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THE COUDÉ THIRD MIRROR CONTROLLER

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3rd MIRROR CONTROLLER

INTRODUCTION

Whenever the 120" telescope is used at the Coude focus an additional flat mirror is needed to deflect the light beam through the polar axis to the Coude Slit Room. This mirror, commonly referred to as the 3rd mirror, must accurately follow the motion of the telescope in the Declination axis to properly position the beam on the slit. Because the light is reflecting off of the flat mirror any inaccuracy in its position will be doubled in the position of the star on the slit.

The original design for the telescope called for the 3rd mirror to be positioned by mechanically sensing a difference in position between the telescope (in Declination) and the 3rd mirror. This method will be described in greater detail later in the technical portion of this report. This mechanical method has been trouble prone in the past and has proved to not be accurate enough. These problems finally became acute enough that a new method of positioning the 3rd mirror was required. The requirements of the new system were that it be accurate, reliable, and that the old system should not be disabled in such a way as to be unusable should the new system fail.

The present 3rd Mirror Controller continues to use as much of the old system as possible. The mechanical measuring of the position difference between the telescope and the 3rd mirror has been replaced with solid state electronics. The use of a microprocessor within the Controller allows us to easily compensate for misallignment of some of the older mechanical parts, to provide displays for troubleshooting, and allows easy modifications in the future.

Because most of the original components were retained it is easy to convert back to the old system if necessary. Behind the main console on the 120" floor is a switch which will reconnect the old system if thrown. There are no special controls for the user to learn. Thus the new Controller should be transparent to the user, except that the 3rd mirror should position more accurately.

The original 3rd mirror system was designed to allow the 3rd mirror to move only when the telescope was slewing. Thus whenever the Slew button was pressed the 3rd mirror motor was enabled and would track the telescope.

This feature has been retained in the new Controller. However, several astronomers voiced a desire to have the 3rd mirror always follow the telescope, even when guiding or setting. Therefore a switch was added to the front panel to enable this automatic tracking. When in the "Manual" position the 3rd mirror will behave as before. When in the "Auto" position the 3rd mirror will continuously track the telescope.

There are some other switches on the front panel along with a display. They are meant for technical personel only and allow for easy troubleshooting of the system. Their function will be described in the next section which is written for the technical personel.

120" THIRD MIRROR CONTROLLER

CONTENTS

HARDWARE DESCRIPTION

The 120 inch Coude focus #3 mirror automatic tilt control has been modified by the installation of a switch that selects either an "OLD" or a "NEW" system. First a discussion of the "OLD" system.

Old System

Mounted on the 3rd mirror housing assembly are two transmitter synchros. These are connected, via a gear train, in a 36:1 "fine-coarse" system. Each of these synchros is electrically connected to one of two torque generating differential synchros located at the main console. Attached to the Declination axis of the telescope are another pair of identically configured transmitting synchros whose outputs are connected to the other side of torque generating synchros. An arm is attached to the shaft of these TG synchros. At the end of each arm is a small bar magnet. Near these magnets are mounted two magnetic reed switches. One on either side (see fig 1).

Should the phase and amplitude of the AC voltage on the "S" windings of the two transmitter synchros disagree, a torque is generated in the TG DG's and the bar magnet comes into close proximity to one of the reed switches. When this switch closes it energizes a relay that applies power to an AC motor on the 3rd mirror cell. This motor moves the 3rd mirror, and the 3rd mirror synchros until the phase and amplitude of the "S" windings are again in close agreement. The TGDS shaft returns to it's center position, the reed switch opens, and the 3rd mirror is considered positioned.

Although only one was discussed, both the coarse and fine operate in an identical manner.

The accuracy of this system depends on a number of factors remaining constant: The physical position of the reed switches, their hysteresis and the field strength of the bar magnet. In order to avoid the above restrictions the following system has been installed.

New System

The output of each of the four synchros is digitized and sequentially applied to a port card. The MPU card selects which synchro is to be read and stores this digital information in a memory location. After all four synchros have been read and this data stored in unique memory locations the MPU inters a "compare-move?" routine.

In this routine the value of the 3rd mirror coarse synchro is compared to that of the telescope Declination coarse synchro. If they do not agree to within a value called the "coarse window" the MPU will energize the appropriate coarse motor relay. As the motor moves the 3rd mirror, and it's synchro, the difference between the digitized data decreases. When this difference is less than the "coarse window" the MPU releases the relay and the motor stops. The mirror is now considered positioned in the coarse part of the two speed system.

In the same manner the MPU now checks the two fine synchros. Their difference is compared to a "fine window" and, as with the coarse, if the difference is not within this window the appropriate relay is energized. When the difference is within this fine window the relay is released and the 3rd mirror is considered positioned. Once positioned any further motion of the mirror is prohibited by the MPU unless one of the following occurs! 1. The telescope slew enable button is pressed, 2. the AUTO/MANUAL switch on the controller is put in the AUTO position, or 3. the MPU detects a difference of 11 degrees or greater. Any one of these three conditions will immediately restore the system to the auto position mode.

The MPU software will also check the position of the Display select switch on the controller front panel. Depending on where whis switch is set the MPU will display data in the 7 seven segment LED displays on the front panel. Selected data can be: Difference, Declination, 3rd mirror position, individual synchro data, etc. A provision is also made to move the 3rd mirror manually. If the AUTO/MAN switch is in the Man position pressing the N button will drive the mirror north, the S button will drive it south. (The system will automatically reposition the mirror if the slew enable button is pressed.

DETAILED CIRCUIT DESCRIPTION

For the following discussion refer to drawing EL-969-3s logic schematic.

Connectors J1, J2, J3, & J4 connect the four synchros to the signal inputs of four EL-814 synchro to digital converter cards. This card uses an Analog Devices SDC 1700/522 synchro to digital converter. This device converts shaft angle of the synchro to a 12 bit digital word. With a shaft angle of zero degrees the output, pins 1 through 12 will be at a logical 0. With a shaft angle of 359+ degrees the output pins will be at a logical 1, with pin 1 being the most significant bit and pin 12 the least significant bit. These output pins are connected via 8097 tri-state buffers G3 & G4, to pins aD thru aS, (aD being the MSB). These pins are in a floating condition untill pin bS (enable bar) is pulled to ground. Pin bR is the busy output and when high indicates the device is in the process of conversion and should not be read.

The outputs of the 4 EL-814 SDC cards are connected in parallel and applied to PB1 0-7 and PA1 0-3 of the EL-745 32 bit port card. (For a detailed description of this card refer to the EL-745 write-up) Software in the EL-825 MPU card will instruct the port card to select one of the SDC's. The digital shaft angle of that SDC will then be read and stored in RAM. The MPU will cycle the port card to the next SDC etc. untill all four have been read and stored in unique RAM locations. The program will now compare the shaft angle of the 3rd mirror coarse synchro and the telescope declination coarse synchro. Assume the AUTO-MAN switch is in the AUTO position or if in MAN position the slew enable button on the telescope paddle has been pressed. If they do not agree to within approximatly 2 degrees the program determins weather the 3rd mirror synchro is larger or smaller in shaft angle and sends the appropiate signal, again via the port card, to A25 EL-970 relay driver card. This card will energize, via cable card B28 and J5, one of the four relays located behind the main console. This relay will apply power to the coarse motor on the 3rd mirror cell and drive the mirror and it's synchros.

When the shaft angles agree to within 2 degrees the MPU will release the relay removing motor power and the mirror will ge considered positioned in the coarse mode.

The program now, in an identicla manner, compares the 3rd mirror and declination fine synchros. If they do not agree to within 2 degrees of shaft angle the MPU energizes the proper relay to apply power to the fine motor on the 3rd mirror cell. When the fine synchros agree the relay is released and the mirror is considered positioned.

Note: Two degrees of shaft angle on the fine synchro translates to 1.5 arc min of the actual 3rd mirror position due to the gear train.

DISPLAY SELECT SWITCH

The display Select Switch is a 15 position hex encoded thumbwheel switch. It is read by PA2 4-7. Depending on it's position the software will display one of the following:

Sw Pos	Info displayed
0	Difference between mirror and dec
1	Combined mirror position
2	Combined dec position
3	Hex raw data from mirror coarse synchro
4	Hex raw data from mirror fine synchro
5	Hex raw data from dec coarse synchro
6	Hes raw data from dec fine synchro
7	Three left digits corrected diff of coarse synchros Three right digits corrected diff of fine synchros
8-15	Not assigned

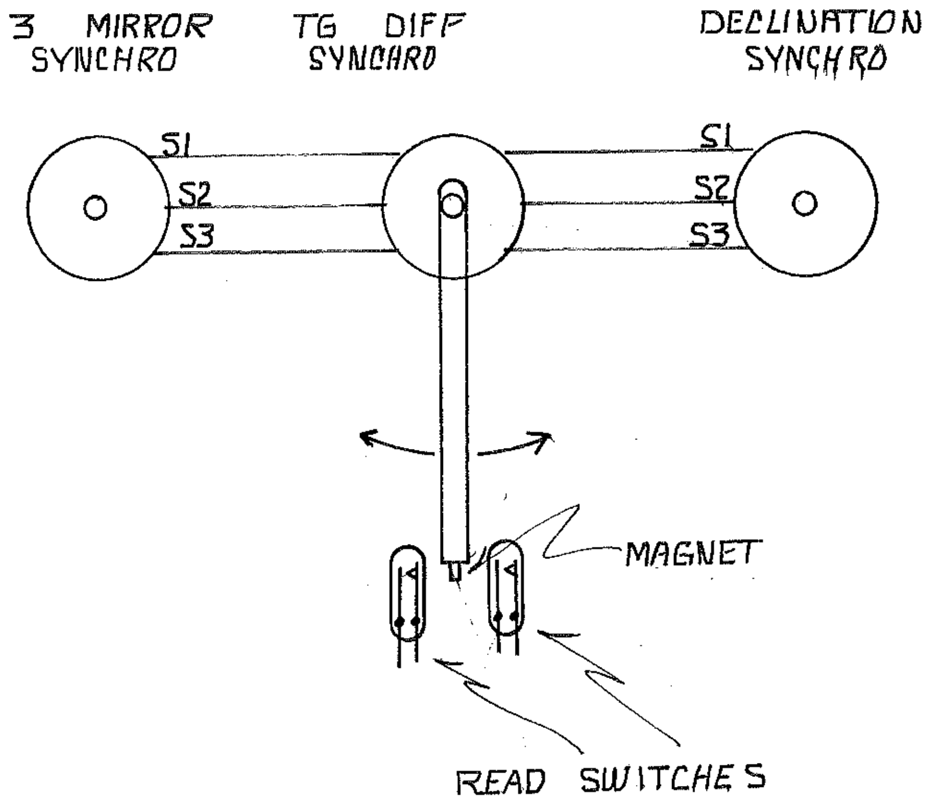

3 MIRROR
SYNCHRO
TG DIFF
SYNCHRO
DECLINATION
SYNCHRO
S1
S2
S3
S1
S2
S3
MAGNET
READ SWITCHES

FIG 1

3rd Mirror Software Description

INIT

This is the system initialization routine. It is executed only once on each power-up. First it sets up the ports. PA1, P2, and PB1 are set as inputs, PB2 is set to outputs except for bit 3 which is set to an input. It sets the stack pointer to $FF. The RAM at $9000 on the port card is tested (see RAMTST).

A table of synchro correction values is now loaded into RAM. FTAB contains a number that is equal to the value of the Dec and Mir coarse synchros when the telescope is at zero degrees declination. When this value is added (modulo 4096) to the digitized synchro data the result will be true declination.

A timer (.25 sec) is started, Telco was to have restarted this timer but that function was never implemented. The code was left intact should the need for communications with Telco ever arise.

RAMTST

Called by INIT

This subroutine checks the RAM on the Port card from address hex 9000 to hex 90FF. It first loads an FF in all locations then reads each location and compares it to FF. Then , in order, loads a 55, AA, and 00 in each location and compares them. It exits with the tested ram all zeros. If an error is detected it will set the carry and jump to the "HELP" routine.

START

This is effectively the main routine. It jumps to the six primary subroutines and after executing each jumps back to it's own beginning.

READ THE 4 SDC's

Called by START this subroutine reads the 4 SDC's and saves the information in location DIFF.LO indexed by the x register.

It first loads PB2 with a busy mask for SDC #1, it reads the busy line and if the SDC is busy (in the process of converting, data not valid) it returns and checks it again. As soon as the SDC is not busy it reads the digitized SDC data and saves it. Then by incrementing x and shifting the busy mask it reads and saves the next SDC. This continues until all 4 have been successfully read and stored.

Returns to START

CK.ACIA

Called by START.

Primarily a routine to communicate with TELCO. Although actual data transfer between the mirror controller and TELCO was deemed not necessary the code was left intact for possible furture use.

A location, impval, is checked to see if Telco has requested data transfer. If a transfer was requested it determines wheather a memory dump or status was asked for. If memory dump, the dump flag is set and the hi and lo addresses for the dump are loaded. Sixty locations are then dumped to Telco. For the orginization of this 60 byte buffer see the program listing. If status was requested it clears the dump flag and reads the 6 status registers. See the program listing for orginization.

Returns to START.

MOVE?

This routine first checks to see if mirror and dec positions agree to within the coarse window and if in the auto mode. If not within the coarse window and in auto mode it determines which direction the mirror is off and energizes the corresponding coarse motor relay. If within the coarse window it checks the difference against the fine window and if necessary energizes the appropriate fine motor relay.

If not in auto mode and slew has not been enabled it will check the North-South pushbuttons and if either has been pushed it will energize the corresponding coarse relay. It will ignore if both buttons are pressed simultaneously.

Upon entry a mask is used on PA2-4 to see if the slew enable button is pushed, if so it sets the slewing flag (SLEW.FL). A check is then made on this flag and "have-been-slewing" flag (BEN.SLW). If either flag is set it jumps to DRIVE. If neither set it clears the move direction register, and masks PA2-7 to see if in the auto mode, if so it jumps to DRIVE. If not it checks PA2-5&6 for either manual move button activated. (if both are pushed it will ignore) If either pushed it will energize the appropriate relay via PB2-4or5 and return to START.

If a jump or branch to the DRIVE lable was taken it sets the ben.slw flag and checks the coarse window flag C.FLAG. If this flag is not set the coarse relays are released,via PB2-4&5 and the fine window flag, F.MOT.FLAG is checked. If not set the fine motor relays are released via PB2-6&7. If either the coarse or fine window flag was set it checks DIFF.NEG.C and DIFF.NEG.F to determin which direction to move and energizes the appropriate relay via PB2-4,5,6,or7.

Returns to START.

Important locations used by MOVE?.

SLEW.FL	If non zero slew enable is pressed.
BEN.SLEW	If non zero telescope has been slewing and not yet within both windows
CK.TR.SW	Auto/Manual switch in Auto position.
MOV.DIR	If bit 6 is on direction is north.
C.FLAG	Non zero = not in coarse window
F.MOT.FLAG	Non zero = not in fine window.

DISP.SEL

Called by START.

Determines, via PA2-0,1,2,3, where the Display Select switch on the controller front panel has been set. It inverts the port since the BCD display switch is negative logic. It will now jump to the routine selected with the Y register containing the switch position times 2.

Returns to START.

UDIV

Called by DMS CONVERT.

This routine was adapted from a routine in "6502 Assembly Language Subroutines" pg 240.

Divides two unsigned 24 bit numbers. Upon entry the divisor is in DVSOR,0,1,2 and the dividend in DVENDO,1,2. At exit the quotient is in DVEND,0,1,2 and any remainder in DVEND,3,4,5.

The program performs unsigned division by the shift and subtract algorithm, shifting quotient and dividend and placing a 1 bit in the quotient each time a subtraction is successful. The carry flag is cleared if the division is proper and set if the divisor is found to be zero. A zero divisor will also result in a return with the result (quotient or remainder) set to zero.

Returns to DMS CONVERT.

DISPLAY

Called by DMS CONVERT.

A routine to display the data in a table called DIS.TAB. First a control word is sent to the LED driver card EL-922. This establishes the mode of display. It then sends sequentially the eight values stored in the table to the driver card.

Returns to DMS CONVERT.

HELP

Called by RAMTST if an error occured during the test of the ram on the port card at hex 9000 to 90FF.

This routine simply displays the word -HELP- in the front panel leds. HELP is stored in HELPTAB. A timer is started, approximatly .5 sec, and when timed out it will return to INIT and test the ram again.

DMS CONVERT

■ Called by DISP.SEL

This routine takes the coarse 24 bit SDC data and divides by a conversion factor to convert to degrees, minutes, seconds.

The value of the display switch times 2 will be in the Y register upon entry.

First the value of the display switch (Y register) is multiplied by three since the main convert routine uses triple precision arithmetic and the Y register must be in multiples of three.

It loads DVEND with the coarse synchro data then loads DVSOR with first number in DMS.TAB and JSRs to UDIV. After returning from UDIV the result is stored in DISP.TAB. This loop is done four times to convert the raw data to unit minutes, ten minutes, unit degrees, and ten degrees. After the 4th pass it stores a 0 in the three lowest positions in DISP.TAB since the hardware requires 8 consecutive numbers. Finally the sign bit is sent to position 8 in DISP.TAB

Returns to START via DISP.SEL.

RAW DATA

Called by DISP.SEL.

Routine to display the Raw data from any one of the four synchros in the three right most LED's.

First a control word must be sent to the driver card to set it to the hex mode of display. Four zeros are now sent to the driver card for the sign digit and the left 3 digits. The synchro data has been stored in two byte locations of which the hi nibble will always be 0. The selected synchro hi byte is read and the hi nibble masked off. This result is sent to the display card as digit 5. The lo byte is read and the hi nibble is shifted into the lo nibble and sent to the card as digit 6. The lo byte is again loaded and the hi nibble masked out and then sent to the card as the final digit.

A short delay loop, approx. 3 msec, is then executed to allow the card to settle.

Returns to START via DISP.SEL.

RAW.COMP

Called by START

A routine that adds an offset to the mirror coarse & fine data, so that when the 3rd mirror is positioned the data from mirror synchros are in agreement with the data from the dec synchros. (If the telescope is in the 5 mirror system an additional 40 degrees is added to the mirror coarse synchro.) The dec data is now subtracted from the mirror data, the result stored in RAW.DIFF.

A comparison is made between the difference and two windows, "cors.win" and "f.pos.win". If the difference is greater than the window the appropriate flag is set, c.flag and/or f.flag.

Returns to START

DIS-DIFF

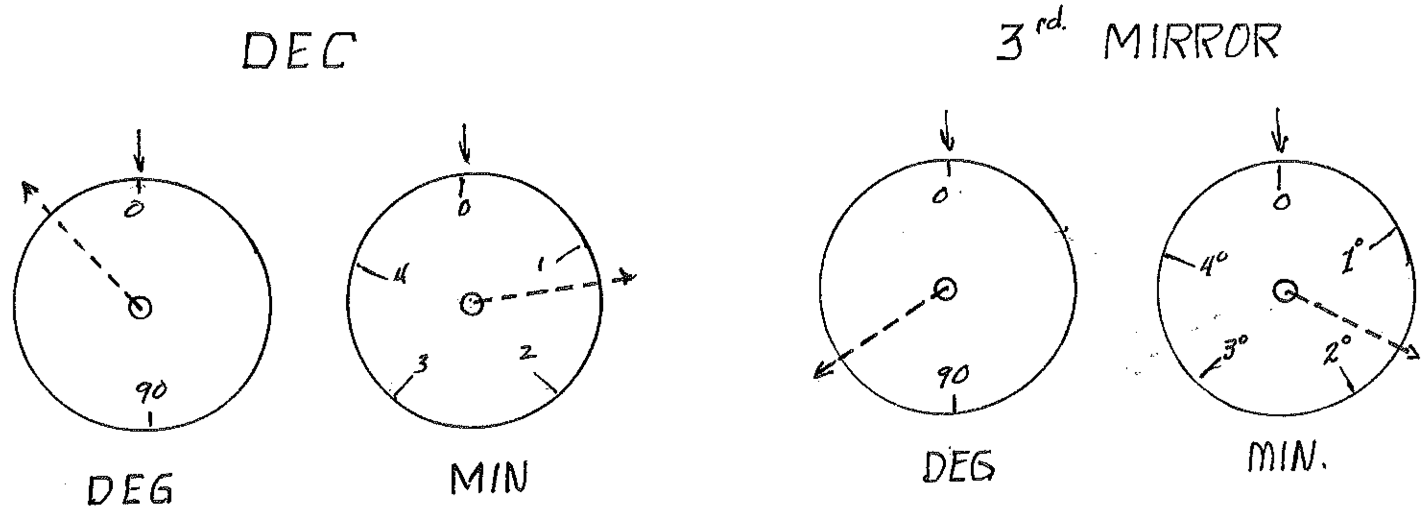
Called by DISP.SEL.

Displays the difference between mirror and dec synchros. The left three digits contain coarse difference and the right three the fine difference. The synchro data is loaded and the appropriate nibble masked in and sent to the display card. After 8 digits have been sent a short (3msec) delay soop is executed to allow the display card to settle.

Returns via DESP.SEL to START.

MULTX100

Since the routine UDIV uses integer numgers this routine multiplies the raw synchro data by a factor of 100. The Y register is loaded with 2 . At MULT2 the 3 byte coarse data is shifted left to effect a multiply x 2, Y is decremented and if not equal to zero a branch back is taken. When Y is equal to zero the data will be original value times 4. This result is stored in temp. The Y register is loaded with 3 at MULT32 and again the data is rolled left until Y equals zero (3 times). The data is now original value times 32 (5 left rolls), to this is added temp and the result returned to temp. Temp now contains the original data times 36 (X32 + X4 = X36). The data is again shifted left and becomes original times 64 (32 shift left = 64). To this is added temp and the result (X36 +X64 = X100) is stored in location MCX1K.



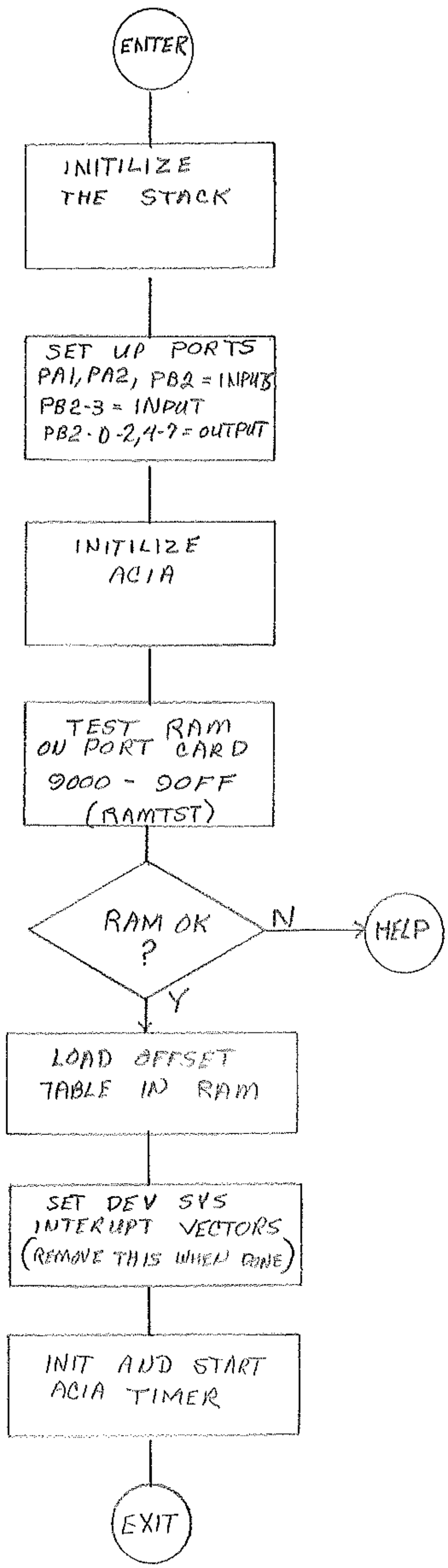
- - - → = POSSIBLE SHAFT ANGLE

FIG 1

FOR ILLISTRATION USE ONLY

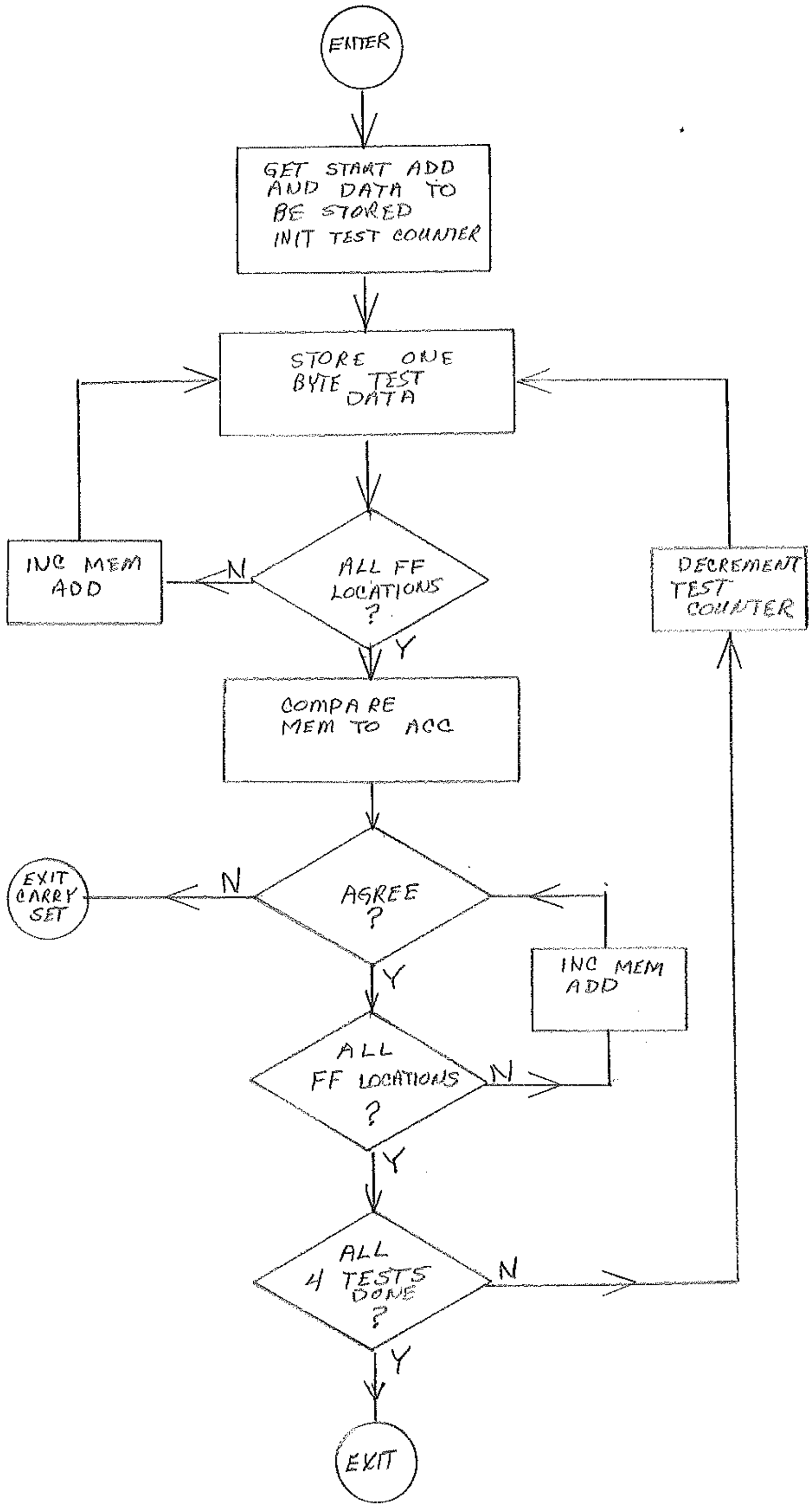
INIT

8000 - 8050



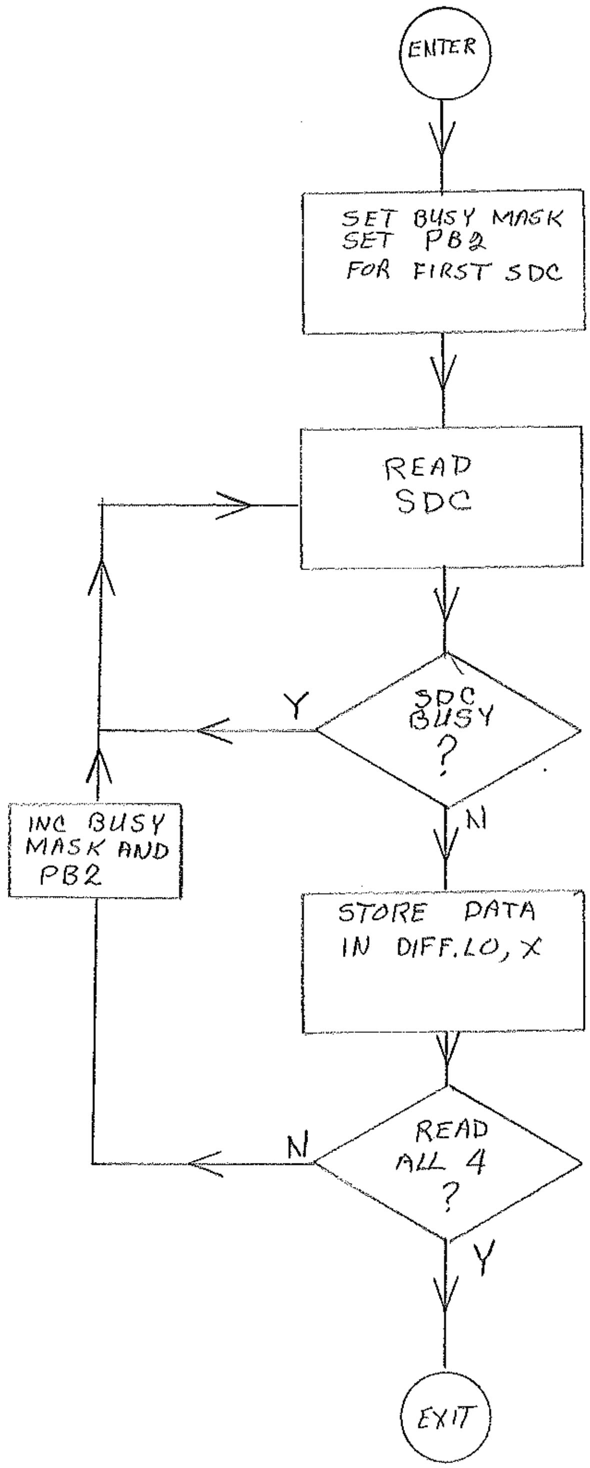
RAMTST

8051 808D



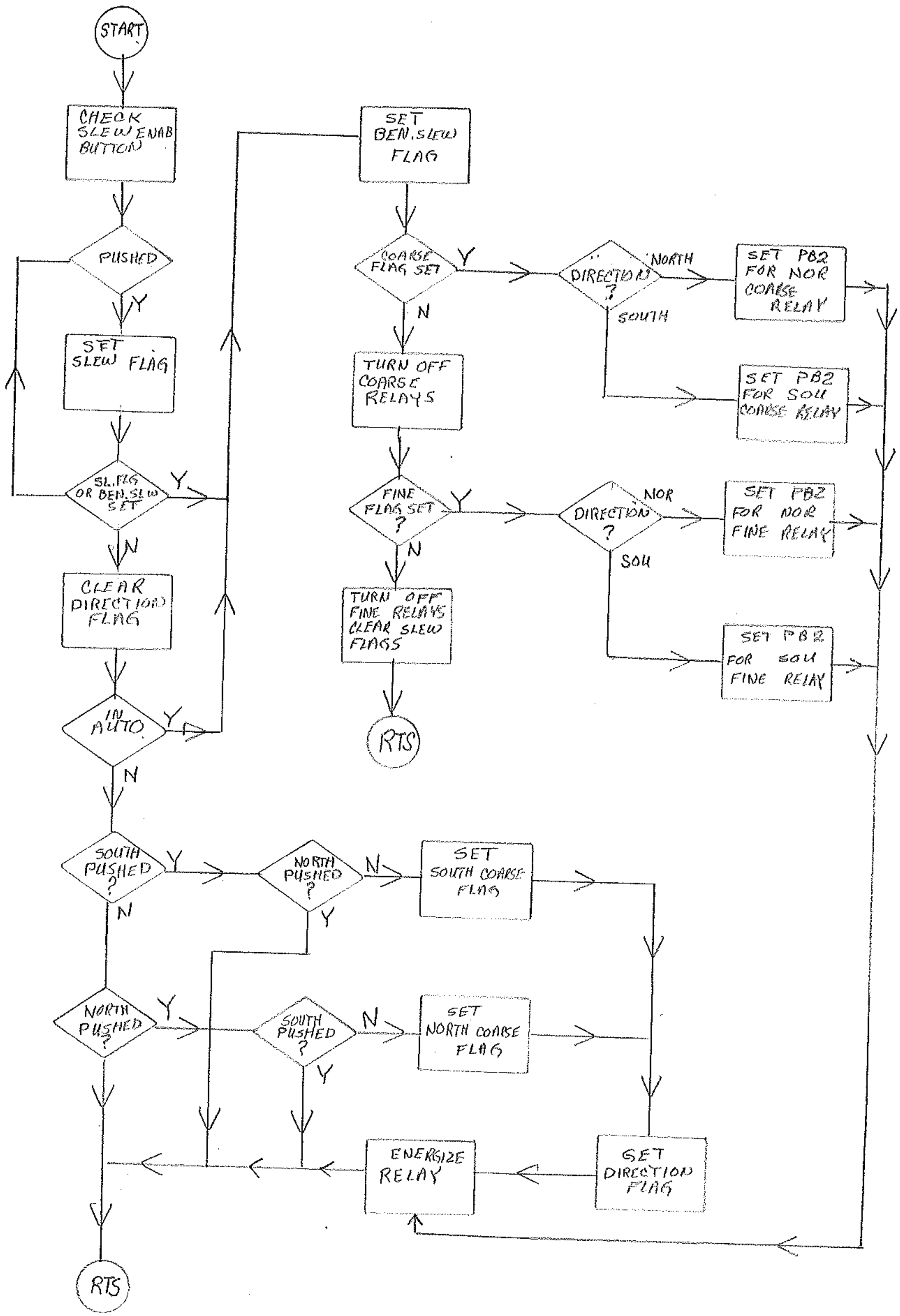
READ SDC'S

80A3 80D6



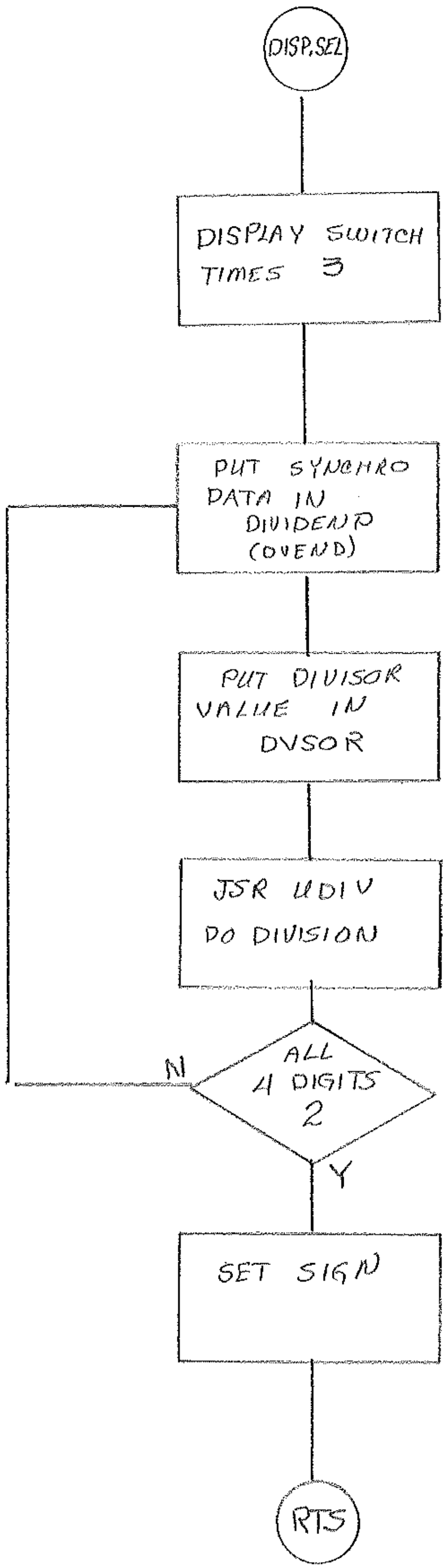
MOVE?

B136 BIDA



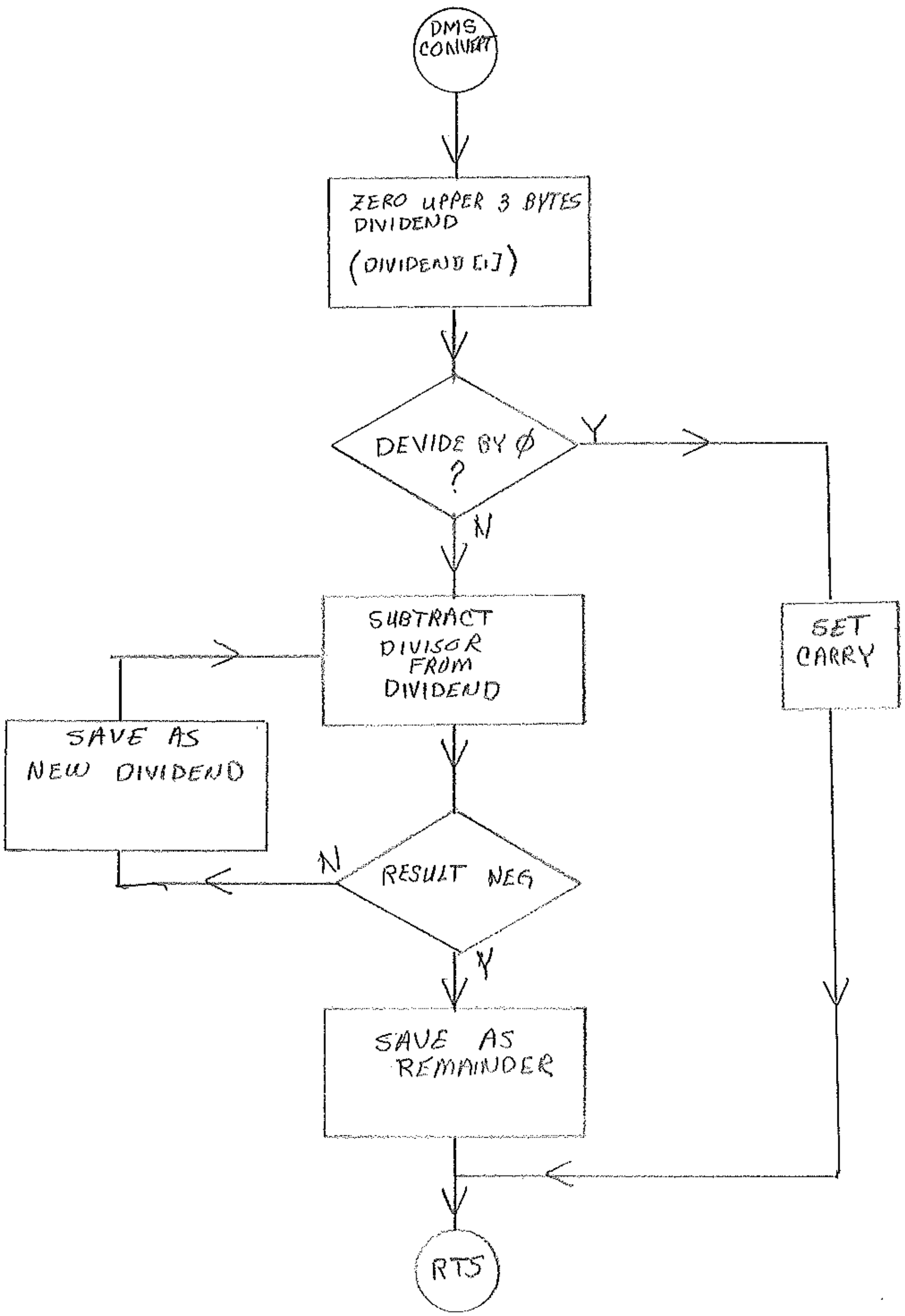
DMS CONVERT

B2FA 8370



UDIV

8219 8299



RAW. COMP

83CA 84F7