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45-FOOT STAND-ALONE COMPUTER CONTROL

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ADDENDUM TO ELECTRONICS DIVISION INTERNAL REPORT NO. 128

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On page 54 of the report, the following changes were made in the program:

STEP NUMBER	OLD SYMBOL	NEW SYMBOL
1373	+	-
1377	2	1
1378	3	7

The effect of these changes is to allow a variable offset to be added to the input sidereal time. This allows the clock to be set to the sidereal time of a site, other than where the telescope is.

The offset is stored in position 39 of the constant card. If an offset of x hours is desired, store in position 39 the constant x + 0.000817 hours.

Example: For an offset of -42 seconds store -42/3600 +0.000817 = 0.01085.

See page 50 of the report for how to record a new constant card.

There was the 0.000817 hour offset present in position 39, in the original program. The above changes have the program include the offset in the preliminary calculations.

CORRECTIONS TO THE REPORT

On the drawing at the top of page 46, change 72° and 36° to 720° and 360°.

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FORTY-FIVE FOOT STAND-ALONE COMPUTER CONTROL

Joseph Greenberg

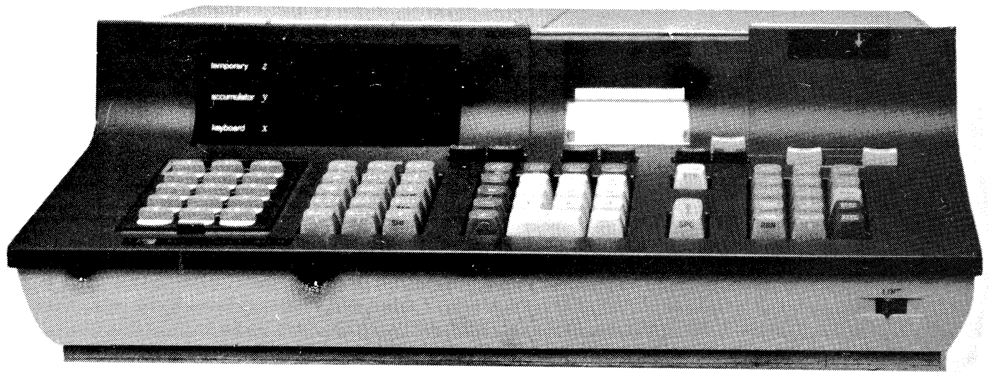
INTRODUCTION

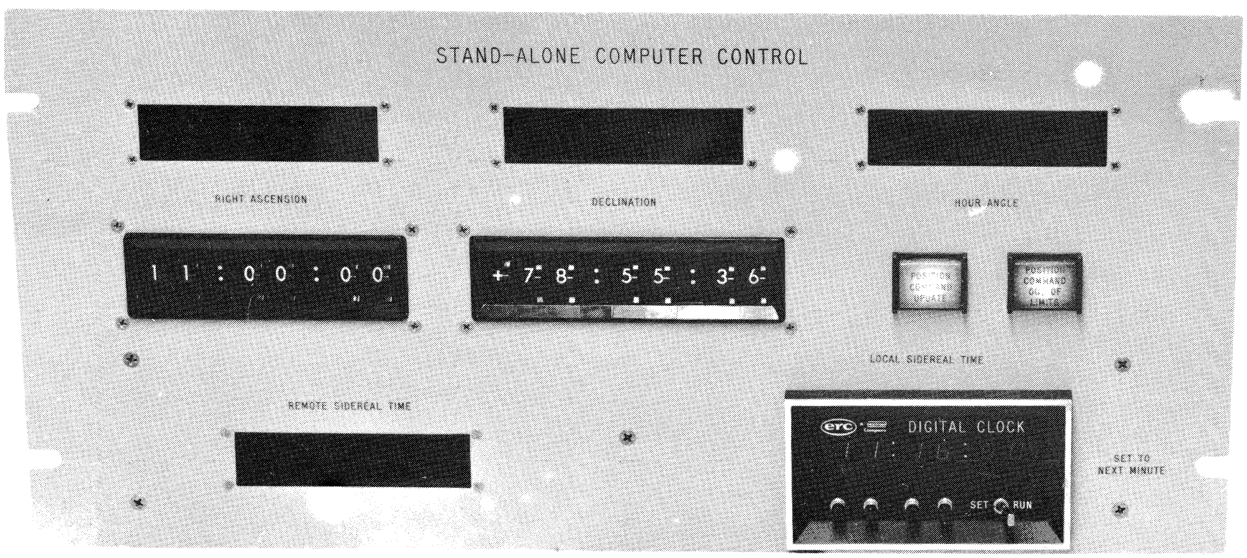
A Hewlett Packard 9810A calculator is used as the stand-alone control of the 45-foot telescope. Upon pushing the "Position Command Update" button, a right ascension and declination are read in from the digiswitches. Using the time from a sidereal clock, the coordinate conversion is made with azimuth and elevation, binary commands given every half second.

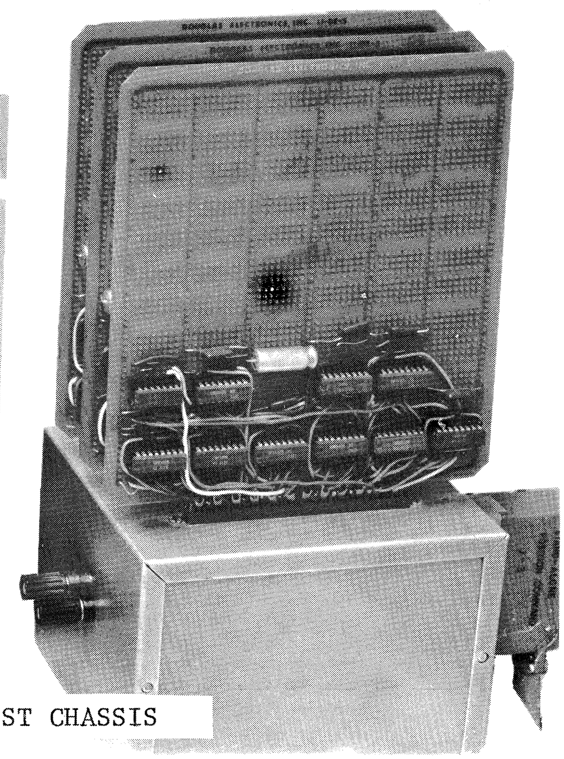
Also, the azimuth and elevation are read from the 'NRAO 45-Foot Telescope Digital Position Control and Readout' and the reverse calculation made. The actual right ascension, declination, and hour angle are output to light-emitting diode displays. The calculations include corrections for refraction. The two remaining displays are the local sidereal time from the digital clock and the remote sidereal time relayed over the link.

OPERATING INSTRUCTIONS

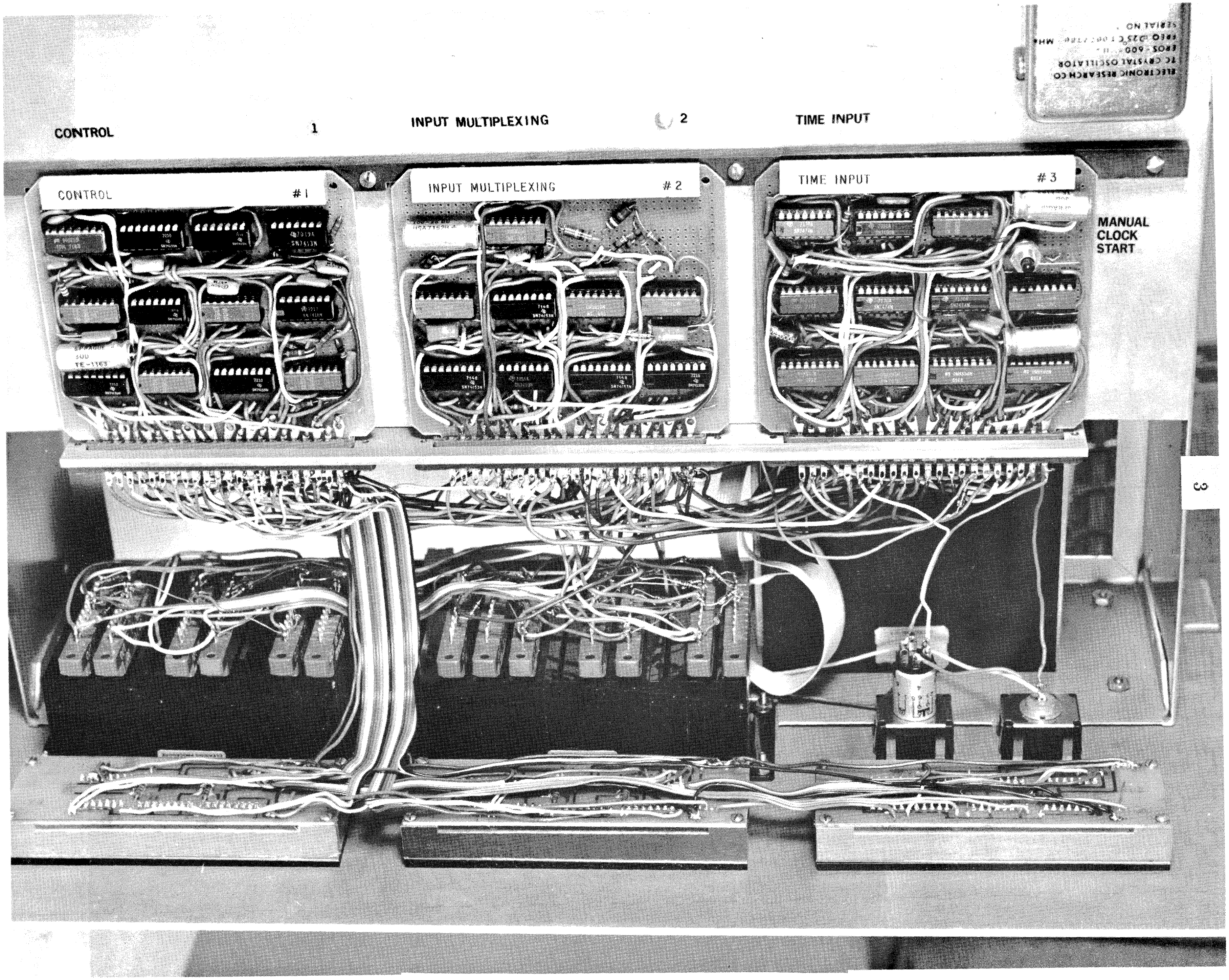
To load the program and constants, press the two calculator keys FMT, GO TO, starting the card-reader motor. To load a card, insert it into the upper slot of the card reader, oriented with the card-side to be used pointing downward. Load, first, sides one and two of the program card, then sides three and four of the constant card. The card-reader motor should them stop.



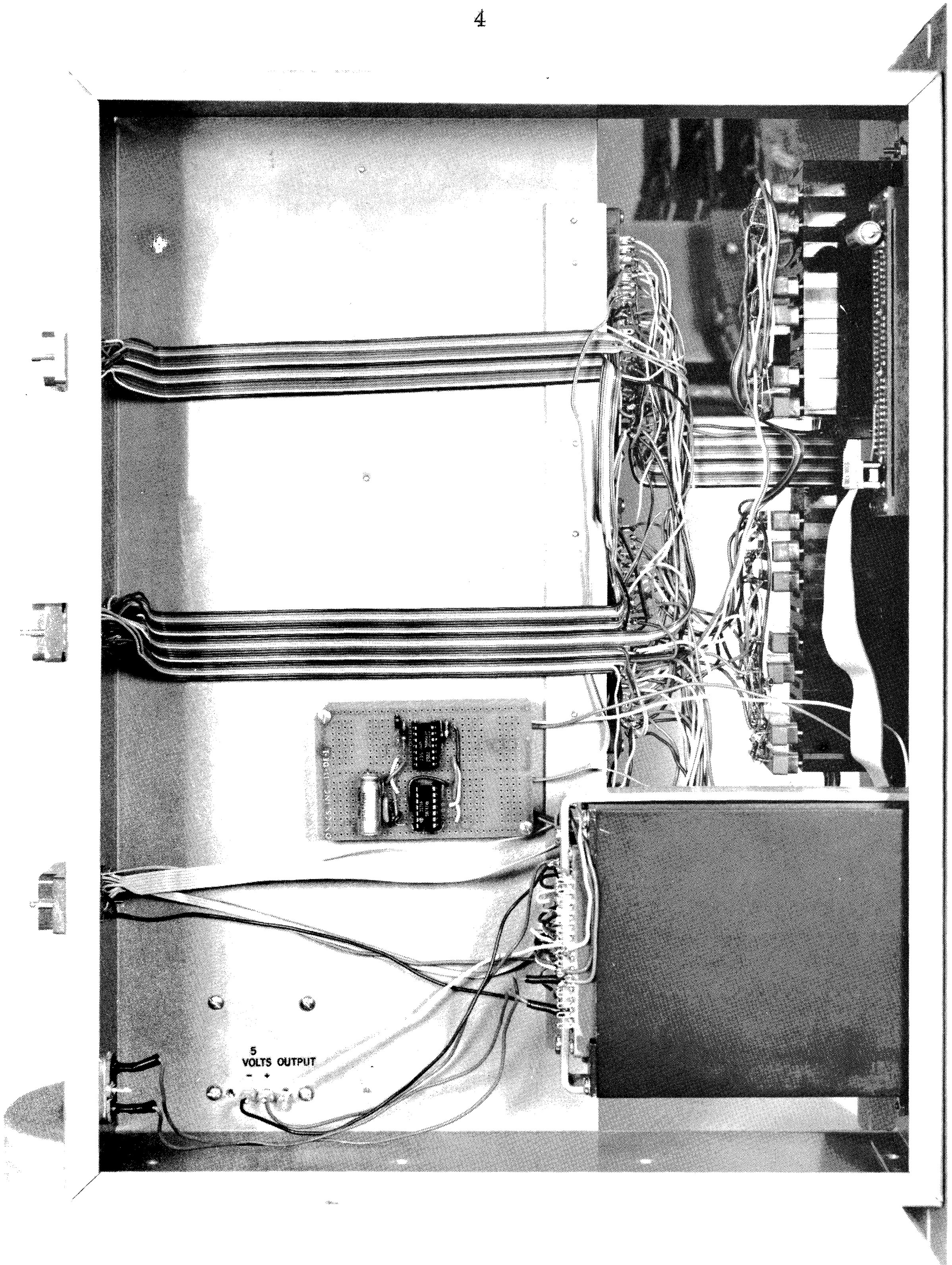




9810A CALCULATOR, STAND-ALONE COMPUTER CONTROL, and TEST CHASSIS



STAND-ALONE COMPUTER CONTROL (TOP VIEW)



STAND-ALONE COMPUTER CONTROL (BOTTOM VIEW)

The display will now flash and the "Position Command Out of Limits" light will come on. Dial in the current r.a. and dec. of the source on the digi-switches. Depress the "Position Command Update" button. The button will light and remain lit for about three seconds. The system should now be tracking. The actual r.a., dec., and hour angle to which the telescope is pointed can be seen on the displays.

Dialing in an illegal r.a. and dec. will cause the "Position Command Out of Limits" light to come on. The system will go into stand-by mode, waiting for the "Update" button to be pushed. The following conditions are illegal:

Having a declination greater than 90 or less than -90°. (See next page for use as a stow position command.)

Having a source whose position is less than the minimum altitude specified on the constant card.

If the system is tracking a source which goes below the minimum altitude, the system will go into stand-by mode, and the "Position Command Out of Limits" light will come on. The corrective action in all cases is to change the r.a. and dec. command to a legal value, then depress the "Update" button.

To set the local sidereal time on the digital clock, toggle the "Set-Run" switch to the "Set" position. Punch in the time to the next highest minute, incrementing each digit with the appropriate button. Toggle the switch back to "Run" before the minute changes. If the time, as relayed over the link, is displayed on the "Remote Sidereal Time" display, then, at the start of the next minute, the clock will automatically start counting. If the display is not on, the clock can be started manually by depressing the button on Card 3 as the minute changes. It is necessary for the digital clock to have the correct time for the system to operate properly.

If a declination less than -90° is dialed in and the "Position Command Update" button is pushed, the printer will display "Position Command Enter Elevation". Type in on the calculator keyboard a six digit, octal elevation, (Ex. 0°=000000, 90°=200000). Press CONTINUE and the printer will display "Enter Azimuth". Type in a seven digit octal azimuth. The first digit is 0 if the azimuth is less than 360° and 1 if the azimuth is greater than or equal to 360°, (Ex. 90°=200000, 450°=1200000). Press CONTINUE. The Position Command will be given, and also stored as a base 64 number in register 34. Dialing in a declination greater than +90° and pushing the POSITION COMMAND UPDATE button will output the position command last stored in register 34. This provides a quick way to issue a repeatedly used command such as the stow position. If desired, once the constant has been stored in register 34, a new constant card can be recorded (see section on Constant Storage, page 50, for the technique). Using this card, it would not be necessary to enter a declination less than -90° at all.

TROUBLE SHOOTING

If the system refuses to operate, key the following sequence on the calculator: STOP, END (The card-reader motor will come on, so make sure there is no card in the slot.), CONTINUE, STOP, CONTINUE. The system should now track upon pushing the "Update" button. If this does not help, turn off the calculator for a few seconds, then reload the program and data.

The logic exerciser is loaded by pressing FMT GTO and loading side 1 of the card.

The sequence 654321 123456 being printed out indicates Cards 4, 5 and 6 are working properly. They must be in the Test Chassis for this test.

The "Position Command Out of Limits" light will flash.

The Hour Angle Display will follow the Sidereal Time.

The R. A. and Dec. Displays follow the Digiswitches.

LOGIC DESCRIPTION

The logic necessary to interface the calculator is contained on six Douglas Electronics circuit boards. Boards numbers one, two, and three are located in the "Stand-Alone Computer Control" chassis. Boards four, five, and six are located in the "45' Telescope Digital Position Control and Readout" box. They are labeled boards 24, 25, and 26, respectively.

The "Stand-Alone Computer Control" box is connected to the calculator by cable J-0, to the "Digital Position Control and Readout" box by cable J-3, and to the link local sidereal time by J-6.

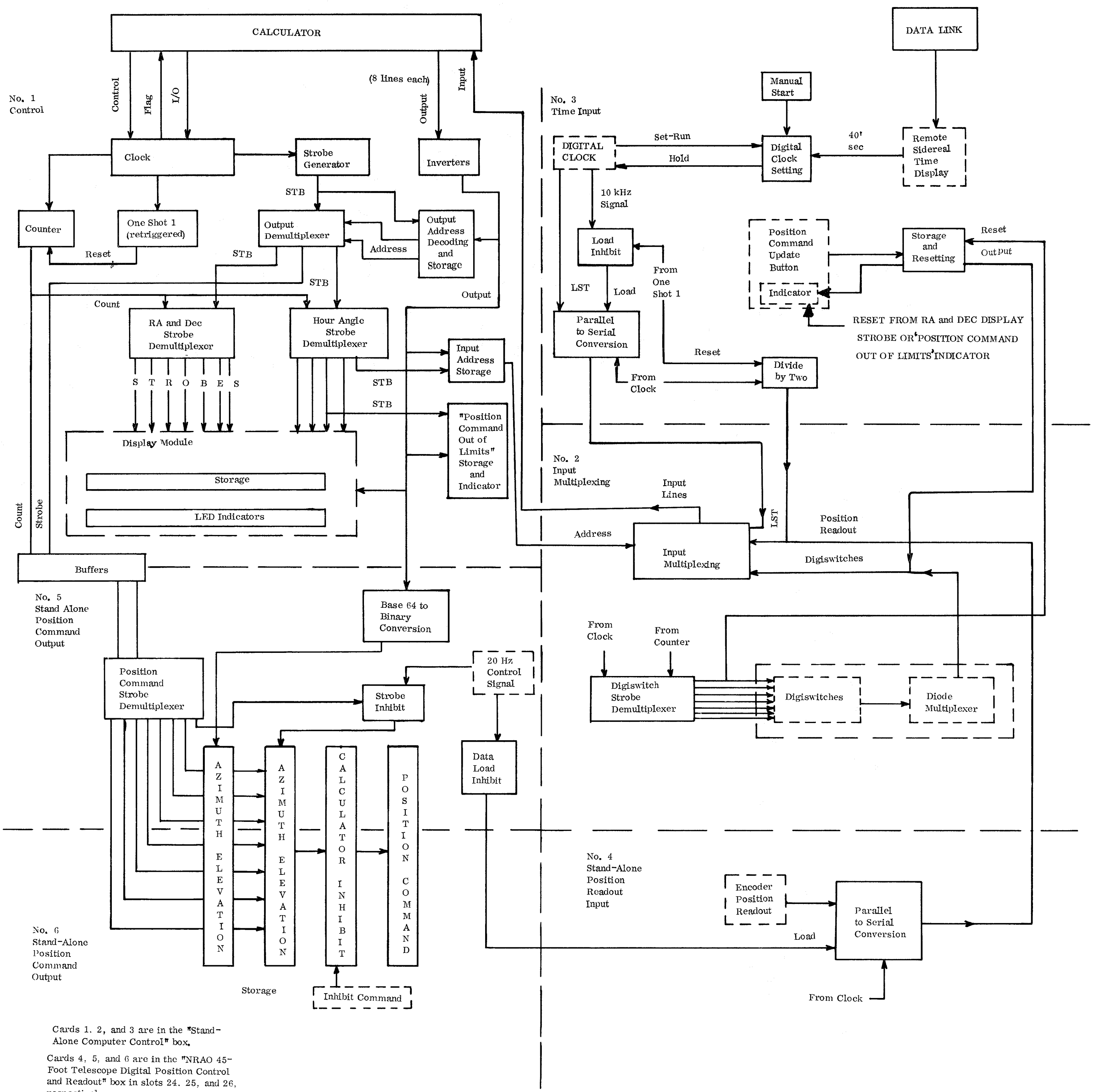
Refer to block diagram of all six boards and the individual board schematics as an aid to understanding.

On the schematics, when a card output pin gets connected to another card, a number such as 4-N is next to the pin: 4 refers to card 4 and N refers to pin N.

The calculator is interfaced with the logic via an HP 11202A I/O TTL Interface. For a full description of the interface refer to the 11202A I/O TTL Interface Preliminary User's Manual.

CARD 1 CONTROL

Board 1 contains the basic timing logic of the system. The "Control" line from the calculator is received by a resistor-capacitor filter and a Schmitt trigger. This was necessary to eliminate noise problems and also provide a

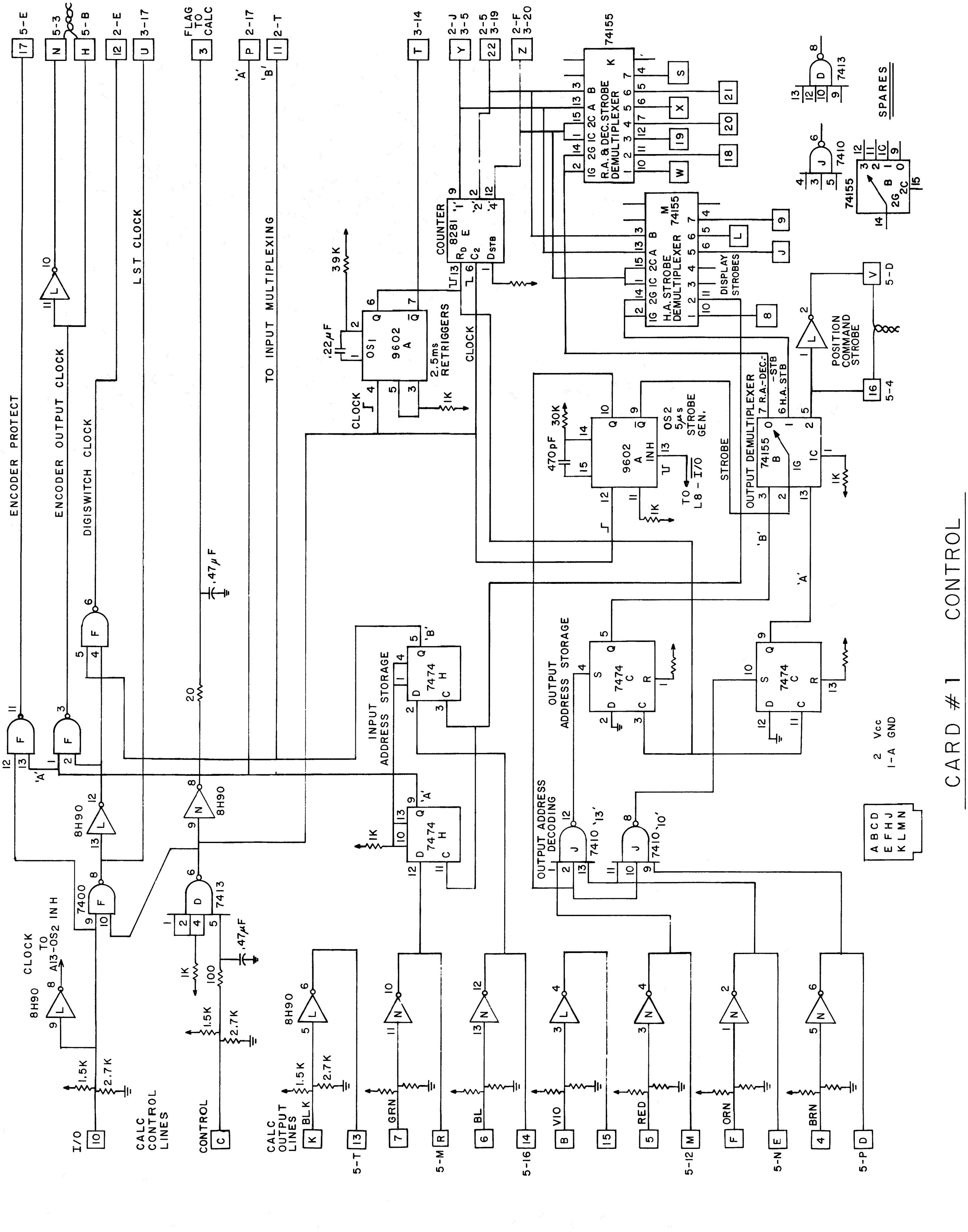


Cards 1, 2, and 3 are in the "Stand-Alone Computer Control" box.

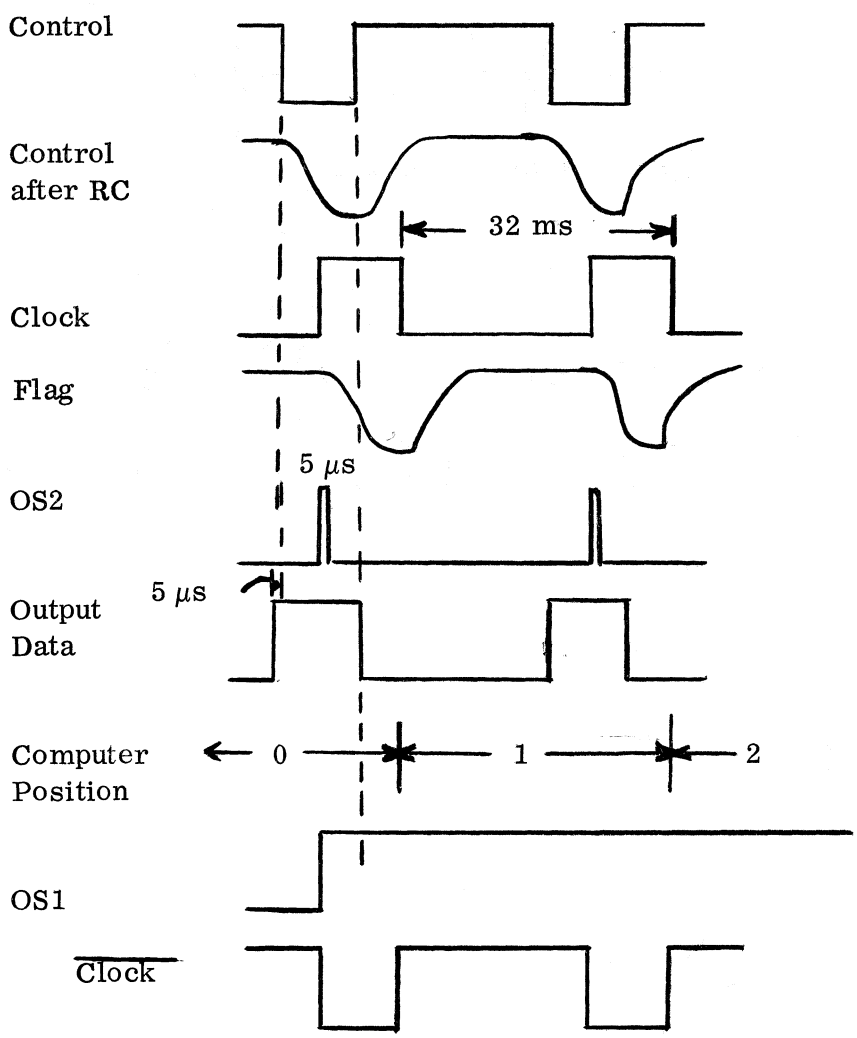
Cards 4, 5, and 6 are in the "NRAO 45-Foot Telescope Digital Position Control and Readout" box in slots 24, 25, and 26, respectively.

A block enclosed by dotted lines indicates a component not on the 6 cards.

BLOCK DIAGRAM OF LOGIC


CARD # 1 CONTROL
ENCODER PROTECT
ENCODER OUTPUT CLOCK
DIGISWITCH CLOCK
LST CLOCK
FLAG TO CALC
TO INPUT MULTIPLEXING
COUNTER 8281 E
2.5ms RETRIGGERS
CLOCK
R.A. & DEC. STROBE DEMULTIPLEXER
H.A. STROBE DEMULTIPLEXER
DISPLAY STROBES
POSITION COMMAND STROBE
OUTPUT DEMULTIPLEXER
7 R.A.-DEC.-STB
6 H.A. STB
OS2 5μs STROBE GEN.
TO L8 - I/O
STROBE
SPARES
INPUT ADDRESS STORAGE
OUTPUT ADDRESS STORAGE
OUTPUT ADDRESS DECODING
TO A13-OS2 INH
CALC CONTROL LINES
CONTROL
CALC OUTPUT LINES
BLK
GRN
BL
VIO
RED
ORN
BRN
2 Vcc
1-A GND
A B C D
E F H J
K L M N

TIMING DIAGRAM



delay. The resistor pull-up is necessary since the calculator outputs are open collector. A high to low transition of "Control" indicates the calculator is ready for input or output.

The "Flag" line gives control back to the calculator when returned in a low state. During output, it signals that the data has been accepted. During input, it tells the calculator the data is ready.

The signal from the Schmitt trigger is the Clock. The Clock is reinverted and passes through an RC filter for a delay. This signal is received as the "Flag" by a Schmitt trigger in the 11202A Interface. The "Flag" is acknowledged by "Control" returning high (see timing diagram).

During an output operation, "Control" goes low eight times. During each cycle, one bit is output from each of the eight output lines; thus, a number from the x-register is output in a sixty-four bit block. The present system allows the input-output operations to occur as rapidly as possible.

One Shot Two (OS2) triggers on the positive edge of the Clock for a five micro-second pulse. During output, the data comes on line five micro-seconds before control goes low and remains until control goes high. Since the "Flag" is delayed by the RC following the clock, "Control" going high is delayed by much more than five micro-seconds. Thus, the data is on line during the entire high time of OS2, making it a convenient strobe (see timing diagram).

The number $-1.23456789012 \times 10^{12}$ would be output in a sixty-four bit block as follows:

$-1.23456789012 \times 10^{12}$

'128'	'64'	'32'	'16'	'8'	'4'	'2'	'1'
0	0	0	0	1	1	0	0
0	0	0	1	0	0	0	1
0	0	0	1	0	0	1	0
0	0	1	1	0	1	0	0
0	1	0	1	0	1	1	0
0	1	1	1	1	0	0	0
1	0	0	1	0	0	0	0
0	0	0	1	0	0	1	0
'8'	'4'	'2'	'1'	'8'	'4'	'2'	'1'
V	B	G	Y	O	R	Br	Bl

Each row represents one cycle. Each column represents one output wire as identified at the bottom by its color. Note it is the resistor color code from right to left. The first row output is the exponent in binary. Negative exponents are represented by two's compliment. The second row represents the sign. A "+" sign is all zeros. The last six rows represent, in order, the twelve digits of the number in BCD, two digits per row.

The output lines have been inverted to get them in positive logic.

The two, three-input nands are used in decoding the output address. Each is gated with two output lines and OS2. They respectively go low when a number with an exponent of 13 or 10 is output. Advantage is taken of the fact that the exponent is output in binary, while everything else is in BCD. The gates are, respectively, across the red and orange ("4" and "8") and brown and orange (2" and "8") output lines. A BCD number can never have one of these pairs both high.

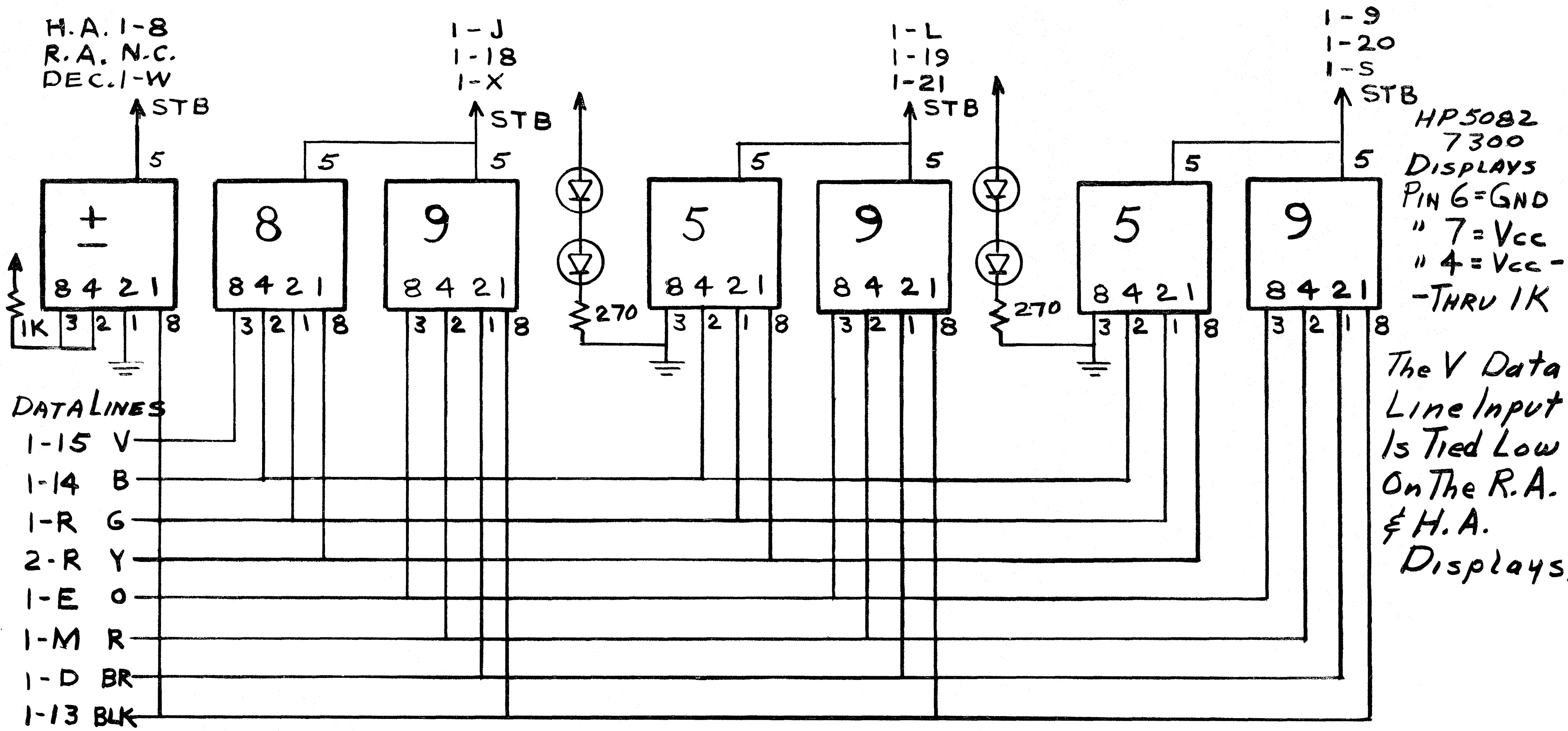
OS1 triggers on the positive edge of the Clock. It has a period about six times the cycle rate. Since it is retriggerable, it stays high until about two milliseconds after the last cycle.

The two flip-flops store the output address. They act as input to the demultiplexer in position B. Initially, the rising edge of OS1 resets the flip-flops, moving the demultiplexer to position 00, which is the R.A. and Dec. Displays, as a default option. The ten nand sets flip-flop "A" which changes the demultiplexer to position 01, the hour angle. The thirteen nand sets the "B" flip-flop, moving the demultiplexer to position 10, the Position Command Output. Note that the output devices can be addressed in any order. Since the exponent is output first, the logic is positioned to the correct address before the significant data is output.

Since the displays have memory, the data is demultiplexed to them so that sixteen wires can transmit sixty-four bits. Eight wires are the eight output lines. Each of the other eight wires represents a row in the sixty-four bit block and goes low during the time the row is on line. To provide these strobes, an octal counter clocks on the negative edge of the Clock (see timing diagram). The count is then fed to a one of eight demultiplexer to provide the strobes to the display digits. OS1 is used to reset the counter to zero after each input-output operation.

OS2 is fed to the one of four demultiplexer in position B as a strobe for the data. From there, it goes to the appropriate one-of-eight demultiplexer.

The right ascension and declination are output as the twelve digits and sign of one, sixty-four bit block. The hour angle is output as the last six digits of a separate block. An address for the Input Multiplexing is output as the 4 and 2 bits of first digit of the same block. This number is stored in the D flip-flops of position "H". The "Position Command Out of Limits" light is activated by the 80 hr. bit of the hour angle.



R.A., DEC. & H.A. DISPLAY

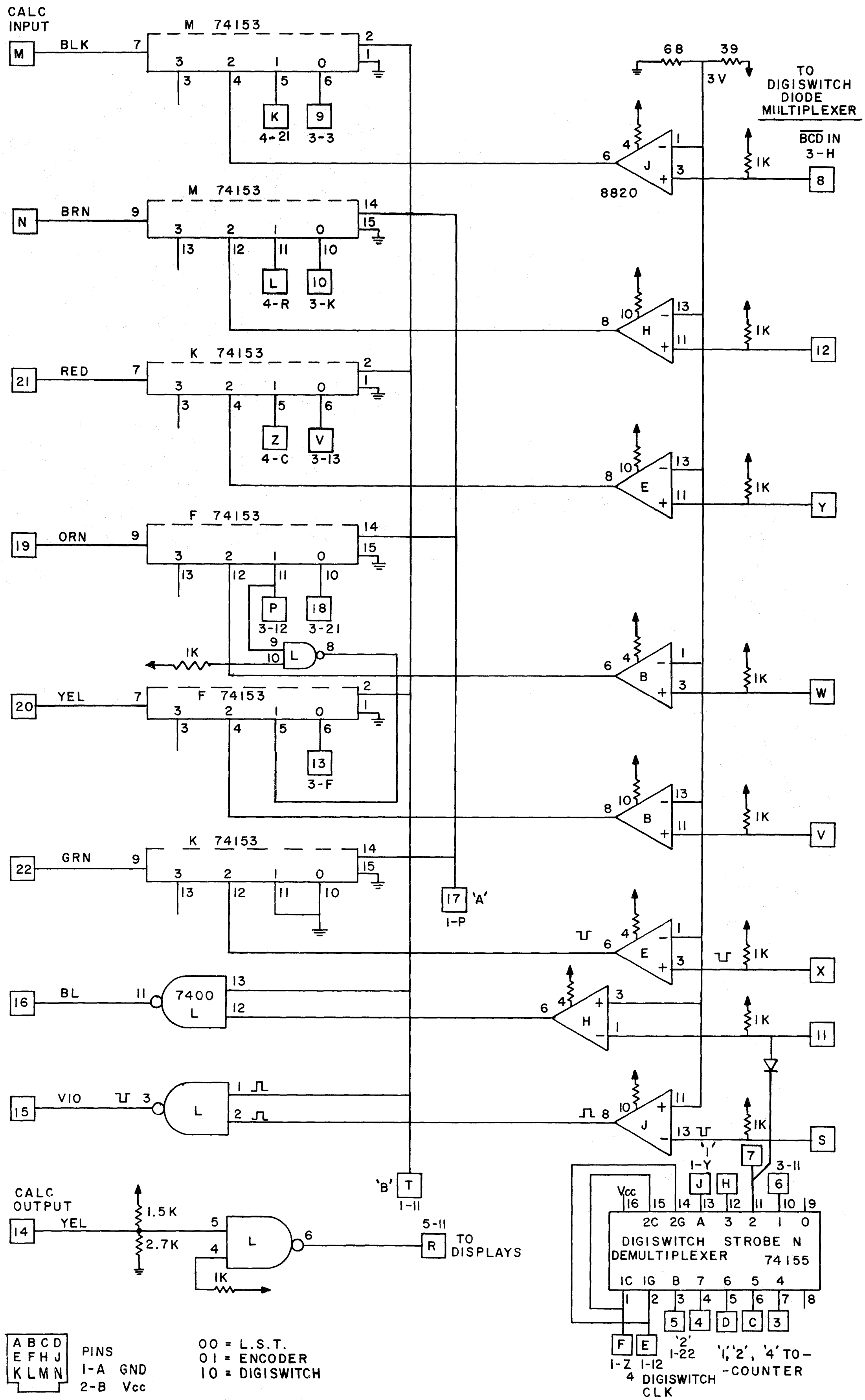
The I/O line goes high for an input operation and low for an output. It is inverted and used to inhibit OS2 during input operations. This prevents the output devices from having garbage stobed into them during an input operation.

The "Encoder Protect" nand provides a signal which goes low when the calculator is in input mode and the input multiplexer is set to the "Position Readout Input Port".

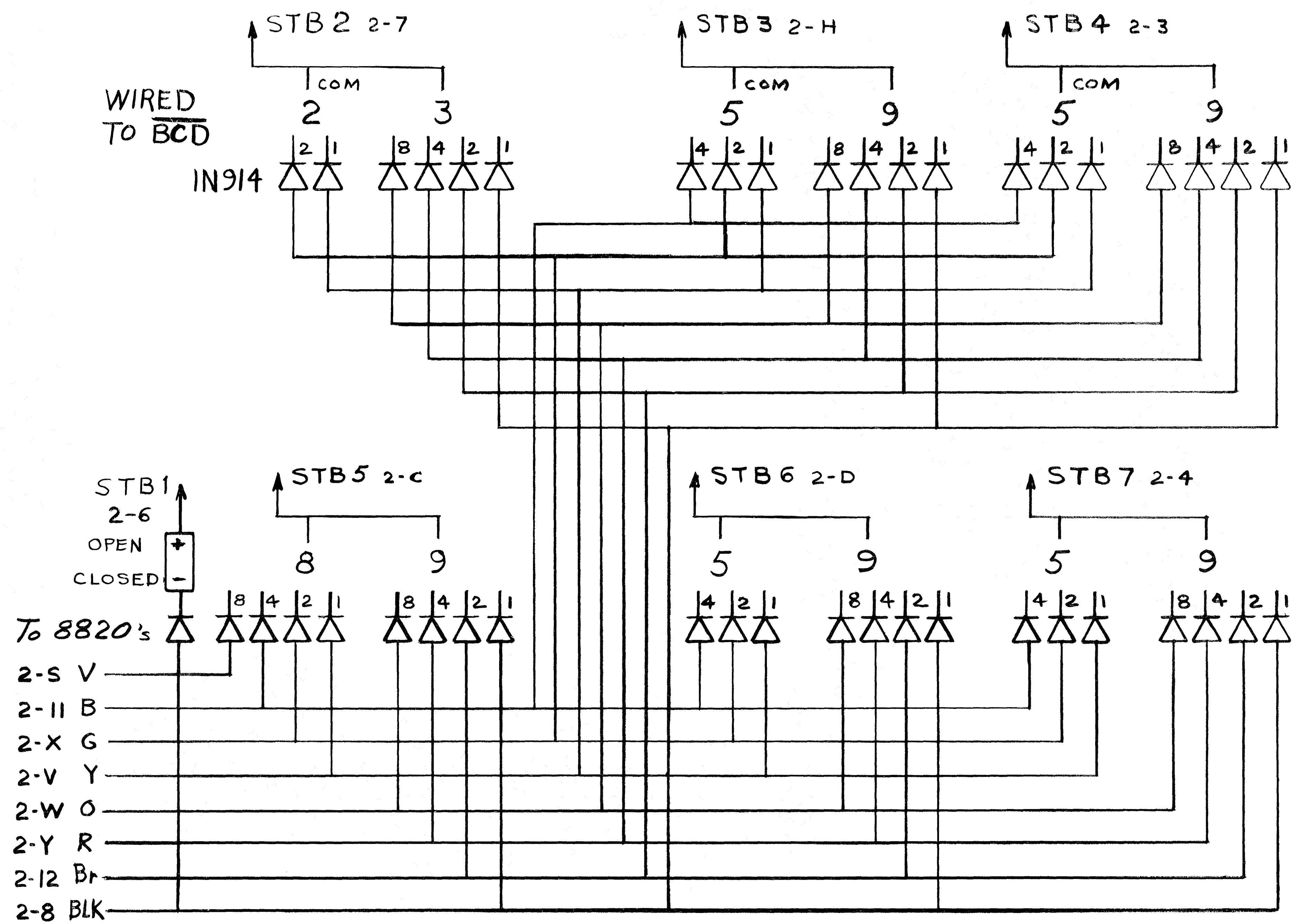
I/O is gated with the Clock to provide a distinct clock for input operations. This is necessary because the encoder output is asynchronously loaded into shift registers. An output operation, preceding the input, would shift out the data if the clock were not inhibited. The LST input data shares this clock because it is updated at a 10 kHz rate, so has time to recover. The digiswitches and encoder each need another gate for the exclusive use of a clock. On the digiswitches, this prevents the "Position Command Update" button from being reset before the digiswitches have been read. Since the encoder is updated at 20 Hz, sharing a clock could cause the data to be wiped out, then read, before it is reupdated. The "Digiswitch Clock", "Encoder Clock", and the "Encoder Protect" derive their signals by appropriate gating with the address flip-flops of the Input Multiplexing.

CARD 2 - INPUT MULTIPLEXING

There are two input modes used in the system. The right ascension and declination digiswitches are input in one, sixty-four bit block of the same format as the output block.



CARD # 2 INPUT MULTIPLEXING

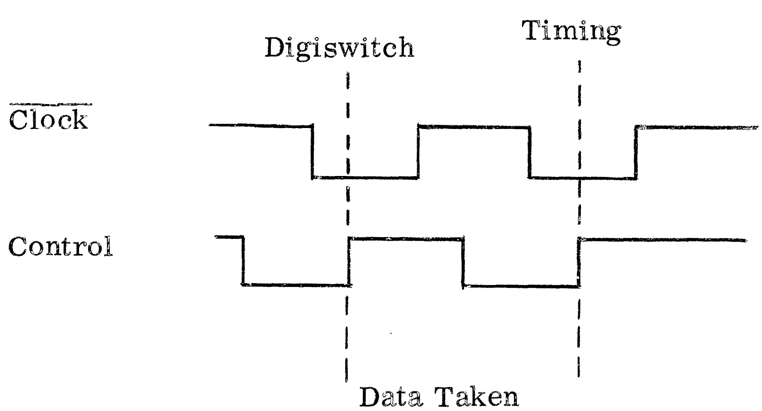


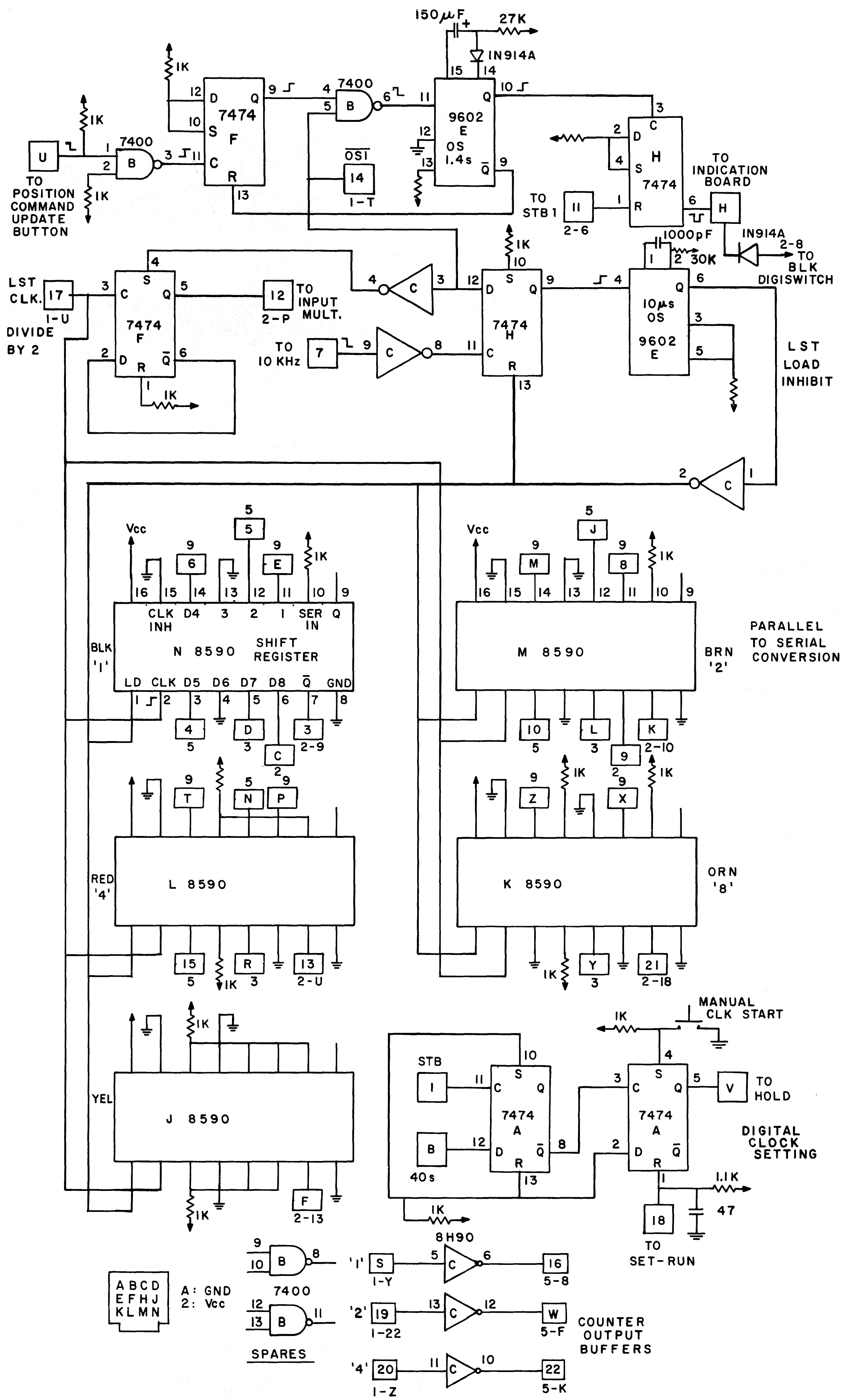
DIGISWITCH WIRING

The digiswitches are wired as shown. A multiplexing scheme is used analogous to that in outputing. Note that the "Digiswitch Clock" to the "Digiswitch Strobe Demultiplexer" on Card 2 corresponds to $\overline{\text{Clock}}$ on the earlier timing diagram. Data is taken on the rising edge of Control which falls inside the strobe. The diodes are necessary to eliminate undesirable current paths. The 8820, dual-line receivers provide the level shifting which corrects for the voltage drop across the diodes.

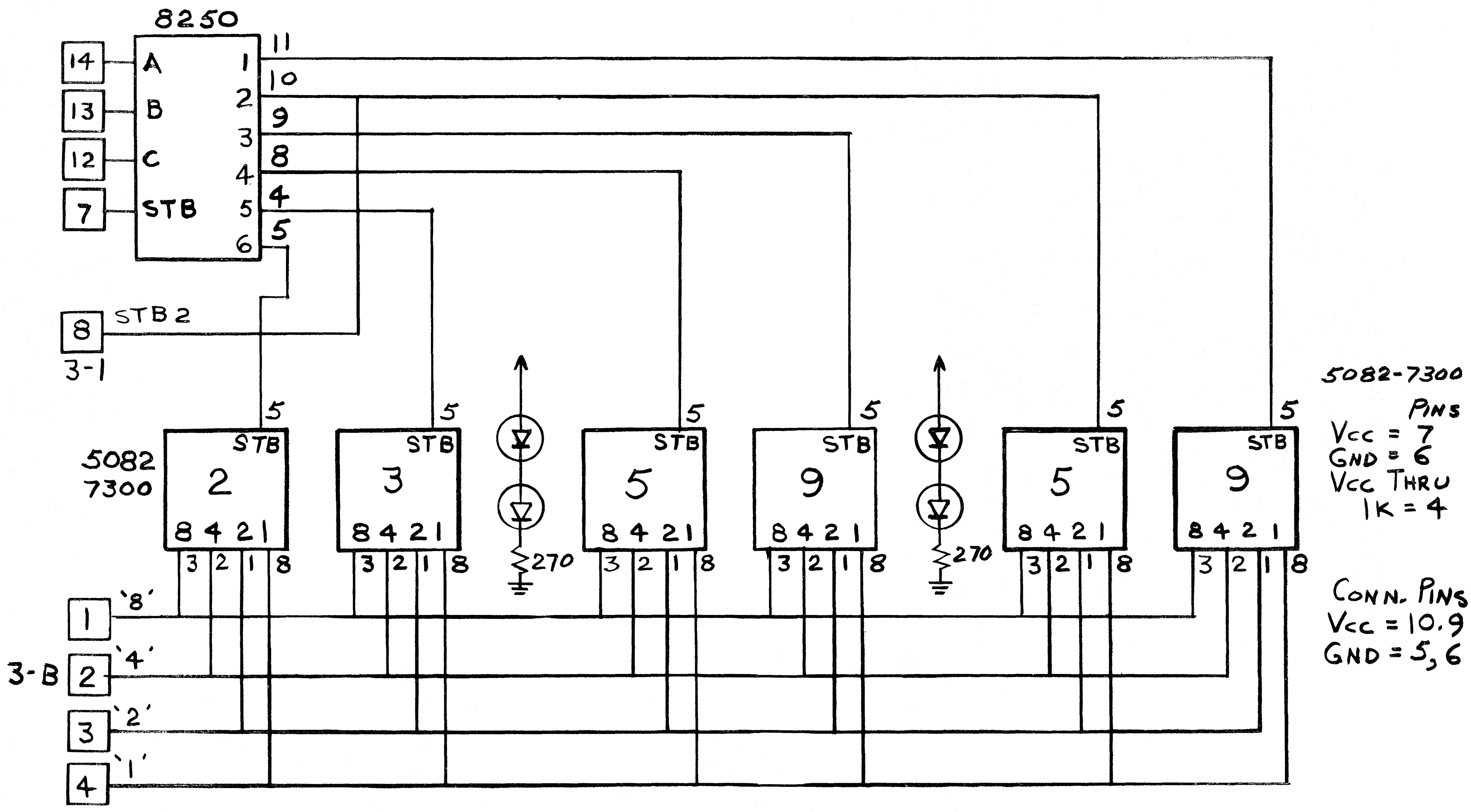
The LST and Position Readout are input one digit at a time, in ASCII coding. To enter a digit, the first four input lines are set to 0011. The last four lines represent the BCD coding. The delimiter 00101100 causes the calculator to perform an "up" operation, with the next digit starting a new number in the x-register. There are numerous delimiters that terminate the input operation. This method allows separate numbers to be placed in the three display registers in one input operation.

The input multiplexing addresses given from Card 1 are as follows: 00 is the Local Sidereal Time; 01 is the Position Readout; 10 is the digiswitches. Two nand gates serve as multiplexers for the blue and violet lines. This is possible since only the digiswitch outputs vary these lines; otherwise, they are to be 00. The multiplexers output into the calculator input lines in negative logic.





CARD # 3 TIME INPUT



Pins 2 & 8 Provide The 40 sec. Signal For Clock Setting.

Remote Sidereal Time Display

CARD 3 - TIME INPUT

An Electronic Research Company Series 2400 Digital Clock supplies the sidereal time. There is an external oscillator accurate to 1.5×10^{-7}. For a write-up of the system, see the appendix. The clock can be set manually or by comparing it with the sidereal time relayed over the link. The "Set-Run" switch being placed in the "Set" position resets the second flip-flop of position "A". This drives low the "Hold" signal to the clock. The clock is to be set by hand to the next highest minute, and the "Set-Run" switch placed back in "Run". The first flip-flop stores the forty second signal of the remote time. The negative transition sets the second flip-flop, releasing the hold signal. The flip-flop can also be set by depressing the "Manual Clock Start" button.

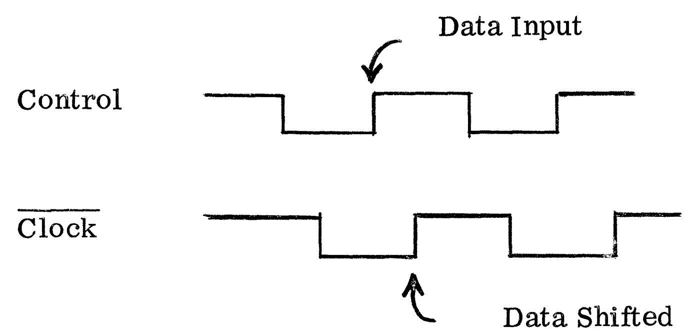
The Remote Sidereal Time Display has the six digits come in in parallel. An 8250 converts the strobe and count into the six strobes needed. Strobe 2 and the '4' bit supply the '40' second signal used in setting the clock.

The time is input in the following matrix:

	1	2	3	4	5	6	7	8
1	0	0	1	1	0	0	-	2
2	0	0	1	1	-	-	-	3
3	0	0	1	0	1	1	0	0
4	0	0	1	1	0	-	-	5
5	0	0	1	1	-	-	-	9
6	0	0	1	0	1	1	0	0
7	0	0	1	1	0	-	-	5
8	0	0	1	1	-	-	-	9
9	0	0	1	1	1	1	1	1
	V	B	G	Y	O	R	Br	Bl

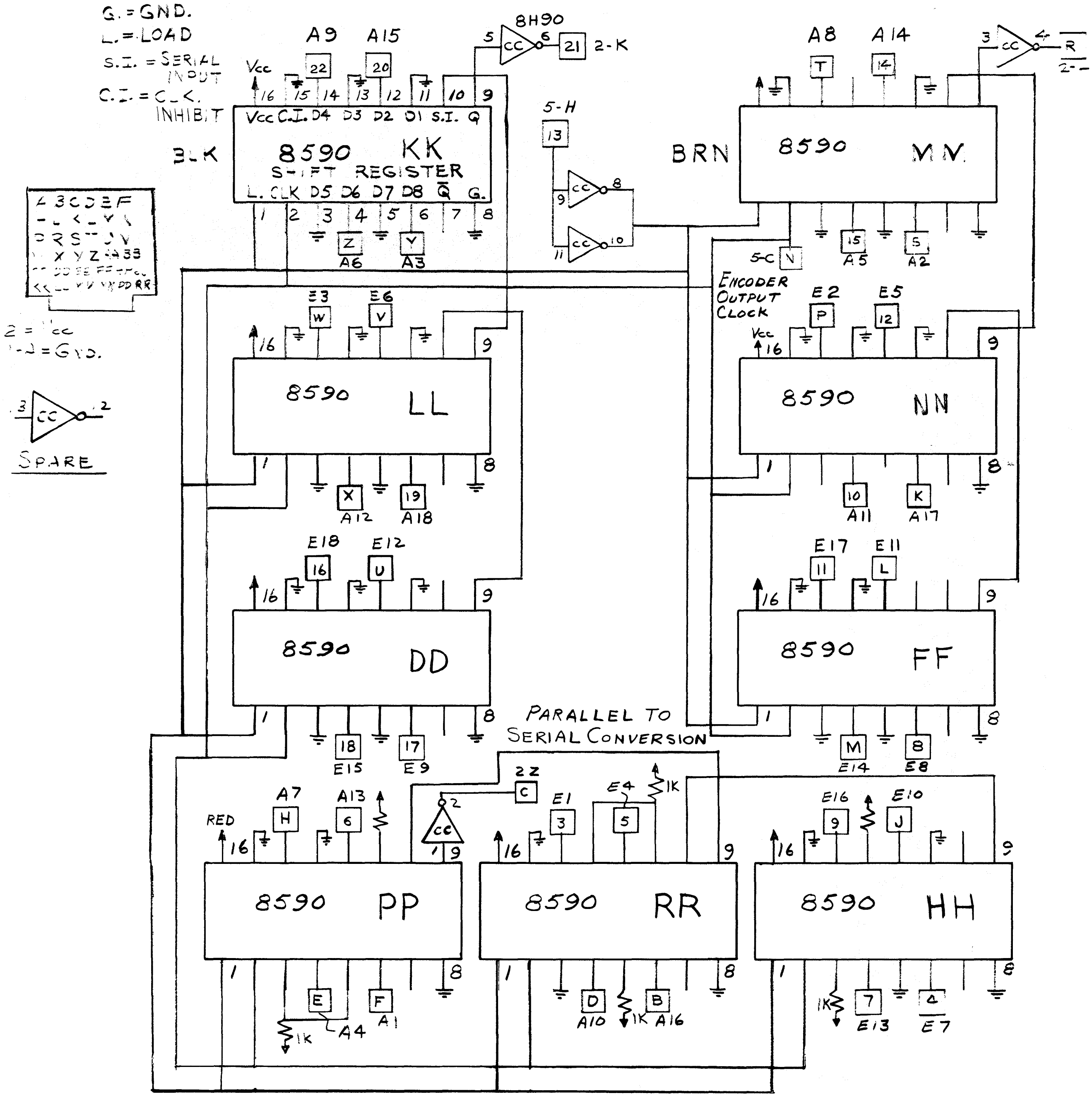
The first three columns are hard-wired at the Input Multiplexer. The last five columns each represent an eight-bit shift register outputing to the Input Multiplexer. The ninth bits are gained by tying the serial inputs high. The first and second, fourth and fifth, and the seventh and eighth rows input the hours, minutes, and seconds, respectively. The third and fifth rows perform an "up" operation. The ninth row is the terminator. The end result is the hours, minutes, and seconds in the z, y, and x registers.

The shift registers are loaded on the falling edge of a 10 kHz signal from the digital clock. The loading is inhibited when $\overline{OSI}$ from card 1 is low. This prevents the shift registers from being loaded while they are shifting. The calculator takes the data when control goes high. After the RC delay, $\overline{Clock}$ goes high and new data is shifted to the input lines.



The divide-by-two outputs to the encoder portion of the Input Multiplexer to provide the signal needed by the ASCII coding. The flip-flop is set by OS1 so that it always starts an input high.

The "Position Command Update" button sets the flip-flop in position F when depressed. The output is gated with $\overline{OSI}$ so that the effect will be delayed if an input-output operation is in progress. This nand's falling edge triggers a one-shot, which resets the first and sets a second flip-flop. This output goes to the black, digiswitch input line, pulling it low. It gets reset at the second cycle of $\overline{Clock}$. The effect on the number input is that an exponent of one instead of zero is entered. The diode protects the flip-flop from acting as a pull-up voltage when $\overline{Q}$ is high.



CARD #4 STAND-ALONE POSITION-
-READOUT INPUT

CARD 4 - STAND-ALONE POSITION READOUT INPUT

The Position Readout is input in the following matrix:

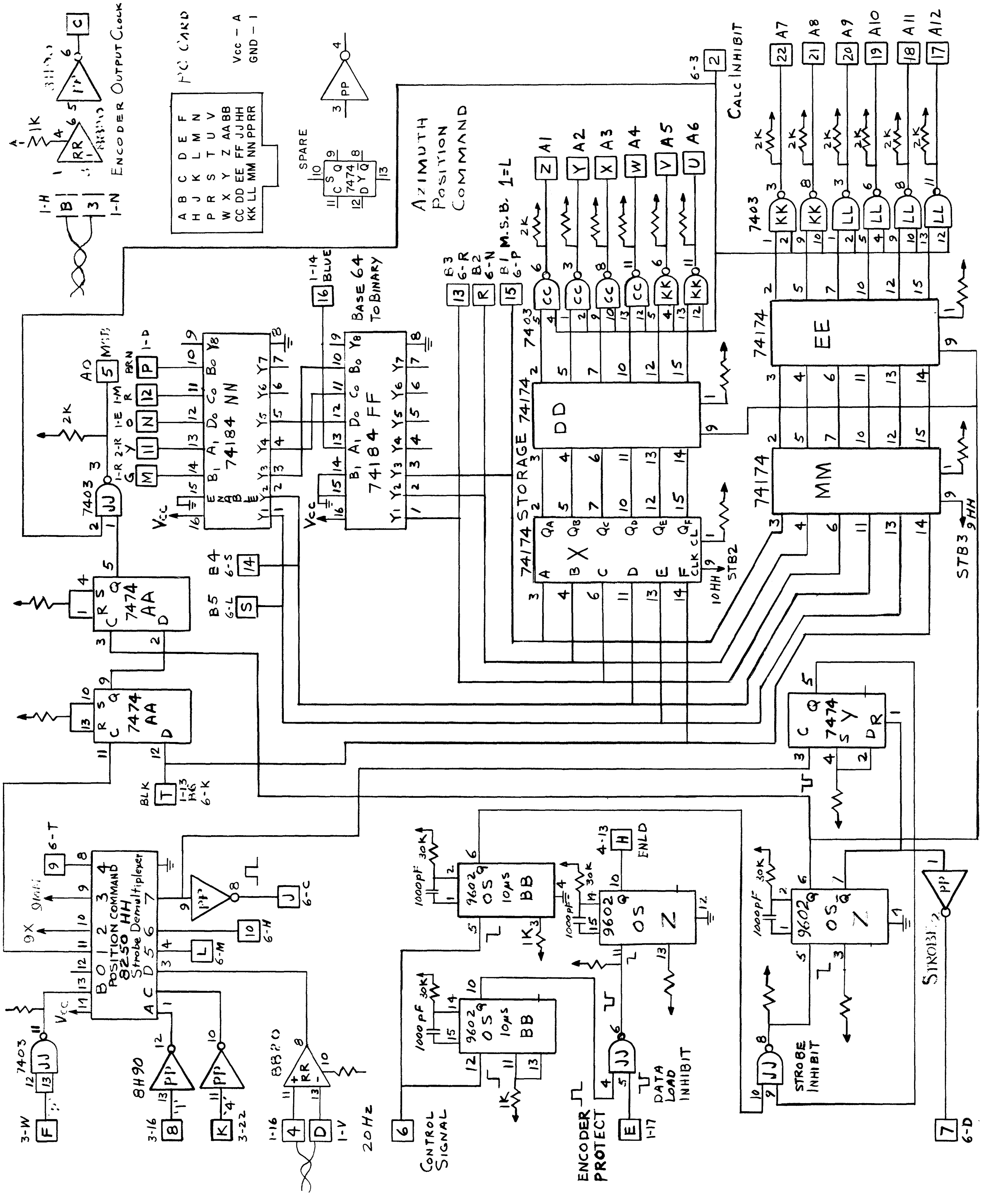
	1	2	3	4	5	6	7	8	
	0	0	1	1	0	1	2	3	MSB
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	4	5	6	
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	7	8	9	
Azimuth	0	0	1	0	1	0	x	0	
	0	0	1	1	0	13	14	15	
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	16	17	18	LSB
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	10	11	12	
	0	0	1	0	1	0	x	0	
	0	0	1	1	0	1	2	3	MSB
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	4	5	6	
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	7	8	9	
Elevation	0	0	1	0	1	0	x	0	
	0	0	1	1	0	13	14	15	
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	16	17	18	LSB
	0	0	1	0	1	1	0	0	
	0	0	1	1	0	10	11	12	
	0	0	1	0	1	0	x	0	
	V	B	G	Y	O	R	Br	Bl	

The first three columns are hard-wired at the Input Multiplexer. The fifth column is the output of the divide by two of Card 3 and the fourth column, the inversion of it. The sixth, seventh, and eighth columns are the outputs of the shift registers of Card 4. Each column represents three shift registers in series. The first row inputs of an octal digit. The numbers 1, 2, and 3 represent the first, second and third most significant bits of the azimuth as a number from 0-360 degrees. Note that the bit telling if the azimuth is 360-720 degrees is not input. The second row performs an "up" operation. The third row inputs the fourth, fifth, and sixth bits as another octal number. The fourth row is another "up", the fifth row another digit, and the sixth row is the terminator. The x means that it is irrelevant whether the bit is a one or zero. The above operation places a number in the x, y, and z registers. Four such operations will input the entire matrix. The shift registers are buffered through inverters which provide negative logic to the calculator.

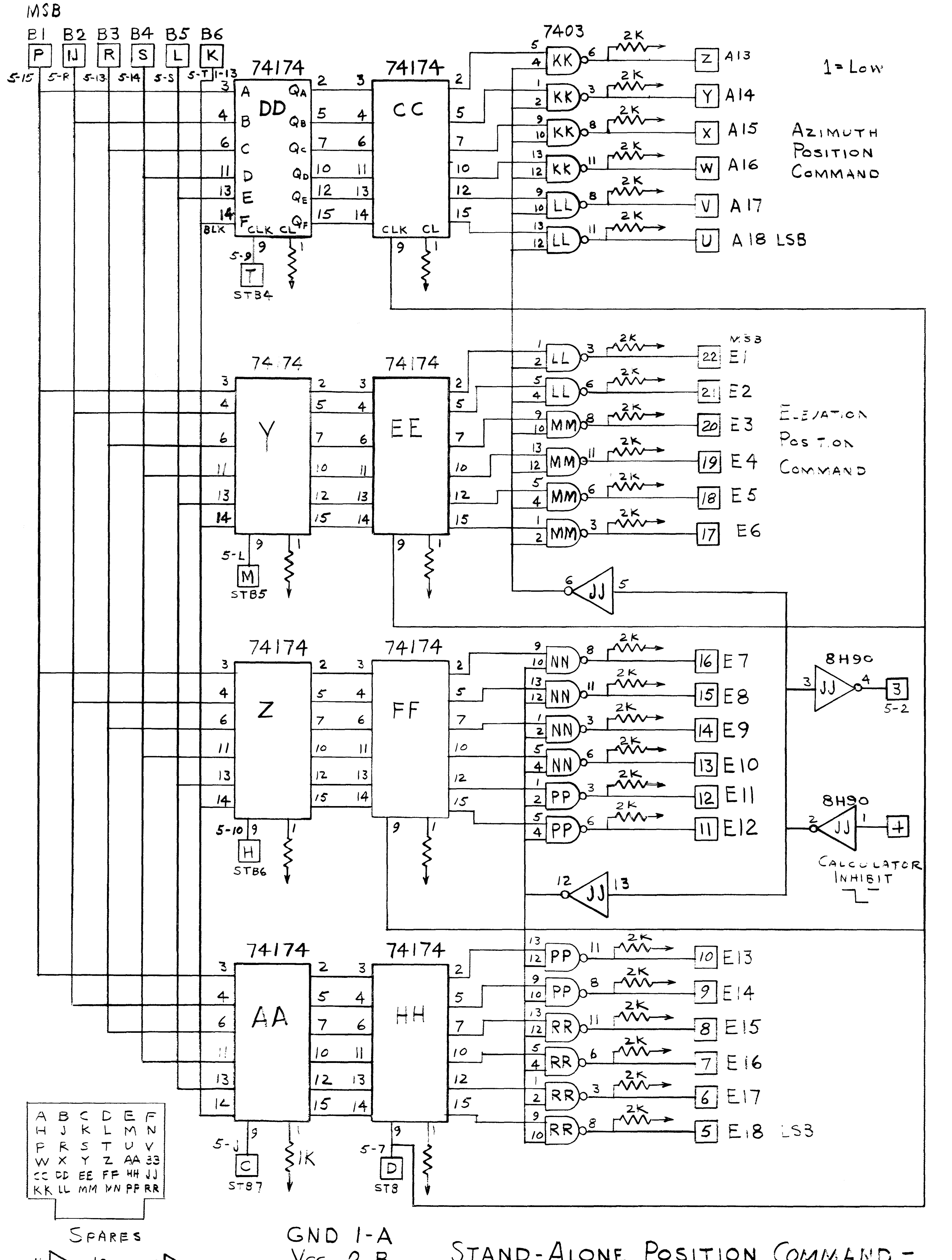
CARDS 5 AND 6 - STAND-ALONE POSITION COMMAND OUTPUT

The strobes for the "Position Command Strobe Demultiplexer" and the "Encoder Output Clock" for the shift registers on Card 4 are received by 8820 Dual-Line Receivers. The count for the demultiplexer is buffered by inverters.

The Position Command is output in the sixty-four bit block described previously. Using the count and the strobe, the "Position Command Strobe Demultiplexer" produces a strobe for each row of the block. The first row is the binary exponent of thirteen. This is decoded on Card 1 into an address. The second row contains the sign and is stored in the flip-flop of position AA. If negative, the most significant bit of the azimuth is one. The remaining eighteen bits of the azimuth and the eighteen bits of the elevation, each are output as a three-digit, base sixty-four number. Each digit, being a number



CARD # 5 STAND-ALONE POSITION COMMAND OUTPUT



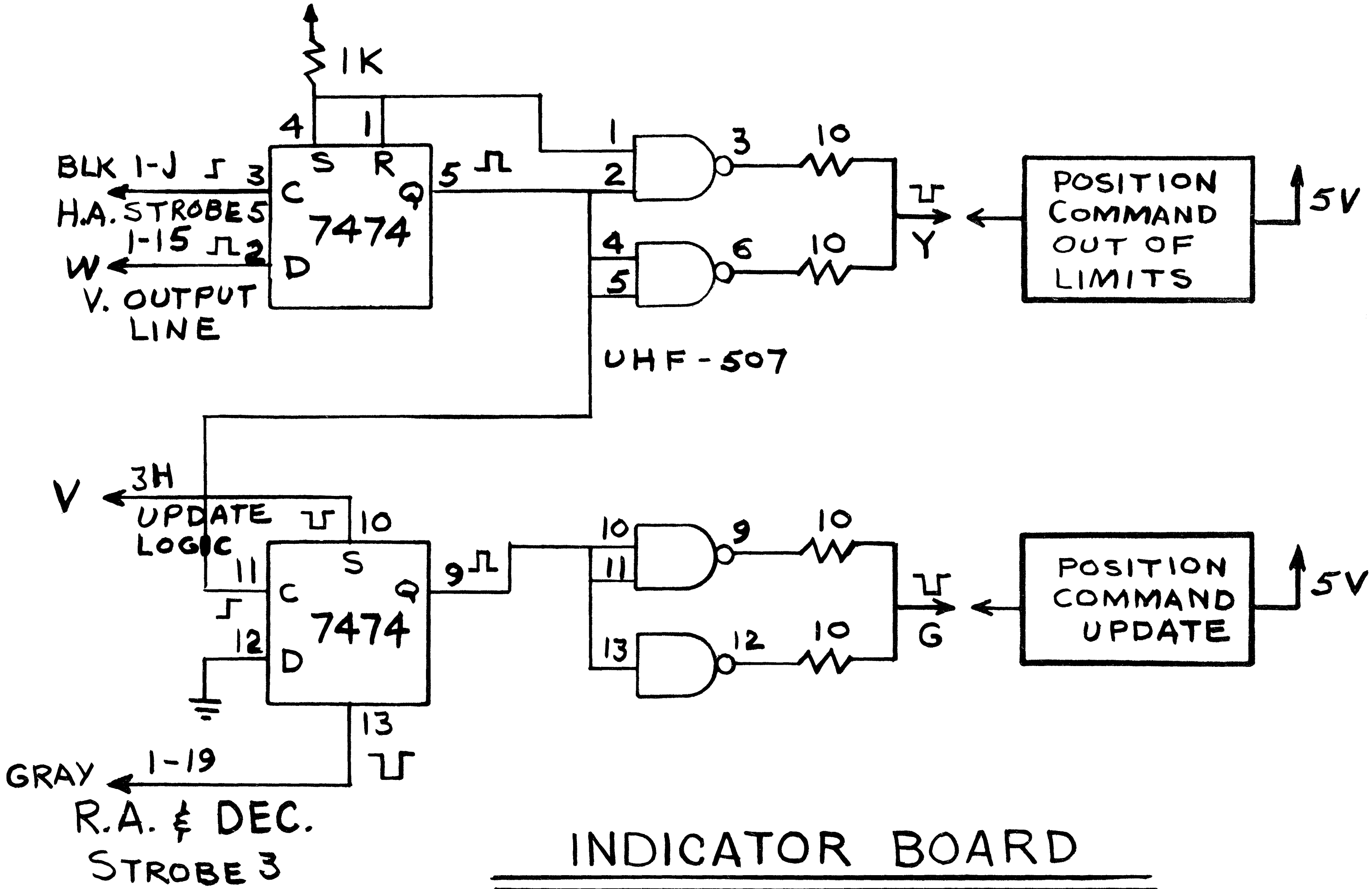
STAND-ALONE POSITION COMMAND - - OUTPUT

CARD #6

from zero to sixty-three, occupies one row. The third, fourth, and fifth rows are the Azimuth Command, while the sixth, seventh, and eighth rows are the Elevation Command. Two 74184 chips act as a base sixty-four to six-bit binary converter. Each row is in turn strobed into its respective 74174 hex-latch. Azimuth bits A0-A12 are on Card 5. Azimuth bits A13-A18 and Elevation bits E1-E18 are on Card 6. After the eighth strobe, the first layer of latches contains the thirty-seven bit, binary command.

Since it is desirable to have all thirty-seven bits updated simultaneously, a second layer of latches is used. The 20 Hz Control Signal from the "Position Control and Readout" box is used to determine when to update these. The strobe pulses from the demultiplexer are negative pulses, so the latches are clocked on the trailing edge. The eighth strobe is inverted so that the leading edge clocks the hex-latch. The trailing edge sets the flip-flop in position Y, indicating that there is new data on the first layer of latches. The 20 Hz Control Signal triggers a ten microsecond one-shot, indicating the second layer of latches can be updated. The one-shot is gated with the flip-flop. If there is new data, another one-shot is triggered, which resets the flip-flop and strobes the second layer of latches. The second layer of latches outputs to thirty-seven, open-collector nands. The gate outputs are in negative logic and can be wire-ored. The calculator can be inhibited by a low signal applied to the nands. A system of four inverters on Card 6 is used to obtain the necessary loading.

The other edge of the 20 Hz Control Signal triggers another one-shot. This is gated with the "Encoder Protect" signal from Card 1. When the "Encoder Protect" line is low, it is forbidden to load new data into the Position Readout shift registers on Card 4. The output of this gate triggers another one-shot which loads the shift registers.



INDICATOR BOARD

INDICATOR BOARD

The "Indicator Board" is not essential to the functioning of the system. It controls the "Position Command Update" and "Position Command Out of Limits" lights. The board is located on the underside of the chassis of the "Stand-Alone Computer Control" box.

The "Position Command Out of Limits" flip-flop receives the "80" hours bit of the hour angle. When this bit is on, the indicator lights.

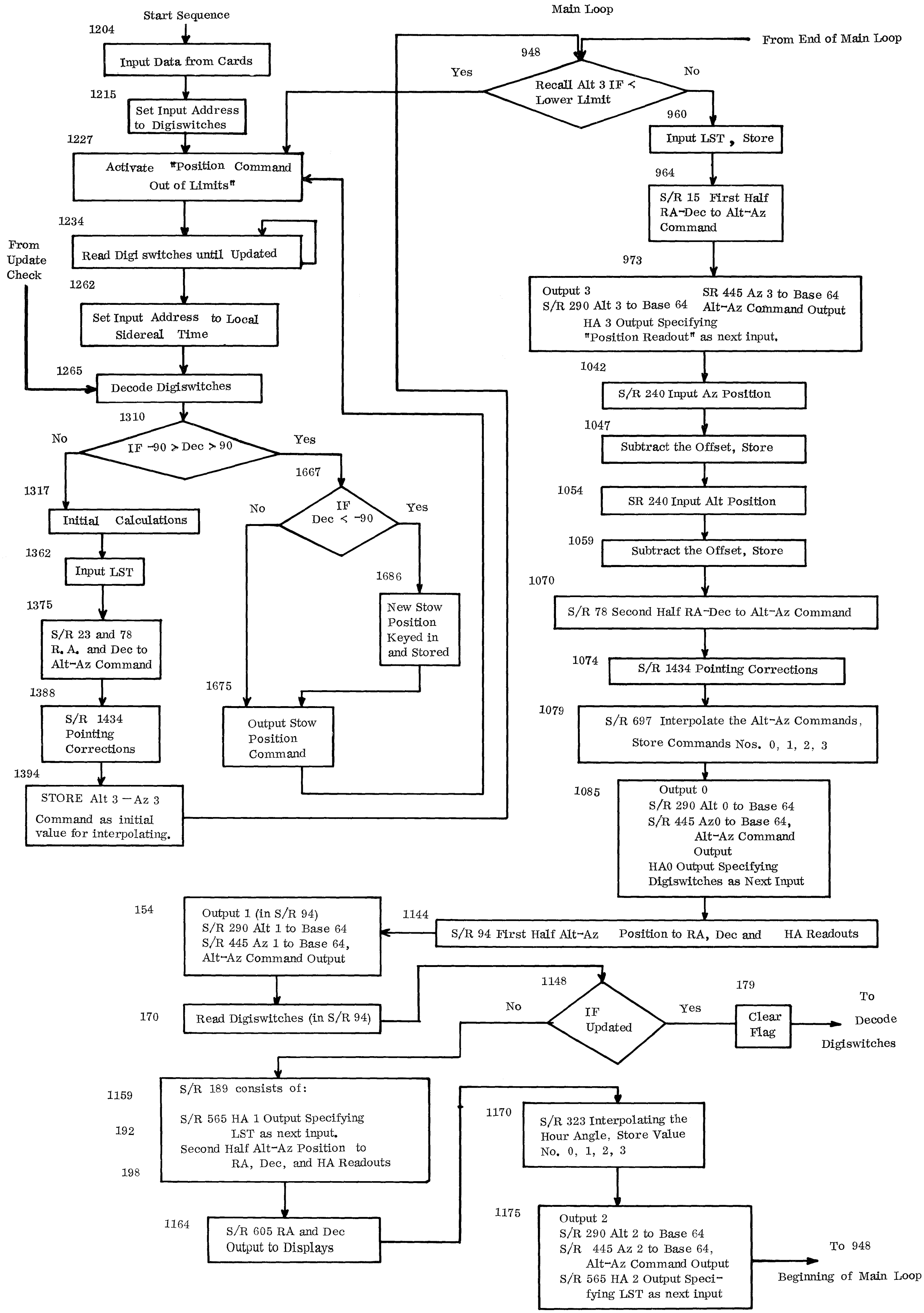
The "Position Command Update" flip-flop is set subsequent to pushing the "Update" button. This lights the other indicator.

If the new values result in an illegal position command, the "Position Command Out of Limits" light coming on resets the "Update" flip-flop. If the new values are legal, the "Update" light will be reset with the first output to the r.a. and dec. displays, about four seconds later.

PROGRAM EXPLANATION

The program is made up of several subroutines organized as shown in the block diagram. An explanation of the block diagram follows. Next the flow-charts showing how each subroutine works are presented. Finally, there is a listing of the program steps showing the effects on the three display registers. Also included is an address list of the constants.

On the block diagram, the corresponding step numbers are to the left of each block.



PROGRAM BLOCK DIAGRAM

The first thing the program does is call for the data cards to be input.

The initialization sets up the logic to the proper addresses.

The digiswitches are next read continuously in a loop. The "Update" button being pushed multiplies the number by ten and allows exit from the loop. The twelve digits are input into one register and now have to be decoded into the decimal r.a. and a decimal dec.

If the value of the declination is greater than ninety the stored stow position is output. A new stow position is keyed in, stored, and output if the declination is less than negative ninety. Then, in either case, the "Position Command Out of Limits" light is activated and the digiswitches are continuously read again.

The "Initial Calculations" consist of terms that need to only be calculated once for a given r.a. and dec.

The local sidereal time is now input. Subroutines 23 and 78 calculate an Altitude-Azimuth Command from the r.a., dec., and time. Subroutine 1434 adds constant offsets and also a term to the altitude to counteract refraction. The Alt-Az Command is stored to be later used as an initial value to interpolate from. This concludes the starting sequence.

The Main Loop starts by recalling the altitude and checking to see if it is below the lower limit specified on the data card. If so, the "Position Command Out of Limits" light is activated and the digiswitches continuously read.

If the altitude is legal, the local sidereal time is input and stored. Using this and previously stored values, Subroutine 15 does the first half of the Right Ascension-Declination to Altitude-Azimuth Command calculation.

The Position Command and Hour Angle are output four times per cycle of the Main Loop. These outputs are evenly spaced and are numbered 0-3.

The first operation in Output Block 3 is to recall Altitude 3. Subroutine 290 then converts Alt. 3 to a three digit, base sixty-four number. Azimuth 3 is similarly recalled. Subroutine 445 converts it to a three digit, base sixty-four number and outputs the entire position command in a sixty-four bit block. Hour Angle 3 is recalled and converted to hours, minutes, and seconds. It is output along with the Position Readout's input address.

Subroutine 240 inputs the Azimuth position in octal and converts it to decimal. An offset is subtracted and the value stored. An identical procedure is used to input the Altitude position.

Now, Subroutine 78 completes the second half of the R.A.-Dec. to Alt.-Az. Command calculation.

Subroutine 1434 adds constant offsets to the altitude and azimuth commands and also a refraction correction to the altitude.

Subroutine 697 interpolates the Alt.-Az. Command to give the four values per cycle. The Subroutine also determines the state of the most significant bit of the Azimuth Command.

Output Block 0 outputs Alt. 0, Az. 0, and H.A. 0 in the same format as Output Block 3. The Hour Angle Output specifies the Digiswitches as the next input.

Subroutine 94 starts with the first half of the Alt.-Az. Position to R. A., Dec., and H.A. Readouts calculation. It then outputs Alt. 1 and Az. 1. The subroutine ends by inputing the Digiswitches.

The Update Check is made on the Digiswitch value outside the subroutine, since it causes trouble to exit from a subroutine without using the Sub/Return instruction. If the Update button has been pushed, the flag is cleared and the program branches back to the Decode Digiswitches section.

Subroutine 189 outputs H.A. 1 and finishes the Alt.-Az. Positions to R.A., Dec., and H.A. Readouts calculation.

Subroutine 605 places the R.A. and Dec. Readouts in the format of a sixty-four bit block in hours, minutes, and seconds, and outputs them to the displays.

Subroutine 323 interpolates the hour angle positions and stores values 0-3.

Output 2 is the same as previous outputs with the local sidereal time specified as the next input.

The program now cycles back to the beginning of the main loop.

The following flow charts of the individual subroutines are arranged in numerical order.

PROGRAM BLOCK LOCATIONS

Step Numbers	Block Name
0000-0004	Go to Start Sequence
0005-0077	Subroutine 23 - First Half R.A.-Dec. to Alt.-Az. Command
0078-0093	Subroutine 78 - Second Half R.A.-Dec. to Alt.-Az. Command
0094-0178	Subroutine 94 - First Half Alt.-Az. Position to R.A., Dec., and H.A. Readouts
0179-0184	Clear Flag
0189-0226	Subroutine 189 - Output 1 (cont.) and Second Half Alt.-Az. Position to R.A., Dec., and H.A. Readouts
0240-0282	Subroutine 240 - Input 'Position Readout', Convert to Decimal
0290-0321	Subroutine 290 - Altitude to Base 64
0323-0444	Subroutine 323 - Interpolating the Hour Angle
0445-0563	Subroutine 445 - Azimuth to Base 64 and Alt.-Az. Command Output
0565-0604	Subroutine 565 - Hour Angle Output specifying Local Sidereal Time as next input
0605-0665	Subroutine 605 - R.A. and Dec. output to displays
0670-0684	Redefining the Latitude

PROGRAM BLOCK LOCATIONS (cont.)

Step Numbers	Block Name
0697-0944	Subroutine 697 - Interpolate the Alt.-Az. Commands
0948-1202	Main Loop
1210-1424	Start Sequence
1434-1585	Subroutine 1434 - Pointing Corrections
1595-1662	Subroutine 1595 - Input 'Position Readout', Invert, Convert to Decimal (Used only in Test Program)
1665	LBL 1 - Stow Position Command, Storage and Output
1855	End

The spaces between blocks are empty.

Start with:
LST in hrs. in x
RA in degrees in 10
cos d cos ϕ in 9
sin d sin ϕ in 8
15 in 11
cos ϕ in 4
sin ϕ in 3

↓

Computes:
HA = LST − RA

$$z = \cos^{-1} (\sin \phi \sin \delta + \cos \phi \cos d \cos HA)$$

$$\cos (Az) = \frac{\sin d - \sin \phi \cos z}{\cos \phi \sin z}$$

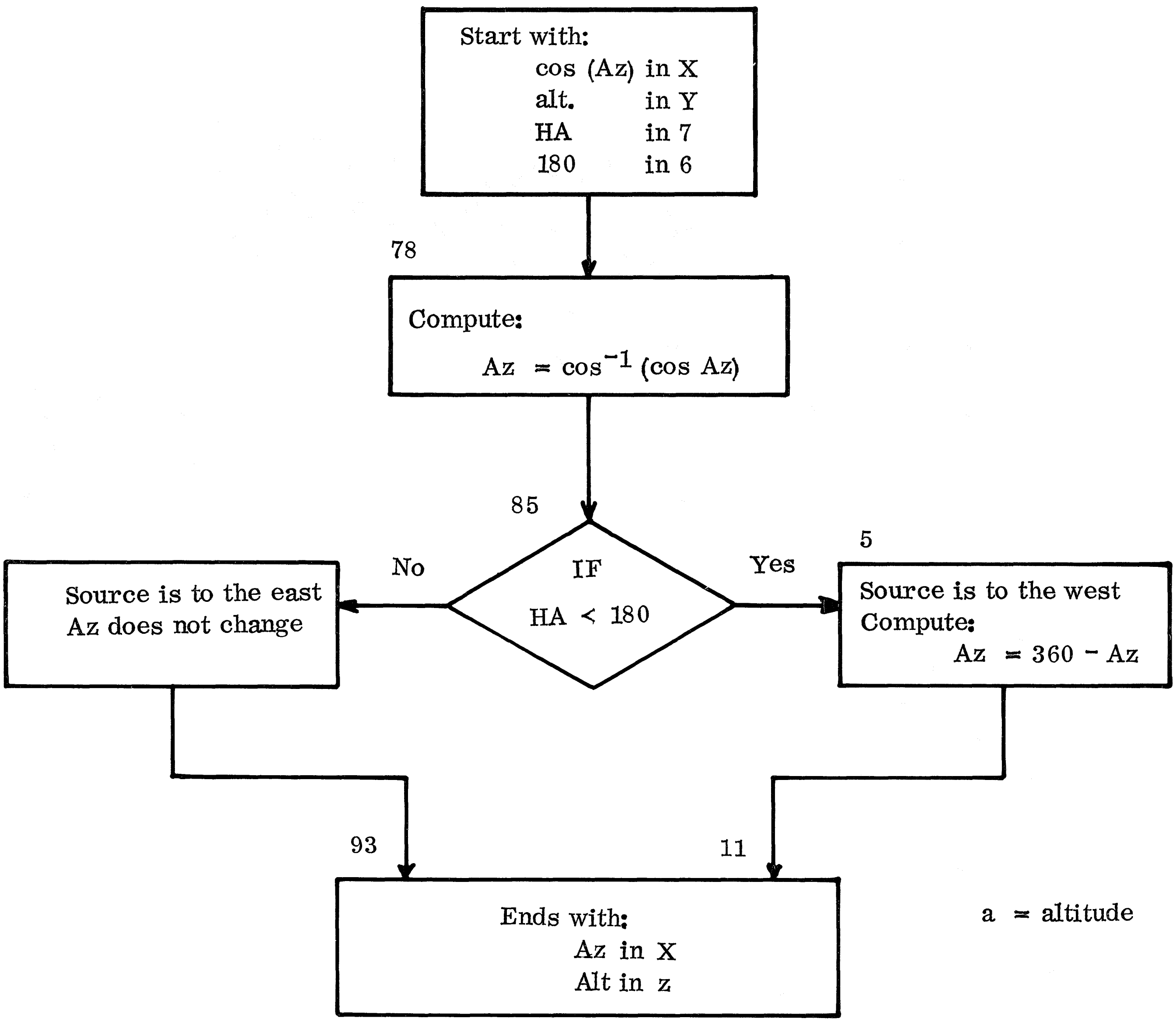
$$a = 90 - z$$

↓

Ends with: cos Az in X
a in Y
a in Z
HA in 7

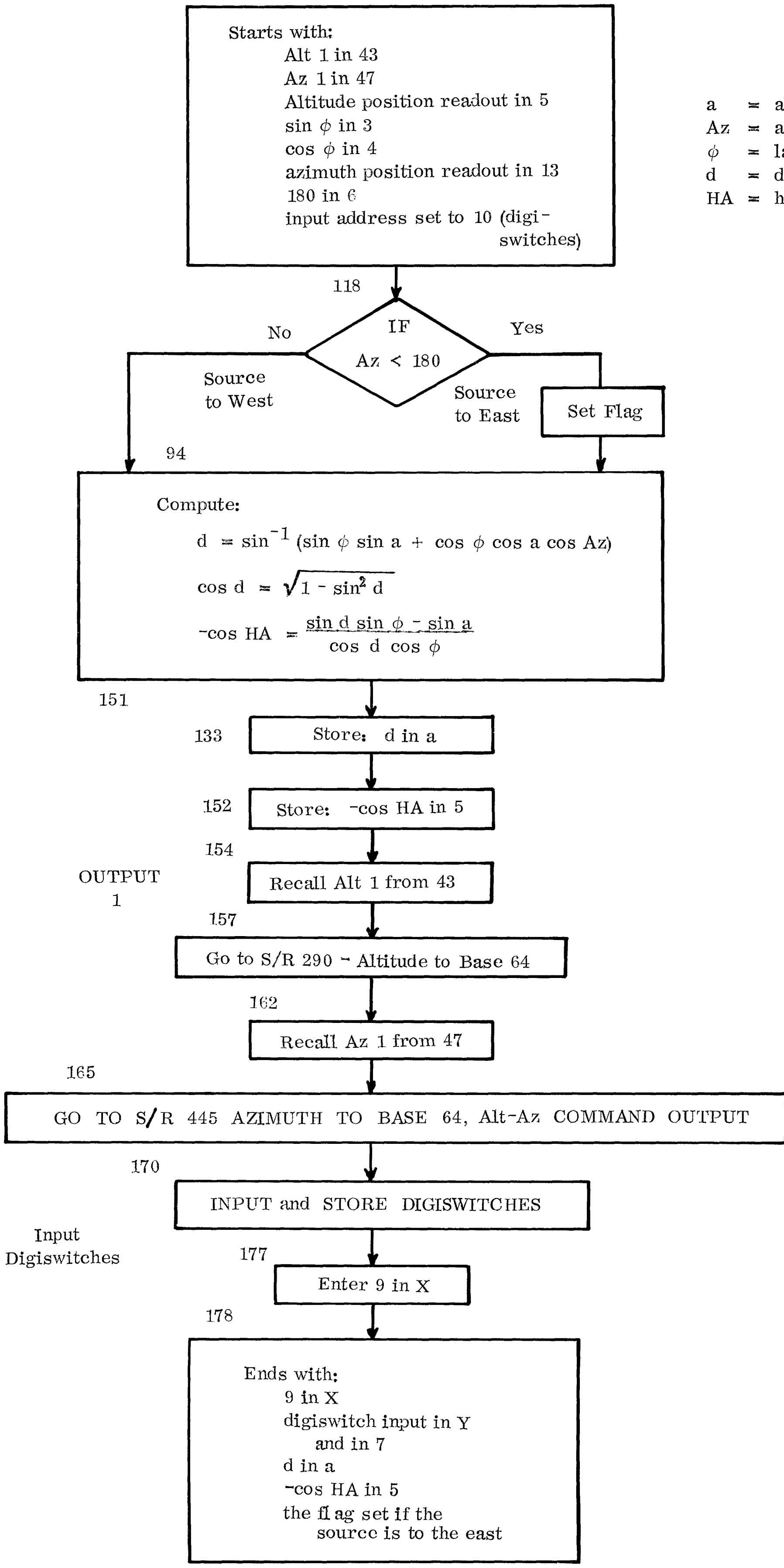
d = declination
ϕ = latitude
z = zenith angle
a = altitude

S/R 23 FIRST HALF RA AND DEC TO ALT-AZ COMMAND

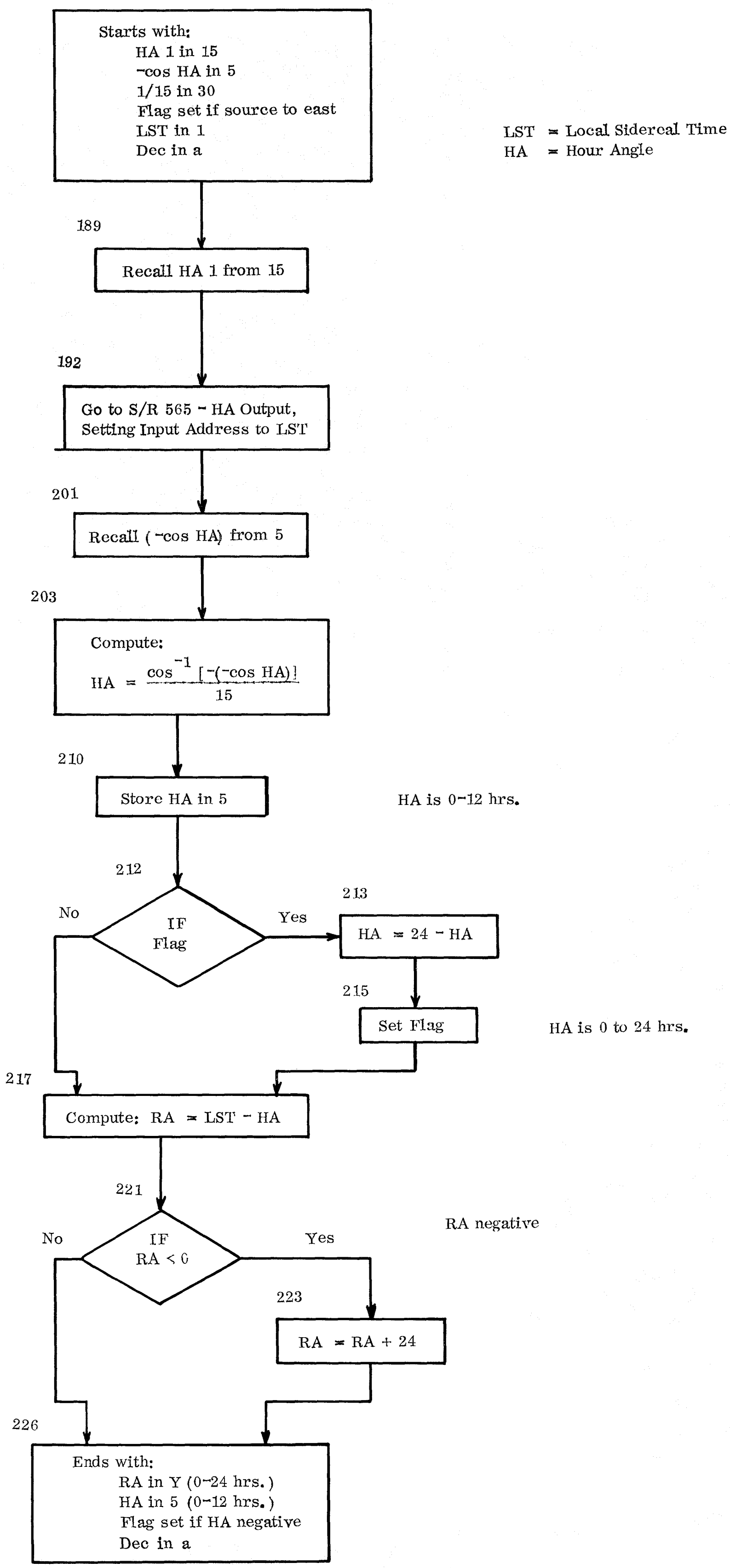


S/R 78 SECOND HALF RA AND DEC TO ALT-AZ COMMAND

a = altitude
Az = azimuth
ϕ = latitude
d = declination
HA = hour angle

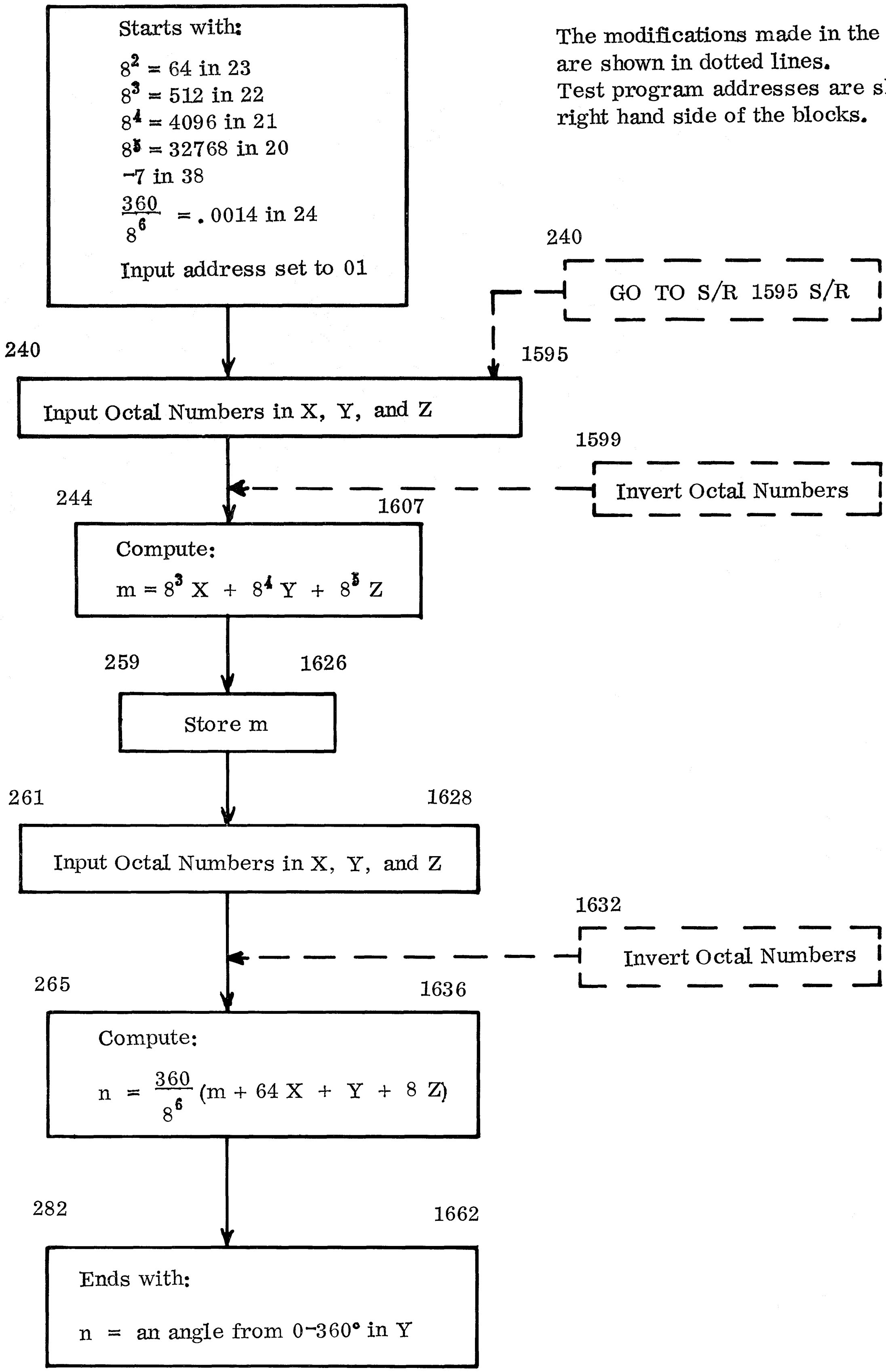


S/R 94 FIRST HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS AND OUTPUT 1

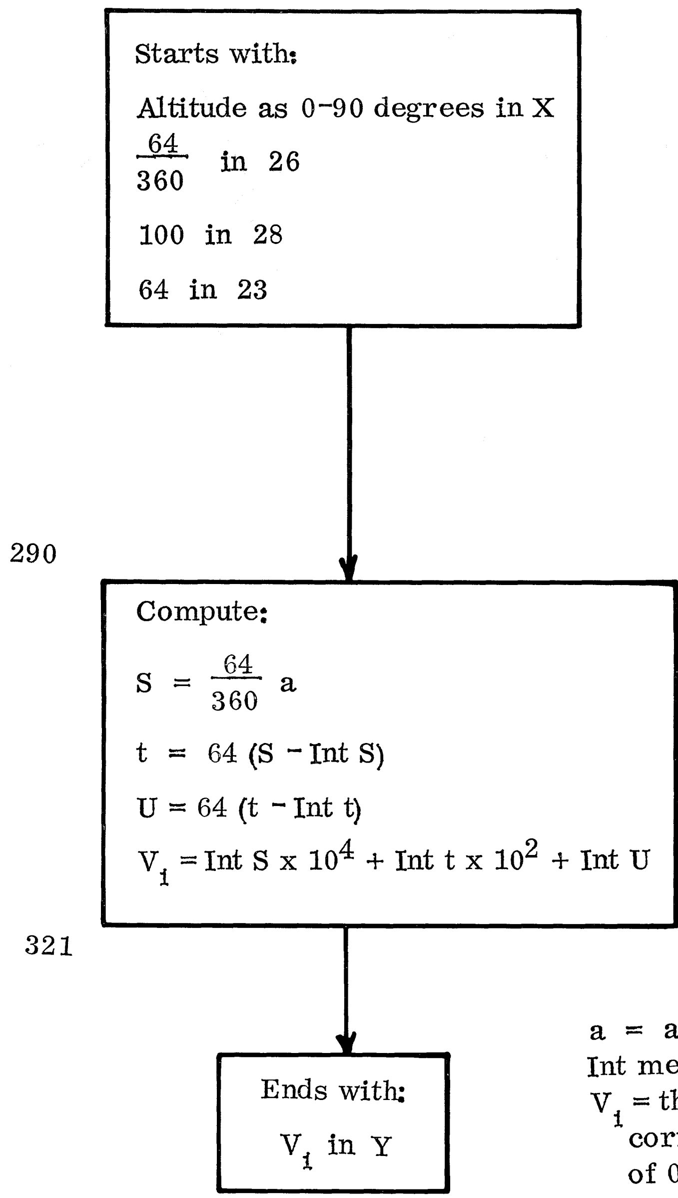


S/R 189 OUTPUT 1 (CONT) AND SECOND HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS

The modifications made in the test program are shown in dotted lines.
Test program addresses are shown on the right hand side of the blocks.

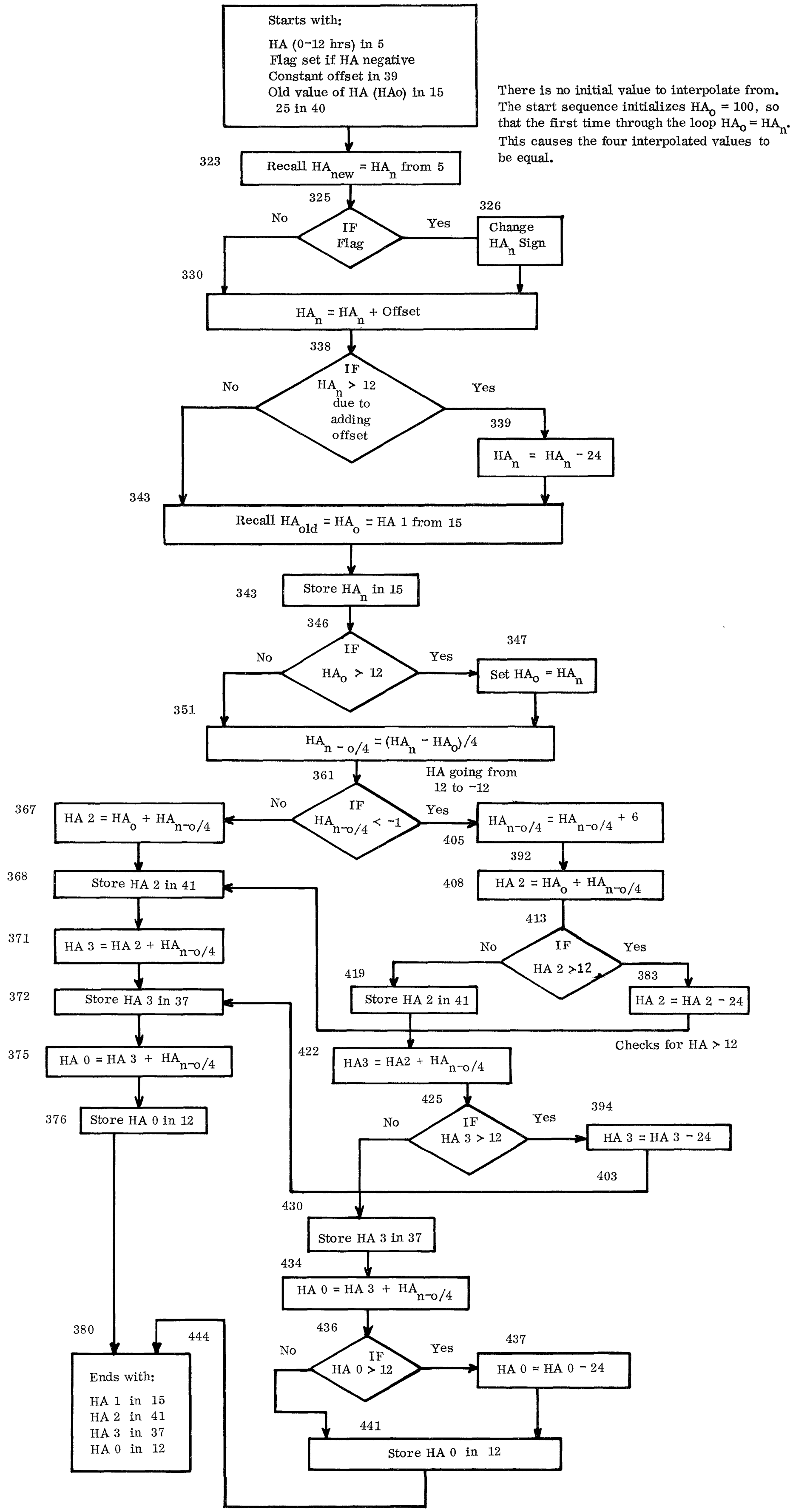


S/R 240 INPUT "POSITION READOUT", CONVERT TO DECIMAL

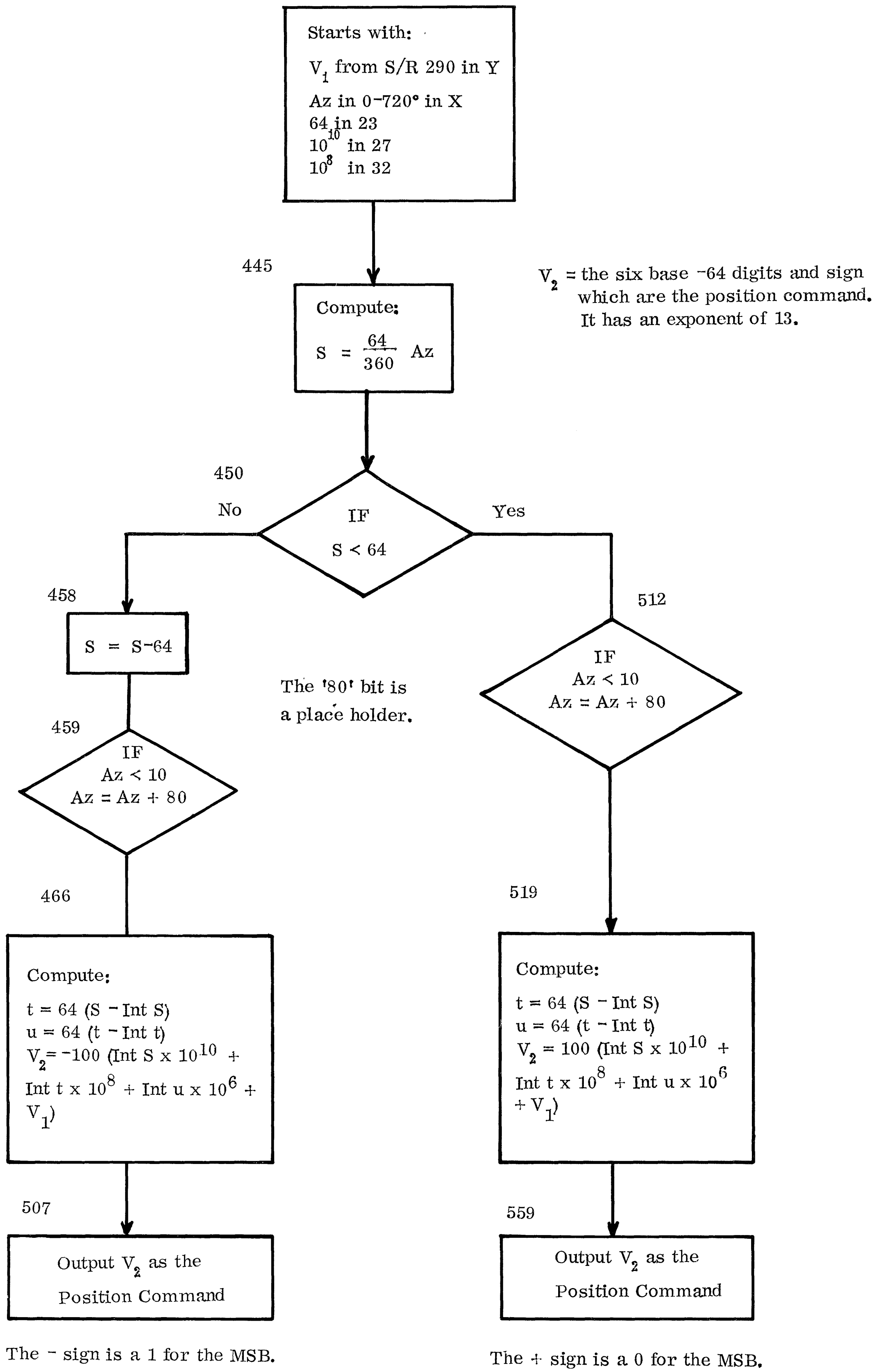


a = altitude
Int means integerize
V_i = the 3 digit base 64 number corresponding to an altitude of 0-360 degrees.

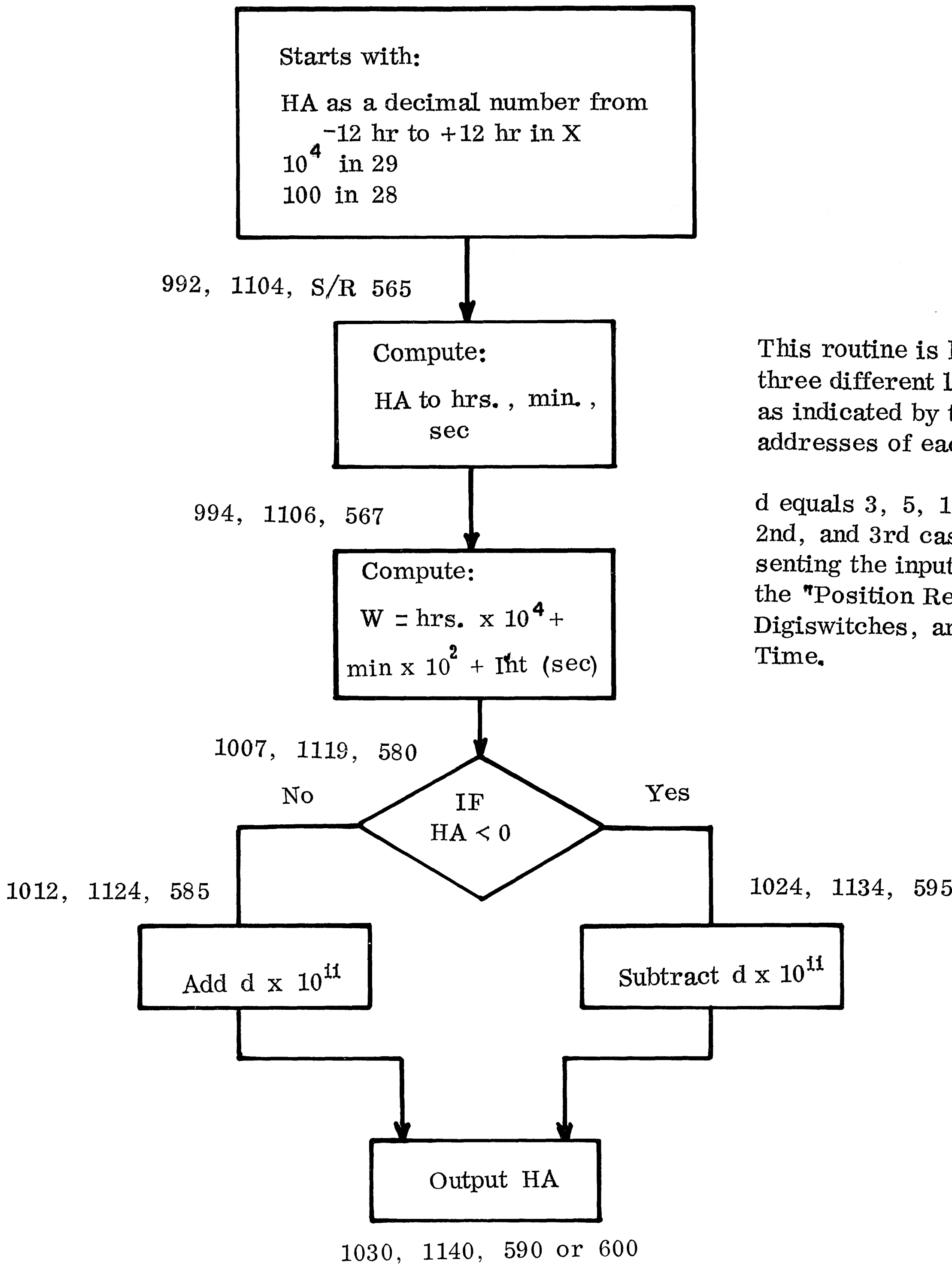
S/R 290 ALTITUDE TO BASE 64



S/R 323 INTERPOLATING THE HOUR ANGLE



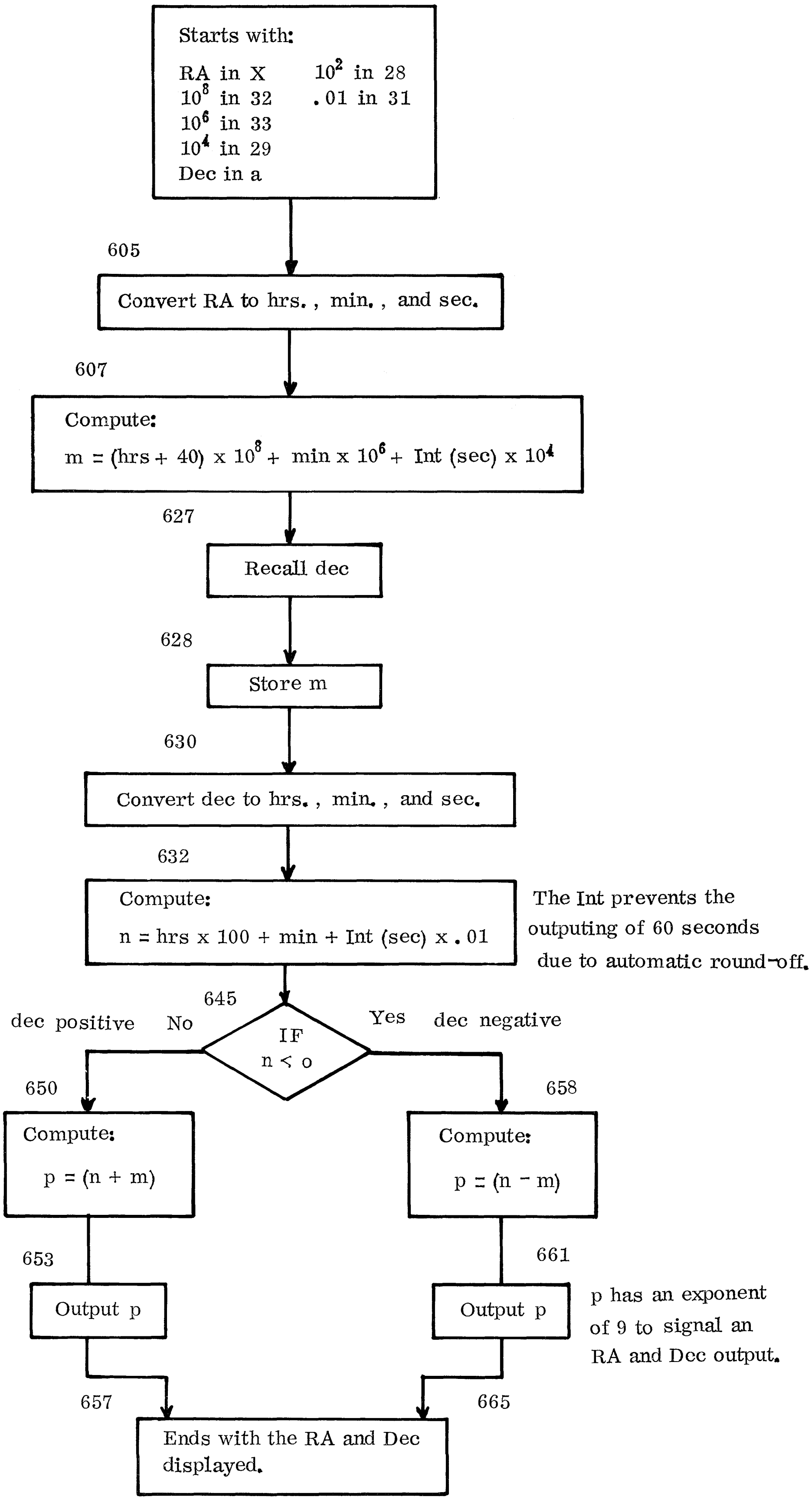
S/R 445 AZIMUTH TO BASE 64 AND ALT-AZ COMMAND OUTPUT



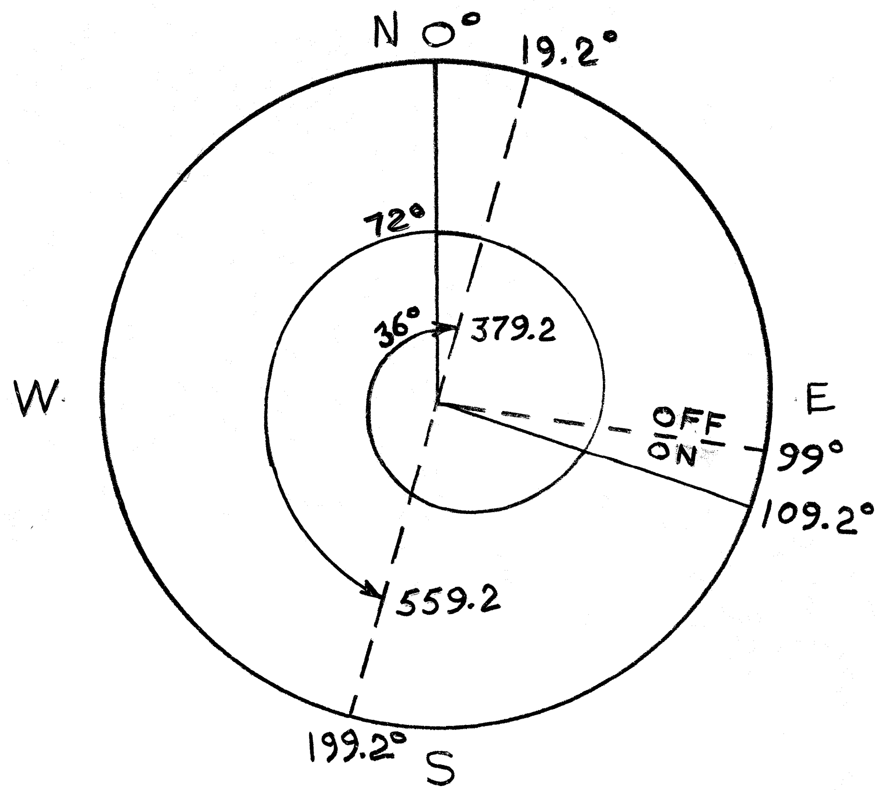
This routine is located in three different locations, as indicated by the three addresses of each block.

d equals 3, 5, 1 in the 1st, 2nd, and 3rd cases, representing the input addresses of the "Position Readout Interface", Digiswitches, and Local Sidereal Time.

HA OUTPUT AND INPUT ADDRESS SETTING



S/R 605 RA AND DEC OUTPUT TO DISPLAYS



S/R 697 INTERPOLATE THE ALT-AZ COMMANDS -
EXPLANATION OF THE FOLLOWING FLOW CHART

The subroutine starts out with a straightforward interpolation of the Altitude Command.

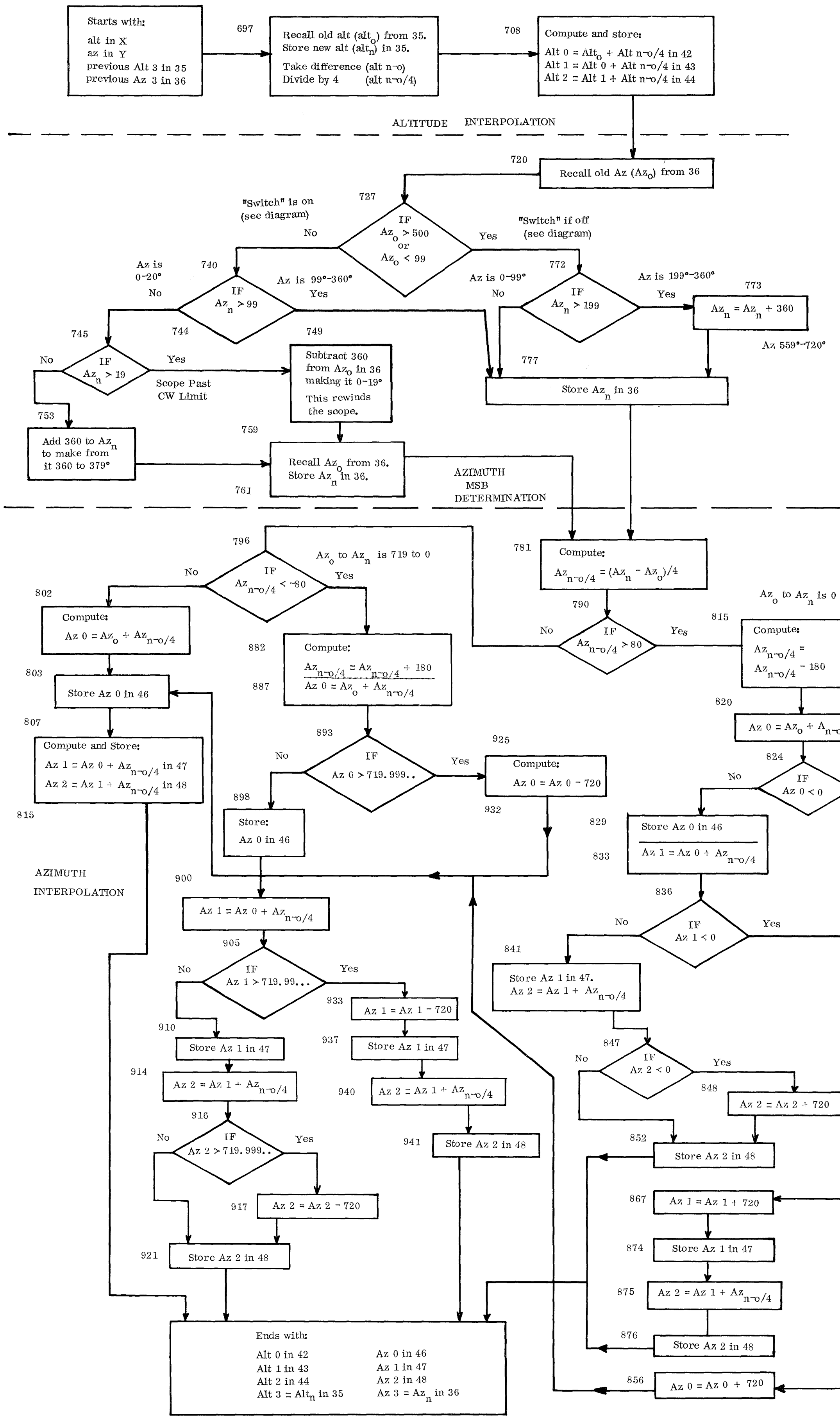
The Azimuth Command is to go from 559.2 to 720 degrees to 0 to 379.2 degrees as shown above. This assumes the telescope can rotate 270 degrees to either side of 109.2 degrees. In the Start sequence, at step 1400, 360 degrees is added to the azimuth if it is greater than 200 degrees. This has the effect of always starting a source tracking on the outside of the above spiral. If a source had an azimuth of 201 degrees it would start at 561 degrees on the spiral. It could not run into the counter-clockwise limit of 200 degrees, since, in the northern latitudes, sources in the south track only from east to west.

An imaginary switch, located at 99 degrees, is used to keep track of which arm of the spiral the scope is located. A physical switch is not needed since the source always starts on the counter-clockwise rotation of the spiral, as defined by the initialization process. This unambiguously defines the starting location of the scope on the spiral.

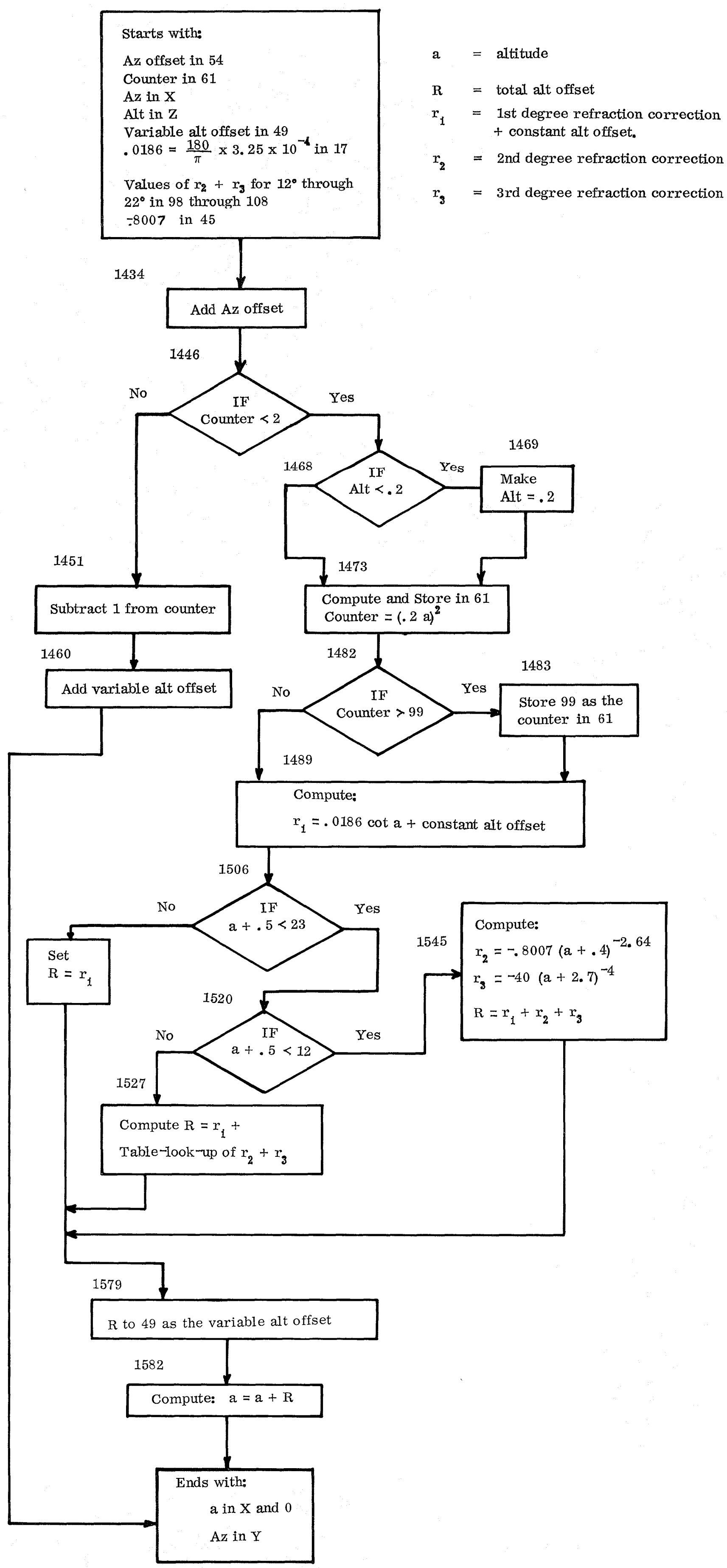
The If Statement at 727 determines the state of the switch by testing where on the spiral the previous Azimuth command was. In the case where the azimuth moves from the off section of the spiral to the on section, the calculations are made as if the new value were in the off section. This does not affect the result because the azimuth for the off value and the on value are the same until the azimuth is 199 degrees. The azimuth would have to change 100 degrees in the two seconds of the cycle for this to happen. Subsequent If Statements determine the effect the on or off state has on the azimuth.

If Statement 745 tests for the clockwise limit of 19 degrees. If this is hit, the scope is rewound 360 degrees. This limit can never be reached in northern latitudes below 45 degrees, since any source that goes south of the zenith will set before it has an hour angle of twelve hours.

Interpolating across the 719 degree to 0 degrees line deserves special consideration. If Statement 790 checks for the 0 to 719 transition, and If Statement 796 checks for the 719 to 0 transition. If the first case is true, 180 is subtracted from one-fourth of the difference. The 180 is added if the second case is true. In the first case, each addition of one-fourth the difference has to be checked to be sure the result is not a negative number. In the second case, each addition has to be checked to make sure the result is not greater than or equal to 720.



S/R 697 INTERPOLATE THE ALT-AZ COMMANDS



S/R 1434 POINTING CORRECTIONS

PROGRAM LISTING

The following sections presents a listing of the program step numbers, step functions, the effects on the display registers, and explanatory remarks.

The following texts are required reading for understanding the programming of the calculator:

Model 9810A Calculator Operating and Programming

Hewlett-Packard 9810A Calculator Mathematics Block Operating Manual

Hewlett-Packard 9810A Calculator 11264A Peripheral Control Block Operating Manual

The program steps are expressed in the mnemonics shown in the Appendix of the Operating and Programming manual.

A remark such as 34=11.3 says that 11.3 is stored in register 34.

An asterisk (*) indicates the remark is futher explained in the description of the individual subroutine.

CONSTANT STORAGE

Most of the constants are stored in registers 00-108 as shown in the following address listing. The values that change during program execution are preceded by 'temp.' on the listing.

In order to change the value of a constant, first type the new value into the x-register. To store the value key XTO _ _ _ , where the blanks represent the register as a three digit number (ex. 003). In order to make a new constant card with the changed values on it, place the blank card into the card-reader slot and key FMT XTO. Record on both sides of the card, then the card-reader motor will stop.

The Latitude can be changed by the following sequence:

FMT GOTO

(Load Program and Constant Cards as usual)

STOP STOP

GOTO 670 STOP

(ENTER Latitude degrees)

UP (↑)

(ENTER Latitude minutes)

UP (↑)

(ENTER Latitude seconds)

CONTINUE

The program will store the revised latitude. Tracking will begin upon the 'Update' button being pushed.

Place the lower altitude limit in register 025 in decimal degrees.

Add 0.00069 to the linear Azimuth offset, to facilitate rounding off, then store this value in register 054.

Registers 017, 045, and 098-108 contain the constants for the refraction correction.

Some constants are stored in the form of program steps. The counter-clockwise limit of scope rotation is stored as steps 1395-1397 to the nearest degree. Also the C.C.W. limit -1 is stored in steps 768-770. The clockwise limit of scope rotation is stored in 746-747. To change these values, key GTO (desired step number) PRGM. The step number and its value will now be displayed. Key in the new value. Key RUN. To record a revised program card, key END RECORD, then record both sides of the new card.

STEP NO.	FUNCTION	X	Y	Z	REMARKS
0000	GTO 1204				
1204	FMT XFR PSE PSE PSE				Inputs the data card. The pauses provide recycling time.
1209	FMT4.1.4				Sets display to fixed mode with 4 places to the right of the decimal point.
1215	5 EEX 10 FMT 42 XTO	5 x 10^{10}			10^{10} sets output address to 01 (h.a.) 5 sets input address to 10 (digi-switches). 00 hrs turns off "Position Command Out of Limits" light.
1223	FMT 32 XFR				Inputs digiswitches to clear "Update Command".
1227	XFR 14 FMT 42 XTO	5.000008x10^{10}			5 and 10^{10} as above. 80 hrs turns on "Position Command Out of Limits" light whose off to on transition turns off the "Update" light.
			DIGISWITCH CHECK LOOP		
1234	CLR 360 XTO b	360			Clears flag and b. Stores 360 in b.
1240	FMT 32 XFR	-6.35959895959			Inputs digiswitches (r.a. and dec.)
1244	XTO 7	-6.35959895959			Stores values.
1246	UP	-6.35959895959	-6.35959895959		
1247	CLX	0	-6.35959895959		
1248	X>Y	0	-6.35959895900		If negative declination:
1249	SFL				Set flag
1250	DN	-6.35959895900	-6.35959895900		And take absolute value
1251	CHS	6.35959895900	-6.35959895900		Note last two significant figures are lost from IF statement
1252	UP	6.35959895900	6.35959895900	-6.359598900	
1253	9	9	6.35959895900		If the number is greater than 9, the update button has been pushed, allowing exit from the loop
1254	X>Y 1234				
1259	EEX 10	10^{10}			
1262	FMT 42 XTO	10^{10}	63.5959895900		Sets input pointed to 00 (LST)
			DIGISWITCH DECODING		
1266	XFR 7	-63.5959895959	-63.5959895900		Recalls lost last 2 digits.
1268	UP	-63.5959895959	-63.5959895959		
1269	G (|Y|)	-63.5959895959	63.5959895959		The "40" bit is on to serve as a place holder so the number 0012 would be input 4012 instead of 1200.
1270	DN UP	63.5959895959	63.5959895959		
1272	INT	63.00	63.5959895959		
1273	-	63.	.5959895959		
1274	RUP		63	.5959895959	
1275	40-	40	23	.5959895959	Subtracts 40
1278	EEX 2 RUP	.5959895959	100	23	
1281	X DN UP	59.59895959	59.59895959	23	
1284	INT-	59.00	.59895959	23	
1286	XEY	.59895959	59	23	
1287	XFR X 28	59.895959	59	23	28 contains 100
1291	XTO a	59.895959	59	23	Stores declination information
1293	INT	59	59	23	
1294	K6 (TABLE 6)	23.9997	0	0	Converts to decimal hours
1296	UP 15 X	15	359.996		Converts to decimal degrees
1300	YTO 10 a	59.895959			Stores r.a. in 10. Recalls dec.
1304	UP INT	59	59.895959		
1306	-EEX 2 X	100	89.5959		
1310	90 X<Y	90	89.5959		If |dec| >90 go to Stow Position Command
1313	_GTO LBL 1 7				
			STOW POSITION COMMAND		
1665	LBL 1				
1667	IFG GTO LBL + 0				Recall a set flag indicates a dec <-90
1672	XFR 34	Stow Position			Recalls and outputs stow position
1675	FMT 42 XTO	Stow Position			
1679	GTO 1227				Returns to main program
1686	LBL +				
1688	FMT 4.1.0				Sets to fix 0 mode
1694	FMT FMT				Sets to alphanumeric mode
1696	CLR π 0 YTO I				Prints: POSITION
1701	XTO I O N CNT				
1706	COMMAND				COMMAND
1713	EN XTO E a CNT				ENTER
1719	ELE INT A XTO				ELEVATION
1725	ION FMT				Returns to normal mode
1729	STP				Stops for keying of 6 digit octal elevation
1730	PNT	123456			
1731	GTO S/R LBL B				

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1821	LBL B	123456			S/R LBL B converts the six digit octal number to a three digit base 64 number
1823	GTO S/R LBL A				
1794	LBL A	123456			50=.1 S/R LBL A converts the last two digits of x to a base 64 digit. The end result is the base 64 digit/10 in Y and INT (the original X/100) in Z 51=8
1796	INT XFR x 50	12345.6			
1801	UP INT -	12345.0	.6		
1804	XFR X 50	1234.50	.6		
1808	UP INT -	1234.00	.5	.6	
1811	YE X 51	1234.00	4.0	.6	
1815	RUP RUP	4.0	.6	1234.00	
1817	+ S/R	4.0	4.6	1234.00	
1827	YTO 35	4.0	4.6	1234.00	Back in S/R LBL B
1830	RUP	1234.00	4.0	4.6	
1831	GTO S/R LBL A	2.4	2.8	12.0	see above
1835	EEX 2 X	100	280	12.0	
1838	YTO + 35	100	280	12.0	
1842	RUP	12	100	280	
1843	GTO S/R LBL A	.8	1.0	0	see above
1847	EEX 4 X	10000	10000	0	
1850	YE + 35 S/R	10000	10284.6	0	Ends with the (3 digit base 64 number/10) in Y
1735	YTO 36	10000	10284.6	0	Back in LBL +
1738	FMT FMT				
1740	EN XTO E a				Prints: ENTER AZIMUTH
1745	CNT A XSQ I M				
1750	I/X XTO H FMT				
1754	STP	1765432			Key in Azimuth as 7 digit octal number
1755	PNT	1765432			
1757	GTO S/R LBL B	56000	62442.6	1	see above
1760	EEX 4	10000	62442.6	1	
1762	X>Y	10000	62442.6	1	This adds 80000 if Y<10000. The 8 bit is not part of the command, but serves as a place-holder since the calculator left justifies
1763	XFR 52 +	80000			
1767	EEX 9 X	10^9	6.24426×10^{13}	1	
1770	EEX 3 XFR X 36	1.02846×10^7	6.24426×10^{13}	1	Recalls elevation and multiplies it by 1000
1776	+ .5	.5	$6.24426102846 \times 10^{13}$	1	
1779	RUP X>Y	1	.5	$6.24426102846 \times 10^{13}$	If true, the M.S.B. of the azimuth is a 1 so the position command is made negative
	RUP CHS UPUP	$-6.24426102846 \times 10^{13}$	$-6.24426102846 \times 10^{13}$	$-6.24426102846 \times 10^{13}$	
1785	DN YTO 34	$-6.24426102846 \times 10^{13}$	$-6.24426102846 \times 10^{13}$	$-6.24426102846 \times 10^{13}$	Stores position command The exponent of 13 is the position command output address
1789	GTO LBL 1				Since the flag has not been reset, this time the stow position command will be output.
1317	DN UP INT	89	89.5959		
1320	-	89	.5959		
1321	UP EEX 2	100	89	.5959	
1324	RUP X	.5959	59.59	89	
1326	DN UP INT	59	59.59	89	
1329	-	59	.59	89	
1330	XEY XFR X 28	59	59	89	28 contains 100
1335	K6	89.9997			Converts to decimal declination

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1337	IFG	89.9997	0	0	Makes declination proper sign
1338	CHS CNT CNT CNT	-89.9997	0	0	d = declination
1342	UP M(SIN) XTO 2	sin (d)	d		Does initial calculations
1346	XFR X3 XTO 8	sin d sin ϕ	d		ϕ = latitude
1351	DN N(COS)	cos d			
1353	XFR X4 XTO9	cos d cosϕ			
1358	CLX XTO 61	0			Initializes counter used in refraction correction.
1362	FMT 32.	59	59	23	INPUT LST
1366	K6 UP	23.9997	23.9997	0	Converts to decimal hrs.
1369	4 EEX 4 CHS +	4×10^{-4}	24.0000		Adds 1.4 sec to allow for the time from inputing LST to Output 3
1374	DN GTO S/R 23	24.0	0	0	Calls Subroutine 23
		S/R 23 - FIRST 1/2 R.A. AND DEC. TO ALT-AZ COMMAND			
23	XFR X 11	360	0	0	15 in 11. Converts to LST in degrees.
27	XFR - 10	H.A.	0		H.A.= L.S.T. - R.A.
31	X<Y XFR + b CNT	HA	0	0	Adds 360 if HA is negative so as to make it a positive number.
36	XTO7 N(cos)	cos HA			
39	XFR X 9	cos d cos ϕ cos HA			
42	XFR + 8	sin d sin ϕ + cos d cos ϕ cos HA			This equals cos(z) z=zenith angle
45	XTO 5 UP	cos z	cos z		
48	XSQ UP 1	1	$\cos^2 z$	cos z	
51	-90	90	$\cos^2 z - 1$	cos z	
55	RUP L (arc) N (cos) -	z	90 - z	$\cos^2 z - 1$	90 - z = alt = a
58	RUP √	$\sqrt{(\cos^2 z - 1)}$	z	a	$\sqrt{\lvert\cos^2 z - 1\rvert} = \sqrt{1 - \cos^2 z} = \sin z$ (This method is much faster for getting sin z)
60	XFR X4	cos ϕ sin z	z	a	
63	XTO a XFR 2 XEY	z	sin d	a	
68	XFR 5	cos z			
70	XFR X3	sin ϕ cos z	sin d	a	
73	-a	cos ϕ sin z	sin d - sin ϕ cos z	a	
75	DIV		cos Az	a	$\frac{\sin d - \sin\phi \cos z}{\cos\phi \sin z} = \cos(Az)$
76	DN S/R	cos Az	a	a	
1379	GTO S/R 78	cos Az	a	a	
		S/R 78 - SECOND 1/2 R.A. AND DEC TO ALT-AZ COMMAND			
78	L (arc) N (cos) UP	Az	Az	a	
81	XFR 7 YE 6	H.A.	180	a	
85	X<Y 5 XXX	H.A.	180	a	By testing the HA the direction of the azimuth is found
5	b	360	180	a	
6	XFR-6	360-Az	180	a	if Az to west, then Az = 360-Az.
9	YE 6 S/R	360-Az	Az	a	It is necessary to return 180 to 6.
		HA	180	a	
90	YE 6	HA	Az	a	Az to east.
92	XEY S/R	Az	HA	a	
1383	RUP XTO 0	a	Az		Initialization
1386	RUP RUP	Az		a	
1388	GTO S/R 1434				
		S/R 1434 POINTING CORRECTIONS			
		Az		a	
1434	XFR + 54 XTO 16	Az		a	Adds constant Az offset.
1441	XFR 61 XEY 2	2	C	a	Recalls counter (c)
1446	X>Y 1465		C		Tests for updating refraction correction
1451	1 XTO - 61	1		a	Decraments counter
1456	XFR 16 RUP	a	Az	C	
1460	XFR + 49 S/R	a	Az	C	Add variable alt.offset.
1465	DN. 2	2	C	a	Updating the refraction correction
1468	X>Y UP UP CNT CNT	.2	a	a	Sets a = .2 if a < .2, since cot (0) = infinity
1473	XDN XSQ XTO 61	$(.2a)^2$	a	a	Provides a number for the counter, telling how often to update the refraction correction.
1479	UP 99	99	C	a	
1482	X<Y XTO 061				If C > 99 sets C = 99.
1487	DN DN 0 (tan) 1/x	cot a	a	a	
1491	XFR X17	.0186 cot a	a	a	$r = 180/\pi \cdot 325 \cdot 10^{-6}$ cot a = refraction correction
1495	XFR + 55 UP	r	r_1	a	Adds alt offset
1500	.5 RUP	a	.5	r_1	
1503	+ 23	23	a + .5	r_1	.5 is added so the numbers are rounded off

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1506	X>Y 1520	23	a + .5	r_1	If true there is a need of using the 2nd and 3rd terms of correction
1511	XFR 16 RUP	r_1	Az	a + .5	
1515	GTO 1579				
1520	12 X>Y 1545	12	a + .5	r_1	If true, it must calculate the 2nd and 3rd terms.
1527	86 +	86	a + 86.5	r_1	Sets pointer for "indirect" table look-up.
1530	YE 16	86	Az	r_1	
1533	DN XEY	r_1	Az	r_1	
1535	XFR + IND 16	$r_1 + r_2 + r_3$	Az	r_1	Adds 2nd and 3rd terms from the table in registers 98 thru 108, corresponding to alts. of 12° thru 22°.
1540	GTO 1579				
1545	.1-	.1	a + .4	r_1	
1548	2.64 CHS XEY	a + .4	-2.64	r_1	
1554	$H(X^Y)$	$(a + .4)^{-2.64}$	-2.64	r_1	
1555	XFR X 45	r_2	-2.64	r_1	Constant multiplier = -.8007.
1559	RUP +	r_1	$r_1 + r_2$	-2.64	
1561	40 UP 2.7	2.7	40	$r_1 + r_2$	
1567	XFR + 0 XSQ XSQ	$(a + 2.7)^4$	40	$r_1 + r_2$	
1572	DIV DN-	$\frac{40}{(a + 2.7)^4}$	$r_1 + r_2 + r_3$	$r_1 + r_2$	
1575	XFR 16	Az	$r_1 + r_2 + r_3$		
1578	XEY	$r_1 + r_2 + r_3$	Az		
1579	XTO 49				Store variable alt offset in 49.
1582	XFR + 0 S/R	$a + r_1 + r_2 + r_3$	Az		Set $a = a + r_1 + r_2 + r_3$
1394	UP	a	a	Az	
1395	200 YTO 35	200	a	Az	200 = C.C.W Limit of scope rotation.
1401	RUP	Az	200	a	The value of step 768 must = C.C.W. limit - 1
1402	X>Y XFR + b CNT				* If Az > 200 adds 360 to Az
1407	XTO 36	Az			Store Az in Az 3
1410	EEX 2	100			Initializes values of H.A.
1412	XTO 37 XTO 12 XTO 15				
1421	GTO 948 CLX				
			MAIN LOOP		
948	XFR 35 UP XFR 25	5	Alt 3		Reg. 25 = lower alt. limit.
945	X>Y 1227 To activate "Position Command Out of Limits"				Tests if below minimum altitude.
960	FMT 32 •	59	59	23	Inputs LST.
964	GTO S/R 15				
		S/R 15 FIRST 1/2 R.A.-DEC. TO ALT-AZ COMMAND			
15	K6	23.999			
17	XFR + 39 XTO 1	24.000			39 = .000817 hrs. Extrapolates time to value at output 3.

CONTINUES STEPS 23 THRU 76 ON PAGE 54

STEP NO.	FUNCTION	X	Y	Z	REMARKS
		cos Az	a	a	
968	YTO 5 XTO 43	cos Az	a	a	
			OUTPUT 3		
973	XFR 35 GTO S/R 290	a_3	a	a	
			S/R 290 ALTITUDE TO BASE 64		
290	XFR X26 UP	7.47	7.47	a	Assume a_3 = 42.02 degrees 26=64/360
295	INT -	7	.47		
297	RUP EEX 4 X	10^4	70000	.47	
301	64 RUP	.47	64	70000	
304	X DN UP INT	30	30.12..	70000	
308	-XFR X28	3000	.12...	70000	28 = 100
313	YE X 23+	3000	3007.8	70000	23 = 64
318	DN INT + S/R	3007	73007	70000	
981	XFR 36 GTO S/R 445	Az_3	73007		
		S/R 445 AZ TO BASE 64 AND ALT-AZ COMMAND OUTPUT			
		719.999	73007	70000	Assume Az_3 = 719.999
445	XFR X26 UP	127.9	127.9	73007	26 = 64/360
450	XFR 23	64	127.9	73007	
453	X>Y 512 XSQ				If true MSB = 0
458	-10	10	63.99	73007	
461	X>Y CNT 80 +				Puts Place-Holder in 10's place since 8 bit not read on output.
466	DN UP INT-	63	.99	73007	
470	YE X 23 XFR X27	6.3×10^{11}	63.995	73007	23 = 64 27 = 10^{10}
478	RUP +	73007	$6.30000073007 \times 10^{11}$	63.995	
480	XEY RUP UP	63.995	63.995	6.3995×10^{11}	
483	INT-	63	.995		
485	YE X 23 XFR X 32	6.3×10^{9}	63.7	$6.3... \times 10^{11}$	32 = 10^8
493	RUP + EEX 6	10^6	$6.3630073007 \times 10^{11}$	63.7	
497	RUP INT X	63	6.3×10^{7}	$6.36... \times 10^{11}$	
500	DN +	6.3×10^{7}	$6.36363073007 \times 10^{11}$		
502	EEX 2 X DN	$6.36... \times 10^{13}$	$6.36... \times 10^{11}$	$6.36... \times 10^{11}$	An exp. of 13 tells the logic to address the "Position Command"
506	CHS	$-6.36... \times 10^{13}$			
507	FMT 42 XTO S/R	$-6.36363073007 \times 10^{13}$			The - sign is a 1 for the MSB
512	10	10	Az < 64	73007	Here the MSB = 0
514 thru 558	Same as 461 thru 505				
559	FMT 42 XTO S/R	$+6.36363073007 \times 10^{13}$			The + sign is a 0 for the MSB
989	XFR 37	HA 3			Assume HA3 = 11.71
992	K7 INT	36	42	11	INT prevents 60 seconds from being output
995	YE X 28	36	4200	11	28=100
999	+	36	4236	11	
1000	DN YE X 29 + CLX	0	114236	11	29 = 10^4
1007	X>Y 1024				If true, the sign is negative.
1012	3 EEX 11 +	3×10^{11}	3.00000114236 x 10"		The 11 sets the output address to H.A.
1017	GTO 1029		3.00000114236 x 10"		The 3 sets the input address to the "Position Readout Interface".
1022	CNT CNT				
1024	3 EEX 11 -	3×10^{11}	-3.00... x 10"		
1029	DN FMT 42 XTO	-3.00000114236 x 10"			Outputs HA
1034	64 EEX 5 CHS XTO-1	,00064			1=LST + reg. 39-64 x 10^{-5}. Extrapolates time to value at reading of Alt.-Az Position.
1042	GTO S/R 240				

ON TEST PROGRAM S/R 240 CALLS S/R 1595

STEP NO.	FUNCTION	X	Y	Z	REMARKS
240	GTO S/R 1595				

S/R 1595 INPUT "POSITION READOUT", INVERT, CONVERT TO DECIMAL

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1595	FMT 32·	0	0	0	Input 3 octal numbers
1599	XFR + 38 YE + 38	-7	-7	0	Inverts octal numbers 38 =-7.
1607	XFR X22 YE X 21	-3584	-28672		$22 = 512 = 8^3$ $21 = 4096 = 8^4$
1615	+DN YE + 38	-32256	-7	0	
1621	YE X 20	-32256	-229376	0	$20 = 32768 = 8^5$
1625	+YTO a	-32256	-261632		Stores value
1628	FMT 32·	0	0	0	Input 3 octal numbers
1632	XFR + 38	-7	0	0	
1636	XFR X 23	-448			23 = 64
1640	XFR + a YE + 38	-262080	-7	0	Recalls and adds value
1647	+8	8	-262087	0	
1649	RUP XFR + 38	-7	8	-262087	
1654	X DN+	-56	-262143	-262087	
1657	XFR 24 CHS X S/R	-.0014	359.99	-262087	$24 = 360/8^6$

NORMAL S/R 240 INPUT "POSITION READOUT", CONVERT TO DECIMAL

STEP NO.	FUNCTION	X	Y	Z	REMARKS
240	FMT 32·	7	7	7	Inputs 3 octal numbers.
244	XFR X22 YE X 21	3584	28672	7	$22 = 512 = 8^3$ $21 = 4096 = 8^4$
252	+ DN YE X 20	32256	229376	7	$20 = 32768 = 8^5$
258	+ YTO a	32256	261632	7	
261	FMT 32·	7	7	7	Inputs three octal numbers.
265	XFR X 23	448	7	7	$23 = 64 = 8^2$
269	XFR + a	262080	7	7	
272	+8 RUP	7	8	262087	
275	X DN +	56	262143	262087	
278	XFR 24 X S/R	.0014	359.99		$24 = 360/8^6$
1047	YE -54 YTO 13	.0014	359.99	262087	54=Az offset, Az to 13
1054	GTO S/R 240	.0014	alt_{in}	52418	Alt input S/R 240 as above
1059	YE -49	.0014	alt_{in}		49 = variable alt offset
1063	YE 5 YTO 0 XFR 43	cos Az	alt command		Alt input now in 5
1070	GTO S/R 78	Az		alt	

S/R 78 - SECOND 1/2 RA AND DEC TO ALT-AZ COMMAND (See earlier description)

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1074	GTO S/R 1434	alt_n	Az	Counter	

S/R 1434 - POINTING CORRECTION (See earlier description)

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1080	GTO S/R 697				

S/R 697 - INTERPOLATE THE ALT-AZ COMMANDS

STEP NO.	FUNCTION	X	Y	Z	REMARKS
697	UP YE 35	alt_n	alt_o	Az	Alt_n = latest value Alt_o = old value
701	XEY-	alt_o	alt_{n-o}	Az	n - o means new-old
703	YE X 40 XEY	$alt_{n-o/4}$	alt_o	Az	40 = .25
708	+YTO 42	$alt_{n-o/4}$	alt 0		
712	+YTO 43		alt 1		
716	+YTO 44		alt 2		Alt 3 in 35
720	XFR 36 XEY 500	500	Az_o	Az_n	
727	X<Y 768 π	500	Az_o	Az_n	* If true, the switch is off.
732	99 X>Y 768 π	99	Az_o	Az_n	If true, the switch is off
739	RUP	Az_n	99	Az_o	The switch is on.
740	X>Y 777 π				If true, the Az is 99° - 360°. If false, the Az is 0 - 19.2°.
745	XEY 19	19	Az_n	Az_o	19 represents the C.W. limit of the scope.
748	X<Y b XTO - 0	360			*b = 360. If true, 360 is subtracted from register 036 $(Az_0)_1$ making it 0-19° and 0 is added to Az_n, to rewind the scope to "switch" off position. If false, 360 is added to Az_n making it 360-379°. Note the dual use of the 36.
753	360+	360 or 0	Az_n		
757	DN UP	Az_n	Az_n		
759	YE 36	Az_n	Az_o		
762	XEY GTO 781 π	Az_o	Az_n		
768	199	199	Az_o	Az_n	The switch is off.
771	RUP X>Y	Az_n	199	Az_o	Adds 360 if 360 > Az_n > 199
773	XFR + b CNT				The value 199 has to be one less than the C.C.W. limit at 1395.
777	RUP YTO 36	Az_o	Az_n	199	
781	- YE X 40	Az_o	$Az_{n-o/4}$		40=25

STEP NO.	FUNCTION	X	Y	Z	REMARKS
786	XEY UP	$Az_{n-o/4}$	$Az_{n-o/4}$	Az_o	
788	80 X<Y 815 π	80	$Az_{n-o/4}$		If true, Az_o to Az_n is 0° to 719°.
795	CHS X>Y 882 π	-80	$Az_{n-o/4}$	Az_o	If true, Az_o to Az_n is 719° to 0°.
801	DN	$Az_{n-o/4}$	Az_o		
802	+ YTO 46 from 866 or 932		Az 0		
807	+YTO 47		Az 1		
811	+YTO 48 S/R		Az 2		
815	180-	180	$Az_{n-o/4}$	Az_o	Az_o to Az_n is 0° - 719°.
819	DN+	$Az_{n-o/4}$	Az 0		
821	UP CLX RUP	Az 0	0	$Az_{n-o/4}$	
824	X<Y 856 π				Tests for negative values due to going from 0 to 719.
829	XTO 46 RUP + RUP RUP	Az 1	0	$Az_{n-o/4}$	
836	X<Y 867 π				Each addition is tested until zero is crossed.
841	XTO 47 RUP + CLX	0	Az 2	0	
847	X>Y YE + 56	0	Az 2		56 = 720
852	YTO 48 S/R				
856	XEY	0	Az 0	$Az_{n-o/4}$	
857	720 +	720	Az 0	$Az_{n-o/4}$	Since the negative value has been found, it is no longer tested for.
861	DN XEY GTO 803	$Az_{n-o/4}$	Az 0	$Az_{n-o/4}$	
867	XEY 720	720	Az 1	$Az_{n-o/4}$	
871	+ DN XEY	$Az_{n-o/4}$	Az 1	$Az_{n-o/4}$	
874	YTO 47 + YTO 48 S/R		Az 2		
882	180 +	180	$Az_{n-o/4}$	Az_o	Az_o to Az_n is 719° to 0°.
886	DN + UP XFR 56	719.9999	$Az_{n-o/4}$	Az 0	
892	RUP X>Y 925 π	Az 0	719.999	$Az_{n-o/4}$	When Az 0 ≥ 720, 720 must be subtracted.
898	XTO 46 RUP + RUP RUP	Az 1	719.999	$Az_{n-o/4}$	
905	X>Y 933 π				
910	XTO 47 RUP + DN	Az 2	719.999	719.999	
916	X>Y - DN CHS CNT	Az 2			
921	XTO 48 S/R				
925	- XEY CHS	Az 0		$Az_{n-o/4}$	
928	RUP GTO 803				
933	- XEY CHS	Az 1		$Az_{n-o/4}$	
936	RUP YTO 47	$Az_{n-o/4}$	Az 1		
940	+ YTO 48 S/R		Az 2		
			OUTPUT 0		
1085	XFR 42 GTO S/R 290	Alt 0			
		S/R 290 - ALTITUDE TO BASE 64. (See Description p. 56)			
1093	XFR 46 GTO S/R 445	Az 0			
		S/R. 445 - AZ TO BASE 64 AND ALT-AZ COMMAND OUTPUT (See Description p. 56)			
1101	XFR 12	HA0=11.71		a	
1104	K7 INT	36	42	11	
1107	YE X 28 +	36	4236	11	28=100
1112	DN YE X 29 + CLX	0	114236	11	29=10^4
1119	X>Y 1134				If true, the HA is negative
1124	5 EEX 11+	5×10^{11}	$5.00000114236 \times 10^{11}$		The 5 says the next input is the digiswitches. EEX 11 says it is an HA output.
1129	GTO 1139				
1134	5 EEX 11 -				
1139	DN FMT 42 XTO	$\pm 5.00000114236 \times 10^{11}$			
1144	GTO S/R 94				

STEP NO.	FUNCTION	X	Y	Z	REMARKS
	S/R 94 - FIRST HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS				
94	XFR 5 M (sin) XTO 5 UP	sin a	sin a		a = Altitude Position Readout
100	XSQ YE X 3 UP 1	1	$\sin^2 a$	sin (a) sin ϕ	ϕ = latitude
106	-DN SQRT	$\sqrt{\lvert \sin^2 a - 1 \rvert}$	sin a sin ϕ	sin a sin ϕ	$\sqrt{\lvert \sin^2 a - 1 \rvert}$ = cos a
109	XFR X 4 UP	cos a cos ϕ	cos a cos ϕ	sin a sin ϕ	
113	XFR 13 YE 6	Az_{in}	180	sin a sin ϕ	
118	X<Y SFL CNT CNT CNT				
123	YE 6 N (cos)	cos Az	cos a cos ϕ	sin a sin ϕ	
126	X DN +	cos a cos Az cos ϕ	sin a sin ϕ + cos a cos Az cos ϕ	= sin d	d = dec
129	DN UP UP XSQ	$\sin^2 d$	sin d	sin d	
133	RUP LM (arc sin) XTO a	d	$\sin^2 d$	sin d	
138	1 - DN SQRT	cos d	sin d	sin d	
142	XFR X 4 YE X 3 YE-5	cos d cos ϕ	sin d sin ϕ - sin a	sin d	
151	DIV YTO 5		$\frac{\sin d \sin \phi - \sin a}{\cos d \cos \phi}$	= - cos HA	
	OUTPUT 1				
154	XFR 43 GTO S/R 290	Alt 1			
	S/R 290 - ALTITUDE TO BASE 64. (See Description p. 56)				
162	XFR 47 GTO S/R 445	Az 1	73007		
	S/R 445 - AZ TO BASE 64 AND ALT-AZ COMMAND OUTPUT. (See Description p. 56)				
170	FMT 32 XFR	6.35959895959			Input digiswitches.
174	XTO 7 UP 9	9	6.35959895959		
178	S/R	9	6.35959895959		
1148	X<Y 0179	9	6.359598959		If true, the "Update" button has been pushed and the dec is positive.
179	SFL IFG 1259				Clears the flag. Sends to 1259 (p. 52)
1153	CHS X>Y 1249	-9	6.359598959		If true, the "Update" button has been pushed and the dec is negative. It is not necessary to clear the flag since it will be set.
1159	GTO S/R 189				
	S/R 189 - OUTPUT 1 (CONTINUED) AND THE SECOND HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS				
189	XFR 15	HA 1			
192	GTO S/R 0565				Did not use short term address since step 198 = 2.
	S/R 565 - HA OUTPUT, SETTING INPUT ADDRESS TO LST.				
565	K 7 INT	36	42	11	Assume HA 1 = 11.71
568	YE X 28 +	36	4236	11	
573	DN YE X 29 + CLX	0	114236	11	
580	X>Y 595 π				
585	EEX 11 + DN	1.00000114236x10"			The 1 of EEX 11 orders LST input
590	FMT 42 STO S/R				
595	EEX 11 - DN				
600	FMT 42 XTO S/R	-1.00000114236x10"			
198	24 UP XFR 5 CHS	cos HA	24		
204	LN (arc cos) XFR X 30	HA/15 (in hrs.)	24		30 = 1/15. HA is 0 to 12 hrs.
210	XTO 5 IFG - DN SFL CNT	HA			Changes HA to a number 0-24 hrs.
217	YE 1-	HA	LST - HA = RA		1 = LST
220	CLX X>Y CNT 24 + S/R	0	RA		Adds 24 if RA negative.
1164	DN GTO S/R 605	RA			Assume RA = 3.37.
	S/R 605 - RA AND DEC OUTPUT TO DISPLAYS				
605	K7 INT	19	22	3	Integerizing the seconds allows the dec to be added as less significant digits.
608	XFR X 29 YE X 33 +	1.900×10^5	2.2190×10^7	3	$29 = 10^4$, $33 = 10^6$
617	40 RUP	3	40	2.2190×10^7	The 40 bit is an undisplayed placeholder
620	+ DN XFR X 32 +	4.3×10^9	4.32219×10^9	2.219×10^7	$32 = 10^8$
627	a YTO a K7 INT	58	59	59	Recalls dec, assume dec = 59.99
633	XFR X 31 + DN	59.58	59	59	31 = .01
639	YE X 28 + CLX	0	5959.58	59	28 = 100
645	X>Y 658 UP				If true, dec negative.
650	a +	4.32219×10^9	$4.32219595958 \times 10^9$	59	Adds in RA
652	DN FMT 42 XTO S/R	$4.32219595958 \times 10^9$			
658	a -	4.32219×10^9	$-4.32219595958 \times 10^9$		
660	DN FMT 42 XTO	$-4.32219595958 \times 10^9$			
665	S/R				
1170	GTO S/R 323				

STEP NO.	FUNCTION	X	Y	Z	REMARKS
			S/R 323 - INTERPOLATING THE HOUR ANGLE		
323	XFR 5 IFG CHS CNT CNT CNT	HA			
330	XFR + 19	HA			19 = .000972 hrs. Extrapolates HA to value at Output 1.
334	UP UP 12	12	HA	HA	
338	X<Y -- UP DN				If true, adding the offset put the HA over 12 hrs.
343	YE 15 X<Y DN CNT CNT CNT	12	HA = HA1	HA_n	If true, it is the first time through the loop.
351	DN - XEY	HA_{n-o}	HA_o	HA_n	
354	XFR X 40 UP 1 CHS	-1	$HA_{n-o/4}$	HA_o	40 = 1/4
361	X>Y 405 π				If true, HA going from 12 to -12
366	DN + → YTO 41	$HA_{n-o/4}$	HA 2	HA_o	
371	+ → YTO 37		HA 3		
375	+ YTO 12 S/R		HA 0		
405	6 +	6	$HA_{n-o/4}$	HA_o	Corrects difference
407	DN + UP 12	12	$HA_{n-o/4}$	HA 2	
412	RUP X>Y 383 π	HA 2	12	$HA_{n-o/4}$	If true, crosses from 12 to -12.
418	RUP YTO 41	$HA_{n-o/4}$	HA 2	12	
422	+ RUP RUP X>Y 394 π	HA 3	12	$HA_{n-o/4}$	
430	XTO 37 RUP + DN	HA 0	12	12	
436	X>Y XEY -- XEY	HA 0	12	12	
441	XTO 12 S/R				
383	XEY 24-	24	HA 2	$HA_{n-o/4}$	
387	DN XEY GTO 368 →	$HA_{n-o/4}$	HA 2		
394	XEY 24-	24	HA 3	$HA_{n-o/4}$	
398	DN XEY GTO 372 →				
			OUTPUT 2		
1175	XFR 44 GTO S/R 290	Alt 2			
			S/R 290 - ALT TO BASE 64. (See Description p. 56)		
1183	XFR 48 GTO S/R 445	Az 2			
			S/R 445 - AZ TO BASE 64 AND ALT-AZ COMMAND OUTPUT. (See Description p. 56)		
1191	XFR 41 GTO S/R 565				
			S/R 565 - HA OUTPUT SETTING INPUT ADDRESS TO LST. (See Description p. 59)		
1199	GTO 948 CLX				
		TO BEGINNING OF MAIN LOOP			

REDEFINING THE LATITUDE

		Sec.	Min.	Deg.	
670	K6	Decimal degrees			Latitude = ϕ
672	UP M(sin) XTO 3	Sin ϕ	ϕ		Stores sin ϕ in 3
676	DN N(cos) XTO 4	Cos ϕ			Stores cos ϕ in 4
680	GTO 1234	TO CONTINUOUSLY READ DIGISWITCHES			

CONSTANT STORAGE

Storage Register	Contents	Comments
0	Temp alt command	
1	Temp time storage	
2	Temp command sin (d)	
3	sin ϕ ϕ = latitude	
4	cos ϕ	
5	Temp command cos z, alt command, input alt, sin alt, HA	
6	180 - temp command Az	
7	Temp command HA, Digiswitch input	
8	Temp command sin d sin ϕ	
9	Temp command cos d cos ϕ	
10	Temp command R.A.	
11	15	
12	Temp HA0	
13	Temp Az position readout	
14	5.000008×10^{10}	Activates "Position Command Out of Limits"
15	Temp HA1	
16	Temp command Az (pointing corr.), Used in IND address	
17	$.0186 = 180/\pi \times 3.25 \times 10^{-4}$	Used in pointing correction
18		
19	.000972 hrs. = 3500 m.s.	H.A. delay = 1 cycle (2340 m.s.) + Input Alt Az Position to OUTPUT 1 (1160 m.s.)
20	$32768 = 8^5$	
21	$4096 = 8^4$	
22	$512 = 8^3$	
23	$64 = 8^2$	
24	$.0014 = 360/8^6$	
25	Minimum altitude	
26	8/45	
27	10^{10}	
28	100	
29	10^4	
30	1/15	
31	.01	
32	10^8	
33	10^6	
34	Stow Position	
35	Temp ALT 3	
36	Temp AZ 3	
37	Temp HA 3	
38	-7	
39	.000817 hrs.	Loop time offset = 1 cycle (2340 m.s.) + Input LST to Output 3 (600 m.s.).

CONSTANT STORAGE (CONT.)

Storage Register	Contents	Comments
40	.25	
41	Temp HA2	
42	Temp ALT0	
43	Temp ALT1, Temp command cos Az	
44	Temp ALT2	
45	$-.8007 = -180/\pi \times 10^{-6} \times 43 \times 325$	Used in pointing correction
46	Temp AZ0	
47	Temp AZ1	
48	Temp AZ2	
49	Temp variable alt. offset	
50	.1	
51	8 } Used in calculating stow position	
52	8×10^4	
53		
54	Linear Azimuth offset + $.00069(360/2^{19})$	
55	.00069	Constant Altitude Offset
56	719.9999999	
57		
58	63.9999999	
59		
60		
61	Temp counter	
62		
63		
64		
65		
66		
67		
68		
69		
70		
71		
72		
73		
74		
75		
76		
77		
78		
79		

CONSTANT STORAGE (CONT.)

Storage Register	Contents	Comments
80		
81		
82		
83		
84		
85		
86		
87		
88		
89		
90		
91		
92		
93		
94		
95		
96		
97		
98	12°, - .0018962	98-108 are 2nd and 3rd term refraction errors for indicated angle
99	13°, - .0015054	
100	14°, - .0012148	
101	15°, - .0009942	
102	16°, - .0008240	
103	17°, - .0006906	
104	18°, - .0005846	
105	19°, - .0004993	
106	20°, - .0004299	
107	21°, - .0003729	
108	22°, - .0003256	

TEST SET UP

The test program is located on a separate card. It is identical to the regular program except for the changes noted in Subroutine 240. The same Constant Card is used.

The Test Chassis holds Cards 4, 5, and 6. It can either be connected to Cable J-3 or plugged directly into the 'Stand-Alone Computer Control' chassis. Supply the Test Chassis with five volts D.C. at four amps and a TTL compatible signal of frequency greater than or equal to 20 Hz. This acts as the 20 Hz Control Signal.

The boards are wired in the Test Chassis identically to the wiring in the '45' Telescope Digital Position Control and Readout' box, except that 36 bits of the Position Command are wired directly to the 36 bits of the Position Readout Input. Position Command bit A0 is not connected since it only tells which arm of the spiral the telescope is to be on. Since the Position Command is inverted and the Position Readout is to be in positive logic, the modification in Subroutine 240 is needed to reinvert the Position Readout.

The Test Chassis simulates how the telescope would behave if it instantaneously followed the Position Command.

CONNECTOR LIST FOR H.P. 9810A CALCULATOR TO 'STAND-ALONE COMPUTER CONTROL'

CONNECTOR: Designation J-0, Type H.P. 11202A I/O TTL Interface to Elco 38 Pins

Panel E Cable P

PIN	TO	FUNCTION	
A			
B			
C			
D			
E			
F			
H			
J			
K			
L			
M			
N			
P			
R	2-15	I7	'Violet'
S	2-16	I6	'Blue'
T			
U			
V	2-M	I0	'Black'
W	GND	GND	
X	2-N	I1	'Brown'
Y			
Z	2-19	I3	'Orange'

PIN	TO	FUNCTION	
AA	2-21	I2	'Red'
BB	1-4	01	'Brown'
CC	1-K	00	'Black'
DD	2-22	I5	'Green'
EE	2-20	I4	'Yellow'
FF	1-F	03	'Orange'
HH	1-5	02	'Red'
JJ	1-10	I/O	
KK	1-C	Control	
LL			
MM	1-7	05	'Green'
NN	2-14	04	'Yellow'
PP	1-3	Flag	
RR			
SS	1-B	07	'Violet'
TT	1-6	06	'Blue'

ABBREVIATIONS: Board Connectors: 1, 2, 3, etc.

ELCO Connectors: J1, J2, J3, etc.

Slot Connectors: S1, S2, S3, etc.

Pin #'s: -3, -x, -B, -22, etc.

EX.: S25-22
Slot 25; Pin 22
J-9 - mm
ELCO J9; Pin mm

CONNECTOR LIST FROM STAND-ALONE COMPUTER CONTROL TO NRAO 45' TELESCOPE DIGITAL POSITION CONTROL AND READOUT

CONNECTOR: Designation J-3 Type Elco 56 Pins

FROM: Panel E Cable P TO: Panel P Cable E

PIN	FROM	TO	FUNCTION		PIN	FROM	TO	FUNCTION
A	1-H	S25-3	{ENCODER OUTPUT		f		Cable wired as 19	
B	1-N	S25-B	CLOCK (Twisted pair)		h			
C			GND		j		twisted pairs	
D			GND		k			
E	1-16	S25-4	{POSITION COMMAND		l			
F	1-V	S25-D	STROBE (Twisted pair)		m			
H	1-17	S25-E	ENCODER PROTECT		n			
J			V_{cc}		p			
K			V_{cc}		r			
					s			
L	1-13	S25-T	OUTPUT	Blk.	t			
M	1-D	S25-P	LINES	Br.	u			
N	1-M	S25-12		Red	v			
P	1-E	S25-N		Orange	w			
R	2-R	S25-11		Yellow	x			
S	1-R	S25-M		Green	y			
T	1-14	S25-16		Blue	z			
U			V_{cc}		AA			
V			V_{cc}		BB			
W			GND		CC			
X	2-K	S24-21	INPUT	Blk.	DD			
Y	2-L	S24-R	LINES	Br.	EE			
Z	2-Z	S24-C		Red	FF			
a			GND		HH			
b	3-22	S25-K	COUNTER	'4'	JJ			
c	3-W	S 25-F	LINES	{'2'	KK			
d	3-16	S25-8		'1'	LL			
e					MM			
					NN			

ABBREVIATIONS: ELCO Connectors: J1, J2, J3, etc.

Slot Connectors: S1, S2, S3, etc.

Pin #'s: -3, -x, -B, -22, etc.

EX: S25-22
Slot-25; Pin 22
J-9 - mm
ELCO J9; Pin mm

CONNECTOR LIST FROM 'DATA LINK 45' SITE' TO 'STAND-ALONE COMPUTER CONTROL'

CONNECTOR: Designation J-6 Type ELCO 38 Pins

From: Panel P Cable E

To : Panel E Cable P

FROM PIN	TO PIN	FUNCTION
A	14	A
B	1	'8'
C	13	B
D	2	'4'
E	12	C
F	3	'2'
H	11	N.C.
J	4	'1'
K	10	V_{cc}
L	5	GND
M	9	V_{cc}
N	6	GND
P		
R	7	STROBE

Cable wired as 19 twisted pairs.

ABBREVIATIONS: ELCO Connectors: J1, J2, J3, etc.

Pin Numbers on Remote Sidereal Time Display: 1, 2, 3, etc.

FOR: BOX STAND-ALONE COMPUTER CONTROL CARD 1 Control

Card 1

FROM	TO	FROM	TO
A	GND	1	GND
B	J0-SS	2	V_{cc}
C	J0-KK	3	J0-PP
D	J3-M	4	J0-BB
E	J3-P	5	J0-HH
F	J0-FF	6	J0-TT
H	J3-A	7	J0-MM
J	H.A. display hrs. stb.	8	H.A. display sign stb.
K	J0-CC	9	H.A. display sec. stb.
L	H.A. display min. stb.	10	J0-JJ
M	J3-N	11	C2-T
N	J3-B	12	C2-E
P	C2-17	13	J3-L
R	J3-S	14	J3-T
S	Dec. display sec. stb.	15	Dec. display '80' degrees output
T	C3-14	16	J3-E
U	C3-17	17	J3-H
V	J3-F	18	R.A. display degrees stb.
W	Dec. display sign stb.	19	R.A. display min. stb.
X	Dec. display degrees stb.	20	R.A. display sec. stb.
Y	C2-J, C3-S	21	Dec. display min. stb.
Z	C2-F, C3-20	22	C2-5, C3-19

ABBREVIATIONS:

CARD CONNECTORS: C1, C2, C3
BNC CONNECTORS : B1, B2, B3, etc.
ELCO CONNECTORS: J1, J2, J3, etc.
SLOT CONNECTORS: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.

EX: S25-22
Slot 25, Pin 22
J9-mm
ELCO J9, Pin mm

FOR: STAND-ALONE COMPUTER CONTROL   CARD 2 Input Multiplexing

Card 2

FROM	TO	FROM	TO
A	GND	1	GND
B	V_{cc}	2	V_{cc}
C	Dec. digiswitch degrees stb.	3	R.A. digiswitch sec. stb.
D	Dec. digiswitch min. stb.	4	Dec. digiswitch sec. stb.
E	C1-12	5	C1-22, C3-19
F	C1-Z, C3-20	6	Dec. digiswitch sign stb., C-11
H	R.A. digiswitch min. stb.	7	R.A. digiswitch hrs. stb.
J	C1-Y, C3-S	8	Black digiswitch output, C3-H
K	J3-X	9	C3-3
L	J3-Y	10	C3-K
M	J0-V	11	Blue digiswitch output
N	J0-X	12	Brown digiswitch output
P	C3-12	13	C3-F
R	J3-R	14	J0-NN
S	Violet digiswitch output	15	J0-R
T	C1-11	16	J0-S
U	C3-13	17	C1-P
V	Yellow digiswitch output	18	C3-21
W	Orange digiswitch output	19	J0-Z
X	Green digiswitch output	20	J0-EE
Y	Red digiswitch output	21	J0-AA
Z	J3-Z	22	J0-DD

ABBREVIATIONS: Card Connectors: C1, C2, C3
BNC Connectors : B1, B2, B3, etc.
ELCO Connectors: J1, J2, J3, etc.
Slot Connectors: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.

EX: S25-22
Slot 25, Pin 22
J9-MM
ELCO J9, Pin MM

FOR: BOX STAND-ALONE COMPUTER CONTROL CARD 3 Time Input

Card 3

FROM	TO	FROM	TO
A	GND, T1-14	1	Remote sidereal time display ten second strobe
B	Remote sidereal time display 4 bit	2	V_{cc}
C	T1-S	3	C2-9
D	T1-M	4	T1-7
E	T1-D	5	T1-H
F	C2-13	6	T1-4
H	C2-8	7	T2-E
J	T1-F	8	T1-B
K	C2-10	9	T1-P
L	T1-K	10	T1-6
M	T1-2	11	C2-6
N	T1-E	12	C2-P
P	T1-A	13	C2-U
R	T1-J	14	C1-T
S	C1-Y, C2-J	15	T1-5
T	T1-1	16	J3-d
U	To update button	17	C1-U
V	T2-F	18	T2-J
W	J3-c	19	C1-22, C2-5
X	T1-C	20	C1-2, C2-F
Y	T1-L	21	C2-18
Z	T1-3	22	J3-b

ABBREVIATIONS: Card Connectors: C1, C2, C3,
BNC Connectors : B1, B2, B3, etc.
ELCO Connectors: J1, J2, J3, etc.
Slot Connectors: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.
E.R.C. Digital Clock Connectors: T1-top conn., T2-bottom conn.

EX: S25-22
Slot 25, Pin 22
J9-MM
ELCO J9, Pin MM

FOR: BOX NRAO 45-FOOT TELESCOPE DIGITAL POSITION CONTROL AND READOUT

CARD: 4 Stand-Alone Position Readout Input

SLOT 24

FROM	TO	FROM	TO
A	GND	1	GND
B	A16	2	V_{cc}
C	J3-Z	3	E1
D	A10	4	E7
E	A4	5	E4
F	A1	6	A13
H	A7	7	E13
J	E10	8	E8
K	A17	9	E16
L	E11	10	A11
M	E14	11	E17
N	S25-C	12	E5
P	E2	13	S25-H
R	J3-Y	14	A14
S	A2	15	A5
T	A8	16	E18
U	E12	17	E9
V	E6	18	E15
W	E3	19	A18
X	A12	20	A15
Y	A3	21	J3-X
Z	A6	22	A9

ABBREVIATIONS: ELCO Connectors: J1, J2, J3, etc.
Slot Connectors: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.

EX: S25-22
Slot 25, Pin 22
J9-MM
ELCO J9, Pin MM

A1 = M.S.B. and
A18 = L.S.B. of the Azimuth Position Readout

E1 = M.S.B. and
E18 = L.S.B. of the Elevation Position Readout

FOR: BOX NRAO 45-FOOT TELESCOPE DIGITAL POSITION CONTROL AND READOUT

CARD 5 Stand Alone Position Command Output

	FROM	TO	FROM	TO
SLOT 25	A	V_{cc}	1	GND
	B	J3-B	2	S26-3
	C	S24-N	3	J3-A
	D	J3-F	4	J3-E
	E	J3-H	5	A0
	F	J3-C	6	20 Hz Control Signal Input
	H	S24-13	7	S26-D
	J	S26-C	8	J3-d
	K	J3-b	9	S26-T
	L	S26-M	10	S26-H
	M	J3-S	11	J3-R
	N	J3-P	12	J3-N
	P	J3-M	13	S26-R
	R	S26-N	14	S26-S
	S	S26-L	15	S26-P
	T	J3-L, S26-K	16	J3-T
	U	A6	17	A12
	V	A5	18	A11
	W	A4	19	A10
	X	A3	20	A9
	Y	A2	21	A8
	Z	A1	22	A7

ABBREVIATIONS: ELCO Connectors: J1, J2, J3, etc.
Slot Connectors: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.

EX: S25-22
Slot 25, Pin 22
J9-MM
ELCO J9, Pin MM

A0 = M.S.B. of the Azimuth Position Command

FOR: BOX NRAO 45-FOOT TELESCOPE DIGITAL POSITION CONTROL AND READOUT

CARD 6 Stand-Alone Position Command Output

	FROM	TO	FROM	TO
SLOT 26	A	GND	1	GND
	B	V_{cc}	2	V_{cc}
	C	S25-J	3	S25-2
	D	S25-7	4	Calculator Inhibit
	E	N.C.	5	E18
	F	N.C.	6	E17
	H	S25-10	7	E16
	J	N.C.	8	E15
	K	S25-T, J3-L	9	E14
	L	S25-S	10	E13
	M	S25-L	11	E12
	N	S25-R	12	E11
	P	S25-15	13	E10
	R	S25-13	14	E9
	S	S25-14	15	E8
	T	S25-9	16	E7
	U	A18	17	E6
	V	A17	18	E5
	W	A16	19	E4
	X	A15	20	E3
	Y	A14	21	E2
	Z	A13	22	E1

ABBREVIATIONS: ELCO Connectors: J1, J2, J3, etc.
Slot Connectors: S1, S2, S3, etc.
Pin #'s : -3, -x, -B, -22, etc.

EX: S25-22
Slot 25, Pin 22
J9-MM
ELCO J9, Pin MM

A18 is the L.S.B. of the Azimuth Position Command

E1 is the M.S.B. of the Elevation Position Command

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

POWER SUPPLY
DIGITAL PRODUCTS

Note 1
Connector T1

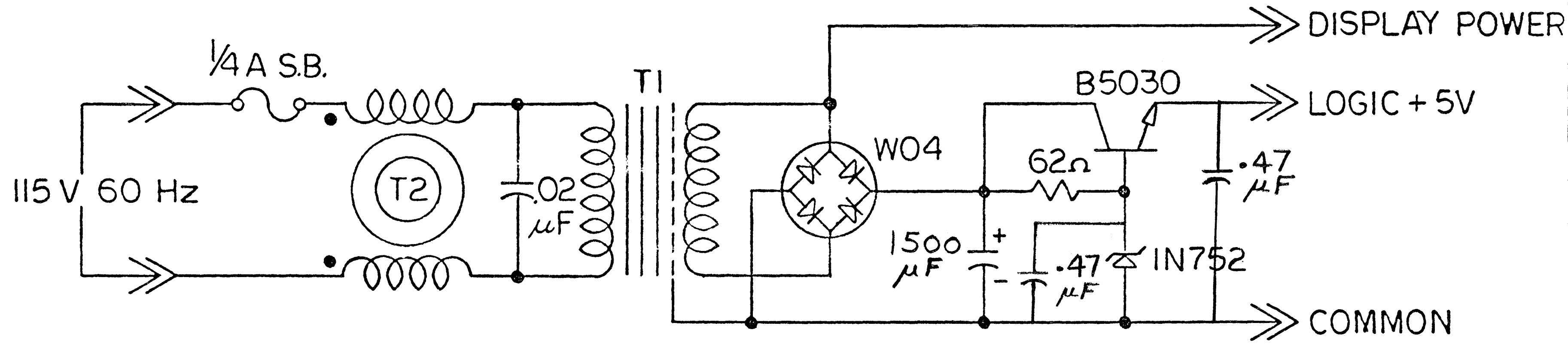
12 Hour Clock Jumper Pin 13 - Pin 11
24 Hour Clock Jumper Pin 12 - Pin 11
100 Hour Clock Jumper None

Note 2
Connector T2

12 Hour Clock Jumper Pin M - Pin L
24 Hour Clock Jumper Pin B - Pin L
100 Hour Clock Jumper Pin B - Pin L

Note 3

Connect N and 8 of T2 for internal osc. operation.



DIGITAL CLOCK CONNECTOR TERMINAL DESIGNATION

T1 - Top

Sec. Units: 4 - A, 2 - B, 8 - C, 1 - D
Sec. Tens: 4 - E, 2 - F, 1 - H
Hour Units: 4 - J, 2 - K, 8 - L, 1 - M
Hour Tens: 4 - N, 2 - P, 8 - R, 1 - S

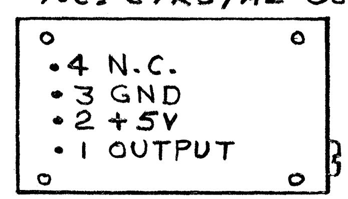
Min. Units: 1 - 4, 2 - 2, 3 - 8, 4 - 1
Min. Tens: 5 - 4, 6 - 2, 7 - 1
8 - NC
9 - NC
10 - NC
11 - , 12 - , 13 - } See Note 1
14 - Com
15 - 5 V

T2 - Bottom

A - Pwr. Interrupt
B - Com.
C - Reset to zero
D - 1 PPS
E - 10 kHz. Displays change on positive edge.
F - Run-Hold
J - Set-Run
L - , M - } See Note 2
N - Internal 1. 0027 MHz Output
P - Unreg. 5 V
R - Com.

2 - AC, 5 - AC } 115 V, 60 Hz Pwr. Input
8 - 1. 0027379 MHz Input
15 - 5 V

ELECTRONICS RESEARCH CO.
T.C. CYRSTAL OSCILLATOR

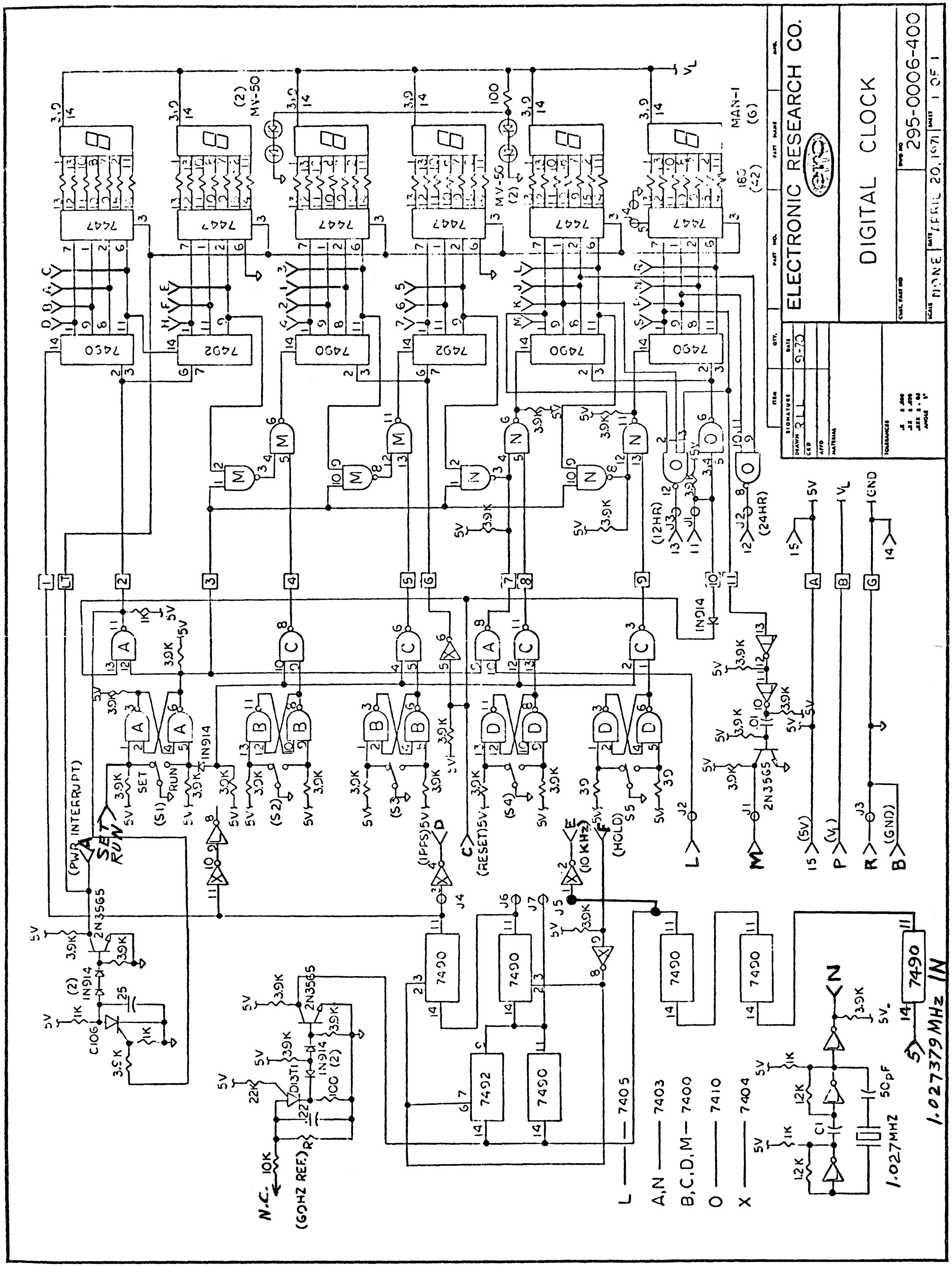


Set To 1.0027379 MHz

FREQ. ADJ.

ACCURATE To 1.5 × 10^-7

SIZE	CODE IDENT. NO.	DWG. NO.
A	13571	295-0007-210
SCALE NONE	WT 4-7-72	SHEET 1 OF 1


ELECTRONIC RESEARCH CO.
DIGITAL CLOCK
295-0006-400
APRIL 20, 1971
1 OF 1
NONE
9-70
MAN-1 (6)
(2) MV-50
1.027379MHz IN
1.027MHZ
(PWR INTERRUPT)
SET RUN
(1PPS)
(RESET)
(HOLD)
(10 KHz)
(12HR)
(24HR)
(GOHZ REF.)
N.C.
L — 7405
A,N — 7403
B,C,D,M — 7400
O — 7410
X — 7404

ACKNOWLEDGEMENTS

Ray Hallman deserves a good portion of my thanks. He taught me about digital logic and guided me in how the system should be built. I would also like to thank Sandy Weinreb for trusting me with the project. Tony Miano, Carolyn Dunkle, and Jeanne Ray also deserve an award for transforming this report into something readable.