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A PDP-15 TO INDUSTRIAL-14 INTERFACE AT
THE LEWIS RESEARCH CENTER'S CYCLOTRON

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16. Abstract

An interface (hardware and software) has been built which permits the loading, monitoring, and control of a Digital Equipment Industrial-14/30 programmable controller by a PDP-15 computer. The interface utilizes the serial mode for data transfer to and from the controller, so that the required hardware is essentially that of a teletype unit except for the speed of transmission. Software described here permits the user to load binary paper tape, read or load individual controller memory locations, and if dersired turn controller outputs on and off directly from the computer.

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INTRODUCTION

The Industrial-14 is a programmable controller manufactured by the digital Equipment Corporation (DEC). This controller is being used in operations at the Lewis Research Center Cyclotron. It is designed to set "on" or "off" a series of outputs, as determined by the state (on or off) of a series of inputs and the program stored in its memory (4096 12-bit words). The controller is capable of utilizing a portion of its memory as counters, timers, or up-down counters. It may operate either in a stand-alone mode or under the direct supervision of another computer.

As supplied by DEC the Industrial 14/30 is designed to be loaded either through the VT-14 video programming te minal or through a DEC PDP-8 computer equipped with the proper interface (ref. 1). One such interface transfers information serially in 8-bit words. Since this is essentially the mode of operation of a teletype unit, however, it is possible to avoid purchasing either the VT-14 or the PDP-8 simply by making minor modifications to the PDP-15 computer already in use at the cyclotron facility. The present report describes those changes in both hardware and software which were required to establish communications between the Industrial-14 and the PDP-15.

HARDWARE MODIFICATIONS

At the Industrial-14 end of the interface hardware consisted of the standard DC-14F serial interface, as supplied by DEC. This is wired to the controller through the serial interface, again as ordinarily done when interfacing the Industrial-14 to either a PDP-8 or VT-14. At the PDP-15 end the link was accomplished through the BA-15 module, which normally accomodates either a second teletype unit or a line printer for the PCP-15. The modifications necessary here were to replace the normal teletype clock which operates at 110 baud rate with an M453 module variable clock which was adjusted to transmit and receive at the 9600 baud rate required by the Industrial-14.

SOFTWARE : GENERAL

In the serial mode information is transferred to the Industrial-14 from the PDP-15 by breaking each 12-bit word into two characters, as described in the Industrial-14 Software Manual (ref. 2) and shown in Figure 1. The first character transmitted contains the six most significant bits of the data word; the second the six least significant bits. The seventh bit of each character is identically 1 in the present operation, while the eighth and final bit of each character is a parity bit.

After transmission of each command, which may consist of as many as three 12-bit words (or six 8-bit characters), the Industrial-14 returns a 2-character, 12-bit word verifying the receipt and execution of the initial command and returning any data requested. The format for the returned data is again described in the Industrial-14 Software Manual and shown in Figure 2. The seventh bit of the first returned character is the external flag, which is set if the instruction has been executed. The seventh bit of the second returned character is the output flag, and is set if, as a result of the last command, information was loaded into the output register of the Industrial-14. The remainder of the two 8-bit characters consists of the contents of that output register, whether or not it has been newly loaded.

SOFTWARE : SPECIFIC

Probrams have been written for the PDP-15, which, treating the Industrial-14 as a peripheral device, will allow the user to clear the Industrial-14 memory, load a program from paper tape to the Industrial-14 memory, access the Industrial-14 memory from the PDP-15 teletype for either loading or examination, and issue to the industrial-14 any of the commands to which it would respond if operating under the supervision of a PDP-8 as intended by DEC. The program is loaded using the usual PDP-15 loader, except that the API must be disabled prior to loading. The main program is .HANDL; the required subroutines are RDPT, LD14, ZERO, RUN, and TALK. Listings of each of these programs are given in the appendix.

The main control program, .HANDL, is controlled via the PDP-15 console switches as to which task is to be performed. After loading the program halts until the appropriate data switch settings are made and the CONTINUE switch is pressed. Data switch settings (OCTAL) are as follows:

000001	Clear Industrial-14
000010	Load Industrial-14 from paper tape
000100	Place Industrial-14 in INTERNAL RUN mode
001000	Call subroutine TALK to control Industrial-14 from PDP-15 teletype.

A request to clear the Industrial-14 simply results in the writing of zeroes into all 4096 12-bit memory locations of the Industrial-14. It is carried out by the subroutine ZERO.

Loading of the Industrial-14 memory from paper tape is carried out by the subroutines RDPT and LD14.

Information on Industrial-14 binary paper tape consists of a series of 8-bit characters, the least significant six bits of which form either the first or second half of an Industrial-14 word. Setting the seventh bit of any character identifies that character as part of an address, while the eighth bit is used to identify dividers and spacers and to set off "comments" which have no meaning for loading purposes. The program to be loaded will be represented by a series of data blocks, with each block consisting of an address followed by a series of instructions. On loading, the first instruction of each data block is loaded into the address specified at the beginning of the block. Subsequent instructions are loaded into sequential locations until another address is encountered or the program is terminated.

After loading, execution within the Industrial-14 may be initiated by using the switch command 000100. This sets the Industrial-14 program counter to zero, enables the output multiplexer, and returns the controller to an internal mode of operation in which stored commands are executed sequentially. At this time the PDP-15 may be returned to its monitor and the Industrial-14 will operate in a stand-alone mode, responding to changes in the state of an input as required.

Frequently, however, particularly during debug operations, it is convenient to control the operation of the Industrial-14 directly. This is carried out through the subroutine TALK. Following selection of this option via the console switches (001000) the teletype will print " ". At this time the user may enter via the teletype, in octal form, any valid Industrial-14 command. Commands consisting of more than one 12-bit word, for example, RDWD 1000 must be entered as one line, with the two words separated by a space (0021 1000). Each line (command) should be terminated by a carriage return. Following the carriage return, the Industrial-14 will execute the command and return any data requested. The returned data will be supplied to the user via the teletype. This mode is particularly useful for debugging operations and for program modifications, as it allows the user to examine or change the contents of any location, as well as control outputs directly. A list of Industrial-14 commands may be found in the DEC Industrial-14 software manual (ref. 2). The user may leave the subroutine TALK by entering an "X" and a carriage return.

Exit from the main program requires that the PDP-15 be stopped and the monitor routine be restarted by the console controls since the API feature of the machine was disabled on loading.

APPENDIX - SOURCE LISTINGS OF THE PROGRAMS

.HANDL, RDPT, LD14, ZERO, RUN, TALK,

```
        .TITLE .HANDL
        /ROUTINE TO HANDLE LOADING FROM  PAPER
        /TAPE, CLEARING,AND RUNNING OF IND-14
        / FROM PDP-15.
IOF=700002
        .GLOBL RDPT,RUN,ZERO,TALK
        IOF
START   HLT
        LAS
        AND (1   /IF SW=1,
        SZA      /CALL ZERO TO CLEAR 14 MEMORY
        JMS* ZERO
        LAS
        AND (10 /IF SW=10,
        SZA      /READ TAPE AND TRANSFER TO
        JMS* RDPT          /INDUSTRIAL-14 OR TT.
        LAS
        AND (100 /IF SW=100, CALL SUBROUTILE
        SZA      /RUN TO START INDUSTRIAL-14
        JMS* RUN
        LAS
        AND (1000
        SZA
        JMS* TALK
        JMP START
        .END
```

```
            .TITLE RDPT
            /DECTAPE FILE NAME PT-14
            /         ROUTINE TO READ PAPER TAPE

RSA=700104
IORS=700314
RRB=700112
RSF=700101
ION=700042
CAF=703302
IOF=700002
            .GLOBL RDPT,BFFR,WC,LD14
            .GLOBL COUNT,LOCAT
RDPT        0
            DBA
RSTRT       CAF
            LAC (775
            PAL
            CLX
START       RSA
            RSF
            JMP .-1
            IORS
            AND (1000
            SZA
            JMP FINI
            RRB         /GET WORD FROM TAPE
            DAC TEMP#
            TCA
            TAD (377  /IS IT A DIVIDER
            SZA
            JMP .+3
            JMS SKIP          /IF DIVIDER SKIP
            JMP START
            LAC TEMP
            AND (200          /IS IT A 200
            SZA
            JMP DUN1          /IF WORD CONTAINS AN 8-PUNCH
                    /GO TO PRINT FOR ALL WORDS IN BUFFER
            LAC TEMP
            AND (100          /DOES WORD HAVE A 7-PUNCH
                    /IF SO IT IS AN ADDRESS
            SZA
            JMP ADRES
            LAC TEMP
            RTL
            RTL
            RTL
            AND (7700
            DAC BFFR,X
REDO        RSA
            RSF
            JMP .-1
            RRB
            DAC TEMP
            TCA
            TAD (377
```

```
            SZA
            JMP  .+3
            JMS  SKIP
            JMP  REDO
            LAC  TEMP
            AND  (77
            TAD  BFFR,X
            DAC  BFFR,X
            AXS  +1
            JMP  START
            JMS* LD14
            JMP  FINI
DUN1        PXA
            DAC  WC#
            SZA
            JMS* LD14
            JMP  RSTRT+1
ADRES       LAC  TEMP
            LLS  +6
            AND  (7700
            DAC  LOCAT1#
            RSA
            RSF
            JMP  .-1
            RRB
            AND  (77
            TAD  LOCAT1
            DAC  LOCAT1
            PXA
            DAC  WC
            SZA
            JMS* LD14
            LAC  LOCAT1
            DAC  LOCAT#
            ISZ  COUNT#
            JMP  RSTRT
FINI        CAF
            JMP* RDPT
SKIP        0
CHK         RSA
            RSF
            JMP  .-1
            IORS
            AND  (1000
            SZA
            JMP  FINI
            RRB
            TCA
            TAD  (377
            SZA
            JMP  CHK
            JMP* SKIP
BFFR        .BLOCK 1000
            .END
```

```
            .TITLE LDI4        /ROUTINE TO LOAD INDUSTRIAL-14
                       /AFETR READING PAPER TAPE
TSF1=704001        /SKIP ON 14 FLAG
TLF1=704002        /CLEAR 14-FLAG
TLS1=704006        /LOAD BUFFER,TRANSMIT,RAISE FLAG
                   /ON COMPLETION
KSF1=704101        /SKIP ON RCVR FLAG
KRB1=704102        /READ RCVR, CLEAR FLAG
CAF=703302         /CLEAR ALL FLAGS
IOF=700002         /INTRRUPT OFF
           /INDUSTRIAL-14 COMMANDS:
LDMEM=000022       /LOAD MEMORY
EEM=000060         /ENTER EXTERNAL MODE
LEM=000040         /LEAVE EXTERNAL MODE
CLRPC=000004       /CLEAR PROGRAM COUNTER
CLR=000170         /CLEAR ALL OUTPUTS
JP14=0024          /JMP
        .GLOBL LDI4,BFFR,WC
        .GLOBL COUNT,LOCAT
LDI4    0
        IOF
        CLX
        LAC* WC
        PAL
        LAC* COUNT
        SZA
        JMS LDAD
        LAC* LOCAT
        DAC RELADR#
BEGIN   LAC (JP14
        JMS .LODE1
        LAC RELADR
        JMS .LODE1
        JMS WAIT
        ISZ RELADR
        LAC (LDMEM
        JMS .LODE1
        LAC* BFFR,X
        JMS .LODE1
        JMS WAIT
        AXS +1
        JMP BEGIN
        JMP* LDI4
LDAD    0
        LAC (EEM
        JMS .LODE1
        JMS WAIT
        LAC (JP14
        JMS .LODE1
        LAC* LOCAT
        JMS .LODE1
        JMS WAIT
        DZM* COUNT
        JMP* LDAD
.LODE1  0
        DAC TEMP#
        RTR
```

```
                RTR
                RTR
                AND (77
                TAD (100
                JMS PRTY
                TLS1
                TSF1
                JMP .-1
                TLF1
                LAC TEMP
                AND (77
                TAD (100
                JMS PRTY
                TLS1
                TSF1
                JMP .-1
                TLF1
                JMP* .LODE1
WAIT            0
                KSF1
                JMP .-1
                KRB1
                KSF1
                JMP .-1
                KRB1
                JMP* WAIT
PRTY            0
                DAC P1#
                LAC (-7
                DAC BITC#
                LAC (1
                DAC MASK#
                DZM P2
GO              LAC P1
                AND MASK
                SZA
                ISZ P2#
                ISZ BITC
                JMP CONT
                JMP SETBIT
CONT            LAC MASK
                CLL
                RAL
                DAC MASK
                JMP GO
SETBIT          LAC P2
                AND (1
                SNA
                JMP ADDP
                LAC P1
                JMP* PRTY
ADDP            LAC P1
                TAD (200
                JMP* PRTY
                .END
```

```
                .TITLE ZERO
                /SUBROUTINE TO CLEAR INDUSTRIAL-14
                /MEMORY AND OUTPUTS
TLS1=704006         /LOAD BUFFER AND TRANSMIT
TSF1=704001         /SKIP ON TRANSMITTER FLAG
TLF1=704002         /CLEAR TRANSMITTER FLAG
IOF=700002
KSF1=704101         /SKIP ON RECEIVER FLAG
KRB1=704102         /READ BUFFER AND CLEAR FLAG
                /INDUSTRIAL-14 COMMANDS
EEM=000060          /ENTER EXTERNAL MODE
LEM=000040          /LEAVE EXTERNAL MODE
LDMEM=000022        /LOAD MEMORY WITH FOLLOWING WORD
CLR=000170          /CLEAR ALL OUTPUTS
CLRPC=000004        /CLEAR PC
RDWD=000031
RDMEM=000021
RDPC=000041
                .GLOBL ZERO
ZERO    0
        IOF
EEML    LAC (EEM
        JMS SENDI
        JMS CHECK
CLEAR   LAC (CLR
        JMS SENDI
        JMS CHECK
        LAC (CLRPC
        JMS SENDI
        JMS CHECK
        LAC (-7777
        DAC ROUND#
        DZM LOC14#
DEP0    LAC (LDMEM
        JMS SENDI
        LAC (0
        JMS SENDI
        JMS CHECK
        ISZ LOC14
        LAC (000024
        JMS SENDI
        LAC LOC14
        JMS SENDI
        JMS CHECK
        ISZ ROUND
        JMP DEP0
        JMP* ZERO
SENDI   0
        DAC TEMP#
        RTR
        RTR
        RTR
        AND (77
        TAD (100
        JMS PRTY
        TLS1
        TSF1
```

```
              JMP .-1
              TLF1
              LAC TEMP
              AND (77
              TAD (100
              JMS PRTY
              TLS1
              TSF1
              JMP .-1
              TLF1
              JMP* SEND1
CHECK         0
WAIT1         KSF1
              JMP .-1
              KRB1
              KSF1
              JMP .-1
              KRB1
              JMP* CHECK
PRTY          0
              DAC P1#
              LAC (-7
              DAC BITC#
              LAC (1
              DAC MASK#
              DZM P2
GO            LAC P1
              AND MASK
              SZA
              ISZ P2#
              ISZ BITC
              JMP CONT
              JMP SETBIT
CONT          LAC MASK
              CLL
              RAL
              DAC MASK
              JMP GO
SETBIT        LAC P2
              AND (1
              SNA
              JMP ADDP
              LAC P1
              JMP* PRTY
ADDP          LAC P1
              TAD (200
              JMP* PRTY
              .END
```

```
                .TITLE RUN
                /PROGRAM TO RUN INDUSTRIAL 14
TSF1=704001
TLF1=704002
TLS1=704006
KSF1=704101
KRB1=704102
CAF=703302
IOF=700002
                /INDUSTRIAL-14 COMMANDS
LEM=000040              /LEAVE EXTERNAL MODE
CLRPC=000004            /CLEAR PC
EOM=000150              /ENABLE OUTPUT MULTIPLEXER
                .GLOBL RUN
RUN      0
         IOF
         LAC (CLRPC
         JMS .LODE
         JMS WAIT
         LAC (EOM
         JMS .LODE
         JMS WAIT
         LAC (LEM
         JMS .LODE
         JMS WAIT
         JMP* RUN
.LODE    0
         DAC TEMP#
         LRS +6
         AND (77
         TAD (100
         JMS PRTY
         TLS1
         TSF1
         JMP .-1
         TLF1
         LAC TEMP
         AND (77
         TAD (100
         JMS PRTY
         TLS1
         TSF1
         JMP .-1
         TLF1
         JMP* .LODE
WAIT     0
         KSF1
         JMP .-1
         KRB1
         KSF1
         JMP .-1
         KRB1
         JMP* WAIT
PRTY     0
         DAC P1#
         LAC (-7
         DAC BITC#
```

```
            LAC (1
            DAC   MASK#
            DZM P2
GO          LAC P1
            AND MASK
            SZA
            ISZ P2#
            ISZ BITC
            JMP CONT
            JMP SETBIT
CONT        LAC MASK
            CLL
            RAL
            DAC MASK
            JMP GO
SETBIT      LAC P2
            AND (1
            SNA
            JMP ADDP
            LAC P1
            JMP* PRTY
ADDP        LAC P1
            TAD (200
            JMP* PRTY
            .END
```

```
          .TITLE TALK
TCF=700402   /CLEAR TELEPRINTER FLAG
IOF=700002
TLS=700406   /LOAD AND PRINT TELEPRINTER
TSF=700401   /SKIP ON TELEPRINTER FLAG
KSF=700301   /SKIP ON KEYBOARD FLAG
KRB=700312   /READ KEYBOARD BUFFER
KSF1=704101  /SKIP ON INDUSTRIAL-14 REPLY FLAG
KRB1=704102  /READ INDUSTRIAL-14 OUTPUT REGISTER
TLS1=704006  /LOAD INDUSTRIAL-14 INPUT BUFFER
TSF1=704001  /SKIP ON INDUSTRIAL-14 FLAG
TLF1=704002  /CLEAR INDUSTRIAL-14 FLAG
          .GLOBL TALK
TALK    0
BEGIN   IOF
        JMP START
DATA    215
        212
        276
        215
        212
START   LAC (5
        PAL
        CLX
CONT    LAC DATA,X
        JMS WRITE
        AXS +1
        JMP CONT
        CLX
RDCMD   KSF
        JMP .-1
        KRB
        SAD (215
        JMP SENDR
        SAD (330
        JMP LEAVE
        TAD (-260
        AND (7
        DAC BFFR,X
        AXR +1
        JMP RDCMD
SENDR   JMS CRLF
        PXA
        DZM WC
        ISZ WC#
        TAD (-4
        SPA
        JMP DONE
        JMP SENDR+3
DONE    LAC WC
        TAD (-1
        TCA
        DAC WC1#
        CLX
        JMP NEXT
NEXT2   AXR +1
NEXT    LAC (-4
```

```
                DAC COUNT#
                CLA
NEXT1           CLL
                PAL
                PAL
                PAL
                AND (7777
                TAD BFFR,X
                AXR +1
                ISZ COUNT
                JMP NEXT1
                JMS LODE
                LAS
                SAD (0200
                JMP N3
                ISZ WC1
                JMP NEXT2
N3              JMS READ
                LAS
                SZA
                JMP N4
                JMP DONE
N4              JMS CRLF
GIVE            LAC F2   /PRINT RETURNED WORD
                AND (1
                SNA
                JMP SKIP
                LAC F1
                AND (1   /FIRST FLAG
                TAD (262
                JMS WRITE
                LAC F2   /SECOND FLAG
                AND (1
                TAD (262
                JMS WRITE
                LAC (240
                JMS WRITE
                LAC (-4
                DAC WC
NUM             LAC ANS /THEN DATA
                LLS +3
                AND (77772
                DAC ANS
                LRS +14
                AND (7
                TAD (262
                JMS WRITE
                ISZ WC
                JMP NUM
SKIP            JMS CRLF
                JMP BEGIN
CRLF            0
                LAC (215
                JMS WRITE
                LAC (212
                JMS WRITE
                JMP* CRLF
```

```
LODE    0
        DAC TEMP1#
        RTP
        RTP
        RTP
        AND (77
        TAD (100
        JMS PRTY
        TLS1
        TSF1
        JMP .-1
        TLF1
        LAC TEMP1
        AND (77
        TAD (100
        JMS PRTY
        TLS1
        TSF1
        JMP .-1
        TLF1
        JMP* LODE
PRTY    0
        DAC P1#
        LAC (-7
        DAC BITC#
        LAC (1
        DAC MASK#
        DZM P2
GO      LAC P1
        AND MASK
        SZA
        ISZ P2#
        ISZ BITC
        JMP CONT1
        JMP SETBIT
CONT1   LAC MASK
        CLL
        RAL
        DAC MASK
        JMP GO
SETBIT  LAC P2
        AND (1
        SNA
        JMP ADDP
        LAC P1
        JMP* PRTY
ADDP    LAC P1
        TAD (200
        JMP* PRTY
READ    0
        KSF1
        JMP .-1
        CLA
        KRB1
        DAC TEMP2#
        LRS +6
        AND (1
```

```
            DAC F1#
            LAC TEMP2
            AND (77
            LLS +6
            AND (7702
            DAC ANS#
            KSF1
            JMP .-1
            CLA
            KRB1
            DAC TEMP2
            LRS +6
            AND (1
            DAC F2#
            LAC TEMP2
            AND (77
            TAD ANS
            DAC ANS
            JMP* READ
WRITE       0
            TLS
            TSF
            JMP .-1
            TCF
            JMP* WRITE
LEAVE       JMS CRLF
            JMP* TALK
BFFR        .BLOCK 50
            .END
            316
```

REFERENCES

1. Industrial 14 Systems Manual. Dec-14-HSMAA-A-D, Digital Equipment Corp., 1974

2. Industrial 14 Software Manual. Dec-14-ISUMA-B-D, Digital Equipment Corp. 1974.
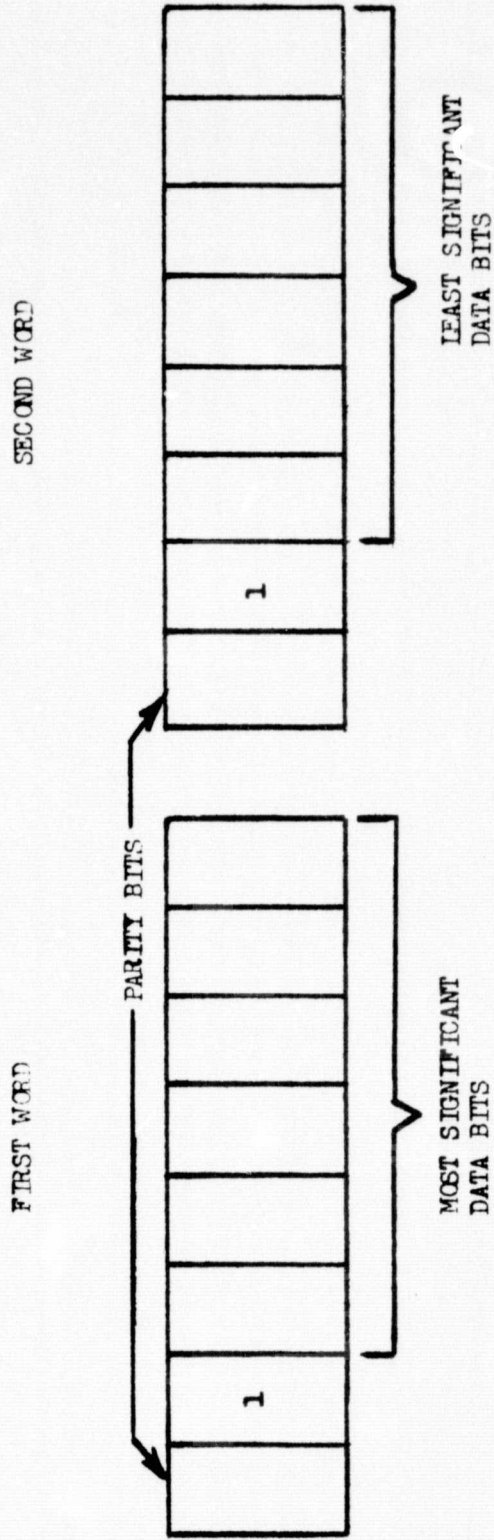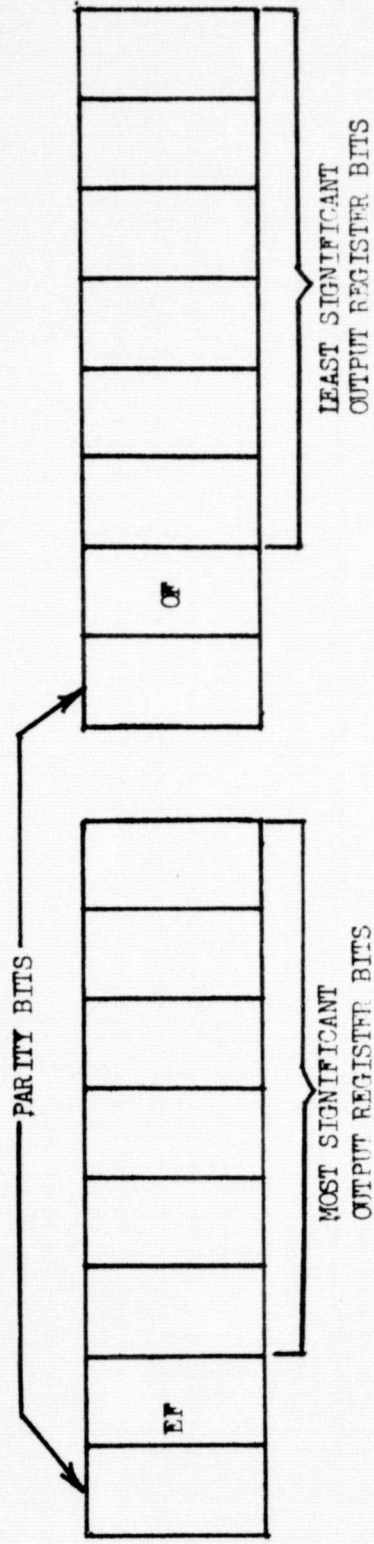
FIRST WORD

SECOND WORD

PARITY BITS

MOST SIGNIFICANT
DATA BITS

LEAST SIGNIFICANT
DATA BITS

FIGURE 1. FORMAT FOR DATA TRANSMISSION TO INDUSTRIAL 14/30

FIRST WORD

SECOND WORD

PARITY BITS

EF

OF

MOST SIGNIFICANT
OUTPUT REGISTER BITS

LEAST SIGNIFICANT
OUTPUT REGISTER BITS

EF=1 : AN EXTERNALLY SUPPLIED INSTRUCTION HAS BEEN EXECUTED
OF=1 : OUTPUT REGISTER HAS BEEN NEWLY LOADED
OF=0 : OUTPUT REGISTER CONTAINS DATA RESULTING FROM AN EARLIER COMMAND

FIGURE 2. FORMAT FOR TRANSFER OF DATA FROM THE INDUSTRIAL 24/30.