(NASA-CR-157581) LORAN-C FLIGHT TEST SOFTWARE (Ohio Univ.) 41 p HC A03/MF A01 CSCL 17G

N78-31069

Unclas
G3/04 29150

TECHNICAL MEMORANDUM (NASA) 61

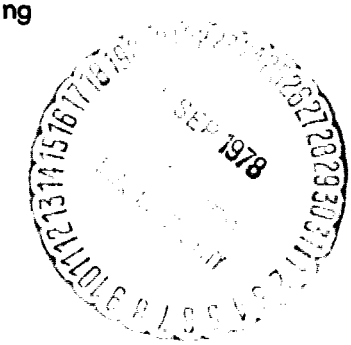
LORAN-C FLIGHT TEST SOFTWARE

Described is the software package developed for the KIM-1 Micro-System and the Mini-L PLL receiver to simplify taking flight test data at Ohio University.

by

James D. Nickum

Avionics Engineering Center
Department of Electrical Engineering
Ohio University
Athens, Ohio 45701



August 1978

Supported by

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Grant NGR 36-009-017

TABLE OF CONTENTS

I. INTRODUCTION

This technical memorandum will describe the flight test software for use with the Mini-L LORAN-C Receiver. In order to describe completely the software programs the interface hardware and timing are also presented. Also included is the description of the address and data bus buffers used in the KIM-1 Micro-system [1].

II. ADDRESS BUFFER HARDWARE

The address and data buffers (ADB) are buffers that allow the easy expansion of the KIM-1 Microcomputer System. Referring to Figure 1, the data bus is buffered using two 8833 bidirectional data buffers. The 7400 logic gates provide the necessary read/write steering logic necessary since the data bus is bidirectional. The 4 diodes provide the decoding for a high impedance level on the KIM-1 data bus during all times when the KIM-1 is accessing any internal (KIM-1) memory or peripheral. This is necessary since the ADB described here are between the outside world and the KIM-1, and not the CPU chip and the outside world.

The address bus buffers employ 3 (three) 8097 tri-state buffers. Since the address bus is an output-only bus, these devices are enabled at all times.

III. WORD GENERATOR HARDWARE AND TIMING

The basic word generator circuit is described in detail in NASA TM-54. The circuit described here differs somewhat with regard to the signal inputs and signal outputs from the one described in NASA TM-54 [2]. The basic purpose of the word generator is to clock a counter at a 1 MHz rate and reset it at the GRI rate. If the output pulse from the Mini-L LORAN-C Receiver is from the master loop, then the word generator counter is cleared to zero. If it is from one of the slave loops the value of the counter is clocked into the word latch, and, therefore, the KIM-1 can read the measured time in microseconds. Refer to Figure 2, the timing logic, and Figure 3, the timing diagram, to describe the operation. The Master, Slave 1 and Slave 2 are treated equally with regard to the interrupt generation. Pulses are ORed to the D input of U16, which generates a 500 ns. pulse LTIME, which is used to clock the latch. Device U17 forms the interrupt request to the KIM-1. The D flip flop U27 catches and one-shots the master output and the latch made up of U25 provides a test bit MTB to the software to determine the master. The $\overline{\text{CNTLD}}$ signal is generated by U27 and this is used to clear the counters on the occurrence of the master. Input LOREN is a LORAN enable output flag for software control of hardware interrupts from the word generator to the KIM-1. The SIRQ and LIRQ are interrupt inputs that were used for earlier versions of the Mini-L receivers. The DECODE O is generated by software and occurs whenever a read of the MSB of the GRI word generator is made. This is used as a hardware reset as the normal reading of the word generator is from LSB to MSB; therefore, when the MSB is

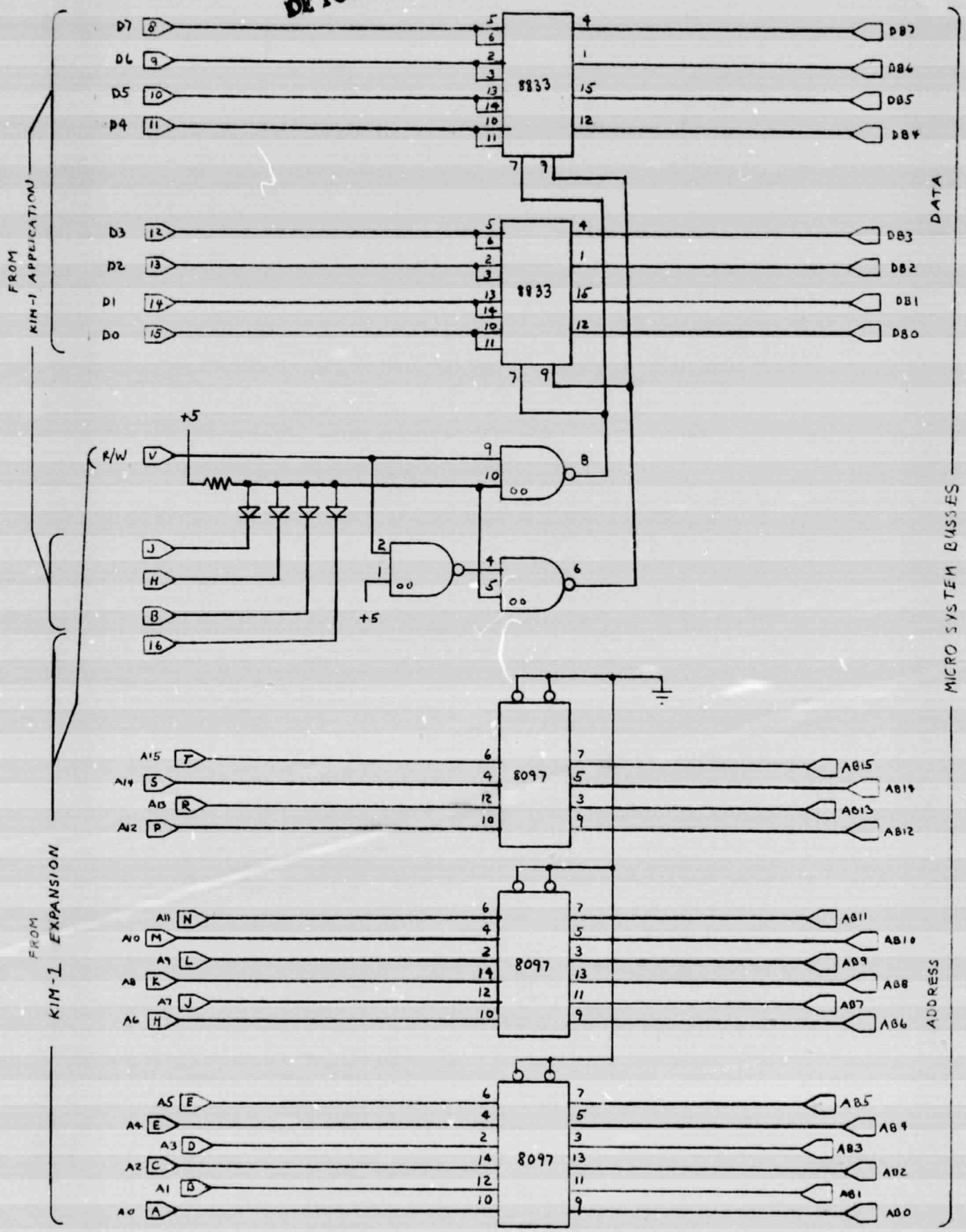


Figure 1. Micro-System Bus Buffers.

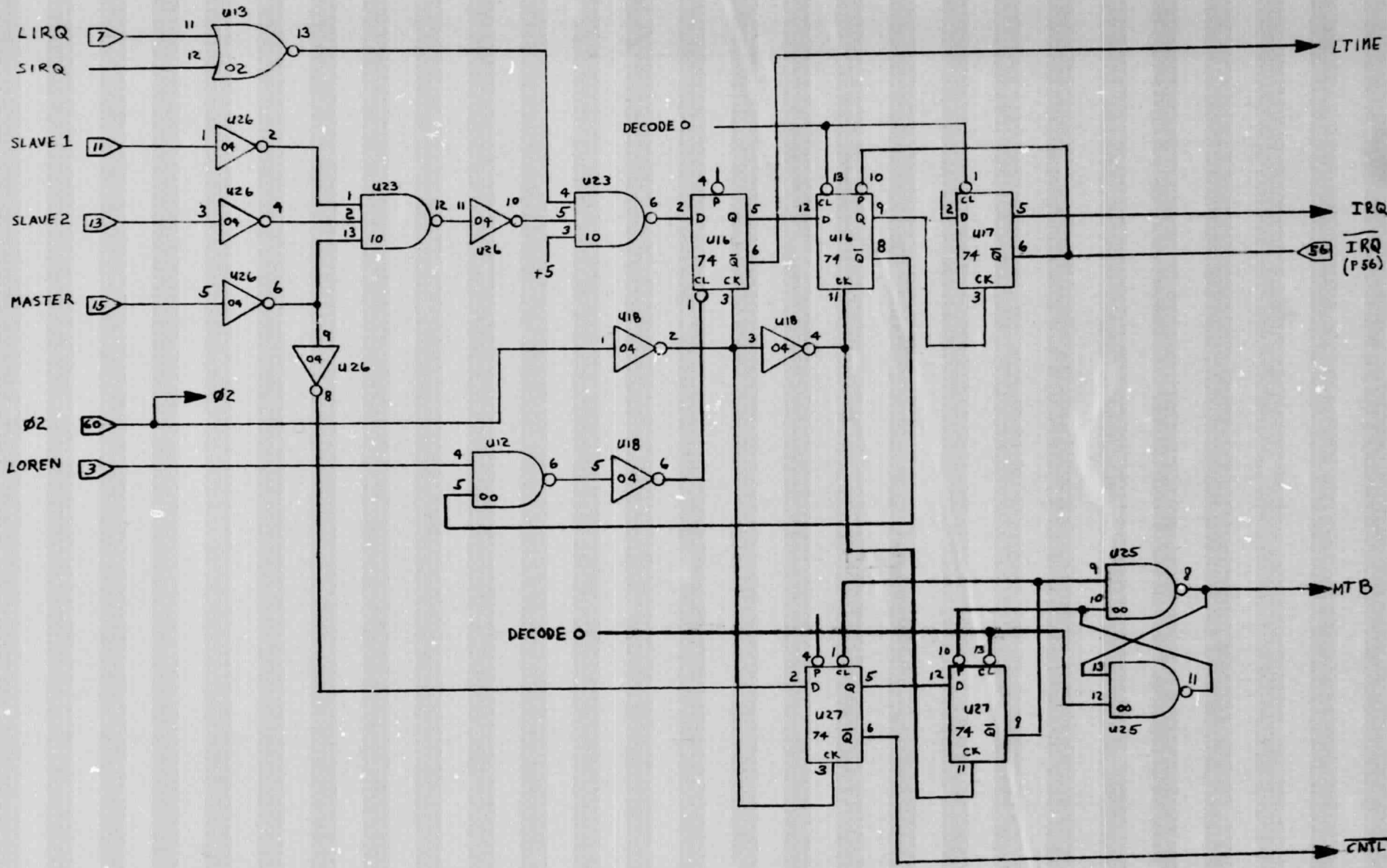
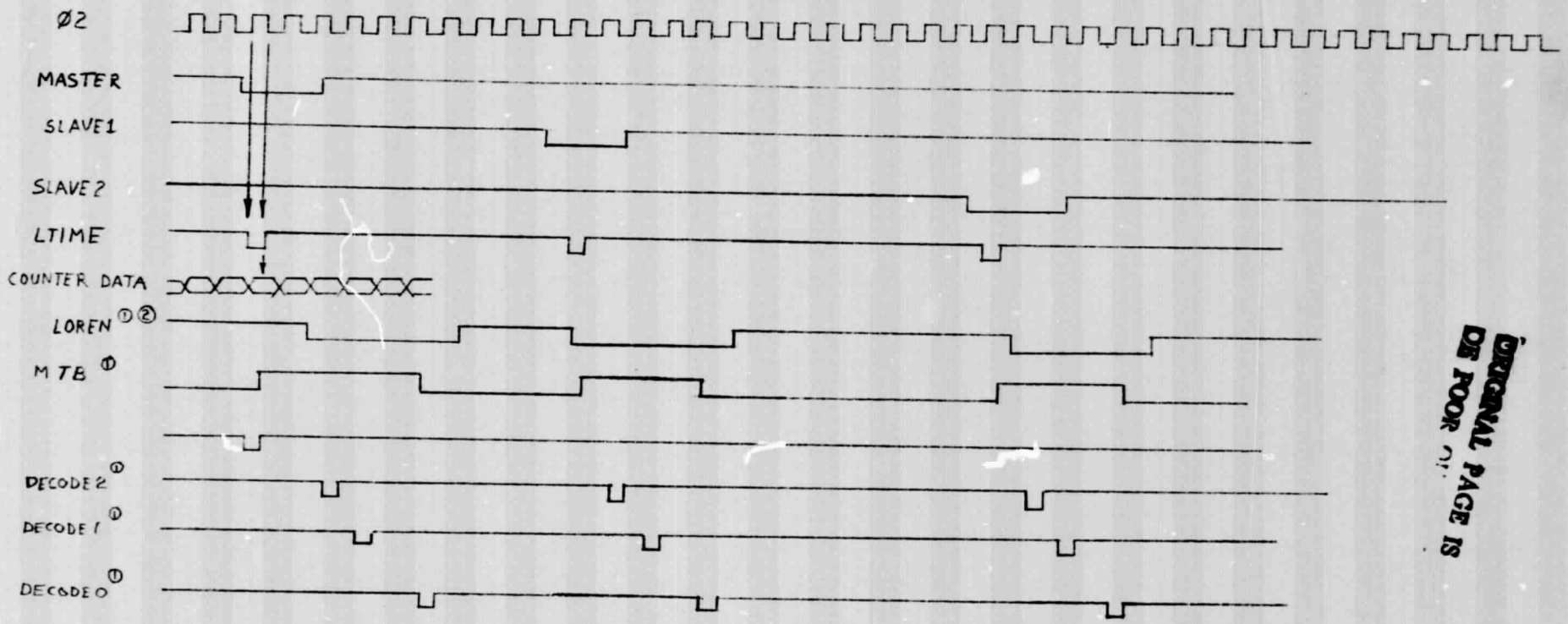


Figure 2. Word Generator Timing Logic.



① NOT TO SCALE
② SOFTWARE GENERATED

Figure 3. Word Generator Timing Diagram.

read the word generator is reset. Figure 4 is the schematic of the counter and latches for the word generator. The counters are clocked on the leading edge of the 1 MHz clock Φ2. The latches are clocked coincident with the trailing edge of Φ2 by LTIME. This allows the counter outputs to stabilize before the contents of the counters are latched. Also provided are an input and output port, U28 for input and U19 and U20 for output. These ports provide sense and flag capabilities to the software program. Figure 5 is the address decoder for the word generator. It provides all of the necessary address decoding for the various functions. It also provides a memory select to the KIM-1 to provide a memory disable for bus access.

IV. FLIGHT TEST SOFTWARE

Figure 6 shows the initialization flow chart. This part of the program sets up the word generator hardware. It also loads the interrupt vector locations, clears and sets all software data and flag locations. The background software is entered directly. Figure 7 is the LIRQ interrupt service routine. This routine determines whether the interrupt came from a master or a slave loop and also keeps track of the average values for the time differences. Essentially this involves adding the time differences of ten measurements, rounding the next to the last digit and shifting right one digit to form an average of ten measurements. Also this routine counts every 10th GRI to form a real time clock based on LORAN-C.

Figure 8 is the flow diagrams for the background processing. This processing occurs continuously between interrupts. Its function is to receive and process appropriate commands from the keyboard that determine what information is to be displayed or stored. The functions that are provided are the display of either of the time differences or the number of data points stored. In addition, the software will automatically multiplex out to a Rustrak chart recorder the last two significant digits of both time differences. A pilot's guidance display (PGD) is provided and either LOP can be selected to be tracked by the pilot. This PGD provides a 20 μs left right steering information to the pilot. Figure 10 is the flow diagram for the NMI interrupt service routine. This routine simply sets a flag that is sensed in the background processing routine. This causes the current value of the GRI clock counter and the two time differences to be stored in RAM. This allows for the collection of data during the flight.

V. SUMMARY

The software and hardware described here are provided to allow an easy and efficient way to collect and display data relating to LORAN-C position fixes generated by the Mini-L receiver. The software provided here has been designed and structured so that modifications and additions can be implemented relatively easily.

There are several subroutines used and they are documented along with a complete program listing of the flight test software in the Appendix. Also provided are instructions for the use of the program.

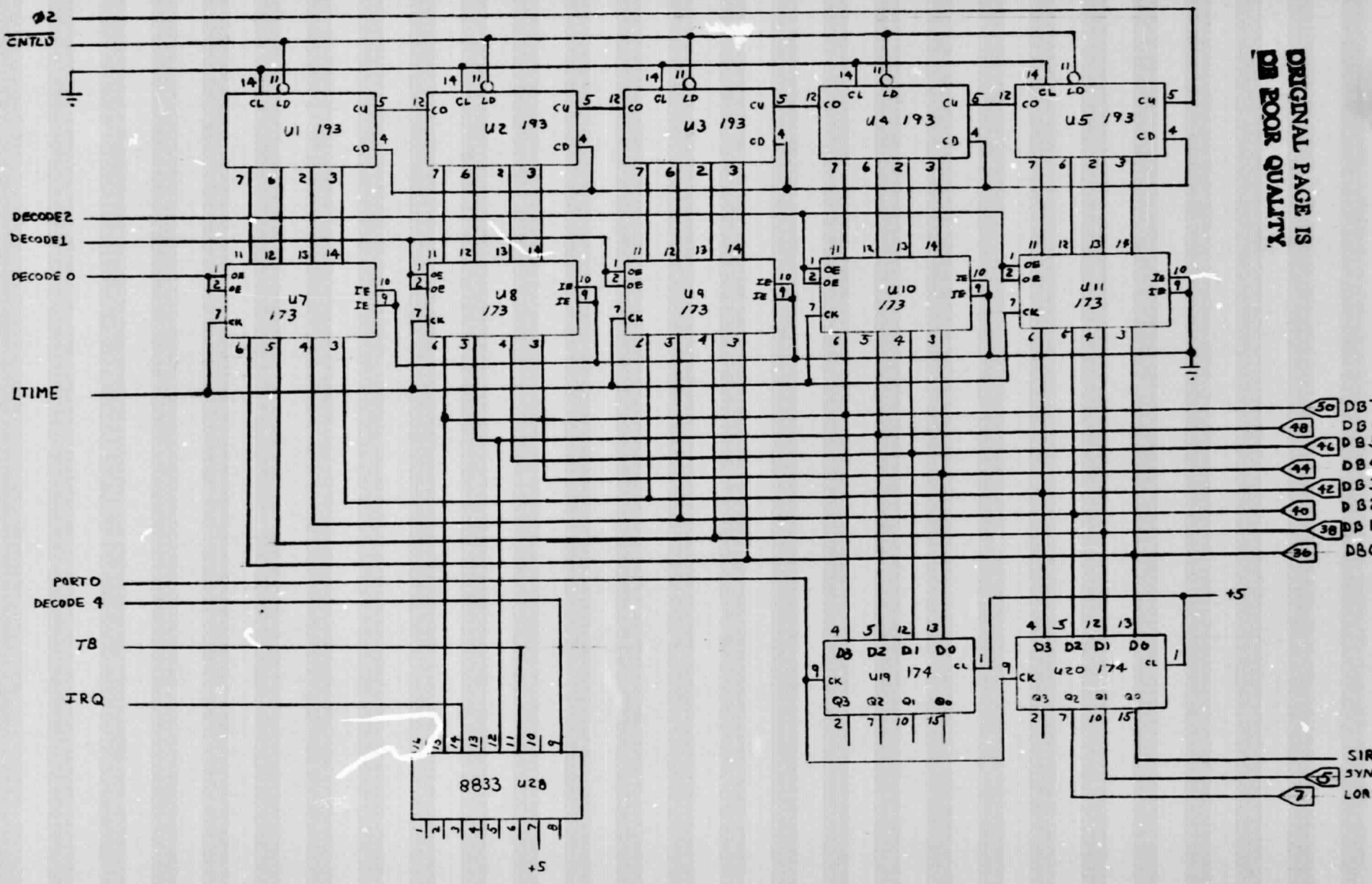


Figure 4. Word Generator Counter-Latch Schematic.

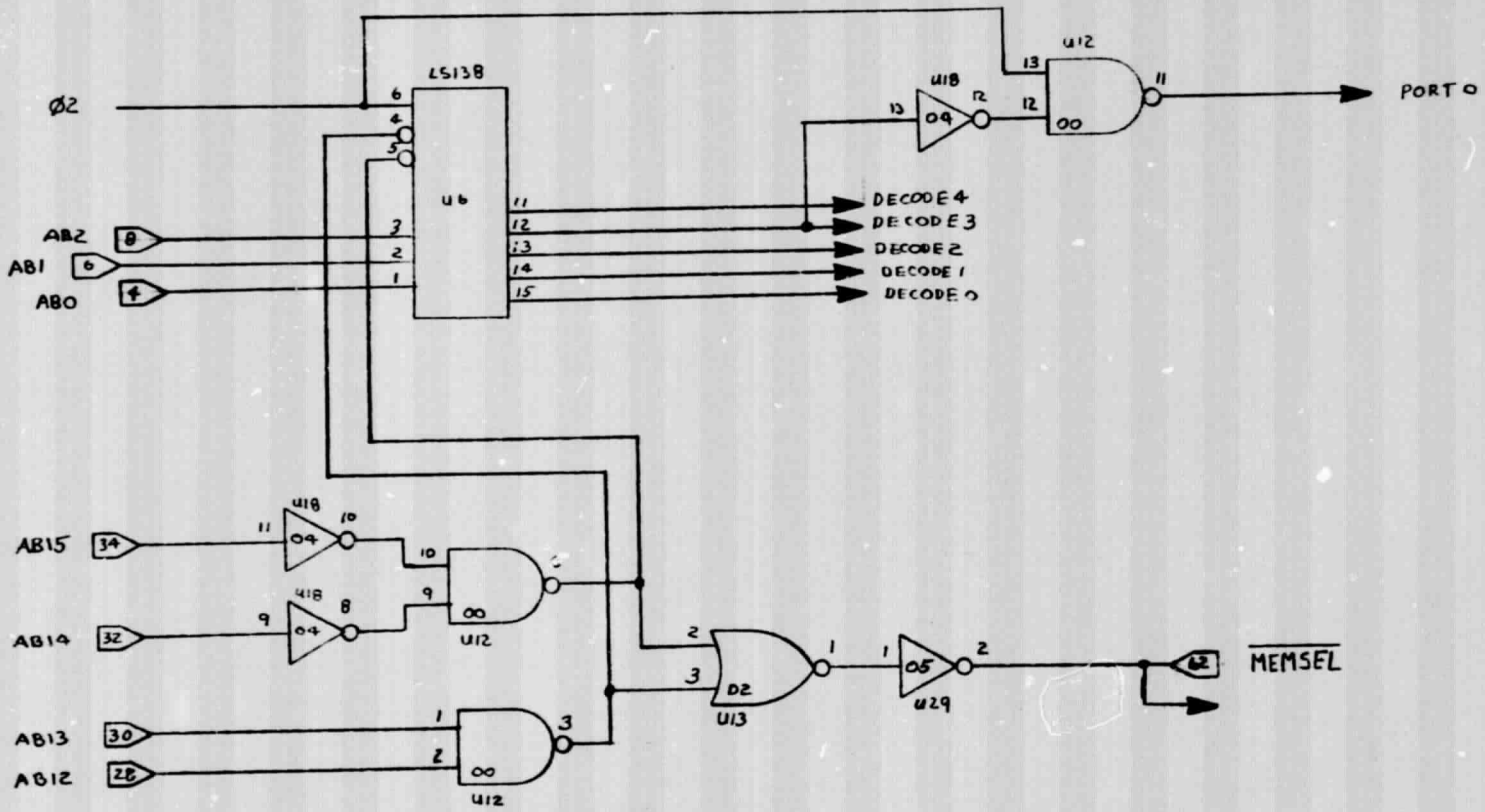


Figure 5. Word Generator Address Decoding.

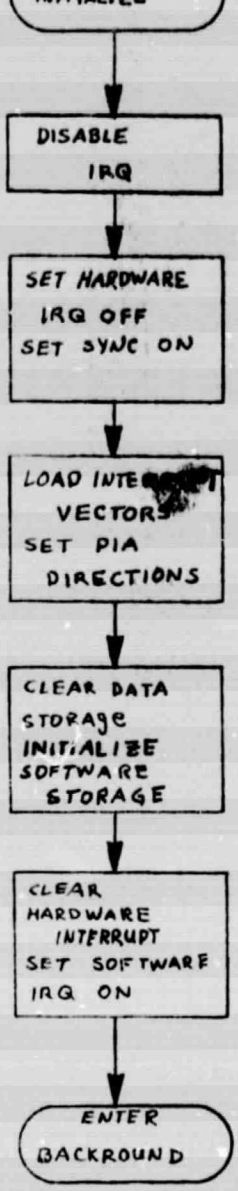


Figure 6. Initialization Flow Diagram.

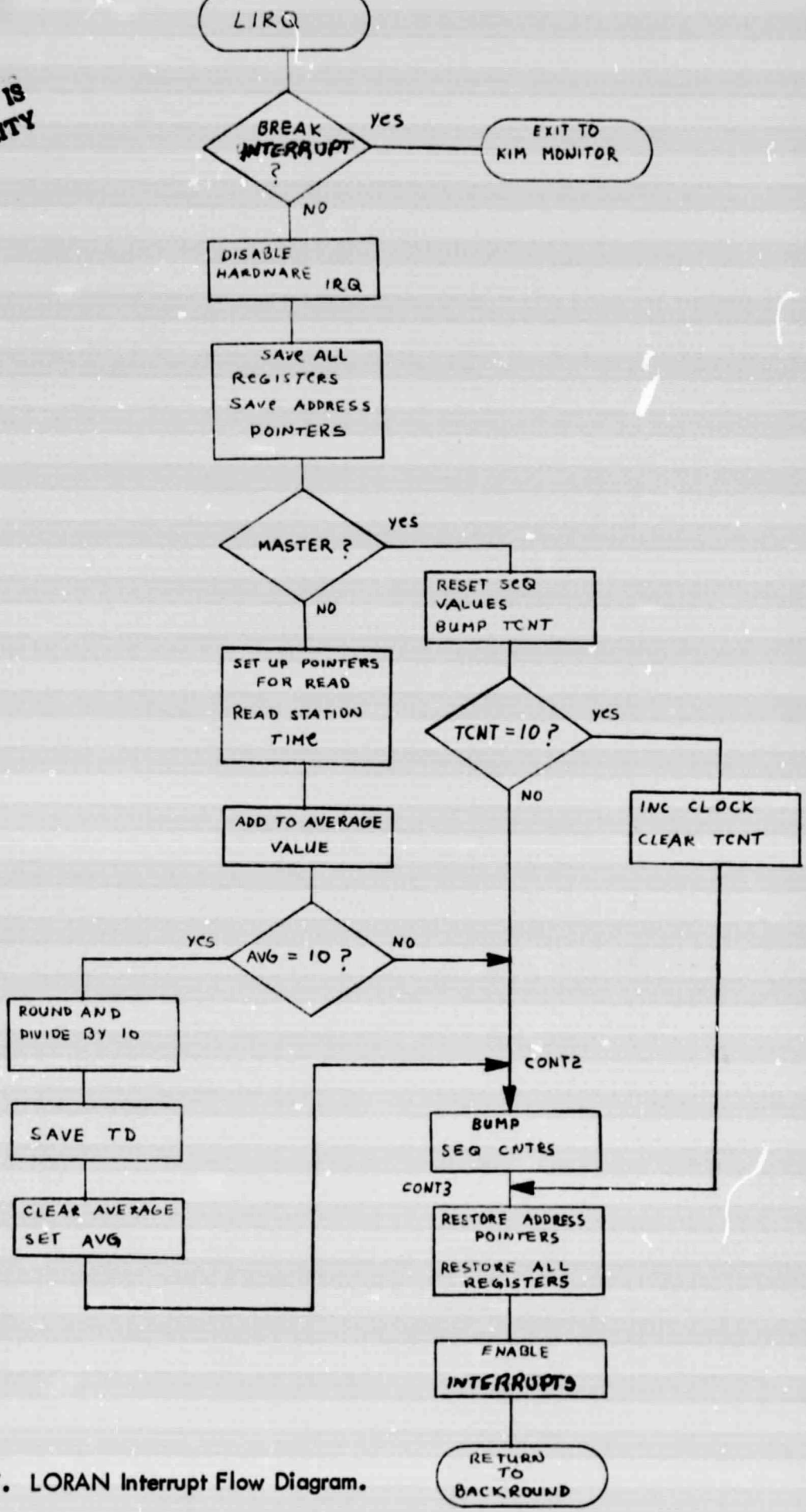


Figure 7. LORAN Interrupt Flow Diagram.

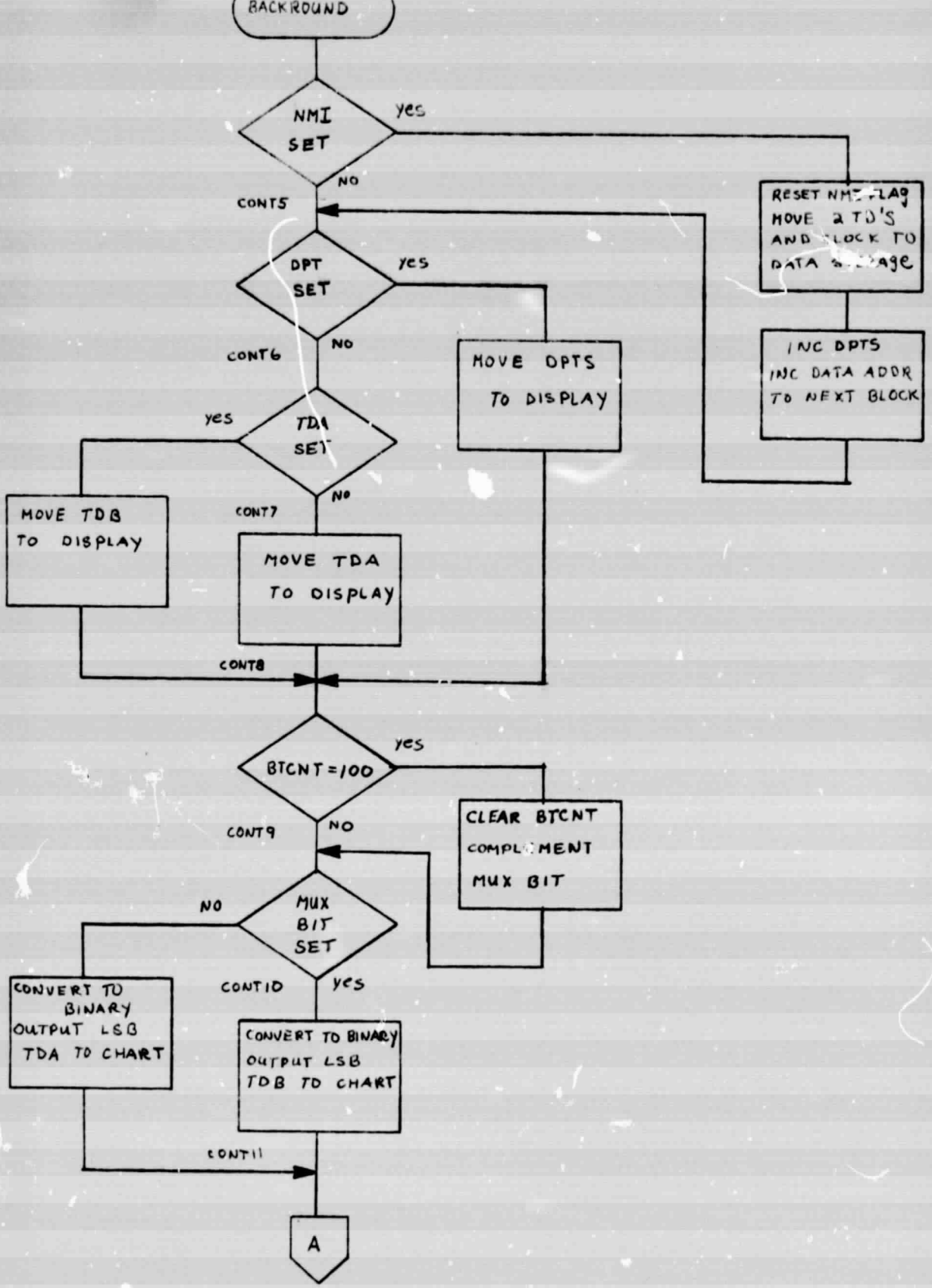


Figure 8a. Background Processing Flow Diagram.

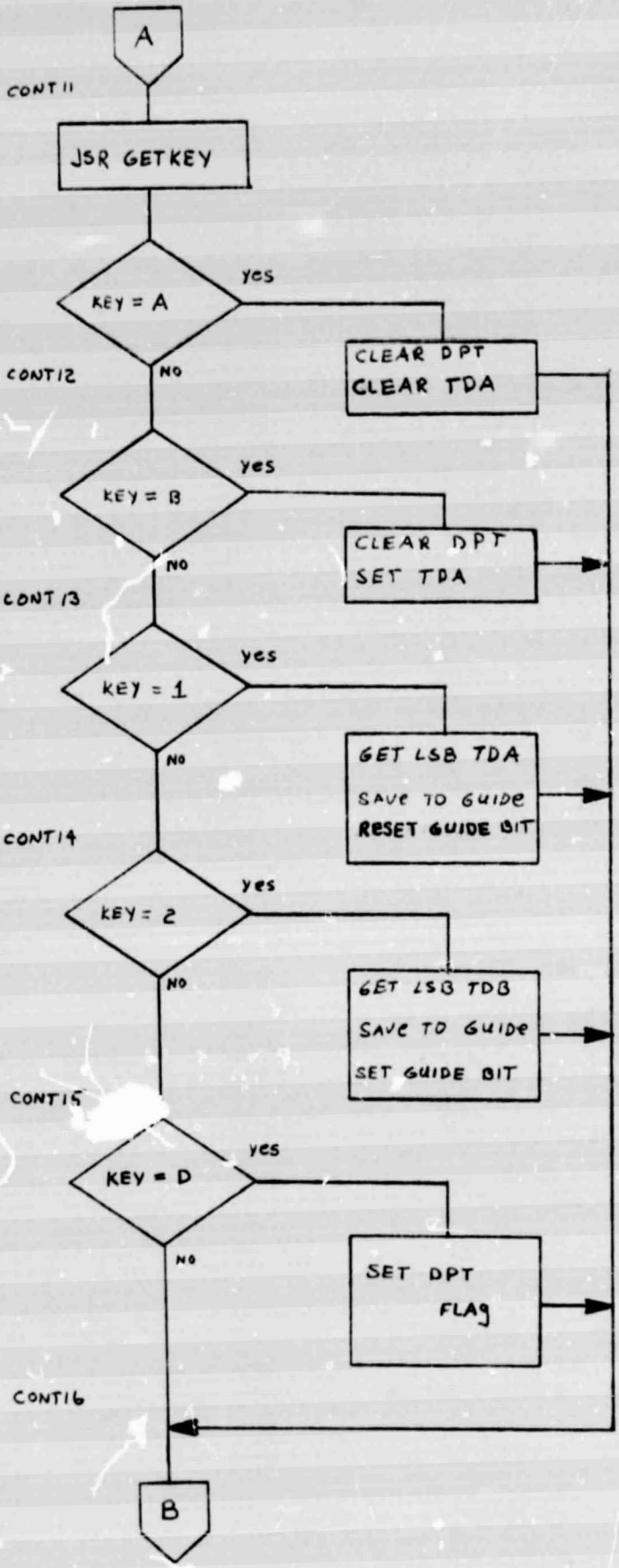


Figure 8b. Background Flow Diagram (Continued).

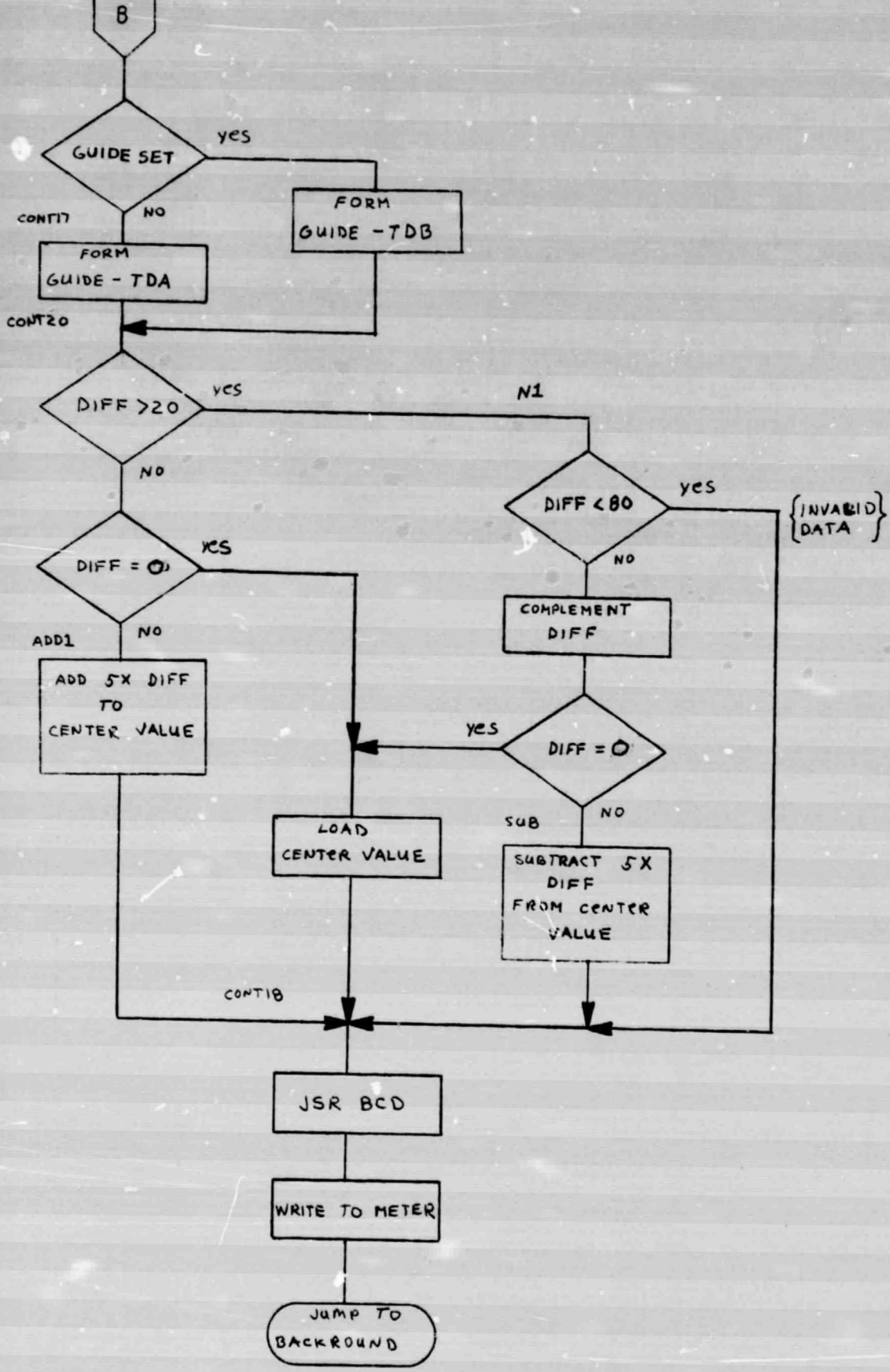


Figure 8c. Background Flow Diagram (Continued).

Figure 9. NMI Interrupt Flow Diagram.

In summary, the flight test software and hardware provided here allows the user to display both LOP time differences. It provides storage for data points that contain both LOP's and an elapsed GRI count. It also provides a display of the number of data points stored, and finally it provides a pilot's steering command from either LOP.

VI. REFERENCES

[1] Nickum, James, "Stand-Alone Development System Using a KIM-1 Microcomputer Module", NASA Technical Memorandum No. 56, Avionics Engineering Center, Department of Electrical Engineering, Ohio University, Athens, Ohio, March 1978.

[2] Nickum, James, "LORAN-C Digital Word Generator for Use with a KIM-1 Microprocessor System", NASA Technical Memorandum No. 54, Avionics Engineering Center, Department of Electrical Engineering, Ohio University, Athens, Ohio, December 1977.

VII. APPENDICES

APPENDIX A

A. Flight Test Software Operation. From cassette tape the program is loaded in two parts. The first part loads locations 0000-0050 Hex. The second part loads locations 0200-050F Hex. The starting address is 0204 Hex. The interrupt command cable from the Mini-L to the KIM-1 Micro-System should be in place before starting.

To begin the program load 0204 Hex into the address on the KIM-1 display. Verify that the IRQ switch on the KIM-1 Micro-System is in the off position. Press GO; the display should show all zeros. If this is not the case, reload the program and start again. To synchronize the software GRI clock with a known time, turn on the IRQ switch on the KIM-1 Micro-System at a known time. About 1 second after the IRQ switch is turned on the display will show the LOP #1 time difference.

B. Data Request Operation. To display LOP #1 time difference press the "A" key on the Keyboard. To display the LOP #2 time difference press the "B" key. To display the number of used data points press the "D" key. Pressing the "ST" key will save the GRI clock, LOP #1 and LOP #2 to the data RAM for later readout. Each press of the "ST" key will cause this data to be stored in consecutive memory locations in RAM.

To cause the pilot's guidance display to provide guidance with respect to LOP #1 press the "1" key. To cause the same for LOP #2 press "2".

The software is self-sychronizing and provided that the Mini-L power or the KIM-1 Micro-System power does not fail the software will run continuously. To stop the software requires a computer reset. If a reset is necessary, then before starting the program again any data that has been recorded in the RAM data memory starting at 0E00 Hex must be saved, as the initialize routine in the flight test software will clear all data to zeros. Record the start time for later data analysis.

C. Key Codes for Flight Test Software.

Key	Description of Function
A	Displays value of LOP #1 in real time.
B	Displays value of LOP #2 in real time.
1	Causes the pilot display to provide steering commands with respect to the value of LOP #1 at the time it is presented.
2	Same as 1 except LOP #2 provides steering.
D	Displays the number of data points already stored.
ST	This key causes the current value of the GRI clock, LOP #1 and LOP #2 to be stored to RAM.

APPENDIX B. Software Listing.

END PASS 1: 0 ERRORS


```
1                *
2                *
3                *     THIS PROGRAM WILL PROVIDE THE NECESSARY SOFTWARE TO
4                *     SUPPORT A FLIGHT TEST  OF THE MINI- L PLL RECIEVER.
5                *     IT PERFORMES MANY FUNCTIONS FOR BOTH MONITORING THE
6                *     PROGRESS OF THE FLIGHT AND ALSO RECORDING SPECIFIC
7                *     DATA RELATED TO THE PATH OF THE FLIGHT WITH REGARD
8                *     TO THE OBSERVED LORAN C TIME DIFFERENCES.  IT CAN ALS
9                *     PROVIDE A RELATIVE MEASURE OF THE TIME OF OCCOURANCE
10               *     OF A PARTICULAR EVENT RELATIVE TO THE GRI OF THE
11               *     LORAN STATIONS BEING TRACKED.
12               *     THE FOLLOWING IS A DEFINITION OF THE INPUT OUTPUT
13               *     PORTS FOR THE PROGRAM. ALSO INCLUDED ARE SOFTWARE
14               *     FLAG DEFINITIONS.
15               *
16               *
17               *
18               *
19               *
20               *     HCNTRL                I   I   I   I   I   I   I   I   I
21               *     $3003                 -------------------------------
22               *                             7   6   5   4   3   2   1   0
23               *
24               *     2  LOREN
25               *     1  SYNCEN
26               *
27               *
28               *
29               *     MTB                   I   I   I   I   I   I   I   I   I
30               *     $3005                 -------------------------------
31               *                             7   6   5   4   3   2   1   0
32               *     7  MASTER TEST BIT
33               *
34               *
35               *
36               *
37               *     DFLAG                 I   I   I   I   I   I   I   I   I
38               *     SOFTWARE              -------------------------------
39               *                             7   6   5   4   3   2   1   0
40               *     7  NMI
41               *     6  TDA
42               *     5  MUX
43               *     4  DPT
44               *     3  GUIDE
45               *
46               *
47               *
48               *
49               *     INPUT                 I   I   I   I   I   I   I   I   I
50               *     $3000  LSBYTE         -------------------------------
51               *     $3001  NSBYTE           7   6   5   4   3   2   1   0
52               *     $3002  MSBYTE
```

```
                        *
                        *
                        *
                        *
                        *       THIS IS THE SYMBOLS DEFINITIONS FOR THE
                        *       PROGRAM
                        *
                        *
0000                    SCANDS  EQU $1F1F
0000                    GETKEY  EQU $1F6A
0000                    INPUT   EQU $3000
0000                    DPIA1   EQU $1701
0000                    DPIA2   EQU $1703
0000                    METER   EQU $1700
0000                    CHART   EQU $1702
0000                    IRQL    EQU $17FE
0000                    NMIL    EQU $17FA
0000                    IOSO    EQU %00000110
0000                    IOSX    EQU %00000100
0000                    IXSO    EQU %00000010
0000                    IXSX    EQU %00000000
0000                    DISP    EQU $00F9
0000                    SAVEA   EQU $00F3
0000                    SAVEP   EQU $00F1
0000                    SAVEX   EQU $00F5
0000                    SAVEY   EQU $00F4
0000                    SAVE1   EQU $1C05
0000                    XINPUT  EQU 02
0000                    XCLK    EQU 04
0000                    XTDA    EQU 06
0000                    XTDB    EQU 08
0000                    XDISP   EQU $0A
0000                    XBINPT  EQU $0C
0000                    XBTDB   EQU $0E
0000                    XVALU1  EQU $10
0000                    XVALU2  EQU $12
0000                    XBVAL1  EQU $14
0000                    XBVAL2  EQU $16
0000                    XDATA   EQU $18
0000                    XAVGA   EQU $1A
0000                    XAVGB   EQU $1C
0000                    MTP     EQU $3004
0000                    HCNTRL  EQU $3003
                        *
                        *
                        *       THIS IS THE BEGINNING OF THE ZERO PAGE
                        *       CONSTANTS, TEMP STORAGE AND ADDRESSING
                        *       POINTERS.
                        *
                        *
0000                            ORG 0000
0000 00 00              PORGIN  BSS 2
0002 00                 AINPUT  HEX 00,30
0003 30
0004 20                 ACLK    HEX 20,00
```

```
     0005 00
107  0006 23          ATDA    HEX 23,00
     0007 00
108  0008 26          ATDB    HEX 26,00
     0009 00
109  000A F9          ADISP   HEX F9,00
     000B 00
110  000C 29          ABINPT  HEX 29,00
     000D 00
111  000E 2C          ABTDB   HEX 2C,00
     000F 00
112  0010 00 00       VALUE1  BSS 2
113  0012 00 00       VALUE2  BSS 2
114  0014 00 00       BVALU1  BSS 2
115  0016 00 00       BVALU2  BSS 2
116  0018 00          ADATA   HEX 00,12
     0019 12
117  001A 2F          AAVGA   HEX 2F,00
     001B 00
118  001C 32          AAVGB   HEX 32,00
     001D 00
119  0020                     ORG $0020
120  0020 00 00 00    CLK     BSS 3
121  0023 00 00 00    TDA     BSS 3
122  0026 00 00 00    TDB     BSS 3
123  0029 00 00 00    BINPT   BSS 3
124  002C 00 00 00    BTDB    BSS 3
125  002F 00 00 00    AVGA    BSS 3
126  0032 00 00 00    AVGB    BSS 3
127  0035 00 00 00    VALUE3  BSS 3
128  0038 00 00 00    BVALU3  BSS 3
129  0040                     ORG $0040
130  0040 09          AVG     HEX 09,09
     0041 09
131  0042 00          SEG     BSS 1
132  0043 00          SEG1    BSS 1
133  0044 00          TCNT    BSS 1
134  0045 00          BTCNT   BSS 1
135  0046 00          DFLAG   BSS 1
136  0047 49          GUIDE   HEX 49
137  0048 00          DPTS    BSS 1
138  0049 00          STORE   BSS 1
139  004A 00          TEMP    BSS 1
140  004B 00          BTEMP   BSS 1
141  004C 00          BYTES   BSS 1
142  0200                     ORG $0200
143  0200 A0 03       XIRQ    ADR LIRQ
144  0202 72 04       XNMI    ADR LNMI
145                     *
146                     *
147                     *      THE INITIALIZATION ROUTINE BEGINS HERE.
148                     *
149                     *
150  0204 78                  SEI          DISABLE SOFTWARE INTERUPTS
151  0205 A9 02               LDA =IXSO
```

ORIGINAL PAGE
OF POOR QUALITY

```
0207 8D 03 30          STA HCNTRL  SET HARDWARE INT OFF
020A AD 00 02          LDA XIRQ
020D 8D FE 17          STA IRQL
0210 AD 01 02          LDA XIRQ+1
0213 8D FF 17          STA IRQL+1
0216 AD 02 02          LDA XNMI
0219 8D FA 17          STA NMIL
021C AD 03 02          LDA XNMI+1
021F 8D FB 17          STA NMIL+1
0222 A9 BF             LDA =$BF
0224 8D 03 17          STA DPIA2
0227 A9 7F             LDA =$7F
0229 8D 01 17          STA DPIA1
022C A2 FF             LDX =$FF
022E 9A                TXS         SET STACK POINTER TO TOP
022F A9 09             LDA =$09
0231 85 40             STA AVG
0233 85 41             STA AVG+1
0235 A9 0E             LDA =$0E
0237 85 19             STA ADATA+1
0239 A9 00             LDA =00
023B 85 18             STA ADATA
023D A2 03             LDX =03
023F A0 00             LDY =00
0241 91 18     LOOP14  STA (ADATA),Y  CLEAR BYTE
0243 C8                INY         INCREMENT INDEX
0244 D0 FB             BNE LOOP14  JUMP TILL DONE
0246 E6 19             INC ADATA+1 BUMP ADDRESS
0248 CA                DEX         TEST OUTSIDE LOOP
0249 10 F6             BPL LOOP14  JUMP TILL DONE
024B A9 0E             LDA =$0E
024D 85 19             STA ADATA+1
024F A9 00             LDA =00
0251 85 18             STA ADATA
0253 A2 14             LDX =20
0255 95 20     LOOP10  STA CLK,X
0257 CA                DEX
0258 10 FB             BPL LOOP10
025A A2 09             LDX =$09
025C 95 42     LOOP11  STA SEQ,X
025E CA                DEX
025F 10 FB             BPL LOOP11
0261 A9 49             LDA =$49
0263 85 47             STA GUIDE
0265 AD 00 30          LDA INPUT
0268 A9 06             LDA =IOSO
026A 8D 03 30          STA HCNTRL
026D 58                CLI
                *
                *
                *      BACKROUND PROCESSING BEGINS HERE
                *
                *
026E A5 46     BAKRND  LDA DFLAG
0270 10 26             BPL CONT3   JUMP IF NMI NOT SET
```

```
207  0272 29 7F          AND =$7F     CLEAR NMI FLAG
208  0274 85 46          STA DFLAG    RETURN FLAGS
209  0276 A0 18          LDY =XDATA
21   0278 A2 04          LDX =XCLK
211  027A 20 86 04       JSR SETUP2   SET UP DATA AND CLOCK
212  027D A9 08          LDA =08
213  027F 20 F1 04       JSR XFER     MOVE POSITION TO DATA STORAGE
214  0282 F8             SED          SET DECIMAL MODE
215  0283 18             CLC          CLEAR CARRY
216  0284 A5 48          LDA DPTS     GET DATA POINTS COUNT
217  0286 69 01          ADC =01      ADD ONE
218  0288 85 48          STA DPTS     SAVE NEW DATA POINT COUNT
219  028A D8             CLD          CLEAR DECIMAL MODE
220  028B A5 18          LDA ADATA    GET DATA ADDRESS POINTER
221  028D 18             CLC
222  028E 69 09          ADC =09
223  0290 85 18          STA ADATA
224  0292 A5 19          LDA ADATA+1
225  0294 69 00          ADC =00
226  0296 85 19          STA ADATA+1
227  0298 A5 46    CONT5 LDA DFLAG    GET FLAGS
228  029A 29 10          AND =$10     MASK DPT BIT
229  029C F0 0D          BEQ CONT6    JUMP IF RESET
230  029E A9 00          LDA =00
231  02A0 85 F9          STA DISP
232  02A2 85 FA          STA DISP+1
233  02A4 A5 48          LDA DPTS     GET DATA POINT COUNTER
234  02A6 85 FB          STA DISP+2   DISPLAY DATA POINTS USED
235  02A8 4C CC 02       JMP CONT8
236  02AB A5 46    CONT6 LDA DFLAG    GET FLAGS
237  02AD 29 40          AND =$40     MASK TDA
238  02AF F0 0F          BEQ CONT7    JUMP IF RESET
239  02B1 A2 08          LDX =XTDB
240  02B3 A0 0A          LDY =XDISP
241  02B5 20 86 04       JSR SETUP2   SETUP TDB OUTPUT
242  02B8 A9 02          LDA =02
243  02BA 20 F1 04       JSR XFER     MOVE TDB TO DISP
244  02BD 4C CC 02       JMP CONT8
245  02C0 A2 06    CONT7 LDX =XTDA
246  02C2 A0 0A          LDY =XDISP
247  02C4 20 86 04       JSR SETUP2   SET UP ADDRESSES
248  02C7 A9 02          LDA =02      SET BYTE COUNT
249  02C9 20 F1 04       JSR XFER     MOVE TDA TO DISPLAY
250  02CC A5 45    CONT8 LDA BTCNT    GET GRI COUNT
251  02CE C9 64          CMP =100
252  02D0 D0 0C          BNE CONT9    JUMP IF EQUAL
253  02D2 A9 00          LDA =00
254  02D4 85 45          STA BTCNT    CLEAR COUNT
255  02D6 A5 46          LDA DFLAG    GET FLAGS
256  02D8 49 FF          EOR =$FF     COMPLEMENT
257  02DA 49 DF          EOR =$DF     COMPLEMENT MUX BIT
258  02DC 85 46          STA DFLAG    SAVE BACK TO FLAGS
259  02DE A5 46    CONT9 LDA DFLAG    GET FLAGS
260  02E0 29 20          AND =$20
261  02E2 F0 12          BEQ CONT10   BRANCH IF RESET
```

```
207  0272 29 7F          AND =$7F     CLEAR NMI FLAG
208  0274 85 46          STA DFLAG    RETURN FLAGS
209  0276 A0 18          LDY =XDATA
210  0278 A2 04          LDX =XCLK
211  027A 20 86 04       JSR SETUP2   SET UP DATA AND CLOCK
212  027D A9 08          LDA =08
213  027F 20 F1 04       JSR XFER     MOVE POSITION TO DATA STORAGE
214  0282 F8             SED          SET DECIMAL MODE
215  0283 18             CLC          CLEAR CARRY
216  0284 A5 48          LDA DPTS     GET DATA POINTS COUNT
217  0286 69 01          ADC =01      ADD ONE
218  0288 85 48          STA DPTS     SAVE NEW DATA POINT COUNT
219  028A D8             CLD          CLEAR DECIMAL MODE
220  028B A5 18          LDA ADATA    GET DATA ADDRESS POINTER
221  028D 18             CLC
222  028E 69 09          ADC =09
223  0290 85 18          STA ADATA
224  0292 A5 19          LDA ADATA+1
225  0294 69 00          ADC =00
226  0296 85 19          STA ADATA+1
227  0298 A5 46     CONT5 LDA DFLAG    GET FLAGS
228  029A 29 10          AND =$10     MASK DPT BIT
229  029C F0 0D          BEQ CONT6    JUMP IF RESET
230  029E A9 00          LDA =00
231  02A0 85 F9          STA DISP
232  02A2 85 FA          STA DISP+1
233  02A4 A5 48          LDA DPTS     GET DATA POINT COUNTER
234  02A6 85 FB          STA DISP+2   DISPLAY DATA POINTS USED
235  02A8 4C CC 02       JMP CONT8
236  02AB A5 46     CONT6 LDA DFLAG    GET FLAGS
237  02AD 29 40          AND =$40     MASK TDA
238  02AF F0 0F          BEQ CONT7    JUMP IF RESET
239  02B1 A2 08          LDX =XTDB
240  02B3 A0 0A          LDY =XDISP
241  02B5 20 86 04       JSR SETUP2   SETUP TDB OUTPUT
242  02B8 A9 02          LDA =02
243  02BA 20 F1 04       JSR XFER     MOVE TDB TO DISP
244  02BD 4C CC 02       JMP CONT8
245  02C0 A2 06     CONT7 LDX =XTDA
246  02C2 A0 0A          LDY =XDISP
247  02C4 20 86 04       JSR SETUP2   SET UP ADDRESSES
248  02C7 A9 02          LDA =02      SET BYTE COUNT
249  02C9 20 F1 04       JSR XFER     MOVE TDA TO DISPLAY
250  02CC A5 45     CONT8 LDA BTCNT    GET GRI COUNT
251  02CE C9 64          CMP =100
252  02D0 D0 0C          BNE CONT9    JUMP IF EQUAL
253  02D2 A9 00          LDA =00
254  02D4 85 45          STA BTCNT    CLEAR COUNT
255  02D6 A5 46          LDA DFLAG    GET FLAGS
256  02D8 49 FF          EOR =$FF     COMPLEMENT
257  02DA 49 DF          EOR =$DF     COMPLEMENT MUX BIT
258  02DC 85 46          STA DFLAG    SAVE BACK TO FLAGS
259  02DE A5 46     CONT9 LDA DFLAG    GET FLAGS
260  02E0 29 20          AND =$20
261  02E2 F0 12          BEQ CONT10   BRANCH IF RESET
```

```
262  02E4 A5 28          LDA TDB+2   LOW BYTE OF TDB
263  02E6 20 FA 04       JSR BCD     CONVERT FOR OUTPUT
264  02E9 C9 40    MODIFY CMP =$40   TEST FOR > $40
265  02EB 90 03          BCC NOCHG   IF <$40 DO NOT MODIFY
266  02ED 18             CLC
267  02EE 69 40          ADC =$40    MODIFY FOR OUTPUT
268  02F0 8D 02 17 NOCHG STA CHART   OUTPUT TO CHART
269  02F3 4C FE 02       JMP CONT11
270  02F6 A5 25    CONT10 LDA TDA+2  GET LOW BYTE OF TDA
271  02F8 20 FA 04       JSR BCD     CONVERT FOR OUTPUT
272  02FB 4C E9 02       JMP MODIFY
273  02FE 20 6A 1F CONT11 JSR GETKEY  GET KEYBOARD KEY
274  0301 C9 0A          CMP =$0A    TEST FOR A
275  0303 D0 03          BNE CONT12  JUMP IF NOT A
276  0305 A5 46          LDA DFLAG   GET FLAGS
277  0307 29 AF          AND =$AF    CLEAR DPT FLAG
278  0309 85 46          STA DFLAG   SAVE TO FLAGS
279  030B 4C 40 03       JMP CONT16
280  030E C9 0B    CONT12 CMP =$0B   TEST FOR B
281  0310 D0 05          BNE CONT13  JUMP IF NOT B
282  0312 A5 46          LDA DFLAG   GET FLAGS
283  0314 29 EF          AND =$EF    CLEAR DPT BIT
284  0316 09 40          ORA =$40    SET TDA BIT
285  0318 85 46          STA DFLAG   RETURN FLAGS
286  031A 4C 49 03       JMP CONT16
287  031D C9 01    CONT13 CMP =01    TEST FOR 1
288  031F D0 0D          BNE CONT14  JUMP IF NOT 1
289  0321 A5 25          LDA TDA+2   GET LSB TDA
290  0323 85 47          STA GUIDE   SAVE TO GUIDE WORD
291  0325 A5 46          LDA DFLAG
292  0327 29 F7          AND =$F7
293  0329 85 46          STA DFLAG   RESET GUIDE BIT
294  032B 4C 49 03       JMP CONT16
295  032E C9 02    CONT14 CMP =02    TEST FOR 2
296  0330 D0 0D          BNE CONT15  JUMP IF NOT 2
297  0332 A5 28          LDA TDB+2   GET LSB TDB
298  0334 85 47          STA GUIDE   SAVE TO GUIDE WORD
299  0336 A5 46          LDA DFLAG
300  0338 09 08          ORA =$08
301  033A 85 46          STA DFLAG   SET GUIDE BIT
302  033C 4C 49 03       JMP CONT16
303  033F C9 0D    CONT15 CMP =$0D   TEST FOR D KEY
304  0341 D0 06          BNE CONT16  JUMP IF NOT EQUAL TO D
305  0343 A5 46          LDA DFLAG   GET FLAGS
306  0345 09 10          ORA =$10    SET DPT FLAG
307  0347 85 46          STA DFLAG   RETURN FLAGS
308  0349 A5 46    CONT16 LDA DFLAG  GET FLAGS
309  034B F8             SED         SET DECIMAL MODE
310  034C 29 08          AND =$08    MASK GUIDE BIT
311  034E F0 09          BEQ CONT17  JUMP IF RESET
312  0350 38             SEC         SET CARRY
313  0351 A5 47          LDA GUIDE   GET GUIDE WORD
314  0353 E5 28          SBC TDB+2   SUBTRACT LSB TDB
315  0355 4C 50 03       JMP CONT20
316  0358 A5 47    CONT17 LDA GUIDE  GET GUIDE VALUE
```

```
262  02E4 A5 28          LDA TDB+2    LOW BYTE OF TDB
263  02E6 20 FA 04       JSR BCD      CONVERT FOR OUTPUT
264  02E9 C9 40  MODIFY  CMP =$40     TEST FOR > $40
265  02EB 90 03          BCC NOCHG    IF <$40 DO NOT MODIFY
266  02ED 18             CLC
267  02EE 69 40          ADC =$40     MODIFY FOR OUTPUT
268  02F0 8D 02 17 NOCHG STA CHART    OUTPUT TO CHART
269  02F3 4C FE 02       JMP CONT11
270  02F6 A5 25  CONT10  LDA TDA+2    GET LOW BYTE OF TDA
271  02F8 20 FA 04       JSR BCD      CONVERT FOR OUTPUT
272  02FB 4C E9 02       JMP MODIFY
273  02FE 20 6A 1F CONT11 JSR GETKEY  GET KEYBOARD KEY
274  0301 C9 0A          CMP =$0A     TEST FOR A
275  0303 D0 09          BNE CONT12   JUMP IF NOT A
276  0305 A5 46          LDA DFLAG    GET FLAGS
277  0307 29 AF          AND =$AF     CLEAR DPT FLAG
278  0309 85 46          STA DFLAG    SAVE TO FLAGS
279  030B 4C 49 03       JMP CONT16
280  030E C9 0B  CONT12  CMP =$0B     TEST FOR B
281  0310 D0 0B          BNE CONT13   JUMP IF NOT B
282  0312 A5 46          LDA DFLAG    GET FLAGS
283  0314 29 EF          AND =$EF     CLEAR DPT BIT
284  0316 09 40          ORA =$40     SET TDA BIT
285  0318 85 46          STA DFLAG    RETURN FLAGS
286  031A 4C 49 03       JMP CONT16
287  031D C9 01  CONT13  CMP =01      TEST FOR 1
288  031F D0 0D          BNE CONT14   JUMP IF NOT 1
289  0321 A5 25          LDA TDA+2    GET LSB TDA
290  0323 85 47          STA GUIDE    SAVE TO GUIDE WORD
291  0325 A5 46          LDA DFLAG
292  0327 29 F7          AND =$F7
293  0329 85 46          STA DFLAG    RESET GUIDE BIT
294  032B 4C 49 03       JMP CONT16
295  032E C9 02  CONT14  CMP =02      TEST FOR 2
296  0330 D0 0D          BNE CONT15   JUMP IF NOT 2
297  0332 A5 28          LDA TDB+2    GET LSB TDB
298  0334 85 47          STA GUIDE    SAVE TO GUIDE WORD
299  0336 A5 46          LDA DFLAG
300  0338 09 08          ORA =$08
301  033A 85 46          STA DFLAG    SET GUIDE BIT
302  033C 4C 49 03       JMP CONT16
303  033F C9 0D  CONT15  CMP =$0D     TEST FOR D KEY
304  0341 D0 06          BNE CONT16   JUMP IF NOT EQUAL TO D
305  0343 A5 46          LDA DFLAG    GET FLAGS
306  0345 09 10          ORA =$10     SET DPT FLAG
307  0347 85 46          STA DFLAG    RETURN FLAGS
308  0349 A5 46  CONT16  LDA DFLAG    GET FLAGS
309  034B F8             SED          SET DECIMAL MODE
310  034C 29 08          AND =$08     MASK GUIDE BIT
311  034E F0 09          BEQ CONT17   JUMP IF RESET
312  0350 38             SEC          SET CARRY
313  0351 A5 47          LDA GUIDE    GET GUIDE WORD
314  0353 E5 28          SBC TDB+2    SUBTRACT LSB TDB
315  0355 4C 50 03       JMP CONT20
316  0358 A5 47  CONT17  LDA GUIDE    GET GUIDE VALUE
```

```
317  035A 38           SEC
318  035B E5 25        SBC TDA+2     FORM GUIDENCE
319  035D C9 20  CONT20 CMP =$20     TEST FOR >20
320  035F B0 0E        BCS N1        IF >20 TEST IF >80
321  0361 AA     ADD1  TAX           SET INDEX
322  0362 F0 24        BEQ CENTER
323  0364 18           CLC
324  0365 A9 49        LDA =$49      SET CENTER VALUE
325  0367 69 05  LOOP12 ADC =05
326  0369 CA           DEX           DEC INDEX
327  036A D0 FB        BNE LOOP12    LOOP TILL INDEX ZERO
328  036C 4C 8A 03     JMP CONT18
329  036F C9 80  N1    CMP =$80      TEST FOR >80
330  0371 90 17        BCC CONT18    IF 20< A <80 JUMP
331  0373 85 48        STA BTEMP     SAVE A
332  0375 38           SEC           SET CARRY
333  0376 A9 00        LDA =00
334  0378 E5 48        SBC BTEMP     FORM COMPLEMENT
335  037A AA     SUB   TAX
336  037B F0 03        BEQ CENTER
337  037D 38           SEC
338  037E A9 49        LDA =$49      SET CENTER VALUE
339  0380 E9 05  LOOP13 SBC =05
340  0382 CA           DEX
341  0383 D0 FB        BNE LOOP13    LOOP TILL ZERO
342  0385 4C 8A 03     JMP CONT18
343  0388 A9 49  CENTER LDA =$49     SET CENTER
344  038A D8     CONT18 CLD          CLEAR DECIMAL MODE
345  038B 20 FA 04     JSR BCD       CONVERT TO BINARY
346  038E 8D 00 17  OUT  STA METER   WRITE TO METER
347  0391 A5 F9        LDA DISP      XCHG DISPLAY HIGH AND LOW BYTES
348  0393 AA           TAX
349  0394 A5 FB        LDA DISP+2
350  0396 85 F9        STA DISP
351  0398 86 FB        STX DISP+2
352  039A 20 1F 1F     JSR SCANDS    SCAN DISPLAY
353  039D 4C 6E 02     JMP BAKRND    LOOP IN BACKROUND
354                 *
355                 *
356                 *       IRQ INTERUPT SERVICE ROUTINE
357                 *
358                 *
359  03A0 85 F3  LIRQ  STA SAVEA     SAVE A ACCUM.
360  03A2 68           PLA           GET STATUS
361  03A3 85 F1        STA SAVEP     SAVE STATUS IN IMAGE
362  03A5 29 10        AND =$10      MASK BRK BIT
363  03A7 F0 03        BEQ UNIT      JUMP IF NOT SET
364  03A9 4C 05 1C     JMP SAVE1
365  03AC A5 F1  UNIT  LDA SAVEP     GET STATUS
366  03AE 48           PHA           RESTORE AS BEFORE INTERUPT
367  03AF 84 F4        STY SAVEY     SAVE Y AINDEX
368  03B1 86 F5        STX SAVEX     SAVE X INDEX
369  03B3 A9 02        LDA =IXSO     DISABLE INTERUPTS
370  03B5 8D 03 30     STA HCNTRL
371  03B8 A5 10        LDA VALUE1    SAVE VALUE1 AND VALUE2
```

```
372  03FA 48                 PHA
373  03FB A5 11              LDA VALUE1+1
374  03FD 48                 PHA
375  03FE A5 12              LDA VALUE2
376  0400 48                 PHA
377  0401 A5 13              LDA VALUE2+1
378  0403 48                 PHA
379  0404 D8                 CLD             CLEAR DECIMAL MODE
380  0405 AD 04 30           LDA MTB         GET MASTER TEST BIT
381  0408 30 65              BMI MASTER      IF SET JUMP
382  040A A5 43              LDA SEQ1
383  040C C9 02              CMP =02         TEST FOR INVALID INDEX
384  040E F0 56              BEQ ERROR       JUMP IF INVALID
385  0410 A0 02              LDY =XINPUT     SET UP INPUT POINTER
386  0412 18                 CLC             CLEAR CARRY
387  0413 A9 14              LDA =XAVGA      SET UP AVERAGE POINTER
388  0415 65 42              ADC SEQ         ADD SEQUENCE
389  0417 AA                 TAX             READY FOR SETUP ADDRESS
390  0418 20 86 04           JSR SETUP2      SET UP THE ADDRESSES
391  041B A0 02              LDY =02
392  041D F8                 SED             SET DECIMAL MODE
393  041E 18                 CLC             CLEAR CARRY
394  041F B1 10              LDA (VALUE1),Y  ADD INPUT VALUE TO AVERAGE
395  0421 71 12              ADC (VALUE2),Y
396  0423 91 10              STA (VALUE1),Y
397  0425 88                 DEY
398  0426 B1 10              LDA (VALUE1),Y
399  0428 71 12              ADC (VALUE2),Y
400  042A 91 10              STA (VALUE1),Y
401  042C 88                 DEY
402  042D B1 12              LDA (VALUE2),Y
403  042F 29 0F              AND =$0F
404  0431 71 10              ADC (VALUE1),Y
405  0433 91 10              STA (VALUE1),Y
406  0435 D8                 CLD             CLEAR DECIMAL MODE
407  0436 A6 43              LDX SEQ1
408  0438 D6 40              DEC AVG,X       DEC AVERAGE COUNTER
409  043A 10 55              BPL CONT2
410  043C A9 02              LDA =02         SET BYTE COUNT
411  043E 20 D4 04           JSR ROUND       ROUND AVERAGE VALUE
412  0441 A9 02              LDA =02         SET BYTE COUNT
413  0443 20 BA 04           JSR SHIFT       DIVIDE BY 10
414  0446 18                 CLC             CLEAR CARRY
415  0447 A9 06              LDA =XTDA       BACKROUND TDA
416  0449 65 42              ADC SEQ
417  044B AA                 TAX             MOVE TO X
418  044C 20 7D 04           JSR SETUP3      SET UP TO POINTER
419  044F A9 02              LDA =02         SET BYTE COUNT
420  0411 20 F1 04           JSR XFER        MOVE BYTES
421  0414 A9 00              LDA =00
422  0416 A0 02              LDY =02
423  0418 91 10      LOOP6   STA (VALUE1),Y  CLEAR AVERAGE VALUE
424  041A 88                 DEY
425  041B 10 FB              BPL LOOP6       LOOP TIL DONE
426  041D A6 43              LDX SEQ1        GET SEQUENCE
```

```
427  041F A9 09          LDA =09      AVG-1 LOOP COUNT
428  0421 95 40          STA AVG,X    SAVE TO PROPER COUNTER
429  0423 4C 51 04       JMP CONT2
430  0426 A9 00    ERROR LDA =00
431  0428 85 42          STA SEQ      CLEAR SEQUENCE
432  042A 85 43          STA SEQ1
433  042C 4C 57 04       JMP CONT3    LOOP BACK
434  042F A9 00    MASTER LDA =00
435  0431 85 42          STA SEQ      CLEAR SEQUENCES
436  0433 85 43          STA SEQ1
437  0435 E6 44          INC TCNT     BUMP GRI COUNTER
438  0437 E6 45          INC BTCNT    BUMP BACKROUND COUNTER
439  0439 A5 44          LDA TCNT
440  043B C9 0A          CMP =10      TEST FOR 10
441  043D D0 18          BNE CONT3    IF NOT 10 JUMP
442  043F 18             CLC          CLEAR CARRY
443  0440 A2 04          LDX =XCLK    SET UP POINTER
444  0442 20 94 04       JSR SETUP1
445  0445 A9 02          LDA =02      SET BYTE COUNT
446  0447 20 9D 04       JSR INCBYT   BUMP TIME
447  044A A9 00          LDA =00
448  044C 85 44          STA TCNT     CLEAR GRI COUNTER
449  044E 4C 57 04       JMP CONT3
450  0451 E6 42    CONT2 INC SEQ
451  0453 E6 42          INC SEQ      INCREMENT SEQ BY 2
452  0455 E6 43          INC SEQ1     INC SEQ1
453  0457 68       CONT3 PLA          RESTORE VALUE1 AND VALUE2
454  0458 85 13          STA VALUE2+1
455  045A 68             PLA
456  045B 85 12          STA VALUE2
457  045D 68             PLA
458  045E 85 11          STA VALUE1+1
459  0460 68             PLA
460  0461 85 10          STA VALUE1
461  0463 A6 F5          LDX SAVEX    RESTORE X
462  0465 A4 F4          LDY SAVEY    RESTORE Y
463  0467 AD 00 30       LDA INPUT    RESET HARDWARE IRQ FLAG
464  046A A9 05          LDA =IOSO
465  046C 8D 03 30       STA HCNTRL   ENABLE INTERUPTS
466  046F A5 F3          LDA SAVEA    RESTORE A
467  0471 40             RTI
468                      *
469                      *
470                      *      NMI INTERUPT SERVICE ROUTINE
471                      *
472                      *
473  0472 85 F3    LNMI  STA SAVEA    SAVE A ACCUM.
474  0474 A5 46          LDA DFLAG    GET FLAGS
475  0476 09 80          ORA =$80
476  0478 85 46          STA DFLAG    SET NMI FLAG
477  047A A5 F3          LDA SAVEA    RESTORE A ACCUM.
478  047C 40             RTI          RETURN
479                      *
480                      *
481                      *
```

```
                        *     THIS ROUTINE IS USED TO LOAD THE PROPER OPERAND
                        *     ADDRESSES BEFORE ENTERING A SUBROUTINE.
                        *     UPON ENTERING, THE X REG. HAS THE ZERO PAGE ADDRESS
                        *     OF THE LSB FOR VALUE1.  THE Y REG. HAS THE ZERO
                        *     PAGE ADDRESS FOR THE LSB OF VALUE2.
                        *
                        *
047D B5 00      SETUP3  LDA PORGIN,X
047F 85 12              STA VALUE2
0481 B5 01              LDA PORGIN+1,X
0483 85 13              STA VALUE2+1
0485 60                 RTS
0486 8A         SETUP2  TXA
0487 48                 PHA             SAVE X INDEX
0488 98                 TYA
0489 AA                 TAX             SET UP SECOND INDEX
048A B5 00              LDA PORGIN,X  GET LSB POINTER SECOND VALUE
048C 85 12              STA VALUE2  SAVE POINTER LSB FOR SUBROUTINE
048E B5 01              LDA PORGIN+1,X  GET MSB POINTER SECOND VALUE
0490 85 13              STA VALUE2+1  SAVE POINTER MSB FOR SUBROUTINE
0492 68                 PLA
0493 AA                 TAX             RESTORE VALUE OF X INDEX
0494 B5 00      SETUP1  LDA PORGIN,X  GET LSB POINTER FIRST VALUE
0496 85 10              STA VALUE1  SAVE POINTER LSB FOR SUBROUTINE
0498 B5 01              LDA PORGIN+1,X  GET MSB POINTER FIRST VALUE
049A 85 11              STA VALUE1+1  SAVE POINTER MSB FOR SUBROUTINE
049C 60                 RTS             RETURN
                        *
                        *
                        *     THIS ROUTINE WILL INCREMENT THE VALUE POINTED TO BY TH
                        *     ADDRESS IN VALUE1.
                        *
                        *
049D A8         INCBYT  TAY             SET UP INDEX
049E F8                 SED             SET DECIMAL MODE
049F 18                 CLC
04A0 B1 10              LDA (VALUE1),Y  GET FIRST BYTE
04A2 69 01              ADC =01         ADD ONE
04A4 91 10              STA (VALUE1),Y  SAVE VALUE
04A6 4C AF 04           JMP CONT1
04A9 B1 10      LOOP9   LDA (VALUE1),Y
04AB 69 00              ADC =00
04AD 91 10              STA (VALUE1),Y
04AF 08         CONT1   PHP
04B0 88                 DEY
04B1 30 04              BMI RETUR1
04B3 28                 PLP
04B4 4C A9 04           JMP LOOP9
04B7 28         RETUR1  PLP
04B8 D8                 CLD             CLEAR DECIMAL MODE
04B9 60                 RTS
                        *
                        *     DIVIDE BY 10 ROUTINE
                        *
04BA 18         SHIFT   CLC             CLEAR CARRY
```

```
537  04BB 85 4A          STA TEMP     SAVE BYTE COUNT
538  04BD A2 03          LDX =03      SHIFT COUNT-1
539  04BF A5 4A    LOOP3 LDA TEMP     GET BYTE COUNT
540  04C1 85 4C          STA BYTES    SET BYTE COUNT
541  04C3 A0 00          LDY =00      INITIALIZE INDEX
542  04C5 B1 10    LOOP2 LDA (VALUE1),Y  FETCH BYTE
543  04C7 6A             ROR A        SHIFT RIGHT 1
544  04C8 91 10          STA (VALUE1),Y  RESTORE BYTE
545  04CA C8             INY          BUMP INDEX
546  04CB C6 4C          DEC BYTES    DEC BYTE COUNTER
547  04CD 10 F8          BPL LOOP2    LOOP TIL NEG.
548  04CF CA             DEX          DEC SHIFT COUNTER
549  04D0 18             CLC          CLEAR CARRY
550  04D1 10 EC          BPL LOOP3    LOOP TIL NEG.
551  04D3 60             RTS          RETURN
552                      *
553                      *
554                      *      THIS ROUTINE WILL ROUND OFF THE
555                      *      VALUE POINTED TO BY VALUE1 THE RESULT
556                      *      IS RETURNED TO VALUE1.  BYTE COUNT-1
557                      *      SHOULD BE IN A BEFORE ENTRY.
558                      *
559                      *
560  04D4 A8       ROUND  TAY          SET BYTE COUNT
561  04D5 B1 10          LDA (VALUE1),Y  GET BYTE
562  04D7 29 0F          AND =$0F     MASK TOP HALF
563  04D9 C9 05          CMP =05
564  04DB 30 12          BMI CONT     IF MINUS RETURN
565  04DD F8             SED          SET DECIMAL MODE
566  04DE 18             CLC          CLEAR CARRY
567  04DF B1 10          LDA (VALUE1),Y  GET BYTE
568  04E1 69 10          ADC =$10     BUMP TO ROUND OFF
569  04E3 91 10          STA (VALUE1),Y  SAVE BACK
570  04E5 88             DEY          DEC INDEX
571  04E6 B1 10    LOOP4 LDA (VALUE1),Y  GET NEXT BYTE
572  04E8 69 00          ADC =00      ADD CARRY
573  04EA 91 10          STA (VALUE1),Y  SAVE BACK
574  04EC 88             DEY          DEC INDEX
575  04ED 10 F7          BPL LOOP4    QUIT IF INDEX NEG.
576  04EF D8       CONT  CLD          CLEAR DECIMAL MODE
577  04F0 60             RTS          RETURN
578                      *
579                      *
580                      *      THIS ROUTINE WILL MOVE THE CONTENTS POINTED
581                      *      TO BY VALUE1 TO LOCATIONS POINTED TO BY VALUE2.
582                      *      ON ENTRY A ACCUM SHOULD CONTAIN BYTE COUNT-1.
583                      *
584                      *
585  04F1 A8       XFER  TAY          SET BYTE COUNT
586  04F2 B1 10    LOOP7 LDA (VALUE1),Y
587  04F4 91 12          STA (VALUE2),Y
588  04F6 88             DEY
589  04F7 10 F9          BPL LOOP7    LOOP TILL DONE
590  04F9 60             RTS          RETURN
591                      *
```

```
592                     *
593                     *       THIS ROUTINE WILL CONVERT A BYTE FROM BINARY
594                     *       TO BCD  BYTE TO BE CONVERTED ENTERS AND
595                     *       LEAVES THROUGH A ACCUM.
596                     *
597                     *
598  04FA 48            BCD     PHA
599  04FB 29 F0                 AND =$F0
600  04FD 4A                    LSR A
601  04FE 85 49                 STA STORE
602  0500 4A                    LSR A
603  0501 4A                    LSR A
604  0502 18                    CLC
605  0503 65 49                 ADC STORE
606  0505 85 49                 STA STORE
607  0507 68                    PLA
608  0508 29 0F                 AND =$0F
609  050A 65 49                 ADC STORE
610  050C 60                    RTS
611                             END

END PASS 2:    0 ERRORS
```

SYMB	ADDR	DEF	REFERENCES									
AAVGA	001A	117										
AAVGB	001C	118										
ABINPT	000C	110										
ABTDB	000E	111										
ACLK	0004	106										
ADATA	0018	116	171	173	179	183	185	220	223	224	226	176
ADD1	0361	321										
ADISP	000A	109										
AINPUT	0002	105										
ATDA	0006	107										
ATDB	0008	108										
AVG	0040	130	168	169	408	428						
AVGA	002F	125										
AVGB	0032	126										
BAKRND	026E	205	353									
BCD	04FA	598	263	271	345							
BINPT	0029	123										
BTCNT	0045	134	250	254	438							
BTDB	002C	124										
BTEMP	004B	140	331	334								
BVALU1	0014	114										
BVALU2	0016	115										
BVALU3	0038	128										
BYTES	004C	141	540	546								
CENTER	0388	343	322	336								
CHART	1702	67	268									
CLK	0020	120	187									
CONT	04EF	576	564									
CONT1	04AF	525	521									
CONT10	02F6	270	261									
CONT11	02FE	273	269									
CONT12	030E	280	275									
CONT13	031D	287	281									
CONT14	032E	295	288									
CONT15	033F	303	296									
CONT16	0349	308	279	286	294	302	304					
CONT17	0358	316	311									
CONT18	038A	344	328	330	342							
CONT2	0451	450	409	429								
CONT20	035D	319	315									
CONT3	0457	453	433	441	449							
CONT5	0298	227	206									
CONT6	02AB	236	229									
CONT7	02C0	245	238									
CONT8	02CC	250	235	244								
CONT9	02DE	259	252									
DFLAG	0046	135	205	208	227	236	255	258	259	276	278	282
			285	291	293	299	301	305	307	308	474	476
DISP	00F9	74	231	232	234	347	349	350	351			
DPIA1	1701	64	164									
DPIA2	1703	65	162									
DPTS	0048	137	216	218	233							
ERROR	0426	430	384									

GETKEY	1F6A	62	273									
GUIDE	0047	136	195	290	298	313	316					
HCNTRL	3003	95	152	198	370	465						
INCBYT	049D	515	446									
INPUT	3000	63	196	463								
IOSO	0006	70	197	464								
IOSX	0004	71										
IRQL	17FE	68	154	156								
IXSO	0002	72	151	369								
IXSX	0000	73										
LIRQ	03A0	359	143									
LNMI	0472	473	144									
LOOP10	0255	187	189									
LOOP11	025C	191	193									
LOOP12	0367	325	327									
LOOP13	0380	339	341									
LOOP14	0241	176	178	181								
LOOP2	04C5	542	547									
LOOP3	04BF	539	550									
LOOP4	04E6	571	575									
LOOP6	0418	423	425									
LOOP7	04F2	586	589									
LOOP9	04A9	522	529									
MASTER	042F	434	381									
METER	1700	66	346									
MODIFY	02E9	264	272									
NTB	3004	94	380									
NMIL	17FA	69	158	160								
NOCHG	02F0	268	265									
N1	036F	329	320									
OUT	038E	346										
PORSIN	0000	104	489	491	498	500	504	506				
RETUR1	04B7	530	527									
ROUND	04D4	560	411									
SAVEA	00F3	75	359	466	473	477						
SAVEP	00F1	76	361	365								
SAVEX	00F5	77	368	461								
SAVEY	00F4	78	367	462								
SAVE1	1C05	79	364									
SCANDS	1F1F	61	352									
SEQ	0042	131	191	388	416	431	435	450	451			
SEQ1	0043	132	382	407	426	432	436	452				
SETUP1	0494	504	444									
SETUP2	0486	494	211	241	247	390						
SETUP3	047D	489	418									
SHIFT	048A	536	413									
STORE	0049	138	601	605	606	609						
SUB	037A	335										
TCNT	0044	133	437	439	448							
TDA	0023	121	270	289	318							
TDB	0026	122	262	297	314							
TEMP	004A	139	537	539								
UNIT	03AC	365	363									
VALUE1	0010	112	371	373	458	460	505	507	394	396	398	400
			404	405	423	518	520	522	524	542	544	561

			567	569	571	573	586					
VALUE2	0012	113	375	377	454	456	490	492	499	501	395	399
			402	587								
VALUE3	0035	127										
XAVGA	001A	92	387									
XAVGB	001C	93										
XBINPT	000C	85										
XBTDB	000E	86										
XBVAL1	0014	89										
XBVAL2	0016	90										
XCLK	0004	81	210	443								
XDATA	0018	91	209									
XDISP	000A	84	240	246								
XFER	04F1	585	213	243	249	420						
XINPUT	0002	80	385									
XIRQ	0200	143	153	155								
XNMI	0202	144	157	159								
XTDA	0006	82	245	415								
XTDB	0008	83	239									
XVALU1	0010	87										
XVALU2	0012	88										

APPENDIX C. Software Subroutines.

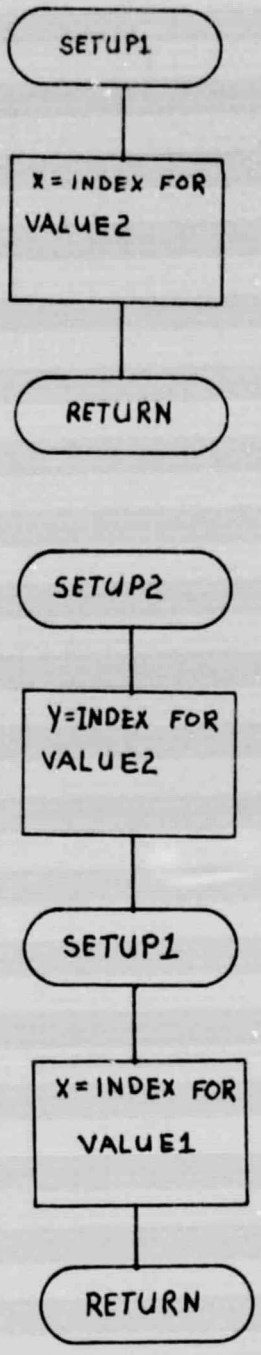


Figure C-1. Pointer Address Setup Flow Diagram.

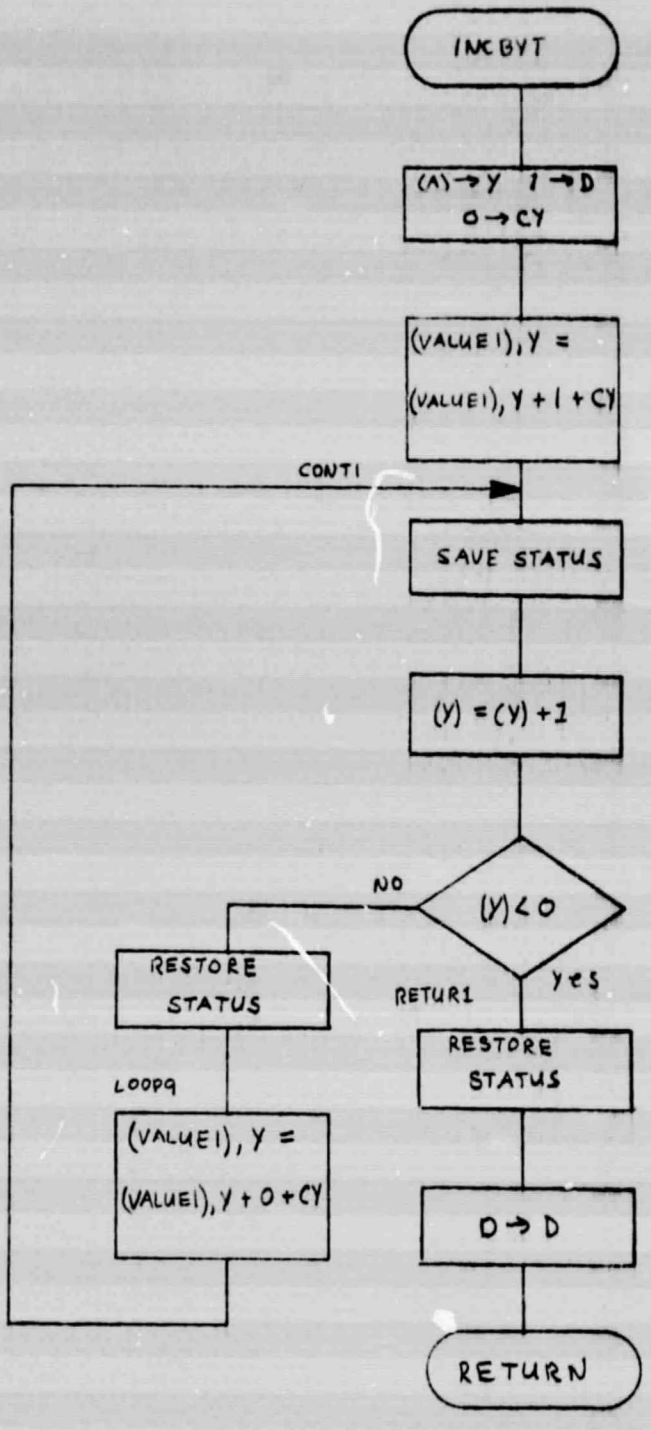


Figure C-2. Increment Byte Flow Diagram.

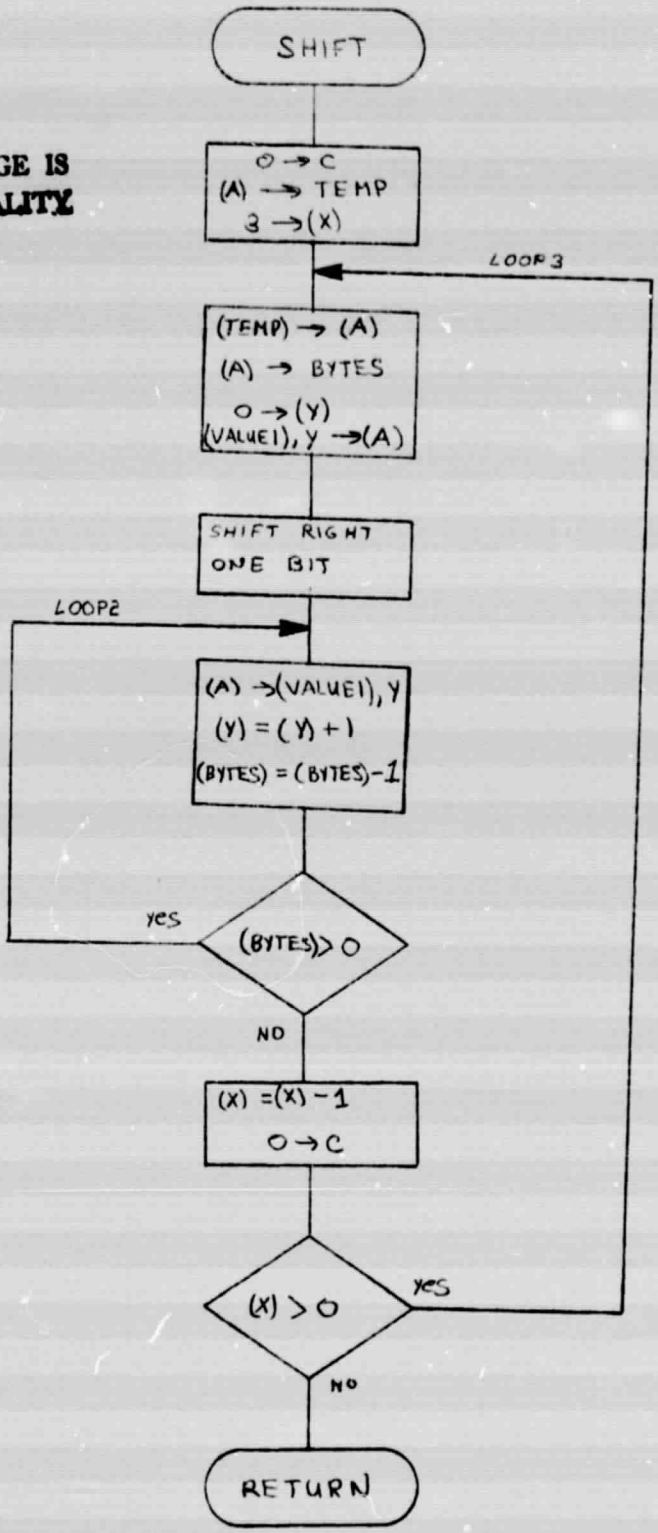


Figure C-3. BCD Shift Flow Diagram.

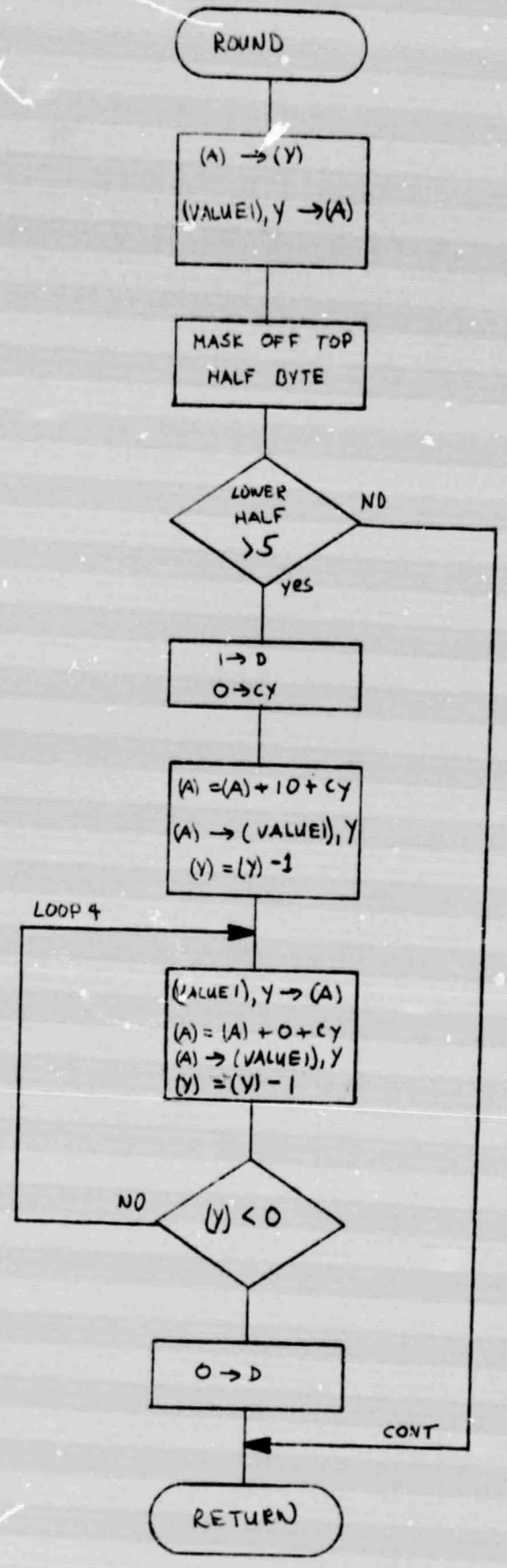


Figure C-4. Least Significant Digit Rounding Flow Diagram.

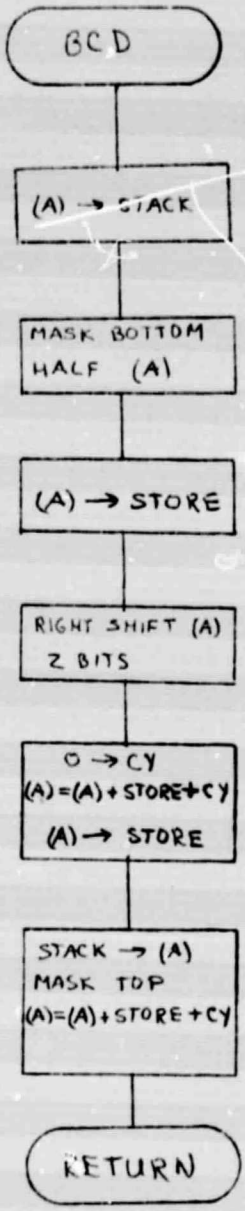


Figure C-5. BCD to Binary Conversion Flow Diagram.

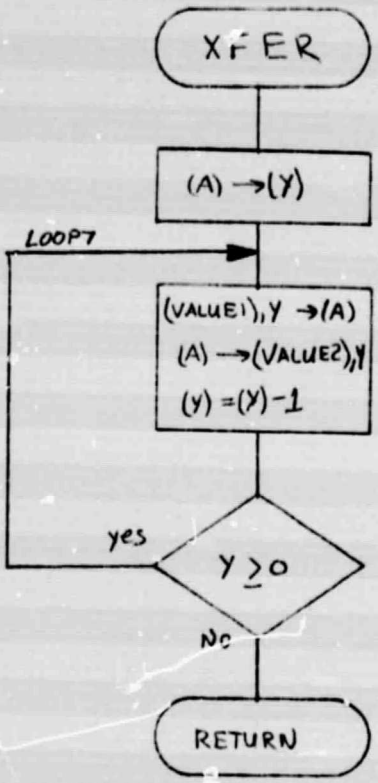


Figure C-6. Transfer Data Flow Diagram.