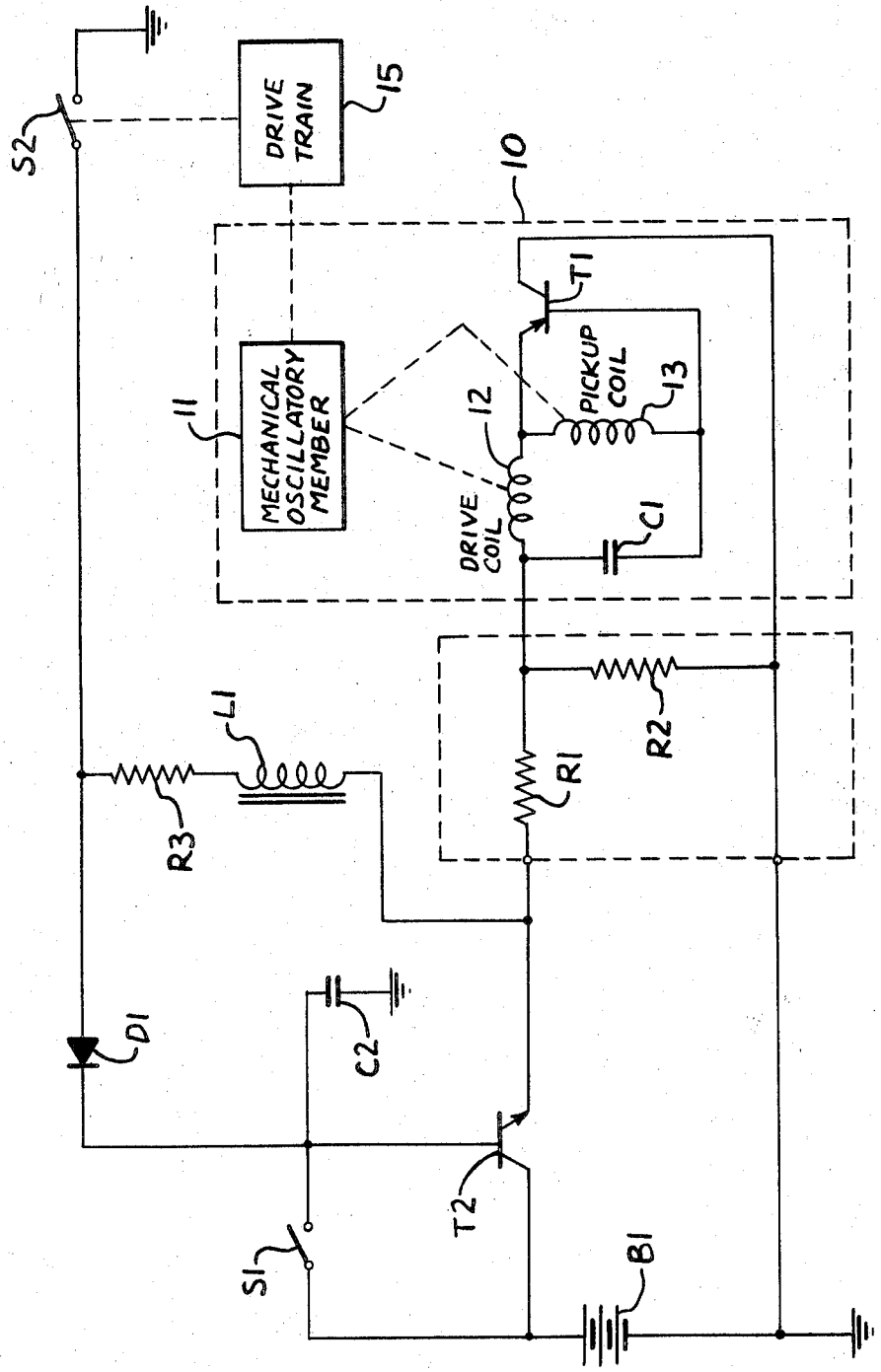
April 29, 1969 C. J. HEERMANS 3,441,820

TIMING SYSTEM HAVING ELECTROMECHANICAL OSCILLATOR WITH FAIL-SAFE IMPROVEMENT

Filed Aug. 18, 1967



INVENTOR
CHARLES J. HEERMANS

by: Wolfe, Hubbard, Voit & Osann
ATTYS.

United States Patent Office 3,441,820 Patented Apr. 29, 1969

3,441,820

TIMING SYSTEM HAVING ELECTRO-MECHANICAL OSCILLATOR WITH FAIL-SAFE IMPROVEMENT

Charles J. Heermans, Chicago, Ill., assignor to General Time Corporation, Stamford, Conn., a corporation of Delaware

Filed Aug. 18, 1967, Ser. No. 661,705
Int. Cl. H02k 33/02
U.S. Cl. 318—127 5 Claims

ABSTRACT OF THE DISCLOSURE

A fail-safe system for a timing system in which the time-keeping standard is an electromechanical oscillator having a mechanical oscillatory member such as a spring-loaded balance wheel, an electrical power source such as a battery, and an electronic impulsing circuit for applying driving impulses from the power source to the oscillatory member. The fail-safe system includes an auxiliary electronic switching means such as a transistor which is connected to the drive train and the impulsing circuit for enabling the circuit in response to driving movement of the drive train, and for disabling the impulsing circuit in response to cessation of driving movement of the drive train. In the specific system illustrated, the transistor representing the auxiliary electronic switching means is maintained in a conductive state, to enable the impulsing circuit, by a capacitor which is periodically recharged by the repetitive opening and closing of a mechanical switch operated by the drive train. An inductor is connected to the mechanical switch so as to draw current from the battery whenever the switch is closed, and then generate a recharging pulse which is applied to the capacitor each time the mechanical switch is open so as to maintain the charge on the capacitor at the required level for maintaining the transistor in its conductive state. If the drive train stops, the mechanical switch is no longer opened and closed, so that the charge on the capacitor is dissipated to render the transistor non-conductive, and thereby disable the impulsing circuit of the oscillator.

The present invention relates generally to timing systems and, more particularly, to timing systems of the type that utilize electromechanical oscillators to control the speed of the drive train of the timing system.

In certain timing systems or timepiece movements that utilize electromechanical oscillators as the time-keeping standard, the electromechanical oscillator operates continuously regardless of whether the drive train is moving. This may be undesirable for a number of reasons, depending upon the particular application involved. For example, in certain fuze systems, it is essential to sterilize the entire timing system in the event of a failure that causes cessation of the drive train. In other applications, it is desirable to stop the electromechanical oscillator whenever the drive train is stopped simply to conserve power.

It is, therefore, a primary object of the present invention to provide an improved timing system of the type that includes an electromechanical oscillator, which includes a fail-safe system for stopping the oscillator automatically in response to cessation of the driving movement of the drive train. Thus, it is a related object of the invention to provide such a timing system in which operation of the electromechanical oscillator is dependent upon operation of the drive train controlled by the oscillator.

Another object of this invention is to provide an improved timing system of the foregoing type which has

low power requirements, and can be economically manufactured at high production rates. In this connection, still another object of the invention is to provide such a system which is susceptible to high volume production.

It is a further object of the invention to provide an improved timing system of the type described above which has a high degree of reliability over long operating periods.

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which the single figure is a schematic diagram of an electromechanical timing system embodying the present invention.

While the invention will be described in connection with a certain preferred embodiment, it will be understood that it is not intended to limit the invention to this particular embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalent arrangements as may be included within the spirit and scope of the invention as defined by the appended claims.

Turning now to the drawing, there is illustrated a timing system having an electromechanical oscillator **10** which includes a mechanical oscillatory member **11** having a predetermined natural frequency of oscillation, such as a spring loaded balance wheel, and an associated electronic impulsing circuit for applying driving impulses to the oscillatory member **11**. The mechanical oscillatory member **11** typically includes a permanently magnetized portion which cooperates with a drive coil **12** in the impulsing circuit so that repetitive driving impulses are applied electromagnetically to the oscillatory member to initiate and sustain the oscillatory movement thereof.

The electromechanical oscillator **10** per se is well known, and thus does not represent one of the novel features of this invention. For example, one such electromechanical oscillator suitable for use in the present invention is described in detail in United States Patent 2,986,683, issued May 30, 1961, to M. J. Lavet et al., entitled, "Driving Balance Wheels More Particularly Applicable to Timing Instruments." Since the structure and operation of such electromechanical oscillators are already well known, the illustrative oscillator **10** will be described only briefly herein.

In the illustrative oscillator **10**, the driving impulses generated in the drive coil **12** are derived from a battery **B1** which is connected to the drive coil **12** through an electronic switching device such as a transistor **T1**. In the particular embodiment illustrated, the battery **B1** and the drive coil **12** are connected through the emitter and collector of the transistor **T1**. Whenever the transistor **T1** is in its conductive state, a pulse of current is transmitted through the drive coil **12**, thereby applying a driving impulse to the oscillatory member **11** via the electromagnetic coupling between the drive coil **12** and the permanently magnetized portion of the member **11**.

In order to synchronize the driving impulses with the natural oscillatory motion of the member **11**, the conductive intervals of the transistor **T1** are controlled by a pick-up coil **13** associated with the permanently magnetized portion of the oscillatory member **11**. The oscillatory movement of the permanently magnetized portion of the member **11** generates repetitive control signals in the pick-up coil **13**, and these signals are applied to the base of the transistor **T1** to render the transistor **T1** conductive at periodic intervals. In this way, the conductive intervals of the transistor **T1**, and thus the driving impulses generated in the drive coil **12**, are perfectly synchronized with the natural oscillatory motion of the member **11**.

To complete the electronic impulsing circuit in the illustrative oscillator **10**, a capacitor C1 is connected between the two coils **12** and **13** to prevent undesirable coupling between the two coils. Also, to reduce the voltage supplied by the battery B1 to the level required at the input to the impulsing circuit, a voltage divider R1, R2 is provided between the battery B1 and the oscillator **10**.

In a complete timing system, the electromechanical oscillator **10** is utilized to control the angular velocity of a conventional drive train indicated schematically by the block **15** in the drawing. For example, the drive train **15** may be a conventional gear train used to drive a plurality of time indicating or control elements at different selected speeds. The connection between the oscillator **10** and the drive train **15** is generally a mechanical one, and thus the connection is usually made at some point on the mechanical oscillatory member **11**. For example, in the particular system described in the Lavet et al. Patent 2,986,683 referred to previously, the oscillatory balance wheel is connected to the associated drive train by means of a pin projecting from the balance wheel for cooperation with a ratchet wheel forming a part of the drive train. The function of the oscillator **10** relative to the drive train **15** may be simply to serve as a part of an escapement mechanism to control the angular velocity of the drive train, or the oscillator may also serve as the power input to the drive train while at the same time controlling the angular velocity thereof.

In accordance with the present invention, a fail-safe control system is operatively associated with the drive train **15** and the electromechanical oscillator **10** for stopping the oscillator automatically in response to cessation of the timing train movement. In one embodiment of the invention, the fail-safe system comprises an auxiliary electronic switching means operatively connected to the electronic impulsing circuit of the electromechanical oscillator for enabling the impulsing circuit to transmit driving impulses to the oscillatory member as long as the drive train is moving, and for automatically disabling the impulsing circuit in response to cessation of the drive train movement. Thus, in the illustrative system shown in the drawing, an auxiliary electronic switching device in the form of a transistor T2 is connected between the battery B1 and the impulsing circuit of the oscillator **10**. More particularly, the collector of the transistor T2 is connected to the positive side of the battery B1, while the emitter of the transistor T2 is connected to the drive coil **12**, via resistor R1, so that any current supplied from the battery B1 to the coil **12** must flow through the collector-emitter circuit of the transistor T2. Consequently, it can be seen that the electronic impulsing circuit of the oscillator **10** is enabled only when the transistor T2 is in its conductive state and, conversely, the impulsing circuit is disabled whenever the transistor T2 is rendered nonconductive.

In order to render the transistor T2 conductive when the timing system is first activated, thereby permitting the oscillator **10** to be started, a start swtch S1 is connected between the battery B1 and the base of the transistor T2 to initially turn on the transistor T2. The start switch S1 is of the momentary type, so that it remains closed just long enough to charge a capacitor C2 connected to the base of the transistor T2, thereby biasing the base of the transistor in the positive direction to turn the transistor on. As will be apparent from the ensuing discussion, the charge on capacitor C2 must be maintained in order to maintain the transistor T2 in the conductive state after the start switch S1 has opened.

During steady state operation of the illustrative fail-safe system, i.e., after the start switch S1 has returned to its normal open position, charging of the capacitor C2 is controlled by means of a mechanical switch S2, which in turn is controlled by the drive train **15**. More particularly, the switch S2 connected to the drive train **15** in such manner that the switch is repetitively opened and closed at a selected rate as long as the drive train **15** is moving. For example, the switch S2 may be biased to its open position, and a suitable camming surface provided on one of the gear wheels or other movable elements of the gear train **15** to repetitively cam the switch S2 to its closed position.

In keeping with the present invention, the switch S2 is connected to the capacitor C2 through a control circuit which functions to maintain a predetermined charge on the capacitor C2 as long as the switch S2 is repetitively opened and closed at a selected rate by the driving movement of the drive train. If the driving movement ceases, however, the control circuit causes the charge on the capacitor C2 to drop below the predetermined level so as to render the transistor T2 nonconductive after a selected time interval. Thus, when S2 is closed, current flows from the collector-emitter circuit of the transistor T2 through an inductor L1 and a resistor R3 and on through the closed switch S2 to ground. This current, which is limited by the resistance of L1 and R3 in series, causes energy to be stored in the inductor L1 in the amount of $\frac{1}{2}$ $L1^2$. When S2 opens, the inductor L1 attempts to maintain the current flow, and the stored energy is diverted to this end. Consequently, a pulse of current generated by the inductor L1 passes through resistor R3 and on through a diode D1 to add to the charge on the capacitor C2. As soon as this pulse is terminated, the capacitor C2 begins to discharge again, but the system is designed so that the charge on the capacitor C2 never drops below the predetermined level required to maintain the transistor T2 in a conductive state, as long as the switch S2 is opened and closed at the selected rate. The diode D1 serves to prevent discharging of the capacitor C2 through the switch S2 when such switch is closed.

In the event of a failure in the timing system which causes the drive train to stop, the switch S2 may be in either the open or closed position, but the cessation of the repetitive opening and closing of the switch S2 causes the transistor T2 to be rendered nonconductive, thereby disabling the impulsing circuit of the electromechanical oscillator **10**. Thus, if S2 is in the open position when the drive train stops, the capacitor C2 continues to discharge through the transistor T2 until it has dropped below the level required to maintain the transistor T2 in a conductive state. If the switch S2 is closed when the drive train is stopped, the charge on the capacitor C2 is dissipated even more quickly because there is still current flowing through the emitter-collector circuit of the transistor, thereby causing more base current to flow. Consequently, it can be seen that the transistor T2 will be rendered nonconductive shortly after the drive train has stopped, regardless of whether the switch S2 is open or closed at the time the driving movement of the drive train is stopped. Moreover, the transistor T2 will also be rendered nonconductive if the capacitor C2 becomes open or shorted, if the diode CR1 becomes open or shorted, if the inductor L1 or the resistor R3 becomes open or shorted to ground, if the inductor L1 becomes internally shorted reducing its inductance substantially, or if the transistor T2 becomes open, so that a completely fail-safe system is provided.

While it will be understood that different values may be assigned to the various circuit elements in the illustrative system for different applications, the following values were employed in one working example:

B1	volts	4.05
T2		2N697
L1	henry	1.0
R3	ohms	150
D1		1N459
C1	mfd	300

Using the above values, it was found that a closure of the switch S2 for 50 milliseconds at a rate of one closure every three seconds maintained a sufficient charge on the

capacitor C2 to render the transistor T2 continuously conductive. It was also found that if the switch S2 was in the open position when the drive train stopped, the transistor T2 was rendered non-conductive in about 83 seconds. After 38 seconds, the transistor T2 was still conductive, but the capacitor C2 had discharged to the point where it could not recuperate if the switch S2 started operating again.

As can be seen from the foregoing detailed description, the fail-safe control system provided by this invention makes the electromechanical oscillator dependent upon operation of the drive train controlled by the oscillator, so that the oscillator is stopped automatically in response to cessation of the driving movement of the drive train. The fail-safe circuit has an extremely low power requirement, and requires only a few low cost parts so that it can be economically manufactured at high production rates. The illustrative system also provides a high degree of reliability over long operating periods.

I claim as my invention:

1. In a timing system having a drive train controlled by an electromechanical oscillator including a mechanical oscillatory member, an electrical power source, and an electronic impulsing circuit for applying driving impulses from said power source to said oscillatory member, the improvement comprising an auxiliary electronic switching means operatively connected to said drive train and said impulsing circuit for enabling said circuit in response to driving movement of said drive train, and for disabling said impulsing circuit in response to cessation of driving movement of said drive train.

2. A timing system as defined in claim 1 in which said auxiliary electronic switching means is a transistor connected between said power source and said impulsing circuit, and including a mechanical switch coupled to said drive train for rendering said transistor conductive in response to driving movement of the drive train, and for rendering said transistor nonconductive in response to cessation of the driving movement of said drive train.

3. In a timing system having a drive train controlled by an electromechanical oscillator including a mechanical oscillatory member, an electrical power source, and an electronic impulsing circuit for applying driving impulses from said power source to said oscillatory member, an improved fail-safe control system comprising a transistor operatively connected between said power source and said impulsing circuit for enabling said impulsing circuit when said transistor is conductive and for disabling said impulsing circuit when said transistor is nonconductive, a capacitor operatively connected to said transistor for maintaining the transistor in a conductive state as long as a predetermined charge is maintained on the capacitor, and switching means operatively connected to said capacitor and to said drive train for supplying repetitive charging pulses to said capacitor in response to driving movement of said train so as to maintain said predetermined charge on said capacitor as long as said drive train is moving.

4. A timing system as defined in claim 3 in which the emitter-collector circuit of said transistor is connected between said power source and said impulsing circuit, said capacitor is connected to the base of said transistor, and an inductor is connected between said emitter-collector circuit and said switching means for drawing current from said emitter-collector circuit when said switching means is closed, and for generating said repetitive charging pulses when said switching means is open.

5. In a timing system having a drive train controlled by an electromechanical oscillator including a mechanical oscillatory member, an electrical power source, and an electronic impulsing circuit for applying driving impulses from said power source to said oscillatory member, a fail-safe control system comprising an auxiliary electronic switching means operatively connected between said power source and said impulsing circuit for enabling and disabling said impulsing circuit, mechanical switching means operatively connected to said drive train for repetitively opening and closing in response to driving movement of said drive train, and electrical control means operatively connected between said auxiliary electronic switching means and said mechanical switching means for enabling said impulsing circuit as long as said mechanical switching means is opened and closed at a prescribed rate, and for disabling said impulsing circuit when said mechanical switching means is opened and closed at a rate below said prescribed rate.

References Cited

UNITED STATES PATENTS

2,986,683	5/1961	Lavet et al.	318—132 X
3,124,731	3/1964	Eysen et al.	318—132
3,134,220	5/1964	Meisner	58—28
3,300,659	1/1967	Watters	307—94
3,332,229	7/1967	Klinck et al.	310—39 X

MILTON O. HIRSHFIELD, *Primary Examiner.*

D. F. DUGGAN, *Assistant Examiner.*

U.S. Cl. X.R.

58—23; 317—50; 318—131, 132