March 5, 1968 J. C. CHASTAIN 3,372,314

MEANS AND TECHNIQUES USEFUL IN TONE RECEIVERS

Filed March 31, 1965 2 Sheets-Sheet 1

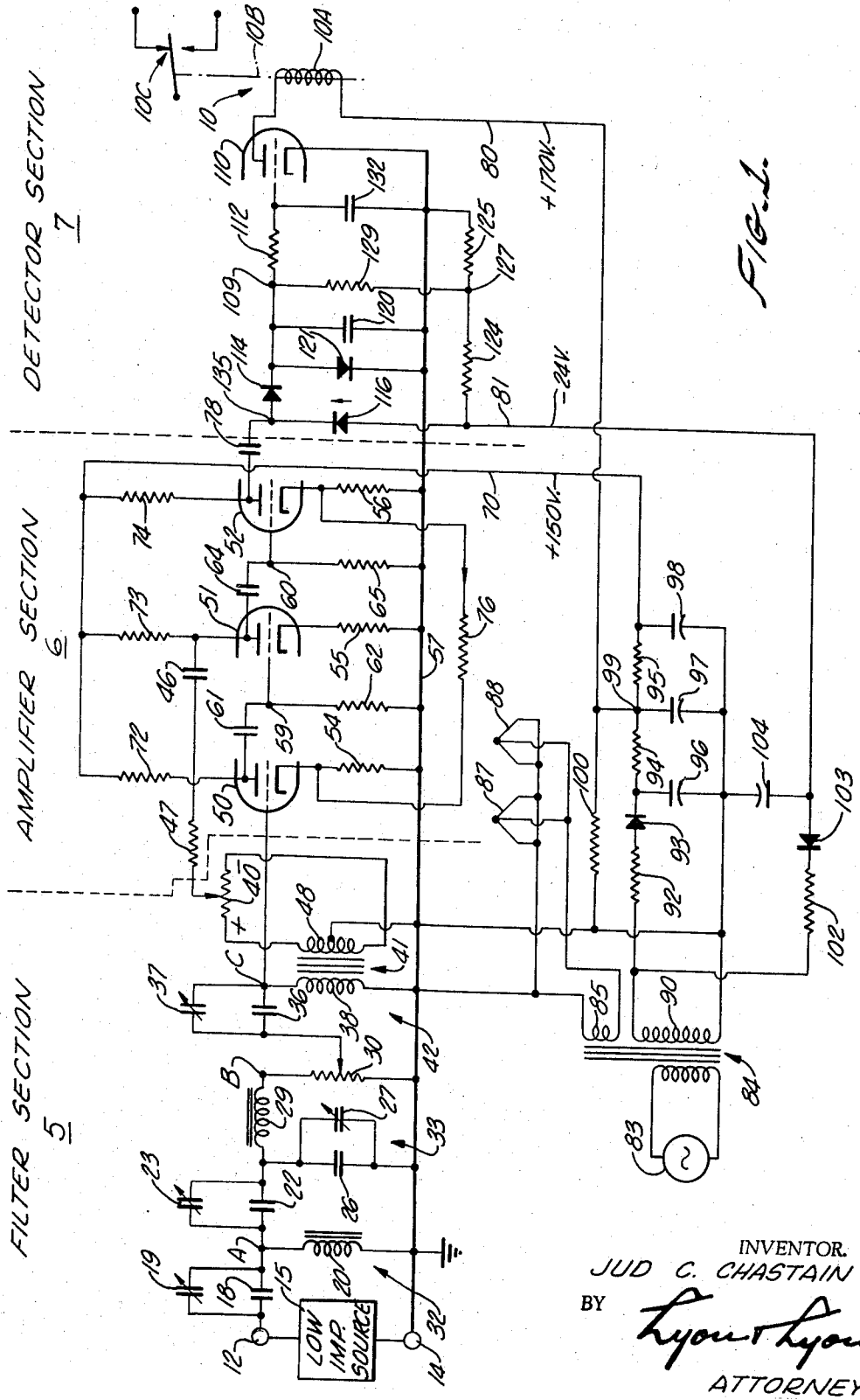


FIG. 1.

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Filed March 31, 1965 2 Sheets-Sheet 2

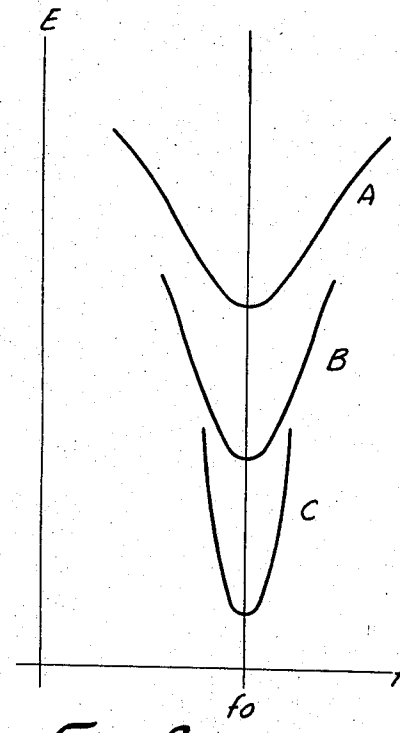
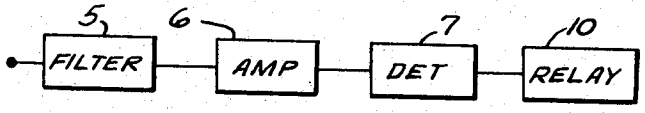


FIG. 2.

FIG. 6.



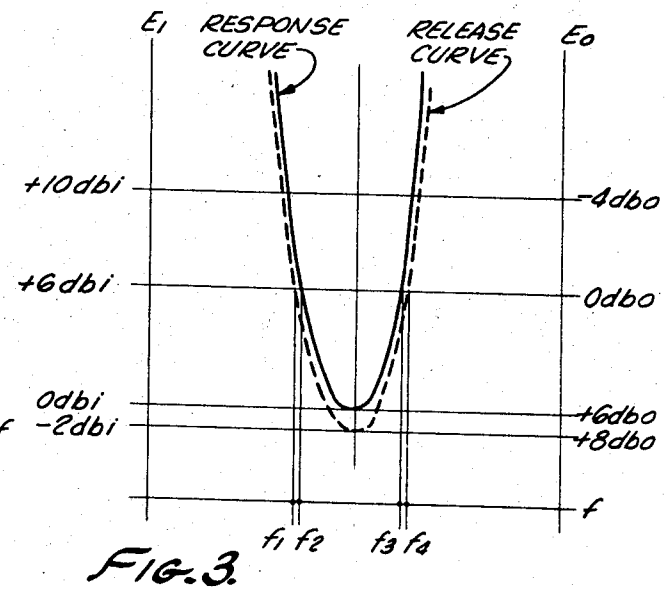


FIG. 3.

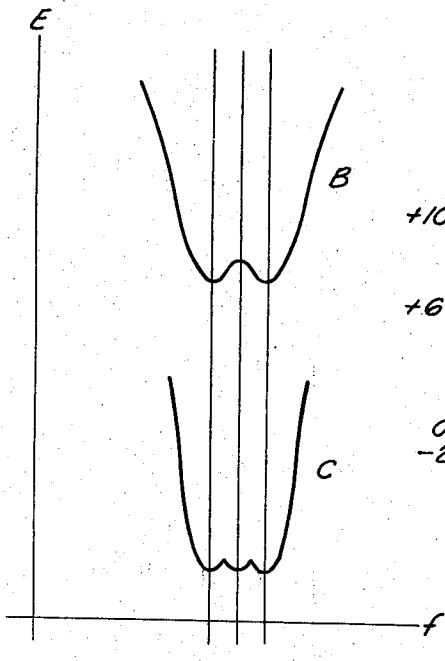


FIG. 5.

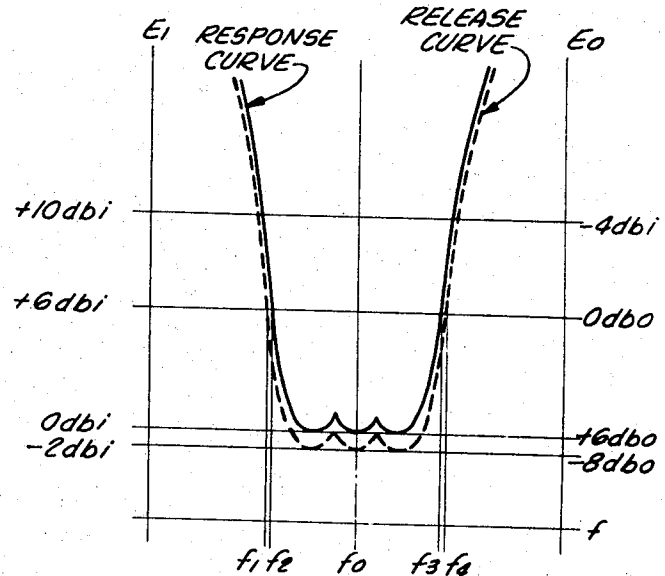


FIG. 4.

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MEANS AND TECHNIQUES USEFUL IN TONE RECEIVERS

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6 Claims. (Cl. 317—147)

ABSTRACT OF THE DISCLOSURE

A tone receiver for a telemeter system has a signal applied thereto. When the signal is applied a relay is energized and when the signal is keyed off, there is no signal at the output terminal and the relay is deenergized. The relay is operated at a fast rate in that the pull-in current is that current required to cause its armature to be moved to its attracted position; and the drop-out current is just that amount of current at which the armature is maintained in its attracted position. The band width of the amplifier circuit is established by three tuned filter sections with the band width being adjusted relative to the keying frequency.

The present invention relates to improved means and techniques particularly useful in tone receivers.

Briefly, the tone receiver described herein is intended for use in a telemeter system to which a signal having a characteristic frequency is applied to input terminals of the receiver. As usually, the signal so applied is turned on and off, i.e. keyed. When the signal is applied, a relay is energized, and when the signal is keyed off, there is no signal at the output terminals and the relay is deenergized or "drops out." The receiver described herein has generally three sections, namely a filter section, an amplifier section, and a detector section. One of the important features of the present invention is the provision of improved means and techniques whereby the relay is operated at a fast rate, considering particularly the large ratio in "pull-in" and "drop-out" currents. The pull-in current is that current required to cause its armature to be moved to its energized or attracted position; and the drop-out current is just that amount of current at which the armature is maintained in its attracted position. In this case, the relay per se may have a ten to one ratio in pull-in and drop-out currents.

One important feature of the invention therefore resides in a relay energizing circuit directed to the solution of the problem of avoiding a large differential in pull-in and drop-out currents of a relay. This improved circuitry is found in the detector section of the apparatus described herein.

Another feature of the present invention involves an amplifier connected in a unique manner with respect to other circuitry for band width adjustment purposes. In general, the band width is established by three tuned filter sections and the band width is adjusted in relationship to the keying frequency, i.e. the rate at which the signal is applied in burst, the keying frequency thus being considered to be a modulation of the audio-frequency signal.

Another important feature of the present invention resides in improved means and techniques whereby the band width of the receiver may be conveniently adjusted in relationship to keying frequency.

Another important object of the present invention is to apply a receiver of the character incorporating novel circuitry whereby the gain is controlled; and as shown herein, the gain control is not at the front end of the receiver as is normally the case, but is between filter sections.

Another specific object of the present invention is to provide an improved tone receiver which is reliable, fast in operation, sensitive only to a particular characteristic frequency and which may be conveniently adjusted to operate satisfactorily at various keying rates.

Another specific object of the present invention is to provide an improved tone receiver in which improved means are provided for discriminating against unwanted frequencies whereby the relay of the receiver is responsive only to a particular characteristic frequency from a group of frequencies which may be present at the input terminals of the receiver.

Another specific object of the present invention is to provide a tone receiver of this character in which the value of the tone amplitude required for relay actuation is frequency dependent.

Another specific object of the present invention is to provide an improved tone receiver of this character in which the value of current required for release of an actuated relay is frequency dependent.

Another specific object of the present invention is to provide an improved tone receiver of this character in which the response band width may be adjusted to the minimum possible width consistent with the rate of information transmission.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may be best understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 illustrates a schematic form of a tone receiver embodying features of the present invention.

FIG. 2 illustrates frequency response graphs at points A, B and C in the filter section of the receiver in FIG. 1 when adjusted for minimum band width, the abscissae being frequency and the ordinates being voltage change in decibels.

FIG. 3 illustrates the response graph of FIG. 2 in relation to the corresponding release graph which is shown in dotted lines, the abscissae being the frequency of the input signal, the ordinates E being the amplitude of the input signal tone referred to as minimum level required to effect relay actuation.

FIG. 4 illustrates graphs like those in FIG. 3, but under conditions when the receiver is adjusted for maximum band width.

FIG. 5 illustrates response graphs at points B and C in FIG. 1 when the filter section has been adjusted for maximum band width.

FIG. 6 is a block diagram of the apparatus shown in FIG. 1.

The tone receiver as illustrated in FIGS. 1 and 6, includes a filter section **5**, an amplifier section **6**, a detector section **7** and a relay **10**, functions to effect the actuation of a relay **10** when, and only when a signal voltage containing a periodic component of appropriate amplitude and frequency is impressed across the input terminals **12** and **14**, and to release the relay **10** upon the disappearance of this signal component or upon an appropriate change in the value of its amplitude and/or frequency. Since the frequency of this component is within the audio range, it is referred to as a signal tone or merely as a tone. For simplification and convenience in describing how this functioning is accomplished, it may be assumed that only a single tone consisting of an alternating voltage of sine wave form and having a discrete frequency between 300 and 1100 cycles per second is applied at any given time. In actual practice, a number of tones may be applied simultaneously without adverse effect, provided adequate

frequency separation exists between the several tones. The required amount of separation is discussed later.

Signal tones are applied to input terminals 12 and 14 from a low impedance source 15 having an output impedance usually not exceeding 27 ohms. This source 15 in series with capacitors 18, 19 and inductance 20 form a series resonant circuit tuned to resonate at approximately a frequency designated f_0. For a given input level, the voltage at point A which is the junction point of capacitors 18, 19 with inductance 20 varies with frequency, as represented by graph A of FIG. 2. The voltage from this point A is coupled through a high impedance comprising capacitors 22, 23 (to minimize the loading effect on the previous tuned circuit), to the parallel resonant circuit comprising capacitors 26, 27 and inductance 29 and potentiometer resistance 30, where further frequency selectively is obtained. The voltage at point B which is the junction point of inductance 29 with resistance 30 varies with input signal frequency, as represented by curve B, FIG. 2. The adjustable capacitor 23 in parallel with capacitor 22 is used to adjust the amount of coupling between these two filter stages 32, 33, i.e. the two described tuned circuits, to approximate critical coupling. When the degree of coupling exceeds the critical point, there is a "flattening" or even an indentation of the peak of the frequency response curve B, FIG. 2. When coupling is appreciably less than critical, there is attenuation of the voltage level at point B. The low resistance potentiometer 30 serves as a gain control by which the desired percentage of the voltage appearing at point B is fed through the series resonant circuit comprising capacitors 36, 37 and inductance 38 (primary winding of transformer 41) which like the two previous filter stages is tuned to resonate at approximately the frequency f_0. This filter stage 42 provides additional frequency discrimination. The "Q," i.e. quality factor and consequently the amount of selectivity of this last stage 42 is controlled by adjustment of the "Q" control potentiometer resistance 40. This control 40 along with capacitor 46 and resistance 47 and the centertapped secondary winding 48 of transformer 41 provide a feedback path extending from an output circuit of tube 51 in a three-stage amplifier comprising triode tubes 50, 51 and 52 to the last filter stage 42. Both the phase and magnitude of the feedback can be controlled by adjustment of the tap on resistance 40. For minimum response band width, the feedback is made positive in an amount just less than that which will support oscillation. The voltage at point C which is the junction point of capacitors 36, 37 with primary winding 38 varies with input signal frequency, as represented by curve C, FIG. 2.

The amplifier 50, 51, 52 follows conventional design involving resistance-capacitance coupling between triode stages.

The cathode of each tube 50, 51 and 52 is connected through a corresponding resistance 54, 55 and 56 to the grounded lead 57 (comprising also the input terminal 14) which may be defined more broader as a source of reference potential.

The control grid of tube 50 is connected to junction point C. The control grid of tubes 51, 52 is connected respectively to the junction point 59, 60. The junction point 59 is the junction point of capacitor 61 and resistance 62 which are connected in series between the anode of tube 50 and grounded lead 57; likewise, the junction point 60 is the junction point of capacitor 64 and resistance 65 which are connected in a series circuit between the anode of tube 51 and the grounded lead 57. The anode of each of tubes 50, 51, 52 is connected to a source of positive potential represented by the positive lead 70 through a corresponding resistance 72, 73 and 74.

A resistance 76 interconnected between the cathodes of tubes 50, 52 provides a feedback path.

Thus, the voltage at point C is applied directly to the grid of the first tube in the amplifier section. The winding 38 provides a path for grid leak current thereby obviating the need for a grid leak resistor which, in turn, minimizes the loading of the last filter stage 42.

The signal appearing at point C passes through three RC coupled amplifier stages with negative feedback from the third to the first stage via resistance 76. This feedback tends to stabilize the gain factor of the amplifier. The "Q" control feedback current mentioned earlier is taken from the anode circuit of the second amplifier stage 51 via capacitor 46 and resistance 47. The output from the amplifier is taken from the anode of the last stage 52 and is applied via capacitor 78 to the detector section. The manner in which this detector section is energized is now described.

The receiver is provided with a power supply that develops unidirectional voltages, both positive and negative D.C. voltages with respect to ground, i.e. the reference potential. These D.C. voltages are plus 150, plus 170 and minus 24 volts appearing respectively on leads 70, 80 and 81.

For these purposes, an A.C. source 83 is connected to the primary winding of transformer 84 having a secondary filament winding 85 connected to supply currents to the heaters 87, 88 of the tubes used.

The secondary winding 90 has one of its terminals grounded and the other one of its terminals connected through a resistance 92 to the anode terminal of rectifier 93 having its cathode terminal connected to a filter circuit which includes the series connected filter resistances 94 and 95 and shunt connected filter capacitors 96, 97 and 98. The lead 80 is connected to the junction point 99 of resistances 94, 95 and also to the ungrounded terminal of resistance 100 having its other terminal grounded. The lead 70 is connected to the junction point of resistance 95 with capacitor 98.

The ungrounded terminal of winding 90 is connected through resistance 102 to the cathode terminal of rectifier 103 having its anode terminal connected to both lead 81 and also the ungrounded terminal of filter capacitor 104.

The detector section includes a relay control tube 110 having its cathode grounded and its grid connected at junction point 109 via resistance 112 to the cathode terminal of diode 114 having its anode terminal connected to not only one terminal of coupling capacitor 78 but also to the cathode terminal of diode 116, the anode terminal of diode 116 being connected to lead 81. Connected between junction point 109 and ground is a capacitor 120 and a diode 121, the cathode terminal of diode 121 being grounded.

A voltage dividing circuit including resistances 124 and 125 is connected between lead 81 and ground and the junction point 127 of resistances 124, 125. A resistance 129 is connected between junction points 109, 127. A capacitor 132 is connected between the grid and cathode of tube 110.

The anode of tube 110 is connected to one terminal of the coil 10A of relay 110, the other terminal of coil 10A being connected to lead 80.

The relay 10 is illustrated as having an armature or plunger represented by the dotted line 10B which serves to operate the movable arm of a single pole double throw relay switch 10C.

When the amplifier output appearing across capacitor 78 is less than 20 volts, peak to peak, the following conditions exist within the detector and relay control section of the receiver: —24 volts is applied at lead 81 from the bias supply section of the power supply; —4 volts is supplied at point 127 by the voltage divider network 124, 125; from point 127, capacitor 120 is charged at —4 volts over resistance 129; capacitor 132 is charged —4 volts from point 127 over resistance 129 and 112; the anode current of tube 110 is cut off by the —4 volts applied to its grid; and relay coil 10A, located in the anode circuit of V2B, is unenergized.

As long as the amplifier output across capacitor **78** is less than 20 volts, peak to peak (p.-p.) (A.C. voltage at point **135**), no current flows through either diode **116** or diode **114** (other than a negligible leakage current) since 20 volts of negative bias appears across diode **116** (−24 volts at lead **81** and −4 volts at point **109**). As the A.C. voltage across capacitor **78** rises above 20 volts, it charges through diode **114** on that portion of the positive half of the cycle which is greater than +10 volts and discharges through diode **116** on that portion of the negative half of the cycle which is less than −10 volts. When this occurs, capacitors **120** and **132** are both charged in the positive direction. With an output level of approximately 23.5 volts, p.-p., the charge on capacitor **132** becomes −1 volt which permits conduction in tube **110** in an amount sufficient to actuate relay **10**. When the voltage across capacitor **78** reaches approximately 25 volts p.-p., capacitor **120** is charged to +.6 volt, and capacitor **132** is charged to approximately −.5 volt. The reason for the more negative charge on capacitor **132** is the voltage drop across resistance **112** due to grid current from tube **110** as the grid voltage approaches zero.

Amplifier output in excess of 25 volts p.-p. results in no further change in the charge on capacitors **120** and **132** since current flows through diode **121** when the voltage at point **109** reaches +.6 volt and effectively prevents any further increase in voltage at this point as the amplifier output rises above 45 volts p.-p. (The forward voltage drop inherent in diode **121** is approximately .6 volt. As a result of the limiting action of diode **121**, the charge on capacitor **132** is always between −.5 and −1 volt when relay **10** is actuated, regardless of how large the amplifier output may be. In practice, the voltage charge is usually −.5 volt since only the most marginal signal level results in a charge between −1 volt and −.5 volt. This in turn means that the time required for the relay **10** to release after the amplifier output has dropped below 40 volts p.-p. is, for all practical purposes, constant regardless of how high the level of the actuating signal tone may have been.

From the foregoing it can be seen that the relay **10** will be actuated when the amplifier output reaches approximately 24 volts p.-p. and will be released when the output drops below 20 volts. p.-p. This is a difference of less than 2 db, and since amplifier output is linearly proportional to input signal tone level, it follows that the difference in tone level between the response and release values is less than 2 db.

Thus, the value of tone amplitude required for relay actuation, termed the "response level," is frequency dependent. This frequency-amplitude relationship is graphically illustrated by the solid curve of FIGS. 3 and 4. As shown by these curves, a frequency range (f_3–f_2) exists within which the response level varies from a minimum value (designated the 0 db signal level) to a level of +6 db. As the tone frequency increases above f_3 or decreases below f_2, the response level increases rapidly. Any applied signal tone having amplitude-frequency coordinates lying within the area bounded by this curve will cause actuation of the relay.

The value of tone amplitude which permits release of the relay after it has been energized is referred to as the release level. This value is also frequency dependent; the amplitude-frequency relationship being virtually the same as that of the response level curve. It is represented by the dashed curves of FIGS. 3 and 4. Any signal tone having amplitude-frequency coordinates lying outside the area bounded by this curve will effect release of the relay if it has previously been actuated. For all practical purposes, the release level curve can be considered as having been derived by the displacement of the corresponding response level curves approximately −2 db along the amplitude axis of the plots.

The application of a signal tone having amplitude-frequency coordinates lying within the area between the response and release curves will result in no change in the state which the relay occupied immediately prior to the application of this most recent tone.

The diference between frequencies f_3 and f_2 shown on FIGS. 3 and 4 is the response band width of the receiver. The difference between f_4 and f_1 is the release band width. The frequency f_0, midway between f_3 and f_2 ($f_2+f_3/2$) is the nominal frequency of the receiver. These values are all determined by the values of the various components within the filter circuit of the receiver as discussed above in connection with FIG. 2.

In practice, the nominal frequency, f_0, is set approximately equal to the signal tone frequency. The response band width is adjusted to the minimum possible width or to the minimum width required by the rate of information transmission. Information transmission is typically accomplished by alternately keying the signal tone on and off. It can be shown by wave analysis that the band width required to transmit this type of information is equal to two times the keying frequency. To this, of course, must be added the frequency drift encountered in the signal tone.

It is desirable to minimize band width for two reasons. The first is noise rejection, since noise is linearly proportional to band width and since it may result in false actuation of the relay. The second is spectrum utilization; the narrower the band width, the greater the number of channels that can be accommodated within a given range of the frequency spectrum.

With the gain control **30** set at its approximate midpoint and with the "Q" control **40** adjusted to give the desired response curve configuration, the input signal level is adjusted at its source to approximately +6 dbi. With this constant input level, the voltage at the input of the amplifier (point C) will vary with frequency of the input signal, as shown by the E_0 axis of FIGS. 3 and 4. With input frequency remaining constant, the voltage varies linearly with the input level.

The frequencies of different signal tones are separated by an amount such that the voltage at point C due to the effect of an adjacent signal tone will not exceed −30 dbo with 0 dbo being defined as the voltage level required to effect actuation of relay **10**.

To obtain maximum band width in the receiver, the coupling between the first two stages of the filter section is increased (by increasing the value of capacitor **23**) beyond the critical value of coupling. This overcoupling produces two resonant frequency points due to the interaction of the tuned circuits on each other. These resonant points occur one on each side of the center frequency. The frequency response at point B is represented by curve B of FIG. 5. The signal from point B is fed to the final stage which is tuned to resonate at approximately f_0. The frequency discrimination characteristics of this final stage is superimposed, so to speak, on the signal coming from point B with the result that a response curve with three "peaks" is obtained. The "Q" control **40** is adjusted so that the signal amplitude at frequency f_0 is approximately equal to that at f_5 and f_6.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. In a tone receiver receptive to a signal of a particular frequency; a pair of input terminals; a first capacitor; a first inductor; said capacitor and said inductor being connected in a first series circuit with said input terminals and being resonant to said particular frequency; one terminal of said inductor being connected to one of said input termials and one terminal of said capacitor being connected to the other one of said input terminals; a second capacitor;

a second inductor; a potentiometer type resistance having an adjustable tap and connected in a second series circuit with said second capacitor and said second inductor with one terminal of said resistance being connected to said one input terminal; said second series circuit being resonant to said particular frequency; one terminal of said second capacitor being connected to said one input terminal; a third coupling capacitor having one of its terminals connected to the junction point of said first inductor and said first capacitor and having the other one of its terminals connected to the junction point of said second inductor and said second capacitor; a transformer having a first winding and a second winding; a fourth capacitor; said fourth capacitor and said primary winding being connected in a series circuit between said resistance tap and said one input terminal; amplifying means having an input circuit and an output circuit; said input circuit having one of its terminals connected to said one input terminal and the other one of its terminals connected to the junction point of said first winding and said fourth capacitor; a potentiometer type resistance connected in shunt with said second winding and having a tap; a fifth capacitor; a third resistance; said fifth capacitor and said third resistance being connected in a series circuit between one terminal of the output circuit of said amplifying means and the tap of the last mentioned potentiometer; the other terminal of the output circuit of said amplifying means being connected to said one input terminal.

2. In a tone receiver of the character described for receiving a signal of a particular frequency, a pair of input terminals; first filter means comprising a series resonant circuit connected between said input terminals; second filter means comprising a parallel resonant circuit connected between said input terminals; second filter means comprising a parallel resonant circuit; capacity coupling means coupling an input terminal of said second filter means to an output terminal of said first filter means; the other output terminal of said first filter means and the other input terminal of said second filter means being connected to said one input terminal; a transformer including a first winding and a second winding; said parallel resonant circuit including a potentiometer type resistance having a tap thereon; a capacitor; one terminal of said first winding being coupled to said tap through the last mentioned capacitor, the other terminal of said first winding being connected to said one input terminal; said first winding being a part of said parallel resonant circuit; amplifying means having an input circuit and an output circuit; a second potentiometre type resistance connected in shunt with said second winding and having a tap; means coupling the output circuit of said amplifying means to the last mentioned tap; and means coupling the input circuit of said amplifying means to said first winding.

3. In a tone receiver of the character described receptive to a signal of a particular frequency, a pair of input terminals; a first capacitor having one of its terminals coupled to one of said input terminals; a first inductor having one of its terminals connected to the other terminal of said capacitor and also coupled to the other one of said input terminals; a potentiometer type resistance having a tap and having one of its terminals connected to said input terminal and the other one of its terminals connected to the other terminal of said inductor; said potentiometer resistance comprising a gain control resistance; a transformer having a first winding and a second winding; amplifying means having an input circuit and an output circuit; a second capacitor interconnecting said tap and one terminal of said first winding, the other terminal of said first winding being connected to said one input terminal; means coupling said first winding to said input circuit of said amplifying means, a potentiometer type resistance having a tap and connected in shunt with said second winding; and means coupling the last mentioned tap to the output circuit of said amplifying means.

4. In an apparatus of the character described, an electromagnetic device having a coil; a control device having a pair of output electrodes and a pair of input electrodes, said coil being connected between said output electrodes; a capacitor connected between said input electrodes; a lead of reference potential connected to one terminal of said capacitor and to one of said input electrodes; a resistance; a second capacitor; a first diode; said second capacitor and said diode each having one of its terminals connected to said lead and each having the other one of its terminals connected through said resistance to the other one of said input electrodes; said second capacitor and said diode having one of its terminals connected at a junction point to said resistance; a source of negative voltage having its positive terminal connected to said lead; a second diode; a third diode; unlike electrodes of said second and third diodes being interconnected at a second junction point; the other electrode of said second diode being connected to the positive terminal of said source; the other electrode of said third diode being connected to the first mentioned junction point; a voltage dividing circuit connected across said source; means connecting an intermediate point on said voltage dividing circuit to said first junction point; unlike electrodes of said first and third diodes being interconnected at said first junction point; and a source of alternating voltage coupled between said lead and said second junction point.

5. In an apparatus of the character described, an electromagnetic operator including a coil for moving a plunger; a tube having a cathode, a control grid, and an anode; said coil being connected between said anode and said cathode; a first capacitor connected between said control grid and said cathode; a resistance; a second capacitor; a first diode; said second capacitor and said first diode each having one of its terminals connected to said cathode, and each having its other terminal connected to one terminal of said resistance at a first junction point, the other terminal of said resistance being connected to said control grid; a source of negative voltage having its positive terminal connected to said cathode; a second diode; a third diode; said second and third diodes having unlike electrodes interconnected at a second junction point; said second diode being interconnected between said first and second junction points; said third diode being interconnected between said second junction point and the negative terminal of said voltage source; a voltage dividing network connected across said source; and means connecting an intermediate point on said voltage dividing circuit to said first junction point; and a source of alternating current connected to said second junction point.

6. In a tone receiver of the character described wherein it is desired to operate a relay, the combination comprising a relay having a coil; a tube having a cathode, a control grid and an anode; said coil being connected between said cathode and said anode; a first capacitor connected between said control grid and said cathode; a second capacitor; a first diode; a first resistance; said second capacitor and said first diode each having one of its terminals connected to said cathode and each having the other one of its terminals connected at a first junction point to one terminal of said resistance, the other terminal of said resistance being connected to said control grid; a second diode; a third diode; unlike electrodes of said second and third diodes being interconnected at a second junction point; said second diode serving to interconnect said first and second junction points; a source of negative voltage having its positive terminal connected to said cathode and its negative terminal connected to one terminal of said third diode, the other terminal of said third diode being connected to said second junction point; amplifying means having an input circuit and an output circuit; means coupling said output circuit between said second junction point and said cathode; a pair of signal input terminals, one of which is connected to said cathode; a series resonant circuit connected between the other of said input

terminals and said cathode; said resonant circuit including a capacitor and an inductance interconnected at a third junction point; a second resonant circuit including a capacitor and an inductor interconnected at a fourth junction point; a potentiometer type resistance having a tap and being interconnected between the other terminals of the last mentioned inductor and capacitor and with one terminal of the last mentioned resistance and the last mentioned capacitor being connected to said cathode; a capacitor coupling said third and fourth junction points; a transformer having a first winding and a second winding; said second winding being center-tapped with its center tap being connected to said cathode; a potentiometer type resistance having a tap and being connected in shunt with said second winding; means coupling the last mentioned tap to the output circuit of said amplifying means;

a capacitor; the last mentioned capacitor being interconnected between the tap of the first potentiometer resistance and one terminal of said first winding; the other terminal of said first winding being connected to said cathode; and the input circuit of said amplifying means being coupled to the junction point of the last mentioned capacitor and said first winding.

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