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

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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.
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THE LEWIS RESEARCH CENTER'S CYCLOTRON

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Lewis Research Center

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.

STAR Category 60
SOFTWARE: GENERAL

In the serial mode information is transferred to the Industrial-14 from the FDP-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:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>000001</td>
<td>Clear Industrial-14</td>
</tr>
<tr>
<td>000010</td>
<td>Load Industrial-14 from paper tape</td>
</tr>
<tr>
<td>001000</td>
<td>Place Industrial-14 in INTERNAL RUN mode</td>
</tr>
<tr>
<td>001000</td>
<td>Call subroutine TALK to control Industrial-14 from PDP-15 teletype</td>
</tr>
</tbody>
</table>
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,
I0F=700002
.GLOBL RDPT, RUN, ZERO, TALK
I0F
START	 HLT
LA S
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 IT.
LAS
AND (100 /IF SW=100, CALL SUBROUTILE
SZA /RUN TO START INDUSTRIAL-14
JMS* RUN
LAS
AND (1000
SZA
JMS* TALK
JMP START
JMP START
.END
.TITLE RDPT
/DECTAPE FILE NAME PT-14
/Routine to read paper tape

RSA=700104
IOPS=700314
RRB=700112
RSF=700121
ION=700042
CAF=703322
IDF=700082

.GLOBL RDPT, BFFP, WC, LD14
.GLOBL COUNT, LOCAT

RDPT 0
DBA
CAF
LAC (775
PAL
CLX
START RSA
RSF
JMP -.1
IOPS
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
LAC TEMP /GO TO PRINT FOR ALL WORDS IN BUFFER
AND (100 /DOES WORD HAVE A 7-PUNCH
SZA
JMP ADRES
LAC TEMP
RTL
RTL
RTL
AND (7700
DAC BFFP, X
REDO RSA
RSF
JMP -.1
RRB
DAC TEMP
TCA
TAD (377

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
SZA
JMP +3
JMS SKIP
JMP REDO
LAC TEMP
AND (77
TAD BFFRX
DAC BFFPX
AXS +1
JMP START
JMS* LD14
JMP FINI
DUNI
PX
DAC WC#
SZA
JMS* LD14
JMP RSTRT+1
ADPES
LAC TEMP
LLS +6
AND (7700
DAC LOCAT1#
RSA
RSF
JMP -1
RRR
AND (77
TAD LOCAT1
DAC LOCAT1
PX
DAC WC
SZA
JMS* LD14
LAC LOCAT1
DAC LOCAT1#
ISZ COUNT1#
JMP RSTRT
FINI
CAF
JMP* RDPT
SKIP 0
CHK RSA
RSF
JMP -1
ICRS
AND (1000
SZA
JMP FINI
RRR
TCA
TAD (377
SZA
JMP CHK
JMP* SKIP
BFFRX
.BLOCK 1000
.END
.TITLE LDI4 /ROUTINE TO LOAD INDUSTRIAL-14

/READ PAPER TAPE

TDFI=7040001 /SKIP ON 14 FLAG
TLFI=7040002 /CLEAR 14-FLAG
TLSI=7040006 /LOAD BUFFER,TRANSMIT,RAISE FLAG

/ON COMPLETION

KDFI=7041001 /SKIP ON RCVR FLAG
KRFI=7041002 /READ RCVR, CLEAR FLAG
CAF=7033002 /CLEAR ALL FLAGS
IOF=7000000 /INTERRUPT OFF

/INDUSTRIAL-14 COMMANDS:

LDMEM=000022 /LOAD MEMORY
EEM=000060 /ENTER EXTERNAL MODE
LEM=000040 /LEAVE EXTERNAL MODE
CP=0000004 /CLEAR PROGRAM COUNTER
CLR=0000170 /CLEAR ALL OUTPUTS
NPI4=000024 /JMP

*GLOBL LDI4,BFFR,WC
*GLOBL COUNT,LOCAT

LD14 0
  IOF
  CLX
  LAC* WC
  PAL
  LAC* COUNT
  SZA
  JMS LDAD
  LAC* LOCAT
  DAC RELADR#

BEGIN
  LAC (NPI4
  JMS .LODE1
  LAC RELADR
  JMS .LODE1
  JMS WAIT
  ISZ RELADR
  LAC (LDMEM
  JMS .LODE1
  LAC* BFFR,X
  JMS .LODE1
  JMS WAIT
  DZ1* COUNT
  JMP* LDAD

LDAD 0
  LAC (EEM
  JMS .LODE1
  JMS WAIT
  LAC (NPI4
  JMS .LODE1
  LAC* LOCAT
  JMS .LODE1
  JMS WAIT
  DZ1* COUNT
  JMP* LDAD

.JLODE1 0
  DAC TEMP#
  RTR
RTR
PTR
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
KPR1
KSF1
JMP .-1
KPR1
JMP* WAIT
PRTY 0
DAC PI#
LAC (-7
DAC BITC#
LAC (1
DAC MASK#
DZM P2
30 LAC PI
AND *MASK
SZA
ISZ P2#
ISZ BITC
JMP CONT
CONT LAC *MASK
CLL
PAL
DAC MASK
JMP GO
SETBIT LAC P2
AND (1
SNA
JMP ADDP
LAC PI
JMP* PRTY
ADDP LAC PI
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
KPR1=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
CLP=000170  / CLEAR ALL OUTPUTS
CLPPC=000004  / CLEAR PC
RDWD=000031
RDMEM=000021
RDPC=000041

ZPEO 0

IOF

EEML LAC (EEM
JMS SENDI
JMS CHECK
CLEAR LAC (CLR
JMS SENDI
JMS CHECK
LAC (CLRP
JMS SENDI
JMS CHECK
LAC (-7777
DAC ROUND
DZM LOC14

DEPO 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 DEPO
JMP* ZERO

SENDI 0
DAC TEMP
RTR
RTR
RTR
AND (77
TAD (100
JMS PRTY
TLS1
TSF1
JMP -1
TLFI
LAC TEMP
AND (77
TAD (100
JMS PRTY
TLSI
TSFI
JMP -1
TLFI
JMP* SENDI

CHECK

WAITI
KSFI
JMP -1
KPRI
KSFI
JMP -1
KPRI
JMP* CHECK

PRTY

DAC PI#
LAC (-7
DAC BITC#
LAC (1
DAC MASK#
DZM P2

GO
LAC PI
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 PI
JMP* PRTY

ADDP
LAC PI
TAD (200
JMP* PRTY
. END
.TITLE RUN
/PROGRAM TO RUN INDUSTRIAL 14

TSFI=704001
TLFI=704002
TLSI=704006
KSFI=704101
KPR1=704122
CAF=705322
IOF=702002

/INDUSTRIAL-14 COMMANDS
LEM=002040 /LEAVE EXTERNAL MODE
CLPPC=002004 /CLEAP PC
EOM=002150 /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#
    LPS +6
    AND (77
    TAD (100
    JMS PRTY
    TLSI
    TSFI
    JMP 1
    TLF1
    LAC TEMP
    AND (77
    TAD (100
    JMS PRTY
    TLSI
    TSFI
    JMP 1
    TLF1
    JMP LODE

.WAIT 0
    KSFI
    JMP 1
    KPR1
    KSFI
    JMP 1
    KPR1
    JMP WAIT

.PRTY 0
    DAC P1#
    LAC (-7
    DAC BITC#
LAC (1
DAC * MASK#
DZM P2
LAC PI
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 PI
JMP* PRTY
ADDP
LAC PI
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
KRF=700312 /READ KEYBOARD BUFFER
KSF1=704101 /SKIP ON INDUSTRIAL-14 REPLY FLAG
KRB1=704102 /READ INDUSTRIAL-14 OUTPUT REGISTER
TSL=704008 /LOAD INDUSTRIAL-14 INPUT BUFFER
TSF1=704001 /SKIP ON INDUSTRIAL-14 FLAG
TLF=704002 /CLEAR INDUSTRIAL-14 FLAG
GLOBAL TALK
TALK 0
BEGIN IOF
DATA 215
212
215
212
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 BFR+, X
AXR +1
JMP RDCMD
SENDR JMS CRLF
PX A
DZM WC
IS Z WC#
TAD (-4
SPA
JMP DONE
JMP SENDR+3
DONE LAC WC
TAD (-1
TCA
DAC WC#
CLX
JMP NEXT
NEXT2 AXR +1
NEXT LAC (-4

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DPI CNT1
CLA
CLL
PAL
PAL
PAL
JMP (1)
TAD BEEP, X
AY0-1
IST CNT1
JMP NT1
JMS LODE
LAC
SAD C220
JMP N1
IST UC1
JMP NT2
N3
JMS READ
LAC
SZA
JMP N4
JMP DONE
N4
GIVE LAC F2 /PRINT RETURNED WOPD
AND (1)
SHA
JMP SKIP
LAC FI
AND (1) /FIRST FLAG
TAD C66
JMS WRITE
LAC F2 /SECOND FLAG
AND (1)
TAD C66
JMS WRITE
LAC C42
JMS WRITE
LAC (-4)
DPC VC
NUM
LAC ANS /THEN DATA
LRS +3
AND (7777)
DPC ANS
LPS +14
AND (7)
TAD C66
JMS WRITE
IST VC
JMP NUM
SKIP
JMS CPLF
JMP REGEN
CRLF 0
LAC C015
JMS WRITE
LAC C012
JMS WRITE
JMP* CPLF
LODE 2
DAC TEMP1#
RTP
RTP
RTP
AND $77
TAD <122
JMP PRTY
TLSI
TSFI
JMP -1
TLFI
LAC TEMP1
AND $77
TAD <122
JMS PRTY
TLSI
TSFI
JMP -1
TLFI
JMP* LODE

PRTY 0
DAC P1#
LAC <7
DAC RITC#
LAC $1
DAC MASK#

30
LAC P1
AND *MASK
SZ4
ISZ P2#
ISZ RITC
JMP CONTI
JMP SETBIT

CONTI
LAC MASK
CLL
PAL
DAC *MASK
JMP GO

SETBIT LAC P2
AND $1
SNA
JMP ADDP
LAC P1
JMP* PRTY

ADDP LAC P1
TAD <220
JMP* PRTY

READ 2
KF1
JMP -1
CLA
KRP1
DAC TEMP2#
LPS +6
AND $1

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
DAC F1#
LAC TEMP2
AND (77
LLS +6
AND (7707
DAC ANS#
XSF1
JMP -1
CLA
XR61
DAC TEMP2
LPS +6
AND (1
DAC PB#
LAC TEMP2
AND (77
TAD ANS
DAC ANS
JMP READ
WRITE 2
TLS
TSF
JMP -1
TCF
JMP WRITE
LEAVE JMS CRLF
JMP TALK
BFFR BLOCK 50
. END
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REFERENCES

