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A NUCLEAR INSTRUMENTATION MODULE (NIM) STANDARD LOGIC PROCESSOR AS A PORTAL SIGNAL ANALYZER

George P. Minges

Chemistry Research and Development
INSTRUMENTATION AND STATISTICAL SYSTEMS

Rockwell International

Energy Systems Group
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

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SUBJECT DESCRIPTORS

Safeguards
Security
Discriminator
Microprocessor

ROCKWELL INTERNATIONAL
ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT
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George P. Minges

Abstract. A general purpose electronic logic processor has been designed into a 2 wide NIM (Nuclear Instrumentation Module) bin module. The unit utilizes a microprocessor to achieve necessary versatility.

The processor's first use is as a new generation signal analyzer for use in radiometric personnel and vehicle portal monitors. Significant improvements have been obtained in sensitivity and stability over existing analog discriminators. The new analyzer is presently being used to update personnel and vehicle portal monitoring systems.

INTRODUCTION

At Rocky Flats, NIM (Nuclear Instrumentation Module) bin electronic devices are in widespread use. A need was realized for a general purpose, NIM bin, mountable logic processor for radiometric equipment. With this thought in mind, and with high priority for an improved version of the analog portal discriminator, work was started toward developing a fully digital portal signal analyzer.

A portal signal analyzer has been fabricated and successfully tested. This report describes the signal analyzer.

DESCRIPTION

The portal signal analyzer is an instrument designed to accept a pulse count from external detectors and suitable pulse height analyzers. It also is fed a signal indicating the presence of a person or object in the active area of the portal monitor.

The instrument functions by averaging and displaying the background count rate continuously until directed by a presence detector to switch to an active mode. In the active mode, the latest average background count is stored and a new count begun. This latter or active count average is then compared to the stored background count to determine if the two counts are "statistically different." If there is no significant difference between the active count and the background count, the instrument will return to its background averaging mode. If a significant difference is noted, the analyzer will alarm remotely, visually, and audibly. It also will display the count rate that produced the alarm until this condition is acknowledged. The background count average and the active count average are both accumulated by a sliding scale (first in, first out) technique. Alarm points are calculated using a standard probability theory during the background averaging mode.

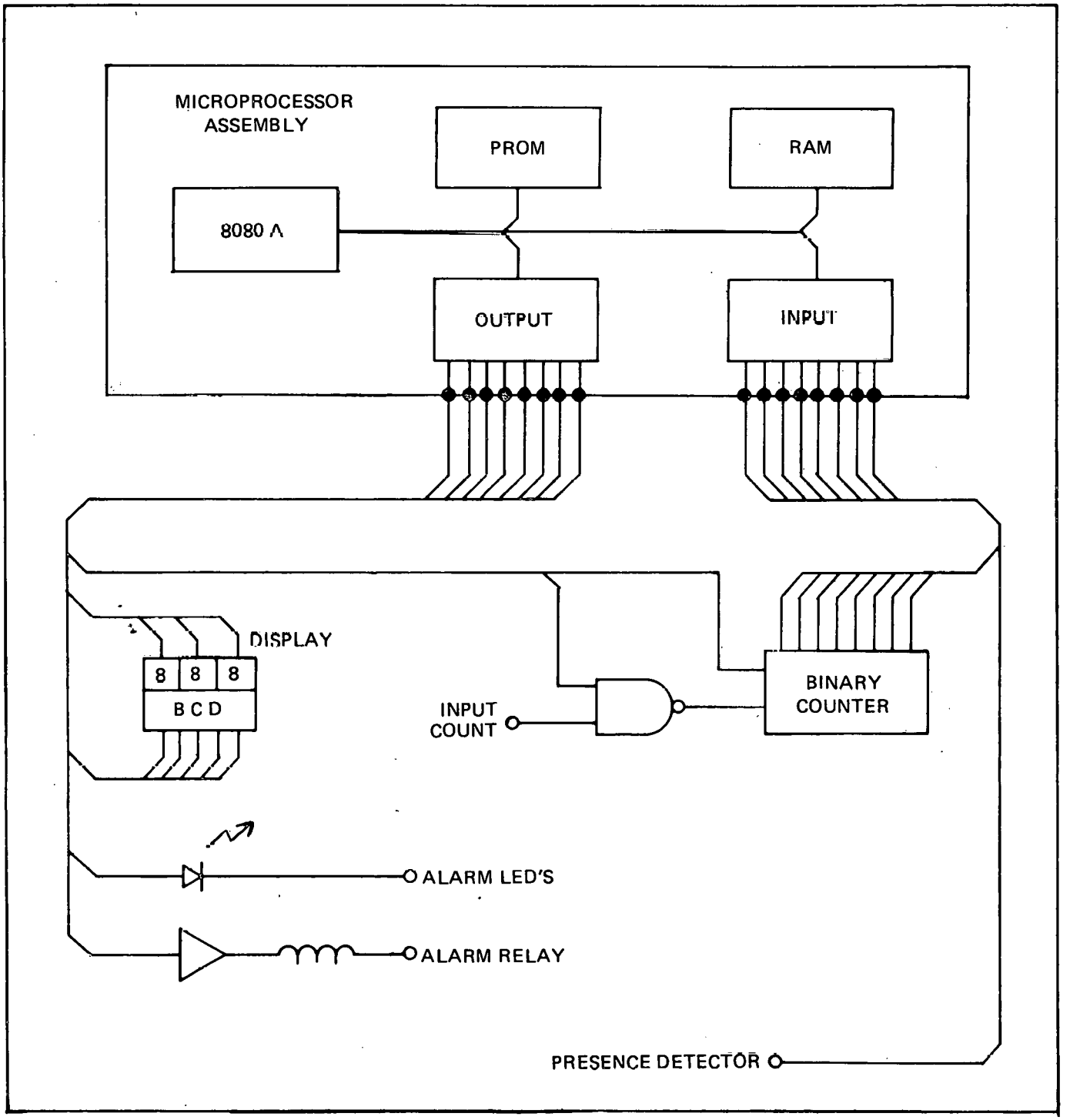
The portal signal analyzer consists of four major parts: microprocessor, counter, display and electronic support, and software. The details of each will be described. Figure 1 shows a block diagram of the instrument; Figures 2 and 3 are photographs of the inside of the unit and of construction details.

Microprocessor

The microprocessor used is a commercially available, Pro-Log single card MPS 880 system* costing approximately three hundred dollars. It was chosen for its size, cost, and use of second-sourced standard electronic components. The microprocessor has a crystal controlled clock, 16 input gates, 24 latched output lines, and measures only 11.4 X 16.5 cm. It has the capability of 4 k bytes of PROM (Programmable Read Only Memory) and 1 k bytes of RAM (Random Access Memory) memory.

*Pro-Log Corporation, 2411 A. Garden Road, Monterey, California 934940.

FIGURE 1. Block Diagram of Portal Signal Analyzer



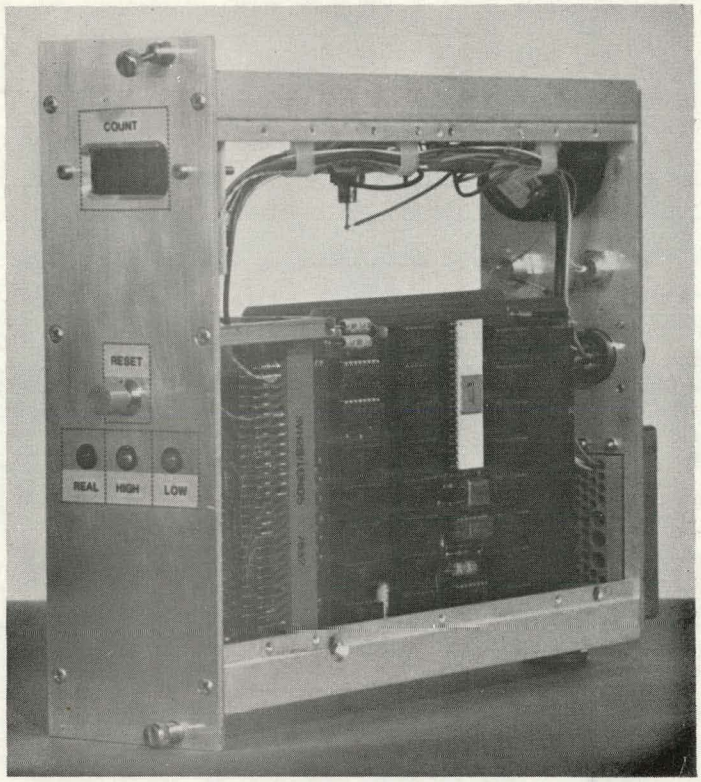


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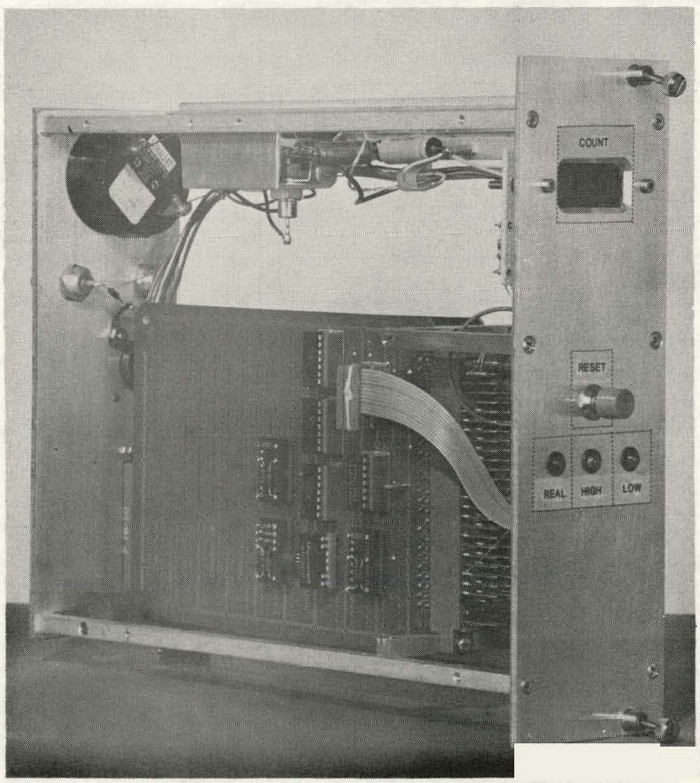
FIGURE 2. Right Front View of Portal Signal Analyzer

FIGURE 3. Left Front View of Portal Signal Analyzer

23039-8



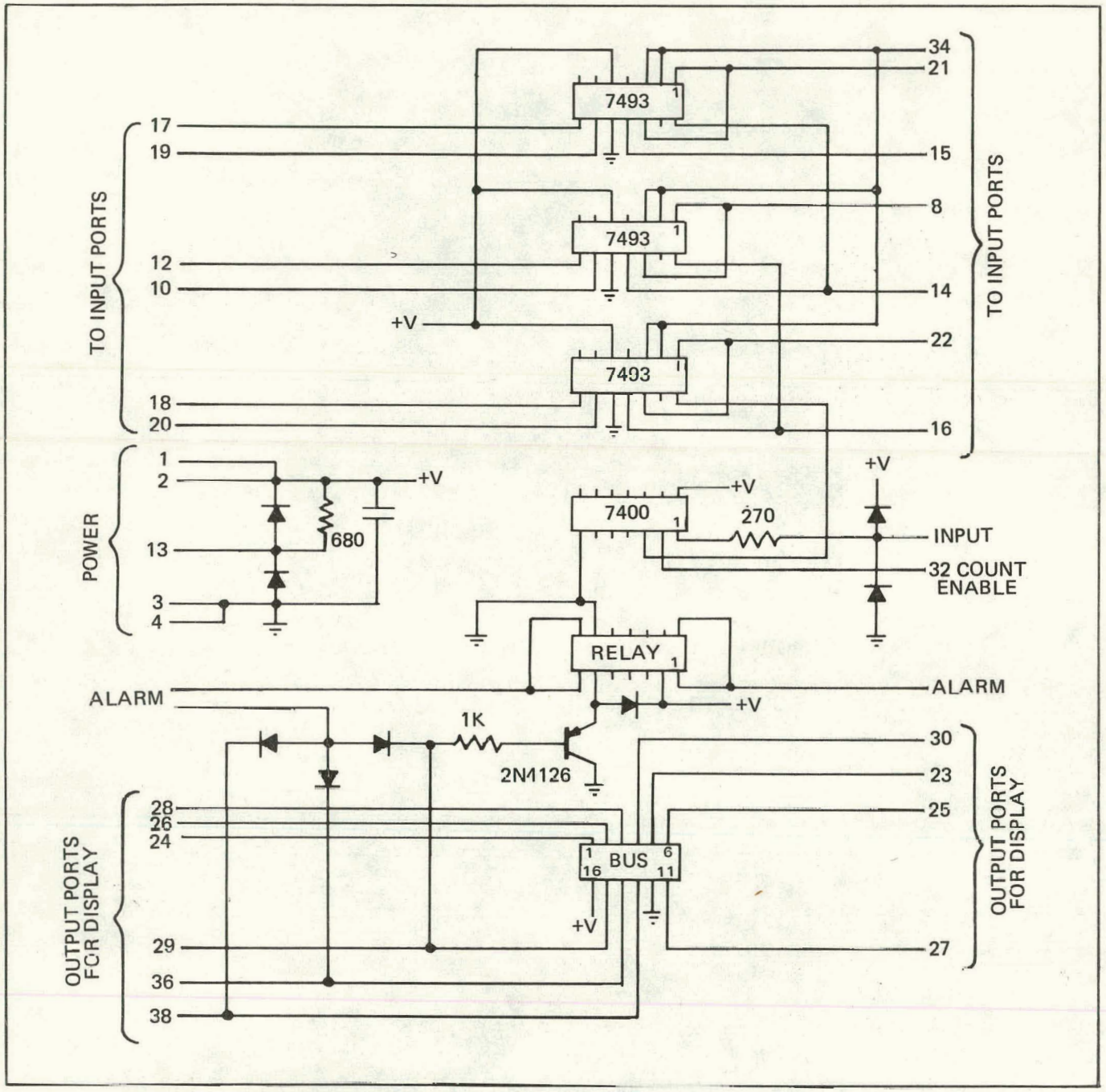


FIGURE 4. Counter Board Schematic of Portal Signal Analyzer

Counter

The counter card contains a 12 bit binary counter, the necessary input and output gating, and is under microprocessor control. A card schematic is shown in Figure 4. The counter card consists of three quad binary counters in tandem. The input to the counter is through a 2-input NAND Schmitt trigger performing the input and hold function. Output from the counter is fed parallel to the microprocessor. One output line from the microporcessor controls the counter reset.

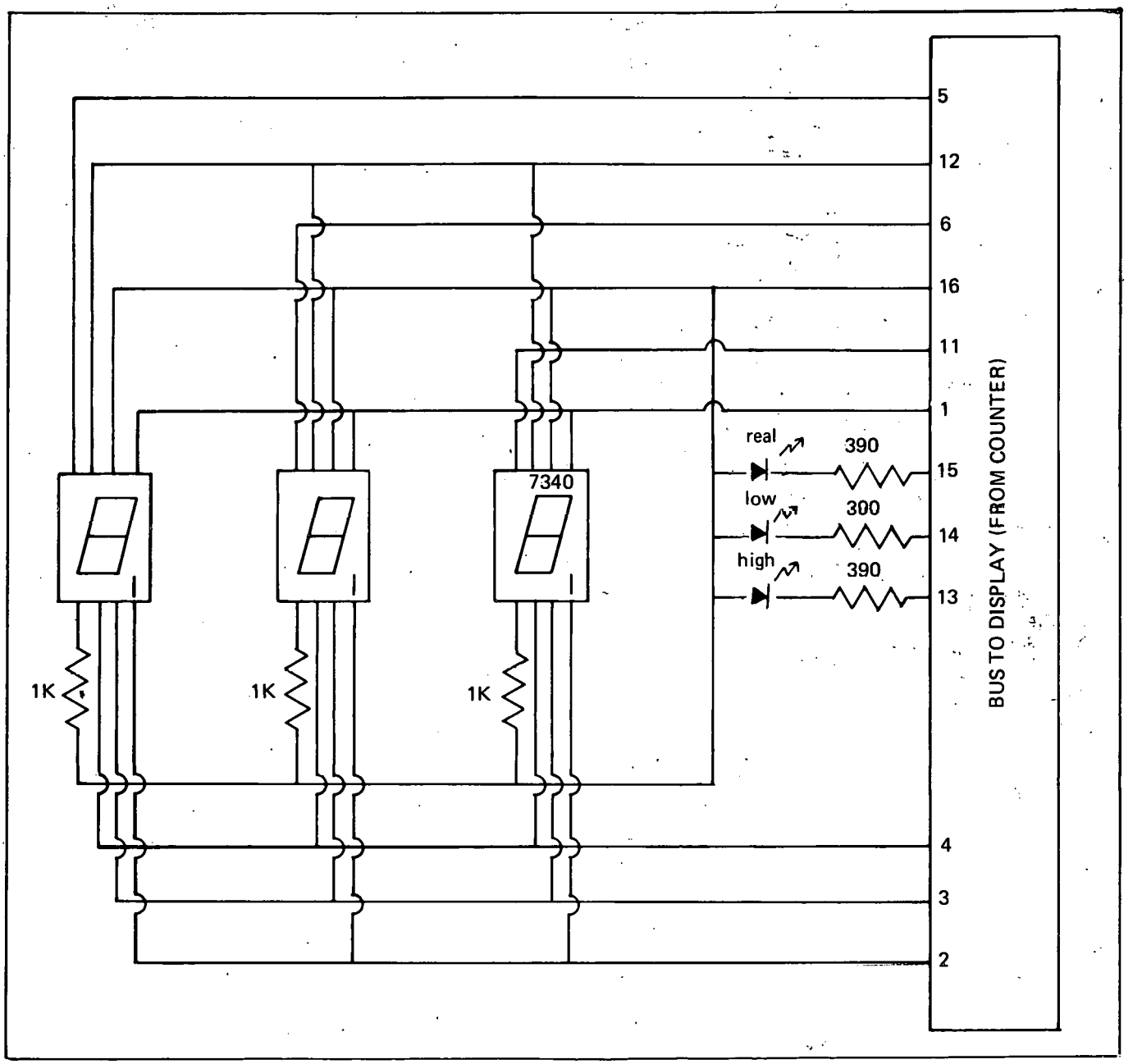


FIGURE 5. Display Board of Portal Signal Analyzer

The counter card also contains miscellaneous components necessary for pulse shaping, current limiting, and the alarm relay for interface to the Plant supervised alarm system.

Display and Electronic Support

The display and support provide operator interface such as decimal numeric count displays and alarm status indicators. This section also covers the power supplies and cabinet. See Figure 5 for display details. For simplicity, the count rate display consists of three individual BCD input numeric indicators. Each digit has its own decoder driver and latches with an enable input. The three digits share a common four-bit data line from the microprocessor output with each digit having its own strobe line.

Alarm indications are given by three light-emitting diodes and an audible device. The green light indicates an abnormally low count being received by the counters. This condition would normally be indicative of external equipment failure. The yellow light indicates that the probability of detection of a source in the active area of the radiometric monitor has fallen to below 50%. This condition would be indicative of abnormally high background radiation. One such cause of this condition could be a shipment of radioactive material.

The red light and audible signal indicate true alarm conditions, i.e., radioactive material within the active zone of the portal monitor. For this condition, a normally closed relay contact has been provided. To fully utilize existing equipment, the analyzer is fabricated in a standard 2 wide NIM bin module. The +12 and the ±5 volt power required for this instrument is derived from the standard NIM bin. The NIM bin provides ±12 and ±6 volts as a standard; therefore, dropping resistors and Zener diodes are used to convert the ±6 volt supplies to the necessary ±5 volts.

Software

The heart of any microprocessor system is in the program. In this instrument, the main program resides in a 1 k byte PROM. A 1 k byte RAM is used as scratch pad memory and temporary data storage location. PROM memory is located at hexadecimal locations 0000 through 03FF with RAM at 1000 through 13FF. For a complete PROM listing, see Appendix A, "Complete PROM listing of Operating System."

Various test and diagnostic programs have been written. These programs reside on PROM and are utilized by inserting them in place of the normal operating PROM. One such routine for false-alarm testing automatically cycles between the background accumulation mode and the active mode. This routine keeps track of the false alarm rate and displays this rate in decimal upon demand. For a complete PROM loading including this test routine, see Appendix B, "Complete PROM Listing of Operating System Plus Test Routine."

To minimize operator tampering and cost, the unit has no operator selectable controls other than the alarm acknowledge push button. The sensitivity and the upper and lower operating limits of the unit resides in PROM. To change the operating parameters of this instrument, the operating PROM must be replaced in a socket in the microprocessor. The new PROM would contain new numerical constants to alter operating characteristics of the instrument. This becomes the outstanding feature of this instrument as its versatility of operation is limited only by the imagination of the person programming the analyzer. With no hardware or wiring changes, this unit can become an entirely different instrument through reprogramming.

CONCLUSIONS

The portal signal analyzer version of the 2 wide NIM bin logic processor has been installed in several portal monitoring systems. Increased sensitivity and reliability have been obtained. There have been no failures in 36 unit-months exposure to field conditions. At present, it appears that all future portal monitoring systems will use this or a similar version of the portal signal analyzer.

Based on successful operation of this unit, several other 2 wide NIM bin logic processors have been prototyped for use. One is a multiple channel portal analyzer for individual zone indentification; another is a coincidence unit for an effluent monitor.

APPENDIX A

Complete PROM Listing of Operating System

```
ASSM 0000

0000 F3                    0000   DI
0001 21 30 10              0010   LXI H,1030H
0004 7C                    0020   MOV A,H
0005 32 00 10              0030   STA 1000H
0008 7D                    0040   MOV A,L
0009 32 01 10              0050   STA 1001H
000C 32 02 10              0060   STA 1002H
000F 21 38 10              0070   LXI H,1038H
0012 7C                    0080   MOV A,H
0013 32 03 10              0090   STA 1003H
0016 7D                    0100   MOV A,L
0017 32 04 10              0110   STA 1004H
001A 32 05 10              0120   STA 1005H
001D 2A 44 10              0130 ST1 LHLD 1044H
0020 7C                    0140   MOV A,H
0021 2F                    0150   CMA
0022 47                    0160   MOV B,A
0023 7D                    0170   MOV A,L
0024 2F                    0180   CMA
0025 4F                    0190   MOV C,A
0026 2A FC 03              0200   LHLD 03FCH
0029 AF                    0210   XRA A
002A 09                    0220   DAD B
002B DA BD 01              0230   JC ALARMLOW
002E 3E 01                 0240   MVI A,01
0030 D3 01                 0250   OUT 01
0032 C3 C8 01              0260   JMP UPPERLIMIT
0035 3E 01                 0270 ST2 MVI A,01
0037 D3 01                 0280   OUT 01
0039 3E 02                 0290   MVI A,02
003B D3 01                 0300   OUT 01
003D 2A 10 10              0310 ST3 LHLD 1010H
0040 EB                    0320   XCHG
0041 2A 12 10              0330   LHLD 1012H
0044 19                    0340   DAD D
0045 EB                    0350   XCHG
0046 2A 14 10              0360   LHLD 1014H
0049 19                    0370   DAD D
004A EB                    0380   XCHG
004B 2A 16 10              0390   LHLD 1016H
004E 19                    0400   DAD D
004F EB                    0410   XCHG
0050 2A 18 10              0420   LHLD 1018H
0053 19                    0430   DAD D
0054 EB                    0440   XCHG
0055 2A 1A 10              0450   LHLD 101AH
0058 19                    0460   DAD D
0059 EB                    0470   XCHG
005A 2A 1C 10              0480   LHLD 101CH
```

```
005D 19          0490  DAD D
005E EB          0500  XCHG
005F 2A 1E 10    0510  LHLD 101EH
0062 19          0520  DAD D
0063 EB          0530  XCHG
0064 2A 20 10    0540  LHLD 1020H
0067 19          0550  DAD D
0068 EB          0560  XCHG
0069 2A 22 10    0570  LHLD 1022H
006C 19          0580  DAD D
006D EB          0590  XCHG
006E 2A 24 10    0600  LHLD 1024H
0071 19          0610  DAD D
0072 EB          0620  XCHG
0073 2A 26 10    0630  LHLD 1026H
0076 19          0640  DAD D
0077 EB          0650  XCHG
0078 2A 28 10    0660  LHLD 1028H
007B 19          0670  DAD D
007C EB          0680  XCHG
007D 2A 2A 10    0690  LHLD 102AH
0080 19          0700  DAD D
0081 EB          0710  XCHG
0082 2A 2C 10    0720  LHLD 102CH
0085 19          0730  DAD D
0086 EB          0740  XCHG
0087 2A 2E 10    0750  LHLD 102EH
008A 19          0760  DAD D
008B 22 40 10    0770  SHLD 1040H
008E 37          0780  STC
008F 3F          0790  CMC
0090 3A 40 10    0800  LDA 1040H
0093 0F          0810  RRC
0094 0F          0820  RRC
0095 0F          0830  RRC
0096 0F          0840  RRC
0097 E6 0F       0850  ANI 0FH
0099 32 43 10    0860  STA 1043H
009C 37          0870  STC
009D 3F          0880  CMC
009E 3A 41 10    0890  LDA 1041H
00A1 0F          0900  RRC
00A2 0F          0910  RRC
00A3 0F          0920  RRC
00A4 0F          0930  RRC
00A5 E6 0F       0940  ANI 0FH
00A7 32 45 10    0950  STA 1045H
00AA 3A 41 10    0960  LDA 1041H
00AD 07          0970  RLC
00AE 07          0980  RLC
00AF 07          0990  RLC
00B0 07          1000  RLC
```

```
00B1 E6 F0          1010  ANI 0F0H
00B3 47             1020  MOV B,A
00B4 3A 43 10       1030  LDA 1043H
00B7 B0             1040  ORA B
00B8 32 44 10       1050  STA 1044H
00BB 31 00 13       1060  LXI SP,1300H
00BE 2A 44 10       1070  LHLD 1044H
00C1 4D             1080  MOV C,L
00C2 44             1090  MOV B,H
00C3 CD 00 00       1100  CALL BINARYBCD
00C6 78             1110  MOV A,B
00C7 32 50 10       1120  STA 1050H
00CA 79             1130  MOV A,C
00CB 32 51 10       1140  STA 1051H
00CE 3A 50 10       1150  LDA 1050H
00D1 E6 0F          1160  ANI 0FH
00D3 32 53 10       1170  STA 1053H
00D6 3A 51 10       1180  LDA 1051H
00D9 0F             1190  RRC
00DA 0F             1200  RRC
00DB 0F             1210  RRC
00DC 0F             1220  RRC
00DD E6 0F          1230  ANI 0FH
00DF 32 54 10       1240  STA 1054H
00E2 3A 51 10       1250  LDA 1051H
00E5 E6 0F          1260  ANI 0FH
00E7 32 55 10       1270  STA 1055H
00EA 2F             1280  CMA
00EB E6 1F          1290  ANI 1FH
00ED D3 00          1300  OUT 00
00EF E6 0F          1310  ANI 0FH
00F1 D3 00          1320  OUT 00
00F3 3A 54 10       1330  LDA 1054H
00F6 2F             1340  CMA
00F7 E6 2F          1350  ANI 2FH
00F9 D3 00          1360  OUT 00
00FB E6 0F          1370  ANI 0FH
00FD D3 00          1380  OUT 00
00FF 3A 53 10       1390  LDA 1053H
0102 2F             1400  CMA
0103 E6 4F          1410  ANI 4FH
0105 D3 00          1420  OUT 00
0107 E6 0F          1430  ANI 0FH
0109 D3 00          1440  OUT 00
010B 2A 44 10       1450  LHLD 1044H
010E 4D             1460  MOV C,L
010F 44             1470  MOV B,H
0110 CD 00 00       1480  CALL SQRT
0113 AF             1490  XRA A
0114 67             1500  MOV H,A
```

```
0
 115 22 60 10          1510  SHLD 1060H
0118 EB                1520  XCHG
0119 2A 60 10          1530  LHLD 1060H
011C 3A FF 03          1540  LDA 03FFH
011F 3D                1550  DCR A
0120 CA 27 01          1560  JZ $+4
0123 19                1570  DAD D
0124 C3 22 01          1580  JMP $-5
0127 7C                1590  MOV A,H
0128 0F                1600  RRC
0129 0F                1610  RRC
012A E6 C0             1620  ANI 0C0H
012C 47                1630  MOV B,A
012D 7D                1640  MOV A,L
012E 0F                1650  RRC
012F 0F                1660  RRC
0130 E6 3F             1670  ANI 3FH
0132 B0                1680  ORA B
0133 32 62 10          1690  STA 1062H
0136 3A 44 10          1700  LDA 1044H
0139 0F                1710  RRC
013A 0F                1720  RRC
013B E6 3F             1730  ANI 3FH
013D 47                1740  MOV B,A
013E 3A 45 10          1750  LDA 1045H
0141 07                1760  RLC
0142 07                1770  RLC
0143 07                1780  RLC
0144 07                1790  RLC
0145 07                1800  RLC
0146 07                1810  RLC
0147 E6 C0             1820  ANI 0C0H
0149 B0                1830  ORA B
014A 32 47 10          1840  STA 1047H
014D 3A 45 10          1850  LDA 1045H
0150 0F                1860  RRC
0151 0F                1870  RRC
0152 E6 3F             1880  ANI 3FH
0154 32 48 10          1890  STA 1048H
0157 2A 47 10          1900  LHLD 1047H
015A 22 30 10          1910  SHLD 1030H
015D 2A 47 10          1920  LHLD 1047H
0160 22 32 10          1930  SHLD 1032H
0163 2A 47 10          1940  LHLD 1047H
0166 22 34 10          1950  SHLD 1034H
0169 2A 47 10          1960  LHLD 1047H
016C 22 36 10          1970  SHLD 1036H
016F 1E FF             1980 WAIT MVI E,0FFH
0171 16 B0             1990  MVI D,0B0H
0173 15                2000  DCR D
```

```
0174 00
0175 00
0176 00
0177 00
0178 00
0179 00
017A C2 73 01
017D AF
017E DB 01
0180 E6 80
0182 C2 00 00
0185 1D
0186 C2 71 01
0189 3E 03
018B D3 01
018D 3A 00 10
0190 47
0191 3A 01 10
0194 3D
0195 32 01 10
0198 1E 10
019A BB
019B DA B4 01
019E 4F
019F DB 01
01A1 2F
01A2 E6 0F
01A4 02
01A5 3A 01 10
01A8 3D
01A9 32 01 10
01AC 4F
01AD DB 00
01AF 2F
01B0 02
01B1 C3 1D 00
01B4 3A 02 10
01B7 32 01 10
01BA C3 90 01
01BD 3E 05
01BF D3 01
01C1 3E 06
01C3 D3 01
01C5 C3 3D 00
01C8 2A FA 03
01CB 7C
01CC 2F
01CD 47
01CE 7D

2010  NOP
2030  NOP
2040  NOP
2050  NOP
2060  NOP
2070  NOP
2080  JNZ WAIT+4
2090  XRA A
2100  IN 01
2110  ANI 80H
2120  JNZ SWMAT
2130  DCR E
2140  JNZ WAIT+2
2150  MVI A,03H
2160  OUT 01
2170  LDA 1000H
2180 GO MOV B,A
2190  LDA 1001H
2200  DCR A
2210  STA 1001H
2220  MVI E,10H
2230  CMP E
2240  JC INI
2250  MOV C,A
2260  IN 01
2270  CMA
2280  ANI 0FH
2290  STAX B
2300  LDA 1001H
2310  DCR A
2320  STA 1001H
2330  MOV C,A
2340  IN 00H
2350  CMA
2360  STAX B
2370  JMP ST1
2380 INI LDA 1002H
2390  STA 1001H
2400  JMP GO
2410 ALARMLOW MVI A,05
2420  OUT 01
2430  MVI A,06
2440  OUT 01
2450  JMP ST3
2460 UPPER LHLD 03FAH
2470  MOV A,H
2480  CMA
2490  MOV B,A
2500  MOV A,L
```

```
01CF 2F
01D0 4F
01D1 03
01D2 2A 44 10
01D5 AF
01D6 09
01D7 DA E1 01
01DA 3E 01
01DC D3 01
01DE C3 35 00
01E1 3E 09
01E3 D3 01
01E5 3E 0A
01E7 D3 01
01E9 C3 3D 00
01EC
```

```
2510   CMA
2520   MOV C,A
2530   INX B
2540   LHLD 1044H
2550   XRA A
2560   DAD B
2570   JC HIGH
2580   MVI A,01
2590   OUT 01
2600   JMP ST2
2610 HIGH MVI A,09H
2620   OUT 01
2630   MVI A,0AH
2640   OUT 01
2650   JMP ST3
2660 SP EQU 6
```

```
0200 16 64
0202 CD 20 02
0205 61
0206 48
0207 CD 12 02
020A 6F
020B 4C
020C CD 12 02
020F 47
0210 4D
0211 C9
0212 06 00
0214 16 0A
0216 CD 20 02
0219 79
021A 07
021B 07
021C 07
021D 07
021E B0
021F C9
0220 1E 09
0222 78
0223 47
0224 79
0225 17
0226 4F
0227 1D
0228 CA 3D 02
022B 78
022C 17
022D D2 35 02
0230 92
0231 B7
0232 C3 23 02
0235 92
0236 D2 23 02
0239 82
023A C3 23 02
023D 79
023E 2F
023F 4F
0240 C9
```

```
0000 BINARYBCD MVI D,64H
0010  CALL UDIV
0020  MOV H,C
0030  MOV C,B
0040  CALL BCD1
0050  MOV L,A
0060  MOV C,H
0070  CALL BCD1
0080  MOV B,A
0090  MOV C,L
0100  RET
0110 BCD1 MVI B,00
0120  MVI D,0AH
0130  CALL UDIV
0140  MOV A,C
0150  RLC
0160  RLC
0170  RLC
0180  RLC
0190  ORA B
0200  RET
0210 UDIV MVI E,09H
0220  MOV A,B
0230 UDV1 MOV B,A
0240  MOV A,C
0250  RAL
0260  MOV C,A
0270  DCR E
0280  JZ UDV2
0290  MOV A,B
0300  RAL
0310  JNC UDV0
0320  SUB D
0330  ORA A
0340  JMP UDV1
0350 UDV0 SUB D
0360  JNC UDV1
0370  ADD D
0380  JMP UDV1
0390 UDV2 MOV A,C
0400  CMA
0410  MOV C,A
0420  RET
```

```
0241 AF
0242 6F
0243 16 01
0245 1E 09
0247 CD 61 02
024A CD 61 02
024D 1D
024E C8
024F 92
0250 D2 54 02
0253 82
0254 F5
0255 7D
0256 3F
0257 17
0258 6F
0259 07
025A 07
025B 57
025C 14
025D F1
025E C3 47 02
0261 67
0262 79
0263 17
0264 4F
0265 78
0266 17
0267 47
0268 7C
0269 17
026A C9
026B
```

```
0430 SQRT XRA A
0440  MOV L,A
0450  MVI D,01
0460  MVI E,09H
0470 SQR1 CALL SHIFT
0480  CALL SHIFT
0490  DCR E
0500  RZ
0510  SUB D
0520  JNC SQR3
0530  ADD D
0540 SQR3 PUSH PSW
0550  MOV A,L
0560  CMC
0570  RAL
0580  MOV L,A
0590  RLC
0600  RLC
0610  MOV D,A
0620  INR D
0630  POP PSW
0640  JMP SQR1
0650 SHIFT MOV H,A
0660  MOV A,C
0661  RAL
0670  MOV C,A
0680  MOV A,B
0690  RAL
0700  MOV B,A
0701  MOV A,H
0710  RAL
0720  RET
0730 PSW EQU 6
```

```
ASSM 0300

0300 3E 01          0000 SWMAT MVI A,01
0302 D3 01          0010  OUT 01
0304 3E 02          0020  MVI A,02
0306 D3 01          0030  OUT 01
0308 2A 30 10       0040  LHLD 1030H
030B EB             0050  XCHG
030C 2A 32 10       0060  LHLD 1032H
030F 19             0070  DAD D
0310 EB             0080  XCHG
0311 2A 34 10       0090  LHLD 1034H
0314 19             0100  DAD D
0315 EB             0110  XCHG
0316 2A 36 10       0120  LHLD 1036H
0319 19             0130  DAD D
031A 22 39 10       0140  SHLD 1039H
031D 31 00 13       0150  LXI SP,1300H
0320 2A 39 10       0160  LHLD 1039H
0323 4D             0170  MOV C,L
0324 44             0180  MOV B,H
0325 CD 00 00       0190  CALL BINARYBCD
0328 78             0200  MOV A,B
0329 32 3C 10       0210  STA 103CH
032C 79             0220  MOV A,C
032D 32 3D 10       0230  STA 103DH
0330 3A 3C 10       0240  LDA 103CH
0333 E6 0F          0250  ANI 0FH
0335 32 5C 10       0260  STA 105CH
0338 3A 3D 10       0270  LDA 103DH
033B E6 0F          0280  ANI 0FH
033D 32 5E 10       0290  STA 105EH
0340 3A 3D 10       0300  LDA 103DH
0343 0F             0310  RRC
0344 0F             0320  RRC
0345 0F             0330  RRC
0346 0F             0340  RRC
0347 E6 0F          0350  ANI 0FH
0349 32 5D 10       0360  STA 105DH
034C 2F             0370  CMA
034D E6 2F          0380  ANI 2FH
034F D3 00          0390  OUT 00
0351 E6 0F          0400  ANI 0FH
0353 D3 00          0410  OUT 00
0355 3A 5E 10       0420  LDA 105EH
0358 2F             0430  CMA
0359 E6 1F          0440  ANI 1FH
035B D3 00          0450  OUT 00
035D E6 0F          0460  ANI 0FH
035F D3 00          0470  OUT 00
0361 3A 5C 10       0480  LDA 105CH
0364 2F             0490  CMA
0365 E6 4F          0500  ANI 4FH
```

```
0367 D3 00
0369 E6 0F
036B D3 00
036D 3A 62 10
0370 4F
0371 AF
0372 47
0373 2A 44 10
0376 09
0377 7C
0378 2F
0379 47
037A 7D
037B 2F
037C 4F
037D 03
037E 2A 39 10
0381 37
0382 3F
0383 09
0384 DA D2 03
0387 22 68 10
038A 1E F0
038C 16 80
038E 15
038F CA 8E 03
0392 1D
0393 CA 8C 03
0396 3E 03
0398 D3 01
039A 3A 03 10
039D 47
039E 3A 04 10
03A1 3D
03A2 32 04 10
03A5 1E 30
03A7 BB
03A8 DA, C9 03
03AB 4F
03AC DB 01
03AE 2F
03AF E6 0F
03B1 02
03B2 3A 04 10
03B5 3D
03B6 32 04 10
03B9 4F
03BA DB 00
03BC 2F
03BD 02
```

```
0510  OUT 00
0520  ANI 0FH
0530  OUT 00
0540  LDA 1062H
0550  MOV C,A
0560  XRA A
0570  MOV B,A
0580  LHLD 1044H
0590  DAD B
0600  MOV A,H
0610  CMA
0620  MOV B,A
0630  MOV A,L
0640  CMA
0650  MOV C,A
0660  INX B
0670  LHLD 1039H
0680  STC
0690  CMC
0700  DAD B
0710  JC REAL
0720  SHLD 1068H
0730 DELAY MVI E,0F0H
0740  MVI D,80H
0750  DCR D
0760  JZ DELAY+4
0770  DCR E
0780  JZ DELAY+2
0790  MVI A,03H
0800  OUT 01
0810  LDA 1003H
0820  MOV B,A
0830 RET LDA 1004H
0840  DCR A
0850  STA 1004H
0860  MVI E,30H
0870  CMP E
0880  JC RESTORE
0890  MOV C,A
0900  IN 01
0910  CMA
0920  ANI 0FH
0930  STAX B
0940  LDA 1004H
0950  DCR A
0960  STA 1004H
0970  MOV C,A
0980  IN 00
0990  CMA
1000  STAX B
```

```
03BE AF                 1010  XRA A
03BF DB 01              1020  IN 01
03C1 E6 80              1030  ANI 80H
03C3 C2 00 03           1040  JNZ SWMAT
03C6 C3 00 00           1050  JMP ST1
03C9 3A 05 10           1060 RESTORE LDA 1005H
03CC 32 04 10           1070  STA 1004H
03CF C3 9E 03           1080  JMP RET
03D2 3E 80              1090 REAL MVI A,80H
03D4 D3 00              1100  OUT 00
03D6 C3 D2 03           1110  JMP REAL
03D9                    1120 SP EQU 6
```

APPENDIX B

Complete PROM Listing of Operating System Test Routine

```
03D6 C3 00 04          1110  JMP TEST*

0400 3E 09             0000  MVI A,09H
0402 32 80 1C          0010  STA 1C80H
0405 32 81 1C          0020  STA 1C81H
0408 3E 04             0030  MVI A,04H
040A 32 82 1C          0040  STA 1C82H
040D 32 83 1C          0050  STA 1C83H
0410 AF                0060  XRA A
0411 32 01 1F          0070  STA 1F01H
0414 32 02 1F          0080  STA 1F02H
0417 32 03 1F          0090  STA 1F03H
041A 32 04 1F          0100  STA 1F04H
041D 31 00 1F          0110  LXI SP,1F00H
0420 21 81 1C          0120 GO LXI H,1C81H
0423 35                0130  DCR M
0424 C2 00 00          0140  JNZ ST1
0427 3A 80 1C          0150  LDA 1C80H
042A 32 81 1C          0160  STA 1C81H
042D 21 83 1C          0170  LXI H,1C83H
0430 35                0180  DCR M
0431 C2 00 00          0190  JNZ SWMAT
0434 3A 82 1C          0200  LDA 1C82H
0437 32 83 1C          0210  STA 1C83H
043A C3 20 04          0220  JMP GO
043D 3E 8F             0230  MVI A,8FH
043F D3 00             0240  OUT 00
0441 3E FF             0250  MVI A,0FFH
0443 D3 00             0260  OUT 00
0445 1E FF             0270  MVI E,0FFH
0447 16 FF             0280 RELOAD MVI D,0FFH
0449 15                0290 WAIT DCR D
044A C2 49 04          0300  JNZ WAIT
044D 1D                0310  DCR E
044E C2 47 04          0320  JNZ RELOAD
0451 F1                0330  POP PSW
0452 F1                0340  POP PSW
0453 3C                0350  INR A
0454 27                0360  DAA
0455 F5                0370  PUSH PSW
0456 F5                0380  PUSH PSW
0457 3A 03 1F          0390  LDA 1F03H
045A E6 0F             0400  ANI 0FH
045C F6 E0             0410  ORI 0E0H
045E D3 00             0420  OUT 00
0460 F6 F0             0430  ORI 0F0H
0462 D3 00             0440  OUT 00
0464 3A 1F 03          0450  LDA 031FH
0467 0F                0460  RRC
```

* TO UTILIZE TEST, THIS CHANGE MUST BE MADE TO THE MAIN PROGRAM

```
0468 0F                  0470  RRC
0469 0F                  0480  RRC
046A 0F                  0490  RRC
046B E6 0F               0500  ANI 0FH
046D F6 D0               0510  ORI 0D0H
046F D3 00               0520  OUT 00
0471 F6 F0               0530  ORI 0F0H
0473 D3 00               0540  OUT 00
0475 1E FF               0550  MVI E,0FFH
0477 16 FF               0560 DONE MVI D,0FFH
0479 15                  0570 DELAY DCR D
047A C2 79 04            0580  JNZ DELAY
047D 1D                  0590  DCR E
047E C2 77 04            0600  JNZ DONE
0481 C3 20 04            0610  JMP GO
0484                     0620 SP EQU 6
0484                     0630 PSW EQU 6
```