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**NASA TECHNICAL
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NASA TM X-73604

NASA TM X-73604

(NASA-TM-X-73604) A PDP-15 TO INDUSTRIAL-14
INTERFACE AT THE LEWIS RESEARCH CENTER'S
CYCLOTRON (NASA) 21 F HC A02/MF A01

N77-19775

CSCI 09B

Unclass

G3/61 21611

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

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March, 1977



1. Report No. NASA TM X-73604	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle A PDP-15 TO INDUSTRIAL-14 INTERFACE AT THE LEWIS RESEARCH CENTER'S CYCLOTRON		5. Report Date	
		6. Performing Organization Code	
7. Author(s) Francis R. Kebberly and Regis F. Leonard		8. Performing Organization Report No. E-9077	
		10. Work Unit No.	
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		11. Contract or Grant No.	
		13. Type of Report and Period Covered Technical Memorandum	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code	
		15. Supplementary Notes	
16. Abstract <p>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 desired turn controller outputs on and off directly from the computer.</p>			
17. Key Words (Suggested by Author(s)) Programmable controller PDP-15 Interface		18. Distribution Statement Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price*

* For sale by the National Technical Information Service, Springfield, Virginia 22161

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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 terminal 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 accommodates 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

Programs 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
START  IOF
        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 SUBROUTINE
        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
IOPS=700314
RRB=700112
RSF=700101
ION=700042
CAF=703302
IOF=700002
      .GLOBL RDPT,BFFR,WC,LDI4
      .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 DUNI /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

```

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```

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

```

```

      .TITLE LD14      /ROUTINE TO LOAD INDUSTRIAL-14
                        /AFETR READING PAPER TAPE
TSFI=704001          /SKIP ON 14 FLAG
TLFI=704002          /CLEAR 14-FLAG
TLSI=704006          /LOAD BUFFER, TRANSMIT, RAISE FLAG
                        /ON COMPLETION
KSFI=704101          /SKIP ON RCVR FLAG
KRBI=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
JPI4=0024             /JMP
                        .GLOBL LD14, BFFR, WC
                        .GLOBL COUNT, LOCAT
LD14      0
           IOF
           CLX
           LAC* WC
           PAL
           LAC* COUNT
           SZA
           JMS LDAD
           LAC* LOCAT
           DAC RELADR#
BEGIN     LAC (JPI4
           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* LD14
LDAD      0
           LAC (EEM
           JMS .LODE1
           JMS WAIT
           LAC (JPI4
           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
TLSI
TSFI
JMP .-1
TLFI
LAC TEMP
AND (77
TAD (100
JMS PRTY
TLSI
TSFI
JMP .-1
TLFI
JMP* .LODEI
WAIT 0
KSF1
JMP .-1
KRBI
KSF1
JMP .-1
KRBI
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

```

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      .TITLE ZERO
      /SUBROUTINE TO CLEAR INDUSTRIAL-14
      /MEMORY AND OUTPUTS
      TLSI=704006      /LOAD BUFFER AND TRANSMIT
      TSFI=704001      /SKIP ON TRANSMITTER FLAG
      TLF1=704002      /CLEAR TRANSMITTER FLAG
      IOF=700002
      KSFI=704101      /SKIP ON RECEIVER FLAG
      KPBI=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 LOCI4#
DEP0     LAC (LDMEM
          JMS SENDI
          LAC (0
          JMS SENDI
          JMS CHECK
          ISZ LOCI4
          LAC (000024
          JMS SENDI
          LAC LOCI4
          JMS SENDI
          JMS CHECK
          ISZ ROUND
          JMP DEP0
          JMP* ZERO
SENDI    0
          DAC TEMP#
          RTR
          RTR
          RTR
          AND (77
          TAD (100
          JMS PRTY
          TLSI
          TSFI

```

```

JMP .-1
TLFI
LAC TEMP
AND (77
TAD (100
JMS PRY
TLSI
TSFI
JMP .-1
TLFI
JMP* SENDI
CHECK 0
WAITI KSF1
JMP .-1
KRBI
KSF1
JMP .-1
KRBI
JMP* CHECK
PRY 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* PRY
ADDP LAC P1
TAD (200
JMP* PRY
.END

```

```

      .TITLE RUN
      /PROGRAM TO RUN INDUSTRIAL 14
TSFI=704001
TLFI=704002
TLSI=704006
KSF1=704101
KPB1=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 PRY
      TLSI
      TSFI
      JMP .-1
      TLF1
      LAC TEMP
      AND (77
      TAD (100
      JMS PRY
      TLSI
      TSFI
      JMP .-1
      TLF1
      JMP* .LODE
WAIT      0
      KSF1
      JMP .-1
      KRBI
      KSF1
      JMP .-1
      KRBI
      JMP* WAIT
PRY      0
      DAC PI#
      LAC (-7
      DAC BITC#

```

```
      LAC C1
      DAC MASK#
GO     DZM P2
      LAC P1
      AND MASK
      SZA
      ISZ P2#
      ISZ BITC
      JMP CONT
CONT   JMP SETBIT
      LAC MASK
      CLL
      RAL
      DAC MASK
      JMP GO
SETBIT LAC P2
      AND C1
      SNA
      JMP ADDP
      LAC P1
      JMP* PRTY
ADDP  LAC P1
      TAD C200
      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
SENDER 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

```

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```

DAC COUNT#
CLA
NEXT1 CLL
PAL
PAL
PAL
AND (7777
TAD BFFF,X
AYR +1
ISZ COUNT
JMP NEXT1
JMS LODE
LAS
SAD (0202
JMP N3
ISZ WC1
JMP NEXT2
N3 JMS READ
LAS
SZA
JMP N4
JMP DONE
N4 JMS CPLF
GIVE LAC F2 /PRINT RETURNED WORD
AND (1
SMA
JMP SKIP
LAC F1
AND (1 /FIRST FLAG
TAD (260
JMS WRITE
LAC F2 /SECOND FLAG
AND (1
TAD (260
JMS WRITE
LAC (240
JMS WRITE
LAC (-4
DAC WC
NUM LAC ANS /THEN DATA
LLS +3
AND (77770
DAC ANS
LPS +14
AND (7
TAD (260
JMS WRITE
ISZ WC
JMP NUM
SKIP JMS CPLF
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 CONTI
          JMP SETBIT
CONTI     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
          KSFI
          JMP .-1
          CLA
          KPPI
          DAC TEMP2#
          LPS +6
          AND (1

```

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```

DAC F1#
LAC TEMP2
AND C77
LLS +6
AND C7700
DAC ANS#
KSF1
JMP .-1
CLA
KPB1
DAC TEMP2
LPS +6
AND C1
DAC F2#
LAC TEMP2
AND C77
TAD ANS
DAC ANS
JMP* READ
WRITE 0
TILS
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.

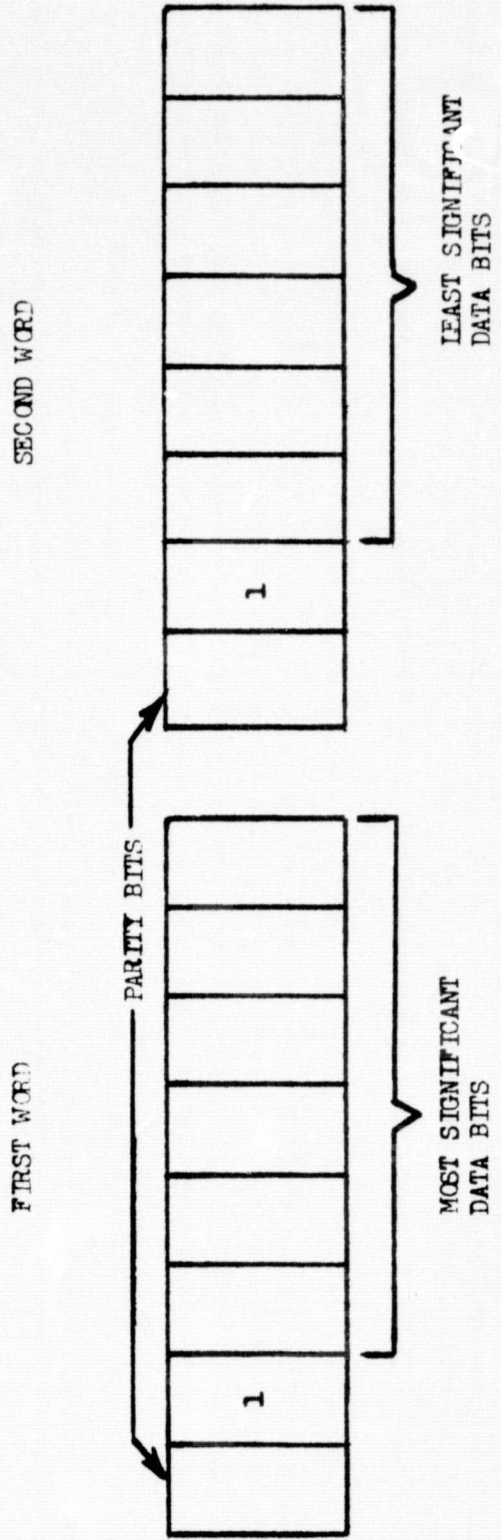
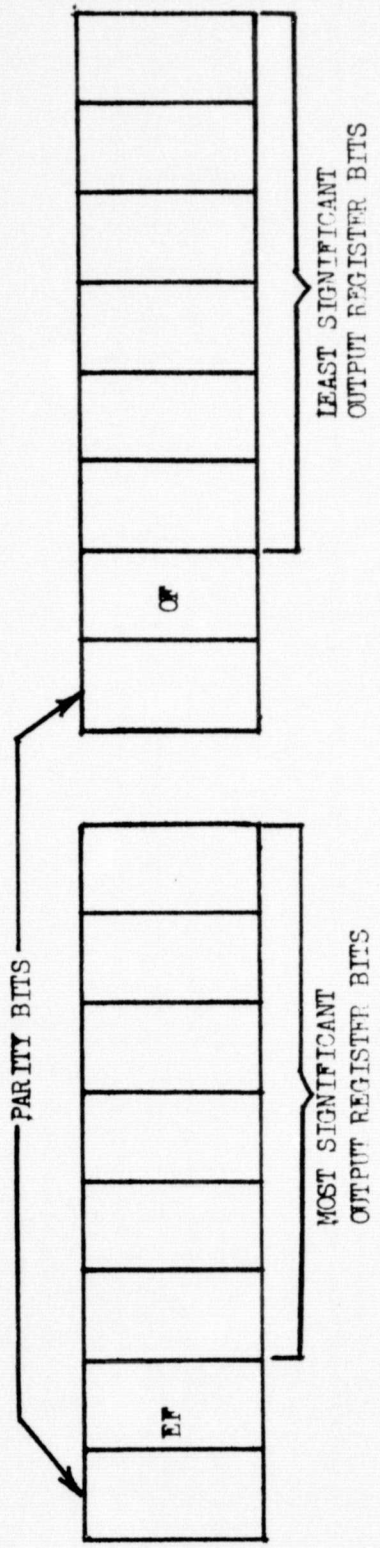


FIGURE 1. FORMAT FOR DATA TRANSMISSION TO INDUSTRIAL 14/30

FIRST WORD

SECOND WORD



- 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 14/30.