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SOLID STATE, SEQUENTIAL CAMERA TRIGGER CIRCUITS

by John F. Fitz

Goddard Space Flight Center

Greenbelt, Md.

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SUMMARY

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The development and operation of two different solid state, sequential camera trigger circuits are described. Although the trigger circuits are special-purpose, the techniques and methods employed in obtaining a design solution may be applied to a wide range of timing and sequencing requirements.

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INTRODUCTION

The two camera trigger circuits described below were designed, developed, fabricated, and installed by Goddard Space Flight Center (GSFC) personnel as rocket-borne support equipment for solar corona experiments flown on Aerobee 150 vehicle flights 4.77 GS (20 July 1963) and 4.78 GS (1 October 1963). Two distinct sequences were required to control solenoid switches which operated the shutters of an infra-red camera and an ultra-violet camera. Preliminary development was started in May 1962 when the experimenter first defined functional and physical requirements. As the experiment evolved, these requirements were periodically modified and corresponding alterations were made in the design. Launch dates and times were governed by specific combinations of solar phenomena, requiring careful coordination throughout to meet rigid time schedules.

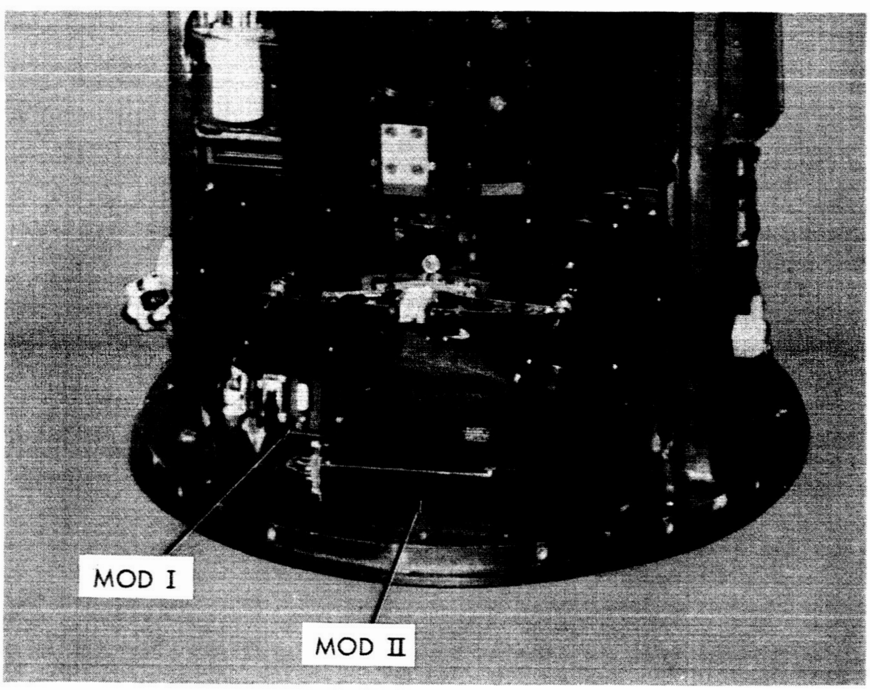

Figure 1—Camera Triggers installed on payload of flight 4.77 GS (end view).

Following bench checks, the completed triggers were installed as shown in Figures 1 and 2, preparatory to environmental tests of the complete payload. Performance of the triggers, throughout test and the subsequent flight fulfilled all requirements, both direct and implied. The design was later turned over to an outside contractor for production of additional units.

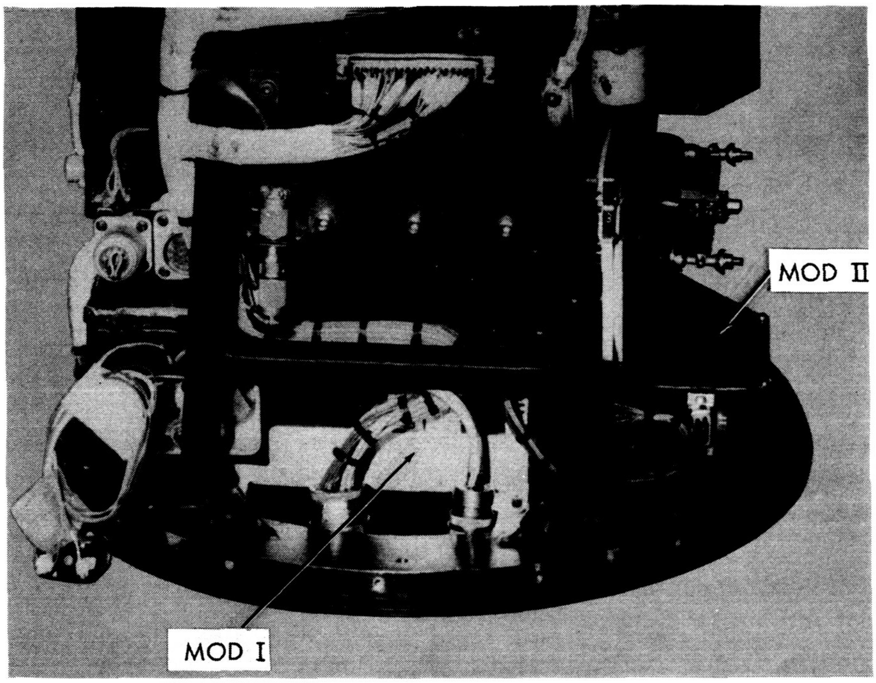

Figure 2—Camera triggers for flight 4.77 GS (side view).

GENERAL DESCRIPTION

The experimenter established the physical limitations for the triggers (Figure 3) and the detailed characteristics of the timed sequences (Tables 1 and 2). The designations "Mod I" and "Mod II" were adopted as a brief, convenient means of identification. Both units were to provide control of externally powered, 28 vdc circuits which actuated camera solenoids within the experiment. In operation, the triggers were to incorporate provision to externally start the sequence and to operate in either a "cycle and hold" or a "cycle continuously" mode. The "cycle and hold" mode was essential to provide a positive method of setting the triggers to the start of a cycle. The arrangement also permitted the option of programming operation of the triggers.

Pin assignments and provision for external control were identical for both triggers. Momentary grounding of pin 2 of the DE-9P connector started the units. Selection of mode of operation was accomplished by shorting pins 7 and 8 for the "cycle and hold" mode, while open circuiting the same pins permitted the trigger to recycle continuously.

The volume allotted to the triggers, together with the environmental requirements for Aerobee flight items, were major considerations in adopting a solid-state design. Analysis of the operation

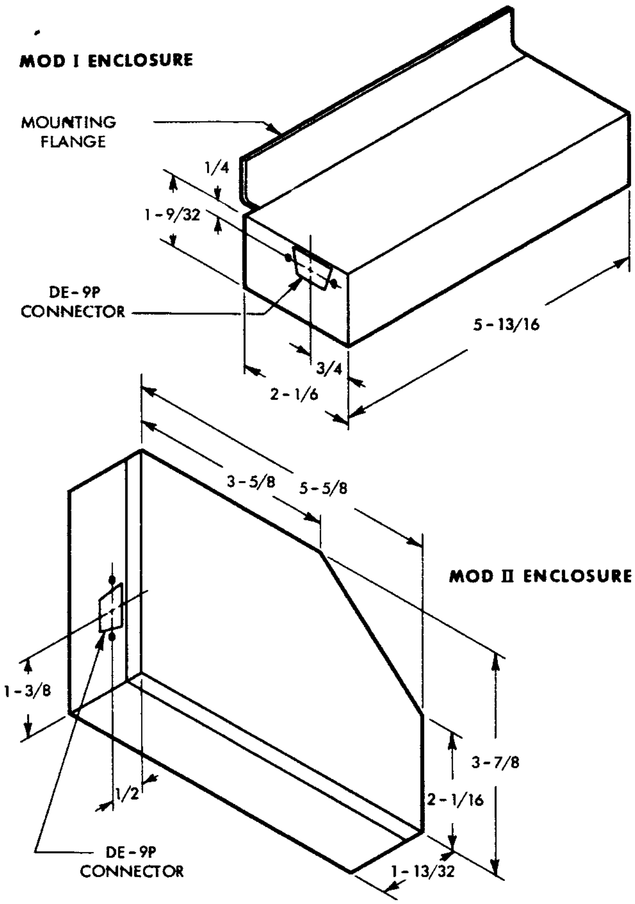

Figure 3—Dimensions of camera trigger enclosures.

Table 1—Mod I Camera Trigger.

Count	Interval	Binary Count	Matrix
1	0	00000001	00000001
2	1/8	00000010	0000001x
4	1/4	00000100	000001xx
8	1/2	00001000	00001xxx
16	1	00010000	0001xxxx
32	2	00100000	001xxxxx
96	8	01100000	011xxxxx
224	16	11100000	111xxxx0
225	Reset	11100001	111xxxx1

By deleting the diodes indicated by "x" in the matrix listing, the total number required was reduced from 72 to 44.

Table 2—Mod II Camera Trigger.

"On" Interval (seconds)	Count*		Binary Count	
	On	Off	On	Off
0.01	0	1	00000000000	00000000001
0.03	51	54	00000110011	00000110110
0.1	104	114	00001101000	00001110010
0.3	164	194	00010100100	00011000010
1	244	344	00011110100	00101011000
3	394	694	00110001010	01010110110
10	744	1744	01011101000	11011010000

*Basic count increment: 0.01 Second (10 milliseconds)
"Off" period is 50 counts (0.5 second), constant.

of the experiment indicated a probability of severe transient loading of the power supply, particularly from operation of the same camera solenoids, controlled by the triggers. Voltage regulators (Figure 4) were provided at the vehicle power distribution box to supply 10 vdc for operation of the triggers. Potentiometers provided as part of the regulators to compensate for component variations, also permitted fine adjustment in the period of the trigger due to sensitivity of the clock multivibrators to input voltage.

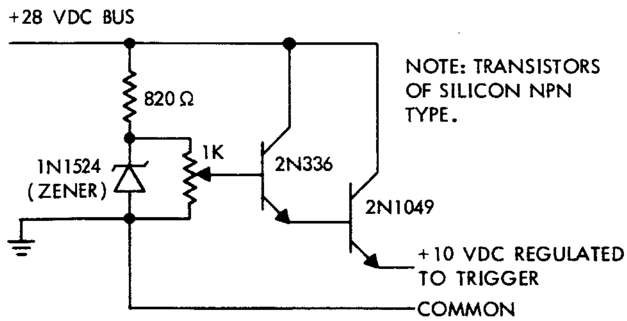

Figure 4—Voltage regulator for camera triggers.

MOD I TRIGGER

The operating cycle for the Mod I (Figure 5) required a series of equal length "On" periods, initiated at fixed times with respect to the start of the cycle. The length of the "On" periods was to be manually adjustable in the range of 20 to 60 milliseconds. Immediately following the last "On" period, the trigger was to return directly to the start of its cycle.

The counting sequence was established, based on 1/8 second (125 milliseconds) increments, as shown in Table 1. The progression of time intervals, each interval but one being double the preceding interval, allowed substantial economy in the arrangement of the diode matrix. Ordinarily, each digit of a binary number is reflected in the matrix by a corresponding diode. In this case, as shown by the columns headed "Binary Count" and "Matrix", 44 diodes were functionally equal to 72, a saving of nearly forty percent.

Referring to the schematic (Appendix A, Figure A1), momentary grounding of pin 2 of the connector sets the control flip-flop to apply power to the clock-multivibrator. The clock output drives a binary counter consisting of eight identical flip-flops. On the selected counts, shown in Table 1, the counter output is gated, through the diode matrix, to a capacitor-coupled common output to trigger a one-shot multivibrator with a relay driver. The period of the one-shot is variable in the range of 20 to 60 milliseconds by means of the 100k potentiometer. On the 225th count, the counter output is gated to the base of the 2N224 transistor, driving the transistor into conduction. The resulting pulse resets the binary counter flip-flops to "zero-positive" ready to start another cycle. If the "cycle and hold" mode has been selected, the same pulse is applied, through connection of pins 7 and 8, to reset the control flip-flop to "Off", cutting off the power to the clock multivibrator. The trigger will then "hold" until pin 2 is again momentarily grounded.

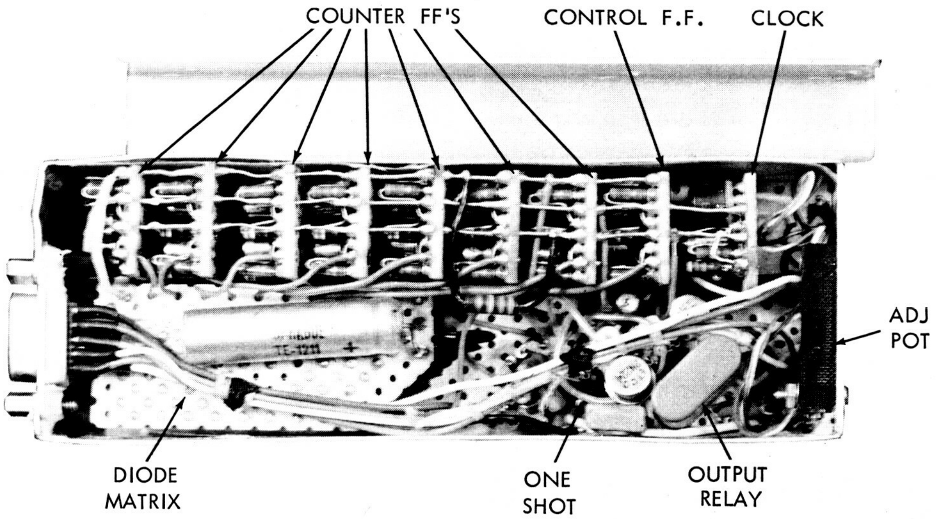

Figure 5—Mod I, assembly before potting.

MOD II TRIGGER

In the Mod II trigger (Figure 6) the length of the "On" and "Off" periods were fixed, permitting the counter outputs to be applied directly. As first stated, the trigger was to provide "On" periods of 1/100, 1/30, 1/10, 1/3, 1, 3, and 10 seconds, separated by constant 1/2 second "Off" intervals. There was no requirement for an immediate return to the start of the cycle.

The combination of the fractional time increments proved to be unsatisfactory for application of counter techniques, in that derivation of a basic counting increment resulted in repeating decimals and would have required an excessively complicated counting system. Conversion of the fractions to decimals, 0.01, 0.03, 0.1, 0.3, permitted the basic counting increment to be established at 0.01 second (10 milliseconds). The counting sequence was then established as shown in Table 2. In the Mod II, the counts are indicated for the start of both "On" and "Off" periods.

As in the Mod I, momentary grounding of pin 2 sets the control flip-flop to apply power to the clock multivibrator. The clock drives the binary counter, comprised, in this instance, of eleven flip-flops. The counter outputs are gated through the diode matrix to one of two direct-coupled output lines, marked "A" and "B" on the schematic and reflecting the "On" or "Off" columns of Table 2. The gated outputs operate a control flip-flop, to actuate the relay through the 2N656 driver transistor.

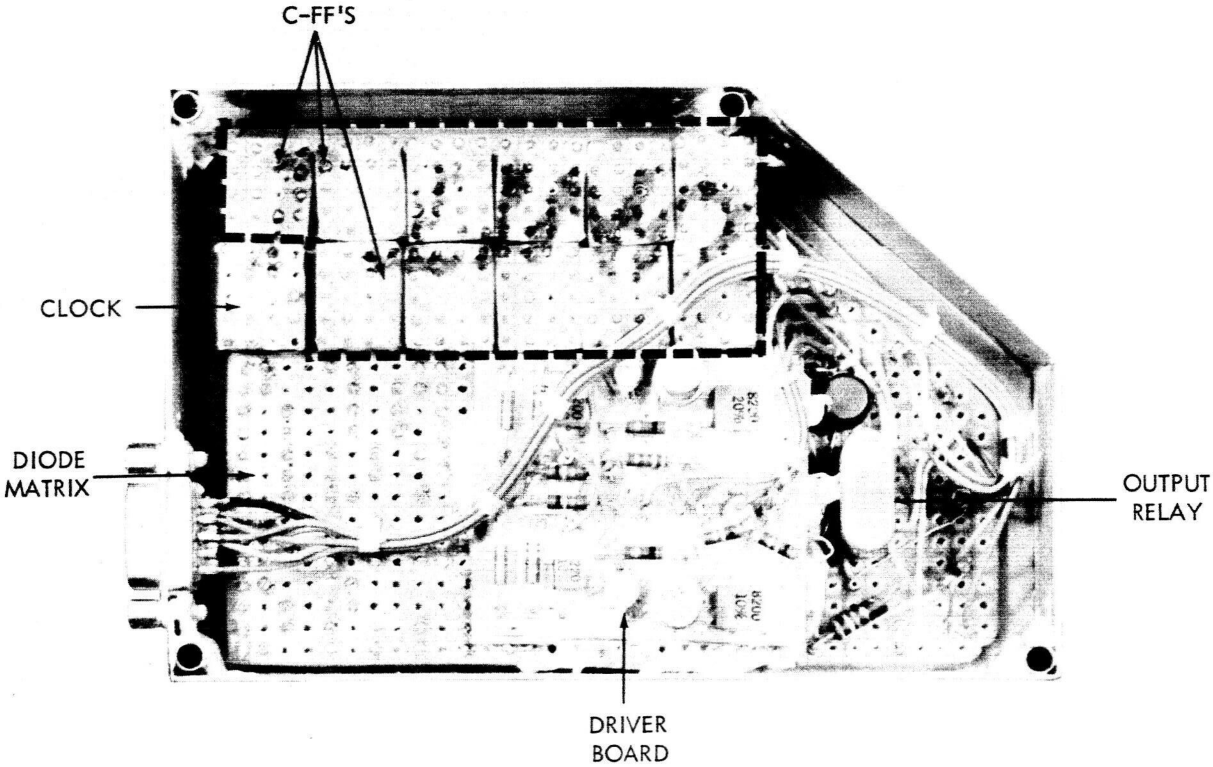

Figure 6—Mod II, assembly before potting.

Appendix A

Camera Trigger Circuit Schematics

This section contains schematic diagrams for Camera Trigger Mod I and Camera Trigger Mod II.

UNLESS OTHERWISE NOTED, ALL DIODES 1N848

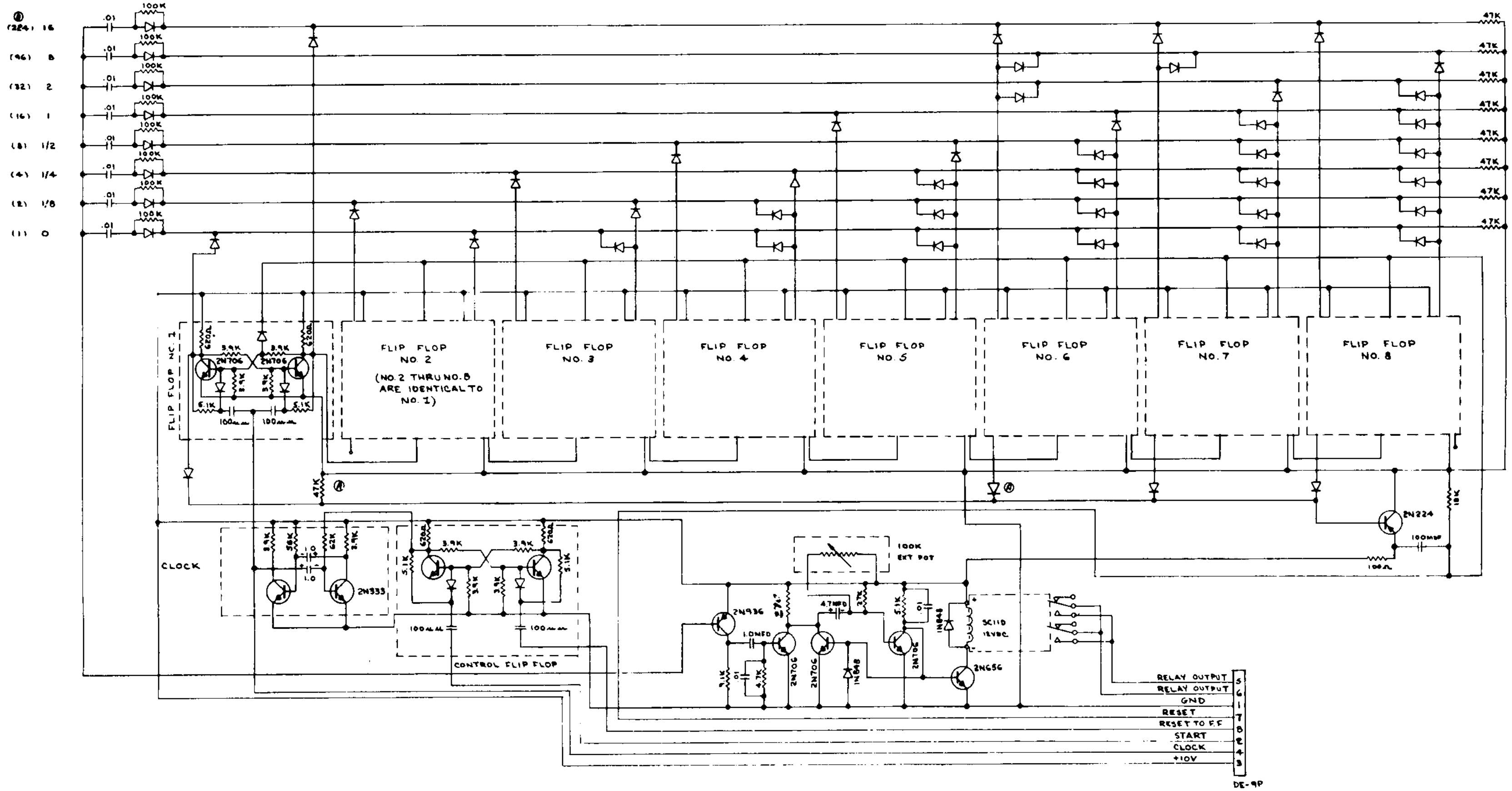

Figure A1—Camera trigger Mod I.

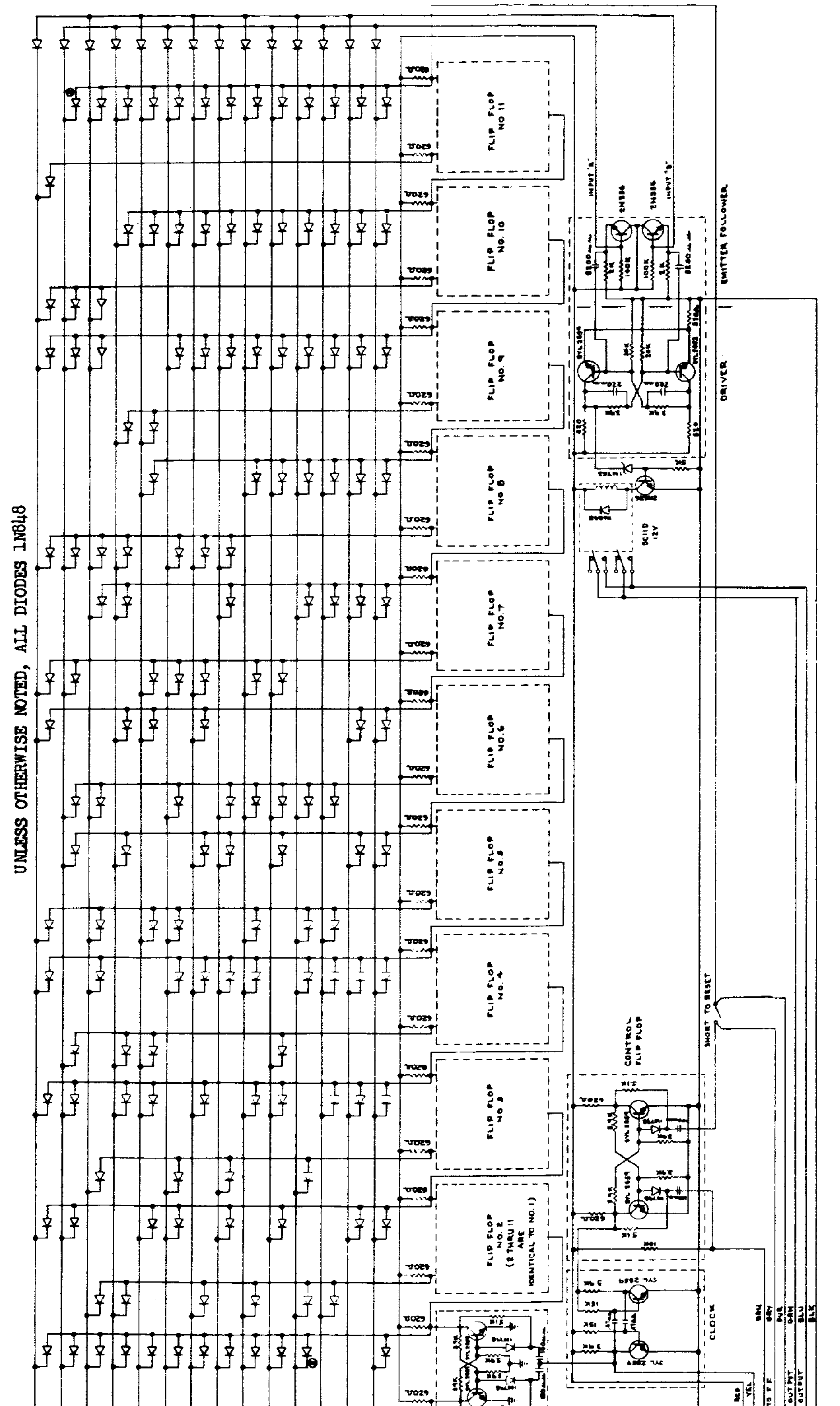

Figure A2—Camera trigger Mod II.