(1)

DEVELOPMENT OF AN ELECTROPHORETIC IMAGE DISPLAY

QUARTERLY TECHNICAL REPORT

November 1, 1981 to January 31, 1982

Sponsored by

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

DARPA Order No. 3802

Contract No. MDA903-79-C-0439

Principal Investigator: Richard Stolzenberger (914) 762-0300

Monitored by: Dr. Robert E. Kahn

Contract Period: 20 Sept. 1979 - 30 Sept. 1981

Prepared by

PHILIPS LABORATORIES
A Division of North American Philips Corporation
Briarcliff Manor, New York 10510

March 1982

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF AN ELECTROPHORETIC IMAGE DISPLAY		5. TYPE OF REPORT & PERIOD COVERED Quarterly Technical Report Nov. 1, 1981 to Jan. 31, 1982
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. Stolzenberger, J. Lalak, K. Wittig		8. CONTRACT OR GRANT NUMBER(s) MDA903-79-C-0439
9. PERFORMING ORGANIZATION NAME AND ADDRESS PHILIPS LABORATORIES, A Division of North American Philips Corp., Briarcliff Manor, New York 10510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARPA Order No. 3802
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, Virginia 22209		12. REPORT DATE March 1982
		13. NUMBER OF PAGES 21
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

electrophoretic image display
control-grid electrode
ion-beam milling
photofabrication
(EPID).
indium oxide
matrix-addressed display
display drive circuits

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this work is to develop an X-Y addressed electrophoretic image display. The problem of indium oxide redeposit onto the walls of the potential wells during ion-beam milling has been solved. A thin layer of SiO_x is evaporated over the row-patterned substrate prior to the application of the mylar dielectric. This layer shields the indium oxide during the ion-beam milling process and is subsequently removed by plasma etching. A sample cell for evaluation by ISI was delivered in January. It is anticipated

over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Cont'd.)

that the yield of mylar EPID cells will be much higher than that in the past due to the SiO_x treatment. A number of cells were fabricated using the photopolymer technology; the cells performed satisfactorily. Bubbles in the suspension, however, have been a problem with these cells. Several causes are being investigated; the evolution of nitrogen gas and poor sealing may be the major contributing causes. Solutions to these problems are being investigated. Work on fixturing and testing procedures for the Phase II cells has begun.

PREFACE

This work is being performed by Philips Laboratories, a Division of North American Philips Corporation, Briarcliff Manor, New York under the overall supervision of Dr. Barry Singer, Director, Component and Device Research Group. Mr. Richard Stolzenberger, Physicist, is the Program Leader; Mr. Joseph Lalak, Electronic Engineer, is responsible for cell fabrication and technology. Mr. Karl Wittig, Electrical Engineer, is responsible for circuit design; Dr. Howard Sorkin, Organic Chemist, is responsible for electrophoretic suspensions.

This program is sponsored by the Defense Advanced Research Projects Agency (DARPA) and was initiated under Contract No. MDA903-79-C-0439. Dr. Robert E. Kahn is the Contracting Officer's Technical Representative for DARPA.

The work described in this tenth Quarterly Technical Report covers the period from 1 November 1981 to 31 January 1982.

SUMMARY

The purpose of this work is to develop an X-Y addressed electrophoretic image display. The problem of indium oxide redeposit onto the walls of the potential wells during ion-beam milling has been solved. A thin layer of SiO_x is evaporated over the row-patterned substrate prior to the application of the mylar dielectric. This layer shields the indium oxide during the ion-beam milling process and is subsequently removed by plasma etching. A sample cell for evaluation by ISI was delivered in January. It is anticipated that the yield of mylar EPID cells will be much higher than that in the past due to the SiO_x treatment. A number of cells were fabricated using the photopolymer technology; the cells performed satisfactorily. Bubbles in the suspension, however, have been a problem with these cells. Several causes are being investigated; the evolution of nitrogen gas and poor sealing may be the major contributing causes. Solutions to these problems are being investigated. Work on fixturing and testing procedures for the Phase II cells has begun.

TABLE OF CONTENTS

1. INTRODUCTION

A number of Phase I displays were fabricated and tested during this quarter. Cells were produced by ion-beam milling and by photopolymer technology. Both methods yielded satisfactory devices, but there were some technological problems associated with each.

The shorting due to indium oxide redeposit has been alleviated by evaporating a thin layer of SiO_x over the row-patterned substrate. Ion-beam-milled cells of good quality and high resistance can now be fabricated. Some pigment sticking remains as a problem in the ion-beam-milled cells. Pigment seems to accumulate in the wells with time.

The photopolymer technique has produced some fine displays with good contrast and virtually no pigment sticking. Bubbles in the photoresist and in the suspension fluid have been discovered, however, and steps are underway to resolve the problem. The repeatability of the photopolymer process for the 12 μm dielectric layer is less than desirable, and work is proceeding on controlling some process variables.

A driver was designed and built to take data from a Commodore "PET" computer and display it one line at a time on a Phase I display.

2. PHASE I

2.1 Fabrication Technology

During the previous quarter, the low resistances between rows and columns were found to be due to the redeposit of In_2O_3 onto the walls of the wells during ion-beam milling. High-angle milling, and etching in dilute aqua regia or dilute buffered hydrofluoric acid proved difficult to control and were only marginally successful. While improvements have been made in the uniformity of the ion beam by optimizing operating parameters, the center of the substrate still receives more milling than the edges.

The most significant process change this quarter has been the introduction of a protective SiO_x layer which is deposited over the patterned row electrodes prior to bonding of the 12 μm Mylar dielectric. This layer shields the In_2O_3 from the ion beam, and thus essentially prevents central milling of the In_2O_3 and subsequent redeposit upon the walls of the wells while the periphery of the substrate reaches completion of milling. The SiO_x layer, however, is a dielectric and must be removed before assembly since it can hold an electrical charge which could interfere with proper device operation.

Linear plasma etching has been chosen over liquid etching for removing any residual SiO_x. From previous experience, we had found that the etchant, dilute buffered hydroflouric acid, attacks the bond between the Mylar and the evaporated column electrode.

A Technics Planar Etch II has been used to etch the SiO_x. Since the exact oxygen content is unknown, a gas mixture was chosen to match, approximately, the etch rates of silicon and SiO_2. This mixture consists of one part N_2, one part CF_4 and one part DE101*. The substrates are etched for 10 minutes at about 125 W of power using 30 cc total volume of gas per minute at a pressure of 200 mTorr.

With this etching process, we can now fabricate high resistance cells of good quality at a reasonable yield. About a half-dozen substrates were produced with this technique,and we expect to fullfill the Phase I requirements shortly with cells made from these substrates.

(*) DE101 is a mixture of 96.5% He, 3% CF_4 and 0.5% O_2.

2.2 Electronics

The drive electronics for the Phase I display was successfully completed and tested, and was used to generate text on a number of EPID devices. During this quarter, the hardware and software were debugged, system integration was completed, and the working driver was demonstrated.

Hardware. With the exception of correcting a few minor design errors, no design changes were made on the driver circuitry; it remains as originally described. Construction bugs were eliminated in the power supply and controller circuits, and the hardware is working properly.

Software. The software design also remained in its original form; there were only a few programming errors which needed to be corrected. The 8048 assembly language code was developed, debugged, and assembled on an Intel MDS development system using an ISIS-II operating system, a CREDIT text editor, and an ASM48 assembler. A program listing is shown in the Appendix.

System Integration. The assembled 8048 software was used with an ICE48 in-circuit-emulator to perform system integration. When the last remaining bugs were eliminated, a UPM PROM programmer was used to burn the debugged software into the resident program memory of the 8048 processor.

Operation. The completed driver was tested with various EPID devices, and performed all functions as expected. Individual lines of text, as well as full pages, were displayed under control of the host computer (a Commodore PET). Software routines were written for the PET to demonstrate the display. The driver responds to commands from the PET for writing a line of text, reversing the tone of an arbitrary sequence of characters and erasing/resetting the display. The ASCII codes for these three functions correspond to those which perform the analogous functions on the PET (LF, DC3 and DC1), respectively.

The IEEE-488 interface permits any computer to be used as a host provided the computer generates the same ASCII character sequences and is compatible with this interface. A photograph of a 64-character ASCII set displayed on an EPID device using this driver is shown in Figure 1.

Figure 1

<u>Problems</u>. Although successfully demonstrated, the display system has two remaining problems. One is the need to adjust the electrode voltages for each individual device; this will eventually be remedied by higher tolerances on the device fabrication. The other is that, during the initial half-select condition, some of the pigment leaves the half-selected element, adversely affecting the brightness. The reasons for this are being investigated. A temporary solution is to half-select every row or column momentarily after resetting the display; this will eliminate the effect during writing.

3. PHASE II

3.1 Fabrication Technology

Work has continued on developing a photofabrication process for forming a thick photopolymer layer which will serve as the dielectric support for the control grid.

Sample photopolymer coatings supplied by Integrated Technologies, Inc. were evaluated and found to be 12 $\mu m \pm 1\ \mu m$ thick and very uniform. In addition, the samples had very little edge rim. An order was placed for a "cavex" coater large enough to coat Phase II substrates. Delivery is scheduled for the end of March 1982.

Process development continued on the Shipley 1300 series photoresist. While some difficulty was experienced in controlling the process variables, many good substrates were produced. A serious photoresist bubbling problem, however, has continued to affect the 1300 series devices. The problem is believed to be caused by nitrogen which evolves during the photochemical reaction. If we define "venting factor" as the ratio of atmospherically exposed photoresist surface area to photoresist volume, then it seems that where the morphology of the structure presents a high venting factor, such as in the fine gridwork of the potential wells, no problem exists since the liberated nitrogen is free to emerge into the atmosphere. In the finger contact area, however, where the venting factor is low, the nitrogen collects under the In_2O_3 electrode and pushes it up to form a bubble which sometimes ruptures, forming a flap or loose piece of electrode. This, of course, is undesirable since flaps or loose pieces can cause shorts in the device.

Several approaches to this bubbling problem were investigated. Among them were: various prebake and postbake procedures, localized postbake of the finger area before photofabrication, and separate application and postbake treatment for the finger and gridwork areas. None of these solutions were without problems such as thermal destruction of photosensitivity in adjacent areas and the creation of bumps and discontinuities in the coating. Finally, a new photoresist with less photoactive component was tried. Initial tests show an order of magnitude improvement in bubbling. The new resist is now being characterized to determine the correct processing parameters.

An active program has begun to either find or synthesize photopolymers which will improve device characteristics or facilitate fabrication. Materials such as photopatternable polyimides are being investigated.

Bubbles or voids in the suspension have been troublesome in the photofabricated cells, and while leaks and incompletely filled cells may be contributing factors, it is felt that nitrogen evolution may be at fault here also. Presumably, steps such as irradiating the cells with UV light before filling to evolve any residual nitrogen and changing to the new photoresist should alleviate this situation.

3.2 Results

Aside from the bubbling problem, the photoresist cells fabricated thus far have good contrast, relatively few defects, and virtually no sticking problems.

4. PLANS FOR NEXT QUARTER

a. Obtain masks and fixtures for Phase II devices.

b. Continue development of Phase II photofabrication techniques on Phase I size cells.

c. Complete Phase I.

d. Design driver for Phase II.

e. Improve suspension speed and contrast.

APPENDIX A

Assembly Language Code for EPID Controller

ASM48 :F1:DRIVER.ASM

ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V4.0 PAGE 1

```
  LOC  OBJ         LINE        SOURCE STATEMENT

  0000 05             1 RESET:  EN I
  0001 0405           2         JMP INIT
  0003 24A8           3         JMP PWROFF
  0005 23E0           4 INIT:   MOV A,#11100000B    ;INITIALIZE INTEL 8291 IEEE-488 INTERFACE
  0007 39             5         OUTL P1,A
  0008 23C5           6         MOV A,#11000101B
  000A 3A             7         OUTL P2,A
  000B 2302           8         MOV A,#00000010B
  000D 02             9         OUTL BUS,A
  000E 2321          10         MOV A,#00100001B
  0010 02            11         OUTL BUS,A
  0011 23C1          12         MOV A,#11000001B
  0013 3A            13         OUTL P2,A
  0014 2301          14         MOV A,#00000001B
  0016 02            15         OUTL BUS,A
  0017 23C2          16         MOV A,#11000010B
  0019 3A            17         OUTL P2,A
  001A 2300          18         MOV A,#00000000B
  001C 02            19         OUTL BUS,A
  001D 23C4          20         MOV A,#11000100B
  001F 3A            21         OUTL P2,A
  0020 2301          22         MOV A,#00000001B
  0022 02            23         OUTL BUS,A
  0023 23C5          24         MOV A,#11000101B
  0025 3A            25         OUTL P2,A
  0026 2381          26         MOV A,#10000001B
  0028 02            27         OUTL BUS,A
  0029 23A8          28         MOV A,#10101000B
  002B 02            29         OUTL BUS,A
  002C 23C6          30         MOV A,#11000110B
  002E 3A            31         OUTL P2,A
  002F 2345          32         MOV A,#01000101B
  0031 02            33         OUTL BUS,A
  0032 23EF          34         MOV A,#11101111B
  0034 02            35         OUTL BUS,A
  0035 23C7          36         MOV A,#11000111B
  0037 3A            37         OUTL P2,A
  0038 230A          38         MOV A,#00001010B
  003A 02            39         OUTL BUS,A
  003B 23C5          40         MOV A,#11000101B
  003D 3A            41         OUTL P2,A
  003E 2300          42         MOV A,#00000000B
  0040 02            43         OUTL BUS,A
  0041 23C8          44         MOV A,#11001000B
  0043 3A            45         OUTL P2,A
  0044 2300          46         MOV A,#00000000B
  0046 A8            47         MOV R0,A
  0047 90            48         MOVX @R0,A
  0048 264E          49 NREV:   JNT0 TREV           ;CHECK TONE REVERSAL SWITCH
  004A BA00          50         MOV R2,#00000000B
  004C 0450          51         JMP SETROW
  004E BA80          52 TREV:   MOV R2,#10000000B
  0050 85            53 SETROW: CLR F0              ;SET ALL ROW REGISTER BITS HIGH
  0051 B800          54         MOV R0,#00000000B
```

```
 LOC  OBJ         LINE        SOURCE STATEMENT

0053 8910          55 RCLOCK:  ORL P1,#00010000B
0055 18            56          INC R0
0056 F8            57           MOV A,R0
0057 036C          58          ADD A,#01101100B
0059 99EF          59          ANL P1,#11101111B
005B 00            60          NOP
005C 00            61          NOP
005D 9653          62          JNZ RCLOCK
005F 997F          63          ANL P1,#01111111B
0061 8910          64          ORL P1,#00010000B
0063 00            65          NOP
0064 00            66          NOP
0065 99EF          67          ANL P1,#11101111B
0067 8980          68          ORL P1,#10000000B
0069 8910          69          ORL P1,#00010000B
006B 00            70          NOP
006C 00            71          NOP
006D 99EF          72          ANL P1,#11101111B
006F 00            73          NOP
0070 00            74          NOP
00071 8910          75          ORL P1,#00010000B
0073 00            76          NOP
0074 00            77          NOP
0075 99EF          78          ANL P1,#11101111B
0077 23C6          79          MOV A,#11000110B    ;ERASE DISPLAY
0079 39            80          OUTL P1,A
007A B801          81          MOV R0,#00000001B
007C 2300          82 ERASE1:  MOV A,#00000000B
007E 62            83          MOV T,A
007F 55            84          STRT T
0080 1684          85 TIME1:   JTF COUNT1
0082 0480          86          JMP TIME1
0084 65            87 COUNT1:  STOP TCNT
0085 C8            88          DEC R0
0086 F8            89          MOV A,R0
0087 967C          90          JNZ ERASE1
0089 23E0          91          MOV A,#11100000B
008B 39            92          OUTL P1,A
008C 8A10          93          ORL P2,#00010000B   ;SET DISPLAY
008E B802          94          MOV R0,#00000010B
0090 2300          95 ARRSET:  MOV A,#00000000B
0092 62            96          MOV T,A
0093 55            97          STRT T
0094 1698          98 TIME2:   JTF COUNT2
0096 0494          99          JMP TIME2
0098 65           100 COUNT2:  STOP TCNT
0099 C8           101          DEC R0
009A F8           102          MOV A,R0
009B 9690         103          JNZ ARRSET
009D 9AEF         104          ANL P2,#11101111B
009F BE00         105 SEQNCE:  MOV R6,#00000000B   ;BEGIN WRITE SEQUENCE
00A1 B920         106 CHLINE:  MOV R1,#00100000B
00A3 23E0         107          MOV A,#11100000B
00A5 39           108          OUTL P1,A
00A6 23C8         109 TEST1:   MOV A,#11001000B    ;READY TO RECEIVE ASCII CHARACTER
```

```
LOC  OBJ          LINE        SOURCE STATEMENT

00A8 3A            110              OUTL P2,A
00A9 2300          111              MOV A,#00000000B
00AB A8            112              MOV R0,A
00AC 90            113              MOVX @R0,A
00AD 9AF7          114              ANL P2,#11110111B
00AF B6B5          115              JF0 READ1
00B1 46B5          116 TEST:        JNT1 READ1
00B3 04B1          117              JMP TEST
00B5 85            118 READ1:       CLR F0               ;RECEIVE ASCII CHARACTER
00B6 08            119              INS A,BUS
00B7 537F          120              ANL A,#01111111B
00B9 AB            121              MOV R3,A
00BA D2E2          122              JB6 ALPHA
00BC B2E2          123              JB5 ALPHA
00BE 03EE          124 KREV:        ADD A,#11101110B     ;TEST FOR TONE REVERSE CHARACTER
00C0 96CE          125              JNZ KERASE
00C2 FA            126              MOV A,R2
00C3 D380          127              XRL A,#10000000B
00C5 AA            128              MOV R2,A
00C6 23C5          129              MOV A,#11000101B
00C8 3A            130              OUTL P2,A
00C9 2303          131              MOV A,#00000011B
00CB 02            132              OUTL BUS,A
00CC 04A6          133              JMP TEST1
00CE FB            134 KERASE:      MOV A,R3             ;TEST FOR ERASE CHARACTER
00CF 03ED          135              ADD A,#11101101B
00D1 96D5          136              JNZ KNEWLN
00D3 2480          137              JMP END2
00D5 FB            138 KNEWLN:      MOV A,R3             ;TEST FOR ENDLINE CHARACTER
00D6 03F6          139              ADD A,#11110110B
00D8 C6F5          140              JZ FULL
00DA 23C5          141              MOV A,#11000101B
00DC 3A            142              OUTL P2,A
00DD 2303          143              MOV A,#00000011B
00DF 02            144              OUTL BUS,A
00E0 04A6          145              JMP TEST1
00E2 F9            146 ALPHA:       MOV AA,R1             ;TEST FOR ALPHANUMERIC CHARACTER
00E3 03C0          147              ADD A,#11000000B
00E5 96E9          148              JNZ STORE
00E7 240A          149              JMP DATSTP
00E9 FB            150 STORE:       MOV A,R3             ;STORE ALPHANUMERIC CHARACTER IN RAM
00EA 4A            151              ORL A,R2
00EB A1            152              MOV @R1,A
00EC 19            153              INC R1
00ED 23C5          154              MOV A,#11000101B
00EF 3A            155              OUTL P2,A
00F0 2303          156              MOV A,#00000011B
00F2 02            157              OUTL BUS,A
00F3 04A6          158              JMP TEST1
00F5 23C5          159 FULL:        MOV A,#11000101B     ;FILL REMAINDER OF LINE WITH BLANKS
00F7 3A            160              OUTL P2,A
00F8 2303          161              MOV A,#00000011B
00FA 02            162              OUTL BUS,A
00FB 23C8          163              MOV A,#11001000B
00FD 3A            164              OUTL P2,A
```

```
LOC  OBJ          SOURCE STATEMENT

00FE F9           WRITE1: MOV A,R1
00FF 03C0                 ADD A,#11000000B
0101 C60B                 JZ WRITE2
0103 2320                 MOV A,#00100000B
0105 4A                   ORL A,R2
0106 A1                   MOV @R1,A
0107 19                   INC R1
0108 04FE                 JMP WRITE1
010A 95           DATSTP: CPL F0
010B BD00         WRITE2: MOV R5,#00000000B   ;LINE DISPLAY SEQUENCE
010D B920         WRITE3: MOV R1,#00100000B
010F F1           WRITE4: MOV A,@R1
0110 F216                 JB7 REV
0112 99F7                 ANL P1,#11110111B
0114 2418                 JMP LOAD
0116 8908         REV:    ORL P1,#00001000B
0118 FD           LOAD:   MOV A,R5            ;LOAD CHARACTER IN COLUMN DRIVER
0119 43C8                 ORL A,#11001000B
011B 3A                   OUTL P2,A
011C F1                   MOV A,@R11
011D 02                   OUTL BUS,A
011E 00                   NOP
011F 00                   NOP
0120 00                   NOP
0121 00                   NOP
0122 BC07                 MOV R4,#00000111B
0124 8901         CCLK:   ORL P1,#00000001B   ;SHIFT COLUMN DRIVER
0126 CC                   DEC R4
0127 FC                   MOV A,R4
0128 00                   NOP
0129 00                   NOP
012A 99FE                 ANL P1,#11111110B
012C 00                   NOP
012D 00                   NOP
012E 9624                 JNZ CCLK
0130 19                   INC R1              ;INCREMENT CHARACTER
0131 F9                   MOV A,R1
0132 03C0                 ADD A,#11000000B
0134 C638                 JZ WRITE
0136 240F                 JMP WRITE4
0138 2300         WRITE:  MOV A,#00000000B    ;WRITE ROW
013A 62                   MMOV T,A
013B 99BF                 ANL P1,#10111111B
013D 8902                 ORL P1,#00000010B
013F 55                   STRT T
0140 1644         TIME3:  JTF COUNT3
0142 2440                 JMP TIME3
0144 65           COUNT3: STOP TCNT
0145 99FD                 ANL P1,#11111101B
0147 8940                 ORL P1,#01000000B
0149 8910                 ORL P1,#00010000B
014B 00                   NOP
014C 00                   NOP
014D 00                   NOP
014E 00                   NOP
```

```
LOC  OBJ        LINE    SOURCE STATEMENT

014F 99EF                       ANL P1,#11101111B
0151 1D                         INC R5                  ;INCREMENT ROW COUNTER
0152 FDD                         MOV A,R5
0153 03F7                       ADD A,#11110111B
0155 C659                       JZ  NXTLN
0157 240D                       JMP WRITE3
0159 1E                 NXTLN:  INC R6                  ;INCREMENT LINE COUNTER
015A FE                         MOV A,R6
015B 03F0                       ADD A,#11110000B
015D C661                       JZZ ENDO
015F 04A1                       JMP CHLINE              ;RETURN TO WRITE SEQUENCE
0161 B665               ENDO:   JFO END1                ;END SEQUENCE
0163 246C                       JMP ENDF
0165 85                 END1:   CLR FO
0166 2385                       MOV A,#10000101B
0168 3A                         OUTL P2,A
0169 2303                       MOV A,#00000011B
016B 02                         OUTL BUS,A
016C 2388               ENDF:   MOV A,#10001000B
016E 3A                         OUTL P2,A
016F 2300                       MOV A,#00000000B
0171 A8                         MOV RO,A
0172 90                         MOVX @RO,A
0173 9AF7                       ANL P2,#11110111B
0175 4679               TEST2:  JNT1 READ2              ;TEST FOR ERASE CHARACTER
0177 2475                       JMP TEST2
0179 08                 READ2:  INS A,BUS
017A 537F                       ANL A,#01111111B
017C 03ED                       ADD A,#11101101B
017E 9665                       JNZ END1
0180 23C5               END2:   MOV A,#11000101B
0182 3A                         OUTL P2,A
0183 2303                       MOV A,#00000011B
0185 02                         OUTL BUS,A
0186 23CB                       MOV A,#11001000B
0188 3A                         OUTL P2,A
0189 2300                       MOV A,#00000000B
018B A8                          MOV RO,A
018C 90                         MOVX @RO,A
018D 9AF7                       ANL P2,#11110111B
018F 4693               TEST3:  JNT1 READ3              ;TEST FOR ENDLINE CHARACTER
0191 248F                       JMP TEST3
0193 08                 READ3:  INS A,BUS
0194 537F                       ANL A,#01111111B
0196 03F6                       ADD A,#11110110B
0198 9680                       JNZ END2
019A 23C5                       MOV A,#11000101B
019C 3A                         OUTL P2,A
019D 2303                       MOV A,#00000011B
019F 02                         OUTL BUS,A
01A0 23CB                       MOV A,#11001000B
01A2 3A                         OUTL P2,A
01A3 23E0                       MOV A,#11100000B
01A5 39                         OUTL P1,A
01A6 0448                       JMP NREV                ;RETURN
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V4.0             PAGE    6

 LOC  OBJ          LINE        SOURCE STATEMENT

 01A8 23C8          275 PWROFF: MOV A,#11001000B    ;POWER-DOWN SEQUENCE (INTERRUPT-INITIATED)
 01AA 3A            276         OUTL P2,A
 01AB 23C6          277         MOV A,#11000110B    ;ERASE DISPLAY
 01AD 39            278         OUTL P1,A
 01AE B801          279         MOV R0,#00000001B
 01B0 2300          280 ERASE2: MOV A,#00000000B
 01B2 62            281         MOV T,A
 01B3 55            282         STRT T
 01B4 16B8          283 TIME4:  JTF COUNT4
 01B6 24B4          284         JMP TIME4
 01B8 65            285 COUNT4: STOP TCNT
 01B9 C8            286         DEC R0
 01BA F8            287         MOV A,R0
 01BB 96B0          288         JNZ ERASE2
 01BD 9A7F          289         ANL P2,#01111111B   ;REMOVE POWER
 01BF 24BF          290 GSTOP:  JMP GSTOP
                    291         END

USER SYMBOLS
ALPHA  00E2   ARRSET 0090   CCLK   0124   CHLINE 00A1   COUNT1 0084   COUNT2 0098   COUNT3 0144   COUNT4 01B8

DATSTP 010A   ENDO   0161   END1   0165   END2   0180   ENDF   016C   ERASE1 007C   ERASE2 01B0   FULL   00F5
INIT   0005   KERASE 00CE   KNEWLN 00D5   KREV   00BE   LOAD   011B   NREV   004B   NXTLN  0159   PWROFF 01A8
GSTOP  01BF   RCLOCK 0053   READ1  00B5   READ2  0179   READ3  0193   RESET  0000   REV    0116   SEGNCE 009F
SETROW 0050   STORE  00E9   TEST   00B1   TEST1  00A6   TEST2  0175   TEST3  01BF   TIME1  0080   TIME2  0094
TIME3  0140   TIME4  01B4   TREV   004E   WRITE  0138   WRITE1 00FE   WRITE2 010B   WRITE3 010D   WRITE4 010F

ASSEMBLY COMPLETE,    NO ERRORS
```

DISTRIBUTION LIST

	Copies
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	(12)
Director Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, Virginia 22209 Attn: Program Mgmt.	(2)
Dr. Ben Kazan Xerox Palo Alto Research Center 3333 Coyote Hill Road Palo Alto, California 94304	(1)
Dr. Stephen E. Saunders Information Sciences Institute University of Southern California 4676 Admiralty Way Marina del Rey, California 90291	(1)
James H. Becker Technical Director Exxon Enterprises, Inc. 328 Gibralter Drive Sunnyvale, California 94086	(1)
M. Robert Miller Electronics Research & Development Command Electronics Technology & Device Laboratory DELET-BD Fort Mommouth, New Jersey 07703	(1)