X-RAY EQUIPMENT FOR LUNAR RECEIVING LABORATORY

Final Report (Part I)

by

N. Spielberg and G. Ziedins

April 1970

Prepared by

PHILIPS LABORATORIES
A Division of North American Philips Corp.
Briarcliff Manor, New York

Prepared for

NASA Manned Spacecraft Center
Lunar Receiving Laboratory
Houston, Texas

NASA CR 108467

APPENDIX A

DESCRIPTION OF INSTRUMENT CONTROL CIRCUITS

APPENDIX A

Table of Contents

DESCRIPTION OF INSTRUMENT CONTROL SYSTEM

Each instrument, the diffractometer and the spectrograph, employs an individual control system. Because of the similarity of both systems, a typical system applicable to either will be described. Where special provisions are pertinent to one of the instruments, the exception will be noted. Connector pin assignments for all connectors mentioned in the following discussion are given in Appendix B.

1. LOGIC CONTROL CIRCUITS

1.1 General

The logic control circuits are designed so that the two instruments can be operated manually by means of push-buttons located on control panel or operated automatically via computer. These two modes of operation are referred to as MANUAL and COMPUTER. When the power is first turned on, and the computer is functioning, the control assumes the MANUAL mode. The operator can transfer to the COMPUTER mode by activating the CONTROL TRANSFER rocker switch. When the COMPUTER mode has been selected, all push buttons except EMERGENCY OFF become disabled so that it is not possible to intervene manually via the control panel. However, the lights always display the states of the various functions.

The basic logic control element is a flip-flop which renders a given instrument function either active or inactive. For example, a control chain could consist of a flip-flop, a driver, a relay and an ac motor. When the flip-flop is set, the driver energizes the relay causing the relay contacts to close and apply ac power to the motor. Upon resetting the flip-flop, the power to the motor is turned off. Because of the relatively low power level delivered by the flip-flop, some type of a driver or amplifier is always used between the flip-flop and the device it controls.

In the MANUAL mode, setting and resetting of the flip-flops is controlled by push buttons located on the control panel; in the COMPUTER mode, by the computer interface circuit.

1.2 Logic Bin

The control circuits are constructed with Digital Equipment M-Series logic modules plus a few special purpose modules built by Philips. The M-series monolithic integrated circuit logic modules employ TTL (transistor-transistor logic) integrated circuits which provide high speed, high fan-out, large capacitance drive capability and excellent noise margin. The module is a plug-in printed circuit board with the TTL logic elements mounted on it and a handle at one end. The module type number is imprinted on the handle.

A complete description of the available M-series modules can be found in Digital's Logic Handbook C-105. Figure A-1 shows the Digital Equipment modules that are used for constructing the control circuits. The special purpose modules built at Philips are shown in Figure A-2.

The modules plug into a Digital Equipment H803 mounting panel which has 64 module connector blocks. The connector block has a 36-pin single slot socket, the back side of which is provided with wire wrap terminals (pins). The terminal arrangement of the connector block is shown in Figure A-3. The pin rows are identified by letters A,...,V and the pin columns by numbers 1 and 2. The interconnection between modules are made on the back side of the mounting panel by wire wrapping.

The module layout as viewed from the wiring side of the mounting panel is shown in Figure A-4. The module locations are identified by row markings (letters A-B) and column markings (numbers 01 to 32). For instance, a module marked A-21 is located in the A row and is the 21st module from the left. The one directly below A-21 is marked B-21. A wired up mounting panel with the modules plugged in (up to 64 units) is referred to as the logic bin. Eight specially-built plug-in connector cards are used to interconnect the logic control circuitry of the bin with the rest of the system. The location of these cards in the bin is shown also in Figure A-4.

The module interconnections shown in the schematics are labeled according to the type of signals they carry. For instance, the designation CL-1 indicates a clock signal. Other lines carrying clock signals would be labeled CL-2, CL-3, etc. The schematic identifies the terminals of the mounting panel according to the connector block and the pin. For example, designation A-20-F2 identifies pin F2 on connector block 20 located in Row A.

1.3 Control Transfer Logic

During both modes of operation, either MANUAL or COMPUTER, the control circuitry in the logic bin controls all the locomotions of the instrument, e.g., goniometer 2θ motion, revolving the specimen holder (Ø), the opening and closing x-ray shutter, etc.

The distinction between the two modes of operation is that directives to these control circuits are given either by an operator from the control panel or by a computer via the computer interface. The function of the control-transfer logic is to select the proper input to the instrument.

The control-transfer logic, also located in the logic bin, consists of a flip-flop, its associated gates, and the gates needed to switch the inputs to the instrument from either the control panel or the computer.

Part of the control-transfer logic, the flip-flop and the gates directly associated with it, is shown in Figure A-5. The gates which select the inputs to the control circuits of the instrument are shown in those drawings dealing with the individual instrument function controls.

The two outputs of the control-transfer flip-flop (4) buffered by gates 1 and 2 (module M627), control all of the input switching gates. Flip-flop 4 in a "reset" state (MAN output at 3.5 V and AUTO output at 0 V) directs the switching gates to accept inputs from the control panel and block those from the computer. In a "set" state (AUTO output at 3.5 V and MAN output at 0 V) flip-flop 4 directs these gates to accept computer generated inputs and block those from the control panel.

Flip-flop 4 is wired to assume a "reset" state (MANUAL control) when power is first turned on (not shown in Figure A-5). The flip-flop is also reset when the rocker switch on the control panel is pushed to MANUAL position. Setting the rocker switch to the MANUAL position will always reset the flip-flop and will override any other command. However, when the rocker switch is pushed to the COMPUTER position, the computer is only alerted that a control-transfer is requested; a computer-generated command must then set the flip-flop in order to transfer the control to the computer. Computer-generated commands can also return the control to the MANUAL mode and then back again to the COMPUTER mode, provided the rocker switch remained in the COMPUTER position.

The control status of the instrument is displayed by the MANUAL and COMPUTER indicator lights on the control panel.

1.4 Clock Pulse Generator

A crystal oscillator, located in the power supply/relay rack, is used as a master clock for the control system. The execution of all commands for the instrument is synchronized by this clock. The oscillator output (166.667 Hz square wave) is brought to the control-circuit bin (H803 panel) via connector card B-23-A1. The circuit shown in Figure A-6 produces microsecond pulses which are generated by the trailing edge of the square wave. Three outputs are provided to satisfy the loading requirements of the M-series logic modules.

1.5 2θ Control

The TWO THETA control determines the stepping rate, direction, and ON/OFF status of the stepping motor. The stepping motor controls the 2θ dimension of the goniometer, where one step of 90° motor rotation corresponds to a 0.01 degree increment of 2θ.

1.5.1 2θ Drive

A motor controller (Stepcon-Controller 045-1P-17-65) located in the power supply/relay rack drives the stepping motor. The controller is provided with two inputs: one for stepping the motor in the CW (clockwise) direction and the other for stepping in the CCW (counterclockwise) direction. In the CW direction, the goniometer 2θ angle is incremented, and in the CCW direction the 2θ is decremented. The logic diagrams indicate the drive direction of increased 2θ angle as FWD (forward) and that of decreased 2θ as REV (reverse).

Figure A-7 is the logic diagram of the control circuit for delivering the input pulses to the motor controller. Gate 7 controls the input of the pulses to the motor controller, as dictated by the 2θ Start/Stop control. Gates 3 and 4, respectively, channel the pulses to the appropriate motor-controller inputs for achieving a FWD or REV 2θ drive, as directed by the 2θ Forward/Reverse Control. The pulse driver for each line amplifies the +3.5 volt logic level of the pulse to 24 Vdc.

When the goniometer reaches either end of the 2Ø travel, a micro-switch located at the end is closed. This opens the corresponding line to the motor controller, thereby preventing further motor advancement. Depressing the appropriate button (FWD or REV) will advance the motor in the opposite direction. An indicator lamp (MECH LIMIT) on the control panel is lit when either of the above limit switches is closed.

1.5.2 2θ Rate Scaler

The stepping rate of the motor is controlled by the pulse rate applied to the motor controller. This pulse rate is obtained by scaling down the frequency of the crystal oscillator.

Stepping rates were selected to obtain 2θ speeds of 50, 5, 2, 1, 0.5, 0.2, 0.1 degrees/min. The top speed of 50°/min is used for slewing. These 2θ speeds correlate with the speeds of the strip-chart recorder which are selectable in 5,2,1 ratios.

The logic diagram for controlling the 2θ stepping rate is shown in Figure A-8. The master clock rate of 10,000 pulses/min is scaled down by the dividers indicated in the blocks. The details of the scaler circuits for the ÷ 10, ÷ 2 and ÷ 5 are shown in Figure A-9 and A-10 respectively. The ÷ 2 scaler consists of a single J-K flip-flop. The gates surrounding the scaler circuits control the amount of scaling carried out as dictated by the 2θ Scaler Control. The scaled-down clock frequency is then applied to a pulse shaper (M302) which generates the 15 μsec pulses in accordance with the applied input frequency.

1.5.3 2θ Scaler Control

The logic diagrams of the 2θ Scaler Control are shown in Figures A-11 and A-12. Figure A-11 shows the flip-flops and gates that are needed for selecting the input commands. The commands come either from the switches on the control panel or from the computer interface, as determined by the AUTO and MAN lines. The gates of the M117 module encode the push-button switch commands to set the proper control flip-flops.

Figure A-12 shows the decoder of the scaler control. This decoder controls the gates of Figure A-8 which, in turn, control the stepping rate of the 2θ drive. The selected stepping rate is displayed by an indicator light on the control panel.

1.5.4 2θ START/STOP Control

The logic diagram of the 2θ START/STOP control is shown in Figure A-13. A control flip-flop operates the start/stop gate (Figure A-7) of the 2θ drive. The state of this flip-flop is also displayed by the indicator lights on the control panel. The gates directly in front of the flip-flop select the source of the two command inputs. Gate 4 "OR's" the stop command to be issued either by the stop switch or by the coincidence circuit (see Par. 1.5.6). The filters in the start and stop lines protect against line transients and also suppress the effects of switch bouncing.

1.5.5 2θ FORWARD/REVERSE Control

The 2θ FORWARD/REVERSE Control is shown in Figure A-14. The flip-flop controls the FWD and REV gates of the 2θ drive circuit (Figure A-7). The state of the flip-flop is also displayed on the control panel. The commands to this flip-flop are similar to those of the 2θ START/STOP control circuit.

1.5.6 Coincidence Control

The stepping motor is stopped when a coincidence is established between the 2θ shaft encoder reading and the setting of either of the two thumb-wheel switches. Figures A-15 to A-19 inclusive show the logic circuitry for the Right Limit (R.L.) thumb-wheel switch. Figures A-20 to A-24 inclusive show the corresponding circuitry for the Left Limit (L.L.) thumb-wheel switch. Figure A-25 shows the comparison logic for both thumb-wheel switches, and Figure A-26 shows the "Halt on Coincidence" control circuitry.

1.6 Ø Control

The Ø parameter is associated with the rotation of the specimen holder about its own axis. Control is provided for starting and stopping the Ø-motor and for selecting its speed (FAST or SLOW). The logic diagram of the Ø control is shown in Figure A-27. On the input side, the operation of the control circuit is identical to the 2θ control described previously. On the output side, the control flip-flops (through the L/R drivers) operate relays (located in the power supply/relay rack) which in turn control the Ø motor. The START/STOP control switches ac power to the motor, and the speed control selects the appropriate motor tap.

1.7 Strip Chart Recorder Control

The Moseley strip-chart recorder can be remotely operated, i.e., the pen lift (UP/DOWN), the chart drive (ON/OFF), and the event marker pen. Remote control is possible only when the front panel pen lift and chart drive switch are in the off position. All control wires are brought out to a connector strip located in the rear of the recorder. Grounding the appropriate terminal activates the corresponding recorder function. This is achieved by closing and opening relay contacts. The logic diagram for operating the pen lift and the chart drive relays is shown in Figure A-28.

The control logic for operating the event-marker pen is somewhat complex because the same marker pen is used to indicate two separate events: 2θ degree marker and Ø revolution marker. Although the event marker is used in this dual role in the diffractometer only, the control circuits for both instruments were made identical so that the logic bins could be readily interchanged.

Normally, the degree-marker logic causes the marker pen to jump from one level to another on every 0.5 degree of 2θ movement. However, when the specimen platform is rotated, one complete revolution is indicated by a level change of the marker pen followed by an immediate return to its previous setting. Note that the revolution marking function is superimposed upon the 2θ degree marking function. The logic diagram for driving the marker pen is shown in Figure A-29.

While the 2θ degree indicator is always active, an option is provided for enabling or disabling the Ø revolution indication. The logic diagram for ON/OFF control of the Ø revolution marker is shown in Figure A-30.

1.8 Shutter Control

The Philips PW-1130 x-ray generator is provided with remote control for opening and closing x-ray shutters on the four sides of the x-ray tube tower by means of switches located on the generator's control panel. (See PW-1130 instruction manual.) A tube tower equipped with such shutters is used only in the diffractometer.

The circuit in the x-ray generator which controls the operation of the shutter currently facing the diffractometer was modified so that this shutter can also be remotely opened and closed by the logic control circuits. The selector switch on the generator's control panel must be in the 0 position to enable the remote control from the logic bin; any other setting of this switch will override the commands from the logic circuits. The logic diagram for operating this shutter is shown in Figure A-31. The modification made in the x-ray generator circuits are shown in the PW-1130 Instruction Manual.

2. POWER SUPPLY/RELAY RACK

The layout of the components located in power supply/relay rack is shown in Figure A-32. Three cables link the circuits of this rack with the rest of the control system. The connector pin assignments for these cable connectors are listed in Appendix B. The schematic diagram of the BCD to 7-segment decoder is shown in Figure A-33. The six relays are mounted on a separate chassis, and the relay wiring diagrams are shown in Figures A-34 to A-37.

Consult the manufacturer's specifications and diagrams for the power supplies, the crystal oscillator, and the stepping-motor controller.

3. CONTROL PANEL

The control panel (Figure 14) is a self-contained package remotely located from the electronics cabinet and is linked to the control circuits via three interconnecting cables. The illuminated push buttons, the indicator lights and the rocker switch are identified by unit numbers shown in Figure A-38. The schematic diagram of the control panel is shown in Figure A-39. The use of unit numbers simplifies the identification of the panel elements. The illuminated Dialco push button, consisting of an indicator light and a momentary switch, is assigned one unit number because it is one assembly, although the switch and the lamp are shown in separate places on the schematic diagram.

The dotted line linking the inverted open arrows represents a connector; the connector number is shown at one end of the line.

The numbers under the inverted arrows identify the contacts of the connector. An inverted arrow designates a socket, and an arrow designates a pin. The details of the various units which are mounted on the panel are shown schematically on the bottom of Figure A-39.

4. PATCH PANEL

The patch panel, mounted on the inside of the electronics cabinet door, has 8 rows of Cinch-Jones barrier terminals with 40 terminals per barrier strip. Mounted on the bottom of the panel are 6 chassis connectors which mate with the system interconnecting cables. All wires from the control circuits inside the cabinet are routed through the patch panel to these six connectors. There is also a rectangular cut-out in the door which provides passage for those cables which do not terminate at this panel. The patch panel is shown schematically in Figures A-40 and A-41.

The terminals of the barrier strip are numbered consecutively from left to right, and the rows of barrier strip are marked alphabetically from A to H. In the schematic diagram, the terminals are represented by boxes; the numbers inside each box list the pin numbers of the connectors to which the wires are routed. Connector numbers are shown both above and below the boxes. The rest of the markings on the schematic diagrams help to identify each wire which is brought out to the barrier strip. Each strip routes wires which belong to the same functional group. These function groups are identified in the diagram by the labels appearing on the left of the alphabetical row marks. A further subdivision of the wires within each group is identified in the diagram by the labels appearing above a corresponding group of boxes. Finally, the labels shown in the center of the boxes identify each individual wire. For example, barrier strip row E routes all the wires which belong to the shaft encoder. The wires belonging to the first digit (LSD) are routed by the terminal numbers 1 through 8 inclusive. The corresponding labels appear in Figure A-40 to the left of row E and also above the first eight boxes of row E. Finally, each individual wire is identified by the label in the center of the box. For both instruments, the diffractometer and the x-ray spectrograph, the patch panel wiring is the same except for a few exceptions which are noted by asterisks in the diagram.

5. SYSTEM INTERCONNECTION

Figure A-42 shows schematically the interconnection of the various parts of the instrument. Cables numbered 1-3 link the control panel to the electronic control circuits. Cable #1 carries all the command signals from the push-button switches to the control circuits, Cable #2 interconnects the thumb-wheel switches with the control logic and Cable #3 carries the display signals to the indicator lights.

Cable #4 goes to the x-ray generator and carries the commands for operating the x-ray shutter, for interconnecting the x-ray generator to the emergency OFF circuit, and for indicating that the x-ray generator is ON.

Cables #5 and #6 go to the glove box. Cable #5 carries power for driving the motors located inside the glove box and cable #6 has all the logic signals (closure status, shaft encoder reading, etc),from the glove box to the logic control circuits.

The pin assignments for the above connectors are given in Appendix B.

Figure 42 also shows the coaxial cables which interconnect the detectors located in the glove box with the Ortec signal processing circuits located in the electronics cabinet.

6. GONIOMETER WIRING

The wiring diagram of the goniometer microswitches, 2θ motor, and the $\emptyset$ motor are shown in Figures A-43 and A-44 for the diffractometer and the x-ray spectrograph, respectively.

7. POWER DISTRIBUTION

The power distribution diagram for the components located in the electronics cabinet is shown in Figure A-45. A main power ON/OFF switch for the cabinet is located on the lower front panel. All of the components shown in the diagram, except for the fan, have also their own power on/off switches.

The main power ON/OFF switch for the electronics cabinet must be ON and the control circuits energized when the power to the x-ray high voltage generator is turned on, because of the interlock that exists between the logic control circuitry and the PW-1130 generator.

8. LIST OF FIGURES

A20 1st Digit (LSD)

A21 2nd Digit

A22 3rd Digit

A23 4th Digit

A24 5th Digit (MSD)

(A20–A24: Coincidence Circuit for Comparing a Digit of L.L. Thumbwheel switch with a corresponding digit of the Shaft Encoder)

A25 Coincidence Circuit for Comparing both Thumbwheel Switches with Shaft Encoder

A26 HALT on Coincidence Control

A27 Ø Control (Specimen Rotation)

A28 Strip-Chart-Recorder Control

A29 Event-Marker Control

A30 Ø Revolution Marker Control

A31 Shutter Control

A32 Power-Supply/Relay Rack Layout

A33 BCD to 7-Segment Decoder

A34 Power Switching to Ø Motor (Diffractometer)

A35 Power Switching to Ø Motor (Spectrograph)

A36 Recorder Control

A37 Power Latch-Up

A38 Control-Panel Layout

A39 Schematic Diagram of Control Panel

A40 Patch Panel (1st Half)

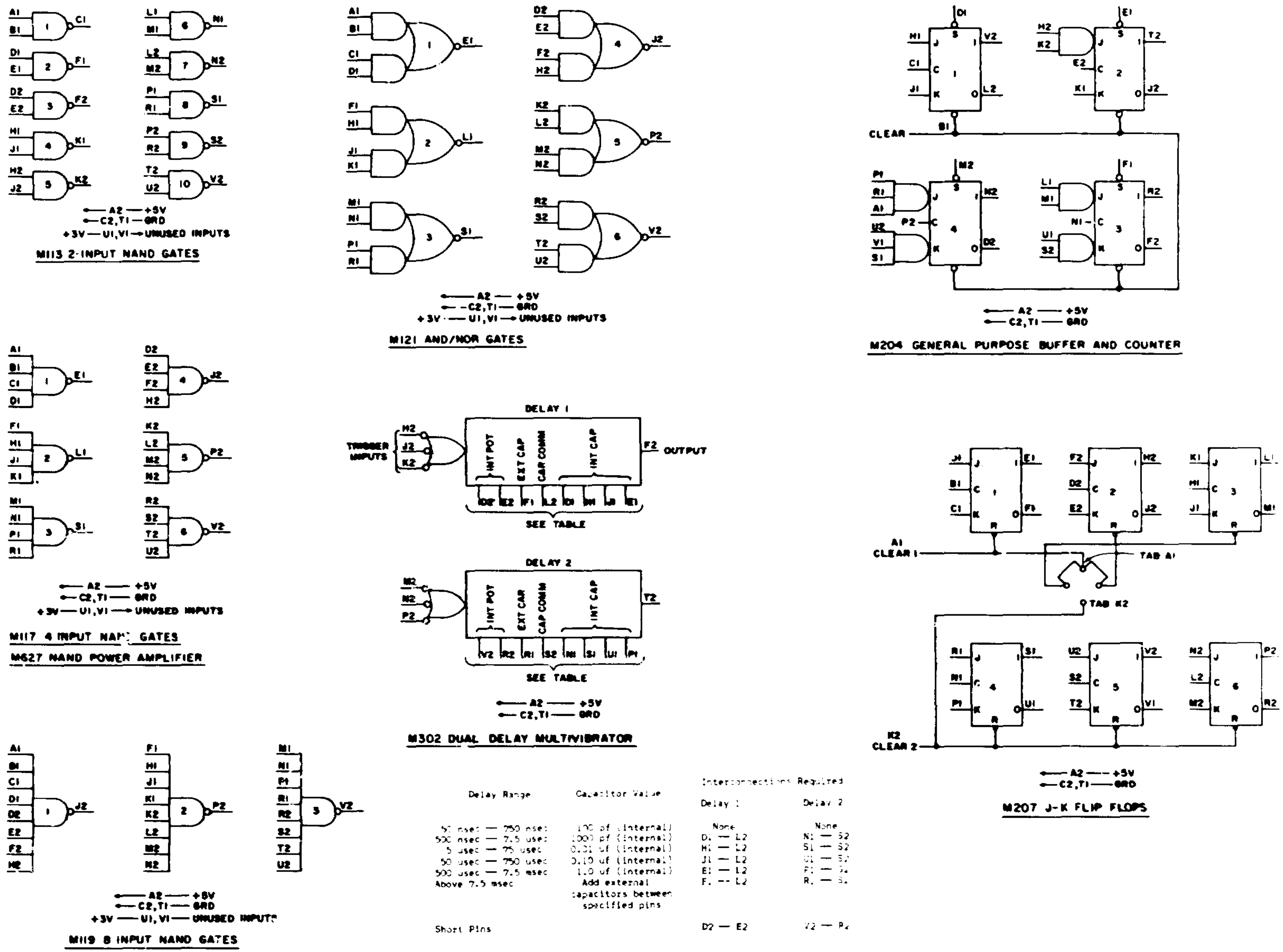
A41 Patch Panel (2nd Half)

A42 System Interconnection

A43 Goniometer Wiring - Diffractometer

A44 Goniometer Wiring - Spectrograph

A45 Power Distribution



Delay Range	Capacitor Value	Interconnections Required: Delay 1	Interconnections Required: Delay 2
50 nsec — 750 nsec	100 pf (internal)	None	None
500 nsec — 7.5 usec	1000 pf (internal)	D1 — L2	N1 — S2
5 usec — 75 usec	0.01 uf (internal)	H1 — L2	S1 — S2
50 usec — 750 usec	0.10 uf (internal)	J1 — L2	U1 — S2
500 usec — 7.5 msec	1.0 uf (internal)	E1 — L2	P1 — S2
Above 7.5 msec	Add external capacitors between specified pins	F1 — L2	R1 — S2
Short Pins		D2 — E2	V2 — P2

TABLE

Figure A-1

Digital Equipment's M-Series Modules

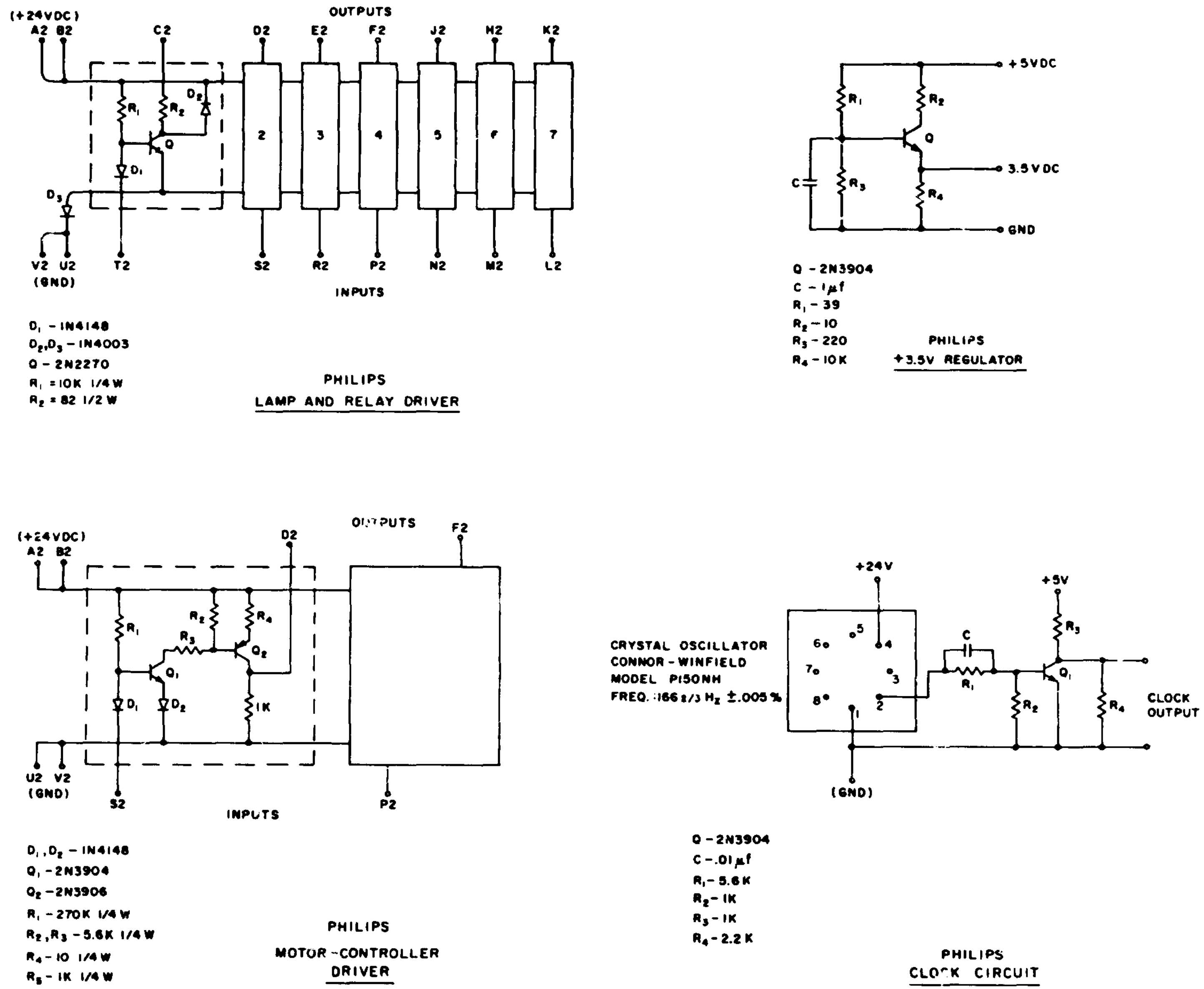


Figure A-2

Special Purpose Philips Modules

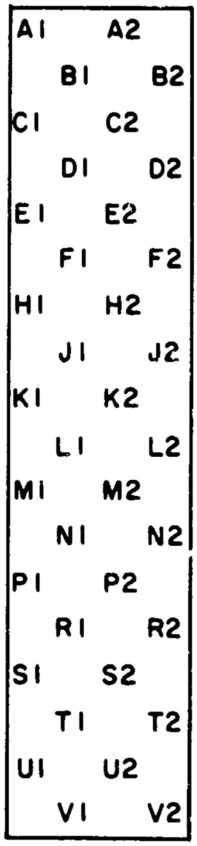


Figure A-3

Connector-Block Pin Arrangement

	B	A	
01			
02	M 204	M 121	
03	M 204	M 121	
04	M 204	M 121	
05	M 204	M 121	
06			
07	M 113	M 121	
08	M 117	M 121	
09	M 302	M 121	
10	M 627	M 117	
11			
12	M 117	M 117	
13	M 113	M 113	
14	M 113	M 119	
15	M 207	M 113	
16	M 113	M 113	
17		M 113	
18	M 113	M 113	
19		M 113	
20	M 117	M 113	
21	M 113	M 207	
22	FILTER	FILTER	
23	OSC. & RELAYS	SWITCHES	B: TO CON. #3R; A 23–28: CONNECTOR CARDS TO PATCH PANEL
24		SHAFT ENC	
25	R.L. SW. SHAFT ENCODER	R.L. SW. L.L. SW. SHAFT ENCODER	B 25–28: CONNECTOR CARDS TO COMP. INTERFACE
26	L.L. SW. SHAFT ENCODER	R.L. THW. SW.	
27	MISC.	L.L. THW. SW.	
28	MISC.	IND. LIGHTS	
29	LAMP RELAY DRIVER	LAMP RELAY DRIVER	
30		LAMP RELAY DRIVER	
31		LAMP RELAY DRIVER	
32		MOTOR CONTROL DRIVER	

Figure A-4

Bin Arrangement

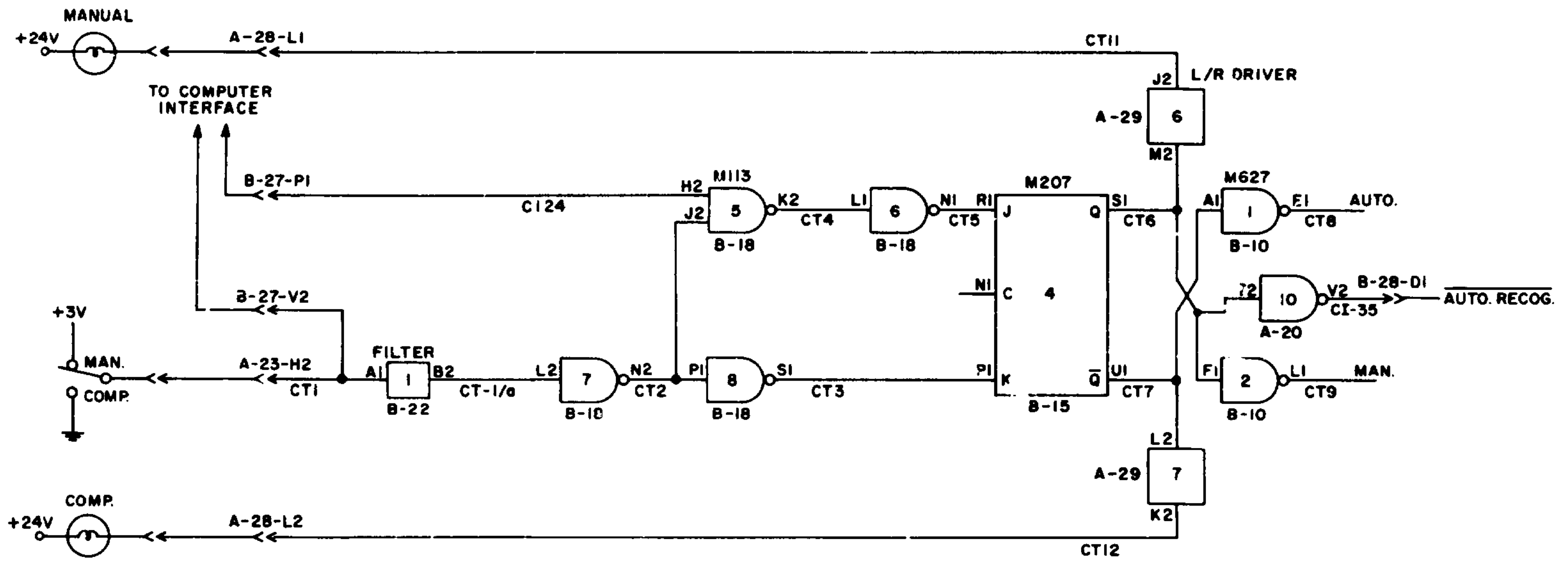


Figure A-5

Control Transfer

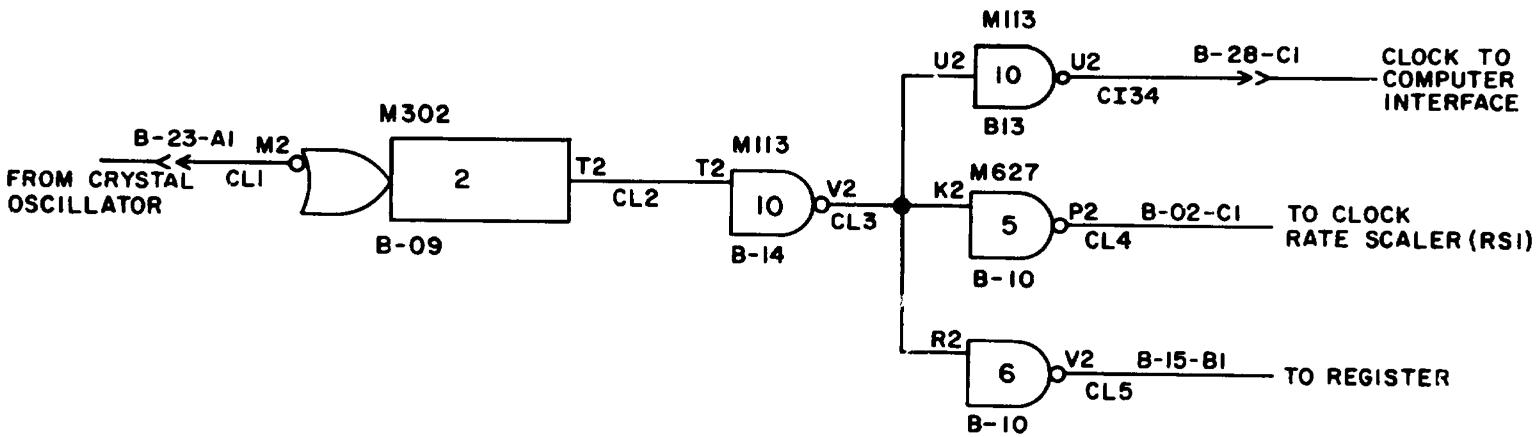


Figure A-6

Clock-Pulse Generator

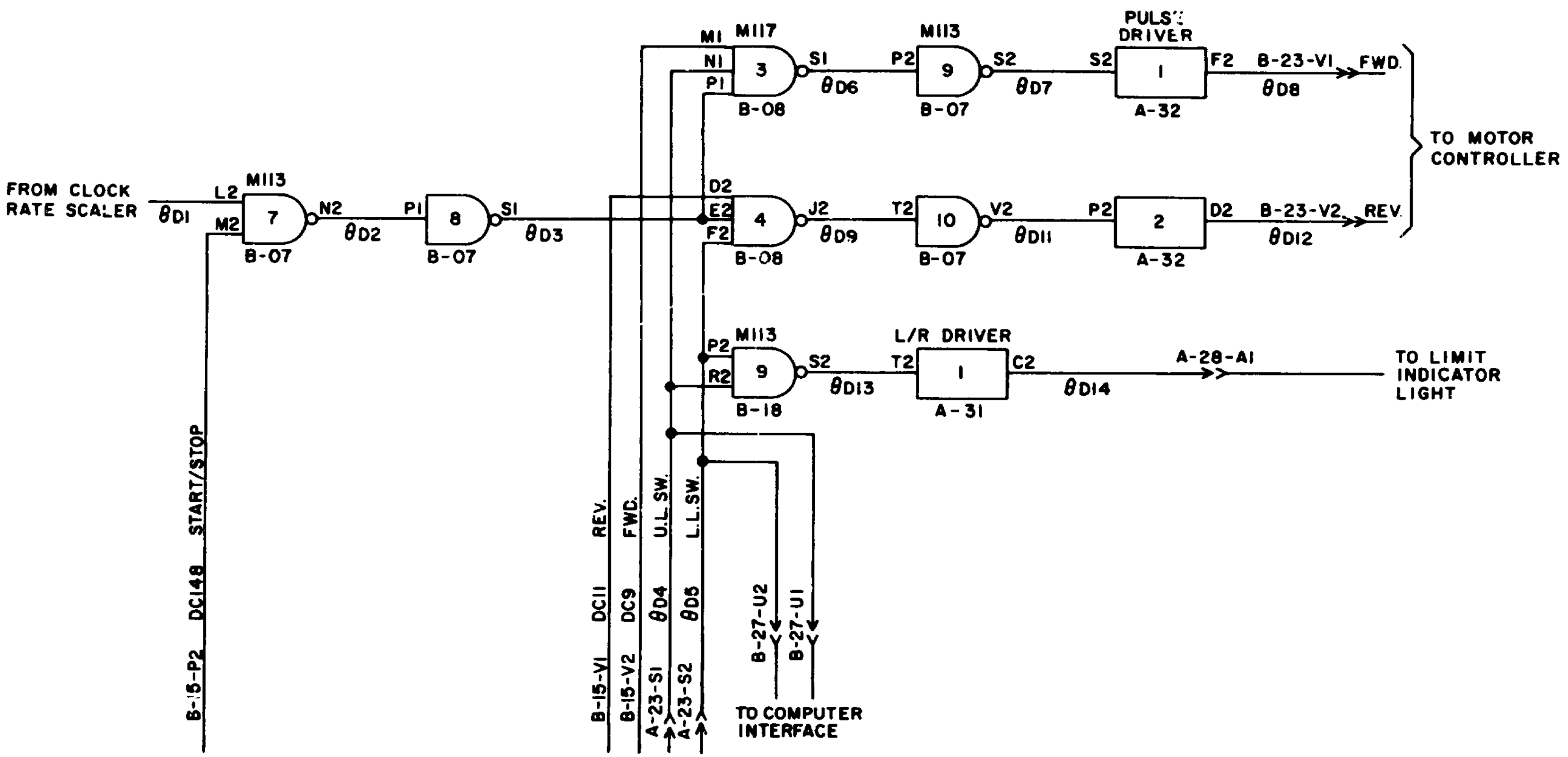


Figure A-7

2θ Drive

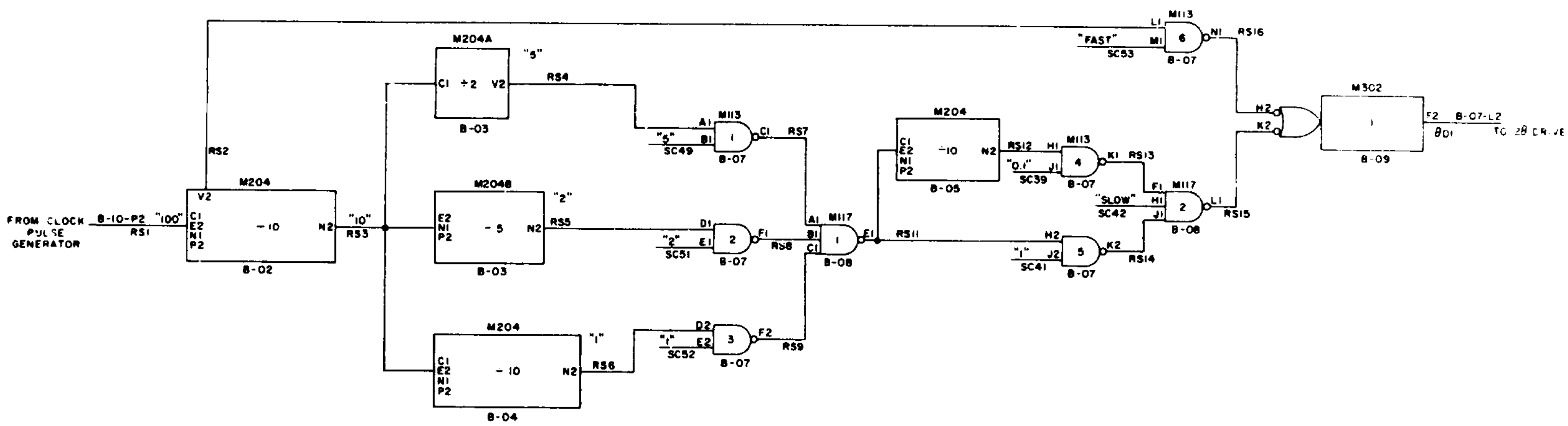


Figure A-8

2θ Rate Scaler

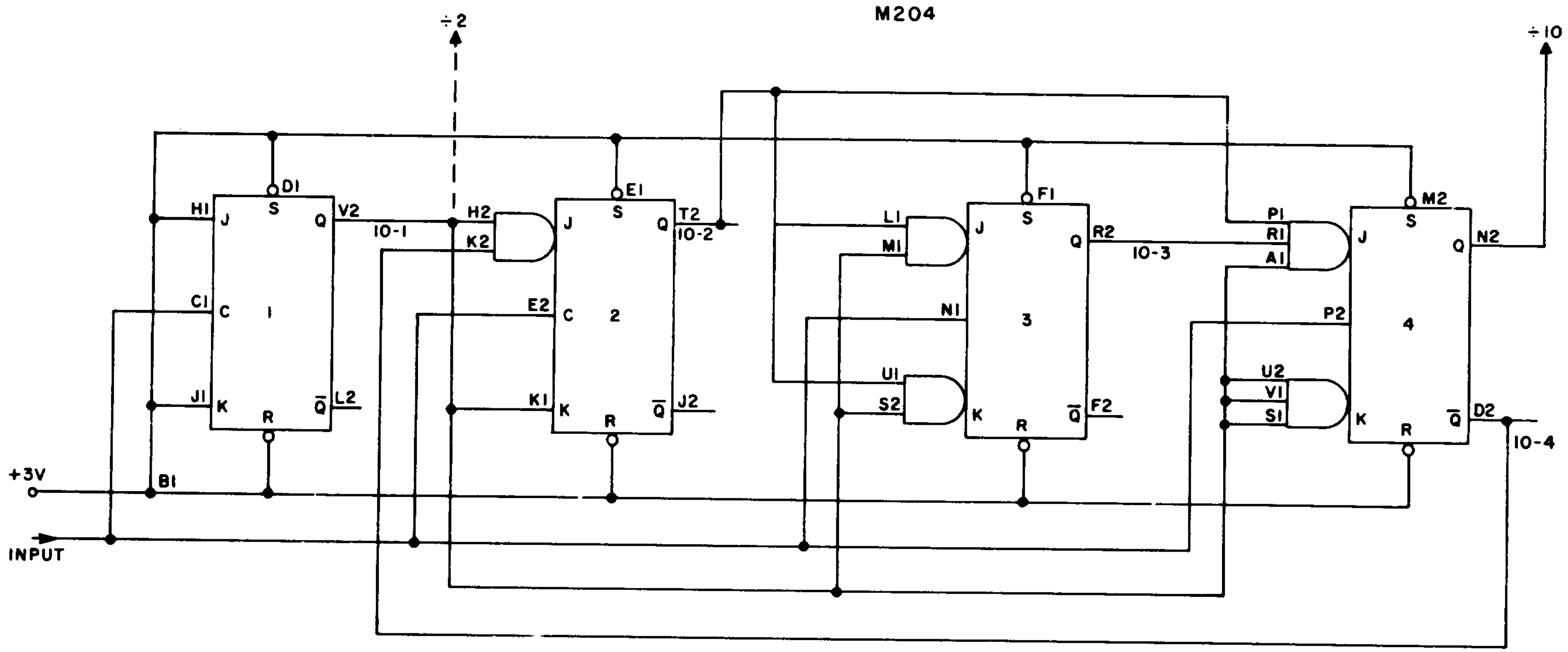


Figure A-9

÷ 10 Scaler

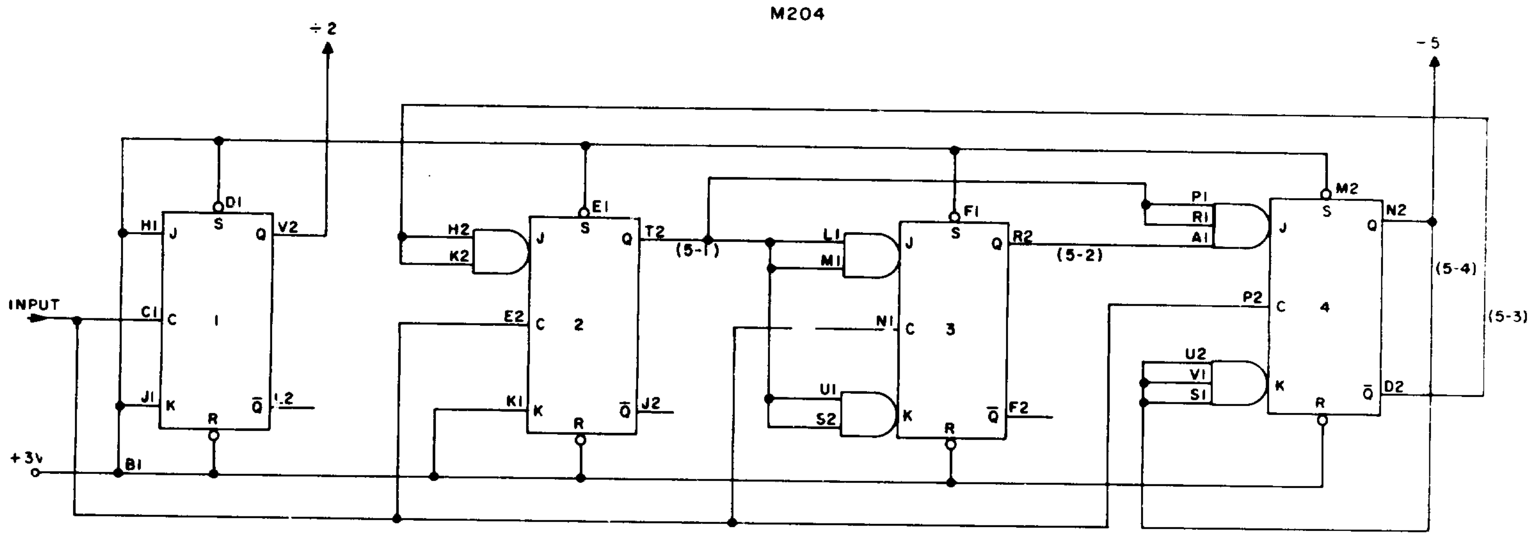


Figure A-10

÷ 2, ÷ 5 Scaler

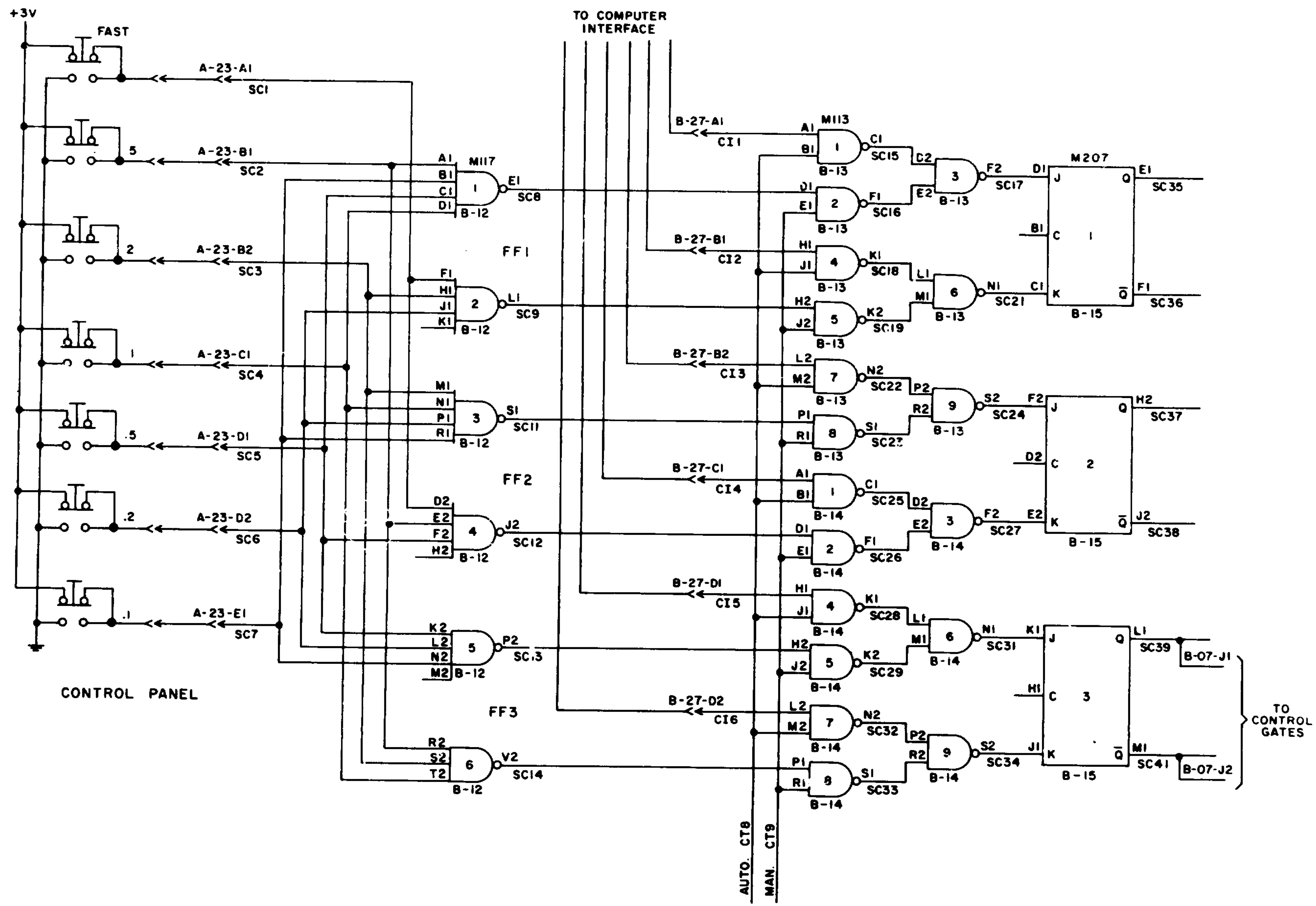
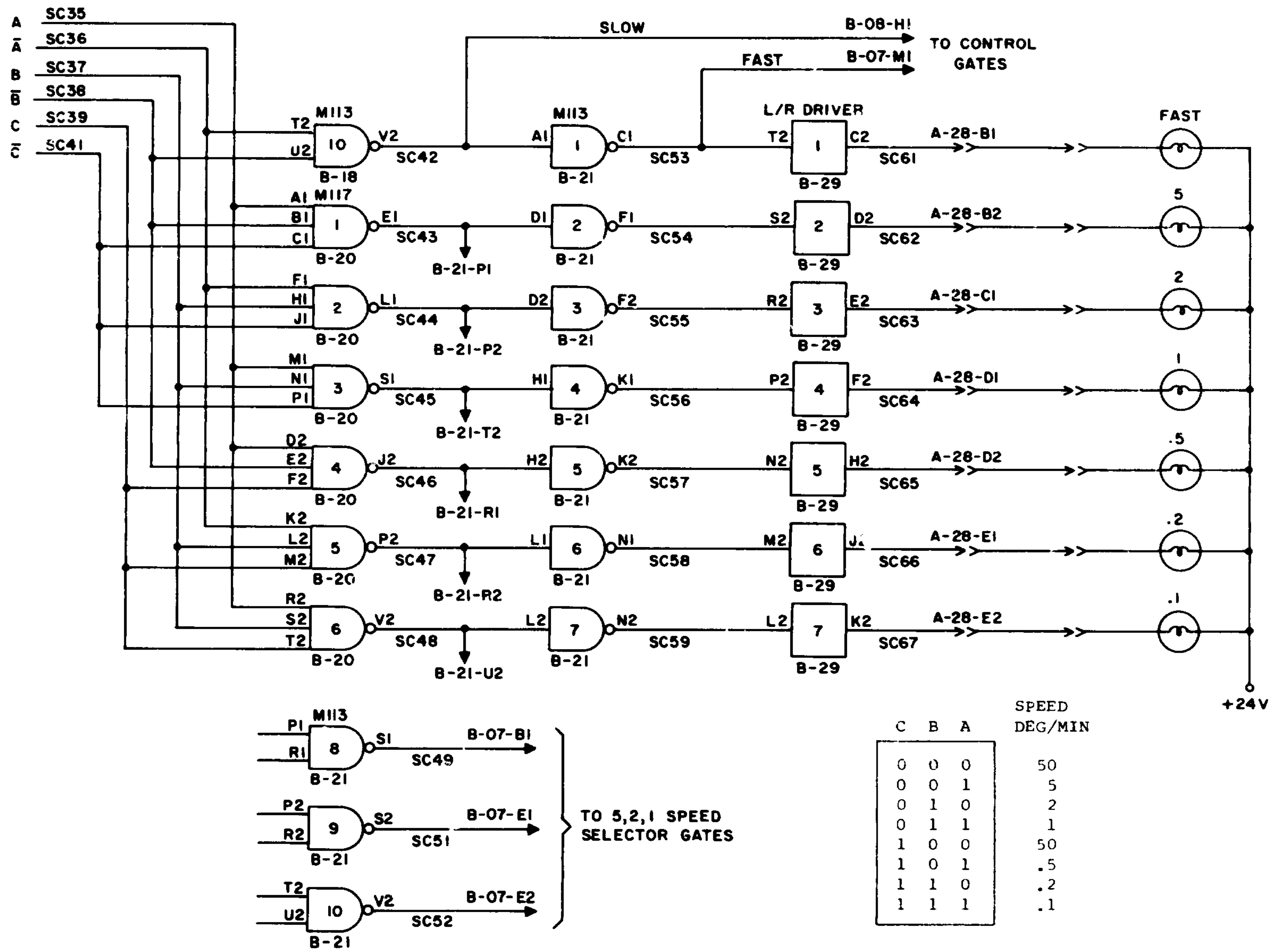


Figure A-11

2θ Scaler Control



C	B	A	SPEED DEG/MIN
0	0	0	50
0	0	1	5
0	1	0	2
0	1	1	1
1	0	0	50
1	0	1	.5
1	1	0	.2
1	1	1	.1

Figure A-12

2θ Scaler Decoder

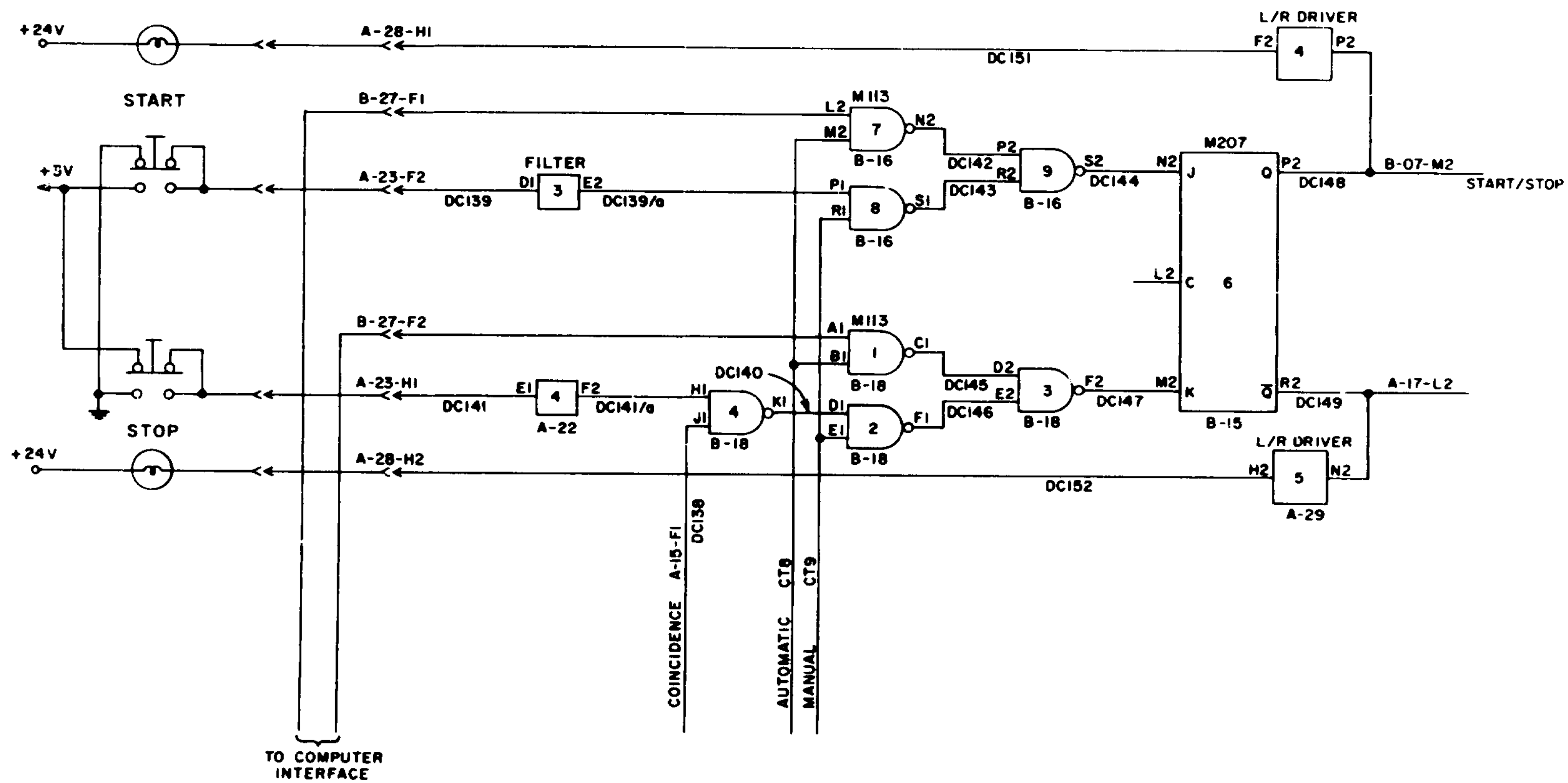


Figure A-13

2θ START/STOP Control

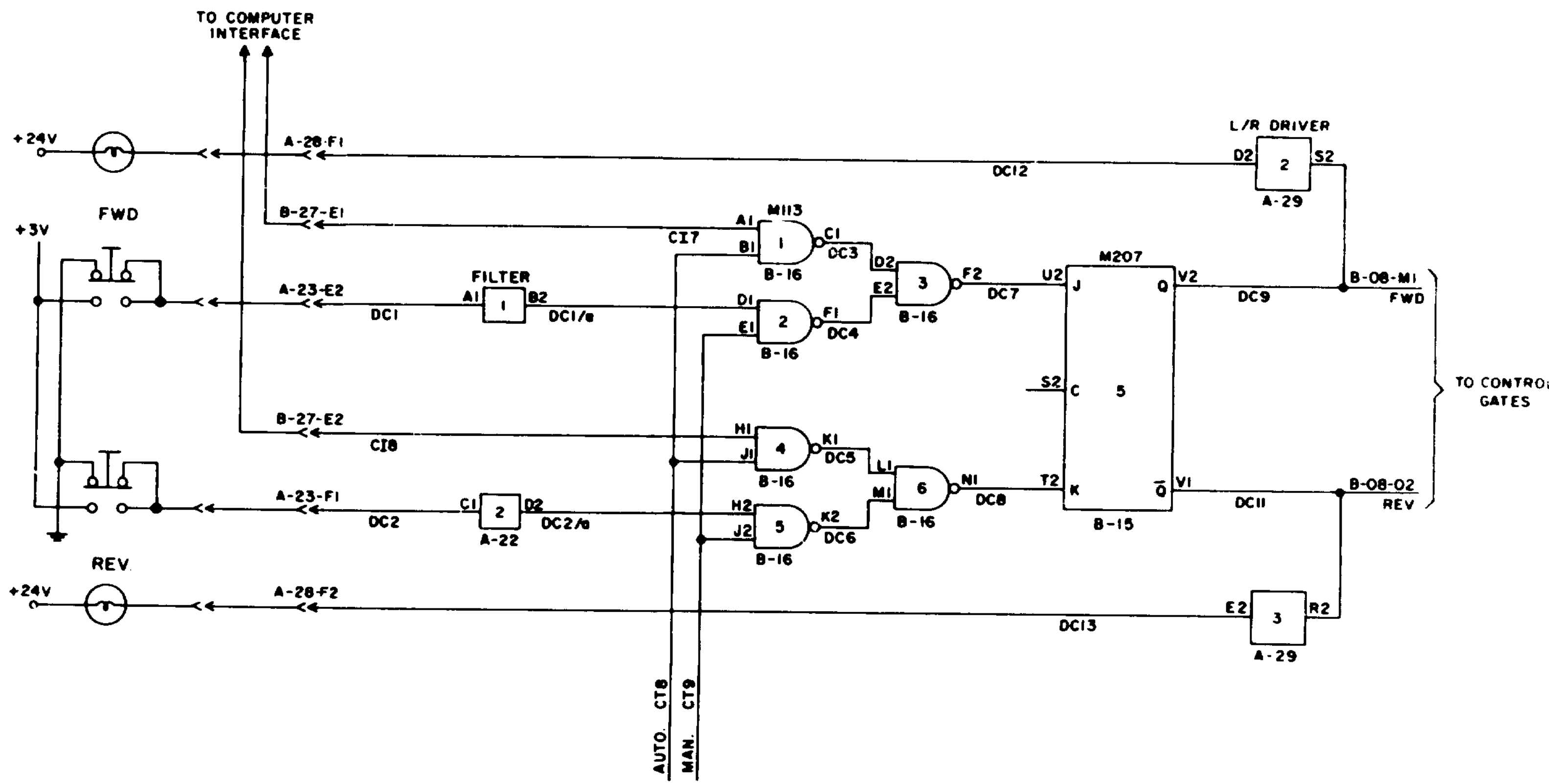


Figure A-14

2θ FORWARD/REVERSE Control

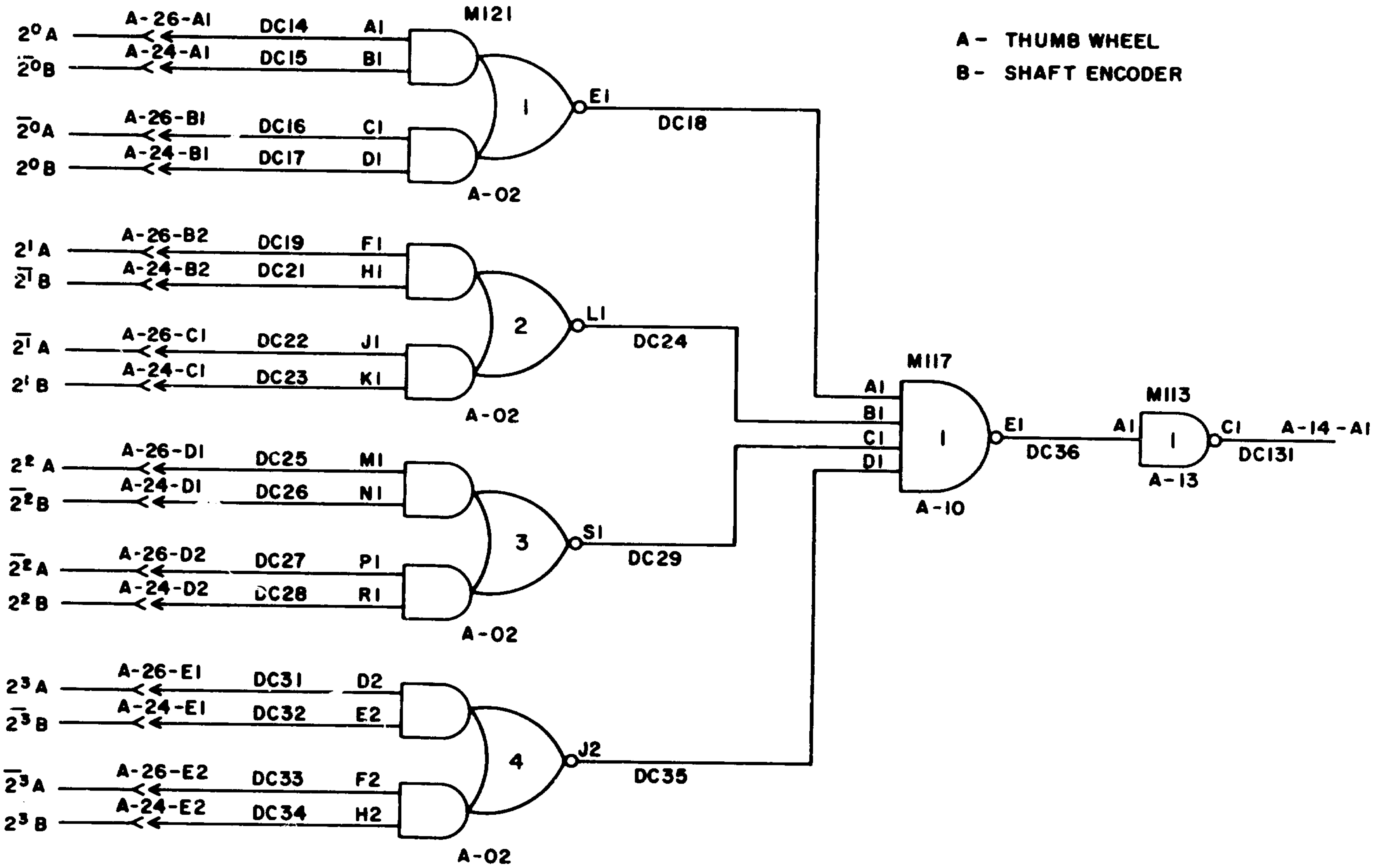


Figure A-15

1ST DIGIT R.L. SWITCH

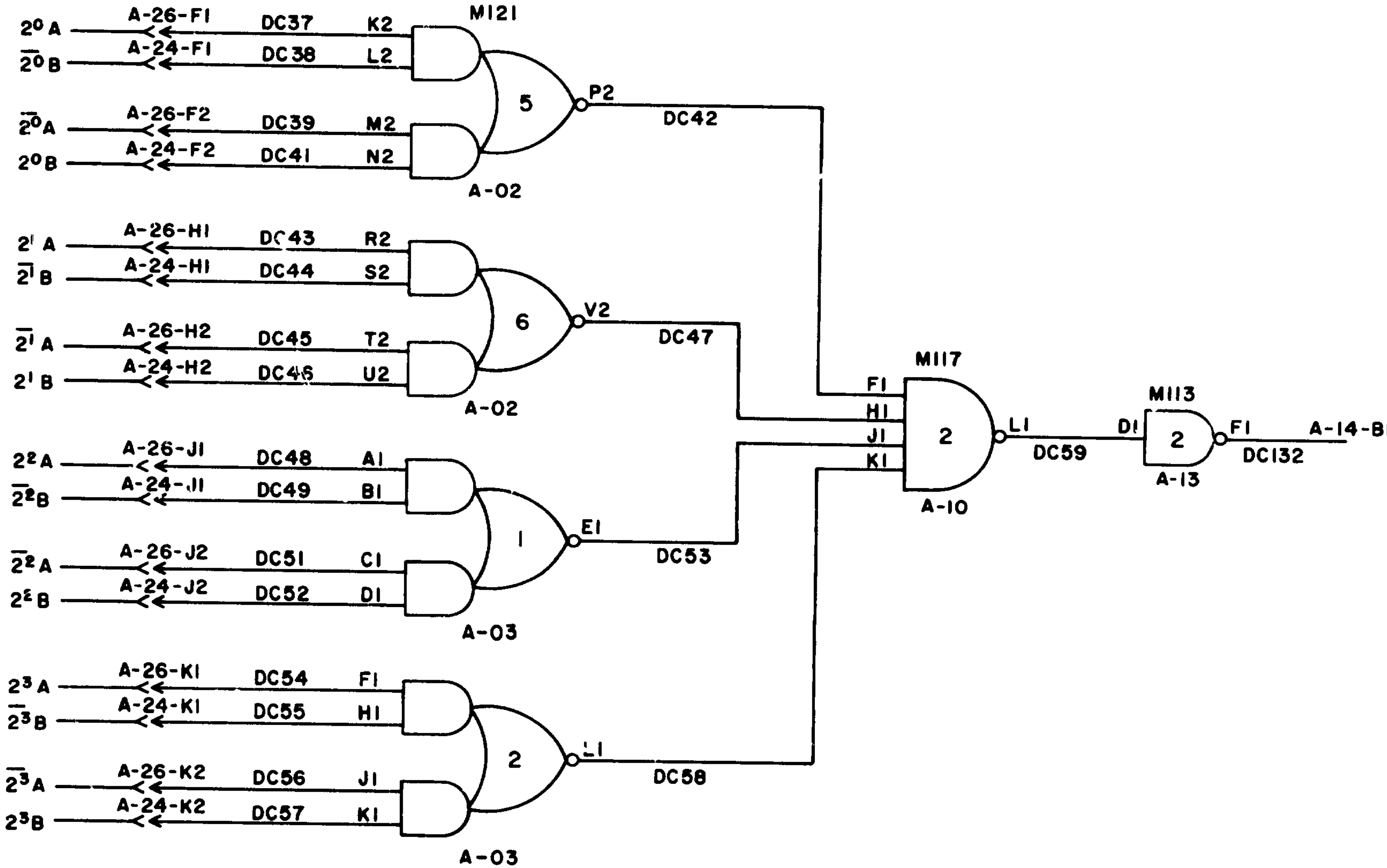


Figure A-16

2ND DIGIT R.L. SWITCH

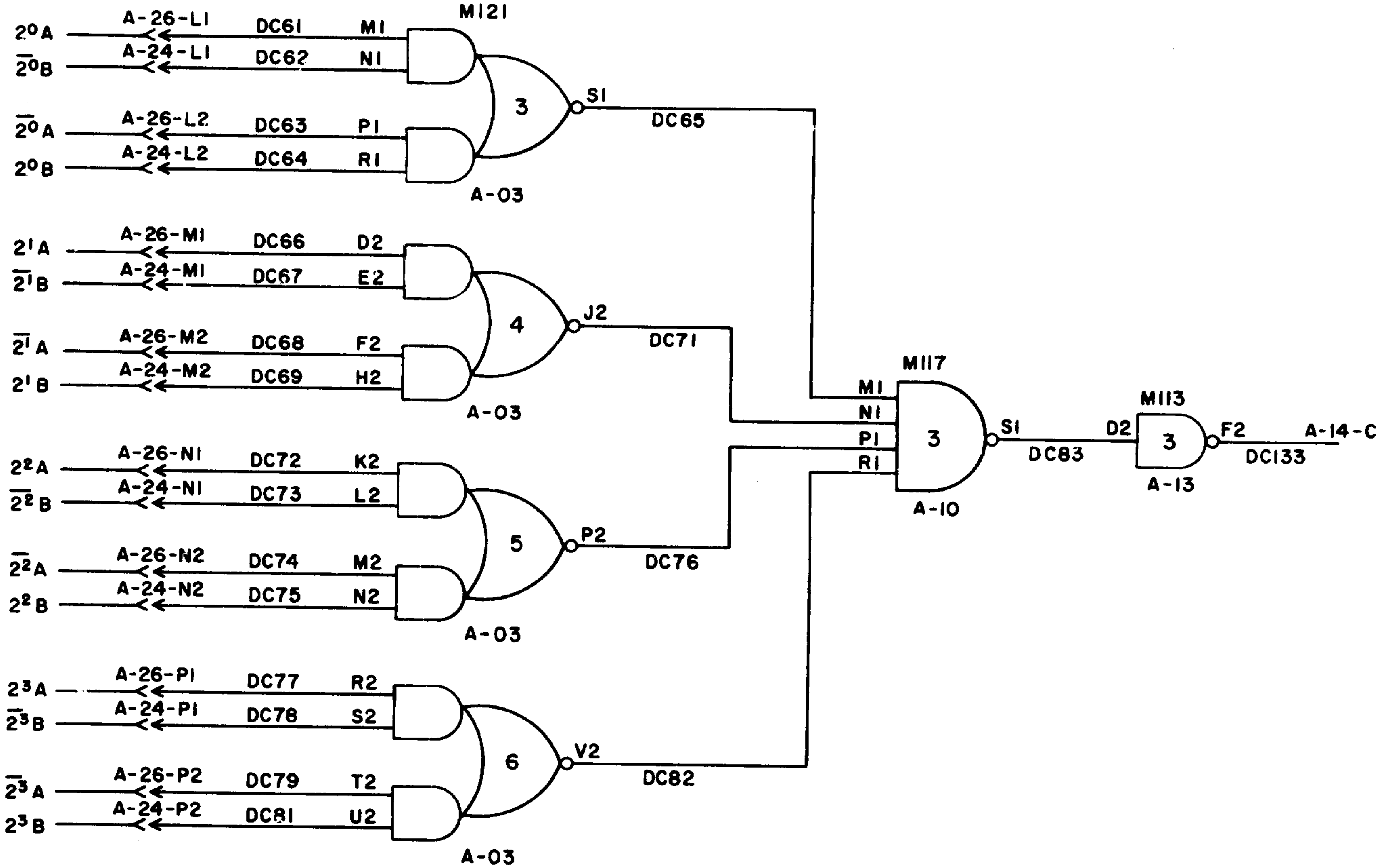


Figure A-17

3RD DIGIT R.L. SWITCH

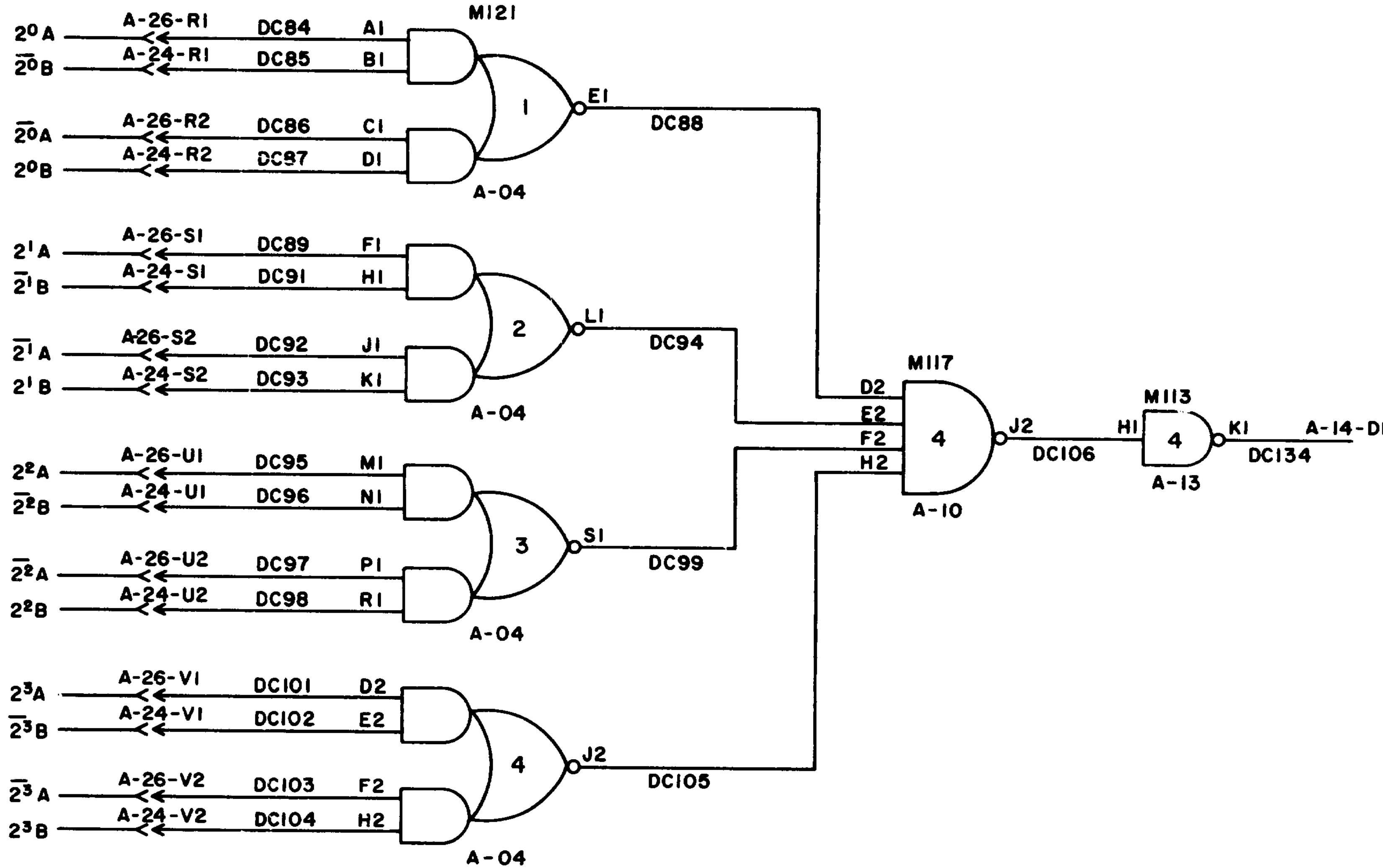


Figure A-18

4TH DIGIT R.L. SWITCH

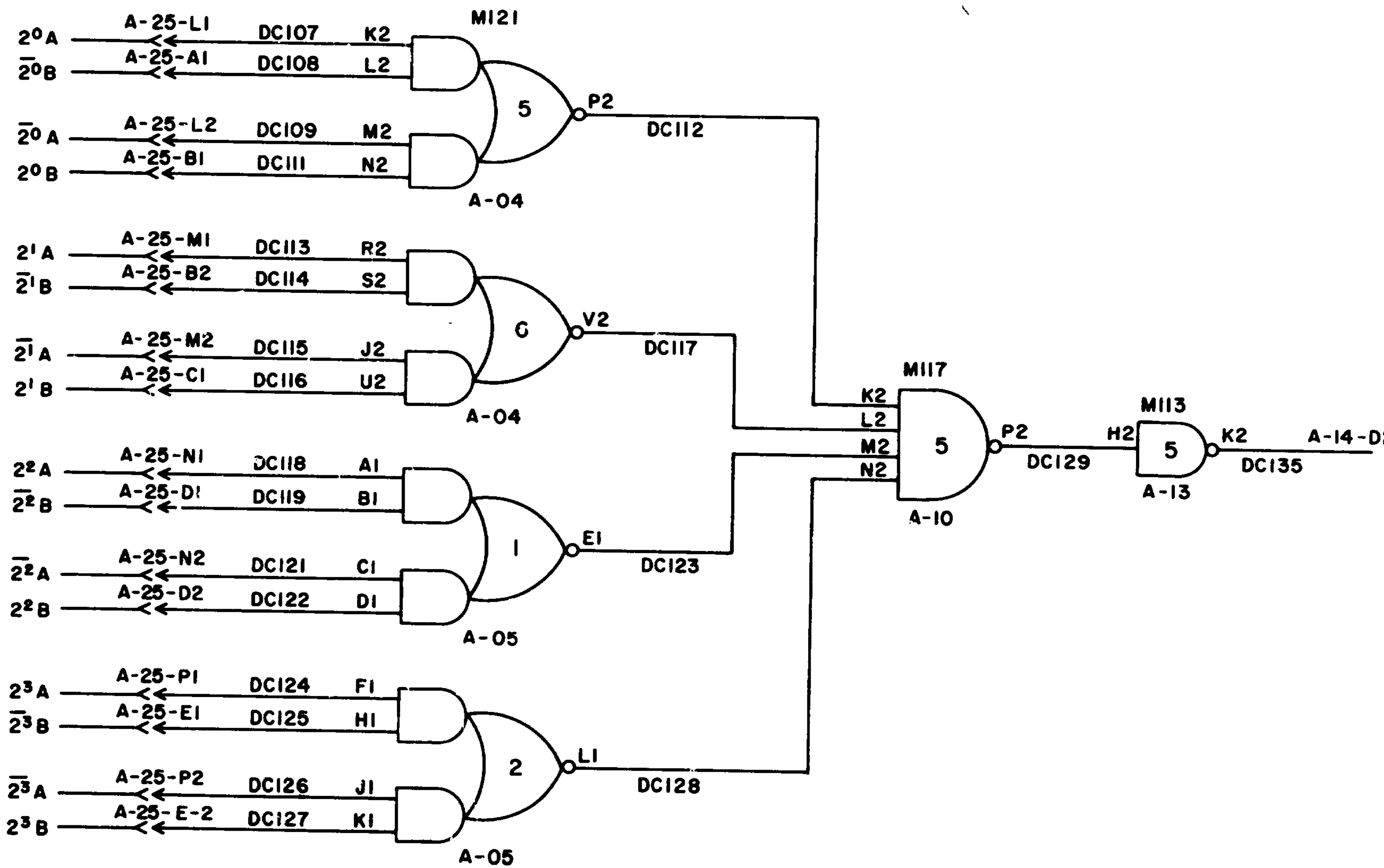


Figure A-19

5TH DIGIT R.L. SWITCH

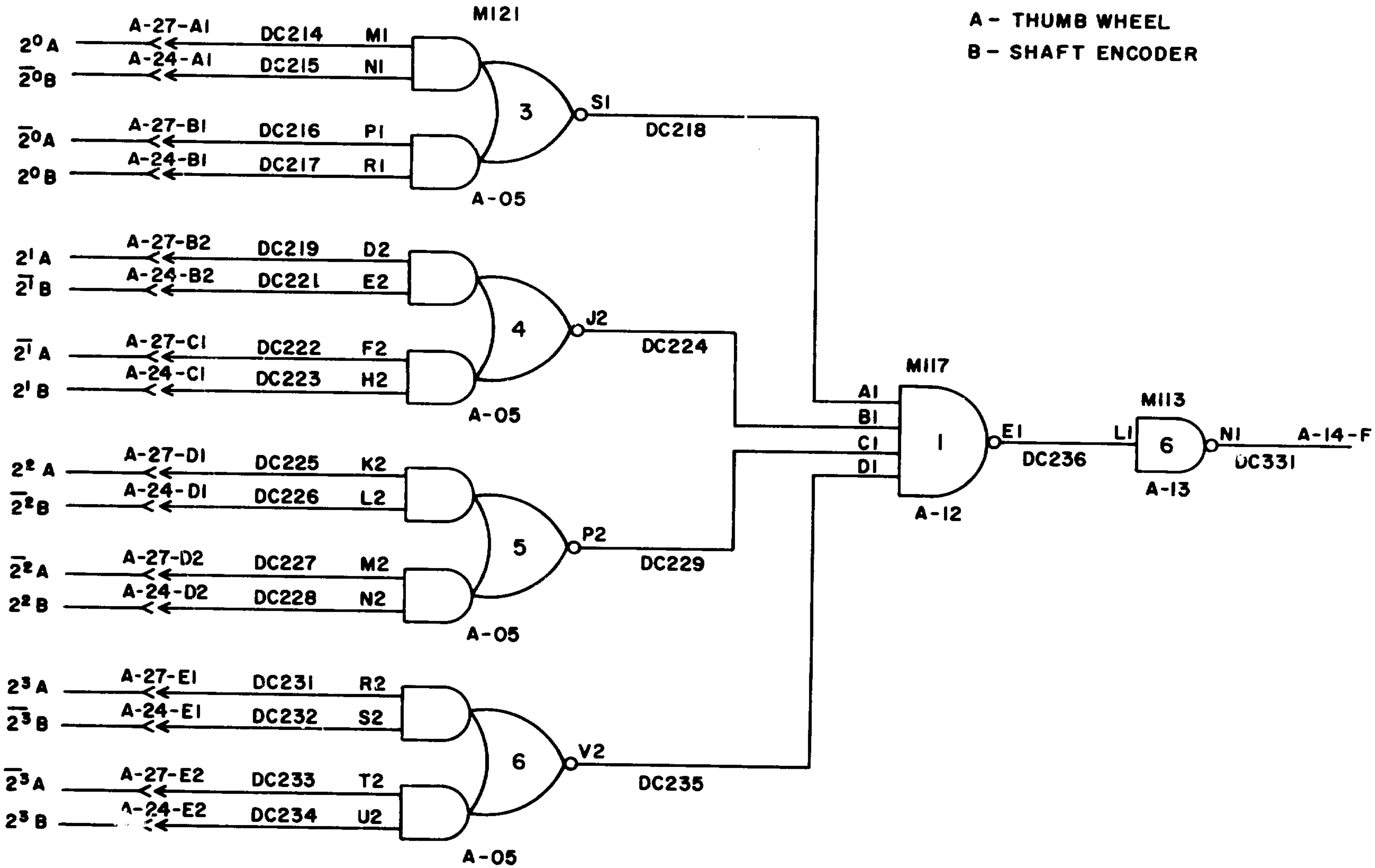


Figure A-20

1ST DIGIT L.L. SWITCH

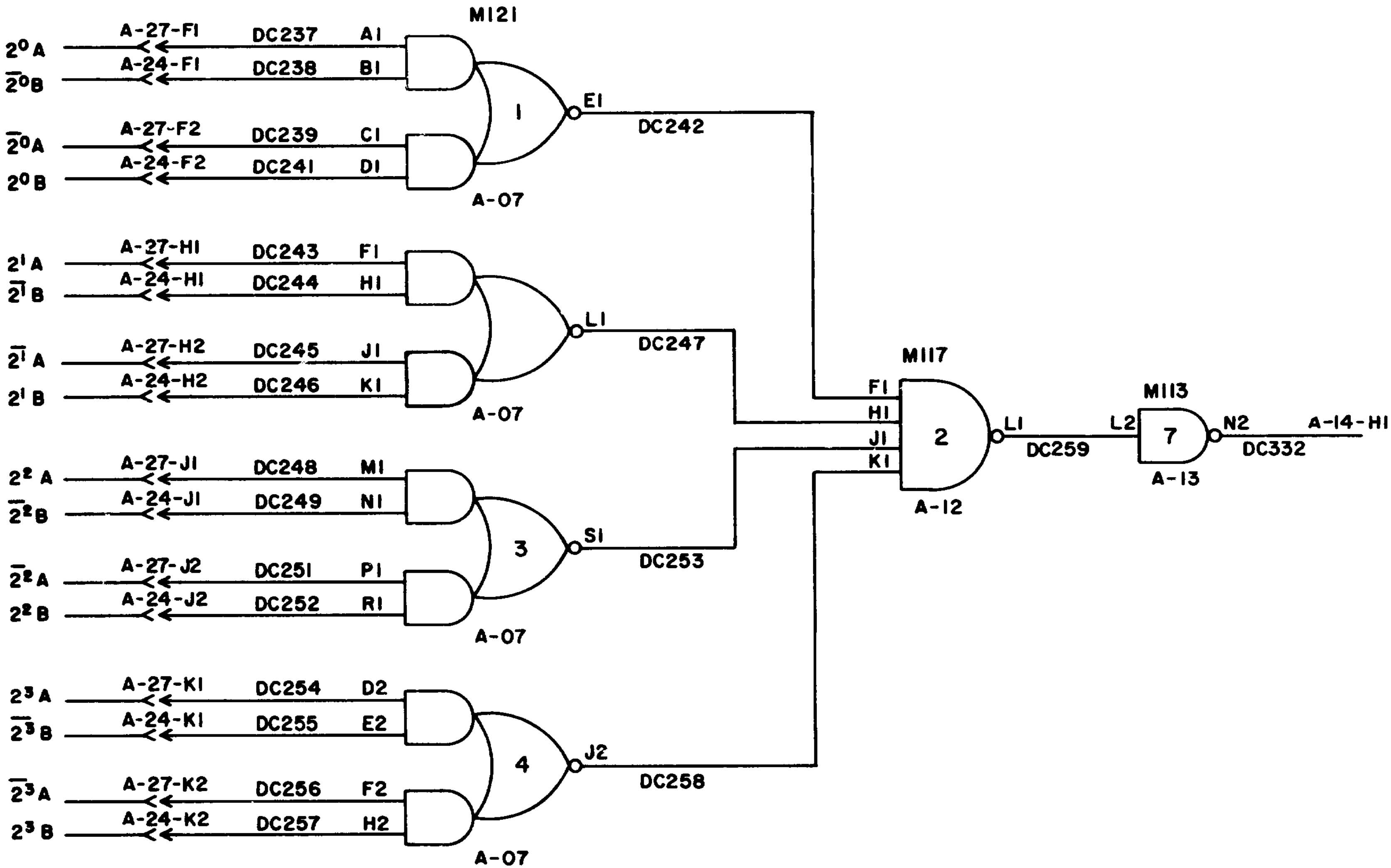


Figure A-21

2ND DIGIT L.L. SWITCH

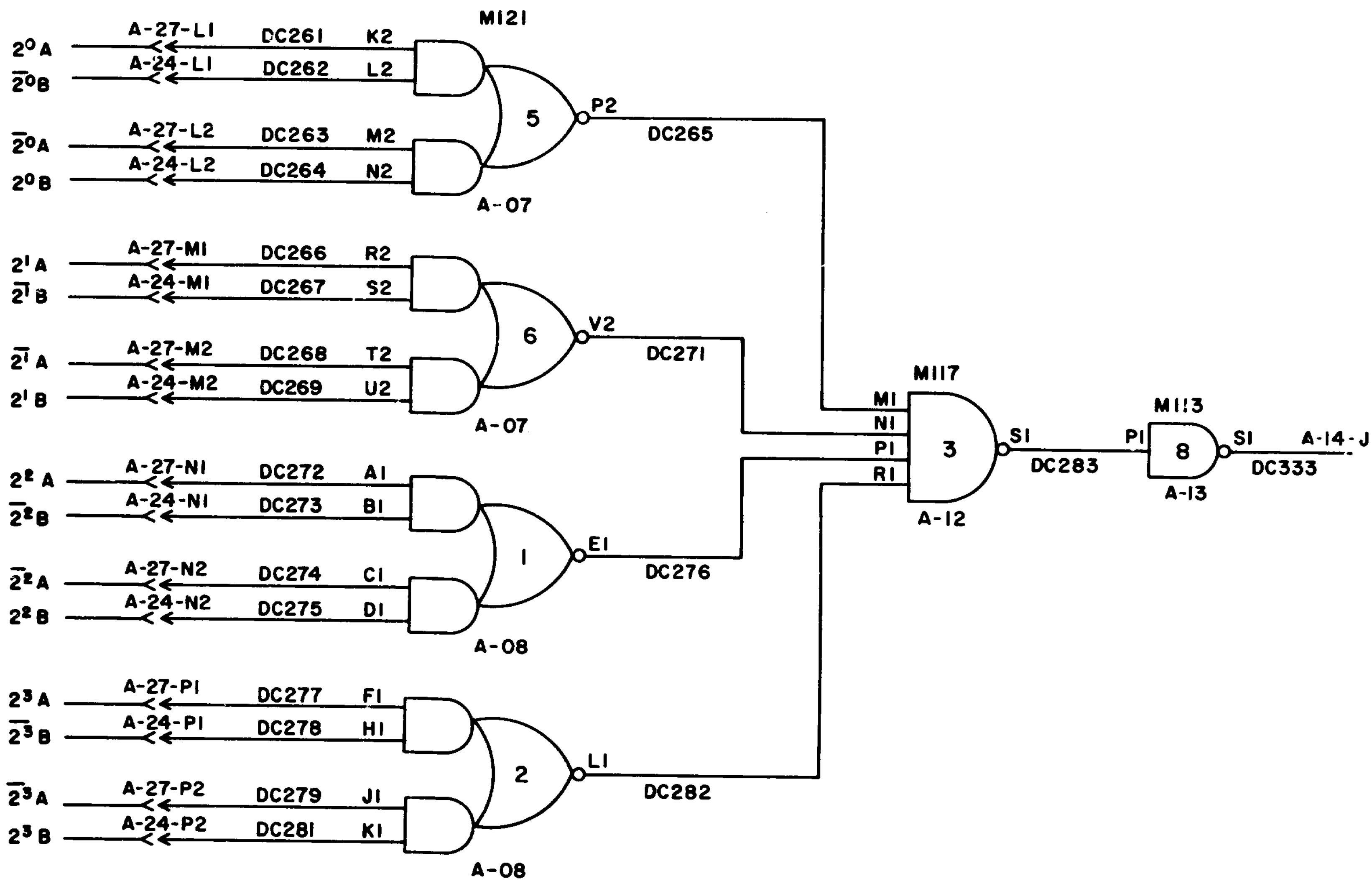


Figure A-22

3RD DIGIT L.L. SWITCH

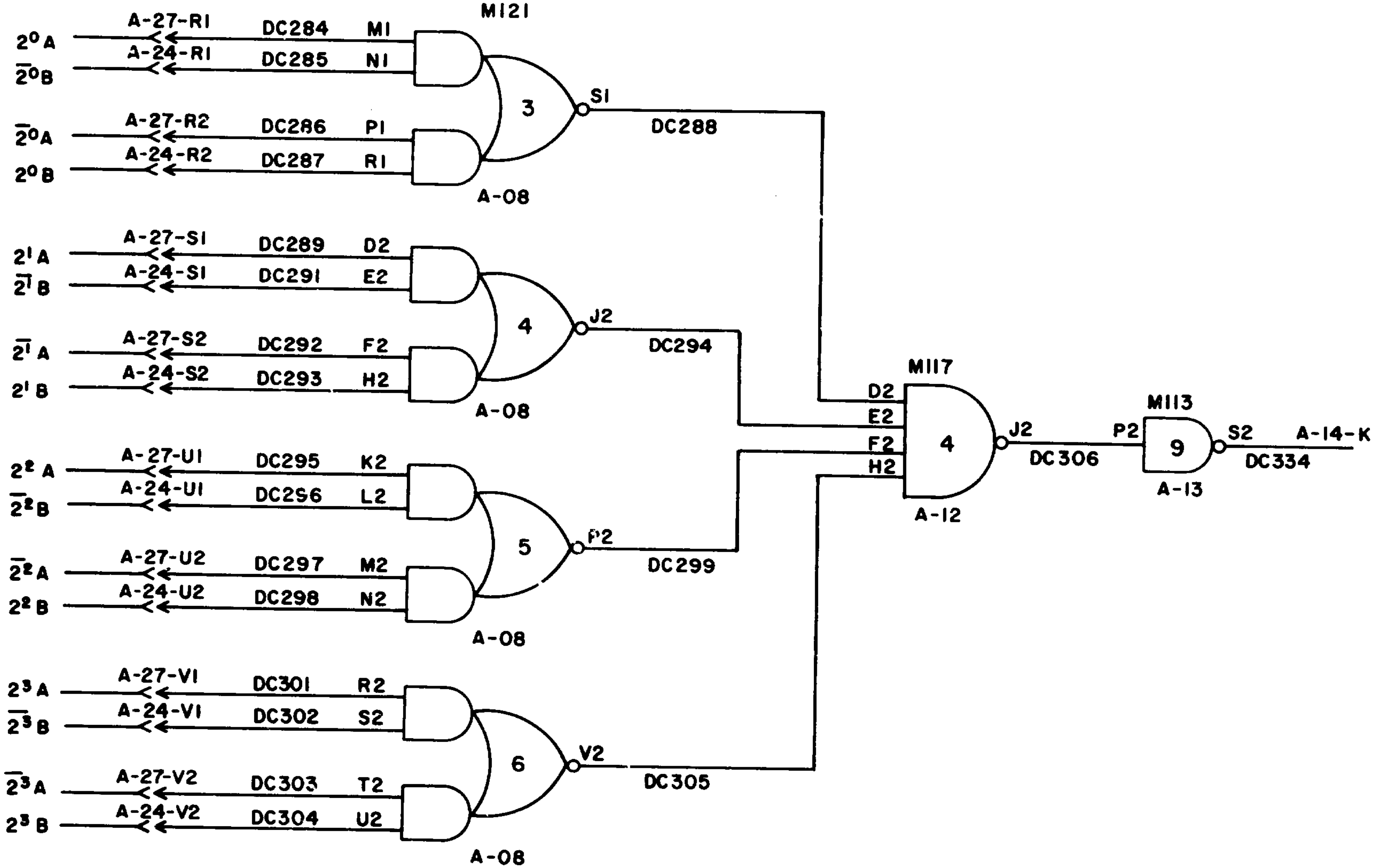


Figure A-23

4TH DIGIT L.L. SWITCH

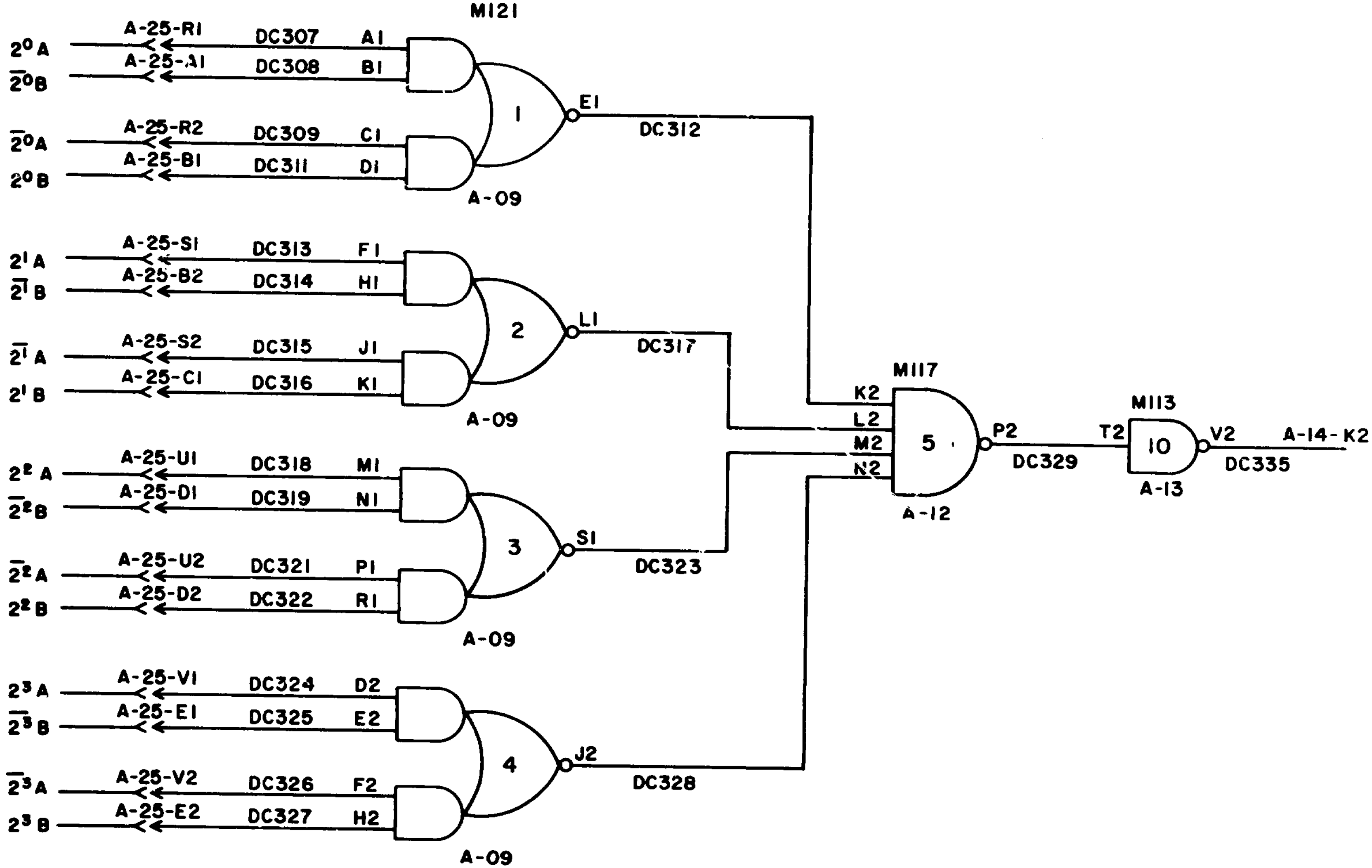
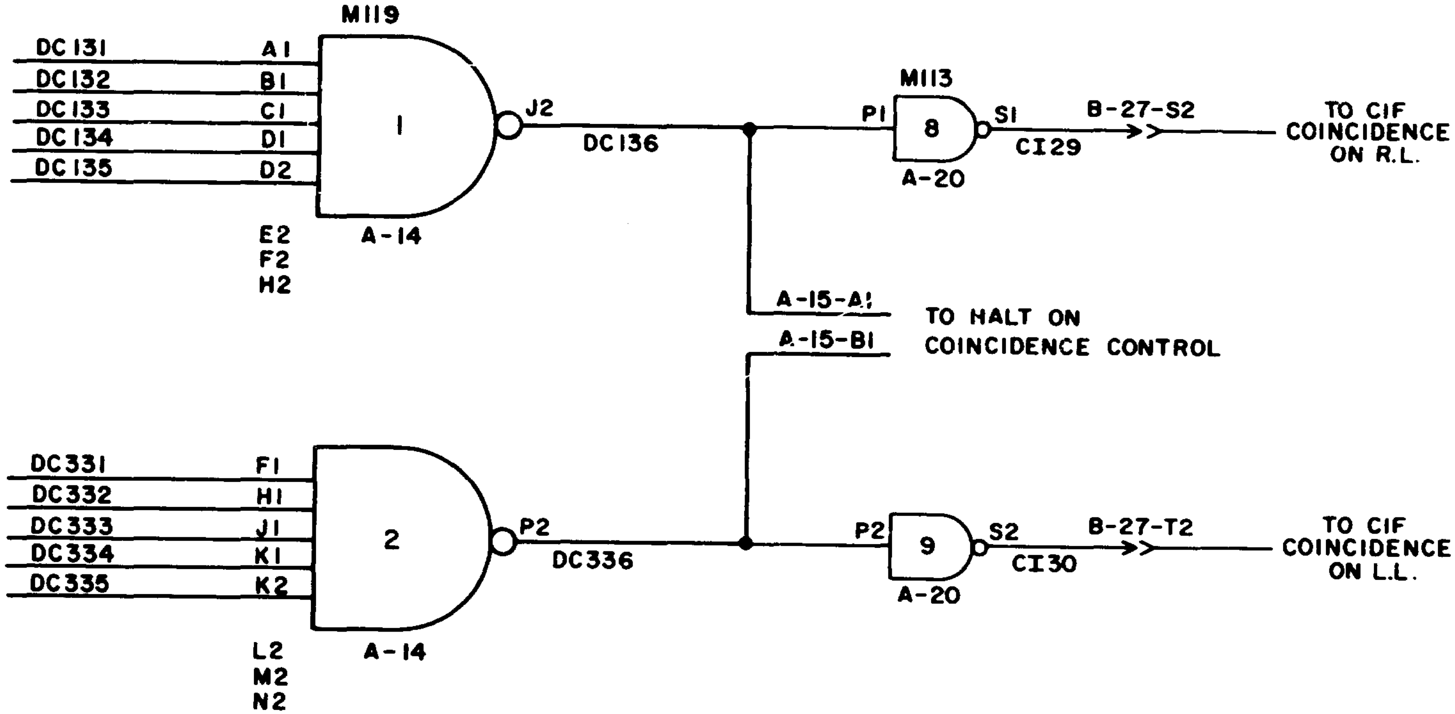


Figure A-24

5TH DIGIT L.L. SWITCH



COINCIDENCE

Figure A-25

Coincidence Circuit for Comparing Both Thumbwheel Switches with Shaft Encoder

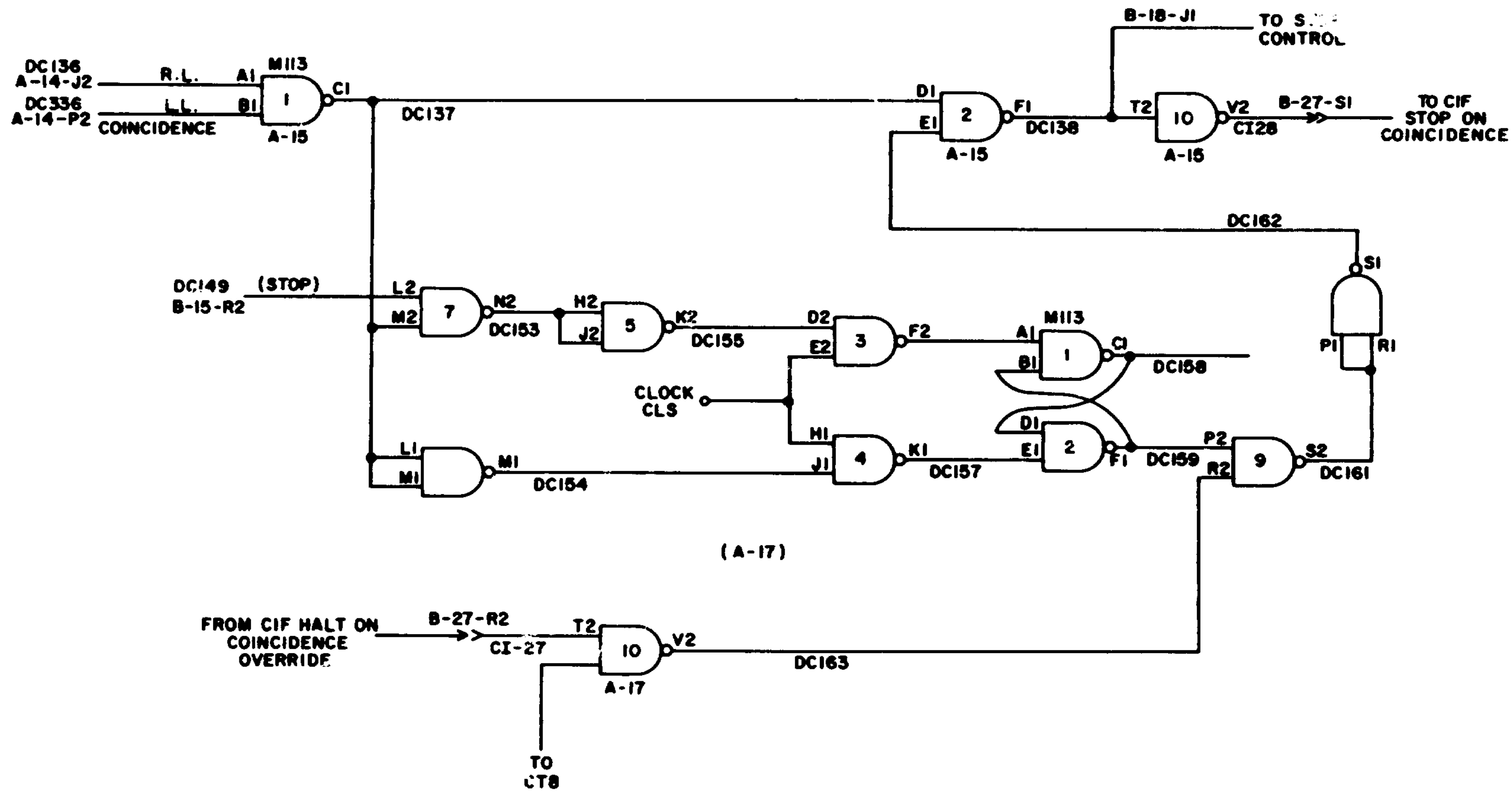


Figure A-26

HALT on Coincidence Control

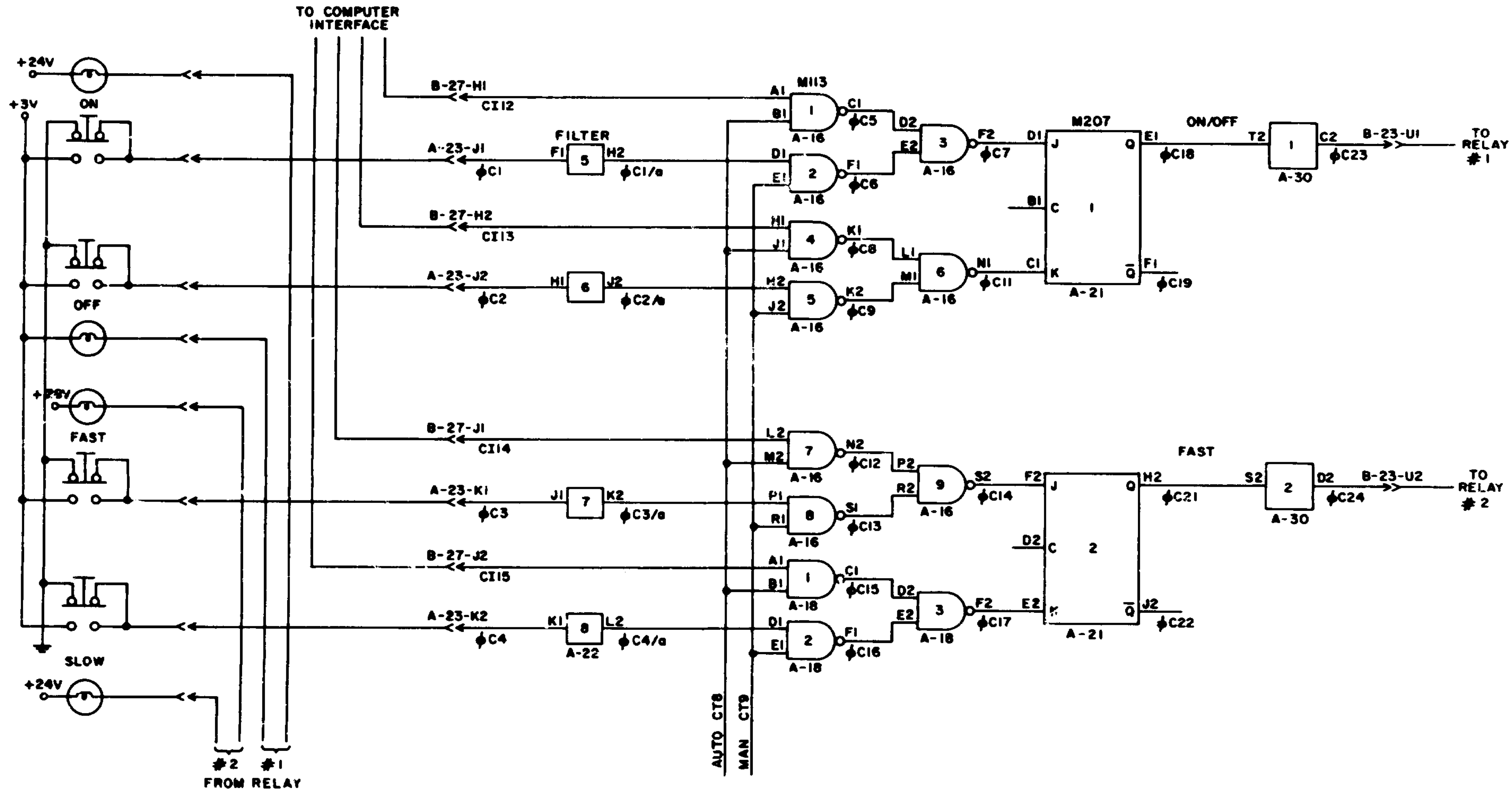


Figure A-27

Ø Control (Specimen Rotation)

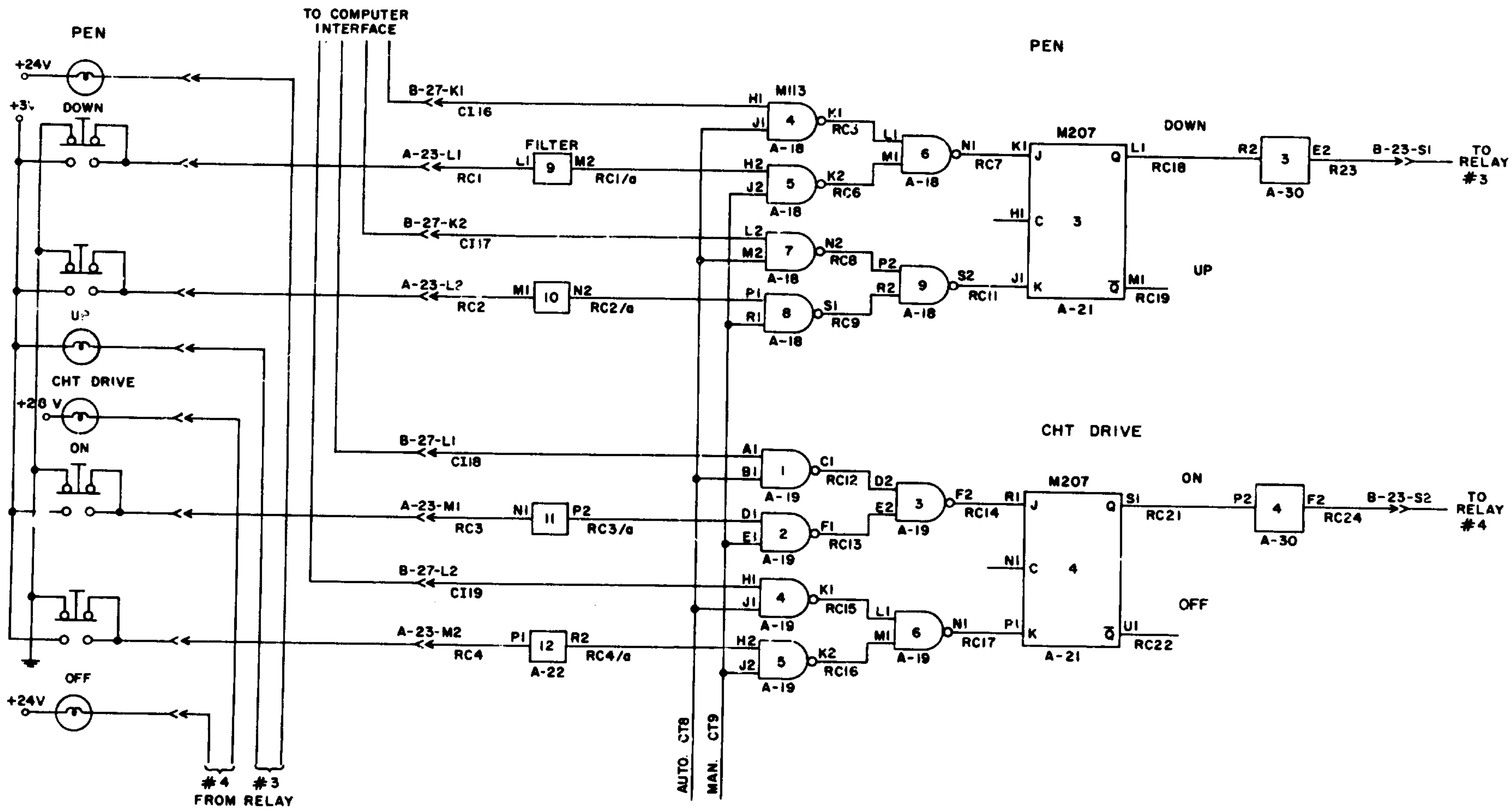


Figure A-28

Strip-Chart-Recorder Control

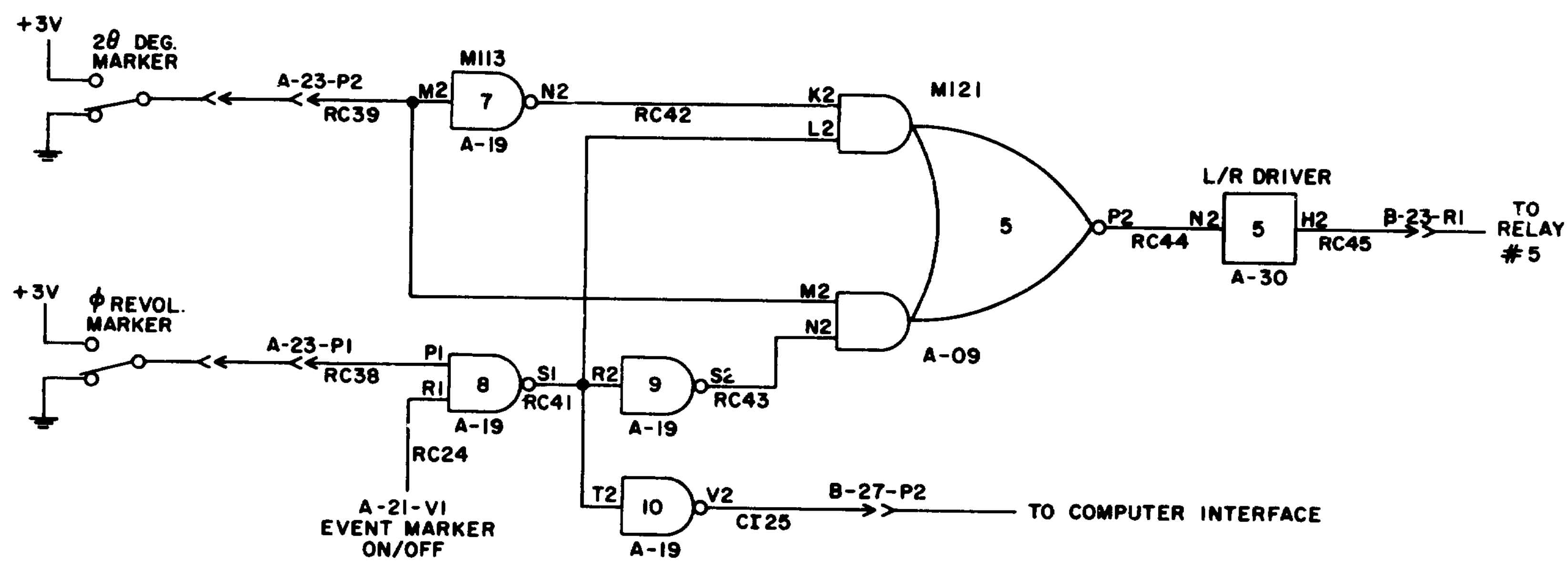


Figure A-29

Event Marker Control

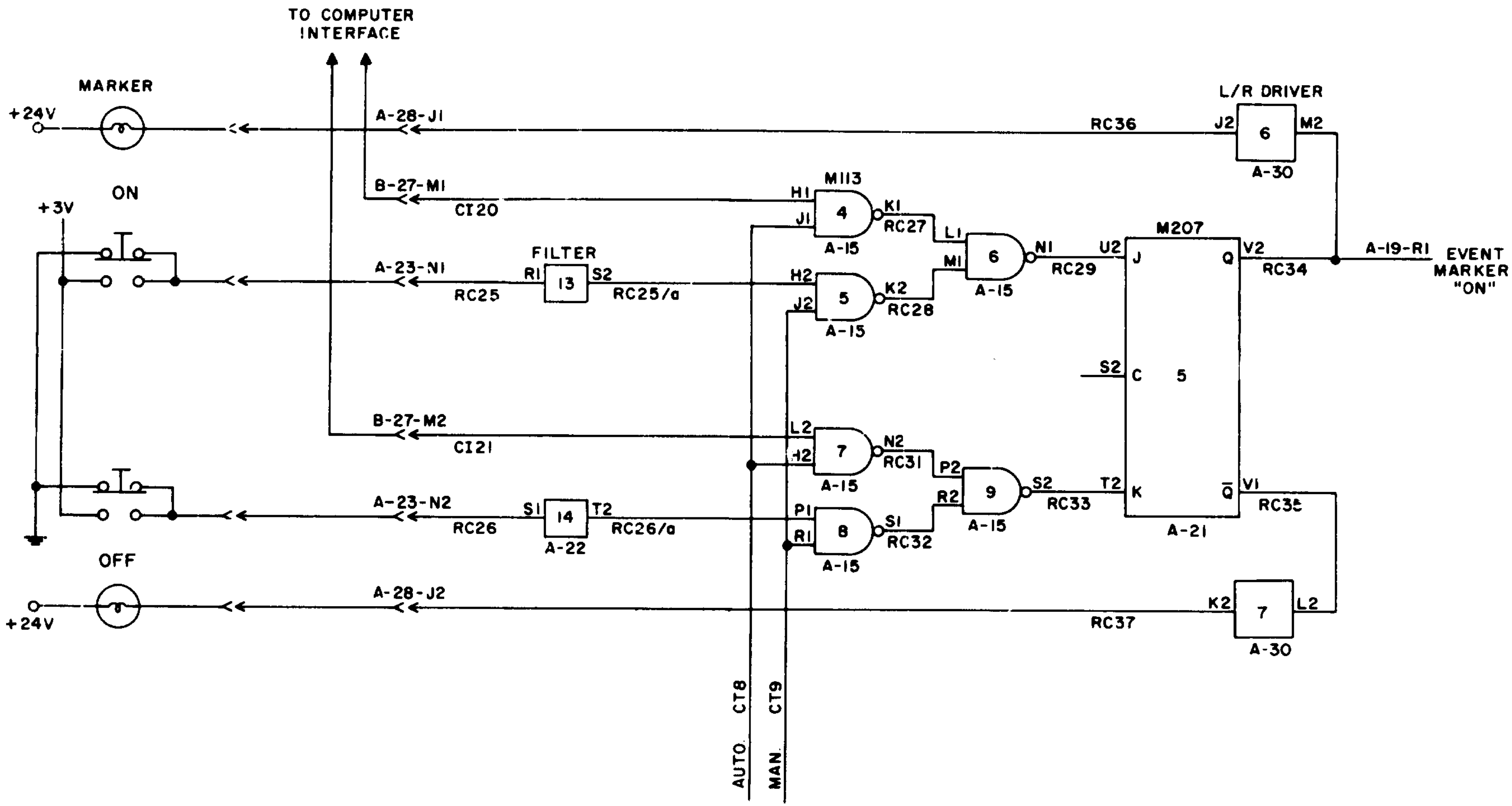


Figure A-30

Ø Revolution Marker Control

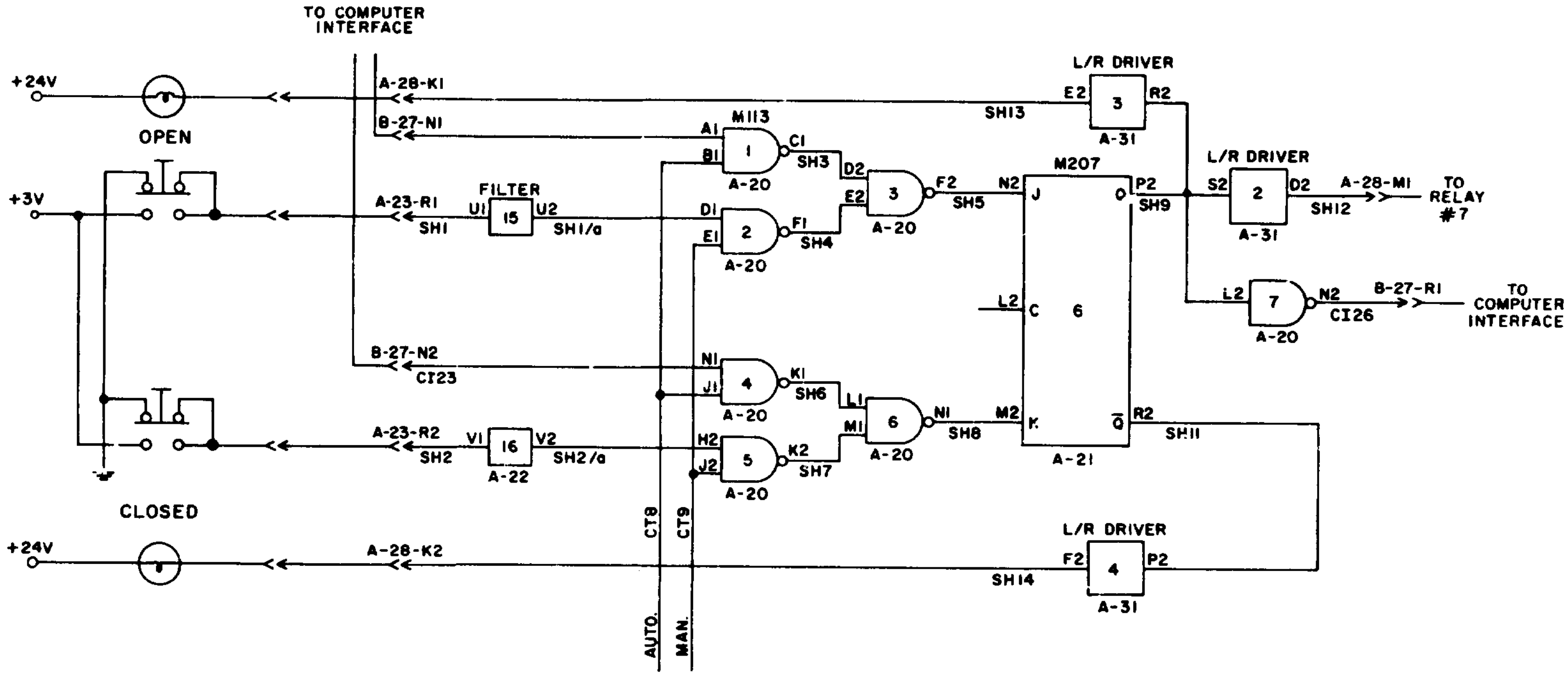


Figure A-31

Shutter Control

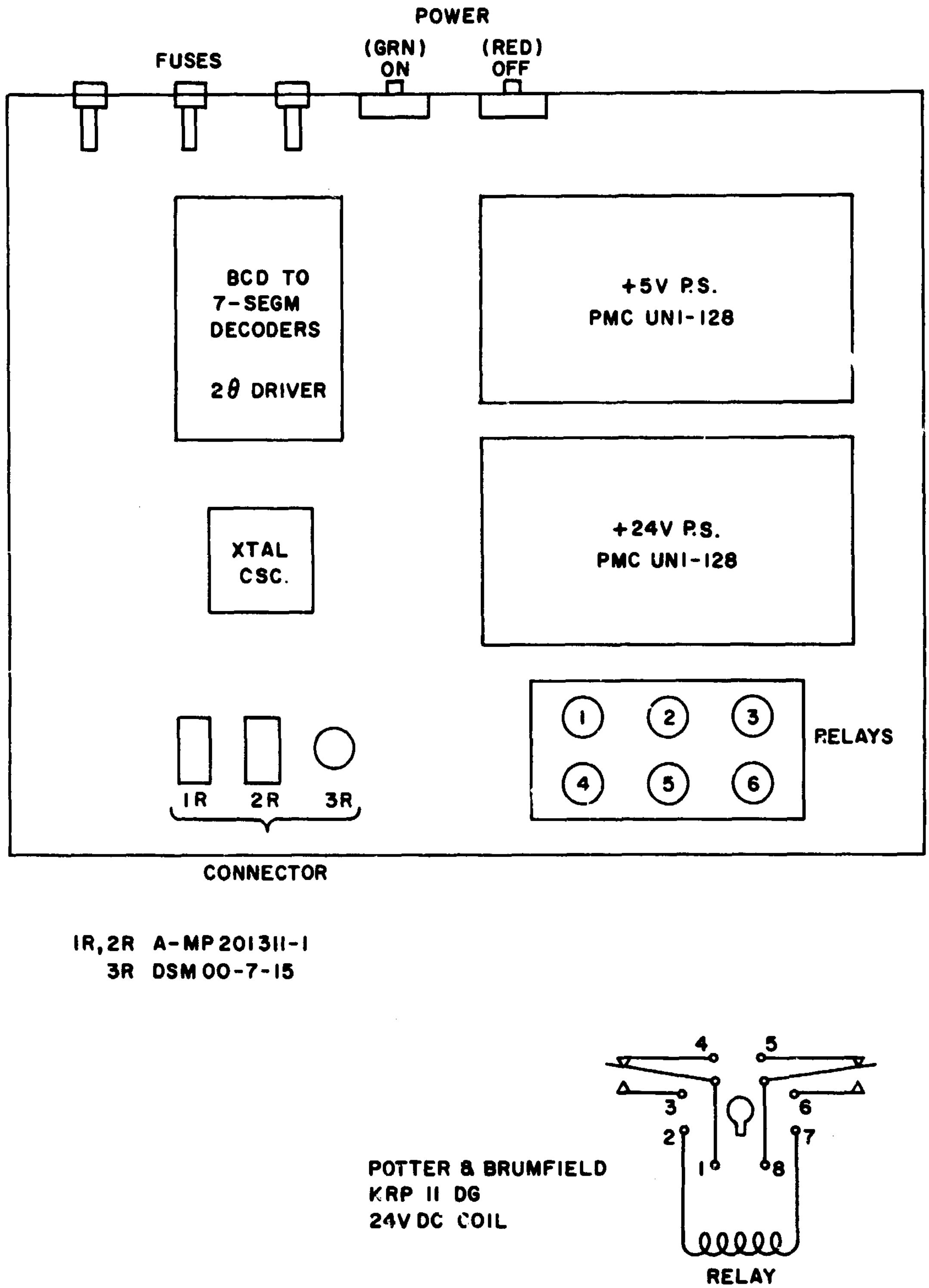


Figure A-32

Power-Supply/Relay Rack Layout

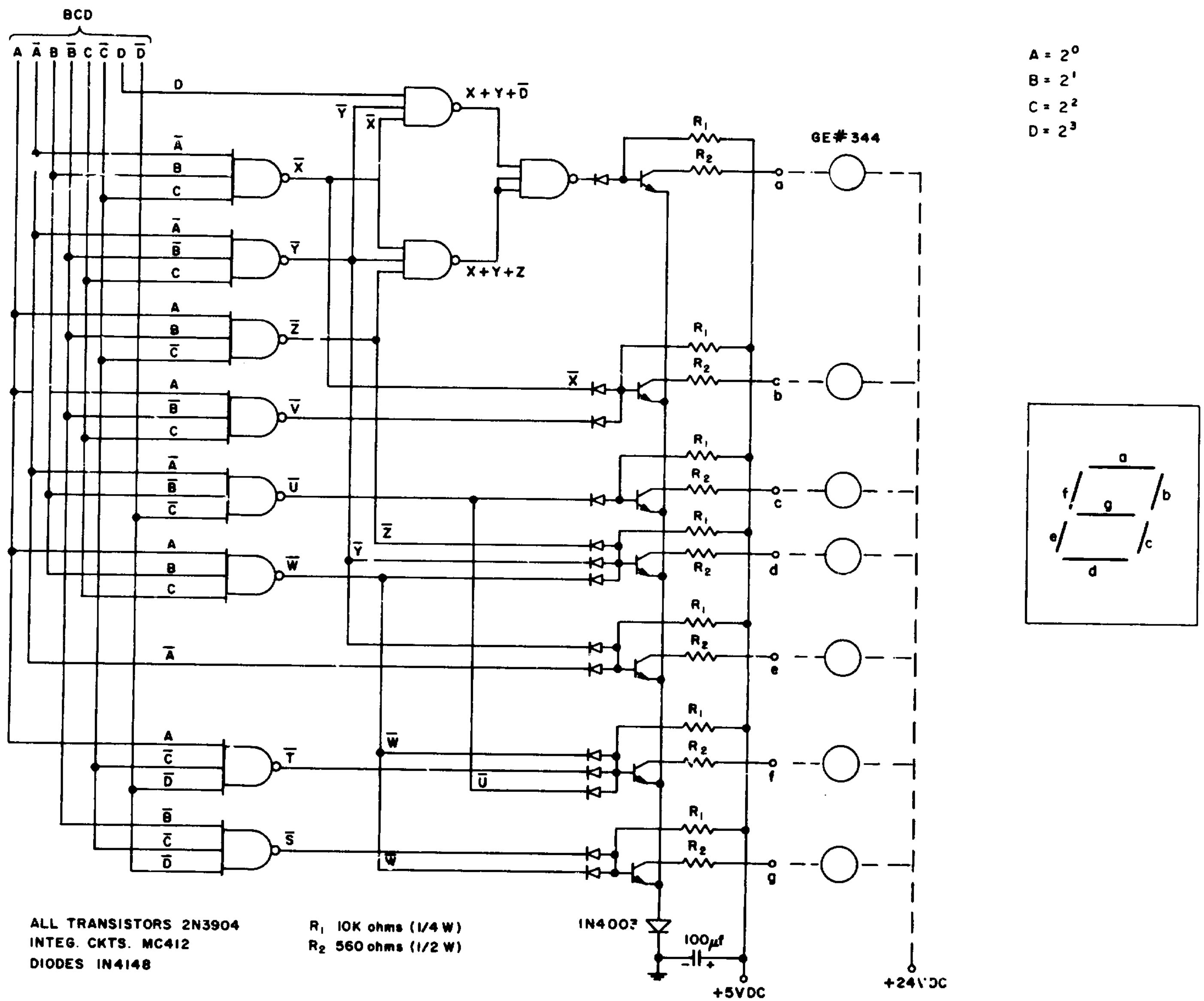


Figure A-33

BCD to 7-Segment Decoder

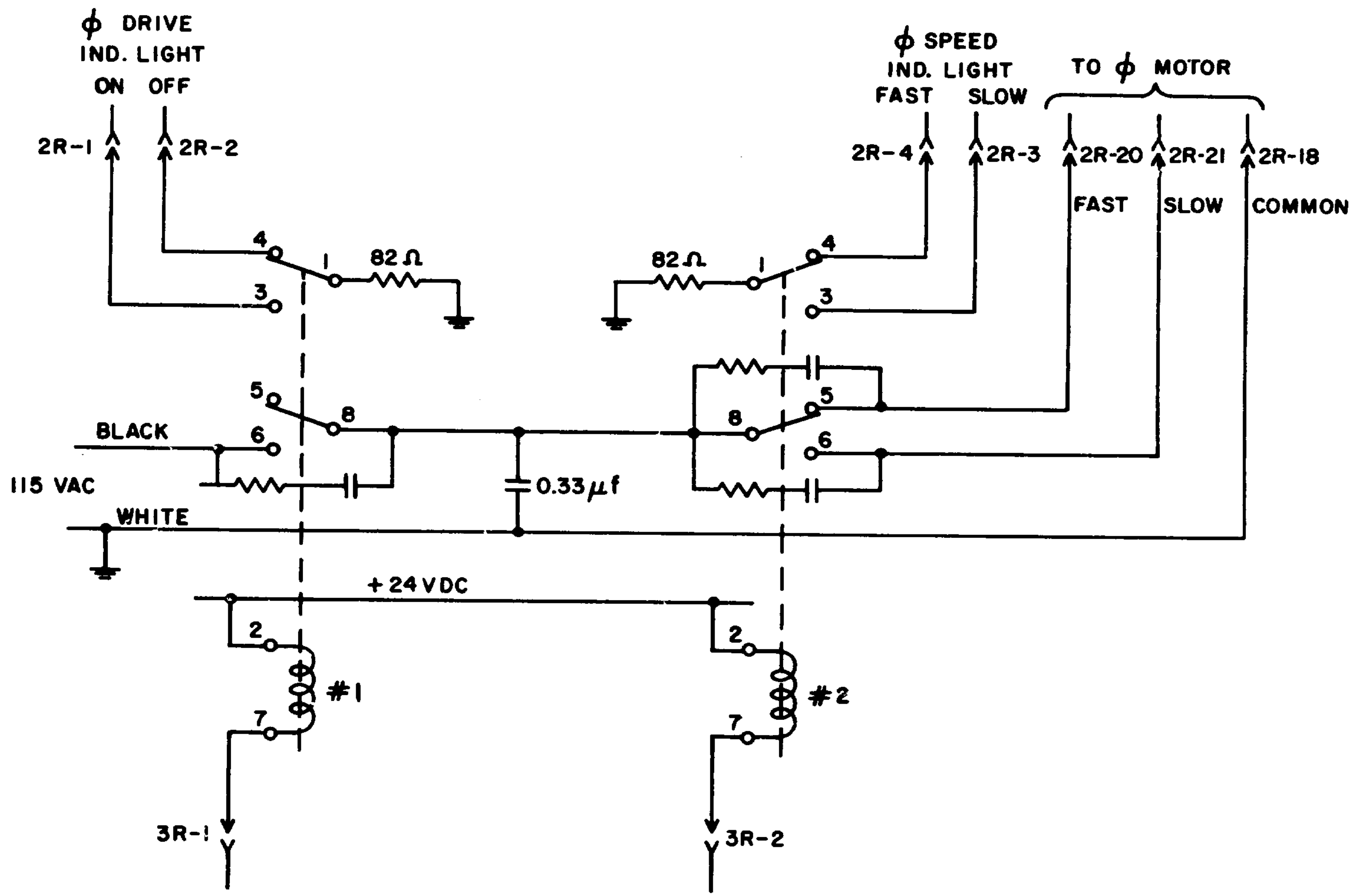


Figure A-34

Power Switching to Ø Motor (Diffractometer)

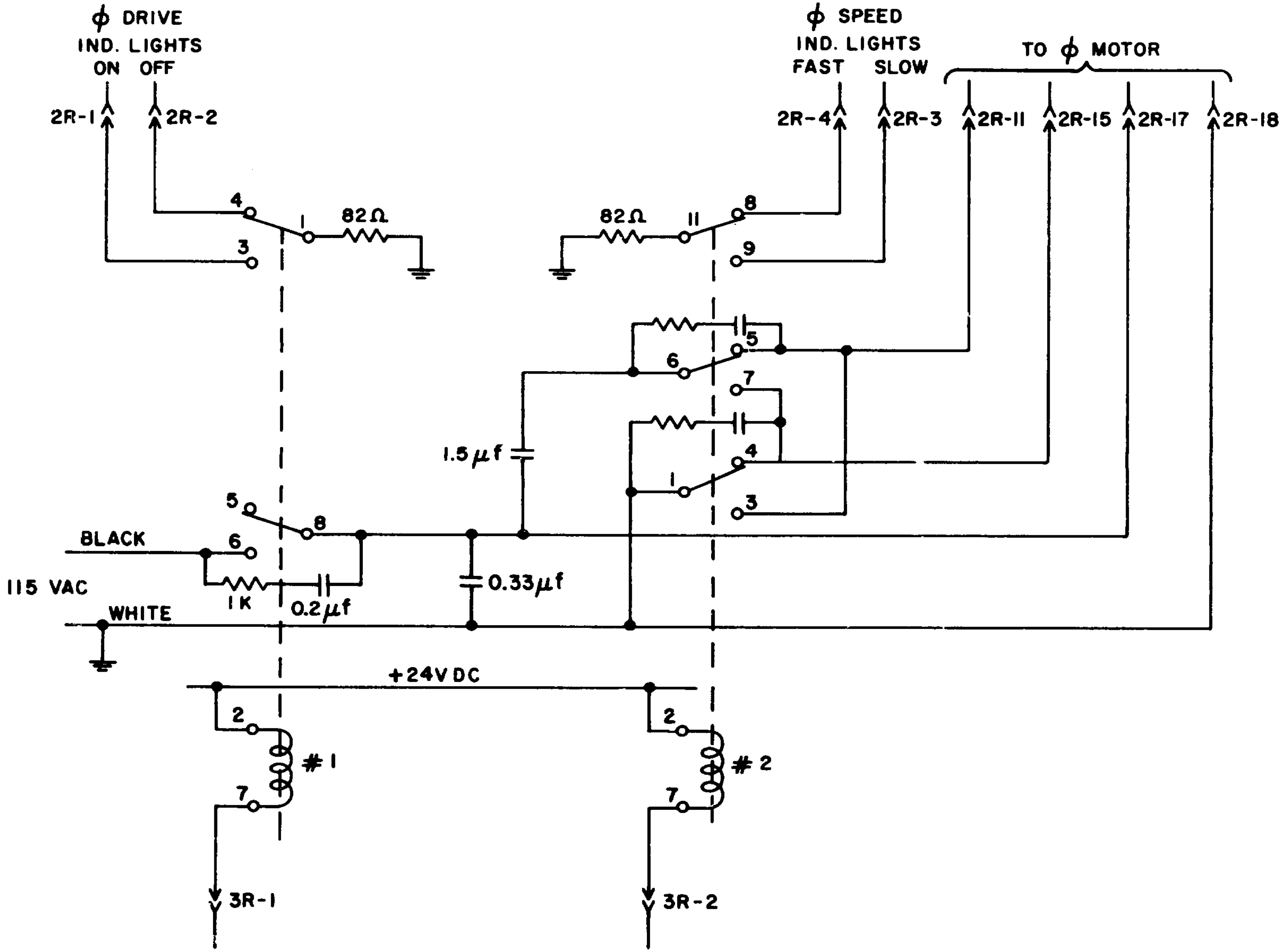


Figure A-35

Power Switching to Ø Motor (Spectrograph)

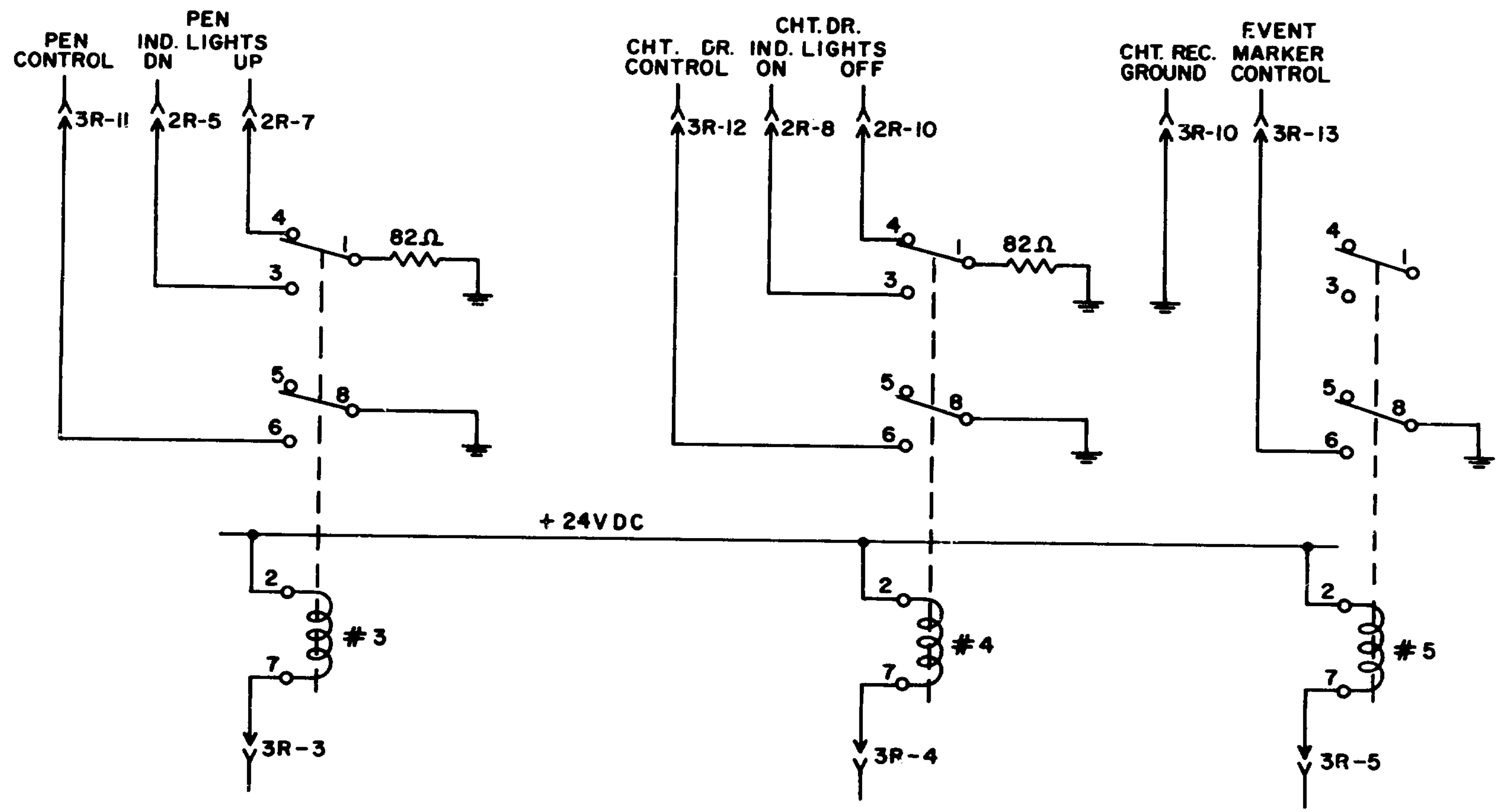


Figure A-36

Recorder Control

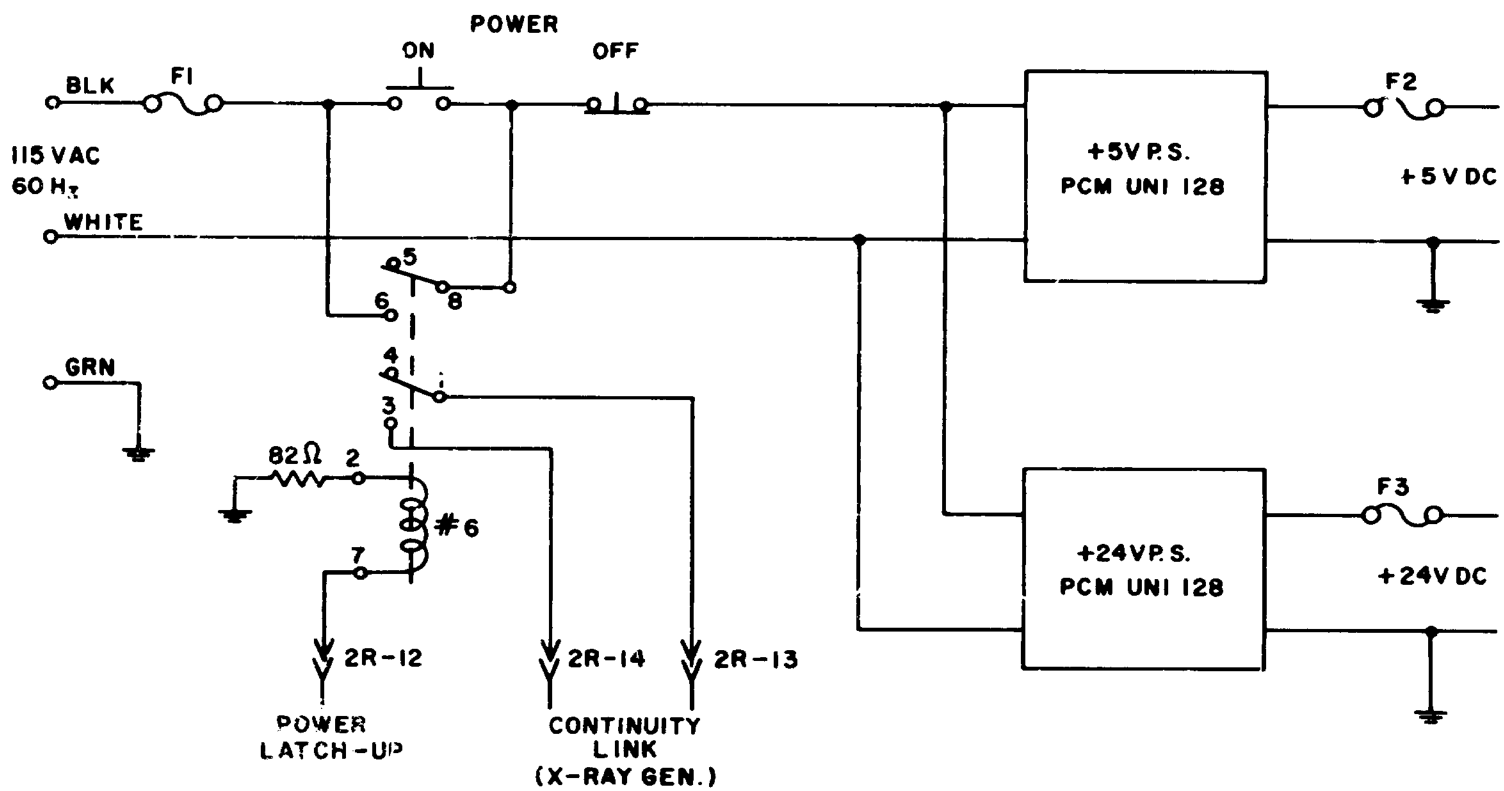


Figure A-37

Power Latch-up

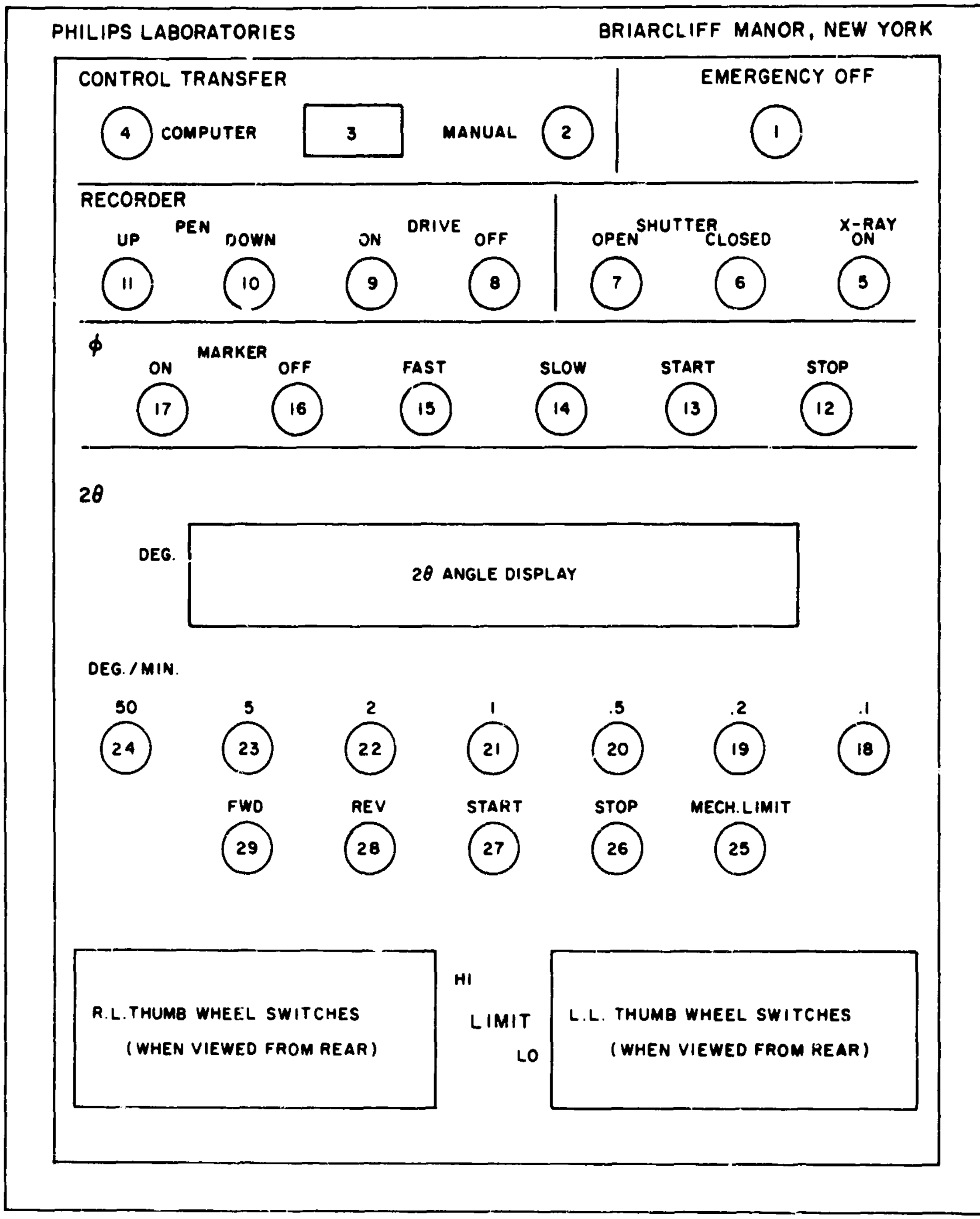


Figure A-38

Control-Panel Layout

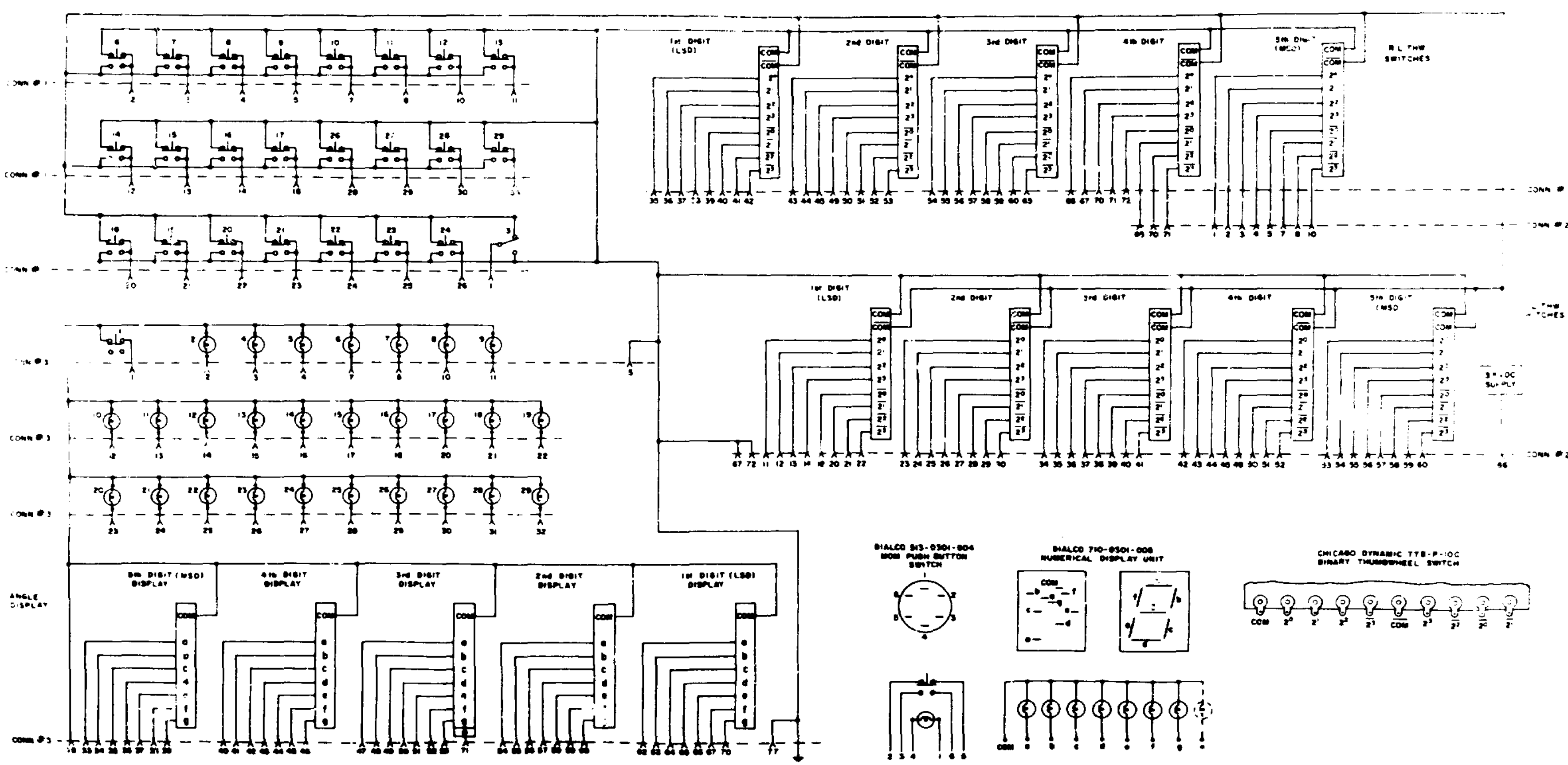


Figure A-39

Schematic Diagram of Control Panel