NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

ELECTRONICS DIVISION INTERNAL REPORT No. 156

140-FT FOCUS/POLARIZATION CONTROL SYSTEM

GEORGE H. PATTON

APRIL 1975

NUMBER OF COPIES: 150

140-FT FOCUS/POLARIZATION CONTROL SYSTEM

George H. Patton

TABLE OF CONTENTS

LIST OF FIGURES

140-FT FOCUS/POLARIZATION CONTROL SYSTEM

George H. Patton

I. Introduction

This report describes the system used to control the focus and polarization of the new Sterling mount recently installed on the 140-ft antenna. The description will include all the electronics up to the power amplifier and drive motors. Unlike the old drive package which had only one means of control, a rate potentiometer located on the console in the control room, the new system includes this mode plus three additional modes: (1) Control via the H-316 computer, (2) position control via digi switches located on the console, and (3) rate control via remote control box located in the service tower.

II. General Description

The new Sterling mount was installed on the 140-ft antenna in conjunction with the antenna conversion to a Cassegrain system. The Cassegrain system which includes provision for nutation of the subreflector required a stronger mount than was previously on the antenna. The new mount was designed to handle this additional loading.

This new mount has the standard two degrees of freedom of movement, the first being along an axis perpendicular to the dish which is used to change the focal distance between the subreflector and the dish (or the distance between the front end box and the dish for prime focus operation) and the second being rotation about the previously mentioned axis which is used to select the desired feed when the antenna is used in the Cassegrain mode (or for polarization when the antenna is used in prime focus). The maximum rate of travel in these two axes is 24 in/min in focal movement and 3.41 rpm in rotation.

Position information is obtained with two 12-bit absolute encoders. These encoders and their associated gearing give a theoretical accuracy of 0.01 inch in focal travel and 0.1 degree in rotation. Both encoders are capable of being indexed electronically via toggle switches in the control room, thus permitting establishment of a reference without mechanically moving the encoder. The indexed positions are displayed on the control console with the focus readout converted from inches to mm. Ranges of travel are as follows:

Focus-Prime focus	$\approx$	36 in (915 mm)
Focus-Cassegrain	$\approx$	5.5 in (140 mm)
Polarization	$\approx$	410°

The mount can be controlled in the following four ways:

(1) Computer Control. In this mode, the H-316 can control both axes of travel. Position information is entered into the computer through the card reader.

(2) Manual Position Control. In this mode, control is through two sets of digi switches (one for each axis) located on the control panel.

(3) Manual Rate Control. In this mode, control is through two rate potentiometers located on the control panel.

(4) Service Tower Control. In this mode, control is through two rate potentiometers contained in a control package located in the service tower.

The first two modes of control operate as a closed loop position servo and will remain at the commanded position $\pm$ 1 count (1 count = 0.01 in in focus and 0.1 degree in polarization) without the brakes being set. The second two modes operate only as variable rate controls and will not necessarily maintain the same position for zero rate command. A heavy package like the nutator can cause the mount to drive back through the gearing. This drift is slow enough as not to cause any physical damage, but to maintain a position once obtained in either of these modes; the brakes should be set.

These four modes of operation will be discussed further in the following section about the control panel.

III. Control Panel

Reference to Figure 1 will aid in the following description of the control panel.

The control panel contains readouts designating position, switches for position selection, switches for control, rate controls, and indicating LED's.

The indicating LED's are used to denote the status of the system as follows:

CASSEGRAIN: This LED is on when the nutator and subreflector are installed in the Sterling mount. In this mode, the upper limit which restricts the focal travel to a small range is selected electronically and the computer is notified via the input status word for the control system.

PRIME FOCUS: This LED is on when the telescope is used in the prime focus mode. The upper limit switch which permits the longest focal travel is selected and the computer is notified via the input status word.

LIMITS: The four limit LED's are used to indicate that the Sterling mount has reached its end of range of travel in the designated direction. When this occurs, all modes of control are automatically removed and the brakes set. The mount can be drawn out of a limit in any mode, except Computer Control, by selecting the desired mode and releasing the brakes. Anytime a limit is reached, the computer is also notified via the input status word. The information relayed to the computer indicates that a limit was reached but contains no information as to which limit.

LIMITS (continued):

There is also a backup limit for the subreflector located on one of the donut support legs. Anytime this limit is reached, the drive to the motor power amplifiers is removed and the brakes on the Sterling mount are set. Indication that this limit was run into is via a LED located on the card cage in the control console and can be seen only by looking in the rear of the console. If this limit is reached, a check should be made to determine why the first limit failed before the resumption of operation.

NOT READY: The NOT READY LED indicates the status of the motor amplifier rack. This includes a check on the +55 V DC power supply, -15 V DC power supply, amplifier over temperature, and state of circuit breakers on the +55 V DC supply to the motor power amplifiers. A fault on any one of these items will turn on the LED, remove all modes of control, and set the brakes on the Sterling mount.

The readouts indicate the indexed position of the two axes of travel. The FOCUS readout is in mm changing in increments of 0.254 mm and updates at least 4 times per second. The POLARIZATION readout is in degrees reading to an accuracy of 0.1 degree. It updates at a rate of approximately 10 times per second.

The four modes of control are as follows:

COMPTR CONTROL: In this mode, control is via the H-316 computer. Pushing the COMPTR CONTROL switch will signal the computer via the input status word that computer control is desired. When the computer acknowledges this request, it will light up the switch. Computer control cannot be obtained when the system is not ready or in a limit. The following commands are used by the computer to communicate with the control panel.

INA 1150: This command will input the status of the control panel with the input word having the following form.

Input Status Word

Bits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	0	0	0	0	1 = 1.2 cm REQUEST	1 = 2 cm REQUEST	1 = 6 cm REQUEST	1 = 18/21 cm REQUEST	1 = 6 & 2 cm REQUEST	SPARE	SPARE	SPARE	1 = CASSEGRAIN MODE	1 = LIMIT REACHED	1 = SYSTEM NOT READY	1 = COMPUTER MODE

Used only when in Cassegrain mode.

INA 1350: This command will input the indexed focus position. Bits 1 thru 4 are zero with bits 5 thru 16 containing the position. The position information is in a binary form with each count representing 0.01 inch. If the posi- information is in the process of updating, the DRL line will not go ready.

INA 1550: This command will input the indexed polarization position. Bits 1 thru 4 are zero with bits 5 thru 16 containing the position. The position information is in a binary form with each count representing 0.1 degree. If the position information is in the process of updating, the DRL line will not go ready.

OTA 250: This command will turn on the following switch lights as a computer acknowledgement of a control panel request.

Bit 16: COMPTR CONTROL

Bit 12: SPARE SWITCH

Bit 11: SPARE SWITCH

Bit 10: SPARE SWITCH

Bit 9: 6 & 2 CM

Bit 8: 18/21 CM

Bit 7: 6 CM

Bit 6: 2 CM

Bit 5: 1.2 CM

Other bits are not active for this command.

A 1 in the above bit locations will turn on the corresponding switch light when an OTA 250 is done, while a 0 in bits 5 thru 12 will turn the light off. The COMPTR CONTROL light, bit 16, can only be turned off by selection of another mode of operation via the control panel.

OTA 450: This command is used to control the focus position when the system is in computer control. The least significant 12 bits of the output word are the only ones recognized by the control system and are required to be in binary form with each bit representing 0.01 inch of travel. Upon execution of this command, the Sterling mount will move to the newly commanded focus position providing the focus drive brakes are released. If the brakes are set, the new position information is stored and the Sterling mount will move to this position after the brakes are released.

OTA 650: This command is the same as the OTA 450 except that it controls the polarization motion of the Sterling mount. Each bit in the output word represents 0.1 degree of rotation.

MANUAL POSITION: In this mode, control is via the two sets of digi switches mounted on the control panel. These sets of switches are used to select the desired position for the Sterling mount. The focus switches are dimensioned in mm's with an uncertainty of 0.25 mm due to the conversion process from mm to inches used in this system. The polariation switches are dimensional in degrees of rotation and are accurate to 0.1 degree. The units on both sets of switches agree with their respective position readouts. The system operates in this mode as a closed loop position servo when the brakes are released. When the brakes are set, the loop is opened and the driving signal is removed from the motor power amplifiers. When this mode of control is initially selected, the current position is entered into the position command register to avoid false movement of the Sterling mount. A new position can be entered into the command register by setting the set of digi switches for the axis of desired motion to the new position and pressing the respective update button (UPDATE FOCUS or UPDATE POL). If the brakes are released, the Sterling mount will automatically move to this new commanded position. If the brakes are set, the new position will be stored and, upon release of the brakes, the mount will then move to this position. The servo loop will maintain the position of the Sterling mount to within ± 0.1 degree of rotation and ± 0.25 mm of focal travel.

MANUAL RATE: Control in this mode is via two RATE controls located on the control panel. These two controls give a continuously adjustable range of rates of travel from zero to full speed for each axis. When the RATE controls are in the OFF position, the brakes are automatically set. To select this mode of control, both RATE controls must be in the OFF position. This prevents initial unwanted movements of the Sterling mount. If the brakes had previously been set before selecting MANUAL RATE control, they must be released by pushing the BRAKE OFF buttons. The brakes will then function automatically with the RATE controls.

SERVICE TOWER: Control in this mode is via a remote control box located in the service tower. The layout of the front panel of the remote control box is shown in Figure 2 and has the following:

POSITION READOUTS: These readouts are direct readouts from the encoders and are not indexed as the readouts in the control room. The output of the encoders, which is in cyclic binary, is converted to BCD in the remote control box and then displayed. By being connected directly to the encoders and bypassing all electronics associated with the readouts in the control room, makes these readouts very useful in troubleshooting encoder problems. The focus readout is in inches reading to 0.01 inch, while the polarization readout is degrees reading to 0.1 degree. For the readouts to be operable, a cable needs to be connected from the remote control box to the test receptacle located on the encoder enclosure on the Sterling mount.

EMERGENCY STOP: When pushed, this button will set the brakes on the Sterling mount, remove the driving signal from the motor power amplifiers, and remove control from the remote control box. To regain control via the remote control box, the EMERGENCY STOP switch must be reset and control given back by pushing the SERVICE TOWER button in the control room.

FOCUS MOTOR and POL MOTOR meters: These meters indicate the respective motor RPM and current.

LIMITS: These LED's indicate that a limit has been exceeded. When a limit is exceeded, the brakes on the Sterling mount are set, drive to the motor power amplifiers is removed, and control via the remote panel is terminated. To regain remote control, the same procedure must be followed as in EMERGENCY STOP.

BRAKES: These switches are used to control the brakes on the Sterling mount. The brakes must be released from the control room before these switches are active.

POSITION CONTROLS: These controls consist of two rate controls and two 3-position switches. The rate controls are adjustable from 0 to full speed for each axis of travel. The three position switches control the direction of travel. Both of these 3-position switches must be in the OFF position before control can be transferred from the control room to the service tower.

LIMIT OVERRIDE: This pushbutton was for initial testing of the Sterling mount and is no longer active.

For the remote control box to be active, a cable must be connected from it to the focus/polarization control terminal box located on the donut containing the Sterling mount.

The remaining switches on the console in the control room are for system selection when the antenna is used in the Cassegrain mode. For these switches to be active, the Sterling mount must be in COMPTR CONTROL. Pushing one of these switches sets a bit in the input status word to be H-316 computer. When the computer acknowledges this flag, it will clear this bit, light the upper half of the pushed switch, and select the proper channels in the Cassegrain receiver. The computer also outputs a new focus and polarization position which will illuminate the desired feed on the Cassegrain building. The following table indicates the receiver channels selected.

Switch	Cassegrain Receiver	
	Channel A	Channel B
1.2 cm	K Band	K Band
2 cm	Ku Band	Ku Band
6 cm	C Band	C Band
18/21 cm	L Band	L Band
6 & 2 cm	C Band	Ku Band

The lower half of the switch will be lighted when both channels A and B of the Cassegrain receiver correspond to correct channel combination for that switch. There are three spare switches for future expansion.

IV. Circuit Description

Figure 3 is a block diagram of the Sterling mount control system. This diagram includes all the electronics up to the rack which contains the power amplifiers and associated circuitry for the focus and polarization drive motors. The electronics can be broken up into three locations: (1) The two encoders and associated IC card located on the Sterling mount, (2) the major portion of the electronics located behind the control panel, and (3) two IC cards located in the H-316 computer rack. These three areas are discussed in the following.

A. Electronics package located on the Sterling mount:

This package contains two encoders, IC card, and three 5 volt power supplies. The encoders are manufactured by Sequential Information Systems, Inc., and have a resolution to 12 bits. The output from the encoders is in cyclic binary form and TTL compatible. Each encoder is powered by a 5 volt, 1 amp supply. The mechanical gearing is such that one count of the polarization encoder is equivalent to 0.1 degree of rotation and one count of the focus encoder represents 0.01 inch of focal travel. The outputs of the encoders are tied both to the IC card for processing and transmission to the control room and to the test receptacle located on the enclosure.

The IC card (Figure 4) latches the encoder readouts into a register upon receiving a preset pulse from the control room. The output from this register is then charged from cyclic binary to natural binary via a chain of exclusive or gates and latched into a parallel to series shift register. The parallel to series shift register is twelve bits wide so that first the polarization position is loaded and shifted out followed by loading the focus position and shifting out. This shifting is accomplished by a series of 24 clock pulsed timed to follow the preset pulse. The clock pulses are also supplied from the control room. The IC card is powered by the third supply.

B. Electronics package located behind control panel:

This package contains the major portion of the control electronics and can best be described by discussing each associated IC card. They are as follows:

RECEIVER AND INDEXER CARD (Location C-1):

This card (Figure 5) contains a series to parallel input register, a storage register, and an adder used to index the position.

The position data received from the Sterling mount is clocked into a 24 bit wide register, with the least significant 12 bits being the polarization position. The position data is then latched into a storage register, provided an enable pulse is not present. The enable pulse is generated each time the H-316 computer reads a position and is used to prevent a position update during this time.

The position information then goes to two 12-bit adders, one for each axis. These adders are used to index the position via a series of toggle switches located behind the control panel and permits setting the encoders to any reference without mechanically moving them. The outputs of the adders are then the indexed positions used in the rest of the control system.

CLOCK AND CONTROL CARD (Location C-2):

This card (Figure 6) is used to generate all the timing signals used in the transmission and processing of the position data and also generates some of the control signals used in mode selection. The signals and their functions are as follows:

PRESET TO FRONT END: This pulse is used to latch the encoder readouts into a storage register and initialize the transmission electronics on the Sterling mount.

CLOCK TO FRONT END: This is a series of 24 C4 pulses to the Sterling mount for data transmission.

CLOCK TO SHIFT REG: This is a series of 24 $\overline{C3}$ pulses to the shift register on the RECEIVER & INDEXER card used to store the transmitted data from the Sterling mount.

LATCH: This signal is used to latch the unindexed positions in the storage register on the RECEIVER & INDEXER card, to start the conversion process on BINARY/BCD & INCHES/MM card, and to keep the DRL line from going ready to avoid the computer reading a changing number.

CLEAR: This signal clears the input shift register on the RECEIVER & INDEXER card before an updated position is received from the Sterling mount.

INITIALIZE: This pulse loads the current focus and polarization positions into the respective command registers on the CONTROL SELECT CARD when either computer or manual position control is initially selected. This pulse is generated when either the COMPTR CONTROL or MANUAL POSITION button is pushed.

FOCUS UPDATE & POL UPDATE: These signals are generated by pushing the respective button on the control panel and are used to latch a new position determined by the digi switches into the corresponding command register located on the CONTROL SELECT card.

C/M (M/C): This is a level used to select the appropriate input command positions from either the computer or control panel.

BIN → BCD, INCHES → MM CARD (Location CP-4):

This card (Figure 7) interfaces the focus display on the control panel to the RECEIVER & INDEXER CARD. The focus position information is a 12-bit binary number with each bit representing 0.01 inch of travel. The display requires a BCD number which has the units of mm. This transformation is accomplished via this card by employing binary and decade counters for the binary to BCD conversion and divide by 100 and divide by 254 circuits for the inches to mm conversion. The display is updated every 16th latch pulse. At this time, a new position number is loaded into the binary counters and the decade counters are cleared. Then the clock is divided by 254 and fed to the count down input of the binary counters. Simultaneously, the clock is divided by 100 and fed to the count up input of the decade counters. When the binary counters reach zero, the clock is stopped and the output of the decade counters is latched into the display storage register. The focus position display is connected directly to the output of this register. The new position number is BCD form and has the dimensions of mm with an accuracy of 0.25 mm.

BCD → BIN & MM → INCHES CARD (Location C-3):

This card (Figure 8) is used to convert the output of the focus digi switches located on the control panel to the form required in the rest of the control system. The units of the focus digi switches are mm's to agree with its position readout. The output format of the switches is also in BCD, while the rest of the control system requires this number to be in a binary form with the units of inches. This conversion is essentially the inverse of that of the focus position display interface. The BCD to binary conversion is accomplished via decade and binary counters and the mm to inches conversion via two divide networks.

The BCD number contained in the digi switches is entered into the decade counters and the binary counters cleared when the UPDATE FOCUS button is pushed. The clock divided by 100 is then fed to the count down input of the decade counter while simultaneously the clock divided by 254 is fed to the count up input of the binary counters. When the decade counters reach zero, the clock is stopped to the binary counters which now containes the digi switch number converted from mm to inches. At this time the update focus latch is generated which strobes the converted focus command position into the command storage register on the focus CONTROL SELECT card.

BCD → BINARY/BINARY → BCD CARD (Location C-4):

This card (Figure 9) interfaces both the polarization readouts and the polarization digi switches to the rest of the control system. Since the position data in the control system has the same units as displayed on the control panel (1 count = 0.1 degree) only a format conversion is needed. The format of the position data is in binary in the control system and BCD on the control panel. This conversion is readily accomplished via BCD to binary and binary to BCD IC chips as shown in Figure 9.

FOCUS CONTROL SELECT CARD (Location C-5):

This card (Figure 10) selects the source of the commanded focus position when in either COMPTR CONTROL or MANUAL POSITION mode of control. This is accomplished by the MANUAL/COMPUTER signal which controls a series of 2 line to 1 line data selections. The two storage registers on this card contain the commanded positions from the computer and from the digi switches located on the control panel. The position contained in the computer storage register can be entered by two means. The first is by the signal FOCUS SET which is generated when the H=316 computer performs an OTA 450. The second is when either the COMPTR CONTROL or MANUAL POSITION control mode is selected at which time the INITIALIZE pulse is generated. This pulse steers the current focus position to both the computer and manual position storage registers via 2 line to 1 line data selectors at which time this position is latched into these two registers. This is necessary to prevent unwanted movement upon initial selection of either of these control modes. The position contained in the digi switch storage register is entered by either pushing the UPDATE FOCUS button on the control panel or by the INITIALIZE pulse as described above. The output of this card is connected to the ARITHMETIC card for comparison to the current focus position.

POL CONTROL SELECT CARD (Location C-6):

This card is the same as the FOCUS CONTROL SELECT card except that it controls the polarization position commands.

ARITHMETIC CARD (Location C-7);

This card (Figure 11) adds the 2's complement of the command position to the actual position for both the focus and polarization axes. The output of the adders is a 12 bit number in offset binary form. The D/A converters used following this card only require 10 input bits, thus the twelve bit number must force these 10 bits to be all ones when the difference number contains a 1 in the sign bit and a 1 any place in bits 10, 11, or 12. Likewise, the 10 bit number must be forced to all zeros when the sign bit is 0 and a 0 appears any place in bits 10, 11, or 12. This is accomplished via the network which generates the signal S_0 and S_1 which control bits 1 thru 9 with bit 10 being the sign bit carried straight through. Bits 1 thru 9 are forced to zeros when $S_0 = 0$ and $S_1 - 1$, or forced to ones when $S_1 = 0$. The outputs of this card go directly to the D/A converters.

INPUT BUS SELECT CARD (Location C-8):

This card (Figure 12) is used to gate the current focus position, polarization position, and system status to the H-316 computer. The output of this card is connected to the input bus gates on the DATA card located in the computer rack. The card is controlled as follows. INA 1350 selects the focus position, INA 1550 selects the polarization position, and INA 1150 selects the system status.

FOCUS D/A CONVERTER CARD (Location C-9):

This card (Figure 13-b) contains an Analog Devices Model DAC-10Z 10-bit D/A converter. This converter produces an analog voltage proportional to the difference in the commanded position and actual position for operation in either COMPTR CONTROL or MANUAL POSITION mode. The range of the output of the D/A is ± 10 volts.

POL D/A CONVERTER (Location C-10):

This card is the same as the FOCUS D/A CONVERTER and produces an error voltage for the polarization axis.

FOCUS ERROR INTEGRATOR (Location A-1):

This card (Figure 13-a) contains two operatonal amplifiers, one used for integration and the other as a buffer amplifier. The time constants associated with the integrators were chosen to give a fast response with little overshoot. Each axis has a different mechanical gearing, thus requiring a different time constant. The values used for each axis are shown in Figure 13-a. The capacitor of the integrator is shunted with a 1000 ohm resistor when not being used, as in the MANUAL RATE and SERVICE TOWER modes.

POL ERROR INTEGRATOR (Location A-2):

This card performs the same as the FOCUS ERROR INTEGRATOR just discussed.

CONTROL PANEL CARD (Location CP-1):

This card (Figure 14) selects the mode of operation, controls the brakes on the Sterling mount, and switches the analog rate signal.

The mode of operation is controlled by four flip flops connected together so that when one is set the other three are reset. Selection of the mode of control is via pushbutton located on the control panel and has the following characteristics: (1) The COMPTR CONTROL mode cannot be selected if the Sterling mount is in a travel limit or if the motor amplifier rack is not ready, (2) the MANUAL POSITION mode may be selected any time, (3) the MANUAL RATE mode cannot be selected if either of the rate controls is not zero, and (4) the SERVICE TOWER cannot be selected when the remote control box is connected and the rate controls are not zero. Reaching a limit or the amplifier rack going not ready will reset all four flip-flops, removing all control until a new mode is selected.

The brakes are also controlled by two flip-flops, one for each axis. These flip-flops can be set and reset by pushbuttons on the control panel. They can also be set by an emergency stop, reaching a limit, or the amplifier rack going not ready. When the flip-flops are not set the brakes can be controlled by two additional means: (1) By the rate pots on the control panel being at zero when in MANUAL RATE control and (2) by the remote control box when in the SERVICE TOWER mode. The relay drives and relays which operate the brakes are located in the amplifier rack.

Selection of the rate voltage used to control the motor amplifiers is via Inselek type L021 analog switches. The range of these switches is ± 5 volts, thus requiring voltage dividers on the inputs. The rate voltages from the local and remote rate pots has a range of ± 15 volts, requiring a divide by three while the rate voltage from the digital control section is ± 10 volts, requiring a divide by two. These divisions are accomplished by resistive networks located on two discreet component IC chips. The outputs of these switches are then sent to buffer amplifiers before being transmitted to the amplifier rack.

RATE BUFFER AMPLIFIER CARD (Location A-3):

This card (Figure 15) contains two operational amplifiers, each having a unity gain, which serve as buffer amplifiers between the analog switches located on the CONTROL PANEL card and the cable going to the amplifier rack.

LIMIT SELECT CARD (Location CP-2):

This card (Figure 16) contains circuitry for prime focus or Cassegrain mode, limit controls, and part of the Cassegrain receiver selection drives.

The prime focus/Cassegrain mode is controlled by a cable pair being shorted at the telescope apex when the nutator and subreflector are installed. When this pair is shorted, the Cassegrain mode is selected which in turn selects the Cassegrain limit switch as the upper limit, sets input status bit 13, and lights the CASSEGRAIN LED on the control panel.

The limit detection circuitry operates from five normally closed switches located on the Sterling mount. Reaching a limit, which opens the respective switch, will turn on the corresponding LED on the control panel, remove all modes of control and set the brakes via the signal LIMIT, notify the computer via ISB 14, and prohibit motor drive in the direction of the detector limit.

The remainder of this card is associated with band selection for the Cassegrain receiver. This consists of five one shot multivibrators (one for each present receiver configuration) which generate approximately a 20 ms pulse when the computer acknowledges a request from the control panel and five lamp drivers which control the lights on the control panel indicating the setting of the receiver. The signals which trigger the one shots come from the RECEIVER SELECT CARD.

RECEIVER SELECT CARD (Location CP-3):

This card (Figure 17) is controlled by the system selection switches located on the control panel and is used for band selection in the Cassegrain receiver. It contains 16 D-type flip-flops, two for each switch located on the control panel, eight lamp drives, and a decoding circuit to control the Cassegrain receiver.

Pushing one of the system select switches on the control panel will set a flip-flop associated with it which in turn sets a bit in the input status word. Bits 05 thru 12 are used for these switches. The computer acknowledges the set input status bit by doing an OTA 250 with a 1 placed in the same position in the output word as the set status bit. This output data commanded will set the second flip-flop associated with the selected switch (which controls the light in the upper half of the selected switch), and clears the first flip-flop set by pushing the switch. When the second flip-flop is set it also generates the signal ACKXN which triggers a one shot multivibrator located on the LIMIT SELECT card. The pulse generated by the one shot (SYSTEM X pulse) is returned to this card where it is decoded to select the proper band combination for the two channels of the Cassegrain receiver. The decoded pulses are then sent to the Cassegrain receiver rack located in the control room.

C. Electronics package located in rack with H-316 computer.

This package contains two IC cards located in the expansion chassis below the computer. One card handles the data on the input and output buses while the other card handles the addressing and control.

CONTROL CARD (Slot 11):

This card (Figure 18) does the address and command decoding from the H-316 computer and generates the following signals.

ENABLE: This pulse is generated when an INA 1150, INA 1350, or INA 1550 is executed. It enables the gates to the input bus on the DATA card and prohibits updating the position information on the RECEIVER & INDEXER card.

STATUS IN, FOC IN, POL IN: These pulses are generated in respective order when an INA 1150, INA 1350, and INA 1550 are executed by the computer. They are used to steer the corresponding information to the input bus via the INPUT BUS SELECT card.

ACK: This pulse is generated when the computer executes an OTA 250 and is gated with the RRL pulse. It is used to control switch lights on the control panel and system selection in the Cassegrain receiver.

FOC SET, POL SET: These pulses are generated by an OTA 450 and OTA 650. They latch their respective computer command positions into a storage register of FOCUS CONTROL SELECT and POL CONTROL SELECT cards. Both of these pulses are gated with the RRL pulse.

LATCH: This pulse comes from the CLOCK & CONTROL card and prohibits the DRL line from going low when the focus and polarization positions are in the process of being updated.

DATA CARD (Slot 10):

This card (Figure 19) gates information onto the input bus for an INA 1150, INA 1350, or an INA 1550. It also latches the information on the output bus into a register for an OTA 250, OTA 450, or an OTA 650. From this register the information is sent to the rest of the control system located behind the control panel.

Figure 20 shows a card which is located in the motor amplifier rack but will be mentioned here. This card contains four operational amplifiers and their associated circuitry.

The tach signal, which has a gradient of 7 volts/1000 RPM, is fed to the differential inputs of an amplifier which has a gain of -0.392. This gain gives an output range of ± 10 volts for maximum recommended motor speed of 3600 RPM. A differential amplifier with unity gain receives the ± 5 volts rate signal from the control system located in the console and feeds it to another amplifier with a gain of -2 to increase the range of the signal to ± 10 volts to be compatible with the tach signal.

The tach and rate signals are then fed to a summing amplifier with a gain of -33. This amplifier also employees zener diodes in the feedback path to limit the output voltage to ± 10 volts, the range required by the motor power amplifiers. The output voltage is then fed directly to the power amplifiers.

There are two of these cards in the amplifier rack, one for each axis of travel.

V. Acknowledgements

Credit should be given to the following people for their help in the building and testing of this system: Doreen Morris, W. Vrable and the Green Bank Machine Shop. Special credit should also be given R. Weimer and D. Schiebel for their suggestions in the system design.

VI. Mnemonic List (Console)

NAME	ORIGIN	DESTINATION	NAME	ORIGIN	DESTINATION
ACK	J10	C8, CP3	L RATE	J4	CP1
ACK xN	CP3	CP2	LATCH	C2	C1, CP4, J10
CASS BL	J5	CP1	LFRPZ	J4	CP1
CASS LIMIT	J5	CP2	LIMIT	CP2	CP1
CCP xx	J9	C5, C6, CP3	LOWER LIMIT	J5	CP2
CCW OFF	CP2	J5	LPRPZ	J4	CP1
CCW LIMIT	J5	CP2	LR IN	J4	CP1
CHx - xACK	J6	CP2	M/C	C2	C5, C6
CLEAR	C2	C1	MAN	J4	CP1
CLOCK	C2	J1	MANA	CP1	C2
COMP	J4	CP1	POL ANALOG OUT	CP1	A3
COMPA	CP1	C2	POL BRAKE RESET	J4	CP1
CW OFF	CP2	J5	POL BRAKE SET	J4	CP1
CW LIMIT	J5	CP2	POL SET	J10	C6
C/M IN	A1, A2	CP1	PRESET	C2	J1
$\overline{\text{C3}}$	C2	C1	PRIME/CASS	J5	CP2
DN OFF	CP2	J5	P xx	C1	C4, C6, C7, C8
EMER STOP	J4, J5	CP1	R RATE	J4	CP1
ENABLE	J10	C1, C8	REMOTE FOC BRAKE	J5	CP1
$\overline{\text{ENABLE}}$	C1	C8	REMOTE POL BRAKE	J5	CP1
FOC SET	J10	C5	$\overline{\text{RRIN}}$	J5	CP1
FOCUS ANALOG OUT	CP1	A3	$\overline{\text{RRPZ}}$	J5	CP1
FOCUS BRAKE RESET	J4	CP1	SERIAL DATA	J1	C1
FOCUS BRAKE SET	J4	CP1	SWLx	CP3	J4
Fxx	C1	C3, C5, C7, C8, CP4	SWx	CP3	J4
IN xx	C8	J9	SWxL	CP2	J11
INA 150	J10	C8	SYSTEM READY	J5	CP1
INA 350	J10	C8	UP OFF	CP2	J5
INA 550	J10	C8	UPDATE FOCUS	C2	C3
INITIALIZE	C2	C5, C6	UPDATE FOCUS LATCH	C3	C5
INTG SW	CP1	A1	UPDATE POL	C2	C6
ISB 13	CP2	C8	UPPER LIMIT	J5	CP2
ISB 14	CP2	C8	XXxx	C3	C5
ISB 15	CP1	C8	YYxx	C4	C6
ISB 16	CP1	C8			
ISB 05-12	CP3	C8			

VII. Mnemonic List (H-316 Computer)

NAME	ORIGIN	DESTINATION
ACK	C11	J12
ADBxx	C9	C11
CCPxx	J11	C10
DRLIN	C9	C11
ENABLE	C11	J12
ENABLE A	C11	C10
FOC IN	C11	J12
FOC SET	C11	J12
INxx	J11	C10
INBxx	C10	C7, C9
LATCH	J12	C11
MSTCL	C11	J12
MSTCL-	C9	C11
OTBxx	C10	C8, C9
POL IN	C11	J12
POL SET	C11	J12
RRLIN	C9	C11
STATUS IN	C11	J12
STORE	C11	C10

Connector List (Console)

CONNECTOR NUMBER	SOURCE OR DESTINATION
J1 ... 38 PIN ELCO	STERLING MOUNT
J2 ... 20 PIN ELCO	FOCUS DIGI SWITCHES
J3 ... 20 PIN ELCO	POLARIZATION DIGI SWITCHES
J4 ... 56 PIN ELCO	CONTROL PANEL
J5 ... 38 PIN ELCO	AMPLIFIER RACK
J6 ... 38 PIN ELCO	CASSEGRAIN RECEIVER RACK
J7 ... BNC	FOCUS RATE TO AMP RACK
J8 ... BNC	POLARIZATION RATE TO AMP RACK
J9 ... 38 PIN ELCO	H-316 COMPUTER
J10 ... 38 PIN ELCO	H-316 COMPUTER
J11 ... 20 PIN ELCO	CONTROL PANEL
J12 ... TWINEX	CASSEGRAIN RECEIVER RACK

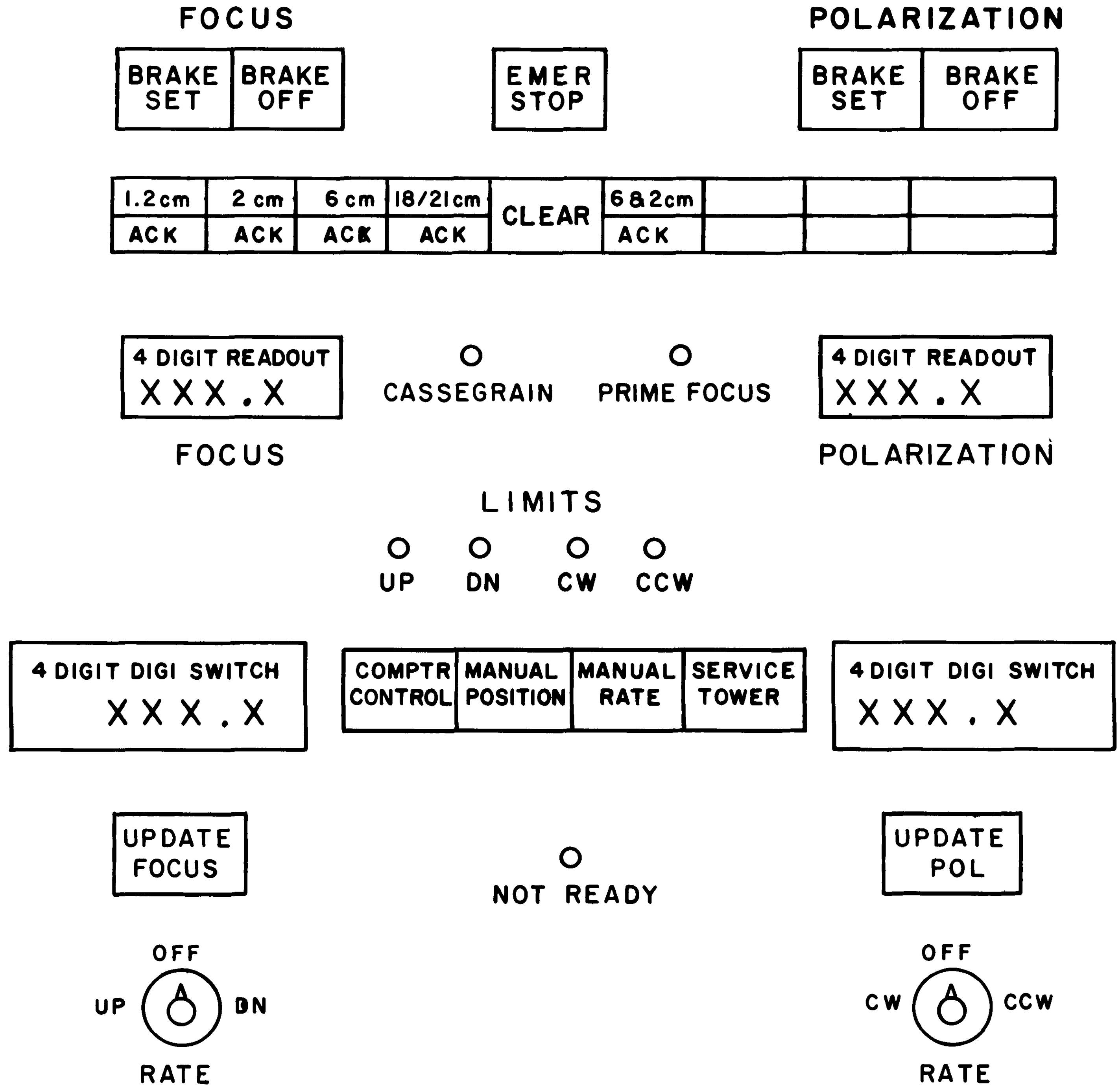


FIG. 1 CONTROL PANEL

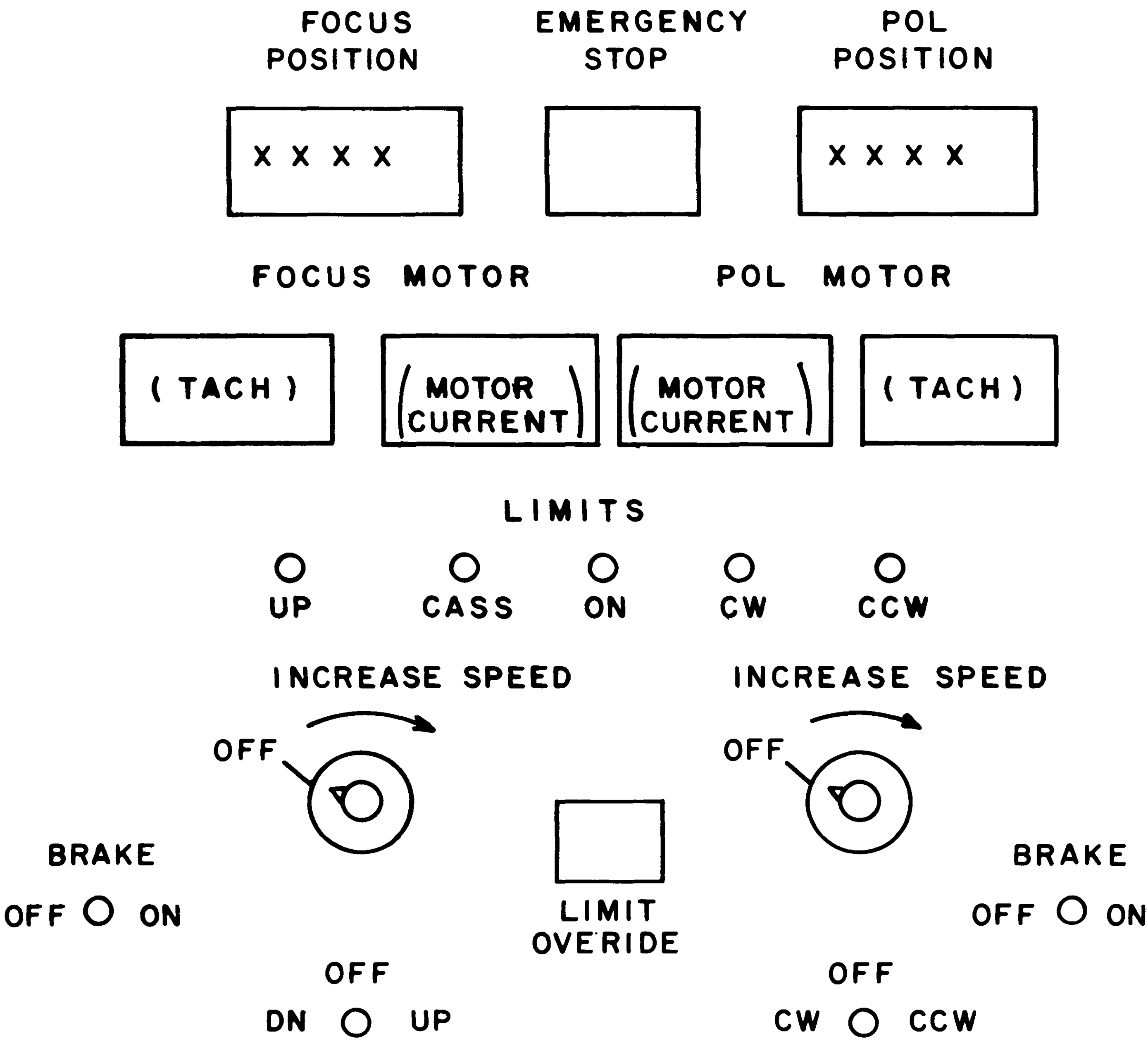


FIG. 2 REMOTE CONTROL BOX FRONT PANEL

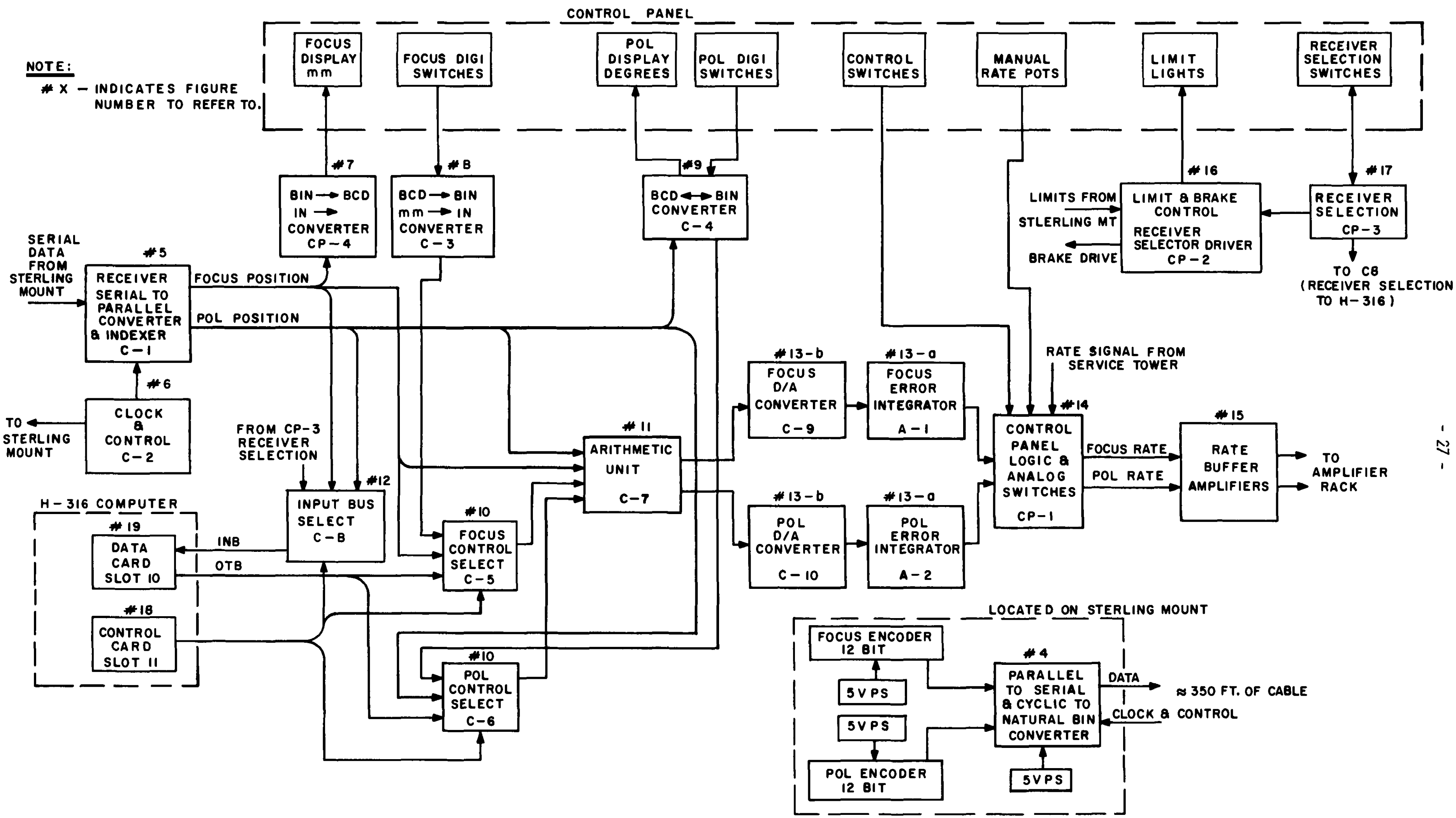
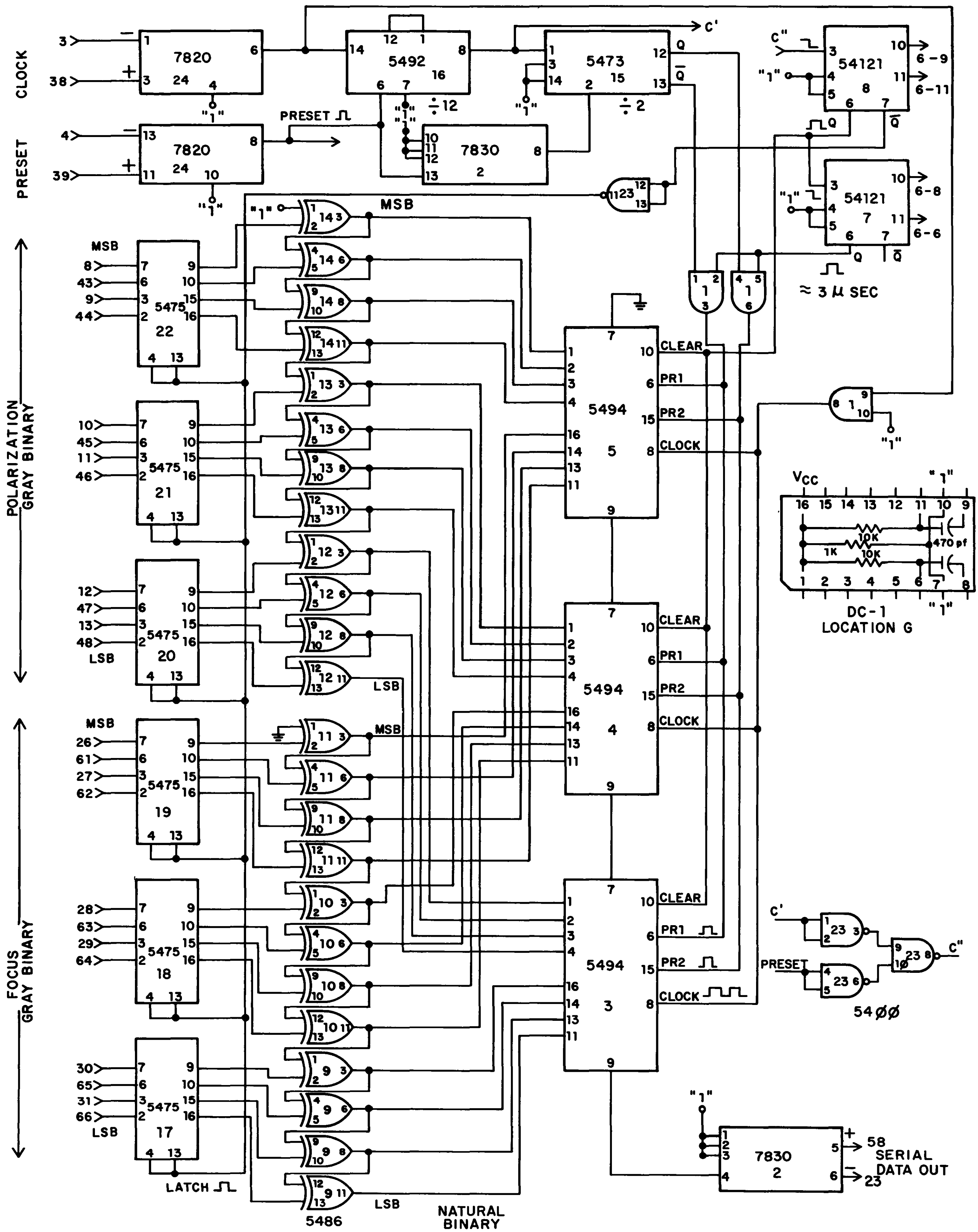
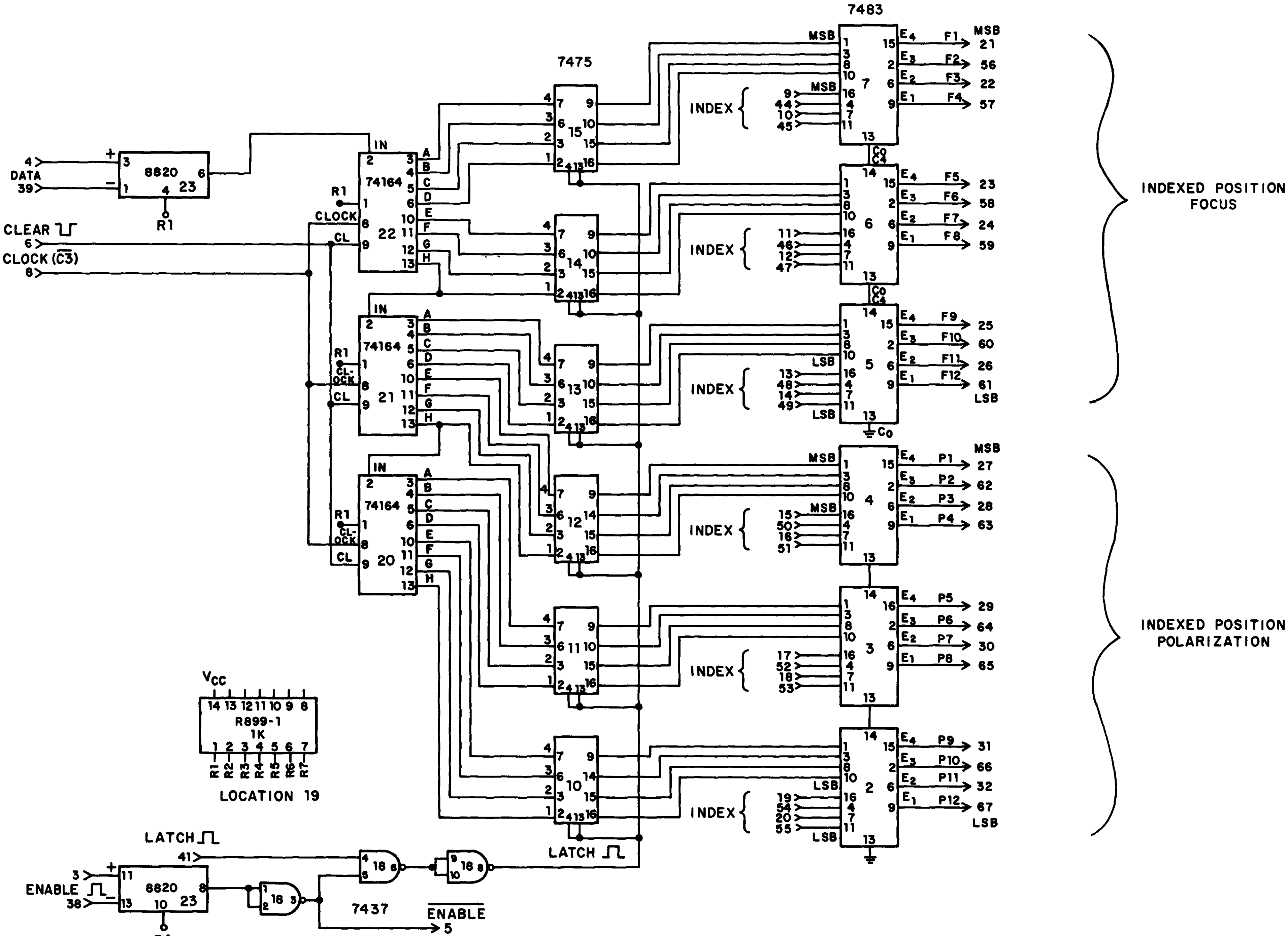


FIG. 3 SYSTEM BLOCK DIAGRAM



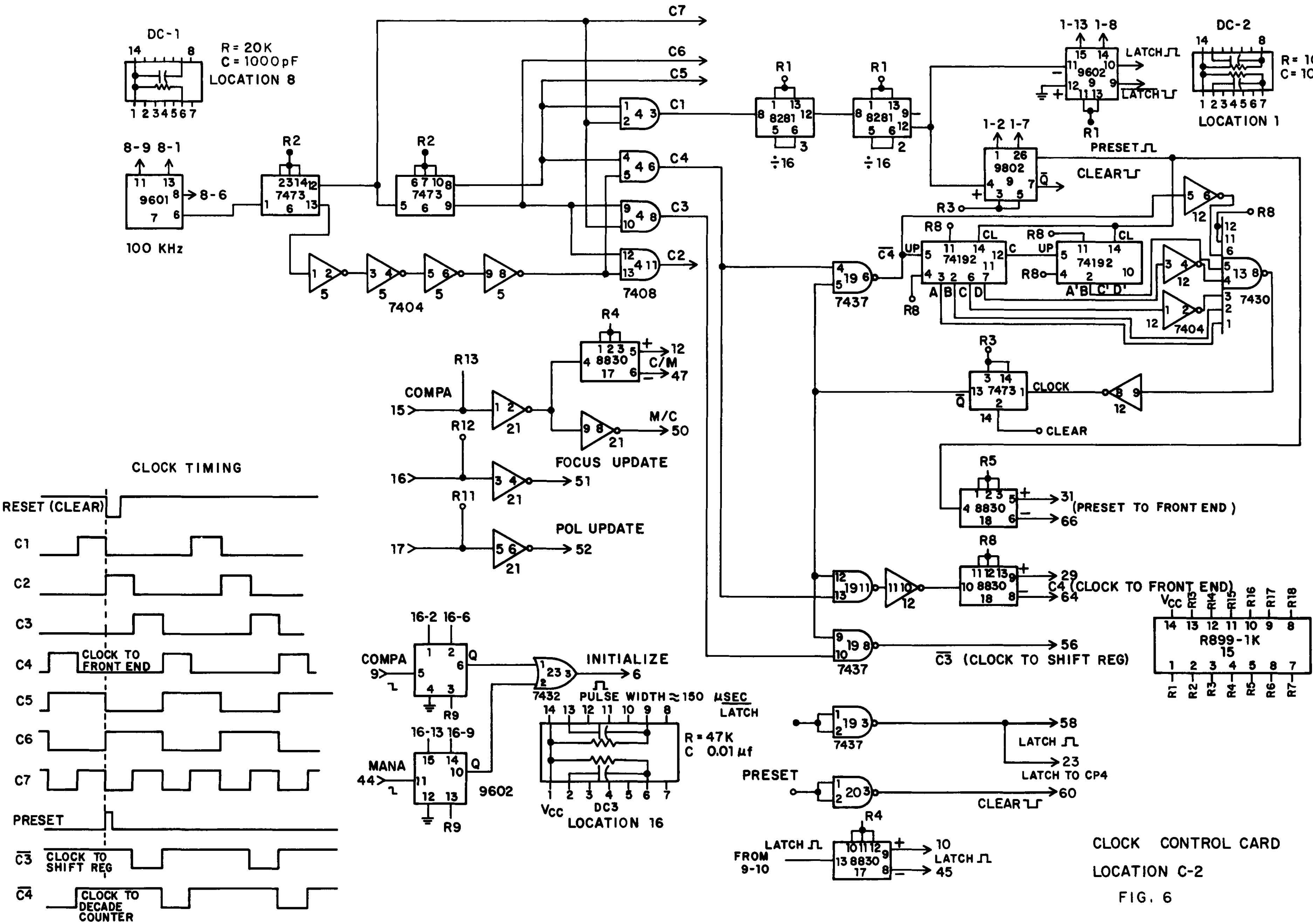
STERLING MOUNT CARD

FIG. 4



RECEIVER & INDEXER CARD (LOCATION C-1)

FIG. 5



CLOCK CONTROL CARD

LOCATION C-2

FIG. 6

NOTE: THE ÷254 CIRCUIT LOADS 253 IN SINCE ONE CLOCK PULSE IS LOST DURING THE LOADING TIME FOR THE CLOCK FREQUENCY USED.

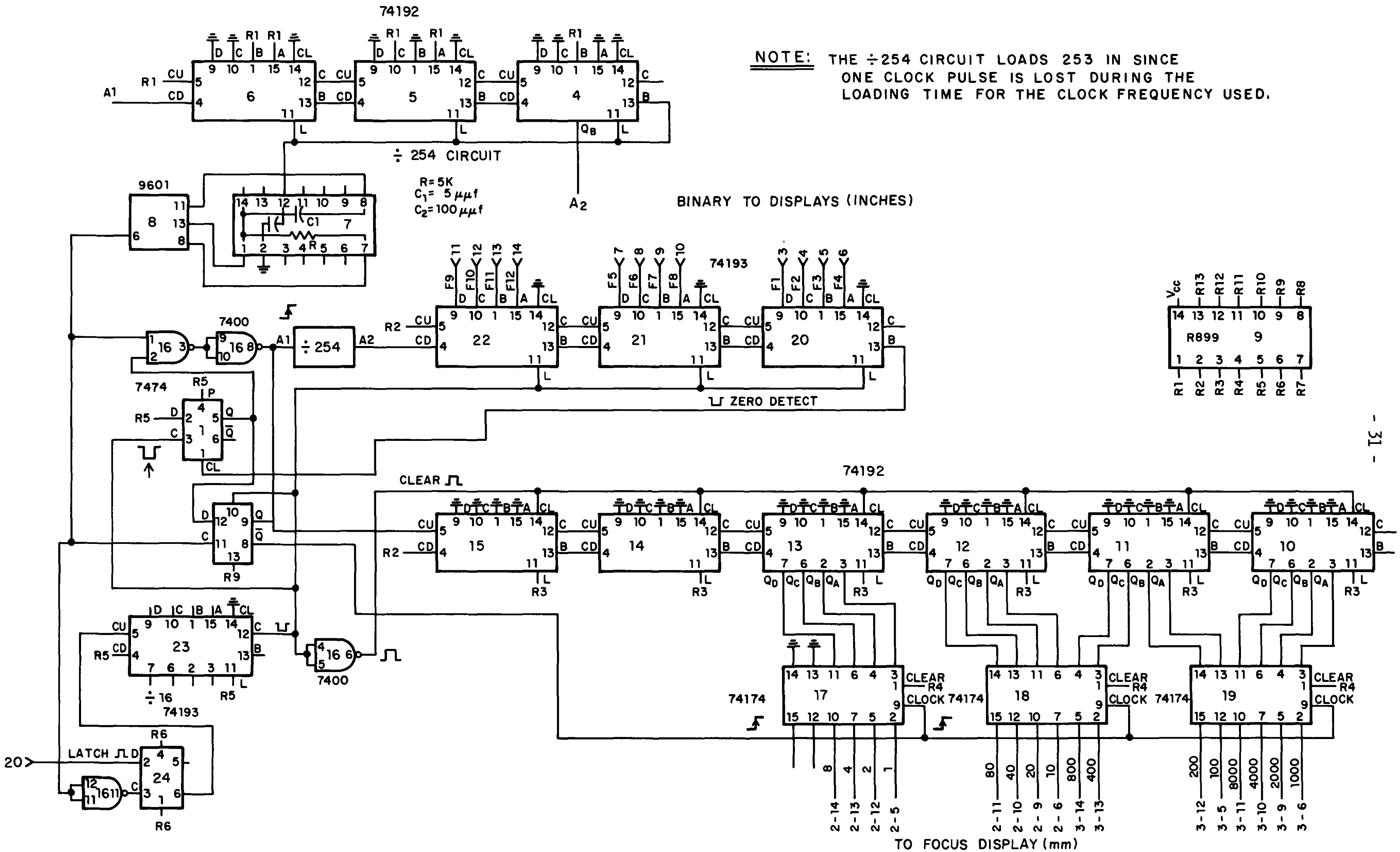
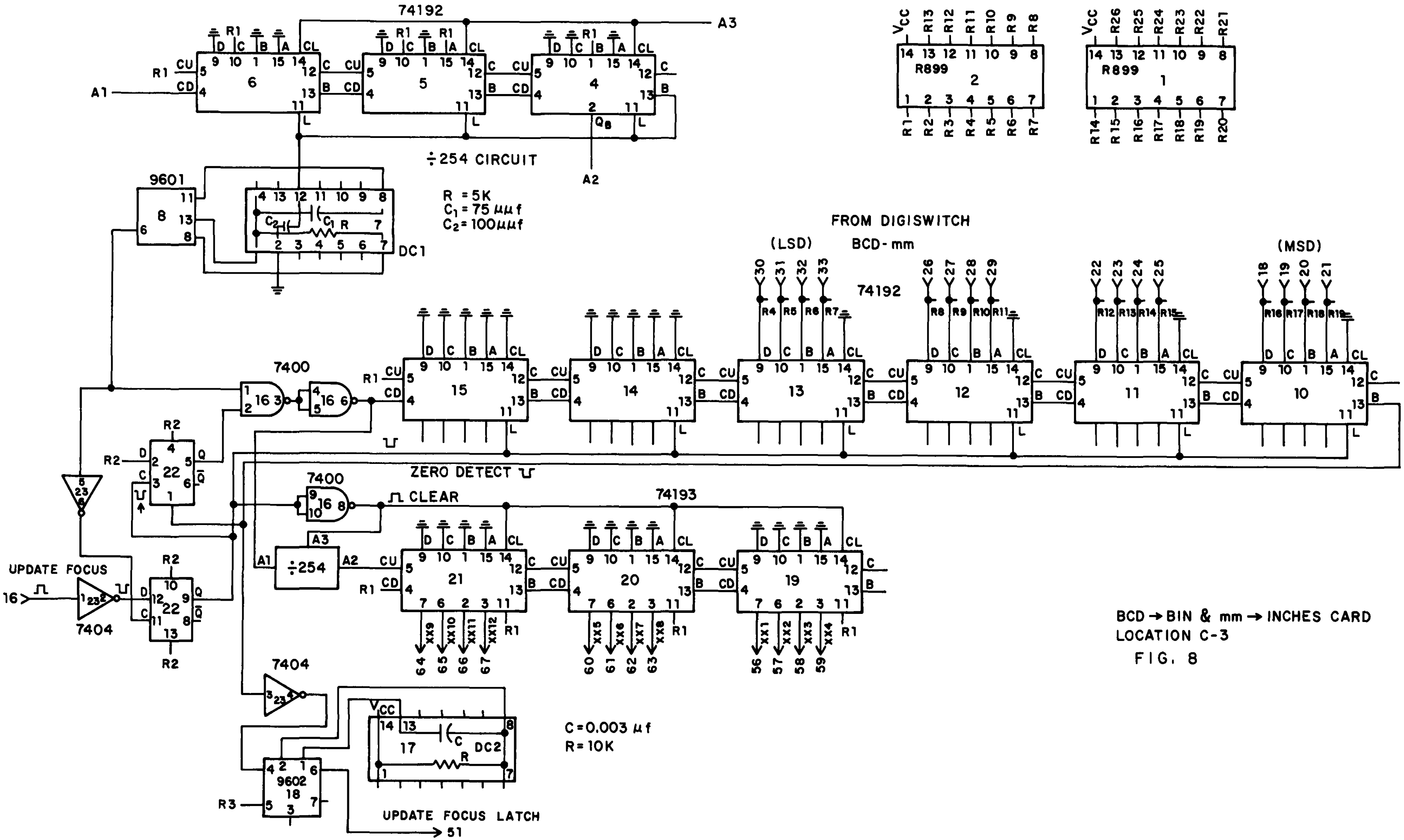
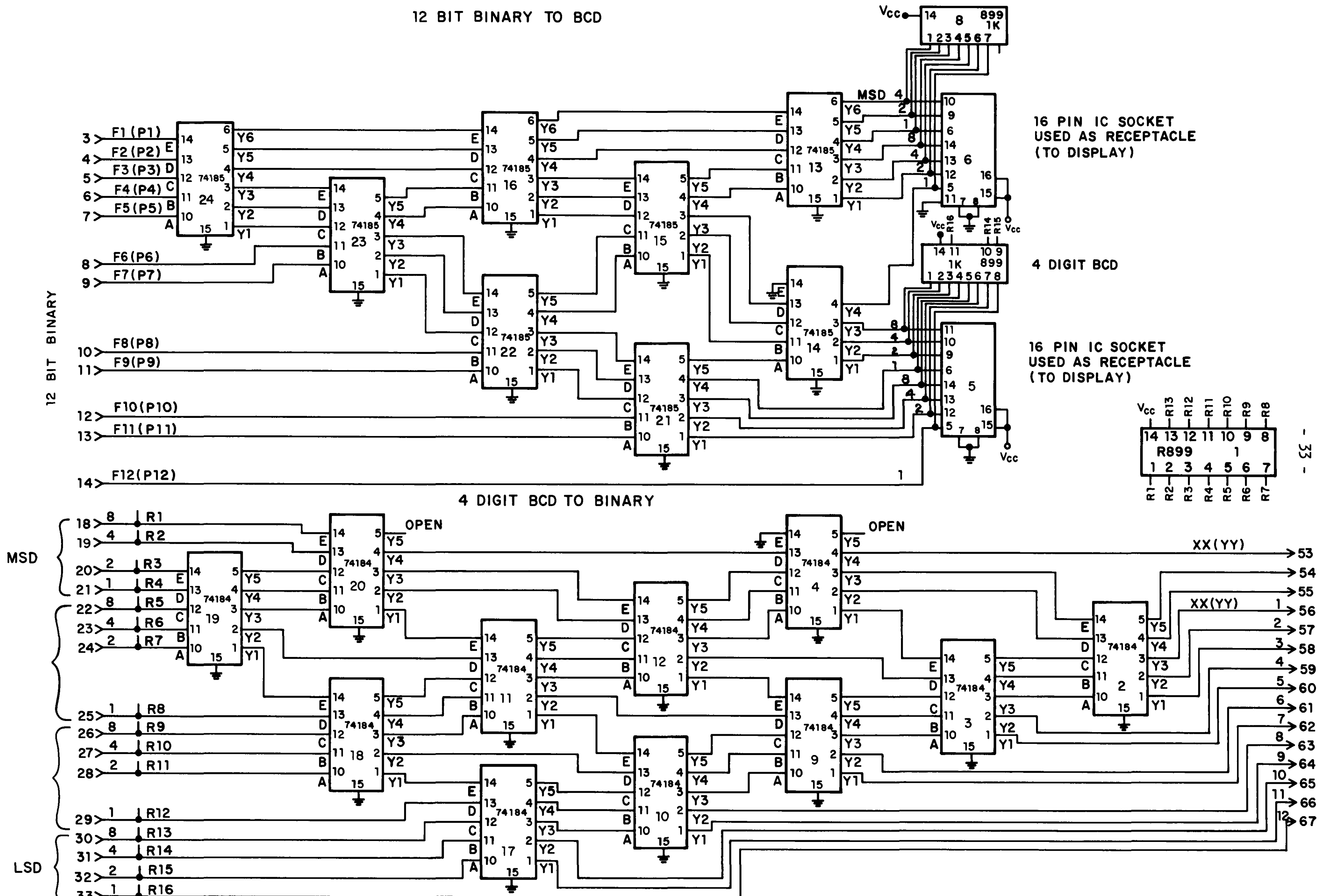


FIG. 7 BINARY/BCD & INCHES/MM CARD LOCATION CP-4

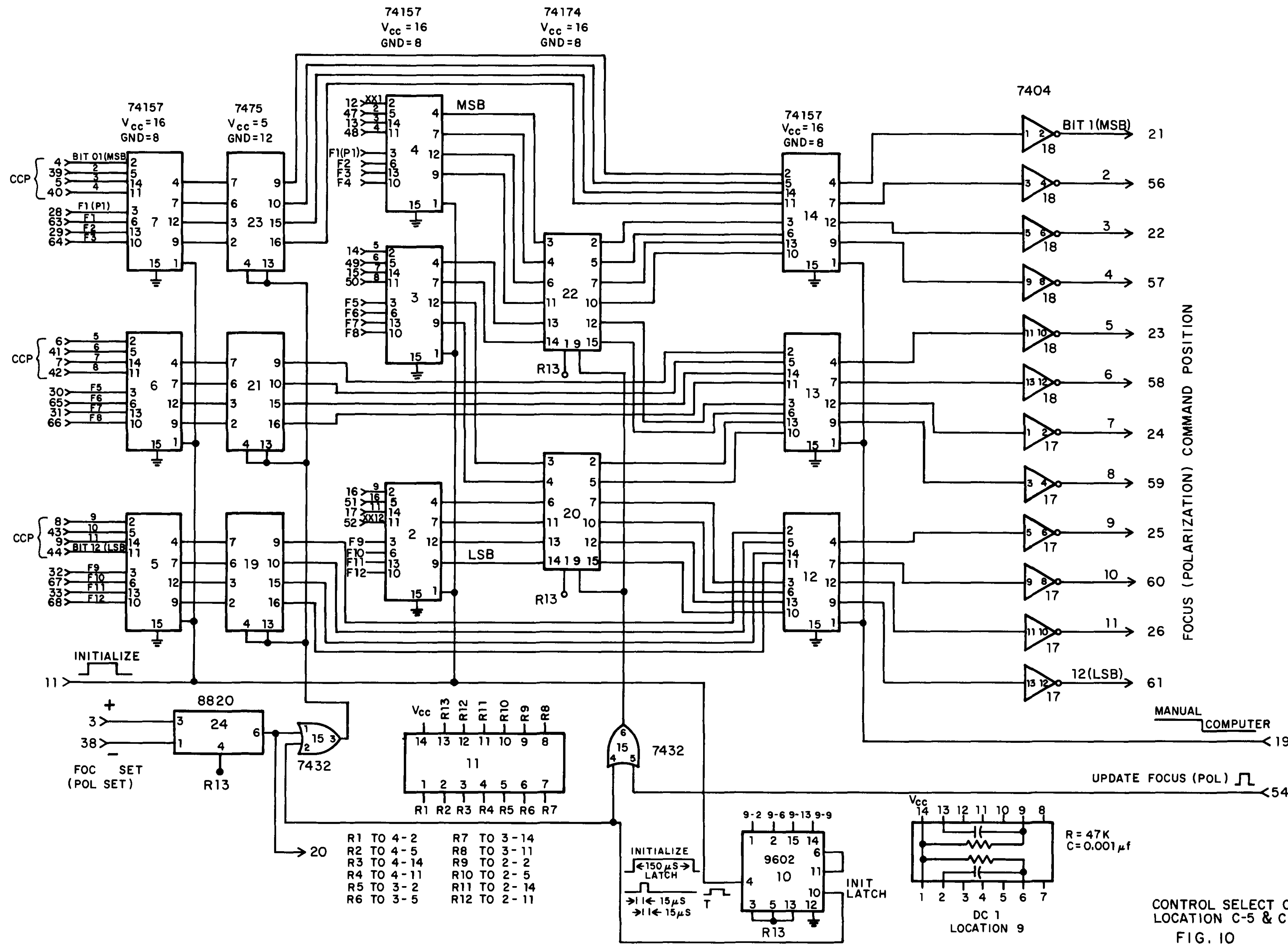


BCD → BIN & mm → INCHES CARD
LOCATION C-3
FIG. 8



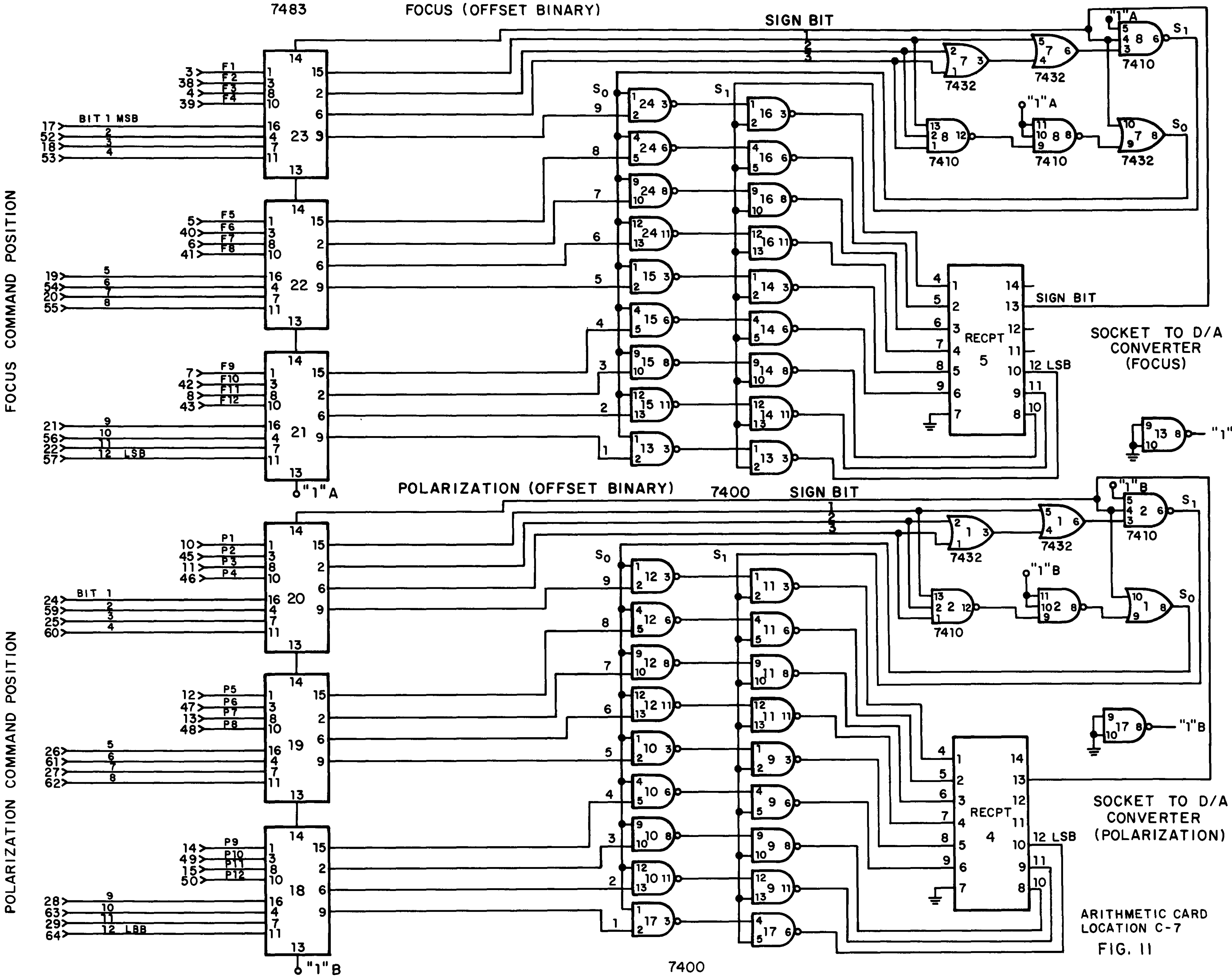
BCD-BINARY / BINARY-BCD CARD
LOCATION C-4

FIG. 9



CONTROL SELECT CARD
LOCATION C-5 & C-6

FIG. 10



ARITHMETIC CARD LOCATION C-7

FIG. 11

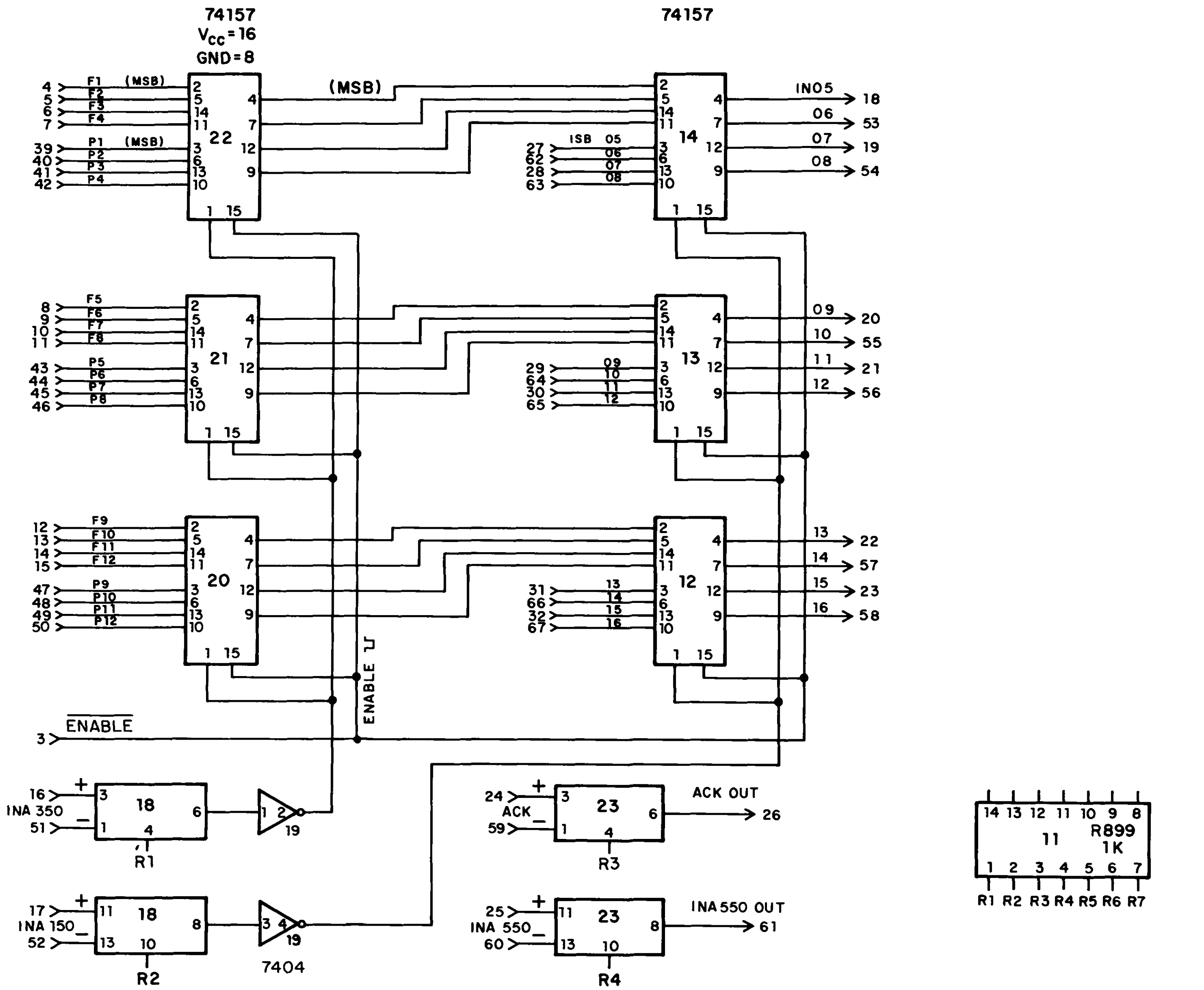
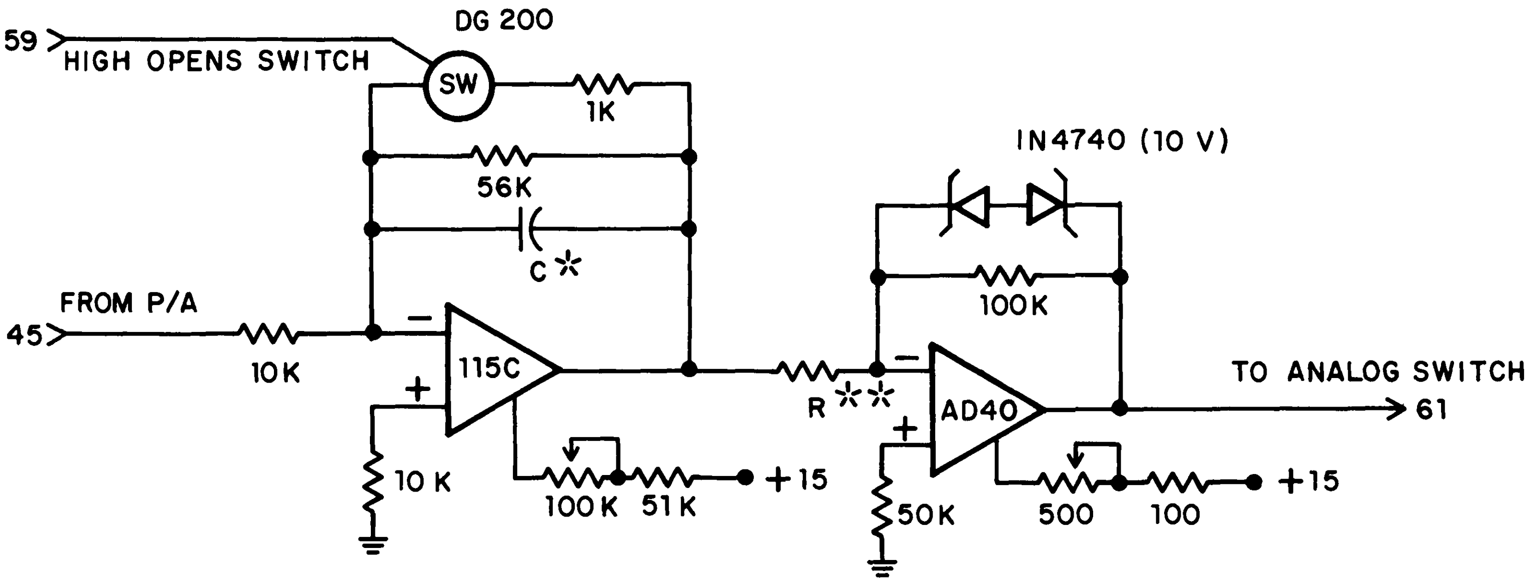


FIG. 12 INPUT BUS SELECT CARD
LOCATION C-8

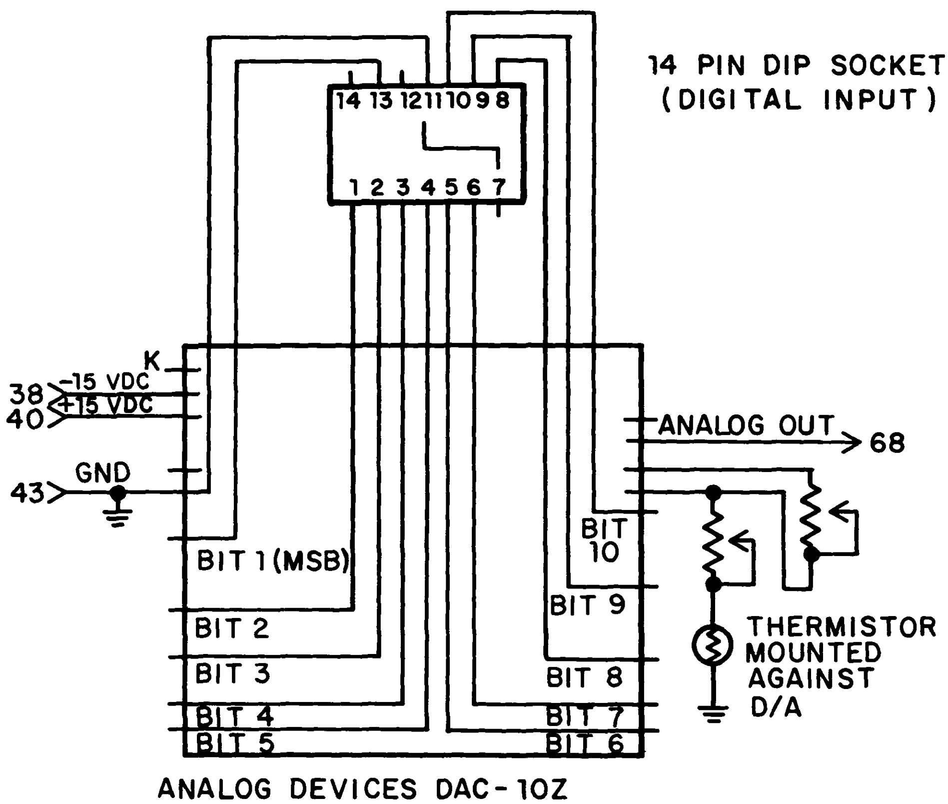


* C = 5.0 μf FOR FOCUS CARD
C = 0.47 μf FOR POL CARD

** R = 34 K FOR FOCUS CARD
R = 100 K FOR FOCUS CARD

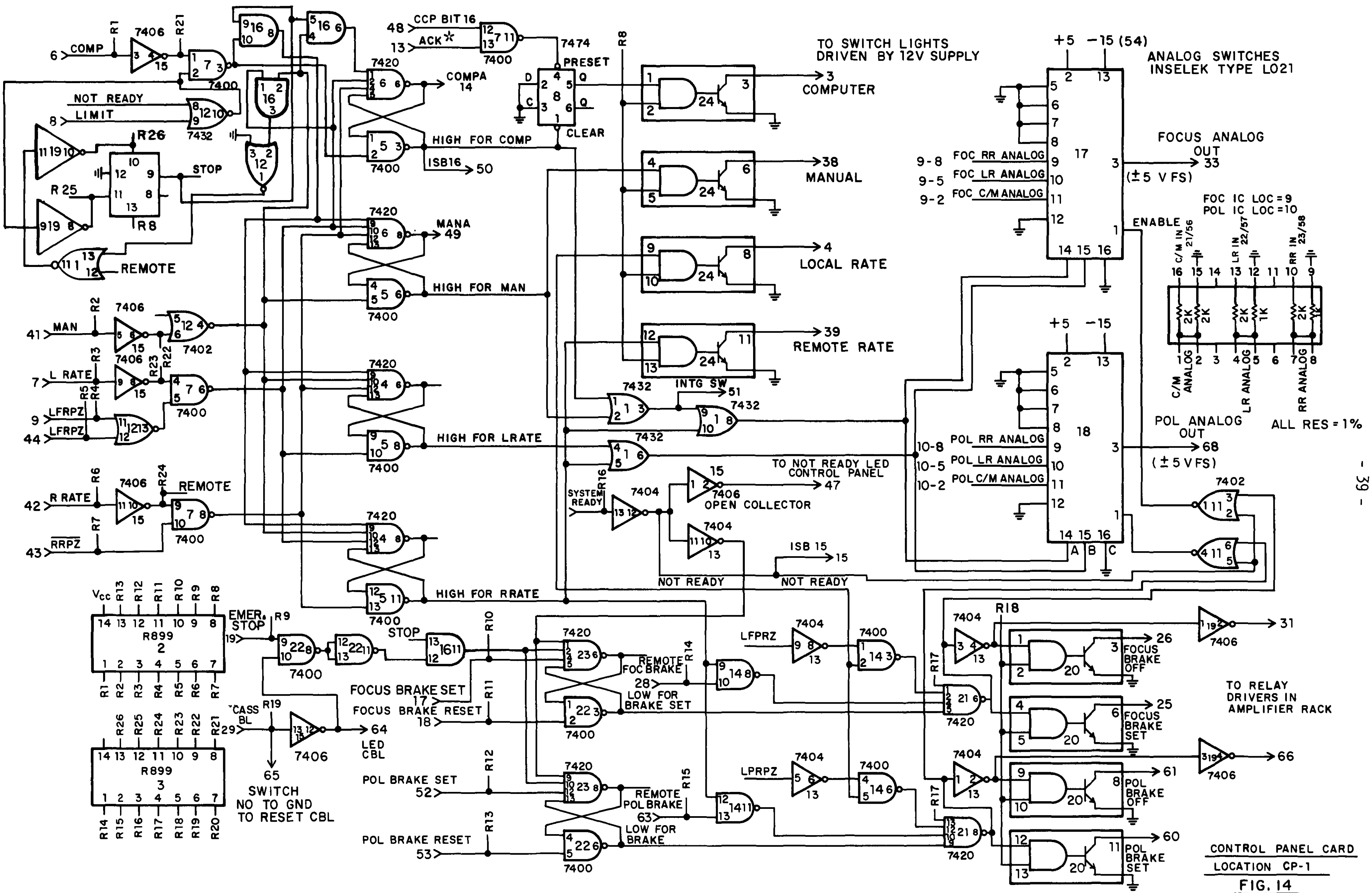
POSITION ERROR INTEGRATOR
LOCATION A1 - FOCUS
LOCATION A2 - POLARIZATION

FIG. 13a



D/A CONVERTER
LOCATION C9 - FOCUS
LOCATION C10 - POLARIZATION

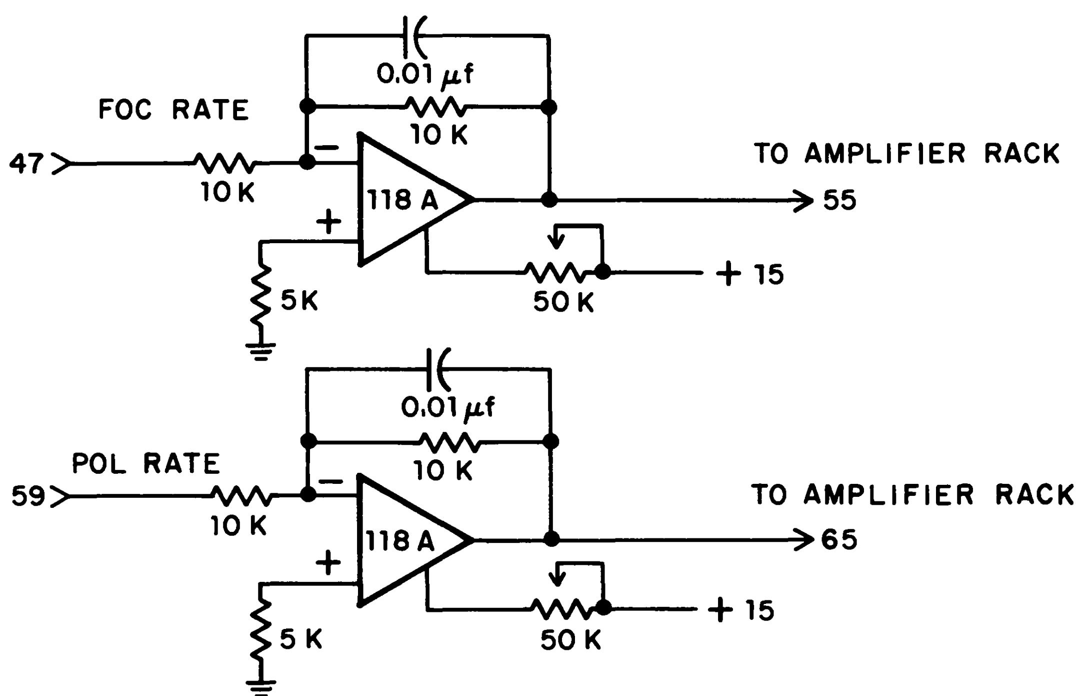
FIG. 13 b



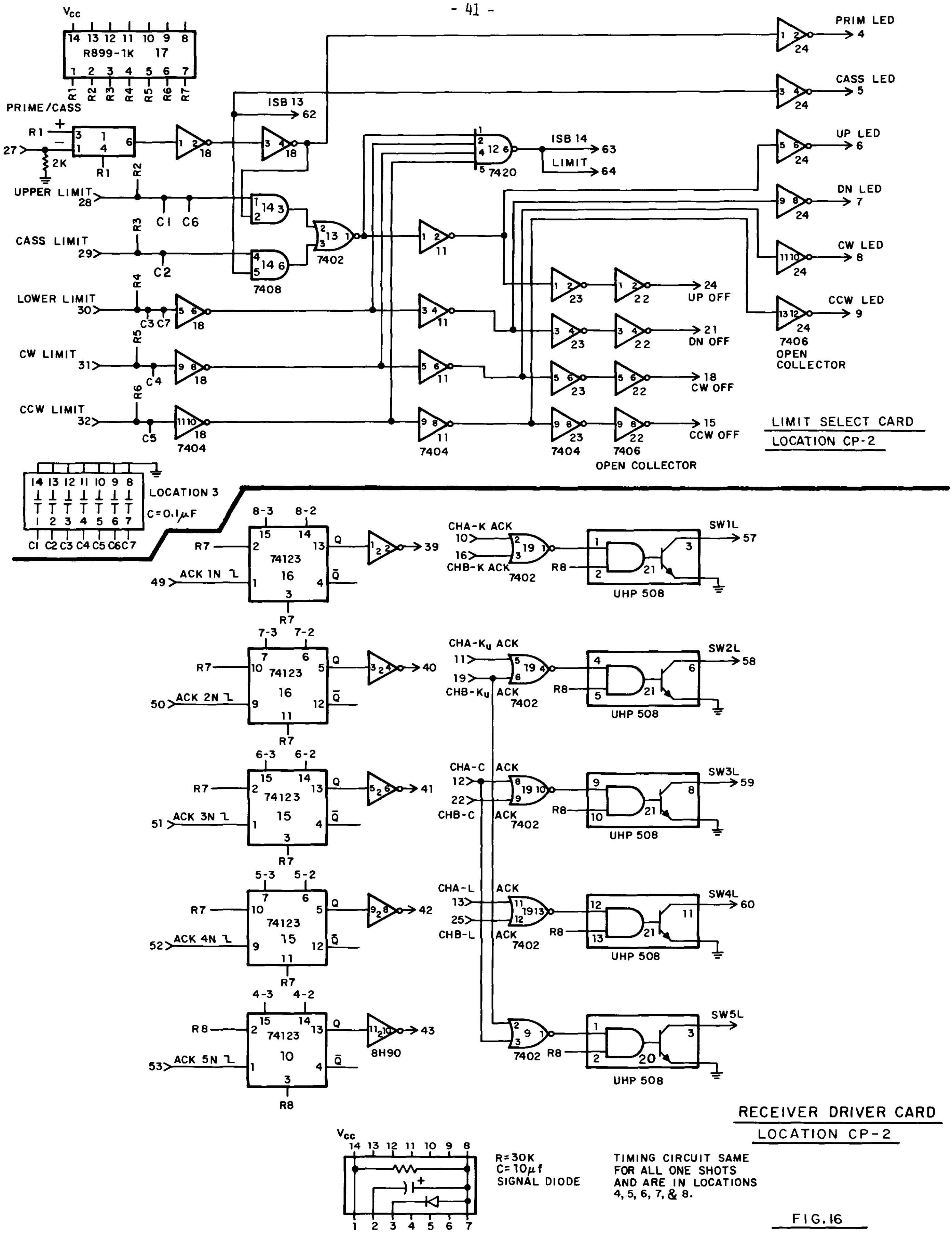
CONTROL PANEL CARD

LOCATION CP-1

FIG. 14



RATE BUFFER AMPLIFIERS
LOCATION A3
FIG. 15



LIMIT SELECT CARD

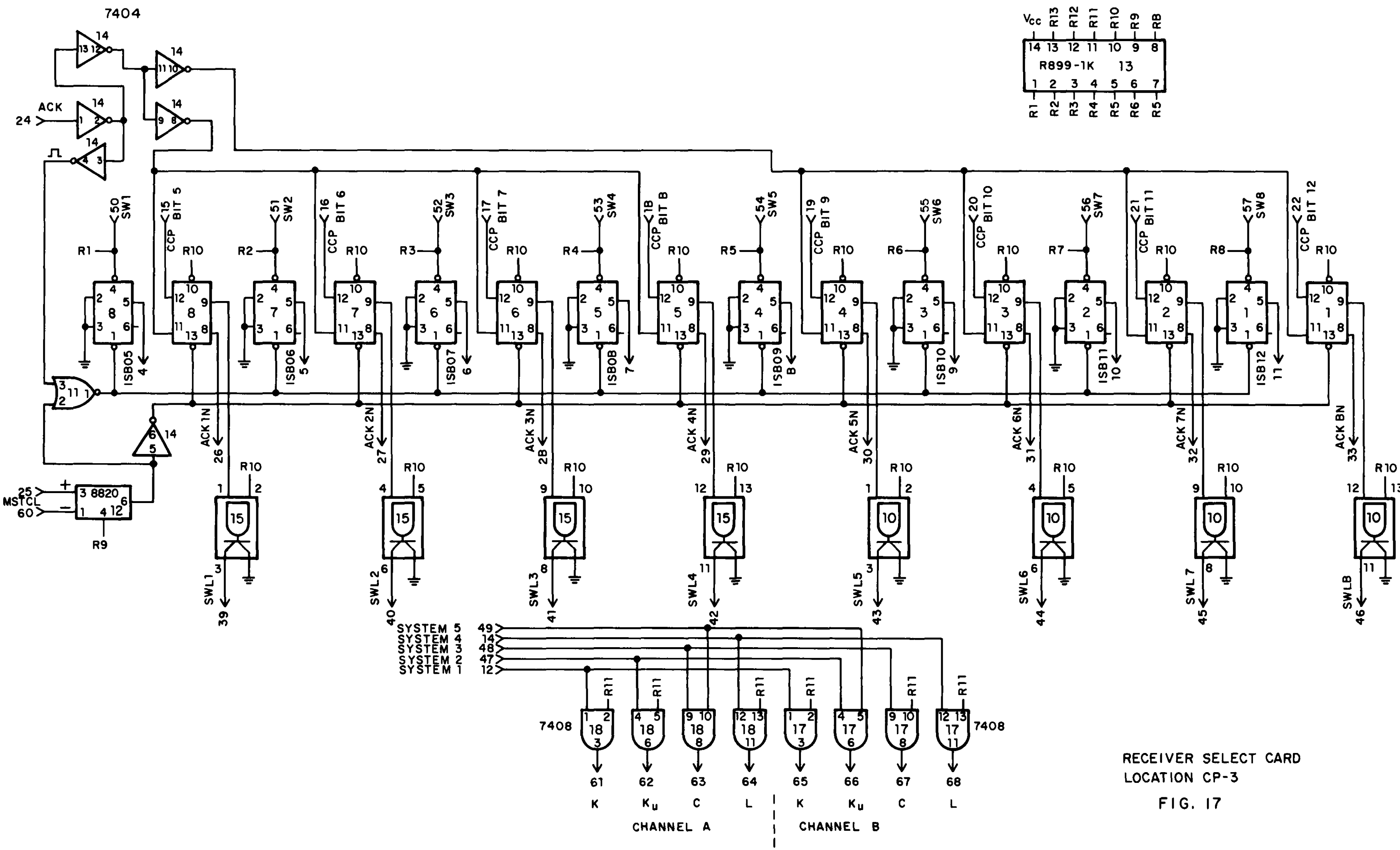
LOCATION CP-2

RECEIVER DRIVER CARD

LOCATION CP-2

TIMING CIRCUIT SAME FOR ALL ONE SHOTS AND ARE IN LOCATIONS 4, 5, 6, 7, & 8.

FIG. 16



RECEIVER SELECT CARD
LOCATION CP-3

FIG. 17

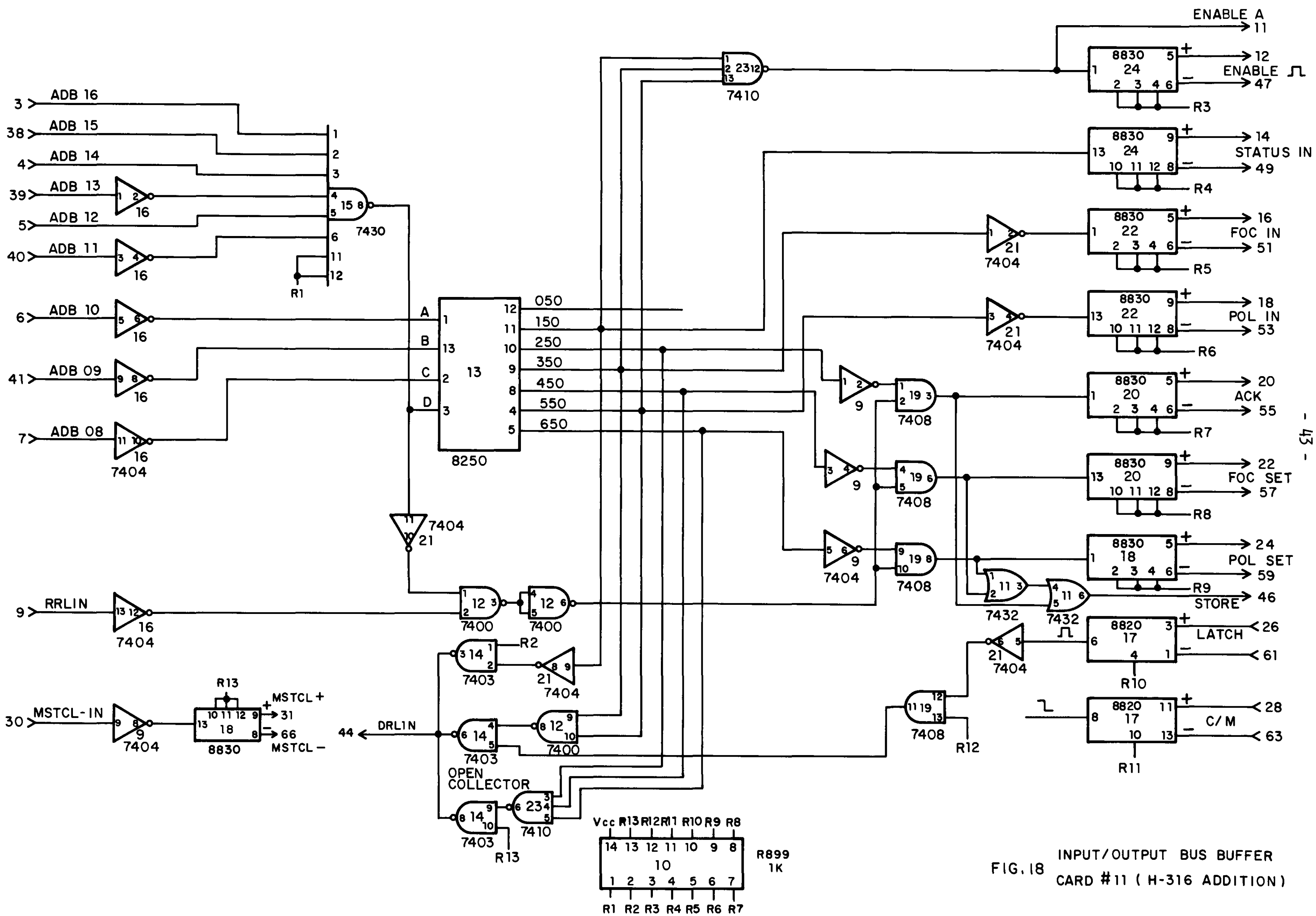


FIG. 18 INPUT/OUTPUT BUS BUFFER
CARD #11 (H-316 ADDITION)

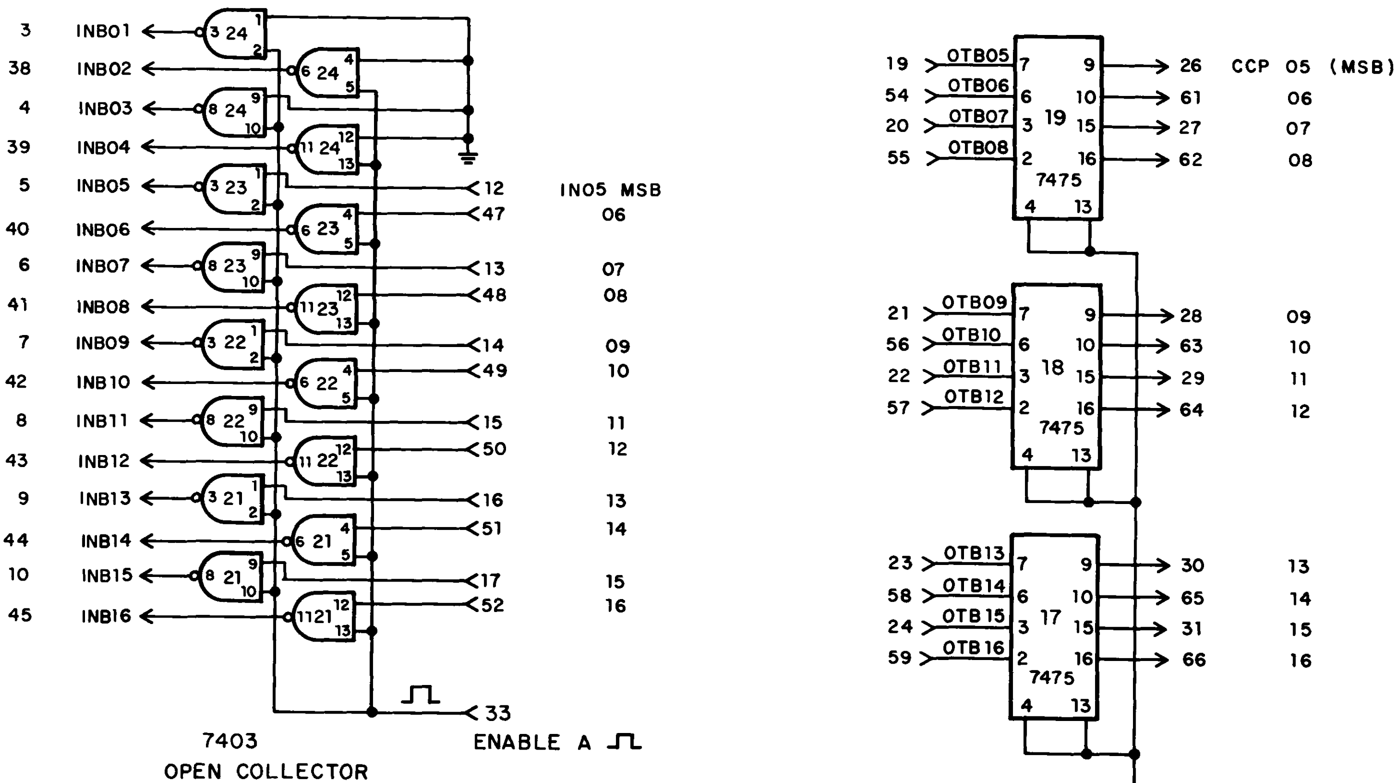


FIG.19 INPUT-OUTPUT BUS BUFFER
CARD 10 (H-316 ADDITION)

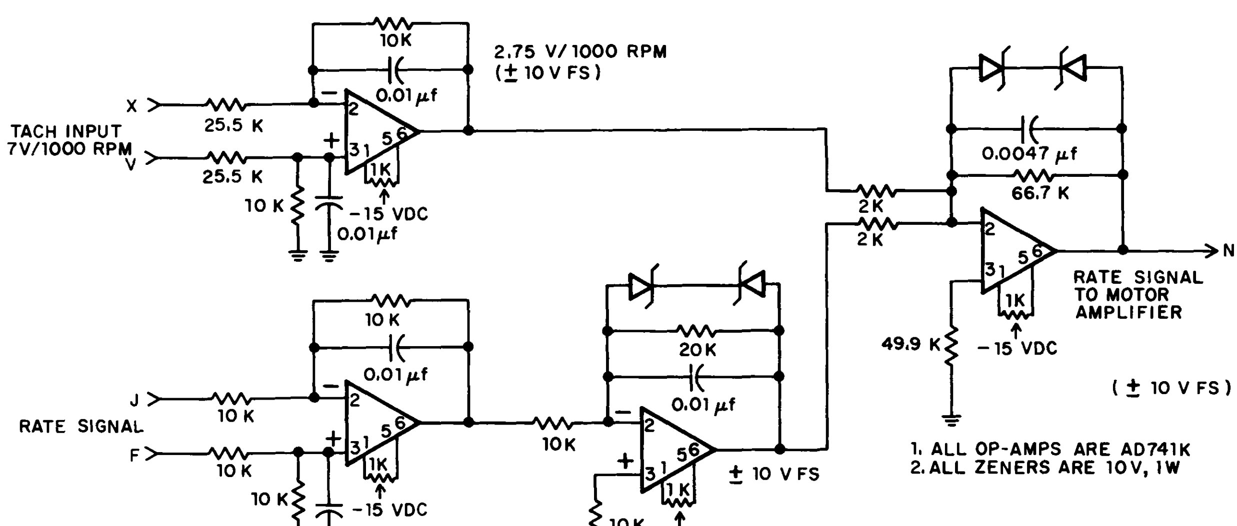


FIG. 20 AMPLIFIER RATE COMMAND CARD
LOCATED IN AMPLIFIER RACK
ONE FOR EACH AXIS OF DRIVE