

Serial Programming Guide for POSIX Operating Systems

5th Edition, 6th Revision
Copyright 1994-2005 by Michael R. Sweet

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in [Appendix C, GNU Free Documentation License](#).

Table of Contents

Introduction.....	1
License.....	1
Organization.....	1
Chapter 1, Basics of Serial Communications.....	3
What Are Serial Communications?.....	3
What Is RS-232?.....	4
Signal Definitions.....	4
Asynchronous Communications.....	5
What Are Full Duplex and Half Duplex?.....	6
Flow Control.....	6
What Is a Break?.....	6
Synchronous Communications.....	6
Accessing Serial Ports.....	7
Serial Port Files.....	7
Opening a Serial Port.....	7
Writing Data to the Port.....	8
Reading Data from the Port.....	8
Closing a Serial Port.....	9
Chapter 2, Configuring the Serial Port.....	11
The POSIX Terminal Interface.....	11
Control Options.....	12
Local Options.....	15
Input Options.....	16
Output Options.....	18
Control Characters.....	19
Chapter 3, MODEM Communications.....	21
What Is a MODEM?.....	21
Communicating With a MODEM.....	21
Standard MODEM Commands.....	23
Common MODEM Communication Problems.....	23
Chapter 4, Advanced Serial Programming.....	25
Serial Port IOCTLs.....	25
Getting the Control Signals.....	26
Setting the Control Signals.....	27
Getting the Number of Bytes Available.....	27
Selecting Input from a Serial Port.....	28
The SELECT System Call.....	28
Using the SELECT System Call.....	28
Using SELECT with the X Intrinsic Library.....	29
Appendix A, Pinouts.....	31
RS-232 Pinouts.....	32
RS-422 Pinouts.....	33
RS-574 (IBM PC/AT) Pinouts.....	33
SGI Pinouts.....	34
Appendix B, ASCII Control Codes.....	35
Control Codes.....	35

Table of Contents

Appendix C, GNU Free Documentation License.....	37
How to use this License for your documents.....	42
Appendix D, Change History.....	43
Edition 5, Revision 6.....	43
Edition 5, Revision 5.....	43
Edition 5, Revision 4.....	43
Edition 5, Revision 3.....	44

Introduction

The Serial Programming Guide for POSIX Operating Systems will teach you how to successfully, efficiently, and portably program the serial ports on your UNIX® workstation or PC. Each chapter provides programming examples that use the POSIX (Portable Standard for UNIX) terminal control functions and should work with very few modifications under IRIX®, HP-UX, SunOS®, Solaris®, Digital UNIX®, Linux®, and most other UNIX operating systems. The biggest difference between operating systems that you will find is the filenames used for serial port device and lock files.

License

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in [Appendix C, GNU Free Documentation License](#).

Organization

This guide is organized into the following chapters and appendices:

- [Chapter 1, Basics of Serial Programming](#)
- [Chapter 2, Configuring the Serial Port](#)
- [Chapter 3, Talking to MODEMs](#)
- [Chapter 4, Advanced Serial Programming](#)
- [Appendix A, RS-232 Pinouts](#)
- [Appendix B, ASCII Control Codes](#)
- [Appendix C, GNU Free Documentation License](#)
- [Appendix D, Change History](#)

Chapter 1, Basics of Serial Communications

This chapter introduces serial communications, RS-232 and other standards that are used on most computers as well as how to access a serial port from a C program.

What Are Serial Communications?

Computers transfer information (data) one or more bits at a time. Serial refers to the transfer of data one bit at a time. Serial communications include most network devices, keyboards, mice, MODEMs, and terminals.

When doing serial communications each word (i.e. byte or character) of data you send or receive is sent one bit at a time. Each bit is either *on* or *off*. The terms you'll hear sometimes are *mark* for the *on* state and *space* for the *off* state.

The speed of the serial data is most often expressed as bits-per-second ("bps") or baudot rate ("baud"). This just represents the number of ones and zeroes that can be sent in one second. Back at the dawn of the computer age, 300 baud was considered fast, but today computers can handle RS-232 speeds as high as 430,800 baud! When the baud rate exceeds 1,000, you'll usually see the rate shown in *kilobaud*, or kbps (e.g. 9.6k, 19.2k, etc). For rates above 1,000,000 that rate is shown in *megabaud*, or Mbps (e.g. 1.5Mbps).

When referring to serial devices or ports, they are either labeled as *Data Communications Equipment* ("DCE") or *Data Terminal Equipment* ("DTE"). The difference between these is simple - every signal pair, like transmit and receive, is swapped. When connecting two DTE or two DCE interfaces together, a serial *null-MODEM* cable or adapter is used that swaps the signal pairs.

What Is RS-232?

RS-232 is a standard electrical interface for serial communications defined by the [Electronic Industries Association \("EIA"\)](#). RS-232 actually comes in 3 different flavors (A, B, and C) with each one defining a different voltage range for the *on* and *off* levels. The most commonly used variety is RS-232C, which defines a mark (on) bit as a voltage between -3V and -12V and a space (off) bit as a voltage between +3V and +12V. The RS-232C specification says these signals can go about 25 feet (8m) before they become unusable. You can usually send signals a bit farther than this as long as the baud is low enough.

Besides wires for incoming and outgoing data, there are others that provide timing, status, and handshaking:

Table 1 - RS-232 Pin Assignments

Pin	Description	Pin	Description	Pin	Description	Pin	Description	Pin	Description
1	Earth Ground	6	DSR - Data Set Ready	11	Unassigned	16	Secondary RXD	21	Signal Quality Detect
2	TXD - Transmitted Data	7	GND - Logic Ground	12	Secondary DCD	17	Receiver Clock	22	Ring Detect
3	RXD - Received Data	8	DCD - Data Carrier Detect	13	Secondary CTS	18	Unassigned	23	Data Rate Select
4	RTS - Request To Send	9	Reserved	14	Secondary TXD	19	Secondary RTS	24	Transmit Clock
5	CTS - Clear To Send	10	Reserved	15	Transmit Clock	20	DTR - Data Terminal Ready	25	Unassigned

Two standards for serial interfaces you may also see are RS-422 and RS-574. RS-422 uses lower voltages and *differential* signals to allow cable lengths up to about 1000ft (300m). RS-574 defines the 9-pin PC serial connector and voltages.

Signal Definitions

The RS-232 standard defines some 18 different signals for serial communications. Of these, only six are generally available in the UNIX environment.

GND - Logic Ground

Technically the logic ground is not a signal, but without it none of the other signals will operate. Basically, the logic ground acts as a reference voltage so that the electronics know which voltages are positive or negative.

TXD - Transmitted Data

The TXD signal carries data transmitted from your workstation to the computer or device on the other end (like a MODEM). A mark voltage is interpreted as a value of 1, while a space voltage is interpreted as a value of 0.

RXD - Received Data

The RXD signal carries data transmitted from the computer or device on the other end to your workstation. Like TXD, mark and space voltages are interpreted as 1 and 0, respectively.

DCD - Data Carrier Detect

The DCD signal is received from the computer or device on the other end of your serial cable. A space voltage on this signal line indicates that the computer or device is currently connected or on line. DCD is not always used or available.

DTR - Data Terminal Ready

The DTR signal is generated by your workstation and tells the computer or device on the other end that you are ready (a space voltage) or not-ready (a mark voltage). DTR is usually enabled automatically whenever you open the serial interface on the workstation.

CTS - Clear To Send

The CTS signal is received from the other end of the serial cable. A space voltage indicates that it is alright to send more serial data from your workstation.

CTS is usually used to regulate the flow of serial data from your workstation to the other end.

RTS - Request To Send

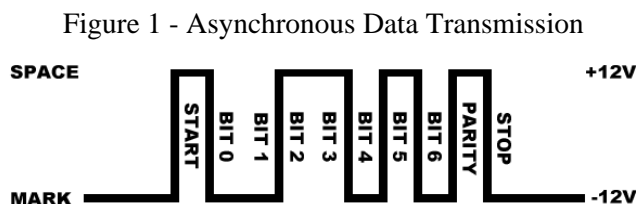
The RTS signal is set to the *space* voltage by your workstation to indicate that more data is ready to be sent.

Like CTS, RTS helps to regulate the flow of data between your workstation and the computer or device on the other end of the serial cable. Most workstations leave this signal set to the space voltage all the time.

Asynchronous Communications

For the computer to understand the serial data coming into it, it needs some way to determine where one character ends and the next begins. This guide deals exclusively with *asynchronous* serial data.

In asynchronous mode the serial data line stays in the mark (1) state until a character is transmitted. A *start* bit precedes each character and is followed immediately by each bit in the character, an optional parity bit, and one or more *stop* bits. The start bit is always a space (0) and tells the computer that new serial data is available. Data can be sent or received at any time, thus the name asynchronous.



The optional parity bit is a simple sum of the data bits indicating whether or not the data contains an even or odd number of 1 bits. With *even parity*, the parity bit is 0 if there is an even number of 1's in the character. With *odd parity*, the parity bit is 0 if there is an odd number of 1's in the data. You may also hear the terms *space parity*, *mark parity*, and *no parity*. Space parity means that the parity bit is always 0, while mark parity means the bit is always 1. No parity means that no parity bit is present or transmitted.

The remaining bits are called stop bits. There can be 1, 1.5, or 2 stop bits between characters and they always have a value of 1. Stop bits traditionally were used to give the computer time to process the previous character, but now only serve to synchronize the receiving computer to the incoming characters.

Asynchronous data formats are usually expressed as "8N1", "7E1", and so forth. These stand for "8 data bits, no parity, 1 stop bit" and "7 data bits, even parity, 1 stop bit" respectively.

What Are Full Duplex and Half Duplex?

Full duplex means that the computer can send and receive data simultaneously - there are two separate data channels (one coming in, one going out).

Half duplex means that the computer cannot send or receive data at the same time. Usually this means there is only a single data channel to talk over. This does not mean that any of the RS-232 signals are not used. Rather, it usually means that the communications link uses some standard other than RS-232 that does not support full duplex operation.

Flow Control

It is often necessary to regulate the flow of data when transferring data between two serial interfaces. This can be due to limitations in an intermediate serial communications link, one of the serial interfaces, or some storage media. Two methods are commonly used for asynchronous data.

The first method is often called "software" flow control and uses special characters to start (XON or DC1, 021 octal) or stop (XOFF or DC3, 023 octal) the flow of data. These characters are defined in the [American Standard Code for Information Interchange \("ASCII"\)](#). While these codes are useful when transferring textual information, they cannot be used when transferring other types of information without special programming.

The second method is called "hardware" flow control and uses the RS-232 CTS and RTS signals instead of special characters. The receiver sets CTS to the space voltage when it is ready to receive more data and to the mark voltage when it is not ready. Likewise, the sender sets RTS to the space voltage when it is ready to send more data. Because hardware flow control uses a separate set of signals, it is much faster than software flow control which needs to send or receive multiple bits of information to do the same thing. CTS/RTS flow control is not supported by all hardware or operating systems.

What Is a Break?

Normally a receive or transmit data signal stays at the mark voltage until a new character is transferred. If the signal is dropped to the space voltage for a long period of time, usually 1/4 to 1/2 second, then a break condition is said to exist.

A break is sometimes used to reset a communications line or change the operating mode of communications hardware like a MODEM. [Chapter 3, Talking to MODEMs](#) covers these applications in more depth.

Synchronous Communications

Unlike asynchronous data, synchronous data appears as a constant stream of bits. To read the data on the line, the computer must provide or receive a common bit clock so that both the sender and receiver are synchronized.

Even with this synchronization, the computer must mark the beginning of the data somehow. The most common way of doing this is to use a data packet protocol like Serial Data Link Control ("SDLC") or High-Speed Data Link Control ("HDLC").

Each protocol defines certain bit sequences to represent the beginning and end of a data packet. Each also defines a bit sequence that is used when there is no data. These bit sequences allow the computer to see the beginning of a data packet.

Because synchronous protocols do not use per-character synchronization bits they typically provide at least a 25% improvement in performance over asynchronous communications and are suitable for remote networking and configurations with more than two serial interfaces.

Despite the speed advantages of synchronous communications, most RS-232 hardware does not support it due to the extra hardware and software required.

Accessing Serial Ports

Like all devices, UNIX provides access to serial ports via *device files*. To access a serial port you simply open the corresponding device file.

Serial Port Files

Each serial port on a UNIX system has one or more device files (files in the `/dev` directory) associated with it:

Table 2 - Serial Port Device Files

System	Port 1	Port 2
IRIX®	/dev/ttyf1	/dev/ttyf2
HP-UX	/dev/tty1p0	/dev/tty2p0
Solaris®/SunOS®	/dev/ttya	/dev/ttyb
Linux®	/dev/ttyS0	/dev/ttyS1
Digital UNIX®	/dev/tty01	/dev/tty02

Opening a Serial Port

Since a serial port is a file, the `open(2)` function is used to access it. The one hitch with UNIX is that device files are usually not accessible by normal users. Workarounds include changing the access permissions to the file(s) in question, running your program as the super-user (root), or making your program set-userid so that it runs as the owner of the device file (not recommended for obvious security reasons...)

For now we'll assume that the file is accessible by all users. The code to open serial port 1 on a PC running Linux is show in [Listing 1](#).

Listing 1 - Opening a serial port.

```
#include <stdio.h>    /* Standard input/output definitions */
#include <string.h>    /* String function definitions */
#include <unistd.h>    /* UNIX standard function definitions */
#include <fcntl.h>     /* File control definitions */
#include <errno.h>     /* Error number definitions */
#include <termios.h>   /* POSIX terminal control definitions */

/*
 * 'open_port()' - Open serial port 1.
 *
 * Returns the file descriptor on success or -1 on error.
 */

int
```

```
open_port(void)
{
    int fd; /* File descriptor for the port */

    fd = open("/dev/ttyS0", O_RDWR | O_NOCTTY | O_NDELAY);
    if (fd == -1)
    {
        /*
         * Could not open the port.
         */

        perror("open_port: Unable to open /dev/ttyS0 - ");
    }
    else
        fcntl(fd, F_SETFL, 0);

    return (fd);
}
```

Other systems would require the corresponding device file name, but otherwise the code is the same.

Open Options

You'll notice that when we opened the device file we used two other flags along with the read+write mode:

```
fd = open("/dev/ttyS0", O_RDWR | O_NOCTTY | O_NDELAY);
```

The *O_NOCTTY* flag tells UNIX that this program doesn't want to be the "controlling terminal" for that port. If you don't specify this then any input (such as keyboard abort signals and so forth) will affect your process. Programs like *getty(1M/8)* use this feature when starting the login process, but normally a user program does not want this behavior.

The *O_NDELAY* flag tells UNIX that this program doesn't care what state the DCD signal line is in - whether the other end of the port is up and running. If you do not specify this flag, your process will be put to sleep until the DCD signal line is the space voltage.

Writing Data to the Port

Writing data to the port is easy - just use the *write(2)* system call to send data it:

```
n = write(fd, "ATZ\r", 4);
if (n < 0)
    fputs("write() of 4 bytes failed!\n", stderr);
```

The *write* function returns the number of bytes sent or -1 if an error occurred. Usually the only error you'll run into is *EIO* when a MODEM or data link drops the Data Carrier Detect (DCD) line. This condition will persist until you close the port.

Reading Data from the Port

Reading data from a port is a little trickier. When you operate the port in raw data mode, each *read(2)* system call will return the number of characters that are actually available in the serial input buffers. If no characters are available, the call will block (wait) until characters come in, an interval timer expires, or an error occurs. The *read* function can be made to return immediately by doing the following:

```
fcntl(fd, F_SETFL, FNDELAY);
```

Serial Programming Guide for POSIX Operating Systems

The *FNDELAY* option causes the *read* function to return 0 if no characters are available on the port. To restore normal (blocking) behavior, call *fcntl()* without the *FNDELAY* option:

```
fcntl(fd, F_SETFL, 0);
```

This is also used after opening a serial port with the *O_NDELAY* option.

Closing a Serial Port

To close the serial port, just use the *close* system call:

```
close(fd);
```

Closing a serial port will also usually set the DTR signal low which causes most MODEMs to hang up.

Chapter 2, Configuring the Serial Port

This chapter discusses how to configure a serial port from C using the POSIX `termios` interface.

The POSIX Terminal Interface

Most systems support the POSIX terminal (serial) interface for changing parameters such as baud rate, character size, and so on. The first thing you need to do is include the file `<termios.h>`; this defines the terminal control structure as well as the POSIX control functions.

The two most important POSIX functions are `tcgetattr(3)` and `tcsetattr(3)`. These get and set terminal attributes, respectively; you provide a pointer to a `termios` structure that contains all of the serial options available:

Table 3 - Termios Structure Members

Member	Description
<code>c_cflag</code>	Control options
<code>c_lflag</code>	Line options
<code>c_iflag</code>	Input options
<code>c_oflag</code>	Output options
<code>c_cc</code>	Control characters
<code>c_ispeed</code>	Input baud (new interface)
<code>c_ospeed</code>	Output baud (new interface)

Control Options

The *c_cflag* member controls the baud rate, number of data bits, parity, stop bits, and hardware flow control. There are constants for all of the supported configurations.

Table 4 - Constants for the *c_cflag* Member

Constant	Description
CBAUD	Bit mask for baud rate
B0	0 baud (drop DTR)
B50	50 baud
B75	75 baud
B110	110 baud
B134	134.5 baud
B150	150 baud
B200	200 baud
B300	300 baud
B600	600 baud
B1200	1200 baud
B1800	1800 baud
B2400	2400 baud
B4800	4800 baud
B9600	9600 baud
B19200	19200 baud
B38400	38400 baud
B57600	57,600 baud
B76800	76,800 baud
B115200	115,200 baud
EXTA	External rate clock
EXTB	External rate clock
CSIZE	Bit mask for data bits
CS5	5 data bits
CS6	6 data bits
CS7	7 data bits
CS8	8 data bits
CSTOPB	2 stop bits (1 otherwise)
CREAD	Enable receiver
PARENB	Enable parity bit
PARODD	Use odd parity instead of even
HUPCL	Hangup (drop DTR) on last close
CLOCAL	Local line - do not change "owner" of port
LOBLK	Block job control output
CNEW_RTSCCTS	Enable hardware flow control (not supported on all platforms)
CRTSCTS	

The `c_cflag` member contains two options that should always be enabled, `CLOCAL` and `CREAD`. These will ensure that your program does not become the 'owner' of the port subject to sporadic job control and hangup signals, and also that the serial interface driver will read incoming data bytes.

The baud rate constants (`CBAUD`, `B9600`, etc.) are used for older interfaces that lack the `c_ispeed` and `c_ospeed` members. See the next section for information on the POSIX functions used to set the baud rate.

Never initialize the `c_cflag` (or any other flag) member directly; you should always use the bitwise AND, OR, and NOT operators to set or clear bits in the members. Different operating system versions (and even patches) can and do use the bits differently, so using the bitwise operators will prevent you from clobbering a bit flag that is needed in a newer serial driver.

Setting the Baud Rate

The baud rate is stored in different places depending on the operating system. Older interfaces store the baud rate in the `c_cflag` member using one of the baud rate constants in table 4, while newer implementations provide the `c_ispeed` and `c_ospeed` members that contain the actual baud rate value.

The `cfsetospeed(3)` and `cfsetispeed(3)` functions are provided to set the baud rate in the `termios` structure regardless of the underlying operating system interface. Typically you'd use the code in [Listing 2](#) to set the baud rate.

Listing 2 - Setting the baud rate.

```
struct termios options;

/*
 * Get the current options for the port...
 */

tcgetattr(fd, &options);

/*
 * Set the baud rates to 19200...
 */

cfsetispeed(&options, B19200);
cfsetospeed(&options, B19200);

/*
 * Enable the receiver and set local mode...
 */

options.c_cflag |= (CLOCAL | CREAD);

/*
 * Set the new options for the port...
 */

tcsetattr(fd, TCSANOW, &options);
```

The `tcgetattr(3)` function fills the `termios` structure you provide with the current serial port configuration. After we set the baud rates and enable local mode and serial data receipt, we select the new configuration using `tcsetattr(3)`. The `TCSANOW` constant specifies that all changes should occur immediately without waiting for output data to finish sending or input data to finish receiving. There are other constants to wait for input and output to finish or to flush the input and output buffers.

Most systems do not support different input and output speeds, so be sure to set both to the same value for maximum portability.

Table 5 - Constants for tcsetattr

Constant	Description
TCSANOW	Make changes now without waiting for data to complete
TCSADRAIN	Wait until everything has been transmitted
TCSAFLUSH	Flush input and output buffers and make the change

Setting the Character Size

Unlike the baud rate, there is no convenience function to set the character size. Instead you must do a little bitmasking to set things up. The character size is specified in bits:

```
options.c_cflag &= ~CSIZE; /* Mask the character size bits */
options.c_cflag |= CS8;    /* Select 8 data bits */
```

Setting Parity Checking

Like the character size you must manually set the parity enable and parity type bits. UNIX serial drivers support even, odd, and no parity bit generation. Space parity can be simulated with clever coding.

- No parity (8N1):

```
options.c_cflag &= ~PARENB
options.c_cflag &= ~CSTOPB
options.c_cflag &= ~CSIZE;
options.c_cflag |= CS8;
```

- Even parity (7E1):

```
options.c_cflag |= PARENB
options.c_cflag &= ~PARODD
options.c_cflag &= ~CSTOPB
options.c_cflag &= ~CSIZE;
options.c_cflag |= CS7;
```

- Odd parity (7O1):

```
options.c_cflag |= PARENB
options.c_cflag |= PARODD
options.c_cflag &= ~CSTOPB
options.c_cflag &= ~CSIZE;
options.c_cflag |= CS7;
```

- Space parity is setup the same as no parity (7S1):

```
options.c_cflag &= ~PARENB
options.c_cflag &= ~CSTOPB
options.c_cflag &= ~CSIZE;
options.c_cflag |= CS8;
```

Setting Hardware Flow Control

Some versions of UNIX support hardware flow control using the CTS (Clear To Send) and RTS (Request To Send) signal lines. If the *CNEW_RTSCS* or *CRTSCS* constants are defined on your system then hardware flow control is probably supported. Do the following to enable hardware flow control:

```
options.c_cflag |= CNEW_RTSCS;    /* Also called CRTSCS */
```

Similarly, to disable hardware flow control:

```
options.c_cflag &= ~CNEW_RTSCS;
```

Local Options

The local modes member *c_lflag* controls how input characters are managed by the serial driver. In general you will configure the *c_lflag* member for *canonical* or *raw* input.

Table 6 - Constants for the *c_lflag* Member

Constant	Description
ISIG	Enable SIGINTR, SIGSUSP, SIGDSUSP, and SIGQUIT signals
ICANON	Enable canonical input (else raw)
XCASE	Map uppercase \lowercase (obsolete)
ECHO	Enable echoing of input characters
ECHOE	Echo erase character as BS-SP-BS
ECHOK	Echo NL after kill character
ECHONL	Echo NL
NOFLSH	Disable flushing of input buffers after interrupt or quit characters
IEXTEN	Enable extended functions
ECHOCTL	Echo control characters as ^char and delete as ~?
ECHOPRT	Echo erased character as character erased
ECHOKE	BS-SP-BS entire line on line kill
FLUSHO	Output being flushed
PENDIN	Retype pending input at next read or input char
TOSTOP	Send SIGTTOU for background output

Choosing Canonical Input

Canonical input is line-oriented. Input characters are put into a buffer which can be edited interactively by the user until a CR (carriage return) or LF (line feed) character is received.

When selecting this mode you normally select the *ICANON*, *ECHO*, and *ECHOE* options:

```
options.c_lflag |= (ICANON | ECHO | ECHOE);
```

Choosing Raw Input

Raw input is unprocessed. Input characters are passed through exactly as they are received, when they are received. Generally you'll deselect the *ICANON*, *ECHO*, *ECHOE*, and *ISIG* options when using raw input:

```
options.c_lflag &= ~(ICANON | ECHO | ECHOE | ISIG);
```

A Note About Input Echo

Never enable input echo (*ECHO*, *ECHOE*) when sending commands to a MODEM or other computer that is echoing characters, as you will generate a feedback loop between the two serial interfaces!

Input Options

The input modes member *c_iflag* controls any input processing that is done to characters received on the port. Like the *c_cflag* field, the final value stored in *c_iflag* is the bitwise OR of the desired options.

Table 7 - Constants for the *c_iflag* Member

Constant	Description
INPCK	Enable parity check
IGNPAR	Ignore parity errors
PARMRK	Mark parity errors
ISTRIP	Strip parity bits
IXON	Enable software flow control (outgoing)
IXOFF	Enable software flow control (incoming)
IXANY	Allow any character to start flow again
IGNBRK	Ignore break condition
BRKINT	Send a SIGINT when a break condition is detected
INLCR	Map NL to CR
IGNCR	Ignore CR
ICRNL	Map CR to NL
IUCLC	Map uppercase to lowercase
IMAXBEL	Echo BEL on input line too long

Setting Input Parity Options

You should enable input parity checking when you have enabled parity in the *c_cflag* member (*PARENB*). The relevant constants for input parity checking are *INPCK*, *IGNPAR*, *PARMRK*, and *ISTRIP*. Generally you will select *INPCK* and *ISTRIP* to enable checking and stripping of the parity bit:

```
options.c_iflag |= (INPCK | ISTRIP);
```

IGNPAR is a somewhat dangerous option that tells the serial driver to ignore parity errors and pass the incoming data through as if no errors had occurred. This can be useful for testing the quality of a communications link, but in general is not used for practical reasons.

PARMRK causes parity errors to be 'marked' in the input stream using special characters. If *IGNPAR* is enabled, a NUL character (000 octal) is sent to your program before every character with a parity error. Otherwise, a DEL (177 octal) and NUL character is sent along with the bad character.

Setting Software Flow Control

Software flow control is enabled using the *IXON*, *IXOFF*, and *IXANY* constants:

```
options.c_iflag |= (IXON | IXOFF | IXANY);
```

To disable software flow control simply mask those bits:

```
options.c_iflag &= ~(IXON | IXOFF | IXANY);
```

The XON (start data) and XOFF (stop data) characters are defined in the *c_cc* array described below.

Output Options

The *c_oflag* member contains output filtering options. Like the input modes, you can select processed or raw data output.

Table 8 - Constants for the *c_oflag* Member

Constant	Description
OPOST	Postprocess output (not set = raw output)
OLCUC	Map lowercase to uppercase
ONLCR	Map NL to CR-NL
OCRNL	Map CR to NL
NOCR	No CR output at column 0
ONLRET	NL performs CR function
OFILL	Use fill characters for delay
OFDEL	Fill character is DEL
NLDLY	Mask for delay time needed between lines
NL0	No delay for NLs
NL1	Delay further output after newline for 100 milliseconds
CRDLY	Mask for delay time needed to return carriage to left column
CR0	No delay for CRs
CR1	Delay after CRs depending on current column position
CR2	Delay 100 milliseconds after sending CRs
CR3	Delay 150 milliseconds after sending CRs
TABDLY	Mask for delay time needed after TABs
TAB0	No delay for TABs
TAB1	Delay after TABs depending on current column position
TAB2	Delay 100 milliseconds after sending TABs
TAB3	Expand TAB characters to spaces
BSDLY	Mask for delay time needed after BSs
BS0	No delay for BSs
BS1	Delay 50 milliseconds after sending BSs
VTDLY	Mask for delay time needed after VTs
VT0	No delay for VTs
VT1	Delay 2 seconds after sending VTs
FFDLY	Mask for delay time needed after FFs
FF0	No delay for FFs
FF1	Delay 2 seconds after sending FFs

Choosing Processed Output

Processed output is selected by setting the *OPOST* option in the *c_oflag* member:

```
options.c_oflag |= OPOST;
```

Of all the different options, you will only probably use the *ONLCR* option which maps newlines into CR-LF pairs. The rest of the output options are primarily historic and date back to the time when line printers and terminals could not keep up with the serial data stream!

Choosing Raw Output

Raw output is selected by resetting the *OPOST* option in the *c_oflag* member:

```
options.c_oflag &= ~OPOST;
```

When the *OPOST* option is disabled, all other option bits in *c_oflag* are ignored.

Control Characters

The *c_cc* character array contains control character definitions as well as timeout parameters. Constants are defined for every element of this array.

Table 9 - Control Characters in the *c_cc* Member

Constant	Description	Key
VINTR	Interrupt	CTRL-C
VQUIT	Quit	CTRL-Z
VERASE	Erase	Backspace (BS)
VKILL	Kill-line	CTRL-U
VEOF	End-of-file	CTRL-D
VEOL	End-of-line	Carriage return (CR)
VEOL2	Second end-of-line	Line feed (LF)
VMIN	Minimum number of characters to read	-
VSTART	Start flow	CTRL-Q (XON)
VSTOP	Stop flow	CTRL-S (XOFF)
VTIME	Time to wait for data (tenths of seconds)	-

Setting Software Flow Control Characters

The *VSTART* and *VSTOP* elements of the *c_cc* array contain the characters used for software flow control. Normally they should be set to DC1 (021 octal) and DC3 (023 octal) which represent the [ASCII](#) standard XON and XOFF characters.

Setting Read Timeouts

UNIX serial interface drivers provide the ability to specify character and packet timeouts. Two elements of the *c_cc* array are used for timeouts: *VMIN* and *VTIME*. **Timeouts are ignored in canonical input mode or when the *NDELAY* option is set on the file via *open* or *fcntl*.**

VMIN specifies the minimum number of characters to read. If it is set to 0, then the *VTIME* value specifies the time to wait for every character read. Note that this does not mean that a *read* call for N bytes will wait for N characters to come in. Rather, the timeout will apply to the first character and the *read* call will return the

number of characters immediately available (up to the number you request).

If *VMIN* is non-zero, *VTIME* specifies the time to wait for the first character read. If a character is read within the time given, any read will block (wait) until all *VMIN* characters are read. That is, once the first character is read, the serial interface driver expects to receive an entire packet of characters (*VMIN* bytes total). If no character is read within the time allowed, then the call to *read* returns 0. This method allows you to tell the serial driver you need exactly N bytes and any *read* call will return 0 or N bytes. However, the timeout only applies to the first character read, so if for some reason the driver misses one character inside the N byte packet then the *read* call could block forever waiting for additional input characters.

VTIME specifies the amount of time to wait for incoming characters in tenths of seconds. If *VTIME* is set to 0 (the default), reads will block (wait) indefinitely unless the *NDELAY* option is set on the port with *open* or *fcntl*.

Chapter 3, MODEM Communications

This chapter covers the basics of dialup telephone Modulator/Demodulator (MODEM) communications. Examples are provided for MODEMs that use the defacto standard "AT" command set.

What Is a MODEM?

MODEMs are devices that modulate serial data into frequencies that can be transferred over an analog data link such as a telephone line or cable TV connection. A standard telephone MODEM converts serial data into tones that can be passed over the phone lines; because of the speed and complexity of the conversion these tones sound more like loud screeching if you listen to them.

Telephone MODEMs are available today that can transfer data across a telephone line at nearly 53,000 bits per second, or 53kbps. In addition, most MODEMs use data compression technology that can increase the bit rate to well over 100kbps on some types of data.

Communicating With a MODEM

The first step in communicating with a MODEM is to open and configure the port for *raw* input as shown in [Listing 3](#).

Listing 3 - Configuring the port for raw input.

```
int          fd;
struct termios options;

/* open the port */
fd = open("/dev/ttyS0", O_RDWR | O_NOCTTY | O_NDELAY);
fcntl(fd, F_SETFL, 0);

/* get the current options */
tcgetattr(fd, &options);

/* set raw input, 1 second timeout */
options.c_cflag |= (CLOCAL | CREAD);
options.c_lflag  &= ~(ICANON | ECHO | ECHOE | ISIG);
options.c_oflag  &= ~OPOST;
options.c_cc[VMIN] = 0;
options.c_cc[VTIME] = 10;

/* set the options */
tcsetattr(fd, TCSANOW, &options);
```

Next you need to establish communications with the MODEM. The best way to do this is by sending the "AT" command to the MODEM. This also allows smart MODEMs to detect the baud you are using. When the MODEM is connected correctly and powered on it will respond with the response "OK".

Listing 4 - Initializing the MODEM.

```
int          /* 0 - 0 = MODEM ok, -1 = MODEM bad */
init_modem(int fd) /* I - Serial port file */
{
    char buffer[255]; /* Input buffer */
    char *bufptr;     /* Current char in buffer */
    int  nbytes;      /* Number of bytes read */
    int  tries;       /* Number of tries so far */

    for (tries = 0; tries < 3; tries++)
    {
        /* send an AT command followed by a CR */
        if (write(fd, "AT\r", 3) < 3)
            continue;

        /* read characters into our string buffer until we get a CR or NL */
        bufptr = buffer;
        while ((nbytes = read(fd, bufptr, buffer + sizeof(buffer) - bufptr - 1)) > 0)
        {
            bufptr += nbytes;
            if (bufptr[-1] == '\n' || bufptr[-1] == '\r')
                break;
        }

        /* nul terminate the string and see if we got an OK response */
        *bufptr = '\0';

        if (strncmp(buffer, "OK", 2) == 0)
            return (0);
    }

    return (-1);
}
```

Standard MODEM Commands

Most MODEMs support the "AT" command set, so called because each command starts with the "AT" characters. Each command is sent with the "AT" characters starting in the first column followed by the specific command and a carriage return (CR, 015 octal). After processing the command the MODEM will reply with one of several textual messages depending on the command.

ATD - Dial A Number

The *ATD* command dials the specified number. In addition to numbers and dashes you can specify tone ("T") or pulse ("P") dialing, pause for one second (","), and wait for a dialtone ("W"):

```
ATDT 555-1212
ATDT 18008008008W1234,1,1234
ATD T555-1212WP1234
```

The MODEM will reply with one of the following messages:

```
NO DIALTONE
BUSY
NO CARRIER
CONNECT
CONNECT baud
```

ATH - Hang Up

The *ATH* command causes the MODEM to hang up. Since the MODEM must be in "command" mode you probably won't use it during a normal phone call.

Most MODEMs will also hang up if DTR is dropped; you can do this by setting the baud to 0 for at least 1 second. Dropping DTR also returns the MODEM to command mode.

After a successful hang up the MODEM will reply with "NO CARRIER". If the MODEM is still connected the "CONNECT" or "CONNECT baud" message will be sent.

ATZ - Reset MODEM

The *ATZ* command resets the MODEM. The MODEM will reply with the string "OK".

Common MODEM Communication Problems

First and foremost, *don't forget to disable input echoing*. Input echoing will cause a feedback loop between the MODEM and computer.

Second, when sending MODEM commands you must terminate them with a carriage return (CR) and not a newline (NL). The C character constant for CR is "\r".

Finally, when dealing with a MODEM make sure you use a baud that the MODEM supports. While many MODEMs do auto-baud detection, some have limits (19.2kbps is common on older MODEMs) that you must observe.

Chapter 4, Advanced Serial Programming

This chapter covers advanced serial programming techniques using the *ioctl(2)* and *select(2)* system calls.

Serial Port IOCTLs

In [Chapter 2, Configuring the Serial Port](#) we used the *tcgetattr* and *tcsetattr* functions to configure the serial port. Under UNIX these functions use the *ioctl(2)* system call to do their magic.

The *ioctl* system call takes three arguments:

```
int ioctl(int fd, int request, ...);
```

The *fd* argument specifies the serial port file descriptor. The *request* argument is a constant defined in the `<termios.h>` header file and is typically one of the constants listed in [Table 10](#).

Table 10 - IOCTL Requests for Serial Ports

Request	Description	POSIX Function
TCGETS	Gets the current serial port settings.	tcgetattr
TCSETS	Sets the serial port settings immediately.	tcsetattr(fd, TCSANOW, &options)
TCSETSF	Sets the serial port settings after flushing the input and output buffers.	tcsetattr(fd, TCSAFLUSH, &options)
TCSETSW	Sets the serial port settings after allowing the input and output buffers to drain/empty.	tcsetattr(fd, TCSADRAIN, &options)
TCSBRK	Sends a break for the given time.	tcsendbreak, tcdrain
TCXONC	Controls software flow control.	tcflow
TCFLSH	Flushes the input and/or output queue.	tcflush
TIOCMGET	Returns the state of the "MODEM" bits.	None
TIOCMSET	Sets the state of the "MODEM" bits.	None
FIONREAD	Returns the number of bytes in the input buffer.	None

Getting the Control Signals

The `TIOCMGET` *ioctl* gets the current "MODEM" status bits, which consist of all of the RS-232 signal lines except **RXD** and **TXD**, listed in [Table 11](#).

To get the status bits, call *ioctl* with a pointer to an integer to hold the bits, as shown in [Listing 5](#).

Listing 5 - Getting the MODEM status bits.

```
#include <unistd.h>
#include <termios.h>

int fd;
int status;

ioctl(fd, TIOCMGET, &status);
```

Table 11 - Control Signal Constants

Constant	Description
TIOCM_LE	DSR (data set ready/line enable)
TIOCM_DTR	DTR (data terminal ready)
TIOCM_RTS	RTS (request to send)
TIOCM_ST	Secondary TXD (transmit)
TIOCM_SR	Secondary RXD (receive)
TIOCM_CTS	CTS (clear to send)
TIOCM_CAR	DCD (data carrier detect)
TIOCM_CD	Synonym for TIOCM_CAR
TIOCM_RNG	RNG (ring)
TIOCM_RI	Synonym for TIOCM_RNG
TIOCM_DSR	DSR (data set ready)

Setting the Control Signals

The `TIOCMSET` *ioctl* sets the "MODEM" status bits defined above. To drop the DTR signal you can use the code in [Listing 6](#).

Listing 6 - Dropping DTR with the TIOCMSET ioctl.

```
#include <unistd.h>
#include <termios.h>

int fd;
int status;

ioctl(fd, TIOCMGET, &status);

status &= ~TIOCM_DTR;

ioctl(fd, TIOCMSET, &status);
```

The bits that can be set depend on the operating system, driver, and modes in use. Consult your operating system documentation for more information.

Getting the Number of Bytes Available

The `FIONREAD` *ioctl* gets the number of bytes in the serial port input buffer. As with `TIOCMGET` you pass in a pointer to an integer to hold the number of bytes, as shown in [Listing 7](#).

Listing 7 - Getting the number of bytes in the input buffer.

```
#include <unistd.h>
#include <termios.h>

int fd;
int bytes;

ioctl(fd, FIONREAD, &bytes);
```

This can be useful when polling a serial port for data, as your program can determine the number of bytes in the input buffer before attempting a read.

Selecting Input from a Serial Port

While simple applications can poll or wait on data coming from the serial port, most applications are not simple and need to handle input from multiple sources.

UNIX provides this capability through the *select(2)* system call. This system call allows your program to check for input, output, or error conditions on one or more file descriptors. The file descriptors can point to serial ports, regular files, other devices, pipes, or sockets. You can poll to check for pending input, wait for input indefinitely, or timeout after a specific amount of time, making the *select* system call extremely flexible.

Most GUI Toolkits provide an interface to *select*; we will discuss the X Intrinsics ("Xt") library later in this chapter.

The SELECT System Call

The *select* system call accepts 5 arguments:

```
int select(int max_fd, fd_set *input, fd_set *output, fd_set *error,
          struct timeval *timeout);
```

The *max_fd* argument specifies the highest numbered file descriptor in the *input*, *output*, and *error* sets. The *input*, *output*, and *error* arguments specify sets of file descriptors for pending input, output, or error conditions; specify NULL to disable monitoring for the corresponding condition. These sets are initialized using three macros:

```
FD_ZERO(&fd_set);
FD_SET(fd, &fd_set);
FD_CLR(fd, &fd_set);
```

The *FD_ZERO* macro clears the set entirely. The *FD_SET* and *FD_CLR* macros add and remove a file descriptor from the set, respectively.

The *timeout* argument specifies a timeout value which consists of seconds (*timeout.tv_sec*) and microseconds (*timeout.tv_usec*). To poll one or more file descriptors, set the seconds and microseconds to zero. To wait indefinitely specify NULL for the timeout pointer.

The *select* system call returns the number of file descriptors that have a pending condition, or -1 if there was an error.

Using the SELECT System Call

Suppose we are reading data from a serial port and a socket. We want to check for input from either file descriptor, but want to notify the user if no data is seen within 10 seconds. To do this we'll need to use the *select* system call, as shown in [Listing 8](#).

Listing 8 - Using SELECT to process input from more than one source.

```
#include <unistd.h>
#include <sys/types.h>
#include <sys/time.h>
#include <sys/select.h>

int          n;
int          socket;
int          fd;
int          max_fd;
fd_set       input;
struct timeval timeout;

/* Initialize the input set */
FD_ZERO(&input);
FD_SET(fd, &input);
FD_SET(socket, &input);

max_fd = (socket > fd ? socket : fd) + 1;

/* Initialize the timeout structure */
timeout.tv_sec  = 10;
timeout.tv_usec = 0;

/* Do the select */
n = select(max_fd, &input, NULL, NULL, &timeout);

/* See if there was an error */
if (n < 0)
    perror("select failed");
else if (n == 0)
    puts("TIMEOUT");
else
{
    /* We have input */
    if (FD_ISSET(fd, &input))
        process_fd();
    if (FD_ISSET(socket, &input))
        process_socket();
}
```

You'll notice that we first check the return value of the *select* system call. Values of 0 and -1 yield the appropriate warning and error messages. Values greater than 0 mean that we have data pending on one or more file descriptors.

To determine which file descriptor(s) have pending input, we use the *FD_ISSET* macro to test the input set for each file descriptor. If the file descriptor flag is set then the condition exists (input pending in this case) and we need to do something.

Using SELECT with the X Intrinsic Library

The X Intrinsic library provides an interface to the *select* system call via the *XtAppAddInput(3x)* and *XtAppRemoveInput(3x)* functions:

```
int XtAppAddInput(XtAppContext context, int fd, int mask,
                  XtInputProc proc, XtPointer data);
void XtAppRemoveInput(XtAppContext context, int input);
```

The *select* system call is used internally to implement timeouts, work procedures, and check for input from the X server. These functions can be used with any Xt-based toolkit including Xaw, Lesstif, and Motif.

Serial Programming Guide for POSIX Operating Systems

The *proc* argument to *XtAppAddInput* specifies the function to call when the selected condition (e.g. input available) exists on the file descriptor. In the previous example you could specify the *process_fd* or *process_socket* functions.

Because Xt limits your access to the *select* system call, you'll need to implement timeouts through another mechanism, probably via *XtAppAddTimeout(3x)*.

Appendix A, Pinouts

This appendix provides pinout information for many of the common serial ports you will find.

RS-232 Pinouts

RS-232 comes in three flavors (A, B, C) and uses a 25-pin D-Sub connector:

Figure 2 - RS-232 Connector

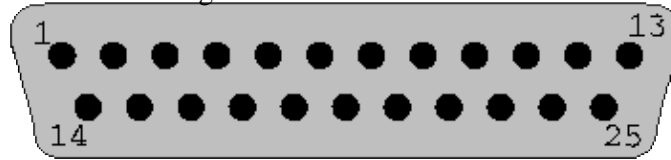


Table 12 - RS-232 Signals

Pin	Description	Pin	Description
1	Earth Ground	14	Secondary TXD
2	TXD - Transmitted Data	15	Transmit Clock
3	RXD - Received Data	16	Secondary RXD
4	RTS - Request To Send	17	Receiver Clock
5	CTS - Clear To Send	18	Unassigned
6	DSR - Data Set Ready	19	Secondary RTS
7	GND - Logic Ground	20	DTR - Data Terminal Ready
8	DCD - Data Carrier Detect	21	Signal Quality Detect
9	Reserved	22	Ring Detect
10	Reserved	23	Data Rate Select
11	Unassigned	24	Transmit Clock
12	Secondary DCD	25	Unassigned
13	Secondary CTS		

RS-422 Pinouts

RS-422 also uses a 25-pin D-Sub connector, but with differential signals:

Figure 3 - RS-422 Connector

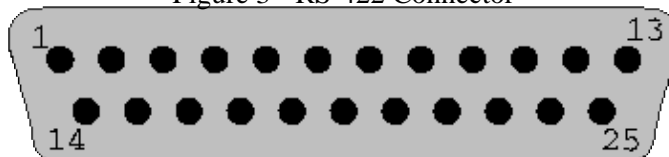


Table 13 - RS-422 Signals

Pin	Description	Pin	Description
1	Earth Ground	14	TXD+
2	TXD- - Transmitted Data	15	Transmit Clock-
3	RXD- - Received Data	16	RXD+
4	RTS- - Request To Send	17	Receiver Clock-
5	CTS- - Clear To Send	18	Unassigned
6	DSR - Data Set Ready	19	RTS+
7	GND - Logic Ground	20	DTR- - Data Terminal Ready
8	DCD- - Data Carrier Detect	21	Signal Quality Detect
9	Reserved	22	Unassigned
10	Reserved	23	DTR+
11	Unassigned	24	Transmit Clock+
12	DCD+	25	Receiver Clock+
13	CTS+		

RS-574 (IBM PC/AT) Pinouts

The RS-574 interface is used exclusively by PC manufacturers and uses a 9-pin male D-Sub connector:

Figure 4 - RS-574 Connector

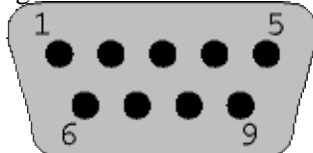


Table 14 - RS-574 (IBM PC/AT) Signals

Pin	Description	Pin	Description
1	DCD - Data Carrier Detect	6	Data Set Ready
2	RXD - Received Data	7	RTS - Request To Send
3	TXD - Transmitted Data	8	CTS - Clear To Send
4	DTR - Data Terminal Ready	9	Ring Detect
5	GND - Logic Ground		

SGI Pinouts

Older SGI equipment uses a 9-pin female D-Sub connector. Unlike RS-574, the SGI pinouts nearly match those of RS-232:

Figure 5 - SGI 9-Pin Connector

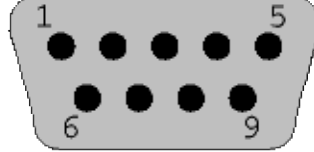


Table 15 - SGI 9-Pin DSUB Signals

Pin	Description	Pin	Description
1	Earth Ground	6	DSR - Data Set Ready
2	TXD - Transmitted Data	7	GND - Logic Ground
3	RXD - Received Data	8	DCD - Data Carrier Detect
4	RTS - Request To Send	9	DTR - Data Terminal Ready
5	CTS - Clear To Send		

The SGI Indigo, Indigo2, and Indy workstations use the Apple 8-pin MiniDIN connector for their serial ports:

Figure 6 - SGI 8-Pin Connector

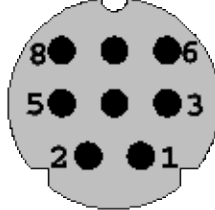


Table 16 - SGI 8-Pin MiniDIN Signals

Pin	Description	Pin	Description
1	DTR - Data Terminal Ready	5	RXD - Received Data
2	CTS - Clear To Send	6	RTS - Request To Send
3	TXD - Transmitted Data	7	DCD - Data Carrier Detect
4	GND - Logic Ground	8	GND - Logic Ground

Appendix B, ASCII Control Codes

This chapter lists the ASCII control codes and their names.

Control Codes

The following ASCII characters are used for control purposes:

Table 17 - ASCII Control Codes

Name	Binary	Octal	Decimal	Hexadecimal
NUL	00000000	000	0	00
SOH	00000001	001	1	01
STX	00000010	002	2	02
ETX	00000011	003	3	03
EOT	00000100	004	4	04
ENQ	00000101	005	5	05
ACK	00000110	006	6	06
BEL	00000111	007	7	07
BS	00001000	010	8	08
HT	00001001	011	9	09
NL	00001010	012	10	0A
VT	00001011	013	11	0B
NP, FF	00001100	014	12	0C

Serial Programming Guide for POSIX Operating Systems

Name	Binary	Octal	Decimal	Hexadecimal
CR	00001101	015	13	0D
SO	00001110	016	14	0E
SI	00001111	017	15	0F
DLE	00010000	020	16	10
XON, DC1	00010001	021	17	11
DC2	00010010	022	18	12
XOFF, DC3	00010011	023	19	13
DC4	00010100	024	20	14
NAK	00010101	025	21	15
SYN	00010110	026	22	16
ETB	00010111	027	23	17
CAN	00011000	030	24	18
EM	00011001	031	25	19
SUB	00011010	032	26	1A
ESC	00011011	033	27	1B
FS	00011100	034	28	1C
GS	00011101	035	29	1D
RS	00011110	036	30	1E
US	00011111	037	31	1F

Appendix C, GNU Free Documentation License

Version 1.2, November 2002

Copyright (C) 2000,2001,2002 Free Software Foundation, Inc.
59 Temple Place, Suite 330, Boston, MA 02111-1307 USA
Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.

0. PREAMBLE

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you". You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section "Entitled XYZ" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "Acknowledgements", "Dedications", "Endorsements", or "History".) To "Preserve the Title" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

- **A.** Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- **B.** List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the

Serial Programming Guide for POSIX Operating Systems

Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.

- **C.** State on the Title page the name of the publisher of the Modified Version, as the publisher.
- **D.** Preserve all the copyright notices of the Document.
- **E.** Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- **F.** Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
- **G.** Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
- **H.** Include an unaltered copy of this License.
- **I.** Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
- **J.** Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
- **K.** For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- **L.** Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- **M.** Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
- **N.** Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
- **O.** Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties--for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined

work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements."

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights,

from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <http://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

```
Copyright (c)  YEAR  YOUR NAME.
Permission is granted to copy, distribute and/or modify this document
under the terms of the GNU Free Documentation License, Version 1.2
or any later version published by the Free Software Foundation;
with no Invariant Sections, no Front-Cover Texts, and no Back-Cover
  Texts.  A copy of the license is included in the section entitled "GNU
Free Documentation License".
```

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

```
with the Invariant Sections being LIST THEIR TITLES, with the
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.

Appendix D, Change History

This appendix lists the changes that have been made in this edition.

Edition 5, Revision 6

The following changes were made for the 6th revision:

- The `select()` example did not correctly use the FD macros.
- The title page and this appendix were not properly updated.

Edition 5, Revision 5

The following changes were made for the 5th revision:

- The `select()` documentation did not correctly describe the FD macros.
- Appendix C was missing the "how to use" part of the GNU FDL.

Edition 5, Revision 4

The following changes were made for the 4th revision:

- Changed the description of the `read()` system call semantics in chapter 1.
- Added descriptions for `VSTART` and `VSTOP` to chapter 2.

Edition 5, Revision 3

The following changes were made for the 3rd revision:

- Now use the GNU Free Documentation License for the guide.
- Changed the examples to use the Linux serial port filenames.
- Put the infrastructure in place to allow for easier translations of the guide.
- The guide text is now fully justified.