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VLA STAND-ALONE COMPUTER CONTROL

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INTRODUCTION

A Hewlett Packard 9810A calculator is used as the stand-alone control ,of the VLA-Two Antenna Prototype. Upon pushing the "Position Command Update" switch, 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 'Antenna Control Test Unit' 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 remaining display is the local sidereal time from the digital clock.

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. Press CONTINUE and load sides one and two of the constant card. The card-reader motor should then stop.

The display will now flash and the "Position Command Out of Limits" L.E.D. will come on. Dial in the r.a. and dec. of the source on the digiswitches. Depress the "Position Command Update" switch. The L.E.D. will flash. In about three seconds, the system will 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" L.E.D. to come on. The system will go into stand-by mode, waiting for the "Update" switch to be pushed. This can be used to halt the telescope at the last position command. The following conditions are illegal:

Having a declination greater than 90 or less than -90°.

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" L.E.D. 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" switch.

TROUBLE SHOOTING

If the system refuses to operate, key the following sequence on the calculator: STOP, END, CONTINUE, (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" switch If this does not help, turn off the calculator for a few seconds, then reload the program and data.

Changing steps 1106-1107 to 23 from 15 will have the tracking program do the Alt-Az to r.a., dec., and h.a. calculation using the Position Command instead of the Monitor Word. This simulates the telescope tracking a source.

LOGIC DESCRIPTION

The logic necessary to interface the calculator is contained on four wirewrap boards. Boards numbers one and two are located in the "Stand-Alone Computer Control" chassis. Boards three and four are located in the "Antenna Control Test Unit". They are labeled boards B and D, respectively.

The "Stand-Alone Computer Control" box is connected to the calculator by cable J-1 to the "Antenna Control Test Unit" box by cable J-2.

Refer to the block diagram of all four 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 4-22 is next to the pin: 4 refers to card 4 and 22 refers to pin 22.

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 Service Manual.

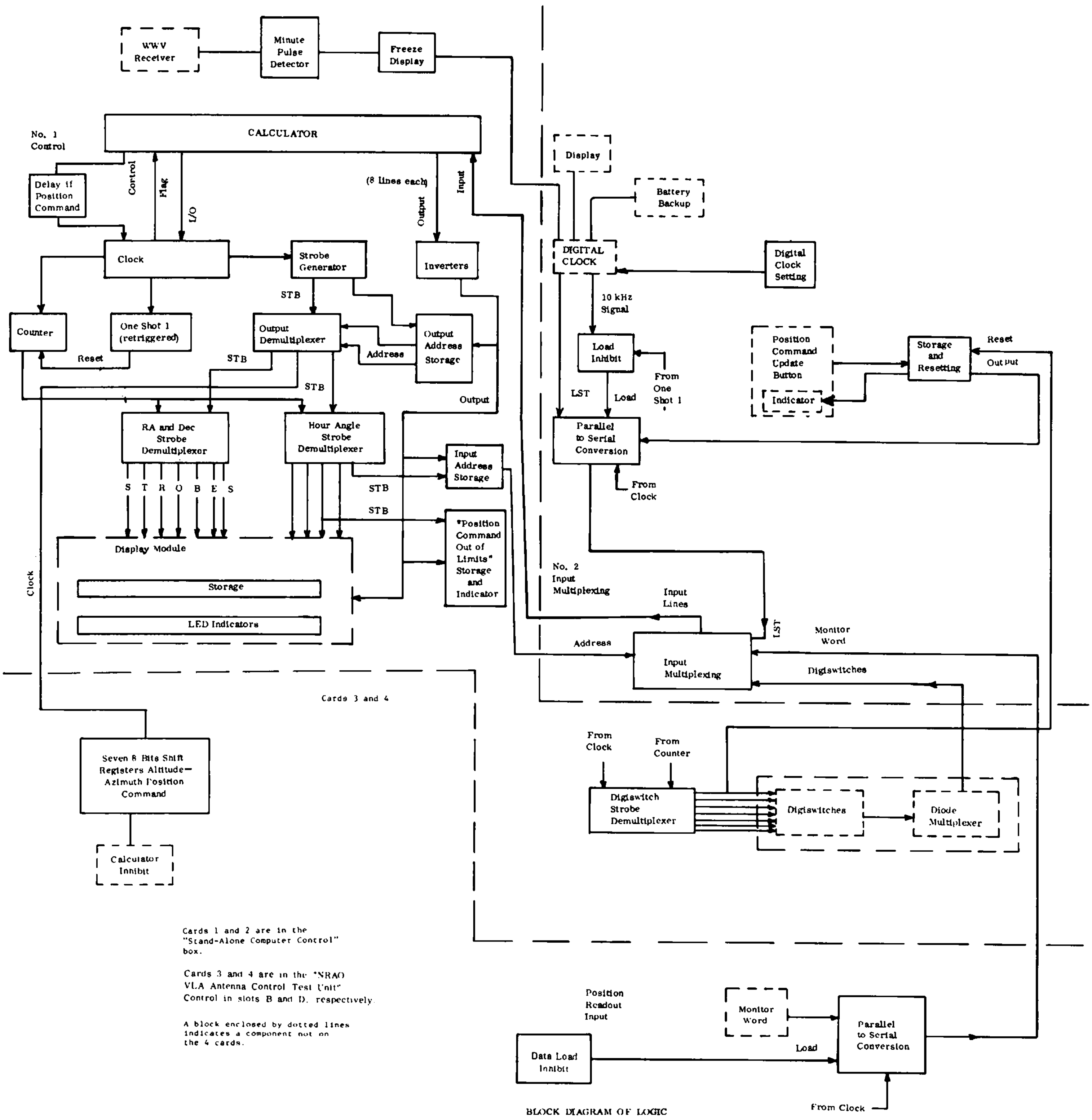
CARD 1 CONTROL

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 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, through two gates, 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 Shmitt 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

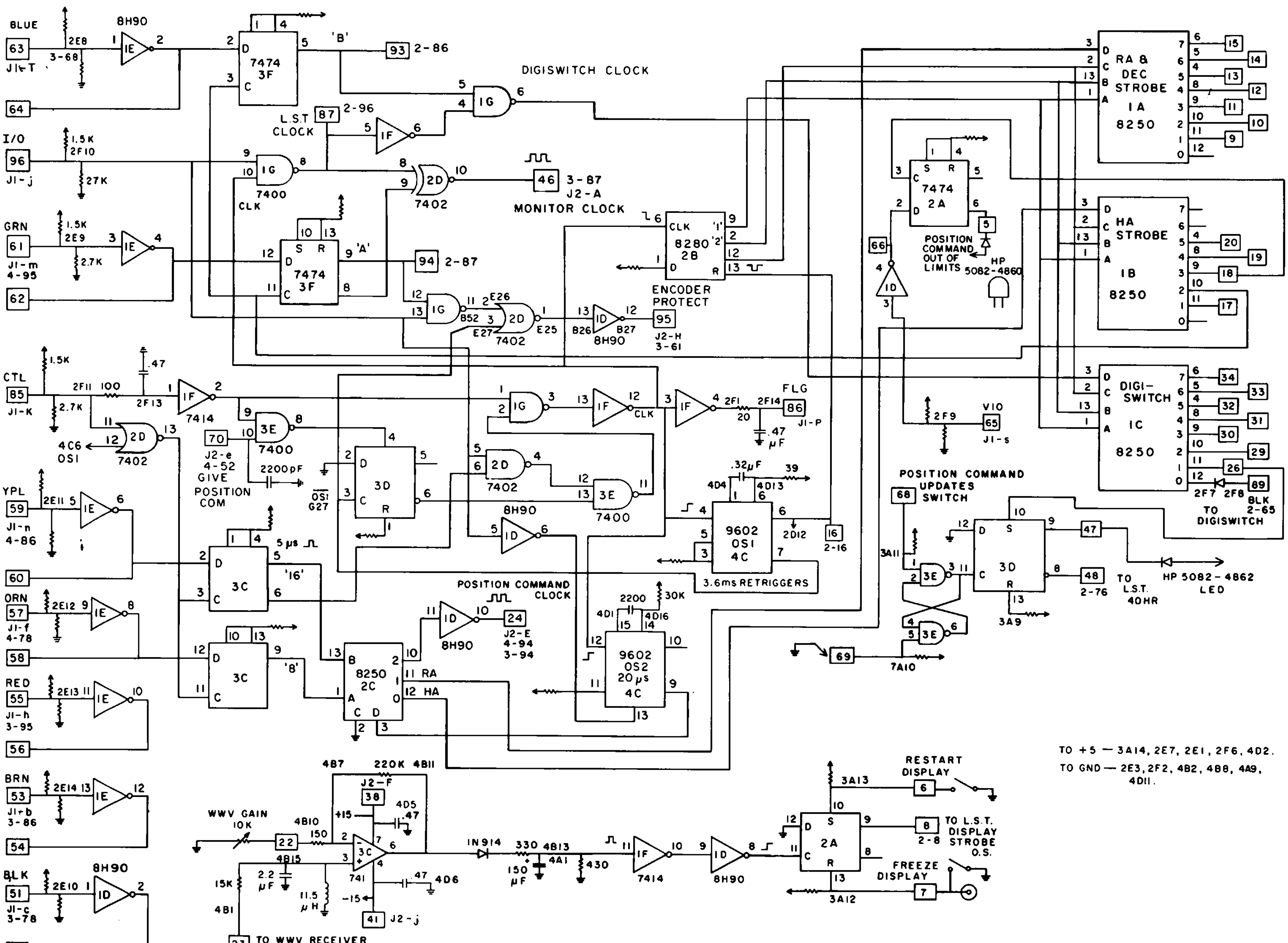


Cards 1 and 2 are in the "Stand-Alone Computer Control" box.

Cards 3 and 4 are in the "NRAO VLA Antenna Control Test Unit" Control in slots B and D, respectively.

A block enclosed by dotted lines indicates a component not on the 4 cards.

BLOCK DIAGRAM OF LOGIC



CARD-1 CONTROL

5

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 twenty 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 twenty 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	0	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 "+" 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.

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

The 16 and 8 bits of the exponent specify the output device. The two flip flops in 3C store this output address. Due to the RC delay there is a time lag from when CTL goes low to when OS1 goes high. The NOR of 2D-13 provides the address strobe pulse at the beginning of the output when CTL and OS1 are both low. This address goes to the demultiplexer in position 2C. An exponent of 0 to 7 indicates the hour angle output. Eight to fifteen indicates the right ascension and declination. Sixteen to thrity-one indicates the Position Command Output. 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. The display wiring can be seen on page 14 of NRAO Electronics Division Internal Report #128.

OS2 is fed to the one of four demultiplexer in position 2C 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 block. The hour angle is output as the third through eighth 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 3F. The "Position Command Out of Limits" light is activated by the 80 hr. bit of the hour angle.

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.

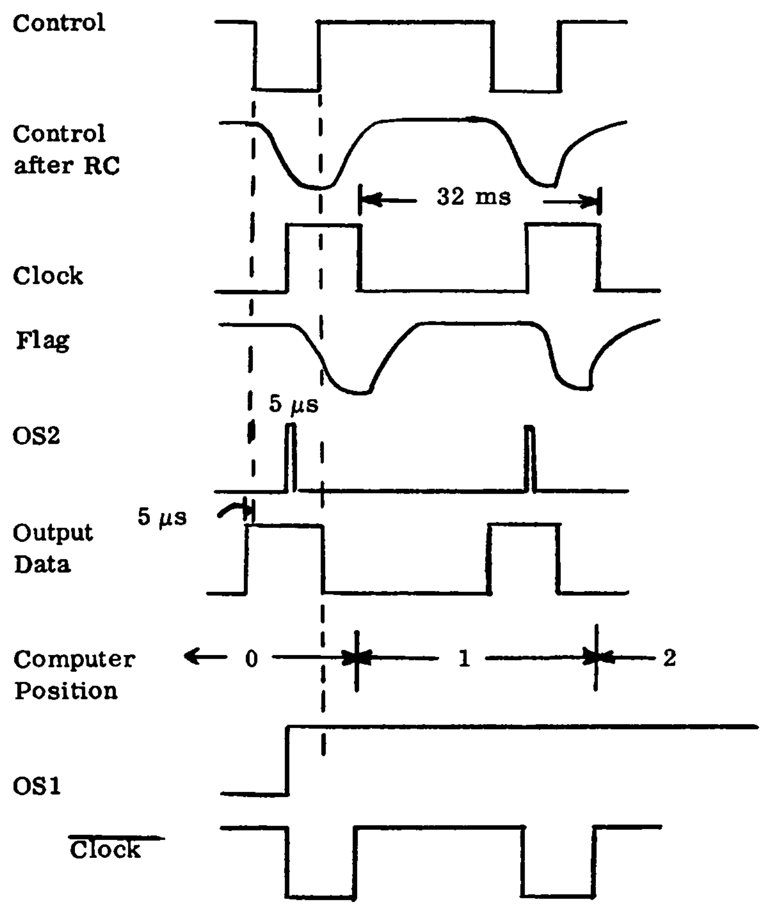
The "Encoder Protect" signal goes low when the calculator is in input mode, the input multiplexer is set to the "Monitor Word Input Port", and OS1 is low. (i.e. When the Monitor Word is being input.)

The Position Command must be shifted into its shift-registers when they are not being read. The Antenna Control Test Unit supplies a five micro-second positive pulse every ten milli-seconds. When the pulse is not on, the data may be shifted in. If the output address is set to the Position Command and the I/O line is low for output, the NOR of 2D4 goes high. The inverted output of flip-flop 3D5 will be high from the clocking action of the trailing edge of the previous firing of $\overline{OS1}$. NAND 3E11 gates these to give a low to the input of NAND 1G3. (See the Position Command Output Timing Diagram, page 9.) Thus 1G3 remains high even though Control has gone low, so the calculator waits. The five microsecond pulse is gated so as not to act when control is high.

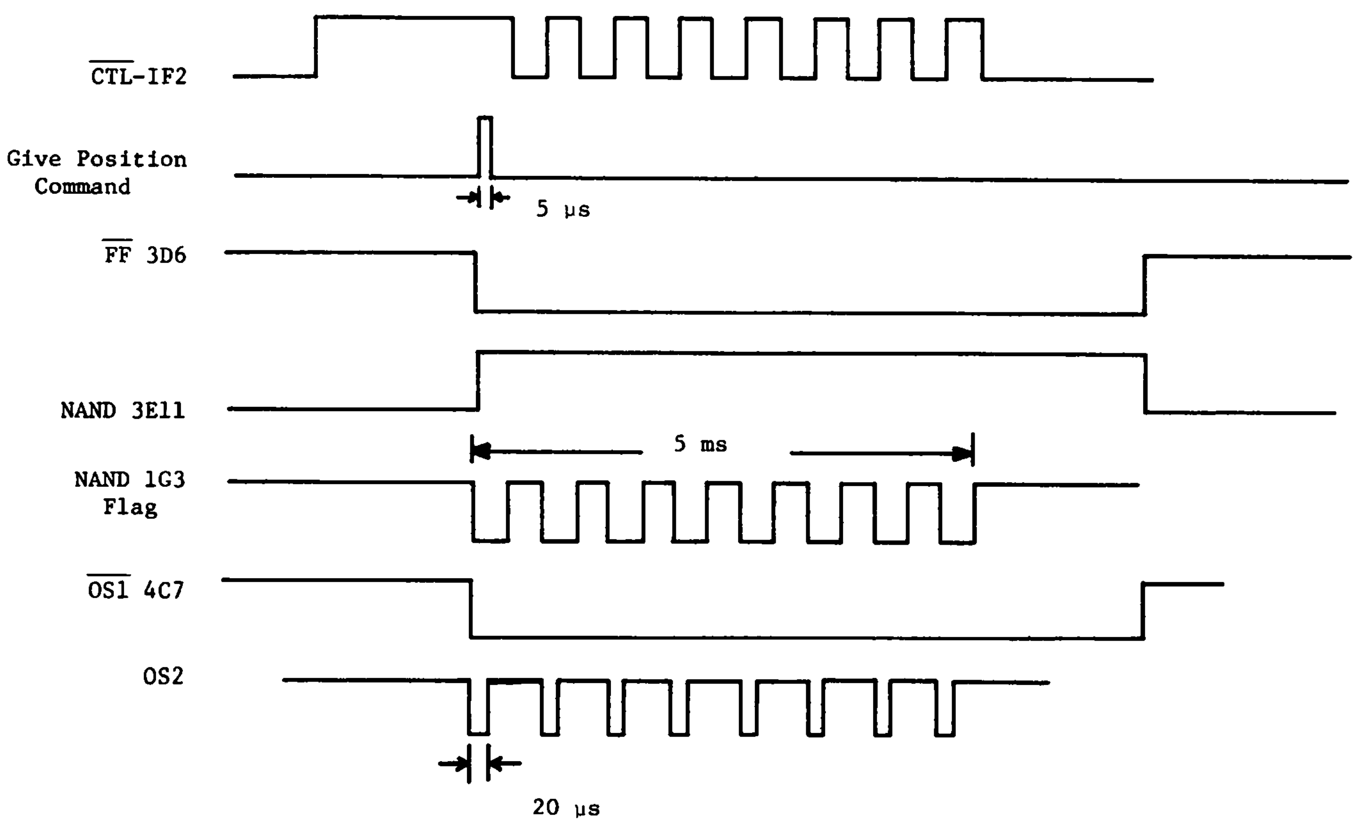
When Control is low, the pulse then sets FF 3D5. This drives NAND 3E11 high and allows the Flag command through. The trailing edge of OS2 clocks the shift registers.

I/O is gated with the Clock to provide a distinct clock for input operations. This is necessary because the Monitor Word 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

TIMING DIAGRAM I



POSITION COMMAND OUTPUT TIMING DIAGRAM



at a 10 kHz rate, so has time to recover. The digiswitches and Monitor Word each need another gate for the exclusive use of a clock. On the digiswitches, this prevents the "Position Command Update" switch from being reset before the digiswitches have been read. Since the Monitor 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", "Monitor Clock", and the "Encoder Protect" derive their signals by appropriate gating with the address flip-flops of the Input Multiplexing.

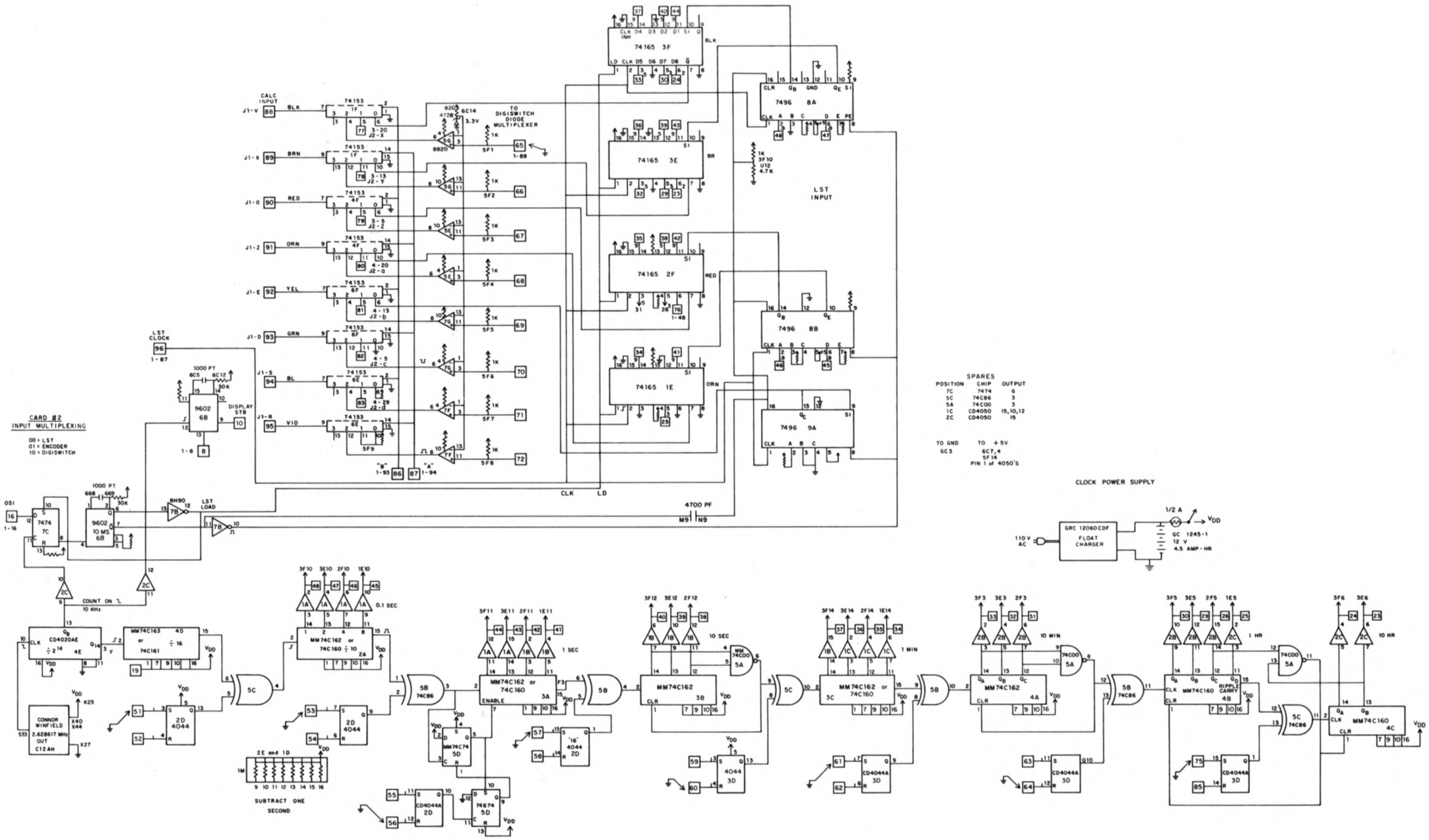
FF 2A9 freezes the clock display when low. The clock still keeps the correct time. The display can be frozen by the front panel pushbutton or by the plug-in extension pushbutton. There is a Restart button on the front panel, also.

A Carigella Standard-Time Receiver is used to receive WWV. A suitable antenna should be provided. WWV provides a 5 millisecond, 1000 Hz pulse every second and a 0.8 second, 1000 Hz pulse at the beginning of each minute. The one minute pulse is used to freeze the display.

The receiver audio output goes into a 1000 Hz tuned amplifier. The amplifier output is rectified and goes into a 50 millisecond RC filter, then a Schmitt Trigger. This filters out the 5 ms. second pulses. The digital signal clocks the flip-flop and freezes the display. The front panel amplifier gain control should be used in conjunction with the volume control to set the triggering level.

CARD 2 - INPUT MULTIPLEXING

There are two input modes used in the sytem. 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
00 = LST
01 = ENCODER
10 = DIGISWITCH
CALC INPUT
TO DIGISWITCH DIODE MULTIPLEXER
LST INPUT
LST CLOCK
LST LOAD
DISPLAY STB
COUNT ON
10 KHz
SPARES
POSITION CHIP OUTPUT
7C 7474 6
5C 74C86 3
5A 74C00 3
1C CD4050 15,10,12
2C CD4050 15
TO GND TO +5V
6C3 6C7,4
5F14
PIN 1 of 4050'S
CLOCK POWER SUPPLY
GRC 12060CDF FLOAT CHARGER
110 V AC
1/2 A
GC 1245-1
12 V
4.5 AMP-HR
SUBTRACT ONE SECOND
0.1 SEC
1 SEC
10 SEC
1 MIN
10 MIN
1 HR
10 HR
CONNOR WINFIELD
2.628617 MHz
4700 PF

The digiswitches are wired as shown on page 17 of Electronics Division Internal Report #128. The 40 hour bit is permanently on as a placeholder. 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. Diodes on the digiswitches 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 input multiplexing addresses given from Card 1 are as follows: 00 is the Local Sidereal Time; 01 is the Monitor Word; 10 is the digiswitches. The multiplexers output into the calculator input lines in negative logic

Card 2 also contains the CMOS Local Sidereal Time digital clock. It is powered by a lead-acid battery with a float charger. Leave the charger plugged in at all times. If this is not possible, turn OFF the clock, then recharge the battery every six months. The clock will remain running for about six days after a power failure. A 2.628617 MHz oscillator is divided by 2^{18} to give a tenth sidereal second or 10.027379 Hz clock. This is divided to hours, minutes, seconds, and tenth seconds. Note the 74C162 has synchronous clear while the 74C160 has an asynchronous clear.

The seven switches under the clock add to the digits by delivering an extra pulse to the respective counter. Note that carrying is still in effect. Caution should be exercised in using the 10 hours switch since it is possible to increment to 28 or more hours if the resetting 24 hours is skipped. The Subtract One Second Switch causes the second counter to be disabled during one of its pulses. This switch should not be depressed more than once per second.

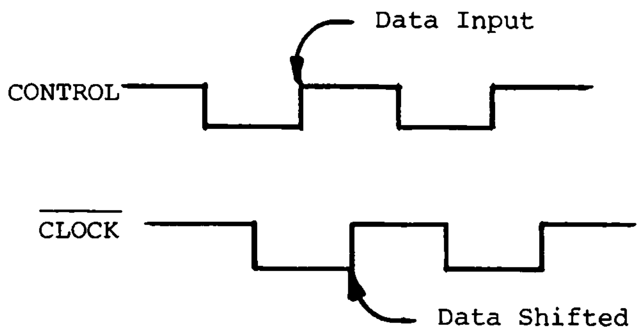
The L.S.T. Display chips are strobed on the positive edge of the 10 kHz signal by a one shot. Counting occurs on the negative edges. The buffers provide the necessary drive power for TTL. Inhibiting the one-shot freezes the display.

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	UP
4	0	0	1	1	0	-	-	5	
5	0	0	1	1	-	-	-	9	
6	0	0	1	0	1	1	0	0	UP
7	0	0	1	1	0	-	-	5	
8	0	0	1	1	-	-	-	9	
9	0	0	1	0	1	1	1	0	
10	0	0	1	1	-	-	-	9	
11	0	0	1	1	1	1	1	1	END
	V	B	G	Y	O	R	Br	Bl	

The first three columns are hard-wired at the Input Multiplexer. The last five columns represent shift registers outputing to the Input Multiplexer. The last rows are gained by tying one-half of a 7496 shift register in each of the columns. The first and second, fourth and fifth, and the seventh through tenth rows input the hours, minutes, and seconds, respectively. The third and fifth rows perform and "up" operation. The ninth row is a decimal point. The eleventh 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 rising edge of a 10 kHz signal from the digital clock. The loading is inhibited when OS1 from card 1 is high. 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, $\overline{\text{Clock}}$ goes high and new data is shifted to the input lines.

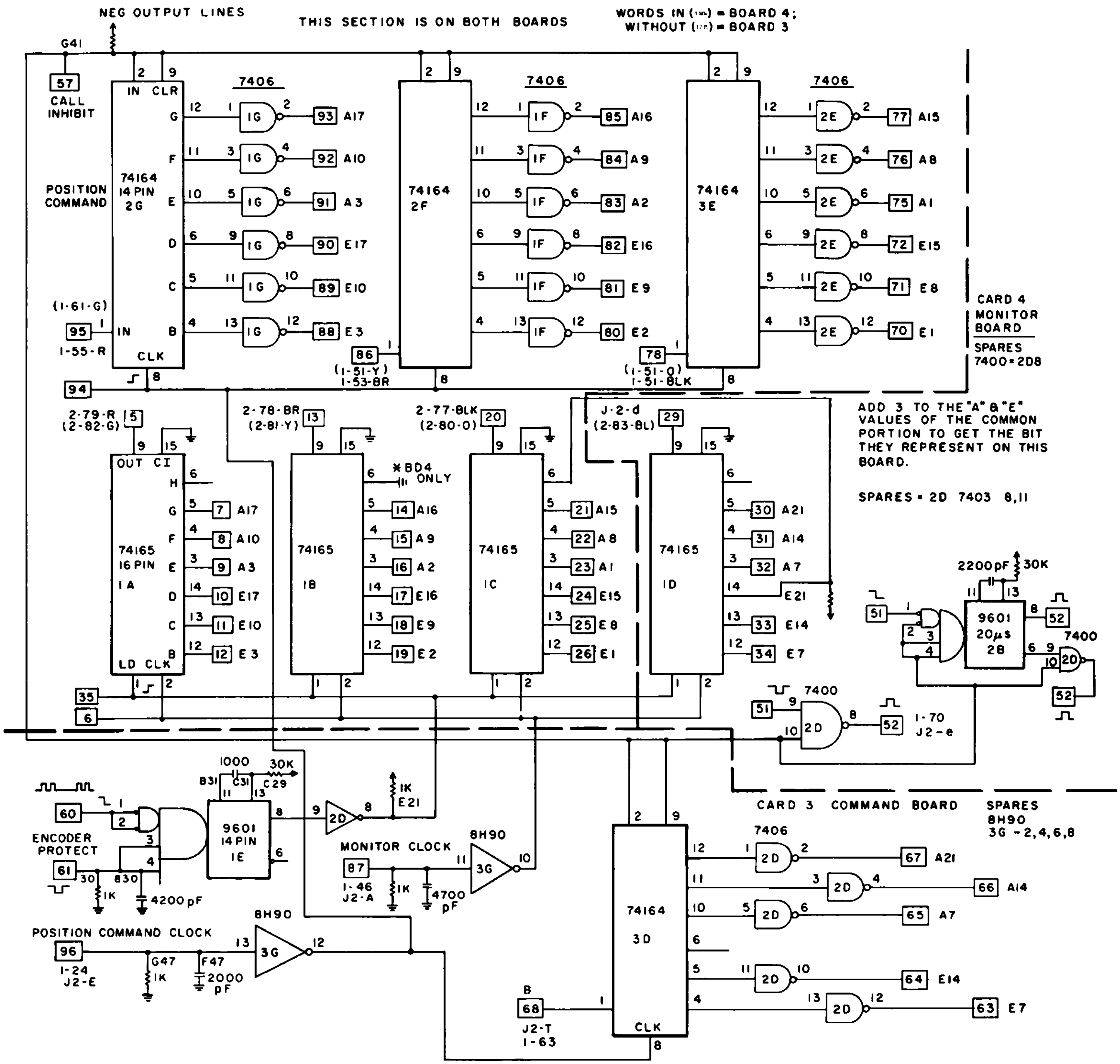


CARD 3 - COMMAND BOARD AND CARD 4 - MONITOR BOARD

The Position Command is output and the Monitor Word is input in the following 64-bit block:

	STORAGE REGISTER	128	64	32	16	8	4	2	1
	7	X	X	X	1	0	X	X	X
AZIMUTH	6	0	MSB	20	19	18	17	16	15
AZIMUTH	5	0	14	13	12	11	10	9	8
AZIMUTH	4	0	7	6	5	4	3	2	LSB
ELEVATION	3	0	0	MSB	19	18	17	16	15
ELEVATION	2	0	14	13	12	11	10	9	8
ELEVATION	1	0	7	6	5	4	3	2	LSB
	0	X	X	X	X	X	X	X	X
		V	B	G	Y	O	R	BR	BLK
MONITOR WORD CHIP POSITIONS			4-1D	4-1A	4-1B	4-1C	3-1A	3-1B	3-1C
POSITION COMMAND CHIP POSITIONS			3-3D	4-2G	4-2F	4-3E	3-2G	3-2F	3-3F

X means it doesn't matter what the level is.


NEG OUTPUT LINES
THIS SECTION IS ON BOTH BOARDS
WORDS IN ( ) = BOARD 4;
WITHOUT ( ) = BOARD 3
CALL INHIBIT
POSITION COMMAND
74164 14 PIN 2G
74164 2F
74164 3E
7406
CARD 4 MONITOR BOARD
SPARES 7400-2D8
ADD 3 TO THE "A" & "E" VALUES OF THE COMMON PORTION TO GET THE BIT THEY REPRESENT ON THIS BOARD.
SPARES = 2D 7403 8,11
74165 16 PIN 1A
74165 1B
74165 1C
74165 1D
*BD4 ONLY
9601 20µs 2B
7400
ENCODER PROTECT
9601 14 PIN 1E
MONITOR CLOCK
8H90
POSITION COMMAND CLOCK
74164 3D
CARD 3 COMMAND BOARD
SPARES 8H90 3G - 2,4,6,8

Note that the upper-left of the schematic contains the logic that is identical on both boards. That is columns 1, 2, and 4 of Card 3 or columns 8, 16, and 32 of Card 4. Board 3 also contains the Position Command, 128 column, while Board 4 contains the Monitor 128 column.

The Position Command is shifted into 74164 shift registers. The 7406's invert the output and are open-collector so they can be wire-ored. The Calculator Inhibit line when grounded clears all the shift registers. This gives all ones on the open-collectors.

A five micro-second pulse from the Antenna Control Test Unit every 10 ms. delays the calculator until it is safe to read the Position Command, as explained in the logic of Card 1. NAND 2D8 on Card 4 gates this pulse with the Calculator Inhibit signal so that the calculator is not delayed if the the Calculator Position Command is inhibited.

The negative edge of a 20 Hz signal from the Antenna Control Test Unit fires the one-shot on Card 3, which loads the Monitor Word into 74165 shift-registers. The one-shot is not fired when the Encoder Protect signal is low. This prevents the shift registers from being loaded while the data is being shifted out.

The commands 3 FMT 4 2 XTO sets the input address to the Monitor Word. Then FMT 3 2 XFR UP FMT 6 X^2 inputs the Monitor Word and places the decimal equivalent of each row into the storage register indicated on the chart.

Having 16 in register 7 gives the 64-bit block the equivalent of an exponent of 16 to set the output address to the Position Command. Keying FMT 6 1/x DN FMT 4 2 XTO converts the binary equivalent of the numbers stored in registers 0-7 into a 64-bit block and outputs it as the Position Command.

The Position Command is output in positive logic. The Monitor Word is input in negative logic.

PROGRAM EXPLANATION

The program is made up of several subroutines organized as shown in the block diagram. An explanation of the block diagram follows. 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.

Definitions:

Hour Angle - The angle, in hours, centered at the pole, from the zenith to the source. Positive 0-12 hours is to the west. Negative 0-12 hours is to the east.

Right Ascension - Sidereal time minus the hour angle. 0 to 24 hours.

Declination - Angle from the celestial equator to the source. Positive to the north. +90° to -90°.

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

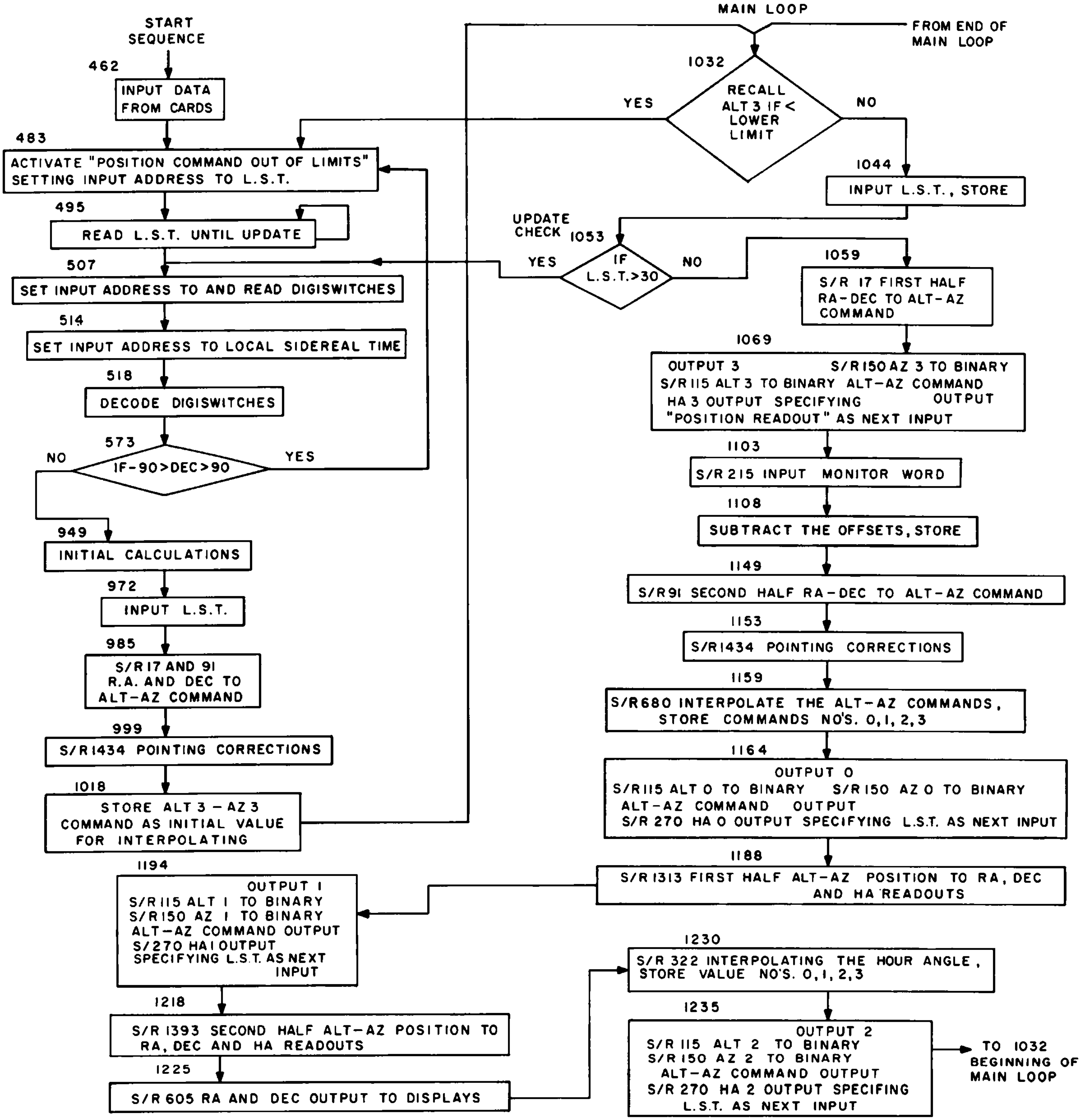
The initialization sets up the logic to the proper addresses.

The time is next read continuously in a loop. The "Update" button being pushed adds 40 hours to the time and allows exit from the loop. The digiswitch twelve digits have been input into one register and now have to be decoded into the decimal r.a. and a decimal dec.

If the absolute value of the declination is greater than ninety, the "Position Command Out of Limits" light is activated and the time 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 input again. Subroutines 17 and 91 calculate an Altitude-Azimuth Command from the r.a., dec., and time. Subroutine 1434 adds constant



PROGRAM BLOCK DIAGRAM

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 time continuously read.

If the altitude is legal, the local sidereal time is input and stored. If the time is greater than 30 hours, the UPDATE switch has been pushed and the program branches back to the Decode Digiswitch section. If not, Subroutine 17 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 115 then converts Alt. 3 to a three digit, base 128 number. Azimuth 3 is similarly recalled. Subroutine 150 converts it to a three digit, base 128 number, then converts the entire position command to binary and outputs it 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 215 inputs the Altitude and Azimuth Monitor Word in binary and converts them to decimal. Offsets are subtracted and the values stored.

Now, Subroutine 91 completes the second half of the R.A.-Dec. to Alt.-Az. Command calculation.

Subroutine 1434 adds constant offsets stored in registers 54 and 55 to the altitude and azimuth commands. $360/2^{21}$ was added to each of these to facilitate rounding off. A variable refraction correction is then added to the altitude.

To the Azimuth offset in 54, also add -60° if the scope is on the southwest leg, -119° for the southeast leg, or -180° for the north leg. The total offset must be between -269° and +90°.

Subroutine 680 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. A fuller explanation will later be given.

Output Block 0 outputs Alt. 0, Az. 0, and H.A. 0 in the same format as Output Block 3.

Subroutine 1313 is the first half of the Alt.-Az. Position to R.A., Dec., and H.A. Readouts calculation. Output 1 follows. Subroutine 1393 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 322 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.

In Electronics Division Internal Report No. 128, "45-Foot Stand-Alone Computer Control", the flow chart of S/R 23 applies to S/R 17 in this report. Likewise S/R 78 applies to S/R 91 here, S/R 94 to S/R 1313, S/R 189 (from step 203 down) to S/R 1393, S/R 323 to S/R 322, S/R 605 to S/R 605 here, and S/R 1434 to S/R 1434.

The subroutines may be used independently also. First press END to clear any subroutine return addresses. To use a subroutine, GO TO the beginning of it, then press CONTINUE.

Examples:

To output a binary Position Command given one in degrees, using Subroutines 115 and 150:

Key - GO TO LBL 1 (enter elevation) CONTINUE GO TO LBL 2 (enter Azimuth) CONTINUE

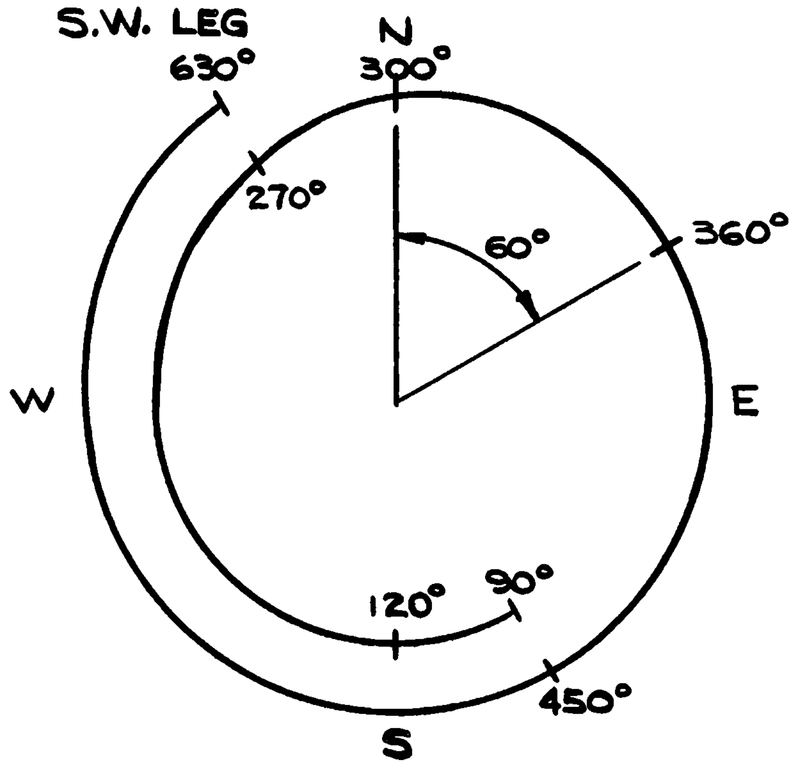
To input the Monitor Word in degrees:

Key - GO TO 0215 CONTINUE. The Altitude will now be in Z and the Azimuth in Y.

PROGRAM BLOCK LOCATIONS

STEP NUMBERS	BLOCK NAME
0000-0002	Go to Start Sequence
0003-0011	Part of Subroutine 91
0017-0084	Subroutine 17 - First Half R.A.-Dec. to Alt.-Az. Command
0091-0109	Subroutine 91 - Second Half R.A.-Dec. to Alt.-Az. Command
0115-0142	Subroutine 115 - Altitude to Binary
0150-0185	Subroutine 150 - Azimuth to Binary and Alt.-Az. Command Output
0190-0206	Redefining the Latitude
0215-0260	Subroutine 215 - Input 'Monitor Word', Convert to Decimal
0270-0307	Subroutine 270 - Hour Angle Output specifying Local Sideral Time as next input
0322-0444	Subroutine 322 - Interpolating the Hour Angle
0454-0600	First Half Start Sequence
0605-0665	Subroutine 605 - R.A. and Dec. Output to displays
0680-0756	Subroutine 680 - Interpolate the Alt.-Az. Commands
0942-1031	Second Half Start Sequence
1032-1263	Main Loop
1266-1305	Subroutine 1266 - Hour Angle Output specifying Position Readout as next input
1313-1372	Subroutine 1313 - First Half Alt.-Az. Position to R.A., Dec., and H.A. Readouts
1393-1424	Subroutine 1393 - Second Half Alt.-Az. Position to R.A., Dec., and H.A. Readouts
1434-1587	Subroutine 1434 - Pointing Corrections
1588	End

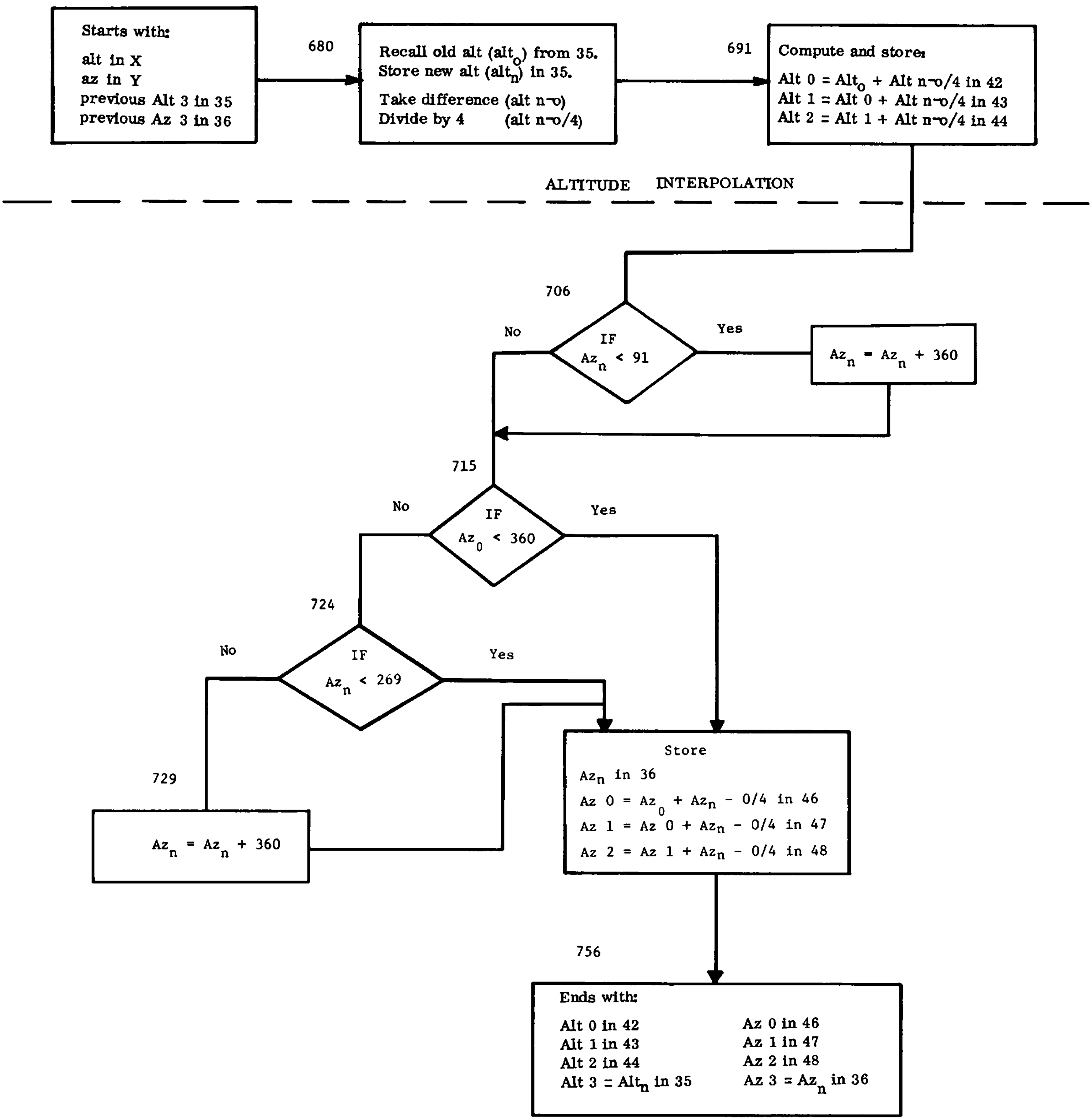
The spaces between blocks are empty.



S/R 680 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 90° to 630° as shown above. This assumes the telescope can rotate 270 degrees to either side of 360 degrees. Note: It takes a command of 300° to point due north due to the 60° offset. In the Start sequence, at step 1013, 360 degrees is added to the azimuth if it is less than 91 degrees. This has the effect of always starting a source tracking on the CCW portion of the above spiral. If a source had an azimuth of 90 degrees it would start at 450 degrees on the spiral. It could not run into the counter-clockwise limit of 90 degrees, since, in the northern latitudes, sources in the south track only from east to west.



S/R 680 INTERPOLATE THE ALT-AZ COMMANDS

If statement 706 prevents an impossible Azimuth of less than 91 degrees. An imaginary switch, located at 360 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 715 determines the state of the switch by testing whether the previous Azimuth command was greater than or less than 360°.

If Statement 724 tests for the clockwise limit of 629 degrees. If this is hit, the scope is rewound 360 degrees by the 360 not being added.

The net result is the Azimuth Command tracks continuously around the spiral, unless a limit is hit, then appropriate rewinding is taken.

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:

<u>Model 9810A Calculator Operating and Programming</u>

<u>Hewlett-Packard 9810A Calculator Mathematics Block Operating Manual</u>

<u>Hewlett-Packard 9810A Calculator Peripheral Control Operating Manual</u>

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

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

STEP NO.	FUNCTION	X	Y	Z	REMARKS
0000	GTO LBL A				
		FIRST HALF START SEQUENCE			
454	LBL A STOP				The STOP and PSE's allow recycling time for the calculator.
457	5 FMT 42 XTO	5			Sets input address to digiswitches and turns off 'Position Command Out of Limits' L.E.D.
462	FMT XFR PSE PSE PSE	PSE			Input the data card.
467	FMT 32 XFR				Input digiswitches to clear 'Update' command.
471	FMT 4·1·4				Set to fixed 4 mode.
477	LBL B				
479	1.08 FMT 42 XTO	1.08			Sets input address to L.S.T. Turns on 'Position Command Out of Limits' L.E.D.
487	CLR 360 XTO b				Clears flag.
493	LBL C				
495	FMT 32	59	59	23	Input L.S.T. until 'Update' switch pushed.
499	DN 30	30	23		
502	X>Y LBL C LBL D				
507	5 FMT 42 XTO				
512	CLX UP FMT 32 XFR	-63.5959895959	0		Input digiswitches.
518	UP RUP X>Y SFL CNT CNT CNT	0	-63.59598960	-63.5959895959	If declination negative, sets flag.
525	FMT 42 XTO	0	-63.59598960	-63.5959895959	Sets input address to L.S.T.
529	DN 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.
531	DN UP	63.5959895959	63.5959895959		
533	INT	63.00	63.5959895959		
534	-	63.	.5959895959		
535	RUP		63	.5959895959	
536	40-	40	23	.5959895959	Subtracts 40
539	EEX 2 RUP	.5959895959	100	23	
542	X DN UP	59.59895959	59.59895959	23	
545	INT-	59.00	.59895959	23	
547	XEY	.59895959	59	23	
548	XFR X 28	59.895959	59	23	28 contains 100
552	XTO a	59.895959	59	23	Stores declination information
554	INT	59	59	23	
555	K6 (TABLE 6)	23.9997	0	0	Converts to decimal hours
557	UP 15 X	15	359.996		Converts to decimal degrees
561	YTO 10 a	59.895959			Stores r.a. in 10. Recalls dec.
565	UP INT	59	59.895959		
567	-EEX 2 X	100	89.5959		
571	90 X<Y GTO LBL B CNT	90	89.5959		If |dec| >90 go to 'Position Command Out of Limits'
578	DN UP INT	89	89.5959		
581	-	89	.5959		
582	UP EEX 2	100	89	.5959	
585	RUP X	.5959	59.59	89	
587	DN UP INT	59	59.59	89	
590	-	59	.59	89	
591	XEY XFR X 28	59	59	89	28 contains 100
596	K6	89.9997			Converts to decimal declination
598	GTO LBL F				

STEP NO.	FUNCTION	X	Y	–	REMARKS
		SECOND HALF START SEQUENCE			
942	LBL F				
944	IFG	89.9997	0	0	Makes declination proper sign
945	CHS CNT CNT CNT	-89.9997	0	0	d = declination
949	UP M(SIN) XTO 92	sin (d)	d		Does initial calculations
954	XFR X93 XTO 8	sin d sin ϕ	d		ϕ = latitude
960	DN N(COS)	cos d			
962	XFR X94 XT09	cos d cosϕ			
968	CLX XTO 61	0			Initializes counter used in refraction correction.
972	FMT 32.	59	59	23	INPUT LST
976	K6 UP	23.9997	23.9997	0	Converts to decimal hrs.
979	4 EEX 4 CHS -	4 x 10^{-4}	23.9993		Subtracts 1.4 sec to allow for the time from inputing LST to Output 3
984	DN GTO S/R 23	24.0	0	0	Calls Subroutine 17
		S/R 17 - FIRST HALF R.A. AND DEC. TO ALT.-AZ. COMMAND			
17	XFR + 39 XTO 91	24			39 = Time Offset
24	XFR X 11	360	0	0	15 in 11. Converts to LST in degrees.
28	XFR - 10	H.A.	0		H.A.= L.S.T. - R.A.
32	X<Y XFR + b CNT	HA	0	0	Adds 360 if HA is negative so as to make it a positive number.
37	XT097 N(cos)	cos HA			
41	XFR X 9	cos d cos ϕ cos HA			
44	XFR + 8	sin d sin ϕ + cos d cos ϕ cos HA			This equals cos(z) z=zenith angle
47	XTO 95 UP	cos z	cos z		
51	XSQ UP 1	1	$\cos^2 z$	cos z	
54	-90	90	$\cos^2 z - 1$	cos z	
58	RUP L (arc) N (cos) -	z	90 - z	$\cos^2 z - 1$	90 - z = alt = a
61	RUP √	$\sqrt{(\cos^2 z - 1)}$	z	a	$\sqrt{-\cos^2 z - 1} = \sqrt{1 - \cos^2 z} = \sin z$ (This method is much faster for getting sin z)
63	XFR X94	cos ϕ sin z	z	a	
67	XTO a XFR 92 XEY	z	sin d	a	
72	XFR 95	cos z			
76	XFR X 93	sin ϕ cos z	sin d	a	
80	-a	cos ϕ sin z	sin d - sin ϕ cos z	a	
82	DIV		cos Az	a	$\frac{\sin d - \sin \phi \cos z}{\cos \phi \sin z} = \cos(Az)$
83	DN S/R	cos Az	a	a	
989	GTO S/R 91	cos Az	a	a	
		S/R 91 - SECOND 1/2 R.A. AND DEC TO ALT-AZ COMMAND			
91	L (arc) N (cos) UP	Az	Az	a	
94	XFR 97 YE 96	H.A.	180	a	
100	X<Y 3 XXX	H.A.	180	a	By testing the HA the direction of the azimuth is found
3	b	360	180	a	
4	XFR-96	360-Az	180	a	if Az to west, then Az = 360-Az.
8	YE 96 S/R	360-Az	Az	a	It is necessary to return 180 to 6.
		HA	180	a	
105	YE96	HA	Az	a	Az to east.
108	XEY S/R	Az	HA	a	
993	RUP XTO 90	a	Az		Initialization
997	RUP RUP	Az		a	
999	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	?	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 up date 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 1580				
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 1580				
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 + 90 XSQ XSQ	$(a + 2.7)^4$	40	$r_1 + r_2$	
1573	DIV DN-	$\frac{40}{(a + 2.7)^4}$	$r_1 + r_2 + r_3$	$r_1 + r_2$	
1576	XFR 16	Az	$r_1 + r_2 + r_3$		
1579	XEY	$r_1 + r_2 + r_3$	Az		
1580	XTO 49				Store variable alt offset in 49.
1583	XFR + 90 S/R END	$a + r_1 + r_2 + r_3$	Az		Set $a = a + r_1 + r_2 + r_3$
1005	UP	a	a	Az	
1006	091 YTO 35	91	a	Az	091 = C.C.W Limit of scope rotation.
1012	RUP	Az	91	a	
1013	X<Y XFR + b CNT				If Az >91 adds 360 to Az
1018	XTO 36	Az			Store Az in Az 3
1021	EEX 2	100			Initializes values of H.A.
1023	XTO 37 XTO 12 XTO 15				

MAIN LOOP

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1032	XFR 35 UP XFR 25	5	Alt 3		Reg. 25 = lower alt. limit.
1039	X>Y GTO LBL 8 C To activate "Position Command Out of Limits"				Tests if below minimum altitude.
1044	FMT 32.	59	59	23	Inputs LST
1048	K6 UP 30	30	23.999	0	Checks to see if the UPDATE switch has been pushed, making the LST >30.
1053	X<Y GTO LBL D D				
1058	DN	23.999			
1059	GTO S/R 17				

S/R 17 FIRST 1/2 R.A.-DEC. TO ALT-AZ COMMAND (See earlier description)

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1063	YTO 95 XTO 43	cos Az	a	a	

OUTPUT 3

STEP NO.	FUNCTION	X	Y	Z	REMARKS
1069	XFR 35 GTO S/R 115	a_3	a	a	

S/R 115 ALTITUDE TO BINARY

STEP NO.	FUNCTION	X	Y	Z	REMARKS
113	LBL 1	Alt_3=45.32°			
115	XFR X26 UP	8.06	8.06		$26 = \frac{64}{360}$
120	INT - XTO 3	8	.06		Converts to base 128
125	CLX 128 X	128	7.28		
129	UP RUP UP INT	7	7.28	128	
133	-XTO 2 DN	.28	128	128	
137	X DN INT XTO 1 S/R	36	128	128	
1077	XFR 36 GTO S/R 150	Az_3			

STEP NO.	FUNCTION	X	Y	Z	REMARKS
		S/R 150 - AZIMUTH TO BINARY AND ALT-AZ COMMAND OUTPUT			
148	LBL 2	Az_3=526.4			
150	XFR X26 UP	93.58	93.58		
155	INT - XTO5	93	.58		
160	CLX 128 X	128	74.52		
164	UP RUP UP INT	74	74.52		
168	- XTO 5 DN	.52	128	128	
172	X DN INT XTO 4	67	128	128	
177	FMT 6 1/X DN				Converts reg 0-7 to binary number. See the
181	FMT 42 XTO S/R				Peripheral Control Operating Manual for explanation of the FMT G Commands
1035	XFR 37 GTO S/R 1266	HA 3			S/R 1266 - H.A. Output Specifying Position Readout as next input.
1266	K7 INT	36	42	11	INT prevents 60 seconds from being output
1269	YE X 28	36	4200	11	28=100
1273	+	36	4236	11	
1274	DN YE X 29 + CLX	0	114236	11	29 = 10^4
1281	X>Y 1296				If true, the sign is negative.
1286	3 EEX 7+	3×10^7	3.0114236×10^7		The 7 sets the output address to H.A.
1290	DN FMT 42 XTO S/R		3.0114236×10^7		The 3 sets the input address to the "Position Readout Interface".
1296	3 EEX 7-	3×10^7	$-3.00... \times 10^7$		
1300	DN FMT 42 XTO S/R	-3.0114236×10^7			Outputs HA
1094	55 EEX 5 CHS XTO- 91	.00055			91 = LST + reg. 55 x 10^{-5}. Extrapolates time to value at reading of Alt.-Az. Position
1103	GTO S/R 215				Going to S/R 223 instead causes the Position Command to be used for the Monitor Word.
		S/R 215 - INPUT 'MONITOR WORD' CONVERT TO DECIMAL			
215	FMT 32 XFR UP				
220	FMT 6 X^2 16384	16384			16384=128^2
228	YE6 X XFR X 3	131072	1523712		
234	UP 128 XTO X 5	128	131072	1523712	
241	XFR X2 +	896	131968	1523712	
245	YE + 1	896	132004	1523712	
248	XFR 24 X	$720/2^{21}$	45.32	1523712	
252	RUP XFR+5 XFR+4	1533251	$720/2^{21}$	45.32	
259	X S/R	1533251	526.4°	45.32°	
1108	YE - 54 CLX	0	Az_{in}	alt_{in}	Subtracts 54 = Az Offset and corrects so that the Az is between 0 and 360°.
1113	X>Y b + CNT CNT				
1118	b X<Y - CNT CNT CNT	360	Az_{in}		
1124	180 X>Y SFL CNT CNT CNT				
			Az Input	Alt Input	
1132	YTO 13	.0014	Az	alt_{in}	Az to 13
1135	DN	Az	alt_{in}	alt_{in}	
1136	YE -49	.0014	alt_{in}		49=variable alt offset
1140	YE 95 YTO 90 XFR 43	cos Az	alt command		Alt input now 95
1149	GTO S/R 91	Az		alt	
		S/R 91 - SECOND ½ RA AND DEC TO ALT-AZ COMMAND (See earlier description)			
1153	GTO S/R 1434	alt_n	Az	Counter	
		S/R 1434 - POINTING CORRECTION (See earlier description)			
1159	GTO S/R 680	alt	Az_n		
		S/R 680 - INTERPOLATE THE ALT-AZ COMMANDS			
680	UP YE 35	alt_n	alt_o	Az	Alt_n = latest value Alt_o = old value
684	XEY -	alt_o	alt_{n-o}	Az	n - o means new - old
686	YE X 40 XEY	$alt_{n-o/4}$	alt_o	Az	40 = .25
691	+YTO 42	$alt_{n-o/4}$	alt 0	Az	
695	+YTO 43		alt 1	Az	
699	+YTO 44		alt 2	Az	Alt 3 in 35
703	DN 91	91	Az_n	Az_n	
706	X>Y b + UP DN				
711	YE 36 b	360	Az_o	Az_n	
715	X>Y 0737	360	Az_o	Az_n	
720	269 RUP X>Y 0735	Az_n	269	Az_o	269 + 360° is the CW limit of scope rotation
729	XFR + b XTO 36	Az_n+360	269	Az_o	
735	RUP UP	Az_o	Az_o	Az_n	
737	DN	Az_o	Az_n	Az_n	
738	YE X40	Az_o	$Az_{n-o/4}$		
743	XEY	$Az_{n-o/4}$	Az_o		
744	+YTO 46	$Az_{n-o/4}$	Az0		
748	+YTO 47	$Az_{n-o/4}$	Az1		
752	+YTO 48	$Az_{n-0/6}$	Az2		
756	S/R				

STEP NO.	FUNCTION	X	Y	Z	REMARKS
			OUTPUT 0		
1164	XFR 42 GTO S/R 115	Az 0			
		S/R 115 - ALTITUTDE TO BINARY(See earlier description)			
1172	XFR 46 GTO S/R 150	Az 0			
		S/R 150 - AZ TO BINARY AND ALT-AZ COMMAND OUTPUT (See earlier description)			
1180	XFR 12	HAO=11.71		a	
1183	GTO S/R 270	36	42	11	HA output
1188	GTO S/R 1313				
		S/R 1313 - FIRST HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS			
1313	XFR 95 M (sin) XTO 95 UP	sin a	sin a		a = Altitude Position Readout
1321	XSQ YE X 93 UP 1	1	$\sin^2 a$	sin (a) sin ϕ	ϕ = latitude
1328	-DN SQRT	$\sqrt{\lvert\sin^2 a - 1\rvert}$	sin a sin ϕ	sin a sin ϕ	$\sqrt{\lvert\sin^2 a - 1\rvert} = \cos a$
1331	XFR X 94 UP	cos a cos ϕ	cos a cos ϕ	sin a sin ϕ	
1336	XFR 13	Az_{in}	cos a cos ϕ	sin a sin ϕ	
1339	N (cos)	cos Az	cos a cos ϕ	sin a sin ϕ	
1340	X DN +	cos a cos Az cos ϕ	sin a sin ϕ + cos a cos Az cos ϕ	= sin d	d = dec
1343	DN UP UP XSQ	$\sin^2 d$	sin d	sin d	
1347	RUP LM (arc sin) XTO a	d	$\sin^2 d$	sin d	
1352	1 - DN SQRT	cos d	sin d	sin d	
1356	XFR X94 YE X93 YE-95	cos d cos ϕ	sin d sin ϕ - sin a	sin d	
1368	DIV YTO 95 S/R		$\frac{(\sin d \sin \phi - \sin a)}{\cos d \cos \phi}$	= - cos HA	
			OUTPUT 1		
1194	XFR 43 GTO S/R 115	Alt 1			
		S/R 115 - ALTITUDE TO BINARY			
1202	XFR 47 GTO S/R 150	Az 1	73007		
		S/R 150 - AZ TO BINARY AND ALT-AZ COMMAND OUTPUT			
1210	XFR 15	HA 1			
1213	GTO S/R 270				
		S/R 270 - HA OUTPUT, SETTING INPUT ADDRESS TO LST			
270	K 7 INT	36	42	11	Assume HA 1 = 11.71
273	YE X 28 +	36	4236	11	
278	DN YE X 29 + CLX	0	114236	11	
285	X>Y 0299				
290	EEX 7 + DN	1.0114236×10^7			The 1 of EEX 7 orders LST input
294	FMT 42 XTO S/R				
299	EEX 7 - DN				
303	FMT 42 XTO S/R	-1.0114236×10^7			
1218	GTO S/R 1393				
		S/R 1393 - SECOND HALF ALT-AZ POSITION TO RA, DEC, AND HA READOUTS			
1393	24 UP XFR 95 CHS	cos HA	24		
1400	LN (arc cos) XFR X 30	HA/15 (in hrs.)	24		30 = 1/15. HA is 0 to 12 hrs.
1406	XTO 95 IFG - DN SFL CNT	HA			Changes HA to a number 0-24 hrs.
1414	YE 91	HA	LST - HA = RA		91 = LST
1418	CLX X>Y CNT 24 + S/R	0	RA		Adds 24 if RA negative.
1224	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				
1230	GTO S/R 322				

STEP NO.	FUNCTION	X	Y	Z	REMARKS
		S/R 322 - INTERPOLATING THE HOUR ANGLE			
322	XFR 95 IFG CHS CNT CNT CNT	HA			
330	XFR + 19	HA			19 = .000988 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			
1235	XFR 44 GTO S/R 115	Alt 2			
		S/R 115 - ALT TO BINARY			
1243	XFR 48 GTO S/R 150	Az 2			
		S/R 150 - AZ TO BINARY AND ALT-AZ COMMAND OUTPUT.			
1251	XFR 41 GTO S/R 270				
		S/R 270 - HA OUTPUT SETTING INPUT ADDRESS TO LST.			
1259	GTO 1032				
		TO BEGINNING OF MAIN LOOP			
		REDEFINING THE LATITUDE			
190	LBL L				
192	K6	Decimal degrees			Latitude = ϕ
194	UP M(sin) XTO 93	Sin ϕ	ϕ		Stores sin ϕ in 93
199	DN N(cos) XTO 94	Cos ϕ			Stores cos ϕ in 94
204	GTO LBL B	TO CONTINUOUSLY READ TIME			

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:

(Load Program and Constant Cards as usual)

STOP STOP

GOTO LBL L

(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 0.0001717 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.

A variable offset to the sidereal time allows the clock to be set to the sidereal time of a site, other than where the telescope is. The offset is stored in register 39 of the constant card and register 50 for the Fast Program. If an offset of x hours is desired, store in register 39 the constant x + 0.000707 hours and in 50 x + 0.000533 hours.

Example: For an offset of -42 seconds store -42/3600 + 0.000707 = -0.01096 in 39 and -42/3600 + .000533 = -0.01113 in 50.

Some constants are stored in the form of program steps. The counter-clockwise limit of scope rotation is stored as steps 1006-1008 to the nearest degree, and also in steps 704-705. The clockwise limit of scope rotation minus 360 is stored in 720-722. 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.

CONSTANT STORAGE

Storage Register	Contents	Comments
0	0	Reg 0-7 used in the FMT 6 X^2 and FMT 6 $\frac{1}{x}$ commands
1		
2		
3		
4		
5		
6		
7	16	
8	Temp command sin d sin ϕ	
9	Temp command cos d cos ϕ	
10	Temp command R.A.	
11	15	
12	Temp HAO	
13	Temp Az position readout	
14		
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	.000988 hrs. = 3560 m.s.	H.A. delay = 1 cycle (2030 ms.s) + Input Alt Az Position to Output 1 (1026 m.s.) + 500 ms since output seconds are integerized
20		
21		
22		
23		
24	$.0003433 = 720/2^{21}$	
25	Minimum altitude	
26	8/45	
27		
28	100	
29	10^4	
30	1/15	
31	.01	
32	10^8	
33	10^6	
34		
35	Temp ALT 3	
36	Temp AZ 3	
37	Temp HA 3	
38		
39	.000707 hrs.	Loop time offset = 1 cycle (2030 m.s.) + Input LST to Output 3 (514 m.s.) = 2544 m.s.

CONSTANT STORAGE (CONT.)

Storage Register	Contents	Comments
40	.25	
41	Temp HA2	
42	Temp ALTO	
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 AZO	
47	Temp AZ1	
48	Temp AZ2	
49	Temp variable alt. offset	
50	.000533 hrs.	Fast program loop time offset = 1 cycle (1.02 sec) + Input LST to Output 3 (.91 sec)
51		
52		
53		
54	Constant Azimuth offset + .0001717 $(360/2^{21})$	(-60 for SW leg, -119 for SE leg, -180 for North leg) must be between -269° and + 90°
55	.0001717	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	Temp ALT Command	
91	Temp Time Storage	
92	Temp Command sin (d)	
93	Sin ϕ - ϕ = latitude	
94	Cos ϕ	
95	Temp Command cos z, ALT Command, Input ALT, sin ALT, HA	
96	180	
97	Temp Command HA	
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	

SIDEREAL TIME PROGRAM

A program which computes the Local Mean Sidereal Time, given the date and Universal Time, is available on one of the 6 inch program cards.

The method is as in the NRAO 360 routine DSIT (=NRAO 2/1 S).

To use it, first key FMT GTO and load both sides of the card. If only one side is accepted key IF FLAG END CONTINUE then load the other side. Key STOP CONTINUE to stop the card reader motor.

INPUT OFFSET-SEC will be printed. The offset will be added to the calculated LMST.

The Equation of Equinoxes offset, which is tabulated in the beginning of the American Ephemeris, can be added to convert from Mean to Apparent Sidereal Time.

If the automatic display freezing capabilities of the WWV clock are used, adding about 0.040 second offset compensates for the RC delay after the amplifier. The delay will vary with volume and WWV GAIN settings.

The UT1 time from WWV can be off up to 0.7 seconds, before they have a leap second. The method of coding UT1 corrections uses a system of double seconds pulses. The first through the seventh seconds pulses, when doubled, indicate a "plus" correction, and from the ninth through the fifteenth a "minus" correction. The eighth seconds pulse is not used. The amount of correction in units of 0.1 second is determined by counting the number of seconds pulses that are doubled. For example, if the first, second, and third seconds pulses are doubled, the UT1 correction is a "plus 0.3 second offset". Or if the ninth, tenth, eleventh, twelfth, thirteenth, and fourteenth seconds pulses are doubled, the UT1 correction is a "minus 0.6 second offset".

Enter the sum of the above offsets, then key CONTINUE.

The month, day, year, and UT1 hour and minute will be similarly requested. The 19 in the year will be assumed if omitted.

The LMST will then be output, and the program will request a new hour and minute.

To also change the date and offset, key END CONTINUE.

A new longitude may be entered in decimal hours in register 20. To save it key FMT XTO and rerecord the second half of the card.

ALT-AZ SCANNING VERSION

This version of the program is on a separate card and again uses the same constant card. When a declination of greater than 90 is entered, while the scope is tracking a source, time-increasing offsets in azimuth and elevation are added. Azimuth and elevation rates can be varied to determine the scan speed.

The additional storage registers used in the program are as follows.

Register	Description
70	R_A - Azimuth Rate
71	R_E - Elevation Rate. The values of these change during program execution.
72	R_a - Azimuth Rate
73	R_e - Elevation Rate. These values remain constant and are to be entered by the user in degrees/sidereal hour.
74	Initial Time
75	Temporary altitude storage.

The offsets are determined by multiplying the respective rate by the time elapsed since the scan command (Updating with a declination greater than 90) has been given.

First enter the R.A. and Dec. of the source in the normal manner. The rate R_A and R_E will be set to zero, so the source will be tracked normally.

Updating with a declination greater than 90 will cause the rates to be set equal to the user stored value (i.e. $R_A = R_a$ and $R_E = R_e$ and the current time stored in 74. The Main Loop will then be reentered and the scope will scan away from the source at the prescribed rates.

Entering another command greater than 90 degrees will cause the reference time to be updated, so the command will return to the source and then once again scan away from it.

A declination less than -90 still stops the telescope and lights the Position Command Out of Limits L.E.D.

Entering a new source will reset the rates to zero. A subsequent, greater than 90 degrees, command will cause scanning away from this source.

To change a rate, enter the new rate in the x-register, then key XTO 072 for the azimuth rate or XTO 073 for the elevation rate. Negative rates can be used.

Following are the changes made in the tracking program to get this version.

CHANGES IN ALT-AZ SCANNING VERSION

STEP NO.	FUNCTION	X	Y	Z	REMARKS
	CHANGE 574-577 FROM GTO LBL B CNT TO 0770 FOR WHERE TO BRANCH WHEN THE DECLINATION IS ILLEGAL				
770	IFG GTO LBL B A				If negative dec, continuously read time
775	XFR 72 XTO 70	Az rate			R_a to R_A
781	XFR 73 XTO 71	El rate			R_e to R_E
787	FMT 32 · K6 XTO 74	LST			
796	GTO 1015				To Main Loop

INSERT THE BELOW IN THE FIRST HALF START SEQUENCE

STEP NO.	FUNCTION	X	Y	Z	REMARKS
507	XTO 70 XTO 71	0			Sets R_A = R_E = 0

BETWEEN 506 = CLX AND 513 = UP. THE ROUTINE NOW EXTENDS FROM 448-600 INSTEAD OF 454-600.
THIS SETS THE RATE = 0 FOR WHEN THE DEC. IS LEGAL.

INSERT IN THE MAIN LOOP BETWEEN 1117 = 1 and 1153 = GTO

STEP NO.	FUNCTION	X	Y	Z	REMARKS
		Az		El	
1118	RUP XTO 75	El	Az		
1122	XFR 91 XFR-74 UP	Δt	Δt	Az	91 = current time
1130	CLX X>Y CLX 24 +	0	Δt	Az	Adds 24 if negative
1136	DN UP XFR x 70 YE x 71	$R_A\Delta t$	$R_E\Delta t$	Az	
1146	YE + 75 RUP +	Az	Az + $R_A\Delta t$	El + $R_E\Delta t$	
1152	XEY	Az + $R_A\Delta t$		El + $R_E\Delta t$	

THE ABOVE PERFORMS THE SCANNING.
CHANGE 1260-3 FROM 1032 to 997 CLX WHERE THE MAIN LOOP NOW BEGINS. THE SECOND HALF START SEQUENCE NOW BEGINS AT 907 INSTEAD OF 942 (LBL F).

FAST VERSION OF PROGRAM

The Fast Version of the program on a different program card outputs the position command every quarter instead of every half second. It accomplishes this by eliminating the reverse calculation of the Monitor Word to the r.a., dec., and Hour Angle. It is identical to the original program except for the changes noted in the following sections. The R.A.-Dec. to Alt.-Az. Calculation is broken up into three instead of two sections. There is still interpolation to obtain four outputs per cycle. The same constant card is used. Loading and operating procedures are identical. The R.A. and Dec. displays reflect what was last input from the digiswitches and not the actual telescope position. The Hour Angle display is not used.

FAST VERSION PROGRAM BLOCK LOCATIONS

Step Numbers	Block Name
0000-0002	Go to Start Sequence
0003-0011	Part of Subroutine 91
0017-0050	Subroutine 17 - First Third R.A. -Dec. to Alt.-Az. Command
0051-0084	Subroutine 51 - Second Third R.A. -Dec. to Alt.-Az. Command
0091-0109	Subroutine 91 - Final Third R.A. -Dec. to Alt.-Az. Command
0115-0142	Subroutine 115 - Altitude to Binary
0150-0185	Subroutine 150 - Azimuth to Binary and Alt.-Az. Command Output
0190-0206	Redefining the Latitude
0454-0608	First Half Start Sequence
0680-0756	Subroutine 680 - Interpolate the Alt.-Az. Commands
0942-1043	Second Half Start Sequence
1044-1203	Main Loop
1434-1587	Subroutine 1434 - Pointing Corrections
1588	End

The spaces between blocks are not used.

CHANGES IN THE FAST VERSION

STEP #	FUNCTION	X	Y	Z	REMARKS
CHANGED ENDING TO THE SECOND HALF START SEQUENCE					
989	UP GTO S/R 51	cos Z	cos Z		
994	GTO S/R 91	Az		a	
998	RUP XTO 90 RUP RUP				
1004	GTO S/R 1434	a	Az		
1010	UP 091	91	a	Az	
1014	YTO35 YTO42 YTO43 YTO44	91	a	Az	
1026	RUP X<Y XFR + b CNT	Az	91	a	
1032	XTO 36 XTO 46 XTO 47 XTO 48	Az			
			MAIN LOOP		
1044	XFR 35 UP XFR 25	5	Alt 3		25 = lower alt. limit
1051	X>Y GTO LBL BC				
1056	FMT 32 ·	59	59	23	Inputs L.S.T.
1060	K6 UP 30 X<Y GTO LBL DD	30	23.999		
1070	YE+50 YTO 91		L.S.T.		
1077	XFR 42 GTO S/R 115	Alt 0			Output 0
1085	XFR 46 GTO S/R 150	Az 0			
1093 CLX UP	XFR 91 GTO S/R 24	cos Az	0		First third RA-Dec to Alt-Az
1102	XFR 43 GTO S/R 115	Alt 1			Output 1
1110	XFR 47 GTO S/R 150	Az 1			
1118	XFR 95 UP GTO S/R 51	cos Z	cos Z		Second third RA-Dec to Alt-Az
1126	YTO 95 XTO 43	cos Az	a		
1132	XFR 44 GTO S/R 115	Alt 2			Output 2
1140	XFR 48 GTO S/R 150	Az 2			
1148	YE95 YTO 90 XFR 43	cos Az	a		
1157	GTO S/R 91 XTO 95	Az		a	Final third RA-Dec to Alt-Az
1164	XFR 35 GTO S/R 115	Alt 3			Output 3
1172	XFR 36 GTO S/R 150	Az 3			
1180	XFR 90 UP UP XFR 95	Az	a	a	
1188	GTO S/R 1434	a	Az		Pointing Corrections
1194	GTO S/R 680				Interpolation
1199	GTO 1044				To beginning Main Loop
	Changes to S/R 17 - Set Step 19 = 5, 20 = 0, and 50 = S/R				
INSERTION TO THE FIRST HALF START SEQUENCE					
		$0'$	-63.59598960	-63.5959895959	
530	EEX 8 X	10^8	-6.359598960×10^9	-63.5959895959	This transfers the digiswitch input to the R.A. and Dec. displays.
533	DN FMT 42 XTO	-6.359598960×10^9	-63.5959895959		
538	G				

THE SECTION NOW ENDS 8 STEPS LATER.

WIRING LIST - PC CONNECTOR

Chassis Type STAND-ALONE COMPUTER CONTROL Rack ___ Chassis ___ Connector ___

Card Type CARD 1 - CONTROL By ___ Page ___ of ___ Rev. ___

PIN	TO	DESC.	FROM	PIN	TO	DESC.	FROM
1				51	3-78 J1-c		Blk. Output Line
2				52	Displays		$\overline{\text{Blk.}}$
3	GND			53	3-86 J1-b		Brn. Output Line
4	+5V			54	Disp.		$\overline{\text{Brn.}}$
5	P.C. Out of Limits LED			55	3-95 J1-h		Red Output Line
6	Restart Disp. Button			56	Disp.		$\overline{\text{Red}}$
7	Freeze Disp Buttons			57	4-78 J1-f		Orn. Output Line
8	2-8		Disp Strobe F.F.	58	Disp		$\overline{\text{Orn.}}$
9	Dec Sign Strobe		RA + Dec Strobe 1	59	4-86 J1-n		Yel. Ouput Line
10	RA Hrs Strobe		2	60	Disp		$\overline{\text{Yel.}}$
11	RA Min Strobe		3	61	4-95 J1-m		Grn.Output Line
12	RA Sec Strobe		4	62	Disp		$\overline{\text{Grn.}}$
13	Dec Deg Strobe		5	63	3-68 J1-t		Blue Output Line
14	Dec Min Strobe		6	64	Disp		$\overline{\text{Blue}}$
15	Dec Sec Strobe		7	65	J1-s		Vio. Output Line
16	2-16		OS1	66	Disp		$\overline{\text{Vio.}}$
17	H.A. Sign Strobe		H.A. Strobe 1	67			
18	H.A. Hrs Strobe		3	68	PC Update Sw.N.O.		
19	H.A. Min Strobe		4	69	PC Update Sw.N.C.		
20	H.A. Sec Strobe		5	70	5 µs PC Pulse 4-52 J2-e		
21				71			
22	10K Pot		741 Gain Pt.	72			
23	WWV Receiver Term #1		741 Amp.	73	GND		
24	P.C. Clock 3-96 J2-E		Demultiplexer	74	GND		
25				75			
26	Digi Dec Sign		Digiswitch STB 1	76			
27	GND			77			
28	GND			78			
29	Digi. RA Hrs		Digiswitch STB 2	79			
30	Digi. RA Min		3	80			
31	Digi. RA Sec		4	81			
32	Digi. Dec Deg		5	82			
33	Digi. Dec Min		6	83			
34	Digi. Dec Sec		7	84			
35				85	CTL J1-k		
36				86	FLG J1-p		
37				87	2-96		LST Clock
38	+15 J2-f			88			
39				89	Blk. Digi In 2-65		Diode
40				90			
41	-15 J2-j			91			
42				92			
43				93	Input Multiplexer 2-86		Input Add. B
44				94	Input Multiplexer 2-87		Input Add. A
45				95	3-61 J2-H		En Protect
46	Encoder CLK3-87 J2-A]			96	I/O J1-j		
47	Update LED			97	GND		
48	LST 40 Hr 2-76		Update F.F.	98	+5V		
49	GND			99			
50	GND			100			

WIRING LIST - PC CONNECTOR

Chassis Type: STAND-ALONE COMPUTER CONTROL — Rack ____ Chassis ____ Connector ____

Card Type: CARD 2 - INPUT MULTIPLEXING — By ____ Page ____ of ____ Rev. ____

PIN	TO	DESC.	FROM	PIN	TO	DESC.	FROM
1				51	.1 Sec NC		
2				52	.1 Sec NO		
3	GND			53	+ 1 Sec NC		
4	+5V			54	+ 1 Sec NO		
5				55	- 1 Sec NO		
6				56	- 1 Sec NC		
7				57	10 Sec NC		
8	LST STB INH1-8			58	10 Sec NO		
9				59	1 Min NO		
10	LST Disp		Strobe	60	1 Min NC		
11				61	10 Min NC		
12				62	10 Min NO		
13				63	1 Hr NO		
14				64	1 Hr NC		
15				65	Digi Out Blk 1-89		8820's
16	OS1 1-16		LST Strobing	66	Brn		
17				67	Red		
18				68	Orn		
19	Battery Supply		Vdd	69	Yel		
20				70	Grn		
21				71	Blue		
22				72	Vio		
23			20 Hr	73	GND		
24			10 Hr	74	GND		
25			8 Hr	75	10 Hr SW NC		
26			4 Hr	76	1-48 F.F.		40 Hr.
27	GND			77	Monitor S/R Blk J2-x 3-20		
28	GND			78	Monitor S/R Brn J2-y 3-13		
29			2 Hr	79	Monitor S/R Red J2-z 3-5		
30			1 Hr	80	Monitor S/R Orn J2-a 4-20		
31			40 Min	81	Monitor S/R Yel J2-b 4-13		
32			20 Min	82	Monitor S/R Grn J2-c 4-5		
33			10 Min	83	Monitor S/R Blue J2-d 4-29		
34	LST		8 Min	84			
35	Display		4 Min	85	10 Hr SW NO		
36			2 Min	86	Input Add B 1-93		Mult Add.
37			1 Min	87	A 1-94		
38			40 Sec	88	Calc J1-V Blk		Multiplexers
39			20 Sec	89	Inputs J1-X Brn		
40			10 Sec	90	J1-a Red		
41			8 Sec	91	J1-Z Orn		
42			4 Sec	92	J1-e Yel		
43			2 Sec	93	J1-d Grn		
44			1 Sec	94	J1-S Blue		
45			.8 Sec	95	J1-R Vio		
46			.4 Sec	96	LST Clock 1-87		
47			.2 Sec	97	GND		
48			.1 Sec	98	+5		
49	GND			99			
50	GND			100			

WIRING LIST - PC CONNECTOR

Chassis Type ANTENNA CONTROL TEST UNIT, SLOT B   Rack ___ Chassis ___ Connector ___

Card Type BOARD 3 COMMAND   By ___ Page ___ of ___ Rev. ___

PIN	TO	DESC.	FROM	PIN	TO	DESC.	FROM
1				51			
2				52			
3	GND			53			
4	+5V			54			
5	2-79		Red Monitor Out	55			
6	Monitor Clock 4-6			56			
7	Monitor A17			57	Calc INH		
8	A10			58			
9	A3			59			
10	E17			60	External Monitor Load Signal		OS
11	E10			61	Encoder Protect 1-95 J2-H		OS J2-H
12	E3			62			
13	2-78		Br Monitor Out	63	PC E7		
14	A16			64	E14		
15	A9			65	A7		
16	A2			66	A14		
17	E16			67	A21		
18	E9			68	Blue Out J2-T 1-63		Blue Comm
19	E2			69			
20	2-77		Blk Monitor Out	70	PC E1		
21	A15			71	E8		
22	A8			72	E15		
23	A1			73	GND		
24	E15			74	GND		
25	E8			75	PC A1		
26	E1			76	A8		
27	GND			77	A15		
28	GND			78	Blk Out 1-51		Blk Comm
29				79			
30				80	PC E2		
31				81	E9		
32				82	E16		
33				83	A2		
34				84	A9		
35	Monitor Ld In 4-35		Monitor Ld Out	85	A16		
36				86	Br Out 1-53		Br. Comm
37				87	Monitor Clock 1-46		
38				88	PC E3		
39				89	E10		
40				90	E17		
41				91	A3		
42				92	A10		
43				93	A17		
44				94	PC Clk 4-94		
45				95	Red Out 1-55		Red Comm
46				96	PC Clock		1-24, J2-E
47				97	GND		
48				98	+5		
49	GND			99			
50	GND			100			

WIRING LIST - PC CONNECTOR

Chassis Type ANTENNA CONTROL TEST UNIT, SLOT D Rack ___ Chassis ___ Connector ___

Card Type BOARD 4 MONITOR By ___ Page ___ of ___ Rev. ___

PIN	TO	DESC.	FROM	PIN	TO	DESC.	FROM
1				51			5 µs $\overline{\text{PC}}$ $\overline{\text{Pulse}}$
2				52	1-70 J2-e		5 µs PC Pulse
3	GND			53			
4	+5			54			
5	2-82		Gr Monitor Out	55			
6	Monitor Clock 3-6			56			
7	Monitor A20			57	Calc INH		
8	A13			58			
9	A6			59			
10	E20			60			
11	E13			61			
12	E6			62			
13	2-81		Yel Monitor Out	63			
14	A19			64			
15	A12			65			
16	A5			66			
17	E19			67			
18	E12			68			
19	E5			69			
20	2-80		Orn Monitor Out	70	PC E4		
21	A18			71	E11		
22	A11			72	E18		
23	A4			73	GND		
24	E18			74	GND		
25	E11			75	PC A4		
26	E4			76	A11		
27	GND			77	A18		
28	GND			78	Orn $\overline{\text{Out}}$ 1-57		Orn Command
29	2-83 J2-d		Blue Monitor Out	79			
30	Monitor A21			80	PC E5		
31	A14			81	E12		
32	A7		E19	82	E19		
33	E14			83	A5		
34	E7			84	A12		
35	Monitor LD Out3-35			85	A19		
36				86	Yel $\overline{\text{Out}}$ 1-59		Yel Command
37				87			
38				88	PC E6		
39				89	E13		
40				90	E20		
41				91	A6		
42				92	A13		
43				93	A20		
44				94	PC ClK 3-94		
45				95	Gr $\overline{\text{Out}}$ 1-61		Gr Command
46				96			
47				97	GND		
48				98	+5		
49	GND			99			
50	GND			100			

CONNECTOR LIST
FOR
HP 9810A CALCULATOR TO STAND-ALONE COMPUTER CONTROL

Designation J-1

Type: HP 11202A I/O TTL Interface to Elco 56 Pins: Panel: E; Cable: P

Pin	To	Function	Pin	To	Function
A			a	2-90 I2	Red
B			b	1-53 01	Brown
C			c	1-51 00	Black
D	GND GND		d	2-93 I5	Green
E	912		e	2-92 I4	Yellow
F	907		f	1-57 03	Orange
H	906		h	1-55 02	Red
J	908		j	1-96 I/O	
K	905		k	1-85 Control	
L			l		
M			m	1-61 05	Green
N	GND ECH		n	1-59 04	Yellow
P	STP		p	1-86 Flag	
R	2-95 I7	Violet	r		
S	2-94 I6	Blue	s	1-65 07	Violet
T			t	1-63 06	Blue
U	GND GND				
V	2-88 I0	Black			
W	GND GND				
X	2-89 I1	Brown			
Y					
Z	2-91 I3	Orange			

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

Pin Numbers: -3, -22, etc.

CONNECTOR LIST FROM STAND-ALONE COMPUTER CONTROL TO NRAO VLA ANTENNA CONTROL

TEST UNIT

CONNECTOR: Designation J-2 Type Elco 56 Pins

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

PIN	FROM	TO	FUNCTION		PIN	FROM	TO	FUNCTION
A	1-46	3-87	Monitor Clock		f	1-38	+15V	
B			GND		h			
C			GND		j	1-41	-15V	
D			GND		k			
E	1-24	3-96	Position Com. Clock		l			
F			GND		m			
H	1-95	3-61	Encoder Protect		n	Vcc		
J					p	Vcc		
K					r	Vcc		
L	J1-c	3-78	Output	Blk.	s	Vcc		
M	J1-b	3-86	Lines	Br.	t	Vcc		
N	J1-h	3-95		Red	v			
P	J1-f	4-78		Orange	w			
R	J1-n	4-86		Yellow	x			
S	J1-m	4-95		Green	y			
T	J1-t	3-68		Blue	z			
U					AA			
V					BB			
W			GND		CC			
X	2-77	3-20	Input	Blk.	DD			
Y	2-78	3-13	Lines	Br.	EE			
Z	2-79	3-5		Red	FF			
a	2-80	4-20		Orange	HH			
b	2-81	4-13		Yellow	JJ			
c	2-82	4-5		Green	KK			
d	2-83	4-29		Blue	LL			
e	1-70	4-52	Give Position Com.		MM			

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

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

Cards : 1-, 2-, 3-, 4-

EX: 2-22

J9 - mm