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ELECTRONIC SHUTTER CONTROL FOR PLANETARY PHOTOGRAPHY WITH AUTOMATIC TIME RECORDING CAPABILITY

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ELECTRONIC SHUTTER CONTROL FOR PLANETARY PHOTOGRAPHY WITH AUTOMATIC TIME RECORDING CAPABILITY

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15610

An electromechanical shutter system incorporating semiconductor electronics and featuring mechanical simplicity is described. The system also incorporates a simple and accurate means of triggering accessory devices at the time of shutter opening. This capability is used to automatically record the times at which exposures are made--a convenience of great importance in planetary photography.

INTRODUCTION

This paper describes an electronic camera shutter control system now in use in New Mexico State University Observatory's planetary camera. The system was intended primarily for use in planetary photography, but its simplicity, reliability, and accuracy should make it attractive for other applications.

Electronic shutter control offers several advantages over the mechanical control commonly used in camera shutters. Triggering the shutter by pressing a switch at the end of a long, flexible cable transmits only a negligible mechanical "shake" to the telescope. The switch can be a snap-action type, permitting hair-trigger sensitivity with concomitant minimization of reflex time. Event pulses at the beginning and end of shutter operation are available for triggering accessory devices (e.g., the automatic time recording system described in this paper). Probably the most important advantage of the electronic system is mechanical simplicity: the complex arrangement of gears, ratchets, levers, and springs that generate time information and motive force in mechanical shutters is, in the electronic system, replaced by a single moving part coupled with electronic time-generating and driving circuits. This results in a high order of mechanical reliability which, with the inherently high reliability of the associated semiconductor electronics, provides a dependable overall system. A final advantage is the wide range of shutter times available; in the system described below continuous adjustment is available over the range .01 second to 100 seconds.

MECHANICAL SYSTEM

The shutter in New Mexico State University Observatory's planetary camera is a common "between-the-lens" leaf type. Most leaf-type shutters operate in a similar manner; the system described below should therefore be adaptable to almost any shutter of this type.

The leaves of the shutter pivot about small pins attached to the shutter frame. They are pivoted in unison to open and close the aperture by an actuating ring that rotates about the shutter opening. The ring is attached to the leaves by additional pivot pins. The fixed and moving pivots for each leaf are closely spaced, so that slight rotation of the actuating ring moves the leaves through the large angle necessary to open and close the shutter. The motion that must be provided to operate the shutter is thus a reciprocation of the actuating ring. In the shutter in use at this observatory, a small tab attached to the ring extends through a slot into the portion of the shutter body that originally housed the mechanical timing and driving system. Reciprocating motion of this tab opens and closes the shutter; the total travel required is approximately 1/8 inch.

The required motion is imparted to the tab by a simple push-pull solenoid arrangement (Figure 1). The single moving part of the actuating system is composed of the L-shaped fork which moves the tab and the two slugs that, under the influence of solenoid fields, pull the fork back and forth. These three pieces bolt together to form a rigid assembly. Both solenoids are wound on a monolithic block of Teflon;[1] the block also provides the guide structure in which the actuating assembly moves. Teflon was chosen principally because of its bearing properties--particularly its very low "stiction." The block is suspended between aluminum angle supports by means of steel bolts screwed into the axial hole from each end; these bolts also increase the magnetic efficiency of the system and provide travel adjustment. Drops of epoxy cement on the ends of the bolts prevent metal-to-metal contact between slug and bolt. Figure 2 is a photograph of the shutter-solenoid assembly.

ELECTRONIC SYSTEM

The general circuit concept used represents an obvious choice, and has been similarly applied elsewhere (Vurek and Conlon, 1963). Time information is generated by a monostable multivibrator whose output is

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[1] Trademark, E. I. DuPont Company.

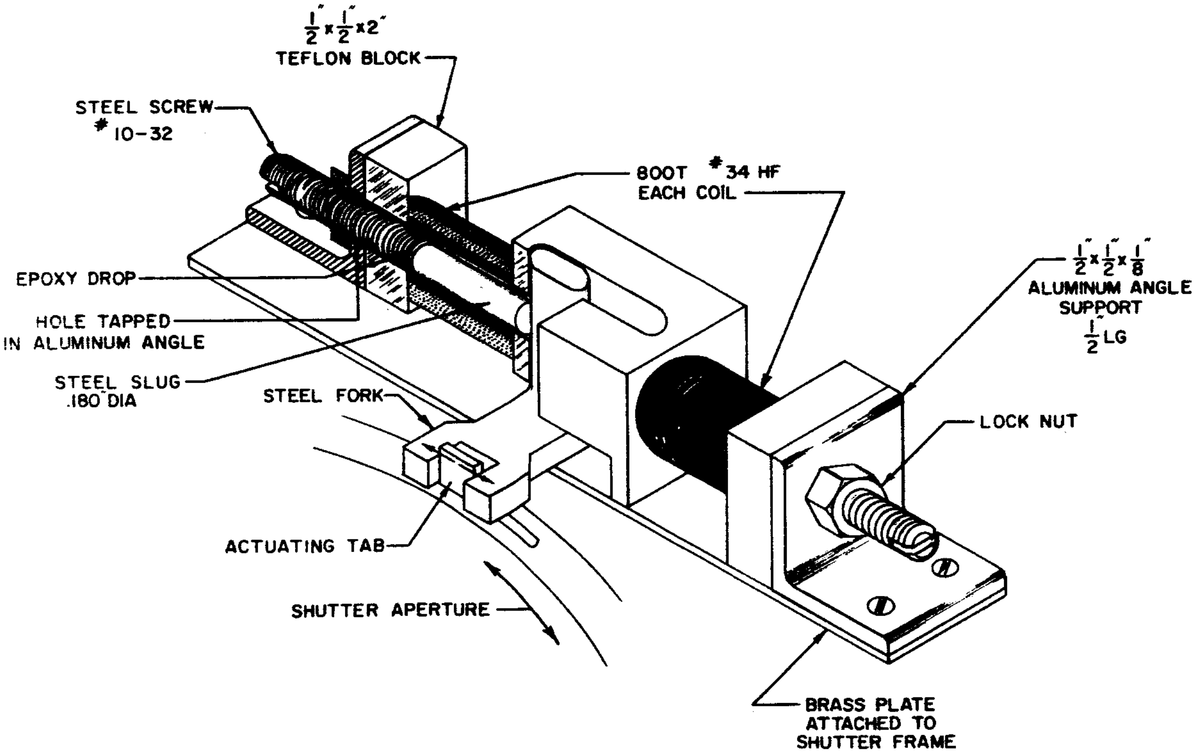

Figure 1

SHUTTER ACTUATOR ASSEMBLY

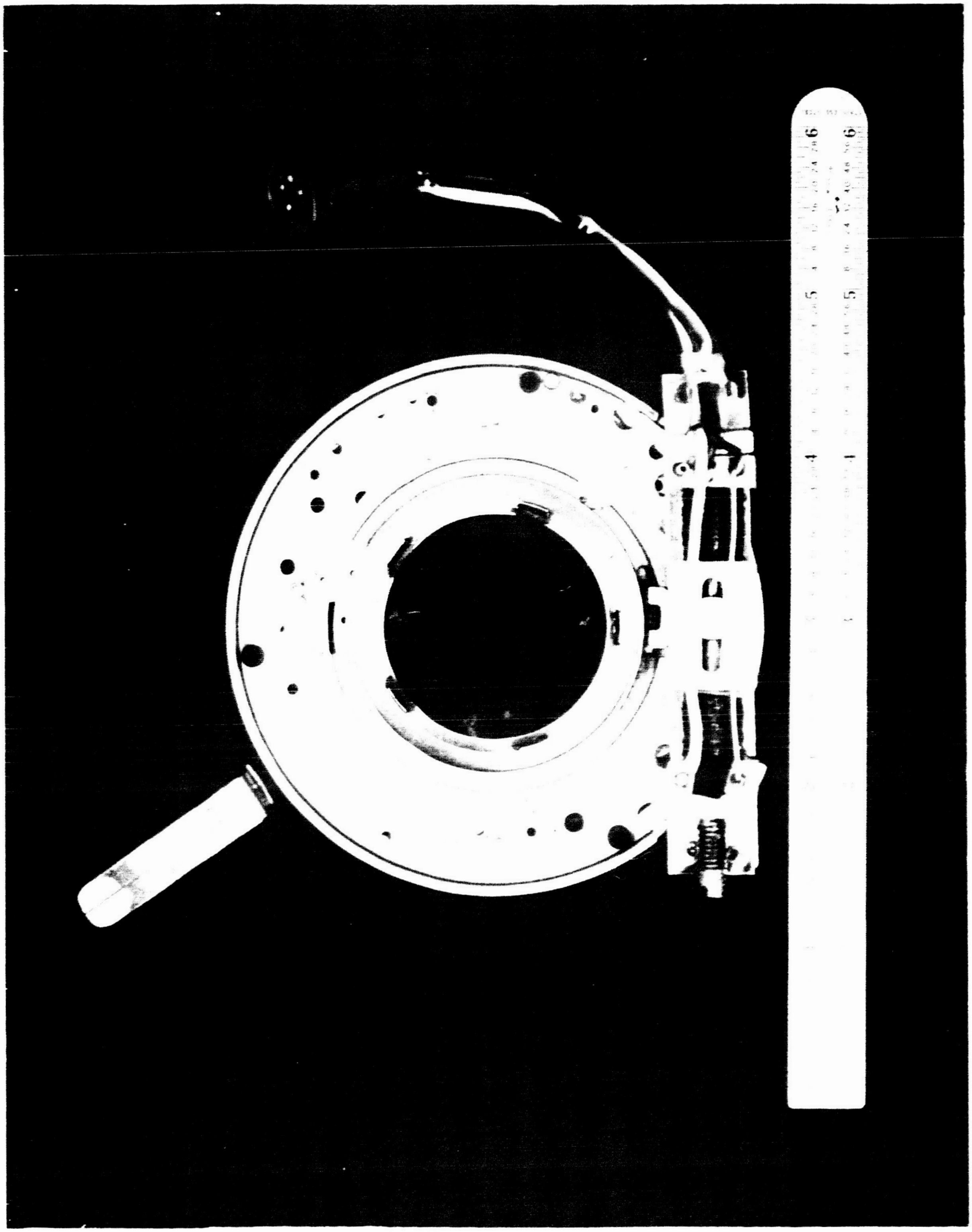

Fig. # 2

used, after isolation and wave-shaping, to drive low-impedance current switches that actuate the solenoids. The present system differs from that described by Vurek and Conlon principally in time generating and output switching techniques. A unique feature of this system is a bistable characteristic that locks the shutter either open or closed. The output circuit is designed to provide a small, constant current (about 50 ma) to both solenoids. Under this quiescent condition the actuator assembly tends to be held at the end of the solenoid block it is nearest to. Large current pulses of short duration provided by the switches move the actuator back and forth; the small quiescent current holds it at the desired end of its travel. The epoxy drops intruded between the bolts and slugs prevent bolt and slug from appearing magnetically as a single piece; much larger current pulses would be necessary to produce motion if this were the case.

The circuit is shown in Figure 3. The one-shot (monostable multivibrator) is composed of a flip-flop (Q_1 and Q_2) and a unijunction transistor relaxation oscillator (Q_3). This circuit is based on a similar circuit given in the *G. E. Transistor Manual* (1962). The quiescent condition of the flip-flop is Q_1 OFF, Q_2 ON. A positive pulse applied through D_1 to the base of Q_2 by closure of S_1 turns Q_2 off; regenerative feedback turns Q_1 on. The timing capacitor (C_{TL} or C_{TS}) selected by RANGE switch S_2 begins to discharge through R_8 and R_T toward the collector voltage of Q_1. When the emitter voltage of the unijunction (Q_3) reaches its firing voltage ηV_{BB}, the unijunction fires, producing a negative pulse across R_{10}. This pulse is applied

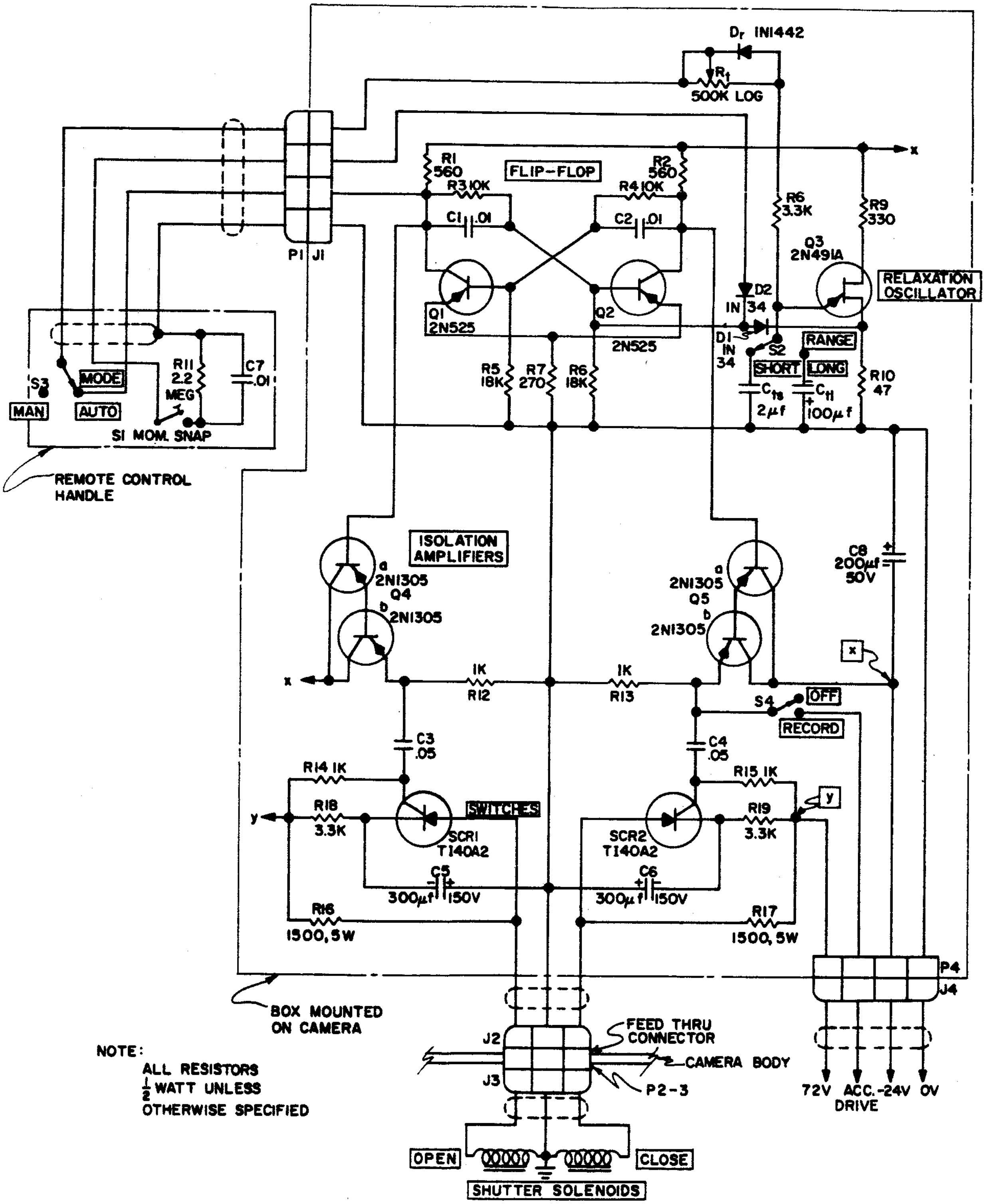

Figure 3

SHUTTER TIMING AND DRIVING CIRCUIT

through D_2 to the base of Q_2, turning it on; regenerative feedback then turns Q_1 off, and the circuit has returned almost to the quiescent state. The timing capacitor (C_{TL} or C_{TS}) must be recharged to bring the circuit wholly to its quiescent state; this is done rapidly by D_R, which is forward biased until C_T is recharged.

The rectangular waveforms appearing at the collectors of Q_1 and Q_2 are current-amplified by Darlington-connected amplifiers Q_4 and Q_5, operating as emitter-followers. The outputs of these stages are differentiated, and the resultant positive pulses trigger controlled rectifier switches SCR_1 and SCR_2. Since the waveform at the collector of Q_1 is a positive-going rectangle, a positive pulse appears at the gate of SCR_1 at the beginning of the time cycle. Conversely, a positive pulse appears at the gate of SCR_2 at the end of the cycle. SCR_1 thus switches to open the shutter; SCR_2 switches to close the shutter.

The energy required to open and close the shutter is stored in capacitors C_5 and C_6, which are "dumped" through the solenoids by the SCR's. C_5 and C_6 are charged through R_{18} and R_{19}, which are sufficiently large to limit current (with SCR's ON) to a value below SCR holding current; this provides positive SCR turnoff. R_{16} and R_{17} "trickle" a constant 50 ma through the solenoids to provide the bistable characteristic.

Time calibration is achieved by placing a small full-circle protractor around the bushing of the timing potentiometer R_T. Times are measured at five-degree intervals using an oscilloscope (for short times) and a clock (for times exceeding the capabilities of the oscilloscope). Times vs. angles are then plotted on log paper, and the angles corresponding to desired time markings are read from the graphs and drawn on the final dial. With the component values shown, times should be continuously adjustable over the range .01 second to 100 seconds approximately, with some overlap of the two ranges.

Switches S_3 and S_4 allow for the incorporation of two special features into the system. If it is desired to open the shutter for an indefinite period of time, S_3 is opened, breaking the timing loop. The shutter is then opened in the normal manner. At the end of the desired period S_3 is closed; the circuit then goes through its regular timing cycle, at the end of which it closes the shutter.

S_4 switches the negative-going rectangle appearing at the emitter of Q_5 to a pin of connector P_4, where it is available for triggering accessory devices (e.g., the time recorder system described below).

AUTOMATIC TIME RECORDING ACCESSORY

It is often necessary in planetary photography to have an accurate record of the precise time at which individual exposures are made. This is especially true of rapidly rotating planets such as Jupiter, where a timing error of 10 seconds would produce a corresponding error of 0°1 in the measured longitude of a Jovian feature. With 60 images being recorded on each photographic plate and perhaps 20 plates being taken on a fully scheduled night, the problem of manual recording of accurate event times would be formidable, if not impossible. Automatic time recording is therefore necessary and such a system is described below.

A Simplex Productograph[2] is used at New Mexico State University Observatory for automatic time recording. This machine prints, on command, the month, day, hour, minute, and second of the command signal; the record is printed on paper tape. The required command signal is a 575 VA switch closure.

The circuit used to trigger the time recorder is shown in Figure 4b. The negative-going rectangle from the collector of Q_5 (in Figure 3) is differentiated by C_1 R_1, and the resultant negative pulse is current-amplified by emitter-follower Q_1. A portion of the resultant negative pulse is steered by D_1 to trigger the one-shot composed of Q_2 and Q_3.[3] A negative-going rectangle 50 ms long appears at the collector of Q_3 and is amplified by the cascaded emitter-follower Q_4 and Q_5. The coil of relay K_1 is the emitter load of Q_5, and is energized when Q_5 is turned on by the one-shot. D_3 provides reverse-voltage suppression to protect Q_5. R_5 allows adjustment of relay closure time, and R_2 selects the fraction of the input pulse necessary to trigger the one-shot.

POWER SUPPLY

Power requirements of the system are moderate. The timing and switch-driving circuit requires -24v DC at a constant 60 ma, the solenoid switching circuit requires -72v DC at 100 ma, with surges to 150 ma, and the time recorder triggering circuit requires -24v DC at

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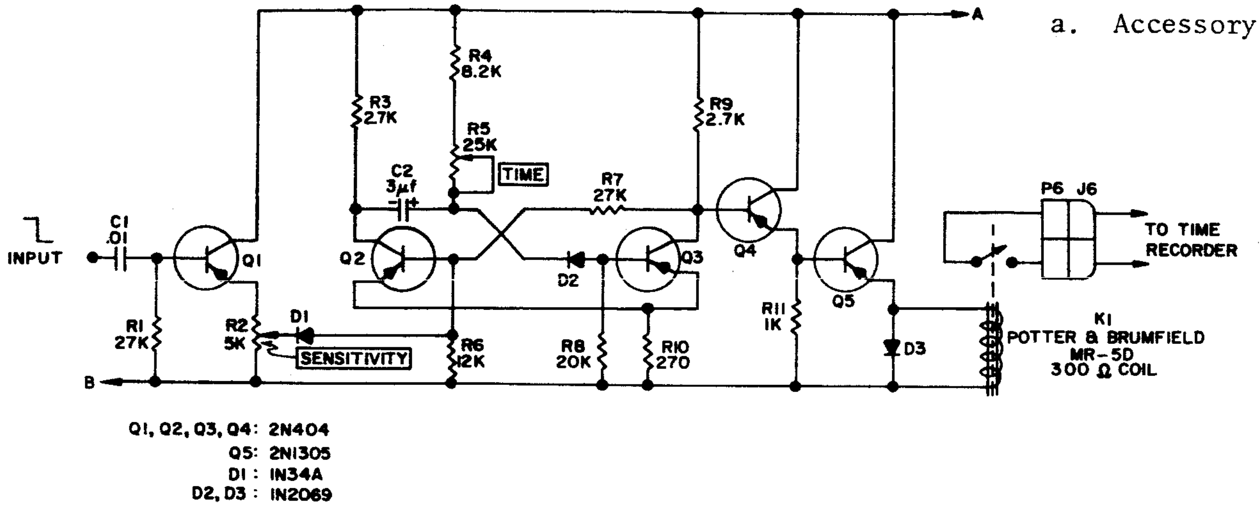
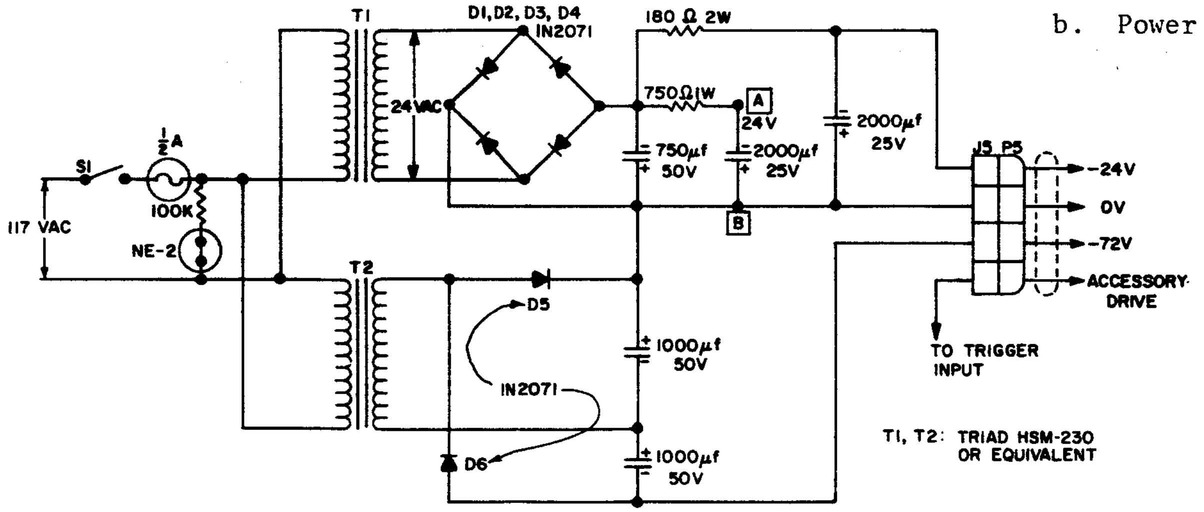
[2] Simplex Time Recorder Co., Gardner, Massachusetts.

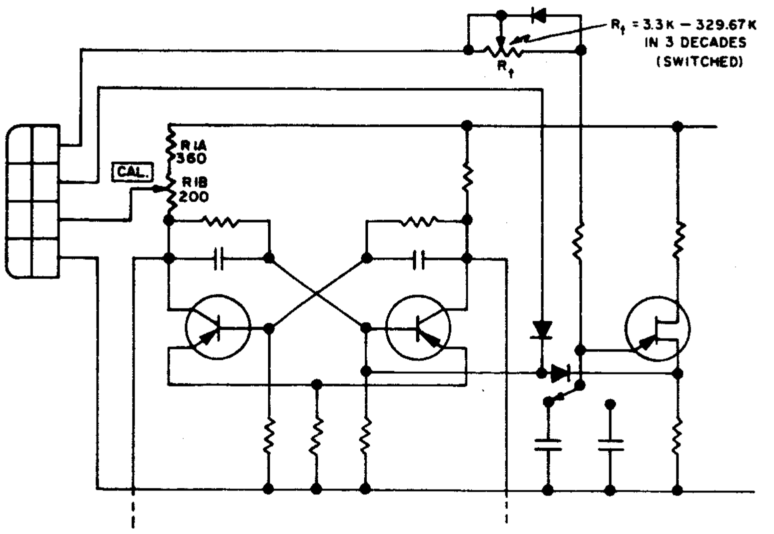
[3] The one-shot is an adaptation of a circuit given in *Transistor Circuit Design* (1963).



a. Accessory Trigger



b. Power Supply



c. Circuit Modification

Figure 4

ANCILLARY CIRCUITS AND MODIFICATION

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