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CONTROLLER FOR THE ECHELLE SPECTROGRAPH (SYSTEM NUMBER EL 653)

T. Cantrall

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CONTROLLER FOR THE ECHELLE SPECTROGRAPH (SYSTEM NUMBER EL 653)

1 INTRODUCTION

1.1 Overall System Description

1.1.1 Optical - Mechanical

The Lick Observatory Coude Echelle Scanner System is a very high resolution spectrograph using Varo image intensifiers with an image dissector to record the data. The nature of an Echelle grating is such that the visible region of the spectrum is dispersed highly and in many different orders. To separate these orders a second dispersing device is necessary -- in our case a small standard grating.

The light from the 120-inch telescope is focused on a slit - the emergent conical beam is collimated by a mirror. The collimated beam is diffracted by the Echelle grating and deflected downward to the cross-disperser which is mounted directly underneath the collimator. This prevents stray light from ever reaching the camera. The cross disperser reflects the beam back to the Echelle grating where it becomes diffracted again. This beam is then brought to a focus by the collimator mirror on the front face of the image tube chain.

Thus the Echelle rotates about a vertical axis and the cross-disperser rotates about a horizontal axis. In order to position a desired wavelength accurately on the image tubes a positional accuracy of about 15 arc sec is necessary for the gratings. Achieving

a small amount through a gear train by a small stepping motor. Limit switches and mechanical stops prevent the table from moving too far. A potentiometer sends coarse position data back to the control box. Mounted on the motor shaft is a cam which operates a micro switch positioned by a rotary solenoid. This is used only during calibration. Each motor has a knob on one end of its shaft to permit manual movement.

CAUTION However, if the motor is moved by hand, all position data is invalid and the system must be recalibrated. (See Section 2.5)

1.2.2 Focus

The focus stage provides linear motion for the collimator focus mirror via a lead screw driven directly by a stepping motor. This stage also has limit switches, mechanical stops and a position potentiometer. The focus stage is never calibrated, as the position potentiometer is accurate enough to provide absolute position data directly.

1.3 Driver Box (EL-653-3WE)

All three stages are cabled back to the driver box mounted on an I-beam in the pit. This box couples position and limit switch data back to the control box and provides the power drivers needed to operate the motors and solenoids.

1.4 Control Box (EL-653-2LA, B, C, F)

This unit is in the slit room and enables the operator to set the position of the gratings and focus mirror. The pulses

2.2 Lamp Test

The unlabled red button forces the digital display logic to illuminate all seven segments of each digit to test for missing or dim segments.

2.3 Meters

Meters are supplied as a coarse position indicator for the two gratings. They read a voltage derived from a position potentiometer on each stage. The meters do not have enough resolution to serve as primary position indicators, but act as a back-up to the more complex digital system. They also give an idea of stage position when power is first turned on (before the digital display has been calibrated). The focus position potentiometer is displayed as a digital number, so no meter is needed.

2.4 Display

2.4.1 Gratings

The grating position is controlled by pulses sent to the driver box. The microprocessor (MPU) counts these pulses and displays the accumulated count. The accuracy of the digital position display depends on the stepping motor responding correctly to every pulse. Each pulse rotates the motor 1.8 degrees. This movement is geared down by a factor of 2700 to give a grating rotation of 2.4 arc sec per pulse.

Calibration is required after turning on power or if a motor is turned by hand.

Calibration is advisable after hitting a limit or pressing the stop button.

2.6 ECH, CR. DISP, FOCUS

These switches are used with the thumbwheel switches to move the stages to a known position or to move a known distance.

Normal procedure is to set the thumbwheels to the new position and push the corresponding button.

The settings of the thumbwheels may be changed while the stage is moving, but if this causes the stage to change direction, a few pulses may be ignored by the motor. These few pulses will not be ignored by the displays, however, resulting in an erroneous position indication.

When a button is pressed, the motor starts at 45 pulses per second and speeds up to 350 pulses per second in about a half second. The speed remains high until the MPU senses that the motor is within 100 pulses of its final position. The motor is slowed down to avoid an abrupt halt.

To overcome the effects of any backlash which may creep into the gear trains, the motor always reaches its final position moving in the forward direction. Thus, when it has been moving in reverse, the motor will overshoot the final position by 200 pulses, stop, and come back 200 pulses in the forward direction.

3 THEORY OF OPERATION

3.1 Control Box (See drawing EL-653-2LA)

The heart of the system is the microprocessor card, EL 608. From this card, 13 of the 16 address lines go to each of two device selector (address decoder) cards, EL 630, whose outputs are used to select which of 12 input or 9 output data words are connected to the microprocessor's 8 bit bidirectional data buss.

The microprocessor (MPU) gets its input via four El 632 "24 BIT INPUT STROBE" cards from pushbutton switches, thumbwheel switches, limit switches, multiplexer outputs and an Analog to Digital converter output. MPU outputs go through thre EL 634 "24 BIT OUTPUT BUFFER" cards as digital display data, thumbwheel enables, inputs to the multiplexer, controls to the analog to digital converter, and signals to the stepping motors.

3.1.1 Microprocessor Card (EL-608-3S)

This cards holds the microprocessor (MPU), G1, 3 address line buffers, G3-5, 2 bidirectional data buffers, G6-7, reset logic, G2 and G9, 256 bytes of RAM, G10, G11, 2048 bytes of EPROM, and address decoding for the RAM and EPROM, G14-16.

Program instructions reside in the EPROM while the RAM is used for any data changes such as the information being used for the displays.

3.1.2 Device Selector (EL-630-2L)

This card decodes the address lines to provide a low level on one of 16 output lines. These outputs are used to enable the I/O cards and reset flip-flops for the specified addresses. It

selector EL 630. The reset line is pulsed at power turn-on to clear all outputs.

The select lines are gated with a pulse (produced by combining $\phi 2$ and the read/write line) to latch data on the MPU buss into the selected output port. $\phi 2$ is gated with R/w to fire a one shot (G4) only during a write operation. This delays the time the latchs are strobed until about 200 n sec after the rising edge of $\phi 2$. This delay is necessary to allow the data from the MPU to stabilize the buss. The output of the one shot is gated with the select inputs to determine which latch is to receive the data. In this system, the outputs are assigned hexadecimal addresses 29 through 2E and 33.

3.1.5 Display (EL-653-2LC)

The display is controlled by two data words from MPU. The word at address 2A contains two BCD numbers that determine which segments of the display digits are turned on. The word at address 2B selects which digits are enabled. Some of the bits in this word enable two digits.

When two are enabled, both halves of the word 2A contain valid segment data. But when only one digit is enabled by word 2B, only the lower 4 bits of word 2A contain valid segment data.

Word 2A is fed into two 7 segment decoder-driver cards, EL 262, that actually turn on the segment lines of the display. EL 262 also gets an input from the lamp test button which causes all segments to be turned on when pressed.

Word 2B goes first through 7406 open collector buffers before going to the LED driver, EL 451, because the input to the EL 451

with the 1v to 5v input signal and is of such a magnitude to cancel a one volt input. This accomplishes the 1v offset. The feedback resistor sets the gain as required to produce a 10 volt output with a maximum (nominal 5v) input which is different in each stage. The Echelle and Cross disperser meters are driven from the outputs of G2 and G3B to serve as coarse position indicators.

The output of the offset and gainsetting op amps are sent to an analog switch where one is selected (by inputs J, K and L) to be inverted and passed on to the ADC's analog input.

The ADC's other input is a positive logic pulse called START (conversion) from the most significant bit of word 33 which initiates the conversion process at its falling edge. The START is also wired to the input strobe, word 31, so the MPU can see that the START is really there.

The ADC output called END OF CONVERSION (EOC), is reset HIGH by the rising edge of the start pulse. When the conversion is over, the EOC lines goes low, signaling the MPU that the data is ready.

The data output of the ADC is a 12 bit word arranged as 3 four bit BCD numbers. This 3 digit number is the stage position as read by the selected position pot.

For Focus, this number is displayed directly as stage position. The grating stages require more accuracy, however, so this data cannot be used directly for determining their position, although it is accurate enough for coarse position during calibrate.

3.1.7 Limit Switches (EL-653-2LD)

Each stage has a forward and a reverse limit switch that will stop motor movement in software and light an LED on the front panel. As an extra precaution, the limits gate the pulses to the motors in El 655.

the MPU switches to its PDP-in-control mode. The data then present would be stored and FF1 cleared by the MPU.

The MPX DATA READY line is fed back to the MPX. When it is cleared, the computer knows its data has been accepted and it can put out a new data word.

When the MPU is ready to send data to the MPX, it will load up MPX bits 2-11 and begin sampling the MPX ACCEPTED DATA output of FF2. The computer will set FF2 with PULSE 2 after it has acquired the data, and the MPU, seeing FF2 go high, clears FF2 and can send a new data word if needed.

3.2 Driver Box (EL-653-3WE)

The driver box, located in the pit, contains two solenoid drivers, and three stepping motor drivers plus associated parts. The limit switches and position pots are fed from the 3 stages to the control box through this unit.

3.2.1 Solenoid Driver (EL 562)

A level applied to the input of a solenoid driver causes 12v to appear at pin M for as long as the input level lasts. An input level will also trigger the 555 O/S whose output applies a 24v pulse to pin M. The 24v pulse is needed to pull the solenoid in, but only 12v is needed to hold it in.

3.2.2 Stepping Motor Driver (EL 572)

The forward and reverse inputs are shaped by two one-shots and fed to an up-down counter, G2, whose output is decoded by G3. The 4 outputs of G3 go high sequentially, one at a time, G4 OR's 2 adjacent outputs to provide overlapping pulses to the power transistors.

3.3.2 Grating Stages (EL-653-2WB)

The grating stage motor drives a worm against a worm wheel for a reduction of 30 to 1 with a ten turn position pot coupled to the worm wheel shaft. The echelle motor's normal range is 30,000 pulses or 150 turns, so the pot will make 5 turns. The cross disperser motor has a range of 20,000 pulses or 100 turns, so its pot will make 3 1/3 turns.

The worm wheel shaft also drives a worm inside the turntable assembly to give an additional 20 to 1 reduction for a total of 2700 to 1. Thus for every step of the motor (1.8^{o}), the table moves $.000667^{o}$ or 2.4 arc sec.

Beyond the normal range reached by the motors are limit switches which, when hit, interrupt the forward and reverse pulses via gates. The software looks at the limits too, and when they are hit interrupts the program. Beyond the limit switches are mechanical stops.

3.3.3 Calibration (see Sections 2.4.1 and 2.5)

Calibration is required after turning on power or if a motor is turned by hand.

Calibration is advisable after hitting a limit switch or pressing the stop button.

The MPU uses the grating stage position pots just to determine coarse position, since they are only accurate to about 10 motor steps and cannot be used directly for calibrating the displays.

Their accuracy is good enough to position a cam wheel attached to the motor shaft to a particular point $\pm 10^{o}$. The cam wheel has a detent into which a microswitch can fall. The MPU watches this switch

4.3 Software Diagnostics

4.3.1 To enter the test loop, press STOP and CALIBRATE. Release STOP first, then CALIBRATE.

To exit the test loop, press STOP.

4.3.2 To zero either Echelle or cross disperser displays (has no effect on grating position), enter test loop, then press ECH. or CR. DISP.

4.3.3 To display position pot data in the focus display, enter the test loop and press both FRD and REV focus push buttons. The position pot data displayed is determined by the right-most digit of the Echelle thumbwheel. The focus pot is selected by zero. 2 selects the Echelle pot, and 4 selects the cross disperser pot.

4.3.4 The following section will be included when the Multiplexer software is added.

To find out how much noise is on a pot signal, enter the test loop, press both FRD and REV focus push buttons, then press ECH, CR. DISP. or FOC for their respective pots. The program continuously samples the pot voltage and remembers the lowest and highest value read. These values are displayed in the Echelle and cross disperser readouts respectively. The difference, and indication of relative noise, is displayed in the focus readout.

To select another pot signal, simply press ECH, CR. DISP, or FOC, whichever is desired. All 3 displays can be zeroed by pressing both FRD and REV focus buttons.

(A1)

SPECIFICATIONS

RESOLUTION: GRATINGS = 2.4 ARC SEC PER STEP

FOCUS = 0.0003125 INCHES PER STEP

CALIBRATION TIME: MINIMUM = 7 SEC

MAXIMUM = 3 MIN 10 SEC

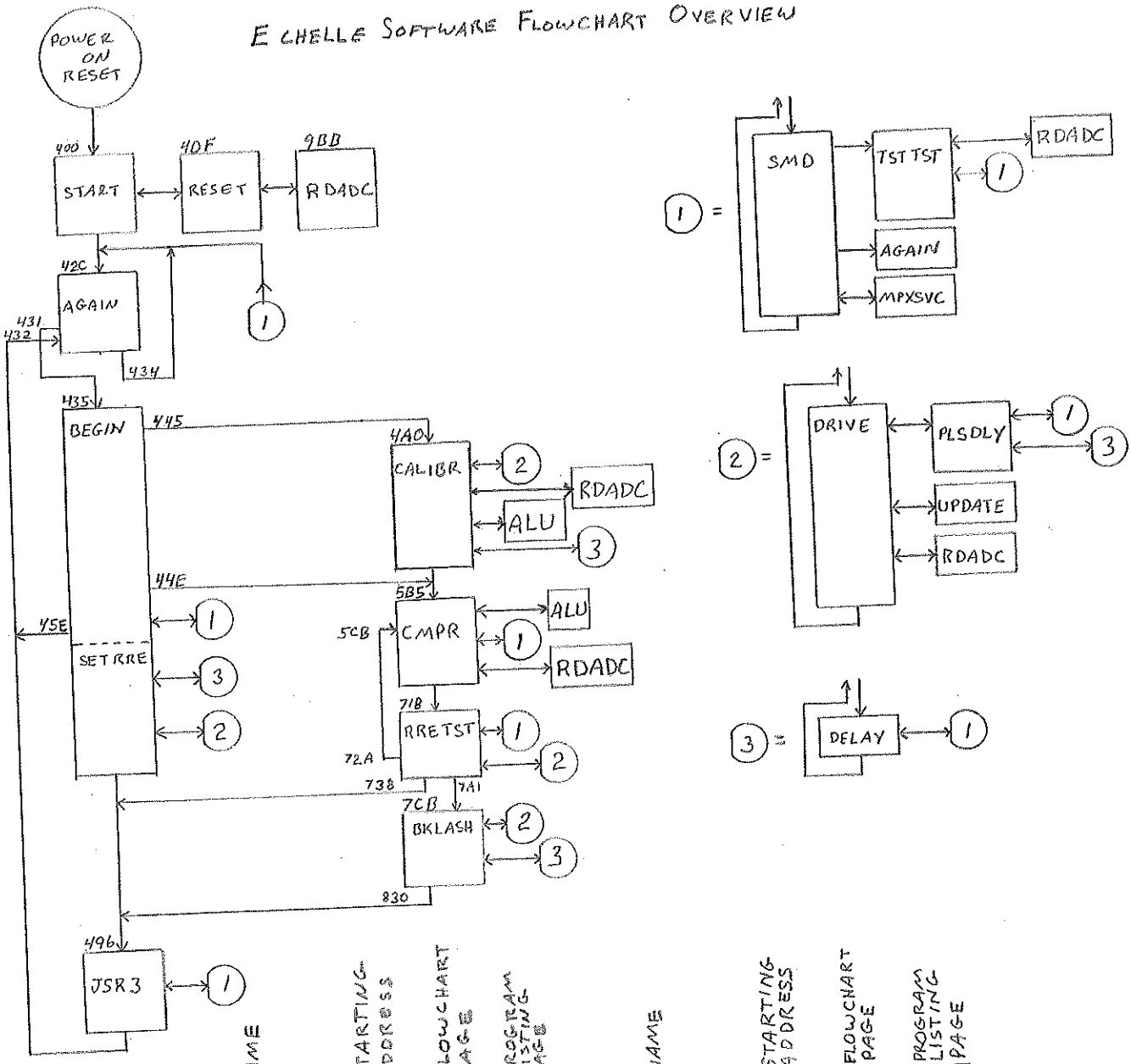
POWER DISSIPATION: DRIVER BOX: NO MOTORS = 17W
ONE MOTOR = 61 W
TWO MOTORS = 105 W

CONTROL BOX: FULL BRIGHT DISPLAY = 50W
FULL DIM DISPLAY = 41 W

HEAT GENERATED BY DRIVER BOX DURING A 10 HOUR NIGHT* : 600 BTU
: 150 KGRAM-CALORIES

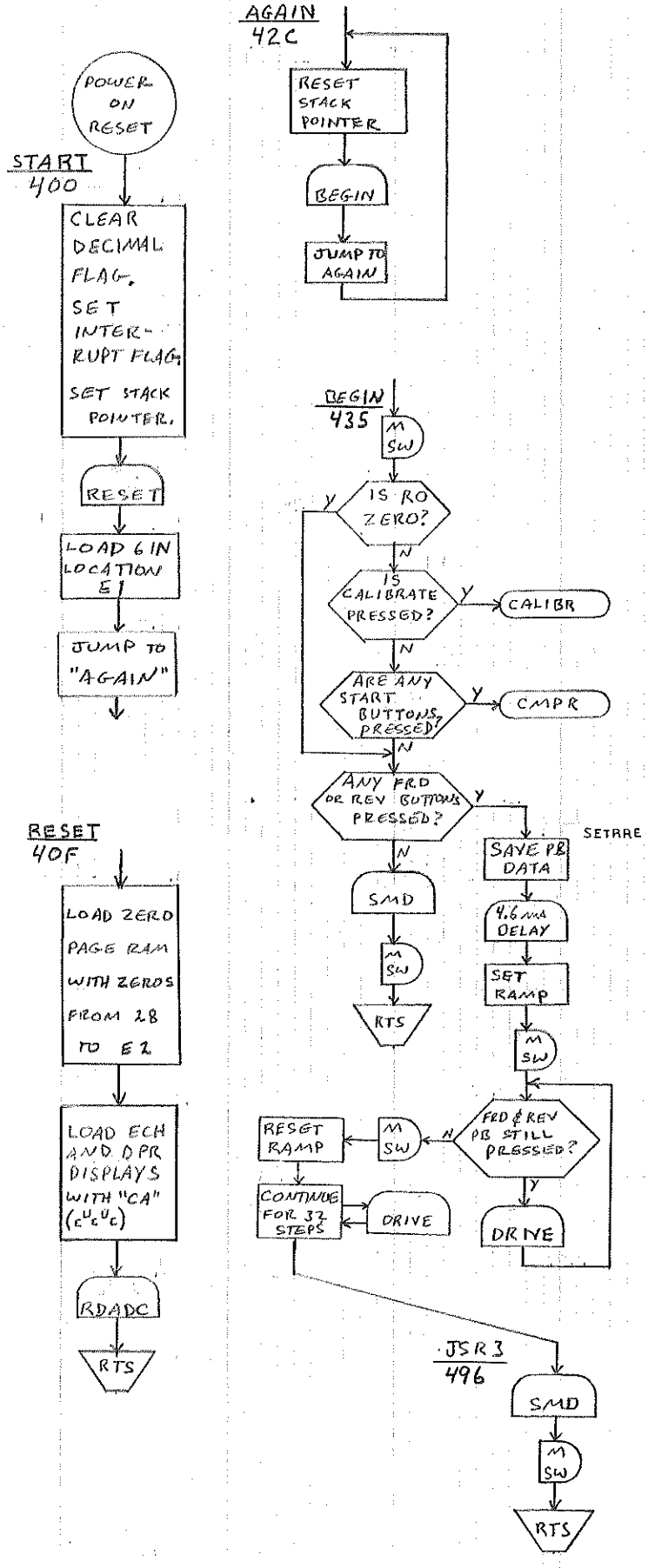
* Assumptions: Both motors run during calibration for 2 min; one motor moved for 15 sec every 10 min.

ECHELLE SOFTWARE FLOWCHART OVERVIEW



NAME	STARTING ADDRESS	FLOWCHART PAGE	PROGRAM LISTING PAGE
START	400	B-2	C-4
RESET	40F	B-2	C-4
AGAIN	42C	B-2	C-4
BEGIN	435	B-2	C-5
SETRRE	45F	B-2	C-5
JSR3	496	B-2	C-6
CALIBR	4A0	B-3	C-8
LIMTST	557	B-3	C-12
CMPR	5B5	B-4	C-14
ECHST	5CB	B-4	C-14
DPRST	636	B-4	C-16
FOCST	6A4	B-4	C-19
RRETST	71B	B-4	C-21

NAME	STARTING ADDRESS	FLOWCHART PAGE	PROGRAM LISTING PAGE
ALU	75E	B-6	C-23
BKLASH	7CB	B-8	C-25
DRIVE	831	B-5	C-27
PLSDLY	86A	B-5	C-28
UPDATE	89B	B-5	C-28
DELAY	8F9	B-5	C-30
SMD	903	B-7	C-31
RDADC	9BB	B-8	C-35
TSTTST	A0B	B-6	C-36



START — INITIALIZES FLAGS AND STACK-POINTER, CALLS RESET, AND LOADS THE CALIBRATE MAGIC NUMBER.

RESET — CLEARS ALL ZERO PAGE RAM, THEN LOADS DISPLAY REGISTERS WITH A "CALIBRATION REQUIRED" CODE. THE JSR TO RDADC SETS FOCUS DISPLAY.

AGAIN — AS A PRECAUTION AGAINST SUBROUTINES FAILING TO UNNEST, THEREBY FILLING THE STACK POINTER, IT IS RESET HERE. ALSO CALLS BEGIN.

BEGIN — EXAMINES PUSH BUTTONS. JUMPS OFF TO CALIBRATE OR COMPARE, OR HANDLES MANUAL PB FUNCTIONS.

JSR3 — MAKES ONE PASS THRU DISPLAY ROUTINE AND CLEARS STATUS WORD. SERVES AS A TERMINATOR FOR OTHER ROUTINES ALSO.

STATUS WORD — OUTPUT BUFFER, R9, AND ITS SOFTWARE COMPANION, RR9, INDICATE WHERE THE PROGRAM IS OPERATING. R9 CAN BE MONITORED AS A TROUBLE-SHOOTING AID.

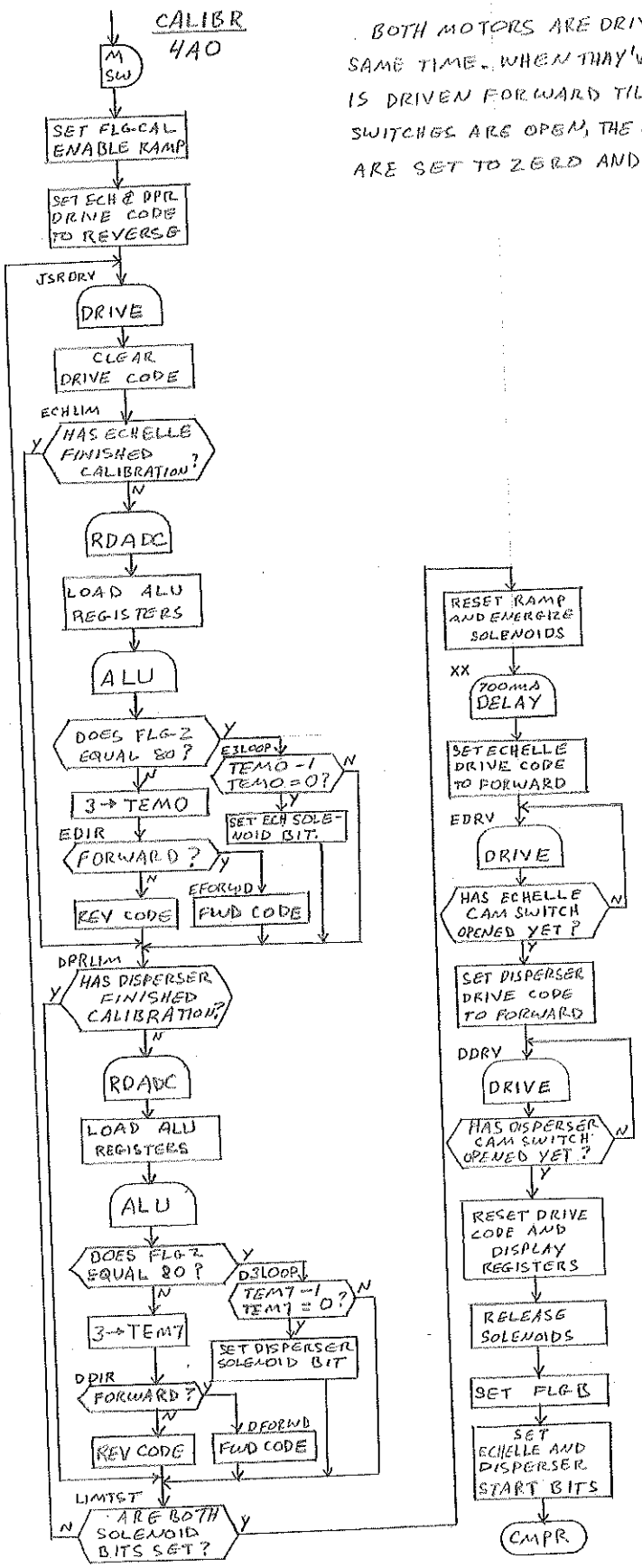
XXX = JUMP TO SUBROUTINE XXX

RTS = RETURN FROM SUBROUTINE

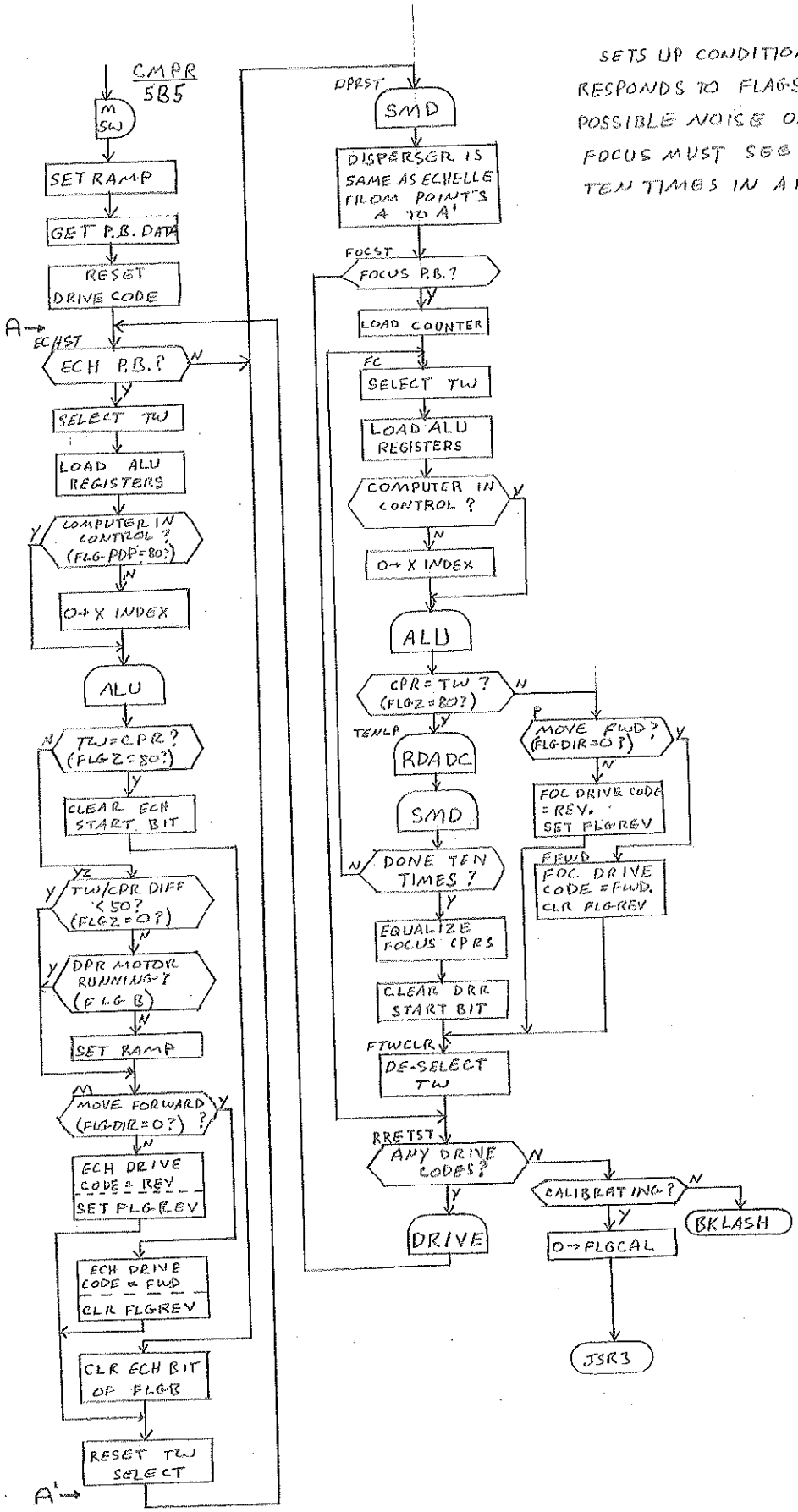
MSW = MODIFY STATUS WORD

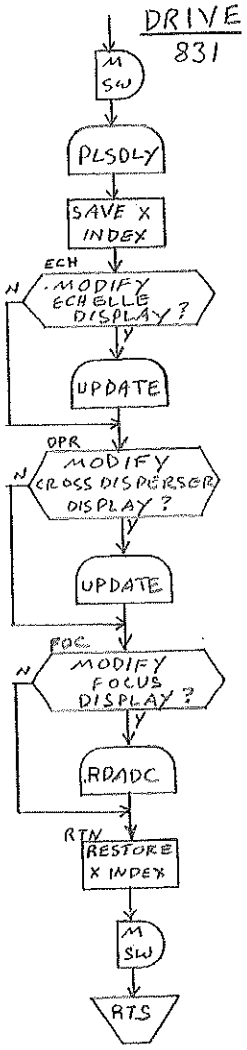
XXX = JUMP TO LOCATION XXX

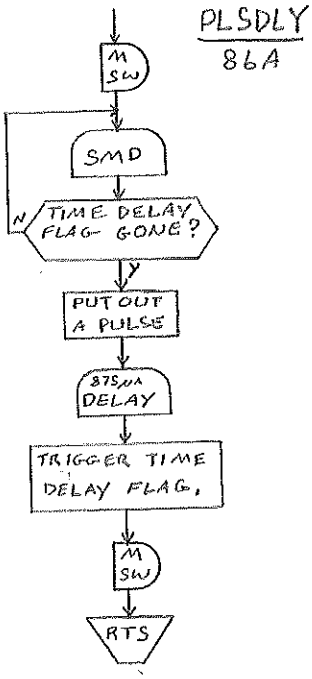
BOTH MOTORS ARE DRIVEN TOWARDS A REFERENCE POINT AT THE SAME TIME. WHEN THEY'VE BOTH REACHED IT, ONE AT A TIME, EACH IS DRIVEN FORWARD TILL ITS CAM SWITCH OPENS. WHEN BOTH CAM SWITCHES ARE OPEN, THE ECHELLE AND CROSS DISPERSER DISPLAYS ARE SET TO ZERO AND CONTROL PASSES TO "CMPR".

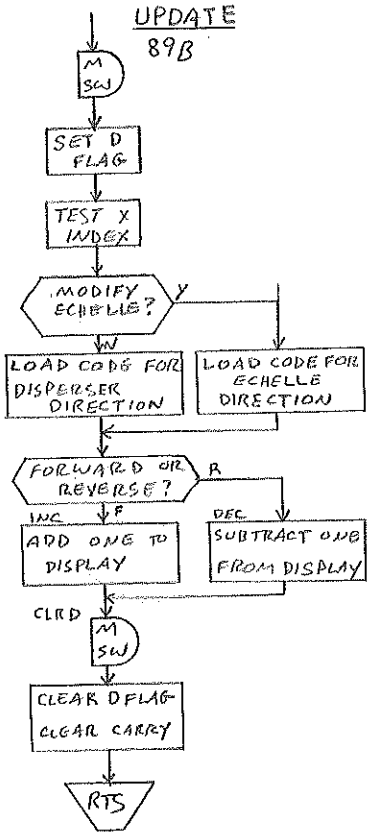


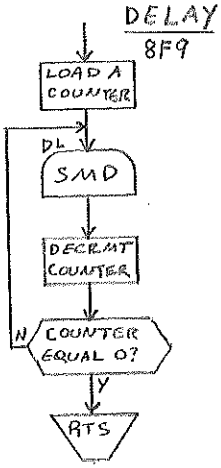
SETS UP CONDITIONS FOR ALU. TESTS AND RESPONDS TO FLAGS SET BY ALU. DUE TO POSSIBLE NOISE ON POSITION POT SIGNALS, FOCUS MUST SEE THE SAME TW=CPR DATA TEN TIMES IN A ROW.









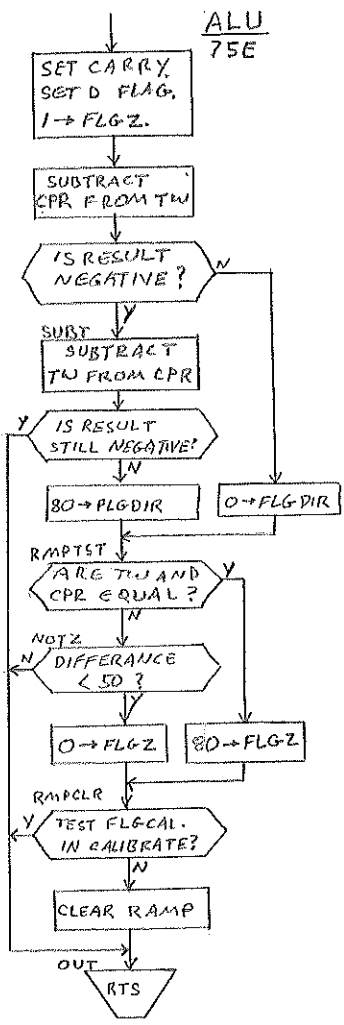


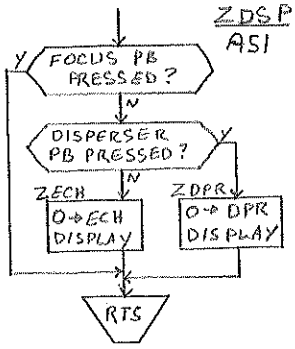
DRIVE IS MOSTLY A CALLING ROUTINE. IT CALLS THE PULSE SUBROUTINE THEN TESTS TO SEE WHICH DISPLAYS TO UPDATE. RDADC UPDATES FOCUS.

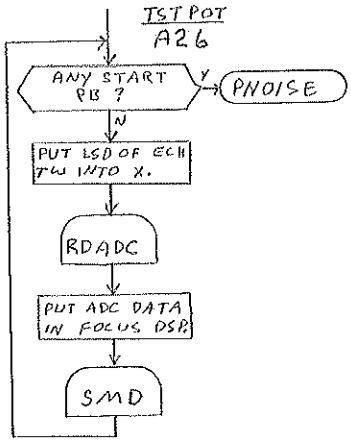
PLSDLY HAVING PREVIOUSLY SETUP A TIME DELAY FLAG, WAITS FOR IT TO TIME OUT THEN USES THE DRIVE CODE (IN REGISTER RRE) TO PUT OUT A PULSE, AND AGAIN TRIGGERS THE TIME DELAY FLAG.

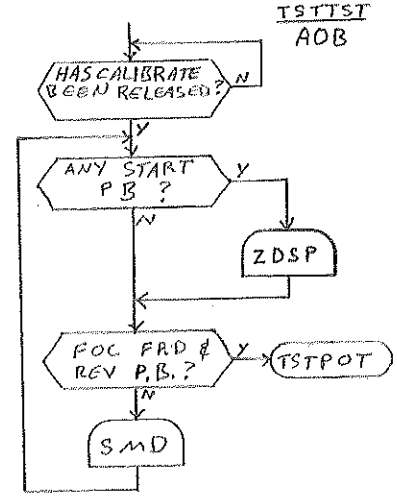
UPDATE CORRECTS THE ECHELLE AND CROSS DISPERSER DISPLAYS.

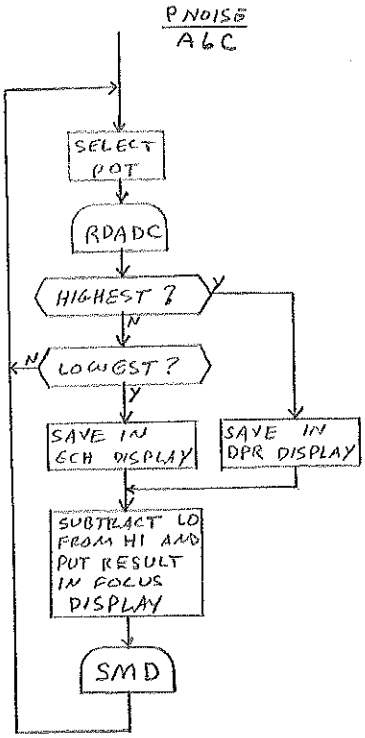
DELAY A TIME WASTER TO WAIT FOR SWITCHES TO STOP BOUNCING, LEVELS TO SETTLE, ETC.











ALU DOES THE ARITHMATIC OF COMPARING TW (THUMBWHEEL) AND CPR (CURRENT POSITION REGISTER) VALUES, AND SETS DIRECTION AND MAGNITUDE FLAGS.

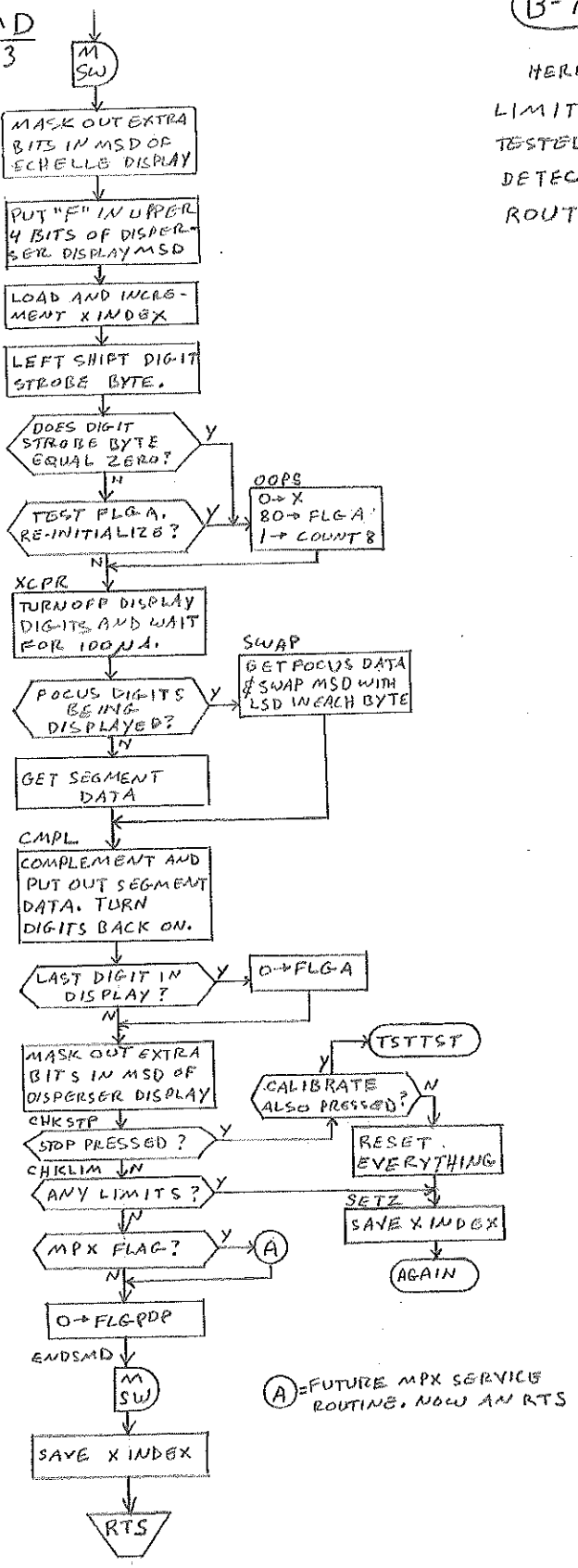
TSTTST REDEFINES SWITCHES FOR RUNNING TEST ROUTINES.

ZDSP PUTS ZERO INTO ECHELLE OR CROSS DISPERSER DISPLAY, WHICHEVER START BUTTON IS PRESSED. IGNORES FOC PB.

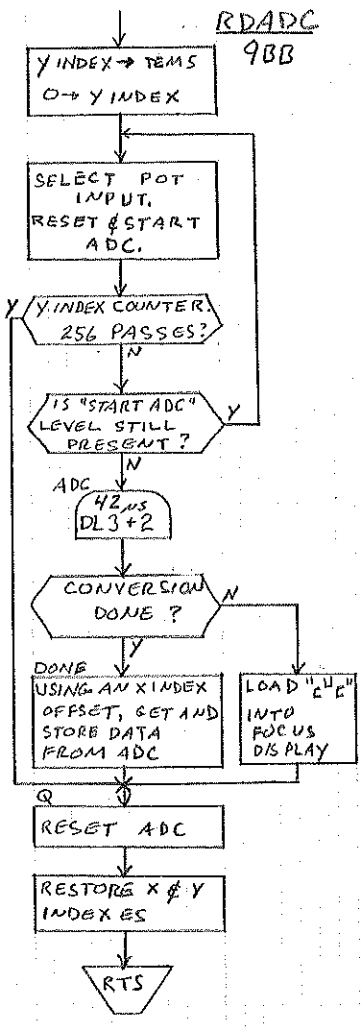
TSTPOT REDEFINES START P.B.s FOR "PNOISE". DISPLAYS SELECTED POSITION POT VALUE IN FOC DISPLAY.

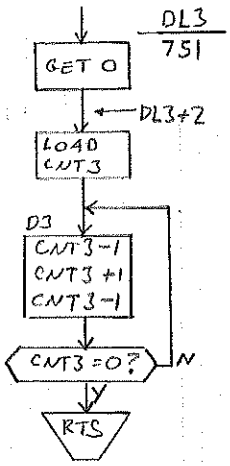
PNOISE NOT WRITTEN YET. WILL PROVIDE A RELATIVE INDICATION OF THE AMOUNT OF NOISE PRESENT ON POSITION POT SIGNAL VOLTAGE

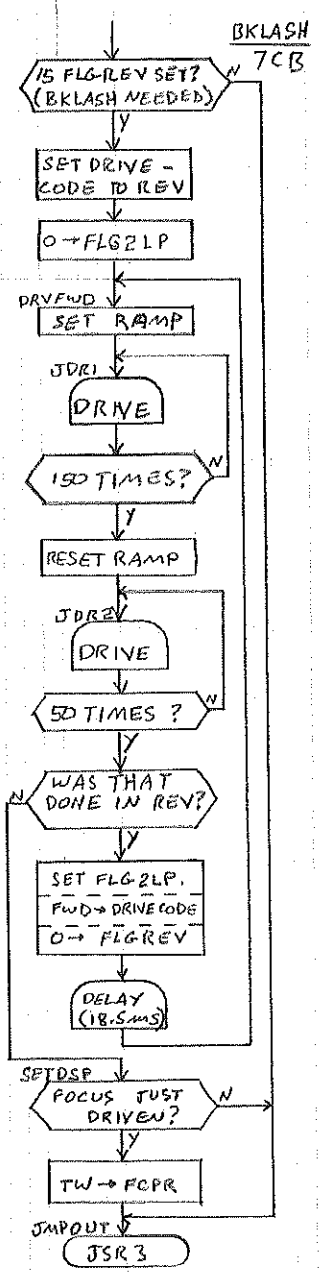
SMD 903



HERE THE DISPLAY IS OPERATED, THE STOP BUTTON, LIMIT SWITCHES, AND MULTIPLEXER FLAG ARE TESTED. IF THE STOP AND CALIBRATE ARE BOTH DETECTED, THE PROGRAM GOES OFF TO MAINTENANCE ROUTINES.







RDADC READS POSITION POT DATA FROM THE ADC.

DL 3 GENERAL PURPOSE DELAY LOOP

BKLASH TO REMOVE ANY MECHANICAL BACKLASH, THE MOTOR CONTINUES TO GO REVERSE FOR 200 STEPS. THEN IT GOES FORWARD 200 STEPS. THUS, THE FINAL POSITION ALWAYS IS REACHED BY MOVING IN THE FORWARD DIRECTION.

```
 R PALH
*TEMP,LPT:<CON9,TEM1,TEM2,TEM3,TEM4,TEM5,TEM6,TEM7,TEM89/C(16)
RD    0E3
RD    0E3
/CON9    /=154
```

C1

PALH-V10A 02/15/78 PAGE 1

```
  1                          /CON9    /=154
  2                 001      FIELD 1
  3                          /ABS LOC = ABSOLUTE LOCATION
  4                 020      *#20
  5     1 020       000      R0,0
  6     1 021       000      R1,0
  7     1 022       000      R2,0
  8     1 023       000      R4,0
  9     1 024       000      R6,0
 10     1 025       000      R7,0
 11     1 026       000      R8,0
 12     1 027       000      R9,0
 13     1 028       000      RA,0
 14     1 029       000      RB,0
 15     1 02A       000      RC,0
 16     1 02B       000      RD,0
 17     1 02C       000      RE,0
 18     1 02D       000      RF,0
 19     1 02E       000      R10,0
 20     1 02F       000      R11,0
 21     1 030       000      R13,0
 22     1 031       000      R15,0
 23                 080      *#80
 24     1 080       000      ECPRA,0
 25     1 081       000      ECPRB,0
 26     1 082       000      ECPRC,0
 27     1 083       000      DCPRA,0
 28     1 084       000      DCPRB,0
 29     1 085       000      DCPRC,0
 30     1 086       000      FCPRA,0  /ABS LOC.
 31     1 087       000      FCPRB,0  /ABS LOC.
 32     1 088       000      EPOTHI,0
 33     1 089       000      EPOTLO,0
 34     1 08A       000      DPOTHI,0
 35     1 08B       000      DPOTLO,0
 36     1 08C       000      COUNT8,0
 37     1 08D       000      FLGA,0
 38     1 08E       000      FLGB,0
 39     1 08F       000      FLGCAL,0
 40     1 090       000      FLGDIR,0
 41     1 091       000      FLGFDP,0
 42     1 092       000      FLGREV,0
 43     1 093       000      FLGZ,0
 44     1 094       000      FLG2LP,0
 45     1 095       000      TEM0,0
 46     1 096       000      TEM2,0
 47     1 097       000      TEM3,0
 48     1 098       000      TEM4,0
 49     1 099       000      TEM5,0
 50     1 09A       000      TEM6,0
 51     1 09B       000      TEM7,0
 52     1 09C       000      CNT1,0
 53     1 09D       000      CNT2,0
 54     1 09E       000      CNT3,0
 55                          /
```

① ② ③ ④ ⑤

EXPLANTATION of COLUMNS

① Line numbers: Reffered to by listings on pages C41-C46.

② Field number: Has no meaning to the actual program. Used only by the PDP-8 during assembly.

③ Address location in RAM or EPROM.

④ Data value or instruction code.

⑤ Mnemonics or location lables.

Columns 3 and 4 are all Hexadecimal.

In column 5, numbers preceeded by "#" are Hexadecimal. All others are Octal.

```
                    /
                    /
              0BD   *#BD
    1 0BD     000   CPRA,0
    1 0BE     000   CPRB,0
    1 0BF     000   CPRC,0
    1 0C0     000   RR0,0
    1 0C1     000   RR1,0
    1 0C2     000   RR6,0
    1 0C3     000   RR7,0
    1 0C4     000   RR8,0
    1 0C5     000   RR9,0
    1 0C6     000   RRA,0
    1 0C7     000   RRC,0
    1 0C8     000   RRD,0
    1 0C9     000   RRE,0
    1 0CA     000   RR13,0
    1 0CB     000   RR15,0
    1 0CC     000   A0,0
    1 0CD     000   AA,0
              0E0   *#E0
    1 0E0     000   0          /ABS LOC
    1 0E1     006   6          /ABS LOC.
    1 0E2     000   0          /ABS LOC
                    /
                    /
              069   ADCI=151
              075   ADCX=165
              065   ADCZ=145
              03D   ANDABX=075
              029   ANDI=51
              025   ANDZ=45
              00A   ASL=12
              006   ASLZ=6
              090   BCC=220
              0B0   BCS=260
              0F0   BEQ=360
              02C   BITA=54
              024   BITZ=44
              030   BMI=60
              0D0   BNE=320
              010   BPL=20
              000   BRK=00
              070   BVS=160
              018   CLC=30
              0D8   CLD=330
              0C9   CMPI=311
              0C6   DECZ=306
              0CA   DEX=312
              088   DEY=210
              049   EORI=111
              045   EORZ=105
              0F6   INCX=366
              0E6   INCZ=346
              0E8   INX=350
```

```
/CON9    /=154

 111              0C8   INY=310
 112              04C   JMP=114
 113              06C   JMPI=154
 114              020   JSR=40
 115              0AD   LDAA=255
 116              0A9   LDAI=251
 117              0B5   LDAX=265
 118              0B1   LDAYI=261
 119              0A5   LDAZ=245
 120              0AE   LDXA=256
 121              0A2   LDXI=242
 122              0A6   LDXZ=246
 123              0A0   LDYI=240
 124              0A4   LDYZ=244
 125              04A   LSR=112
 126              046   LSRZ=106
 127              0EA   NOP=352
 128              01D   ORAABX=035
 129              009   ORAI=11
 130              005   ORAZ=5
 131              048   PHA=110
 132              008   PHP=10
 133              068   PLA=150
 134              060   RTS=140
 135              0E9   SBCI=351
 136              0F5   SBCX=365
 137              0E5   SBCZ=345
 138              038   SEC=70
 139              0F8   SED=370
 140              078   SEI=170
 141              08D   STAA=215
 142              095   STAX=225
 143              091   STAYI=221
 144              085   STAZ=205
 145              086   STXZ=206
 146              084   STYZ=204
 147              0AA   TAX=252
 148              0A8   TAY=250
 149              0BA   TSX=272
 150              08A   TXA=212
 151              09A   TXS=232
 152              098   TYA=230
 153                    /
 154                    /
```

```
                    /TEM1    /=168
              400   *2000
1 400         0D8   START,CLD
1 401         078    SEI
1 402         0A2    LDXI   /SET STACK POINTER.
1 403         0CF     317
1 404         09A    TXS
1 405         020    JSR
1 406         000     0
1 407         40F     RESET
1 408         0A9    LDAI
1 409         006     006
1 40A         085    STAZ
1 40B         0E1     341    /PART OF THE CALIBRATE MAGIC NUMBER.
1 40C         04C    JMP
1 40D         000     0
1 40E         42C     AGAIN
                    /
1 40F         0A9   RESET,LDAI   /SET Z-PAGE=0.
1 410         000     000
1 411         0A2    LDXI
1 412         0BA     272   /TOP OF Z-PAGE.(BA+28=E2)
1 413         095   DECR,STAX
1 414         028     050   /BOTTOM OF Z-PAGE(29 IS LOWEST LOCATION).
1 415         0CA    DEX
1 416         0D0    BNE
1 417         FFB     DECR-1-.
1 418         0A9    LDAI   /LOAD ERROR
1 419         0CA     312   /CODE IN
1 41A         085    STAZ   /ALL CPR'S.
1 41B         081     ECPRB
1 41C         085    STAZ
1 41D         082     ECPRC
1 41E         085    STAZ
1 41F         084     DCPRB
1 420         085    STAZ
1 421         085     DCPRC
1 422         085    STAZ
1 423         080     ECPRA
1 424         085    STAZ
1 425         083     DCPRA
1 426         0A2    LDXI   /OFFSET CODE.
1 427         000     000
1 428         020    JSR    /INITIALIZE
1 429         000     0     /FOCUS CPR'S.
1 42A         9BB     RDADC
1 42B         060    RTS
                    /
1 42C         0A2   AGAIN,LDXI
1 42D         0CF     317
1 42E         09A    TXS   /SET STACK.
1 42F         020    JSR
1 430         000     0
1 431         435     BEGIN
1 432         04C    JMP
```

```
210   1 433   000    0
211   1 434   42C    AGAIN
212                 /
213   1 435   0A9  BEGIN,LDAI
214   1 436   002    002   /SET
215   1 437   085   STAZ
216   1 438   027    R9    /STATUS
217   1 439   085   STAZ
218   1 43A   0C5    RR9   /WORD.
219   1 43B   0A5  EXAMR0,LDAZ
220   1 43C   020    R0
221   1 43D   085   STAZ
222   1 43E   098    TEM4
223   1 43F   0F0   BEQ   /IF R0=0,
224   1 440   00E    EXAMR1-1-.   /BRANCH.
225   1 441   010   BPL   /IF BIT 7=0,
226   1 442   003    AUTO-1-.   /BRANCH.
227   1 443   04C  CALIB,JMP /IF BIT 7
228   1 444   000    0     /=1, CALIBRATE.
229   1 445   4A0    CALIBR
230   1 446   0A5  AUTO,LDAZ
231   1 447   098    TEM4
232   1 448   029   ANDI   /EXAMINE
233   1 449   00E    016   /ALL START SW.
234   1 44A   0F0   BEQ   /IF NONE SET,
235   1 44B   003    EXAMR1-1-.   /BRANCH.
236   1 44C   04C   JMP    /IF PRESENT,
237   1 44D   000    0     /JUMP TO
238   1 44E   5B5    CMPR  /COMPARE.
239   1 44F   0A5  EXAMR1,LDAZ
240   1 450   021    R1   /FWD &REV P.B. REG.
241   1 451   085   STAZ
242   1 452   0C1    RR1
243   1 453   029   ANDI
244   1 454   03F    077
245   1 455   0D0   BNE    /IF PRESENT,
246   1 456   008    SETRRE-1-.  /BRANCH.
247   1 457   020   JSR
248   1 458   000    0
249   1 459   903    SMD
250   1 45A   0A9   LDAI
251   1 45B   000    000   /RESET
252   1 45C   085   STAZ   /STATUS
253   1 45D   027    R9    /WORD.
254   1 45E   060   RTS
255                 /
256   1 45F   085  SETRRE,STAZ /STORE
257   1 460   0C9    RRE   /P.B. DATA.
258   1 461   0A9   LDAI   /SWITCH CONTACT BOUNCE
259   1 462   010    020   /TIME DELAY(4.6MS).
260   1 463   020   JSR
261   1 464   000    0
262   1 465   8F9    DELAY
263   1 466   0A5   LDAZ
264   1 467   0C8    RRD
```

```
265   1 468   009   ORAI   /"OR" RAMP BIT.
266   1 469   020    040
267   1 46A   085   STAZ
268   1 46B   028    RD     /SET RAMP BIT.
269   1 46C   085   STAZ
270   1 46D   0C8    RRD
271   1 46E   0A9   LDAI
272   1 46F   080    200   /SET
273   1 470   085   STAZ
274   1 471   027    R9    /STATUS
275   1 472   085   STAZ
276   1 473   0C5    RR9   /WORD.
277   1 474   0A5  JSR1,LDAZ /LOOK
278   1 475   021    R1    /FOR P.B.'S.
279   1 476   029   ANDI
280   1 477   03F    077 /ARE EITHER FWD
281   1 478   0F0   BEQ   / OR REV PRESENT?
282   1 479   006    XBEGIN-1-. /NO,BRANCH.
283   1 47A   020   JSR    /YES,CONTINUE.
284   1 47B   000    0
285   1 47C   831    DRIVE
286   1 47D   04C   JMP
287   1 47E   000    0
288   1 47F   474    JSR1
289                 /
290   1 480   0A9  XBEGIN,LDAI
291   1 481   008    010    /SET STATUS
292   1 482   085   STAZ   /WORD.
293   1 483   027    R9
294   1 484   085   STAZ
295   1 485   0C5    RR9
296   1 486   0A5   LDAZ
297   1 487   0C8    RRD   /RESET
298   1 488   029   ANDI
299   1 489   0DF    337   /RAMP
300   1 48A   085   STAZ
301   1 48B   028    RD    /BIT.
302   1 48C   085   STAZ
303   1 48D   0C8    RRD
304   1 48E   0A0   LDYI
305   1 48F   020    040
306   1 490   020  DECY,JSR /MOVE 32 MORE
307   1 491   000    0         /STEPS DURING
308   1 492   831    DRIVE /RAMP DOWN.
309   1 493   088   DEY
310   1 494   0D0   BNE    /IF Y NOT=0,
311   1 495   FFA    DECY-1-./BRANCH.
312                 /
313   1 496   020  JSR3,JSR
314   1 497   000    0
315   1 498   903    SMD
316   1 499   0A9   LDAI
317   1 49A   000    000   /RESET
318   1 49B   085   STAZ   /STATUS
319   1 49C   027    R9    /WORD.
```

/TEM1 /=168

```
320   1 49D   085   STAZ
321   1 49E   0C5    RR9
322   1 49F   060   RTS
```

```
                        /TEM2   /=194
1 4A0   0A9   CALIBR,LDAI  /SET STATUS WORD.
1 4A1   001     001
1 4A2   085    STAZ
1 4A3   027     R9
1 4A4   085    STAZ
1 4A5   0C5     RR9
1 4A6   0A9    LDAI  /SET FLAG.
1 4A7   080     200
1 4A8   085    STAZ
1 4A9   08F     FLGCAL
                /
1 4AA   0A5    LDAZ  /SET RAMP BIT.
1 4AB   0C8     RRD
1 4AC   009    ORAI
1 4AD   020     040
1 4AE   085    STAZ
1 4AF   02B     RD
1 4B0   085    STAZ
1 4B1   0C8     RRD
                /
1 4B2   0A9    LDAI  /GRATING MOTORS TO REV.
1 4B3   00A     012
1 4B4   085    STAZ
1 4B5   0C9     RRE
                /
1 4B6   020   JSRDRV,JSR
1 4B7   000     0
1 4B8   831     DRIVE
1 4B9   0A9    LDAI  /RESET THE DRIVE REG.
1 4BA   000     000
1 4BB   085    STAZ
1 4BC   0C9     RRE
1 4BD   0A5   ECHLIM,LDAZ /IF ECH SOLENOID BIT IS SET,
1 4BE   0CA     RR13 /IT HAS REACHED IT'S POTLIM, SO
1 4BF   029    ANDI  /SKIP TO DISPERSER SECTION.
1 4C0   008     010
1 4C1   0F0    BEQ
1 4C2   003     3
1 4C3   04C    JMP
1 4C4   000     0
1 4C5   50A     DPRLIM
                /
1 4C6   0A2    LDXI  /ECH OFFSET CODE.
1 4C7   002     002
1 4C8   020    JSR
1 4C9   000     0
1 4CA   9BB     RDADC /GET DATA FROM POT.
1 4CB   0A9    LDAI  /SET UP CPRA,B,C BEFORE GOING TO ALU.
1 4CC   000     000
1 4CD   085    STAZ
1 4CE   0BD     CPRA
1 4CF   0A5    LDAZ
1 4D0   088     EPOTHI
1 4D1   085    STAZ
```

```
378   1 4D2   0BE    CPRB
379   1 4D3   0A5   LDAZ
380   1 4D4   089    EPOTLO
381   1 4D5   085   STAZ
382   1 4D6   0BF    CPRC
383   1 4D7   0A2   LDXI   /THIS OFFSET MAKES R6,7,8 IN ALU LOOK LIKE
384   1 4D8   0BA    272   /0,6,0 RESPECTIVELY.
385   1 4D9   020   JSR
386   1 4DA   000    0     /COMPUTES DISTANCE TO AND DIRECTION
387   1 4DB   75E    ALU   /OF THE POTLIM MAGIC NUMBER.
388   1 4DC   0A5   LDAZ   /IF THE DISTANCE TO THE MAGIC NUMBER
389   1 4DD   093    FLGZ /IS ZERO, FLGZ WILL BE SET.
390   1 4DE   030   BMI
391   1 4DF   007    E3LOOP-1-.
392   1 4E0   0A9   LDAI   /IF THE FLAG WASN'T SET,
393   1 4E1   003    003   /LOAD THE 3 LOOP COUNTER
394   1 4E2   085   STAZ    /FOR USE LATER WHEN
395   1 4E3   095    TEMO   /THE FLAG IS SET.
396   1 4E4   04C   JMP
397   1 4E5   000    0
398   1 4E6   4F7    EDIR
399                 /
400   1 4E7   0C6   E3LOOP,DECZ /THIS COUNTER ROUTINE MAKES THE
401   1 4E8   095    TEMO /ADC RETURN THE SAME DATA 3 TIMES IN A
402   1 4E9   0F0   BEQ    /ROW AT THE POTLIM MAGIC NUMBER.
403   1 4EA   003    3
404   1 4EB   04C   JMP
405   1 4EC   000    0
406   1 4ED   50A    DPRLIM
407   1 4EE   0A5   LDAZ   /IF ADC INDICATES 3 RIGHT ANSWERS IN A ROW,
408   1 4EF   0CA    RR13 /SET THE SOLENOID BIT,
409   1 4F0   009   ORAI
410   1 4F1   008    010
411   1 4F2   085   STAZ
412   1 4F3   0CA    RR13
413   1 4F4   04C   JMP    /BUT JUMP AROUND SETTING THE DRIVE BIT.
414   1 4F5   000    0
415   1 4F6   50A    DPRLIM
416                 /
417   1 4F7   0A5   EDIR,LDAZ /CHECK THE DIRECTION FLAG:0=FWD.
418   1 4F8   090    FLGDIR
419   1 4F9   0F0   BEQ
420   1 4FA   009    EFORWD-1-.
421   1 4FB   0A5   LDAZ   /SET REV CODE.
422   1 4FC   0C9    RRE
423   1 4FD   009   ORAI
424   1 4FE   002    002
425   1 4FF   085   STAZ
426   1 500   0C9    RRE
427   1 501   04C   JMP
428   1 502   000    0
429   1 503   50A    DPRLIM
430   1 504   0A5   EFORWD,LDAZ /SET FWD CODE.
431   1 505   0C9    RRE
432   1 506   009   ORAI
```

```
433   1 507   001     001
434   1 508   085    STAZ
435   1 509   0C9     RRE
436                  /
437   1 50A   0A5    DPRLIM,LDAZ /FOR COMMENTS, SEE SIMILAR
438   1 50B   0CA     RR13 /PARTS OF ECHLIM ABOVE.
439   1 50C   029    ANDI
440   1 50D   004     004
441   1 50E   0F0    BEQ
442   1 50F   003     3
443   1 510   04C    JMP
444   1 511   000     0
445   1 512   557     LIMTST
446                  /
447   1 513   0A2    LDXI
448   1 514   004     004
449   1 515   020    JSR
450   1 516   000     0
451   1 517   9BB     RDADC
452   1 518   0A9    LDAI
453   1 519   000     000
454   1 51A   085    STAZ
455   1 51B   0BD     CPRA
456   1 51C   0A5    LDAZ
457   1 51D   08A     DPOTHI
458   1 51E   085    STAZ
459   1 51F   0BE     CPRB
460   1 520   0A5    LDAZ
461   1 521   08B     DPOTLO
462   1 522   085    STAZ
463   1 523   0BF     CPRC
464   1 524   0A2    LDXI
465   1 525   08A     272
466   1 526   020    JSR
467   1 527   000     0
468   1 528   75E     ALU
469   1 529   0A5    LDAZ
470   1 52A   093     FLGZ
471   1 52B   030    BMI
472   1 52C   007     D3LOOP-1-*
473   1 52D   0A9    LDAI
474   1 52E   003     003
475   1 52F   085    STAZ
476   1 530   09B     TEM7
477   1 531   04C    JMP
478   1 532   000     0
479   1 533   544     DDIR
480                  /
481   1 534   0C6    D3LOOP,DECZ
482   1 535   09B     TEM7
483   1 536   0F0    BEQ
484   1 537   003     3
485   1 538   04C    JMP
486   1 539   000     0
487   1 53A   557     LIMTST
```

```
488   1 53B   0A5   LDAZ
489   1 53C   0CA    RR13
490   1 53D   009   ORAI
491   1 53E   004    004
492   1 53F   085   STAZ
493   1 540   0CA    RR13
494   1 541   04C   JMP
495   1 542   000    0
496   1 543   557    LIMTST
497                 /
498   1 544   0A5   DDIR,LDAZ
499   1 545   090    FLGDIR
500   1 546   0F0   BEQ
501   1 547   009    DFORWD-1-.
502   1 548   0A5   LDAZ
503   1 549   0C9    RRE
504   1 54A   009   ORAI
505   1 54B   008    010
506   1 54C   085   STAZ
507   1 54D   0C9    RRE
508   1 54E   04C   JMP
509   1 54F   000    0
510   1 550   557    LIMTST
511   1 551   0A5   DFORWD,LDAZ
512   1 552   0C9    RRE
513   1 553   009   ORAI
514   1 554   004    004
515   1 555   085   STAZ
516   1 556   0C9    RRE
```

```
                    /TEM3   /=99
1 557   0A5   LIMTST,LDAZ
1 558   0CA     RR13
1 559   029    ANDI
1 55A   00C     014
1 55B   0C9    CMPI
1 55C   00C     014   /HAVE BOTH POT-LIMITS BEEN HIT?
1 55D   0F0    BEQ    /IF SO, CONTINUE.
1 55E   003     3
1 55F   04C    JMP    /IF NOT,GO BACK TO DRIVE MOTORS.
1 560   000     0
1 561   4B6     JSRDRV
                /
1 562   0A5    LDAZ   /IF BOTH HAVE BEEN HIT,
1 563   0C8     RRD   /RESET THE RAMP BIT.
1 564   029    ANDI
1 565   0DF     337
1 566   085    STAZ
1 567   02B     RD
1 568   085    STAZ
1 569   0C8     RRD
1 56A   0A5    LDAZ   /SET THE SOLENOIDS.
1 56B   0CA     RR13
1 56C   085    STAZ
1 56D   030     R13
                /
1 56E   0A9    LDAI   /THIS DELAY IS TO ALLOW
1 56F   00A     012   /THE RAMP TIME TO DECAY.
1 570   085    STAZ   /SET OUTER LOOP
1 571   096     TEM2 /FOR 10 TIMES.
1 572   0A9   XX,LDAI/SET INNER LOOP
1 573   000     0     /FOR 256 TIMES.
1 574   020    JSR
1 575   000     0
1 576   8F9     DELAY
1 577   0C6    DECZ   /THE WHOLE DELAY TAKES
1 578   096     TEM2 /ABOUT 700MS.
1 579   0D0    BNE
1 57A   FF7     XX-1-.
                /
1 57B   0A9    LDAI   /SET THE ECHELLE
1 57C   001     001   /MOTOR TO FORWARD.
1 57D   085    STAZ
1 57E   0C9     RRE
1 57F   020   EDRV,JSR
1 580   000     0
1 581   831     DRIVE
1 582   0A5    LDAZ   /LOOK AT THE DETENT
1 583   022     R2    /MICROSWITCH.
1 584   029    ANDI   /HAS IT FALLEN INTO
1 585   040     100   /THE DETENT?
1 586   0D0    BNE
1 587   FF7     EDRV-1-. /IF NOT, BRANCH.
                /
1 588   0A9    LDAI   /SET THE CROSS
```

C13


```
572   1 589   004    004  /DISPERSER MOTOR TO FORWARD.
573   1 58A   085   STAZ
574   1 58B   0C9    RRE
575   1 58C   020   DDRV,JSR
576   1 58D   000    0
577   1 58E   831    DRIVE
578   1 58F   0A5   LDAZ  /LOOK AT THE DETENT
579   1 590   022    R2   /MICROSWITCH.
580   1 591   029   ANDI  /HAS IT FALLEN INTO
581   1 592   080    200  / THE DETENT YET?
582   1 593   0D0   BNE
583   1 594   FF7    DDRV-1-. /IF NOT,BRANCH.
584   1 595   0A9   LDAI   /IF IT HAS, STOP THE CROSS
585   1 596   000    0     /DISPERSER MOTOR.
586   1 597   085   STAZ
587   1 598   0C9    RRE
588   1 599   085   STAZ   /RESET CPR'S SO READOUT
589   1 59A   080    ECPRA /SHOWS "00000".
590   1 59B   085   STAZ
591   1 59C   083    DCPRA
592   1 59D   085   STAZ
593   1 59E   081    ECPRB
594   1 59F   085   STAZ
595   1 5A0   084    DCPRB
596   1 5A1   085   STAZ
597   1 5A2   082    ECPRC
598   1 5A3   085   STAZ
599   1 5A4   085    DCPRC
600   1 5A5   0A5   LDAZ
601   1 5A6   0CA    RR13
602   1 5A7   029   ANDI  /RELEASE BOTH SOLENOIDS.
603   1 5A8   0F3    363
604   1 5A9   085   STAZ
605   1 5AA   030    R13
606   1 5AB   085   STAZ
607   1 5AC   0CA    RR13
608   1 5AD   0A9   LDAI
609   1 5AE   0C0    300  /SET BOTH FLAG B  BITS.
610   1 5AF   085   STAZ
611   1 5B0   08E    FLGB
612   1 5B1   0A9   LDAI
613   1 5B2   006    006  /LOAD BOTH START BITS
614   1 5B3   085   STAZ  /BEFORE GOING TO COMPARE.
615   1 5B4   098    TEM4
```

```
                    /TEM4   /=243
                    /COMPARE PART 1.
1 5B5   0A9   CMPR,LDAI
1 5B6   010     020   /SET
1 5B7   085    STAZ   /STATUS
1 5B8   027     R9    /WORD.
1 5B9   085    STAZ
1 5BA   0C5     RR9
1 5BB   0A5    LDAZ
1 5BC   0C8     RRD   /SET
1 5BD   009    ORAI
1 5BE   020     040   /RAMP
1 5BF   085    STAZ
1 5C0   02B     RD    /BIT.
1 5C1   085    STAZ
1 5C2   0C8     RRD
1 5C3   0A5    LDAZ
1 5C4   098     TEM4 /LOAD (R0 --> TEM4)
1 5C5   085    STAZ   /"START"
1 5C6   0C0     RR0   /DATA.
1 5C7   0A9   CLRRE,LDAI
1 5C8   000     000
1 5C9   085    STAZ   /RESET
1 5CA   0C9     RRE   /RRE.
                /
1 5CB   0A5   ECHST,LDAZ  /ISOLATE
1 5CC   0C0     RR0   /ECHELLE
1 5CD   029    ANDI   /START
1 5CE   002     002   /BIT.
1 5CF   0D0    BNE    /IF THERE,
1 5D0   003     3      /BRANCH.
1 5D1   04C    JMP    /IF NOT,
1 5D2   000     0
1 5D3   636     DPRST /JUMP.
1 5D4   0A5    LDAZ /IF START BIT PRESENT,
1 5D5   0C8     RRD   /SET
1 5D6   009    ORAI
1 5D7   010     020   /ECHELLE
1 5D8   085    STAZ
1 5D9   02B     RD    /TW
1 5DA   085    STAZ
1 5DB   0C8     RRD   /CODE.
1 5DC   0A5    LDAZ    /PRELOAD ALU REGISTERS.
1 5DD   080     ECPRA
1 5DE   085    STAZ
1 5DF   0BD     CPRA
1 5E0   0A5    LDAZ
1 5E1   081     ECPRB
1 5E2   085    STAZ
1 5E3   0BE     CPRB
1 5E4   0A5    LDAZ
1 5E5   082     ECPRC
1 5E6   085    STAZ
1 5E7   0BF     CPRC
1 5E8   0A5    LDAZ   /ARE WE UNDER COMPUTER CONTROL?
```

```
 671   1 5E9  091    FLGPDP
 672   1 5EA  030   BMI
 673   1 5EB  002    2
 674   1 5EC  0A2   LDXI
 675   1 5ED  000    000
 676   1 5EE  020   JSR
 677   1 5EF  000    0
 678   1 5F0  75E    ALU
 679   1 5F1  0A5   LDAZ
 680   1 5F2  093    FLGZ
 681   1 5F3  010   BPL    /IF TW=CPR,CONTINUE;
 682   1 5F4  009    YZ-1-,/OTHERWISE,BRANCH.
 683   1 5F5  0A5   LDAZ
 684   1 5F6  0C0    RRO
 685   1 5F7  029   ANDI   /RESET ECHELLE
 686   1 5F8  0FD    375   /START BIT.
 687   1 5F9  085   STAZ
 688   1 5FA  0C0    RRO
 689   1 5FB  04C   JMP     /GO RESET FLGB.
 690   1 5FC  000    0
 691   1 5FD  628    ETWCLR-6
 692   1 5FE  0F0   YZ,BEQ   /SKIP SETTING THE RAMP IF DIFF<50.
 693   1 5FF  00C    M-1-.
 694   1 600  024   BITZ /CONTENTS OF ACCUM ARE
 695   1 601  08E    FLGB /IGNORED,JUST M7,M6 OF FLGB.
 696   1 602  070   BVS    /LOOK FOR BIT 6 (DPR).
 697   1 603  008    M-1-.
 698   1 604  0A5   LDAZ   /IF FLGB BIT IS ABSENT,
 699   1 605  0C8    RRD   /SET THE RAMP AGAIN.
 700   1 606  009   ORAI
 701   1 607  020    040
 702   1 608  085   STAZ
 703   1 609  02B    RD
 704   1 60A  085   STAZ
 705   1 60B  0C8    RRD
 706   1 60C  0A5   M,LDAZ   /IF NOT =, DETERMINE
 707   1 60D  090    FLGDIR /DIRECTION.
 708   1 60E  0F0   BEQ    /FLAG NOT SET=FWD.
 709   1 60F  00B    EFWD-1-.
 710   1 610  0A5   LDAZ   /SET DRIVE REGISTER.
 711   1 611  0C9    RRE
 712   1 612  009   ORAI
 713   1 613  002    002
 714   1 614  085   STAZ
 715   1 615  0C9    RRE
 716   1 616  085   STAZ
 717   1 617  092    FLGREV
 718   1 618  04C   JMP
 719   1 619  000    0
 720   1 61A  62E    ETWCLR
 721   1 61B  0A5   EFWD,LDAZ
 722   1 61C  0C9    RRE
 723   1 61D  009   ORAI
 724   1 61E  001    001
 725   1 61F  085   STAZ
```

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 726   1 620   0C9    RRE
 727   1 621   0A9   LDAI
 728   1 622   000    000
 729   1 623   085   STAZ  /RESET THE FLAG.
 730   1 624   092    FLGREV
 731   1 625   04C   JMP
 732   1 626   000    0
 733   1 627   62E    ETWCLR
 734   1 628   0A5   LDAZ
 735   1 629   08E    FLGB
 736   1 62A   029   ANDI
 737   1 62B   07F    177
 738   1 62C   085   STAZ
 739   1 62D   08E    FLGB
 740   1 62E   0A5  ETWCLR,LDAZ  /RESET
 741   1 62F   0C8    RRD
 742   1 630   029   ANDI  /THUMBWHEEL
 743   1 631   0EF    357
 744   1 632   085   STAZ  /SELECT
 745   1 633   02B    RD
 746   1 634   085   STAZ  /CODE.
 747   1 635   0C8    RRD
 748                 /
 749   1 636   020  DPRST,JSR
 750   1 637   000    0
 751   1 638   903    SMD
 752   1 639   0A5   LDAZ
 753   1 63A   0C0    RRO
 754   1 63B   029   ANDI  /IS DPR START
 755   1 63C   004    004  /BIT SET?
 756   1 63D   0D0   BNE   /IF SET,
 757   1 63E   003    3     /BRANCH.
 758   1 63F   04C   JMP   /IF NOT,
 759   1 640   000    0
 760   1 641   6A4    FOCST /JUMP.
 761   1 642   0A5   LDAZ   /IF SET,
 762   1 643   0C8    RRD
 763   1 644   009   ORAI  /SET
 764   1 645   008    010
 765   1 646   085   STAZ  /DPR
 766   1 647   02B    RD
 767   1 648   085   STAZ  /TW CODE.
 768   1 649   0C8    RRD
 769   1 64A   0A5   LDAZ   /PRELOAD ALU REGISTERS.
 770   1 64B   083    DCPRA
 771   1 64C   085   STAZ
 772   1 64D   08D    CPRA
 773   1 64E   0A5   LDAZ
 774   1 64F   084    DCPRB
 775   1 650   085   STAZ
 776   1 651   08E    CPRB
 777   1 652   0A5   LDAZ
 778   1 653   085    DCPRC
 779   1 654   085   STAZ
 780   1 655   08F    CPRC
```

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 781   1 656   0A5   LDAZ  /IS COMPUTER IN CONTROL?
 782   1 657   091    FLGPDP
 783   1 658   030   BMI
 784   1 659   002    2
 785   1 65A   0A2   LDXI
 786   1 65B   000    000
 787   1 65C   020   JSR
 788   1 65D   000    0
 789   1 65E   75E    ALU
 790   1 65F   0A5   LDAZ  /CHECK FOR TW/CPR
 791   1 660   093    FLGZ /EQUALITY.
 792   1 661   010   BPL   /IF=, CONTINUE;
 793   1 662   009    Y-1-. /OTHERWISE, BRANCH.
 794   1 663   0A5   LDAZ
 795   1 664   0C0    RRO
 796   1 665   029   ANDI  /RESET DISPERSER
 797   1 666   0FB    373   /START BIT.
 798   1 667   085   STAZ
 799   1 668   0C0    RRO
 800   1 669   04C   JMP
 801   1 66A   000    0
 802   1 66B   696    DTWCLR-6
 803   1 66C   0F0  Y,BEQ   /SKIP SETTING THE RAMP IF DIFF <50.
 804   1 66D   00C    N-1-.
 805   1 66E   024   BITZ
 806   1 66F   08E    FLGB
 807   1 670   030   BMI
 808   1 671   008    N-1-.
 809   1 672   0A5   LDAZ
 810   1 673   0C8    RRD
 811   1 674   009   ORAI
 812   1 675   020    040
 813   1 676   085   STAZ
 814   1 677   02B    RD
 815   1 678   085   STAZ
 816   1 679   0C8    RRD
 817   1 67A   0A5  N,LDAZ  /IF NOT=, DETERMINE
 818   1 67B   090    FLGDIR /MOTOR DIRECTION.
 819   1 67C   0F0   BEQ   /FLAG NOT SET=FWD.
 820   1 67D   008    DFWD-1-.
 821   1 67E   0A5   LDAZ  /SET DRIVE REGISTER.
 822   1 67F   0C9    RRE
 823   1 680   009   ORAI
 824   1 681   008    010
 825   1 682   085   STAZ
 826   1 683   0C9    RRE
 827   1 684   085   STAZ
 828   1 685   092    FLGREV
 829   1 686   04C   JMP
 830   1 687   000    0
 831   1 688   69C    DTWCLR
 832   1 689   0A5  DFWD,LDAZ
 833   1 68A   0C9    RRE
 834   1 68B   009   ORAI
 835   1 68C   004    004
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 836   1 68D   085   STAZ
 837   1 68E   0C9    RRE
 838   1 68F   0A9   LDAI
 839   1 690   000    000
 840   1 691   085   STAZ
 841   1 692   092    FLGREV
 842   1 693   04C   JMP
 843   1 694   000    0
 844   1 695   69C    DTWCLR
 845   1 696   0A5   LDAZ
 846   1 697   08E    FLGB
 847   1 698   029   ANDI
 848   1 699   0BF    277
 849   1 69A   085   STAZ
 850   1 69B   08E    FLGB
 851   1 69C   0A5  DTWCLR,LDAZ /FETCH
 852   1 69D   0C8    RRD   /TW CODE,
 853   1 69E   029   ANDI   /COMPLEMENT OF
 854   1 69F   0F7    367   /DFR TW CODE,
 855   1 6A0   085   STAZ   /STORE TO
 856   1 6A1   02B    RD    /RESET
 857   1 6A2   085   STAZ   /TW BIT,
 858   1 6A3   0C8    RRD
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```
                    /TEM5   /=191
                    /COMPARE PART 2.
1 6A4   0A5   FOCST,LDAZ
1 6A5   0C0     RRO
1 6A6   029    ANDI  /ISOLATE FOCUS
1 6A7   008     010  /START BIT.
1 6A8   0D0    BNE   /IF SET,
1 6A9   003     3     /BRANCH.
1 6AA   04C    JMP   /IF NOT,
1 6AB   000     0    /JUMP.
1 6AC   71B     RRETST
1 6AD   0A9    LDAI
1 6AE   00A     012
1 6AF   085    STAZ
1 6B0   095     TEMO /LOAD A COUNTER.
1 6B1   0A5   FC,LDAZ /IF START BIT IS THERE,
1 6B2   0C8     RRD
1 6B3   009    ORAI  /SET
1 6B4   004     004
1 6B5   085    STAZ  /FOCUS
1 6B6   02B     RD   /TW
1 6B7   085    STAZ  /CODE.
1 6B8   0C8     RRD
1 6B9   0A9    LDAI
1 6BA   000     000
1 6BB   085    STAZ
1 6BC   0BD     CPRA
1 6BD   0A5    LDAZ
1 6BE   086     FCPRA
1 6BF   085    STAZ
1 6C0   0BE     CPRB
1 6C1   0A5    LDAZ
1 6C2   087     FCPRB
1 6C3   029    ANDI  /DELETE UNUSED DIGIT.
1 6C4   0F0     360
1 6C5   085    STAZ
1 6C6   0BF     CPRC
1 6C7   0A5    LDAZ  /ARE WE IN COMPUTER CONTROL?
1 6C8   091     FLGPDP
1 6C9   030    BMI
1 6CA   002     2    /IF SO,DON'T CHANGE THE X INDEX.
1 6CB   0A2    LDXI
1 6CC   000     000
1 6CD   020    JSR
1 6CE   000     0
1 6CF   75E     ALU
1 6D0   0A5    LDAZ  /CHECK FOR TW/CPR
1 6D1   093     FLGZ /EQUALITY.
1 6D2   010    BPL   /IF=, CONTINUE;
1 6D3   003     3     /OTHERWISE, BRANCH.
1 6D4   04C    JMP
1 6D5   000     0
1 6D6   6F3     TENLP
1 6D7   0A5    LDAZ  /IF NOT=, DETERMINE
1 6D8   090     FLGDIR /MOTOR DIRECTION.
```

```
914   1 6D9  0F0   BEQ   /FLAG NOT SET=FWD.
915   1 6DA  00B    FFWD-1-.
916   1 6DB  0A5   LDAZ
917 — 1 6DC  0C9    RRE  /SET DRIVE REGISTER.
918   1 6DD  009   ORAI
919   1 6DE  020    040  /FOCUS REVERSE CODE.
920   1 6DF  085   STAZ
921   1 6E0  0C9    RRE
922   1 6E1  085   STAZ
923   1 6E2  092    FLGREV
924   1 6E3  04C   JMP
925   1 6E4  000    0
926   1 6E5  713    FTWCLR
927   1 6E6  0A5  FFWD,LDAZ
928   1 6E7  0C9    RRE
929   1 6E8  009   ORAI
930   1 6E9  010    020  /FOCUS FORWARD CODE.
931   1 6EA  085   STAZ
932   1 6EB  0C9    RRE
933   1 6EC  0A9   LDAI
934   1 6ED  000    000
935   1 6EE  085   STAZ
936   1 6EF  092    FLGREV
937   1 6F0  04C   JMP
938   1 6F1  000    0
939   1 6F2  713    FTWCLR
940   1 6F3  08A  TENLP,TXA
941   1 6F4  048   PHA   /SAVE X REG.
942   1 6F5  0A2   LDXI
943   1 6F6  000    000  /ADDRESS OFFSET.
944   1 6F7  020   JSR
945   1 6F8  000    0
946   1 6F9  9BB    RDADC
947   1 6FA  068   PLA
948   1 6FB  0AA   TAX   /RESTORE X REG.
949   1 6FC  020   JSR
950   1 6FD  000    0
951   1 6FE  903    SMD
952   1 6FF  0C6   DECZ
953   1 700  095    TEMO /DECRMT COUNTER,AND
954   1 701  0D0   BNE   /LOOP TILL COUNTER=0.
955   1 702  FAE    FC-1-.
956   1 703  0A5   LDAZ  /EQUALIZE
957   1 704  024    R6
958   1 705  009   ORAI  /BLANK THE LEAST SIG. DIGIT.
959   1 706  00F    017
960   1 707  085   STAZ  /FOCUS
961   1 708  087    FCPRB
962   1 709  0A5   LDAZ
963   1 70A  025    R7   /CPR'S.
964   1 70B  085   STAZ
965   1 70C  086    FCPRA
966   1 70D  0A5   LDAZ
967   1 70E  0C0    RRO
968   1 70F  029   ANDI  /RESET FOCUS
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 969    1 710    0F7     367  /START BIT.
 970    1 711    085    STAZ
 971    1 712    0C0     RR0
 972    1 713    0A5   FTWCLR,LDAZ /CLEAR
 973    1 714    0C8     RRD
 974    1 715    029    ANDI  /FOC
 975    1 716    0FB     373
 976    1 717    085    STAZ  /TW
 977    1 718    028     RD
 978    1 719    085    STAZ  /CODE.
 979    1 71A    0C8     RRD
 980    1 71B    018   RRETST,CLC
 981    1 71C    0D8    CLD
 982    1 71D    0A5    LDAZ
 983    1 71E    0C9     RRE
 984    1 71F    0F0    BEQ   /TEST FOR DRIVE CODES.
 985    1 720    00A     CALTST-1-. /IF NONE,BRANCH.
 986    1 721    020    JSR
 987    1 722    000     0
 988    1 723    831     DRIVE
 989    1 724    0A9    LDAI
 990    1 725    000     000  /CLEAR DRIVE
 991    1 726    085    STAZ  /REGISTER.
 992    1 727    0C9     RRE
 993    1 728    04C    JMP
 994    1 729    000     0
 995    1 72A    5CB     ECHST
 996    1 72B    0A5   CALTST,LDAZ
 997    1 72C    08F     FLGCAL /TEST FOR FLAG.
 998    1 72D    0D0    BNE   /IF PRESENT,
 999    1 72E    003     3      /BRANCH.
1000    1 72F    04C    JMP   /IF ABSENT,
1001    1 730    000     0     /JUMP.
1002    1 731    7CB     BKLASH
1003    1 732    0A9    LDAI  /IF PRESENT,
1004    1 733    000     000
1005    1 734    085    STAZ  /RESET.
1006    1 735    08F     FLGCAL
1007    1 736    04C    JMP
1008    1 737    000     0
1009    1 738    496     JSR3
1010                    /
1011    1 739    0A9   DL1,LDAI
1012    1 73A    000     0
1013    1 73B    085    STAZ
1014    1 73C    09C     CNT1
1015    1 73D    020   D1,JSR
1016    1 73E    000     0
1017    1 73F    745     DL2
1018    1 740    0C6    DECZ
1019    1 741    09C     CNT1
1020    1 742    0D0    BNE
1021    1 743    FF9     D1-1-.
1022    1 744    060    RTS
1023                    /
```

```
1024    1 745   0A9   DL2,LDAI
1025    1 746   000     0
1026    1 747   085    STAZ
1027    1 748   09D     CNT2
1028    1 749   020   D2,JSR
1029    1 74A   000     0
1030    1 74B   751     DL3
1031    1 74C   0C6    DECZ
1032    1 74D   09D     CNT2
1033    1 74E   0D0    BNE
1034    1 74F   FF9     D2-1-,
1035    1 750   060    RTS
1036                   /
1037    1 751   0A9   DL3,LDAI
1038    1 752   000     0
1039    1 753   085    STAZ
1040    1 754   09E     CNT3
1041    1 755   0C6   D3,DECZ
1042    1 756   09E     CNT3
1043    1 757   0E6    INCZ
1044    1 758   09E     CNT3
1045    1 759   0C6    DECZ
1046    1 75A   09E     CNT3
1047    1 75B   0D0    BNE
1048    1 75C   FF8     D3-1-,
1049    1 75D   060    RTS
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1050                        /TEM6   /=215
1051                                /SETS DIRECTION,RESETS RAMP BIT IF CLOSER
1052    1 75E   038  ALU,SEC /THAN 50 STEPS,SETS OR RESETS FLGDIR,AND
1053    1 75F   0F8   SED    /MODIFIES FLGZ(1=>50;0=<50;80=ZERO).
1054    1 760   0A9   LDAI
1055    1 761   001    001
1056    1 762   085   STAZ
1057    1 763   093    FLGZ
1058    1 764   0B5   LDAX   /X NOT=0, IS CALIBRATE MODE.
1059    1 765   024    R6
1060    1 766   0E5   SBCZ
1061    1 767   0BF    CPRC
1062    1 768   085   STAZ
1063    1 769   0C2    RR6
1064    1 76A   0B5   LDAX
1065    1 76B   025    R7
1066    1 76C   0E5   SBCZ
1067    1 76D   0BE    CPRB
1068    1 76E   085   STAZ
1069    1 76F   0C3    RR7
1070    1 770   0B5   LDAX
1071    1 771   026    R8
1072    1 772   029   ANDI
1073    1 773   00F    017
1074    1 774   0E5   SBCZ
1075    1 775   0BD    CPRA
1076    1 776   085   STAZ
1077    1 777   0C4    RR8
1078    1 778   090   BCC    /IF CARRY IS CLEARED, RESULT WAS NEGATIVE AND
1079    1 779   007     SUBT-1-. /SUBTRACTION MUST BE DONE IN REVERSE ORDER.
1080    1 77A   0A9   LDAI
1081    1 77B   000    000
1082    1 77C   085   STAZ   /SINCE RESULT WAS POSITIVE,
1083    1 77D   090    FLGDIR  /RESET FLAG.
1084    1 77E   04C   JMP
1085    1 77F   000    0
1086    1 780   7A0    RMPTST
1087    1 781   038  SUBT,SEC
1088    1 782   0A5   LDAZ   /DO SUBTRACTION
1089    1 783   0BF    CPRC  /UPSIDE DOWN TO GET
1090    1 784   0F5   SBCX   /A POSITIVE RESULT
1091    1 785   024    R6    /TO USE IN SEEING
1092    1 786   085   STAZ   /HOW FAR AWAY THE RAMP
1093    1 787   0C2    RR6   /DOWN POINT IS.
1094    1 788   0A5   LDAZ
1095    1 789   0BE    CPRB
1096    1 78A   0F5   SBCX
1097    1 78B   025    R7
1098    1 78C   085   STAZ
1099    1 78D   0C3    RR7
1100    1 78E   0B5   LDAX   /MASK OUT UPPER
1101    1 78F   026    R8    /FOUR BITS.
1102    1 790   029   ANDI
1103    1 791   00F    017
1104    1 792   085   STAZ
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1105    1 793   0C4     RR8
1106    1 794   0A5    LDAZ
1107    1 795   0BD     CPRA
1108    1 796   0E5    SBCZ
1109    1 797   0C4     RR8
1110    1 798   085    STAZ
1111    1 799   0C4     RR8
1112    1 79A   090    BCC    /IF CARRY IS CLEAR THIS TIME,
1113    1 79B   021     OUT-1-,/SOMETHING IS WRONG;JUMP OUT.
1114    1 79C   0A9    LDAI
1115    1 79D   080     200
1116    1 79E   085    STAZ   /SET FLAG.
1117    1 79F   090     FLGDIR
1118    1 7A0   0A5   RMPTST,LDAZ  /IF THE MOST
1119    1 7A1   0C4     RR8  /SIGNIFICANT DIGIT
1120    1 7A2   0D0    BNE    /IS NOT ZERO,
1121    1 7A3   019     OUT-1-, /BRANCH.
1122    1 7A4   0A5    LDAZ   /IF THE MIDDLE
1123    1 7A5   0C3     RR7   /SIGNIFICANT DIGIT
1124    1 7A6   0D0    BNE    /IS NOT ZERO,
1125    1 7A7   015     OUT-1-, /BRANCH.
1126    1 7A8   038    SEC
1127    1 7A9   0A5    LDAZ    /IF THE TW AND THE DISPLAY
1128    1 7AA   0C2     RR6    /ARE NOT EQUAL,GO TEST
1129    1 7AB   0D0    BNE     /FOR <50.
1130    1 7AC   013     NOTZ-1-.
1131    1 7AD   0A9    LDAI   /IF RR6 IS ALSO=0,
1132    1 7AE   080     200   /SET THE ZERO FLAG.
1133    1 7AF   085    STAZ
1134    1 7B0   093     FLGZ
1135    1 7B1   0A5   RMPCLR,LDAZ
1136    1 7B2   08F     FLGCAL /IF IN CALIB,DONT RESET RAMP.
1137    1 7B3   030    BMI
1138    1 7B4   008     OUT-1-.
1139    1 7B5   0A5    LDAZ
1140    1 7B6   0C8     RRD
1141    1 7B7   029    ANDI
1142    1 7B8   0DF     337   /RESET THE RAMP BIT.
1143    1 7B9   085    STAZ
1144    1 7BA   028     RD
1145    1 7BB   085    STAZ
1146    1 7BC   0C8     RRD
1147    1 7BD   018   OUT,CLC
1148    1 7BE   0D8    CLD
1149    1 7BF   060    RTS
1150                   /
1151    1 7C0   0E9   NOTZ,SBCI
1152    1 7C1   050     120    /IS DIFFERENCE < 50?
1153    1 7C2   0B0    BCS
1154    1 7C3   FF9     OUT-1-.         /NO.
1155    1 7C4   0A9    LDAI             /YES.
1156    1 7C5   000     0
1157    1 7C6   085    STAZ
1158    1 7C7   093     FLGZ
1159    1 7C8   04C    JMP
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1160   1 7C9   000     0
1161   1 7CA   7B1     RMPCLR
1162                  /
1163   1 7CB   0A5   BKLASH,LDAZ
1164   1 7CC   092     FLGREV
1165   1 7CD   0F0    BEQ    /IF FLAG NOT SET,
1166   1 7CE   05F     JMPOUT-1-, /BRANCH.
1167   1 7CF   085    STAZ   /IF FLAG SET,
1168   1 7D0   0C9     RRE   /STORE REV CODE.
1169   1 7D1   0A9    LDAI
1170   1 7D2   000     000
1171   1 7D3   085    STAZ   /RESET
1172   1 7D4   094     FLG2LP /FLAG.
1173   1 7D5   0A5   DRVFWD,LDAZ
1174   1 7D6   0C8     RRD
1175   1 7D7   009    ORAI
1176   1 7D8   020     040   /SET
1177   1 7D9   085    STAZ   /RAMP
1178   1 7DA   02B     RD    /BIT.
1179   1 7DB   085    STAZ
1180   1 7DC   0C8     RRD
1181   1 7DD   0A0    LDYI /150 STEPS
1182   1 7DE   096     226   /DURING RAMP UP.
1183   1 7DF   020   JDR1,JSR
1184   1 7E0   000     0
1185   1 7E1   831     DRIVE
1186   1 7E2   088    DEY    /DECR Y REG.
1187   1 7E3   0D0    BNE    /IS Y REG > 0?
1188   1 7E4   FFA     JDR1-1-,  /YES.
1189   1 7E5   0A5    LDAZ   /NO,
1190   1 7E6   0C8     RRD
1191   1 7E7   029    ANDI   /RESET
1192   1 7E8   0DF     337
1193   1 7E9   085    STAZ   /RAMP
1194   1 7EA   02B     RD    /BIT.
1195   1 7EB   085    STAZ
1196   1 7EC   0C8     RRD
1197   1 7ED   0A0    LDYI   /50 STEPS
1198   1 7EE   032     62   /DURING RAMP DOWN.
1199   1 7EF   020   JDR2,JSR
1200   1 7F0   000     0
1201   1 7F1   831     DRIVE
1202   1 7F2   088    DEY    /DECR Y REG.
1203   1 7F3   0D0    BNE    /IS Y REG > 0?
1204   1 7F4   FFA     JDR2-1-, /YES.
1205   1 7F5   0A5    LDAZ   /LOOK AT THE
1206   1 7F6   094     FLG2LP /LOOP FLAG.
1207   1 7F7   0D0    BNE    /IF FLAG IS SET,
1208   1 7F8   015     SETDSP-1-, /BRANCH.
1209   1 7F9   0A9    LDAI   /IF NOT, THEN
1210   1 7FA   0FF     377   /SET
1211   1 7FB   085    STAZ   /THE
1212   1 7FC   094     FLG2LP /FLAG
1213   1 7FD   0A5    LDAZ   /AND GENERATE
1214   1 7FE   092     FLGREV /A
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1215   1 7FF   04A   LSR    /FORWARD
1216   1 800   085   STAZ   /CODE.
1217   1 801   0C9    RRE   /STORE.
1218   1 802   0A9   LDAI   /RESET
1219   1 803   000    000   /REVERSE
1220   1 804   085   STAZ   /FLAG.
1221   1 805   092    FLGREV
1222   1 806   0A9   LDAI   /PAUSE FOR 82mS
1223   1 807   000    0      /BETWEEN DIRECTIONS.
1224   1 808   020   JSR
1225   1 809   000    0
1226   1 80A   8F9    DELAY
1227   1 80B   04C   JMP
1228   1 80C   000    0
1229   1 80D   7D5    DRVFWD
1230   1 80E   0A5  SETDSP,LDAZ
1231   1 80F   0C9    RRE   /CHECK DRIVE CODE TO
1232   1 810   029   ANDI   /SEE IF FOCUS WAS DRIVEN.
1233   1 811   030    060
1234   1 812   0F0   BEQ    /IF CODE IS ABSENT, SKIP NEXT PART.
1235   1 813   01A    JMPOUT-1-.
1236   1 814   0A5   LDAZ   /IF PRESENT,
1237   1 815   0C8    RRD
1238   1 816   009   ORAI
1239   1 817   004    004
1240   1 818   085   STAZ
1241   1 819   02B    RD
1242   1 81A   085   STAZ   /SET FOCUS TW CODE.
1243   1 81B   0C8    RRD
1244   1 81C   0A5   LDAZ   /THEN
1245   1 81D   024    R6    /EQUALIZE FOCUS CPR'S.
1246   1 81E   009   ORAI   /BLANK THE LEAST SIG. DIGIT.
1247   1 81F   00F    017
1248   1 820   085   STAZ
1249   1 821   087    FCPRB
1250   1 822   0A5   LDAZ
1251   1 823   025    R7
1252   1 824   085   STAZ
1253   1 825   086    FCPRA
1254   1 826   0A5   LDAZ
1255   1 827   0C8    RRD
1256   1 828   029   ANDI
1257   1 829   0FB    373   /CLEAR FOC TW CODE.
1258   1 82A   085   STAZ
1259   1 82B   02B    RD
1260   1 82C   085   STAZ
1261   1 82D   0C8    RRD
1262   1 82E   04C  JMPOUT,JMP
1263   1 82F   000    0
1264   1 830   496    JSR3
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1265                        /TEM7   /=214
1266    1 831   0A5   DRIVE,LDAZ
1267    1 832   0C5     RR9   /SET
1268    1 833   009    ORAI
1269    1 834   040     100   /STATUS
1270    1 835   085    STAZ
1271    1 836   027     R9    /WORD.
1272    1 837   085    STAZ
1273    1 838   0C5     RR9
1274    1 839   020    JSR
1275    1 83A   000     0
1276    1 83B   86A     PLSDLY
1277    1 83C   086    STXZ
1278    1 83D   096     TEM2 /SAVE X REG CONTENTS.
1279    1 83E   0A5   ECH,LDAZ
1280    1 83F   0C9     RRE
1281    1 840   029    ANDI
1282    1 841   003     003   /ECHELLE MASK.
1283    1 842   0F0    BEQ    /MOVE ECH MOTORS?
1284    1 843   005     DPR-1-. /IF NOT,BRANCH.
1285    1 844   0A2    LDXI   /IF YES,LOAD
1286    1 845   002     002   /ECH ADD. OFFSET.
1287    1 846   020    JSR
1288    1 847   000     0
1289    1 848   89B     UPDATE /CHANGE ECH CPR.
1290    1 849   0A5   DPR,LDAZ
1291    1 84A   0C9     RRE
1292    1 84B   029    ANDI
1293    1 84C   00C     014   /CROSS DISPERSER MASK.
1294    1 84D   0F0    BEQ    /MOVE DPR MOTOR?
1295    1 84E   005     FOC-1-. /IF NOT, BRANCH.
1296    1 84F   0A2    LDXI   /IF YES,LOAD
1297    1 850   005     005   /DPR ADD. OFFSET.
1298    1 851   020    JSR
1299    1 852   000     0
1300    1 853   89B     UPDATE /CHANGE DPR CPR.
1301    1 854   0A5   FOC,LDAZ /DOES FOCUS
1302    1 855   0C9     RRE
1303    1 856   029    ANDI   /REQUIRE
1304    1 857   030     060
1305    1 858   0F0    BEQ    /UPDATING?
1306    1 859   005     RTN-1-.  /NO, BRANCH.
1307    1 85A   0A2    LDXI   /YES, GET OFFSET CODE.
1308    1 85B   000     000
1309    1 85C   020    JSR
1310    1 85D   000     0
1311    1 85E   9BB     RDADC
1312    1 85F   0A6   RTN,LDXZ
1313    1 860   096     TEM2 /RESTORE X REG.
1314    1 861   0A5    LDAZ
1315    1 862   0C5     RR9   /RESET
1316    1 863   029    ANDI
1317    1 864   0BF     277   /STATUS
1318    1 865   085    STAZ
1319    1 866   027     R9    /WORD.
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1320    1 867   085   STAZ
1321    1 868   0C5    RR9
1322    1 869   060   RTS
1323                  /
1324    1 86A   0A5   PLSDLY,LDAZ /SET STATUS
1325    1 86B   0C5    RR9   /WORD.
1326    1 86C   009   ORAI
1327    1 86D   004    004
1328    1 86E   085   STAZ
1329    1 86F   027    R9
1330    1 870   085   STAZ
1331    1 871   0C5    RR9
1332    1 872   020   WAIT,JSR
1333    1 873   000    0
1334    1 874   903    SMD
1335    1 875   0A5   LDAZ
1336    1 876   021    R1
1337    1 877   029   ANDI
1338    1 878   040    100
1339    1 879   0D0   BNE
1340    1 87A   FF7    WAIT-1-.
1341    1 87B   0A5   LDAZ
1342    1 87C   0C9    RRE
1343    1 87D   085   STAZ
1344    1 87E   02C    RE
1345    1 87F   0A9   LDAI
1346    1 880   000    000
1347    1 881   085   STAZ
1348    1 882   02C    RE    /OUTPUT PULSE.
1349    1 883   0A9   LDAI   /SET UP NUMBER
1350    1 884   003    003   /OF DELAY LOOPS.
1351    1 885   020   JSR
1352    1 886   000    0
1353    1 887   8F9    DELAY
1354    1 888   0A5   LDAZ
1355    1 889   0C8    RRD
1356    1 88A   009   ORAI
1357    1 88B   040    100
1358    1 88C   085   STAZ
1359    1 88D   02B    RD
1360    1 88E   029   ANDI
1361    1 88F   0BF    277
1362    1 890   085   STAZ
1363    1 891   02B    RD    /TIME DELAY TRIGGER.
1364    1 892   0A5   LDAZ
1365    1 893   0C5    RR9   /RESET
1366    1 894   029   ANDI
1367    1 895   0F8    373    /STATUS
1368    1 896   085   STAZ
1369    1 897   027    R9    /WORD.
1370    1 898   085   STAZ
1371    1 899   0C5    RR9
1372    1 89A   060   RTS
1373                  /
1374    1 89B   0A5   UPDATE,LDAZ
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1375   1 89C  0CB    RR15
1376   1 89D  009   ORAI  /SET STATUS
1377   1 89E  080    200  /WORD
1378   1 89F  085   STAZ
1379   1 8A0  031    R15
1380   1 8A1  085   STAZ
1381   1 8A2  0CB    RR15
1382   1 8A3  0F8   SED
1383   1 8A4  08A   TXA   /NEXT 21 LINES CHECK WHICH OF TWO
1384   1 8A5  0C9   CMPI  /OPOSITE GOING MOTORS TO UPDATE.
1385   1 8A6  002    2    /TEST FOR ECH OR DPR.
1386   1 8A7  0D0   BNE
1387   1 8A8  007    DPRFRD-1-.
1388   1 8A9  0A5   LDAZ
1389   1 8AA  0C9    RRE
1390   1 8AB  029   ANDI
1391   1 8AC  001    1
1392   1 8AD  04C   JMP
1393   1 8AE  000    0
1394   1 8AF  8B4    DPRFRD+4
1395   1 8B0  0A5  DPRFRD,LDAZ
1396   1 8B1  0C9    RRE
1397   1 8B2  029   ANDI
1398   1 8B3  004    4
1399   1 8B4  0D0   BNE
1400   1 8B5  003    3
1401   1 8B6  04C   JMP
1402   1 8B7  000    0
1403   1 8B8  8D1    DEC
1404   1 8B9  018  INC,CLC /IF INCR,
1405   1 8BA  0A9   LDAI  /ADD
1406   1 8BB  001    001  /ONE
1407   1 8BC  075   ADCX  /TO
1408   1 8BD  080    200  /LSD.
1409   1 8BE  095   STAX
1410   1 8BF  080    200
1411   1 8C0  0CA   DEX
1412   1 8C1  0A9   LDAI  /ADD
1413   1 8C2  000    000  /PREVIOUS
1414   1 8C3  075   ADCX  /CARRY.
1415   1 8C4  080    200
1416   1 8C5  095   STAX
1417   1 8C6  080    200
1418   1 8C7  0CA   DEX
1419   1 8C8  0A9   LDAI  /ADD
1420   1 8C9  000    000  /PREVIOUS
1421   1 8CA  075   ADCX  /CARRY
1422   1 8CB  080    200  /AND
1423   1 8CC  095   STAX  /JUMP.
1424   1 8CD  080    200
1425   1 8CE  04C   JMP
1426   1 8CF  000    0
1427   1 8D0  8EE    CLRD
1428   1 8D1  0A5  DEC,LDAZ
1429   1 8D2  0CB    RR15
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1430   1 8D3  009   ORAI
1431   1 8D4  040    100  /SET STATUS
1432   1 8D5  085   STAZ  /WORD.
1433   1 8D6  031    R15
1434   1 8D7  085   STAZ
1435   1 8D8  0CB    RR15
1436   1 8D9  038   SEC
1437   1 8DA  0B5   LDAX  /GET (INDIRECT) CPR'S.
1438   1 8DB  080    200  /LEAST SIG DIGITS.
1439   1 8DC  0E9   SBCI  /SUBTRACT ONE.
1440   1 8DD  001    001
1441   1 8DE  095   STAX  /STORE (INDIRECT).
1442   1 8DF  080    200
1443   1 8E0  0CA   DEX   /DECR X REG FOR NEXT CPR.
1444   1 8E1  0B5   LDAX
1445   1 8E2  080    200
1446   1 8E3  0E9   SBCI
1447   1 8E4  000    000  /SUBTRACT ANY BORROW
1448   1 8E5  095   STAX  /THAT MAY BE PRESENT.
1449   1 8E6  080    200
1450   1 8E7  0CA   DEX
1451   1 8E8  0B5   LDAX
1452   1 8E9  080    200
1453   1 8EA  0E9   SBCI  /SUBTRACT ANY
1454   1 8EB  000    000  /BORROW THAT
1455   1 8EC  095   STAX  /MAY BE
1456   1 8ED  080    200  /PRESENT.
1457   1 8EE  0A5  CLRD,LDAZ
1458   1 8EF  0CB    RR15
1459   1 8F0  029   ANDI  /RESET STATUS
1460   1 8F1  03F    077  /WORD.
1461   1 8F2  085   STAZ
1462   1 8F3  031    R15
1463   1 8F4  085   STAZ
1464   1 8F5  0CB    RR15
1465   1 8F6  0D8   CLD
1466   1 8F7  018   CLC
1467   1 8F8  060   RTS
1468                      /289 US PER LOOP PLUS 8US.
1469   1 8F9  085  DELAY,STAZ
1470   1 8FA  0CD    AA
1471   1 8FB  020  DL,JSR
1472   1 8FC  000    0
1473   1 8FD  903    SMD
1474   1 8FE  0C6   DECZ
1475   1 8FF  0CD    AA
1476   1 900  0D0   BNE
1477   1 901  FF9    DL-1-.
1478   1 902  060   RTS
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1479                        /TEM8   /=188
1480                                /275 USEC PER PASS.
1481    1 903   0A5   SMD,LDAZ
1482    1 904   0C5     RR9
1483    1 905   009    ORAI
1484    1 906   020     040
1485    1 907   085    STAZ  /SET STATUS WORD.
1486    1 908   027     R9
1487    1 909   085    STAZ
1488    1 90A   0C5     RR9
1489    1 90B   0A5    LDAZ  /THIS GROUP
1490    1 90C   080     ECPRA/OF INSTRUCTIONS
1491    1 90D   029    ANDI  /MASKS OUT ANY
1492    1 90E   00F     017  /BITS MORE
1493    1 90F   085    STAZ  /SIGNIFICANT
1494    1 910   080     ECPRA/THAN THE
1495    1 911   0A5    LDAZ  /WANTED DATA.
1496    1 912   083     DCPRA
1497    1 913   009    ORAI  /BLANK UNUSED DIGIT.
1498    1 914   0F0     360
1499    1 915   085    STAZ
1500    1 916   083     DCPRA
1501    1 917   0A6    LDXZ  /RESTORE X REG.
1502    1 918   09A     TEM6
1503    1 919   0E8    INX
1504    1 91A   006    ASLZ
1505    1 91B   08C     COUNT8 /DISPLAY STROBE.
1506    1 91C   0F0    BEQ   /IF COUNT8 TURNS UP
1507    1 91D   004     OOPS-1-. /ALL ZERO'S, RESET.
1508    1 91E   0A5    LDAZ   /IS THIS TO BE
1509    1 91F   08D     FLGA /THE FIRST
1510    1 920   030    BMI    /OF 8 PASSES?
1511    1 921   00A     XCPR-1-. /IF NOT,BRANCH.
1512    1 922   0A2   OOPS,LDXI  /SET X REG
1513    1 923   000     000 /TO ZERO.
1514    1 924   0A9    LDAI
1515    1 925   080     200
1516    1 926   085    STAZ
1517    1 927   08D     FLGA /SET FLAG A.
1518    1 928   0A9    LDAI
1519    1 929   001     001
1520    1 92A   085    STAZ
1521    1 92B   08C     COUNT8 /INITIALIZE.
1522    1 92C   0A9   XCPR,LDAI /BLANK DIGITS
1523    1 92D   000     000  /DURING
1524    1 92E   085    STAZ   /DATA
1525    1 92F   029     RB   /CHANGE.
1526    1 930   0A9    LDAI  /THESE INSTRUCTIONS PROVIDE A 100USEC
1527    1 931   007     007  /DELAY TO ALLOW THE CURRENT TO
1528    1 932   085    STAZ  /THE DISPLAY DIGITS JUST TURNED
1529    1 933   0CC     A0   /OFF TO DECAY SO THERE IS NONE
1530    1 934   0C6   DEL,DECZ  /FLOWING WHEN THE NEXT DIGITS ARE
1531    1 935   0CC     A0   /TURNED ON. THIS AVOIDS "GHOSTS".
1532    1 936   0E6    INCZ
1533    1 937   0CC     A0
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1534   1 938   0C6   DECZ
1535   1 939   0CC    A0
1536   1 93A   0D0   BNE
1537   1 93B   FF8    DEL-1-.
1538   1 93C   08A   TXA    /ISOLATE FOCUS ADDRESS
1539   1 93D   0C9   CMPI   /OFFSET CODE & SEE IF
1540   1 93E   006    006   /FCPRA IS INVOLVED THIS TIME.
1541   1 93F   0F0   BEQ    /IF IT IS INVOLVED,
1542   1 940   067    SWAP-1-. /BRANCH.
1543   1 941   0C9   CMPI   /TEST TO SEE IF FCPRB
1544   1 942   007    007   /IS INVOLVED THIS TIME.
1545   1 943   0F0   BEQ    /IF IT IS INVOLVED,
1546   1 944   063    SWAP-1-. /BRANCH.
1547   1 945   0B5   LDAX     /LOAD
1548   1 946   080    200     /HARDWARE
1549   1 947   049  CMPL,EORI     /WITH
1550   1 948   0FF    377    /COMPLEMENTED
1551   1 949   085   STAZ     /SEGMENT
1552   1 94A   028    RA     /DATA.
1553   1 94B   0A5   LDAZ   /LOAD
1554   1 94C   08C    COUNT8 /HARDWARE
1555   1 94D   085   STAZ    /WITH
1556   1 94E   029    RB    /DIGIT DATA.
1557   1 94F   010   BPL   /WAS THAT THE LAST DIGIT?
1558   1 950   004    4     /IF NOT,BRANCH.
1559   1 951   0A9   LDAI    /IF IT WAS,
1560   1 952   000    000
1561   1 953   085   STAZ    /CLEAR
1562   1 954   08D    FLGA /FLAG A.
1563   1 955   0A5   LDAZ   /CLEAR UNUSED DIGIT.
1564   1 956   083    DCPRA
1565   1 957   029   ANDI
1566   1 958   00F    017
1567   1 959   085   STAZ
1568   1 95A   083    DCPRA
1569   1 95B   0A5  CHKSTP,LDAZ
1570   1 95C   021    R1    /LOOK AT STOP BIT.
1571   1 95D   010   BPL     /IS STOP ABSENT?
1572   1 95E   028    CHKLIM-1-. /IF SO,BRANCH.
1573   1 95F   0A5   LDAZ
1574   1 960   020    R0
1575   1 961   010   BPL     /IF CALIB IS NOT PRESSED,BRANCH.
1576   1 962   003    3
1577   1 963   04C   JMP
1578   1 964   000    0
1579   1 965   A0B    TSTTST
1580   1 966   0A9   LDAI    /IF STOP PB IS PRESENT,
1581   1 967   000    000   /RESET THE FOLLOWING:
1582   1 968   085   STAZ   /COMPUTER FLAG,
1583   1 969   091    FLGPDP
1584   1 96A   085   STAZ  /MPX DATA FLAGS,
1585   1 96B   02D    RF
1586   1 96C   085   STAZ
1587   1 96D   02A    RC    /OUTPUT TO MPX,
1588   1 96E   085   STAZ
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1589   1 96F   02B     RD    /TW,TD,RAMP,
1590   1 970   085    STAZ
1591   1 971   0C8     RRD
1592   1 972   085    STAZ
1593   1 973   030     R13   /ADC, POT, SOLENOIDS,
1594   1 974   085    STAZ
1595   1 975   0CA     RR13
1596   1 976   085    STAZ
1597   1 977   02C     RE    /DRIVE REGISTER,
1598   1 978   085    STAZ
1599   1 979   0C9     RRE
1600   1 97A   085    STAZ
1601   1 97B   08F     FLGCAL /CALIBRATE FLAG,
1602   1 97C   085    STAZ  /REVERSE FLAG,
1603   1 97D   092     FLGREV
1604   1 97E   085    STAZ  /STATUS WORD.
1605   1 97F   027     R9
1606   1 980   085    STAZ
1607   1 981   0C5     RR9
1608   1 982   086   SETZ,STXZ        /SAVE X REG.
1609   1 983   09A     TEM6
1610   1 984   04C    JMP
1611   1 985   000     0
1612   1 986   42C     AGAIN /RETURN TO CONTROL.
1613   1 987   0A5   CHKLIM,LDAZ
1614   1 988   022     R2    /LIMIT REGISTER.
1615   1 989   029    ANDI    /MASK OUT DETENT SWITCHES.
1616   1 98A   03F     077
1617   1 98B   0F0    BEQ     /ANY LIMITS?
1618   1 98C   003     3      /NO,BRANCH.
1619   1 98D   04C    JMP   /YES, STOP EVERYTHING!
1620   1 98E   000     0
1621   1 98F   982     SETZ
1622                  /
1623   1 990   0A5    LDAZ    /CHKMPX.
1624   1 991   023     R4
1625   1 992   029    ANDI   /MASK OUT
1626   1 993   001     001   /"MPX DATA READY" BIT.
1627   1 994   0F0    BEQ    /IS MPX BIT PRESENT?
1628   1 995   003     003   /NO,BRANCH.
1629   1 996   020    JSR    /YES,
1630   1 997   000     0     /SERVICE THE
1631   1 998   A6F     MPXSVC /MULTIPLEXER.
1632   1 999   0A9    LDAI   /RESET THE COMPUTER FLAG.
1633   1 99A   000     0
1634   1 99B   085    STAZ
1635   1 99C   091     FLGPDP
1636   1 99D   0A5   ENDSMD,LDAZ
1637   1 99E   0C5     RR9
1638   1 99F   029    ANDI
1639   1 9A0   0DF     337   /RESET
1640   1 9A1   085    STAZ   /STATUS
1641   1 9A2   027     R9    /WORD.
1642   1 9A3   085    STAZ
1643   1 9A4   0C5     RR9
```

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1644    1 9A5   086    STXZ  /SAVE X REG.
1645    1 9A6   09A     TEM6
1646    1 9A7   060    RTS
1647                   /
1648    1 9A8   0B5    SWAP,LDAX  /GET FOCUS
1649    1 9A9   080      200  /DIGIT DATA.
1650    1 9AA   04A    LSR   /MOVE LEFT NUMBER
1651    1 9AB   04A    LSR   /OVER TO THE RIGHT
1652    1 9AC   04A    LSR   /POSITION,
1653    1 9AD   04A    LSR
1654    1 9AE   085    STAZ  /AND SAVE.
1655    1 9AF   097     TEM3
1656    1 9B0   0B5    LDAX  /GET SAME SAME DATA
1657    1 9B1   080      200  /AND MOVE RIGHT
1658    1 9B2   00A    ASL   /NUMBER INTO
1659    1 9B3   00A    ASL   /LEFT POSITION.
1660    1 9B4   00A    ASL
1661    1 9B5   00A    ASL
1662    1 9B6   005    ORAZ  /COMBINE TWO SHIFTED
1663    1 9B7   097     TEM3 /PARTS OF THE DATA.
1664    1 9B8   04C    JMP
1665    1 9B9   000     0
1666    1 9BA   947     CMPL
```

```
1667                        /TEM9   /=198
1668   1 9BB   084   RDADC,STYZ  /SAVE Y REG.
1669   1 9BC   099     TEM5      / FOC: X=0
1670   1 9BD   0A0    LDYI       / ECH: X=2
1671   1 9BE   000     000       / DPR: X=4
1672   1 9BF   0A5    LDAZ
1673   1 9C0   0CA     RR13
1674   1 9C1   01D    ORAABX/RESET ADC,
1675   1 9C2   000     0     /SELECT MPX
1676   1 9C3   A05     ADCRST/INPUT"FOCUS".
1677   1 9C4   085    STAZ
1678   1 9C5   030     R13
1679   1 9C6   085    STAZ
1680   1 9C7   0CA     RR13
1681   1 9C8   0A5    LDAZ
1682   1 9C9   0CA     RR13
1683   1 9CA   03D    ANDABX/START ADC AND
1684   1 9CB   000     0     /RESET OTHER
1685   1 9CC   A06     ADCST/TWO POT BITS.
1686   1 9CD   085    STAZ
1687   1 9CE   0CA     RR13
1688   1 9CF   085    STAZ
1689   1 9D0   030     R13
1690   1 9D1   088    DEY    /DECR Y AND TEST FOR ZERO.
1691   1 9D2   0F0    BEQ    /IF THE LOOP HAS BEEN DONE
1692   1 9D3   024     Q-1-./256 TIMES, GIVE UP AND CONTINUE.
1693   1 9D4   0A5    LDAZ
1694   1 9D5   02F     R11   /IF START BIT STILL
1695   1 9D6   029    ANDI   /PRESENT, DO IT AGAIN.
1696   1 9D7   002     002   /ISOLATE ADC START BIT.
1697   1 9D8   0D0    BNE
1698   1 9D9   FE5     RDADC+3-./RESTART 5 LINES BELOW RDADC.
1699   1 9DA   0A9   ADC,LDAI          /SET UP A
1700   1 9DB   002     002    /DELAY TIME OF 42USEC.
1701   1 9DC   020    JSR
1702   1 9DD   000     0
1703   1 9DE   753     DL3+2
1704   1 9DF   0A5    LDAZ
1705   1 9E0   02F     R11
1706   1 9E1   029    ANDI
1707   1 9E2   001     001
1708   1 9E3   0F0    BEQ     /BRANCH IF "EOC" IS LOW.
1709   1 9E4   009     DONE-1-.
1710   1 9E5   0A9    LDAI    /IF STILL HIGH, SOMETHING
1711   1 9E6   0EE     356    /IS WRONG.
1712   1 9E7   085    STAZ    /LOAD ERROR CODE
1713   1 9E8   086     FCFRA /INTO FOC
1714   1 9E9   085    STAZ    /DISPLAYS.
1715   1 9EA   087     FCFRB
1716   1 9EB   04C    JMP
1717   1 9EC   000     0
1718   1 9ED   9F8     Q
1719   1 9EE   0A5   DONE,LDAZ  /IF DONE, LOAD
1720   1 9EF   02E     R10    /MSD DATA AND
1721   1 9F0   095    STAX   /STORE Z-PAGE,X.
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1722    1 9F1   086     206   /POTHI.
1723    1 9F2   0A5    LDAZ
1724    1 9F3   02F     R11   /LSD
1725    1 9F4   029    ANDI   /SAVE 4
1726    1 9F5   0F0     360   /UPPER BITS.
1727    1 9F6   095    STAX
1728    1 9F7   087     207   /POTLO.
1729    1 9F8   0A5  Q,LDAZ    /RESET
1730    1 9F9   0CA     RR13  /ANALOG
1731    1 9FA   029    ANDI   /MULTIPLEXER.
1732    1 9FB   00F     017
1733    1 9FC   085    STAZ
1734    1 9FD   030     R13
1735    1 9FE   085    STAZ
1736    1 9FF   0CA     RR13
1737    1 A00   0A6    LDXZ   /RESTORE
1738    1 A01   096     TEM2  /X REGISTER.
1739    1 A02   0A4    LDYZ   /RESTORE
1740    1 A03   099     TEM5  /Y REGISTER.
1741    1 A04   060    RTS
1742                   /
1743    1 A05   090   ADCRST,220 /FOCUS
1744    1 A06   01F   ADCST,037 /
1745    1 A07   0C0   EADCR,300 /ECH
1746    1 A08   04F   EADCS,117 /
1747    1 A09   0A0   DADCR,240 / DISP
1748    1 A0A   02F   DADCS,057 /
1749                   /
1750    1 A0B   0A5   TSTTST,LDAZ
1751    1 A0C   020     R0
1752    1 A0D   030    BMI
1753    1 A0E   0FC     374    /WAIT FOR CAL. TO GO AWAY.
1754    1 A0F   0A5   TSTLP,LDAZ
1755    1 A10   020     R0
1756    1 A11   029    ANDI
1757    1 A12   00E     016    /ANY START P.B.?
1758    1 A13   0F0    BEQ
1759    1 A14   003     3      /IF NOT,BRANCH.
1760    1 A15   020    JSR
1761    1 A16   000     0
1762    1 A17   A51     ZDSP   /E=2,D=4.
1763                   /
1764    1 A18   0A5    LDAZ
1765    1 A19   021     R1
1766    1 A1A   029    ANDI
1767    1 A1B   030     060    /FOCUS FRD & REV PB'S.
1768    1 A1C   0C9    CMPI
1769    1 A1D   030     060
1770    1 A1E   0F0    BEQ
1771    1 A1F   006     TSTPOT-1-.     /IF PRESENT,BRANCH.
1772    1 A20   020    JSR
1773    1 A21   000     0
1774    1 A22   903     SMD
1775    1 A23   04C    JMP
1776    1 A24   000     0
```

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1777    1 A25   A0F     TSTLP
1778                   /
1779                   /PUTS POS'N POT DATA IN FOCUS DISPLAY.
1780    1 A26   0A9    TSTPOT,LDAI
1781    1 A27   000      0
1782    1 A28   085     STAZ
1783    1 A29   09A      TEM6   /SET X INDEX FOR SMD
1784    1 A2A   0A5     LDAZ
1785    1 A2B   020      R0
1786    1 A2C   029     ANDI
1787    1 A2D   00E      016    /ANY START PB'S?
1788    1 A2E   0F0     BEQ
1789    1 A2F   003      3
1790    1 A30   04C     JMP     /IF SO, DISPLAY
1791    1 A31   000      0      /NOISE DEVIATION.
1792    1 A32   A6C      PNOISE
1793    1 A33   0A5     LDAZ
1794    1 A34   0C8      RRD
1795    1 A35   009     ORAI
1796    1 A36   010      020
1797    1 A37   085     STAZ
1798    1 A38   02B      RD     /SET TW CODE FOR ECH.
1799    1 A39   0A5     LDAZ
1800    1 A3A   024      R6
1801    1 A3B   029     ANDI
1802    1 A3C   00F      017
1803    1 A3D   0AA     TAX     /PUT LSD OF ECH TW IN X INDEX.
1804    1 A3E   086     STXZ    / 0=FOCUS, 2=ECH, 4= DPR
1805    1 A3F   096      TEM2
1806    1 A40   020     JSR
1807    1 A41   000      0
1808    1 A42   9BB      RDADC /GET POT DATA.
1809    1 A43   0B5     LDAX
1810    1 A44   086      206
1811    1 A45   085     STAZ
1812    1 A46   086      206
1813    1 A47   0B5     LDAX
1814    1 A48   087      207
1815    1 A49   085     STAZ
1816    1 A4A   087      207    /PUT POT DATA IN FOC DISPLAY.
1817    1 A4B   020     JSR
1818    1 A4C   000      0
1819    1 A4D   903      SMD
1820    1 A4E   04C     JMP
1821    1 A4F   000      0
1822    1 A50   A2A      TSTPOT+4
1823                   /
1824                   /SETS SELECTED DISPLAY TO ZERO.
1825    1 A51   029    ZDSP,ANDI
1826    1 A52   006      006    /MASK OUT FOC.
1827    1 A53   0D0     BNE     /BRANCH IF BIT STILL THERE.
1828    1 A54   001      1
1829    1 A55   060     RTS     /DO NOTHING IF IT'S FOC PB.
1830                   /
1831    1 A56   029     ANDI
```

```
1832    1 A57   002     002    /MASK OUT DPR.
1833    1 A58   0D0    BNE
1834    1 A59   009      ZECH-1-.   /BRANCH IF BIT STILL THERE.
1835    1 A5A   0A9    ZDPR,LDAI   /IF BIT'S GONE,SET DPR=0.
1836    1 A5B   000      0
1837    1 A5C   085    STAZ
1838    1 A5D   083      DCPRA
1839    1 A5E   085    STAZ
1840    1 A5F   084      DCPRB
1841    1 A60   085    STAZ
1842    1 A61   085      DCPRC
1843    1 A62   060    RTS
1844                   /
1845    1 A63   0A9    ZECH,LDAI   /IF BIT 2 REMAINS,SET ECH=0.
1846    1 A64   000      0
1847    1 A65   085    STAZ
1848    1 A66   080      ECPRA
1849    1 A67   085    STAZ
1850    1 A68   081      ECPRB
1851    1 A69   085    STAZ
1852    1 A6A   082      ECPRC
1853    1 A6B   060    RTS
1854                   /
1855    1 A6C   04C    FNOISE,JMP
1856    1 A6D   000      0
1857    1 A6E   A26      TSTPDT
1858                   /
1859    1 A6F   060    MPXSVC,RTS
1860                   /
1861            BFC    *5774   /BFC
1862    1 BFC   000    00
1863    1 BFD   004    04
1864                   $
```

AA	0CD	DECR	413	FLGDIR	090	RESET	40F
ADC	9DA	DECY	490	FLGFDP	091	RF	02D
ADCI	069	DECZ	0C6	FLGREV	092	RMPCLR	7B1
ADCRST	A05	DEL	934	FLGZ	093	RMPTST	7A0
ADCST	A06	DELAY	8F9	FLG2LP	094	RRA	0C6
ADCX	075	DEX	0CA	FOC	854	RRC	0C7
ADCZ	065	DEY	088	FOCST	6A4	RRD	0C8
AGAIN	42C	DFORWD	551	FTWCLR	713	RRE	0C9
ALU	75E	DFWD	689	INC	8B9	RRETST	71B
ANDABX	03D	DL	8FB	INCX	0F6	RR0	0C0
ANDI	029	DL1	739	INCZ	0E6	RR1	0C1
ANDZ	025	DL2	745	INX	0E8	RR13	0CA
ASL	00A	DL3	751	INY	0C8	RR15	0CB
ASLZ	006	DONE	9EE	JDR1	7DF	RR6	0C2
AUTO	446	DPOTHI	08A	JDR2	7EF	RR7	0C3
A0	0CC	DPOTLO	08B	JMPI	06C	RR8	0C4
BCC	090	DPR	849	JMPOUT	82E	RR9	0C5
BCS	0B0	DPRFRD	8B0	JSR	020	RTN	85F
BEGIN	435	DPRLIM	50A	JSRDRV	4B6	RTS	060
BEQ	0F0	DPRST	636	JSR1	474	R0	020
BITA	02C	DRIVE	831	JSR3	496	R1	021
BITZ	024	DRVFWD	7D5	LDAA	0AD	R10	02E
BKLASH	7CB	DTWCLR	69C	LDAI	0A9	R11	02F
BMI	030	D1	73D	LDAX	0B5	R13	030
BNE	0D0	D2	749	LDAYI	0B1	R15	031
BPL	010	D3	755	LDAZ	0A5	R2	022
BRK	000	D3LOOP	534	LDXA	0AE	R4	023
BVS	070	EADCR	A07	LDXI	0A2	R6	024
CALIB	443	EADCS	A08	LDXZ	0A6	R7	025
CALIBR	4A0	ECH	83E	LDYI	0A0	R8	026
CALTST	72B	ECHLIM	4BD	LDYZ	0A4	R9	027
CHKLIM	987	ECHST	5CB	LIMTST	557	SBCI	0E9
CHKSTP	95B	ECPRA	080	LSR	04A	SBCX	0F5
CLC	018	ECPRB	081	LSRZ	046	SBCZ	0E5
CLD	0D8	ECPRC	082	M	60C	SEC	038
CLRD	8EE	EDIR	4F7	MPXSVC	A6F	SED	0F8
CLRRE	5C7	EDRV	57F	N	67A	SEI	078
CMPI	0C9	EFORWD	504	NOTZ	7C0	SETDSP	80E
CMPL	947	EFWD	61B	OOPS	922	SETRRE	45F
CMPR	5B5	ENDSMD	99D	ORAABX	01D	SETZ	982
CNT1	09C	EORI	049	ORAI	009	SMD	903
CNT2	09D	EORZ	045	ORAZ	005	STAA	08D
CNT3	09E	EPOTHI	088	OUT	7BD	START	400
COUNT8	08C	EPOTLO	089	PHA	048	STAX	095
CPRA	0BD	ETWCLR	62E	PHP	008	STAYI	091
CPRB	0BE	EXAMR0	43B	PLA	068	STAZ	085
CPRC	0BF	EXAMR1	44F	PLSDLY	86A	STXZ	086
DADCR	A09	E3LOOP	4E7	PNOISE	A6C	STYZ	084
DADCS	A0A	FC	6B1	Q	9F8	SUBT	781
DCPRA	083	FCPRA	086	RA	028	SWAP	9A8
DCPRB	084	FCPRB	087	RB	029	TAX	0AA
DCPRC	085	FFWD	6E6	RC	02A	TAY	0A8
DDIR	544	FLGA	08D	RD	02B	TEM0	095
DDRV	58C	FLGB	08E	RDADC	9BB	TEM2	096
DEC	8D1	FLGCAL	08F	RE	02C	TEM3	097

C40

/TEM8 /=188


```
TEM4    098
TEM5    099
TEM6    09A
TEM7    09B
TENLP   6F3
TSTLP   A0F
TSTPOT  A26
TSTTST  A0B
TSX     0BA
TXA     08A
TXS     09A
TYA     098
UPDATE  89B
WAIT    872
XBEGIN  480
XCPR    92C
XX      572
Y       66C
YZ      5FE
ZDPR    A5A
ZDSP    A51
ZECH    A63
1865
ERRORS DETECTED: 0
LINKS GENERATED: 0
```

C41

AA 75# 1470 1475
ADC 1699#
ADCI 82#
ADCRST 1676 1743#
ADCST 1685 1744#
ADCX 83# 1407 1414 1421
ADCZ 84#
AGAIN 171 203# 211 1612
ALU 387 468 678 789 904 1052#
ANDABX 85# 1683
ANDI 86# 232 243 279 298 358 439 520 532 566
580 602 643 685 736 742 754 796 847 853
863 892 968 974 1072 1102 1141 1191 1232 1256
1281 1292 1303 1316 1337 1360 1366 1390 1397 1459
1491 1565 1615 1625 1638 1695 1706 1725 1731 1756
1766 1786 1801 1825 1831
ANDZ 87#
ASL 88# 1658 1659 1660 1661
ASLZ 89# 1504
AUTO 226 230#
AO 74# 1529 1531 1533 1535
BCC 90# 1078 1112
BCS 91# 1153
BD 58
BEGIN 208 213#
BEQ 92# 223 234 281 360 402 419 441 483 500
524 692 708 803 819 914 984 1165 1234 1283
1294 1305 1506 1541 1545 1617 1627 1691 1708 1758
1770 1788
BITA 93#
BITZ 94# 694 805
BKLASH 1002 1163#
BMI 95# 390 471 672 783 807 898 1137 1510 1752
BNE 96# 180 245 310 554 568 582 645 756 865
954 998 1020 1033 1047 1120 1124 1129 1187 1203
1207 1339 1386 1399 1476 1536 1697 1827 1833
BPL 97# 225 681 792 907 1557 1571 1575
BRK 98#
BVS 99# 696
CALIB 227#
CALIBR 229 324#
CALTST 985 996#
CHKLIM 1572 1613#
CHKSTP 1569#
CLC 100# 980 1147 1404 1466
CLD 101# 157 981 1148 1465
CLRD 1427 1457#
CLRRE 636#
CMPI 102# 522 1384 1539 1543 1768
CMPL 1549# 1666
CMPR 238 618#
CNT1 52# 1014 1019
CNT2 53# 1027 1032
CNT3 54# 1040 1042 1044 1046
COUNT8 36# 1505 1521 1554
CPRA 59# 374 455 661 772 885 1075 1107
CPRB 60# 378 459 665 776 889 1067 1095
CPRC 61# 382 463 669 780 895 1061 1089
DADCR 1747#

C42

DADCS 1748#
DCPRA 27# 195 591 770 1496 1500 1564 1568 1838
DCPRB 28# 189 595 774 1840
DCPRC 29# 191 599 778 1842
DDIR 479 498#
DDRV 575# 583
DEC 1403 1428#
DECR 177# 181
DECY 306# 311
DECZ 103# 400 481 552 952 1018 1031 1041 1045 1474
1530 1534
DEL 1530# 1537
DELAY 262 551 1226 1353 1469#
DEX 104# 179 1411 1418 1443 1450
DEY 105# 309 1186 1202 1690
DFORWD 501 511#
DFWD 820 832#
DL 1471# 1477
DL1 1011#
DL2 1017 1024#
DL3 1030 1037# 1703
DONE 1709 1719#
DPOTHI 34# 457
DPOTLO 35# 461
DPR 1284 1290#
DPRFRD 1387 1394 1395#
DPRLIM 364 406 415 429 437#
DPRST 649 749#
DRIVE 285 308 351 563 577 988 1185 1201 1266#
DRVFWD 1173# 1229
DTWCLR 802 831 844 851#
D1 1015# 1021
D2 1028# 1034
D3 1041# 1048
D3LOOP 472 481#
EADCR 1745#
EADCS 1746#
ECH 1279#
ECHLIM 356#
ECHST 641# 995
ECPRA 24# 193 589 659 1490 1494 1848
ECPRB 25# 185 593 663 1850
ECPRC 26# 187 597 667 1852
EDIR 398 417#
EDRV 561# 569
EFORWD 420 430#
EFWD 709 721#
ENDSMD 1636#
EORI 106# 1549
EORZ 107#
EPOTHI 32# 376
EPOTLO 33# 380
ETWCLR 691 720 733 740#
EXAMR0 219#
EXAMR1 224 235 239#
E0 76
E3LOOP 391 400#
FC 874# 955
FCPRA 30# 887 965 1253 1713
FCPRB 31# 891 961 1249 1715

(C43)

FFWD 915 927#
FLGA 37# 1509 1517 1562
FLGB 38# 611 695 735 739 806 846 850
FLGCAL 39# 333 997 1006 1136 1601
FLGDIR 40# 418 499 707 818 913 1083 1117
FLGPDP 41# 671 782 897 1583 1635
FLGREV 42# 717 730 828 841 923 936 1164 1214 1221
1603
FLGZ 43# 389 470 680 791 906 1057 1134 1158
FLG2LP 44# 1172 1206 1212
FOC 1295 1301#
FOCST 760 861#
FTWCLR 926 939 972#
INC 1404#
INCX 108#
INCZ 109# 1043 1532
INX 110# 1503
INY 111#
JDR1 1183# 1188
JDR2 1199# 1204
JMPI 113#
JMPOUT 1166 1235 1262#
JSR 114# 162 198 206 247 260 283 306 313 349
368 385 449 466 549 561 575 676 749 787
902 944 949 986 1015 1028 1183 1199 1224 1274
1287 1298 1309 1332 1351 1471 1629 1701 1760 1772
1806 1817
JSRDRV 349# 528
JSR1 277# 288
JSR3 313# 1009 1264
LDAA 115#
LDAI 116# 165 173 182 213 250 258 271 290 316
324 330 344 352 371 392 452 473 543 547
557 571 584 608 612 618 636 727 838 870
882 933 989 1003 1011 1024 1037 1054 1080 1114
1131 1155 1169 1209 1218 1222 1345 1349 1405 1412
1419 1514 1518 1522 1526 1559 1580 1632 1699 1710
1780 1835 1845
LDAX 117# 1058 1064 1070 1100 1437 1444 1451 1547 1648
1656 1809 1813
LDAYI 118#
LDAZ 119# 219 230 239 263 277 296 335 356 375
379 388 407 417 421 430 437 456 460 469
488 498 502 511 518 530 538 564 578 600
624 632 641 650 658 662 666 670 679 683
698 706 710 721 734 740 752 761 769 773
777 781 790 794 809 817 821 832 845 851
861 874 886 890 896 905 912 916 927 956
962 966 972 982 996 1088 1094 1106 1118 1122
1127 1135 1139 1163 1173 1189 1205 1213 1230 1236
1244 1250 1254 1266 1279 1290 1301 1314 1324 1335
1341 1354 1364 1374 1388 1395 1428 1457 1481 1489
1495 1508 1553 1563 1569 1573 1613 1623 1636 1672
1681 1693 1704 1719 1723 1729 1750 1754 1764 1784
1793 1799
LDXA 120#
LDXI 121# 159 175 196 203 366 383 447 464 674
785 900 942 1285 1296 1307 1512
LDXZ 122# 1312 1501 1737

LDYI 123# 304 1181 1197 1670
LDYZ 124# 1739
LIMTST 445 487 496 510 518#
LSR 125# 1215 1650 1651 1652 1653
LSRZ 126#
M 693 697 706#
MPXSVC 1631 1859#
N 804 808 817#
NOTZ 1130 1151#
OOPS 1507 1512#
ORAABX 128# 1674
ORAI 129# 265 337 409 423 432 490 504 513 626
652 700 712 723 763 811 823 834 876 918
929 958 1175 1238 1246 1268 1326 1356 1376 1430
1483 1497 1795
ORAZ 130# 1662
OUT 1113 1121 1125 1138 1147# 1154
PHA 131# 941
PHP 132#
PLA 133# 947
PLSDLY 1276 1324#
PNOISE 1792 1855#
Q 1692 1718 1729#
RA 13# 1552
RB 14# 1525 1556
RC 15# 1587
RD 16# 268 301 340 535 629 655 703 745 766
814 856 879 977 1144 1178 1194 1241 1259 1359
1363 1589 1798
RDADC 200 370 451 946 1311 1668# 1698 1808
RE 17# 1344 1348 1597
RESET 164 173#
RF 18# 1585
RMPCLR 1135# 1161
RMPTST 1086 1118#
RRA 68#
RRC 69#
RRD 70# 264 270 297 303 336 342 531 537 625
631 651 657 699 705 741 747 762 768 810
816 852 858 875 881 973 979 1140 1146 1174
1180 1190 1196 1237 1243 1255 1261 1355 1591 1794
RRE 71# 257 347 355 422 426 431 435 503 507
512 516 560 574 587 639 711 715 722 726
822 826 833 837 917 921 928 932 983 992
1168 1217 1231 1280 1291 1302 1342 1389 1396 1599
RRETST 869 980#
RR0 62# 635 642 684 688 753 795 799 862 967
971
RR1 63# 242
RR13 72# 357 408 412 438 489 493 519 539 601
607 1595 1673 1680 1682 1687 1730 1736
RR15 73# 1375 1381 1429 1435 1458 1464
RR6 64# 1063 1093 1128
RR7 65# 1069 1099 1123
RR8 66# 1077 1105 1109 1111 1119
RR9 67# 218 276 295 321 329 623 1267 1273 1315
1321 1325 1331 1365 1371 1482 1488 1607 1637 1643
RTN 1306 1312#
RTS 134# 201 254 322 1022 1035 1049 1149 1322 1372
1467 1478 1646 1741 1829 1843 1853 1859

R0 5# 220 1574 1751 1755 1785
R1 6# 240 278 1336 1570 1765
R10 19# 1720
R11 20# 1694 1705 1724
R13 21# 541 605 1593 1678 1689 1734
R15 22# 1379 1433 1462
R2 7# 565 579 1614
R4 8# 1624
R6 9# 957 1059 1091 1245 1800
R7 10# 963 1065 1097 1251
R8 11# 1071 1101
R9 12# 216 253 274 293 319 327 621 1271 1319
1329 1369 1486 1605 1641
SBCI 135# 1151 1439 1446 1453
SBCX 136# 1090 1096
SBCZ 137# 1060 1066 1074 1108
SEC 138# 1052 1087 1126 1436
SED 139# 1053 1382
SEI 140# 158
SETDSP 1208 1230#
SETRRE 246 256#
SETZ 1608# 1621
SMD 249 315 751 951 1334 1473 1481# 1774 1819
STAA 141#
START 157#
STAX 142# 177 1409 1416 1423 1441 1448 1455 1721 1727
STAY1 143#
STAZ 144# 167 184 186 188 190 192 194 215 217
221 241 252 256 267 269 273 275 292 294
300 302 318 320 326 328 332 339 341 346
354 373 377 381 394 411 425 434 454 458
462 475 492 506 515 534 536 540 545 559
573 586 588 590 592 594 596 598 604 606
610 614 620 622 628 630 634 638 654 656
660 664 668 687 702 704 714 716 725 729
738 744 746 765 767 771 775 779 798 813
815 825 827 836 840 849 855 857 872 878
880 884 888 894 920 922 931 935 960 964
970 976 978 991 1005 1013 1026 1039 1056 1062
1068 1076 1082 1092 1098 1104 1110 1116 1133 1143
1145 1157 1167 1171 1177 1179 1193 1195 1211 1216
1220 1240 1242 1248 1252 1258 1260 1270 1272 1318
1320 1328 1330 1343 1347 1358 1362 1368 1370 1378
1380 1432 1434 1461 1463 1469 1485 1487 1493 1499
1516 1520 1524 1528 1551 1555 1561 1567 1582 1584
1586 1588 1590 1592 1594 1596 1598 1600 1602 1604
1606 1634 1640 1642 1654 1677 1679 1686 1688 1712
1714 1733 1735 1782 1797 1811 1815 1837 1839 1841
1847 1849 1851
STXZ 145# 1277 1608 1644 1804
STYZ 146# 1668
SUBT 1079 1087#
SWAP 1542 1546 1648#
TAX 147# 948 1803
TAY 148#
TEM0 45# 395 401 873 953
TEM2 46# 546 553 1278 1313 1738 1805
TEM3 47# 1655 1663
TEM4 48# 222 231 615 633

C46

TEM5 49# 1669 1740
TEM6 50# 1502 1609 1645 1783
TEM7 51# 476 482
TENLP 911 940#
TSTLP 1754# 1777
TSTPOT 1771 1780# 1822 1857
TSTTST 1579 1750#
TSX 149#
TXA 150# 940 1383 1538
TXS 151# 161 205
TYA 152#
UPDATE 1289 1300 1374#
WAIT 1332# 1340
XBEGIN 282 290#
XCPR 1511 1522#
XX 547# 555
Y 793 803#
YZ 682 692#
ZDPR 1835#
ZDSP 1762 1825#
ZECH 1834 1845#

V3A

BITMAP V4 FIELD 1

(D1)

```
          0000000000000000111111111111111122222222222222223333333333333333
          0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF

 1 000  00000000000000000000000000000000111111111111111111000000000000000
 1 040

 1 080  11111111111111111111111111111111000000000000000000000000000000111
 1 0C0  11111111111111000000000000000000111000000000000000000000000000000

 1 100
 1 140

 1 180
 1 1C0

 1 200
 1 240

 1 280
 1 2C0

 1 300
 1 340

 1 380
 1 3C0

 1 400  11111111111111111111111111111111111111111111111111111111111111111
 1 440  11111111111111111111111111111111111111111111111111111111111111111

 1 480  11111111111111111111111111111111111111111111111111111111111111111
 1 4C0  11111111111111111111111111111111111111111111111111111111111111111

 1 500  11111111111111111111111111111111111111111111111111111111111111111
 1 540  11111111111111111111111111111111111111111111111111111111111111111

 1 580  11111111111111111111111111111111111111111111111111111111111111111
 1 5C0  11111111111111111111111111111111111111111111111111111111111111111

 1 600  11111111111111111111111111111111111111111111111111111111111111111
 1 640  11111111111111111111111111111111111111111111111111111111111111111

 1 680  11111111111111111111111111111111111111111111111111111111111111111
 1 6C0  11111111111111111111111111111111111111111111111111111111111111111

 1 700  11111111111111111111111111111111111111111111111111111111111111111
 1 740  11111111111111111111111111111111111111111111111111111111111111111

 1 780  11111111111111111111111111111111111111111111111111111111111111111
 1 7C0  11111111111111111111111111111111111111111111111111111111111111111
```

BITMAP V4 FIELD 1 (D2)

```
          0000000000000000111111111111111122222222222222223333333333333333
          0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF

 1 800 1111111111111111111111111111111111111111111111111111111111111111
 1 840 1111111111111111111111111111111111111111111111111111111111111111

 1 880 1111111111111111111111111111111111111111111111111111111111111111
 1 8C0 1111111111111111111111111111111111111111111111111111111111111111

 1 900 1111111111111111111111111111111111111111111111111111111111111111
 1 940 1111111111111111111111111111111111111111111111111111111111111111

 1 980 1111111111111111111111111111111111111111111111111111111111111111
 1 9C0 1111111111111111111111111111111111111111111111111111111111111111

 1 A00 1111111111111111111111111111111111111111111111111111111111111111
 1 A40 1111111111111111111111111111111111111111111111111111100000000000

 1 A80
 1 AC0

 1 B00
 1 B40

 1 B80
 1 BC0 0000000000000000000000000000000000000000000000000000000000001100

 1 C00
 1 C40

 1 C80
 1 CC0

 1 D00
 1 D40

 1 D80
 1 DC0

 1 E00
 1 E40

 1 E80
 1 EC0

 1 F00
 1 F40

 1 F80
 1 FC0
```

PROM LOADING INSTRUCTIONS

(Computer responses are underlined. Comments are in parenthesis.)

(The PDP-8/I is used with OS/8 to edit and assemble programs for the Echelle system. A PROM programmer that operates from the PDP-8/I through multiplexer 3 is used to load OS/8 Binary files into 1Kx8 EPROMs (type 2708), which are then plugged into a Microprossesor board.)

(The ASCII source files must be assembled into a BINARY file first.) (These source files can be found on an Archive tape. See the Lick Programmer for a copy)

```
.R PALH
*ECH<CON9,TEM1,TEM2,TEM3,TEM4,TEM5,TEM6,TEM7,TEM89
RD   0343
RD   0343
ERRORS DETECTED: 0
LINKS GENERATED: 0

.
```

(Turn from programmer power off, "program inhibit" on, ground yourself and insert a PROM with pin one up. Turn power on and proceed.)

```
.R ABSLDR
*PROM.SV/I                  (Hit "return")
*ECH/G=16426$               (Hit "ESC", NOT "$")
1ST CORE 2(000) OR 4(000)?2
PROM (270)4 OR (270)8 ?8
```

(The number of unprogrammed locations will be displayed in the PDP-8's MQ register. When the errors appear, turn "program inhibit" off. In a few seconds, the errors will all be gone. Wait for another 60 sec, then turn "program inhibit" on and hit CONTROL/C on the keyboard.) (Turn programmer power off, ground yourself, and carefully remove the PROM. Insert a new PROM, and turn power back on. Proceed for the second PROM as for the first, noting that the response to "1ST CORE 2(000) OR 4(000)?" is "4" not "2".)

```
.R ABSLDR
*PROM.SV/I
*ECH/G=16426$
1ST CORE 2(000) OR 4(000)?4
PROM (270)4 OR (270)8 ?8
```