The Linux SCSI programming HOWTO

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This document deals with programming the Linux generic SCSI interface.

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1 What's New?

Newer kernels have changed the interface a bit. This affects a section formerly entitled 'rescanning the devices'. Now it is possible to add/remove SCSI devices on the fly.

Since kernel 1.3.98 some important header files have been moved/split (sg.h and scsi.h).

Some stupid bugs have been replaced by newer ones.

2 Introduction

This document is a guide to the installation and programming of the Linux generic SCSI interface.

It covers kernel prerequisites, device mappings, and basic interaction with devices. Some simple C programming examples are included. General knowledge of the SCSI command set is required; for more information on the SCSI standard and related information, see the appendix to this document.

Note the plain text version of this document lacks cross references (they show up as "").

3 What Is The Generic SCSI Interface?

The generic SCSI interface has been implemented to provide general SCSI access to (possibly exotic) pieces of SCSI hardware. It was developed by Lawrence Foard (`entropy@world.std.com`) and sponsored by Killy Corporation (see the comments in `scsi/sg.h`).

The interface makes special device handling possible from user level applications (i.e. outside the kernel). Thus, kernel driver development, which is more risky and difficult to debug, is not necessary.

However, if you don't program the driver properly it is possible to hang the SCSI bus, the driver, or the kernel. Therefore, it is important to properly program the generic driver and to first back up all files to avoid losing data. Another useful thing to do before running your programs is to issue a `sync` command to ensure that any buffers are flushed to disk, minimizing data loss if the system hangs.

Another advantage of the generic driver is that as long as the interface itself does not change, all applications are independent of new kernel development. In comparison, other low-level kernel drivers have to be synchronized with other internal kernel changes.

Typically, the generic driver is used to communicate with new SCSI hardware devices that require special user applications to be written to take advantage of their features (e.g. scanners, printers, CD-ROM jukeboxes). The generic interface allows these to be written quickly.

4 What Are The Requirements To Use It?

4.1 Kernel Configuration

You must have a supported SCSI controller, obviously. Furthermore, your kernel must have controller support as well as generic support compiled in. Configuring the Linux kernel (via `make config` under /usr/src/linux) typically looks like the following:

```
 ...
*
* SCSI support
*
SCSI support? (CONFIG_SCSI) [n] y
*
* SCSI support type (disk, tape, CDrom)
*
 ...
Scsi generic support (CONFIG_CHR_DEV_SG) [n] y
*
* SCSI low-level drivers
*
 ...
```

If available, modules can of course be build instead.

4.2 Device Files

The generic SCSI driver uses its own device files, separate from those used by the other SCSI device drivers. They can be generated using the `MAKEDEV` script, typically found in the `/dev` directory. Running `MAKEDEV sg` produces these files:

```
crw-------   1 root     system    21,   0 Aug 20 20:09 /dev/sga
crw-------   1 root     system    21,   1 Aug 20 20:09 /dev/sgb
crw-------   1 root     system    21,   2 Aug 20 20:09 /dev/sgc
crw-------   1 root     system    21,   3 Aug 20 20:09 /dev/sgd
crw-------   1 root     system    21,   4 Aug 20 20:09 /dev/sge
crw-------   1 root     system    21,   5 Aug 20 20:09 /dev/sgf
crw-------   1 root     system    21,   6 Aug 20 20:09 /dev/sgg
crw-------   1 root     system    21,   7 Aug 20 20:09 /dev/sgh
                                    |    |
                                major,   minor device numbers
```

Note that these are character devices for raw access. On some systems these devices may be called `/dev/{sg0,sg1,...}`, depending on your installation, so adjust the following examples accordingly.

4.3 Device Mapping

These device files are dynamically mapped to SCSI id/LUNs on your SCSI bus (LUN = logical unit). The mapping allocates devices consecutively for each LUN of each device on each SCSI bus found at time of the SCSI scan, beginning at the lower LUNs/ids/buses. It starts with the first SCSI controller and continues without interruption with all following controllers. This is currently done in the initialisation of the SCSI driver.

For example, assuming you had three SCSI devices hooked up with ids 1, 3, and 5 on the first SCSI bus (each having one LUN), then the following mapping would be in effect:

```
/dev/sga -> SCSI id 1
/dev/sgb -> SCSI id 3
/dev/sgc -> SCSI id 5
```

If you now add a new device with id 4, then the mapping (after the next rescan) will be:

```
/dev/sga -> SCSI id 1
/dev/sgb -> SCSI id 3
/dev/sgc -> SCSI id 4
/dev/sgd -> SCSI id 5
```

Notice the change for id 5 – the corresponding device is no longer mapped to `/dev/sgc` but is now under `/dev/sgd`.

Luckily newer kernels allow for changing this order.

4.3.1 Dynamically insert and remove SCSI devices

If a newer kernel and the `/proc` file system is running, a non-busy device can be removed and installed 'on the fly'.

To remove a SCSI device:

```
echo "scsi remove-single-device a b c d" > /proc/scsi/scsi
```

and similar, to add a SCSI device, do

```
echo "scsi add-single-device a b c d" > /proc/scsi/scsi
```

where

```
a == hostadapter id (first one being 0)
b == SCSI channel on hostadapter (first one being 0)
c == ID
d == LUN (first one being 0)
```

So in order to swap the `/dev/sgc` and `/dev/sgd` mappings from the previous example, we could do

```
echo "scsi remove-single-device 0 0 4 0" > /proc/scsi/scsi
echo "scsi remove-single-device 0 0 5 0" > /proc/scsi/scsi
echo "scsi add-single-device 0 0 5 0" > /proc/scsi/scsi
echo "scsi add-single-device 0 0 4 0" > /proc/scsi/scsi
```

since generic devices are mapped in the order of their insertion.

When adding more devices to the scsi bus keep in mind there are limited spare entries for new devices. The memory has been allocated at boot time and has room for 2 more devices.

5 Programmers Guide

The following sections are for programmers who want to use the generic SCSI interface in their own applications. An example will be given showing how to access a SCSI device with the INQUIRY and the TESTUNITREADY commands.

When using these code examples, note the following:

- the location of the header files `sg.h` and `scsi.h` has changed in kernel version 1.3.98. Now these files are located at `/usr/src/linux/include/scsi`, which is hopefully linked to `/usr/include/scsi`. Previously they were in `/usr/src/linux/drivers/scsi`. We assume a newer kernel in the following text.
- the generic SCSI interface was extended in kernel version 1.1.68; the examples require at least this version. But please avoid kernel version 1.1.77 up to 1.1.89 and 1.3.52 upto 1.3.56 since they had a broken generic scsi interface.
- the constant DEVICE in the header section describing the accessed device should be set according to your available devices (see section 8.

6 Overview Of Device Programming

The header file `include/scsi/sg.h` contains a description of the interface (this is based on kernel version 1.3.98):

```
struct sg_header
 {
  int pack_len;
                  /* length of incoming packet (including header) */
  int reply_len;   /* maximum length of expected reply */
  int pack_id;     /* id number of packet */
  int result;      /* 0==ok, otherwise refer to errno codes */
  unsigned int twelve_byte:1;
               /* Force 12 byte command length for group 6 & 7 commands  */
  unsigned int other_flags:31;                 /* for future use */
```

```
  unsigned char sense_buffer[16]; /* used only by reads */
  /* command follows then data for command */
};
```

This structure describes how a SCSI command is to be processed and has room to hold the results of the execution of the command. The individual structure components will be discussed later in section 8.

The general way of exchanging data with the generic driver is as follows: to send a command to an opened generic device, `write()` a block containing these three parts to it:

```
struct sg_header
SCSI command
data to be sent with the command
```

To obtain the result of a command, `read()` a block with this (similar) block structure:

```
struct sg_header
data coming from the device
```

This is a general overview of the process. The following sections describe each of the steps in more detail.

NOTE: Up to recent kernel versions, it is necessary to block the SIGINT signal between the `write()` and the corresponding `read()` call (i.e. via `sigprocmask()`). A return after the `write()` part without any `read()` to fetch the results will block on subsequent accesses. This signal blocking has not yet been included in the example code. So better do not issue SIGINT (a la ^C) when running these examples.

7 Opening The Device

A generic device has to be opened for read and write access:

```
int fd = open (device_name, O_RDWR);
```

(This is the case even for a read-only hardware device such as a cdrom drive).

We have to perform a `write` to send the command and a `read` to get back any results. In the case of an error the return code is negative (see section B for a complete list).

8 The Header Structure

The header structure `struct sg_header` serves as a controlling layer between the application and the kernel driver. We now discuss its components in detail.

int pack_len

defines the size of the block written to the driver. This is defined within the kernel for internal use.

int reply_len

defines the size of the block to be accepted at reply. This is defined from the application side.

int pack_id

This field helps to assign replies to requests. The application can supply a unique id for each request. Suppose you have written several commands (say 4) to one device. They may work in parallel, one being the fastest. When getting replies via 4 reads, the replies do not have to have the order of the requests. To identify the correct reply for a given request one can use the `pack_id` field. Typically its value is incremented after each request (and wraps eventually). The maximum amount of outstanding requests is limited by the kernel to SG_MAX_QUEUE (eg 4).

int result

the result code of a `read` or `write` call. This is (sometimes) defined from the generic driver (kernel) side. It is safe to set it to null before the `write` call. These codes are defined in `errno.h` (0 meaning no error).

unsigned int twelve_byte:1

This field is necessary only when using non-standard vendor specific commands (in the range 0xc0 - 0xff). When these commands have a command length of 12 bytes instead of 10, this field has to be set to one before the write call. Other command lengths are not supported. This is defined from the application side.

unsigned char sense_buffer[16]

This buffer is set after a command is completed (after a `read()` call) and contains the SCSI sense code. Some command results have to be read from here (e.g. for `TESTUNITREADY`). Usually it contains just zero bytes. The value in this field is set by the generic driver (kernel) side.

The following example function interfaces directly with the generic kernel driver. It defines the header structure, sends the command via `write`, gets the result via `read` and does some (limited) error checking. The sense buffer data is available in the output buffer (unless a NULL pointer has been given, in which case it's in the input buffer). We will use it in the examples which follow.

Note: Set the value of `DEVICE` to your device descriptor.

```
#define DEVICE "/dev/sgc"

/* Example program to demonstrate the generic SCSI interface */
#include <stdio.h>
#include <unistd.h>
#include <string.h>
#include <fcntl.h>
#include <errno.h>
#include <scsi/sg.h>


#define SCSI_OFF sizeof(struct sg_header)
```

```
static unsigned char cmd[SCSI_OFF + 18];      /* SCSI command buffer */
int fd;                                 /* SCSI device/file descriptor */

/* process a complete SCSI cmd. Use the generic SCSI interface. */
static int handle_SCSI_cmd(unsigned cmd_len,         /* command length */
                           unsigned in_size,         /* input data size */
                           unsigned char *i_buff,    /* input buffer */
                           unsigned out_size,        /* output data size */
                           unsigned char *o_buff     /* output buffer */
                           )
{
    int status = 0;
    struct sg_header *sg_hd;

    /* safety checks */
    if (!cmd_len) return -1;            /* need a cmd_len != 0 */
    if (!i_buff) return -1;             /* need an input buffer != NULL */
#ifdef SG_BIG_BUFF
    if (SCSI_OFF + cmd_len + in_size > SG_BIG_BUFF) return -1;
    if (SCSI_OFF + out_size > SG_BIG_BUFF) return -1;
#else
    if (SCSI_OFF + cmd_len + in_size > 4096) return -1;
    if (SCSI_OFF + out_size > 4096) return -1;
#endif

    if (!o_buff) out_size = 0;      /* no output buffer, no output size */

    /* generic SCSI device header construction */
    sg_hd = (struct sg_header *) i_buff;
    sg_hd->reply_len   = SCSI_OFF + out_size;
    sg_hd->twelve_byte = cmd_len == 12;
    sg_hd->result = 0;
#if     0
    sg_hd->pack_len    = SCSI_OFF + cmd_len + in_size; /* not necessary */
    sg_hd->pack_id;     /* not used */
    sg_hd->other_flags; /* not used */
#endif

    /* send command */
    status = write( fd, i_buff, SCSI_OFF + cmd_len + in_size );
    if ( status < 0 || status != SCSI_OFF + cmd_len + in_size ||
                       sg_hd->result ) {
        /* some error happened */
        fprintf( stderr, "write(generic) result = 0x%x cmd = 0x%x\n",
                    sg_hd->result, i_buff[SCSI_OFF] );
        perror("");
        return status;
    }
```

```
    if (!o_buff) o_buff = i_buff;       /* buffer pointer check */

    /* retrieve result */
    status = read( fd, o_buff, SCSI_OFF + out_size);
    if ( status < 0 || status != SCSI_OFF + out_size || sg_hd->result ) {
        /* some error happened */
        fprintf( stderr, "read(generic) status = 0x%x, result = 0x%x, "
                         "cmd = 0x%x\n",
                         status, sg_hd->result, o_buff[SCSI_OFF] );
        fprintf( stderr, "read(generic) sense "
                "%x %x %x %x %x %x %x %x %x %x %x %x %x %x %x %x\n",
                sg_hd->sense_buffer[0],         sg_hd->sense_buffer[1],
                sg_hd->sense_buffer[2],         sg_hd->sense_buffer[3],
                sg_hd->sense_buffer[4],         sg_hd->sense_buffer[5],
                sg_hd->sense_buffer[6],         sg_hd->sense_buffer[7],
                sg_hd->sense_buffer[8],         sg_hd->sense_buffer[9],
                sg_hd->sense_buffer[10],        sg_hd->sense_buffer[11],
                sg_hd->sense_buffer[12],        sg_hd->sense_buffer[13],
                sg_hd->sense_buffer[14],        sg_hd->sense_buffer[15]);
        if (status < 0)
            perror("");
    }
    /* Look if we got what we expected to get */
    if (status == SCSI_OFF + out_size) status = 0; /* got them all */

    return status;  /* 0 means no error */
}
```

While this may look somewhat complex at first appearance, most of the code is for error checking and reporting (which is useful even after the code is working).

`Handle_SCSI_cmd` has a generalized form for all SCSI commands types, falling into each of these categories:

```
       Data Mode              | Example Command
=============================================
neither input nor output data | test unit ready
 no input data, output data   | inquiry, read
 input data, no output data   | mode select, write
   input data, output data    | mode sense
```

9 Inquiry Command Example

One of the most basic SCSI commands is the `INQUIRY` command, used to identify the type and make of the device. Here is the definition from the SCSI-2 specification (for details refer to the SCSI-2 standard).

Table 44: INQUIRY Command

Bit / Byte	7	6	5	4	3	2	1	0
0	Operation Code (12h)							
1	Logical Unit Number			Reserved				EVPD
2	Page Code							
3	Reserved							
4	Allocation Length							
5	Control							

The output data are as follows:

Table 45: Standard INQUIRY Data Format

Bit / Byte	7	6	5	4	3	2	1	0
0	Peripheral Qualifier			Peripheral Device Type				
1	RMB			Device-Type Modifier				
2	ISO Version		ECMA Version			ANSI-Approved Version		
3	AENC	TrmIOP	Reserved			Response Data Format		
4	Additional Length (n-4)							
5	Reserved							
6	Reserved							
7	RelAdr	WBus32	WBus16	Sync	Linked	Reserved	CmdQue	SftRe
8	(MSB)							
- -	---			Vendor Identification				---
15								(LSB)
16	(MSB)							
- -	---			Product Identification				---
31								(LSB)

32	(MSB)	
- -	Product Revision Level	---
35		(LSB)
36		
- -	Vendor Specific	---
55		
56		
- -	Reserved	---
95		
	Vendor-Specific Parameters	
96		
- -	Vendor Specific	---
n		

The next example uses the low-level function `handle_SCSI_cmd` to perform the Inquiry SCSI command.

We first append the command block to the generic header, then call `handle_SCSI_cmd`. Note that the output buffer size argument for the `handle_SCSI_cmd` call excludes the generic header size. After command completion the output buffer contains the requested data, unless an error occurred.

```
#define INQUIRY_CMD     0x12
#define INQUIRY_CMDLEN  6
#define INQUIRY_REPLY_LEN 96
#define INQUIRY_VENDOR  8       /* Offset in reply data to vendor name */

/* request vendor brand and model */
static unsigned char *Inquiry ( void )
{
  unsigned char Inqbuffer[ SCSI_OFF + INQUIRY_REPLY_LEN ];
  unsigned char cmdblk [ INQUIRY_CMDLEN ] =
      { INQUIRY_CMD,  /* command */
                0,  /* lun/reserved */
                0,  /* page code */
                0,  /* reserved */
  INQUIRY_REPLY_LEN,  /* allocation length */
                0 };/* reserved/flag/link */

  memcpy( cmd + SCSI_OFF, cmdblk, sizeof(cmdblk) );

  /*
   * +------------------+
   * | struct sg_header | <- cmd
```

```
     * +------------------+
     * | copy of cmdblk   | <- cmd + SCSI_OFF
     * +------------------+
     */

    if (handle_SCSI_cmd(sizeof(cmdblk), 0, cmd,
                        sizeof(Inqbuffer) - SCSI_OFF, Inqbuffer )) {
        fprintf( stderr, "Inquiry failed\n" );
        exit(2);
    }
    return (Inqbuffer + SCSI_OFF);
}
```

The example above follows this structure. The Inquiry function copies its command block behind the generic header (given by `SCSI_OFF`). Input data is not present for this command. `Handle_SCSI_cmd` will define the header structure. We can now implement the function `main` to complete this working example program.

```
void main( void )
{
  fd = open(DEVICE, O_RDWR);
  if (fd < 0) {
    fprintf( stderr, "Need read/write permissions for "DEVICE".\n" );
    exit(1);
  }

  /* print some fields of the Inquiry result */
  printf( "%s\n", Inquiry() + INQUIRY_VENDOR );
}
```

We first open the device, check for errors, and then call the higher level subroutine. Then we print the results in human readable format including the vendor, product, and revision.

Note: There is more information in the Inquiry result than this little program gives. You may want to extend the program to give device type, ANSI version etc. The device type is of special importance, since it determines the mandatory and optional command sets for this device. If you don't want to program it yourself, you may want to use the scsiinfo program from Eric Youngdale, which requests nearly all information about an SCSI device. Look at tsx-11.mit.edu in pub/Linux/ALPHA/scsi.

10 The Sense Buffer

Commands with no output data can give status information via the sense buffer (which is part of the header structure). Sense data is available when the previous command has terminated with a CHECK CONDITION status. In this case the kernel automatically retrieves the sense data via a REQUEST SENSE command. Its structure is:

```
+=====-========-========-========-========-========-========-========-========+
```

Bit|Byte	7	6	5	4	3	2	1	0
0	Valid	Error Code (70h or 71h)						
1	Segment Number							
2	Filemark	EOM	ILI	Reserved	Sense Key			
3	(MSB)							
- - -	---	Information						---
6								(LSB)
7	Additional Sense Length (n-7)							
8	(MSB)							
- - -	---	Command-Specific Information						---
11								(LSB)
12	Additional Sense Code							
13	Additional Sense Code Qualifier							
14	Field Replaceable Unit Code							
15	SKSV							
- - -	---	Sense-Key Specific						---
17								
18								
- - -	---	Additional Sense Bytes						---
n								

Note: The most useful fields are Sense Key (see section B.3), Additional Sense Code and Additional Sense Code Qualifier (see section C). The latter two are used combined as a pair.

11 Example Using Sense Buffer

Here we will use the TEST UNIT READY command to check whether media is loaded into our device. The header declarations and function `handle_SCSI_cmd` from the inquiry example will be needed as well.

Table 73: TEST UNIT READY Command

Bit|Byte	7	6	5	4	3	2	1	0

0	Operation Code (00h)	
1	Logical Unit Number	Reserved
2	Reserved	
3	Reserved	
4	Reserved	
5	Control	

Here is the function which implements it:

```
#define TESTUNITREADY_CMD 0
#define TESTUNITREADY_CMDLEN 6

#define ADD_SENSECODE 12
#define ADD_SC_QUALIFIER 13
#define NO_MEDIA_SC 0x3a
#define NO_MEDIA_SCQ 0x00

int TestForMedium ( void )
{
  /* request READY status */
  static unsigned char cmdblk [TESTUNITREADY_CMDLEN] = {
      TESTUNITREADY_CMD, /* command */
                      0, /* lun/reserved */
                      0, /* reserved */
                      0, /* reserved */
                      0, /* reserved */
                      0};/* control */

  memcpy( cmd + SCSI_OFF, cmdblk, sizeof(cmdblk) );

  /*
   * +------------------+
   * | struct sg_header | <- cmd
   * +------------------+
   * | copy of cmdblk   | <- cmd + SCSI_OFF
   * +------------------+
   */

  if (handle_SCSI_cmd(sizeof(cmdblk), 0, cmd,
                           0, NULL)) {
      fprintf (stderr, "Test unit ready failed\n");
```

```
        exit(2);
    }

    return
     *(((struct sg_header*)cmd)->sense_buffer +ADD_SENSECODE) !=
                                                    NO_MEDIA_SC ||
     *(((struct sg_header*)cmd)->sense_buffer +ADD_SC_QUALIFIER) !=
                                                    NO_MEDIA_SCQ;
}
```

Combined with this `main` function we can do the check.

```
void main( void )
{
  fd = open(DEVICE, O_RDWR);
  if (fd < 0) {
    fprintf( stderr, "Need read/write permissions for "DEVICE".\n" );
    exit(1);
  }

  /* look if medium is loaded */

  if (!TestForMedium()) {
    printf("device is unloaded\n");
  } else {
    printf("device is loaded\n");
  }
}
```

The file `generic_demo.c` from the appendix contains both examples.

12 Ioctl Functions

There are two ioctl functions available:

- `ioctl(fd, SG_SET_TIMEOUT, &Timeout);` sets the timeout value to `Timeout` * 10 milliseconds. `Timeout` has to be declared as int.
- `ioctl(fd, SG_GET_TIMEOUT, &Timeout);` gets the current timeout value. `Timeout` has to be declared as int.

13 Driver Defaults

13.1 Transfer Lengths

Currently (at least up to kernel version 1.1.68) input and output sizes have to be less than or equal than 4096 bytes unless the kernel has been compiled with `SG_BIG_BUFF` defined, if which case it is limited to `SG_BIG_BUFF` (e.g. 32768) bytes. These sizes include the generic header as well as the command block on input. `SG_BIG_BUFF` can be safely increased upto (131072 - 512). To take advantage of this, a new kernel has to be compiled and booted, of course.

13.2 Timeout And Retry Values

The default timeout value is set to one minute (`Timeout` = 6000). It can be changed through an ioctl call (see section 12). The default number of retries is one.

14 Obtaining The Scsi Specifications

There are standards entitled SCSI-1 and SCSI-2 (and possibly soon SCSI-3). The standards are mostly upward compatible.

The SCSI-1 standard is (in the author's opinion) mostly obsolete, and SCSI-2 is the most widely used. SCSI-3 is very new and very expensive. These standardized command sets specify mandatory and optional commands for SCSI manufacturers and should be preferred over the vendor specific command extensions which are not standardized and for which programming information is seldom available. Of course sometimes there is no alternative to these extensions.

Electronic copies of the latest drafts are available via anonymous ftp from:

- ftp.cs.tulane.edu:pub/scsi
- ftp.symbios.com:/pub/standards
- ftp.cs.uni-sb.de:/pub/misc/doc/scsi

(I got my SCSI specification from the Yggdrasil Linux CD-ROM in the directory /usr/doc/scsi-2 and /usr/doc/scsi-1).

The SCSI FAQ also lists the following sources of printed information:

The SCSI specification: Available from:

```
Global Engineering Documents
15 Inverness Way East
Englewood Co  80112-5704
(800) 854-7179
  SCSI-1: X3.131-1986
  SCSI-2: X3.131-199x
```

```
        SCSI-3 X3T9.2/91-010R4 Working Draft

(Global Engineering Documentation in Irvine, CA (714)261-1455??)

SCSI-1: Doc \# X3.131-1986 from ANSI, 1430 Broadway, NY, NY 10018

IN-DEPTH EXPLORATION OF SCSI can be obtained from
Solution Technology, Attn: SCSI Publications, POB 104, Boulder Creek,
CA 95006, (408)338-4285, FAX (408)338-4374

THE SCSI ENCYLOPEDIA and the SCSI BENCH REFERENCE can be obtained from
ENDL Publishing, 14426 Black Walnut Ct., Saratoga, CA 95090,
(408)867-6642, FAX (408)867-2115

SCSI: UNDERSTANDING THE SMALL COMPUTER SYSTEM INTERFACE was published
by Prentice-Hall, ISBN 0-13-796855-8
```

15 Related Information Sources

15.1 HOWTOs and FAQs

The Linux **SCSI-HOWTO** by Drew Eckhardt covers all supported SCSI controllers as well as device specific questions. A lot of troubleshooting hints are given. It is available from sunsite.unc.edu in /pub/Linux/docs/LDP and its mirror sites.

General questions about SCSI are answered in the **SCSI-FAQ** from the newsgroup Comp.Periphs.Scsi (available on tsx-11 in pub/linux/ALPHA/scsi and mirror sites).

15.2 Mailing list

There is a **mailing list** for bug reports and questions regarding SCSI development under Linux. To join, send email to `majordomo@vger.rutgers.edu` with the line `subscribe linux-scsi` in the body of the message. Messages should be posted to `linux-scsi@vger.rutgers.edu`. Help text can be requested by sending the message line "help" to `majordomo@vger.rutgers.edu`.

15.3 Example code

sunsite.unc.edu: apps/graphics/hpscanpbm-0.3a.tar.gz

This package handles a HP scanjet scanner through the generic interface.

tsx-11.mit.edu: BETA/cdrom/private/mkisofs/cdwrite-1.3.tar.gz

The cdwrite package uses the generic interface to write a cd image to a cd writer.

sunsite.unc.edu: apps/sound/cds/cdda2wav*.src.tar.gz

A shameless plug for my own application, which copies audio cd tracks into wav files.

16 Other useful stuff

Things that may come in handy. I don't have no idea if there are newer or better versions around. Feedback is welcome.

16.1 Device driver writer helpers

These documents can be found at the sunsite.unc.edu ftp server and its mirrors.

/pub/Linux/docs/kernel/kernel-hackers-guide

The LDP kernel hackers guide. May be a bit outdated, but covers the most fundamental things.

/pub/Linux/docs/kernel/drivers.doc.z

This document covers writing character drivers.

/pub/Linux/docs/kernel/tutorial.doc.z

Tutorial on writing a character device driver with code.

/pub/Linux/docs/kernel/scsi.paper.tar.gz

A Latex document describing howto write a SCSI driver.

/pub/Linux/docs/hardware/DEVICES

A list of device majors and minors used by Linux.

16.2 Utilities

tsx-11.mit.edu: ALPHA/scsi/scsiinfo*.tar.gz

Program to query a scsi device for operating parameters, defect lists, etc. An X-based interface is available which requires you have Tk/Tcl/wish installed. With the X-based interface you can easily alter the settings on the drive.

tsx-11.mit.edu: ALPHA/kdebug

A gdb extension for kernel debugging.

17 Other SCSI Access Interfaces

In Linux there is also another SCSI access method via SCSI_IOCTL_SEND_COMMAND ioctl calls, which is deprecated. Special tools like 'scsiinfo' utilize it.

There are some other similar interfaces in use in the un*x world, but not available for Linux:

1. CAM (Common Access Method) developed by Future Domain and other SCSI vendors. Linux has little support for a SCSI CAM system yet (mainly for booting from hard disk). CAM even supports target mode, so one could disguise ones computer as a peripheral hardware device (e.g. for a small SCSI net).
2. ASPI (Advanced SCSI Programming Interface) developed by Adaptec. This is the de facto standard for MS-DOS machines.

There are other application interfaces from SCO(TM), NeXT(TM), Silicon Graphics(TM) and SUN(TM) as well.

18 Final Comments

The generic SCSI interface bridges the gap between user applications and specific devices. But rather than bloating a lot of programs with similar sets of low-level functions, it would be more desirable to have a shared library with a generalized set of low-level functions for a particular purpose. The main goal should be to have independent layers of interfaces. A good design would separate an application into low-level and hardware independent routines. The low-level routines could be put into a shared library and made available for all applications. Here, standardized interfaces should be followed as much as possible before making new ones.

By now you should know more than I do about the Linux generic SCSI interface. So you can start developing powerful applications for the benefit of the global Linux community now...

19 Acknowledgments

Special thanks go to Jeff Tranter for proofreading and enhancing the text considerably as well as to Carlos Puchol for useful comments. Drew Eckhardt's and Eric Youngdale's help on my first (dumb) questions about the use of this interface has been appreciated.

A Appendix

B Error handling

The functions `open`, `ioctl`, `write` and `read` can report errors. In this case their return value is -1 and the global variable errno is set to the error number. The errno values are defined in `/usr/include/errno.h`. Possible values are:

Function	Error	Description
open	ENXIO	not a valid device
	EACCES	access mode is not read/write (O_RDWR)

```
         | EBUSY        | device was requested for nonblocking access,
         |              | but is busy now.
         | ERESTARTSYS  | this indicates an internal error. Try to
         |              | make it reproducible and inform the SCSI
         |              | channel (for details on bug reporting
         |              | see Drew Eckhardts SCSI-HOWTO).
ioctl    | ENXIO        | not a valid device
read     | EAGAIN       | the device would block. Try again later.
         | ERESTARTSYS  | this indicates an internal error. Try to
         |              | make it reproducible and inform the SCSI
         |              | channel (for details on bug reporting
         |              | see Drew Eckhardts SCSI-HOWTO).
write    | EIO          | the length is too small (smaller than the
         |              | generic header struct). Caution: Currently
         |              | there is no overlength checking.
         | EAGAIN       | the device would block. Try again later.
         | ENOMEM       | memory required for this request could not be
         |              | allocated. Try later again unless you
         |              | exceeded the maximum transfer size (see above)
select   |              | none
close    |              | none
```

For read/write positive return values indicate as usual the amount of bytes that have been successfully transferred. This should equal the amount you requested.

B.1 Error status decoding

Furthermore a detailed reporting is done via the kernels `hd_status` and the devices `sense_buffer` (see section 10) both from the generic header structure.

The meaning of `hd_status` can be found in `drivers/scsi/scsi.h`: This `unsigned int` is composed out of different parts:

```
  lsb  |    ...    |    ...    | msb
=======|===========|===========|============
status | sense key | host code | driver byte
```

These macros from `drivers/scsi/scsi.h` are available, but unfortunately cannot be easily used due to weird header file interdependencies. This has to be cleaned.

```
        Macro          | Description
=======================|================================================
status_byte(hd_status) | The SCSI device status. See section Status codes
msg_byte(hd_status)    | From the device. See section SCSI sense keys
host_byte(hd_status)   | From the kernel. See section Hostcodes
driver_byte(hd_status) | From the kernel. See section midlevel codes
```

B.2 Status codes

The following status codes from the SCSI device (defined in `scsi/scsi.h`) are available.

```
Value | Symbol
======|====================
0x00  | GOOD
0x01  | CHECK_CONDITION
0x02  | CONDITION_GOOD
0x04  | BUSY
0x08  | INTERMEDIATE_GOOD
0x0a  | INTERMEDIATE_C_GOOD
0x0c  | RESERVATION_CONFLICT
```

Note that these symbol values have been **shifted right once**. When the status is CHECK_CONDITION, the sense data in the sense buffer is valid (check especially the additional sense code and additional sense code qualifier).

These values carry the meaning from the SCSI-2 specification:

Table 27: Status Byte Code

Bits of Status Byte								Status
7	6	5	4	3	2	1	0	
R	R	0	0	0	0	0	R	GOOD
R	R	0	0	0	0	1	R	CHECK CONDITION
R	R	0	0	0	1	0	R	CONDITION MET
R	R	0	0	1	0	0	R	BUSY
R	R	0	1	0	0	0	R	INTERMEDIATE
R	R	0	1	0	1	0	R	INTERMEDIATE-CONDITION MET
R	R	0	1	1	0	0	R	RESERVATION CONFLICT
R	R	1	0	0	0	1	R	COMMAND TERMINATED
R	R	1	0	1	0	0	R	QUEUE FULL
All Other Codes								Reserved

Key: R = Reserved bit

A definition of the status byte codes is given below.

GOOD. This status indicates that the target has successfully completed the command.

CHECK CONDITION. This status indicates that a contingent allegiance condition has occurred (see 6.6).

CONDITION MET. This status or INTERMEDIATE-CONDITION MET is returned whenever the requested operation is satisfied (see the SEARCH DATA and PRE-FETCH commands).

BUSY. This status indicates that the target is busy. This status shall be returned whenever a target is unable to accept a command from an otherwise acceptable initiator (i.e., no reservation conflicts). The recommended initiator recovery action is to issue the command again at a later time.

INTERMEDIATE. This status or INTERMEDIATE-CONDITION MET shall be returned for every successfully completed command in a series of linked commands (except the last command), unless the command is terminated with CHECK CONDITION, RESERVATION CONFLICT, or COMMAND TERMINATED status. If INTERMEDIATE or INTERMEDIATE-CONDITION MET status is not returned, the series of linked commands is terminated and the I/O process is ended.

INTERMEDIATE-CONDITION MET. This status is the combination of the CONDITION MET and INTERMEDIATE statuses.

RESERVATION CONFLICT. This status shall be returned whenever an initiator attempts to access a logical unit or an extent within a logical unit that is reserved with a conflicting reservation type for another SCSI device (see the RESERVE and RESERVE UNIT commands). The recommended initiator recovery action is to issue the command again at a later time.

COMMAND TERMINATED. This status shall be returned whenever the target terminates the current I/O process after receiving a TERMINATE I/O PROCESS message (see 5.6.22). This status also indicates that a contingent allegiance condition has occurred (see 6.6).

QUEUE FULL. This status shall be implemented if tagged queuing is implemented. This status is returned when a SIMPLE QUEUE TAG, ORDERED QUEUE TAG, or HEAD OF QUEUE TAG message is received and the command queue is full. The I/O process is not placed in the command queue.

B.3 SCSI Sense Keys

These kernel symbols (from `scsi/scsi.h`) are predefined:

Value	Symbol
0x00	NO_SENSE
0x01	RECOVERED_ERROR
0x02	NOT_READY
0x03	MEDIUM_ERROR
0x04	HARDWARE_ERROR

```
0x05  | ILLEGAL_REQUEST
0x06  | UNIT_ATTENTION
0x07  | DATA_PROTECT
0x08  | BLANK_CHECK
0x0a  | COPY_ABORTED
0x0b  | ABORTED_COMMAND
0x0d  | VOLUME_OVERFLOW
0x0e  | MISCOMPARE
```

A verbatim list from the SCSI-2 doc follows (from section 7.2.14.3):

Table 69: Sense Key (0h-7h) Descriptions

Sense Key	Description
0h	NO SENSE. Indicates that there is no specific sense key information to be reported for the designated logical unit. This would be the case for a successful command or a command that received CHECK CONDITION or COMMAND TERMINATED status because one of the filemark, EOM, or ILI bits is set to one.
1h	RECOVERED ERROR. Indicates that the last command completed successfully with some recovery action performed by the target. Details may be determinable by examining the additional sense bytes and the information field. When multiple recovered errors occur during one command, the choice of which error to report (first, last, most severe, etc.) is device specific.
2h	NOT READY. Indicates that the logical unit addressed cannot be accessed. Operator intervention may be required to correct this condition.
3h	MEDIUM ERROR. Indicates that the command terminated with a non-recovered error condition that was probably caused by a flaw in the medium or an error in the recorded data. This sense key may also be returned if the target is unable to distinguish between a flaw in the medium and a specific hardware failure (sense key 4h).
4h	HARDWARE ERROR. Indicates that the target detected a non-recoverable hardware failure (for example, controller failure, device failure, parity error, etc.) while performing the command or during a self test.
5h	ILLEGAL REQUEST. Indicates that there was an illegal parameter in the command descriptor block or in the additional parameters supplied as data for some commands (FORMAT UNIT, SEARCH DATA, etc.). If the target detects an invalid parameter in the command

		descriptor block, then it shall terminate the command without altering the medium. If the target detects an invalid parameter in the additional parameters supplied as data, then the target may have already altered the medium. This sense key may also indicate that an invalid IDENTIFY message was received (5.6.7).
6h		UNIT ATTENTION. Indicates that the removable medium may have been changed or the target has been reset. See 6.9 for more detailed information about the unit attention condition.
7h		DATA PROTECT. Indicates that a command that reads or writes the medium was attempted on a block that is protected from this operation. The read or write operation is not performed.

Table 70: Sense Key (8h-Fh) Descriptions

Sense Key	Description
8h	BLANK CHECK. Indicates that a write-once device or a sequential-access device encountered blank medium or format-defined end-of-data indication while reading or a write-once device encountered a non-blank medium while writing.
9h	Vendor Specific. This sense key is available for reporting vendor specific conditions.
Ah	COPY ABORTED. Indicates a COPY, COMPARE, or COPY AND VERIFY command was aborted due to an error condition on the source device, the destination device, or both. (See 7.2.3.2 for additional information about this sense key.)
Bh	ABORTED COMMAND. Indicates that the target aborted the command. The initiator may be able to recover by trying the command again.
Ch	EQUAL. Indicates a SEARCH DATA command has satisfied an equal comparison.
Dh	VOLUME OVERFLOW. Indicates that a buffered peripheral device has reached the end-of-partition and data may remain in the buffer that has not been written to the medium. A RECOVER BUFFERED DATA command(s) may be issued to read the unwritten data from the buffer.
Eh	MISCOMPARE. Indicates that the source data did not match the data read from the medium.

```
|   Fh   |  RESERVED.                                                            |
+=======================================================================+
```

B.4 Host codes

The following host codes are defined in `drivers/scsi/scsi.h`. They are set by the kernel driver.

```
Value | Symbol         | Description
======|================|=======================================
0x00  | DID_OK         | No error
0x01  | DID_NO_CONNECT | Couldn't connect before timeout period
0x02  | DID_BUS_BUSY   | BUS stayed busy through time out period
0x03  | DID_TIME_OUT   | TIMED OUT for other reason
0x04  | DID_BAD_TARGET | BAD target
0x05  | DID_ABORT      | Told to abort for some other reason
0x06  | DID_PARITY     | Parity error
0x07  | DID_ERROR      | internal error
0x08  | DID_RESET      | Reset by somebody
0x09  | DID_BAD_INTR   | Got an interrupt we weren't expecting
```

B.5 Driver codes

The midlevel driver categorizes the returned status from the lowlevel driver based on the sense key from the device. It suggests some actions to be taken such as retry, abort or remap. The routine scsi_done from scsi.c does a very differentiated handling based on host_byte(), status_byte(), msg_byte() and the suggestion. It then sets the driver byte to show what it has done. The driver byte is composed out of two nibbles: the driver status and the suggestion. Each half is composed from the below values being 'or'ed together (found in scsi.h).

```
Value | Symbol         | Description of Driver status
======|================|=======================================
0x00  | DRIVER_OK      | No error
0x01  | DRIVER_BUSY    | not used
0x02  | DRIVER_SOFT    | not used
0x03  | DRIVER_MEDIA   | not used
0x04  | DRIVER_ERROR   | internal driver error
0x05  | DRIVER_INVALID | finished (DID_BAD_TARGET or DID_ABORT)
0x06  | DRIVER_TIMEOUT | finished with timeout
0x07  | DRIVER_HARD    | finished with fatal error
0x08  | DRIVER_SENSE   | had sense information available

Value | Symbol         | Description of suggestion
======|================|=======================================
0x10  | SUGGEST_RETRY  | retry the SCSI request
0x20  | SUGGEST_ABORT  | abort the request
0x30  | SUGGEST_REMAP  | remap the block (not yet implemented)
```

```
0x40  | SUGGEST_DIE    | let the kernel panic
0x80  | SUGGEST_SENSE  | get sense information from the device
0xff  | SUGGEST_IS_OK  | nothing to be done
```

C Additional sense codes and additional sense code qualifiers

When the status of the executed SCSI command is CHECK_CONDITION, sense data is available in the sense buffer. The additional sense code and additional sense code qualifier are contained in that buffer.

From the SCSI-2 specification I include two tables. The first is in lexical, the second in numerical order.

C.1 ASC and ASCQ in lexical order

The following table list gives a list of descriptions and device types they apply to.

```
+=============================================================================+
|           D - DIRECT ACCESS DEVICE                                          |
|           .T - SEQUENTIAL ACCESS DEVICE                                     |
|           . L - PRINTER DEVICE                                              |
|           .  P - PROCESSOR DEVICE                                           |
|           .  .W - WRITE ONCE READ MULTIPLE DEVICE                           |
|           .  . R - READ ONLY (CD-ROM) DEVICE                                |
|           .  .  S - SCANNER DEVICE                                          |
|           .  .  .O - OPTICAL MEMORY DEVICE                                  |
|           .  .  . M - MEDIA CHANGER DEVICE                                  |
|           .  .  .  C - COMMUNICATION DEVICE                                 |
|           .  .  .  .                                                       |
| ASC ASCQ  DTLPWRSOMC  DESCRIPTION                                           |
| --- ----              ------------------------------------------------------ |
| 13h  00h  D   W  O    ADDRESS MARK NOT FOUND FOR DATA FIELD                 |
| 12h  00h  D   W  O    ADDRESS MARK NOT FOUND FOR ID FIELD                   |
| 00h  11h       R      AUDIO PLAY OPERATION IN PROGRESS                      |
| 00h  12h       R      AUDIO PLAY OPERATION PAUSED                           |
| 00h  14h       R      AUDIO PLAY OPERATION STOPPED DUE TO ERROR             |
| 00h  13h       R      AUDIO PLAY OPERATION SUCCESSFULLY COMPLETED           |
| 00h  04h   T    S     BEGINNING-OF-PARTITION/MEDIUM DETECTED                |
| 14h  04h   T          BLOCK SEQUENCE ERROR                                  |
| 30h  02h  DT  WR O    CANNOT READ MEDIUM - INCOMPATIBLE FORMAT              |
| 30h  01h  DT  WR O    CANNOT READ MEDIUM - UNKNOWN FORMAT                   |
| 52h  00h   T          CARTRIDGE FAULT                                       |
| 3Fh  02h  DTLPWRSOMC  CHANGED OPERATING DEFINITION                          |
| 11h  06h      WR O    CIRC UNRECOVERED ERROR                                |
| 30h  03h  DT          CLEANING CARTRIDGE INSTALLED                          |
| 4Ah  00h  DTLPWRSOMC  COMMAND PHASE ERROR                                   |
| 2Ch  00h  DTLPWRSOMC  COMMAND SEQUENCE ERROR                                |
| 2Fh  00h  DTLPWRSOMC  COMMANDS CLEARED BY ANOTHER INITIATOR                 |
```

2Bh	00h	DTLPWRSO C	COPY CANNOT EXECUTE SINCE HOST CANNOT DISCONNECT
41h	00h	D	DATA PATH FAILURE (SHOULD USE 40 NN)
4Bh	00h	DTLPWRSOMC	DATA PHASE ERROR
11h	07h	W O	DATA RESYCHRONIZATION ERROR
16h	00h	D W O	DATA SYNCHRONIZATION MARK ERROR
19h	00h	D O	DEFECT LIST ERROR
19h	03h	D O	DEFECT LIST ERROR IN GROWN LIST
19h	02h	D O	DEFECT LIST ERROR IN PRIMARY LIST
19h	01h	D O	DEFECT LIST NOT AVAILABLE
1Ch	00h	D O	DEFECT LIST NOT FOUND
32h	01h	D W O	DEFECT LIST UPDATE FAILURE
40h	NNh	DTLPWRSOMC	DIAGNOSTIC FAILURE ON COMPONENT NN (80H-FFH)
63h	00h	R	END OF USER AREA ENCOUNTERED ON THIS TRACK
00h	05h	T S	END-OF-DATA DETECTED
14h	03h	T	END-OF-DATA NOT FOUND
00h	02h	T S	END-OF-PARTITION/MEDIUM DETECTED
51h	00h	T O	ERASE FAILURE
0Ah	00h	DTLPWRSOMC	ERROR LOG OVERFLOW
11h	02h	DT W SO	ERROR TOO LONG TO CORRECT
03h	02h	T	EXCESSIVE WRITE ERRORS
3Bh	07h	L	FAILED TO SENSE BOTTOM-OF-FORM
3Bh	06h	L	FAILED TO SENSE TOP-OF-FORM
00h	01h	T	FILEMARK DETECTED
14h	02h	T	FILEMARK OR SETMARK NOT FOUND
09h	02h	WR O	FOCUS SERVO FAILURE
31h	01h	D L O	FORMAT COMMAND FAILED
58h	00h	O	GENERATION DOES NOT EXIST

Table 71: (continued)

ASC	ASCQ	DTLPWRSOMC	DESCRIPTION
1Ch	02h	D O	GROWN DEFECT LIST NOT FOUND
00h	06h	DTLPWRSOMC	I/O PROCESS TERMINATED
10h	00h	D W O	ID CRC OR ECC ERROR
22h	00h	D	ILLEGAL FUNCTION (SHOULD USE 20 00, 24 00, OR 26 00)
64h	00h	R	ILLEGAL MODE FOR THIS TRACK
28h	01h	M	IMPORT OR EXPORT ELEMENT ACCESSED
30h	00h	DT WR OM	INCOMPATIBLE MEDIUM INSTALLED
11h	08h	T	INCOMPLETE BLOCK READ
48h	00h	DTLPWRSOMC	INITIATOR DETECTED ERROR MESSAGE RECEIVED
3Fh	03h	DTLPWRSOMC	INQUIRY DATA HAS CHANGED
44h	00h	DTLPWRSOMC	INTERNAL TARGET FAILURE
3Dh	00h	DTLPWRSOMC	INVALID BITS IN IDENTIFY MESSAGE
2Ch	02h	S	INVALID COMBINATION OF WINDOWS SPECIFIED
20h	00h	DTLPWRSOMC	INVALID COMMAND OPERATION CODE
21h	01h	M	INVALID ELEMENT ADDRESS

24h	00h	DTLPWRSOMC	INVALID FIELD IN CDB
26h	00h	DTLPWRSOMC	INVALID FIELD IN PARAMETER LIST
49h	00h	DTLPWRSOMC	INVALID MESSAGE ERROR
11h	05h	WR O	L-EC UNCORRECTABLE ERROR
60h	00h	S	LAMP FAILURE
5Bh	02h	DTLPWRSOM	LOG COUNTER AT MAXIMUM
5Bh	00h	DTLPWRSOM	LOG EXCEPTION
5Bh	03h	DTLPWRSOM	LOG LIST CODES EXHAUSTED
2Ah	02h	DTL WRSOMC	LOG PARAMETERS CHANGED
21h	00h	DT WR OM	LOGICAL BLOCK ADDRESS OUT OF RANGE
08h	00h	DTL WRSOMC	LOGICAL UNIT COMMUNICATION FAILURE
08h	02h	DTL WRSOMC	LOGICAL UNIT COMMUNICATION PARITY ERROR
08h	01h	DTL WRSOMC	LOGICAL UNIT COMMUNICATION TIME-OUT
4Ch	00h	DTLPWRSOMC	LOGICAL UNIT FAILED SELF-CONFIGURATION
3Eh	00h	DTLPWRSOMC	LOGICAL UNIT HAS NOT SELF-CONFIGURED YET
04h	01h	DTLPWRSOMC	LOGICAL UNIT IS IN PROCESS OF BECOMING READY
04h	00h	DTLPWRSOMC	LOGICAL UNIT NOT READY, CAUSE NOT REPORTABLE
04h	04h	DTL O	LOGICAL UNIT NOT READY, FORMAT IN PROGRESS
04h	02h	DTLPWRSOMC	LOGICAL UNIT NOT READY, INITIALIZING COMMAND REQUIRED
04h	03h	DTLPWRSOMC	LOGICAL UNIT NOT READY, MANUAL INTERVENTION REQUIRED
25h	00h	DTLPWRSOMC	LOGICAL UNIT NOT SUPPORTED
15h	01h	DTL WRSOM	MECHANICAL POSITIONING ERROR
53h	00h	DTL WRSOM	MEDIA LOAD OR EJECT FAILED
3Bh	0Dh	M	MEDIUM DESTINATION ELEMENT FULL
31h	00h	DT W O	MEDIUM FORMAT CORRUPTED
3Ah	00h	DTL WRSOM	MEDIUM NOT PRESENT
53h	02h	DT WR OM	MEDIUM REMOVAL PREVENTED
3Bh	0Eh	M	MEDIUM SOURCE ELEMENT EMPTY
43h	00h	DTLPWRSOMC	MESSAGE ERROR
3Fh	01h	DTLPWRSOMC	MICROCODE HAS BEEN CHANGED
1Dh	00h	D W O	MISCOMPARE DURING VERIFY OPERATION
11h	0Ah	DT O	MISCORRECTED ERROR
2Ah	01h	DTL WRSOMC	MODE PARAMETERS CHANGED
07h	00h	DTL WRSOM	MULTIPLE PERIPHERAL DEVICES SELECTED
11h	03h	DT W SO	MULTIPLE READ ERRORS
00h	00h	DTLPWRSOMC	NO ADDITIONAL SENSE INFORMATION
00h	15h	R	NO CURRENT AUDIO STATUS TO RETURN
32h	00h	D W O	NO DEFECT SPARE LOCATION AVAILABLE
11h	09h	T	NO GAP FOUND
01h	00h	D W O	NO INDEX/SECTOR SIGNAL
06h	00h	D WR OM	NO REFERENCE POSITION FOUND

Table 71: (continued)

ASC	ASCQ	DTLPWRSOMC	DESCRIPTION
---	----		----------
02h	00h	D WR OM	NO SEEK COMPLETE

03h	01h	T	NO WRITE CURRENT
28h	00h	DTLPWRSOMC	NOT READY TO READY TRANSITION, MEDIUM MAY HAVE CHANGED
5Ah	01h	DT WR OM	OPERATOR MEDIUM REMOVAL REQUEST
5Ah	00h	DTLPWRSOM	OPERATOR REQUEST OR STATE CHANGE INPUT (UNSPECIFIED)
5Ah	03h	DT W O	OPERATOR SELECTED WRITE PERMIT
5Ah	02h	DT W O	OPERATOR SELECTED WRITE PROTECT
61h	02h	S	OUT OF FOCUS
4Eh	00h	DTLPWRSOMC	OVERLAPPED COMMANDS ATTEMPTED
2Dh	00h	T	OVERWRITE ERROR ON UPDATE IN PLACE
3Bh	05h	L	PAPER JAM
1Ah	00h	DTLPWRSOMC	PARAMETER LIST LENGTH ERROR
26h	01h	DTLPWRSOMC	PARAMETER NOT SUPPORTED
26h	02h	DTLPWRSOMC	PARAMETER VALUE INVALID
2Ah	00h	DTL WRSOMC	PARAMETERS CHANGED
03h	00h	DTL W SO	PERIPHERAL DEVICE WRITE FAULT
50h	02h	T	POSITION ERROR RELATED TO TIMING
3Bh	0Ch	S	POSITION PAST BEGINNING OF MEDIUM
3Bh	0Bh	S	POSITION PAST END OF MEDIUM
15h	02h	DT WR O	POSITIONING ERROR DETECTED BY READ OF MEDIUM
29h	00h	DTLPWRSOMC	POWER ON, RESET, OR BUS DEVICE RESET OCCURRED
42h	00h	D	POWER-ON OR SELF-TEST FAILURE (SHOULD USE 40 NN)
1Ch	01h	D O	PRIMARY DEFECT LIST NOT FOUND
40h	00h	D	RAM FAILURE (SHOULD USE 40 NN)
15h	00h	DTL WRSOM	RANDOM POSITIONING ERROR
3Bh	0Ah	S	READ PAST BEGINNING OF MEDIUM
3Bh	09h	S	READ PAST END OF MEDIUM
11h	01h	DT W SO	READ RETRIES EXHAUSTED
14h	01h	DT WR O	RECORD NOT FOUND
14h	00h	DTL WRSO	RECORDED ENTITY NOT FOUND
18h	02h	D WR O	RECOVERED DATA - DATA AUTO-REALLOCATED
18h	05h	D WR O	RECOVERED DATA - RECOMMEND REASSIGNMENT
18h	06h	D WR O	RECOVERED DATA - RECOMMEND REWRITE
17h	05h	D WR O	RECOVERED DATA USING PREVIOUS SECTOR ID
18h	03h	R	RECOVERED DATA WITH CIRC
18h	01h	D WR O	RECOVERED DATA WITH ERROR CORRECTION & RETRIES APPLIED
18h	00h	DT WR O	RECOVERED DATA WITH ERROR CORRECTION APPLIED
18h	04h	R	RECOVERED DATA WITH L-EC
17h	03h	DT WR O	RECOVERED DATA WITH NEGATIVE HEAD OFFSET
17h	00h	DT WRSO	RECOVERED DATA WITH NO ERROR CORRECTION APPLIED
17h	02h	DT WR O	RECOVERED DATA WITH POSITIVE HEAD OFFSET
17h	01h	DT WRSO	RECOVERED DATA WITH RETRIES
17h	04h	WR O	RECOVERED DATA WITH RETRIES AND/OR CIRC APPLIED
17h	06h	D W O	RECOVERED DATA WITHOUT ECC - DATA AUTO-REALLOCATED
17h	07h	D W O	RECOVERED DATA WITHOUT ECC - RECOMMEND REASSIGNMENT
17h	08h	D W O	RECOVERED DATA WITHOUT ECC - RECOMMEND REWRITE
1Eh	00h	D W O	RECOVERED ID WITH ECC CORRECTION
3Bh	08h	T	REPOSITION ERROR
36h	00h	L	RIBBON, INK, OR TONER FAILURE

37h	00h	DTL	WRSOMC	ROUNDED PARAMETER
5Ch	00h	D	O	RPL STATUS CHANGE
39h	00h	DTL	WRSOMC	SAVING PARAMETERS NOT SUPPORTED
62h	00h		S	SCAN HEAD POSITIONING ERROR
47h	00h	DTLPWRSOMC		SCSI PARITY ERROR
54h	00h		P	SCSI TO HOST SYSTEM INTERFACE FAILURE
45h	00h	DTLPWRSOMC		SELECT OR RESELECT FAILURE

Table 71: (concluded)

ASC	ASCQ	DTLPWRSOMC	DESCRIPTION
3Bh	00h	TL	SEQUENTIAL POSITIONING ERROR
00h	03h	T	SETMARK DETECTED
3Bh	04h	L	SLEW FAILURE
09h	03h	WR O	SPINDLE SERVO FAILURE
5Ch	02h	D O	SPINDLES NOT SYNCHRONIZED
5Ch	01h	D O	SPINDLES SYNCHRONIZED
1Bh	00h	DTLPWRSOMC	SYNCHRONOUS DATA TRANSFER ERROR
55h	00h	P	SYSTEM RESOURCE FAILURE
33h	00h	T	TAPE LENGTH ERROR
3Bh	03h	L	TAPE OR ELECTRONIC VERTICAL FORMS UNIT NOT READY
3Bh	01h	T	TAPE POSITION ERROR AT BEGINNING-OF-MEDIUM
3Bh	02h	T	TAPE POSITION ERROR AT END-OF-MEDIUM
3Fh	00h	DTLPWRSOMC	TARGET OPERATING CONDITIONS HAVE CHANGED
5Bh	01h	DTLPWRSOM	THRESHOLD CONDITION MET
26h	03h	DTLPWRSOMC	THRESHOLD PARAMETERS NOT SUPPORTED
2Ch	01h	S	TOO MANY WINDOWS SPECIFIED
09h	00h	DT WR O	TRACK FOLLOWING ERROR
09h	01h	WR O	TRACKING SERVO FAILURE
61h	01h	S	UNABLE TO ACQUIRE VIDEO
57h	00h	R	UNABLE TO RECOVER TABLE-OF-CONTENTS
53h	01h	T	UNLOAD TAPE FAILURE
11h	00h	DT WRSO	UNRECOVERED READ ERROR
11h	04h	D W O	UNRECOVERED READ ERROR - AUTO REALLOCATE FAILED
11h	0Bh	D W O	UNRECOVERED READ ERROR - RECOMMEND REASSIGNMENT
11h	0Ch	D W O	UNRECOVERED READ ERROR - RECOMMEND REWRITE THE DATA
46h	00h	DTLPWRSOMC	UNSUCCESSFUL SOFT RESET
59h	00h	O	UPDATED BLOCK READ
61h	00h	S	VIDEO ACQUISITION ERROR
50h	00h	T	WRITE APPEND ERROR
50h	01h	T	WRITE APPEND POSITION ERROR
0Ch	00h	T S	WRITE ERROR
0Ch	02h	D W O	WRITE ERROR - AUTO REALLOCATION FAILED
0Ch	01h	D W O	WRITE ERROR RECOVERED WITH AUTO REALLOCATION
27h	00h	DT W O	WRITE PROTECTED

```
| 80h  XXh     \                                                          |
| THROUGH       >       VENDOR SPECIFIC.                                  |
| FFh  XX      /                                                          |
|                                                                         |
| XXh  80h     \                                                          |
| THROUGH       >       VENDOR SPECIFIC QUALIFICATION OF STANDARD ASC.    |
| XXh  FFh     /                                                          |
|                       ALL CODES NOT SHOWN ARE RESERVED.                 |
|-------------------------------------------------------------------------|
```

C.2 ASC and ASCQ in numerical order

Table 364: ASC and ASCQ Assignments

```
+=========================================================================+
|           D - DIRECT ACCESS DEVICE                                      |
|           .T - SEQUENTIAL ACCESS DEVICE                                 |
|           . L - PRINTER DEVICE                                          |
|           .  P - PROCESSOR DEVICE                                       |
|           .  .W - WRITE ONCE READ MULTIPLE DEVICE                       |
|           .  . R - READ ONLY (CD-ROM) DEVICE                            |
|           .  .  S - SCANNER DEVICE                                      |
|           .  .  .O - OPTICAL MEMORY DEVICE                              |
|           .  .  . M - MEDIA CHANGER DEVICE                              |
|           .  .  .  C - COMMUNICATION DEVICE                             |
|           .  .  .  .                                                   |
| ASC ASCQ  DTLPWRSOMC  DESCRIPTION                                       |
| --- ----              ------------------------------------------------- |
|  00  00   DTLPWRSOMC  NO ADDITIONAL SENSE INFORMATION                   |
|  00  01    T          FILEMARK DETECTED                                 |
|  00  02    T    S     END-OF-PARTITION/MEDIUM DETECTED                  |
|  00  03    T          SETMARK DETECTED                                  |
|  00  04    T    S     BEGINNING-OF-PARTITION/MEDIUM DETECTED            |
|  00  05    T    S     END-OF-DATA DETECTED                              |
|  00  06   DTLPWRSOMC  I/O PROCESS TERMINATED                            |
|  00  11   R           AUDIO PLAY OPERATION IN PROGRESS                  |
|  00  12   R           AUDIO PLAY OPERATION PAUSED                       |
|  00  13   R           AUDIO PLAY OPERATION SUCCESSFULLY COMPLETED       |
|  00  14   R           AUDIO PLAY OPERATION STOPPED DUE TO ERROR         |
|  00  15   R           NO CURRENT AUDIO STATUS TO RETURN                 |
|  01  00   DW  O       NO INDEX/SECTOR SIGNAL                            |
|  02  00   DWR OM      NO SEEK COMPLETE                                  |
|  03  00   DTL W SO    PERIPHERAL DEVICE WRITE FAULT                     |
|  03  01    T          NO WRITE CURRENT                                  |
|  03  02    T          EXCESSIVE WRITE ERRORS                            |
|  04  00   DTLPWRSOMC  LOGICAL UNIT NOT READY, CAUSE NOT REPORTABLE      |
|  04  01   DTLPWRSOMC  LOGICAL UNIT IS IN PROCESS OF BECOMING READY      |
|  04  02   DTLPWRSOMC  LOGICAL UNIT NOT READY, INITIALIZING COMMAND REQUIRED |
```

04	03	DTLPWRSOMC	LOGICAL UNIT NOT READY, MANUAL INTERVENTION REQUIRED
04	04	DTL O	LOGICAL UNIT NOT READY, FORMAT IN PROGRESS
05	00	DTL WRSOMC	LOGICAL UNIT DOES NOT RESPOND TO SELECTION
06	00	DWR OM NO	REFERENCE POSITION FOUND
07	00	DTL WRSOM	MULTIPLE PERIPHERAL DEVICES SELECTED
08	00	DTL WRSOMC	LOGICAL UNIT COMMUNICATION FAILURE
08	01	DTL WRSOMC	LOGICAL UNIT COMMUNICATION TIME-OUT
08	02	DTL WRSOMC	LOGICAL UNIT COMMUNICATION PARITY ERROR
09	00	DT WR O	TRACK FOLLOWING ERROR
09	01	WR O	TRA CKING SERVO FAILURE
09	02	WR O	FOC US SERVO FAILURE
09	03	WR O	SPI NDLE SERVO FAILURE

Table 364: (continued)

		D - DIRECT ACCESS DEVICE	
		.T - SEQUENTIAL ACCESS DEVICE	
		. L - PRINTER DEVICE	
		. P - PROCESSOR DEVICE	
		. .W - WRITE ONCE READ MULTIPLE DEVICE	
		. . R - READ ONLY (CD-ROM) DEVICE	
		. . S - SCANNER DEVICE	
		. . .O - OPTICAL MEMORY DEVICE	
		. . . M - MEDIA CHANGER DEVICE	
		. . . C - COMMUNICATION DEVICE	
		. . . .	
ASC	ASCQ	DTLPWRSOMC	DESCRIPTION
0A	00	DTLPWRSOMC	ERROR LOG OVERFLOW
0B	00		
0C	00	T S	WRITE ERROR
0C	01	D W O	WRITE ERROR RECOVERED WITH AUTO REALLOCATION
0C	02	D W O	WRITE ERROR - AUTO REALLOCATION FAILED
0D	00		
0E	00		
0F	00		
10	00	D W O	ID CRC OR ECC ERROR
11	00	DT WRSO	UNRECOVERED READ ERROR
11	01	DT W SO	READ RETRIES EXHAUSTED
11	02	DT W SO	ERROR TOO LONG TO CORRECT
11	03	DT W SO	MULTIPLE READ ERRORS
11	04	D W O	UNRECOVERED READ ERROR - AUTO REALLOCATE FAILED
11	05	WR O	L-EC UNCORRECTABLE ERROR
11	06	WR O	CIRC UNRECOVERED ERROR
11	07	W O	DATA RESYCHRONIZATION ERROR
11	08	T	INCOMPLETE BLOCK READ
11	09	T	NO GAP FOUND

11	0A	DT		O	MISCORRECTED ERROR
11	0B	D	W	O	UNRECOVERED READ ERROR - RECOMMEND REASSIGNMENT
11	0C	D	W	O	UNRECOVERED READ ERROR - RECOMMEND REWRITE THE DATA
12	00	D	W	O	ADDRESS MARK NOT FOUND FOR ID FIELD
13	00	D	W	O	ADDRESS MARK NOT FOUND FOR DATA FIELD
14	00	DTL	WRSO		RECORDED ENTITY NOT FOUND
14	01	DT	WR	O	RECORD NOT FOUND
14	02	T			FILEMARK OR SETMARK NOT FOUND
14	03	T			END-OF-DATA NOT FOUND
14	04	T			BLOCK SEQUENCE ERROR
15	00	DTL	WRSOM		RANDOM POSITIONING ERROR
15	01	DTL	WRSOM		MECHANICAL POSITIONING ERROR
15	02	DT	WR	O	POSITIONING ERROR DETECTED BY READ OF MEDIUM
16	00	DW		O	DATA SYNCHRONIZATION MARK ERROR
17	00	DT	WRSO		RECOVERED DATA WITH NO ERROR CORRECTION APPLIED
17	01	DT	WRSO		RECOVERED DATA WITH RETRIES
17	02	DT	WR	O	RECOVERED DATA WITH POSITIVE HEAD OFFSET
17	03	DT	WR	O	RECOVERED DATA WITH NEGATIVE HEAD OFFSET
17	04		WR	O	RECOVERED DATA WITH RETRIES AND/OR CIRC APPLIED
17	05	D	WR	O	RECOVERED DATA USING PREVIOUS SECTOR ID
17	06	D	W	O	RECOVERED DATA WITHOUT ECC - DATA AUTO-REALLOCATED
17	07	D	W	O	RECOVERED DATA WITHOUT ECC - RECOMMEND REASSIGNMENT
17	08	D	W	O	RECOVERED DATA WITHOUT ECC - RECOMMEND REWRITE
18	00	DT	WR	O	RECOVERED DATA WITH ERROR CORRECTION APPLIED
18	01	D	WR	O	RECOVERED DATA WITH ERROR CORRECTION & RETRIES APPLIED
18	02	D	WR	O	RECOVERED DATA - DATA AUTO-REALLOCATED
18	03		R		RECOVERED DATA WITH CIRC
18	04		R		RECOVERED DATA WITH LEC
18	05	D	WR	O	RECOVERED DATA - RECOMMEND REASSIGNMENT
18	06	D	WR	O	RECOVERED DATA - RECOMMEND REWRITE

Table 364: (continued)

		D - DIRECT ACCESS DEVICE				
		.T - SEQUENTIAL ACCESS DEVICE				
		. L - PRINTER DEVICE				
		. P - PROCESSOR DEVICE				
		. .W - WRITE ONCE READ MULTIPLE DEVICE				
		. . R - READ ONLY (CD-ROM) DEVICE				
		. . S - SCANNER DEVICE				
		. . .O - OPTICAL MEMORY DEVICE				
		. . . M - MEDIA CHANGER DEVICE				
		. . . C - COMMUNICATION DEVICE				
		. . . .				
ASC	ASCQ	DTLPWRSOMC				DESCRIPTION
---	----					---
19	00	D			O	DEFECT LIST ERROR

19	01	D O	DEFECT LIST NOT AVAILABLE
19	02	D O	DEFECT LIST ERROR IN PRIMARY LIST
19	03	D O	DEFECT LIST ERROR IN GROWN LIST
1A	00	DTLPWRSOMC	PARAMETER LIST LENGTH ERROR
1B	00	DTLPWRSOMC	SYNCHRONOUS DATA TRANSFER ERROR
1C	00	D O	DEFECT LIST NOT FOUND
1C	01	D O	PRIMARY DEFECT LIST NOT FOUND
1C	02	D O	GROWN DEFECT LIST NOT FOUND
1D	00	D W O	MISCOMPARE DURING VERIFY OPERATION
1E	00	D W O	RECOVERED ID WITH ECC
1F	00		
20	00	DTLPWRSOMC	INVALID COMMAND OPERATION CODE
21	00	DT WR OM	LOGICAL BLOCK ADDRESS OUT OF RANGE
21	01	M	INVALID ELEMENT ADDRESS
22	00	D	ILLEGAL FUNCTION (SHOULD USE 20 00, 24 00, OR 26 00)
23	00		
24	00	DTLPWRSOMC	INVALID FIELD IN CDB
25	00	DTLPWRSOMC	LOGICAL UNIT NOT SUPPORTED
26	00	DTLPWRSOMC	INVALID FIELD IN PARAMETER LIST
26	01	DTLPWRSOMC	PARAMETER NOT SUPPORTED
26	02	DTLPWRSOMC	PARAMETER VALUE INVALID
26	03	DTLPWRSOMC	THRESHOLD PARAMETERS NOT SUPPORTED
27	00	DT W O	WRITE PROTECTED
28	00	DTLPWRSOMC	NOT READY TO READY TRANSITION(MEDIUM MAY HAVE CHANGED)
28	01	M	IMPORT OR EXPORT ELEMENT ACCESSED
29	00	DTLPWRSOMC	POWER ON, RESET, OR BUS DEVICE RESET OCCURRED
2A	00	DTL WRSOMC	PARAMETERS CHANGED
2A	01	DTL WRSOMC	MODE PARAMETERS CHANGED
2A	02	DTL WRSOMC	LOG PARAMETERS CHANGED
2B	00	DTLPWRSO C	COPY CANNOT EXECUTE SINCE HOST CANNOT DISCONNECT
2C	00	DTLPWRSOMC	COMMAND SEQUENCE ERROR
2C	01	S	TOO MANY WINDOWS SPECIFIED
2C	02	S	INVALID COMBINATION OF WINDOWS SPECIFIED
2D	00	T	OVERWRITE ERROR ON UPDATE IN PLACE
2E	00		
2F	00	DTLPWRSOMC	COMMANDS CLEARED BY ANOTHER INITIATOR
30	00	DT WR OM	INCOMPATIBLE MEDIUM INSTALLED
30	01	DT WR O	CANNOT READ MEDIUM - UNKNOWN FORMAT
30	02	DT WR O	CANNOT READ MEDIUM - INCOMPATIBLE FORMAT
30	03	DT	CLEANING CARTRIDGE INSTALLED
31	00	DT W O	MEDIUM FORMAT CORRUPTED
31	01	D L O	FORMAT COMMAND FAILED
32	00	D W O	NO DEFECT SPARE LOCATION AVAILABLE
32	01	D W O	DEFECT LIST UPDATE FAILURE
33	00	T	TAPE LENGTH ERROR
34	00		
35	00		
36	00	L	RIBBON, INK, OR TONER FAILURE

Table 364: (continued)

```
|           D - DIRECT ACCESS DEVICE                                          |
|           .T - SEQUENTIAL ACCESS DEVICE                                     |
|           . L - PRINTER DEVICE                                              |
|           .  P - PROCESSOR DEVICE                                           |
|           .  .W - WRITE ONCE READ MULTIPLE DEVICE                           |
|           .  . R - READ ONLY (CD-ROM) DEVICE                                |
|           .  .  S - SCANNER DEVICE                                          |
|           .  .  .O - OPTICAL MEMORY DEVICE                                  |
|           .  .  . M - MEDIA CHANGER DEVICE                                  |
|           .  .  .  C - COMMUNICATION DEVICE                                 |
|           .  .  .  .                                                       |
| ASC ASCQ  DTLPWRSOMC  DESCRIPTION                                           |
| --- ----              ------------------------------------------------- |
|  37  00   DTL WRSOMC  ROUNDED PARAMETER                                     |
|  38  00                                                                     |
|  39  00   DTL WRSOMC  SAVING PARAMETERS NOT SUPPORTED                       |
|  3A  00   DTL WRSOM   MEDIUM NOT PRESENT                                    |
|  3B  00    TL         SEQUENTIAL POSITIONING ERROR                          |
|  3B  01    T          TAPE POSITION ERROR AT BEGINNING-OF-MEDIUM            |
|  3B  02    T          TAPE POSITION ERROR AT END-OF-MEDIUM                  |
|  3B  03     L         TAPE OR ELECTRONIC VERTICAL FORMS UNIT NOT READY      |
|  3B  04     L         SLEW FAILURE                                          |
|  3B  05     L         PAPER JAM                                             |
|  3B  06     L         FAILED TO SENSE TOP-OF-FORM                           |
|  3B  07     L         FAILED TO SENSE BOTTOM-OF-FORM                        |
|  3B  08    T          REPOSITION ERROR                                      |
|  3B  09         S     READ PAST END OF MEDIUM                               |
|  3B  0A         S     READ PAST BEGINNING OF MEDIUM                         |
|  3B  0B         S     POSITION PAST END OF MEDIUM                           |
|  3B  0C         S     POSITION PAST BEGINNING OF MEDIUM                     |
|  3B  0D           M   MEDIUM DESTINATION ELEMENT FULL                       |
|  3B  0E           M   MEDIUM SOURCE ELEMENT EMPTY                           |
|  3C  00                                                                     |
|  3D  00   DTLPWRSOMC  INVALID BITS IN IDENTIFY MESSAGE                      |
|  3E  00   DTLPWRSOMC  LOGICAL UNIT HAS NOT SELF-CONFIGURED YET              |
|  3F  00   DTLPWRSOMC  TARGET OPERATING CONDITIONS HAVE CHANGED              |
|  3F  01   DTLPWRSOMC  MICROCODE HAS BEEN CHANGED                            |
|  3F  02   DTLPWRSOMC  CHANGED OPERATING DEFINITION                          |
|  3F  03   DTLPWRSOMC  INQUIRY DATA HAS CHANGED                              |
|  40  00   D           RAM FAILURE (SHOULD USE 40 NN)                        |
|  40  NN   DTLPWRSOMC  DIAGNOSTIC FAILURE ON COMPONENT NN (80H-FFH)          |
|  41  00   D           DATA PATH FAILURE (SHOULD USE 40 NN)                  |
|  42  00   D           POWER-ON OR SELF-TEST FAILURE (SHOULD USE 40 NN)      |
|  43  00   DTLPWRSOMC  MESSAGE ERROR                                         |
```

44	00	DTLPWRSOMC		INTERNAL TARGET FAILURE
45	00	DTLPWRSOMC		SELECT OR RESELECT FAILURE
46	00	DTLPWRSOMC		UNSUCCESSFUL SOFT RESET
47	00	DTLPWRSOMC		SCSI PARITY ERROR
48	00	DTLPWRSOMC		INITIATOR DETECTED ERROR MESSAGE RECEIVED
49	00	DTLPWRSOMC		INVALID MESSAGE ERROR
4A	00	DTLPWRSOMC		COMMAND PHASE ERROR
4B	00	DTLPWRSOMC		DATA PHASE ERROR
4C	00	DTLPWRSOMC		LOGICAL UNIT FAILED SELF-CONFIGURATION
4D	00			
4E	00	DTLPWRSOMC		OVERLAPPED COMMANDS ATTEMPTED
4F	00			
50	00	T		WRITE APPEND ERROR
50	01	T		WRITE APPEND POSITION ERROR
50	02	T		POSITION ERROR RELATED TO TIMING
51	00	T	O	ERASE FAILURE
52	00	T		CARTRIDGE FAULT

Table 364: (continued)

		D - DIRECT ACCESS DEVICE		
		.T - SEQUENTIAL ACCESS DEVICE		
		. L - PRINTER DEVICE		
		. P - PROCESSOR DEVICE		
		. .W - WRITE ONCE READ MULTIPLE DEVICE		
		. . R - READ ONLY (CD-ROM) DEVICE		
		. . S - SCANNER DEVICE		
		. . .O - OPTICAL MEMORY DEVICE		
		. . . M - MEDIA CHANGER DEVICE		
		. . . C - COMMUNICATION DEVICE		
		. . . .		
ASC	ASCQ	DTLPWRSOMC		DESCRIPTION
53	00	DTL WRSOM		MEDIA LOAD OR EJECT FAILED
53	01	T		UNLOAD TAPE FAILURE
53	02	DT WR OM		MEDIUM REMOVAL PREVENTED
54	00	P		SCSI TO HOST SYSTEM INTERFACE FAILURE
55	00	P		SYSTEM RESOURCE FAILURE
56	00			
57	00	R		UNABLE TO RECOVER TABLE-OF-CONTENTS
58	00	O		GENERATION DOES NOT EXIST
59	00	O		UPDATED BLOCK READ
5A	00	DTLPWRSOM		OPERATOR REQUEST OR STATE CHANGE INPUT (UNSPECIFIED)
5A	01	DT WR OM		OPERATOR MEDIUM REMOVAL REQUEST
5A	02	DT W O		OPERATOR SELECTED WRITE PROTECT
5A	03	DT W O		OPERATOR SELECTED WRITE PERMIT
5B	00	DTLPWRSOM		LOG EXCEPTION

5B	01	DTLPWRSOM		THRESHOLD CONDITION MET
5B	02	DTLPWRSOM		LOG COUNTER AT MAXIMUM
5B	03	DTLPWRSOM		LOG LIST CODES EXHAUSTED
5C	00	D	O	RPL STATUS CHANGE
5C	01	D	O	SPINDLES SYNCHRONIZED
5C	02	D	O	SPINDLES NOT SYNCHRONIZED
5D	00			
5E	00			
5F	00			
60	00		S	LAMP FAILURE
61	00		S	VIDEO ACQUISITION ERROR
61	01		S	UNABLE TO ACQUIRE VIDEO
61	02		S	OUT OF FOCUS
62	00		S	SCAN HEAD POSITIONING ERROR
63	00		R	END OF USER AREA ENCOUNTERED ON THIS TRACK
64	00		R	ILLEGAL MODE FOR THIS TRACK
65	00			
66	00			
67	00			
68	00			
69	00			
6A	00			
6B	00			
6C	00			
6D	00			
6E	00			
6F	00			

Table 364: (concluded)

D - DIRECT ACCESS DEVICE
.T - SEQUENTIAL ACCESS DEVICE
. L - PRINTER DEVICE
. P - PROCESSOR DEVICE
. .W - WRITE ONCE READ MULTIPLE DEVICE
. . R - READ ONLY (CD-ROM) DEVICE
. . S - SCANNER DEVICE
. . .O - OPTICAL MEMORY DEVICE
. . . M - MEDIA CHANGER DEVICE
. . . C - COMMUNICATION DEVICE
. . . .

ASC	ASCQ	DTLPWRSOMC	DESCRIPTION
70	00		
71	00		
72	00		
73	00		

```
|  74  00                                                                    |
|  75  00                                                                    |
|  76  00                                                                    |
|  77  00                                                                    |
|  78  00                                                                    |
|  79  00                                                                    |
|  7A  00                                                                    |
|  7B  00                                                                    |
|  7C  00                                                                    |
|  7D  00                                                                    |
|  7E  00                                                                    |
|  7F  00                                                                    |
|                                                                            |
|  80  xxh \                                                                 |
|   THROUGH >  VENDOR SPECIFIC.                                              |
|  FF  xxh /                                                                 |
|                                                                            |
|  xxh 80 \                                                                  |
|  THROUGH >  VENDOR SPECIFIC QUALIFICATION OF STANDARD ASC.                 |
|  xxh FF /                                                                  |
|               ALL CODES NOT SHOWN OR BLANK ARE RESERVED.                   |
+============================================================================+
```

D A SCSI command code quick reference

Table 365 is a numerical order listing of the command operation codes.

Table 365: SCSI-2 Operation Codes

```
+============================================================================+
|           D - DIRECT ACCESS DEVICE                       Device Column Key |
|           .T - SEQUENTIAL ACCESS DEVICE                  M = Mandatory     |
|           . L - PRINTER DEVICE                           O = Optional      |
|           .  P - PROCESSOR DEVICE                        V = Vendor Specific|
|           .  .W - WRITE ONCE READ MULTIPLE DEVICE        R = Reserved      |
|           .  . R - READ ONLY (CD-ROM) DEVICE                               |
|           .  .  S - SCANNER DEVICE                                         |
|           .  .  .O - OPTICAL MEMORY DEVICE                                 |
|           .  .  . M - MEDIA CHANGER DEVICE                                 |
|           .  .  .  C - COMMUNICATION DEVICE                                |
|           .  .  .  .                                                       |
|        OP DTLPWRSOMC Description                                           |
|----------+----------+-------------------------------------------------------|
|        00 MMMMMMMMMM TEST UNIT READY                                       |
|        01  M         REWIND                                                |
|        01 O V OO OO  REZERO UNIT                                           |
|        02 VVVVVV  V                                                        |
```

```
|        03 MMMMMMMMMM REQUEST SENSE                                          |
|        04   O        FORMAT                                                 |
|        04 M      O   FORMAT UNIT                                            |
|        05 VMVVVV  V  READ BLOCK LIMITS                                      |
|        06 VVVVVV  V                                                         |
|        07         O  INITIALIZE ELEMENT STATUS                              |
|        07 OVV O  OV  REASSIGN BLOCKS                                        |
|        08          M GET MESSAGE(06)                                        |
|        08 OMV OO OV  READ(06)                                               |
|        08    O       RECEIVE                                                |
|        09 VVVVVV  V                                                         |
|        0A   M        PRINT                                                  |
|        0A          M SEND MESSAGE(06)                                       |
|        0A    M       SEND(06)                                               |
|        0A OM  O  OV  WRITE(06)                                              |
|        0B O   OO OV  SEEK(06)                                               |
|        0B   O        SLEW AND PRINT                                         |
|        0C VVVVVV  V                                                         |
|        0D VVVVVV  V                                                         |
|        0E VVVVVV  V                                                         |
|        0F VOVVVV  V  READ REVERSE                                           |
|        10   O O      SYNCHRONIZE BUFFER                                     |
|        10 VM VVV     WRITE FILEMARKS                                        |
|        11 VMVVVV     SPACE                                                  |
|        12 MMMMMMMMMM INQUIRY                                                |
|        13 VOVVVV     VERIFY(06)                                             |
|        14 VOOVVV     RECOVER BUFFERED DATA                                  |
|        15 OMO OOOOOO MODE SELECT(06)                                        |
|        16 M   MM MO  RESERVE                                                |
|        16  MM   M    RESERVE UNIT                                           |
|        17 M   MM MO  RELEASE                                                |
|        17  MM   M    RELEASE UNIT                                           |
|        18 OOOOOOOO   COPY                                                   |
|        19 VMVVVV     ERASE                                                  |
|        1A OMO OOOOOO MODE SENSE(06)                                        |
|        1B  O         LOAD UNLOAD                                           |
|        1B       O    SCAN                                                   |
|        1B   O        STOP PRINT                                             |
|        1B O   OO O   STOP START UNIT                                        |
+=============================================================================+
```

Table 365: (continued)

```
+=============================================================================+
|           D - DIRECT ACCESS DEVICE                    Device Column Key     |
|           .T - SEQUENTIAL ACCESS DEVICE               M = Mandatory         |
|           . L - PRINTER DEVICE                        O = Optional          |
|           .  P - PROCESSOR DEVICE                     V = Vendor Specific   |
|           .  .W - WRITE ONCE READ MULTIPLE DEVICE     R = Reserved          |
```

```
|           .  . R - READ ONLY (CD-ROM) DEVICE                                |
|           .  .  S - SCANNER DEVICE                                          |
|           .  .  .O - OPTICAL MEMORY DEVICE                                  |
|           .  .  . M - MEDIA CHANGER DEVICE                                  |
|           .  .  .  C - COMMUNICATION DEVICE                                 |
|           .  .  .  .                                                       |
|        OP DTLPWRSOMC Description                                            |
|----------+----------+-------------------------------------------------------|
|        1C OOOOOOOOOO RECEIVE DIAGNOSTIC RESULTS                             |
|        1D MMMMMMMMMM SEND DIAGNOSTIC                                        |
|        1E OO  OO OO  PREVENT ALLOW MEDIUM REMOVAL                           |
|        1F                                                                   |
|        20 V   VV V                                                          |
|        21 V   VV V                                                          |
|        22 V   VV V                                                          |
|        23 V   VV V                                                          |
|        24 V   VVM    SET WINDOW                                            |
|        25       O    GET WINDOW                                            |
|        25 M   M  M   READ CAPACITY                                          |
|        25      M     READ CD-ROM CAPACITY                                  |
|        26 V   VV                                                           |
|        27 V   VV                                                           |
|        28          O GET MESSAGE(10)                                        |
|        28 M   MMMM   READ(10)                                               |
|        29 V   VV O   READ GENERATION                                        |
|        2A          O SEND MESSAGE(10)                                       |
|        2A       O    SEND(10)                                              |
|        2A M   M  M   WRITE(10)                                             |
|        2B  O         LOCATE                                                |
|        2B         O  POSITION TO ELEMENT                                   |
|        2B O   OO O   SEEK(10)                                               |
|        2C V      O   ERASE(10)                                              |
|        2D V   O  O   READ UPDATED BLOCK                                     |
|        2E O   O  O   WRITE AND VERIFY(10)                                   |
|        2F O   OO O   VERIFY(10)                                             |
|        30 O   OO O   SEARCH DATA HIGH(10)                                   |
|        31       O    OBJECT POSITION                                       |
|        31 O   OO O   SEARCH DATA EQUAL(10)                                  |
|        32 O   OO O   SEARCH DATA LOW(10)                                    |
|        33 O   OO O   SET LIMITS(10)                                         |
|        34       O    GET DATA BUFFER STATUS                                |
|        34 O   OO O   PRE-FETCH                                              |
|        34  O         READ POSITION                                         |
|        35 O   OO O   SYNCHRONIZE CACHE                                      |
|        36 O   OO O   LOCK UNLOCK CACHE                                      |
|        37 O      O   READ DEFECT DATA(10)                                   |
|        38     O  O   MEDIUM SCAN                                            |
|        39 OOOOOOOO   COMPARE                                                |
```

3A	OOOOOOOO	COPY AND VERIFY
3B	OOOOOOOOOO	WRITE BUFFER
3C	OOOOOOOOOO	READ BUFFER
3D	O O	UPDATE BLOCK
3E	O OO O	READ LONG
3F	O O O	WRITE LONG

Table 365: (continued)

D - DIRECT ACCESS DEVICE		Device Column Key
.T - SEQUENTIAL ACCESS DEVICE		M = Mandatory
. L - PRINTER DEVICE		O = Optional
. P - PROCESSOR DEVICE		V = Vendor Specific
. .W - WRITE ONCE READ MULTIPLE DEVICE		R = Reserved
. . R - READ ONLY (CD-ROM) DEVICE		
. . S - SCANNER DEVICE		
. . .O - OPTICAL MEMORY DEVICE		
. . . M - MEDIA CHANGER DEVICE		
. . . C - COMMUNICATION DEVICE		
. . . .		
OP	DTLPWRSOMC	Description
40	OOOOOOOOOO	CHANGE DEFINITION
41	O	WRITE SAME
42	O	READ SUB-CHANNEL
43	O	READ TOC
44	O	READ HEADER
45	O	PLAY AUDIO(10)
46		
47	O	PLAY AUDIO MSF
48	O	PLAY AUDIO TRACK INDEX
49	O	PLAY TRACK RELATIVE(10)
4A		
4B	O	PAUSE RESUME
4C	OOOOOOOOOO	LOG SELECT
4D	OOOOOOOOOO	LOG SENSE
4E		
4F		
50		
51		
52		
53		
54		
55	OOO OOOOOO	MODE SELECT(10)
56		
57		
58		

59		
5A OOO OOOOOO	MODE SENSE(10)	
5B		
5C		
5D		
5E		
5F		

Table 365: (concluded)

D - DIRECT ACCESS DEVICE	Device Column Key
.T - SEQUENTIAL ACCESS DEVICE	M = Mandatory
. L - PRINTER DEVICE	O = Optional
. P - PROCESSOR DEVICE	V = Vendor Specific
. .W - WRITE ONCE READ MULTIPLE DEVICE	R = Reserved
. . R - READ ONLY (CD-ROM) DEVICE	
. . S - SCANNER DEVICE	
. . .O - OPTICAL MEMORY DEVICE	
. . . M - MEDIA CHANGER DEVICE	
. . . C - COMMUNICATION DEVICE	
. . . .	

OP	DTLPWRSOMC	Description
A0		
A1		
A2		
A3		
A4		
A5	M	MOVE MEDIUM
A5	O	PLAY AUDIO(12)
A6	O	EXCHANGE MEDIUM
A7		
A8	O	GET MESSAGE(12)
A8	OO O	READ(12)
A9	O	PLAY TRACK RELATIVE(12)
AA	O	SEND MESSAGE(12)
AA	O O	WRITE(12)
AB		
AC	O	ERASE(12)
AD		
AE	O O	WRITE AND VERIFY(12)
AF	OO O	VERIFY(12)
B0	OO O	SEARCH DATA HIGH(12)
B1	OO O	SEARCH DATA EQUAL(12)
B2	OO O	SEARCH DATA LOW(12)
B3	OO O	SET LIMITS(12)
B4		

```
|        B5                                                                    |
|        B5         0  REQUEST VOLUME ELEMENT ADDRESS                          |
|        B6                                                                    |
|        B6         0  SEND VOLUME TAG                                         |
|        B7        0   READ DEFECT DATA(12)                                    |
|        B8                                                                    |
|        B8         0  READ ELEMENT STATUS                                     |
|        B9                                                                    |
|        BA                                                                    |
|        BB                                                                    |
|        BC                                                                    |
|        BD                                                                    |
|        BE                                                                    |
|        BF                                                                    |
+==============================================================================+
```

E Example programs

Here is the C example program, which requests manufacturer/model and reports if a medium is loaded in the device.

```
#define DEVICE "/dev/sgc"
/* Example program to demonstrate the generic SCSI interface */
#include <stdio.h>
#include <unistd.h>
#include <string.h>
#include <fcntl.h>
#include <errno.h>
#include <scsi/sg.h>

#define SCSI_OFF sizeof(struct sg_header)
static unsigned char cmd[SCSI_OFF + 18];      /* SCSI command buffer */
int fd;                                 /* SCSI device/file descriptor */

/* process a complete scsi cmd. Use the generic scsi interface. */
static int handle_scsi_cmd(unsigned cmd_len,         /* command length */
                           unsigned in_size,         /* input data size */
                           unsigned char *i_buff,    /* input buffer */
                           unsigned out_size,        /* output data size */
                           unsigned char *o_buff     /* output buffer */
                           )
{
    int status = 0;
    struct sg_header *sg_hd;

    /* safety checks */
    if (!cmd_len) return -1;            /* need a cmd_len != 0 */
```

```
    if (!i_buff) return -1;            /* need an input buffer != NULL */
#ifdef SG_BIG_BUFF
    if (SCSI_OFF + cmd_len + in_size > SG_BIG_BUFF) return -1;
    if (SCSI_OFF + out_size > SG_BIG_BUFF) return -1;
#else
    if (SCSI_OFF + cmd_len + in_size > 4096) return -1;
    if (SCSI_OFF + out_size > 4096) return -1;
#endif

    if (!o_buff) out_size = 0;

    /* generic scsi device header construction */
    sg_hd = (struct sg_header *) i_buff;
    sg_hd->reply_len   = SCSI_OFF + out_size;
    sg_hd->twelve_byte = cmd_len == 12;
    sg_hd->result = 0;
#if     0
    sg_hd->pack_len    = SCSI_OFF + cmd_len + in_size; /* not necessary */
    sg_hd->pack_id;     /* not used */
    sg_hd->other_flags; /* not used */
#endif

    /* send command */
    status = write( fd, i_buff, SCSI_OFF + cmd_len + in_size );
    if ( status < 0 || status != SCSI_OFF + cmd_len + in_size ||
                      sg_hd->result ) {
        /* some error happened */
        fprintf( stderr, "write(generic) result = 0x%x cmd = 0x%x\n",
                    sg_hd->result, i_buff[SCSI_OFF] );
        perror("");
        return status;
    }

    if (!o_buff) o_buff = i_buff;       /* buffer pointer check */

    /* retrieve result */
    status = read( fd, o_buff, SCSI_OFF + out_size);
    if ( status < 0 || status != SCSI_OFF + out_size || sg_hd->result ) {
        /* some error happened */
        fprintf( stderr, "read(generic) result = 0x%x cmd = 0x%x\n",
                sg_hd->result, o_buff[SCSI_OFF] );
        fprintf( stderr, "read(generic) sense "
                "%x %x %x %x %x %x %x %x %x %x %x %x %x %x %x %x\n",
                sg_hd->sense_buffer[0],         sg_hd->sense_buffer[1],
                sg_hd->sense_buffer[2],         sg_hd->sense_buffer[3],
                sg_hd->sense_buffer[4],         sg_hd->sense_buffer[5],
                sg_hd->sense_buffer[6],         sg_hd->sense_buffer[7],
                sg_hd->sense_buffer[8],         sg_hd->sense_buffer[9],
```

```
                sg_hd->sense_buffer[10],        sg_hd->sense_buffer[11],
                sg_hd->sense_buffer[12],        sg_hd->sense_buffer[13],
                sg_hd->sense_buffer[14],        sg_hd->sense_buffer[15]);
        if (status < 0)
            perror("");
    }
    /* Look if we got what we expected to get */
    if (status == SCSI_OFF + out_size) status = 0; /* got them all */

    return status;  /* 0 means no error */
}

#define INQUIRY_CMD     0x12
#define INQUIRY_CMDLEN  6
#define INQUIRY_REPLY_LEN 96
#define INQUIRY_VENDOR  8       /* Offset in reply data to vendor name */

/* request vendor brand and model */
static unsigned char *Inquiry ( void )
{
  unsigned char Inqbuffer[ SCSI_OFF + INQUIRY_REPLY_LEN ];
  unsigned char cmdblk [ INQUIRY_CMDLEN ] =
      { INQUIRY_CMD,  /* command */
                0,  /* lun/reserved */
                0,  /* page code */
                0,  /* reserved */
  INQUIRY_REPLY_LEN,  /* allocation length */
                0 };/* reserved/flag/link */

  memcpy( cmd + SCSI_OFF, cmdblk, sizeof(cmdblk) );

  /*
   * +------------------+
   * | struct sg_header | <- cmd
   * +------------------+
   * | copy of cmdblk   | <- cmd + SCSI_OFF
   * +------------------+
   */

  if (handle_scsi_cmd(sizeof(cmdblk), 0, cmd,
                      sizeof(Inqbuffer) - SCSI_OFF, Inqbuffer )) {
      fprintf( stderr, "Inquiry failed\n" );
      exit(2);
  }
  return (Inqbuffer + SCSI_OFF);
}

#define TESTUNITREADY_CMD 0
```

```
#define TESTUNITREADY_CMDLEN 6

#define ADD_SENSECODE 12
#define ADD_SC_QUALIFIER 13
#define NO_MEDIA_SC 0x3a
#define NO_MEDIA_SCQ 0x00
int TestForMedium ( void )
{
  /* request READY status */
  static unsigned char cmdblk [TESTUNITREADY_CMDLEN] = {
      TESTUNITREADY_CMD, /* command */
                      0, /* lun/reserved */
                      0, /* reserved */
                      0, /* reserved */
                      0, /* reserved */
                      0};/* reserved */

  memcpy( cmd + SCSI_OFF, cmdblk, sizeof(cmdblk) );

  /*
   * +------------------+
   * | struct sg_header | <- cmd
   * +------------------+
   * | copy of cmdblk   | <- cmd + SCSI_OFF
   * +------------------+
   */

  if (handle_scsi_cmd(sizeof(cmdblk), 0, cmd,
                           0, NULL)) {
      fprintf (stderr, "Test unit ready failed\n");
      exit(2);
  }

  return
   *(((struct sg_header*)cmd)->sense_buffer +ADD_SENSECODE) !=
                                                    NO_MEDIA_SC ||
   *(((struct sg_header*)cmd)->sense_buffer +ADD_SC_QUALIFIER) !=
                                                    NO_MEDIA_SCQ;
}

void main( void )
{
  fd = open(DEVICE, O_RDWR);
  if (fd < 0) {
    fprintf( stderr, "Need read/write permissions for "DEVICE".\n" );
    exit(1);
  }
```

```
  /* print some fields of the Inquiry result */
  printf( "%s\n", Inquiry() + INQUIRY_VENDOR );

  /* look if medium is loaded */
  if (!TestForMedium()) {
    printf("device is unloaded\n");
  } else {
    printf("device is loaded\n");
  }
}
```