March 31, 1964 L. M. THORNDYKE 3,127,522

TIME CONTROLLED SWITCH USING SATURABLE CORE INPUT

Filed Jan. 30, 1959

Fig. 1.

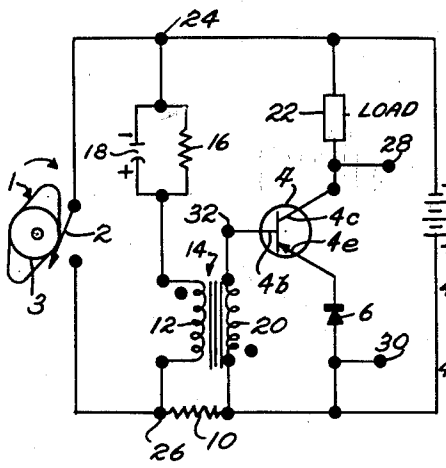


Fig. 5.

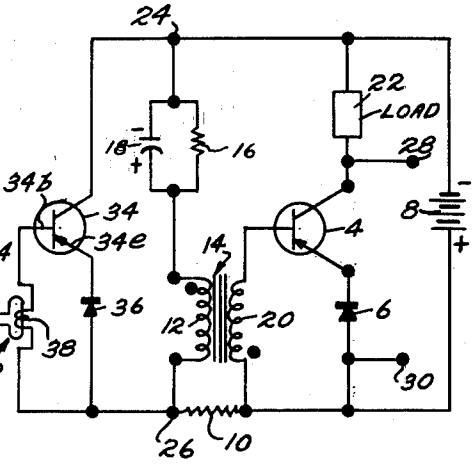


Fig. 2.

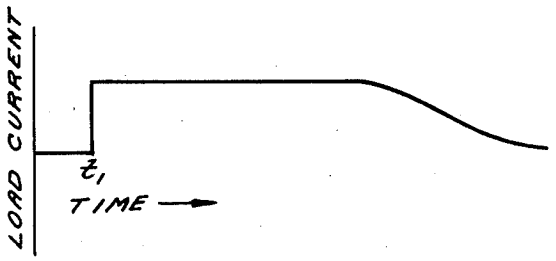


Fig. 3.

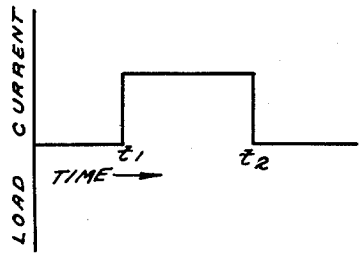
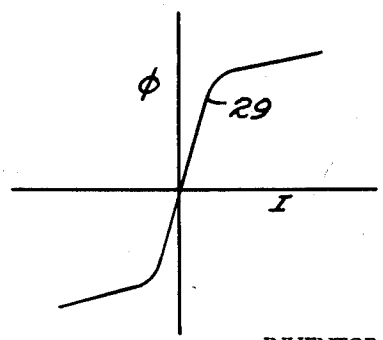


Fig. 4.



INVENTOR

LLOYD M. THORNDYKE

BY Cushman, Darby & Cushman

ATTORNEYS

United States Patent Office 3,127,522 Patented Mar. 31, 1964

3,127,522

TIME CONTROLLED SWITCH USING SATURABLE CORE INPUT

Lloyd M. Thorndyke, Roseville, Minn., assignor to Sperry Rand Corporation, New York, N.Y., a corporation of Delaware

Filed Jan. 30, 1959, Ser. No. 790,271
5 Claims. (Cl. 307—88.5)

This invention relates generally to a controllable electrical switching circuit, and particularly such a circuit which may be activated by a relatively small current signal for controlling the flow of relatively high load currents in an arc-less manner.

The invention has many areas of application but will be specifically described relative to card punching machines, no limitation thereto being intended.

The high currents necessary to operate relays of present tabulating card equipment impose serious maintenance problems caused basically by arcing and resulting in contact pitting and pulse length variation due to contact erosion. In present day equipment of this sort, the punch solenoids or reading station solenoids are controlled by cam actuated contacts. Since solenoids, by their very nature, are inductive elements, sudden changes in the current may cause intolerably high voltage surges resulting in a sustained current arc across the mechanical contacts. It is also desirable to control accurately the pulse length of the current delivered to the solenoid. In present day equipment, an arc occurring upon the opening of the control contacts may greatly increase the pulse length and drastically alter the shape of the pulse. Changing the length and shape of the ideal square wave input may interfere with the timing of the machine cycle.

The circuit of this invention utilizes a power transistor capable of handling high currents in the secondary or load side of a transformer as a master circuit breaker activated by the closure of current contacts on the low current primary side of said transformer to eliminate these difficulties.

It is accordingly an object of the present invention to provide a controllable switching circuit by which a rather large current can be switched non-inductively through a load without the conventionally attendant arcing problems and therefore without seriously affecting any control contacts employed with the switching device of the circuit.

Another object of this invention in conjunction with the foregoing object is the provision of a power transistor as said switching device with collector and emitter electrode junctions effectively acting as non-arcing connections coupling said load to the current supply.

Still another object of this invention in conjunction with the first mentioned object is to provide a load control circuit which is isolated from the switching control system by means of a transformer.

Yet another object of this invention in conjunction with any of the foregoing objects is to provide a means whereby precise timing of the current to the load can be maintained.

Still other objects of this invention will become apparent to those of ordinary skill in the art by reference to the following detailed description of the exemplary embodiments of the apparatus and the appended claims. The various features of the exemplary embodiments according to the invention may best be understood with reference to the accompanying drawings wherein:

FIGURE 1 illustrates an exemplary embodiment of this invention;

FIGURE 2 illustrates an exemplary waveform associated with the embodiment of FIGURE 1;

FIGURE 3 illustrates another exemplary waveform associated with the embodiment of FIGURE 1;

FIGURE 4 shows the magnetic characteristics of the transformer core and

FIGURE 5 shows a modification of the circuit shown in FIGURE 1.

FIGURE 1 shows a low current switching device including cam 1 and associated mechanical switch 2 which may be opened or closed by a motor driven cam mechanism located on a shaft 3 of, for example, the card punching equipment (not shown) previously mentioned. With switch 2 in the open position as illustrated, the high current switch device comprising transistor 4 will be in its high impedance or "off" (non-conductive) state since emitter terminal 4*e* is held at a negative potential with respect to the base electrode 4*b* by means of a voltage drop across an impedance such as the forwardly biased diode 6. With transistor 4 non-conducting, current flows from the D.-C. voltage source 8 through resistor 10 and the primary winding 12 of transformer 14 to the parallel combination comprised of resistor 16 and capacitor 18. This direction of current flow will be termed the forward direction. The current flow through resistor 16 causes capacitor 18 to charge up to a potential determined by the source 8 and the ratio of the resistance value of resistor 16 to the sum of that for resistors 10 and 16 and has the polarity shown.

When switch 2 is closed, capacitor 18 immediately discharges because of the short circuit provided, thereby sending a current surge downwardly, i.e., in a direction reverse to the flow of the forward or capacitor charging current, through the primary winding 12 of transformer 14. With the transformer windings polarized as indicated by the standard dot convention, the discharging current in the reverse direction through the primary winding causes a large negative potential to be applied to the base electrode 4*b* by way of transformer secondary 20, thereby rapidly driving transistor 4 into its low impedance or saturated state so as to be conductive or "on." When transistor 4 is conducting, a very low impedance (in the order of a fraction of an ohm) is presented between the emitter electrode 4*e* and the collector 4*c* so that load 22 is then effectively placed directly across the potential source 8 and the current flow therefrom through the transistor and load is limited for all practical purposes only by the resistance of the load. When the circuit is employed in a card punching machine, load 22 may be considered the punch or reading station solenoids, but of course in other applications the load may of a different nature and for this invention may be of any nature desired.

Transformer 14 preferably has a linear characteristic and when the initial charging current flowing through resistors 10 and 16 is of such a magnitude that the core becomes nearly saturated in one direction when switch 2 is closed, the change in flux caused by the reverse current will be maintained for a considerable time. As a result, the transistor 4 will be kept at collector saturation for a relatively long time interval while switch 2 remains closed. FIGURE 2 shows the shape of the current pulse applied to load 22 when switch 2 is kept open until capacitor 18 is completely charged and then closed at time *t*, for an extended interval of time. It can be seen that the load current remains constant for a period of time until the capacitor 18 is nearly discharged. When the change of flux caused by the capacitor discharge decreases, the negative voltage applied to the base electrode 4*b* also decreases. This in turn causes transistor 4 to approach its non-conducting state and as a result the load current begins to fall exponentially as determined by the R-C time constant of the circuit.

FIGURE 3 illustrates the load current wave-form ob-

tained when the switch is left open until the capacitor reaches its full charge, closed at time t, for only a brief interval, and then reopened at time t_2. When the switch is first closed, the transistor 4 is driven from its non-conducting state to its conducting state as aforementioned. Now when the switch is reopened, the capacitor discharge ceases abruptly due to the then open reverse or discharging circuit between junctions 24 and 26, and the forward current again flows from potential source 8 to recharge the capacitor. As a result, transistor 4 is rendered non-conducting almost instantaneously resulting in an extremely sharp square wave current pulse through the load. It is therefore possible to control the pulse length to a high degree by proper timing of the interrupter contacts.

Since switch 2 in the low current (less than 1 ampere) path must be closed before load current is able to flow, there is no danger of arcing at the contacts of switch 2 due to high current densities or inductive voltage surges. Further, since the emitter and collector junctions effectively act as the high current switch connections or "contacts," but are immoveable and effectively arc shielded, no arcing takes place in the high current circuit even if load 22 is inductive.

If a load current of magnitude greater than can be carried by a single transistor is required for some applications, additional circuits comprised of a power transistor with a diode in the emitter circuit (or other means for biasing the transistor normally non-conductive) can be placed in parallel with that shown in FIGURE 1 between terminals 28 and 30, the base electrodes being tied together as at junction 32.

Resistors 10 and 16 are of such values (typically 330 and 50 ohms respectively) as to provide a relatively high combined impedance as compared to the emitter to collector impedance of transistor 4 when in its conducting state. This insures that the major portion of the current from source 8 then flows through the load. By proper adjustment of these two resistors and by a proper design of transformer 14, these three elements may serve as a safety feature in a case where the load becomes short circuited. If the transformer is designed to operate on the linear portion of its core saturation curve just below the knee of the curve as shown by point 29 of FIGURE 4, any additional current caused, for example, by a short circuiting of the load, causes an increase in the emitter to base current. This increase in current flowing through secondary 20 is sufficient to saturate the core 14. With the core in a saturated state, the rate of change of flux with respect to time is sharply reduced and therefore the voltage applied to the base is also reduced causing the base electrode 4*b* to again become positive with respect to the emitter 4*e*. The transistor is therefore rendered non-conducting preventing any further current flow through the load. This technique protects the transistor from damage which might otherwise result from a high current flow due to short circuiting or the like in the load.

In an experimental model of my current switching circuit, a 2N174 power transistor produced by the Delco Corporation was used as the load switching element 4. With a source potential 8 of 50 volts and an electrolytic capacitor 18 of 1000 micro-farads, it was possible to produce a high current pulse of approximately 20 amperes having a rise time and fall time of only 60 micro-seconds. Also, with the transformer operating as described above, this 20 ampere pulse lasted for approximately 25 milliseconds before suffering the degradation caused by the completion of the capacitor discharge through primary winding 12.

It should be understood that the matter contained in the foregoing paragraph is to be considered as illustrative and is not intended to limit the invention to these particular circuit component values.

It may be desirable in some applications to eliminate the mechanical contacts in the low current switching means described in connection with FIGURE 1 and replace them with an electronically operated switching means, it is possible to completely eliminate maintenance problems resulting from the use of mechanical type contacts. FIGURE 5 illustrates an electronically operated low current switch. In this circuit, the switching device including a switching means of FIGURE 1 is replaced by an electronically operated second power type transistor 34 such as a Delco 2N174 and a forwardly biased diode 36. Coil 38 is preferably the pick-up winding of a magnetic transducing head 39 used to sense the presence or absence of a magnetic field. The mechanical contact type of driving cam 1 (FIGURE 1) which has a variable radial distance from its axis of rotation to its periphery 1 is replaced in FIGURE 5 by a circular, non-magnetic cam 40 in which one or more discrete specially disposed magnetized areas are formed preferably by embedding permanent-type magnets 42 and 43 in the cam.

Transistor 34 is normally held in a non-conducting state by the negative potential applied to its emitter terminal 34*e* through diode 36 as previously explained in connection with FIGURE 1. Capacitor 18 therefore becomes charged with a voltage having the polarity as shown in the same manner as before when switch 2 was left open. As cam 40 rotates in the direction shown by arrow 44 it is assumed the negative pole of each magnet 42, 43 leads the positive pole thereof. The magnetic field produced by magnet 42 first induces the negative lobe of a sine wave voltage in coil 38 while the flux therein is increased in a negative direction. This negative signal induced in coil 38 is in turn applied to the base terminal 34*b* of transistor 34. Transistor 34 now assumes its conducting state since its base electrode is negative with respect to its emitter, and effectively short circuits capacitor 18 causing a reverse current to flow downwardly through the primary winding 12 of transformer 14. This induces a negative voltage in secondary winding 20 and drives transistor 4 into conduction as already described. As the magnet 42 continues its motion and starts to leave the area of transducer 39, a point is reached where the rate of change of flux linking coil 38 reduces to zero, then begins increasing. This increase induces a positive sine wave voltage lobe in coil 38 and transistor 34 returns to its non-conducting state.

A square wave current therefore flows through load 22 while magnet 42 passes transducer 39 with the duration of the square wave being determined by the speed of cam 40 and the arcuate length of the outer end of magnet 42. Magnet 43 causes another similar square wave current through load 22. If the poles of magnets 42 and 43 were reversed so that each would cause the positive lobe of the resultant sine wave to be generated first the duration of the square wave current through the load would be a function not only of the speed of cam 40 but also of the separation distance between magnets 42 and 43 as measured in the direction opposite to arrow 44. In such case the duration of the square wave load current started by the negative signal induced by magnet 42 and ended by the positive signal induced by magnet 43 is shorter than the subsequent one started by magnet 43 and ended by magnet 42. Of course, a third magnet could be employed to make the load current duration equal.

Any other non-mechanical sensing means may be employed, for example a photoelectric cell, to replace the magnetic type shown in FIGURE 5. Further condenser 18 in FIGURES 1 and 5 may be replaced by a battery poled as shown in the drawing and the results would be similar.

This invention can be effectively used with any type load but is preferable for a solenoid load as in a magnetic tape to punched card converter where is it desired to energize solenoids to punch digital information, stored as magnetic spots on a tape or drum, onto a tabulating card.

It can be seen therefore from the above detailed description that my invention provides a relatively simple electronic means whereby a well defined high load current pulse can be initiated by the closure of a control contact in a low current branch of a circuit so as to prevent damage to either the control contacts or the load circuit switching means encountered in prior art relay type switching devices.

Other modifications and applications of this invention not described herein will become apparent to those of ordinary skill in the art after reading this dsclosure. Therefore it is intended that the matter contained in the foregoing description and accompanying drawings be construed as illustrative and not limitative, the scope of the invention being defined in the appended claims.

What is claimed is:

1. A controllable switching circuit for a load comprising a switching device having three electrodes and being capable of passing current from a first to a second of said electrodes only when the third electrode receives a predetermined input signal, a load connected to said second electrode thereby forming a series combination including said switching device and load, a voltage source for producing said current, means for coupling said source across said series combination, a transformer having primary and secondary windings, said secondary winding being coupled between said first and third electrodes, means for making said switching device normally non-conductive of said current, means including a condenser in series with said primary winding for coupling the primary winding across said voltage source, and switching means coupled across said primary winding and condenser, the arrangement being such that when said switching means is open, said condenser is charged by the voltage source current flowing in a first direction through said primary winding so as to cause said switching device to be maintained non-conductive, while when said switching means is closed, said condenser is discharged through the primary winding causing a current therein in a direction opposite to said first direction and thereby effecting said predetermined input signal to the switching device so as to allow current from the voltage source to pass through said first and second electrodes to said load, said switching means being operative after a predetermined time to stop the discharging of said condenser and allow it to be recharged thereby ending said predetermined input signal and causing the current to said load to cease.

2. A circuit as in claim 1 wherein said transformer has a linear saturation curve characteristic and is operated near a knee of a linear portion thereof whereby the current to said load is substantially a square wave and any short circuiting or the like in the load causes said switching device to become non-conductive even if said condenser is still being discharged.

3. A circuit as in claim 1 wherein said switching means is a cam operated mechanical switch contact which stays closed only for said predetermined length of time.

4. A circuit as in claim 1 wherein said switching means includes a second switching device having three electrodes two of which are coupled across said primary winding and condenser for providing a discharge current path for said condenser only when the third electrode of said second switching device receives a given input signal, and means including a magnetic transducer operating in conjunction with means for carrying and sequentially presenting to said transducer two magnetized areas, for providing said given input signal and causing said second switching device to become conductive and non-conductive in response to the sensing of each of said magnetized areas, said switching means including means for making said second switching device normally non-conductive except when receiving said given input signal.

5. A circuit as in claim 4 wherein each of said switching devices is a transistor.

References Cited in the file of this patent

UNITED STATES PATENTS

2,412,345	Lindenblad	Dec. 10, 1946
2,429,844	Rotham et al.	Oct. 28, 1947
2,474,550	Short et al.	June 28, 1949
2,587,631	Kuehne	Mar. 4, 1952
2,609,143	Stibitz	Sept. 2, 1952
2,758,206	Hamilton	Aug. 7, 1956
2,808,990	Van Allen	Oct. 28, 1957
2,820,152	Mathis et al.	Jan. 14, 1958
2,864,007	Clapper	Dec. 7, 1958
2,890,353	Van Overbeek	June 9, 1959
2,942,160	Ricketts et al.	June 21, 1960
2,968,770	Sylvan	Jan. 17, 1961
3,032,685	Loomis	May 1, 1962
3,034,019	Hetzler	May 8, 1962
3,046,470	Blocher	July 24, 1962

OTHER REFERENCES

"Design Techniques To Achieve Reliability in Inertial Sub-Systems," by Bjorndahl, published in Proceedings of the Retma Symposium on Applied Reliability, Dec. 20, 1956, pages 91–98.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,127,522 March 31, 1964

Lloyd M. Thorndyke

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 3, for "means, it" read -- means. By employing the latter type switching means, it --; line 30, for "increased" read -- increasing --; column 5, line 11, for "dsclosure" read -- disclosure --.

Signed and sealed this 4th day of August 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents