

Nov. 29, 1949

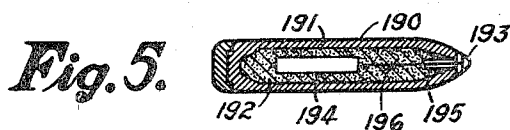
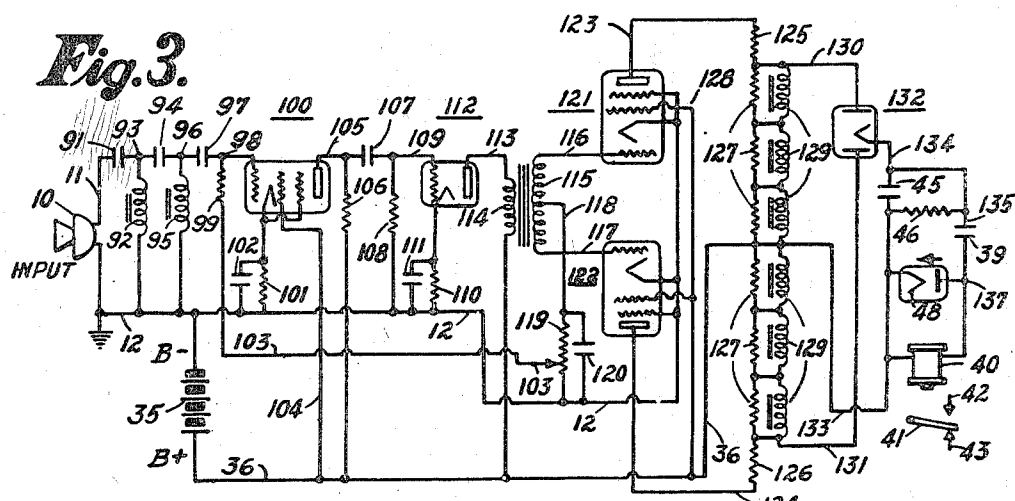
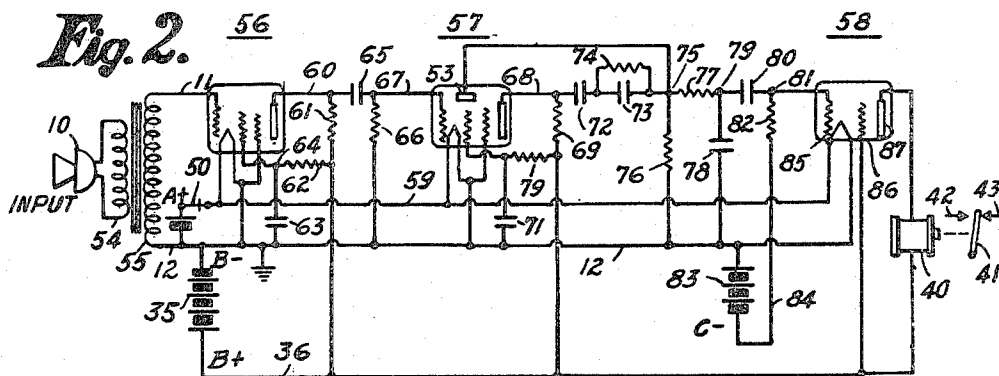
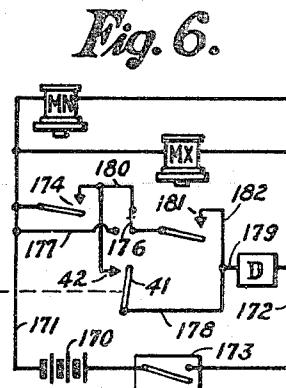
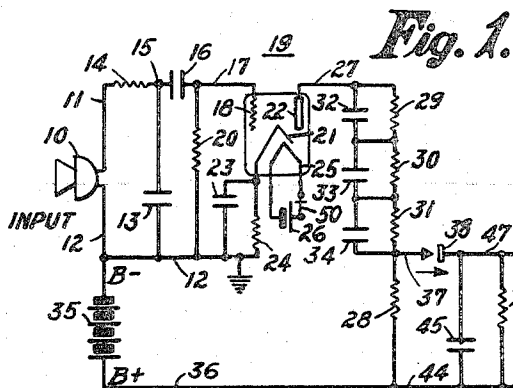
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2,489,255

SOUND RESPONSIVE CONTROL

Filed March 15, 1941

2 Sheets-Sheet 1



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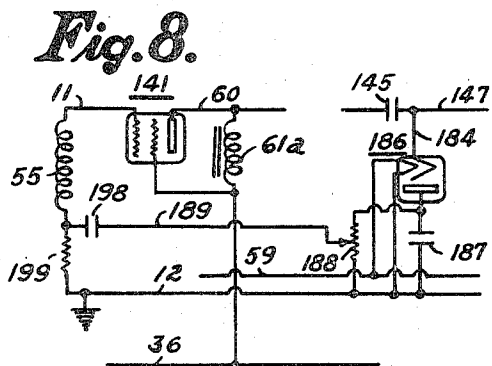
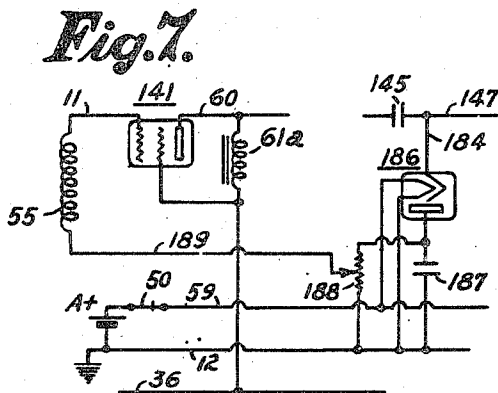
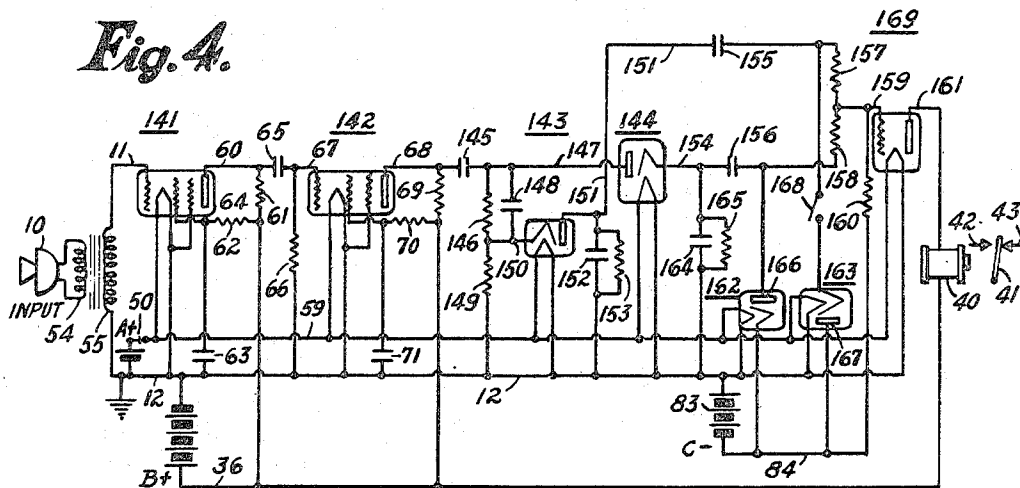
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2,489,255

SOUND RESPONSIVE CONTROL

Filed March 15, 1941

2 Sheets-Sheet 2



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SOUND RESPONSIVE CONTROL

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Application March 15, 1941, Serial No. 383,561

15 Claims. (Cl. 102—70.2)

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This invention relates generally to a sound responsive control device and more particularly to a device for controlling detonation of an anti-aircraft shell by responding to the sudden reduction in frequency or pitch of sound received from the motor or propeller of an airplane as the shell passes nearby.

While the invention is described particularly in relation to an anti-aircraft shell passing an airplane or other aircraft it will be appreciated that the invention is not limited to such application alone but may be of value in detecting the passage of a sound producing element past a sound detector in accordance with the invention whenever the velocity of the receiver relative to the sound producing element is sufficient to give an appreciable drop in sound frequency in passing.

A war tank or other motorized vehicle or a warship having a motor sound or other sound of characteristic pitch may be detected and thereby detonate a mine equipped with the invention if it passes closely enough and at sufficient speed by the receiver-detector to provide an appreciable reduction in pitch at the sound receiver associated with the mine.

The invention thus makes it possible to detonate a shell or mine within its effective range of destructive damage to a sound producing target without requiring actual contact with the target.

The velocities of the sound producer and sound receiver relative to each other and to the surrounding air determine the frequency of sound received from any given produced sound frequency. Ordinarily general wind or air drift has so little effect on operating results for the present purpose that it will be neglected and still air will be assumed in the present description.

The relations of the received frequency and the frequency at the sound source are expressed in a physical law known as "Doppler's principle." In accordance with this principle, on approach to a sound source the frequency of sound received at the receiver will be increased over the frequency produced at the source in proportion to the apparent increase in the velocity of sound by the addition of the velocity of approach of the receiver in the air toward the source to the normal velocity of sound, and on departure from the source the frequency at the receiver will be reduced from the source frequency in proportion to the apparent reduction in velocity of sound by the subtraction of the velocity of the receiver in the air away from the source from the normal velocity of sound. If the sound source is also moving toward the receiver the increase in fre-

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quency at the receiver is at a much greater rate than that caused by movement only of the receiver toward the source. If the source is moving away from a fixed receiver the frequency will be reduced at a lower rate than by movement only of the receiver away from the source.

These several relations may be expressed by the formula

$$\frac{f_o}{f_s} = \frac{V + V_o}{V - V_s}$$

in which f_s equals the frequency of sound at the source, f_o equals the observed frequency of sound at the observer, V equals velocity of sound in air toward the observer, V_o equals the velocity of the observer toward the source and V_s equals the velocity of the source toward the observer.

Thus if a sound receiver and sound source are approaching each other by motion of either toward the other the received frequency is increased over the frequency at the source, and if the receiver and source are separating by motion of either away from the other V_o and V_s become negative so that V_o is subtracted numerically from V and V_s is added numerically to V and the received frequency is reduced from the frequency at the source.

In any case net relative movement of either receiver or source toward the other will produce an increase in frequency of sound received in comparison with sound source and the increase will be greater as the relative velocity of approach is greater. Similarly a net relative movement of either receiver or source away from the other will reduce the frequency received and the amount of reduction will be greater as the relative velocity of movement apart becomes greater.

It will be appreciated that either receiver or sound source may be moving at an angle with a direct line between them and that only the component of velocity along this direct line is to be considered the effective velocity in determining the received frequency. Any velocity of either receiver or source at right angles to a line between them is ineffective to change the received frequency.

In the case of an anti-aircraft shell passing near an airplane at any considerable relative speed for example a sound receiver in the shell will receive a higher sound frequency from the plane as a sound source on approach and a lower frequency on departure, and there will be a rapid reduction in frequency at or near the point at which the shell passes nearest to the plane.

At lower levels in the trajectory of a high ve-

locity anti-aircraft shell the shell velocity may be several times greater than the velocity of sound and at higher levels the shell velocity falls below the velocity of sound, but the shell velocity will ordinarily be considerably higher than the plane velocity except near the very top limit of the shell trajectory.

Whenever the shell and plane pass near each other, however, there will be a change from a net approach velocity to a net departure velocity and a consequent reduction over a short time period in sound frequency received at the shell from the plane. The rate of frequency reduction during this short time period and the relation of the major amount of reduction and the moment of passing are determined by the relative velocities of the shell and plane and sound and by their relative position at the time of passing, that is whether the shell passes ahead or behind the plane or somewhat to the side, but in any event a major and rapid change in frequency will occur in connection with the close approach and passing, with or without a reduction in amplitude, and this can be detected in accordance with the present invention within the effective range of explosion of the shell for damage to the nearby plane.

One serious difficulty in anti-aircraft defense at the present time is in detonating the anti-aircraft shell at the proper altitude to be within its effective range in relation to the aircraft target, since the detonating altitude must be determined in advance at the ground by setting a time fuse or other time detonator based on observation of the existing course of the plane and prediction of the expected course and position of the plane some little time after firing of the shell from the gun until the shell rises to the altitude of the plane.

A considerable part of aircraft attack is either by high altitude bombing or by dive bombing. In the first case a timing control error of less than one per cent may cause premature or late detonation of the shell out of the effective range from the plane. In the case of dive bombing the altitude of the plane and its horizontal position are both ordinarily changing so rapidly that it is extremely difficult if not impossible to set the detonation timer to detonate the shell within its effective range from the plane.

The present invention provides a device in the shell itself to detect the approximate moment of passage of the shell within its effective range from the plane and to detonate the shell within that range, by detecting the change in characteristics of the motor sound or propeller sound in passing. In the case of planes flying at various altitudes the shell may pass one plane outside its effective range at a lower altitude without detonating and pass another plane at a higher altitude within its effective range and detonate at the latter altitude. In some cases the shell might be detonated in passing a plane on the downward phase of its trajectory.

In accordance with the present invention the anti-aircraft shell would be provided with a simple detonation timing element as a maximum and minimum limit control, and the actual moment of detonation within these limits would be determined by the sound change detector disclosed. A considerable range of error could be tolerated in the limit timer without interfering with proper detonation of the shell and thus a simpler and cheaper timer could be employed for the limit timer than would be needed if this timer were

also required to provide detonation at exact range.

The limit timer serves primarily as a safety device, to prevent detonation of the shell by the sound responsive device for a minimum time until the shell is at a safe distance from the firing gun, and to cause detonation of the shell in any event after a maximum time allowing for the shell to reach the top of its trajectory and start downward some distance but to detonate the shell before it returns close enough to the earth to damage objects on the ground.

It is a general object of the invention to provide a control device for operating a work circuit responsive to the change in sound occurring in passage of the control device by a sound source or occurring in the passage of a sound source by the control device.

A further object is to provide a control device of such character which is responsive to the rapid reduction in sound frequency received in passing.

Another object is to provide a control device for detonating an explosive upon close passage of a sound producing element having a characteristic sound.

An additional object is to provide a control device for detonating an anti-aircraft shell responsive to the change of sound received from the plane and resulting from close passage of the shell by the plane.

A further object is to provide a control device on an anti-aircraft shell for detonating the shell responsive to a rapid reduction of sound frequency received by the device from the plane as the shell passes the plane.

Another object is to provide in an anti-aircraft shell a control device for detonating the shell including a minimum time limit element preventing detonation of the shell for a minimum time after firing from the gun, a maximum time limit element causing detonation of the shell at a maximum time after firing from the gun if it has not already been detonated and a sound responsive element for detonating the shell between such limits responsive to the rapid change of sound characteristic received from a plane upon close passage of the shell near the plane.

Other objects and advantages will be apparent in the following description and claims in connection with the drawings.

Referring now to the drawings,

Fig. 1 shows a schematic circuit diagram of one embodiment of the invention.

Fig. 2 shows a schematic circuit diagram of a somewhat different form of the invention, having additional amplification and an electronic tube output stage.

Fig. 3 shows a schematic circuit diagram of another embodiment of the invention, providing more selective filtering and automatic volume control and a somewhat different arrangement for the frequency responsive part of the circuit.

Fig. 4 shows a schematic circuit diagram of another embodiment of the invention providing compensation for amplitude reduction not accompanied by frequency reduction.

Fig. 5 shows a schematic diagram of one arrangement of the sound responsive detonator control device in a shell.

Fig. 6 shows a schematic circuit diagram for the minimum and maximum limit timers in connection with the output relay of the detonator control device in an anti-aircraft shell.

Fig. 7 shows a modification of the circuit of Fig. 4 providing limited automatic volume control.

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Fig. 8 shows another modification of Fig. 4 providing automatic volume control only for quite rapid changes in sound intensity.

Referring now to Fig. 1, the sound input is received by the microphone 10 which provides electrical waves across the input leads 11 and 12 corresponding to the sound waves received. This microphone may be of the moving coil type or moving diaphragm type or crystal type, for example. Maximum limits may be provided for movement or bending in connection with the shock of initial acceleration and air resistance. The input circuit impedance in each case would be suitably matched with the microphone impedance.

Condenser 13, across leads 12 and 15 in connection with the series resistor 14 serves to by pass the very high frequencies and condenser 16 in combination with resistor 20 serves to limit passage of low frequencies, to limit the range of response of the device as desired. The resulting signal voltage is applied to the control grid 18 of the electronic amplifier tube 19, across the high resistance 20 between leads 17 and 12.

The cathode 21 is connected via resistor 24 to lead 12 to provide self-bias for the grid, and the condenser 23 provides a by-pass around resistor 24 in the operating range of signal frequencies. The cathode 21 may be indirectly heated as shown by the heater 25 or may be directly heated by direct connection across the A battery 26.

The output from the anode 22 of the tube 19 is connected via the series resistors 28, 29, 30, 31 and lead 36 to the positive end of the B battery 35, with the negative end of this battery connected to lead 12. The condensers 32, 33, 34 shunt the resistors 29, 30, 31 respectively, and with the resistors are graded in value to provide an impedance to the A. C. component of the signal voltage across leads 37, 27 varying inversely with frequency but at a lower rate than the frequency. The resistors 29, 30, 31 are all of high value in relation to the condenser impedance in the high part of the frequency operating range so that the condensers 32, 33, 34 determine the effective impedance between leads 27 and 37 primarily at the high frequencies and have less but considerable influence on the impedance at low frequencies, and thus also determine the A. C. voltage between these leads and also the A. C. voltage between leads 37, 44 across resistor 28. As the impedance across leads 44, 27 falls with increasing signal frequency the A. C. component of the anode cathode current increases and causes a greater voltage across the resistance 28.

This voltage across resistor 28 and leads 37, 44 is a maximum for high frequencies and a minimum for low frequencies since the impedance of condensers 32, 33, 34 is inversely proportional to the frequency.

Thus for sound waves of high frequency a relatively low voltage appears between leads 37 and 27, and a high voltage appears across leads 37, 44. This A. C. voltage across leads 37, 44 is converted to pulsating D. C. voltage by half-wave rectification by the rectifier 38 and serves to charge condenser 39 from lead 37 via rectifier 38, lead 47, condenser 39, rectifier 48, lead 44. Condenser 45 between leads 47, 44 is also charged during the same half-waves and serves to maintain the voltage of condenser 39 to a considerable extent during the half-waves of opposite polarity. However the size of condenser 39 is related to the resistance of the charging circuit and the dis-

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charge resistance 46 across condenser 45 so that a number of cycles of the A. C. wave and corresponding sound waves must occur to fully charge condenser 39 and will require from one-third second to several seconds for example as desired. The longer this storage period is to be on approach the larger is the capacity of condenser 39.

For sound waves of low frequency the impedance of the condensers 32, 33, 34 is much greater and a considerably greater voltage appears between leads 37 and 27 which results in a considerably lower voltage across resistor 28 and leads 37—44. When this low frequency follows immediately after a brief period of high frequency, condenser 45 will discharge via resistance 46 and condenser 39 will discharge via resistor 46 and relay 40 and will energize relay 40 momentarily, to separate its armature 41 from back contact 43 and to engage front contacts 42. Either of these contacts can be used to control a circuit to operate a thermal or percussion detonator to set off the explosive charge.

Thus in absence of sound waves no current will be available in the circuit of relay 40 and the relay will remain deenergized. If sound waves of high frequency are received, as in approaching an airplane, a small pulsating current of one polarity will charge condenser 39 but relay 40 will be short-circuited by rectifier 48 to maintain it deenergized on these pulses and condenser 45 across resistor 46 blocks discharge of condenser 39 sufficiently between pulses to prevent energization of relay 40. If sound-waves of considerably lower frequency are received however as in passing the plane, the charging voltage is greatly reduced and condenser 45 discharges within a few cycles via resistor 46 and thus condenser 39 discharges through relay 40 to energize relay 40 and operate the detonator. The discharge of condenser 39 provides current of polarity opposite to that of the charging current and thus the rectifier 48 does not then short circuit relay 40 and the discharge passes through relay 40.

The arrangement of multiple condenser resistor combinations between leads 27 and 36 in Fig. 1 permits response to a wider range of frequency to be obtained for a given voltage change. However it may be found for a particular set of operating conditions for the intended use of the sound-responsive device that a narrow frequency range will be sufficient or preferred and a single condenser in shunt with a single high resistance between leads 27 and 37 will provide the desired voltage change across resistor 28 for a given frequency change.

The rectifier 38 is shown schematically and may preferably be in the form of an electronic tube, although a dry disc type might be used.

In the embodiment of the invention illustrated in Fig. 2 a transformer 54—55 is introduced between the microphone and input leads 11—12, which in turn feed into a conventional two stage resistance-capacity coupled amplifier employing tubes 56 and 57.

A power output tube 58 is employed in the output stage and a slightly different frequency responsive circuit arrangement is employed preliminarily to the output stage.

Condensers 63 and 71 in the screen grid leads and condensers 65 and 72 and condenser 73 and its shunt resistor 74 in the anode leads determine the lower frequency limits of the amplifier and the internal anode-cathode capacity in the tubes determines the upper limits of frequency.

The auxiliary anode or diode element 53

of tube 57 serves to short circuit one half of the A. C. signal component at lead junction 75 so that the signal voltage across resistor 76 between point 75 and B minus lead 12 is pulsating D. C.

This pulsating D. C. signal voltage is applied via resistor 77 to charge condenser 78 when the sound frequency is high as in approaching a plane. The high frequency signal current finds low impedance in condensers 72 and 73 and thus very little of the signal voltage appears across these condensers between lead 68 and point 75 and most of the signal voltage therefore appears across resistor 76 to charge condenser 78.

When the sound frequency drops as in passing the plane, the signal voltage frequency drops correspondingly and condensers 72, 73 offer sufficient impedance to this low frequency so that a major part of the signal voltage appears across these condensers and consequently less voltage appears across resistor 76. Therefore condenser 78 discharges via resistors 76, 77.

The grid 85 of output tube 58 is connected at point 81 via high resistance 82 and lead 84 to the minus terminal of C battery 83, and at point 81 is also connected via condenser 80 to point 79 and condenser 78.

Normally in absence of any incoming signal the C battery maintains a charge on condenser 80 with the right side of condenser 80 negative with respect to lead 12, substantially the full voltage of the C battery appearing across condenser 80 and no charge appearing on condenser 78.

Upon receipt of an incoming high frequency signal however, as in approaching a plane, a pulsating D. C. voltage appears across resistor 76 which charges condenser 78 and opposes the voltage of the C battery so as to reduce and reverse the charge on condenser 80. Condenser 80 discharges negatively and charges positively over a period of several hundred signal cycles for example with condenser 78 serving to maintain the opposition voltage to a considerable extent during the blank periods between pulses in successive cycles.

The current in this reversal of charge on condenser 80 causes a voltage drop across resistor 82 in the same direction as the C battery so that the grid 85 becomes more negative and the current in the anode 87 circuit of tube 58 is reduced and relay 40 remains deenergized.

When the signal frequency is reduced on passing the plane the voltage across resistor 76 drops considerably and the opposition to the C battery is thus greatly reduced and condenser 80 starts to discharge positively. This discharge current is in the opposite direction to the previous charge reversal current and immediately causes a voltage drop across resistor 82 which opposes the C battery and thus reduces the negative bias on the grid 85. This causes the anode current in tube 58 to increase sufficiently to energize relay 40 so as to operate the detonator.

Fig. 3 shows an embodiment of the invention in which the final frequency change responsive circuit directly controlling relay 40 is similar to the corresponding circuit of Fig. 1 except that a full wave rectifier tube 132 is employed to convert the A. C. signal voltage to D. C. to charge condensers 45 and 39, and except that an inductive choke and resistor combination is employed in Fig. 3 to obtain a voltage varying with frequency instead of a condenser resistor combination as in Fig. 1.

Other arrangements of the amplifier and filter are also illustrated in Fig. 3 including a band pass filter on the input and a limiting automatic volume control circuit in connection with the amplifier to make the complete device less sensitive to fluctuations in the amplitude of the sound waves which may occur independently of any significant change in frequency.

In this embodiment the input leads 11—12 feed into a multiple stage high frequency pass selector network comprising the series condensers 91, 94, 97 and the shunt inductive chokes 92, 95 to filter out frequencies below the significant range of sound from the plane or other sound producing target. The internal anode-cathode capacity will serve to limit the upper end of the frequency range to which the present device is responsive, but if additional filtering of very high frequencies is desired one or more small condensers may be placed across leads 11 and 12 or leads 98 and 12 or both.

The two amplification stages employ the pentode tube 100 and the triode 112 with self-bias of the control grids provided by the resistors 101 and 110 and the respective shunting condensers 102 and 111. The series condenser 107 and the shunt resistors 106 and 108 provide the usual resistance-capacity coupling between the two stages.

The output of the second amplification stage at the anode lead 113 of tube 112 is fed into the primary 114 of the transformer 114—115, and the outer ends of the secondary winding 115 are connected to the control grids of two pentode tubes 121 and 122. The center point of the transformer secondary is connected via lead 118 and potentiometer 119 to the ground lead 12, the potentiometer 119 being shunted by condenser 120. A tap on the potentiometer is connected via lead 103 and high resistance 99 to the control grid of the first tube 100 to provide limited automatic volume control of the signal voltage output of the amplifier to the dual rectifier tubes 121—122 and the remaining frequency responsive circuit. The suppressor grids of tubes 121—122 are connected to the cathodes and the screen grids are connected to the B plus lead 36 via lead 128.

The output leads 123, 124 from the anodes of the tubes 121, 122 are connected to opposite ends of a chain of resistors 125, 127, 126, and a chain of choke coils 129 is connected across the several resistors 127 individually and collectively. These coils and resistors may be preferably graded in impedance values to provide an effective total impedance increasing with increasing frequency but not as rapidly as the increase of frequency. In a manner similar to that of the resistance-capacity chain circuit between leads 37 and 27 in Fig. 1 the impedance and voltage drop between the leads 130 and 131 vary with frequency. The resistance-capacity chain of Fig. 1 provides decreasing impedance with increasing frequency, and the resistance-inductance chain of Fig. 3 provides increasing impedance with increasing frequency. In Fig. 1 the resultant voltage across resistor 28 increases with increasing frequency and this is applied to the cumulative charge condensers 45 and 39 to operate the output relay 40 responsive to a drop in voltage and frequency, and in Fig. 3 the voltage across the resistance-inductance chain increases similarly with increasing frequency and this voltage is applied to the cumulative charge condensers 45 and 39 to operate relay 40 responsive to a drop in voltage and frequency.

In Fig. 3 the A. C. signal voltage component across the leads 130—131 is rectified by the full wave rectifier tube 132, and the output leads 134 and 133 supply double frequency pulsating D. C. across condenser 45 which helps to steady the D. C. across resistance 46 for charging condenser 39 via rectifier 48. Rectifier 48 is shown as an electronic tube rectifier for example. The full wave rectification provided by tube 132 allows the condenser 45 and resistor 46 to have a time constant of one-half that of the half wave rectification illustrated in Fig. 2 for example thereby reducing by about one half the time for response of the circuit to the drop in frequency.

As in the circuit of Fig. 1 the condenser 39 charges over a considerable number of cycles of the sound waves on approaching the sound source and when the sound frequency drops in passing the sound source condenser 45 discharges rapidly through resistor 46 and condenser 39 discharges through resistance 46 and relay 40 to energize relay 40 momentarily. On the high frequency of approach relay 40 is substantially short-circuited by rectifier 48 but on the low frequency of and after passing the polarity of the voltage across the relay and rectifier is reversed so that the discharge current cannot pass through the rectifier and passes through relay 40 and energizes it.

In the embodiment illustrated in Fig. 4, the input and the two amplification stages involving tubes 141 and 142 are substantially the same as in Fig. 2, except that no second anode is needed in the second amplifier tube 142. The frequency responsive circuit beyond the second amplifier tube differs considerably from Fig. 2, however, and provides automatic compensation for changes in the average amplitude of the signal corresponding to changes in the intensity of the sound waves to prevent operation of the terminating relay. This feature of the circuit of Fig. 4 makes the device substantially non-responsive to a drop in sound intensity not accompanied by a drop in frequency but makes the device responsive to a rapid drop in frequency whether the sound intensity falls or remains unchanged.

In Fig. 4 the condenser 145 and two resistors 146 and 149 are connected in series across the output of the second amplifier tube 142 between the anode lead 68 and the grounded cathode lead 12, and condenser 148 is connected across resistor 146. Condenser 145 is at the anode end of this series circuit and serves primarily to block direct current so that only the alternating current signal component appears across resistors 146, 149.

Resistors 146 and 149 may be approximately equal in value for example and condenser 148 offers a much lower impedance than resistor 146 to high frequencies such as occur in approaching a plane, but offers increased impedance which may approach that of resistor 146 at low frequencies such as occur in passing or moving away from the plane.

In approaching, the signal voltage across condenser 148 and between leads 147 and 150 is relatively low and the signal voltage across resistor 149 and between leads 150 and 12 is relatively high. On passing the signal voltage increases across condenser 148 and leads 147, 150 and drops across resistor 149 and leads 150, 12. The A. C. impedance of the combination of resistors 146 and 149 and condenser 148 is considerably higher than the impedance of the shunt circuit on the left side of condenser 145 via resistor 69 and the battery, so that the total voltage between leads 147 and 12 does not change materially with rise and fall of frequency.

Two rectifier tubes 143 and 144 are connected in opposite polarity arrangement with leads 147 and 150. The cathode of tube 143 is connected to lead 150 and the anode of tube 144 is connected to lead 147. The anode of tube 143 is connected via lead 151, condenser 155, the equal resistors 157, 158, condenser 156 and lead 154 to the cathode of tube 144. Condensers 155 and 156 are of equal capacity.

Condenser 152 and shunt resistor 153 are connected between lead 151 and ground lead 12, and condenser 164 and shunt resistor 165 are connected between lead 154 and ground lead 12, thus serving to steady the pulsating D. C. output of the rectifiers 143 and 144.

One half of the A. C. signal voltage waves across resistor 149 is rectified by rectifier tube 143 and appears as D. C. between leads 151 and 12. This may be called the negative half of the wave and negative D. C. The other half, which may be called the positive half, of the A. C. signal voltage waves across combination of resistors 146 and 149 is rectified by rectifier tube 144 and appears as positive D. C. between leads 154 and 12.

Lead 151 is connected to lead 154 via condenser 155, resistors 157, 158 and condenser 156 as previously described and with positive D. C. on lead 154 and negative D. C. on lead 151 the difference in voltage between these leads controls the charge on condensers 155 and 156. Any change in this voltage difference will cause a change in the charge on condensers 155 or 156 or both and will cause some voltage to appear across one or both of resistors 157, 158.

The grid of the output tube 169, illustrated as a triode, is connected to the negative bias battery 83 via resistor 160 and lead 84 and is also connected via lead 159 to the electrical midpoint between resistors 157 and 158. As long as the voltage drop across resistor 157 is equal to that across 158 and remains the same with respect to the ground lead 12 this grid remains at sufficient negative bias to prevent relay 40 from being energized in the anode circuit 161. As will subsequently appear in this description this condition prevails upon a reduction in signal intensity without reduction in frequency. As will also appear, any reduction in frequency will unbalance the voltages on resistors 157, 158 and will make the grid of tube 169 more positive so as to energize relay 40.

Rectifier tube 162 has its anode connected to the outer end of resistor 158 and its cathode connected to the negative grid bias lead 84, so that the outer end of resistor 158 and the right side of condenser 156 cannot become positive with respect to the negative grid bias lead 84 but must remain as negative as lead 84 or more negative than this lead.

The operation of the frequency change responsive circuit to the right of condenser 145 will now be considered under various conditions. Assume first that high frequency sound of constant intensity is received. Then the voltage appearing across resistor 146 and shunt condenser 148 will be relatively low and that across resistor 149 will be relatively high as previously described and the total voltage across leads 147 and 12 will be slightly greater than the voltage across leads 150 and 12.

Thus the D. C. voltages to the right of rectifiers 143 and 144 will be somewhat higher between leads 154 and 12 than between leads 151 and 12, and because of the opposite polarity connection of the rectifiers the D. C. voltage applied to the

left side of condenser 156 will be positive and that applied to the left side of condenser 155 will be negative. Condenser 156 will be charged immediately via rectifier 162 and the grid bias battery 83. Condenser 155 will be discharged from its normal voltage as determined by battery 83 and its charge may be reversed in polarity if sufficient sound intensity is received since the negative voltage on lead 151 opposes the grid bias battery. This change of charge will take place over a number of cycles of the sound waves for example, because of limiting resistance 157, 158 and high resistance 160 and at the beginning of this discharge the negative voltage between leads 151 and 12 appears mostly across resistor 160 and increases the negative grid bias of tube 169, maintaining relay 40 deenergized.

When condenser 155 has become discharged to the new stable level established by the incoming high frequency sound the grid bias returns to its normal level and still maintains relay 40 deenergized.

Now if the sound intensity is greatly reduced without change in frequency, the total signal voltage will be reduced and the positive voltage on lead 154 and negative voltage on lead 151 will be reduced proportionately. A current will flow via resistors 157, 158 between condensers 155 and 156 until the charge on the condensers becomes stabilized at the new voltage level but this will not change the grid bias appreciably at the mid point or neutral point between the resistors. If there is any change it will make the grid more negative because the voltage between leads 154—12 is slightly higher than the voltage between leads 151—12.

The reduction in signal voltage on lead 151 reduces opposition to battery 83 in charging condenser 155 and thus if this were the only effect a charging current flowing down through resistor 157 and resistor 160 and would cause a voltage drop in resistor 160 making grid lead 159 more positive. However this effect is overcome by the corresponding reduction in signal voltage on lead 154 which reduces aid to battery 83 in charging condenser 156. This would produce a current equal and opposite to that which would be produced in resistor 160 by the voltage change on lead 151 and thus the two effects neutralize and current flows only via resistors 157 and 158 and substantially no current flows in lead 159 or resistor 160 so the grid bias is substantially unchanged despite the reduction in signal intensity.

If the sound frequency drops materially as in the passing of a plane while the intensity remains constant the voltage across resistor 146 and condenser 148 will rise materially and the voltage across resistor 149 will fall so that now the voltage between leads 147 and 12 will be considerably greater than the voltage between leads 150 and 12. Thus the positive D. C. voltage between leads 154 and 12 will be about the same as before but will be considerably greater than the negative D. C. voltage between leads 151 and 12, the latter being materially reduced. Thus the charge across condenser 156 does not change much but the charge on condenser 155 must change to adjust to the new less negative signal voltage.

This signal voltage opposes battery 83 in charging condenser 155 and with a smaller signal voltage the charge on condenser 155 from the battery increases, with the charging current flowing via resistors 157 and 158 and rectifier 162 to negative bias lead 84 and battery 83. Since the

voltage between 154 and 12 remains substantially unchanged the voltage drop in resistor 158 causes grid lead 159 to become more positive and thus to allow current in the anode circuit 161 to energize relay 40.

If a large reduction in signal intensity occurred with the reduction in frequency the total voltage would drop and because of the frequency drop the voltage on lead 151 would drop more than that on lead 154. The voltage on the latter lead might even rise if the frequency drop was large and amplitude drop small. However the effects on the two leads 151 and 154 of reduction in total voltage by drop in intensity are equal and opposite and substantially neutralize as described above but the effects of frequency reduction are different on the two leads as described above and the grid voltage becomes more positive so as to cause operation of relay 40.

In the embodiment of Fig. 4 described the condenser 155 may require some time from one third second to one or two seconds for example on approaching to be sufficiently charged so that the subsequent discharge on passing will cause energization of the relay. This may serve as a safety measure to make the device selective for the sustained sound of the plane as against other more rapidly varying sounds such as gun fire and explosions and echoes of these sounds at various frequencies.

If it is desired to make the device of Fig. 4 responsive substantially instantaneously to approach and passing however, the additional rectifier tube 163 can be included between the outer end of resistor 157 and the negative bias lead 84, with the anode of the rectifier 163 connected to the lead 84. The effect of this additional circuit can be seen by closure of switch 168 in Fig. 4 for example, which permits the discharge current resulting from appearance of the high frequency signal to pass rapidly through the low impedance path of the rectifier so as to change the condenser charge rapidly on approach, but does not short circuit the resistors 157 and 160 on passing when the polarity is reversed.

For many applications the circuit of Fig. 4 will be satisfactory even though in some cases the response will be delayed until immediately after passing, but where it is desired to obtain response at or immediately before the moment of passing, an automatic volume control circuit is preferably added to the embodiment of Fig. 4 to reduce substantially any changes in the average amplitude of the A. C. signal voltage, across resistors 146 and 149, which would result from fluctuations in sound intensity. Two forms of suitable automatic volume control circuits are shown in Figs. 7 and 8. The A. V. C. circuit is connected between lead 147 and input 11—55 for example. The circuit of Fig. 7 includes lead 184, rectifier tube 186, condenser 187 and its shunt resistor 188 connected between the anode of rectifier 186 and ground lead 12, and a connection via wire 189 between a tap on resistor 188 and the return side of the input transformer secondary 55 to apply any desired rectified part of the signal voltage to the input. This rectified voltage adjusts the amplification of the tube 141 to reduce changes in effective value of signal voltage at lead 147 caused by changes in sound intensity. With this arrangement tube 141 will preferably be of the variable mutual conductance type, and the initial increase in signal voltage on approaching the sound source at some little distance will not be obstructed appreciably but any increase in sig-

nal voltage due to increasing sound intensity at the higher intensity in the moment immediately before passing will thus be minimized.

As modified by addition of the A. V. C. circuit of Fig. 7, the inductance 61a is substituted for resistor 61 of Fig. 4, the resistor 62 and condenser 63 are omitted and inductance 61a and screen grid of tube 141 are now connected direct to lead 36. Also in Fig. 7 the lower side of winding 55 is connected via the A. V. C. circuit to ground lead 12 instead of directly to ground as in Fig. 4.

The alternate form of the A. V. C. circuit shown in Fig. 8 is similar to that of Fig. 7 except that a resistor 199 is placed in the return lead between winding 55 of the input transformer and ground lead 12 and a condenser 198 is connected in lead 189 between the upper end of resistor 199 and potentiometer 188. The circuit of Fig. 8 applies a desired part of rectified signal voltage from across resistors 146, 149 to the grid of tube 141 as in Fig. 7 except that in Fig. 8 the condenser 198 blocks any slow changes of rectified signal voltage from passing through to this grid, and permits only the more rapid changes to reach this grid so as to greatly reduce any rapid voltage change resulting from any rapid change in sound intensity.

The value of condenser 198 may be chosen with respect to the resistance 199 so that this combination will have a time constant of the order of $\frac{1}{4}$ second to one second for example. Any substantial changes of sound intensity occurring within less than the time constant would provide a voltage change through the A. V. C. circuit to the grid of tube 141 to counteract any corresponding change in the signal voltage since the change in charge on condenser 198 would produce a temporary voltage drop in resistor 199 which would change the operating point of the grid until the condenser charge had become substantially stabilized at the new voltage. Any slow voltage changes would allow the condenser charge to change gradually with such small current through resistor 199 that no appreciable voltage drop would occur and no appreciable change in the operating point of the grid would occur.

Summarizing the operation of the device of Fig. 4 as originally described with switch 168 open, the incoming sound waves are converted to electrical waves and amplified with some filtering to narrow the band of frequencies as desired for the particular use of the device and the amplified electrical waves are applied across two parts of a resistance capacity circuit, one part comprising resistor 146 and shunt condenser 148 and the second part comprising resistor 149. The total voltage of the electrical waves on the two parts is rectified at positive polarity and applied to lead 154, and the voltage on the second part only is rectified at negative polarity and applied to lead 151.

The voltage on lead 154 is proportional to the intensity of the sound independent of frequency, and the voltage on lead 151 varies directly with sound frequency and directly with sound intensity and thus this voltage on lead 151 is determined by the combination of the frequency and intensity effects.

The voltages on leads 151 and 154 are then connected to the ends of the balanced condenser-resistor combination 155—157—158—156, with the grid and grid bias circuit of the output tube connected to the midpoint. At high frequencies these voltages substantially balance each other but at low frequencies the voltage on lead 154 is greater than that on lead 151. Thus the effects

of intensity or amplitude changes substantially neutralize each other at high frequencies and the remaining frequency change effect controls the grid bias to control relay 40.

In Fig. 4 alone, however, if the sound intensity should increase materially with the considerable drop in sound frequency immediately before passing the sound source, this increase in sound intensity would produce an increase in signal voltage which might be sufficient to overcome the effect of frequency reduction and prevent proper reduction in negative bias of the grid lead 153 and thus prevent operation of relay 40 until immediately after passing when frequency and amplitude both decline and the relay would be operated as described above.

However, with the inclusion of an A. V. C. circuit as above described any material increase of signal amplitude is prevented despite increase in sound intensity immediately before passing, and thus the frequency drop without material change in signal voltage causes operation of relay 40 as previously described.

The initiation of operation of the sound responsive control device of any of the forms illustrated in the several figures in preparation for receiving and translating the sound waves would preferably be accomplished by closure of an inertia switch 50 in the heater circuit for the tube or tubes. This switch would preferably be closed and maintained closed by the centrifugal force of rapid rotation of the shell in flight resulting from the rifling of the gun, for maximum safety against premature explosion in handling. The switch may be of the self-locking type however if desired.

Fig. 6 shows schematically one form of maximum and minimum time protection device which is preferably employed with the sound responsive control in an anti-aircraft-shell in accordance with the invention.

Two time delay relays or switch devices MN and MX are employed, MN providing a minimum time limit and MX providing a maximum time limit. The minimum time limit provides an initial waiting period after firing the shell before the sound responsive control can operate the detonator, so that the shell will be safely away from the gun. The maximum time limit assures that the shell will be detonated automatically before it returns near the ground in case it was not detonated by action of the sound responsive control.

The battery 170 of Fig. 6 may be independent or may be a part of the batteries of the remaining figures of drawings. Battery 170 supplies the negative power lead 171 and also supplies the positive power lead 172 when the switch 173 is closed. This is preferably an inertia switch which is closed and remains closed as a result of the centrifugal force of the rapid rotation of the shell in flight. The switch may be of the toggle type, however, if desired so that it will remain locked in closed position after being closed during the firing of the shell.

Closure of switch 173 energizes minimum time relay MN across leads 171, 172 to start timing immediately and after its time period this relay closes its contact 174. Closure of switch 173 also energizes maximum time relay MX across leads 171, 172 and this relay closes its contact 181 after its time period if the shell has not been previously exploded.

A circuit is provided from negative power lead 171 via contact 174 when closed by relay MN and 75 via contact 42 and armature 41, leads 178, 179

and the detonator D to positive lead 172. Armature 41 is controlled by relay 40 in the sound responsive control device of any of the Figures 1 to 4 and 7 and 8, so that the circuit to the detonator is prepared by operation of minimum time relay MN and is completed by action of the sound responsive control.

If the shell remains unexploded until relay MX closes its contact 181 this contact provides a shunt circuit around the contact 42 and armature 41 of relay 40 and completes a circuit to operate detonator D directly. This circuit may be traced from lead 171 via closed contact 174, lead 180, switch 176, closed contact 181, leads 182, 179 and detonator D to lead 172.

This circuit has a safety feature in the inclusion of contact 174 of relay MN so that detonation by closure of contact 181 of relay MX cannot occur until after the minimum time period even if the MX relay contact 181 is closed prematurely from any cause.

Where it is desired to have the MX timer act independently of the MN timer the contact 181 is disconnected from lead 180 and connected to lead 177 and power lead 171 directly by changing the position of switch 176.

If desired the minimum time relay MN—174 may be omitted, and the time lag of a few seconds required to bring the heaters of the tubes up to emission temperature may be employed as the minimum time limit. In this case the detonator D would be operated directly between leads 171—172 by armature 41 and contact 42 of relay 40 or the detonator would be substituted for relay 40 in the output circuit of the sound responsive control. The last mentioned arrangement would have the advantage of avoiding any danger of premature explosion by possible fluttering of relay contacts, which in the other arrangements would have to be avoided by suitable mounting of the relay and using a low mass armature and high return spring tension on the armature.

A partly schematic cross-section-view of a shell with one arrangement of the sound responsive control is shown in Fig. 5. Within the outer casing 190 may be a narrow inner lining 191 of shrapnel or readily fractured hard material. In some instances the lining and casing may be combined and be broken into fragments of sufficient size to puncture the parts and surfaces of an airplane upon detonation of the high powered explosive 192 packed within the shell.

The microphone of the sound responsive control may preferably be mounted in the nose of the shell and connected by lead 196 to the inner case 194 containing the sound responsive control circuit elements of one of the types illustrated in the remaining figures of the drawings for example other than the microphone. The batteries, condensers, resistors tubes and the like are arranged compactly substantially along the axis of the shell so as to balance the shell and minimize the effect of centrifugal forces produced by the rapid rotation of the shell in flight.

The time fuse 195 may provide only the maximum time limit such as that of timer MX in Fig. 6 or may provide both minimum and maximum time limits, and may be of clockwork or inertia fluid dashpot types or electronic type employing the charge or discharge time of a condenser, or it may be of the direct acting slow burning fuse type.

It will be appreciated that the details of construction of the shell itself form no part of the present invention, but that one aspect of the in-

vention lies in the combination of the sound responsive control with the shell as more particularly set forth in the claims.

It will be understood that in describing and claiming operation of the present device responsive to passage by the plane or other sound source, this does not mean necessarily that the device operates or responds only after passage but that it may preferably operate in many cases substantially at or immediately before the moment of passage. In the case of an anti-aircraft shell and airplane for example the shell will more often pass somewhat ahead of or to the side or behind the plane than it will pass so close as to barely miss the sound source of the plane. Under these conditions of nearby passage the velocity component of the shell relative to the plane along a direct line between them will usually fall quite rapidly in the half second or so immediately before the shell passes the level of the plane. This will cause a drop in frequency to occur immediately before passing so that the device may detect this frequency drop and detonate the shell immediately before or substantially at the moment of passing.

In the case of a shell fired at an angle with the vertical and somewhat ahead of an oncoming plane near the top of the shell trajectory where the shell-velocity is near that of the plane, the frequency may not drop sufficiently to operate the device until after passage because the velocity of the plane approaching the shell has the effect of sustaining the frequency to a considerable extent until after the shell passes the line of flight of the plane. If the shell velocity is considerably higher than that of the plane and is at a considerable angle with the line of flight of the plane then there will ordinarily be sufficient drop in frequency to detonate the shell substantially upon passage so that the plane will strike through a curtain of shrapnel or shell fragments scattered by explosion of the shell.

A shell designed for use of this sound responsive detonator control will preferably be arranged to scatter its fragments well to the sides and rear as well as forward.

It will be appreciated that when sufficient output power is available as in Figs. 2 and 4, a hot wire resistance element may be used to set off the detonator directly if desired instead of energizing relay 40 to close an auxiliary circuit for this purpose. In such case relay 40 may be omitted and the heating time of the cathode heaters may be employed as the protective minimum time factor for example, with an inertia switch 50 similar to that indicated schematically at 173 in Fig. 6 to close the circuit for the cathode heaters of the several tubes, and with the maximum protective timer in the form of a direct acting maximum time fuse. A gas discharge tube may be employed for tube 169 in Fig. 4 if desired for greater power output.

Although a number of rectifier and other tubes are shown in the several figures, this is primarily for simplicity of illustration and several rectifiers may be included in one tube jacket with common heater connections or several of the rectifiers may be provided by adding secondary anodes or auxiliary diode elements in some of the amplifier tubes to minimize space requirements.

The circuit constants for the amplifier and filter will be determined by the conditions of use of the sound responsive device such as the degree of amplification desired and the range of

frequencies to be passed, and can be readily determined by one skilled in the art, and the automatic volume control circuit constants may be determined similarly.

One set of circuit constants which may be used in the frequency responsive output circuits for an approach sound frequency in a range of 200 to 1000 cycles per second for example may be as follows.

In Fig. 1 for example resistors 28, 29, 30, 31 may be 5000 ohms with condensers 32, 33, 34 at .03 microfarad, .06 microfarad and .15 microfarad capacitance respectively. Capacitance 45 may be 0.5 microfarad with resistor 46 at 1000 ohms, capacitance 39 at 10 microfarads and relay 40 at 15000 ohms impedance.

In Fig. 2 for example resistance 69 may be 0.5 megohm. Capacitance 72 may be .001 microfarad and capacitance 73 may be .0005 microfarad with resistance 74 of 1 megohm and resistance 76 also 1 megohm. Resistance 77 may be 2 megohms and condenser 78 may be .002 microfarad. Capacitance 80 may be 0.1 microfarad and resistance 82 may be 30 megohms.

In Fig. 3 the inductances 129 may be graded at one half, 1 and 2 henries for example and capacitance 45 may be .25 microfarad, or one half of its value in Fig. 1. The remainder of the common elements may have substantially the same value as in Fig. 1.

In Fig. 4 resistance 69 may be 0.5 megohm. Capacitance 145 may be .002 microfarad, resistances 146 and 149 each 1 megohm, and capacitance 148 may be .001 microfarad. Resistances 153 and 165 may be each 1 megohm and capacitance 152 and 146 are each .005 microfarad. Resistances 157 and 158 may be 6 megohms each and capacitances 155 and 156 may be 0.1 microfarad each. The constants for the remainder of the output circuit may be the same as Fig. 2.

In Figs. 7 and 8 capacitance 187 may be .01 microfarad, resistance 188 may be 1 megohm and inductance 61a may be 100 henries. In Fig. 8 the resistance 199 may be 2 megohms and capacitance 198 may be 0.25 microfarad.

In general the absolute values are not critical but the relative values should be maintained substantially balanced in the circuits involving impedance balance as in the circuit 155, 157, 158, 156 in Fig. 4 for example, the impedance of relay 40 or other output element is adapted to the output tube or other output circuit, and the frequency selective circuit employs inductance or capacitance or both adapted to the range of sound frequency to be expected.

It will be understood that the invention is not limited to the particular circuit constants or to the range of frequency mentioned but that these values are stated as one example of their mutual relation in connection with several forms of the invention.

Where the sound frequency of approach is defined within fairly narrow limits the sensitivity of the frequency responsive circuit may be considerably increased by employing a tuned circuit between leads 27 and 36 of Fig. 1 for example. A resistance in series with parallel capacitance and inductance for parallel resonance to the approach frequency and with leads 37, 44 connected across the parallel inductance-capacitance would provide a large voltage change in the output circuit upon any appreciable drop in received frequency immediately before passing. A resistance could be placed in series with the inductance

across the capacitance to extend the range of frequency response.

Similarly a series resonance tuned circuit can be employed by placing a coupling transformer across the leads 27, 36 and connecting capacitance, resistance and inductance in series across the output of the transformer, with the leads 37, 44 connected across either the inductance alone or the inductance and resistance.

A tuned circuit could be similarly employed in the circuits of the remaining figures of the drawings.

As already indicated in this specification a sound responsive device in accordance with the invention will operate properly responsive to passage whether the sound receiver passes a stationary sound source or the sound source passes a stationary receiver or both are moving in passing so long as there is considerable relative velocity between them in approach before passing and a considerable drop in relative velocity in passing, and it will be understood that the expression "passage of sound source" and "passage of a sound receiver" and the like used in the claims includes passage of either sound source or receiver by the other.

It will be appreciated that compactness is an important consideration in connection with the use of a sound responsive detonator control device is an anti-aircraft shell and in the choice of types of tubes and of related circuit constants for the various resistance and capacitance elements and the like. Some suitable amplifier tubes of the small size used in ultra high frequency work and portable radios are now available and the number of units of the present device that may be required for anti-aircraft defense may justify the manufacture of special tubes of these small sizes and containing the desired combination of elements now available in the larger sizes and would thus reduce space requirements.

It will be further understood that various combinations of the circuits or component parts of the several figures may be made and that rearrangements of the circuits may be made as well as substitution of equivalent parts as will be obvious to those skilled in the art, within the spirit of the invention as defined in the claims.

I claim:

1. In a device for detecting passage of an object producing sound of characteristic pitch, the combination of means for receiving such sound and translating the sound energy into electrical energy of a frequency substantially proportional to such pitch, means for storing such electrical energy of the high frequency associated with sound pitch received as increased by the effect of relative approach velocity between said object and said receiving means, means for releasing such energy from said storing means responsive to the reduction from said high frequency to a low frequency as said relative velocity of approach becomes substantially reduced upon close passage of said object, and means responsive to such released stored energy.

2. In a device for detecting passage of an object producing sound of characteristic pitch, the combination of means for receiving such sound and translating the sound energy into electrical energy of a frequency substantially proportional to such pitch, and means for storing such electrical energy of increased frequency associated with sound pitch received as increased by the substantial relative approach velocity between said

object and said receiving means and for releasing said stored energy responsive to a rapid drop in such electrical energy from such high frequency to a low frequency in connection with reduction in sound pitch received as decreased by reduction in such relative approach velocity associated with close passage of said object, and means responsive to such released stored energy.

3. In a device for detecting close passage of an article relative to a source of sound at relatively high speed, in accordance with the rapid reduction in sound frequency received from such source in connection with such passage, a sound receiver associated with said article, means in said sound receiver to translate the sound energy received into oscillating electrical energy of a frequency substantially proportional to the sound frequency, a frequency selective electrical impedance device providing an electrical voltage of effective value varying directly with the frequency of such electrical energy, means including an electrical condenser connected to said impedance device and adapted to have its electrical charge changed in accordance with the effective value of such voltage, circuit means for restoring the charge on said condenser toward its initial value before such change, and operating to so restore such charge responsive to substantial reduction in such effective value of voltage accompanying reduction in frequency, and an output device operating only responsive to energy released in such restoring of the charge on said condenser.

4. In a device for detecting close passage of an article relative to a second body having a source of sound at relatively high speed in accordance with the rapid reduction in sound frequency from such source in connection with such passage, a sound receiver associated with said article, means in said sound receiver to translate the sound energy received into oscillating electrical energy of a frequency substantially proportional to the sound frequency, an amplifier for such electrical energy, a frequency selective electrical impedance device connected to said amplifier to provide an electrical voltage varying directly with the frequency of such electrical energy, means including an electrical storage element connected to said impedance device to provide a change in its stored energy in accordance with the effective value of such voltage, means responsive to reduction of the effective value of such voltage accompanying a reduction in frequency to restore the stored energy toward its original value before such change and including an output device responsive to the energy released in such restoring of energy by said restoring means.

5. In a device as in claim 4, means responsive to the effective voltage value of such electrical energy to substantially reduce changes in the effective voltage value due to changes in sound intensity received.

6. In a device for detecting close passage of an article relative to a source of sound in accordance with the rapid reduction in sound frequency received as a result of reduction in relative approach velocity in connection with close passage at relatively high speed, a sound receiver in said article means in said sound receiver to translate the sound energy received into oscillating electrical energy of a frequency substantially proportional to the sound frequency, an amplifier for such electrical energy, a frequency selective electrical impedance device connected to said amplifier to provide an electrical voltage varying directly with the frequency of such electrical en-

ergy, means including an electrical storage element connected to said impedance device to provide a change in its stored energy in accordance with the effective value of such voltage, means responsive to reduction of the effective value of such voltage accompanying a reduction in frequency to restore the stored energy toward its original value before such change and including an output device responsive only to the energy released in such restoring of energy by said restoring means and means responsive to the effective voltage value of the electrical energy output of the amplifier to oppose the effective voltage value provided by said impedance device to substantially compensate for reduction of the latter voltage resulting from reduction in sound intensity without a concurrent reduction in sound frequency, whereby the output device will not be operated under the last stated sound condition but will be operated responsive to reduction in sound frequency.

7. A sound responsive device for detecting passage of a sound source by the rapid drop in sound frequency associated with such passing in accordance with "Doppler's principle," including a translating device for receiving sound waves and converting them to electrical waves of corresponding frequency, an amplifier and frequency selective network connected to said translating device to limit the range of frequency passed, a selective impedance device connected to said amplifier and network to provide a voltage substantially proportional to the frequency of said electrical waves, means including an electrical storage device connected to said impedance device to have its stored charge changed in accordance with the average value of such voltage and restored responsive to reduction of such value, and a polarized output device responsive only to change in electrical energy released in such restoration of said stored charge.

8. A detonator control device for detonating an explosive charge responsive to the drop in sound frequency received in connection with close relative passage between the charge and a sound producing target, including means associated with said explosive charge for receiving and translating sound waves into electrical waves of corresponding frequency, means for amplifying such electrical waves, frequency selective impedance means for providing a voltage generally proportional to the frequency of the amplified waves, means including an electrical storage means connected to said selective impedance means to have a substantial voltage applied to the storage means to change the electrical charge on the same from an initial value to a different value resulting from a brief period of sustained high frequency electrical waves associated with high relative velocity of approach between said explosive charge and said target, and to restore the electrical charge on said storage means quite rapidly toward said initial value responsive to reduction of said voltage resulting from reduction in relative velocity on such close passage, and a polarized output device operating to detonate the explosive charge responsive only to the energy released in such restoration of charge of said storage means.

9. A detonator control device for detonating an anti-aircraft shell at close passage by an aircraft responsive to the rapid drop in sound frequency which may be received at the shell from the aircraft as a sound source in connection

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with such passage, including means on said shell for receiving sound waves from the aircraft and translating such waves into electrical waves of corresponding frequency, means for amplifying such electrical waves, frequency selective impedance means for providing a voltage generally proportional to the frequency of the amplified waves, means including an electrical storage means connected to said selective impedance means to change the electrical charge on said storage means from an initial value to a different value resulting from a brief period of sustained high frequency waves associated with high relative velocity of approach of the shell and aircraft toward each other and to restore the charge quite rapidly toward its initial value responsive to reduction of said voltage and frequency resulting from reduction in relative velocity of approach upon close passage, and a polarized output device operating to detonate the shell responsive only to the energy released in such restoration of charge.

10. In a sound responsive control device for detecting passage of a sound source of characteristic sound frequency by the drop in sound frequency received accompanying change in relative velocity in connection with such passage, a microphone, amplifying means having its input connected to said microphone and providing output signal voltage and output return leads, a series resistance and shunt capacitance network in series with additional resistance across the output leads of the amplifier to provide a substantial voltage across said additional resistance for the high frequency signal voltage accompanying the sound received in approach and a low voltage across said additional resistance for the lower frequency accompanying the sound received in nearby passage, a rectifier and capacitance in series across said additional resistance, another resistance across the last named capacitance, a larger capacitance and another rectifier connected in series across said other resistance with the polarity of the two rectifiers in the same direction, and a translating device connected in shunt with the last named rectifier to be operated by change of voltage across said resistances resulting from reduction in received sound frequency accompanying such passage of the sound source.

11. In a sound responsive control device for detecting passage of a sound source of characteristic sound frequency by the drop in sound frequency received accompanying change in relative velocity in connection with such passage, a microphone, amplifying means having its input connected to said microphone and providing output signal voltage and output return leads, a high impedance across the output leads of the amplifier and comprising two parts in series and having a capacitance connected in only one part, a rectifier connected to the remaining second part of said impedance to provide a negative rectified voltage output with respect to said return lead representative of the sound frequency received by the microphone, a resistance and capacitance connected to the output of said rectifier and adapted to steady the rectified voltage; an output tube having an anode, a cathode and a control grid therefor, a negative bias voltage element and resistor connected between said cathode and grid, and a larger capacitance connected between the negative voltage side of said rectifier output and said grid to con-

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trol the grid bias in accordance with changes in the negative rectified voltage representative of sound frequency changes, and a connection between said cathode and said return lead, and a translating device in circuit with the anode and a voltage supply to be operated upon change in grid bias resulting from such drop in received sound frequency.

12. In a sound responsive control device for detecting passage of a sound source of characteristic sound frequency by the drop in sound frequency received accompanying change in relative velocity in connection with such passage, a microphone, amplifying means having its input connected to said microphone, an impedance network connected to the output of the amplifier and including resistance and inductance in shunt with said resistance and additional resistance in series therewith to provide across said shunt resistance and inductance a substantial voltage for the high frequency signal voltage accompanying the sound received in approach and a low voltage for the lower frequency accompanying the sound received in nearby passage, a rectifier connected to said shunt resistance and inductance to provide a rectified voltage output varying in accordance with the effective value of the voltage across said shunt resistance and inductance, a condenser and resistance connected to the rectifier to steady its rectified output voltage, and a larger condenser and a polarized output device connected in series across the output of said rectifier whereby the charge on said larger condenser will be changed by the high voltage output accompanying the high frequency sound received in approach somewhat before passage and the charge will be restored again to operate said polarized output device by the drop in voltage output accompanying the drop in frequency of sound received upon such passage.

13. In a sound responsive control device for detecting passage of a sound source of characteristic sound frequency by the drop in sound frequency received accompanying change in relative velocity in connection with such passage, a microphone, amplifying means having its input connected to said microphone and providing output signal voltage and output return leads, an impedance network connected across said output leads and comprising two parts, one part providing a relatively low voltage output and the second part providing a relatively high voltage output for high frequency signal voltage accompanying sound received on approach and said one part providing a relatively high voltage output and said second part providing a relatively low voltage output for low frequency signal voltage accompanying sound received on passage, a load of relatively low impedance to the signal voltage connected across the whole of said high impedance whereby the total voltage across said whole high impedance will not be changed materially by changes of the voltage on either part with respect to the other part, a rectifier and stabilizing condenser and resistor connected across the whole of said high impedance to provide a voltage output of one polarity with respect to the return lead of the amplifier and of effective voltage value representative of intensity of sound received by the microphone, a second rectifier and stabilizing condenser and resistor connected across the second part of said

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impedance to provide a voltage output of polarity opposite to the first and of effective voltage value representative of the combined effect of sound intensity and sound frequency received, a circuit interconnecting the outputs of the two rectifiers and including a condenser, two substantially equal resistors and another condenser substantially equal to the last mentioned condenser and all connected in series in electrical balance with respect to the midpoint of the circuit, an output tube having an anode, cathode and a control grid with the control grid connected to the midpoint of the last recited circuit and with the cathode connected to the return lead of the output of the amplifier, a negative grid bias voltage supply and very high series resistance connected between the cathode and control grid, a rectifier connected between said negative bias voltage supply and the point of connection of the second named condenser and resistor in said last recited circuit and with its polarity in the same direction as that of the first named rectifier, and a translating device in circuit with the anode of said output tube and a voltage supply whereby said translating device will be operated by a change in grid bias caused by unbalance of the voltages in such balanced circuits responsive to reduction of sound frequency but will not be operated by reduction in sound intensity alone.

14. In a device as in claim 13, an automatic volume control circuit connected between the output and input of the amplifier to reduce changes in the average effective value of the output voltage of the amplifier resulting from changes in the relatively high sound intensity accompanying close approach.

15. An arrangement for producing a trigger-

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ing effect in proximity to an object adapted to radiate radiant-wave energy comprising, means responsive to received energy radiated by said object for generating a periodic electrical wave the frequency of which varies in accordance with the characteristic frequency of said received energy, said means and said object having relative movement toward one another, energy storage means, means for varying the energy of such storage means from an initial value to a different value in response to the periodic electrical wave characteristic of relative approach between said received energy responsive means and said object, means responsive to the change of frequency of said periodic wave produced as said received energy responsive means and said object pass one another at their closest point of approach to restore the energy of said storage means toward said initial value to produce a control effect, and means for utilizing said control effect to produce said triggering effect.

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