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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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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 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>Setting</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>000100</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.

IOF=700002

.GLOBL RDPT, RUN, ZERO, TALK

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 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=700184
IOPS=700314
RRB=700112
RSF=700211
ION=700042
CAF=700332
IOF=700022

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

RDPT 0
DBA

RSTRT CAF
LAC (775
PAL
CLX

START RSA
RSF
JMP -.1
IOPS
AND (1000
SZA
JMP FINI

RBB /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 R-PUNCH
LAC TEMP
AND (100 /GO TO PRINT FOR ALL WORDS IN BUFFER
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
.TITLE LDI4       /ROUTINE TO LOAD INDUSTRIAL-14
               /AFTER READING PAPER TAPE
TSLF=704001    /SKIP ON 14 FLAG
TLF1=704022    /CLEAR 14-FLAG
TSLI=704006    /LOAD BUFFER, TRANSMIT, RAISE FLAG
               /ON COMPLETION
KSLF=704101    /SKIP ON RCVR FLAG
KSPI=704102    /READ RCVR, CLEAR FLAG
CAF=703302     /CLEAR ALL FLAGS
IOF=700002     /INTERRUPT OFF
               /INDUSTRIAL-14 COMMANDS:
LDMEM=000022   /LOAD MEMORY
EEM=000060     /ENTER EXTERNAL MODE
LEM=000040     /LEAVE EXTERNAL MODE
CLPPC=000044   /CLEAR PROGRAM COUNTER
CLR=0000170    /CLEAR ALL OUTPUTS
JPI4=0024      /JMP
               *.GLOBL LDI4, BFR, WC
               *.GLOBL COUNT, LOCAT
LD14 0
I OF
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* BFR, 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
RTP
RTP
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* .LODE1

WAIT 0
KSF1
JMP -1
KRBI
KSF1
JMP -1
KRBI
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=724101 /SKIP ON RECEIVER FLAG
KPR1=724102 /READ BUFFER AND CLEAR FLAG
/INDUSTRIAL-14 COMMANDS
EEM=000002 /ENTER EXTERNAL MODE
LEM=000040 /LEAVE EXTERNAL MODE
LDMEM=000022 /LOAD MEMORY WITH FOLLOWING WORD
CLP=000170 /CLEAR ALL OUTPUTS
CLPPC=000044 /CLEAR PC
RDWD=000031
RDME=000021
RDPC=000041
.GLOBL ZERO
ZEPO 0
IOF
EEM
LAC (EEM
JMS SENDI
JMS CHECK
CLEAR
LAC (CLP
JMS SENDI
JMS CHECK
LAC (CLPPC
JMS SENDI
JMS CHECK
LAC (-7777
DAC ROUND#
DZM LOCl4#
DEP0
LAC (LDMEM
JMS SENDI
LAC (0
JMS SENDI
JMS CHECK
ISZ LOCl4
LAC (000024
JMS SENDI
LAC LOCl4
JMS SENDI
JMS CHECK
ISZ ROUND
JMP DEPO
JMP* ZERO
SENDI 0
DAC TEMP#
RTR
RTR
RTR
AND (77
TAD (100
JMS PRTY
TLSI
TSFI
.TITLE RUN
/PROGRAM TO RUN INDUSTRIAL 14

TSFI=704001
TLFI=704002
TLSI=704006
KSF1=724121
KPR1=724122
CAF=703302

IOF=702202
/KSFI=724101
/KPR1=724122

/INDUSTRIAL-14 COMMANDS
LEM=000040 /LEAVE EXTERNAL MODE
CLRPC=002004 /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#
  LPS +6
  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* .LODE

.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
LAC P1
AND MASK
SZA
ISZ P2#
ISZ BITC
JMP CONT
JMP SETBIT
CONT
LAC MASK
CLL
RAL
DAC MASK
JMP GO
SETHIT
LAC P2
AND (1
SNA
JMP ADDP
LAC P1
JMP* PRTY
ADDP
LAC P1
TAD (200
JMP* PRTY
*END
TITLE  T A L.. I<

..I C F 70040:
/CLEAR TELEPRINTER FLAG
101
.
.;'0000.'

/LOAD AND PRINT TELEPRINTER
SF-70(140:

/Skip ON TELEPRINTER FLAG
w:)

/Skip ON KEYBOARD FLAG
KRB 700;

/READ KEYBOARD BUFFER
KSF 1 -704:

/Skip ON INDUSTRIAL-14 REPLY FLAG
LRO

/READ INDUSTRIAL-14 OUTPUT REGISTER
rUSI-

/LOAD INDUSTRIAL-14 INPUT BUFFER
TE, F1 7040•

/Skip ON INDUSTRIAL-14 FLAG
II..F .t

/CLEAR INDUSTRIAL-14 FLAG
II..F .t
DAC COUNT
CLA
CPL
PAL
PUL
MID (7777
TAD BEEP, X
AY? +1
IST COUNT
JMP NEXTI
JMS LODE
LAS
SAD C222
JMP N3
IST UC1
JMP NEXT2
N3
JMS READ
LAS
SZA
JMP N4
JMP DONE
N4
GIVE LAC F2 /PRINT RETURNED MOPD
AND 01
SNA
JMP SKIP
LAC F1
AND 01 /FIRST FLAG
TAD C960
JMS WRITE
LAC F2 /SECOND FLAG
AND 01
TAD C960
JMS WRITE
LAC C940
JMS WRITE
LAC C-4
DAC VC
NUM LAC AUS /THEN DATA
LLS +3
AND 7777772
DAC AUS
LPS +14
AND 07
TAD C960
JMS WRITE
IST VC
JMP NUM
SKIP JMS CPLF
JMP RESIN
CRLF 0
LAC C215
JMS WRITE
LAC C212
JMS WRITE
JMP* CPLF
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
DAC F1#
LAC TEMP2
AND C77
LLS +C
AND C77C2
DAC ANS#
K3FI
JMP -1
CLA
K3FI
DAC TEMP2
LPS +C
AND C1
DAC F2#
LAC TEMP2
AND C77
TAD ANS
DAC ANS
JMP READ
WRITE 2
TLS
TSF
JMP -1
TCF
JMP WRITE
LEAVE
JMS CRPF
JMP TALK
BFFR
.BLOCK 50
.END
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REFERENCES


FIGURE 1. FORMAT FOR DATA TRANSMISSION TO INDUSTRIAL 14/30
**FIGURE 2.** FORMAT FOR TRANSFER OF DATA FROM THE INDUSTRIAL 14/30.