of said second resonating portion of said first resonator, and a second resistor connected in parallel with said first resistor and its associated series connected resonating portion.

8. The bandpass filter circuit of claim 1 wherein said resistance means includes a first resistor connected in series with said electrodes of said first resonating portion of said second resonator, and a second resistor connected in parallel with said first resistor and its associated series connected resonating portion.

9. The bandpass filter circuit of claim 1 wherein said resistance means includes a first resistor connected in series with said electrodes of said second resonating portion of said first resonator, a second resistor connected in series with said electrodes of said first resonating portion of said second resonator, and a third resistor connected in shunt relation with said first and second resistors and their respective associated series connected resonating portions.

10. In a bandpass filter circuit for passing frequencies within a predetermined passband which includes first and second resonators each having first and second

resonating portions with a pair of electrodes, input signal means coupled to the electrodes of the first resonating portion of the first resonator for applying therebetween signals including signals which fall within said predetermined passband of the filter circuit, a coupling circuit for coupling signals from the electrodes of the second resonating portion of the first resonator to the electrodes of the first resonating portion of the second resonator, and means coupled to the electrodes of the second resonating portion of the second resonator for receiving the signal translated therethrough; the improvement wherein each of the first and second resonators comprises a single quartz crystal wafer and first and second pairs of electrodes thereon forming first and second resonating portions, with each pair including electrodes on opposite sides of said wafer, each of said first and second resonators acting to couple signals through said wafer thereof from said first resonating portion to said second resonating portion thereof, and wherein said coupling circuit includes resistance means and capacitance means, with said resistance means being connected in series circuit with said pair of electrodes of said second resonating portion of said first resonator and with said pair of electrodes of said first resonating portion of said second resonator, said resistance means having a value such that the characteristic curve of the filter circuit in the passband is of substantially symmetrical Gaussian shape to reduce undesired impulse-type signal transients.

11. The combination of claim 10 wherein said capacitance means includes a first capacitor connected across said electrodes of said second resonating portion of said first resonator, and a second capacitor connected across said first resonating portion of said second resonator.

12. The combination of claim 11 wherein said resistance means is a single resistor connected in series between one electrode of said second resonating portion of said first resonator and one electrode of said first resonating portion of said second resonator.

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