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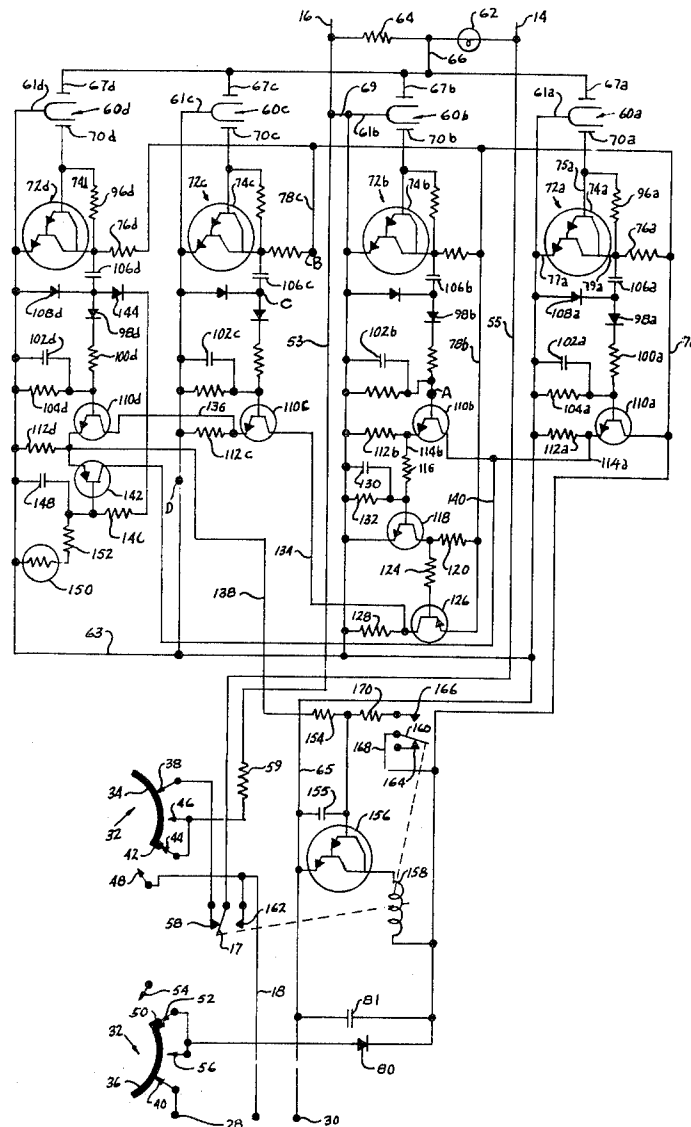
[54] **TONE DECODER RESPONSIVE TO COMBINED TONES**
 15 Claims, 3 Drawing Figs.

[52] U.S. Cl. **340/171,**
 179/84, 340/311

[51] Int. Cl. **H04m 11/02**

[50] Field of Search **340/171,**
 311; 325/466, 55, 64; 179/84 (VF)

ABSTRACT: A tone decoder responsive to predetermined combinations of tones presented for predetermined time intervals comprises plural electromechanical tone detector devices coupled to interrelated switchable devices so arranged that an output function will be initiated only when the combination and time duration of tones presented to the tone detectors satisfies the requirements of the interrelated switchable devices so as to permit application of a voltage through the interrelated switchable devices to an output load device.



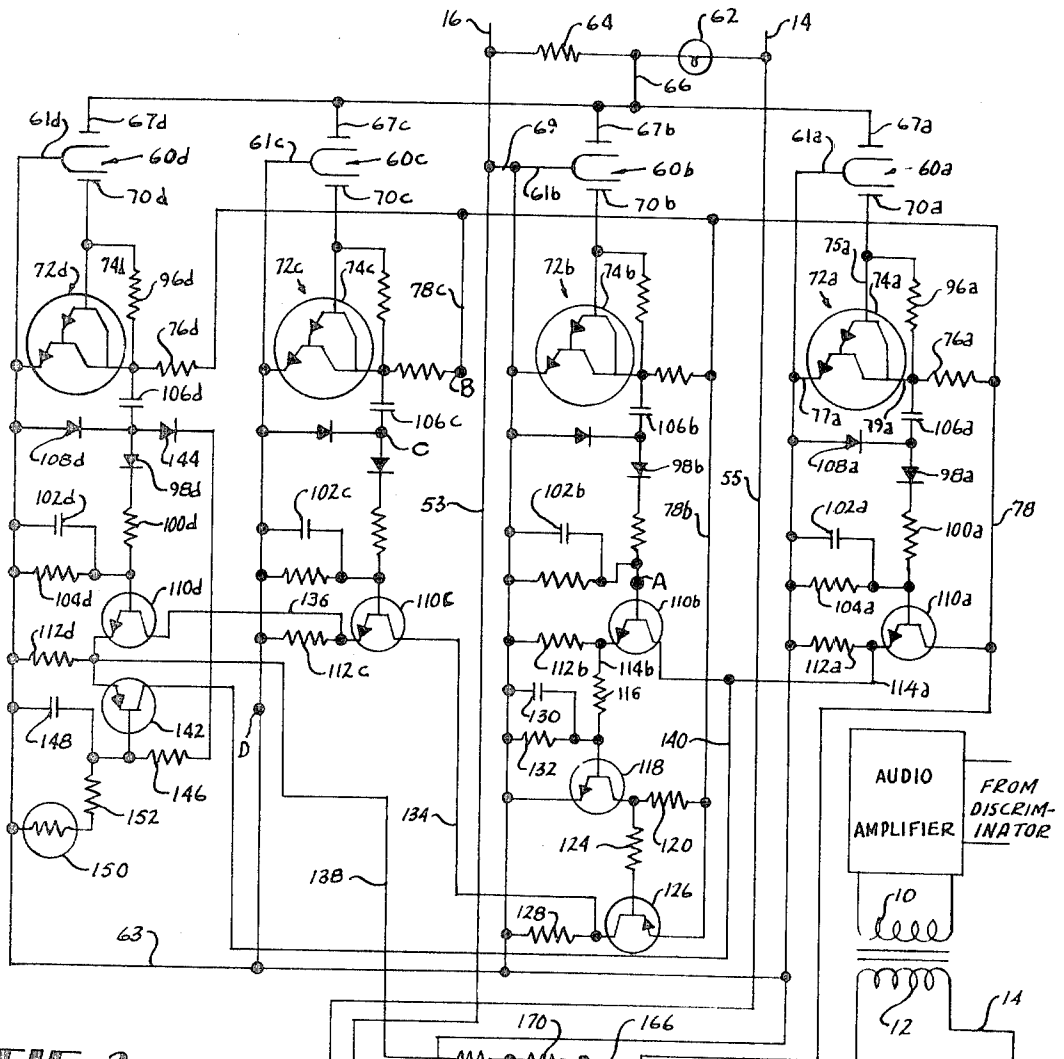


FIG. 2

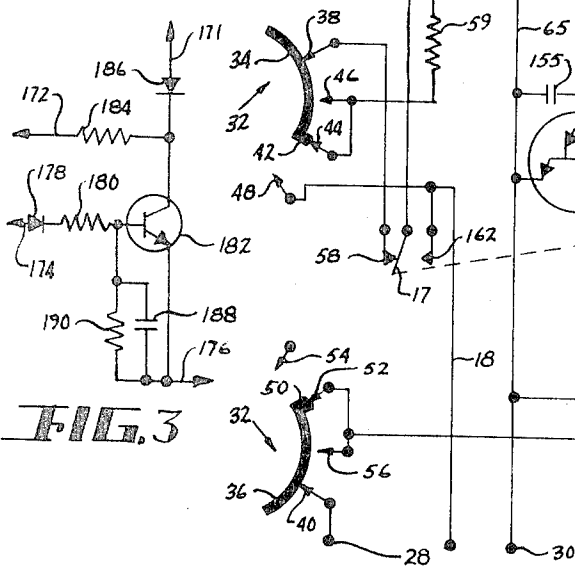


FIG. 3

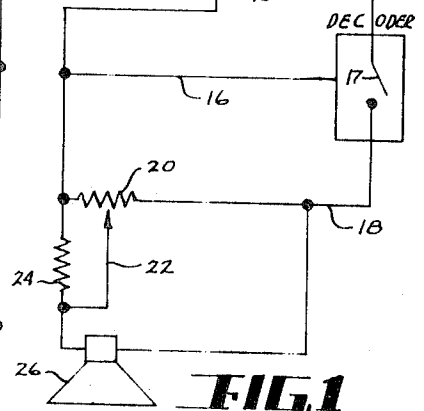


FIG. 4

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contact with a relay contact 58, which is common to the feeder contact 38 continuously engaging the arcuate contact member 34.

The input conductor 16 connects through conductor 53 to one end of a resistor 59. The opposite end of the resistor 59 is common with the stationary switch contacts 44 and 46. As a result of these connections applicable to the DETECTOR position of the switch 32, the signals received from the audio output transformer by the decoder circuit are placed across the resistor 59.

The code detection or decoding circuitry is built around the performance of four tuning fork units 60a, 60b, 60c and 60d. The tuning fork units, which are electrically conductive, are grounded through conductors 61a, 61b, 61c and 61d joined in common by a conductor 63 which is grounded to the negative side of the power supply through the conductor 65. The input signal received by the conductors 14 and 16 is given a reference to the same ground by a conductor 69 which grounds the input conductor 16 to grounded conductor 61b. The signal received from the conductors 14 and 16 therefore appears to the decoder circuitry as a varying voltage on the conductor 14.

Piezoelectric elements 67a, 67b, 67c and 67d are adhered, one each, to one tine of each of the tuning forks 60a through 60d. The piezoelectric elements 67a through 67d, as will be described, each receive the input signal from the input conductor 14. The input signal may typically vary over a 5 to 1 or greater voltage range while the decoder apparatus is preferably operated with a 3 to 1 range of voltage applied to the elements 67a through 67d. A compression of the input voltage to the preferred 3 to 1 range is obtained by dropping the voltage signal on the conductor 14 to ground through a filament lamp 62 in series with a resistor 64. The reduced signal thus developed on the resistor 64 is applied by a conductor 66 to a common input line 68 for the several piezoelectric elements 67a through 67d.

The piezoelectric elements are preferably ceramic plates adhered to the tuning forks with a cement and, in conventional fashion, the inner and outer surfaces of each piezoelectric element have a conductive coating such that the voltage signals from conductor 66 are applied to one face of each piezoelectric element, while the opposite face of each piezoelectric element is grounded through the tuning fork.

As well understood in the art, the alternating voltage signals thus applied across the piezoelectric elements will cause the piezoelectric elements to flex in harmony with the alternating voltage signals applied thereto. For the purposes of the present invention, each of the tuning forks 60a through 60d is tuned to vibrate naturally at a different frequency, no one of which is a close harmonic of any of the others.

The mode of natural vibration here referred to is that mode in which the tines move toward and then away from one another in the manner of the cutting blades of a pair of scissors. When a signal which matches the natural frequency of any one of the tuning forks appears on the conductor 14, the piezoelectric element affixed to such matching tuning fork will excite the tine to which it is affixed. The opposite tine of the same fork vibrates reactively and in resonance with the directly excited tine and, with a continuation of the exciting frequency, the amplitude of vibration between the two tines of the tuning fork reaches a large value. The remaining forks, which are not in resonance with the signal frequency then on the conductor 14, will each be excited by the piezoelectric element affixed thereto and will each tend to vibrate at its own natural frequency. However, this tendency toward natural vibration in the remaining forks will compete with the vibrations of the piezoelectric elements affixed thereto and, accordingly, the remaining forks will vibrate with only a nominal amplitude. Due to this competition, the tuning forks 60a through 60d will vibrate with large amplitudes only when a signal containing their own natural frequency appears on the conductor 14.

Each of the tuning forks 60a through 60d has a second piezoelectric element affixed to that tine thereof which is opposite to the tine carrying the piezoelectric element in the group 67a through 67d. These second piezoelectric elements are identified by the reference numbers 70a, 70b, 70c and 70d. The piezoelectric elements 70a through 70d are each flexed in proportion to the vibrations occurring in the tuning fork to which it is attached. If, for example, the tuning fork 60a is being excited by a nonresonant frequency signal applied to its piezoelectric element 67a, it will vibrate with only a small amplitude and only a feeble signal will be induced in the second piezoelectric element 70a attached thereto. On the other hand, should the tuning fork 60a receive a signal from its piezoelectric element 67a which is at or close to resonance with its natural frequency, large amplitude vibrations will occur in the tuning fork and a comparatively strong voltage signal will be developed in the piezoelectric element 70a. The tuning forks 60a through 60d thus operate as electromechanical frequency detectors in which an incoming signal which is in resonance with the natural frequency of the tuning fork is passed from one of its piezoelectric elements to the other of its piezoelectric elements, and all signals which are off-resonance are substantially attenuated so as not to be efficiently transmitted from one of its piezoelectric elements to the other. For convenience, the piezoelectric elements 67a through 67d are hereinafter referred to as driving elements, and the piezoelectric elements 70a through 70d are hereinafter referred to as driven elements.

Associated with each driven element 70a through 70d is a switch circuit, the several switch circuits being designated generally by the reference numbers 72a, 72b, 72c and 72d. Directing attention first to the switch circuit 72a coupled to the driven element 70a, the circuit includes a Darlington amplifier transistor 74a. The Darlington amplifier transistor, as well known to those skilled in the art, is a three terminal transistor having a base terminal 75a, an emitter terminal 77a and a collector terminal 79a. The signal output of the driven element 70a is connected directly to the base terminal 75a of the amplifier 74a. The emitter terminal for the amplifier 74a is connected directly to the conductor 61a which is a circuit ground. The collector terminal of the amplifier 74a is connected through resistor 76a to a conductor 78 which, for the circuit condition illustrated, is connected to the positive side of the power supply through a forward going diode 80, contact 52 of the control switch 32, tab 50 on the arcuate contact member 36 and the feeder contact 40. Capacitor 81 connected between the conductor 78 and the negative side of the voltage supply at conductor 65 reduces voltage fluctuations in the conductor 78.

The amplifier 74a has its collector and base terminals interconnected by a resistor 96a which is a biasing resistor to stabilize the operation of the amplifier and which, by having a high resistance value, permits the emitter terminal to be connected directly to ground.

The output of the amplifier 74a, taken from the collector terminal of the amplifier is coupled to the base of a transistor 110a through a coupling circuit comprising a capacitor 106a, diode 98a and resistor 100a.

When the tuning fork 60a flexes the driven piezoelectric element 70a so as to produce a positive voltage at the base terminal of the amplifier 74a, the amplifier becomes conductive between its emitter and collector terminals, whereby the collector terminal 79a becomes an effective ground. When the tuning fork flexes oppositely, the piezoelectric element generates a negative voltage which reverses the bias on the amplifier 74a and renders the amplifier essentially nonconductive between its emitter and collector terminals. The collector voltage therefore rises to substantially the voltage value of the voltage supplied at the input terminal 28. The collector voltage at the collector terminal 79a thus swings between essentially zero (ground) and a positive value approximately that of the supply voltage as the tuning fork 60a vibrates.

At those times when the voltage at collector terminal 79a is positive, the capacitor 106a charges, drawing current from ground through a resistor 112a in the emitter circuit of transistor 110a, resistor 100a and diode 98a. This current renders transistor 110a conductive between its emitter and collector elements, thus applying a positive voltage equal essentially to that of capacitor 102a to a conductor 114a. Further, when the collector terminal 79a is positive, the capacitor 106a draws current from one plate of a capacitor 102a, thus charging the capacitor 102a.

When the voltage at the collector terminal 79a drops to zero, the capacitor 106a discharges to ground through a diode 108a connected between the grounded conductor 61a and the capacitor 106a. At this same time, the capacitor 102a undergoes a slow discharge to ground through the resistor 104a thereacross.

A secondary discharge path for the capacitor 102a exists in the path to ground formed by the base and emitter elements of the transistor 110a and the resistor 112a. However, this secondary discharge path accepts only a nominal current from the capacitor 102a due to the fact that the voltage on the resistor 112a closely follows the voltage on the capacitor 102a during discharge of the capacitor 102a. Thus, the resistor 112a receives only sufficient current from the discharging capacitor 102a to sustain a collector current in the transistor 110a adequate to maintain a voltage on the resistor 112a substantially matching the voltage on the capacitor 102a.

The discharge path for the capacitor 102a being determined primarily by the resistor 104a, the value of this resistor is preferably set to a value sufficiently large that the capacitor 102a will not fully discharge during resonant vibration of the tuning fork 60a but will quickly discharge to a voltage level insufficient to sustain conductivity between the collector and emitter of transistor 110a when vibration of the tuning fork ceases or, more accurately, drops to an amplitude too small to bias the amplifier 74a by flexure of the driven element 70a.

Accordingly, when the tuning fork 60a is driven in resonant vibration by the driving element 67a, a positive voltage is sustained on the conductor 114a. Quickly after the piezoelectric element 67a ceases to drive the tuning fork 60a, the positive voltage on the conductor 114a disappears. In practical effect, then, the switch circuit 72a responds to resonant vibration of the tuning fork 60a to apply a positive voltage to the conductor 114a and responds to discontinuance of such resonant vibration to remove the positive voltage from the conductor 114a.

The construction of the switch circuit 72b is substantially the same as the construction of the described switch circuit 72a. The various components of the switch circuit 72b which function in similar manner as those components already described with reference to the circuit 72a are given the same Arabic reference numbers as those employed with reference to the switch circuit 72a but distinguished with the suffix "b" in the circuit of 72b.

The circuit of 72b thus includes an amplifier 74b which becomes conductive on receipt of a positive pulse from the driven element 70b, thereby charging the coupling circuit capacitors 102b and 106b and biasing a transistor 110b to a conductive state. When the amplifier 74b receives a negative pulse from the driven element 70b, a controlled discharge of the capacitor 102b sustains the conductive state in the transistor 110b for a limited period of time.

The conductive state established and sustained in the transistor 110b during resonant vibration of the tuning fork 60b results in application to a conductor 114b of whatever positive voltage then exists on the conductor 114a.

Of course, when the transistor 110a is not conducting, no positive voltage is present on the conductor 114a and the conductor 114b remains at substantially ground potential since the resistor 112a is carrying essentially no current. When the transistor 110a is conducting, the voltage developed across resistor 112a is relayed to the collector of transistor 110b through the conductor 114a and essentially the positive volt-

age across resistor 112a appears across the resistor 112b and therefore on the conductor 114b.

In practical effect, then, a voltage cannot develop on the conductor 114b associated with the switch circuit 72b until after the switch circuit 72a has been energized by resonant vibration of the tuning fork 60a, and even then, not unless the tuning fork 60b also vibrates resonantly in essentially the same interval of time. If the tuning fork 60b does not vibrate at some time during an interval when the transistor 110a conducts, no voltage can appear on the conductor 114b.

Assuming periods of conductivity for the transistors 110a and 110b overlap, a condition will exist in which a positive voltage will appear on the conductor 114b. When this occurs, current through the resistor 116 and the base-emitter circuit of a transistor 118 to the grounded conductor 61b allows a collector current from the voltage supply conductor 78b to pass through the resistor 120 in the collector circuit of transistor 118.

This collector current in the transistor 118 effectively grounds the collector of transistor 118. On grounding of this collector, the base of a transistor 126 has a current path to ground through resistor 124. The emitter of transistor 126 is common to the positive voltage supply through conductor 78b and, accordingly, a current flow through the emitter of transistor 126 and resistor 124 to the effectively grounded collector of transistor 118 renders the transistor 126 conductive, placing a positive voltage across the resistor 128 located between the collector of transistor 126 and grounded conductor 61b.

For reasons which will become more apparent in the following, it is desired to hold the voltage across the resistor 128 for an extended period of time. This is accomplished by providing an RC timing circuit comprising a capacitor 130 and a resistor 132 connected in parallel between the base of transistor 118 and grounded conductor 61b. When the transistors 110a and 110b are simultaneously conducting, capacitor 130 accumulates energy in the form of an electrical charge passed through resistor 116. When either one of transistors 100a and 110b becomes nonconductive, capacitor 130 discharges slowly through a parallel resistance circuit comprising the resistor 132 and the emitter of transistor 118. The sustained current flow thereby produced in the base-emitter circuit of transistor 118 holds that transistor in a conductive state whereby its collector remains substantially at ground so as to perpetuate an emitter current in transistor 126 and an appearance of the positive voltage across the resistor 128, and therefore on a conductor 134.

The switch circuits 72c and 72d are constructed similarly to the switch circuits 72a and 72b and where similar components function in a similar manner to those already described with reference to the switching circuits 72a and 72b, like Arabic reference numbers are used with the suffix "c" identifying components of the switch circuit 72c and the suffix "d" identifying components of the switch circuit 72d.

Upon receipt by the piezoelectric driving element 67c of a frequency matching or close to the natural frequency of the tuning fork 60c, that tuning fork vibrates so as to excite the driven piezoelectric element 70c. A conductive state is thereby produced in the transistor 110c.

Transistor 110c is without a collector voltage unless a voltage appears on the conductor 134. For the reasons above described, a voltage can appear on the conductor 134 only after essentially simultaneous resonant vibration of the tuning forks 60a and 60b has occurred. It follows that transistor 110c can act in response to a vibration of the tuning fork 60c only when the tuning forks 60a and 60b are simultaneously vibrating or if, following simultaneous vibration of the tuning forks 60a and 60b, the tuning fork 60c has been excited within the discharge period for the capacitor 130.

Assuming simultaneity of operation of the tuning forks 60a and 60b has occurred, and the tuning fork 60c has been excited before discharge of the capacitor 130 to a level too low to sustain conductivity in the transistor 118, the conduc-

tivity established in transistor 110c will place the positive voltage on capacitor 102c across the resistor 112c.

When this positive voltage appears across the resistor 112c, transistor 110d is furnished with a collector voltage through a conductor 136, thus enabling the transistor 110d to respond to resonant vibration of the tuning fork 60d. As apparent from the preceding remarks transistor 110d cannot respond to vibration of the tuning fork 60d unless there is or has been simultaneous vibration of the tuning forks 60a and 60b and unless there is also a vibration of both the tuning forks 60c and 60d.

When these prerequisites have been met, transistor 110d becomes conductive and a positive voltage is developed across an output load resistor 112d. The development of a voltage across resistor 112d initiates an output function to be described subsequently.

The described mode by which a voltage is caused to appear across the resistor 112d represents only one mode in which the described circuitry can initiate the performance of an output function. The previously described mode requires simultaneous operation of the tuning forks 60a and 60b concurrent with or followed by simultaneous operation of the tuning forks 60c and 60d.

An alternate mode by which a voltage can be placed upon the resistor 112d requires only simultaneous vibration of the tuning forks 60a and 60d. When the tuning fork 60a is vibrating, a voltage appears on resistor 112a, as described, and this voltage is relayed through conductors 114a and 140 to the collector of a transistor 142. When the tuning fork 60d is also vibrating, the voltage appearing at the collector of the amplifier 74d and which is coupled to the transistor 110d through diode 98d and resistor 100d is also coupled through a parallel circuit comprising a diode 144 and a resistor 146 to a capacitor 148 which progressively charges with continued vibration of the tuning fork 60d. With the concurrence of a collector voltage for transistor 142 and a base voltage produced by charging of capacitor 148, transistor 142 becomes conductive so as to place a positive voltage across resistor 112d. This mode of placing a voltage on the resistor 112d initiates the same output function as can be initiated by the described simultaneous operations of the tuning forks 60a and 60b and the tuning forks 60c and 60d.

Referring further to the second mode of operation, which requires simultaneous vibration of only the tuning forks 60a and 60d, the switching of transistor 142 by simultaneity of resonant vibration of the tuning forks 60a and 60d is delayed for a short interval by the capacitor 148 in which must accumulate charge before an effective emitter current can appear in transistor 142. The result is that a mere coincidence of signals from the driven piezoelectric elements 70a and 70d will not initiate an output function. Rather, the simultaneity between vibration of the tuning forks 60a and 60d must persist for a period of time sufficient to charge the capacitor 148 to a voltage level effective to switch the transistor 142 before an output function can be initiated. Careful control of this delay period for switching the transistor 142 is afforded by the thermistor 150 in series with the resistor 152, the thermistor 150 providing temperature compensation for holding the delayed on period for transistor 142 to a nearly constant value.

The present circuitry contemplates that several cycles of tuning fork vibration will be required to charge the capacitor 148. During a portion of each cycle, the capacitor 148 loses a part of its charge through resistor 152 and thermistor 150. The thermistor is employed to hold this discharge path to a substantially constant value, thereby holding substantially constant the number of tuning fork cycles required to charge the capacitor 148 to a level high enough to allow a switching current to flow in the emitter of transistor 142.

As will be described with reference to the overall circuit operation, simultaneous operation of the tuning forks 60a and 60d will be employed for a mode of operation referred to as "group call." Such group call will be initiated by simultaneous

tone signals of fixed time duration, one to excite the tuning fork 60a and the other to excite the tuning fork 60d. If the time delay associated with switching of the transistor 142 should, through thermal instability, extend beyond the time duration of the group call tone signals, the effort to initiate a group call will fail. On the other hand, if the time delay for switching of the transistor 142 becomes too short, the probability of false signalling rises. It is to reduce false signalling as much as possible while at the same time precluding an excessive delay in the switching of the transistor 142 that the temperature compensating thermistor 150 is provided in the base circuit of transistor 142.

It will be noted of course that the capacitors 102a, 102b, 102c and 102d interpose similar time delays to the switching of the transistors 110a, 110b, 110c and 110d. However, these time delays are made very short as compared to the time delay interposed by the capacitor 148 in the group call mode.

As described, an output function is initiated by the appearance of a voltage across the resistor 112d. This voltage is relayed through a conductor 138 and a resistor 154 to a capacitor 155 which charges through resistor 154. The voltage thus developed on capacitor 155 appears on the base of a Darlington amplifier transistor 156. The emitter of this amplifier is grounded to the grounded conductor 65. The collector receives an operating voltage from the positive voltage conductor 78 through a relay coil 158.

When the amplifier 156 receives a sufficient voltage developed on the capacitor 155, the collector of the amplifier is effectively grounded through the second emitter of amplifier 156, thereby placing a positive voltage across the relay coil 158. The capacitor 155 interposes a time delay to this switching action so that switching will occur only after a reasonably prolonged voltage appears on conductor 138.

Relay coil 158 controls two relay switchblades, one of which was previously identified by the number 17, and the other of which is identified by the reference number 160.

As previously described, the switchblade 17 is common to the audio input conductor 14. When relay coil 158 is energized, switchblade 17 removes the audio signal from the resistor 59 and applies the audio signal to a contact 162. Contact 162 is connected through conductor 18 to the speaker 26. As a result, the audio signal has been transferred from the resistor 59 to the speaker so that the audio signals can be heard.

On energization of the coil 158, relay switchblade 160 leaves an isolated contact 164 to engage a contact 166. Switchblade 160 is connected to the voltage supply conductor 78 through conductor 168. The positive supply voltage is thus applied to contact 166 when the coil 158 is energized.

The positive voltage at the contact 166 is relayed through resistor 170 to the base of the amplifier 156. The application of this positive voltage to the base of the amplifier 156 causes that amplifier to hold itself conductive irrespective of the continued presence or absence of a positive voltage from the conductor 138. Thus, the presence of a positive voltage on the conductor 138 for a period of time sufficient to charge the capacitor 155 to a voltage level effective to switch the amplifier 156 to its conductive state results in an energization of the relay coil 158 which is self-sustained until such time as the presence of the positive voltage supply on the conductor 78 has been interrupted.

This sustained energization of the coil 158 operates to hold the relay switchblade 17 against the switch contact 162 with the result that the audio signals received from the audio amplifier and which have satisfied the code requirements of the decoder circuit are now removed from resistor 59 and applied directly to the speaker 26. A proper sequence of tones encoded in the audio signals from the audio amplifier has accordingly succeeded in applying any further audio signals to the speaker which was previously disconnected from the audio amplifier.

In an intended mode of operation, the control switch 32 would be in the DETECTOR position illustrated in FIG. 2 and the relay coil 158 would be deenergized because a proper tone

signal had not yet been received from the audio amplifier. Upon receipt of a proper tone signal, the voice signals are automatically applied to the speaker 26 through energization of the coil 158. This permits an operator at the remote station to hear any message directed to him without the operator having to adjust the control switch.

At any suitable time after the message has been received, the operator may silence the speaker 26 and, at the same time, prepare the circuitry for receipt of another message preceded by a proper tone sequence by moving the control switch 32 in the counterclockwise direction to its unstable RESET position. In the RESET position, the supply voltage is removed from the switch contact 52, thereby deenergizing the relay coil 158 and permitting the switchblade 160 to return to the contact 164 so as to interrupt the supply of voltage to the amplifier 156. The circuitry by which the relay coil 158 is held energized is thereby interrupted. An energized state of the coil 158 can be again restored only upon receipt by the decoder circuitry of a proper sequence of tones.

For any of various reasons, the remote operator may desire to monitor all messages being broadcast on the wave band to which his receiver is tuned. The operator can accomplish this objective at any time by moving the control switch 32 in the clockwise direction from the position illustrated in the drawing so as to move the tab 42 on the arcuate contact member 34 to engagement with the contact 48. This removes the audio signals from resistor 59 and applies the signals directly to the conductor 18 connected to the speaker 26. Such adjustment enables the speaker 26 to be operated by audio signals from the audio amplifier at the will of the remote operator and for prolonged periods of time without an unnecessary consumption of power in the relay coil 158.

As apparent from the preceding description, the decoder circuitry is designed to respond to two different groupings of tone signals, either one of which can cause energization of the coil 158. The first grouping comprises the two frequencies required to produce resonant vibration of the two tuning forks 60a and 60d when simultaneously received by the decoder circuitry. The second grouping comprises the two frequencies required to vibrate the tuning forks 60a and 60b, simultaneously received, provided the two frequencies required to vibrate the tuning forks 60c and 60d are also simultaneously received by the decoder circuitry within the time delay period allowed by discharge of the capacitor 130.

A third group of tone signals which can satisfy the code requirements of the decoder comprises the four frequencies required to vibrate the tuning forks 60a through 60d provided these four frequencies are sustained for a period of time long enough to charge the capacitor 155 to a voltage level sufficient to render the amplifier 156 conductive. As will be described more fully in the following, this possible code is not used in the practice of the present invention.

The described decoder circuit is designed for use in operations requiring a central calling station which can communicate with any one of a plurality of remote receiving stations. An example of such an operation is that of a taxicab service wherein a home office receives a request for a cab and then, by selective call, instructs one only of its cabs to respond to the request. To selectively call an individual remote station or cab, the central station simultaneously broadcasts the two frequencies corresponding to the particular tuning forks 60a and 60b of the selected remote station. By way of example, this burst of simultaneously transmitted tones may be transmitted for one second to allow ample time for switching of both of the switch circuits 72a and 72b in the remote station. There may be a number of remote stations having identical tone frequencies in their tuning forks 60a and 60b which will also respond to this initial burst of tones by having their switch circuits 72a and 72b also switch to conductive states.

A short interval of time after this first tone burst, 0.2 seconds for example, the central station transmits a second tone burst comprising the two frequencies corresponding to the tuning forks 72c and 72d of the particular remote station

sought to be called. This second tone burst may again last for one second, as an example. Again, there may be several remote stations which contain tuning forks 60c and 60d responding to the same frequencies as the particular station sought to be called. However, the present invention contemplates that there will be no two remote stations having switch circuits 72a and 72b responding to the first tone burst and switch circuits 72c and 72d also responding to the second tone burst. Thus, the sequence of two successive tone bursts, each comprising two tones, initiated by the central station will satisfy the decoder requirements of only one remote station.

It will be noted that a remote station having tuning forks 60c and 60d capable of responding to the first tone burst from the central station will be unable to respond to this tone burst for the reason that its tuning fork 60a and 60b must first be vibrated before a voltage will be available for response to a tone burst capable of vibrating its tuning forks 60c and 60d.

In the preferred practice of the present invention, all remote stations have one fork, either 60a or 60d, tuned to a first frequency, and another fork, the other of 60a and 60d, tuned to a second frequency. This enables the central station, by transmitting a single tone burst comprising these first and second frequencies to resonantly drive the tuning forks 60a and 60d at all remote stations. This tone burst is prolonged for a period of time, such as four seconds, sufficient to charge the capacitor 148 in each of the remote stations whereupon all remote stations are prepared to simultaneously receive the same message. As previously noted, this mode of operation wherein all remote stations are simultaneously called is referred to as a group call.

In practicing the present invention, a central station equipped with a capability of broadcasting 12 separate tone signals is capable of selectively calling over 1,400 remote stations each containing no more than four tuning forks.

It was previously mentioned that a simultaneous burst of all four tones to operate the tuning forks 60a, 60b, 60c and 60d, if sustained for the time required to charge the capacitor 155, is a code combination capable of operating the decoder circuit, but that this code combination is not used in the practice of the present invention. One obvious reason this code combination is not used is that a selective call capability will not exist in this mode unless the time duration of these tones can be limited to an interval less than that required to effect a group call, which requires only the tones for the forks 60a and 60d. It is to render such precise timing unnecessary that calling by one burst of all four tones present in a given remote station is not employed.

Exclusion of this mode of calling is normally achieved by rendering the central station incapable of transmitting a four tone burst. However, this does not guarantee against a sustained shock condition at the remote station which might mechanically vibrate all four tuning forks in that remote station for a period of time long enough to simulate the possible calling mode based upon simultaneous vibration of all four tuning forks in the remote station.

When a remote station is to be employed in an environment where a prolonged shock condition capable of mechanically vibrating all of its tuning forks can be expected, the operating mode involving four simultaneously transmitted tones can be positively excluded by adding to the circuitry of FIG. 2 the supplemental circuitry illustrated in FIG. 3. When the supplemental circuit is used, the conductor 171 of FIG. 3 is connected at A in FIG. 2 to the base of the transistor 110b. The conductor 172 in FIG. 3 is connected at B to the positive voltage line 78c. The conductor 174 of FIG. 3 is connected at C to the right plate, as viewed in FIG. 2, of the capacitor 106c. The conductor 176 of FIG. 3 is grounded to the grounded conductor 61c at D in FIG. 2.

With the supplemental circuit of FIG. 3 thus assembled into the principal circuit of FIG. 2, the operation of the decoder circuitry is modified in the following manners. Upon simultaneous receipt of tones capable of vibrating the tuning forks 60a and 60b, the switch circuits 72a and 72b operate to

render their transistors 110a and 110b conductive as before. However, if the tuning fork 60c is also vibrated at the same time the tuning fork 60b is vibrating, positive voltage pulses taken from the capacitor 106c in the switch circuit 72c are coupled to the base of a transistor 182 in the supplemental circuit of FIG. 3 through a diode 178 and a resistor 180. The emitter of the transistor 182 is grounded through the conductor 176. The collector of the transistor 182 receives positive voltage from the supply conductor 78c through conductor 172 and resistor 184.

Accordingly, the positive pulses from the capacitor 106c render the transistor 182 conductive between its emitter and collector, thereby substantially grounding the collector of transistor 182. This in turn grounds the base of transistor 110b through the conductor 171 and diode 186 appearing in FIG. 3. As a result, transistor 110b is rendered incapable of responding to voltage pulses from the driven piezoelectric element 70b and no positive voltage will appear on the conductor 134. This produces the further result that the transistor 110c will be incapable of responding to voltage pulses from the driven piezoelectric element 70c.

The supplemental circuitry of FIG. 3 thus has the effect of incapacitating both the switch circuits 72b and 72c when the tuning forks 60b and 60c are simultaneously vibrating. The further effect is that the decoder circuit cannot respond to simultaneously received tones capable of vibrating all tuning forks 60a through 60d.

It will be noted that the supplemental circuit of FIG. 3 will not interfere with response of the FIG. 2 decoder circuitry to the group call code which uses simultaneous vibration of only the tuning forks 60a and 60d for a prolonged period, but will block a response of the FIG. 2 decoder to simultaneous vibration of all of its tuning forks for periods of time shorter than required for the group call code.

The capacitor 188 and resistor 190 disposed in parallel between the base of transistor 182 and grounded conductor 176 in the supplemental circuitry of FIG. 3 hold the transistor 182 conductive in response to pulses from the capacitor 106c so long as the tuning forks 60b and 60c continue simultaneous resonant vibration, but promptly dissipate any voltage appearing on the base of transistor 182 when simultaneous vibration of the tuning forks 60b and 60c ceases, thus preparing the decoder circuitry for response to a proper code.

Although the preferred embodiment of the device has been described, it will be understood that within the purview of this invention various changes may be made in the form, details, proportion and arrangement of parts, the combination thereof and mode of operation, which generally stated consist in a device capable of carrying out the objects set forth, as disclosed and defined in the appended claims.

Having thus described our invention, we claim:

1. A decoder circuit for selectively responding to frequency signals received from a source of frequency signals comprising, in combination: a source of voltage, an impedance device, first nonconductive means switchable to a conductive state, a first series circuit connecting said first nonconductive means and said impedance device in series with said voltage source, first detector means responsive to a first frequency signal to switch said first nonconductive means to a conductive state, second nonconductive means switchable to a conductive state, second detector means responsive to a second frequency signal to switch said second nonconductive means to a conductive state, third nonconductive means switchable to a conductive state, means responsive to a voltage across said impedance device to switch said third nonconductive means to a conductive state, an output device, a second series circuit connecting said output device and said second and third nonconductive means in series with said voltage source, and means to apply frequency signals from said source of frequency signals to said first and second detector means.

2. The decoder circuit according to claim 1 wherein said means responsive to a voltage across said impedance device includes energy accumulating means to accumulate energy in

response to a voltage across said impedance device and to release said energy to sustain conductivity of said third nonconductive means for a limited time after discontinuance of said voltage across said impedance device.

3. The decoder circuit of claim 2 including means responsive to said second detector means upon receipt thereof of its selected frequency signal to disable said first detector means.

4. The decoder circuit of claim 1 wherein said first nonconductive means includes a pair of nonconductive elements each switchable to a conductive state and means connecting said pair in series relation, said first detector means comprises a pair of detector elements responsive to different frequencies present in said first frequency signal, one of said pair of detector elements responding to said first frequency signal to switch one of said pair of nonconductive elements to a conductive state and the other of said pair of detector elements responding to said first frequency signal to switch the other of said nonconductive elements to a conductive state.

5. The decoder circuit of claim 4 wherein said second nonconductive means comprises a second pair of nonconductive elements and means connecting said second pair in series relation, said second detector means comprising a second pair of detector elements responsive to different frequencies present in said second frequency signal, one of said second pair of detector elements responding to said second frequency signal to switch one of said second pair of nonconductive elements to a conductive state, the other of said second pair of detector elements responding to said second frequency signal to switch the other of said second pair of nonconductive elements to a conductive state.

6. A decoder circuit for responding to a selected first and second frequencies received from a source of frequencies to energize a load device comprising, in combination: a first nonconductive device switchable to a conductive state, a first frequency detector producing a first output signal on receipt of said first frequency, first means responsive to said first output signal to switch said first device to a conductive state, a second nonconductive device switchable to a conductive state, a second frequency detector producing a second output signal on receipt of said second frequency, second means responsive to said second output signal to switch said second device to a conductive state, said second means including charge accumulating means to delay the switching of said second nonconductive device to its conductive state upon receipt of said second frequency, means applying frequencies from said source to said first and second frequency detectors, a source of voltage, and conductor means connecting said load device and said voltage source in series with said first and second nonconductive devices whereby voltage from said voltage source is applied to said load device upon simultaneous receipt by said first and second detectors of said first and second frequencies for a time sufficient to overcome the delay interposed by said chargeable means.

7. A decoder circuit for selectively responding to frequency signals received from a source of frequency signals comprising, in combination: a first frequency detector producing a first output signal on receipt of a first frequency, a first nonconductive device switchable to a conductive state, first means responsive to the output signal of said first detector to switch said first device to a conductive state, a second frequency detector producing a second output signal on receipt of a second frequency, a second nonconductive device switchable to a conductive state, second means responsive to the output signal of said second detector to switch said second device to a conductive state, a third frequency detector producing a third output signal on receipt of a third frequency, a third nonconductive device switchable to a conductive state, third means responsive to the output signal of said third detector to switch said third device to a conductive state, a fourth frequency detector producing a fourth output signal on receipt of a fourth frequency, a fourth nonconductive device switchable to a conductive state, fourth means responsive to the output signal of said fourth detector to switch said fourth

device to a conductive state, a source of voltage, an impedance device, a first series circuit connecting said first and second devices and said impedance device in series with said voltage source, a fifth nonconductive device switchable to a conductive state, means responsive to a voltage across said impedance device to switch said fifth device to a conductive state, an output load device, a second series circuit connecting said output load device and said third, fourth and fifth devices in series with said voltage source, and means to apply frequency signals from said source of frequency signals to said first, second, third and fourth frequency detectors.

8. The decoder circuit of claim 7 wherein said means responsive to a voltage across said impedance device includes energy accumulating means to accumulate energy in response to a voltage across said impedance device and release said energy to sustain conductivity of said fifth nonconductive device for a limited time after discontinuance of said voltage across said impedance device.

9. The decoder circuit of claim 7 including means responsive to said third means upon receipt thereof of said third output signal to disable said second means.

10. A decoder circuit for selectively responding to frequencies received from a source of frequencies, comprising in combination: a first normally nonconductive switchable device, a first frequency detector producing a first output voltage signal on receipt of a selected first frequency, first amplifier means responsive to said first output voltage signal, first coupling means responsive to the output of said first amplifier means to switch said first switchable device to a conductive state, a second normally nonconductive switchable device, a second frequency detector producing a second output voltage signal on receipt of a selected second frequency, second amplifier means responsive to said second output voltage signal, second coupling means responsive to said second output voltage signal, second coupling means responsive to the output of said second amplifier means to switch said second switchable device to a conductive state, a third normally nonconductive switchable device, a third frequency detector producing a third output voltage signal on receipt of a selected third frequency, third amplifier means responsive to said third output voltage signal, third coupling means responsive to the output of said third amplifier means to switch said third switchable device to a conductive state, a fourth normally nonconductive switchable device, a fourth frequency detector producing a fourth output voltage signal on receipt of a selected fourth frequency, fourth amplifier means responsive to said fourth output voltage signal, fourth coupling means responsive to the output of said fourth amplifier means to switch said fourth device to a conductive state, a source of voltage, an impedance device, a first series circuit

connecting said first and second switchable devices and said impedance device in series with said voltage source, a fifth normally nonconductive switchable device, means responsive to a voltage across said impedance device to switch said fifth device to a conductive state, an output load device, a second series circuit connecting said output load device and said third, fourth and fifth switchable devices in series with said voltage source, and means to simultaneously apply frequencies from said source of frequencies to said first, second, third and fourth frequency detectors.

11. The decoder circuit of claim 10 wherein means responsive to a voltage across said impedance device includes charge accumulating means accumulating charge in response to a voltage across said impedance device and releasing said charge to sustain conductivity of said fifth switchable device for a limited time after discontinuance of said voltage across said impedance device.

12. The decoder circuit according to claim 11 including a sixth normally nonconductive switchable device, third circuit means connecting said sixth switchable device across the output of said second amplifier means, and means responsive to the output of said third amplifier means to switch said sixth switchable device to a conductive state, said decoder circuit being so constructed and arranged that said output load device cannot receive a voltage thereacross until after said first and second frequencies have been applied to said first and second frequency detectors and said third and fourth frequencies are applied to said third and fourth frequency detectors during the period of sustained conductivity of said fifth switchable device provided by said charge accumulating means.

13. The decoder circuit of claim 11 including a seventh normally nonconductive switchable device, a third series circuit connecting said first and seventh switchable devices in series with said voltage source and said output load device, and seventh means responsive to the output of said fourth amplifier means to render said seventh switchable means conductive.

14. The decoder circuit of claim 13 wherein said seventh means includes charge accumulating means delaying the response of said seventh switchable means to the output of said fourth amplifier means.

15. The decoder circuit of claim 10 wherein said frequency detectors each comprise a fork having a piezoelectric driving element adhered to one tine thereof and a piezoelectric driven element adhered to another tine thereof, said means to simultaneously apply said frequencies comprising means simultaneously applying said frequencies to said piezoelectric driving elements of said forks, said output voltage signals being generated by said driven piezoelectric elements.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,581,283 Dated May 25, 1971

Inventor(s) Robert J. Reddel & Edward J. Brauner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 39, for "100a" read ---110a---.

Column 13, lines 33-35, omit the following expression: "second a selected second frequency, second amplifier means responsive to said second output voltage signal,".

Column 14, line 11, after "wherein" insert ---said---.

Signed and sealed this 26th day of October 1971.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents