# Disk diagnostic

## Purpose

The disc diagnostic is a tool for disc drive producers to check out the hardware and software involved in disc drive production.

## Overview

Discdiag is a command line program designed to read and write sectors from a disc. It can be used to check out disc drivers as well as hardware. It uses simple commands to read, write and show data within sectors, as well as automatically check it. It is fully scriptable, meaning that it can be both used immediately from the command line, as well has have those commands written into complex scripts that run fully automated tests against the disc drive.

## Implementation

Disçdiag features a separate I/O interface module that implements opening, closing, read and write sectors, show the size of the disc, and show what disks are online for testing.

It has been ported to Windows, Linux and DOS/BIOS. The diagnostic uses the fact that all of these systems can access disc sectors directly.

## Files in the project

cdiscdiag Batch file that creates the Linux executable.

cdiscdiag.bat Batch file that creates the Windows executables.

cdiscdiag\_dos.bat Batch file that creates the DOS/BIOS executable.

discdiag.exe Windows or dos executable.

discdiag\_linux.exe Windows "Linux pseudo executable".

Discdiag The linux executable.

discio.h General header file for OS specific functions.

linuxio.c The Linux I/O and specifics library.

readme.txt A quick explanation of the files in the project.

winio.c The Windows I/O specifics library.

stubio.c A test/no-op I/O implementation that reads and writes an array.

dosio.c A DOS/BIOS implementation of the I/O.

## Commands

The diagnostic executes lines from the console. Each command is of the format:

command [parameter]…

The command is an alphanumeric label. Any number of parameters can appear. They may be labels, quoted strings, numeric values, or even full expressions.

Multiple commands can appear on a line as:

Command [; command]

At any place on a command line, the character “!” introduces a comment. The rest of the line will be ignored. If the “!” character appears within a quoted string, it will not be treated as a comment.

Each command usually has multiple forms, a short form and a long form, such as:

p

Or

print

The purpose of this is to allow short commands to be typed in immediately, and then the longer versions can be used for building scripts that are more “self documenting”. Of course the use of the long versions is entirely optional.

## Workings of the diagnostic

Discdiag centers around two commands, read and write:

read [lba [num]]

write [lba [num]]

Which can be shortened to “r” and “w”. Discdiag contains two buffers, the write and the read buffers:

Write buffer

Read buffer

The write buffer contains all data that is to be written to the disk. The read buffer contains all data that is read from the disk. For each of the read and write commands, some number of sectors starting at buffer location 0 are written to the disk or read from the disk.

The reason for the buffer is that disk operations are more efficient in blocks of sectors. Also, this matches the way the disk is actually used. It is written and read in varying size blocks. The buffers are sized to be fairly large, 256 sectors of 512 bytes each (on Windows and Linux) so that disk write and read tests and be performed as efficient whole buffer operations.

The object of having the separated buffers is that a predefined pattern can be set up in the write buffer, then written to disk, read back, and then checked for correctness. This can either be done by simply comparing the buffers to each other, or by comparing the read buffer to a known pattern.

Everything in the diagnostic is enumerated in terms of sectors. Thus, the number of sectors to be read or written is specified. The disks are listed by the size in terms of sectors. A sector contains 512 bytes, a convention that goes back to the PDP-11 days.

The lbas, or Logical Block Address, number the sectors from 0 to N, where N is the size of the disk-1.

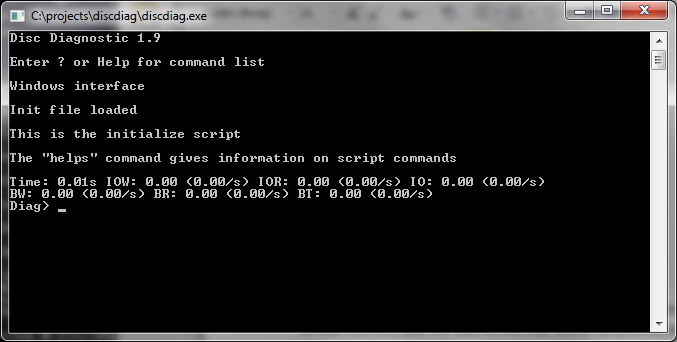
Thus:

Diag> r 10 5

Means read 5 sectors starting at LBA 10 from the disk to the read buffer starting at location 0, and proceeding to location 9.

## Starting discdiag

Discdiag is executed as a command line program as a cmd, term or dos shell:



It must be executed with administrator privileges in order to see the raw drives in use. This is done in Windows by right clicking the discdiag.exe file and selecting “Run as administrator”. It is done in Linux by running the command as sudo (root permissions). In DOS it is run as normal, since that system has no permissions needed.

The first command you want to run is to list the available disks using the “listdrives” or “ld” command:

Diag> ld

Physical drives available:

Drive 0 (\\.\PhysicalDrive0) available 3907029168 lbas

This lists the available drives and the number of sectors they contain (lbas). Drives in discdiag are numbered from 0 to 9. The logical name of the drive is listed next, and then the size in sectors (lbas).

On all systems drive 0 is typically the boot drive and contains the operating system. For this reason, selecting drive 0 generates a warning:

\*\*\* Warning: You have selected the system drive

This is to remind you that you can damage the disk you are standing on with discdiag. In addition, all drives are write protected by default. To enable write access, the “unprot” command must be used.

The operating system name of the drive also appears in the ld command. In Linux, this is the path, /dev/sd?, of the drive in the device tree. In Windows, it is a special path name used to reference the physical drive. In DOS, there are no names of drives, only numbers, so the drive is simply listed as “driveN”, where N is the drive number.

In Windows and DOS, the drive is commonly associated with a “drive letter”, such as C:. This is not the same thing as a disk drive, because in Windows and DOS, there can be multiple “logical drives” per disk. Discdiag always deals with physical disks, no matter what they contain.

To access a drive, it must be set active. This is done with the “drive” command:

Diag> drive 1

Only one disk is active at a time. Once the drive is selected, all other commands dealing with the disk refer to the active drive.

Here’s a typical sequence dealing with the active drive, and reading from the MBR (Master Boot Record):

Disc Diagnostic 1.9

Enter ? or Help for command list

Windows interface

Init file loaded

This is the initialize script

The "helps" command gives information on script commands

Time: 0.00s IOW: 0.00 (0.00/s) IOR: 0.00 (0.00/s) IO: 0.00 (0.00/s)

BW: 0.00 (0.00/s) BR: 0.00 (0.00/s) BT: 0.00 (0.00/s)

Diag> ld

Physical drives available:

Drive 0 (\\.\PhysicalDrive0) available 3907029168 lbas

Diag> drive 0

\*\*\* Warning: You have selected the system drive

Time: 0.00s IOW: 0.00 (0.00/s) IOR: 0.00 (0.00/s) IO: 0.00 (0.00/s)

BW: 0.00 (0.00/s) BR: 0.00 (0.00/s) BT: 0.00 (0.00/s)

Diag> r

Time: 0.01s IOW: 0.00 (0.00/s) IOR: 1.00 (100.00/s) IO: 1.00 (100.00/s)

BW: 0.00 (0.00/s) BR: 512.00 (50.00k/s) BT: 512.00 (50.00k/s)

Diag> dr

Contents of sector:

00000000: 33 c0 8e d0 bc 00 7c 8e c0 8e d8 be 00 7c bf 00 "3@.P<.|.@.X>.|?"

00000010: 06 b9 00 02 fc f3 a4 50 68 1c 06 cb fb b9 04 00 "..9..|s$Ph..K{9."

00000020: bd be 07 80 7e 00 00 7c 0b 0f 85 0e 01 83 c5 10 ".=>..~..|......E"

00000030: e2 f1 cd 18 88 56 00 55 c6 46 11 05 c6 46 10 00 ".bqM..V.UFF..FF."

00000040: b4 41 bb aa 55 cd 13 5d 72 0f 81 fb 55 aa 75 09 ".4A;\*UM.]r..{U\*u"

00000050: f7 c1 01 00 74 03 fe 46 10 66 60 80 7e 10 00 74 ".wA..t.~F.f`.~.."

00000060: 26 66 68 00 00 00 00 66 ff 76 08 68 00 00 68 00 "t&fh....f⌂v.h..h"

00000070: 7c 68 01 00 68 10 00 b4 42 8a 56 00 8b f4 cd 13 ".|h..h..4B.V..tM"

00000080: 9f 83 c4 10 9e eb 14 b8 01 02 bb 00 7c 8a 56 00 "...D..k.8..;.|.V"

00000090: 8a 76 01 8a 4e 02 8a 6e 03 cd 13 66 61 73 1c fe "..v..N..n.M.fas."

000000a0: 4e 11 75 0c 80 7e 00 80 0f 84 8a 00 b2 80 eb 84 "~N.u..~......2.k"

000000b0: 55 32 e4 8a 56 00 cd 13 5d eb 9e 81 3e fe 7d 55 ".U2d.V.M.]k..>~}"

000000c0: aa 75 6e ff 76 00 e8 8d 00 75 17 fa b0 d1 e6 64 "U\*un⌂v.h..u.z0Qf"

000000d0: e8 83 00 b0 df e6 60 e8 7c 00 b0 ff e6 64 e8 75 "dh..0\_f`h|.0⌂fdh"

000000e0: 00 fb b8 00 bb cd 1a 66 23 c0 75 3b 66 81 fb 54 "u.{8.;M.f#@u;f.{"

000000f0: 43 50 41 75 32 81 f9 02 01 72 2c 66 68 07 bb 00 "TCPAu2.y..r,fh.;"

00000100: 00 66 68 00 02 00 00 66 68 08 00 00 00 66 53 66 "..fh....fh....fS"

00000110: 53 66 55 66 68 00 00 00 00 66 68 00 7c 00 00 66 "fSfUfh....fh.|.."

00000120: 61 68 00 00 07 cd 1a 5a 32 f6 ea 00 7c 00 00 cd "fah...M.Z2vj.|.."

00000130: 18 a0 b7 07 eb 08 a0 b6 07 eb 03 a0 b5 07 32 e4 "M. 7.k. 6.k. 5.2"

00000140: 05 00 07 8b f0 ac 3c 00 74 09 bb 07 00 b4 0e cd "d....p,<.t.;..4."

00000150: 10 eb f2 f4 eb fd 2b c9 e4 64 eb 00 24 02 e0 f8 "M.krtk}+Iddk.$.`"

00000160: 24 02 c3 49 6e 76 61 6c 69 64 20 70 61 72 74 69 "x$.CInvalid part"

00000170: 74 69 6f 6e 20 74 61 62 6c 65 00 45 72 72 6f 72 "ition table.Erro"

\*\*\* Hit return to continue \*\*\*

00000180: 20 6c 6f 61 64 69 6e 67 20 6f 70 65 72 61 74 69 "r loading operat"

00000190: 6e 67 20 73 79 73 74 65 6d 00 4d 69 73 73 69 6e "ing system.Missi"

000001a0: 67 20 6f 70 65 72 61 74 69 6e 67 20 73 79 73 74 "ng operating sys"

000001b0: 65 6d 00 00 00 63 7b 9a 62 53 2f 8e 00 00 80 20 "tem...c{.bS/...."

000001c0: 21 00 07 df 13 0c 00 08 00 00 00 20 03 00 00 df " !..\_....... ..."

000001d0: 14 0c 07 fe ff ff 00 28 03 00 00 58 dd e8 00 00 "\_...~⌂⌂.(...X]h."

000001e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 "................"

000001f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 55 aa "...............U"

Time: 0.66s IOW: 0.00 (0.00/s) IOR: 0.00 (0.00/s) IO: 0.00 (0.00/s)

BW: 0.00 (0.00/s) BR: 0.00 (0.00/s) BT: 0.00 (0.00/s)

Diag>

The fact that it is the MBR can be seen by the standard message “Invalid partition table”, and similar messages. On the PC, all MBRs look this way, on all of DOS, Windows and Linux systems.

## Reads, writes and compares

Discdiag can be used to simply explore the drive sector by sector, but there are better tools for this, and there are tools that understand the file structure of the disk as well. To read and write a disk, any data on the disk is going to be corrupted. Before doing that, you need to take the disk off line from the file system. If you don’t do this, the operating system is going to attempt to read and write from the same drive, causing problems.

By type of operating system, this is what you need to do before executing the diagnostic:

Windows From the start menu, right click on computer, select “manage”, then in the computer manager select “storage”, then “disk manager”. Then right click on the disk to be tested and perform “delete volume”. This removes the file system and takes it offline.

Linux Unmount the target drive (“umount”).

DOS DOS does not really have a way to demount drives, nor does it need it. Drives that are not being accessed are not touched, nor are there (usually) any background tasks. Thus you simply need to reformat the drive with a file system after testing to set it back on line.

When reading from the disk drive (“r” or “read” commands), as mentioned, the data goes to the read buffer. You can then view it with the “dr” or “dumpread” command. This command optionally takes the number of sectors to dump, or uses the default of 1 sector.

To see what is to be written, the “dw” or “dumpwrite” command is used, which does the same for the write buffer. The write buffer starts by default as all 0’s, which is not a very interesting pattern. There are a pair of commands to form and check for patterns to write and read:

Pt/pattn [pat [val [cnt]]]

c/comp [pat [val [cnt]]]

The “pt” or pattern command sets up patterns in the write buffer to be written out to the disk. The “c” or compare command checks those patterns exist in the read buffer. Thus, executing:

Diag> pt; w; r; c

1. Writes the default pattern to a single sector on the disk at sector 0.
2. Reads back sector 0.
3. Compares that the first sector of the read buffer contains the default pattern.

In fact, this is the basic test sequence, and most tests are variations on this theme.

## Patterns

There are 5 test patterns available in discdiag. One of these is a “composite pattern” meaning that it can be used with other patterns to create complex combinations. More about that later.

cnt Byte incrementing count.

dwcnt 32 bit incrementing count.

val Numeric 32 bit value, big endian.

rand Random byte value.

lba Only the first 32 bits get LBA, rest is $ff. LBA starts at [val], and increments across buffer. Note that this only writes the first dword of each sector, use another pattern to fill the background.

buffs Compare the read and write buffers to each other. This allows complex patterns to be built up in the write buffer.

### Patterning the write buffer

Here is the default pattern, a “byte count” sequence:

Diag> pt

Time: 0.00s IOW: 0.00 (0.00/s) IOR: 0.00 (0.00/s) IO: 0.00 (0.00/s)

BW: 0.00 (0.00/s) BR: 0.00 (0.00/s) BT: 0.00 (0.00/s)

Diag> dw

Contents of sector:

00000000: 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f "..............."

00000010: 10 11 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f "................"

00000020: 20 21 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f ". !"#$%&'()\*+,-."

00000030: 30 31 32 33 34 35 36 37 38 39 3a 3b 3c 3d 3e 3f "/0123456789:;<=>"

00000040: 40 41 42 43 44 45 46 47 48 49 4a 4b 4c 4d 4e 4f "?@ABCDEFGHIJKLMN"

00000050: 50 51 52 53 54 55 56 57 58 59 5a 5b 5c 5d 5e 5f "OPQRSTUVWXYZ[\]^"

00000060: 60 61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f "\_`abcdefghijklmn"

00000070: 70 71 72 73 74 75 76 77 78 79 7a 7b 7c 7d 7e 7f "opqrstuvwxyz{|}~"

00000080: 80 81 82 83 84 85 86 87 88 89 8a 8b 8c 8d 8e 8f "⌂..............."

00000090: 90 91 92 93 94 95 96 97 98 99 9a 9b 9c 9d 9e 9f "................"

000000a0: a0 a1 a2 a3 a4 a5 a6 a7 a8 a9 aa ab ac ad ae af ". !"#$%&'()\*+,-."

000000b0: b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 ba bb bc bd be bf "/0123456789:;<=>"

000000c0: c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 ca cb cc cd ce cf "?@ABCDEFGHIJKLMN"

000000d0: d0 d1 d2 d3 d4 d5 d6 d7 d8 d9 da db dc dd de df "OPQRSTUVWXYZ[\]^"

000000e0: e0 e1 e2 e3 e4 e5 e6 e7 e8 e9 ea eb ec ed ee ef "\_`abcdefghijklmn"

000000f0: f0 f1 f2 f3 f4 f5 f6 f7 f8 f9 fa fb fc fd fe ff "opqrstuvwxyz{|}~"

00000100: 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f "⌂..............."

00000110: 10 11 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f "................"

00000120: 20 21 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f ". !"#$%&'()\*+,-."

00000130: 30 31 32 33 34 35 36 37 38 39 3a 3b 3c 3d 3e 3f "/0123456789:;<=>"

00000140: 40 41 42 43 44 45 46 47 48 49 4a 4b 4c 4d 4e 4f "?@ABCDEFGHIJKLMN"

00000150: 50 51 52 53 54 55 56 57 58 59 5a 5b 5c 5d 5e 5f "OPQRSTUVWXYZ[\]^"

00000160: 60 61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f "\_`abcdefghijklmn"

00000170: 70 71 72 73 74 75 76 77 78 79 7a 7b 7c 7d 7e 7f "opqrstuvwxyz{|}~"

00000180: 80 81 82 83 84 85 86 87 88 89 8a 8b 8c 8d 8e 8f "⌂..............."

00000190: 90 91 92 93 94 95 96 97 98 99 9a 9b 9c 9d 9e 9f "................"

000001a0: a0 a1 a2 a3 a4 a5 a6 a7 a8 a9 aa ab ac ad ae af ". !"#$%&'()\*+,-."

000001b0: b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 ba bb bc bd be bf "/0123456789:;<=>"

000001c0: c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 ca cb cc cd ce cf "?@ABCDEFGHIJKLMN"

000001d0: d0 d1 d2 d3 d4 d5 d6 d7 d8 d9 da db dc dd de df "OPQRSTUVWXYZ[\]^"

000001e0: e0 e1 e2 e3 e4 e5 e6 e7 e8 e9 ea eb ec ed ee ef "\_`abcdefghijklmn"

000001f0: f0 f1 f2 f3 f4 f5 f6 f7 f8 f9 fa fb fc fd fe ff "opqrstuvwxyz{|}~"

So this is then set up in the write buffer ready to be written to disk.

For the pt command, the default number of sectors to pattern in the write buffer is the full buffer. That is, discdiag assumes you want to set up the entire buffer even if you only write part of it out. Typically you would only need to change that if you want to save the time it takes to setup the buffer. That is, if you only wanted to write 10 sectors, specifying 10 sectors only would save execution time while performing a pattern command.

To specify a pattern, the name of the pattern is used:

Diag> pt cnt

Gives the name of the (default) byte count pattern. The next parameter after the pattern name is an optional parameter to the pattern, which is only used with the “val”, “rand”and “lba” patterns. To specify the number of sectors to be patterned, you have to specify that parameter, even if it is not used. Typically you can just say “0” for the unused parameter:

Diag> pt cnt 0 10

This would set up the byte count pattern on the first 10 sectors in the write buffer.

An alternative to the byte count pattern is a 32 bit (big endian) count. The byte count pattern repeats every 256 bytes. The 32 bit count pattern repeats every 33,554,432 sectors, so it is a better check for “aliasing” of LBA addresses, or having the sector addressing mechanisms of the drive give more than one sector to a given address.

Diag> pt dwcnt 0 10

Formats the write buffer with a 32 bit big endian count for 10 sectors.

The val or value pattern places a 32 bit word that you specify, repeated into the write buffer.

Diag> pt val 0x11223344 10

Formats the write buffer with the big endian value 0x11223344 repeated 128 times per sector for 10 sectors.

The random pattern uses the random number to generate bytes within a sector. The bytes generated are always the same for each sector, meaning that the sectors anywhere on disk can be compared for the same pattern.

Diag> pt rand 0 10

Formats the write buffer with a random byte pattern for 10 sectors.

The lba pattern is used to mark the first 32 bits of each sector with the lba of that sector (big endian). This is used to identify each sector on the disk so that the addressing mechanisms of the driver/disk drive can be verified.

The lba pattern is the only “composite” pattern. It only writes the first 32 bits/4 bytes of the sector, and leaves the rest of the sector intact. This both allows the write buffer to be patterned quickly, as well as gives the ability to form composites with other patterns.

The parameter for the pattern is the starting lba number to be used. The write buffer will be written with lba numbers starting with the parameter, then incrementing until the last sector written.

Diag> pt lba 40 10

Would format the write buffer with lbas, starting with number 40, and proceeding to number 49, for 10 sectors.

The buffs pattern is only used for comparisons.

### Verifying patterns in the read buffer

The pt or pattern command sets up patterns in the write buffer. Typically these patterns are written from the write buffer to the disk, then read back into the read buffer. The same format of command can be used to compare that the read buffer contains the patterns written into the write buffer.

Diag> c cnt 0 10

Verifies that the read buffer contains 10 sectors of the byte count pattern.

Examples of other compare commands:

Diag> c

Compares all of the sectors in the read buffer to the byte count pattern, since the default pattern is cnt, and the default length is the number of sectors in the read buffer.

Diag> c dwcnt 0 10

Verify read buffer to the 32 bit count pattern for 10 sectors.

Diag> c val 0x12345678 10

Verify read buffer contains the 32 bit pattern 0x12345678 for 10 sectors.

Diag> c rand 0 10

Diag> lba 20 10

Verifies only the lba numbers are correct for 10 sectors in the read buffer.

Diag> buffs

Verifies the write buffer and the read buffer have the same data. So for example:

Diag> pt cnt; pt lba 0; w 0 bufsiz; r 0 bufsiz; c buffs

Would set up a byte count pattern in the write buffer, then label each sector starting with 0 lba. The Entire buffer would be written out to disk at lba 0, then read back, then the read buffer is compared to the write buffer.

This allows the composite pattern of the byte count pattern, with lba labeling, to be both written out to disk and then compared to the resulting data read back.

### Miscompares and controlling error actions

When the read buffer is checked, a miscompare appears as:

\*\*\* Error: Buffer miscompare: 00000001: 00 s/b 01

The first number is the hex address within the buffer, from 0 to N. This is followed by the byte found in the read buffer, and then the value it should have had (s/b or Should/Be).

How many bytes of miscompare are printed is controlled by the “cm” or “compare mode” command:

cm <mode>

Where mode is:

one Print only the first error encountered in the buffer.

all Print all errors found in buffer.

fail Quit the program and return to immediate mode on any error.

The default is:

Diag> cm one

The fail mode is used to stop any testing on buffer miscompares. The normal mode is simply to print the miscompare and continue. Note that a miscompare in the fail mode is considered a script error, and this affects automated scripting behavior. See ***Fully automated scripts and errors.***

## Values

Any numeric parameter in the diagnostic is represented by a 64 bit signed value. These can be specified in alternate radixes as well:

10 Decimal 10

010 Octal 8

0x10 Hexadecimal 16

## Expressions

Anywhere the diagnostic accepts a number it can also take an expression. These expressions generally follow C syntax and operator priority, but do not include assignment expressions:

+a Affirmation

-a Negation

(a) Subexpression

a+b Addition

a-b Subtraction

a\*b Multiplication

a/b Integer division

a%b Modulo

a<b Comparisions

a>b

a<=b

a>=b

a=b

a!=b

Note that a=b means compare for equality, not assignment, as in C. The priorities are:

1. (a).
2. +a, -a.
3. a\*b, a/b, a%b
4. a+b, a-b.
5. a<b, a>b, a<=b, a>=b, a=b, a!=b.

As in C, comparison operators result in 0 if false, 1 if true.

## Variables

Anywhere that the diagnostic takes a number or expression, it can also take a variable. Variables are named by any of the characters a to z or A to Z followed by a to z, A to Z and 0 to 9. Example variables are:

Myval

ThisValue

Note that case is not significant in variables.

Variables keep 64 bit signed values, and substitute their value where they appear. Variables can be set by the command “s” or “set”:

Diag> s myvalue 1

Would set the variable “myvalue” to 1.

Variables are not automatically set to 0. If a variable is used before it is set, it is an error.

## Printing

Printing from diagnostic scripts can be used to annotate and format results and tests. The simplest print commands are:

echo <text>…

echon <text>…

The echo commands simply copy all of the characters after the “echo” or “echon” command and any spaces to the console, stopping on the end of line or end of command (“;”). Echo outputs a newline after the text. Echon does not.

The ability to output numbers, as well as output advanced formatting, is available with the commands:

p fmt [val]…

pn fmt [val]…

The “p” or “print” commands take a format string and zero or more numeric parameters. The format is based on C language “printf” formatting. The format characters allowed are:

%d Decimal

%x Hexadecimal

%o Octal

The format of each format specification is:

%[width[.precision]]f

Where f is the format character. The width and precision are optional.

A typical print command is:

Diag> p “Iteration count: %d” i

As for echo, the command ending indicates if a line terminator is to be output. “p” or “print” terminate the output. “pn” or “printn” does not.

## Program control

The most elementary program control is the loop command:

l [num]

The loop command repeats the command line before it from the beginning:

Diag> p "hi"; l 5

hi

Iteration: 1

hi

Iteration: 2

hi

Iteration: 3

hi

Iteration: 4

hi

Iteration: 5

The loop count parameter determines the number of times the loop will take place. This parameter is optional, and the default is to loop forever. Each loop counter is tracked separately, so the line:

Diag> l 10; l 10

Will loop in total 100 times (10\*10).

The default is for loop to print the count, or iteration it is currently on. This can be suppressed by using “lq”, “loopq” or “loop quietly”.

The loop commands give a quick and easy way to form loops in the diagnostic. More advanced looping constructs are available that span multiple lines.

## Program store

## Fully automated scripts and errors

## The Acceptance test

## Construction of the diagnostic

## Compiling for different targets