THE DESIGN OF AN AUTOMATIC TESTER FOR MECHANICAL CAM TIMERS

A Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science

by

Paul Allen Whitacre, B.S.

The Ohio State University
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Approved by

F. C. Weimer
Adviser
Department of Electrical Engineering

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CHAPTER I

INTRODUCTION

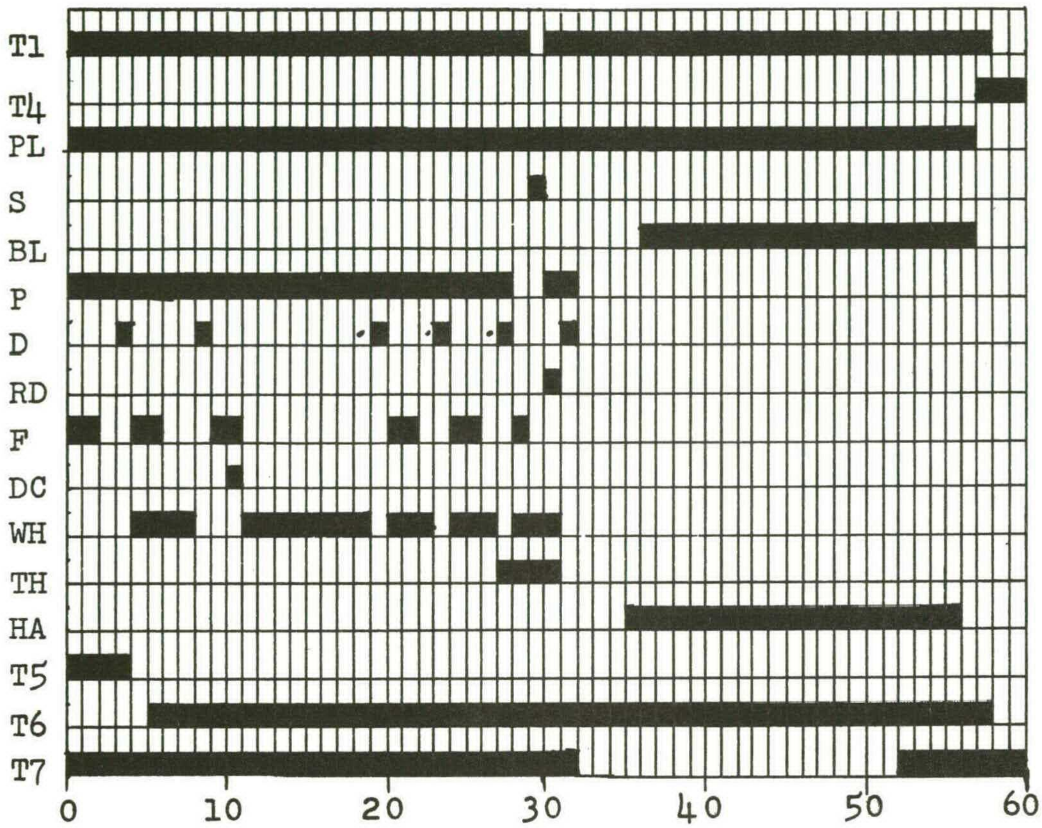
1.1 Background

This thesis topic developed from a need for an efficient and complete testing procedure for the assembled KitchenAid dishwashers at The Hobart Manufacturing Company, Troy, Ohio. The cam timers are tested before they are assembled on the dishwashers. The existing method of testing the cam timers consists of having an operator watch a series of lamps. The lamps monitor the output circuits of the timer.

The objective of this thesis is to design and build an automatic tester which will monitor each output circuit of the timer and obtain a decision of acceptance or rejection of the timer.

1.2 A Description of the Cam Timer

The basic function of the cam timer in a dishwashing machine is to control the fill, wash, rinse, and dry cycles. A timing chart of one dishwashing cycle is shown in Figure 1. The timer consists of a set of contacts which are opened and closed by rotating cams (Figure 2). The present timer consists of nine cams and nineteen output functions (Figure 5). The cams are driven by a motor and a windup escapement. The escapement impulses the cams 6 degrees every 45 seconds. The escapement also allows the cams to be rotated independently of the motor; thus, the timer can be set in a desired part of the dishwashing cycle by an operator.



Each Small Division is 45 Seconds
or 6° Quick Impulse

T1 - Timer Motor- Normal
T4 - Timer Motor- Reset
PL - Pilot Light
BL - Blower Motor
P - Pump Motor
S - Water Heat- Sanitize
D - Drain Valve
RD - Rinse Agent Dispenser
F - Fill Valve
DC - Detergent Dispenser
WH - Water Heat- Normal
TH - Thermostat
HA - Air Heater
T5 - Rinse Hold
T6 - Timer Advance Motor
T7 - Utensil

Fig. 1

Timing Chart of the Dishwashing Cycle

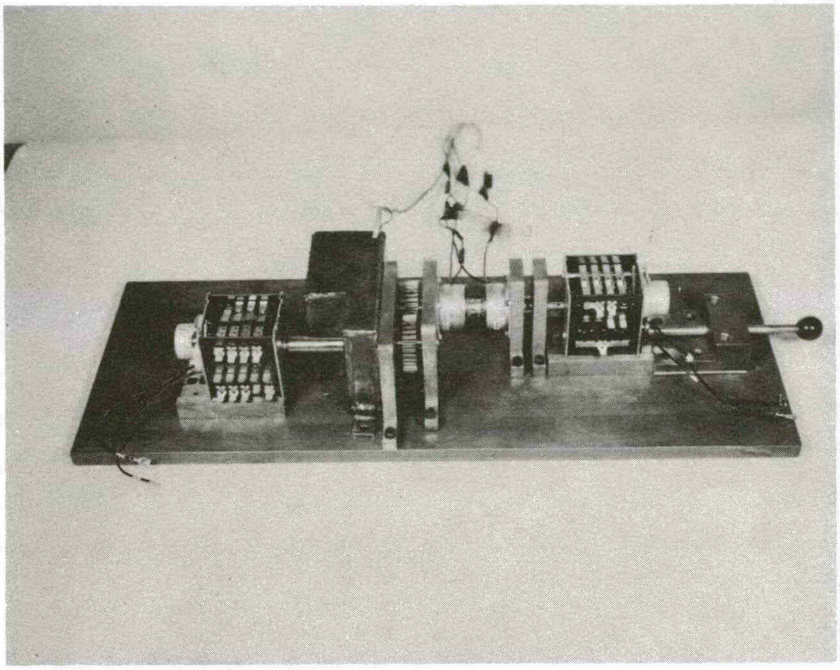


Fig. 2

The Mechanical Layout of the Tester

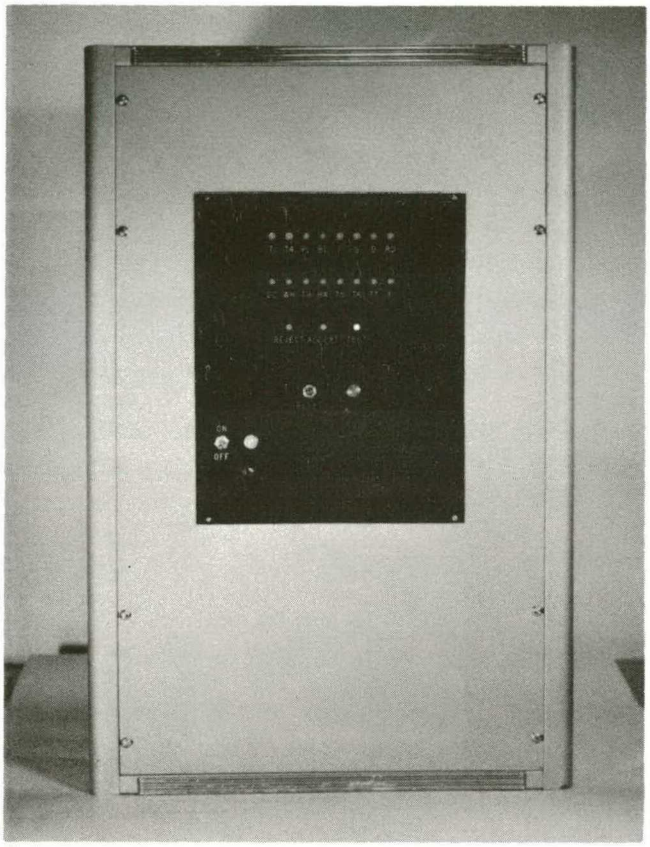


Fig. 3

Front View of the Tester

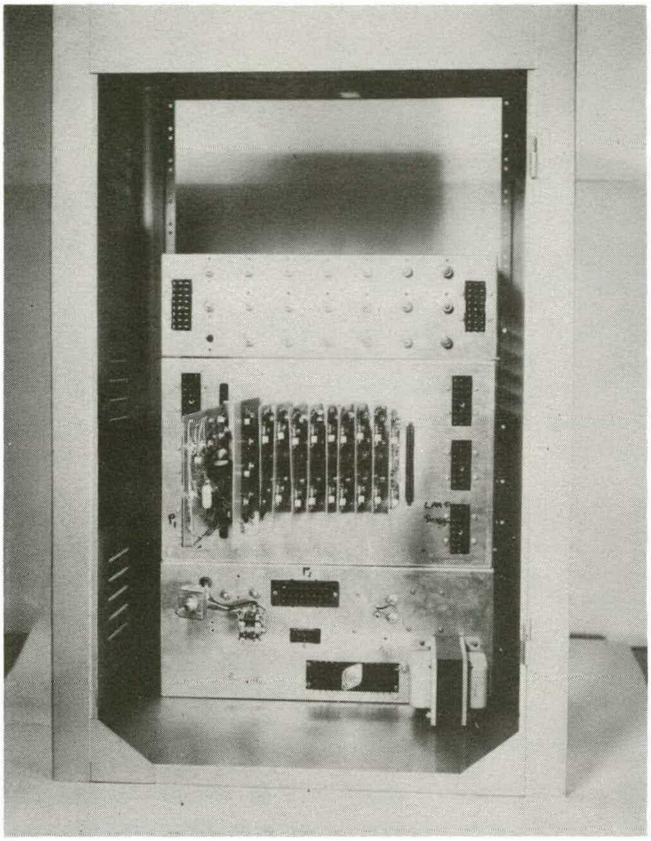
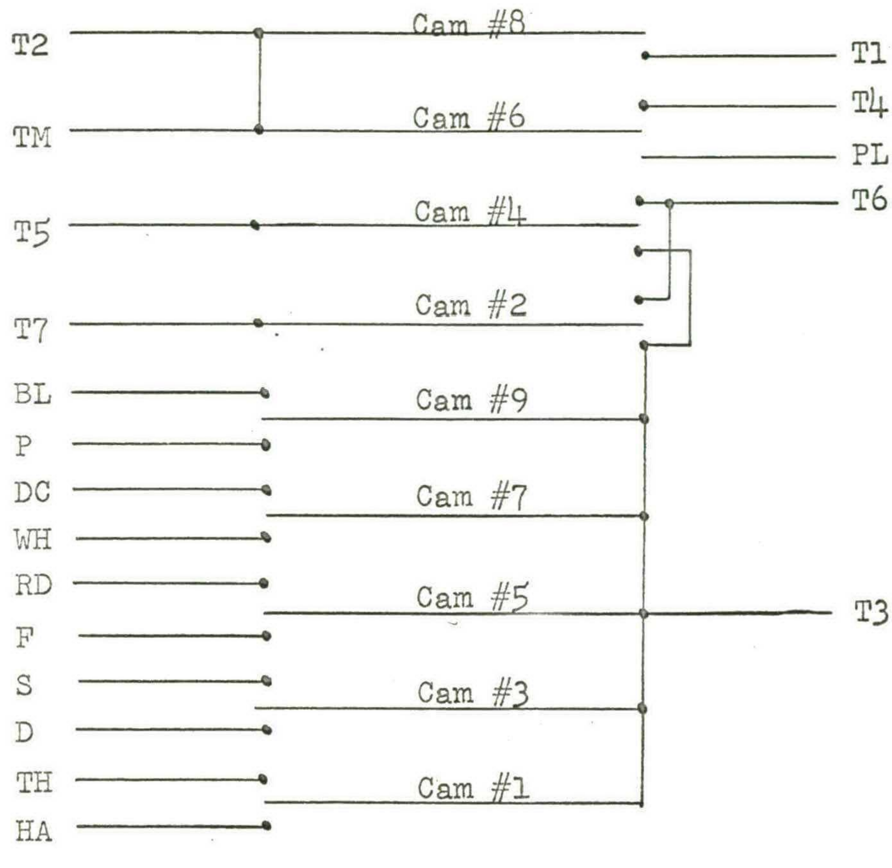


Fig. 4

Rear View of the Tester



TM - 115-volt input
T2 - 115-volt input
T3 - 115-volt input

Fig. 5

Circuitry of the Cam Timer

CHAPTER II

GENERAL CONSIDERATIONS IN THE METHOD OF TESTING THE CAM TIMERS

2.1 Statement of the Problem

The problem is to determine if the relative phase and duration of the output functions of the timer are within preset limits. The method used to determine the above criteria should have the following features:

(1) The operation of the automatic tester must be independent of the initial position of the timer that is to be tested.

(2) A reset button must be pushed before the test commences.

(3) A decision of acceptance or rejection of the timer is to be displayed.

(4) A decision of acceptance or rejection of each output function of the timer is to be displayed.

2.2 Proposed Method of Testing the Cam Timers

The method proposed to test a cam timer is to compare the corresponding output functions of a test timer and a master timer, as both are rotated through 360 degrees or one cycle. The problem encountered in this method is to align accurately the two timers into the same electrical phase in the beginning of the test.

The first attempt at aligning the timers was of a mechanical nature. The output shaft has a flat located ± 3 degrees with respect to the first impulse of the timing cycle (Figure 6). The test and master timers were aligned by means of this flat. This method failed because a tolerance of ± 3 degrees upon the location of the flat allowed the two timers to be out of phase by one timing impulse.

It is proposed to align the timers electrically by monitoring the pilot light contacts of the test and master timers. The pilot light contact opens and closes once during one cycle. At the instant the pilot light contact closes, the timer is at the beginning of the dishwashing cycle (Figure 1).

A brake is used to hold the master timer at the beginning of its cycle, a clutch to couple and decouple

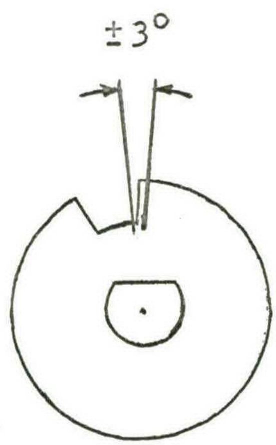


Fig. 6

The Relative Alignment of the Flat on the Shaft to the First Timing Impulse the two timers, and a 6-revolution-per-minute motor to rotate the timers. The mechanical layout used is shown in Figures 2 and 7. The two zero-backlash gears are used to obtain the proper direction of rotation for each timer. With the clutch and the brake engaged, a timer is placed on the test fixture. The clutch is disengaged, and the motor is energized. The master timer is held at the beginning of the dish-washing cycle by the brake, and the test timer is rotated until its pilot light contact closes. The motor is turned off, and the clutch is engaged. At the end of a short time delay, the brake is released, and the motor is turned on. The two timers are rotated 360 degrees during which time their corresponding output functions are compared for differences. When the pilot light contact of the master timer closes, the motor is turned off and the brake engaged. A decision of acceptance or rejection of the test timer is displayed.

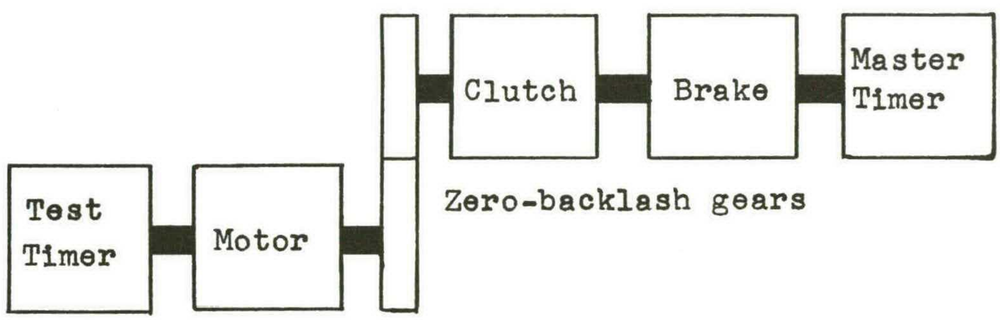


Fig. 7

Block Diagram of the Mechanical
Layout of the Tester

CHAPTER III

THE LOGIC DESIGN OF THE AUTOMATIC TIMER TESTER

3.1 Power Supply Requirements

Motorola diode transistor integrated circuits are used to implement the logic. Appendix I gives the specifications for the logic circuits. A power supply with +5.6 volts is used to obtain as large a voltage change as possible at the collector of each transistor. The +5.6 volt supply is to deliver a maximum of 2.0 amperes to supply power to 25 six-volt, forty-milliampere lamps, and 6 six-volt, sixty-milliampere reed relays. The negative supply is -5.6 volts. The power supply uses standard zener diode regulation techniques.[1] The schematic of the power supply is shown in Appendix II.

3.2 The Design of the Power Logic

A reset button, which controls two relays, is used to reset and to connect the power supply to the logic circuits. Thus, the logic is reset to its initial state at the same time the power is turned on. The motor, brake, and clutch should not be on at the same time. Logic is needed to detect and stop the operation of the tester if this condition occurs.

Figure 8 shows the circuit used to mechanize the above three conditions. Appendix III and Appendix IV give, respectively, the symbols for the Boolean operations and variables used in the logic. When the reset button is pushed, relay R is energized. Then relay P is energized through the normally-closed contact y' and the normally-open contact r_3. Relay P stays energized through its normally-open contact p_1 and the normally-closed contact y'. The power supply is connected to the logic through the normally-open contacts p_2 and p_3. The normally-open contacts r_1 and r_2 of relay R are used to reset the logic.

The function Y detects when the motor, brake, and clutch are on at the same time.

$$Y = \overline{M \cdot B \cdot C}$$

M - Motor

B - Brake

C - Clutch

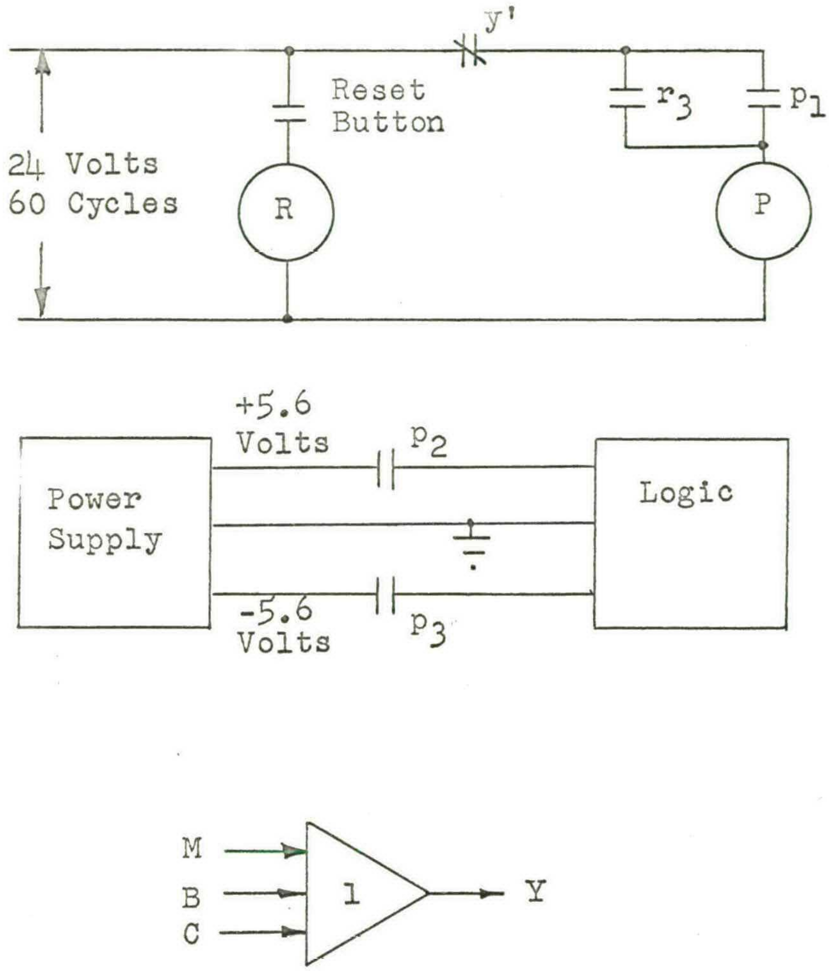


Fig. 8

The Power Logic

A reed relay coil with normally-closed contact y' is the load in the collector circuit of power gate (1). Thus, the contact y' opens when Y equals a logic 0, and relay P de-energizes. With relay P de-energized, the power supply is disconnected from the logic.

3.3 The Design of the Control Logic

The input variables that are used for control purposes are obtained from the pilot light contacts of the test and master timers. When the pilot light contact closes, it triggers a flip-flop into the "off" state. Figure 9 is a diagram of the circuit used to accomplish this. P_T is the output of the flip-flop that detects the closing of TT, the pilot light contact of the test timer. Reed relay K energizes after TT closes. This causes the normally-open contact k to close, and a negative pulse triggers P_T to a logic 1. Appendix III gives the truth tables for a flip-flop. Flip-flop (1) is reset by the normally-open contact r_1. Figure 10 is a diagram of the circuit used to detect the closing of MT, the pilot light contact of the master timer.

Figure 11 shows a timing chart for the control of the M (motor), C (clutch), and B (brake) functions with the inputs P_T and P_M. At the time t equals t_2, the motor is energized and the brake released. However, there is no change in P_T or P_M. A time-delay stage which turns the motor on and brake off is introduced. The time delay starts when P_T changes to a logic 1. At the time t equals t_2, a signal from the time-delay stage

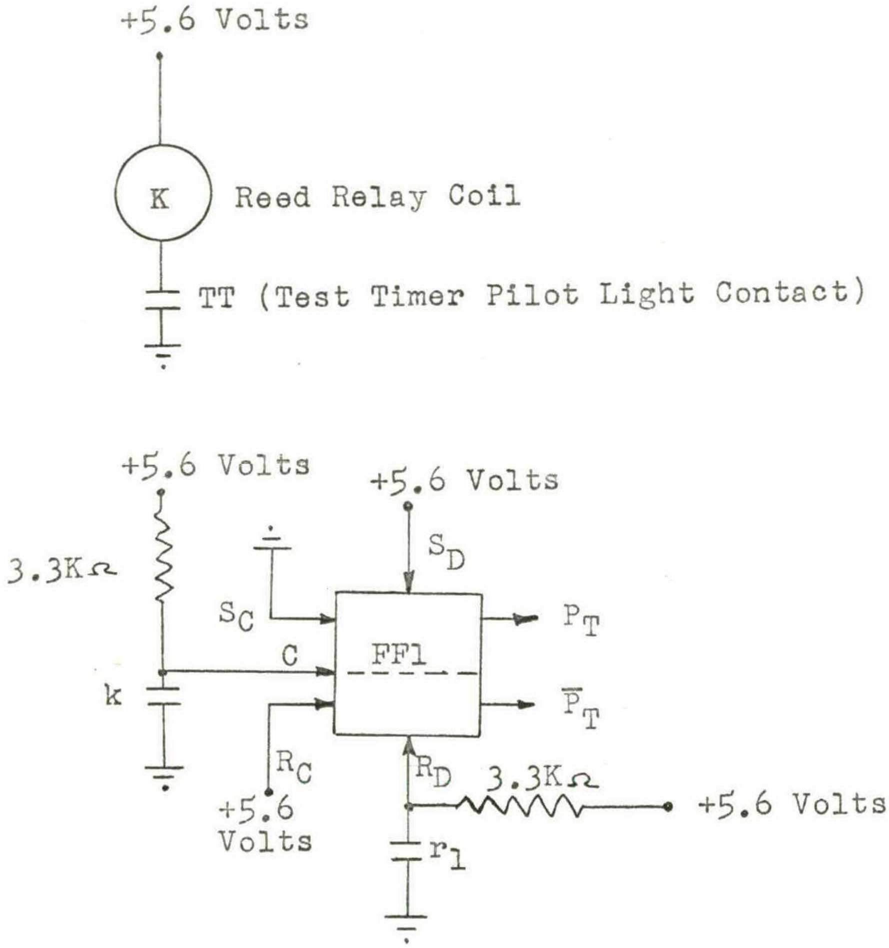


Fig. 9

The Circuit Used to Detect the Closing of TT

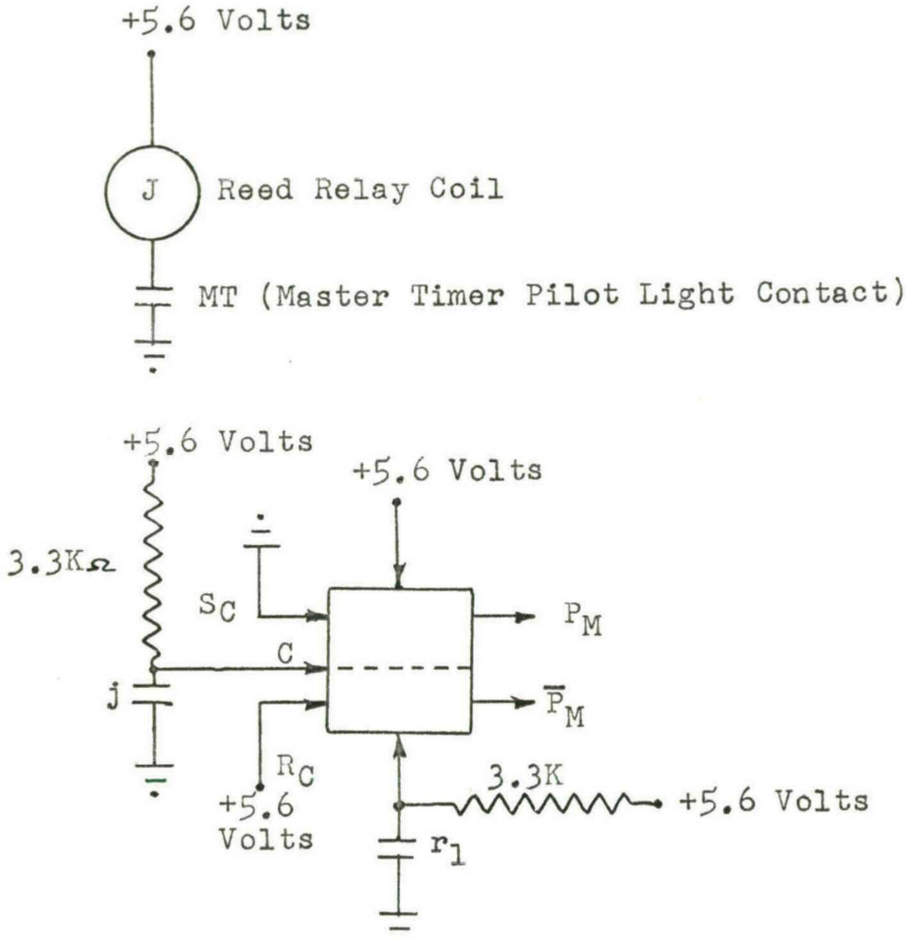
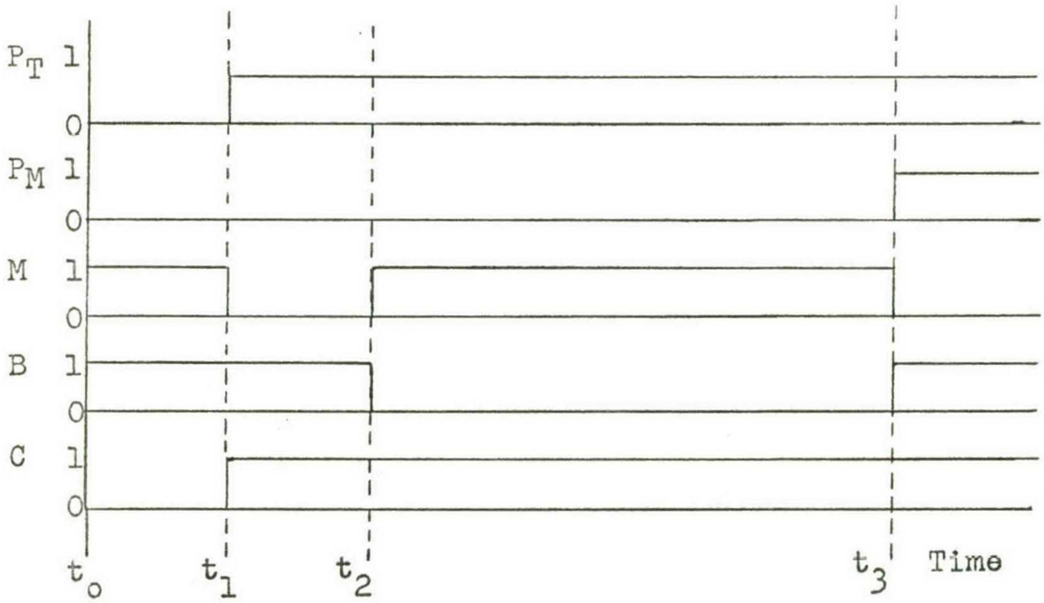


Fig. 10

The Circuit Used to Detect the Closing of MT



t_o - Start of the Test Cycle

t_1 - Contact TT Closes

t_2 - End of the Time Delay

t_3 - Contact MT Closes

Fig. 11

A Timing Chart of the Control Functions

causes X_1, the output of a flip-flop, to change to a logic 1. By closing a start button at the beginning of the test cycle, S, the output of a flip-flop, is changed to a logic 1. Figure 12 gives the timing chart of the control logic for one cycle. The variable

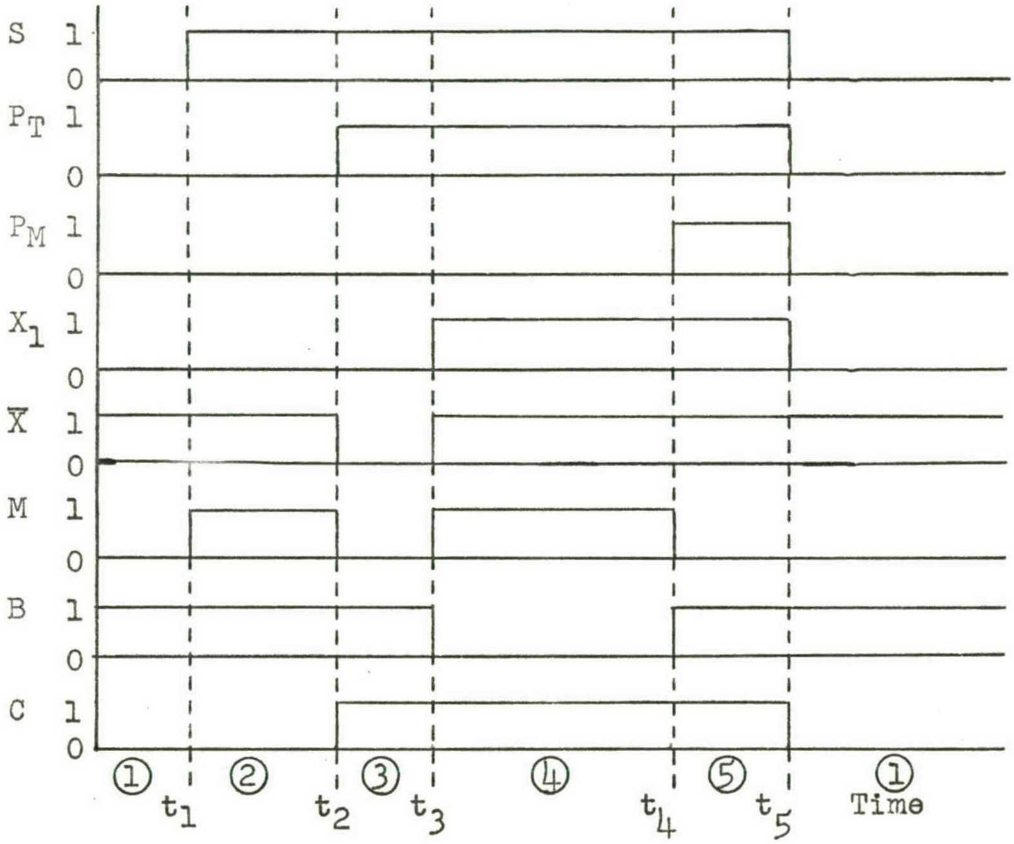
$$\overline{X} = \overline{P_T \cdot X_1}$$

is shown also.

The variables S, P_T, P_M, and X are used to control the output functions M, B, and C. From the timing chart, it is observed that there are five stable states. The primitive flow chart corresponding to these states is shown in Figure 13. The stable states are circled. From the primitive flow chart, a merged flow chart is obtained by combining "row" states ①, ②, and ⑤ and "row" states ③ and ④. "Don't care" terms are utilized in this step.[2] This choice of merging results in only one feedback variable.

F, the feedback variable, is coded as shown in Figure 14. Figure 15 shows the Karnaugh maps for the functions f, M, and B.

$$f = f \cdot \overline{P}_M + X$$
$$M = S \cdot \overline{X} \cdot \overline{P}_M$$
$$B = \overline{f} + X$$
$$C = P_T$$



t_1 - The start button is pushed

t_2 - The contact TT closes

t_3 - The time delay ends

t_4 - The contact MT closes

t_5 - The reset button is pushed

Fig. 12

A Timing Chart of the Input and Output Control Functions

P_M,X,S	000	001	011	101	M	B	C
	(1)	2	x	x	0	1	0
	x	(2)	3	x	1	1	0
	x	4	(3)	x	0	1	1
	x	(4)	x	5	1	0	1
	1	x	x	(5)	0	1	1

Fig. 13

Primitive Flow Chart

x's - "Don't Care" Terms

P_M,X,S		000	001	011	101
f	0	(1)	(2)	3	(5)
	1	x	(4)	(3)	5

Fig. 14

Merged Flow Chart

S,f \ P_M,X	00	01	11	10
00	0	x	x	x
01	x	x	x	x
11	1	1	x	0
10	0	1	x	0

$f = f \cdot \overline{P}_M + X$

S,f \ P_M, X	00	01	11	10
00	0	x	x	x
01	x	x	x	x
11	1	0	x	x
10	1	x	x	0

$M = S \cdot \overline{X} \cdot \overline{P}_M$

S,f \ P_M, X	00	01	11	10
00	1	x	x	x
01	x	x	x	x
11	0	1	x	x
10	1	x	x	1

x's - "Don't Care" Terms

$B = \overline{f} + X$

Fig. 15

By comparing the truth tables of f and a set, reset flip-flop, it is observed that they are identical. Figure 16 illustrates this.

Figures 17 and 18 show, respectively, a block diagram and timing chart for the functions used in the control logic. G is the output of a power NAND gate which turns on a test lamp when the logic is reset.

Direct Set- Reset		
S_D	R_D	Q
0	1	1
1	0	0
1	1	No Change

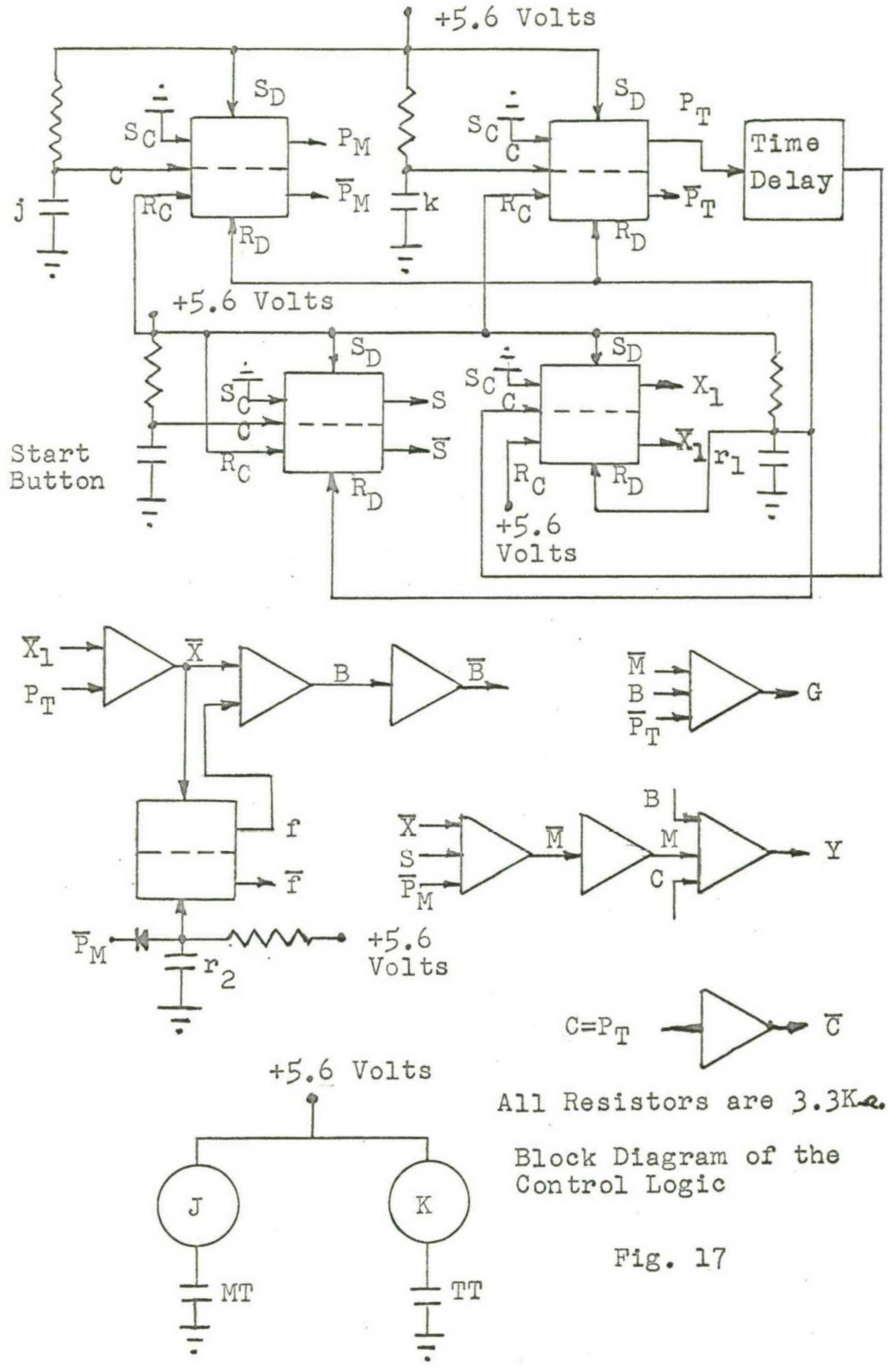
Truth Table of the flip-flop

$\overline{X}$	$\overline{F}_M$	f
0	1	1
1	0	0
1	1	0
1	1	1

Truth Table of f

Fig. 16

The Truth Tables of f and the Direct Set- Reset Flip-flop



All Resistors are 3.3KΩ.

Block Diagram of the Control Logic

Fig. 17

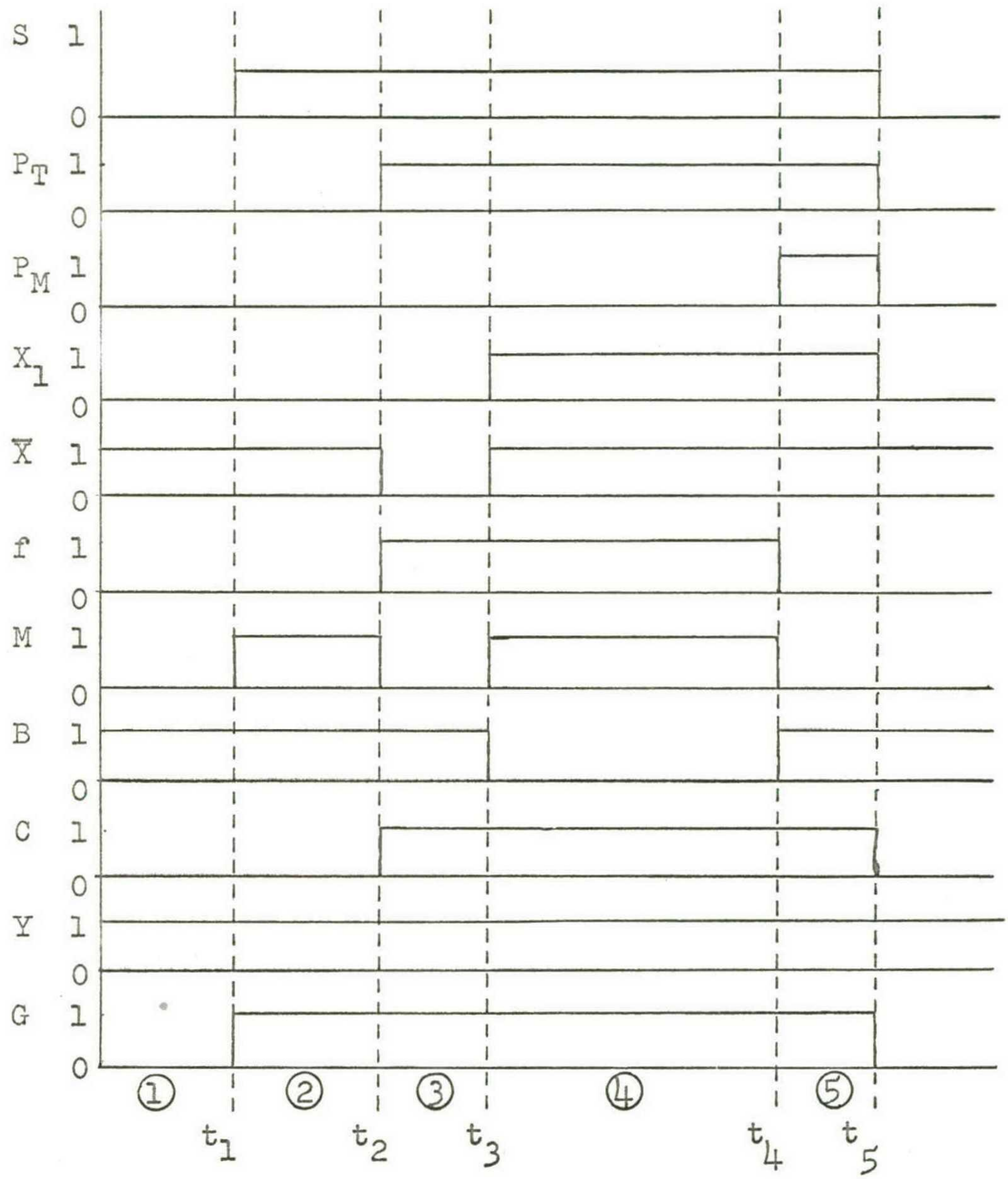


Fig. 18

A Timing Chart of All the Control Logic

3.4 The Design of the Comparison Logic

Each corresponding circuit of the test and master timers is compared by an exclusive OR gate. Figure 19 shows the four NAND gates used to implement the exclusive OR function. A time-delay stage determines if the corresponding circuits of the timers differ by a preset time increment.

The output of the time-delay stage is a negative pulse that triggers a flip-flop into the "off" state. Q_i, the output of the i-th flip-flop, is the input to a lamp driver. If T_i, the input from the i-th circuit in the test timer, is faulty, the following conditions occur:

$$Q_i = 1$$

$$C_i = 0$$

When C_i, the output of the i-th lamp driver, equals a logic 0, the i-th lamp is turned on. This displays which circuit is faulty in the timer. The flip-flop is reset by the function $\bar{X}$ during the next test cycle.

The outputs of the individual comparison circuits are the inputs to a final AND gate, which determines whether the timer is accepted or rejected. Figure 20 shows the AND gate mechanized with NAND gates and inverters. The output is

$$R_T = \prod_{i=1}^{16} C_i$$

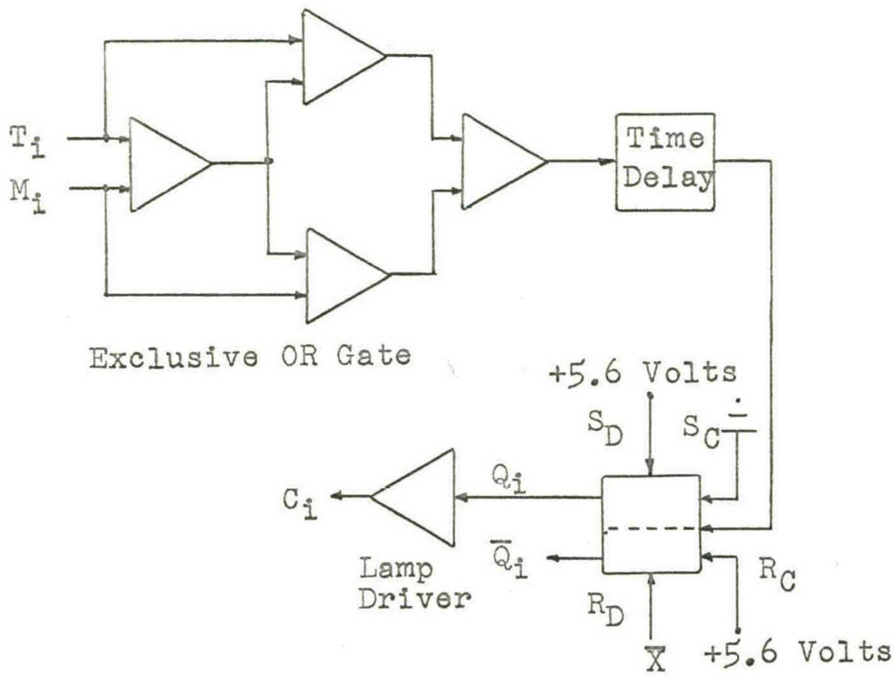


Fig. 19

Individual Comparison Stage

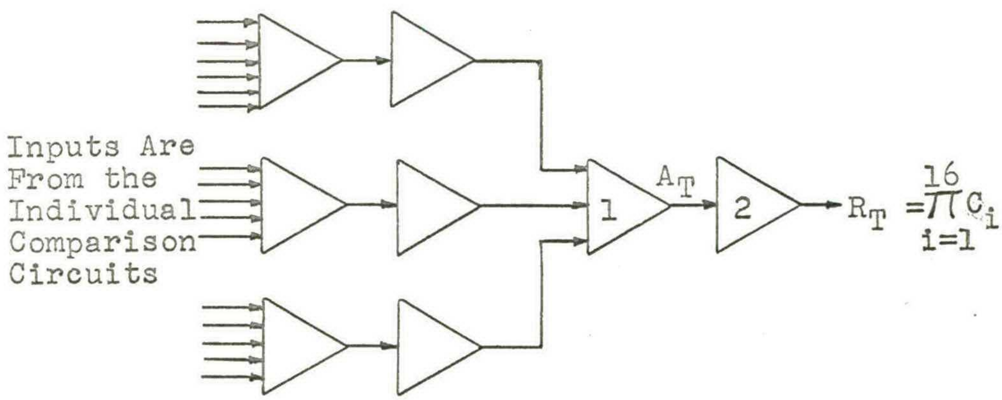


Fig. 20

Final AND Gate

where C_i is the output of each comparison circuit.

$$A_T = \overline{R}_T$$

Gate (1) is a lamp driver for the accept lamp, and inverter (2) is a lamp driver for the reject lamp.

The time-delay circuit is shown in Figure 21. The circuit is a unijunction transistor relaxation oscillator.[3] The basic equation for the time needed "to fire" the unijunction transistor (UJT) is derived as follows:

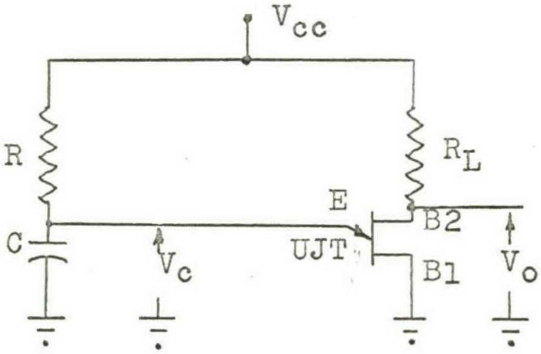


Fig. 21

Unijunction Transistor Relaxation Oscillator

$$V_c = V_{cc}\,(1 - e^{-t/RC}) \qquad (1)$$

When $$V_c = \eta V_{cc} \qquad (2)$$

where η = The intrinsic stand-off ratio of the UJT

the transistor's emitter (E) to base 1 (B1) junction is forward-biased. This allows capacitor C to discharge and the resistance (R_{BB}) from base 2 (B2) to base 1 (B1) reduces. A negative pulse appears at B2. Equation (2) is substituted into equation (1), and the time is determined as a function of R and C:

$$t = -RC\ln(1 - \eta)$$

With $$\eta = 0.7$$

$$t \doteq 1.2RC$$

Since one impulse of the timer corresponds to 167 milliseconds, the minimum and maximum time delays, respectively, are 15 milliseconds and 500 milliseconds. With a 10μf. capacitor

$$R_{MIN} \doteq 1K\Omega$$

$$R_{MAX} \doteq 50K\Omega$$

A 50KΩ potentiometer is used to charge the 10μf. capacitor (Figure 22). The fall time of the pulse at B2 of the unijunction transistor is too long to trigger a flip-flop. Therefore, the pulse is differentiated by a 0.1μf. capacitor, and the 15KΩ voltage divider adjusts the amplitude of the pulse to the correct voltage level needed to drive the two NAND gates.

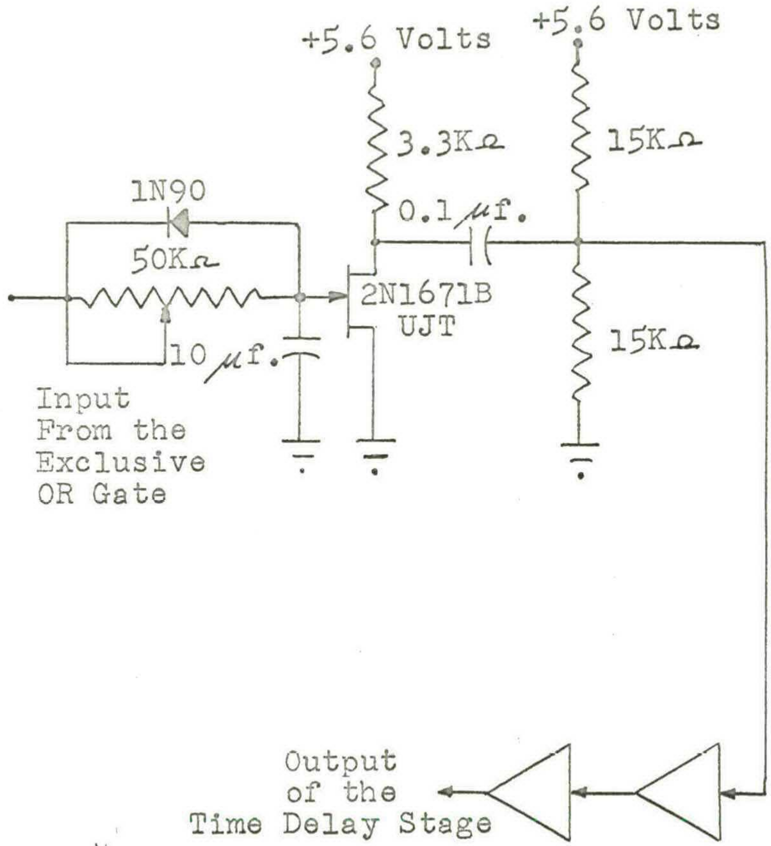


Fig. 22

Time-Delay Stage

3.5 A Description of the Power Control Circuits for the Motor, Brake, and Clutch

A method of transfer is needed from the voltage of the logic circuits to the operating voltage of the control devices. A single-pole, normally-open reed relay is used to mechanize this transfer. The reed relay coil is in the collector circuit of a gate, whose output is the complement of the desired output function. Thus, when the function is a logic 1, the reed relay contact is closed.

The electromagnetic brake and clutch operate on 90 volts d-c. Figure 23 shows the circuit used to control the brake and clutch. One circuit is needed for each. Upon closure of the reed relay contact, the silicon-controlled rectifier (SCR) conducts every other half cycle of the 115-volt, 60-cycle supply voltage. The 150Ω-dropping resistor and $4\mu f.$ capacitor provide approximately 90 volts d-c. to the brake and clutch. There is a sizable ripple content to the voltage, but it is not objectionable.

The motor operates on 115 volts, 60 cycles. Figure 24 shows the circuit used to control the motor. The SCR's are connected back-to-back; thus, they provide a solid-state switch for the motor. The leakage current from the anode to the gate of each SCR is used "to fire" the

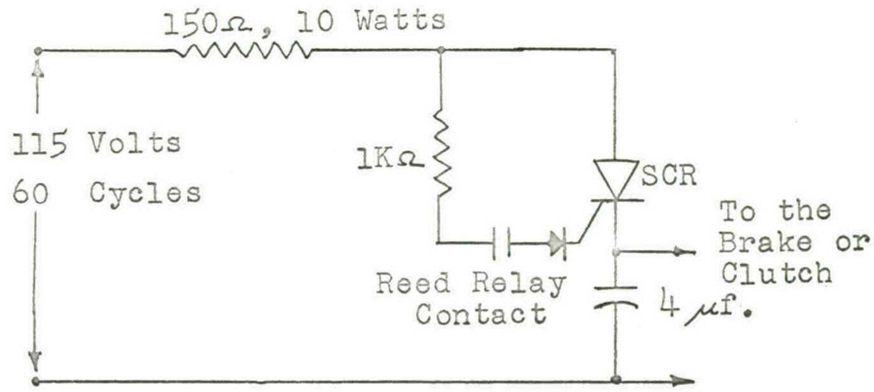


Fig. 23

Control Circuit for the
Brake and Clutch

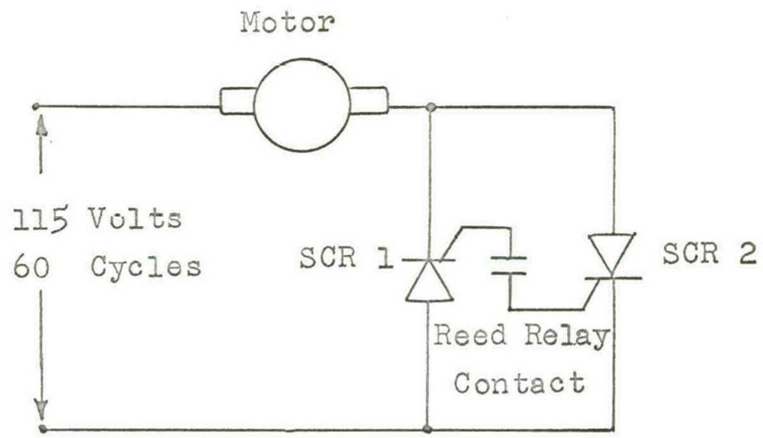


Fig. 24

Control Circuit for the Motor

SCR's when the reed relay contact is closed.

CHAPTER IV

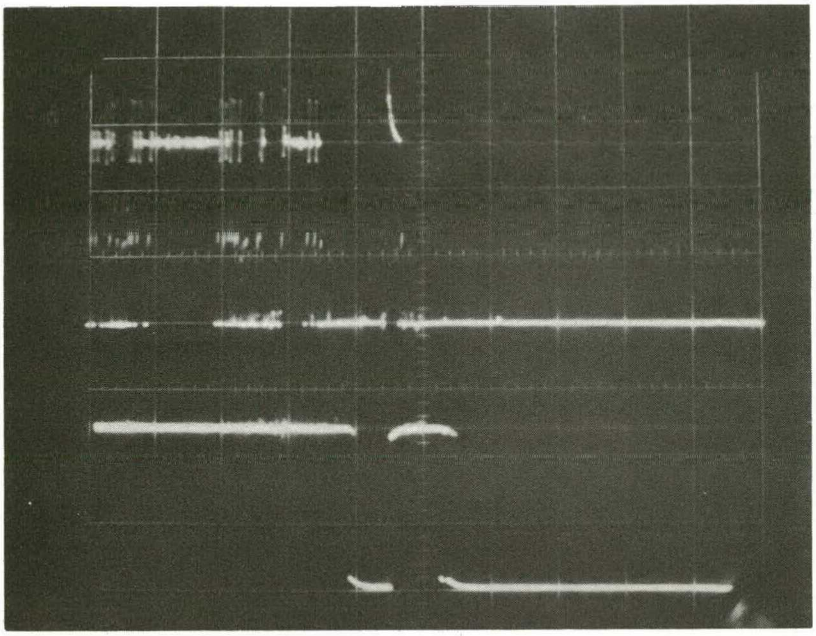
EXPERIMENTAL DATA AND RESULTS

4.1 Experimental Data

Since the entire test depends upon the alignment of the test and master timers, it is essential that the flip-flops, whose outputs are P_T and P_M, are not triggered by contact bounce of their respective pilot light contacts. The upper trace of Figure 25 shows the voltage across the pilot light contact of the test timer as it closes. The upper trace of Figure 26 shows the voltage across the same contact as it closes, with an R-C filter across the contact. Experimentally, 100Ω in series with a 33μf. capacitor was effective in damping the noise.

Figure 25 shows the contact bounce across the pilot light contact and the output of the corresponding reed relay contact. Note that the contact bounce is transferred to the relay contact.

Figure 26 is the same as Figure 25 except that an R-C filter is across the pilot light contact. It is observed that the transfer of the noise to the reed relay



Sweep Rate: 1 millisec/cm.

Amplitude

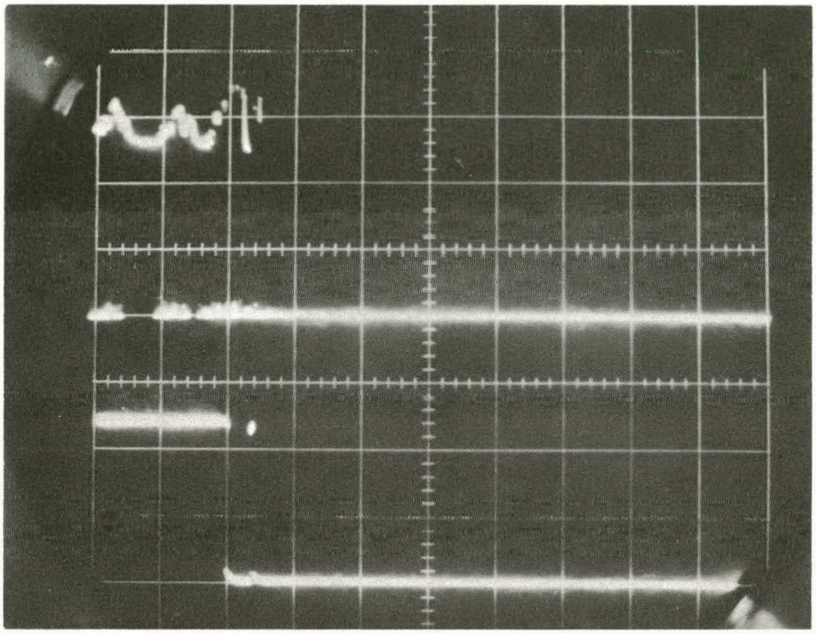
Upper Trace: 2 volts/cm.
Lower Trace: 2 volts/cm.

Upper Trace: Voltage across contact TT without an R-C filter

Lower Trace: Voltage across contact k

Fig. 25

The Transient Voltage Across the Pilot Light Contact of the Test Timer Without an R-C Filter



Sweep Rate: 1 millisec/cm.

Amplitude

Upper Trace: 2 volts/cm.
Lower Trace: 2 volts/cm.

Upper Trace: Voltage across contact TT with an R-C filter

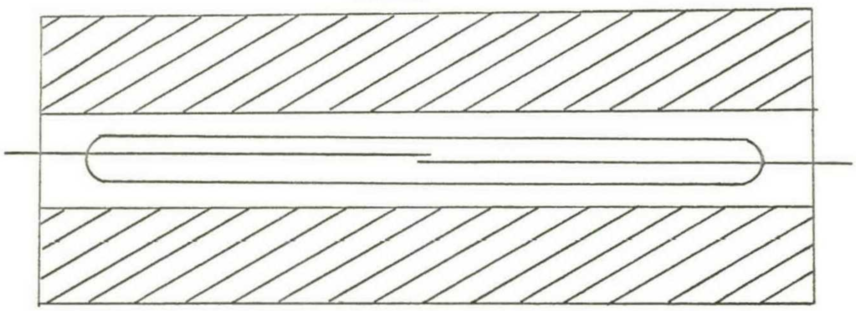
Lower Trace: Voltage across contact k

Fig. 26

The Transient Voltage Across the Pilot Light Contact of the Test Timer With an R-C Filter contact is reduced except for one large pulse. This pulse is believed to be due to an imperfection in the cam. Moreover, the filter eliminates a source of noise that feeds back into the +5.6 volt supply. Without the filter, the motor will not stop when the pilot light contact of the test timer closes. This is due to noise from the contact changing the state of the flip-flop, whose output is P_T.

Also, it was discovered that the reed relays were a source of noise. Upon opening and closing the contacts of the reed relays, the state of the flip-flops changed. Diode suppression of the reed relay coils proved ineffective. Suppression of the reed relay contacts with .01 μf. capacitors helped, but did not eliminate the problem. The construction of the reed relay is such that the contacts are coupled magnetically to the coil (Figure 27). The coil has approximately 10,000 turns so that the contact and coil act as a pulse transformer for any voltage change across the contact. This problem was solved by using a separate power supply for the reed relay coils.

The final noise problem is due to noise pickup from the a-c. line of the motor. It is observed on the oscilloscope that the logic calls for the motor to be



Reed Contact is Enclosed
in the Glass Tube

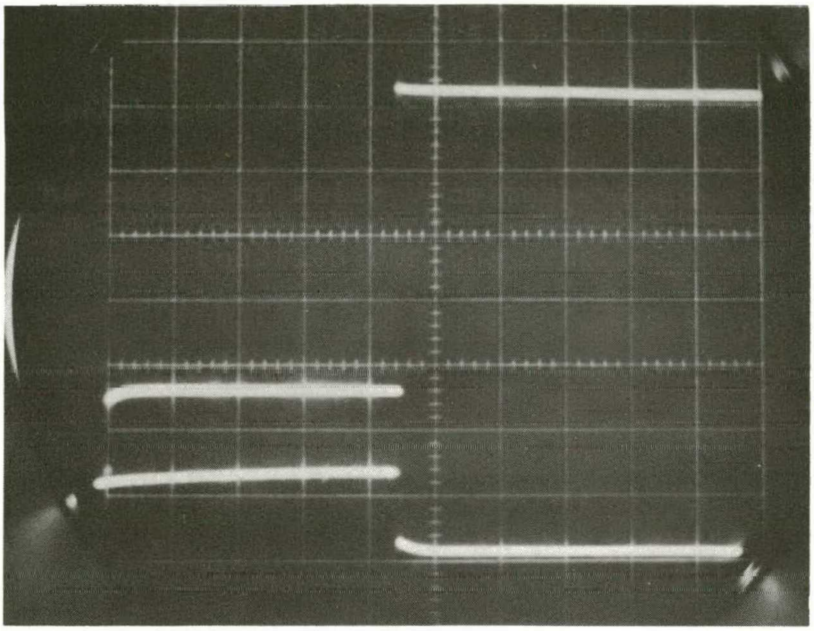
Fig. 27

Construction of the Reed Relay

energized in the middle of the test cycle. However, the flip-flop, whose output is f, changes state as the motor energizes. Figure 28 illustrates this. Figure 29 shows the same noise except that the logic output for the motor did not change. The bottom trace is M. The motor has successfully energized and is rotating the test and master timers. The upper trace is the +5.6 volt supply. At 2.2 milliseconds after M has switched to a logic 1, a noise signal is observed in the +5.6 volt supply. This noise signal is radio-frequency noise from the motor. It is coupled to the +5.6 volt supply from the a-c. line of the motor.

Figure 30 shows T_i, the input from the test timer, and C_i, the output from an individual comparison stage. Both inputs to the exclusive OR gate are a logic 1 until the contact of the test timer closes. Then the input from the test timer changes to a logic 0. After 35 milliseconds the output of the lamp driver changes to a logic 0.

Figure 31 shows the relative alignment of the test and master pilot light contacts. The contacts are aligned within 2 milliseconds of each other. This corresponds to 1.2 per cent of one impulse of the timing cycle.



Sweep Rate: .5 millisec/cm.

Amplitude

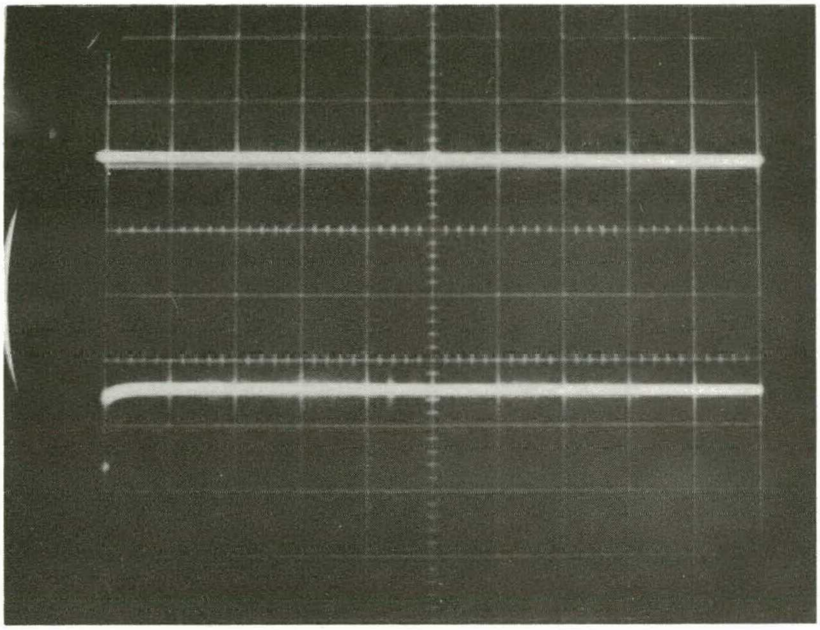
Upper Trace: 1 volt/cm.
Lower Trace: 2 volts/cm.

Upper Trace: Voltage at the output of an inverter for the function M.

Lower Trace: Voltage at the output of a NAND gate for the function M.

Fig. 28

The Effect of Noise Upon the Output Function For the Motor



Sweep Rate: .5 millisec/cm.

Amplitude

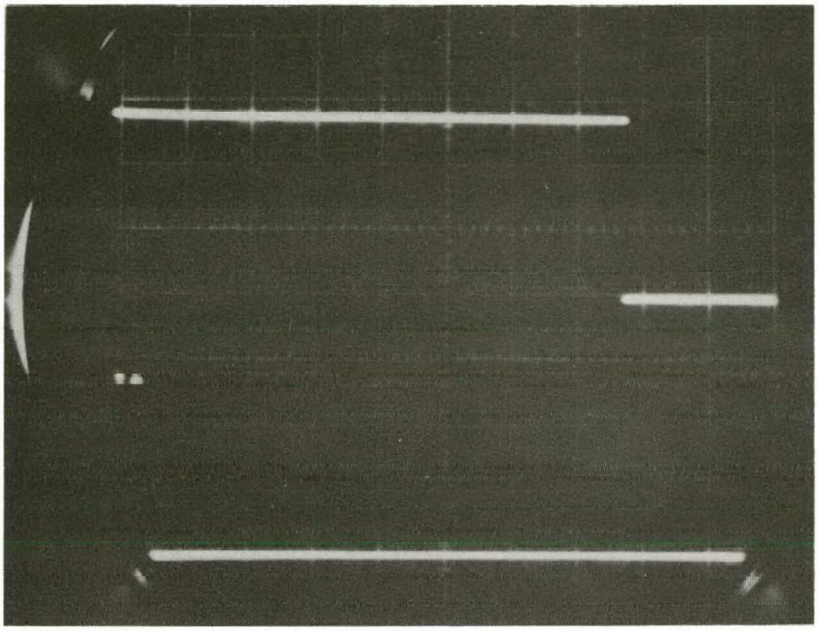
Upper Trace: 2 volts/cm.
Lower Trace: 2 volts/cm.

Upper Trace: +5.6 Voltage Supply.

Lower Trace: Voltage of the output function M.

Fig. 29

A Display of Noise in the Power Supply



Sweep Rate: 5 millisec/cm.

Amplitude

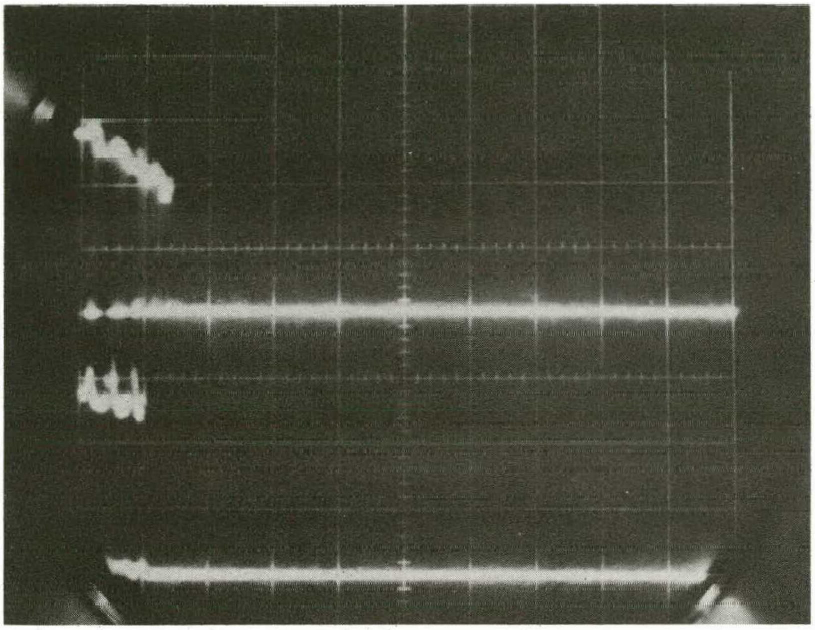
Upper Trace: 2 volts/cm.
Lower Trace: 2 volts/cm.

Upper Trace: Output of an individual comparison circuit.

Lower Trace: Input to the exclusive OR gate from a faulty timer circuit.

Fig. 30

A Display of the Input and Output Voltages of an Individual Comparison Circuit



Sweep Rate: 5 millisec/cm.

Amplitude

Upper Trace: 2 volts/cm.
Lower Trace: 2 volts/cm.

Upper Trace: Voltage across the contact MT with an R-C filter.

Lower Trace: Voltage across the contact TT with an R-C filter.

Fig. 31

A Display of the Voltage Across the Pilot Light Contacts of the Master and Test Timers

4.2 Experimental Results

It was found upon assembling the complete system that the flip-flops in the logic were sensitive to noise. The sources of noise were determined to be the following:

(1) Radiation from fluorescent lamps.

(2) Radiation from the motor.

(3) Electrical noise from the motor.

(4) Electrical noise from the reed relays.

(5) Electrical noise from the timer contacts.

The radiation from the fluorescent lamps was shielded effectively. The electrical noise from the reed relays was eliminated by using a separate +5.6 volt supply for them. The electrical noise from the timer contacts was filtered by an R-C network.

The remaining problem is to filter the electrical noise from the motor. By substituting a 115-volt, 100-watt lamp for the motor and rotating the system by hand, it was confirmed that the noise is from the motor. The logic successfully sequenced through the test cycle.

It was determined that a test timer can be aligned accurately with a master timer. Thus, a comparison of the corresponding circuits of each timer is a feasible method of testing the timers.

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Discussion of the Experimental Results

Since noise affected the logic circuits, the design should be modified to improve the noise immunity of the system. The following changes are recommended by the author:

(1) The zero-volt line should be isolated from the chassis.

(2) The chassis should be connected to earth ground.

(3) All cables should be shielded.

(4) The a-c. and d-c. leads should be kept as far apart as physically possible.

(5) The motor should be filtered effectively for radio-frequency noise.

With the above steps taken, it is the author's opinion that the tester will operate successfully.

Since high-speed logic is not necessary for the successful operation of this tester, it would be better if the logic were mechanized by discrete components. The transistors of the flip-flops could be biased completely into the saturation and cut-off regions.

The requirements of the design as stated in Section 2.1 were met successfully. It was demonstrated that a test timer can be aligned electrically with a master timer.

BIBLIOGRAPHY

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2. Maley, G. E., and Earle, J., _The Logic Design of Transistor Digital Computers_, Englewood Cliffs, New Jersey: Prentice-Hall, Inc.; 1963.
3. "General Electric Transistor Manual", sixth edition, General Electric Company (1962). pp. 191-195.

APPENDIX I

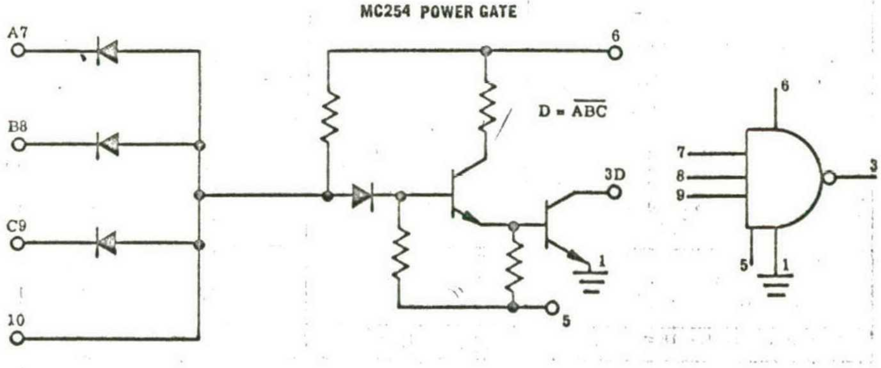
MOTOROLA DIODE TRANSISTOR LOGIC INTEGRATED CIRCUIT DATA

3-Input Diode Transistor Logic NAND/NOR Power Gate.

MAXIMUM RATINGS ($T_A = 25°C$)

Characteristic	Symbol	Rating	Unit
Applied Voltage	$V_{7,8,9}$ V_5 $V_{3,6}$	+8 -6 +6	Vdc
Forward Current	I_5 thru 10	30	mAdc
Load Current	I_3	75	mAdc
Operating Temperature Range	T_J	0 to 75	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

MC254 POWER GATE



MC254 (continued)

ELECTRICAL CHARACTERISTICS (V_4 = 4 Vdc, V_5 = 2 Vdc, V_1 = 0, T_J = 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Output Breakdown Voltage	BV_3				Vdc
(I_8 = 5μAdc, V_7 = 0		6	-	-	
"1" Output Current	I_3				μAdc
($V_{7,8\ or\ 9}$ = 1.0Vdc, V_3 = 5Vdc)		-	-	100	
($V_{7,8\ or\ 9}$ = 0.75Vdc, V_3 = 5Vdc, T_J = 75° C)		-	-	100	
($V_{7,8\ or\ 9}$ = 1.1Vdc, V_3 = 5Vdc, T_J = 0° C)		-	-	100	
"0" Output Current	I_3				mAdc
($V_{7,8\ or\ 9}$ = 2.0Vdc, V_3 = 0.55, T_J = 0 to 75° C)		30	-	-	
Input Breakdown Voltage					Vdc
(I_7 = 10μAdc, V_8 = 0)	BV_7	8.0	-	-	
(I_8 = 10μAdc, V_7 = 0)	BV_8	8.0	-	-	
(I_9 = 10μAdc, V_7 = 0)	BV_9	8.0	-	-	
Input Leakage Current					μAdc
(V_7 = 5Vdc, V_8 = 0)	I_7	-	-	0.50	
(V_7 = 5Vdc, V_8 = 0, T_J = 75° C)	I_7	-	-	25	
(V_8 = 5Vdc, V_7 = 0)	I_8	-	-	0.50	
(V_8 = 5Vdc, V_7 = 0, T_J = 75° C)	I_8	-	-	25	
(V_9 = 5Vdc, V_7 = 0)	I_9	-	-	0.50	
(V_9 = 5Vdc, V_7 = 0, T_J = 75° C)	I_9	-	-	25	
Input Turn-Off Current					mAdc
(Alternately, V_7, V_8, V_9 = 0)	I_7, I_8, I_9	-	-	-4.5	
(Alternately, V_7, V_8, V_9 = 0, T_J = 0 to 75° C)	I_7, I_8, I_9	-	-		
(V_{10} = 0)	I_{10}	-	-	-5.5	
Output Capacitance	C_3				pf
(V_3 = 2.0Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)		-	-	15	
Input Capacitance					pf
(V_7 = 2.0Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_7	-	-	10	
(V_8 = 2.0Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_8	-	-	10	
(V_9 = 2.0Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_9	-	-	10	
Power Supply					mW
(Output "OFF", V_7 = 0)		-	-	23	
(Output "ON")		-	-	66	
Switching Times					nsec
Turn-On Delay	t_{on}	-	-	35	
Turn-Off Delay	t_{off}	-	-	100	
Average Propagation Delay	t_{pd}	-	40	-	nsec

MC258

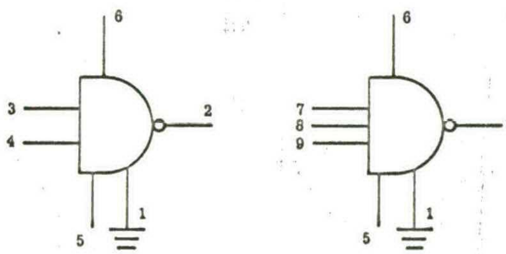
MC250 DTL SERIES

Dual (3-2) Input Diode Transistor Logic NAND/NOR Gate.

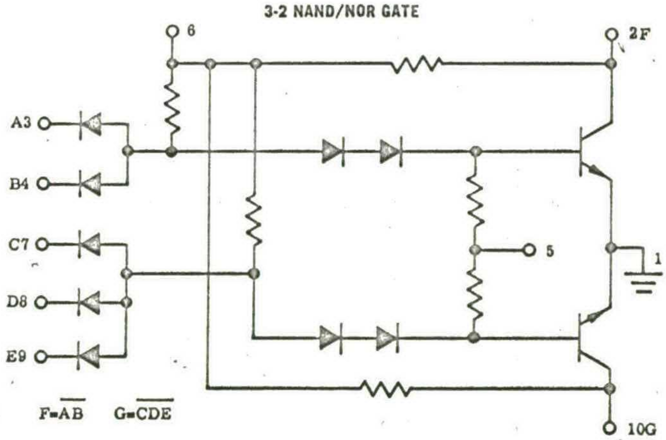
MAXIMUM RATINGS ($T_J = 25°C$ unless otherwise noted)

Characteristic	Symbol	Rating	Unit
Applied Voltage	$V_{3,4,6 \text{ thru } 9}$ V_5 $V_{2,10}$	+8 -8 +6	Vdc
Forward Current	$I_{2,10}$ $I_{2 \text{ thru } 4, 7 \text{ thru } 10}$	+30 -30	mAdc
Operating Temperature Range	T_J	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

MC258



3-2 NAND/NOR GATE



MC258 (continued)

ELECTRICAL CHARACTERISTICS

(V_4 = 4 Vdc, V_5 = 2 Vdc, V_1 = 0, T_J = 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Output Saturation Voltage					Vdc
(I_2 = 8mAdc, V_3 = V_4 = 2Vdc, T_J = 0 to 75° C)	V_2	-	-	0.55	
(I_{10} = 8mAdc, V_7 = V_8 = V_9 = 2Vdc T_J = 0 to 75° C)	V_{10}	-	-	0.55	
Output "Off" Voltage					Vdc
(I_2 = 100μAdc, V_3 = 1.0Vdc	V_2	3.5	-	-	
(I_2 = 100μAdc, V_3 = 0.75Vdc, T_J = 75° C)	V_2	3.5	-	-	
(I_2 = 100μAdc, V_3 = 1.1Vdc, T_J = 0° C)	V_2	3.5	-	-	
(I_{10} = 100μAdc, V_7 = 1.0Vdc	V_{10}	3.5	-	-	
(I_{10} = 100μAdc, V_7 = 0.75Vdc, T_J = 75° C)	V_{10}	3.5	-	-	
(I_{10} = 100μAdc, V_7 = 1.1Vdc, T_J = 0° C)	V_{10}	3.5	-	-	
Input Breakdown Voltage					Vdc
(I_3 = 10μAdc, V_4 = 0)	BV_3	8	-	-	
(I_4 = 10μAdc, V_3 = 0)	BV_4	8	-	-	
(I_7 = 10μAdc, V_8 = 0)	BV_7	8	-	-	
(I_8 = 10μAdc, V_7 = 0)	BV_8	8	-	-	
(I_9 = 10μAdc, V_7 = 0)	BV_9	8	-	-	
Input Leakage Current	I_3, I_4, I_7, I_8, I_9				μAdc
(Diode under test at 5Vdc, all other inputs = 0)		-	-	0.50	
(Diode under test at 5Vdc, all other inputs = 0, T_J = 75° C)		-	-	25	
Input Turn-Off Current	I_3, I_4, I_7, I_8, I_9				mAdc
(Alternately V_3, V_4, V_7, V_8, V_9 = 0)		-	-	-2.3	
(Alternately V_3, V_4, V_7, V_8, V_9 = 0, T_J = 0 to 75° C)		-	-	-2.5	
Output Capacitance					pf
(V_2 = 2.0Vdc, V_3 = 0, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_2	-	-	10	
(V_{10} = 2.0Vdc, V_7 = 0, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_{10}	-	-	10	

MC258 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Input Capacitance					pf
(V_3 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_3	-	-	10	
(V_4 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_4	-	-	10	
(V_7 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_7	-	-	10	
(V_8 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_8	-	-	10	
(V_9 = 2Vdc, V_{in} = 25mVrms, f = 1mc unused pins grounded)	C_9	-	-	10	
Power Consumption Power Supply	-				mW
(Output "Off", $V_3 = V_7 = 0$)		-	-	20	
(output "On")		-	-	34	
Switching Times					nsec
Turn-On Delay	t_{on}	-	-	60	
Turn-Off Delay	t_{off}	-	-	60	
Average Propagation Delay	t_{pd}	-	30	-	nsec

MC259

MC250 DTL SERIES

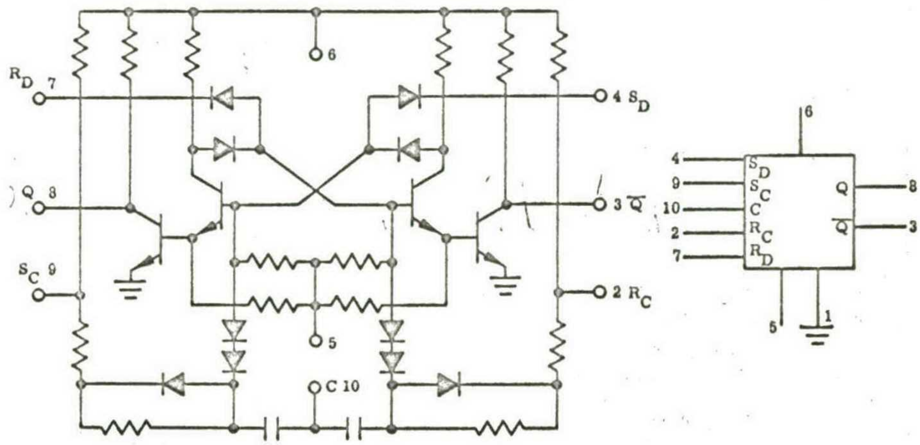
Diode Transistor Logic Flip-Flop.

MAXIMUM RATINGS ($T_J = 25°C$)

Characteristic	Symbol	Rating	Unit
Applied Voltage	$V_{2,3,4,6,7,8,9,10}$	+8	Vdc
	V_5	-8	
Forward Current	$I_{3,8}$	+50	mAdc
	$I_{2,3,4,}$ 7 thru 10	-30	
Operating Temperature Range	T_J	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

MC259 (continued)

MC259 BINARY ELEMENT



MC259 (continued)

ELECTRICAL CHARACTERISTICS

(V_4 = 4 Vdc, V_5 = 2 Vdc, V_1 = 0, T_J = 25°C unless otherwise noted)

Characteristic	Logic Symbol	Logic State	Symbol	Minimum	Typical	Maximum	Unit
OUTPUT LEVEL							
"Off" Voltage							
(I_8 = -200μAdc, V_4 = 0.55Vdc, V_7 = 2.0Vdc, T_A = 0 to 75°C)	Q	1	V_8	2.5	-	-	Vdc
(I_3 = -200μAdc, V_4 = 2.0Vdc, V_7 = 0.6Vdc, T_A = 0 to 75°C)	$\overline{Q}$	1	V_3	2.5	-	-	Vdc
"On" Voltage							
(I_8 = 16mAdc, V_4 = 2.0Vdc, V_7 = 0.55Vdc, T_A = 0 to 75°C)	Q	0	V_8	-	-	0.55	Vdc
(I_3 = 16mAdc, V_4 = 0.55Vdc, V_7 = 2.0Vdc, T_A = 0 to 75°C)	$\overline{Q}$	0	V_3	-	-	0.55	Vdc
DIRECT SET-RESET INPUTS							
"Up" Voltage	S_D	1	V_4	2.0	-	-	Vdc
	R_D	1	V_7	2.0	-	-	Vdc
"Down" Voltage	S_D	0	V_4	-	-	0.55	Vdc
	R_D	0	V_7	-	-	0.55	Vdc
"Up" Current							
(V_4 = 5Vdc, T_J = 75°C)	S_D	1	I_4	-	-	25	μAdc
(V_7 = 5Vdc, T_J = 75°C)	R_D	1	I_7	-	-	25	μAdc
"Down" Current							
(V_4 = 0)	S_D	0	I_4	-	-	-2.3	mAdc
(V_7 = 0)	R_D	0	I_7	-	-	-2.3	mAdc
CLOCKED SET-RESET INPUTS							
"Down" Current							
($V_{9,10}$ = 0, T_J = 25°C)	S_C	0	I_9	-	-	-1.75	mAdc
($V_{2,10}$ = 0, T_J = 25°C)	R_C	0	I_2	-	-	-1.75	mAdc
Effective Clock Input Capacitance			C_{10}	-	75	-	pf
SWITCHING TIME							
Clocked Set-Reset Mode							
Turn-On Delay			t_{on}	-	-	100	nsec
Turn-Off Delay			t_{off}	-	-	75	nsec
Direct Set-Reset Mode							
Turn-On Delay			t_{on}	-	-	100	nsec
Turn-Off Delay			t_{off}	-	-	75	nsec
POWER CONSUMPTION				-	16	-	mW

MC262

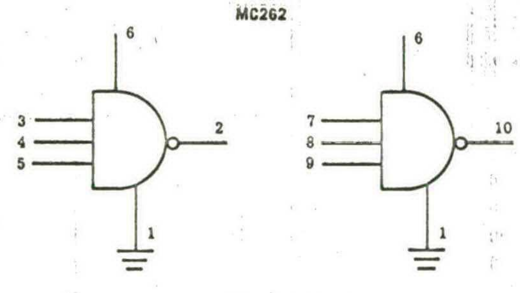
MC250 DTL SERIES

Dual (3-3) Input Diode Transistor Logic NAND/NOR Gate.

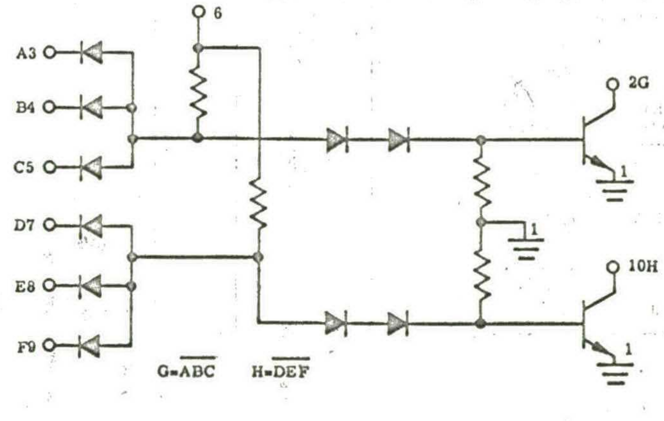
MAXIMUM RATINGS (T_J = 25°C unless otherwise noted)

Characteristic	Symbol	Rating	Unit
Applied Voltage	V_3 thru 9 $V_{2,10}$	+8 +6	Vdc
Forward Current	$I_{2,10}$ I_2 thru 5, 7 thru 10	+30 -30	mAdc
Operating Temperature Range	T_J	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

MC262



3-3 NAND/NOR GATE



MC262 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Output Capacitance					pf
(V_2 = 2.0Vdc, V_3 = 0, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_2	-	-	10	
(V_{10} = 2.0Vdc, V_7 = 0, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_{10}	-	-	10	
Input Capacitance					pf
(V_3 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_3	-	-	10	
(V_4 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_4	-	-	10	
(V_5 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_5	-	-	10	
(V_7 - 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_7	-	-	10	
(V_8 = 2Vdc, V_{in} = 25mVrms, f = 1mc, unused pins grounded)	C_8	-	-	10	
(V_9 = 2Vdc, V_{in} = 25mVrms, f = 1mc,	C_9	-	-	10	
Power Consumption from Power Supply					mW
(Output "Off", V_3 = V_7 = 0)		-	-	19	
(Output "On")		-	-	12	
Switching Times					nsec
Turn-On Delay	t_{on}	-	-	60	
Turn-Off Delay	t_{off}	-	-	60	
Average Propagation Delay	t_{pd}	-	30	-	nsec

MC262 (continued)

ELECTRICAL CHARACTERISTICS

($V_6 = 4$ Vdc, $V_5 = 2$ Vdc, $V_1 = 0$, $T_J = 25°C$ unless otherwise noted)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Output Breakdown Voltage					Vdc
($I_2 = 5\mu$Adc, $V_3 = 0$)	BV_2	6	-	-	
($I_{10} = 5\mu$Adc, $V_7 = 0$)	BV_{10}	6	-	-	
"1" Output Current					Adc
($V_3 = 1.0$Vdc, $V_2 = 5$Vdc)	I_2	-	-	50	
($V_3 = 0.75$Vdc, $V_2 = 5$Vdc, $T_J = 75°C$)	I_2	-	-	50	
($V_3 = 1.1$Vdc, $V_2 = 5$Vdc, $T_J = 0°C$)	I_2	-	-	50	
($V_7 = 1.0$Vdc, $V_{10} = 5$Vdc)	I_{10}	-	-	50	
(V_7 0.75Vdc, $V_{10} = 5$Vdc, $T_J = 75°C$)	I_{10}	-	-	50	
($V_7 = 1.1$Vdc, $V_{10} = 5$Vdc, $T_J = 0°C$)	I_{10}	-	-	50	
"0" Output Current					mAdc
($V_{in} = 2$Vdc, $V_2 = 0.55$, $T_J = 0$ to $75°C$)	I_2	10	-	-	
($V_{in} = 2$Vdc, $V_{10} = 0.55$, $T_J = 0$ to $75°C$)	I_{10}	10	-	-	
Input Breakdown Voltage					Vdc
($I_3 = 10\mu$Adc, $V_4 = 0$)	BV_3	8	-	-	
($I_4 = 10\mu$Adc, $V_3 = 0$)	BV_4	8	-	-	
($I_5 = 10\mu$Adc, $V_3 = 0$)	BV_5	8	-	-	
($I_7 = 10\mu$Adc, $V_8 = 0$)	BV_7	8	-	-	
($I_8 = 10\mu$Adc, $V_7 = 0$)	BV_8	8	-	-	
($I_9 = 10\mu$Adc, $V_7 = 0$)	BV_9	8	-	-	
Input Leakage Current	$I_3, I_4, I_5, I_7, I_8, I_9$				μAdc
(Diode under test at 5Vdc, all other inputs = 0)		-	-	0.50	
(Diode under test at 5Vdc, all other inputs = 0, $T_J = 75°C$)		-	-	25	
Input Turn-Off Current	$I_3, I_4, I_5, I_7, I_8, I_9$				mAdc
(Alternately $V_3, V_4, V_5, V_7, V_8, V_9 = 0$)		-	-	-2.3	
(Alternately $V_3, V_4, V_5, V_7, V_8, V_9 = 0$, $T_J = 0$ to $75°C$)		-	-	-2.5	

MC267

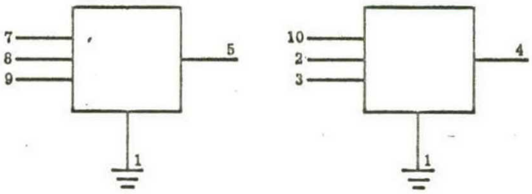
MC250 DTL SERIES

Diode Transistor Logic Dual-Diode Array.

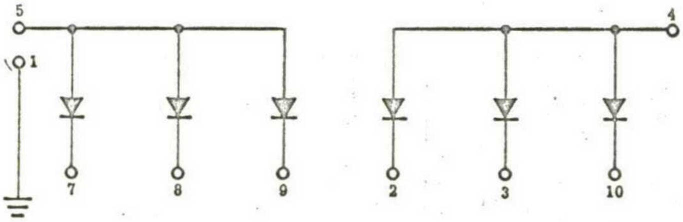
MAXIMUM RATINGS ($T_A = 25°C$)

Characteristic	Symbol	Rating	Unit
Applied Voltage	$V_{2,3,}$ 7 thru 10	8	Vdc
Forward Current	I_2 thru 5, 7 thru 10	30	mAdc
Operating Temperature Range	T_J	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

MC267



DUAL DIODE ARRAY



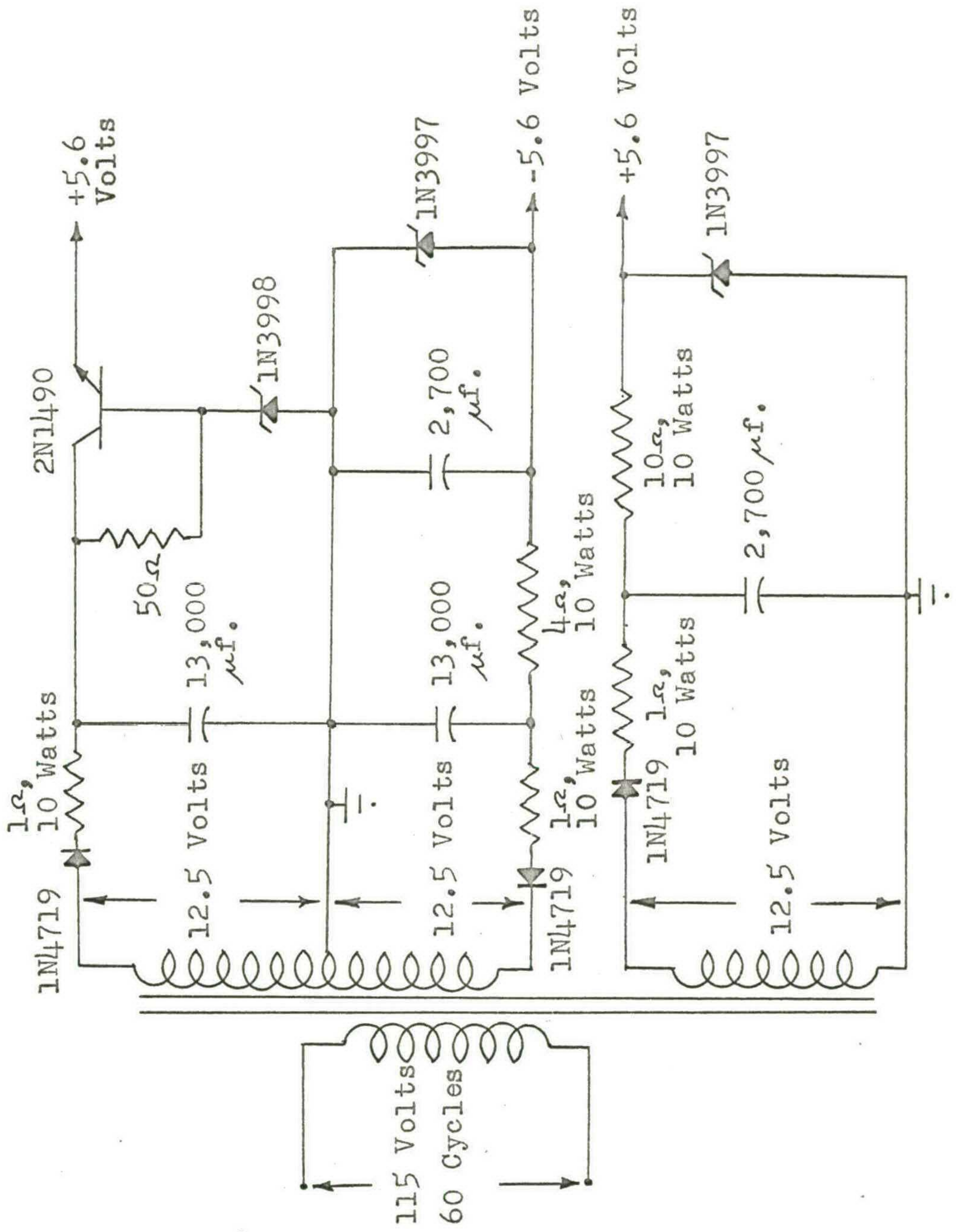
MC267 (continued)

ELECTRICAL CHARACTERISTICS (T_J = 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Diode Breakdown Voltage					Vdc
($I_{2,3,10}$ = 10μAdc, $V_4 = V_1 = 0$)	$V_{2,3,10}$	8	-	-	
($I_{7,8,9}$ = 10μAdc, $V_5 = V_1 = 0$)	$V_{7,8,9}$	8	-	-	
Diode Forward Voltage					Vdc
(I_4 = 2mAdc, $V_{2,3,10} = V_1 = 0$)	V_4	-	-	0.85	
(I_5 = 2mAdc, $V_{7,8,9} = V_1 = 0$)	V_5	-	-	0.85	
Diode Reverse Leakage Current					μAdc
($V_{2,3,10}$ = 5Vdc, $V_4 = V_1 = 0$)	$I_{2,3,10}$	-	-	0.50	
($V_{2,3,10}$ = 5Vdc, $V_4 = V_1 = 0$, T_J = 75°C)				25	
($V_{7,8,9}$ = 5Vdc, $V_5 = V_1 = 0$)	$I_{7,8,9}$	-	-	0.50	
($V_{7,8,9}$ = 5Vdc, $V_5 = V_1 = 0$, T_J = 75°C)				25	
Input Capacitance					pf
($V_{2,3,10}$ = 2Vdc, $V_4 = V_1 = 0$, f = 1mc, V_{in} = 25mVrms, unused inputs grounded)	$C_{2,3,10}$	-	-	10	
($V_{7,8,9}$ = 2Vdc, $V_5 = V_1 = 0$, f = 1mc, V_{in} = 25mVrms, unused inputs grounded)	$C_{7,8,9}$	-	-	10	
Reverse Recovery Time					nsec
($I_{F2,3,10} = I_{R2,3,10}$ = 2mAdc, $V_4 = V_1 = 0$, Recover to 0.2mAdc)	$t_{rr2,3,10}$	-	-	4	
($I_{F7,8,9} = I_{R7,8,9}$ = 2mAdc $V_5 = V_1 = 0$, recover to 0.2mAdc)	$t_{rr7,8,9}$	-	-	4	
Diode Forward Conductance Change with Temperature	$\Delta V_{F2,3,10}$	-	-1.7	-	mV/°C
	$\Delta V_{F7,8,9}$	-	-1.7	-	

APPENDIX II

SCHEMATIC OF THE POWER SUPPLY



+5.6 Volts
2N1490
1N3998
1N3997
-5.6 Volts
+5.6 Volts
1N3997
50Ω
13,000 μf.
13,000 μf.
2,700 μf.
4Ω, 10 Watts
10Ω, 10 Watts
2,700 μf.
1Ω, 10 Watts
1Ω, 10 Watts
1Ω, 10 Watts
1N4719
1N4719
1N4719
12.5 Volts
12.5 Volts
12.5 Volts
115 Volts
60 Cycles

APPENDIX III

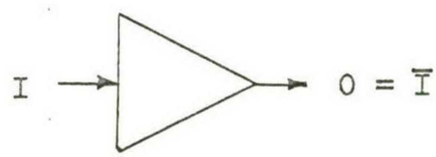
DESCRIPTION OF THE SYMBOLS USED FOR BOOLEAN OPERATIONS

Positive logic is used. Thus a 1 represents +5.6 volts and a 0 represents zero-volts. The Boolean AND and OR operations are represented, respectively, by a "." and "+". The Boolean complement of a variable is represented by a bar over the variable.

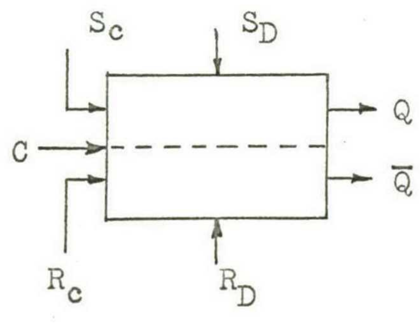
Thus, $R_T = \overline{A}_T$

means R_T is the complement of A_T.

The block diagram shown below represents a NAND gate.



The block diagram shown below represents a flip-flop.



The definitions of the symbols are the following:

(1) S_C is the a-c. set input.

(2) R_C is the a-c. reset input.

(3) S_D is the d-c. set input.

(4) R_D is the d-c. reset input.

(5) C is the clock input.

(6) Q is the output.

(7) $\overline{Q}$ is the complement of the output.

The truth tables for a flip-flop are shown below.

Clocked Set - Reset		
S_c	R_c	Q
0	0	?
0	1	1
1	0	0
1	1	No Change

Direct Set - Reset		
S_D	R_D	Q
0	0	*
0	1	1
1	0	0
1	1	No Change

* Both Q and $\overline{Q}$ are in state 1 until either S_D or R_D rises.

APPENDIX IV

DEFINITIONS OF THE BOOLEAN VARIABLES

1. A_T is the output of a power NAND gate that controls the accept lamp.
2. B is the logic output for the brake.
3. C is the logic output for the clutch.
4. C_i is the output of the i-th individual comparison circuit.
5. f is the feedback variable in the control logic.
6. G is the output of a power NAND gate that controls the reset lamp.
7. J is the reed relay coil controlled by the pilot light contact of the master timer.
8. j is the normally-open contact of the reed relay coil J.
9. K is the reed relay coil controlled by the pilot light contact of the test timer.
10. k is the normally-open contact of reed relay coil K.
11. M is the logic output for the motor.
12. M_i is the i-th circuit in the master timer.
13. MT is the pilot light contact of the master timer.
14. P is the relay which controls the power to the logic.

15. p_1 is the normally-open contact of P.

16. p_2 is the normally-open contact of P.

17. p_3 is the normally-open contact of P.

18. Q_i is the output of the flip-flop in the i-th individual comparison circuit.

19. R is the relay used to reset the logic.

20. r_1 is a normally-open contact of R.

21. r_2 is a normally-open contact of R.

22. r_3 is a normally-open contact of R.

23. R_T is the output of an inverter that controls a reject lamp.

24. S is the output of a flip-flop that is controlled by the start button.

25. T_i is the i-th circuit of the test timer.

26. TT is the pilot light contact of the test timer.

27. Y is the output of a power NAND gate that prevents the motor, brake, and clutch from being on at the same time.

28. y' is the normally-closed contact of a reed relay in the collector circuit of a power NAND gate, whose output is Y.

APPENDIX V

HAYDON ELECTROMAGNETIC BRAKES AND CLUTCHES

ELECTROMAGNETIC CLUTCHES AND BRAKES

UNIQUE ADVANTAGES

- The magnetic coupling takes place in milliseconds . . . no mechanical lag, no clearances to take up.
- Torque is applied smoothly . . . gear train backlash or belt windup is absorbed by the gradual torque build-up.
- Torque can be adjusted electrically . . . infinite control allows stepless control of engagement speed.
- Engaging faces of units are completely self-adjusting — no wear take-up or mechanical torque adjustments necessary.
- Magnetic clutch is a model of simplicity — only a few compact parts — no bands, links or cams to wear out or break.
- Power requirements are low . . . the Haydon 25 Series units, capable of coupling a 1 HP drive at 3000 RPM, utilize only 7 Watts @ 90 Volts DC.

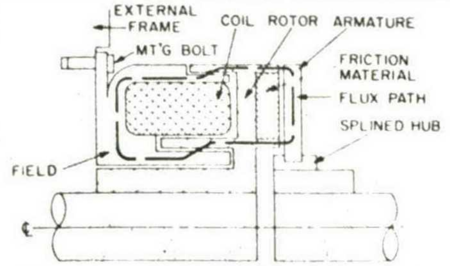
In any given series there are three basic types . . .

CLUTCH-COUPLING • CLUTCH • BRAKE

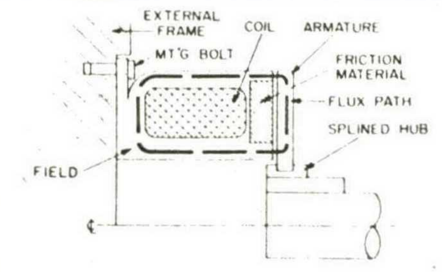
The *clutch-coupling* and *the clutch* consist of three basic elements: the *field*, the *rotor* and the *armature*. The field and its coil are held stationary. The rotor is normally driven by a prime mover such as an electric motor and the armature is attached to the load. When the field coil is energized, a flux path is set up and the armature is magnetically attracted to the rotor. Through friction, the armature and the load to which it is connected will lock in at the same speed as the rotor, as long as the field coil is energized. When the field coil is de-energized, the armature disengages, no torque is transmitted, and the armature and load come to rest.

The brake consists of two basic elements: the *field* and the *armature*. The field and its coil are held stationary. The armature and the load are driven by a prime mover such as an electric motor. When the field coil is energized, a flux path is set up and the armature and the load to which it is connected will be brought to rest if sufficient excitation is applied. The prime mover is normally disconnected or de-energized when the field coil is energized. When the field coil is de-energized, the armature disengages from the field, no torque is transmitted, and the load and prime mover are again independent of the brake.

Friction material used has been carefully selected for stable operation and for its ability to withstand the most severe application. Do not allow oil or grease to contaminate the friction surfaces.



CLUTCH AND CLUTCH COUPLING FLUX PATH
(CLUTCH-COUPLING TYPE SHOWN)



BRAKE FLUX PATH

HAYDON CLUTCHES and BRAKES

Haydon manufactures clutches, clutch couplings and brakes in both flange and bearing mounted types. Presently three sizes are available: Series 08, with approximately 0.875" diameter frictional elements and a static torque rating of 2 lb. in.; Series 17, with approximately 1.725" diameter frictional elements and a static torque rating of 12 lb. in.; and Series 25, with approximately 2.64" diameter frictional elements and 70 lb. in. static torque rating.

The 17 and 25 Series are available in all standard types, both flange and bearing mounted, except brakes, which are flange mounted only. The 08 Series is available as standard in all types, flange mounted only. Bearing mounted 08 Series are available on special order. Anti-backlash armatures on Series 08 and return spring armatures on Series 17 & 25 are available on special order.

OUTSTANDING FEATURES

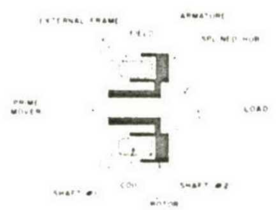
- New design, new manufacturing methods*, and new magnetic circuits enable Haydon to offer a better clutch at substantially lower prices.
- Friction faces extend to the maximum diameter of the units, providing 25% greater friction area and a correspondingly longer life than conventional units.
- Rotor surrounds the field coil to provide high flux magnetic coupling, lower unit force and stable operation.
- Haydon clutches and brakes have the highest torque to size ratings in the industry, with adequate safety factors.
- Improved magnetic circuit provides low residual torque and fast torque build-up and decay times.
- New construction allows larger bore sizes to be used.

** patents applied for*

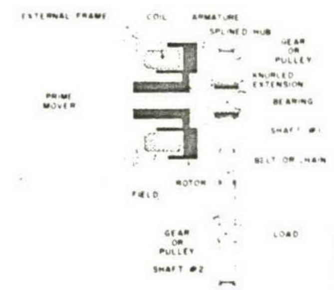
STANDARD TYPES

There are basically *three* types of units . . .

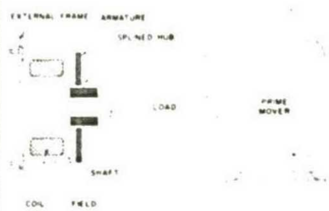
1. *Clutch Coupling* – Used to couple two in-line shafts. The rotor is attached to one shaft and the armature to the other.
2. *Clutch* – Used to couple two parallel shafts. The rotor and the armature are mounted on the same shaft. The armature is bearing mounted on the shaft and is free to rotate independent of it. A knurled extension or extended hub with keyway is provided on the hub allowing the press fit of a gear or pulley to it for driving over to the parallel shaft.
3. *Brake* – Used to stop or hold the armature and load to which it is attached. The armature is attached to a shaft which is connected to the load. The standard brake unit is furnished for in-line connection similar to the clutch-coupling unit.



CLUTCH COUPLING
(FLANGE MOUNTING TYPE SHOWN)



CLUTCH
(FLANGE MOUNTING TYPE SHOWN)

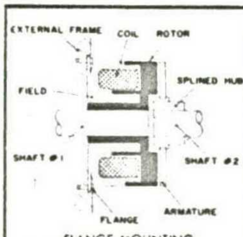


BRAKE
(FLANGE MOUNTING TYPE SHOWN)

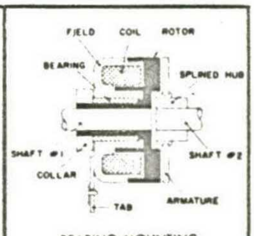
Mounting is of two types...

FLANGE or BEARING

Flange mounting is utilized to mount the stationary field assembly on a fixed frame. The field is mechanically isolated from the driving members and shafts. In bearing mounting, the field is supported by a sleeve bearing between the field and rotor. A pin tab on the field is used to hold it loosely in position to a fixed frame, thereby restraining it from rotating with the driving members.



FLANGE MOUNTING
(CLUTCH COUPLING TYPE SHOWN)



BEARING MOUNTING
(CLUTCH COUPLING TYPE SHOWN)

APPLICATION DATA

Always place the clutch, clutch-coupling or brake on the highest speed shaft practical. The torque required is inversely proportional to the speed, as shown in the formula for torque capacity. Therefore, the higher the speed of the shaft, the smaller the size of the clutch or brake required. The actual location of the clutch, clutch-coupling or brake will normally be dictated by space or shaft size limitations.

The torque requirement of a given size clutch or clutch-coupling is dependent on whether the torque is required during or after acceleration. The torque capacity of the clutch or clutch-coupling when the load is applied during acceleration is taken as the torque available at the maximum slip speed at which the load is operated.

The torque capacity of the clutch or clutch-coupling when the load is applied after acceleration is taken as the static torque rating of the unit. When in doubt, select the clutch or clutch-coupling unit size based on maximum torque requirement during acceleration.

The torque requirement of a given size brake is based on load application after acceleration – the static torque rating of the unit. This will provide a braking time at least equivalent to the time required for a similar-sized clutch to accelerate the same load. For very rapid and accurate stopping times inertia and time constants of the system become important. Such applications should be referred to the Factory.

The following formula and tables may be used to determine the size of the clutch, clutch-coupling or brake unit required for the majority of standard applications. However, for special applications involving such considerations as high inertia loads, heavy duty cycles, rapid acceleration or stopping consult a Haydon Sales Representative or the Factory.

The formula shown below may be used for standard clutch, clutch-coupling and brake applications.

$$T = \frac{HP \times 5250 \times K}{N}$$

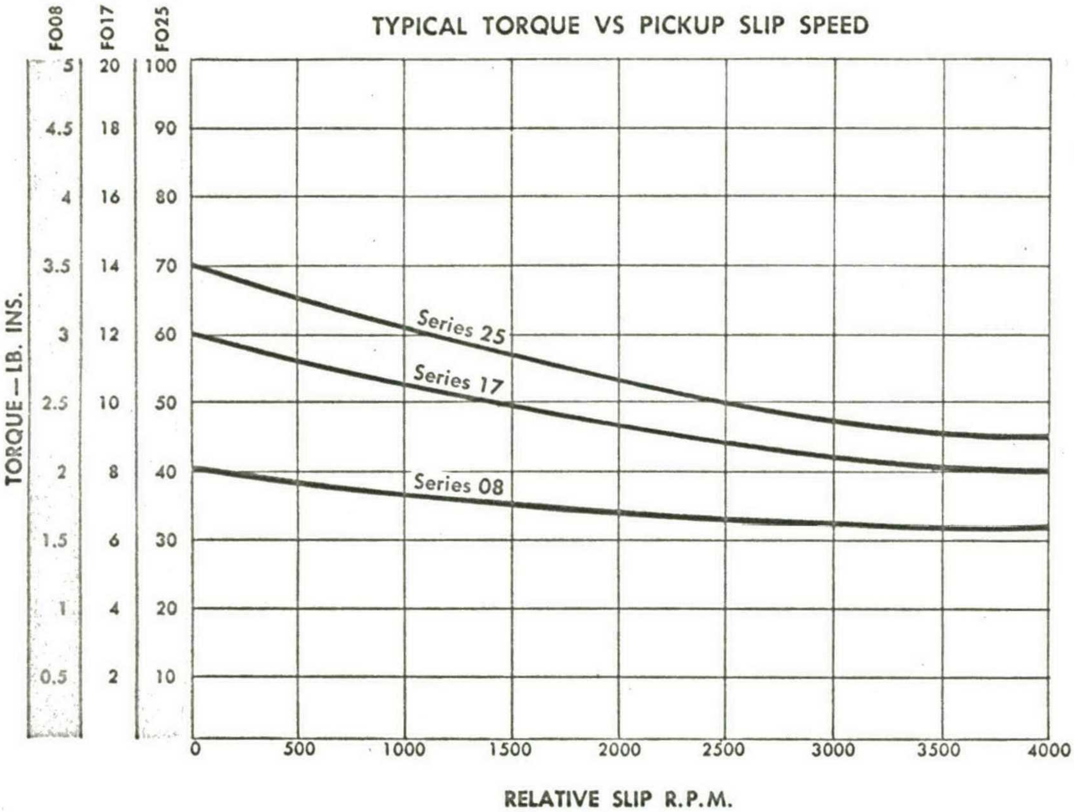
where T = Torque capacity required – (lb. ft.)

HP = Horsepower driving

N = Maximum speed of clutch or brake – (rpm)

K = Service factor = 2

The torque capacity of the clutch, clutch-coupling or brake selected must exceed "T", derived from the formula above. This torque is based on the rated coil current.



Series 08 ☐ Series 17 ☐ Series 25 ☐

SELECTION CHART FOR CLUTCHES AND CLUTCH COUPLINGS.
Load is applied before clutch is energized. Service Factor: 2

TORQUE AT VARIOUS HORSEPOWERS—LB. INS.

SHAFT SPEED AT CLUTCH (R.P.M.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	2
100	3.15	6.30	12.6	31.5	42.0	52.5	63.0	78.8	105	158	210	315	473	630	945	1260
200	1.58	3.15	6.30	15.8	21.0	26.3	31.5	39.4	52.5	78.8	105	158	237	315	473	630
300	1.05	2.10	4.20	10.5	14.0	17.5	21.0	26.3	35.0	52.5	70.0	105	158	210	315	420
400	.79	1.58	3.15	7.88	10.5	13.1	15.8	19.7	26.3	39.4	52.5	78.8	118	158	237	315
500	.63	1.26	2.52	6.30	8.40	10.5	12.6	15.8	21.0	31.5	42.0	63.0	94.5	126	189	252
600	.53	1.05	2.10	5.25	7.00	8.75	10.5	13.1	17.5	26.3	35.0	52.2	78.8	105	158	210
700	.45	.90	1.80	4.50	6.00	7.50	9.00	11.3	15.0	22.5	30.0	45.0	67.5	90.0	135	180
800	.39	.79	1.58	3.94	5.25	6.57	7.88	9.85	13.1	19.7	26.3	39.4	59.1	78.8	118	158
900	.35	.70	1.40	3.50	4.67	5.83	7.00	8.75	11.7	17.5	23.4	35.0	52.5	70.0	105	140
1000	.32	.63	1.26	3.15	4.20	5.25	6.30	7.88	10.5	15.8	21.0	31.5	47.3	63.0	94.5	126
1100	.29	.57	1.15	2.86	3.82	4.77	5.73	7.16	9.55	14.3	19.1	28.6	42.9	57.3	85.9	115
1200	.26	.53	1.05	2.63	3.50	4.38	5.25	6.56	8.75	13.1	17.5	26.3	39.4	52.5	78.8	105
1500	.21	.42	.84	2.10	2.80	3.50	4.20	5.25	7.00	10.5	14.0	21.0	31.5	42.0	63.0	84.0
1800	.18	.35	.70	1.75	2.34	2.92	3.50	4.38	5.83	8.75	11.7	17.5	26.3	35.0	52.5	70.0
2000	.16	.32	.63	1.58	2.10	2.63	3.15	3.94	5.25	7.88	10.5	15.8	23.7	31.5	47.3	63.0
2400	.13	.26	.53	1.31	1.75	2.19	2.63	3.28	4.37	6.56	8.75	13.1	19.7	26.3	39.4	52.5
3000	.11	.21	.42	1.05	1.40	1.75	2.10	2.63	3.50	5.25	7.00	10.5	15.8	21.0	31.5	42.0
3600	.09	.18	.35	.88	1.17	1.46	1.75	2.19	2.92	4.38	5.83	8.75	13.1	17.5	26.3	35.0
4000	.08	.16	.32	.79	1.05	1.31	1.58	1.97	2.63	3.94	5.25	7.88	11.8	15.8	23.7	31.5
4600	.07	.14	.27	.69	.91	1.14	1.37	1.71	2.28	3.42	4.57	6.85	10.3	13.7	20.6	27.4
5000	.06	.13	.25	.63	.84	1.05	1.26	1.58	2.10	3.15	4.20	6.30	9.45	12.6	18.9	25.2

UNIT SELECTION BASED UPON PICKUP TORQUE SPEED DIFFERENCES

CASE 1 Load is applied during acceleration. Rating is based on torque available at the pickup slip speed, which is the difference in speed between the rotor and the armature.

SELECTION CHART FOR CLUTCHES, CLUTCH COUPLINGS AND BRAKES.
Load is applied after clutch has attained full speed. Service Factor: 2

TORQUE AT VARIOUS HORSEPOWERS—LB. INS

SHAFT SPEED AT CLUTCH OR BRAKE (R.P.M.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	2
100	3.15	6.30	12.6	31.5	42.0	52.5	63.0	78.8	105	158	210	315	473	630	945	1260
200	1.58	3.15	6.30	15.8	21.0	26.3	31.5	39.4	52.5	78.8	105	158	237	315	473	630
300	1.05	2.10	4.20	10.5	14.0	17.5	21.0	26.3	35.0	52.5	70.0	105	158	210	315	420
400	.79	1.58	3.15	7.88	10.5	13.1	15.8	19.7	26.3	39.4	52.5	78.8	118	158	237	315
500	.63	1.26	2.52	6.30	8.40	10.5	12.6	15.8	21.0	31.5	42.0	63.0	94.5	126	189	252
600	.53	1.05	2.10	5.25	7.00	8.75	10.5	13.1	17.5	26.3	35.0	52.5	78.8	105	158	210
700	.45	.90	1.80	4.50	6.00	7.50	9.00	11.3	15.0	22.5	30.0	45.0	67.5	90.0	135	180
800	.39	.79	1.58	3.94	5.25	6.57	7.88	9.85	13.1	19.7	26.3	39.4	59.1	78.8	118	158
900	.35	.70	1.40	3.50	4.67	5.83	7.00	8.75	11.7	17.5	23.4	35.0	52.5	70.0	105	140
1000	.32	.63	1.26	3.15	4.20	5.25	6.30	7.88	10.5	15.8	21.0	31.5	47.3	63.0	94.5	126
1100	.29	.57	1.15	2.86	3.82	4.77	5.73	7.16	9.55	14.3	19.1	28.6	42.9	57.3	85.9	115
1200	.26	.53	1.05	2.63	3.50	4.38	5.25	6.56	8.75	13.1	17.5	26.3	39.4	52.5	78.8	105
1500	.21	.42	.84	2.10	2.80	3.50	4.20	5.25	7.00	10.5	14.0	21.0	31.5	42.0	63.0	84.0
1800	.18	.35	.70	1.75	2.34	2.92	3.50	4.38	5.83	8.75	11.7	17.5	26.3	35.0	52.5	70.0
2000	.16	.32	.63	1.58	2.10	2.63	3.15	3.94	5.25	7.88	10.5	15.8	23.7	31.5	47.3	63.0
2400	.13	.26	.53	1.31	1.75	2.19	2.63	3.28	4.37	6.56	8.75	13.1	19.7	26.3	39.4	52.5
3000	.11	.21	.42	1.05	1.40	1.75	2.10	2.63	3.50	5.25	7.00	10.5	15.8	21.0	31.5	42.0
3600	.09	.18	.35	.88	1.17	1.46	1.75	2.19	2.92	4.38	5.83	8.75	13.1	17.5	26.3	35.0
4000	.08	.16	.32	.79	1.05	1.31	1.58	1.97	2.63	3.94	5.25	7.88	11.8	15.8	23.7	31.5
4600	.07	.14	.27	.69	.91	1.14	1.37	1.71	2.28	3.42	4.57	6.85	10.3	13.7	20.6	27.4
5000	.06	.13	.25	.63	.84	1.05	1.26	1.58	2.10	31.5	4.20	6.30	9.45	12.6	18.9	25.2

CASE 2 Load is applied after clutch or brake unit is up to speed. Rating is based on the unit's static torque, at zero slip speed. All standard brake ratings fall into this classification.

MOUNTING AND INSTALLATION DIMENSIONS *

FIG. NO.	UNIT	MTG. STYLE	MOD. NO.	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	CLUTCH COUPLING	Flange	FH 08	.88	.84	.71	.65	005 .010 set	.07	.24	.43	# 2-56 set scr. 2 120° apart	.050	1.1985 1.2005	4 holes 096 .090 dia. on 1.028 1.034 circle. (# 2-56 screw)	.19	12.	.50	See Bores & Keyways	See Bores & Keyways	–	.188 -.003	.020 ±.005 set	.88	–
2	CLUTCH COUPLING	Flange	FH 17	1.78	1.39	1.14	1.01	.005 min set	.12	.43	.60	# 6-32 set scr. 2 120° apart	.065	2.436 2.437	4 holes .187 dia. on 2.125 circle. (# 8 screw)	.80	12.	.50			.750 .751	.130	.100 ±.005 set	1.82	# 6-32 set scr. 2 120° apart
2	CLUTCH COUPLING	Flange	FH 25	2.64	1.86	1.56	1.36	.005 min. set	.14	.59	1.01	# 8-32 set scr. 2 120° apart	.110	3.499 3.500	4 holes .188 dia. on 3.125 circle. (# 8 screw)	.80	12.	.50			1.061 1.062	.270	.170 - 005 set	2.64	# 8-32 set scr. 2 120° apart
3	CLUTCH COUPLING	Bearing	FG 17	1.78	1.59	1.34	1.21	.005 min. set	.12	.43	.60	# 6-32 set scr. 2 120° apart	.065	1.060 -.010	.180 + 010	.80	12.	.50			.89	.130	–	1.33	# 6-32 set scr. 2 120° apart
3	CLUTCH COUPLING	Bearing	FG 25	2.64	2.04	1.74	1.54	.005 min. set	.14	.59	1.01	# 8-32 set scr. 2 120° apart	.065	1.500 - 010	.180 - .010	.80	12.	.50			1.27	.140	–	1.77	# 8-32 set scr. 2 120° apart
4	CLUTCH	Flange	FL 08	.88	A1.08 B1.22	.73	.65	self aligning	A .250 B .375	.51 .38	See Bores & Keyways	See Bores & Keyways	.050	1.1985 1.2005	4 holes 096 .090 dia. on 1.028 1.034 circle. (# 2-56 screw)	.19	12.	.50			–	.188 -.003	020 + 005 set	.88	–
5	CLUTCH	Flange	FL 17	1.78	1.65	1.15	1.01		.375	.750			.065	2.436 2.437	4 holes .187 dia. on 2.125 circle. (# 8 screw)	.80	12.	.50			.750 .751	.130	.100 + 005 set	1.82	# 6-32 set scr. 2 120° apart
5	CLUTCH	Flange	FL 25	2.64	3.26	1.56	1.36		1.53	2.08			.110	3.499 3.500	4 holes .188 dia. on 3.125 circle. (# 8 screw)	.80	12.	.50			1.061 1.062	.270	.170 ±.005 set	2.64	# 8-32 set scr. 2 120° apart
6	CLUTCH	Bearing	FJ 17	1.78	1.85	1.35	1.21		.375	.750			.065	1.060 ±.010	.180 ± .010	.80	12.	.50			.89	.130	–	1.33	# 6-32 set scr. 2 120° apart
6	CLUTCH	Bearing	FJ 25	2.64	3.45	1.74	1.54		1.53	2.08			.065	1.500 ±.010	.180 ± .010	.80	12.	.50			1.27	.140	–	1.77	# 8-32 set scr. 2 120° apart
7	BRAKE	Flange	FS 08	.88	.84	.71	.65	.005 .010 set	.07	.24	.43	# 2-56 set scr. 2 120° apart	.050	1.1985 1.2005	4 holes .096 .090 dia. on 1.028 1.034 circle. (# 2-56 screw)	.19	12.	.50			–	–	–	.88	–
8	BRAKE	Flange	FS 17	1.78	1.26	1.01	.88	.005 min. set	.12	.43	.60	# 6-32 set scr. 2 120° apart	.065	2.436 2.437	4 holes .187 dia. on 2.125 circle. (# 8 screw)	.80	12.	.50			.750 .751	–	–	1.82	–
8	BRAKE	Flange	FS 25	2.64	1.75	1.45	1.25	.005 min. set	.14	.59	1.01	# 8-32 set scr. 2 120° apart	.110	3.499 3.500	4 holes .188 dia. on 3.125 circle. (# 8 screw)	.80	12.	.50			1.061 1.062	–	–	2.64	–

* For drawing references see page 6.

ROTOR BORES AND KEYWAYS *

R	FH08, FL08.			FG17, FJ17 (set screws only) FL17, FH17 (keyed)			FL25, FG25 FJ25, FH25		
Shaft Dia.	.1240 .1250	.1865 .1875	.2490 .2500	.2480 .2500	.3105 .3125	.3730 .3750	.373 .375	.498 .500	.623 .625
Rotor Bore	.1252 .1257	.1877 .1882	.2505 .2515	.2505 .2515	.3130 .3140	.3755 .3765	.3754 .3769	.5004 .5019	.6254 .6269
Keyway	.062 .065 Pin†			1/16 x 1/32		3/32 x 3/64	3/32 x 3/64	1/8 x 1/16	3/16 x 3/32*
Dim. "a"	– –	– –	– –	.285 .290	.347 .352	.420 .425	.419 .425	.559 .565	.679 .685
Dim. "b"	– –	– –	– –	.063 .065	.063 .065	.095 .097	.094 .097	.125 .128	.188 .191

KEYWAY DIMENSIONS

*Special keys are provided with this bore only, to fit standard 3/16 x 3/32 keyslot. †Keyway provided on special order.

ARMATURE BORE AND KEYWAYS *

Q	FH08, FS08			FL08			FH17, FG17, FS17			FL17, FJ17			FH25, FG25, FS25			FL25, FJ25		
Shaft Dia.	.1240 .1250	.1865 .1875	.2490 .2500	– –	.1865 .1875	.2490 .2500	.2480 .2500	.3105 .3125	.3730 .3750	.2490 .2500	– –	.3740 .3750	.373 .375	.498 .500	.623 .625	.374 .375	.499 .500	– –
Armature Bore	.1252 .1257	.1877 .1882	.2505 .2515	1/8" Bore Special Order	.1877 .1886	.2505 .2515	.2505 .2515	.3130 .3140	.3755 .3765	.2505 .2515	5/16" BORE SPECIAL ORDER	.3755 .3765	.3754 .3769	.5004 .5019	.6254 .6269	.3760 .3770	.5010 .5020	– –
Keyway	Set Screws Only†			FREE RUNNING HUB ON SLEEVE BEARING			Set Screws Only†			FREE RUNNING HUB ON SLEEVE BEARING			3/32x3/64	1/8x1/16	3/16x3/32*	FREE RUNNING HUB ON SLEEVE BEARING		
Dim. "a"	–	–	–	–	–	–	–	–	–	–	–	–	.419 .425	.559 .565	.679 .685	–	–	–
Dim. "b"	–	–	–	–	–	–	–	–	–	–	–	–	.094 .097	.125 .128	.188 .191	–	–	–
H Dia. over Str. Knurl Clutch Only	– –	– –	– –	–	.382 HUB 'A'	.507 HUB 'B'	– –	– –	– –	.504 .510	– –	.628 .634	–	–	–	1.000 .998 (No Knurl)		
J Press Fit Hole Clutch Only	– –	– –	– –	– –	.374 .376	.500 .503	– –	– –	– –	.500 .503	– –	.625 .628	–	–	–	1/16 x 1/8 Key .88 Long		

ENGINEERING DRAWINGS

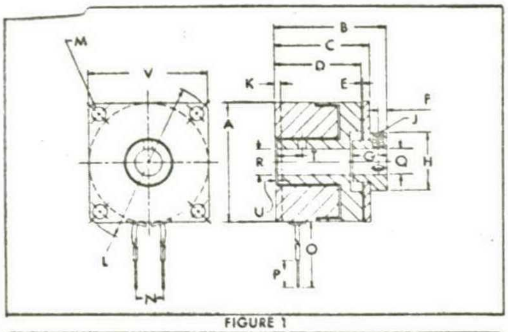


FIGURE 1

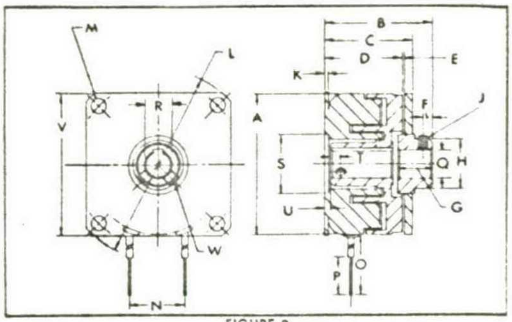


FIGURE 2

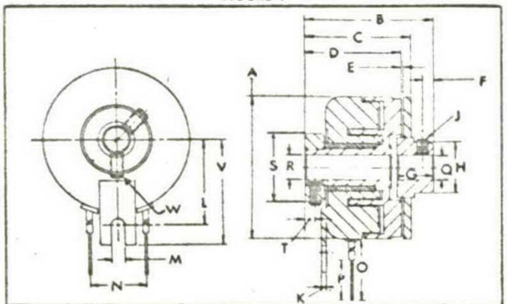


FIGURE 3

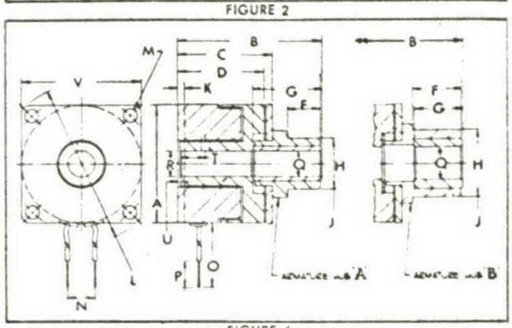


FIGURE 4

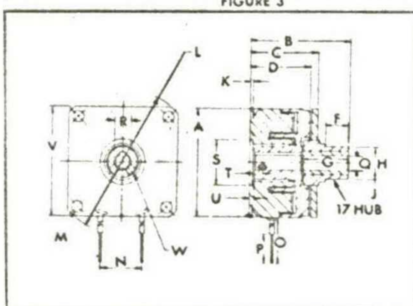
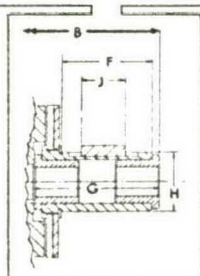


FIGURE 5



FJ 25. FL25 HUB DETAIL

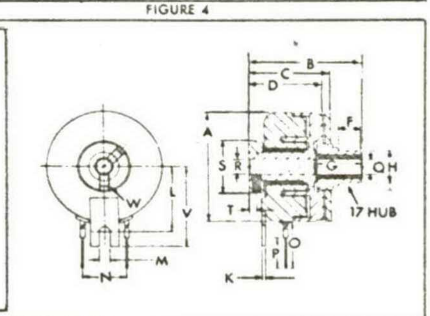


FIGURE 6

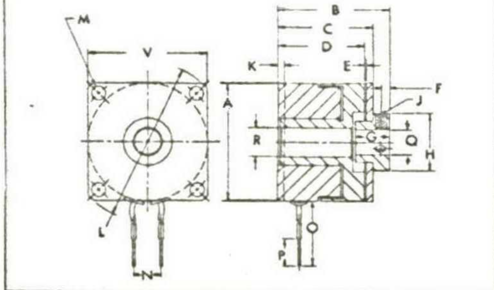


FIGURE 7

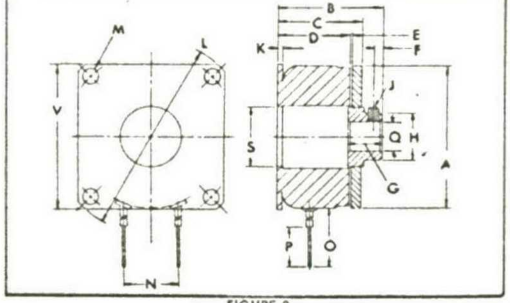


FIGURE 8

SPECIFICATIONS

	SERIES 08	SERIES 17	SERIES 25
CLUTCH COUPLING			
Flange Mtd.	FH08	FH17	FH25
Bearing Mtd.	*	FG17	FG25
CLUTCH			
Flange Mtd.	FL08	FL17	FL25
Bearing Mtd.	*	FJ17	FJ25
BRAKE			
Flange Mtd.	FS08	FS17	FS25
*Available on special order			
RATED STATIC Torque	2 lb. in.*	12 lb. in.	70 lb. in.
INERTIA (lb. in.²)			
Clutch Coupling Armature & Hub	0.0009	0.032	0.26
Clutch Armature & Hub	0.0014	0.032	0.28
Brake Armature & Hub	0.0009	0.032	0.26
Clutch Coupling & Clutch Rotor (bearing mtd. unit)	0.0019	0.066	0.39
Clutch Coupling & Clutch Rotor (flange mtd. unit)	0.0019	0.063	0.37
TIME CONSTANT with Haydon FC control (one unit only)			
Build-up (milliseconds)	3	7	25
Decay (milliseconds)	2	3	20
STANDARD COIL VOLTAGES	6, 12, 24/28 or 90 VDC Others available on special order		
RATED COIL CURRENT & RESISTANCE (20°C)	Amps. / Ohms	Amps. / Ohms	Amps. / Ohms
24/28V Coil	0.120 / 236	0.210 / 133	0.254 / 110
90V Coil	0.040 / 2220	0.063 / 1420	0.078 / 1149
POWER CONSUMPTION (Nominal)	3.6 Watts	5.7 Watts	7.0 Watts
WEIGHT			
FH	1.2 oz.	0.50 lb.	1.72 lb.
FL	1.3 oz.	0.51 lb.	1.82 lb.
FS	1.1 oz.	0.40 lb.	1.30 lb.
FG	—	0.50 lb.	1.70 lb.
FJ	—	0.51 lb.	1.80 lb.
INDUCTANCE (H)			
28V Coil	.7	1.0	2.7
90V Coil	6.8	11	28

*¼" Bore 08 Series Brake—1.5 lb. in.(non-mag. & mag. shafting); ¼" Bore 08 Series Clutch & Clutch Coupling—1.5 lb. in.(non-mag. shafting), 2.0 lb. in.(magnetic shafting); All other 08 units—2.0 lb. in. static torque rating.

APPENDIX VI

PARTS LIST OF THE AUTOMATIC TESTER

MATERIAL LIST

No.	Integrated Circuits
4	Motorola MC254G
44	Motorola MC258G
27	Motorola MC259G
22	Motorola MC262G
2	Motorola MC267G
	Semiconductors
1	RCA 2N1490 Transistors
26	RCA 2N1302 Transistors
20	G.E. 2N1671B Unijunction Transistors
1	G.E. 2N2647 Unijunction Transistors
3	Sylvania 1N457A Diodes
43	Sylvania 1N90 Diodes
2	Motorola 1N4003 Diodes
2	Motorola 1N3997A Zener Diodes
1	Motorola 1N3998 Zener Diode
3	Motorola 1N4719 Rectifiers
4	Motorola MCR230506 Silicon-Controlled Rectifiers
	Capacitors
2	Sprague 13000 μf. 25 WVDC Capacitors

No.	Capacitors
2	2,700 μf., 25 WVDC Sprague Capacitors
20	10 μf., 20 WVDC Kemet Capacitors
20	Kemet Series "C" 33 μf.
1	Kemet Series "C" 300 μf.
17	.15 μf., 20 WVDC Sprague Capacitors
22	.1 μf., 20 WVDC Sprague Capacitors
2	.47 μf., 20 WVDC Sprague Capacitors
2	4 μf., 200 WVDC Sprague Capacitors
	Plugs and Sockets
7	Cinch-Jones S324CCT
1	Cinch-Jones P324AB
1	Cinch-Jones P324CCT
1	Cinch-Jones S324AB
1	Cinch-Jones P310AB
1	Cinch-Jones S310CCT
11	Amphenol Series 143 (22 pin)
1	Amphenol Series 143 (18 pin)
1	Elco Series 5007 (24 pin)
1	Elco Series 5007 (24 pin)
	Printed Circuit Boards
10	3786-XWD
1	3788-XWD
1	3792-XWD

No.	Switches
1	DPDT Toggle Switch M-80728 (On-Off)
2	Switchcraft "Littel" Push Button Switches
	Lights
1	125-volt Neon Pilot Light
25	6-volt Sylvania Lamps
25	Red Profax Lens Caps
	Resistors
150	1,000Ω, 1/2 Watt
100	3,300Ω, 1/2 Watt
45	15KΩ, 1/2 Watt
1	120KΩ, 1/2 Watt
2	150Ω, 10 Watts
1	50Ω, 5 Watts
4	1Ω, 10 Watts
20	50KΩ, Ohmite Potentiometers
1	Triad Type F83-A Filament Transformer
1	Triad Type F25-X Filament Transformer
1	Bud Type CR-1728 Deluxe Cabinet Rack
1	Bud Type CB-1378 7" Panel-mounting Chassis
1	Bud Type CB-1372 5-1/4" Panel-mounting Chassis
1	Bud Type CB-1375 10-1/2" Panel-mounting Chassis
2	Potter and Brumfield 3PDT Relay Type KA14AG

No.	Resistors
100	Integrated Circuit Multi-lead pads (10 lead)
5	SPNO BRSR1-901 Reed Relay
1	SPNC BRSR1-902 Reed Relay