PDP-11 Simulator Usage
06-Jul-2006

This memorandum documents the DEC PDP-11 simulator.

1 Simulator Files

To compile the PDP-11, you must define VM_PDP11 as part of the compilation command line. If you want expanded file support, you must also define USE_INT64 and USE_ADDR64 as part of the compilation command line.

```
sim/         scp.h
             sim_console.h
             sim_defs.h
             sim_ether.h
             sim_fio.h
             sim_rev.h
             sim_sock.h
             sim_tape.h
             sim_timer.h
             sim_tmxr.h
             scp.c
             sim_console.c
             sim_ether.c
             sim_fio.c
             sim_sock.c
             sim_tape.c
             sim_timer.c
             sim_tmxr.c

sim/pdp11/   pdp11_cpumod.h
             pdp11_cr_dat.h
             pdp11_defs.h
             pdp11_mscp.h
             pdp11_uqssp.h
             pdp11_xq.h
             pdp11_xq_bootrom.h
             pdp11_cpu.c
             pdp11_cpumod.c
             pdp11_cr.c
             pdp11_dl.c
             pdp11_dz.c
             pdp11_fp.c
             pdp11_hk.c
             pdp11_io.c
             pdp11_lp.c
             pdp11_pclk.c
             pdp11_pt.c
             pdp11_rf.c
             pdp11_rh.c
             pdp11_rk.c
             pdp11_rl.c
             pdp11_rp.c
             pdp11_rq.c
             pdp11_rx.c
             pdp11_ry.c
             pdp11_stddev.c
             pdp11_sys.c
```

```
pdp11_tc.c
pdp11_tm.c
pdp11_tq.c
pdp11_ts.c
pdp11_tu.c
pdp11_vh.c
pdp11_xq.c
pdp11_xu.c
```

2 PDP-11 Features

The PDP-11 simulator is configured as follows:

```
device name(s)    simulates

CPU               PDP-11 CPU with 256KB of memory
PTR,PTP           PC11 paper tape reader/punch
TTI,TTO           DL11 console terminal
CR                CR11/CD11 card reader
LPT               LP11 line printer
CLK               KW11-L line frequency clock
PCLK              KW11-P programmable clock
TTIX,TTOX         KL11/DL11 additional serial lines (up to 16)
DZ                DZ11 8-line terminal multiplexer (up to 4)
VH                DHU11/DHQ11 8-line terminal multiplexer (up to 4)
RK                RK11/RK05 cartridge disk controller with eight drives
HK                RK611/RK06,RK07 cartridge disk controller with eight
                  drives
RF                RF11/RS11 fixed head disk
RL                RL11(RLV12)/RL01,RL02 cartridge disk controller with
                  four drives
RH                RH11/RH70 Massbus adapter (up to 2)
RP                RP04/05/06/07, RM02/03/05/80 Massbus disks with eight
                  drives
RQ                RQDX3/UDA50 MSCP controller with four drives
RQB               second RQDX3/UDA50 MSCP controller with four drives
RQC               third RQDX3/UDA50 MSCP controller with four drives
RQD               fourth RQDX3/UDA50 MSCP controller with four drives
RX                RX11/RX01 floppy disk controller with two drives
RY                RX211/RX01 floppy disk controller with two drives
TC                TC11/TU56 DECtape controller with eight drives
TM                TM11/TU10 magnetic tape controller with eight drives
TS                TS11/TSV05 magnetic tape controller with one drive
TQ                TQK50/TU81 TMSCP magnetic tape controller with four
                  drives
TU                TM02/TM03 magnetic tape formatter with eight drives
XQ                DELQA/DEQNA Qbus Ethernet controller
XQB               second DELQA/DEQNA Qbus Ethernet controller
XU                DELUA/DEUNA Unibus Ethernet controller
XUB               Second DELUA/DEUNA Unibus Ethernet controller
```

The DZ, VH, RK, HK, RL, RP, RQ, RQB, RQC, RQD, RX, RY, TC, TM, TS, TQ, XQ, XQB, XU, and XUB devices can be set DISABLED. TTIX, TTOX, RF, RQB, RQC, RQD, RY, TS, XQB, XU, and XUB are disabled by default.

The PDP-11 simulator implements several unique stop conditions:

- Abort during exception vector fetch, and register STOP_VEC is set
- Abort during exception stack push, and register STOP_SPA is set
- Trap condition 'n' occurs, and register STOP_TRAP<n> is set
- Wait state entered, and no I/O operations outstanding (i.e., no interrupt can ever occur)
- A simulated DECtape runs off the end of its reel, and flag STOP_OFFR is set

The LOAD command supports standard binary format tapes. The DUMP command is not implemented.

2.1 CPU and System

2.1.1 CPU

The CPU options include CPU type, CPU instruction set options for the specified type, and the size of main memory.

```
SET CPU 11/03                set CPU type to 11/03
SET CPU 11/04                set CPU type to 11/04
SET CPU 11/05                set CPU type to 11/05
SET CPU 11/20                set CPU type to 11/20
SET CPU 11/23                set CPU type to 11/23
SET CPU 11/23+               set CPU type to 11/23+
SET CPU 11/24                set CPU type to 11/24
SET CPU 11/34                set CPU type to 11/34
SET CPU 11/40                set CPU type to 11/40
SET CPU 11/44                set CPU type to 11/44
SET CPU 11/45                set CPU type to 11/45
SET CPU 11/53                set CPU type to 11/53
SET CPU 11/60                set CPU type to 11/60
SET CPU 11/70                set CPU type to 11/70
SET CPU 11/73                set CPU type to 11/73
SET CPU 11/73B               set CPU type to 11/73B
SET CPU 11/83                set CPU type to 11/83
SET CPU 11/84                set CPU type to 11/84
set CPU 11/93                set CPU type to 11/93
set CPU 11/94                set CPU type to 11/94
SET CPU U18                  deprecated; same as 11/45
SET CPU URH11                deprecated; same as 11/84
SET CPU URH70                deprecated; same as 11/70
SET CPU Q22                  deprecated; same as 11/73
SET CPU NOEIS                disable EIS instructions
SET CPU EIS                  enable EIS instructions
SET CPU NOFIS                disable FIS instructions
SET CPU FIS                  enable FIS instructions
SET CPU NOFPP                disable FPP instructions
SET CPU FPP                  enable FPP instructions
SET CPU NOCIS                disable CIS instructions
SET CPU CIS                  enable CIS instructions
SET CPU 16K                  set memory size = 16KB
SET CPU 32K                  set memory size = 32KB
SET CPU 48K                  set memory size = 48KB
SET CPU 64K                  set memory size = 64KB
SET CPU 96K                  set memory size = 96KB
SET CPU 128K                 set memory size = 128KB
```

```
SET CPU 192K                    set memory size = 192KB
SET CPU 256K                    set memory size = 256KB
SET CPU 384K                    set memory size = 384KB
SET CPU 512K                    set memory size = 512KB
SET CPU 768K                    set memory size = 768KB
SET CPU 1024K (or 1M)           set memory size = 1024KB
SET CPU 2048K (or 2M)           set memory size = 2048KB
SET CPU 3072K (or 3M)           set memory size = 3072KB
SET CPU 4096K (or 4M)           set memory size = 4096KB
```

The CPU types and their capabilities are shown in the following table:

type	bus	mem	MMU?	Umap?	EIS?	FIS?	FPP?	CIS?
11/03	Q	64K	no	no	std	opt	no	no
11/04	U	64K	no	no	no	no	no	no
11/05	U	64K	no	no	no	no	no	no
11/20	U	64K	no	no	no	no	no	no
11/23	Q	4M	std	no	std	no	opt	opt
11/23+	Q	4M	std	no	std	no	opt	opt
11/24	U	4M	std	std	std	no	opt	opt
11/34	U	256K	std	no	std	no	opt	no
11/40	U	256K	std	no	std	opt	no	no
11/44	U	4M	std	std	std	no	opt	opt
11/45	U	256K	std	no	std	no	opt	no
11/53	Q	4M	std	no	std	no	std	opt
11/60	U	256K	std	no	std	no	std	no
11/70	U	4M	std	std	std	no	opt	no
11/73	Q	4M	std	no	std	no	std	opt
11/73B	Q	4M	std	no	std	no	std	opt
11/83	Q	4M	std	no	std	no	std	opt
11/84	U	4M	std	std	std	no	std	opt
11/93	Q	4M	std	no	std	no	std	opt
11/94	U	4M	std	std	std	no	std	opt

If a capability is standard, it cannot be disabled; if a capability is not included, it cannot be enabled.

The CPU implements a SHOW command to display the I/O address assignments:

```
SHOW CPU IOSPACE                show I/O space address assignments
```

If memory size is being reduced, and the memory being truncated contains non-zero data, the simulator asks for confirmation. Data in the truncated portion of memory is lost. Initial memory size is 256KB. If memory size is increased to more than 256KB, or the bus structure is changed, the simulator disables peripherals that can't run in the current bus structure.

These switches are recognized when examining or depositing in CPU memory:

```
-v                              interpret address as virtual
-d                              if mem mgt enabled, force data space
-k                              if mem mgt enabled, force kernel mode
-s                              if mem mgt enabled, force supervisor mode
-u                              if mem mgt enabled, force user mode
-p                              if mem mgt enabled, force previous mode
```

CPU registers include the architectural state of the PDP-11 processor as well as the control registers for the interrupt system.

```
name                size        comments

PC                  16          program counter
R0..R5              16          R0..R5, current register set
SP                  16          stack pointer, current mode
R00..R05            16          R0..R5, register set 0
R10..R15            16          R0..R5, register set 1
KSP                 16          kernel stack pointer
SSP                 16          supervisor stack pointer
USP                 16          user stack pointer
PSW                 16          processor status word
  CM                2           current mode, PSW<15:14>
  PM                2           previous mode, PSW<13:12>
  RS                2           register set, PSW<11>
  IPL               3           interrupt priority level, PSW<7:5>
  T                 1           trace bit, PSW<4>
  N                 1           negative flag, PSW<3>
  Z                 1           zero flag, PSW<2>
  V                 1           overflow flag, PSW<1>
  C                 1           carry flag, PSW<0>
PIRQ                16          programmed interrupt requests
STKLIM              16          stack limit
FAC0H..FAC5H        32          FAC0..FAC5, high 32 bits
FAC0L..FAC5L        32          FAC0..FAC5, low 32 bits
FPS                 16          floating point status
FEA                 16          floating exception address
FEC                 4           floating exception code
MMR0..3             16          memory management registers 0..3
{K/S/U}{I/D}{PAR/PDR}{0..7}
                    16          memory management registers
IREQ[0:7]           32          interrupt pending flags, IPL 0-7
TRAPS               18          trap pending flags
WAIT                0           wait state flag
WAIT_ENABLE         0           wait state enable flag
STOP_TRAPS          18          stop on trap flags
STOP_VECA           1           stop on read abort in trap or interrupt
STOP_SPA            1           stop on stack abort in trap or interrupt
PCQ[0:63]           16          PC prior to last jump, branch, or interrupt;
                                Most recent PC change first
WRU                 8           interrupt character
```

The CPU can maintain a history of the most recently executed instructions. This is controlled by the `SET CPU HISTORY` and `SHOW CPU HISTORY` commands:

```
SET CPU HISTORY             clear history buffer
SET CPU HISTORY=0           disable history
SET CPU HISTORY=n           enable history, length = n
SHOW CPU HISTORY            print CPU history
SHOW CPU HISTORY=n          print first n entries of CPU history
```

The maximum length for the history is 262144 entries.

2.1.2 System Registers (SYSTEM)

The SYSTEM device implements registers that among CPU types:

name	models	size	comments
SR	11/04, 11/05, 11/20, 11/23+, 11/34, 11/40, 11/44, 11/45, 11/60, 11/70, 11/73B, 11/83, 11/84, 11/93, 11/94	16	switch register or configuration register
DR	11/04, 11/05, 11/20, 1123+, 11/24, 11/34, 11/70, 11/73B, 11/83, 11/84, 11/93, 11/94	16	display register or board LEDs
MEMERR	11/44, 11/60, 11/70, 11/53, 11/73, 11/73B, 11/83, 11/84, 11/93, 11/94	16	memory error register
CCR	11/44, 11/60, 11/70, 11/53, 11/73, 11/73B, 11/83, 11/84, 11/93, 11/94	16	cache control register
MAINT	11/23+, 11/44, 11/70, 11/53, 11/73, 11/73B, 11/83, 11/84, 11/93, 11/94	16	maintenance register
HITMISS	11/44, 11/60, 11/70, 11/53, 11/73, 11/73B, 11/83, 11/84, 11/93, 11/94	16	hit/miss register
CPUERR	11/24, 11/44, 11/70, 11/53, 11/73, 11/73B, 11/83, 11/84, 11/93, 11/94	16	CPU error register
MBRK	11/45, 11/70	16	microbreak register
SYSID	11/70	16	system ID (default = 1234 hex)
JCSR	11/53, 11/73B, 11/83, 11/84, 11/93, 11/94	16	board control/status
JPCR	11/23+, 11/53, 11/73B, 11/83, 11/84, 11/93, 11/94	16	page control register
JASR	11/93, 11/94	16	additional status
UDCR	11/84, 11/94	16	Unibus map diag control
UDDR	11/84, 11/94	16	Unibus map diag data
UCSR	11/84, 11/94	16	Unibus map control/status
ULAST	11/24	23	last Unibus map result

2.2 I/O Devices

2.2.1 Unibus and Qbus DMA Devices

DMA peripherals function differently, depending on whether the CPU type supports the Unibus or the Qbus, and whether the Unibus supports 22b direct memory access (11/70 with RH70 controllers):

```
peripheral  11/70       all         Qbus
            +RH70       other
                        Unibus

RK          18b         18b         disabled if mem > 256K
HK          18b         18b         disabled if mem > 256K
RL          18b         18b         22b RLV12
RP          22b         18b         22b third party
RQ          18b         18b         22b RQDX3
RY          18b         18b         disabled if mem > 256K
TC          18b         18b         disabled
TM          18b         18b         disabled if mem > 256K
TS          18b         18b         22b TSV05
TQ          18b         18b         22b TQK50
TU          22b         18b         22b third party
VH          18b         18b         22b DHQ11
XQ          disabled    22b         DELQA
XU          18b         18b         disabled
```

Non-DMA peripherals work the same in all configurations. Unibus-only peripherals are disabled in a Qbus configuration, and Qbus-only peripherals are disabled in a Unibus configuration. In addition, Qbus DMA peripherals with only 18b addressing capability are disabled in a Qbus configuration with more than 256KB memory.

2.2.2 I/O Device Addressing

PDP-11 I/O space is not large enough to allow all possible devices to be configured simultaneously at fixed addresses. Instead, many devices have floating addresses; that is, the assigned device address depends on the presence of other devices in the configuration:

```
DZ11              all instances have floating addresses
DHU11/DHQ11       all instances have floating addresses
RL11              first instance has fixed address, rest floating
RX11/RX211        first instance has fixed address, rest floating
DEUNA/DELUA       first instance has fixed address, rest floating
MSCP disk         first instance has fixed address, rest floating
TMSCP tape        first instance has fixed address, rest floating
```

To maintain addressing consistency as the configuration changes, the simulator implements DEC's standard I/O address and vector autoconfiguration algorithms for devices DZ, VH, RL, RX, RY, XU, RQ, and TQ. This allows the user to enable or disable devices without needing to manage I/O addresses and vectors. For example, if RY is enabled while RX is present, RY is assigned an I/O address in the floating I/O space range; but if RX is disabled and then RY is enabled, RY is assigned the fixed "first instance" I/O address for floppy disks.

Autoconfiguration cannot solve address conflicts between devices with overlapping fixed addresses. For example, with default I/O page addressing, the PDP-11 can support either a TM11 or a TS11, but not both, since they use the same I/O addresses.

In addition to autoconfiguration, most devices support the `SET <device> ADDRESS` command, which allows the I/O page address of the device to be changed, and the `SET <device> VECTOR` command, which allows the vector of the device to be changed. Explicitly setting the I/O address of a device that normally uses autoconfiguration DISABLES autoconfiguration for that device and for the entire system. As a consequence, the user may have to manually configure all other autoconfigured devices, because the autoconfiguration algorithm no longer recognizes the explicitly configured device. A device can be reset to

autoconfigure with the SET <device> AUTOCONFIGURE command. Auto-configuration can be restored for the entire system with the SET CPU AUTOCONFIGURE command.

The current I/O map can be displayed with the SHOW CPU IOSPACE command. Addresses that have set by autoconfiguration are marked with an asterisk (*).

All devices support the SHOW <device> ADDRESS and SHOW <device> VECTOR commands, which display the device address and vector, respectively.

2.3 Programmed I/O Devices

2.3.1 PC11 Paper Tape Reader (PTR)

The paper tape reader (PTR) reads data from a disk file. The POS register specifies the number of the next data item to be read. Thus, by changing POS, the user can backspace or advance the reader.

The paper tape reader implements these registers:

```
name              size        comments

BUF               8           last data item processed
CSR               16          control/status register
INT               1           interrupt pending flag
ERR               1           error flag (CSR<15>)
BUSY              1           busy flag (CSR<11>)
DONE              1           device done flag (CSR<7>)
IE                1           interrupt enable flag (CSR<6>)
POS               32          position in the input file
TIME              24          time from I/O initiation to interrupt
STOP_IOE          1           stop on I/O error
```

Error handling is as follows:

```
error         STOP_IOE        processed as

not attached      1           report error and stop
                  0           out of tape

end of file       1           report error and stop
                  0           out of tape

OS I/O error      x           report error and stop
```

2.3.2 PC11 Paper Tape Punch (PTP)

The paper tape punch (PTP) writes data to a disk file. The POS register specifies the number of the next data item to be written. Thus, by changing POS, the user can backspace or advance the punch.

The paper tape punch implements these registers:

```
name              size        comments

BUF               8           last data item processed
CSR               16          control/status register
```

```
INT             1          interrupt pending flag
ERR             1          error flag (CSR<15>)
DONE            1          device done flag (CSR<7>)
IE              1          interrupt enable flag (CSR<6>)
POS             32         position in the output file
TIME            24         time from I/O initiation to interrupt
STOP_IOE        1          stop on I/O error
```

Error handling is as follows:

```
error         STOP_IOE      processed as

not attached      1         report error and stop
                  0         out of tape

OS I/O error      x         report error and stop
```

2.3.3 DL11 Terminal Input (TTI)

The terminal interfaces (TTI, TTO) can be set to one of three modes, 7P, 7B or 8B:

```
mode  input characters        output characters

UC    high-order bit cleare,  high order-bit cleared,
      lower case converted    lower case converted
      to upper case           to upper case
7P    high-order bit cleared  high-order bit cleared,
                              non-printing characters suppressed
7B    high-order bit cleared  high-order bit cleared
8B    no changes              no changes
```

The default mode is 8B.

The terminal input (TTI) polls the console keyboard for input. It implements these registers:

```
name            size       comments

BUF             8          last data item processed
CSR             16         control/status register
INT             1          interrupt pending flag
ERR             1          error flag (CSR<15>)
DONE            1          device done flag (CSR<7>)
IE              1          interrupt enable flag (CSR<6>)
POS             32         number of characters input
TIME            24         keyboard polling interval
```

2.3.4 DL11 Terminal Output (TTO)

The terminal output (TTO) writes to the simulator console window. It implements these registers:

```
name            size       comments

BUF             8          last data item processed
CSR             16         control/status register
INT             1          interrupt pending flag
```

```
ERR             1           error flag (CSR<15>)
DONE            1           device done flag (CSR<7>)
IE              1           interrupt enable flag (CSR<6>)
POS             32          number of characters input
TIME            24          time from I/O initiation to interrupt
```

2.3.5 LP11 Line Printer (LPT)

The line printer (LPT) writes data to a disk file. The POS register specifies the number of the next data item to be written. Thus, by changing POS, the user can backspace or advance the printer.

The line printer implements these registers:

```
name            size        comments

BUF             8           last data item processed
CSR             16          control/status register
INT             1           interrupt pending flag
ERR             1           error flag (CSR<15>)
DONE            1           device done flag (CSR<7>)
IE              1           interrupt enable flag (CSR<6>)
POS             32          position in the output file
TIME            24          time from I/O initiation to interrupt
STOP_IOE        1           stop on I/O error
```

Error handling is as follows:

```
error         STOP_IOE      processed as

not attached    1           report error and stop
                0           out of paper

OS I/O error    x           report error and stop
```

2.3.6 KW11-L Line-Time Clock (CLK)

The line-time clock (CLK) frequency can be adjusted as follows:

```
SET CLK 60HZ                set frequency to 60Hz
SET CLK 50HZ                set frequency to 50Hz
```

The default is 60Hz.

The line-time clock implements these registers:

```
name            size        comments

CSR             16          control/status register
INT             1           interrupt pending flag
DONE            1           device done flag (CSR<7>)
IE              1           interrupt enable flag (CSR<6>)
TIME            24          clock interval
```

The line-time clock autocalibrates; the clock interval is adjusted up or down so that the clock tracks actual elapsed time.

2.3.7 KW11-P Programmable Clock (PCLK)

The programmable clock (PCLK) line frequency can be adjusted as follows:

```
SET PCLK 60HZ                set frequency to 60Hz
SET PCLK 50HZ                set frequency to 50Hz
```

The default is 60Hz.

The programmable clock implements these registers:

```
name              size        comments

CSR               16          control/status register
CSB               16          count set buffer
CNT               16          current count
INT               1           interrupt pending flag
OVFL              1           overflow (error) flag (CSR<15>)
DONE              1           device done flag (CSR<7>)
IE                1           interrupt enable flag (CSR<6>)
UPDN              1           up/down count mode (CSR<4>)
MODE              1           single/repeat mode (CSR<3>)
RUN               1           clock run (CSR<0>)
TIME[0..3]        32          clock interval, rates 0..3
TPS[0..3]         32          ticks per second, rates 0..3
```

The programmable clock autocalibrates; the clock interval is adjusted up or down so that the clock tracks actual elapsed time. Operation at the highest clock rate (100Khz) is not recommended. The programmable clock is disabled by default.

2.4 Floppy Disk Drives

2.4.1 RX11/RX01 Floppy Disk (RX)

RX11 options include the ability to set units write enabled or write locked:

```
SET RXn LOCKED               set unit n write locked
SET RXn WRITEENABLED         set unit n write enabled
```

The RX11 supports the BOOT command.

The RX11 implements these registers:

```
name              size        comments

RXCS              12          status
RXDB              8           data buffer
RXES              8           error status
RXERR             8           error code
RXTA              8           current track
RXSA              8           current sector
STAPTR            3           controller state
BUFPTR            3           buffer pointer
INT               1           interrupt pending flag
ERR               1           error flag (CSR<15>)
```

```
TR              1          transfer ready flag (CSR<7>)
IE              1          interrupt enable flag (CSR<6>)
DONE            1          device done flag (CSR<5>)
CTIME           24         command completion time
STIME           24         seek time, per track
XTIME           24         transfer ready delay
STOP_IOE        1          stop on I/O error
SBUF[0:127]     8          sector buffer array
```

Error handling is as follows:

```
error         STOP_IOE      processed as

not attached      1         report error and stop
                  0         disk not ready
```

RX01 data files are buffered in memory; therefore, end of file and OS I/O errors cannot occur.

2.4.2 RX211/RX02 Floppy Disk (RY)

RX211 options include the ability to set units write enabled or write locked, single or double density, or autosized:

```
SET RYn LOCKED              set unit n write locked
SET RYn WRITEENABLED        set unit n write enabled
SET RYn SINGLE              set unit n single density
SET RYn DOUBLE              set unit n double density (default)
SET RYn AUTOSIZE            set unit n to autosize at ATTACH
```

The RX211 supports the BOOT command. The RX211 is disabled in a Qbus system with more than 256KB of memory.

The RX211 implements these registers:

```
name            size       comments

RYCS            16         status
RYBA            16         buffer address
RYWC            8          word count
RYDB            16         data buffer
RYES            12         error status
RYERR           8          error code
RYTA            8          current track
RYSA            8          current sector
STAPTR          4          controller state
INT             1          interrupt pending flag
ERR             1          error flag (CSR<15>)
TR              1          transfer ready flag (CSR<7>)
IE              1          interrupt enable flag (CSR<6>)
DONE            1          device done flag (CSR<5>)
CTIME           24         command completion time
STIME           24         seek time, per track
XTIME           24         transfer ready delay
STOP_IOE        1          stop on I/O error
SBUF[0:255]     8          sector buffer array
```

Error handling is as follows:

```
error          STOP_IOE        processed as

not attached       1           report error and stop
                   0           disk not ready
```

RX02 data files are buffered in memory; therefore, end of file and OS I/O errors cannot occur.

2.5 Cartridge Disk Drives

2.5.1 RK11/RK05 Cartridge Disk (RK)

RK11 options include the ability to make units write enabled or write locked:

```
SET RKn LOCKED                 set unit n write locked
SET RKn WRITEENABLED           set unit n write enabled
```

Units can also be set `ENABLED` or `DISABLED`. The RK11 supports the `BOOT` command. The RK11 is disabled in a Qbus system with more than 256KB of memory.

The RK11 implements these registers:

```
name               size        comments

RKCS               16          control/status
RKDA               16          disk address
RKBA               16          memory address
RKWC               16          word count
RKDS               16          drive status
RKER               16          error status
INTQ               9           interrupt queue
DRVN               3           number of last selected drive
INT                1           interrupt pending flag
ERR                1           error flag (CSR<15>)
DONE               1           device done flag (CSR<7>)
IE                 1           interrupt enable flag (CSR<6>)
INT                1           interrupt pending flag
STIME              24          seek time, per cylinder
RTIME              24          rotational delay
STOP_IOE           1           stop on I/O error
```

Error handling is as follows:

```
error          STOP_IOE        processed as

not attached       1           report error and stop
                   0           disk not ready

end of file        x           assume rest of disk is zero

OS I/O error       x           report error and stop
```

2.5.2 RK611/RK06,RK07 Cartridge Disk (HK)

RK611 options include the ability to set units write enabled or write locked, to set the drive type to RK06, RK07, or autosize, and to write a DEC standard 044 compliant bad block table on the last track:

```
SET HKn LOCKED                set unit n write locked
SET HKn WRITEENABLED          set unit n write enabled
SET HKn RK06                  set type to RK06
SET HKn RK07                  set type to RK07
SET HKn AUTOSIZE              set type based on file size at ATTACH
SET HKn BADBLOCK              write bad block table on last track
```

The type options can be used only when a unit is not attached to a file. The bad block option can be used only when a unit is attached to a file. Units can be set ENABLED or DISABLED. The RK611 supports the BOOT command. The RK611 is disabled in a Qbus system with more than 256KB of memory.

The RK611 implements these registers:

```
name              size        comments

HKCS1             16          control/status 1
HKWC              16          word count
HKBA              16          bus address
HKDA              16          desired surface, sector
HKCS2             16          control/status 2
HKDS[0:7]         16          drive status, drives 0-7
HKER[0:7]         16          drive errors, drives 0-7
HKDB[0:2]         16          data buffer silo
HKDC              16          desired cylinder
HKOF              8           offset
HKMR              16          maintenance register
HKSPR             16          spare register
INT               1           interrupt pending flag
ERR               1           error flag (CSR<15>)
DONE              1           device done flag (CSR1<7>)
IE                1           interrupt enable flag (CSR1<6>)
STIME             24          seek time, per cylinder
RTIME             24          rotational delay
STOP_IOE          1           stop on I/O error
```

Error handling is as follows:

```
error         STOP_IOE        processed as

not attached      1           report error and stop
                  0           disk not ready

end of file       x           assume rest of disk is zero

OS I/O error      x           report error and stop
```

2.5.3 RL11(RLV12)/RL01,RL02 Cartridge Disk (RL)

RL11 options include the ability to set units write enabled or write locked, to set the drive type to RL01, RL02, or autosize, and to write a DEC standard 044 compliant bad block table on the last track:

```
SET RLn LOCKED                set unit n write locked
SET RLn WRITEENABLED          set unit n write enabled
```

```
SET RLn RL01                set type to RL01
SET RLn RL02                set type to RL02
SET RLn AUTOSIZE            set type based on file size at ATTACH
SET RLn BADBLOCK            write bad block table on last track
```

The type options can be used only when a unit is not attached to a file. The bad block option can be used only when a unit is attached to a file. Units can be set ENABLED or DISABLED. The RL11 supports the BOOT command. In a Unibus system, the RL behaves like an RL11 with 18b addressing; in a Qbus (Q22) system, the RL behaves like the RLV12 with 22b addressing.

The RL11 implements these registers:

```
name            size        comments

RLCS            16          control/status
RLDA            16          disk address
RLBA            16          memory address
RLBAE           6           memory address extension (RLV12)
RLMP..RLMP2     16          multipurpose register queue
INT             1           interrupt pending flag
ERR             1           error flag (CSR<15>)
DONE            1           device done flag (CSR<7>)
IE              1           interrupt enable flag (CSR<6>)
STIME           24          seek time, per cylinder
RTIME           24          rotational delay
STOP_IOE        1           stop on I/O error
```

Error handling is as follows:

```
error         STOP_IOE      processed as

not attached      1         report error and stop
                  0         disk not ready

end of file       x         assume rest of disk is zero

OS I/O error      x         report error and stop
```

2.6 Massbus Subsystems

2.6.1 RH70/RH11 Massbus Adapters (RHA, RHB)

The RH70/RH11 Massbus adapters interface Massbus peripherals to the memory bus or Unibus of the CPU. The simulator provides two Massbus adapters. The first, RHA, is configured for the RP family of disk drives. The second, RHB, is configured for the TU family of tape controllers. By default, RHA is enabled and RHB is disabled. In a Unibus system, the RH adapters implement 22b addressing for the 11/70 and 18b addressing for all other models. In a Qbus system, the RH adapters always implement 22b addressing.

Each RH adapter implements these registers:

```
name            size        comments

CS1             16          control/status register 1
WC              16          word count
BA              16          bus address
```

```
CS2             16          control/status register 2
DB              16          data buffer
BAE             6           bus address extension
CS3             16          control/status register 3
IFF             1           transfer complete interrupt request flop
INT             1           interrupt pending flag
SC              1           special condition (CSR1<15>)
DONE            1           device done flag (CSR1<7>)
IE              1           interrupt enable flag (CSR1<6>)
```

2.6.2 RP04/05/06/07, RM02/03/05/80 Disk Pack Drives (RP)

The RP controller implements the Massbus family of large disk drives. RP options include the ability to set units write enabled or write locked, to set the drive type to one of six disk types or autosize, and to write a DEC standard 044 compliant bad block table on the last track:

```
SET RPn LOCKED              set unit n write locked
SET RPn WRITEENABLED        set unit n write enabled
SET RPn RM03                set type to RM03
SET RPn RM05                set type to RM05
SET RPn RM80                set type to RM80
SET RPn RP04                set type to RP04
SET RPn RP06                set type to RP06
SET RPn RP07                set type to RP07
SET RPn AUTOSIZE            set type based on file size at ATTACH
SET RPn BADBLOCK            write bad block table on last track
```

The type options can be used only when a unit is not attached to a file. The bad block option can be used only when a unit is attached to a file. Units can be set `ENABLED` or `DISABLED`. The RP controller supports the `BOOT` command.

The RP controller implements the registers listed below. Registers suffixed with [0:7] are replicated per drive.

```
name            size        comments

CS1[0:7]        16          current operation
DA[0:7]         16          desired surface, sector
DS[0:7]         16          drive status
ER1[0:7]        16          drive errors
OF[0:7]         16          offset
DC[0:7]         16          desired cylinder
ER2[0:7]        16          error status 2
ER3[0:7]        16          error status 3
EC1[0:7]        16          ECC syndrome 1
EC2[0:7]        16          ECC syndrome 2
MR[0:7]         16          maintenance register
MR2[0:7]        16          maintenance register 2 (RM only)
HR[0:7]         16          holding register (RM only)
STIME           24          seek time, per cylinder
RTIME           24          rotational delay
STOP_IOE        1           stop on I/O error
```

Error handling is as follows:

```
error       STOP_IOE        processed as
```

```
not attached      1           report error and stop
                  0           disk not ready

end of file       x           assume rest of disk is zero

OS I/O error      x           report error and stop
```

2.6.3 TM02/TM03/TE16/TU45/TU77 Magnetic Tapes (TU)

The TU controller implements the Massbus family of 800/1600bpi magnetic tape drives. TU options include the ability to select the formatter type (TM02 or TM03), to set the drive type to one of three drives (TE16, TU45, or TU77), and to set the drives write enabled or write locked.

```
SET TU TM02                   set controller type to TM02
SET TU TM03                   set controller type to TM03
SET TUn TE16                  set drive type to TE16
SET TUn TU45                  set drive type to TU45
SET TUn TU77                  set drive type to TU77
```

Magnetic tape units can be set to a specific reel capacity in MB, or to unlimited capacity:

```
SET TUn CAPAC=m               set unit n capacity to m MB (0 = unlimited)
SHOW TUn CAPAC                show unit n capacity in MB
```

Units can be set ENABLED or DISABLED. The TU controller supports the BOOT command.

The TU controller implements the following registers:

```
name              size        comments

CS1               6           current operation
FC                16          frame count
FS                16          formatter status
ER                16          formatter errors
CC                16          check character
MR                16          maintenance register
TC                16          tape control register
TIME              24          operation execution time
STOP_IOE          1           stop of I/O error
```

Error handling is as follows:

```
error             processed as

not attached      tape not ready; if STOP_IOE, stop

end of file       bad tape

OS I/O error      parity error; if STOP_IOE, stop
```

2.7 RQDX3/UDA50 MSCP Disk Controllers (RQ, RQB, RQC, RQD)

The simulator implements four MSCP disk controllers, RQ, RQB, RQC, RQD. Initially, RQB, RQC, and RQD are disabled. Each RQ controller simulates an RQDX3 MSCP disk controller with four disk drives. RQ

options include the ability to set units write enabled or write locked, and to set the drive type to one of many disk types:

```
SET RQn LOCKED                set unit n write locked
SET RQn WRITEENABLED          set unit n write enabled
SET RQn RX50                  set type to RX50
SET RQn RX33                  set type to RX33
SET RQn RD51                  set type to RD51
SET RQn RD52                  set type to RD52
SET RQn RD53                  set type to RD53
SET RQn RD54                  set type to RD54
SET RQn RD31                  set type to RD31
SET RQn RA81                  set type to RA81
SET RQn RA82                  set type to RA82
set RQn RA71                  set type to RA71
SET RQn RA72                  set type to RA72
SET RQn RA90                  set type to RA90
SET RQn RA92                  set type to RA92
SET RQn RRD40                 set type to RRD40 (CD ROM)
SET RQn RAUSER{=n}            set type to RA82 with n MB's
SET -L RQn RAUSER{=n}         set type to RA82 with n LBN's
```

The type options can be used only when a unit is not attached to a file. RAUSER is a "user specified" disk; the user can specify the size of the disk in either MB (1000000 bytes) or logical block numbers (LBN's, 512 bytes each). The minimum size is 5MB; the maximum size is 2GB without extended file support, 1TB with extended file support.

Units can be set `ENABLED` or `DISABLED`. Each RQ controller supports the `BOOT` command. In a Unibus system, an RQ supports 18b addressing and identifies itself as a UDA50. In a Qbus system, an RQ supports 22b addressing and identifies itself as an RQDX3.

Each RQ controller implements the following special `SHOW` commands:

```
SHOW RQn TYPE                 show drive type
SHOW RQ RINGS                 show command and response rings
SHOW RQ FREEQ                 show packet free queue
SHOW RQ RESPQ                 show packet response queue
SHOW RQ UNITQ                 show unit queues
SHOW RQ ALL                   show all ring and queue state
SHOW RQn UNITQ                show unit queues for unit n
```

Each RQ controller implements these registers:

```
name              size        comments

SA                16          status/address register
S1DAT             16          step 1 init host data
CQBA              22          command queue base address
CQLNT             8           command queue length
CQIDX             8           command queue index
RQBA              22          request queue base address
RQLNT             8           request queue length
RQIDX             8           request queue index
FREE              5           head of free packet list
RESP              5           head of response packet list
PBSY              5           number of busy packets
```

```
CFLGS           16          controller flags
CSTA            4           controller state
PERR            9           port error number
CRED            5           host credits
HAT             17          host available timer
HTMO            17          host timeout value
CPKT[0:3]       5           current packet, units 0-3
PKTQ[0:3]       5           packet queue, units 0-3
UFLG[0:3]       16          unit flags, units 0-3
INT             1           interrupt request
ITIME           1           response time for initialization steps
                            (except for step 4)
QTIME           24          response time for 'immediate' packets
XTIME           24          response time for data transfers
PKTS[33*32]     16          packet buffers, 33W each, 32 entries
```

Some DEC operating systems, notably RSX11M/M+, are very sensitive to the timing parameters. Changing the default values may cause M/M+ to crash on boot or to hang during operation.

Error handling is as follows:

```
error           processed as

not attached    disk not ready

end of file     assume rest of disk is zero

OS I/O error    report error and stop
```

2.8 RF11/RS11 Fixed Head Disk (RF)

RF11 options include the ability to set the number of platters to a fixed value between 1 and 8, or to autosize the number of platters:

```
SET RF 1P                   one platter (256K)
SET RF 2P                   two platters (512K)
SET RF 3P                   three platters (768K)
SET RF 4P                   four platters (1024K)
SET RF 5P                   four platters (1280K)
SET RF 6P                   four platters (1536K)
SET RF 7P                   four platters (1792K)
SET RF 8P                   four platters (2048K)
SET RF AUTOSIZE             autosized on ATTACH
```

The default is one platter. The RF11 supports the BOOT command. The RF11 is disabled at startup and is automatically disabled in a Qbus system.

The RF11 implements these registers:

```
name            size        comments

RFCS            16          control/status
RFWC            16          word count
RFCMA           16          current memory address
RFDA            16          current disk address
RFDAE           16          disk address extension
```

```
RFDBR           16          data buffer
RFMR            16          maintenance register
RFWLK           32          write lock switches
INT             1           interrupt pending flag
ERR             1           device error flag
DONE            1           device done flag
IE              1           interrupt enable flag
TIME            24          rotational delay, per word
BURST           1           burst flag
STOP_IOE        1           stop on I/O error
```

The RF11 is a DMA device. If BURST = 0, word transfers are scheduled individually; if BURST = 1, the entire transfer occurs in a single DMA transfer.

Error handling is as follows:

```
error         STOP_IOE      processed as

not attached      1         report error and stop
                  0         non-existent disk
```

RF11 data files are buffered in memory; therefore, end of file and OS I/O errors cannot occur.

2.9 TC11/TU56 DECtape (DT)

DECtapes drives are numbered 1-8; in the simulator, drive 8 is unit 0. DECtape options include the ability to make units write enabled or write locked.

```
SET DTn LOCKED              set unit n write locked
SET DTn WRITEENABLED        set unit n write enabled
```

Units can be set `ENABLED` or `DISABLED`. The TC11 supports the `BOOT` command. The TC11 is automatically disabled in a Qbus system.

The TC11 supports supports PDP-8 format, PDP-11 format, and 18b format DECtape images. `ATTACH` assumes the image is in PDP-11 format; the user can force other choices with switches:

```
-t                          PDP-8 format
-f                          18b format
-a                          autoselect based on file size
```

The DECtape controller is a data-only simulator; the timing and mark track, and block header and trailer, are not stored. Thus, the WRITE TIMING AND MARK TRACK function is not supported; the READ ALL function always returns the hardware standard block header and trailer; and the WRITE ALL function dumps non-data words into the bit bucket.

The TC controller implements these registers:

```
name            size        comments

TCST            16          status register
TCCM            16          command register
TCWC            16          word count register
TCBA            16          bus address register
TCDT            16          data register
```

```
INT             1          interrupt pending flag
ERR             1          error flag
DONE            1          done flag
IE              1          interrupt enable flag
CTIME           31         time to complete transport stop
LTIME           31         time between lines
DCTIME          31         time to decelerate to a full stop
SUBSTATE        2          read/write command substate
POS[0:7]        32         position, in lines, units 0-7
STATT[0-7]      31         unit state, units 0-7
STOP_OFFR       1          stop on off-reel error
```

It is critically important to maintain certain timing relationships among the DECtape parameters, or the DECtape simulator will fail to operate correctly.

- LTIME must be at least 6
- DCTIME needs to be at least 100 times LTIME

Acceleration time is set to 75% of deceleration time.

2.10 Magnetic Tape Controllers

2.10.1 TM11 Magnetic Tape (TM)

TM options include the ability to make units write enabled or write locked.

```
SET TMn LOCKED              set unit n write locked
SET TMn WRITEENABLED        set unit n write enabled
```

Magnetic tape units can be set to a specific reel capacity in MB, or to unlimited capacity:

```
SET TMn CAPAC=m             set unit n capacity to m MB (0 = unlimited)
SHOW TMn CAPAC              show unit n capacity in MB
```

Units can be set `ENABLED` or `DISABLED`.

The TM11 supports the `BOOT` command. The bootstrap supports both original and DEC standard boot formats. Originally, a tape bootstrap read and executed the first record on tape. To allow for ANSI labels, the DEC standard bootstrap skipped the first record and read and executed the second. The DEC standard is the default; to bootstrap an original format tape, use the command `BOOT -O MTn`. The TM11 is automatically disabled in a Qbus system with more than 256KB of memory.

The TM controller implements these registers:

```
name            size       comments

MTS             16         status
MTC             16         command
MTCMA           16         memory address
MTBRC           16         byte/record count
INT             1          interrupt pending flag
ERR             1          error flag
DONE            1          device done flag
IE              1          interrupt enable flag
STOP_IOE        1          stop on I/O error
```

```
TIME            24          delay
UST[0:7]        16          unit status, units 0-7
POS[0:7]        32          position, units 0-7
```

Error handling is as follows:

```
error           processed as

not attached    tape not ready; if STOP_IOE, stop

end of file     bad tape

OS I/O error    parity error; if STOP_IOE, stop
```

2.10.2 TS11/TSV05 Magnetic Tape (TS)

TS options include the ability to make the unit write enabled or write locked.

```
SET TS LOCKED               set unit write locked
SET TS WRITEENABLED         set unit write enabled
```

The TS drive can be set to a specific reel capacity in MB, or to unlimited capacity:

```
SET TS0 CAPAC=m             set capacity to m MB (0 = unlimited)
SHOW TS0 CAPAC              show capacity in MB
```

The TS11 supports the BOOT command. The bootstrap supports only DEC standard boot formats. To allow for ANSI labels, the DEC standard bootstrap skipped the first record and read and executed the second. In a Unibus system, the TS behaves like the TS11 and implements 18b addresses. In a Qbus system, the TS behaves like the TSV05 and implements 22b addresses.

The TS controller implements these registers:

```
name            size        comments

TSSR            16          status register
TSBA            16          bus address register
TSDBX           16          data buffer extension register
CHDR            16          command packet header
CADL            16          command packet low address or count
CADH            16          command packet high address
CLNT            16          command packet length
MHDR            16          message packet header
MRFC            16          message packet residual frame count
MXS0            16          message packet extended status 0
MXS1            16          message packet extended status 1
MXS2            16          message packet extended status 2
MXS3            16          message packet extended status 3
MXS4            16          message packet extended status 4
WADL            16          write char packet low address
WADH            16          write char packet high address
WLNT            16          write char packet length
WOPT            16          write char packet options
WXOPT           16          write char packet extended options
ATTN            1           attention message pending
BOOT            1           boot request pending
```

```
OWNC            1           if set, tape owns command buffer
OWNM            1           if set, tape owns message buffer
TIME            24          delay
POS             32          position
```

Error handling is as follows:

```
error           processed as

not attached    tape not ready

end of file     bad tape

OS I/O error    fatal tape error
```

2.10.3 TQK50 TMSCP Disk Controller (TQ)

The TQ controller simulates the TQK50 TMSCP disk controller. TQ options include the ability to set units write enabled or write locked, and to specify the controller type and tape length:

```
SET TQn LOCKED              set unit n write locked
SET TQn WRITEENABLED        set unit n write enabled
SET TQ TK50                 set controller type to TK50
SET TQ TK70                 set controller type to TK70
SET TQ TU81                 set controller type to TU81
SET TQ TKUSER{=n}           set controller type to TK50 with
                            tape capacity of n MB
```

User-specified capacity must be between 50 and 2000 MB.

Regardless of the controller type, individual units can be set to a specific reel capacity in MB, or to unlimited capacity:

```
SET TQn CAPAC=m             set unit n capacity to m MB (0 = unlimited)
SHOW TQn CAPAC              show unit n capacity in MB
```

The TQ controller supports the BOOT command. In a Unibus system, the TQ supports 18b addressing. In a Qbus system, the TQ supports 22b addressing.

The TQ controller implements the following special SHOW commands:

```
SHOW TQ TYPE                show controller type
SHOW TQ RINGS               show command and response rings
SHOW TQ FREEQ               show packet free queue
SHOW TQ RESPQ               show packet response queue
SHOW TQ UNITQ               show unit queues
SHOW TQ ALL                 show all ring and queue state
SHOW TQn UNITQ              show unit queues for unit n
```

The TQ controller implements these registers:

```
name            size        comments

SA              16          status/address register
S1DAT           16          step 1 init host data
CQBA            22          command queue base address
```

```
CQLNT           8       command queue length
CQIDX           8       command queue index
RQBA            22      request queue base address
RQLNT           8       request queue length
RQIDX           8       request queue index
FREE            5       head of free packet list
RESP            5       head of response packet list
PBSY            5       number of busy packets
CFLGS           16      controller flags
CSTA            4       controller state
PERR            9       port error number
CRED            5       host credits
HAT             17      host available timer
HTMO            17      host timeout value
CPKT[0:3]       5       current packet, units 0-3
PKTQ[0:3]       5       packet queue, units 0-3
UFLG[0:3]       16      unit flags, units 0-3
POS[0:3]        32      tape position, units 0-3
OBJP[0:3]       32      object position, units 0-3
INT             1       interrupt request
ITIME           1       response time for initialization steps
                        (except for step 4)
QTIME           24      response time for 'immediate' packets
XTIME           24      response time for data transfers
PKTS[33*32]     16      packet buffers, 33W each, 32 entries
```

Some DEC operating systems, notably RSX11M/M+, are very sensitive to the timing parameters. Changing the default values may cause M/M+ to crash on boot or to hang during operation.

Error handling is as follows:

```
error           processed as

not attached    tape not ready

end of file     end of medium

OS I/O error    fatal tape error
```

2.11 Communications Devices

2.11.1 KL11/DL11 Additional Terminal Interfaces

For early system programs, the PDP-11 simulator supports up to sixteen additional KL11/DL11 terminal interfaces. The additional terminals consist of two independent devices, TTIX and TTOX. The entire set is modeled as a terminal multiplexer, with TTIX as the master controller. The additional terminals perform input and output through Telnet sessions connected to a user-specified port. The number of lines is specified with a SET command:

```
SET TTIX LINES=n            set number of additional lines to n [1-16]
```

The ATTACH command specifies the port to be used:

```
ATTACH TTIX <port>          set up listening port
```

where port is a decimal number between 1 and 65535 that is not being used for other TCP/IP activities. The additional terminals are disabled by default.

The additional terminals can be set to one of four modes: UC, 7P, 7B, or 8B.

mode	input characters	output characters
UC	lower case converted to upper case, high-order bit cleared	lower case converted to upper case, high-order bit cleared, non-printing characters suppressed
7P	high-order bit cleared	high-order bit cleared, non-printing characters suppressed
7B	high-order bit cleared	high-order bit cleared
8B	no changes	no changes

The default mode is UC. Finally, each line supports output logging. The `SET TTOXn LOG` command enables logging on a line:

`SET TTOXn LOG=filename`	log output of line n to filename

The `SET TTOXn NOLOG` command disables logging and closes the open log file, if any.

Once TTIX is attached and the simulator is running, the terminals listen for connections on the specified port. They assume that the incoming connections are Telnet connections. The connections remain open until disconnected either by the Telnet client, a `SET TTIX DISCONNECT` command, or a `DETACH TTIX` command.

Other special commands:

`SHOW TTIX CONNECTIONS`	show current connections
`SHOW TTIX STATISTICS`	show statistics for active connections
`SET TTOXn DISCONNECT`	disconnects the specified line.

The input device (TTIX) implements these registers:

name	size	comments
CSR[0:15]	16	input control/stats register, lines 0-15
BUF[0:15]	16	input buffer, lines 0-15
IREQ	16	interrupt requests, lines 0-15

The output device (TTOX) implements these registers:

name	size	comments
CSR[0:15]	16	input control/stats register, lines 0-15
BUF[0:15]	8	input buffer, lines 0-15
IREQ	16	interrupt requests, lines 0-15
TIME[0:15]	31	time from I/O initiation to interrupt, lines 0-15

The additional terminals do not support save and restore. All open connections are lost when the simulator shuts down or TTIX is detached.

2.11.2 DZ11 Terminal Multiplexer (DZ)

The DZ11 is an 8-line terminal multiplexer. Up to 4 DZ11's (32 lines) are supported. The number of lines can be changed with the command

```
SET DZ LINES=n                set line count to n
```

The line count must be a multiple of 8, with a maximum of 32.

The DZ11 supports three character processing modes, 7P, 7B, and 8B:

```
mode  input characters        output characters

7P    high-order bit cleared  high-order bit cleared,
                              non-printing characters suppressed
7B    high-order bit cleared  high-order bit cleared
8B    no changes              no changes
```

The default is 8B.

The DZ11 supports logging on a per-line basis. The command

```
SET DZ LOG=line=filename
```

enables logging for the specified line to the indicated file. The command

```
SET DZ NOLOG=line
```

disables logging for the specified line and closes any open log file. Finally, the command

```
SHOW DZ LOG
```

displays logging information for all DZ lines.

The terminal lines perform input and output through Telnet sessions connected to a user-specified port. The `ATTACH` command specifies the port to be used:

```
ATTACH {-am} DZ <port>        set up listening port
```

where port is a decimal number between 1 and 65535 that is not being used for other TCP/IP activities. The optional switch -m turns on the DZ11's modem controls; the optional switch -a turns on active disconnects (disconnect session if computer clears Data Terminal Ready). Without modem control, the DZ behaves as though terminals were directly connected; disconnecting the Telnet session does not cause any operating system-visible change in line status.

Once the DZ is attached and the simulator is running, the DZ will listen for connections on the specified port. It assumes that the incoming connections are Telnet connections. The connection remains open until disconnected by the simulated program, the Telnet client, a `SET DZ DISCONNECT` command, or a `DETACH DZ` command.

Other special DZ commands:

```
SHOW DZ CONNECTIONS           show current connections
SHOW DZ STATISTICS            show statistics for active connections
SET DZ DISCONNECT=linenumber  disconnects the specified line.
```

The DZ11 implements these registers:

```
name              size        comments

CSR[0:3]          16          control/status register, boards 0..3
RBUF[0:3]         16          receive buffer, boards 0..3
LPR[0:3]          16          line parameter register, boards 0..3
TCR[0:3]          16          transmission control register, boards 0..3
MSR[0:3]          16          modem status register, boards 0..3
TDR[0:3]          16          transmit data register, boards 0..3
SAENB[0:3]        1           silo alarm enabled, boards 0..3
RXINT             4           receive interrupts, boards 3..0
TXINT             4           transmit interrupts, boards 3..0
MDMTCL            1           modem control enabled
AUTODS            1           autodisconnect enabled
```

The DZ11 does not support save and restore. All open connections are lost when the simulator shuts down or the DZ is detached.

2.11.3 DHQ11 Terminal Multiplexer (VH)

The DHQ11 is an 8-line terminal multiplexer for Qbus systems. Up to 4 DHQ11's are supported.

The DHQ11 is a programmable asynchronous terminal multiplexer. It has two programming modes: DHV11 and DHU11. The register sets are compatible with these devices. For transmission, the DHQ11 can be used in either DMA or programmed I/O mode. For reception, there is a 256-entry FIFO for received characters, dataset status changes, and diagnostic information, and a programmable input interrupt timer (in DHU mode). The device supports 16-, 18-, and 22-bit addressing. The DHQ11 can be programmed to filter and/or handle XON/XOFF characters independently of the processor. The DHQ11 supports programmable bit width (between 5 and 8) for the input and output of characters.

The DHQ11 has a rocker switch for determining the programming mode. By default, the DHV11 mode is selected, though DHU11 mode is recommended for applications that can support it. The VH controller may be adjusted on a per controller basis as follows:

```
SET VHn DHU                 use the DHU programming mode and registers
SET VHn DHV                 use the DHV programming mode and registers
```

DMA output is supported. In a real DHQ11, DMA is not initiated immediately upon receipt of TX.DMA.START but is dependent upon some internal processes. The VH controller mimics this behavior by default. It may be desirable to alter this and start immediately, though this may not be compatible with all operating systems and diagnostics. You can change the behavior of the VH controller as follows:

```
SET VHn NORMAL              use normal DMA procedures
SET VHn FASTDMA             set DMA to initiate immediately
```

The terminal lines perform input and output through Telnet sessions connected to a user-specified port. The ATTACH command specifies the port to be used:

```
ATTACH VH <port>            set up listening port
```

where port is a decimal number between 1 and 65535 that is not being used for other TCP/IP activities. This port is the point of entry for al lines on all VH controllers.

Modem and auto-disconnect support may be set on an individual controller basis. The SET MODEM command directs the controller to report modem status changes to the computer. The SET HANGUP command turns on active disconnects (disconnect session if computer clears Data Terminal Ready).

```
SET VHn [NO]MODEM             disable/enable modem control
SET VHn [NO]HANGUP            disable/enable disconnect on DTR drop
```

Once the VH is attached and the simulator is running, the VH will listen for connections on the specified port. It assumes that the incoming connections are Telnet connections. The connection remains open until disconnected by the simulated program, the Telnet client, a `SET VH DISCONNECT` command, or a `DETACH VH` command.

Other special VH commands:

```
SHOW VH CONNECTIONS           show current connections
SHOW VH STATISTICS            show statistics for active connections
SET VH DISCONNECT=linenumber  disconnects the specified line.
```

The DHQ11 implements these registers, though not all can be examined from SCP:

```
  name            size        comments

  CSR[0:3]        16          control/status register, boards 0..3
  RBUF[0:3]       16          receive buffer, boards 0..3
  LPR[0:3]        16          line parameter register, boards 0..3
  RXINT           4           receive interrupts, boards 3..0
  TXINT           4           transmit interrupts, boards 3..0
```

[more to be described...]

The DHQ11 does not support save and restore. All open connections are lost when the simulator shuts down or the VH is detached.

2.12 Ethernet Controllers

2.12.1 DELQA/DEQNA Qbus Ethernet Controllers (XQ, XQB)

The simulator implements two DELQA/DEQNA Qbus Ethernet controllers (XQ, XQB). Initially, XQ is enabled, and XQB is disabled. Options allow control of the MAC address, the controller mode, and the sanity timer.

```
SET  XQ MAC=<mac-address>     ex. 08-00-2B-AA-BB-CC
SHOW XQ MAC
```

These commands are used to change or display the MAC address. <mac-address> is a valid ethernet MAC, delimited by dashes or periods. The controller defaults to 08-00-2B-AA-BB-CC, which should be sufficient if there is only one SIMH controller on your LAN. Two cards with the same MAC address will see each other's packets, resulting in a serious mess.

```
SET  XQ TYPE={DEQNA|[DELQA]}
SHOW XQ TYPE
```

These commands are used to change or display the controller mode. DELQA mode is better and faster but may not be usable by older or non-DEC OS's. Also, be aware that DEQNA mode is not supported by many modern OS's. The DEQNA-LOCK mode of the DELQA card is emulated by setting the the controller to

DEQNA -- there is no need for a separate mode. DEQNA-LOCK mode behaves exactly like a DEQNA, except for the operation of the VAR and MOP processing.

```
SET  XQ SANITY={ON|[OFF]}
SHOW XQ SANITY
```

These commands change or display the INITIALIZATION sanity timer (DEQNA jumper W3/DELQA switch S4). The INITIALIZATION sanity timer has a default timeout of 4 minutes, and cannot be turned off, just reset. The normal sanity timer can be set by operating system software regardless of the state of this switch. Note that only the DEQNA (or the DELQA in DEQNA-LOCK mode (=DEQNA)) supports the sanity timer -- it is ignored by a DELQA in Normal mode, which uses switch S4 for a different purpose.

```
SET  XQ POLL={DEFAULT|4..2500}
SHOW XQ POLL
```

These commands change or display the service polling timer. The polling timer is calibrated to run the service thread 200 times per second. This value can be changed to accomodate particular system requirements for more (or less) frequent polling.

```
SHOW XQ STATS
```

This command will display the accumulated statistics for the simulated Ethernet controller.

To access the network, the simulated Ethernet controller must be attached to a real Ethernet interface:

```
ATTACH XQ0 {ethX|<device_name>}           ex. eth0 or /dev/era0
SHOW XQ ETH
```

where X in 'ethX' is the number of the Ethernet controller to attach, or the real device name. The X number is system dependant. If you only have one Ethernet controller, the number will probably be 0. To find out what your system thinks the Ethernet numbers are, use the SHOW XQ ETH command. The device list can be quite cryptic, depending on the host system, but is probably better than guessing. If you do not attach the device, the controller will behave as though the Ethernet cable were unplugged.

XQ and XQB have the following registers:

name	size	comments
SA0	16	station address word 0
SA1	16	station address word 1
SA2	16	station address word 2
SA3	16	station address word 3
SA4	16	station address word 4
SA5	16	station address word 5
RBDL	32	receive buffer descriptor list
XBDL	32	trans(X)mit buffer descriptor list
CSR	16	control status register
VAR	16	vector address register
INT	1	interrupt request flag

One final note: because of its asynchronous nature, the XQ controller is not limited to the ~1.5Mbit/sec of the real DEQNA/DELQA controllers, nor the 10Mbit/sec of a standard Ethernet. Attach it to a Fast Ethernet (100 Mbit/sec) card, and "Feel the Power!" :-)

2.12.2 DELUA/DEUNA Unibus Ethernet Controllers (XU, XUB)

The simulator implements two DELUA/DEUNA Unibus Ethernet controllers (XU, XUB). Its operation is analogous to the DELQA/DEQNA controller.

2.13 CR11/CD11 Card Reader (CR)

The card reader (CR) implements a single controller (either the CR11 or the CD11) and card reader (e.g., Documation M200, GDI Model 100) by reading a file and presenting lines or cards to the simulator. Card decks may be represented by plain text ASCII files, card image files, or column binary files. The CR11 controller is also compatible with the CM11-F, CME11, and CMS11.

Card image files are a file format designed by Douglas W. Jones at the University of Iowa to support the interchange of card deck data. These files have a much richer information carrying capacity than plain ASCII files. Card Image files can contain such interchange information as card-stock color, corner cuts, special artwork, as well as the binary punch data representing all 12 columns. Complete details on the format, as well as sample code, are available at Prof. Jones's site: http://www.cs.uiowa.edu/~jones/cards/.

The card reader can be configured to support either of the two controllers supported by DEC:

```
SET CR CR11       set controller type to CR11
SET CR CD11       set controller type to CD11
```

The controller type must be set before attaching a virtual card deck to the device. You may NOT change controller type once a file is attached.

The primary differences are summarized in the table below. By default, CR11 simulation is selected.

	CR11	CD11
BR	6	4
registers	4	3
data transfer	BR	DMA
card rate	200-600	1000-1200
hopper cap.	<= 1000	1000-2250
cards	Mark-sense & punched	punched only

Examples of the CR11 include the M8290 and M8291 (CMS11). All card readers use a common vector at 0230 and CSR at 177160. Even though the CR11 is normally configured as a BR6 device, it is configured for BR4 in this simulation.

The card reader supports ASCII, card image, and column binary format card “decks.” When reading plain ASCII files, lines longer than 80 characters are silently truncated. Card image support is included for 80 column Hollerith, 82 column Hollerith (silently ignoring columns 0 and 81), and 40 column Hollerith (mark-sense) cards. Column binary supports 80 column card images only. All files are attached read-only (as if the -R switch were given).

```
ATTACH –A CR <file>               file is ASCII text
ATTACH –B CR <file>               file is column binary
ATTACH –I CR <file>               file is card image format
```

If no flags are given, the file extension is evaluated. If the filename ends in .TXT, the file is treated as ASCII text. If the filename ends in .CBN, the file is treated as column binary. Otherwise, the CR driver looks for a card image header. If a correct header is found the file is treated as card image format, otherwise it is treated as ASCII text.

The correct character translation MUST be set if a plain text file is to be used for card deck input. The correct translation SHOULD be set to allow correct ASCII debugging of a card image or column binary input deck. Depending upon the operating system in use, how it was generated, and how the card data will be read and used, the translation must be set correctly so that the proper character set is used by the driver. Use the following command to explicitly set the correct translation:

```
SET TRANSLATION={DEFAULT|026|026FTN|029|EBCDIC}
```

This command should be given after a deck is attached to the simulator. The mappings above are completely described at http://www.cs.uiowa.edu/~jones/cards/codes.html. Note that DEC typically used 029 or 026FTN mappings.

DEC operating systems used a variety of methods to determine the end of a deck (recognizing that 'hopper empty' does not necessarily mean the end of a deck. Below is a summary of the various operating system conventions for signaling end of deck:

RT-11:	12-11-0-1-6-7-8-9 punch in column 1
RSTS/E:	12-11-0-1 or 12-11-0-1-6-7-8-9 punch in column 1
RSX:	12-11-0-1-6-7-8-9 punch
VMS:	12-11-0-1-6-7-8-9 punch in first 8 columns
TOPS:	12-11-0-1 or 12-11-0-1-6-7-8-9 punch in column 1

Using the AUTOEOF setting, the card reader can be set to automatically generate an EOF card consisting of the 12-11-0-1-6-7-8-9 punch in columns 1-8. When set to CD11 mode, this switch also enables automatic setting of the EOF bit in the controller after the EOF card has been processed. [The CR11 does not have a similar capability.] By default AUTOEOF is enabled.

```
SET CR AUTOEOF
SET CR NOAUTOEOF
```

The default card reader rate for the CR11 is 285 cpm, while the default rate for the CD11 is 1000 cpm. The reader rate can be set to its default value or to anywhere in the range 200..1200 cpm. This rate may be changed while the unit is attached.

```
SET CR RATE={DEFAULT|200..1200}
```

It is standard operating procedure for operators to load a card deck and press the momentary action RESET button to clear any error conditions and alert the processor that a deck is available to read. Use the following command to simulate pressing the card reader RESET button,

```
SET CR RESET
```

Another common control of physical card readers is the STOP button. An operator could use this button to finish the read operation for the current card and terminate reading a deck early. Use the following command to simulate pressing the card reader STOP button.

```
SET CR STOP
```

The simulator does not support the BOOT command. The simulator does not stop on file I/O errors. Instead the controller signals a reader check to the CPU.

The CR controller implements these registers:

```
name            size        comments
BUF             8           ASCII value of last column processed
CRS             16          CR11 status register
CRB1            16          CR11 12-bit Hollerith character
CRB2            16          CR11 8-bit compressed character
CRM             16          CR11 maintenance register
CDST            16          CD11 control/status register
CDCC            16          CD11 column count
CDBA            16          CD11 current bus address
CDDB            16          CD11 data buffer, 2nd status
BLOWER          2           blower state value
INT             1           interrupt pending flag
ERR             1           error flag (CRS<15>)
IE              1           interrupt enable flag (CRS<6>)
POS             32          file position - do not alter
TIME            24          delay time between columns
```

The CD11 simulation includes the Rev. J modification to make the CDDB act as a second status register during non-data transfer periods.

3 Symbolic Display and Input

The PDP-11 simulator implements symbolic display and input. Display is controlled by command line switches:

```
-a              display as ASCII character
-c              display as two character ASCII string
-m              display instruction mnemonics
```

Input parsing is controlled by the first character typed in or by command line switches:

```
' or -a         ASCII character
" or -c         two character ASCII string
alphabetic      instruction mnemonic
numeric         octal number
```

Instruction input uses standard PDP-11 assembler syntax. There are sixteen instruction classes:

```
class           operands                examples                comments

no operands     none                    HALT, RESET
3b literal      literal [0-7]           SPL
6b literal      literal [0-077]         MARK
8b literal      literal [0-0377]        EMT, TRAP
register        register                RTS
sop             specifier               SWAB, CLR, ASL
reg-sop         register, specifier     JSR, XOR, MUL
fop             flt specifier           ABSf, NEGf
ac-fop          flt reg, flt specifier  LDf, MULf
ac-sop          flt reg, specifier      LDEXP, STEXP
ac-moded sop    flt reg, specifier      LDCif, STCfi
dop             specifier, specifier    MOV, ADD, BIC
cond branch     address                 BR, BCC, BNE
sob             register, address       SOB
```

```
cc clear          cc clear instructions   CLC, CLV, CLZ, CLN      combinable
cc set            cc set instructions     SEC, SEV, SEZ, SEN      combinable
```

For floating point opcodes, F and D variants, and I and L variants, may be specified regardless of the state of FPS.

The syntax for specifiers is as follows:

```
syntax            specifier   displacement      comments

Rn                0n          -
Fn                0n          -                 only in flt reg classes
(Rn)              1n          -
@(Rn)             7n          0                 equivalent to @0(Rn)
(Rn)+             2n          -
@(Rn)+            3n          -
-(Rn)             4n          -
@-(Rn)            5n          -
{+/-}d(Rn)        6n          {+/-}d
@{+/-}d(Rn)       7n          {+/-}d
#n                27          n
@#n               37          n
.+/-n             67          +/-n - 4
@.+/-n            77          +/-n - 4
{+/-}n            67          {+/-}n - PC - 4   if on disk, 37 and n
@{+/-}n           77          {+/-}n - PC - 4   if on disk, invalid
```