

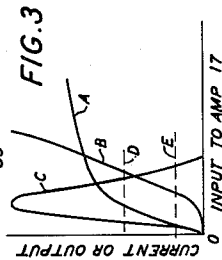
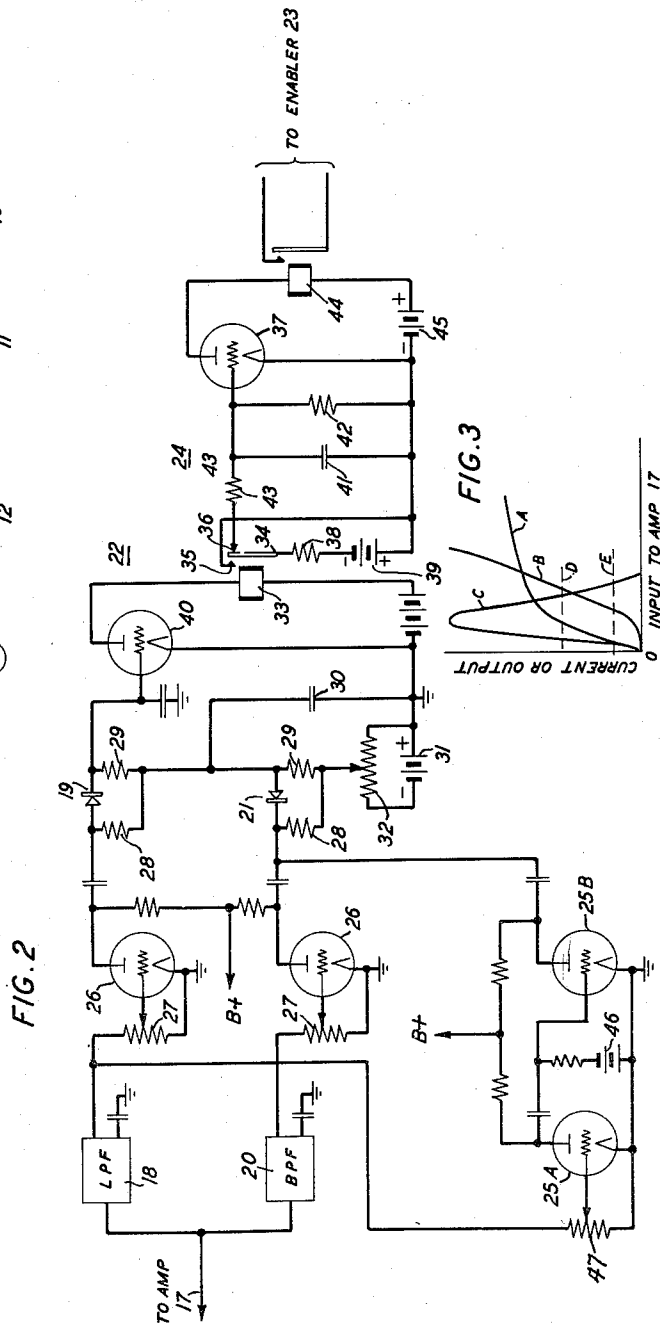
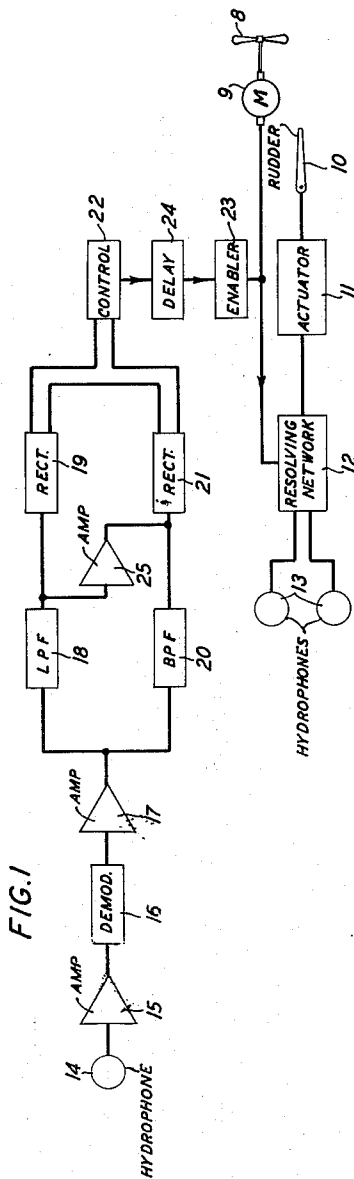
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CONTROL CIRCUITS

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CONTROL CIRCUITS

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This invention relates to control circuits and more particularly to anti-countermining protection circuits of the general type disclosed in the application Serial No. 538,525, filed June 2, 1944 of Paul G. Edwards and now Patent Number 2,995,100, for signal triggered and signal controlled steering systems for torpedoes of the type disclosed in the application Serial No. 538,435, filed June 2, 1944 of Alton C. Dickieson and now Patent Number 2,997,970.

In one form of torpedo control system, illustrated in the above-identified applications, the rudder is adapted to be controlled by a steering circuit operable in accordance with signals emanating from the target, such as a ship. After the torpedo is launched, it is intended to be quiescent until a target, e.g. ship, to be attacked thereby comes within the effective range thereof. During the period involved, the steering circuit is disabled and, when a target comes within range of the torpedo, this circuit is enabled by the operation of a trigger circuit responsive to signals emanating from the target.

In order to prevent operation of the trigger circuit by signals emanating from ships which the torpedo cannot overtake, the trigger circuit comprises an operate channel responsive only to signals characteristic of ships which the torpedo can overtake, and a non-operate channel responsive to signals of other character, the two channels being associated so that the trigger circuit will be effective to enable the steering system only when the output of the operate channel is greater than that of the non-operate channel. Also, in order to prevent false operation of the trigger circuit by signals of short duration, means are provided for allowing enabling of the steering system only when the output of the operate channel exceeds that of the non-operate channel for a prescribed period.

In one particular construction, the two channels have their input ends connected in common to an amplifier and each includes a filter and a detector or rectifier energized in accordance with the output of the respective filter. The outputs of the two channels are combined in difference relation and the resultant signal is impressed upon the input circuit of a direct current amplifier biased at cut-off and having a relay in the output circuit thereof, this relay controlling the circuit for enabling the steering circuit and being effective to cause enabling of this circuit only if it remains operated for a prescribed period or portion of such period.

The possibility exists that while the torpedo is quiescent, explosion noises, such as are produced in countermining operations, may be produced in the vicinity of the torpedo. Such noises may include components of the character requisite for operation of the trigger circuit so that false operation of the trigger circuit might occur. As has been pointed out in the above-identified application of Paul G. Edwards, discrimination between explosion and ship signals may be effected upon the basis of the difference in the rate of increase of the two types of signals at the input to the trigger circuit and means may be provided, utilizing this difference, for protecting against false operation of the trigger circuit by explosion noises.

One object of this invention is to prevent operation of a trigger circuit by signals of other than a prescribed character. More specifically, one object of this invention is to improve anti-countermining protection circuits for

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signal triggered, signal controlled steering circuits for torpedoes.

In accordance with one feature of this invention, in a trigger circuit of the construction described above, means are provided for selectively controlling the direct current amplifier on the basis of the difference in rate of increase of ship and explosion signals in such manner that the relay in the output circuit of this amplifier will remain operated for the prescribed period requisite for enabling of the steering circuit when the trigger circuit is energized in response to ship signals but will operate and then release in a time of less duration than this period when the trigger circuit is energized in response to explosion noises.

More specifically, in accordance with a feature of this invention, the relay and the amplifier for energizing the two channels are associated in such manner that the relay will operate for a relatively low input to this amplifier and will release for a higher input, and means are provided for selectively controlling the time requisite for the relay current to vary from the operate to the release value so that for ship signals this time is greater than the period requisite for enabling of the steering circuit whereas for explosion noises this time is less than the period noted.

In one illustrative circuit, an auxiliary channel is connected between the output side of the filter in the operate channel and the input side of the detector or rectifier in the non-operate channel, the auxiliary channel including a class C amplifier biased below cut-off whereby the component of the output of the non-operate channel due to the auxiliary channel varies in amplitude with filter output differently than the output of the operate channel, specifically so that this component is of amplitude relative to that of the output of the operate channel increasing as the filter output increases.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

FIG. 1 is a block diagram of a torpedo control system illustrative of one embodiment of this invention;

FIG. 2 is a circuit diagram of a portion of a typical trigger circuit constructed in accordance with this invention, for use in a control system such as illustrated in FIG. 1; and

FIG. 3 is a graph illustrating the relation between the relay current or the outputs of the operate and non-operate channels and the input to the amplifier connected to these channels.

Referring now to the drawing, the system shown in FIG. 1 comprises a steering system including a propeller 8, a motor 9 therefor, a rudder 10 which is deflectable in one direction or the other by an actuator 11 in accordance with the polarity of a control signal obtained from a resolving network 12 which is associated with a pair of hydrophones 13 mounted upon opposite sides of a torpedo. The steering system may be of the form disclosed in detail in the application Serial No. 491,795, filed June 22, 1943 of Donald D. Robertson and, therefore, need not be described in detail here. Suffice it to say that this system, when enabled, serves to guide the torpedo to the target, such as a ship, in accordance with signals, such as propeller and other noises, emanating from the target or ship. The steering system normally is disabled and is rendered operative by operation of a trigger system which is similar generally to that disclosed in the application of Alton C. Dickieson identified hereinabove.

The trigger system comprises a hydrophone 14 the output of which is supplied to a high frequency amplifier 15 provided with automatic volume control. The output of the amplifier 15 is supplied to a demodulator 16 and the

low frequency signals thus obtained are amplified by a low frequency amplifier 17. The amplified low frequency signals are transmitted to two signal channels, one of which, referred to hereinafter as the operate channel, comprises a low-pass filter 18 and a rectifier 19 and the other of which, referred to hereinafter as the non-operate channel, comprises a band-pass filter 20 and a rectifier 21. The low-pass filter 18 passes only frequencies within a preassigned range characteristic of signals, e.g. the envelope of ship's noise, of ships which the torpedo can overtake; the band-pass filter is designed to pass a somewhat higher band of frequencies.

The outputs of the two rectifiers 19 and 21 are combined in difference relation to produce a resultant signal in accordance with which a control element 22 is controlled. The control element when operated effects operation of an enabler 23 provided that the element remains operated for a preassigned period, or portion of this period, determined by a delay element 24.

The operation of the system as described thus far is set forth fully in the aforementioned application of Alton C. Dickieson and, therefore, need not be described in detail here. It may be pointed out briefly, however, that the operate and non-operate channels are substantially balanced for random submarine noise and are associated with the control element 22 in such manner that this element can operate only when the output of the rectifier 19 exceeds that of the rectifier 21. After the torpedo is launched, it lies quiescent, the steering system being disabled, until a ship having such speed that the torpedo could overtake it comes within the effective range of the torpedo. For such ships, the envelope of ship's noise is of a frequency within the pass-band of the filter 18 so that the output of the operate channel exceeds that of the non-operate channel and the control element 22 operates; for ships of greater speeds the envelope frequency is above this range and, therefore, the output of the non-operate channel exceeds that of the operate channel so that the control element remains unoperated. If the control element 22 remains operated for the prescribed time determined by the delay element 24, the enabler 23 is operated and as a result the steering system is enabled and the torpedo proceeds to the target. Because of the time factor introduced by the delay element 24, it will be appreciated that false enabling of the steering system by signals of short duration received by the hydrophone 14 is prevented.

Explosion signals, such as are produced in countermining operations, may include components of the character passed by the operate channel and these components might be of sufficient intensity to cause operation of the control element 22 and consequent false enabling of the steering system. To prevent such false enabling of the steering system, in accordance with one feature of this invention, means are provided for preventing operation of the control element 22 for the requisite time when explosion signals are received by the hydrophone 14. Generally, this means comprises an auxiliary guard channel including an amplifier 25 connected between the output side of the low-pass filter 18 and the input side of the rectifier 21 and of such character that for explosion noises the control signal obtained from the rectifiers 19 and 21 passes from a value sufficient to effect operation of the control element to a value insufficient to sustain operation of this element in a time less than the period set by the delay element 24, whereas for ship signals the time noted is longer than the period. This difference in times is predicated upon the difference in the rate of increase in intensity of the two types of signals. The general principles involved will be understood from the following considerations:

Inasmuch as both the rectifiers 19 and 21 are energized in accordance with the output of the low-pass filter 18 when signals of the character passed by the filter are

received by the hydrophone 14, the control signal supplied to the control element 22 at any instant will be dependent upon the relative amplitudes of the outputs of the two rectifiers at that instant. If the amplifier were such that the input-output characteristics of the two rectifiers corresponding to signals passed by the filter 18 were substantially the same, the control signal would be zero or substantially so and the control element would not operate. However, if these characteristics are different, for example, are displaced in time, it will be seen that the control signal will increase and then decrease and that the time required for the control signal to pass from a specified value to a lower value for an increasing output from the filter 18 will be dependent upon the rate of increase in the filter output.

This rate in time is dependent upon the rate of increase in signal intensity at the hydrophone 14. For ship signals, as is apparent, the signal intensity at the hydrophone 14 increases at a rate dependent upon the speed of the ship as it comes within range of the torpedo. For explosion signals, the rate of increase in signal intensity is considerably higher. Hence, if the guard channel is of such construction that for signals passed by the filter 18 the output voltage of the rectifier 21 is delayed appropriately in amplitude with respect to the output voltage of the rectifier 19, the time required for the control signal to pass from the value requisite to effect operation of the control element 22 to the value insufficient to sustain operation of this element when explosion signals are received will be less than the period set by the delay element 24 requisite for operation of the enabler 23 whereas, for ship signals, this time will be equal to or greater than this period. Thus, the control element will be responsive only for a preassigned range of inputs to the amplifier 17 and the time required for the control signal to pass from the operate to the non-operate value is determined by the rate of increase in intensity in signals received by the hydrophone 14.

A typical circuit for realization of the results above-noted is illustrated in FIG. 2. As shown in this figure, each of the filters is associated with a respective amplifier 26, the two amplifiers being similar and the input circuits therefor being adjusted by respective potentiometers 27 so that, as noted heretofore, the operate and non-operate channels are substantially balanced for random submarine noise. Each amplifier 26 includes in its output circuit the respective rectifier 19 or 21, which may be of the copper oxide disc type, bridged by similar pairs of resistances 28 and 29. The alternating current circuit for the two amplifiers 26 may be completed by way of condenser 30. The two resistances 29 are connected in series in the input circuit for the direct current amplifier device 40, which normally is biased at or beyond cut-off by way of the bias battery 31 and associated resistor 32. As shown in FIG. 2, the rectifiers 19 and 21 are poled oppositely, the polarities being such that the voltage appearing across the resistor 29 associated with the rectifier 19 opposes the blocking bias on the amplifier 40 and the voltage appearing across the resistor 29 associated with the rectifier 21 aids the blocking bias. Of course, the voltage across each resistor is proportional to the potential of the respective rectifier. Advantageously, the rectifier and resistor combinations in the two channels are substantially identical.

The output circuit of the amplifier device 40 includes a relay 33 having an armature 34 and two contacts 35 and 36, the relay being of such construction that it will operate upon a preassigned value of energizing current and will remain operated until the energizing current falls somewhat below the preassigned value. The armature 34 is connected to the input circuit of a discharge device 37 of the trigger type, in series with a resistance 38 and a source 39 such as a battery. The input circuit for the device 37 includes also a condenser 41 and a resistance 42 in shunt therewith, one terminal of the condenser being connected to the contact 36 by way of a resistance 43 and the other

terminal being connected to both the source 39 and the contact 35. The output circuit of the device 37 includes a relay 44 for controlling the enabler 23 and a source 45, such as battery, of a capacity insufficient to establish a breakdown voltage across the main gap of the device 37 but sufficient to impress a sustaining voltage across this gap.

When the direct current amplifier 40 is non-conducting, the armature 34 is in engagement with the contact 36 so that the condenser 41 is charged by the source 39 through the resistances 38 and 43. As indicated, the negative terminal of the source 39 is connected to the control electrode of the device 37 at this time so that this device is blocked. When the output of the rectifier 19 sufficiently exceeds that of the rectifier 21, the device 40 is rendered conductive and the relay 33 operates to transfer its armature 34 from contact 36 to contact 35 so that the charging circuit for the condenser 41 is opened and this condenser discharges through the resistance 42. At a time after operation of the relay, determined by the parameters of the condenser 41 and resistance 42, the potential of the control electrode of the device 37 will decrease to such value that the device 37 will fire so that relay 44 will operate and the enabler 23 will be energized. Thus, a delay is introduced between operation of the relay 33 and operation of the relay 44.

If, after the relay 33 operates and before elapse of the time requisite to result in operation of the device 37, the relay 33 releases, the condenser 41 will again be charged through the resistors 38 and 43. The constants of the condenser 41 and charging and discharging resistances associated therewith are correlated in ways known in the art so that a requisite for operation of the relay 44 is that the relay 33 operate for a prescribed portion of a preassigned period. In a specific circuit, operation of the relay 33 for at least 80 percent of a five-second period has been found to provide a satisfactory delay interval sufficient to enable differentiation between explosion and ship signals and also to prevent false operation of the enabler by transient signal pulses.

The guard channel comprises an amplifier 25A substantially identical with the amplifiers 26 and a class C amplifier 25B, biased below cut-off by a source 46, such as a battery. The amplifier 25A is energized from the output of the low-pass filter 18 by way of an input potentiometer 47 and in turn energizes the amplifier 25B. The output of the amplifier 25B is supplied to the rectifier 21 as shown. Because of the class of the amplifier 25B and inasmuch as it is biased below cut-off, only the positive peak portions of the input to this amplifier produce a direct current voltage component in the output of the rectifier 21 and the input-output characteristic of the guard channel is delayed with respect to that of the operate channel.

The general relationships involved are illustrated in FIG. 3 wherein curve A illustrates the relation between the output of the rectifier 19 and the input to the amplifier 17, curve B shows the relation between the output of the rectifier 21 and the input to the amplifier 17 and curve C illustrates the relation between the output of the direct current amplifier 40, i.e. the current supplied to the relay 33, and the input to the amplifier 17. The relay current requisite for operation of the relay is indicated at D and the current for which the relay releases is indicated at E. It is apparent that as the input to the amplifier 17 increases, because of the difference in the input-output characteristics for the operate and auxiliary channels, the relative amplitudes of the outputs of the rectifiers 19 and 21 vary in such manner that the output of the amplifier 40 first increases and then decreases. Thus, the relay 33 will operate for a relatively low input to the amplifier 17 and will remain operated until, at a higher value of input to the amplifier 17, it will release. The time required for the relay current to pass from the operate value to the release value obviously will be deter-

mined by the rate of increase in the input to the amplifier 17.

As has been pointed out hereinabove, for ships approaching the torpedo the ship signal intensity at the hydrophone 14 will increase at a certain rate whereas for explosion noises the rate of increase in intensity at the hydrophone 14 is considerably higher. Thus, there is a difference in the rate of increase in the input to the amplifier 17 for ship and explosion noises and, consequently, in the time required for the current to relay 33 to pass from the operate value to the release value. For ship noises, the rate of increase in input to the amplifier 17 is relatively low so that the relay 33 remains operated a time greater than the period set by the delay element 24; hence, the trigger device 37 will operate and the enabler 23 will be actuated to enable the steering system. However, for explosion noises, the input to the amplifier 17 increases at a higher rate so that the relay 33 will remain operated for but a short time insufficient to result in operation of the device 37; hence, the enabler 23 will not be actuated. Thus, the trigger circuit guards against false enabling of the steering system by explosion signals.

Although a specific embodiment of the invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A control system for a torpedo having normally disabled steering means, said system comprising means for enabling said steering means, a control element for said enabling means, delay means for preventing actuation of said enabling means in response to operation of said control element unless said control element remains operated for a preassigned time, signal responsive means for effecting operation of said control element in response to signals emanating from a ship, said signal responsive means including a hydrophone, means for resolving the output of said hydrophone into a control signal related in amplitude thereto, and means for energizing said control element in accordance with the amplitude of said control signal, said element being operable only when said control signal is of at least a prescribed amplitude, and guard means for preventing actuation of said enabling means in response to explosion signals received by said hydrophone, said guard means comprising means for reducing said control signal to less than said prescribed amplitude in less than said preassigned time when explosion signals are received by said hydrophone.

2. A control system for a torpedo having normally disabled steering means, said system comprising means for enabling said steering means, a control element for said enabling means, an energizing circuit for said control element, said element being operable only when a signal of at least a preassigned amplitude is impressed upon said circuit, delay means for preventing actuation of said enabling means in response to operation of said control element unless said control element remains operated for a preassigned time, signal responsive means for effecting operation of said control element in response to signals emanating from a ship, said signal responsive means including a hydrophone, means for resolving the output of said hydrophone into a control signal related in amplitude thereto and means for impressing said control signal upon said circuit, and guard means for preventing actuation of said enabling means when the intensity of signals received by said hydrophone increases at greater than a preassigned rate, said guard means comprising auxiliary circuit means energized proportionately to the intensity of signals at said hydrophone for impressing upon said circuit a signal in opposition to said control signal and of amplitude relative to said control signal increasing as the intensity of signals at said hydrophone increases.

3. A control system in accordance with claim 2 wherein

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said auxiliary circuit means comprises a class C amplifier biased beyond cut-off.

4. A control system in accordance with claim 2 wherein said resolving means comprises a filter energized in accordance with the output of said hydrophone and a rectifier energized in accordance with the output of said filter, and wherein said guard means comprises an auxiliary channel having its input end connected to the output side of said filter, said system comprising also rectifier means energized in accordance with the output of said channel and connected in opposing relation with said rectifier.

5. A control circuit comprising a current responsive control element adapted to operate upon a preassigned current and to release upon a lower current, operating means controlled by said element, an amplifier for energizing said element, said amplifier having an input circuit including a pair of translating devices poled in opposing relation, a first signal channel including one of said devices at the output end thereof, a second signal channel including the other of said devices at the output end thereof, and common energizing means for said first and second channels, said first and second channels having different amplitude input-output characteristics such that the amplitude of the output of said second channel relative to that of the output of said first channel increases with increasing output of said energizing means.

6. A control circuit in accordance with claim 5 comprising means for preventing operation of said operating means in response to operation of said control element unless said control element remains operated for a prescribed time.

7. A control circuit comprising a relay having an energizing winding and adapted to operate upon a preassigned current and to release upon a lower current, operating means controlled by said relay, a direct current amplifier having an output circuit including said winding and having an input circuit including a pair of rectifiers poled in opposition and means biasing said amplifier beyond cut-off, one of said rectifiers being poled so that its output voltage opposes the bias due to said biasing means, a first and a second signal channel having different input-output characteristics such that the output of the second channel relative to that of the first channel increases for increasing inputs, said first signal channel including said one rectifier at the output end thereof, said second signal channel including the other of said rectifiers at the output end thereof and including also a class C amplifier biased beyond cut-off, and means for energizing said first and second channels from a common source said class C amplifier having its input connected to said energizing means and its output connected to said other rectifier.

8. A control circuit comprising a current responsive element adapted to operate upon a preassigned current and to release upon a lower current, operating means controlled by said element, an energizing circuit for said element, a signal translating device, and means for resolving the output of said device into a current in said circuit which, as the output of said device increases, first increases to a maximum and then decreases, said resolving means comprising a pair of signal channels energized

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in accordance with the output of said device and means for combining the outputs of said channels in difference relation, one of said channels including means allowing translation by said one channel of only signals above a preassigned amplitude and said channels having different input-output characteristics such that the output of said one channel relative to that of the other channel increases as the input to said channels increases.

9. In combination, an amplifier having a control electrode normally biased beyond cut-off, an output circuit for said amplifier including a current responsive element operable only when the current in said circuit is of at least a preassigned magnitude, a signal translating device, operating means energized in accordance with the output of said device and connected to said control electrode for applying to said control electrode a voltage in opposition to the bias thereon and proportional to the output of said device, and means energized in accordance with the output of said device simultaneously with said operating means for reducing said voltage to a value such that said current is below said magnitude, in a time which decreases as the rate of increase in output of said device increases.

10. In combination, a signal receiving device, a current responsive control element adapted to operate upon a preassigned current and to release upon a lower current, operating means controlled by said control element, means for preventing operation of said operating means in response to operation of said control element unless said element remains operated for a prescribed time, and means for resolving an increasing output of said device into a current supplied to said element which is of an amplitude between the operate and release currents for said element for said prescribed time only when said output of said device increases at less than a preassigned rate.

11. In combination, a signal receiving device, a relay having a preassigned operating current and a lower release current, operating means controlled by said relay, means for preventing operation of said operating means in response to operation of said relay unless said relay remains operated for a prescribed time, means for resolving an increasing output of said device into a proportionately increasing current supplied to said relay, and means for reducing the current supplied to said relay by said resolving means from the operating to the release value for said relay in less than said prescribed time if said output of said device increases at greater than a preassigned rate.

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