United States Patent

[11] 3,588,533

[72] Inventor **Richard S. Rhoton**
Pittsburgh, Pa.

[21] Appl. No. **752,824**
[22] Filed **Aug. 15, 1968**
[45] Patented **June 28, 1971**
[73] Assignee **Westinghouse Electric Corporation**
Pittsburgh, Pa.

[54] **LOW FREQUENCY BAND-PASS FILTER FOR USE IN FAILSAFE APPLICATIONS**
9 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **307/233,** 307/295
[51] **Int. Cl.** **H03k 5/08**
[50] **Field of Search** 307/233, 295, 261; 328/138, 140

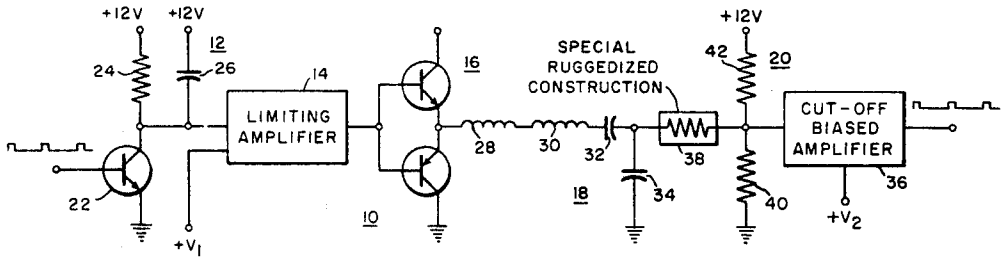
[56] **References Cited**

UNITED STATES PATENTS

3,147,408	9/1964	Yamamoto et al.	307/295X
3,207,925	9/1965	Berger	307/261X
3,218,575	11/1965	Wittman	307/261X

Primary Examiner—Roy Lake
Assistant Examiner—James B. Mullins
Attorneys—F. H. Henson, R. G. Brodahl and M. F. Oglo

ABSTRACT: A low frequency band-pass filter is of a construction inherently providing a single predetermined output mode under any conditions of failure of its individual components or combinations thereof. The filter employs cooperation between the Q of a resonant circuit, a resistive divider, and a threshold circuit to define pass bandwidth.



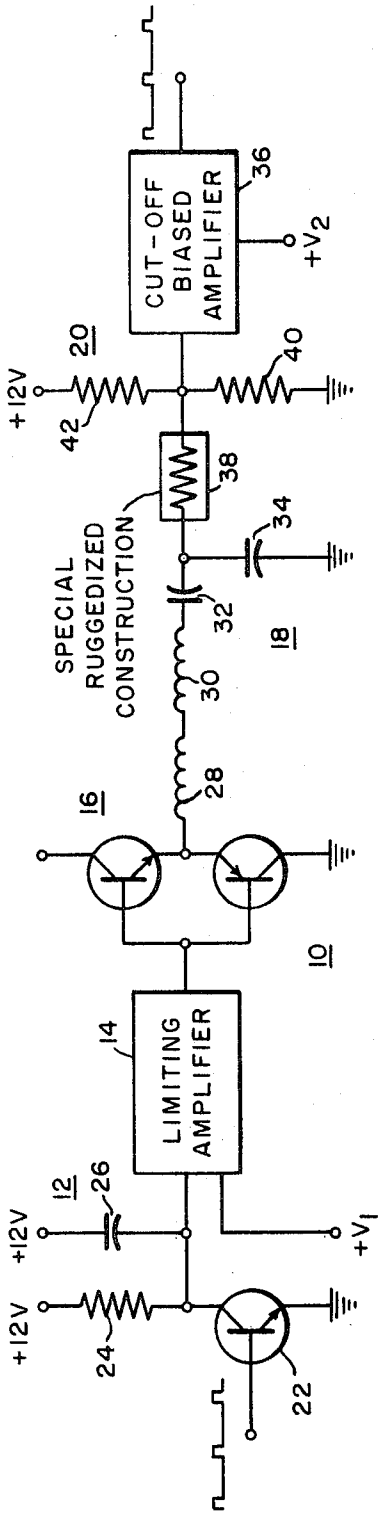


FIG. 1.

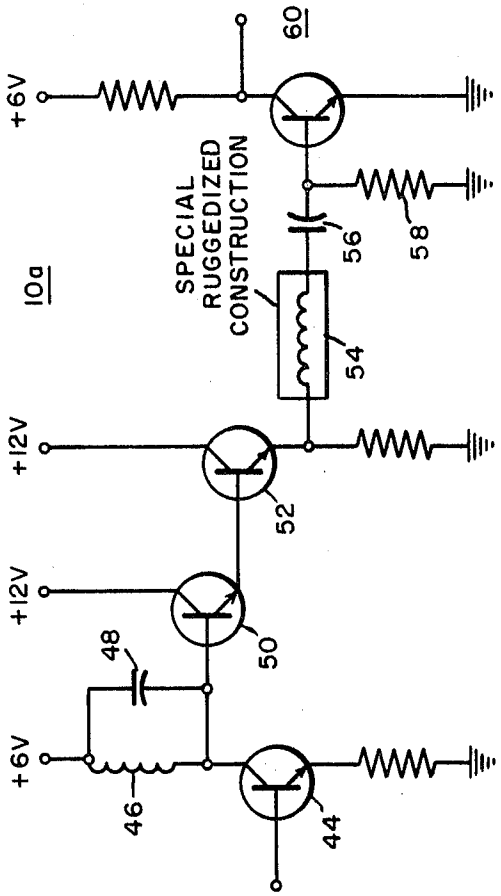


FIG. 3.

WITNESSES

Robert C. Baird

James K. Young

INVENTOR

Richard S. Rhoton.

BY

Michael F. Oglo

ATTORNEY

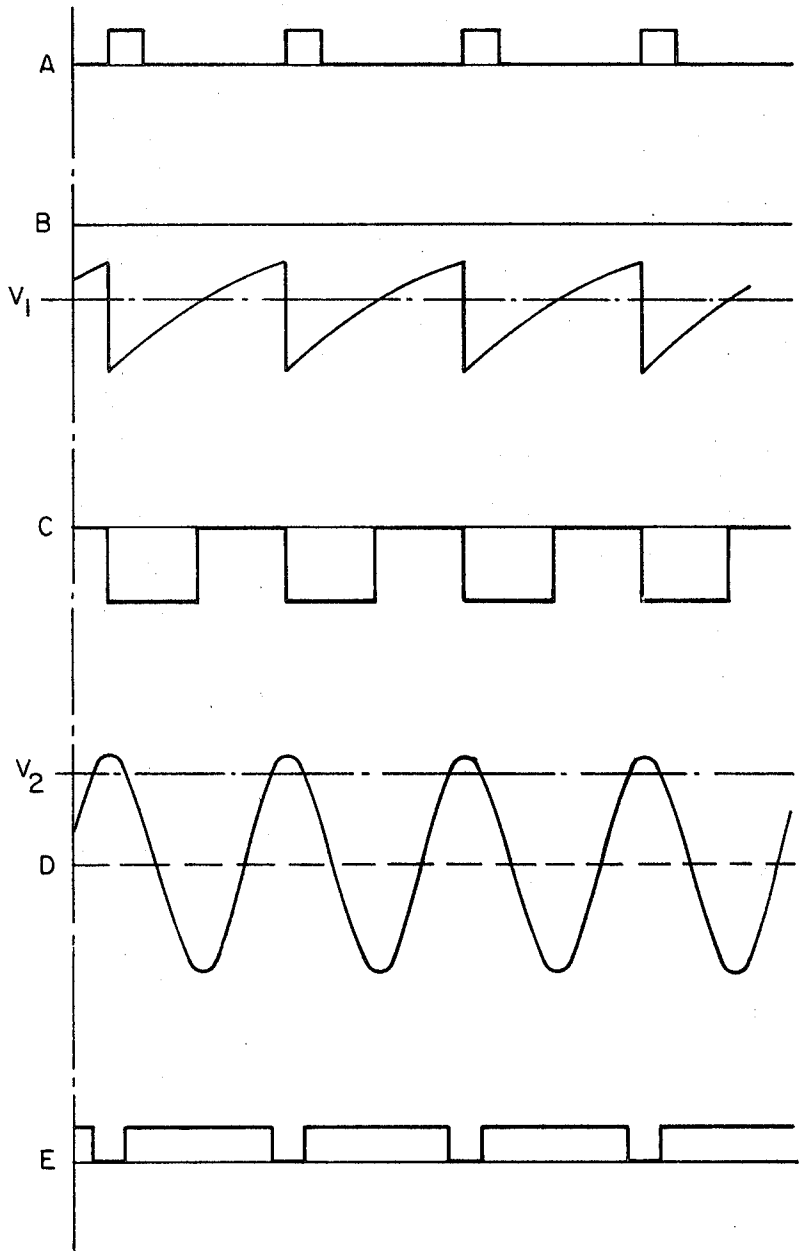


FIG. 2.

LOW FREQUENCY BAND-PASS FILTER FOR USE IN FAILSAFE APPLICATIONS

SPECIAL DEFINITIONS

The term "vital function," as used herein, refers to one in which an incorrect mode of operation could have a catastrophic effect. An example of this would be in controlling train movements in an automated railway system.

The term "failsafe" denotes a characteristic by which apparatus for performing a vital function is made inherently immune to failure conditions which would cause a catastrophic effect. This is done by choosing the construction and components such that their failure will cause a predetermined "-safe failure mode," and adapting the apparatus to avoid catastrophic effects in the presence of this failure mode.

Our approach in providing a safe failure mode is to adapt the apparatus to provide presence of a dynamic signal as an indication of nonfailure, and to construct and arrange the apparatus to cause a safe failure mode in response to absence of the dynamic signal. Such a dynamic signal will sometimes hereinafter be referred to as "dynamic failsafe signal."

BACKGROUND OF THE INVENTION

This invention relates to a low frequency band-pass filter of special utility in failsafe applications.

The copending application of G. Thorne-Booth entitled "-Signalling System For Determining The Presence Of A Train Vehicle," Ser. No. 662,711, filed Aug. 23, 1967 (W. E. Case 39,086) employs the transmission of audio frequency (AF) signals through running rails for detection of the presence of and for control of trains in the various signal block sections of the track system. The signals in that system are modulated by a frequency shift-phase reversal scheme of modulation. Under this scheme the AF signals are continuously phase reversed, or phase reversed and frequency shifted, at a rate of 18 times per second. Such modulation is continuous during the system's normal operation. In making his system failsafe, the 18 phase reversals per second has been adapted as a "dynamic failsafe signal." It has been proposed that a low frequency band-pass filter be used to detect the presence of this dynamic failsafe signal. The scheme of train control associated with the signalling system is adapted to cause a safe failure mode in response to absence of dynamic output from the filter. Thus for the filter circuit per se to be failsafe, it is necessary that it have no dynamic output under any failure or combination of failures therein.

Also, it is proposed that the same filter be employed for the dual function of being a phase shifter for synchronization signals derived from this phase reversal. Therefore, it is desirable that the filter circuit be readily synthesizable to provide desired phase shifts of the output relative to the input.

Accordingly, the objectives of the present invention include provision of:

1. A novel low frequency band-pass filter circuit which is of a construction and arrangement providing absence of any dynamic output under any failure or combination of failures thereof.

2. A filter circuit in accordance with the preceding objective which is predominantly constructed of components which are standard stock items.

3. A filter circuit in accordance with the first enumerated objective which is readily synthesizable to provide a desired phase shift of the output relative to the input.

SUMMARY OF THE INVENTION

The filter circuit of the invention takes a periodic pulse and first develops from it an approximately symmetrical waveform which fills the period. This is applied to a high Q series resonant circuit through some sort of a limiter. The signal in the resonant circuit is applied to a threshold device having a predetermined threshold level chosen to define the band-pass and threshold. The circuit is adapted to provide no dynamic output in the event of failure of any components or combination of component. The phase relationship of output can be predetermined by choice of coupling from the resonant circuit to the threshold device.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a circuit diagram of one embodiment of the present invention;

FIG. 2 is a family of waveforms connected with the operation of the circuit of FIG. 1, the waveforms D and E not necessarily being in the timed relationship shown with respect to waveforms A, B and C; and

FIG. 3 is a circuit diagram of an alternate form of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawing and in particular to FIGS. 1 and 2, a low frequency filter circuit **10** broadly comprises a pulse stretcher stage **12**, a conventional limiting amplifier **14**, a driver **16**, a series resonant network **18**, and a threshold stage **20**. This particular embodiment is used as a frequency selective network for an input train of pulses of a specified frequency, waveform A, FIG. 2. A typical pulse frequency would be 18 cycles per second. (These pulses being derived from phase reversals in the modulation scheme for a railway signal block signal system described in the preamble). The embodiment is further of particular utility as a failsafe filter circuit in a system in which absence of a dynamic signal at the output of the filter is the filter's predefined safe failure mode.

Transistor **22** and its associated collector resistor **24** and collector capacitor **26** form a pulse stretching circuit which conventionally stretches each input pulse as shown in waveform B. The collector voltage is applied to the limiting amplifier **14** which clamps the excursion of the signal to a reference voltage V_1 and inverts the signal. This results in waveform C at the output of amplifier **14**. The limiting amplifier is of any suitable construction such as the commercially available transistor-modular types. Resistor **24**, capacitor **26** and reference voltage V_1 are chosen appropriately in order to get a symmetric square wave, waveform C, of the specified frequency. As such it has the largest possible fundamental content of any pulse signal at the specified frequency, which is important in driving the subsequent resonant network. The square wave is then applied to a high current driver **16**. A high current driver is necessary because the following stage is a series resonant circuit having a low impedance level.

A key element of the invention is series resonant network **18** which comprises inductors **28** and **30**, and capacitors **32** and **34**. The series resonant network has the characteristic of having a large voltage gain which is very closely defined by the Q of the circuit. In most cases this is primarily determined by the Q of the inductors. In some cases the Q of the capacitors may come into play. In operation with a normal input signal coming into circuit **10**, the signal into the series resonant network **18** is limited to a predetermined amplitude by amplifier **14**. The action of series resonant network **18** is to produce a sinusoidal signal of predetermined amplitude, waveform D, which is present across capacitor **34**. This voltage gain happens only at the resonant frequency of the network so that if a signal comes which is "off frequency," the Q of the network is low and there is no associated voltage gain.

From across capacitor **34** the signal is applied to threshold stage **20** which consists of a conventional cutoff biased amplifier **36** and a resistive network at its front end. The amplifier may be of transistor-modular construction. Amplifier **36** remains cut off until its input exceeds a reference voltage V_2 applied thereto. The resistive network consists of a large valued resistance **38** and a small valued resistance **40** series connected to ground, and another small valued resistor **42** tying their junction to the positive supply voltage (assuming an NPN transistor as the input of amplifier **36**). Typical values for

these resistors are: resistor 38—20K; resistor 40—2K; and resistor 42—2K. The resistive network takes the large signal obtained from the series resonant network and attenuates it down to the level suitable to drive amplifier 36. In the absence of the resistive network, the resonant circuit would still give a large enough signal to drive the following threshold circuit even with an off resonance input. Resistors 38, 40 and 42 divide the resonant circuit's output such that it will not trigger the final threshold circuit unless the input is close to the resonant frequency of circuit 18. Thus, the effect of the resistance network is to insure that off-resonance signals will cause the output of circuit 10 to be in the zero output mode, which is the circuits "failsafe" failure mode.

As denoted by legend in the drawings, the large resistance 38 is of a "special ruggedized construction" to restrict occurrence of any nonfailsafe mode of failure until after a failsafe component would otherwise fail under the same failure stimuli. This will be be described in greater detail later in the specification.

The threshold circuit 36 can be any type of threshold device provided that it does not oscillate or have unstable characteristics. Examples include the Schmitt trigger, or a transistor circuit using the forward junction voltage of its base emitter path.

Output from amplifier 36 is present only when the series resonant circuit provides enough voltage gain to overcome the divider network consisting of resistors 38, 40 and 42, and this of course must give out a signal large enough to trigger the threshold circuit. As shown by waveforms D and E, the voltage V_2 which determines the cutoff of amplifier 36, is so chosen to produce a pulse every cycle of a signal in the resonant network.

The band-pass of the filter is synthesizable by choice of the Q of the series resonant circuit and choice of the level of threshold. Using the previous illustrative input pulse of 18 c.p.s., a typical band-pass provided by circuit 10 would be ± 1 c.p.s.

Different phase relationships of output relative to input can be readily synthesizable by substitution of a resistor in place of capacitor 34, and/or substitution of threshold circuits which act upon the negative peak of the sinusoidal signal of waveform D (typically by substituting PNP circuitry for NPN circuitry).

The use of two separate inductances 28 and 30 in the construction of series resonant network 18 has significance in predetermining the safe failure mode of circuit 10. If a single inductance were employed there would exist the possibility of the single inductance short circuiting and applying an "off frequency" signal to the next stage. By employing two inductances, the shorting of either one would detune the circuit and thereby cause a no-output, safe failure mode. The possibility of simultaneous shorting of both inductances 28 and 30 is negligible.

Reference is now made to the alternate construction shown in FIG. 3. Filter circuit 10*a* has several differences. Here the input is a transitor 44 having a parallel tuned resonant network consisting of inductance 46 and capacitance 48 in its collector circuit. In this way the harmonic content of the input signal is increased for the same purpose as in circuit 10. The transistor operates as a constant current driver to the parallel resonant network. This provides additional rejection of unwanted frequencies but in many cases it is not necessary. The output of the tuned network is isolated and transformed to a lower impedance level by the dual emitter-follower transistors 50 and 52 connected in Darlington configuration.

The signal is then applied to a conventional series inductance-capacitance tuned network consisting of inductance 54, capacitance 56 and resistor 58. The resistor may be changed to a capacitor as mentioned in the discussion of modifications to circuit 10. Again the voltage gain is present. Again one of the components, in this instance, inductance 54 is of a "special ruggedized construction" for restriction of its nonfailsafe modes of failure. In circuit 10*a*, the divider consists of the resistor 58 and the impedances of inductance 54 and capacitor 56. The final stage 60 is a conventional threshold circuit using the forward conduction voltage of the base-emitter junction of a transitor 60 as is threshold level. The output again in this case is a series of pulses.

As hereinabove noted, resistor 38 in circuit 10 has been ruggedized for restriction of its nonfailsafe modes of failure. There are basically two possible modes of failure of a resistor: (a) to have its resistance value drift upward; or (b) to short circuit or otherwise decrease in resistance value. Any increase in value of the resistor affect the output of the circuit in the sense of decreasing output, which is in the direction of its predefined safe failure mode. Thus, there is no need for concern over drifting to higher resistance values. On the other hand, short circuiting of the resistor would cause a weak signal to appear stronger in the threshold action of the subsequent stage, and therefore this would be a nonfailsafe mode of failure. One way of restricting occurrence of short circuiting is to use a wire wound resistor and to "pot" same in a suitable epoxy. In this way the windings are physically separate from one another and fully protected against moisture and other environmental effects. One would literally have to take a hammer to this construction to cause shorting of any of the windings. Obviously the transistors of the other stages of circuit 10 would cease to operate upon application of such mechanical stimuli, which would result in a no-output safe failure condition of circuit 10. Similarly, the amount of heat required to affect the windings when thusly encased in epoxy would also cause the transistor stages to cease to operate. Since resistors tend to drift to higher values of resistance rather than lower values, aging would not cause resistor 38 to tend toward a nonfailsafe mode of failure.

Inductor 54 in circuit 10*a* is also of a specialized ruggedized construction. The purpose here is also to restrict occurrence of short circuiting of the inductor. Short circuiting would result in direct application of output from the Darlington connected transistors to the threshold circuit without divider action. Like the previously described resistor, the inductance 54 could be ruggedized by potting to hold its windings separate. Equivalent ruggedizing effects could also be achieved by use of known techniques and materials for application of high mechanical strength and temperature resistant insulation to a wire.

The operations of circuits 10 and 10*a* have been illustrated in connection with a periodic pulse of narrow pulse width. It will be appreciated that they could be employed with square wave or sinusoidal inputs just as well. In such instances the first stage which transforms the input into a symmetric wave could be omitted.

The advantages of the invention will be apparent from the preceding description. Filtering is achieved by a combination of the mechanisms of resonance filtering and threshold action. Each of these mechanisms is accomplished by circuit structures having safe failure modes, providing a highly reliable failsafe protection for vital systems. Also the circuit construction inherently employs components in such a way that normal drift or change in their characteristics will tend to cause the absence of an output, which is the filter's predefined safe failure mode. The likelihood of occurrence of any changes which work in the opposite direction can be substantially eliminated by employing only one specially constructed component per circuit, and the balance of the components need only be regular stock items.

While a preferred embodiment of the invention has been described, it should be understood that various modifications and changes in the arrangement of parts may be made within the scope and spirit of the present invention.

I claim:

1. A filter circuit comprising:

a wave-shaping circuit responsive to a periodic pulse signal, each pulse of which has a width substantially shorter than the cyclic period, said wave-shaping circuit transforming each pulse into a symmetric waveform of the same period as the periodic pulse signal;

circuit means responsive to each said symmetric waveform for limiting the excursion of said symmetric waveform to predetermined amplitude limits;

a series resonant circuit means having a predetermined Q connected to receive the output signal of said circuit means for limiting; and

threshold circuit means cooperating with one extreme of the excursion of the output signal of the series resonant circuit means to pass only those signals which are within a predetermined band-pass centered about the center frequency of the series resonant circuit means.

2. Apparatus in accordance with claim 1, with;

the series resonant circuit means comprising a lumped constant-type resonant circuit including first and second series connected inductance elements, each having a fixed inductance such that if the inductance of one of said inductance elements changes a given amount the output signal from said series resonant circuit is no longer within said predetermined band-pass.

3. In a filter circuit for filtering a periodic pulse signal wherein the width of each pulse is substantially shorter than the cyclic period interval of said pulse signal, the combination comprising:

a wave-shaping circuit which transforms each pulse of an input signal into a symmetric interval of waveform having opposite excursions and of the same frequency as the periodic pulse signal;

circuit means connected to said wave-shaping circuit for limiting the excursion of said input signal to predetermined amplitude limits;

series resonant circuit means having a predetermined Q connected to receive the output signal of said circuit means for limiting; and

a threshold circuit means cooperating with one extreme of the excursion of the output signal of the series resonant circuit means to pass only those signals which are within a predetermined band-pass centered about the center frequency of the series resonant circuit means.

4. A circuit in accordance with claim 8, with;

said circuit means for wave-shaping is a pulse stretcher.

5. A circuit in accordance with claim 3, with;

said threshold circuit means comprises a cutoff biased amplifier having a predetermined cutoff voltage and the output of said series resonant circuit means is coupled to said amplifier means through a resistive voltage divider network comprising a voltage dropping resistor and a coupling resistor, said voltage dropping resistor having s substantially higher value than said coupling resistor, said voltage dropping resistor being of the wire wound construction and so constructed and arranged that its windings are physically separated by a separation means, said separation means being so chosen to be immune to failure except under a physical stimulus which would also render the active stages of the filter circuit inoperative.

6. A filter circuit comprising:

circuit means for limiting the excursion of an input signal to predetermined amplitude limits;

series resonant circuit means having a predetermined Q connected to receive the output signal of said circuit means for limiting, said series resonant circuit means comprising a lump constant-type resonant circuit including a series connected inductance having its windings physically separated by a separation means being so chosen as to be substantially immune to failure under a physical stimulus which would also render the active stage of the filter circuit inoperative; and

a threshold circuit means cooperating with one extreme of the excursion of the output signal of the series resonant circuit means to pass only those signals which are within a predetermined band-pass centered about the center frequency of the series resonant circuit means.

7. A filter circuit comprising:

a wave-shaping circuit responsive to a periodic pulse signal each pulse of which has a width which is substantially shorter than the cyclic period, said wave-shaping circuit transforming each pulse into a symmetric waveform of the same period as the periodic pulse signal;

series resonant circuit means having a predetermined Q connected to receive the output signal from said wave-shaping circuit, said series resonant circuit including a series connected inductance of ruggedized construction which is immune to failure except under response to a physical stimulus which would also render the active stage of the filter circuit inoperative; and

threshold circuit means connected to said series resonant circuit and operative to pass only those signals which are within a predetermined band-pass centered about the center frequency of the series resonant circuit means.

8. The combination claimed in claim 7 including means for impedance matching connected between said wave-shaping circuit and said series resonant circuit

9. The combination claimed in claim 8 wherein said means for impedance matching comprising a Darlington circuit.