Cygwin User’s Guide
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Abstract

Cygwin User’s Guide
Chapter 1

Cygwin Overview

1.1 What is it?

Cygwin is a Linux-like environment for Windows. It consists of a DLL (cygwin1.dll), which acts as an emulation layer providing substantial POSIX (Portable Operating System Interface) system call functionality, and a collection of tools, which provide a Linux look and feel. The Cygwin DLL works with all x86 and AMD64 versions of Windows NT since Windows XP SP3. The API follows the Single Unix Specification as much as possible, and then Linux practice. The major differences between Cygwin and Linux is the C library (newlib instead of glibc).

With Cygwin installed, users have access to many standard UNIX utilities. They can be used from one of the provided shells such as bash or from the Windows Command Prompt. Additionally, programmers may write Win32 console or GUI applications that make use of the standard Microsoft Win32 API and/or the Cygwin API. As a result, it is possible to easily port many significant UNIX programs without the need for extensive changes to the source code. This includes configuring and building most of the available GNU software (including the development tools included with the Cygwin distribution).

1.2 Quick Start Guide for those more experienced with Windows

If you are new to the world of UNIX, you may find it difficult to understand at first. This guide is not meant to be comprehensive, so we recommend that you use the many available Internet resources to become acquainted with UNIX basics (search for “UNIX basics” or “UNIX tutorial”).

To install a basic Cygwin environment, run the setup.exe program and click Next at each page. The default settings are correct for most users. If you want to know more about what each option means, see Section 2.1. Use setup.exe any time you want to update or install a Cygwin package. If you are installing Cygwin for a specific purpose, use it to install the tools that you need. For example, if you want to compile C++ programs, you need the gcc-g++ package and probably a text editor like nano. When running setup.exe, clicking on categories and packages in the package installation screen will provide you with the ability to control what is installed or updated.

After installation, you can find Cygwin-specific documentation in the /usr/share/doc/Cygwin/ directory.

Developers coming from a Windows background will be able to write console or GUI executables that rely on the Microsoft Win32 API instead of Cygwin using the mingw32 or mingw64 cross-compiler toolchains. The -shared option to GCC allows to write Windows Dynamically Linked Libraries (DLLs). The resource compiler windres is also provided.

1.3 Quick Start Guide for those more experienced with UNIX

If you are an experienced UNIX user who misses a powerful command-line environment, you will enjoy Cygwin. Developers coming from a UNIX background will find a set of utilities they are already comfortable using, including a working UNIX shell. The compiler tools are the standard GNU compilers most people will have previously used under UNIX, only ported to the
Windows host. Programmers wishing to port UNIX software to Windows NT will find that the Cygwin library provides an easy way to port many UNIX packages, with only minimal source code changes.

Note that there are some workarounds that cause Cygwin to behave differently than most UNIX-like operating systems; these are described in more detail in Section 3.9.

Use the graphical command setup.exe any time you want to update or install a Cygwin package. This program must be run manually every time you want to check for updated packages since Cygwin does not currently include a mechanism for automatically detecting package updates.

By default, setup.exe only installs a minimal subset of packages. Add any other packages by clicking on the + next to the Category name and selecting the package from the displayed list. You may search for specific tools by using the Setup Package Search at the Cygwin web site.

After installation, you can find Cygwin-specific documentation in the /usr/share/doc/Cygwin/ directory.

For more information about what each option in setup.exe means, see Section 2.1.

1.4 Are the Cygwin tools free software?

Yes. Parts are GNU software (gcc, gas, ld, etc.), parts are covered by the standard X11 license, some of it is public domain, some of it was written by Red Hat and placed under the GNU General Public License (GPL) or GNU Lesser General Public License (LGPL). None of it is shareware. You don’t have to pay anyone to use it but you should be sure to read the copyright section of the FAQ for more information on how the GNU GPL may affect your use of these tools.

1.5 A brief history of the Cygwin project

_Cygwin began development in 1995 at Cygnus Solutions (now part of Red Hat, Inc.). The first thing done was to enhance the development tools (gcc, gdb, gas, etc.) so that they could generate and interpret Win32 native object files. The next task was to port the tools to Win NT/9x. We could have done this by rewriting large portions of the source to work within the context of the Win32 API. But this would have meant spending a huge amount of time on each and every tool. Instead, we took a substantially different approach by writing a shared library (the Cygwin DLL) that adds the necessary UNIX-like functionality missing from the Win32 API (fork, spawn, signals, select, sockets, etc.). We call this new interface the Cygwin API. Once written, it was possible to build working Win32 tools using UNIX-hosted cross-compilers, linking against this library.

From this point, we pursued the goal of producing Windows-hosted tools capable of rebuilding themselves under Windows 9x and NT (this is often called self-hosting). Since neither OS ships with standard UNIX user tools (fileutils, textutils, bash, etc...), we had to get the GNU equivalents working with the Cygwin API. Many of these tools were previously only built natively so we had to modify their configure scripts to be compatible with cross-compilation. Other than the configuration changes, very few source-level changes had to be made since Cygwin provided a UNIX-like API. Running bash with the development tools and user tools in place, Windows 9x and NT looked like a flavor of UNIX from the perspective of the GNU configure mechanism. Self hosting was achieved as of the beta 17.1 release in October 1996.

The entire Cygwin toolset was available as a monolithic install. In April 2000, the project announced a New Cygwin Net Release which provided the native non-Cygwin Win32 program setup.exe to install and upgrade each package separately. Since then, the Cygwin DLL and setup.exe have seen continuous development.

The biggest major improvement in this development was the 1.7 release in 2009, which dropped Windows 95/98/Me support in favor of using Windows NT features more extensively. It adds a lot of new features like case-sensitive filenames, NFS interoperability, IPv6 support and much more.

The latest big improvement is the 64 bit Cygwin DLL which allows to run natively on AMD64 Windows machines. The first release available in a 64 bit version was 1.7.19._
1.6 Highlights of Cygwin Functionality

1.6.1 Introduction

When a binary linked against the library is executed, the Cygwin DLL is loaded into the application’s text segment. Because we are trying to emulate a UNIX kernel which needs access to all processes running under it, the first Cygwin DLL to run creates shared memory areas and global synchronization objects that other processes using separate instances of the DLL can access. This is used to keep track of open file descriptors and to assist fork and exec, among other purposes. Every process also has a per_process structure that contains information such as process id, user id, signal masks, and other similar process-specific information.

The DLL is implemented as a standard DLL in the Win32 subsystem. Under the hood it’s using the Win32 API, as well as the native NT API, where appropriate.

Note
Some restrictions apply for calls to the Win32 API. For details, see Section 2.2.2, as well as Section 3.1.8.

The native NT API is used mainly for speed, as well as to access NT capabilities which are useful to implement certain POSIX features, but are hidden to the Win32 API.

Due to some restrictions in Windows, it’s not always possible to strictly adhere to existing UNIX standards like POSIX.1. Fortunately these are mostly corner cases.

Note that many of the things that Cygwin does to provide POSIX compatibility do not mesh well with the native Windows API. If you mix POSIX calls with Windows calls in your program it is possible that you will see uneven results. In particular, Cygwin signals will not work with Windows functions which block and Windows functions which accept filenames may be confused by Cygwin’s support for long filenames.

1.6.2 Permissions and Security

Windows NT includes a sophisticated security model based on Access Control Lists (ACLs). Cygwin maps Win32 file ownership and permissions to ACLs by default, on file systems supporting them (usually NTFS). Solaris style ACLs and accompanying function calls are also supported. The chmod call maps UNIX-style permissions back to the Win32 equivalents. Because many programs expect to be able to find the /etc/passwd and /etc/group files, we provide utilities that can be used to construct them from the user and group information provided by the operating system.

Users with Administrator rights are permitted to chown files. With version 1.1.3 Cygwin introduced a mechanism for setting real and effective UIDs. This is described in Section 3.6. As of version 1.5.13, the Cygwin developers are not aware of any feature in the Cygwin DLL that would allow users to gain privileges or to access objects to which they have no rights under Windows. However there is no guarantee that Cygwin is as secure as the Windows it runs on. Cygwin processes share some variables and are thus easier targets of denial of service type of attacks.

1.6.3 File Access

Cygwin supports both POSIX- and Win32-style paths, using either forward or back slashes as the directory delimiter. Paths coming into the DLL are translated from POSIX to native NT as needed. From the application perspective, the file system is a POSIX-compliant one. The implementation details are safely hidden in the Cygwin DLL. UNC pathnames (starting with two slashes) are supported for network paths.

The layout of this POSIX view of the Windows file system space is stored in the /etc/fstab file. Actually, there is a system-wide /etc/fstab file as well as a user-specific fstab file /etc/fstab.d/$USER.

At startup the DLL has to find out where it can find the /etc/fstab file. The mechanism used for this is simple. First it retrieves it’s own path, for instance C:\Cygwin\bin\cygwin1.dll. From there it deduces that the root path is C:\Cygwin. So it looks for the fstab file in C:\Cygwin\etc\fstab. The layout of this file is very similar to the layout of
the `fstab` file on Linux. Just instead of block devices, the mount points point to Win32 paths. An installation with `setup.exe` installs a `fstab` file by default, which can easily be changed using the editor of your choice.

The `fstab` file allows mounting arbitrary Win32 paths into the POSIX file system space. A special case is the so-called cygdrive prefix. It’s the path under which every available drive in the system is mounted under its drive letter. The default value is `/cygdrive`, so you can access the drives as `/cygdrive/c, /cygdrive/d, etc... The cygdrive prefix can be set to some other value (`/mnt` for instance) in the `fstab` file(s).

The library exports several Cygwin-specific functions that can be used by external programs to convert a path or path list from Win32 to POSIX or vice versa. Shell scripts and Makefiles cannot call these functions directly. Instead, they can do the same path translations by executing the `cygpath` utility program that we provide with Cygwin.

Win32 applications handle filenames in a case preserving, but case insensitive manner. Cygwin supports case sensitivity on file systems supporting that. Windows only supports case sensitivity when a specific registry value is changed. Therefore, case sensitivity is not usually the default.

Cygwin supports creating and reading symbolic links, even on Windows filesystems and OS versions which don’t support them. See Section 3.1.6 for details.

Hard links are fully supported on NTFS and NFS file systems. On FAT and other file systems which don’t support hardlinks, the call returns with an error, just like on other POSIX systems.

On file systems which don’t support unique persistent file IDs (FAT, older Samba shares) the inode number for a file is calculated by hashing its full Win32 path. The inode number generated by the stat call always matches the one returned in `d_ino` of the `dirent` structure. It is worth noting that the number produced by this method is not guaranteed to be unique. However, we have not found this to be a significant problem because of the low probability of generating a duplicate inode number.

Cygwin supports Extended Attributes (EAs) via the Linux-specific function calls `getxattr`, `setxattr`, `listxattr`, and `removexattr`. All EAs on Samba or NTFS are treated as user EAs, so, if the name of an EA is "foo" from the Windows perspective, it’s transformed into "user.foo" within Cygwin. This allows Linux-compatible EA operations and keeps tools like `attr` or `setfattr` happy.

`chroot` is supported. Kind of. Chroot is not a concept known by Windows. This implies some serious restrictions. First of all, the `chroot` call isn’t a privileged call. Any user may call it. Second, the chroot environment isn’t safe against native windows processes. Given that, chroot in Cygwin is only a hack which pretends security where there is none. For that reason the usage of chroot is discouraged. Don’t use it unless you really, really know what you’re doing.

### 1.6.4 Text Mode vs. Binary Mode

It is often important that files created by native Windows applications be interoperable with Cygwin applications. For example, a file created by a native Windows text editor should be readable by a Cygwin application, and vice versa.

Unfortunately, UNIX and Win32 have different end-of-line conventions in text files. A UNIX text file will have a single newline character (LF) whereas a Win32 text file will instead use a two character sequence (CR+LF). Consequently, the two character sequence must be translated on the fly by Cygwin into a single character newline when reading in text mode.

This solution addresses the newline interoperability concern at the expense of violating the POSIX requirement that text and binary mode be identical. Consequently, processes that attempt to `lseek` through text files can no longer rely on the number of bytes read to be an accurate indicator of position within the file. For this reason, Cygwin allows you to choose the mode in which a file is read in several ways.

### 1.6.5 ANSI C Library

We chose to include Red Hat’s own existing ANSI C library “newlib” as part of the library, rather than write all of the lib C and math calls from scratch. Newlib is a BSD-derived ANSI C library, previously only used by cross-compilers for embedded systems development. Other functions, which are not supported by newlib have been added to the Cygwin sources using BSD implementations as much as possible.

The reuse of existing free implementations of such things as the glob, regexp, and getopt libraries saved us considerable effort. In addition, Cygwin uses Doug Lea’s free malloc implementation that successfully balances speed and compactness. The library accesses the malloc calls via an exported function pointer. This makes it possible for a Cygwin process to provide its own malloc if it so desires.
1.6.6 Process Creation

The `fork` call in Cygwin is particularly interesting because it does not map well on top of the Win32 API. This makes it very difficult to implement correctly. Currently, the Cygwin fork is a non-copy-on-write implementation similar to what was present in early flavors of UNIX.

As the child process is created as new process, both the main executable and all the dlls loaded either statically or dynamically have to be identical as to when the parent process has started or loaded a dll. While Windows does not allow to remove binaries in use from the file system, they still can be renamed or moved into the recycle bin, as outlined for `unlink(2)` in Section 1.7.45.2. To allow an existing process to fork, the original binary files need to be available via their original file names, but they may reside in a different directory when using the DotLocal (.local) Dll Redirection feature. Since NTFS does support hardlinks, when the fork fails we try again, but create a private directory containing hardlinks to the original files as well as the .local file now. The base directory for the private hardlink directory is `/var/run/cygfork/`, which you have to create manually for now if you need to protect fork against updates to executables and dlls on your Cygwin instance. As hardlinks cannot be used across multiple NTFS file systems, please make sure your executable and dll replacing operations operate on the same single NTFS file system as your Cygwin instance and the `/var/run/cygfork/` directory. Note that this private hardlink directory also does help for when a wrong dll is found in the parent process’ current working directory. To enable creating the hardlinks, you need to stop all currently running Cygwin processes after creating this directory, once per Cygwin installation:

```
$ mkdir --mode=a=rwxt /var/run/cygfork
```

We create one hardlink directory per user, application and application age, and remove it when no more processes use that directory. To indicate whether a directory still is in use, we define a mutex name similar to the directory name. As mutexes are destroyed when no process holds a handle open any more, we can clean up even after power loss or similar: Both the parent and child process, at exit they lock the mutex with almost no timeout and close it, to get the closure promoted synchronously. If the lock succeeded before closing, directory cleanup is started: For each directory found, the corresponding mutex is created with lock. If that succeeds, the directory is removed, as it is unused now, and the corresponding mutex handle is closed.

Before fork, when about to create hardlinks for the first time, the mutex is opened and locked with infinite timeout, to wait for the cleanup that may run at the same time. Once locked, the mutex is unlocked immediately, but the mutex handle stays open until exit, and the hardlinks are created. It is fine for multiple processes to concurrently create the same hardlinks, as the result really should be identical. Once the mutex is open, we can create more hardlinks within this one directory without the need to lock the mutex again.

The first thing that happens when a parent process forks a child process is that the parent initializes a space in the Cygwin process table for the child. It then creates a suspended child process using the Win32 CreateProcess call. Next, the parent process calls `setjmp` to save its own context and sets a pointer to this in a Cygwin shared memory area (shared among all Cygwin tasks). It then fills in the child’s .data and .bss sections by copying from its own address space into the suspended child’s address space. After the child’s address space is initialized, the child is run while the parent waits on a mutex. The child discovers it has been forked and longjumps using the saved jump buffer. The child then sets the mutex the parent is waiting on and blocks on another mutex. This is the signal for the parent to copy its stack and heap into the child, after which it releases the mutex the child is waiting on and returns from the fork call. Finally, the child wakes from blocking on the last mutex, recreates any memory-mapped areas passed to it via the shared area, and returns from fork itself.

While we have some ideas as to how to speed up our fork implementation by reducing the number of context switches between the parent and child process, fork will almost certainly always be inefficient under Win32. Fortunately, in most circumstances the spawn family of calls provided by Cygwin can be substituted for a fork/exec pair with only a little effort. These calls map cleanly on top of the Win32 API. As a result, they are much more efficient. Changing the compiler’s driver program to call spawn instead of fork was a trivial change and increased compilation speeds by twenty to thirty percent in our tests.

However, spawn and exec present their own set of difficulties. Because there is no way to do an actual exec under Win32, Cygwin has to invent its own Process IDs (PIDs). As a result, when a process performs multiple exec calls, there will be multiple Windows PIDs associated with a single Cygwin PID. In some cases, stubs of each of these Win32 processes may linger, waiting for their exec’d Cygwin process to exit.

1.6.6.1 Problems with process creation

The semantics of `fork` require that a forked child process have exactly the same address space layout as its parent. However, Windows provides no native support for cloning address space between processes and several features actively undermine a reliable `fork` implementation. Three issues are especially prevalent:
• DLL base address collisions. Unlike *nix shared libraries, which use "position-independent code", Windows shared libraries assume a fixed base address. Whenever the hard-wired address ranges of two DLLs collide (which occurs quite often), the Windows loader must "rebase" one of them to a different address. However, it may not resolve collisions consistently, and may rebase a different dll and/or move it to a different address every time. Cygwin can usually compensate for this effect when it involves libraries opened dynamically, but collisions among statically-linked dlls (dependencies known at compile time) are resolved before cygwin1.dll initializes and cannot be fixed afterward. This problem can only be solved by removing the base address conflicts which cause the problem, usually using the rebaseall tool.

• Address space layout randomization (ASLR). Starting with Vista, Windows implements ASLR, which means that thread stacks, heap, memory-mapped files, and statically-linked dlls are placed at different (random) locations in each process. This behaviour interferes with a proper fork, and if an unmovable object (process heap or system dll) ends up at the wrong location, Cygwin can do nothing to compensate (though it will retry a few times automatically).

• DLL injection by BLODA. Badly-behaved applications which inject dlls into other processes often manage to clobber important sections of the child’s address space, leading to base address collisions which rebasing cannot fix. The only way to resolve this problem is to remove (usually uninstall) the offending app.

In summary, current Windows implementations make it impossible to implement a perfectly reliable fork, and occasional fork failures are inevitable.

1.6.7 Signals

When a Cygwin process starts, the library starts a secondary thread for use in signal handling. This thread waits for Windows events used to pass signals to the process. When a process notices it has a signal, it scans its signal bitmask and handles the signal in the appropriate fashion.

Several complications in the implementation arise from the fact that the signal handler operates in the same address space as the executing program. The immediate consequence is that Cygwin system functions are interruptible unless special care is taken to avoid this. We go to some lengths to prevent the sig_send function that sends signals from being interrupted. In the case of a process sending a signal to another process, we place a mutex around sig_send such that sig_send will not be interrupted until it has completely finished sending the signal.

In the case of a process sending itself a signal, we use a separate semaphore/event pair instead of the mutex. sig_send starts by resetting the event and incrementing the semaphore that flags the signal handler to process the signal. After the signal is processed, the signal handler signals the event that it is done. This process keeps intraprocess signals synchronous, as required by POSIX.

Most standard UNIX signals are provided. Job control works as expected in shells that support it.

1.6.8 Sockets

Socket-related calls in Cygwin basically call the functions by the same name in Winsock, Microsoft’s implementation of Berkeley sockets, but with lots of tweaks. All sockets are non-blocking under the hood to allow to interrupt blocking calls by POSIX signals. Additional bookkeeping is necessary to implement correct socket sharing POSIX semantics and especially for the select call. Some socket-related functions are not implemented at all in Winsock, as, for example, socketpair. Starting with Windows Vista, Microsoft removed the legacy calls rcmd(3), rexec(3) and rresvport(3). Recent versions of Cygwin now implement all these calls internally.

An especially troublesome feature of Winsock is that it must be initialized before the first socket function is called. As a result, Cygwin has to perform this initialization on the fly, as soon as the first socket-related function is called by the application. In order to support sockets across fork calls, child processes initialize Winsock if any inherited file descriptor is a socket.

AF_UNIX (AF_LOCAL) sockets are not available in Winsock. They are implemented in Cygwin by using local AF_INET sockets instead. This is completely transparent to the application. Cygwin’s implementation also supports the getpeereid BSD extension. However, Cygwin does not yet support descriptor passing.
1.6.9  Select

The UNIX select function is another call that does not map cleanly on top of the Win32 API. Much to our dismay, we discovered that the Win32 select in Winsock only worked on socket handles. Our implementation allows select to function normally when given different types of file descriptors (sockets, pipes, handles, and a custom /dev/windows Windows messages pseudo-device).

Upon entry into the select function, the first operation is to sort the file descriptors into the different types. There are then two cases to consider. The simple case is when at least one file descriptor is a type that is always known to be ready (such as a disk file). In that case, select returns immediately as soon as it has polled each of the other types to see if they are ready. The more complex case involves waiting for socket or pipe file descriptors to be ready. This is accomplished by the main thread suspending itself, after starting one thread for each type of file descriptor present. Each thread polls the file descriptors of its respective type with the appropriate Win32 API call. As soon as a thread identifies a ready descriptor, that thread signals the main thread to wake up. This case is now the same as the first one since we know at least one descriptor is ready. So select returns, after polling all of the file descriptors one last time.

1.7  What’s new and what changed in Cygwin

1.7.1  What’s new and what changed in 3.0

- Support for CLOCK_REALTIME_COARSE, CLOCK_MONOTONIC_COARSE, CLOCK_MONOTONIC_RAW, CLOCK_BOOTTIME, CLOCK_REALTIME_ALARM, CLOCK_BOOTTIME_ALARM clocks.
- Support for case sensitive directories via chattr(1). This feature requires Windows 10 1803 or later and WSL installed.
- New file ioctls’s FS_IOC_GETFLAGS and FS_IOC_SETFLAGS. The actual inode flags are Cygwin-specific. This allows to set or reset DOS attributes, file sparseness, FS level encryption and compression, as well as directory case sensitivity programatically.
- New tools chattr(1) and lsattr(1) to utilize setting and viewing the aforementioned new ioctl’s on the command line.
- Support for exFAT.
- Support Linux-specific open(2) flag O_PATH.
- Support Linux-specific linkat(2) flag AT_EMPTY_PATH.
- Support overrun counter for posix timers (via timer_getoverrun() or siginfo_t::si_overrun).
- New APIs: secure_getenv, signalfd, timerfd_create, timerfd_gettime, timerfd_settime, timer_getoverrun.
- clock_nanosleep, pthread_condattr_setclock and timer_create now support all clocks, except CLOCK_PROCESS_CPUTIME_ID and CLOCK_THREAD_CPUTIME_ID.
- clock_setres is a no-op now.
- Use the new POSIX unlink semantics on NTFS starting with Windows 10 1709. Deleting an in-use file now actually removes the file, rather than moving it to the recycler bin.
- Use the new POSIX rename semantics on NTFS starting with Windows 10 1809. Renaming a file to another in-use file now actually removes the other file, rather than moving it to the recycler bin.
- open(..., O_TMPFILE) now moves the file to the trash bin immediately, to free the parent directory.
- Wctype functions updated to Unicode 11.0.
- Remove matherr, and SVID and X/Open math library configurations. Default math library configuration is now IEEE.
- Improve uname(2) for newly built applications.
- Kerberos/MSV1_0 S4U authentication replaces two old methods: Creating a token from scratch and Cygwin LSA authentication package.
• Cygwin PIDs have been decoupled from Windows PID. Cygwin PIDs are now incrementally dealt in the range from 2 up to 65535, POSIX-like. Native Windows processes not started by Cygwin processes are mapped into the range beyond 65535.

• fork(2) now is able to recover from when an in-use executable/dll is removed or replaced during process runtime. This feature is disabled by default and limited to exes/dlls on the same NTFS partition as the Cygwin installation. For more information and how to enable, please refer to Section 1.6.6.

1.7.2 What’s new and what changed in 2.11

• SO_RCVTIMEO and SO_SNDBTIMEO socket options are now honored.
• /proc/cpuinfo now reports L3 cache size on Intel CPUs.
• New APIs: clearenv, pthread_trigsjoin_np, pthread_timedjoin_np, sched_getcpu.
• New APIs for POSIX Asynchronous I/O: aio_cancel, aio_error, aio_fsync, aio_read, aio_return, aio_suspend, aio_write, lio_listio. New Header: <aio.h>.
• Drop denormal-operand exception from FE_ALL_EXCEPT, as on Linux.
• Rename the --file option of setfacl(1) to --set-file, as on Linux.
• Support Unicode 10.
• Following glibc, ‘union wait’ has now been removed. Applications using union wait and these macros will have to migrate to the POSIX-specified int status type.

1.7.3 What’s new and what changed in 2.10

• New open(2) flags O_TMPFILE and O_NOATIME.
• scanf/wscanf now handle the POSIX %m modifier.
• scanf now handles the %I[ conversion.
• Improved hostprogs compatibility for cross-compiling the Linux kernel. New headers: <asm/bsperlong.h>, <asm/posix_types.h>.
• Built-in implementation of Stack Smashing Protection compiler feature. New APIs: __stack_chk_fail, __stack_chk_guard.
• Built-in implementation of _FORTIFY_SOURCE guards for functions in <stdio.h>, <stdlib.h>, <string.h>, <strings.h>, <unisid.h>, <wchar.h>, <sys/poll.h>, and <sys/socket.h>. New APIs: __chk_fail, __gets_chk, __memcpy_chk, __memmove_chk, __mempcpy_chk, __memset_chk, __strcat_chk, __strncpy_chk, __strncat_chk, __strncpy_chk, __vsnprintf_chk, __vsprintf_chk.
• New APIs: sigtimedwait, wmempcpy.

1.7.4 What’s new and what changed in 2.9

• New APIs: explicit_bzero, strnstr.
• New APIs: pthread_mutex_timedwait, pthread_rwlock_timedrdlock, pthread_rwlock_timedwrlock.
• New API: renameat2.
• Improved implementation of <elf.h>.
• strptime(3) supports %s (seconds since Epoch) now, analogue to strftime.
1.7.5 What’s new and what changed in 2.8

- New API: timingsafe_bcmp, timingsafe_memcmp
- New API: dladdr
- New API: getloadavg
- Cygcheck and strace now always generate output with Unix LF line endings, rather than with DOS/Windows CR LF line endings.
- Fork now preserves the load order of unrelated dlopen’d modules.
- Pthread_cond_wait now acts like Linux and BSD: Resume waiting for the condition variable as if it was not interrupted, rather than returning 0.
- The internal `<sys/_locale.h>` header was renamed to `<xlocale.h>` for source compatibility with other systems.
- Try harder supporting Netapp drives.

1.7.6 What’s new and what changed in 2.7

- Support for `/proc/<PID>/environ`.
- - New API: getentropy, getrandom.

1.7.7 What’s new and what changed in 2.6

- Support for POSIX-1.2008 locale objects and per-thread locales.
- locale(1) now supports a -i/--input option to fetch the current input locale (this is basically equivalent to the current keyboard layout setting).
- Drop support for very old SUNWNFS filesystem.
- Raise number of supported partitions per disk (for raw access) to 63.
- Further header file improvements in terms of feature test macros.
- Add a workaround for filesystems not supporting the FileAllInformation info class.
- Support AzureAD accounts.
- “nobody” account support for WinFSP.
- New API: pthread_getname_np, pthread_setname_np.
1.7.8 What's new and what changed in 2.5

- Full set of POSIX.1e ACL API functions now implemented. New APIs: acl_add_perm, acl_calc_mask, acl_clear_perms, acl_copy_entry, acl_copy_ext, acl_copy_int, acl_create_entry, acl_delete_def_file, acl_delete_entry, acl_delete_perm, acl_dup, acl_free, acl_from_text, acl_get_entry, acl_get_fd, acl_get_file, acl_get_permset, acl_get_qualifier, acl_get_tag_type, acl_init, acl_set_fd, acl_set_file, acl_set_permset, acl_set_qualifier, acl_set_tag_type, acl_size, acl_to_text, acl_valid.

- Most libacl extensions now implemented, too: New APIs: acl_check, acl_cmp, acl_entries, acl_equiv_mode, acl_error, acl_extended_fd, acl_extended_file, acl_extended_file_nofollow, acl_from_mode, acl_get_perm, acl_to_any_text.

- Including <sys/acl.h> now *only* includes the POSIX ACL API. To include the old Solaris API, include <cygwin/acl.h>.

- First implementation of pthread_barrier/pthread_barrierattr functions. New APIs: pthread_barrierattr_init, pthread_barrierattr_setpshared, pthread_barrierattr_destroy, pthread_barrier_init, pthread_barrier_destroy, pthread_barrier_wait.

- Enabled console reports requested by escape sequences: Requesting primary and secondary device attributes, requesting cursor position report; see https://cygwin.com/ml/cygwin-patches/2012-q3/msg00019.html

- New APIs: clog10, clog10f, nexttoward, nexttowardf, nexttowardl.

- Add missing long double functions. New APIs: acoshl, acosl, asinhl, asinl, atan2l, atanhl, atanl, cacoshl, cacosl, cargl, casinhl, casinl, catanh, catanl, ccsinh, cschl, cschl, cceil, cexpfl, clog10l, clogf, conjfl, copysignl, csinh, csinl, cssqrtl, ctanh, ctanl, erfcl, erfl, expfl, exp2fl, expl, expm1l, fabsl, fdiml, floorl, fmaxl, fminl, fmodl, froundl, ilogbl, isinf, isnanl, ldexpl, lgammal, lgammal_r, lroundl, log10l, log1pl, log2l, logbl, logl, lroundd, modfl, nearbyintl, nextafterl, pow10l, powl, remainderl, renqoul, rintl, scalbl, scalblnl, scalblnl, sincosl, sinhl, sinl, tanhl, tanl, tgammal, trunc.

- In calls to chmod treat ACLs with extra ACEs *only* for Admins and SYSTEM like a trivial ACL.

- Bump POSIX option macros to POSIX.1-2008.

- Profiling data, specifically pc sampling, now covers all threads of a program and not just the main thread. Environment variable GMON_OUT_PREFIX enables multiple gmon.out files to preserve profiling data after fork or from multiple program runs.

- Feature test macros, which control which symbols are exposed in the standard headers, have been completely overhauled for compatibility with glibc.

- The isinf, isnanf, and isnanl functions are signed, returning -1 for negative infinity for compatibility with glibc.

1.7.9 What's new and what changed in 2.4

- New, unified implementation of POSIX permission and ACL handling. The new ACLs now store the POSIX ACL MASK/CLASS_OBJ permission mask, and they allow to inherit the S_ISGID bit. ACL inheritance now really works as desired, in a limited, but theoretically equivalent fashion even for non-Cygwin processes.

- To accommodate standard Windows ACLs, the POSIX permissions of the owner and all other users in the ACL are computed using the Windows AuthZ API. This may slow down the computation of POSIX permissions noticeably in some circumstances, but is generally more correct. The new code also ignores SYSTEM and Administrators group permissions when computing the MASK/CLASS_OBJ permission mask on old ACLs, and it doesn’t deny access to SYSTEM and Administrators group based on the value of MASK/CLASS_OBJ when creating the new ACLs.

- The new code now handles the S_ISGID bit on directories as on Linux: Setting S_ISGID on a directory causes new files and subdirs created within to inherit its group, rather than the primary group of the user who created the file. This only works for files and directories created by Cygwin processes.

- cygpath has a new -U option, which creates cygdrive paths using the unambiguous /proc/cygdrive prefix.

- New API: rpmatch.

- Align setfacl(1) usage a bit closer to the usage on Linux. Rename -d option to -x, --substitute to --set. Add --no-mask and --mask options. Allow to use the -b and -k option combined to allow reducing an ACL to only reflect standard POSIX permissions.

- Fix (numeric and monetary) decimal point and thousands separator in fa_IR and ps_AF locales to be aligned with Linux.

- utmpname/utmpxname are now defined as int functions as on Linux.
1.7.10 What’s new and what changed in 2.3

- strftime(3) supports %s (seconds since Epoch) now.
- posix_madvise(POSIX_MADV_WILLNEED) now utilizes OS functionality available starting with Windows 8/Server 2012.
- posix_madvise(POSIX_MADV_DONTNEED) now utilizes OS functionality available starting with Windows 8.1/Server 2012R2.
- sysconf() now supports returning CPU cache information:

```
_SC_LEVEL1_ICACHE_SIZE, _SC_LEVEL1_ICACHE_ASSOC, _SC_LEVEL1_ICACHE_LINESIZE,
_SC_LEVEL1_DCACHE_SIZE, _SC_LEVEL1_DCACHE_ASSOC, _SC_LEVEL1_DCACHE_LINESIZE,
_SC_LEVEL2_CACHE_SIZE, _SC_LEVEL2_CACHE_ASSOC, _SC_LEVEL2_CACHE_LINESIZE,
_SC_LEVEL3_CACHE_SIZE, _SC_LEVEL3_CACHE_ASSOC, _SC_LEVEL3_CACHE_LINESIZE,
_SC_LEVEL4_CACHE_SIZE, _SC_LEVEL4_CACHE_ASSOC, _SC_LEVEL4_CACHE_LINESIZE
```

- New API: aligned_alloc, at_quick_exit, quick_exit.
- Add support for Parallels Desktop FS (prlfs).

1.7.11 What’s new and what changed in 2.2

- New APIs: getcontext, setcontext, makecontext, swapcontext.
- New functions: sigsetjmp, siglongjmp.
  These were only available as macros up to now, but POSIX requires that siglongjmp has to be available as function.

1.7.12 What’s new and what changed in 2.1

- Handle pthread stack sizes as in GLibc: Default to RLIMIT_STACK resource. Allow to set RLIMIT_STACK via setrlimit. Default RLIMIT_STACK to value from executable header as described on the MSDN website Thread Stack Size Default.
- First cut of an implementation to allow signal handlers running on an alternate signal stack.
- New API sigaltstack, plus definitions for SA_ONSTACK, SS_ONSTACK, SS_DISABLE, MINSIGSTKSZ, SIGSTKSZ.
- New API: sethostname.

1.7.13 What’s new and what changed in 2.0

- basename(3) now comes in two flavors, POSIX and GNU. The POSIX version is the default. You get the GNU version after

```c
#define __GNU_SOURCE
#include <string.h>
```

1.7.14 What’s new and what changed in 1.7.35

- Performance improvements of the new account DB handling.
- Since 1.7.34, chmod does not always affect the POSIX permission mask as returned by stat(2) or printed by ls(1), due to the improved POSIX ACL handling. However, that’s still far from perfect, so, as a temporary workaround, chmod now checks if secondary groups and users in the ACL have more permissions than the primary group. If so, the permissions of the secondary users and groups will be reduced according to the mask given by the new primary group permissions. I.e., chmod 600 will remove all permissions from the primary group as well as all secondary user and group entries in the ACL.
- Change handling of group permissions if owner SID == group SID. Now the group permissions don’t mirror the user permissions anymore, thus leading to less hassle with security-conscious applications.
• Allow group SID to be the same as owner SID for "Microsoft Accounts". Those have the group in their user token set to the owner SID by default. Drop the workaround to change their primary group to "Users". It’s not required anymore due to the aforementioned changes.

• Change getfacl long options from --all to --access and from --dir to --default, along the lines of the Linux getfacl tool.

• Don’t raise a SIGSYS signal in the XSI IPC functions if cygserver is not running. Just return -1 with errno set to ENOSYS.

• New APIs: cabsl, cimagl, creall, finitel, hypotl, sqrtl.

• New API: issetugid.

1.7.15 What's new and what changed in 1.7.34

• Cygwin can now generate passwd/group entries directly from Windows user databases (local SAM or Active Directory), thus allowing to run Cygwin without having to create /etc/passwd and /etc/group files. Introduce /etc/nsswitch.conf file to configure passwd/group handling.

For bordercase which require to use /etc/passwd and /etc/group files, change mkpasswd/mkgroup to generate passwd/group entries compatible with the entries read from SAM/AD.

For a description of this exciting new feature see Section 3.6.

• Add -b/--remove-all option to setfacl to reduce the ACL to only the entries representing POSIX permission bits.

• Add -k/--remove-default option to setfacl to remove all default ACL entries from an ACL.

• Add restore action to regtool.

• Make gethostbyname2 handle numeric host addresses as well as the reserved domain names "localhost" and "invalid" per RFC 6761.

• Revamp Solaris ACL implementation to more closely work like POSIX ACLs are supposed to work. Finally implement a CLASS_OBJ emulation. Update getfacl(1)/setfacl(1) accordingly.

• The xdr functions are no longer exported for newly built executables. Use libtirpc-devel instead.

• 32 bit only: Change default values for socket buffer size to raise performance on 10Gb networks.

• When spawning a process under another user account, merge the user’s default Windows environment into the new process’ environment.

• New APIs: qsort_r, __bsd_qsort_r.

• New API: wcstold.

• New APIs: __fbufsize, __flbf, __fpending, __freadable, __freading, __fsetlocking, __fwritable, __fwriting.

• New APIs: clearerr_unlocked, feof_unlocked, ferror_unlocked, fflush_unlocked, fgetc_unlocked, fgetc_unlocked, fgetwc_unlocked, fgetws_unlocked, fileno_unlocked, fputc_unlocked, fputc_unlocked, fputs_unlocked, fputs_unlocked, fputwc_unlocked, fputws_unlocked, fread_unlocked, fwrite_unlocked, getwc_unlocked, getwchar_unlocked, putwc_unlocked, putwchar_unlocked.

• New API: sockatmark.

1.7.16 What's new and what changed in 1.7.33

• /proc/cygdrive is a new symlink pointing to the current cygdrive prefix. This can be utilized in scripts to access paths via cygdrive prefix, even if the cygdrive prefix has been changed by the user.

• /proc/partitions now prints the windows mount points the device is mounted on. This allows to recognize the underlying Windows devices of the Cygwin raw device names.

• New API: quotactl, designed after the Linux/BSD function, but severely restricted: Windows only supports user block quotas on NTFS, no group quotas, no inode quotas, no time constraints.
• New APIs: ffsl, ffsll (glibc extensions).
• New API: stime (SVr4).
• Provide Cygwin documentation (PDFs and HTML) for offline usage in /usr/share/doc/cygwin-\{version\}.
• New internal exception handling based on SEH on 64 bit Cygwin.
• When exec'ing applications, check if $PATH exists and is non-empty. If not, add PATH variable with Cygwin installation directory as content to Windows environment to allow loading of Cygwin system DLLs.
• Disable CYGWIN "dosfilewarning" option by default.
• Improve various header files for C++- and standards-compliance.
• Doug Lea malloc implementation update from 2.8.3 to the latest 2.8.6.
• atexit(3) is now exported as statically linked function from libcygwin.a. This allows reliable access to the DSO handle of the caller for newly built executables. The former atexit entry point into the DLL remains for backward compatibility only.

1.7.17 What's new and what changed in 1.7.32

• Export __cxa_atexit and __cxa_finalize to allow C++ standards-compliant destructor handling in libstdc++ and g++ compiled code. Please note that, in order to benefit from this new feature, C++ code must be recompiled with the upcoming gcc 4.8.3-3 release which will enable the -fuse-cxa-atexit flag by default, and that C++ applications using this feature will not run on older Cygwin releases.
• Support more recent CPU flags in /proc/cpuinfo.

1.7.18 What's new and what changed in 1.7.31

• Improve performance of send(2), sendto(2), sendmsg(2) when using small input buffers.
• The default pthread_mutex type is now PTHREAD_MUTEX_NORMAL, rather than PTHREAD_MUTEX_ERRORCHECK, just as on Linux.
• Align pthread_attr stack functions more closely to Linux.
• Mark pthread_attr_getstackaddr and pthread_attr_setstackaddr as deprecated, as on Linux.

1.7.19 What's new and what changed in 1.7.29

• Allow quoting of arguments to the CYGWIN environment variable, i.e., set CYGWIN=error_start="c:\bin\someprogram -T"
• Console screen clearing works more like xterm or mintty.

1.7.20 What's new and what changed in 1.7.28

• popen now supports the Glibc 'e' flag to set the FD_CLOEXEC flag on the pipe in a thread-safe way.
• New netinet/ip6.h header.
• Switch to BSD FILE stream fopen/exit semantics, as in all BSD variants and Linux/GLibc: Don’t fflush/lseek a FILE stream on fclose and exit, if it only has been read from.

1.7.21 What's new and what changed in 1.7.27

• Don’t create native symlinks with target paths having long path prefixes "\\?" if the target path is shorter than MAX_PATH characters. This works around a Windows 8.1 bug: The ShellExecuteW fails if the lpFile parameter points to a native NTFS symlink with a target path prefixed with "\\?".
1.7.22 What's new and what changed in 1.7.26

• getaddrinfo now supports glibc-specific International Domain Name (IDN) extension flags: AI_IDN, AI_CANONIDN, AI_IDN_ALLOW_UNASSIGNED, AI_IDN_USE_STD3_ASCII_RULES.

• getnameinfo now supports glibc-specific International Domain Name (IDN) extension flags: NI_IDN, NI_IDN_ALLOW_UNASSIGNED, NI_IDN_USE_STD3_ASCII_RULES.

• Slightly improve randomness of /dev/random emulation.

• Allow to use advisory locking on any device. POSIX fcntl and lockf locking works with any device, BSD flock locking only with devices backed by an OS handle. Right now this excludes console windows on pre Windows 8, as well as almost all virtual files under /proc from BSD flock locking.

• The header /usr/include/exceptions.h, containing implementation details for 32 bit Windows’ exception handling only, has been removed.

• Preliminary, experimental support of the posix_spawn family of functions. New associated header /usr/include/spawn.h.

1.7.23 What's new and what changed in 1.7.25

• Change magic number associated with process information block so that 32-bit Cygwin processes don’t try to interpret 64-bit information and vice-versa.

• Redefine content of mtget tape info struct to allow fetching the number of partitions on a tape.

1.7.24 What's new and what changed in 1.7.24

• Allow application override of posix_memalign.

1.7.25 What's new and what changed in 1.7.23

• Added CYGWIN environment variable keyword “wincmdln” which causes Cygwin to send the full windows command line to any subprocesses.

1.7.26 What's new and what changed in 1.7.22

• Support for /dev/mem, /dev/kmem and /dev/port removed, since OS support was limited to 32 bit Windows XP only.

• Added cygwin GetCommandLine wrappers which will allow Cygwin programs to (appear to) use the Windows command line functions.

• regcomp(3) now allows character values >= 0x80 if the current codeset is ASCII (default codeset in the “C”/“POSIX” locale). This allows patterns containing arbitrary byte values as GLibc’s regcomp.

1.7.27 What's new and what changed in 1.7.21

• New API: rawmemchr.
1.7.28 What's new and what changed in 1.7.19

- Drop support for Windows 2000 and Windows XP pre-SP3.
- Add support for building a 64 bit version of Cygwin on x86_64 natively.
- Add support for creating native NTFS symlinks starting with Windows Vista by setting the CYGWIN=winsymlinks:native or CYGWIN=winsymlinks:nativestrict option.
- Add support for AFS filesystem.
- Preliminary support for mandatory locking via fcntl/flock/lockf, using Windows locking semantics. New F_LCK_MANDATORY fcntl command.
- New APIs: __b64_ntop, __b64_pton, arc4random, arc4random_addrandom, arc4random_buf, arc4random_stir, arc4random_uniform.

1.7.29 What's new and what changed in 1.7.18

- Added Windows console cursor appearance support.
  - Show/Hide Cursor mode (DECTCEM): "ESC[?25h" / "ESC[?25l"
  - Set cursor style (DECSCUSR): "ESC[n q" (note the space before the q); where n is 0, 1, 2 for block cursor, 3, 4 for underline cursor (all disregarding blinking mode), or > 4 to set the cursor height to a percentage of the cell height.
- For performance reasons, Cygwin does not try to create sparse files automatically anymore, unless you use the new "sparse" mount option.
- New API: cfsetspeed.

1.7.30 What's new and what changed in 1.7.17

- Support the "e" flag to fopen(3). This is a Glibc extension which allows to fopen the file with the O_CLOEXEC flag set.
- Support the "x" flag to fopen(3). This is a Glibc/C11 extension which allows to open the file with the O_EXCL flag set.

1.7.31 What's new and what changed in 1.7.16

- New API: getmntent_r, memrchr.
- Recognize ReFS filesystem.

1.7.32 What's new and what changed in 1.7.15

- CYGWIN=pipe_byte option now forces the opening of pipes in byte mode rather than message mode.

1.7.33 What's new and what changed in 1.7.14

- Add mouse reporting modes 1005, 1006 and 1015 to console window.

1.7.34 What's new and what changed in 1.7.13

- mkpasswd and mkgroup now try to print an entry for the TrustedInstaller account existing since Windows Vista/Server 2008.
- Terminal typeahead when switching from canonical to non-canonical mode is now properly flushed.
1.7.35  What’s new and what changed in 1.7.12

• Cygwin now automatically populates the /dev directory with all existing POSIX devices.

• Add virtual /proc/PID/mountinfo file.

• flock now additionally supports the following scenario, which requires to propagate locks to the parent process:

```c
{  
flock -n 9 || exit 1
# ... commands executed under lock ...  
} 9>/var/lock/mylockfile
```

Only propagation to the direct parent process is supported so far, not to grand parents or sibling processes.

• Add a "detect_bloda" setting for the CYGWIN environment variable to help finding potential BLODAs.

1.7.36  What’s new and what changed in 1.7.11

• New `pldd` command for listing DLLs loaded by a process.

• New API: `scandirat`.

• Change the way remote shares mapped to drive letters are recognized when creating the cygdrive directory. If Windows claims the drive is unavailable, don’t show it in the cygdrive directory listing.

• Raise default stacksize of pthreads from 512K to 1 Meg. It can still be changed using the pthread_attr_setstacksize call.

1.7.37  What’s new and what changed in 1.7.10

• Drop support for Windows NT4.

• The CYGWIN environment variable options "envcache", "strip_title", "title", "tty", and "upcaseenv" have been removed.

• If the executable (and the system) is large address aware, the application heap will be placed in the large memory area. The `pflags` tool from the rebase package can be used to set the large address awareness flag in the executable file header.

• The registry setting "heap_chunk_in_mb" has been removed, in favor of a new per-executable setting in the executable file header which can be set using the `pflags` tool. See Section 2.3 for more information.

• The CYGWIN=tty mode using pipes to communicate with the console in a pseudo tty-like mode has been removed. Either just use the normal Windows console as is, or use a terminal application like mintty.

• New `getconf` command for querying confstr(3), pathconf(3), sysconf(3), and limits.h configuration.

• New `tzset` utility to generate a POSIX-compatible TZ environment variable from the Windows timezone settings.

• The `password` command now allows an administrator to use the -R command for other user accounts: passwd -R username.

• Pthread spinlocks. New APIs: `pthread_spin_destroy`, `pthread_spin_init`, `pthread_spin_lock`, `pthread_spin_trylock`, `pthread_spin_unlock`.

• Pthread stack address management. New APIs: `pthread_attr_getstack`, `pthread_attr_getstackaddr`, `pthread_attr_getguardsize`, `pthread_attr_setstack`, `pthread_attr_setstackaddr`, `pthread_attr_setguardsize`, `pthread_getattr_np`.

• POSIX Clock Selection option. New APIs: `clock_nanosleep`, `pthread_condattr_getclock`, `pthread_condattr_setclock`.

• `clock_gettime(3)` and `clock_getres(3)` accept per-process and per-thread CPU-time clocks, including CLOCK_PROCESS_CPUTIME_ID and CLOCK_THREAD_CPUTIME_ID. New APIs: `clock_gettimeid`, `pthread_gettimeid`.

• GNU/glibc error.h error reporting functions. New APIs: `error`, `error_at_line`. New exports: `error_message_count`, `error_one_per_line`, `error_print_program`. Also, `error` and `strerror_r` no longer clobber `strerror` storage.

• C99 `<tgmath.h>` type-generic macros.
• /proc/loadavg now shows the number of currently running processes and the total number of processes.

• Added /proc/devices and /proc/misc, which lists supported device types and their device numbers.

• Added /proc/swaps, which shows the location and size of Windows paging file(s).

• Added /proc/sysvipc/msg, /proc/sysvipc/sem, and /proc/sysvipc/shm which provide information about System V IPC message queues, semaphores, and shared memory.

• /proc/version now shows the username of whomever compiled the Cygwin DLL as well as the version of GCC used when compiling.

• dlopen now supports the Glibc-specific RTLD_NODELETE and RTLD_NOOPEN flags.

• The printf(3) and wprintf(3) families of functions now handle the %m conversion flag.

• Other new API: clock_settime, __fpurge, getgrouplist, get_current_dir_name, getpt, ppoll, psiginfo, psignal, ptsname_r, sys_siglist, pthread_setschedprio, pthread_sigqueue, sysinfo.

1.7.38 What's new and what changed in 1.7.9

• New API: strchrnul.

1.7.39 What's new and what changed in 1.7.8

• Drop support for Windows NT4 prior to Service Pack 4.

• Reinstatatable Cygwin’s ability to delete an empty directory which is the current working directory of the same or another process. Same for any other empty directory which has been opened by the same or another process.

• Cygwin now ships the C standard library fenv.h header file, and implements the related APIs (including GNU/glibc extensions): feclearexcept, fedisbleexcept, feenableexcept, fegetenv, fegetexcept, fegetexceptflag, fegetprec, fegetround, feholdexcept, feraiseexcept, fetestexcept, fetestround, fetestzero, fetestenv, and predefines both default and no-mask FP environments. See the GNU C Library manual for full details of this functionality.

• Support for the C99 complex functions, except for the "long double" implementations. New APIs: cacos, cacosf, cacosh, cacoshf, carg, cargf, casin, casinf, casinh, casinhf, catan, catanf, catanh, catanhf, ccos, ccosf, ccosh, ccoshf, cexp, cexpf, cimag, cimagf, clog, clogf, conj, conjf, cpow, cpowf, cproj, cprojf, creal, crealf, csin, csinf, csinh, csinhf, csqrt, csqrtf, ctan, ctanf, ctanh, ctanhf.

• Fix the width of "CJK Ambiguous Width" characters to 1 for singlebyte charsets and 2 for East Asian multibyte charsets. (For UTF-8, it remains dependent on the specified language, and the "@cjknarrow" locale modifier can still be used to force width 1.)

• The strerror_r interface now has two flavors; if _GNU_SOURCE is defined, it retains the previous behavior of returning char * (but the result is now guaranteed to be NUL-terminated); otherwise it now obeys POSIX semantics of returning int.

• /proc/sys now allows unfiltered access to the native NT namespace. Access restrictions still apply. Direct device access via /proc/sys is not yet supported. File system access via block devices works. For instance (note the trailing slash!)

```
bash$ cd /proc/sys/Device/HarddiskVolumeShadowCopy1/
```

• Other new APIs: llround, llroundf, madvise, pthread_yield. Export program_invocation_name, program_invocation_short_name. Support TIOCNPGRP, TIOCSNPGRP ioctls.
1.7.40 What's new and what changed in 1.7.7

- Partially revert the 1.7.6 change to set the Win32 current working directory (CWD) always to an invalid directory, since it breaks backward compatibility too much. The Cygwin CWD and the Win32 CWD are now kept in sync again, unless the Cygwin CWD is not usable as Win32 CWD. See the reworked Section 3.1.8 for details.

- Make sure to follow the Microsoft security advisory concerning DLL hijacking. See the Microsoft Security Advisory (2269637) "Insecure Library Loading Could Allow Remote Code Execution" for details.

- Allow to link against -lbinmode instead of /lib/binmode.o. Same for -textmode, -textreadmode and -automode. See Section 3.2.4 for details.

1.7.41 What's new and what changed in 1.7.6

- Add new mount options "dos" and "ihash" to allow overriding Cygwin default behaviour on broken filesystems not recognized by Cygwin.

- Add new mount option "bind" to allow remounting parts of the POSIX file hierarchy somewhere else.

- Ttys and ptys are handled as securable objects using file-like permissions and owner/group information. chmod and chown now work on ttys/ptys. A new mechanism is used to propagate pty handles safely to other processes, which does not require to use Cygserver.

- Pass on coresize settings made with setrlimit(2). This allows shells to disable creating stackdump files in child processes via

  ```bash
  ulimit -c 0
  ```

  in bash or

  ```bash
  limit coredumpsize 0
  ```

  in tcsh.

- Locale categories contain all localization strings additionally as wide-char strings. locale(1) prints these values just as on Linux. nl_langinfo(3) allows to fetch them.

- New interfaces mkostemp(3) and mkostemps(3) are added.

- New virtual file /proc/filesystems.

- clock_gettime(3) and clock_getres(3) accept CLOCK_MONOTONIC.

- DEPRECATED with 1.7.7: Cygwin handles the current working directory entirely on its own. The Win32 current working directory is set to an invalid path to be out of the way. [...]
1.7.44 What's new and what changed in 1.7.2

• Localization support has been much improved.
  – Cygwin now handles locales using the underlying Windows locale support. The locale must exist in Windows to be recognized. Locale aliases from the file /usr/share/locale/locale.alias are also allowed, as long as their replacement is supported by the underlying Windows.
  – New tool "locale" to fetch locale information and default locales based on the Windows default settings as well as lists of all supported locales and character sets.
  – Added support for the charsets GEORGIAN-PS, PT154, and TIS-620.
  – Support for the various locale modifiers to switch charsets as on Linux.
  – Default charset in the "C" or "POSIX" locale has been changed back from UTF-8 to ASCII, to avoid problems with applications expecting a singlebyte charset in the "C"/"POSIX" locale. Still use UTF-8 internally for filename conversion in this case.
  – LC_COLLATE, LC_MONETARY, LC_NUMERIC, and LC_TIME localization is enabled via Windows locale support. LC_MESSAGES is enabled via a big table with localized strings.
  – fnmatch(3), regcomp(3), regexec(3) calls are now multibyte-aware.
  – printf(3), wprintf(3) families of functions now handle the grouping flag, the apostrophe ’, per POSIX-1.2008. The integer portion of the result of a decimal conversion (%i, %d, %u, %f, %F, %g, %G) will be formatted with thousands’ grouping characters.
  – strftime(3), wcsftime(3), and strptime(3) now handle the E and O format modifiers to print/scan alternative date and time representations or to use alternative digits in locales which support this. Additionally these functions now also support the padding modifiers ‘0’ and ‘+’, as well as a field width per POSIX-1.2008.
  – New strftime(3) call.
• Support open(2) flags O_CLOEXEC and O_TTY_INIT flags. Support fcntl flag F_DUPFD_CLOEXEC. Support socket flags SOCK_CLOEXEC and SOCK_NONBLOCK. Add new Linux-compatible API calls accept4(2), dup3(2), and pipe2(2). Support the signal SIGPWR.
• Enhanced Windows console support.
  – The console’s backspace keycode can be changed using ’stty erase’.
  – Support of combining Alt and AltGr modifiers in console window (compatible with xterm and mintty), so that e.g. Alt-@ sends ESC @ also on keyboards where @ is mapped to an AltGr combination.
  – Report mouse wheel scroll events in mouse reporting mode 1000 (note: this doesn’t seem to work on all systems, assumedly due to driver interworking issues). Add mouse reporting mode 1002 to report mouse drag movement. Add mouse reporting mode 1003 to report any mouse movement. Add focus event reporting (mode 1004), compatible with xterm and mintty.
  – Add escape sequences for not bold (22), not invisible (28), not blinking (25) (compatible with xterm and mintty).
  – Support VT100 line drawing graphics mode in console window (compatible with xterm and mintty).
• Handle native DOS paths always as if mounted with "posix=0,noacl".
• Handle UNC paths starting with slashes identical to /cygdrive paths. In other words, use the /cygdrive mount flags for these paths as well.
• Recognize NWFS filesystem and workaround broken OS call.
• New support for eXtensible Data Record (XDR) encoding and decoding, as defined by RFCs 1014, 1832, and 4506. The XDR protocol and functions are useful for cross-platform data exchange, and are commonly used as the core data interchange format for Remote Procedure Call (RPC) and NFS.
1.7.45 What's new and what changed from 1.5 to 1.7

1.7.45.1 OS related changes

• Windows 95, 98 and Me are not supported anymore. The new Cygwin 1.7 DLL will not run on any of these systems.
• Add support for Windows 7 and Windows Server 2008 R2.

1.7.45.2 File Access related changes

• Mount points are no longer stored in the registry. Use /etc/fstab and /etc/fstab.d/$USER instead. Mount points created with mount(1) are only local to the current session and disappear when the last Cygwin process in the session exits.
• Cygwin creates the mount points for /, /usr/bin, and /usr/lib automatically from its own position on the disk. They don’t have to be specified in /etc/fstab.
• If a filename cannot be represented in the current character set, the character will be converted to a sequence Ctrl-X + UTF-8 representation of the character. This allows to access all files, even those not having a valid representation of their filename in the current character set. To always have a valid string, use the UTF-8 charset by setting the environment variable $LANG, $LC_ALL, or $LC_CTYPE to a valid POSIX value, such as "en_US.UTF-8".
• PATH_MAX is now 4096. Internally, path names can be as long as the underlying OS can handle (32K).
• struct dirent now supports d_type, filled out with DT_REG or DT_DIR. All other file types return as DT_UNKNOWN for performance reasons.
• The CYGWIN environment variable options "ntsec" and "smbntsec" have been replaced by the per-mount option "acl"/"noacl".
• The CYGWIN environment variable option "ntea" has been removed without substitute.
• The CYGWIN environment variable option "check_case" has been removed in favor of real case-sensitivity on file systems supporting it.
• Creating filenames with special DOS characters ‘”, ‘*’, ‘:’, ‘<’, ‘>’, ‘|’ is supported.
• Creating files with special DOS device filename components (“aux”, “nul”, “prn”) is supported.
• File names are case sensitive if the OS and the underlying file system supports it. Works on NTFS and NFS. Does not work on FAT and Samba shares. Requires to change a registry key (see the User’s Guide). Can be switched off on a per-mount basis.
• Due to the above changes, managed mounts have been removed.
• Incoming DOS paths are always handled case-insensitive and get no POSIX permission, as if they are mounted with noacl,posix=0 mount flags.
• unlink(2) and rmdir(2) try very hard to remove files/directories even if they are currently accessed or locked. This is done by utilizing the hidden recycle bin directories and marking the files for deletion.
• rename(2) rewritten to be more POSIX conformant.
• access(2) now performs checks using the real user ID, as required by POSIX; the old behavior of querying based on effective user ID is available through the new faccessat(2) and euidaccess(2) APIs.
• Add st_birthtim member to struct stat.
• File locking is now advisory, not mandatory anymore. The fcntl(2) and the new lockf(2) APIs create and maintain locks with POSIX semantics, the flock(2) API creates and maintains locks with BSD semantics. POSIX and BSD locks are independent of each other.
• Implement atomic O_APPEND mode.
• New open(2) flags O_DIRECTORY, O_EXEC and O_SEARCH.
- Make the "plain file with SYSTEM attribute set" style symlink default again when creating symlinks. Only create Windows shortcut style symlinks if CYGWIN=winsymlinks is set in the environment.

- Symlinks now use UTF-16 encoding for the target filename for better internationalization support. Cygwin 1.7 can read all old style symlinks, but the new style is not compatible with older Cygwin releases.

- Handle NTFS native symlinks available since Vista/2008 as symlinks (but don’t create Vista/2008 symlinks due to unfortunate OS restrictions).

- Recognize NFS shares and handle them using native mechanisms. Recognize and create real symlinks on NFS shares. Get correct stat(2) information and set real mode bits on open(2), mkdir(2) and chmod(2).

- Recognize MVFS and workaround problems manipulating metadata and handling DOS attributes.

- Recognize Netapp DataOnTap drives and fix inode number handling.

- Recognize Samba version beginning with Samba 3.0.28a using the new extended version information negotiated with the Samba developers.

- Stop faking hardlinks by copying the file on filesystems which don’t support hardlinks natively (FAT, FAT32, etc.). Just return an error instead, just like Linux.

- List servers of all accessible domains and workgroups in // instead of just the servers in the own domain/workgroup.


- New file conversion API for conversion from Win32 to POSIX path and vice versa (cygwin_conv_path, cygwin_create_path, cygwin_conv_path_list).

- New openat family of functions: openat, faccessat, fchmodat, fchownat, fstatat, futimesat, linkat, mkdirat, mkfifoat, mknodat, readlinkat, renamet, symlinkat, unlinkat.

- Other new APIs: posix_fadvise, posix_fallocate, funopen, fopencookie, open_memstream, open_wmemstream, fmemopen, fdopendir, fpurge, mkstemps, eaccess, euidaccess, canonicalize_file_name, fexecve, execvpe.

### 1.7.45.3 Network related changes

- New implementation for blocking sockets and select on sockets which is supposed to allow POSIX-compatible sharing of sockets between threads and processes.

- send/sendto/sendmsg now send data in 64K chunks to circumvent an internal buffer problem in WinSock (KB 201213).

- New send/rece option MSG_DONTWAIT.

- IPv6 support. New APIs getaddrinfo, getnameinfo, freeaddrinfo, gai_strerror, inf6addr_any, inf6addr_loopback. On IPv6-less systems, replacement functions are available for IPv4. On systems with IPv6 enabled, the underlying WinSock functions are used. While I tried hard to get the functionality as POSIXy as possible, keep in mind that a *fully* conformant implementation of getaddrinfo and other stuff is only available starting with Windows Vista/2008.

- Resolver functions (res_init, res_query, res_search, res_querydomain, res_mkquery, res_send, dn_comp, dn_expand) are now part of Cygwin. Applications don’t have to link against minires anymore. Actually, this *is* the former libminires.a.

- rcmd is now implemented inside of Cygwin, instead of calling the WinSock function. This allows rsh(1) usage on Vista/2008 and later, which dropped this function from WinSock.

- Define multicast structures in netinet/in.h. Note that fully conformant multicast support is only available beginning with Vista/2008.

- Improve get_ifconf. Redefine struct ifreq and subsequent datastructures to be able to keep more information. Support SIOCGIFINDEX, SIOCGIFDSTADDR and the Cygwin specific SIOCGIFFRNDLYNAM. Support real interface flags on systems supporting them.

- Other new APIs: bindresvport, bindresvport_sa, gethostbyname2, iruserok_sa, rcmd_af, resvport_af. getfaddr, freefaddr, if_nametoindex, if_indextoname, if_nameindex, if_freenameindex.

- Add /proc/net/if_inet6.
1.7.45.4 Device related changes

- Reworked pipe implementation which uses overlapped IO to create more reliable interruptible pipes and fifos.
- The CYGWIN environment variable option "binmode" has been removed.
- Improved fifo handling by using native Windows named pipes.
- Detect when a stdin/stdout which looks like a pipe is really a tty. Among other things, this allows a debugged application to recognize that it is using the same tty as the debugger.
- Support UTF-8 in console window.
- In the console window the backspace key now emits DEL (0x7f) instead of BS (0x08), Alt-Backspace emits ESC-DEL (0x1b,0x7f) instead of DEL (0x7f), same as the Linux console and xterm. Control-Space now emits an ASCII NUL (0x0) character.
- Support up to 64 serial interfaces using /dev/ttyS0 - /dev/ttyS63.
- Support up to 128 raw disk drives /dev/sda - /dev/sddx.

1.7.45.5 Other POSIX related changes

- A lot of character sets are supported now via a call to setlocale(). The setting of the environment variables $LANG, $LC_ALL or $LC_CTYPE will be used. For instance, setting $LANG to "de_DE.ISO-8859-15" before starting a Cygwin session will use the ISO-8859-15 character set in the entire session. The default locale in the absence of one of the aforementioned environment variables is "C.UTF-8".
- Allow multiple concurrent read locks per thread for pthread_rwlock_t.
- Implement pthread_kill(thread, 0) as per POSIX.
- Only declare expected functions in <strings.h>, don’t include <string.h> from here.
- Support for WCONTINUED, WIFCONTINUED() added to waitpid and wait4.
- New APIs: _Exit, confstr, insque, remque, sys_sigabbrev, posix_madvise, posix_memalign, reallocf, exp10, exp10f, pow10, pow10f, lrint, lrintf, rint, rintf, ilrint, ilrintf, lrintl, lrintlf, mbsnrtowcs, strcasestr, stpcpy, stpcpy, wcpcpy, wcpncpy, wcsnlen, wcsntombs, wcsftime, wcstod, wcstof, wcstol, wcstoll, wcstoul, wcstoull, wcstoumax, wcswrnm, wcsxfrm, wcscasecmp, wcscasecmp, fgetwc, fgetws, fputwc, fputws, fwrite, getwc, getwchar, putwc, putwchar, ungetwc, asprintf, dprintf, vasprintf, vdprintf, wprintf, fwprintf, swprintf, vwprintf, vfwprintf, vsprintf, vswprintf, vwscanf, fwscanf, vsscanf.

1.7.45.6 Security related changes

- Getting a domain user’s groups is hopefully more bulletproof now.
- Cygwin now comes with a real LSA authentication package. This must be manually installed by a privileged user using the /bin/cyglsa-config script. The advantages and disadvantages are noted in https://cygwin.com/ml/cygwin-developers/2006-11/msg00000.html
• Cygwin now allows storage and use of user passwords in a hidden area of the registry. This is tried first when Cygwin is called by privileged processes to switch the user context. This allows, for instance, ssh public key sessions with full network credentials to access shares on other machines.

• New options have been added to the mkpasswd and mkgroup tools to ease use in multi-machine and multi-domain environments. The existing options have a slightly changed behaviour.

1.7.45.7 Miscellaneous

• New ldd utility, similar to Linux.

• New link libraries libdl.a, libresolv.a, librt.a.

• Fallout from the long path names: If the current working directory is longer than 260 bytes, or if the current working directory is a virtual path (like /proc, /cygdrive, //server), don’t call native Win32 programs since they don’t understand these paths.

• On the first usage of a DOS path (C:\foo, \foo\bar), the Cygwin DLL emits a scary warning that DOS paths shouldn’t be used. This warning may be disabled via the new CYGWIN=nodosfilewarning setting.

• The CYGWIN environment variable option “server” has been removed. Cygwin automatically uses cygserver if it’s available.

• Allow environment of arbitrary size instead of a maximum of 32K.

• Don’t force uppercase environment when started from a non-Cygwin process. Except for certain Windows and POSIX variables which are always uppercased, preserve environment case. Switch back to old behaviour with the new CYGWIN=upcaseenv setting.

• Detect and report a missing DLL on process startup.

• Add /proc/registry32 and /proc/registry64 paths to access 32 bit and 64 bit registry on 64 bit systems.

• Add the ability to distinguish registry keys and registry values with the same name in the same registry subtree. The key is called “foo” and the value will be called “foo%val” in this case.

• Align /proc/cpuinfo more closely to Linux content.

• Add /proc/$PID/mounts entries and a symlink /proc/mounts pointing to /proc/self/mounts as on Linux.

• Optimized strstr and memmem implementation.

• Remove backwards compatibility with old signal masks. (Some *very* old programs which use signal masks may no longer work correctly).

• Cygwin now exports wrapper functions for libstdc++ operators new and delete, to support the toolchain in implementing full C++ standards conformance when working with shared libraries.

• Different Cygwin installations in different paths can be run in parallel without knowing of each other. The path of the Cygwin DLL used in a process is a key used when creating IPC objects. So different Cygwin DLLs are running in different namespaces.

• Each Cygwin DLL stores its path and installation key in the registry. This allows troubleshooting of problems which could be a result of having multiple concurrent Cygwin installations.
Chapter 2

Setting Up Cygwin

2.1 Internet Setup

To install the Cygwin net release, go to https://cygwin.com/ and run either setup-x86.exe to install the 32 bit version of Cygwin, or setup-x86_64.exe to install the 64 bit version of Cygwin. This will download a GUI installer which can be run to download a complete cygwin installation via the internet. Follow the instructions on each screen to install Cygwin.

Note For easier reading the installer is called setup.exe throughout the following sections. This refers likewise to both installer applications, setup-x86.exe for 32 bit, as well as setup-x86_64.exe for 64 bit. Apart from the target architecture they are the same thing.

The setup.exe installer is designed to be easy for new users to understand while remaining flexible for the experienced. The volunteer development team is constantly working on setup.exe; before requesting a new feature, check the wishlist in the Git README. It may already be present in the Git version!

On Windows Vista and later, setup.exe will check by default if it runs with administrative privileges and, if not, will try to elevate the process. If you want to avoid this behaviour and install under an unprivileged account just for your own usage, run setup.exe with the --no-admin option.

Since the default value for each option is the logical choice for most installations, you can get a working minimal Cygwin environment installed by simply clicking the Next button at each page. The only exception to this is choosing a Cygwin mirror, which you can choose by experimenting with those listed at https://cygwin.com/mirrors.html. For more details about each of page of the setup.exe installation, read on below. Please note that this guide assumes that you have a basic understanding of Unix (or a Unix-like OS). If you are new to Unix, you will also want to make use of other resources.

2.1.1 Download Source

Cygwin uses packages to manage installing various software. When the default Install from Internet option is chosen, setup.exe creates a local directory to store the packages before actually installing the contents. Download from Internet performs only the first part (storing the packages locally), while Install from Local Directory performs only the second (installing the contents of the packages).

The Download from Internet option is mainly for creating a base Cygwin package tree on one computer for installation on several machines with Install from Local Directory; copy the entire local package tree to another machine with the directory tree intact. For example, you might create a C:\cache\ directory and place setup.exe in it. Run setup.exe to Install from Internet or Download from Internet, then copy the whole C:\cache\ to each machine and instead choose Install from Local Directory.

Though this provides some basic mirroring functionality, if you are managing a large Cygwin installation, to keep up to date we recommend using a mirroring tool such as wget. A helpful user on the Cygwin mailing list created a simple demonstration script to accomplish this; search the list for mkcygwget for ideas.
2.1.2 Selecting an Install Directory

The Root Directory for Cygwin (default C:\cygwin) will become / within your Cygwin installation. You must have write access to the parent directory, and any ACLs on the parent directory will determine access to installed files.

The Install For options of All Users or Just Me should always be left on the default All Users, unless you do not have write access to HKEY_LOCAL_MACHINE in the registry or the All Users Start Menu. This is true even if you are the only user planning to use Cygwin on the machine. Selecting Just Me will cause problems for programs such as crond and sshd. If you do not have the necessary permissions, but still want to use these programs, consult the Cygwin mailing list archives about others’ experiences.

2.1.3 Local Package Directory

The Local Package Directory is the cache where setup.exe stores the packages before they are installed. The cache must not be the same folder as the Cygwin root. Within the cache, a separate directory is created for each Cygwin mirror, which allows setup.exe to use multiple mirrors and custom packages. After installing Cygwin, the cache is no longer necessary, but you may want to retain the packages as backups, for installing Cygwin to another system, or in case you need to reinstall a package.

2.1.4 Connection Method

The Direct Connection method of downloading will directly connect. If your system is configured to use a proxy server or auto-configuration scripts, the Use System Proxy Settings method uses those settings. Alternatively, you can manually enter proxy settings into the Use HTTP/FTP Proxy section.

2.1.5 Choosing Mirrors

Since there is no way of knowing from where you will be downloading Cygwin, you need to choose at least one mirror site. Cygwin mirrors are geographically distributed around the world; check the list at https://cygwin.com/mirrors.html to find one near you. You can select multiple mirrors by holding down CTRL and clicking on each one. If you have the URL of an unlisted mirror (for example, if your organization has an internal Cygwin mirror) you can add it.

2.1.6 Choosing Packages

For each selected mirror site, setup.exe downloads a small text file called setup.bz2 that contains a list of packages available from that site along with some basic information about each package which setup.exe parses and uses to create the chooser window. For details about the format of this file, see the setup.exe homepage.

The chooser is the most complex part of setup.exe. Packages are grouped into categories, and one package may belong to multiple categories (assigned by the volunteer package maintainer). Each package can be found under any of those categories in the hierarchical chooser view. By default, setup.exe will install only the packages in the Base category and their dependencies, resulting in a minimal Cygwin installation. However, this will not include many commonly used tools such as gcc (which you will find in the Devel category). Since setup.exe automatically selects dependencies, be careful not to unselect any required packages. In particular, everything in the Base category is required.

You can change setup.exe’s view style, which is helpful if you know the name of a package you want to install but not which category it is in. Click on the View button and it will rotate between Category (the default), Full (all packages), and Pending (only packages to be installed, removed or upgraded). If you are familiar with Unix, you will probably want to at least glance through the Full listing for your favorite tools.

Once you have an existing Cygwin installation, the setup.exe chooser is also used to manage your Cygwin installation. Information on installed packages is kept in the /etc/setup/ directory of your Cygwin installation; if setup.exe cannot find this directory it will act as if you have no Cygwin installation. If setup.exe finds a newer version of an installed package available, it will automatically mark it to be upgraded. To Uninstall, Reinstall, or get the Source for an existing package, click on Keep to toggle it. Also, to avoid the need to reboot after upgrading, make sure to close all Cygwin windows and stop all Cygwin processes before setup.exe begins to install the upgraded package.
To avoid unintentionally upgrading, use the **Pending** view to see which packages have been marked for upgrading. If you don’t want to upgrade a package, click on the new version number to toggle it until it says **Keep**. All packages can be set to stay at the installed version by pressing the **Keep** button in the top right part of the chooser window.

A previous version of each package is usually available, in case downgrading is required to avoid a serious bug in the current version of the package. Packages also occasionally have testing (or “experimental”) versions available. Previous and experimental versions can be chosen by clicking on the package’s **New** column until the required version appears.

All available experimental packages can be selected by pressing the **Exp** in the top right part of the chooser window. Be warned, however, that the next time you run `setup.exe` it will try to replace all old or experimental versions with the current version, unless told otherwise.

### 2.1.7 Download and Installation Progress

First, `setup.exe` will download all selected packages to the local directory chosen earlier. Before installing, `setup.exe` performs a checksum on each package. If the local directory is a slow medium (such as a network drive) this can take a long time. During the download and installation, `setup.exe` shows progress bars for the current task and total remaining disk space.

### 2.1.8 Shortcuts

You may choose to install "Cygwin Terminal" shortcuts on the Desktop and/or Start Menu. These shortcuts run `mintty`, which will start your default shell as specified in `/etc/passwd`.

### 2.1.9 Post-Install Scripts

Last of all, `setup.exe` will run any post-install scripts to finish correctly setting up installed packages. When the last post-install script is completed, `setup.exe` will display a box announcing the completion. A few packages, such as the OpenSSH server, require some manual site-specific configuration. Relevant documentation can be found in the `/usr/doc/Cygwin/` or `/usr/share/doc/Cygwin/` directory.

### 2.1.10 Troubleshooting

Unfortunately, the complex setup process means that odd problems can occur. If you’re having trouble downloading packages, it may be network congestion, so try a different mirror and/or a different protocol (i.e., HTTP instead of FTP). If you notice something is not working after running setup, you can check the `setup.exe` log file at `/var/log/setup.log.full`. Make a backup of this file before running `setup.exe` again, and follow the steps for Reporting Problems with Cygwin.

### 2.2 Environment Variables

#### 2.2.1 Overview

All Windows environment variables are imported when Cygwin starts. Apart from that, you may wish to specify settings of several important environment variables that affect Cygwin’s operation.

The **CYGWIN** variable is used to configure a few global settings for the Cygwin runtime system. Typically you can leave **CYGWIN** unset, but if you want to set one or more options, you can set it using a syntax like this, depending on the shell in which you’re setting it. Here is an example in CMD syntax:

```
C:\> set CYGWIN=error_start:C:\cygwin\bin\gdb.exe glob
```

This is, of course, just an example. For the recognized settings of the **CYGWIN** environment variable, see Section 3.5.

Locale support is controlled by the **LANG** and **LC_xxx** environment variables. For a more detailed description see Section 2.4.
The **PATH** environment variable is used by Cygwin applications as a list of directories to search for executable files to run. This environment variable is converted from Windows format (e.g., `C:\Windows\system32;C:\Windows`) to UNIX format (e.g., `/cygdrive/c/Windows/system32;/cygdrive/c/Windows`) when a Cygwin process first starts. Set it so that it contains at least the `x:\cygwin\bin` directory where "x:\cygwin" is the "root" of your cygwin installation if you wish to use cygwin tools outside of bash. This is usually done by the batch file you’re starting your shell with.

The **HOME** environment variable is used by many programs to determine the location of your home directory. This environment variable, if it exists, is converted from Windows format when a Cygwin process first starts. However, it’s usually set in the shell profile scripts in the `/etc` directory, and it’s **not** recommended to set the variable in your Windows environment.

The **TERM** environment variable specifies your terminal type. It is automatically set to `cygwin` if you have not set it to something else.

The **LD_LIBRARY_PATH** environment variable is used by the Cygwin function `dlopen()` as a list of directories to search for `.dll` files to load. This environment variable is converted from Windows format to UNIX format when a Cygwin process first starts. Most Cygwin applications do not make use of the `dlopen()` call and do not need this variable.

The **GMON_OUT_PREFIX** environment variable is helpful in some situations when profiling Cygwin programs. For more information, see Section 4.5.3.2. Only software developers with a need to profile their programs have a use for this variable.

In addition to **PATH**, **HOME**, **LD_LIBRARY_PATH**, and **GMON_OUT_PREFIX**, there are three other environment variables which, if they exist in the Windows environment, are converted to UNIX format: **TMPDIR**, **TMP**, and **TEMP**. The first is not set by default in the Windows environment but the other two are, and they point to the default Windows temporary directory. If set, these variables will be used by some Cygwin applications, possibly with unexpected results. You may therefore want to unset them by adding the following two lines to your `~/.bashrc` file:

```bash
unset TMP
unset TEMP
```

This is done in the default `~/.bashrc` file. Alternatively, you could set `TMP` and `TEMP` to point to `/tmp` or to any other temporary directory of your choice. For example:

```bash
export TMP=/tmp
export TEMP=/tmp
```

### 2.2.2 Restricted Win32 environment

There is a restriction when calling Win32 API functions which require a fully set up application environment. Cygwin maintains its own environment in POSIX style. The Win32 environment is usually stripped to a bare minimum and not at all kept in sync with the Cygwin POSIX environment.

If you need the full Win32 environment set up in a Cygwin process, you have to call

```c
#include <sys/cygwin.h>
cygwinInternal (CW_SYNC_WINENV);
```

to synchronize the Win32 environment with the Cygwin environment. Note that this only synchronizes the Win32 environment once with the Cygwin environment. Later changes using the `setenv` or `putenv` calls are not reflected in the Win32 environment. In these cases, you have to call the aforementioned `cygwin_internal` call again.

### 2.3 Changing Cygwin’s Maximum Memory

Cygwin’s heap is extensible. However, it does start out at a fixed size and attempts to extend it may run into memory which has been previously allocated by Windows. In some cases, this problem can be solved by changing a field in the file header which is utilized by Cygwin since to keep the initial size of the application heap. If the field contains 0, which is the default, the application heap defaults to a size of 384 Megabyte on 32 bit Cygwin, 512 Megabyte on 64 bit Cygwin. If the field is set to any other value between 4 and 2048, Cygwin tries to reserve as much Megabytes for the application heap. The field used for this is the "LoaderFlags" field in the NT-specific PE header structure (`((IMAGE_NT_HEADER)->OptionalHeader.LoaderFlags`).
This value can be changed for any executable by using a more recent version of the `peflags` tool from the `rebase` Cygwin package. Example:

```bash
$ peflags --cygwin-heap foo.exe
foo.exe: initial Cygwin heap size: 0 (0x0) MB
$ peflags --cygwin-heap=500 foo.exe
foo.exe: initial Cygwin heap size: 500 (0x1f4) MB
```

Heap memory can be allocated up to the size of the biggest available free block in the processes virtual memory (VM). By default, the VM per process is 2 GB for 32 processes. To get more VM for a process, the executable must have the "large address aware" flag set in the file header. You can use the aforementioned `peflags` tool to set this flag. On 64 bit systems this results in a 4 GB VM for a process started from that executable. On 32 bit systems you also have to prepare the system to allow up to 3 GB per process. See the Microsoft article 4-Gigabyte Tuning for more information.

### 2.4 Internationalization

#### 2.4.1 Overview

Internationalization support is controlled by the `LANG` and `LC_xxx` environment variables. You can set all of them but Cygwin itself only honors the variables `LC_ALL`, `LC_CTYPE`, and `LANG`, in this order, according to the POSIX standard. The content of these variables should follow the POSIX standard for a locale specifier. The correct form of a locale specifier is

```
/language[_[TERRITORY][.charset][@modifier]]
```

"language" is a lowercase two character string per ISO 639-1, or, if there is no ISO 639-1 code for the language (for instance, "Lower Sorbian"), a three character string per ISO 639-3.

"TERRITORY" is an uppercase two character string per ISO 3166, charset is one of a list of supported character sets. The modifier doesn’t matter here (though some are recognized, see below). If you’re interested in the exact description, you can find it in the online publication of the POSIX manual pages on the homepage of the Open Group.

Typical locale specifiers are

```
"de_CH"    language = German, territory = Switzerland, default charset
"fr_FR.UTF-8"    language = french, territory = France, charset = UTF-8
"ko_KR.eucKR"    language = korean, territory = South Korea, charset = eucKR
"syr_SY"    language = Syriac, territory = Syria, default charset
```

If the locale specifier does not follow the above form, Cygwin checks if the locale is one of the locale aliases defined in the file `/usr/share/locale/locale.alias`. If so, and if the replacement localename is supported by the underlying Windows, the locale is accepted, too. So, given the default content of the `/usr/share/locale/locale.alias` file, the below examples would be valid locale specifiers as well.

```
"catalan"    defined as "ca_ES.ISO-8859-1" in locale.alias
"japanese"   defined as "ja_JP.eucJP" in locale.alias
"turkish"    defined as "tr_TR.ISO-8859-9" in locale.alias
```

The file `/usr/share/locale/locale.alias` is provided by the gettext package under Cygwin.

At application startup, the application’s locale is set to the default "C" or "POSIX" locale. This locale defaults to the ASCII character set on the application level. If you want to stick to the "C" locale and only change to another charset, you can define this by setting one of the locale environment variables to "C.charset". For instance

```
"C.ISO-8859-1"
```

**Note**

The default locale in the absence of the aforementioned locale environment variables is "C.UTF-8".
Windows uses the UTF-16 charset exclusively to store the names of any object used by the Operating System. This is especially important with filenames. Cygwin uses the setting of the locale environment variables \texttt{LC\_ALL}, \texttt{LC\_CTYPE}, and \texttt{LANG}, to determine how to convert Windows filenames from their UTF-16 representation to the singlebyte or multibyte character set used by Cygwin.

The setting of the locale environment variables at process startup is effective for Cygwin’s internal conversions to and from the Windows UTF-16 object names for the entire lifetime of the current process. Changing the environment variables to another value changes the way filenames are converted in subsequently started child processes, but not within the same process.

However, even if one of the locale environment variables is set to some other value than "C", this does only affect how Cygwin itself converts filenames. As the POSIX standard requires, it’s the application’s responsibility to activate that locale for its own purposes, typically by using the call

```
setlocale (LC\_ALL, "");
```

early in the application code. Again, so that this doesn’t get lost: If the application calls setlocale as above, and there is none of the important locale variables set in the environment, the locale is set to the default locale, which is "C.UTF-8".

But what about applications which are not locale-aware? Per POSIX, they are running in the "C" or "POSIX" locale, which implies the ASCII charset. The Cygwin DLL itself, however, will nevertheless use the locale set in the environment (or the "C.UTF-8" default locale) for converting filenames etc.

When the locale in the environment specifies an ASCII charset, for example "C" or "en\_US.ASCII", Cygwin will still use UTF-8 under the hood to translate filenames. This allows for easier interoperability with applications running in the default "C.UTF-8" locale.

The language and territory are used to fetch locale-dependent information from Windows. If the language and territory are not known to Windows, the \texttt{setlocale} function fails.

The following modifiers are recognized. Any other modifier is simply ignored for now.

- For locales which use the Euro (EUR) as currency, the modifier "@euro" can be added to enforce usage of the ISO-8859-15 character set, which includes a character for the "Euro" currency sign.
- The default script used for all Serbian language locales (sr\_BA, sr\_ME, sr\_RS, and the deprecated sr\_CS and sr\_SP) is cyrillic. With the "@latin" modifier it gets switched to the latin script with the respective collation behaviour.
- The default charset of the "be\_BY" locale (Belarusian/Belarus) is CP1251. With the "@latin" modifier it’s UTF-8.
- The default charset of the "tt\_RU" locale (Tatar/Russia) is ISO-8859-5. With the "@iqtelif" modifier it’s UTF-8.
- The default charset of the "uz\_UZ" locale (Uzbek/Uzbekistan) is ISO-8859-1. With the "@cyrillic" modifier it’s UTF-8.
- There’s a class of characters in the Unicode character set, called the "CJK Ambiguous Width" characters. For these characters, the width returned by the wcwidth/wcswidth functions is usually 1. This can be a problem with East-Asian languages, which historically use character sets where these characters have a width of 2. Therefore, wcwidth/wcswidth return 2 as the width of these characters when an East-Asian charset such as GBK or SJIS is selected, or when UTF-8 is selected and the language is specified as "zh" (Chinese), "ja" (Japanese), or "ko" (Korean). This is not correct in all circumstances, hence the locale modifier "@cjknarrow" can be used to force wcwidth/wcswidth to return 1 for the ambiguous width characters.
- For the same class of "CJK Ambiguous Width" characters, it may be desirable to handle them as double-width even when a non-CJK language setting is selected. This supports e.g. certain graphic symbols used by "Powerline" and provided by "Powerline fonts". Some terminals have options to enforce this width handling (xterm -cjk\_width, mintty -o Charwidth=ambig-wide, putty configuration) but that alone makes character rendering and locale information inconsistent for those characters. The locale modifier "@cjkwide" supports consistent locale response with this option; it forces wcwidth/wcswidth to return 2 for the ambiguous width characters.

\subsection*{2.4.2 How to set the locale}

- Assume that you’ve set one of the aforementioned environment variables to some valid POSIX locale value, other than "C" and "POSIX". Assume further that you’re living in Japan. You might want to use the language code "ja" and the territory "JP", thus setting, say, \texttt{LANG} to "ja\_JP". You didn’t set a character set, so what will Cygwin use now? The default character set is determined by the default Windows ANSI codepage for this language and territory. Cygwin uses a character set which is the typical Unix-equivalent to the Windows ANSI codepage. For instance:
• You don’t want to use the default character set? In that case you have to specify the charset explicitly. For instance, assume you’re from Japan and don’t want to use the japanese default charset EUC-JP, but the Windows default charset SJIS. What you can do, for instance, is to set the LANG variable in the mintty Cygwin Terminal in the "Text" section of its "Options" dialog. If you’re starting your Cygwin session via a batch file or a shortcut to a batch file, you can also just set LANG there:

```bash
@echo off
C:
chdir C:\cygwin\bin
set LANG=ja_JP.SJIS
bash --login -l
```

**Note**
For a list of locales supported by your Windows machine, use the new `locale -a` command, which is part of the Cygwin package. For a description see `locale(1)`

**Note**
For a list of supported character sets, see Section 2.4.5

• Last, but not least, most singlebyte or doublebyte charsets have a big disadvantage. Windows filesystems use the Unicode character set in the UTF-16 encoding to store filename information. Not all characters from the Unicode character set are available in a singlebyte or doublebyte charset. While Cygwin has a workaround to access files with unusual characters (see Section 3.4.4), a better workaround is to use always the UTF-8 character set.

UTF-8 is the only multibyte character set which can represent every Unicode character.

```bash
set LANG=es_MX.UTF-8
```

For a description of the Unicode standard, see the homepage of the Unicode Consortium.

### 2.4.3 The Windows Console character set

Sometimes the Windows console is used to run Cygwin applications. While terminal emulations like the Cygwin Terminal mintty or xterm have a distinct way to set the character set used for in- and output, the Windows console hasn’t such a way, since it’s not an application in its own right.

This problem is solved in Cygwin as follows. When a Cygwin process is started in a Windows console (either explicitly from cmd.exe, or implicitly by, for instance, running the C:\cygwin\Cygwin.bat batch file), the Console character set is determined by the setting of the aforementioned internationalization environment variables, the same way as described in Section 2.4.2.

What is that good for? Why not switch the console character set with the applications requirements? After all, the application knows if it uses localization or not. However, what if a non-localized application calls a remote application which itself is localized? This can happen with ssh or rlogin. Both commands don’t have and don’t need localization and they never call setlocale. Setting one of the internationalization environment variable to the same charset as the remote machine before starting ssh or rlogin fixes that problem.
2.4.4 Potential Problems when using Locales

You can set the above internationalization variables not only when starting the first Cygwin process, but also in your Cygwin shell on the fly, even switch to yet another character set, and yet another. In bash for instance:

```
bash$ export LC_CTYPE="nl_BE.UTF-8"
```

However, here’s a problem. At the start of the first Cygwin process in a session, the Windows environment is converted from UTF-16 to UTF-8. The environment is another of the system objects stored in UTF-16 in Windows.

As long as the environment only contains ASCII characters, this is no problem at all. But if it contains native characters, and you’re planning to use, say, GBK, the environment will result in invalid characters in the GBK charset. This would be especially a problem in variables like `PATH`. To circumvent the worst problems, Cygwin converts the `PATH` environment variable to the charset set in the environment, if it’s different from the UTF-8 charset.

---

**Note**

Per POSIX, the name of an environment variable should only consist of valid ASCII characters, and only of uppercase letters, digits, and the underscore for maximum portability.

---

Very old symbolic links may pose a problem when switching charsets on the fly. A symbolic link contains the filename of the target file the symlink points to. When a symlink had been created with versions of Cygwin prior to Cygwin 1.7, the current ANSI or OEM character set had been used to store the target filename, dependent on the old `CYGWIN` environment variable setting `codepage` (see Section 3.5.2. If the target filename contains non-ASCII characters and you use another character set than your default ANSI/OEM charset, the target filename of the symlink is now potentially an invalid character sequence in the new character set. This behaviour is not different from the behaviour in other Operating Systems. Recreate the symlink if that happens to you.

2.4.5 List of supported character sets

Last but not least, here’s the list of currently supported character sets. The left-hand expression is the name of the charset, as you would use it in the internationalization environment variables as outlined above. Note that charset specifiers are case-insensitive. `EUCJP` is equivalent to `eucJP` or `eUcJp`. Writing the charset in the exact case as given in the list below is a good convention, though.

The right-hand side is the number of the equivalent Windows codepage as well as the Windows name of the codepage. They are only noted here for reference. Don’t try to use the bare codepage number or the Windows name of the codepage as charset in locale specifiers, unless they happen to be identical with the left-hand side. Especially in case of the "CPxxx" style charsets, always use them with the trailing "CP".

This works:

```
set LC_ALL=en_US.CP437
```

This does **not** work:

```
set LC_ALL=en_US.437
```


<table>
<thead>
<tr>
<th>Charset</th>
<th>Codepage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>20127 (US_ASCII)</td>
</tr>
<tr>
<td>CP437</td>
<td>437 (OEM United States)</td>
</tr>
<tr>
<td>CP720</td>
<td>720 (DOS Arabic)</td>
</tr>
<tr>
<td>CP737</td>
<td>737 (OEM Greek)</td>
</tr>
<tr>
<td>CP775</td>
<td>775 (OEM Baltic)</td>
</tr>
<tr>
<td>CP850</td>
<td>850 (OEM Latin 1, Western European)</td>
</tr>
</tbody>
</table>
CP852 852 (OEM Latin 2, Central European)
CP855 855 (OEM Cyrillic)
CP857 857 (OEM Turkish)
CP858 858 (OEM Latin 1 + Euro Symbol)
CP862 862 (OEM Hebrew)
CP866 866 (OEM Russian)
CP874 874 (ANSI/OEM Thai)
CP932 932 (Shift_JIS, not exactly identical to SJIS)
CP1125 1125 (OEM Ukraine)
CP1250 1250 (ANSI Central European)
CP1251 1251 (ANSI Cyrillic)
CP1252 1252 (ANSI Latin 1, Western European)
CP1253 1253 (ANSI Greek)
CP1254 1254 (ANSI Turkish)
CP1255 1255 (ANSI Hebrew)
CP1256 1256 (ANSI Arabic)
CP1257 1257 (ANSI Baltic)
CP1258 1258 (ANSI/OEM Vietnamese)
ISO-8859-1 28591 (ISO-8859-1)
ISO-8859-2 28592 (ISO-8859-2)
ISO-8859-3 28593 (ISO-8859-3)
ISO-8859-4 28594 (ISO-8859-4)
ISO-8859-5 28595 (ISO-8859-5)
ISO-8859-6 28596 (ISO-8859-6)
ISO-8859-7 28597 (ISO-8859-7)
ISO-8859-8 28598 (ISO-8859-8)
ISO-8859-9 28599 (ISO-8859-9)
ISO-8859-10 - (not available)
ISO-8859-11 - (not available)
ISO-8859-13 28603 (ISO-8859-13)
ISO-8859-14 - (not available)
ISO-8859-15 28605 (ISO-8859-15)
ISO-8859-16 - (not available)
Big5 950 (ANSI/OEM Traditional Chinese)
EUCCN or euc-CN 936 (ANSI/OEM Simplified Chinese)
EUCJP or euc-JP 20932 (EUC Japanese)
EUCKR or euc-KR 949 (EUC Korean)
GB2312 936 (ANSI/OEM Simplified Chinese)
GBK 936 (ANSI/OEM Simplified Chinese)
GEORGIAN-PS - (not available)
KOI8-R 20866 (KOI8-R Russian Cyrillic)
KOI8-U 21866 (KOI8-U Ukrainian Cyrillic)
PT514 - (not available)
SJIS - (not available, almost, but not exactly CP932)
TIS620 or TIS-620 874 (ANSI/OEM Thai)
UTF-8 or utf8 65001 (UTF-8)

2.5 Customizing bash

To set up bash so that cut and paste work properly, click on the “Properties” button of the window, then on the ”Misc” tab. Make sure that ”QuickEdit mode” and ”Insert mode” are checked. These settings will be remembered next time you run bash from that shortcut.

Your home directory should contain three initialization files that control the behavior of bash. They are .profile, .bashrc and .inputrc. The Cygwin base installation creates stub files when you start bash for the first time.
.profile (other names are also valid, see the bash man page) contains bash commands. It is executed when bash is started as login shell, e.g. from the command bash --login. This is a useful place to define and export environment variables and bash functions that will be used by bash and the programs invoked by bash. It is a good place to redefine PATH if needed. We recommend adding a ";" to the end of PATH to also search the current working directory (contrary to DOS, the local directory is not searched by default). Also to avoid delays you should either unset MAILCHECK or define MAILPATH to point to your existing mail inbox.

.bashrc is similar to .profile but is executed each time an interactive bash shell is launched. It serves to define elements that are not inherited through the environment, such as aliases. If you do not use login shells, you may want to put the contents of .profile as discussed above in this file instead.

```
shopt -s nocaseglob
```

will allow bash to glob filenames in a case-insensitive manner. Note that .bashrc is not called automatically for login shells. You can source it from .profile.

.inputrc controls how programs using the readline library (including bash) behave. It is loaded automatically. For full details see the Function and Variable Index section of the GNU readline manual. Consider the following settings:

```
# Ignore case while completing
set completion-ignore-case on
# Make Bash 8bit clean
set meta-flag on
set convert-meta off
set output-meta on
```

The first command makes filename completion case insensitive, which can be convenient in a Windows environment. The next three commands allow bash to display 8-bit characters, useful for languages with accented characters. Note that tools that do not use readline for display, such as less and ls, require additional settings, which could be put in your .bashrc:

```
alias less='/bin/less -r'
alias ls='/bin/ls -F --color=tty --show-control-chars'
```
Chapter 3

Using Cygwin

This chapter explains some key differences between the Cygwin environment and traditional UNIX systems. It assumes a working knowledge of standard UNIX commands.

3.1 Mapping path names

3.1.1 Introduction

The Cygwin DLL supports both POSIX- and Win32-style paths. Directory delimiters may be either forward slashes or backslashes. Paths using backslashes or starting with a drive letter are always handled as Win32 paths. POSIX paths must only use forward slashes as delimiter, otherwise they are treated as Win32 paths and file access might fail in surprising ways.

Note

Although the Cygwin DLL supports Win32 paths, not all Cygwin applications support them. Moreover, the usage of Win32 paths circumvents important internal path handling mechanisms. This usage is therefore strongly deprecated and may be removed in a future release of Cygwin. See Section 3.1.7 and Section 3.1.8 for more information.

POSIX operating systems (such as Linux) do not have the concept of drive letters. Instead, all absolute paths begin with a slash (instead of a drive letter such as "c:" ) and all file systems appear as subdirectories (for example, you might buy a new disk and make it be the /disk2 directory).

Because many programs written to run on UNIX systems assume the existence of a single unified POSIX file system structure, Cygwin maintains a special internal POSIX view of the Win32 file system that allows these programs to successfully run under Windows. Cygwin uses this mapping to translate from POSIX to Win32 paths as necessary.

3.1.2 The Cygwin Mount Table

The /etc/fstab file is used to map Win32 drives and network shares into Cygwin’s internal POSIX directory tree. This is a similar concept to the typical UNIX fstab file. The mount points stored in /etc/fstab are globally set for all users. Sometimes there’s a requirement to have user specific mount points. The Cygwin DLL supports user specific fstab files. These are stored in the directory /etc/fstab.d and the name of the file is the Cygwin username of the user, as it’s created from the Windows account database or stored in the /etc/passwd file (see Section 3.6.2). The structure of the user specific file is identical to the system-wide fstab file.

The file fstab contains descriptive information about the various file systems. fstab is only read by programs, and not written; it is the duty of the system administrator to properly create and maintain this file. Each filesystem is described on a separate line; fields on each line are separated by tabs or spaces. Lines starting with ’#’ are comments.
The first field describes the block special device or remote filesystem to be mounted. On Cygwin, this is the native Windows path which the mount point links in. As path separator you MUST use a slash. Usage of a backslash might lead to unexpected results. UNC paths (using slashes, not backslashes) are allowed. If the path contains spaces these can be escaped as ‘\040’.

The second field describes the mount point for the filesystem. If the name of the mount point contains spaces these can be escaped as “\040”.

The third field describes the type of the filesystem. Cygwin supports any string here, since the file system type is usually not evaluated. So it doesn’t matter if you write FAT into this field even if the filesystem is NTFS. Cygwin figures out the filesystem type and its capabilities by itself.

The only two exceptions are the file system types cygdrive and usertemp. The cygdrive type is used to set the cygdrive prefix. For a description of the cygdrive prefix see Section 3.1.4, for a description of the usertemp file system type see Section 3.1.5

The fourth field describes the mount options associated with the filesystem. It is formatted as a comma separated list of options. It contains at least the type of mount (binary or text) plus any additional options appropriate to the filesystem type. The list of the options, including their meaning, follows.

```plaintext
acl     - Cygwin uses the filesystem’s access control lists (ACLs) to implement real POSIX permissions (default). This flag only affects filesystems supporting ACLs (NTFS, for instance) and is ignored otherwise.
auto    - Ignored.
binary  - Files default to binary mode (default).
bind    - Allows to remount part of the file hierarchy somewhere else. In contrast to other entries, the first field in the fstab line specifies an absolute POSIX path. This path is remounted to the POSIX path specified as the second path. The conversion to a Win32 path is done on the fly. Only the root path and paths preceding the bind entry in the fstab file are used to convert the POSIX path in the first field to an absolute Win32 path. Note that symlinks are ignored while performing this path conversion.
cygexec - Treat all files below mount point as cygwin executables.
dos     - Always convert leading spaces and trailing dots and spaces to characters in the UNICODE private use area. This allows to use broken filesystems which only allow DOS filenames, even if they are not recognized as such by Cygwin.
exec    - Treat all files below mount point as executable.
ihash   - Always fake inode numbers rather than using the ones returned by the filesystem. This allows to use broken filesystems which don’t return unambiguous inode numbers, even if they are not recognized as such by Cygwin.
noacl   - Cygwin ignores filesystem ACLs and only fakes a subset of permission bits based on the DOS readonly attribute. This behaviour is the default on FAT and FAT32. The flag is ignored on NFS filesystems.
nosuid  - No suid files are allowed (currently unimplemented).
notexec - Treat all files below mount point as not executable.
nouser  - Mount is a system-wide mount.
override - Force the override of an immutable mount point (currently "/").
posix=0  - Switch off case sensitivity for paths under this mount point (default for the cygdrive prefix).
posix=1  - Switch on case sensitivity for paths under this mount point (default for all other mount points).
sparse  - Switch on support for sparse files. This option only makes sense on NTFS and then only if you really need sparse files.
          Cygwin does not try to create sparse files by default for performance reasons.
text    - Files default to CRLF text mode line endings.
user    - Mount is a user mount.
```


While normally the execute permission bits are used to evaluate executability, this is not possible on filesystems which don’t support permissions at all (like FAT/FAT32), or if ACLs are ignored on filesystems supporting them (see the aforementioned acl mount option). In these cases, the following heuristic is used to evaluate if a file is executable: Files ending in certain extensions (.exe, .com, .lnk) are assumed to be executable. Files whose first two characters are "#!", "MZ", or ":\n" are also considered to be executable. The exec option is used to instruct Cygwin that the mounted file is "executable". If the exec option is used with a directory then all files in the directory are executable. This option allows other files to be marked as executable and avoids the overhead of opening each file to check for "magic" bytes. The cygexec option is very similar to exec, but also prevents Cygwin from setting up commands and environment variables for a normal Windows program, adding another small performance gain. The opposite of these options is the notexec option, which means that no files should be marked as executable under that mount point.

A correct root directory is quite essential to the operation of Cygwin. A default root directory is evaluated at startup so a fstab entry for the root directory is not necessary. If it’s wrong, nothing will work as expected. Therefore, the root directory evaluated by Cygwin itself is treated as an immutable mount point and can’t be overridden in /etc/fstab... unless you think you really know what you’re doing. In this case, use the override flag in the options field in the /etc/fstab file. Since this is a dangerous thing to do, do so at your own risk.

/usr/bin and /usr/lib are by default also automatic mount points generated by the Cygwin DLL similar to the way the root directory is evaluated. /usr/bin points to the directory the Cygwin DLL is installed in, /usr/lib is supposed to point to the /lib directory. This choice is safe and usually shouldn’t be changed. An fstab entry for them is not required.

nouser mount points are not overridable by a later call to mount. Mount points given in /etc/fstab are by default nouser mount points, unless you specify the option user. This allows the administrator to set certain paths so that they are not overridable by users. In contrast, all mount points in the user specific fstab file are user mount points.

The fifth and sixth field are ignored. They are so far only specified to keep a Linux-like fstab file layout.

Note that you don’t have to specify an fstab entry for the root dir, unless you want to have the root dir pointing to somewhere entirely different (hopefully you know what you’re doing), or if you want to mount the root dir with special options (for instance, as text mount).

Example entries:

- Just a normal mount point:
  ```
  c:/foo /bar fat32 binary 0 0
  ```

- A mount point for a textmode mount with case sensitivity switched off:
  ```
  C:/foo /bar/baz ntfs text,posix=0 0 0
  ```

- A mount point for a Windows directory with spaces in it:
  ```
  C:/Documents\040and\040Settings /docs ext3 binary 0 0
  ```

- A mount point for a remote directory, don’t store POSIX permissions in ACLs:
  ```
  //server/share/subdir /srv/subdir smbfs binary,noacl 0 0
  ```

- This is just a comment:
  ```
  # This is just a comment
  ```

- Set the cygdrive prefix to /mnt:
  ```
  none /mnt cygdrive binary 0 0
  ```

- Remount /var to /usr/var:
  ```
  /var /usr/var none bind
  ```

Assuming /var points to C:/cygwin/var, /usr/var now also points to C:/cygwin/var. This is equivalent to the Linux bind option available since Linux 2.4.0.
Whenever Cygwin generates a Win32 path from a POSIX one, it uses the longest matching prefix in the mount table. Thus, if C:\ is mounted as /c and also as /, then Cygwin would translate C:/foo/bar to /c/foo/bar. This translation is normally only used when trying to derive the POSIX equivalent current directory. Otherwise, the handling of MS-DOS filenames bypasses the mount table.

If you want to see the current set of mount points valid in your session, you can invoke the Cygwin tool `mount` without arguments:

Example 3.1 Displaying the current set of mount points

```
bash$ mount
f:/cygwin/bin on /usr/bin type ntfs (binary,auto)
f:/cygwin/lib on /usr/lib type ntfs (binary,auto)
f:/cygwin on / type ntfs (binary,auto)
e:/src on /usr/src type vfat (binary)
c: on /cygdrive/c type ntfs (binary,posix=0,user,noumount,auto)
e: on /cygdrive/e type vfat (binary,posix=0,user,noumount,auto)
```

You can also use the `mount` command to add new mount points, and the `umount` to delete them. However, since they are only stored in memory, these mount points will disappear as soon as your last Cygwin process ends. See `mount(1)` and `umount(1)` for more information.

### 3.1.3 UNC paths

Apart from the unified POSIX tree starting at the / directory, UNC pathnames starting with two slashes and a server name (//machine/share/...) are supported as well. They are handled as POSIX paths if only containing forward slashes. There’s also a virtual directory // which allows to enumerate the fileservers known to the local machine with `ls`. Same goes for the UNC paths of the type //machine, which allow to enumerate the shares provided by the server machine. For often used UNC paths it makes sense to add them to the mount table (see Section 3.1.2 so they are included in the unified POSIX path tree.

### 3.1.4 The cygdrive path prefix

As already outlined in Section 1.6.3, you can access arbitary drives on your system by using the cygdrive path prefix. The default value for this prefix is /cygdrive, and a path to any drive can be constructed by using the cygdrive prefix and appending the drive letter as subdirectory, like this:

```
bash$ ls -l /cygdrive/f/somedir
```

This lists the content of the directory F:somedir.

The cygdrive prefix is a virtual directory under which all drives on a system are subsumed. The mount options of the cygdrive prefix is used for all file access through the cygdrive prefixed drives. For instance, assuming the cygdrive mount options are binary,posix=0, then any file /cygdrive/x/file will be opened in binary mode by default (mount option binary), and the case of the filename doesn’t matter (mount option posix=0).

The cygdrive prefix flags are also used for all UNC paths starting with two slashes, unless they are accessed through a mount point. For instance, consider these /etc/fstab entries:

```
//server/share /mysrv ntfs posix=1,acl 0 0
none /cygdrive cygdrive posix=0,noacl 0 0
```

Assume there’s a file \server\share\foo on the share. When accessing it as /mysrv/foo, then the flags posix=1,acl of the /mysrv mount point are used. When accessing it as //server/share/foo, then the flags for the cygdrive prefix, posix=0, noacl are used.

**Note**

This only applies to UNC paths using forward slashes. When using backslashes the flags for native paths are used. See Section 3.1.7.
The cygdrive prefix may be changed in the fstab file as outlined above. Please note that you must not use the cygdrive prefix for any other mount point. For instance this:

```
none /cygdrive cygdrive binary 0 0
D: /cygdrive/d somefs text 0 0
```

will not make file access using the /mnt/d path prefix suddenly using textmode. If you want to mount any drive explicitly in another mode than the cygdrive prefix, use a distinct path prefix:

```
none /cygdrive cygdrive binary 0 0
D: /mnt/d somefs text 0 0
```

To simplify scripting, Cygwin also provides a `/proc/cygdrive` symlink, which allows to use a fixed path in scripts, even if the actual cygdrive prefix has been changed, or is different between different users. So, in scripts, conveniently use the `/proc/cygdrive` symlink to successfully access files independently from the current cygdrive prefix:

```
$ mount -p
Prefix  Type   Flags
/mnt    user   binmode
$ cat > x.sh <<EOF
cd /proc/cygdrive/c/Windows/System32/Drivers/etc
ls -l hosts
EOF
$ sh -c ./x.sh
-rwxrwx---+ 1 SYSTEM SYSTEM 826 Sep 4 22:43 hosts
```

### 3.1.5 The usertemp file system type

On Windows, the environment variable `TEMP` specifies the location of the temp folder. It serves the same purpose as the `/tmp/` directory in Unix systems. In contrast to `/tmp/`, it is by default a different folder for every Windows user. By using the special purpose usertemp file system, that temp folder can be mapped to `/tmp/`. This is particularly useful in setups where the administrator wants to write-protect the entire Cygwin directory. The usertemp file system can be configured in `/etc/fstab` like this:

```
none /tmp usertemp binary,posix=0 0 0
```

### 3.1.6 Symbolic links

Symbolic links are not present and supported on Windows until Windows Vista/Server 2008, and then only on some filesystems. Since POSIX applications are rightfully expecting to use symlinks and the `symlink(2)` system call, Cygwin had to find a workaround for this Windows flaw.

Cygwin creates symbolic links potentially in multiple different ways:

- The default symlinks are plain files containing a magic cookie followed by the path to which the link points. They are marked with the DOS SYSTEM attribute so that only files with that attribute have to be read to determine whether or not the file is a symbolic link.

  > **Note**
  
  Cygwin symbolic links are using UTF-16 to encode the filename of the target file, to better support internationalization. Symlinks created by old Cygwin releases can be read just fine. However, you could run into problems with them if you’re now using another character set than the one you used when creating these symlinks (see Section 2.4.4).

- The shortcut style symlinks are Windows `.lnk` shortcut files with a special header and the DOS READONLY attribute set. This symlink type is created if the environment variable `CYGWIN` (see Section 3.5) is set to contain the string `winsymlinks` or `winsymlinks:lnk`. On the MVFS filesystem, which does not support the DOS SYSTEM attribute, this is the one and only supported symlink type, independently from the `winsymlinks` setting.
• Native Windows symlinks are only created on Windows Vista/2008 and later, and only on filesystems supporting reparse points. Due to to their weird restrictions and behaviour, they are only created if the user explicitly requests creating them. This is done by setting the environment variable `CYGWIN` to contain the string `winsymlinks:native` or `winsymlinks:nativestrict`. For the difference between these two settings, see Section 3.5. On AFS, native symlinks are the only supported type of symlink due to AFS lacking support for DOS attributes. This is independent from the `winsymlinks` setting.

Creation of native symlinks follows special rules to ensure the links are usable outside of Cygwin. This includes dereferencing any Cygwin-only symlinks that lie in the target path.

• On the NFS filesystem, Cygwin always creates real NFS symlinks.

All of the above four symlink types are recognized and used as symlinks under all circumstances. However, if the default plain file symlink type is lacking its DOS SYSTEM bit, or if the shortcut file is lacking the DOS READONLY attribute, they are not recognized as symlink.

Apart from these four types, there’s also a fifth type, which is recognized as symlink but never generated by Cygwin, directory junctions. This is an older reparse point type, supported by Windows since Windows 2000. Filesystem junctions on the other hand are not handled as symlinks, since otherwise they would not be recognized as filesystem borders by commands like `find -xdev`.

### 3.1.7 Using native Win32 paths

Using native Win32 paths in Cygwin, while often possible, is generally inadvisable. Those paths circumvent all internal integrity checking and bypass the information given in the Cygwin mount table.

The following paths are treated as native Win32 paths by the Cygwin DLL (but not necessarily by Cygwin applications):

• All paths starting with a drive specifier

```
C:\foo
C:/foo
```

• All paths containing at least one backslash as path component

```
C:/foo/bar\baz/...
```

• UNC paths using backslashes

```
\\server\share\...
```

When accessing files using native Win32 paths as above, Cygwin uses a default setting for the mount flags. All paths using DOS notation will be treated as case insensitive, and permissions are just faked as if the underlying drive is a FAT drive. This also applies to NTFS and other filesystems which usually are capable of case sensitivity and storing permissions.

### 3.1.8 Using the Win32 file API in Cygwin applications

Special care must be taken if your application uses Win32 file API functions like `CreateFile` to access files using relative pathnames, or if your application uses functions like `CreateProcess` or `ShellExecute` to start other applications.

When a Cygwin application is started, the Windows idea of the current working directory (CWD) is not necessarily the same as the Cygwin CWD. There are a couple of restrictions in the Win32 API, which disallow certain directories as Win32 CWD:

• The Windows subsystem only supports CWD paths of up to 258 chars. This restriction doesn’t apply for Cygwin processes, at least not as long as they use the POSIX API (`chdir`, `getcwd`). This means, if a Cygwin process has a CWD using an absolute path longer than 258 characters, the Cygwin CWD and the Windows CWD differ.

• The Win32 API call to set the current directory, `SetCurrentDirectory`, fails for directories for which the user has no permissions, even if the user is an administrator. This restriction doesn’t apply for Cygwin processes, if they are running under an administrator account.
• SetCurrentDirectory does not support case-sensitive filenames.
• Last, but not least, SetCurrentDirectory can’t work on virtual Cygwin paths like /proc or /cygdrive. These paths only exist in the Cygwin realm so they have no meaning to a native Win32 process.

As long as the Cygwin CWD is usable as Windows CWD, the Cygwin and Windows CWDs are in sync within a process. However, if the Cygwin process changes its working directory into one of the directories which are unusable as Windows CWD, we’re in trouble. If the process uses the Win32 API to access a file using a relative pathname, the resulting absolute path would not match the expectations of the process. In the worst case, the wrong files are deleted.

To workaround this problem, Cygwin sets the Windows CWD to a special directory in this case. This special directory points to a virtual filesystem within the native NT namespace (\??\PIPE\). Since it’s not a real filesystem, the deliberate effect is that a call to, for instance, CreateFile ("foo", ...); will fail, as long as the processes CWD doesn’t work as Windows CWD.

So, in general, don’t use the Win32 file API in Cygwin applications. If you really need to access files using the Win32 API, or if you really have to use CreateProcess to start applications, rather than the POSIX exec(3) family of functions, you have to make sure that the Cygwin CWD is set to some directory which is valid as Win32 CWD.

3.1.9 Additional Path-related Information

The cygpath program provides the ability to translate between Win32 and POSIX pathnames in shell scripts. See cygpath(1) for the details.

The HOME, PATH, and LD_LIBRARY_PATH environment variables are automatically converted from Win32 format to POSIX format (e.g. from c:\cygwin\bin to /bin, if there was a mount from that Win32 path to that POSIX path) when a Cygwin process first starts.

Symbolic links can also be used to map Win32 pathnames to POSIX. For example, the command ln -s //pollux/home/joe/data /data would have about the same effect as creating a mount point from //pollux/home/joe/data to /data using mount, except that symbolic links cannot set the default file access mode. Other differences are that the mapping is distributed throughout the file system and proceeds by iteratively walking the directory tree instead of matching the longest prefix in a kernel table. Note that symbolic links will only work on network drives that are properly configured to support the "system" file attribute. Many do not so by default (the Unix Samba server does not by default, for example).

3.2 Text and Binary modes

3.2.1 The Issue

On a UNIX system, when an application reads from a file it gets exactly what’s in the file on disk and the converse is true for writing. The situation is different in the DOS/Windows world where a file can be opened in one of two modes, binary or text. In the binary mode the system behaves exactly as in UNIX. However on writing in text mode, a NL (\n, ˆJ) is transformed into the sequence CR (\r, ˆM) NL.

This can wreak havoc with the seek/seek calls since the number of bytes actually in the file may differ from that seen by the application.

The mode can be specified explicitly as explained in the Programming section below. In an ideal DOS/Windows world, all programs using lines as records (such as bash, make, sed ...) would open files (and change the mode of their standard input and output) as text. All other programs (such as cat, cmp, tr ...) would use binary mode. In practice with Cygwin, programs that deal explicitly with object files specify binary mode (this is the case of od, which is helpful to diagnose CR problems). Most other programs (such as sed, cmp, tr) use the default mode.

3.2.2 The default Cygwin behavior

The Cygwin system gives us some flexibility in deciding how files are to be opened when the mode is not specified explicitly. The rules are evolving, this section gives the design goals.
a. If the filename is specified as a POSIX path and it appears to reside on a file system that is mounted (i.e. if its pathname starts with a directory displayed by `mount`), then the default is specified by the mount flag. If the file is a symbolic link, the mode of the target file system applies.

b. If the file is specified via a MS-DOS pathname (i.e., it contains a backslash or a colon), the default is binary.

c. Pipes, sockets and non-file devices are opened in binary mode. For pipes opened through the pipe() system call you can use the setmode() function (see Section 3.2.4 to switch to textmode. For pipes opened through popen(), you can simply specify text or binary mode just like in calls to fopen().

d. Sockets and other non-file devices are always opened in binary mode.

e. When redirecting, the Cygwin shells uses rules (a-d). Non-Cygwin shells always pipe and redirect with binary mode. With non-Cygwin shells the commands `cat filename | program` and `program < filename` are not equivalent when `filename` is on a text-mounted partition.

The programs `u2d` and `d2u` can be used to add or remove CR’s from a file. `u2d` add’s CR’s before a NL. `d2u` removes CR’s. Use the --help option to these commands for more information.

### 3.2.3 Binary or text?

UNIX programs that have been written for maximum portability will know the difference between text and binary files and act appropriately under Cygwin. Most programs included in the official Cygwin distributions should work well in the default mode.

Binmode is the best choice usually since it’s faster and easier to handle, unless you want to exchange files with native Win32 applications. It makes most sense to keep the Cygwin distribution and your Cygwin home directory in binmode and generate text files in binmode (with UNIX LF lineendings). Most Windows applications can handle binmode files just fine. A notable exception is the mini-editor Notepad, which handles UNIX lineendings incorrectly and only produces output files with DOS CRLF lineendings.

You can convert files between CRLF and LF lineendings by using certain tools in the Cygwin distribution like `dos2unix` and `unix2dos` from the dos2unix package. You can also specify a directory in the mount table to be mounted in textmode so you can use that directory for exchange purposes.

As application programmer you can decide on a file by file base, or you can specify default open modes depending on the purpose for which the application open files. See the next section for a description of your choices.

### 3.2.4 Programming

In the `open()` function call, binary mode can be specified with the flag `O_BINARY` and text mode with `O_TEXT`. These symbols are defined in `fcntl.h`.

The `mkstemp()` and `mkstemps()` calls force binary mode. Use `mkstemp()` or `mkstemps()` with the same flags as `open()` for more control on temporary files.

In the `fopen()` and `popen()` function calls, binary mode can be specified by adding a `b` to the mode string. Text mode is specified by adding a `t` to the mode string.

The mode of a file can be changed by the call `setmode(fd,mode)` where `fd` is a file descriptor (an integer) and `mode` is `O_BINARY` or `O_TEXT`. The function returns `O_BINARY` or `O_TEXT` depending on the mode before the call, and EOF on error.

There’s also a convenient way to set the default open modes used in an application by just linking against various object files provided by Cygwin. For instance, if you want to make sure that all files are always opened in binary mode by an application, regardless of the mode of the underlying mount point, just add the file `/lib/binmode.o` to the link stage of the application in your project, like this:

```
$ gcc my_tiny_app.c /lib/binmode.o -o my_tiny_app
```

Even simpler:

```
$ gcc my_tiny_app.c -lbinmode -o my_tiny_app
```
This adds code which sets the default open mode for all files opened by `my_tiny_app` to binary for reading and writing.

Cygwin provides the following libraries and object files to set the default open mode just by linking an application against them:

<table>
<thead>
<tr>
<th>Library</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/lib/libautomode.a, /lib/automode.o</td>
<td>Open files for reading in textmode, open files for writing in binary mode</td>
</tr>
<tr>
<td>/lib/libbinmode.a, /lib/binmode.o</td>
<td>Open files for reading and writing in binary mode</td>
</tr>
<tr>
<td>/lib/libtextmode.a, /lib/textmode.o</td>
<td>Open files for reading and writing in textmode</td>
</tr>
<tr>
<td>/lib/libtextreadmode.a, /lib/textreadmode.o</td>
<td>Open files for reading in textmode, keep default behaviour for writing.</td>
</tr>
</tbody>
</table>

### 3.3 File permissions

On FAT or FAT32 filesystems, files are always readable, and Cygwin uses the DOS read-only attribute to determine if they are writable. Files are considered to be executable if the filename ends with `.bat`, `.com` or `.exe`, or if its content starts with `#!`. Consequently `chmod` can only affect the "w" mode, it silently ignores actions involving the other modes. This means that `ls -l` needs to open and read files. It can thus be relatively slow.

On NTFS, file permissions are evaluated using the Access Control Lists (ACLs) attached to a file. This can be switched off by using the "noacl" option to the respective mount point in the `/etc/fstab` or `/etc/fstab.d/$USER` file. For more information on file permissions, see Section 3.6.

On NFS shares, file permissions are exactly the POSIX permissions transmitted from the server using the NFSv3 protocol, if the NFS client is the one from Microsoft’s "Services For Unix", or the one built into Windows Vista or later.

Only the user and group ownership is not necessarily correct.

### 3.4 Special filenames

#### 3.4.1 Special files in /etc

Certain files in Cygwin’s `/etc` directory are read by Cygwin before the mount table has been established. The list of files is:

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/fstab</td>
<td></td>
</tr>
<tr>
<td>/etc/fstab.d/$USER</td>
<td></td>
</tr>
<tr>
<td>/etc/passwd</td>
<td></td>
</tr>
<tr>
<td>/etc/group</td>
<td></td>
</tr>
</tbody>
</table>

These files are read using native Windows NT functions which have no notion of Cygwin symlinks or POSIX paths. For that reason there are a few requirements as far as `/etc` is concerned.

To access these files, the Cygwin DLL evaluates its own full Windows path, strips off the innermost directory component and adds "etc". Let’s assume the Cygwin DLL is installed as `C:\cygwin\bin\cygwin1.dll`. First the DLL name as well as the innermost directory (bin) is stripped off: `C:\cygwin\`. Then "etc" and the filename to look for is attached: `C:\cygwin\etc\fstab`. So the `/etc` directory must be parallel to the directory in which the cygwin1.dll exists and `/etc` must not be a Cygwin symlink pointing to another directory. Consequentially none of the files from the above list, including the directory `/etc/fstab.d` is allowed to be a Cygwin symlink either.

However, native NTFS symlinks and reparse points are transparent when accessing the above files so all these files as well as `/etc` itself may be NTFS symlinks or reparse points.

Last but not least, make sure that these files are world-readable. Every process of any user account has to read these files potentially, so world-readability is essential. The only exception are the user specific files `/etc/fstab.d/$USER`, which only have to be readable by the $USER user account itself.
3.4.2 Invalid filenames

Filenames invalid under Win32 are not necessarily invalid under Cygwin. There are a few rules which apply to Windows filenames. Most notably, DOS device names like AUX, COM1, LPT1 or PRN (to name a few) cannot be used as filename or extension in a native Win32 application. So filenames like prn.txt or foo.aux are invalid filenames for native Win32 applications.

This restriction doesn’t apply to Cygwin applications. Cygwin can create and access files with such names just fine. Just don’t try to use these files with native Win32 applications.

3.4.3 Forbidden characters in filenames

Some characters are disallowed in filenames on Windows filesystems. These forbidden characters are the ASCII control characters from ASCII value 1 to 31, plus the following characters which have a special meaning in the Win32 API:

```
*  :  <  >  ?  |  \n```

Cygwin can’t fix this, but it has a method to workaround this restriction. All of the above characters, except for the backslash, are converted to special UNICODE characters in the range 0xf000 to 0xf0ff (the "Private use area") when creating or accessing files by adding 0xf000 to the forbidden characters’ code points.

The backslash has to be exempt from this conversion, because Cygwin accepts Win32 filenames including backslashes as path separators on input. Converting backslashes using the above method would make this impossible.

Additionally Win32 filenames can’t contain trailing dots and spaces for DOS backward compatibility. When trying to create files with trailing dots or spaces, all of them are removed before the file is created. This restriction only affects native Win32 applications. Cygwin applications can create and access files with trailing dots and spaces without problems.

An exception from this rule are some network filesystems (NetApp, NWFS) which choke on these filenames. They return with an error like "No such file or directory" when trying to create such files. Cygwin recognizes these filesystems and works around this problem by applying the same rule as for the other forbidden characters. Leading spaces and trailing dots and spaces will be converted to UNICODE characters in the private use area. This behaviour can be switched on explicitly for a filesystem or a directory tree by using the mount option dos.

3.4.4 Filenames with unusual (foreign) characters

Windows filesystems use Unicode encoded as UTF-16 to store filename information. If you don’t use the UTF-8 character set (see Section 2.4) then there’s a chance that a filename is using one or more characters which have no representation in the character set you’re using.

**Note**

In the default "C" locale, Cygwin creates filenames using the UTF-8 charset. This will always result in some valid filename by default, but again might impose problems when switching to a non-"C" or non-"UTF-8" charset.

**Note**

To avoid this scenario altogether, always use UTF-8 as the character set.

If you don’t want or can’t use UTF-8 as character set for whatever reason, you will nevertheless be able to access the file. How does that work? When Cygwin converts the filename from UTF-16 to your character set, it recognizes characters which can’t be converted. If that occurs, Cygwin replaces the non-convertible character with a special character sequence. The sequence starts with an ASCII CAN character (hex code 0x18, equivalent Control-X), followed by the UTF-8 representation of the character. The result is a filename containing some ugly looking characters. While it doesn’t **look** nice, it **is** nice, because Cygwin knows how to convert this filename back to UTF-16. The filename will be converted using your usual character set. However, when Cygwin recognizes an ASCII CAN character, it skips over the ASCII CAN and handles the following bytes as a UTF-8 character. Thus, the filename is symmetrically converted back to UTF-16 and you can access the file.
Note

Please be aware that this method is not entirely foolproof. In some character set combinations it might not work for certain native characters. Only by using the UTF-8 charset you can avoid this problem safely.

3.4.5 Case sensitive filenames

In the Win32 subsystem filenames are only case-preserved, but not case-sensitive. You can’t access two files in the same directory which only differ by case, like `Abc` and `aBc`. While NTFS (and some remote filesystems) support case-sensitivity, the NT kernel does not support it by default. Rather, you have to tweak a registry setting and reboot. For that reason, case-sensitivity can not be supported by Cygwin, unless you change that registry value.

If you really want case-sensitivity in Cygwin, you can switch it on by setting the registry value

```
HKLM\SYSTEM\CurrentControlSet\Control\Session Manager\kernel\obcaseinsensitive
```

to 0 and reboot the machine.

Note

When installing Microsoft's Services For Unix (SFU), you're asked if you want to use case-sensitive filenames. If you answer "yes" at this point, the installer will change the aforementioned registry value to 0, too. So, if you have SFU installed, there's some chance that the registry value is already set to case sensitivity.

After you set this registry value to 0, Cygwin will be case-sensitive by default on NTFS and NFS filesystems. However, there are limitations: while two programs `Abc.exe` and `aBc.exe` can be created and accessed like other files, starting applications is still case-insensitive due to Windows limitations and so the program you try to launch may not be the one actually started. Also, be aware that using two filenames which only differ by case might result in some weird interoperability issues with native Win32 applications. You’re using case-sensitivity at your own risk. You have been warned!

Even if you use case-sensitivity, it might be feasible to switch to case-insensitivity for certain paths for better interoperability with native Win32 applications (even if it’s just Windows Explorer). You can do this on a per-mount point base, by using the "posix=0" mount option in `/etc/fstab` or your `/etc/fstab.d/$USER` file.

/cygdrive paths are case-insensitive by default. The reason is that the native Windows `%PATH%` environment variable is not always using the correct case for all paths in it. As a result, if you use case-sensitivity on the `/cygdrive` prefix, your shell might claim that it can’t find Windows commands like `attrib` or `net`. To ease the pain, the `/cygdrive` path is case-insensitive by default and you have to use the "posix=1" setting explicitly in `/etc/fstab` or `/etc/fstab.d/$USER` to switch it to case-sensitivity, or you have to make sure that the native Win32 `%PATH%` environment variable is using the correct case for all paths throughout.

Note that mount points as well as device names and virtual paths like `/proc` are always case-sensitive! The only exception are the subdirectories and filenames under `/proc/registry`, `/proc/registry32` and `/proc/registry64`. Registry access is always case-insensitive. Read on for more information.

3.4.6 Case sensitive directories

Windows 10 1803 introduced a new feature: NTFS directories can be marked as case-sensitive, independently of the `obcaseinsensitive` registry key discussed in the previous section. This new per-directory case-sensitivity requires setting a flag in the NTFS filesystem header which is, unfortunately, undocumented. The result is that you have to activate Windows Subsystem for Linux (WSL), a feature available via Programs and Features -> Turn Windows features on or off. You only have to activate WSL, you don’t have to install any actual Linux. After turning WSL on and performing the compulsory reboot, case-sensitive directories are activated.

Of course, there’s a drawback. While these case-sensitive directories work like charm on the local machine, there are massive interoperability problems when trying to access these directories from remote machines at the time of writing this. We opened a bug report for that at Microsoft’s WSL issue tracker, if you’re interested in the details.
Note

If you want case-sensitivity and need interoperability with remote machines, better stick to switching the kernel to case-sensitivity as outlined in Section 3.4.5

With WSL activated and starting with Cygwin 3.0.0, Cygwin’s `mkdir` system call automatically created all directories below the Cygwin installation directory as case-sensitive. With Cygwin 3.0.2, this feature had been disabled again for hopefully obvious reasons.

However, you can still use Cygwin’s new `chattr(1)` tool with the `-C` option to control case-sensitivity of directories on NTFS filesystems.

Please keep in mind that switching off case-sensitivity on a directory has a condition attached to it: If the directory contains two files which only differ in case (e.g., `foo` and `FOO`), Windows refuses to convert the dir back to case-insensitive. First you have to fix the filename collision, i.e., you have to rename one of these files.

### 3.4.7 POSIX devices

While there is no need to create a POSIX `/dev` directory, the directory is automatically created as part of a Cygwin installation. It’s existence is often a prerequisite to run certain applications which create symbolic links, fifos, or UNIX sockets in `/dev`. Also, the directories `/dev/shm` and `/dev/mqueue` are required to exist to use named POSIX semaphores, shared memory, and message queues, so a system without a real `/dev` directory is functionally crippled.

Apart from that, Cygwin automatically simulates POSIX devices internally. The `/dev` directory is automatically populated with existing POSIX devices by Cygwin in a way comparable with a udev based virtual `/dev` directory under Linux.

Cygwin supports the following character devices commonly found on POSIX systems:

```
/dev/null
/dev/zero
/dev/full
/dev/console  Pseudo device name for the current console window of a session.
    Cygwin’s /dev/console is not quite comparable with the console device on UNIX machines.
/dev/cons0  Console sessions are numbered from /dev/cons0 upwards.
/dev/cons1  Console device names are pseudo device names, only accessible...
            ... from processes within this very console session. This is due to a restriction in Windows.
/dev/tty   The current controlling tty of a session.
/dev/ptmx  Pseudo tty master device.
/dev/pty0  Pseudo ttys are numbered from /dev/pty0 upwards as they are
/dev/pty1  requested.
...
/dev/ttyS0  Serial communication devices. ttyS0 == Win32 COM1,
/dev/ttyS1  ttyS1 == COM2, etc.
...
/dev/pipe
/dev/fifo
/dev/kmsg  Kernel message pipe, for usage with sys logger services.
/dev/random Random number generator.
/dev/urandom
/dev/dsp   Default sound device of the system.
```
Cygwin also has several Windows-specific devices:

```
/dev/com1 The serial ports, starting with COM1 which is the same as ttyS0.
/dev/com2 Please use /dev/ttySx instead.
...
/dev/conin Same as Windows CONIN$. 
/dev/conout Same as Windows CONOUT$.
/dev/clipboard The Windows clipboard, text only
/dev/windows The Windows message queue.
```

Block devices are accessible by Cygwin processes using fixed POSIX device names. These POSIX device names are generated using a direct conversion from the POSIX namespace to the internal NT namespace. E.g. the first harddisk is the NT internal device \device\harddisk0\partition0 or the first partition on the third harddisk is \device\harddisk2\partition1. The first floppy in the system is \device\floppy0, the first CD-ROM is \device\cdrom0 and the first tape drive is \device\tape0.

The mapping from physical device to the name of the device in the internal NT namespace can be found in various places. For hard disks and CD/DVD drives, the Windows "Disk Management" utility (part of the "Computer Management" console) shows that the mapping of "Disk 0" is \device\harddisk0. "CD-ROM 2" is \device\cdrom2. Another place to find this mapping is the "Device Management" console. Disks have a "Location" number, tapes have a "Tape Symbolic Name", etc. Unfortunately, the places where this information is found is not very well-defined.

For external disks (USB-drives, CF-cards in a cardreader, etc) you can use Cygwin to show the mapping. `/proc/partitions` contains a list of raw drives known to Cygwin. The `df` command shows a list of drives and their respective sizes. If you match the information between `/proc/partitions` and the `df` output, you should be able to figure out which external drive corresponds to which raw disk device name.

**Note**

Apart from tape devices which are not block devices and are by default accessed directly, accessing mass storage devices raw is something you should only do if you know what you're doing and know how to handle the information. **Writing** to a raw mass storage device you should only do if you **really** know what you're doing and are aware of the fact that any mistake can destroy important information, for the device, and for you. So, please, handle this ability with care. You have been warned.

Last but not least, the mapping from POSIX `/dev` namespace to internal NT namespace is as follows:

```
<table>
<thead>
<tr>
<th>POSIX device name</th>
<th>Internal NT device name</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dev/st0</td>
<td>\device\tape0, rewind</td>
</tr>
<tr>
<td>/dev/nst0</td>
<td>\device\tape0, no-rewind</td>
</tr>
<tr>
<td>/dev/st1</td>
<td>\device\tape1</td>
</tr>
<tr>
<td>/dev/nst1</td>
<td>\device\tape1</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>/dev/st15</td>
<td></td>
</tr>
<tr>
<td>/dev/nst15</td>
<td></td>
</tr>
<tr>
<td>/dev/fd0</td>
<td>\device\floppy0</td>
</tr>
<tr>
<td>/dev/fd1</td>
<td>\device\floppy1</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>/dev/sr0</td>
<td>\device\cdrom0</td>
</tr>
<tr>
<td>/dev/sr1</td>
<td>\device\cdrom1</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>/dev/scd0</td>
<td>\device\cdrom0</td>
</tr>
<tr>
<td>/dev/scd1</td>
<td>\device\cdrom1</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>/dev/scd15</td>
<td></td>
</tr>
</tbody>
</table>
```
if you don’t like these device names, feel free to create symbolic links as they are created on Linux systems for convenience:

```
ln -s /dev/sr0 /dev/cdrom
ln -s /dev/nst0 /dev/tape
```

### 3.4.8 The .exe extension

Win32 executable filenames end with .exe but the .exe need not be included in the command, so that traditional UNIX names can be used. However, for programs that end in .bat and .com, you cannot omit the extension.

As a side effect, the `ls filename` gives information about `filename.exe` if `filename.exe` exists and `filename` does not. In the same situation the function call `stat("filename",...)` gives information about `filename.exe`. The two files can be distinguished by examining their inodes, as demonstrated below.

```
bash$ ls *
a a.exe b.exe
bash$ ls -i a a.exe
445885548 a 435996602 a.exe
bash$ ls -i b b.exe
432961010 b 432961010 b.exe
```

If a shell script `myprog` and a program `myprog.exe` coexist in a directory, the shell script has precedence and is selected for execution of `myprog`. Note that this was quite the reverse up to Cygwin 1.5.19. It has been changed for consistency with the rest of Cygwin.

The `gcc` compiler produces an executable named `filename.exe` when asked to produce `filename`. This allows many makefiles written for UNIX systems to work well under Cygwin.

### 3.4.9 The /proc filesystem

Cygwin, like Linux and other similar operating systems, supports the /proc virtual filesystem. The files in this directory are representations of various aspects of your system, for example the command `cat /proc/cpuinfo` displays information such as what model and speed processor you have.

One unique aspect of the Cygwin /proc filesystem is /proc/registry, see next section.

The Cygwin /proc is not as complete as the one in Linux, but it provides significant capabilities. The procps package contains several utilities that use it.
3.4.10  The /proc.registry filesystem

The /proc.registry filesystem provides read-only access to the Windows registry. It displays each KEY as a directory and each VALUE as a file. As anytime you deal with the Windows registry, use caution since changes may result in an unstable or broken system. There are additionally subdirectories called /proc/registry32 and /proc/registry64. They are identical to /proc/registry on 32 bit host OSes. On 64 bit host OSes, /proc/registry32 opens the 32 bit processes view on the registry, while /proc/registry64 opens the 64 bit processes view.

Reserved characters ('/', '\', ':', and '%') or reserved names ('.', and '..') are converted by percent-encoding:

bash$ regtool list -v '\HKEY_LOCAL_MACHINE\SYSTEM\MountedDevices'
...
\DosDevices\C: (REG_BINARY) = cf a8 97 e8 00 08 fe f7
...
bash$ cd /proc/registry/HKEY_LOCAL_MACHINE/SYSTEM
bash$ ls -l MountedDevices
...-r-r---- 1 Admin SYSTEM 12 Dec 10 11:20 %5CDosDevices%5CC%3A
...
bash$ cd -x MountedDevices/%5CDosDevices%5CC%3A
00000000 cf a8 97 e8 00 08 fe f7 01 00 00 00

The unnamed (default) value of a key can be accessed using the filename @.

If a registry key contains a subkey and a value with the same name foo, Cygwin displays the subkey as foo and the value as foo%val.

3.4.11  The @pathnames

To circumvent the limitations on shell line length in the native Windows command shells, Cygwin programs, when invoked by non-Cygwin processes, expand their arguments starting with "@" in a special way. If a file pathname exists, the argument @pathname expands recursively to the content of pathname. Double quotes can be used inside the file to delimit strings containing blank space. In the following example compare the behaviors /bin/echo when run from bash and from the Windows command prompt.

Example 3.2 Using @pathname

bash$ /bin/echo 'This is a long line' > mylist
bash$ /bin/echo @mylist
@mylist
bash$ cmd
c:
> c:\cygwin\bin\echo @mylist
This is a long line

3.5  The CYGWIN environment variable

3.5.1  Implemented options

The CYGWIN environment variable is used to configure many global settings for the Cygwin runtime system. It contains the options listed below, separated by blank characters. Many options can be turned off by prefixing with no.

* (no)dosfilewarning - If set, Cygwin will warn the first time a user uses an "MS-DOS" style path name rather than a POSIX-style path name. Defaults to off.
* (no)export - If set, the final values of these settings are re-exported to the environment as CYGWIN again. Defaults to off.
• **error_start:Win32filepath** - if set, runs Win32filepath when cygwin encounters a fatal error, which is useful for debugging. Win32filepath is usually set to the path to gdb or dumper, for example C:\cygwin\bin\gdb.exe. There is no default set.

• **(no)glob[:ignorecase]** - if set, command line arguments containing UNIX-style file wildcard characters (brackets, braces, question mark, asterisk, escaped with \) are expanded into lists of files that match those wildcards. This is applicable only to programs run from non-Cygwin programs such as a CMD prompt. That means that this setting does not affect globbing operations for shells such as bash, sh, tcs, zsh, etc. Default is set.

This option also accepts an optional [no]ignorecase modifier. If supplied, wildcard matching is case insensitive. The default is noignorecase

• **(no)pipe_byte** - causes Cygwin to open pipes in byte mode rather than message mode.

• **proc_retry:n** - causes fork() and exec*() to retry n times when a child process fails due to certain windows-specific errors. These errors usually occur when processes are being started while a user is logging off.

• **(no)reset_com** - if set, serial ports are reset to 9600-8-N-1 with no flow control when used. This is done at open time and when handles are inherited. Defaults to set.

• **(no)wincmdln** - if set, the windows complete command line (truncated to ~32K) will be passed on any processes that it creates in addition to the normal UNIX argv list. Defaults to not set.

• **winsymlinks:{lnk,native,nativestrict}** - if set to just winsymlinks or winsymlinks:lnk, Cygwin creates symlinks as Windows shortcuts with a special header and the R/O attribute set.

If set to winsymlinks:native or winsymlinks:nativestrict, Cygwin creates symlinks as native Windows symlinks on filesystems and OS versions supporting them.

The difference between winsymlinks:native and winsymlinks:nativestrict is this: If the filesystem supports native symlinks and Cygwin fails to create a native symlink for some reason, it will fall back to creating Cygwin default symlinks with winsymlinks:native, while with winsymlinks:nativestrict the symlink(2) system call will immediately fail.

For more information on symbolic links, see Section 3.1.6.

### 3.5.2 Obsolete options

Certain CYGWIN options available in past releases have been removed over time for one reason or another. These obsolete options are listed below.

• **(no)binmode** - This option has been removed because all file opens default to binary mode, unless the open mode has been specified explicitly in the open(2) call.

• **(no)detect_bloda** - No case of a BLODA found by this option has been reported in years.

• **check_case** - This option has been removed in favor of real case sensitivity and the per-mount option "posix=[0|1]". For more information, read the documentation in Section 3.1.2 and Section 3.4.5.

• **codepage: [ansi|oem]** - This option controlled which character set is used for file and console operations. Since Cygwin is now doing all character conversion by itself, depending on the application call to the setlocale() function, and in turn by the setting of the environment variables $LANG, $LC_ALL, or $LC_CTYPE, this setting became superfluous.

• **(no)envcache** - Originally, envcache controlled caching of environment variable conversion between Win32 and POSIX. The default setting works fine, the option was just useless.

• **forkchunk: [intval]** - This option allowed to influence the fork() function in the way the memory of the parent process gets copied to the child process. This functionality was only useful for Windows 95/98/Me.

• **(no)ntea** - This option has been removed since it only fakes security which is considered dangerous and useless. It also created an uncontrollably large file on FAT and was entirely useless on FAT32.

• **(no)ntsec** - This option has been removed in favor of the per-mount option "acl"/"noacl". For more information, read the documentation in Section 3.1.2.
• (no)server - Originally this option had to be enabled on the client side to use features only available when running cygserver. This option has been removed because Cygwin now always tries to contact cygserver if a function is called which requires cygserver being available. For more information, read the documentation in Section 3.7.

• (no)smbntsec - This option has been removed in favor of the per-mount option "acl"/"noacl". For more information, read the documentation in Section 3.1.2.

• (no)strip_title - Removed because setting the Window title can be controlled by the application via Escape sequences.

• (no)title - Removed because setting the Window title can be controlled by the application via Escape sequences.

• (no)transparent_exe - This option has been removed because the behaviour it switched on is now the standard behaviour in Cygwin.

• (no)traverse - This option has been removed because traverse checking is not quite correctly implemented by Microsoft and it’s behaviour has been getting worse with each new OS version. This complicates its usage so the option has been removed for now.

• (no)tty - If set, Cygwin enabled extra support (i.e., termios) for UNIX-like ttys in the Windows console. This option has been removed because it can be easily replaced by using a terminal like mintty, and it does not work well with some Windows programs.

• (no)upcaseenv - This option could be used to convert all environment variables to uppercase. This was the default behavior in older releases of Cygwin. Since keeping the case of environment variables intact is POSIXly correct, Cygwin now does not change the case of environment variables, except for a restricted set to maintain minimal backward compatibility. The current list of always uppercased variables is:

<table>
<thead>
<tr>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMONPROGRAMFILES</td>
</tr>
<tr>
<td>COMSPEC</td>
</tr>
<tr>
<td>PATH</td>
</tr>
<tr>
<td>SYSTEMDRIVE</td>
</tr>
<tr>
<td>SYSTEMROOT</td>
</tr>
<tr>
<td>TEMP</td>
</tr>
<tr>
<td>TMP</td>
</tr>
<tr>
<td>WINDIR</td>
</tr>
</tbody>
</table>

3.6 POSIX accounts, permission, and security

This section discusses how the Windows security model is utilized in Cygwin to implement POSIX account information, POSIX-like permissions, and how the Windows authentication model is used to allow cygwin applications to switch users in a POSIX-like fashion.

The setting of POSIX-like file and directory permissions is controlled by the mount option (no)acl which is set to acl by default.

We start with a short overview. Note that this overview must be necessarily short. If you want to learn more about the Windows security model, see the Access Control article in MSDN documentation.

POSIX concepts and in particular the POSIX security model are not discussed here, but assumed to be understood by the reader. If you don’t know the POSIX security model, search the web for beginner documentation.

3.6.1 Brief overview of Windows security

In the Windows security model, almost any "object" is securable. "Objects" are files, processes, threads, semaphores, etc.

Every object has a data structure attached, called a "security descriptor" (SD). The SD contains all information necessary to control who can access an object, and to determine what they are allowed to do to or with it. The SD of an object consists of five parts:
• Flags which control several aspects of this SD. This is not discussed here.
• The SID of the object owner.
• The SID of the object owner group.
• A list of "Access Control Entries" (ACE), called the "Discretionary Access Control List" (DACL).
• Another list of ACEs, called the "Security Access Control List" (SACL), which doesn’t matter for our purpose. We ignore it here.

Every ACE contains a so-called "Security IDentifier" (SID) and other stuff which is explained a bit later. Let’s talk about the SID first.

A SID is a unique identifier for users, groups, computers and Active Directory (AD) domains. SIDs are basically comparable to POSIX user ids (UIDs) and group ids (GIDs), but are more complicated because they are unique across multiple machines or domains. A SID is a structure of multiple numerical values. There’s a convenient convention to type SIDs, as a string of numerical fields separated by hyphen characters. Here’s an example:

**SID of a machine "foo":**

S-1-5-21-165875785-1005667432-441284377

**SID of a user "johndoe" of the system "foo":**

S-1-5-21-165875785-1005667432-441284377-1023

The first field is always "S", which is just a notational convention to show that this is a SID. The second field is the version number of the SID structure. So far there exists only one version of SIDs, so this field is always 1. The third and fourth fields represent the "authority" which can be thought of as a type or category of SIDs. There are a couple of built-in accounts and accounts with very special meaning which have certain well known values in these third and fourth fields. However, computer and domain SIDs always start with "S-1-5-21". The next three fields, all 32 bit values, represent the unique 96 bit identifier of the computer system. This is a hopefully unique value all over the world, but in practice it’s sufficient if the computer SIDs are unique within a single Windows network.

As you can see in the above example, SIDs of users (and groups) are identical to the computer SID, except for an additional part, the so-called "relative identifier" (RID). So the SID of a user is always uniquely attached to the system on which the account has been generated.

It’s a bit different in domains. The domain has its own SID, and that SID is identical to the SID of the first domain controller, on which the domain is created. Domain user SIDs look exactly like the computer user SIDs, the leading part is just the domain SID and the RID is created when the user is created.

Ok, consider you created a new domain "bar" on some new domain controller and you would like to create a domain account "johndoe":

**SID of a domain "bar.local":**

S-1-5-21-186985262-1144665072-740312968

**SID of a user "johndoe" in the domain "bar.local":**

S-1-5-21-186985262-1144665072-740312968-1207

So you now have two accounts called johndoe, one account created on the machine "foo", one created in the domain "bar.local". Both have different SIDs and not even the RID is the same. How do the systems know it’s the same account? After all, the name is the same, right? The answer is, these accounts are not identical. All machines on the network will treat these SIDs as identifying two separate accounts. One is "FOO\johndoe", the other one is "BAR\johndoe" or "johndoe@bar.local". Different SID, different account. Full stop.

Starting with Cygwin 1.7.34, Cygwin uses an automatic, internal translation from Windows SID to POSIX UID/GID. This mechanism, which is the preferred method for the SID<=>UID/GID mapping, is described in detail in Section 3.6.2.

Prior to Cygwin 1.7.34, the last part of the SID, the so called "Relative IDentifier" (RID), was by default used as UID and/or GID when you created the /etc/passwd and /etc/group files using the mkpasswd and mkgroup tools. These tools as well
as reading accounts from `/etc/passwd` and `/etc/group` files is still present in recent versions of Cygwin, but you should switch to the aforementioned automatic translation, unless you have very specific needs. Again, see Section 3.6.2 for the details.

Do you still remember the SIDs with special meaning? In official notation they are called "well-known SIDs". For example, POSIX has no GID for the group of "all users" or "world" or "others". The last three rwx bits in a unix-style permission value just represent the permissions for "everyone who is not the owner or is member of the owning group". Windows has a SID for these poor souls, the "Everyone" SID. Other well-known SIDs represent circumstances under which a process is running, rather than actual users or groups. Here are a few examples for well-known SIDs:

<table>
<thead>
<tr>
<th>SID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-1-0</td>
<td>Simply everyone...</td>
</tr>
<tr>
<td>S-1-5-3</td>
<td>Processes started via the task scheduler are members of this group.</td>
</tr>
<tr>
<td>S-1-5-4</td>
<td>Only processes of users which are logged in via an interactive session are members here.</td>
</tr>
<tr>
<td>S-1-5-11</td>
<td>Users which have gone through the authentication process and survived. Anonymously accessing users are not included here.</td>
</tr>
<tr>
<td>S-1-5-18</td>
<td>A special account which has all kinds of dangerous rights, sort of an uber-root account.</td>
</tr>
</tbody>
</table>

For a full list please refer to the MSDN document Well-known SIDs. The Cygwin package called "csih" provides a tool, `/usr/lib/csih/getAccountName.exe`, which can be used to print the (possibly localized) name for the various well-known SIDs.

Naturally, well-known SIDs are the same on each machine, so they are not unique to a machine or domain. They have the same meaning across the Windows network.

Additionally, there are a couple of well-known builtin groups, which have the same SID on every machine and which have certain user rights by default:

<table>
<thead>
<tr>
<th>Group</th>
<th>SID</th>
</tr>
</thead>
<tbody>
<tr>
<td>administrators</td>
<td>S-1-5-32-544</td>
</tr>
<tr>
<td>users</td>
<td>S-1-5-32-545</td>
</tr>
<tr>
<td>guests</td>
<td>S-1-5-32-546</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

For instance, every account is usually member in the "Users" group. All administrator accounts are member of the "Administrators" group. That’s all about it as far as single machines are involved. In a domain environment it’s a bit more tricky. Since these SIDs are not unique to a machine, every domain user and every domain group can be a member of these well known groups. Consider the domain group "Domain Admins". This group is by default in the "Administrators" group. Let’s assume the above computer called "foo" is a member machine of the domain "bar.local". If you stick the user "BAR\johndoe" into the group "Domain Admins", this guy will automatically be a member of the administrators group on "foo" when logging on to "foo". Neat, isn’t it?

Back to ACE and ACL. POSIX is able to create three different permissions, the permissions for the owner, for the group and for the world. In contrast the Windows ACL has a potentially infinite number of members... as long as they fit into 64K. Every member is an ACE. ACE consist of three parts:

- The type of the ACE (allow ACE or deny ACE).
- Permission bits, 32 of them.
- The SID for which the permissions are allowed or denied.

The two (for us) important types of ACEs are the "access allowed ACE" and the "access denied ACE". As the names imply, the allow ACE tells the system to allow the given permissions to the SID, the deny ACE results in denying the specific permission bits.

The possible permissions on objects are more detailed than in POSIX. For example, the permission to delete an object is different from the permission to change object data, and even changing object data can be separated into different permission bits for different kind of data. But there’s a problem with the definition of a "correct" ACL which disallows mapping of certain POSIX permissions cleanly. See Section 3.6.3.
POSIX is able to create only three different permissions? Not quite. Newer operating systems and file systems on POSIX systems also provide access control lists. Two different APIs exist for accessing these ACLs, the Solaris API and the POSIX API. Cygwin implements the original Solaris API to access Windows ACLs in a Unixy way. Online man pages for the Solaris ACL API can be found on http://docs.oracle.com. For an overview see acl(5).

3.6.2 Mapping Windows accounts to POSIX accounts

For as long as Cygwin has existed, it has stored user and group information in /etc/passwd and /etc/group files. Under the assumption that these files would never be too large, the first process in a process tree, as well as every execing process within the tree would parse them into structures in memory. Thus every Cygwin process would contain an expanded copy of the full information from /etc/passwd and /etc/group.

This approach has a few downsides. One of them is that the idea that these files will always be small, is flawed. Another one is that reading the entire file is most of the time entirely useless, since most processes only need information on their own user and the primary group. Last but not least, the passwd and group files have to be maintained separately from the already existing Windows user databases, the local SAM and Active Directory.

On the other hand, we have to have this mapping between Windows SIDs and POSIX uid/gid values, so we need a mechanism to convert SIDs to uid/gid values and vice versa.

Microsoft "Services for UNIX" (SFU) (deprecated since Windows 8/Server 2012) never used passwd/group files. Rather, SFU used a fixed, computational mapping between SIDs and POSIX uid/gid which even has Active Directory support. It allows us to generate uid/gid values from SIDs and vice versa. The mechanism is documented, albeit in a confusing way and spread over multiple MSDN articles.

Starting with Cygwin 1.7.34, Cygwin utilizes an approach inspired by the mapping method as implemented by SFU, with a few differences for backward compatibility and to handle some border cases differently.

3.6.2.1 Mapping Windows SIDs to POSIX uid/gid values

The following description assumes you’re comfortable with the concept of Windows SIDs and RIDs. For a brief introduction, see Section 3.6.1.

Cygwin’s mapping between SIDs and uid/gid values works in two ways.

- Read /etc/passwd and /etc/group files if they exist, just as in the olden days, mainly for backward compatibility.
- If no files are present, or if an entry is missing in the files, ask Windows.

At least, that’s the default behaviour now. It will be configurable using a file /etc/nsswitch.conf, which is discussed in Section 3.6.2.4. Let’s explore the default for now.

If the passwd or group files are present, they will be scanned on demand as soon as a mapping from SIDs to uid/gid or account names is required. The new mechanism will never read the entire file into memory, but only scan for the requested entry and cache this one in memory.

If no entry is found, or no passwd or group file was present, Cygwin will ask the OS.

Note

If the first process in a Cygwin process tree determines that no /etc/passwd or /etc/group file is present, no other process in the entire process tree will try to read the files later on. This is done for self-preservation. It’s rather bad if the uid or gid of a user changes during the lifetime of a process tree.

For the same reason, if you delete the /etc/passwd or /etc/group file, this will be ignored. The passwd and group records read from the files will persist in memory until either a new /etc/passwd or /etc/group is created, or you exit all processes in the current process tree.

See the note in Section 3.6.2.4 for some comprehensive examples.
So if we’ve drawn a blank reading the files, we’re going to ask the OS. First thing, we ask the local machine for the SID or the username. The OS functions `LookupAccountSid` and `LookupAccountName` are pretty intelligent. They have all the stuff built in to ask for any account of the local machine, the Active Directory domain of the machine, the Global Catalog of the forest of the domain, as well as any trusted domain of our forest for the information. One OS call and we’re practically done...

Except, the calls only return the mapping between SID, account name and the account’s domain. We don’t have a mapping to POSIX uid/gid and we’re missing information on the user’s home dir and login shell.

Let’s discuss the SID<=>uid/gid mapping first. Here’s how it works.

- **Well-known SIDs** in the NT_AUTHORITY domain of the S-1-5-RID type, or aliases of the S-1-5-32-RID type are mapped to the uid/gid value RID. Examples:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;SYSTEM&quot; S-1-5-18</td>
<td>=&gt; uid/gid: 18</td>
</tr>
<tr>
<td>&quot;Users&quot; S-1-5-32-545</td>
<td>=&gt; uid/gid: 545</td>
</tr>
</tbody>
</table>

- **Other well-known SIDs** in the NT_AUTHORITY domain (S-1-5-X-RID):

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-5-X-RID</td>
<td>=&gt; uid/gid: 0x1000 * X + RID</td>
</tr>
</tbody>
</table>

  **Example:**

  "NTLM Authentication" S-1-5-64-10 => uid/gid: 0x4000A == 262154

- **Other well-known SIDs**:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-X-Y</td>
<td>=&gt; uid/gid: 0x10000 + 0x100 * X + Y</td>
</tr>
</tbody>
</table>

  **Example:**

  "LOCAL" S-1-2-0 => uid/gid: 0x10200 == 66048
  "Creator Group" S-1-3-1 => uid/gid: 0x10301 == 66305

- **Logon SIDs**: The LogonSid of the current user’s session is converted to the fixed uid 0xffff == 4095 and named "CurrentSession". Any other LogonSid is converted to the fixed uid 0xffe == 4094 and named "OtherSession".

- **Mandatory Labels**:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-16-RID</td>
<td>=&gt; uid/gid: 0x60000 + RID</td>
</tr>
</tbody>
</table>

  **Example:**

  "Medium Mandatory Level" S-1-16-8192 => uid/gid: 0x62000 == 401408

- **Accounts from the local machine’s user DB (SAM)**:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-5-21-X-Y-Z-RID</td>
<td>=&gt; uid/gid: 0x30000 + RID</td>
</tr>
</tbody>
</table>

  **Example:**

  "Administrator" S-1-5-21-X-Y-Z-500 => uid/gid: 0x301f4 == 197108

- **Accounts from the machine’s primary domain**:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-5-21-X-Y-Z-RID</td>
<td>=&gt; uid/gid: 0x100000 + RID</td>
</tr>
</tbody>
</table>

  **Example:**

  "Domain Users" S-1-5-21-X-Y-Z-513 => uid/gid: 0x100201 == 1049089

- **Accounts from a trusted domain of the machine’s primary domain**:

<table>
<thead>
<tr>
<th>SID Type</th>
<th>UID/GID</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1-5-21-X-Y-Z-RID</td>
<td>=&gt; uid/gid: trustPosixOffset(domain) + RID</td>
</tr>
</tbody>
</table>
trustPosixOffset? This needs a bit of explanation. This value exists in Windows domains already since before Active Directory days. What happens is this. If you create a domain trust between two domains, a trustedDomain entry will be added to both databases. It describes how this domain trusts the other domain. One attribute of a trust is a 32 bit value called trustPosixOffset. For each new trust, trustPosixOffset will get some automatic value. In recent AD domain implementations, the first trusted domain will get trustPosixOffset set to 0x80000000. Following domains will get lower values. Unfortunately the domain admins are allowed to set the trustPosixOffset value for each trusted domain to some arbitrary 32 bit value, no matter what the other trustPosixOffset are set to, thus allowing any kind of collisions between the trustPosixOffset values of domains. That’s not exactly helpful, but as the user of this value, we have to trust the domain admins to set trustPosixOffset to sensible values, or to keep it at the system chosen defaults.

So, for the first (or only) trusted domain of your domain, the automatic offset is 0x80000000. An example for a user of that trusted domain is

| S-1-5-21-X-Y-Z-1234 | <=> uid/gid 0x800004d2 == 2147484882 |

There’s one problem with this approach. Assuming you’re running in the context of a local SAM user on a domain member machine. Local users don’t have the right to fetch this kind of domain information from the DC, they’ll get permission denied. In this case Cygwin will fake a sensible trustPosixOffset value.

Another problem is if the AD administrators chose an unreasonably small trustPosixOffset value. Anything below the hexadecimal value 0x100000 (the POSIX offset of the primary domain) is bound to produce collisions with system accounts as well as local accounts. The right thing to do in this case is to notify your administrator of the problem and to ask for moving the offset to a more reasonable value. However, to reduce the probability for collisions, Cygwin overrides this offset with a sensible fixed replacement offset.

• Local accounts from another machine in the network:

There’s no SID<=>uid/gid mapping implemented for this case. The problem is, there’s no way to generate a bijective mapping. There’s no central place which keeps an analogue of the trustPosixOffset, and there’s the additional problem that the LookupAccountSid and LookupAccountName functions cannot resolve the SIDs, unless they know the name of the machine this SID comes from. And even then it will probably suffer a Permission denied error when trying to ask the machine for its local account.

Now we have a semi-bijective mapping between SIDs and POSIX uid/gid values, but given that we have potentially users and groups in different domains having the same name, how do we uniquely distinguish between them by name? Well, we can do that by making their names unique in a per-machine way. Dependent on the domain membership of the account, and dependent of the machine being a domain member or not, the user and group names will be generated using a domain prefix and a separator character between domain and account name. The separator character is the plus sign, +.

• Well-known and builtin accounts will be named as in Windows:

| "SYSTEM", "LOCAL", "Medium Mandatory Level", ... |

• If the machine is not a domain member machine, only local accounts can be resolved into names, so for ease of use, just the account names are used as Cygwin user/group names:

| "corinna", "bigfoot", "None", ... |

• If the machine is a domain member machine, all accounts from the primary domain of the machine are mapped to Cygwin names without domain prefix:

| "corinna", "bigfoot", "Domain Users", ... |

while accounts from other domains are prepended by their domain:

| "DOMAIN1+corinna", "DOMAIN2+bigfoot", "DOMAIN3+Domain Users", ... |

• Local machine accounts of a domain member machine get a Cygwin user name the same way as accounts from another domain: The local machine name gets prepended:

| "MYMACHINE+corinna", "MYMACHINE+bigfoot", "MYMACHINE+None", ... |
• If LookupAccountSid fails, Cygwin checks the accounts against the known trusted domains. If the account is from one of the trusted domains, an artificial account name is created. It consists of the domain name, and a special name created from the account RID:

"MY.DOM+User(1234)", "MY.DOM+Group(5678)"

Otherwise we know nothing about this SID, so it will be mapped to the fake accounts Unknown+User/Unknown+Group with uid/gid -1.

3.6.2.2 Caching account information

The information fetched from the Windows account database or the /etc/passwd and /etc/group files is cached by the process. The cached information is inherited by Cygwin child processes. A Cygwin process invoked from a Windows command, such as CMD.exe, will start a new Cygwin process tree and the caching starts from scratch (unless cygserver is running, but read on).

While usually working fine, this has some drawbacks. Consider a shell calling id. id fetches all group information from the current token and caches them. Unfortunately id doesn’t start any child processes, so the information is lost as soon as id exits.

But there’s another caching mechanism available. If cygserver is running it will provide passwd and group entry caching for all processes in every Cygwin process tree started after cygserver. So, if you start a Cygwin Terminal and cygserver is running at the time, mintty, the shell, and all child processes will use cygserver caching. If you start a Cygwin Terminal and cygserver is not running at the time, none of the processes started inside this terminal window will use cygserver caching.

The advantage of cygserver caching is that it’s system-wide and, as long as cygserver is running, unforgettable. Every Cygwin process on the system will have the cygserver cache at its service. Additionally, all information requested from cygserver once, will be cached inside the process itself and, again, propagated to child processes.

If you automatically start Cygwin processes as Windows services at system startup, you may wish to consider starting cygserver first in order to take advantage of this system-wide caching. To assure that cygserver has started prior to starting sshd or other Cygwin processes, you may wish to create service startup dependencies. Cygserver should probably wait for Windows TCPIP and AFD services before it starts, and then other Cygwin process should start after cygserver. Example Windows commands to accomplish this (after the services already exist) are shown below. You will need an administrative prompt to run the sc config commands.

```
# Delay Cygserver until TCPIP and AFD have started
# Note the (odd) required space character after "depend="
sc config cygserver depend= tcpip/afd

# Delay sshd until after Cygserver has started
# Again note the (odd) required space character after "depend="
sc config sshd depend= cygserver

# View the Cygserver service details
sc qc cygserver
```

Note that this sc config command replaces any existing dependencies. The above changes will not impact the running instance, only future instances.

```
# To remove all dependencies from the cygserver service
sc config cygserver depend= /
```

3.6.2.3 Cygwin user names, home dirs, login shells

Obviously, if you don’t maintain passwd and group files, you need to have a way to maintain the other fields of a passwd entry as well. A couple of things come to mind:
• You want to use a Cygwin username different from your Windows username.

  Note
  This is only supported via /etc/passwd. A Cygwin username maintained in the Windows user databases would require very costly (read: slow) search operations.

• You want to change the primary group of a user. For AD accounts this is not supported. The primary group of a user is always the Windows primary group set in Active Directory and can’t be changed. For SAM accounts, you can add the primary group to the SAM description field of the user. See Section 3.6.2.4.10 for more info.

• You want a home dir different from the default /home/$USERNAME.

• You want to specify a different login shell than /bin/bash.

• You want to add specific content to the pw_gecos field.

For simple needs you can create /etc/passwd and/or /etc/group files with entries for your account and tweak that. For bigger installations, maintaining per-client files is rather troublesome. Also, no two environments are the same, so the needs are pretty different. Therefore Cygwin supports configuring how to fetch home directory, login shell, and gecos information in /etc/nsswitch.conf. See the next section for detailed information how to configure Cygwin’s account handling.

3.6.2.4 The /etc/nsswitch.conf file

On Linux and some other UNIXy OSes, we have a file called /etc/nsswitch.conf. Among other things, it determines how passwd and group entries are generated. That’s what Cygwin now provides as well.

The /etc/nsswitch.conf file is optional. If you don’t have one, Cygwin uses sensible defaults.

  Note
  The /etc/nsswitch.conf file is read exactly once by the first process of a Cygwin process tree. If there was no /etc/nsswitch.conf file when this first process started, then no other process in the running Cygwin process tree will try to read the file.

If you create or change /etc/nsswitch.conf, you have to restart all Cygwin processes that need to see the change. If the process you want to see the change is a child of another process, you need to restart all of that process’s parents, too.

For example, if you run vim inside the default Cygwin Terminal, vim is a child of your shell, which is a child of mintty. If you edit /etc/nsswitch.conf in that vim instance, your shell won’t immediately see the change, nor will vim if you restart it from that same shell instance. This is because both are getting their nsswitch information from their ancestor, mintty. You have to start a fresh terminal window for the change to take effect.

By contrast, if you leave that Cygwin Terminal window open after making the change to /etc/nsswitch.conf, then restart a Cygwin service like cron, cron will see the change, because it is not a child of mintty or any other Cygwin process.

(Technically, it is a child of cygrunsrv, but that instance also restarts when you restart the service.)

The reason we point all this out is that the requirements for restarting things are not quite as stringent as when you replace cygwin1.dll. If you have three process trees, you have three independent copies of the nsswitch information. If you start a fresh process tree, it will see the changes. As long as any process in an existing process tree remains running, all processes in that tree will continue to use the old information.

So, what settings can we perform with /etc/nsswitch.conf? Let’s start with an example /etc/nsswitch.conf file set up to all default values:

```
# /etc/nsswitch.conf
passwd: files db
group: files db

db_enum: cache builtin
db_home: /home/%U
db_shell: /bin/bash
db_gecos: <empty>
```
3.6.2.4.1 The /etc/nsswitch.conf syntax

The first line, starting with a hash # is a comment. The hash character starts a comment, just as in shell scripts. Everything up to the end of the line is ignored. So this:

```
foo: bar # baz
```

means, set "foo" to value "bar", ignore everything after the hash.

The other lines define the available settings. The first word up to a colon is a keyword. Note that the colon must follow immediately after the keyword. This is a valid line:

```
foo: bar
```

This is not valid:

```
foo : bar
```

Apart from this restriction, the remainder of the line can have as many spaces and TABs as you like.

3.6.2.4.2 The passwd: and group: settings

The two lines starting with the keywords passwd: and group: define where Cygwin gets its passwd and group information from. files means, fetch the information from the corresponding file in the /etc directory. db means, fetch the information from the Windows account databases, the SAM for local accounts, Active Directory for domain account. Examples:

```
passwd: files
```

Read passwd entries only from /etc/passwd.

```
group: db
```

Read group entries only from SAM/AD.

```
group: files # db
```

Read group entries only from /etc/group (db is only a comment).

```
passwd: files db
```

Read passwd entries from /etc/passwd. If a user account isn’t found, try to find it in SAM or AD. This is the default for both, passwd and group information.

```
group: db files
```

This is a valid entry, but the order will be ignored by Cygwin. If both settings, files and db are specified, Cygwin will always try the files first, then the db.

passwd: and group: are the two basic settings defining where to get the account information from. The following settings starting with db_, define certain aspects of the Windows account database search and how to generate passwd and group information from the database.

3.6.2.4.3 The db_enum: setting

db_enum: defines the depth of a database search, if an application calls one of the enumeration functions getpwent or getgrent. The problem with these functions is, they neither allow to define how many entries will be enumerated when calling them in a loop, nor do they allow to add some filter criteria. They were designed back in the days, when only /etc/passwd and /etc/group files existed and the number of user accounts on a typical UNIX system was seldomly a three-digit number.

These days, with user and group databases sometimes going in the six-digit range, they are a potential burden. For that reason, Cygwin does not enumerate all user or group accounts by default, but rather just a very small list, consisting only of the accounts cached in memory by the current process, as well as a handful of predefined builtin accounts.

```
db_enum: allows to specify the accounts to enumerate in a fine-grained manner. It takes a list of sources as argument:
```

```
The recognized sources are the following:

**none**  No output from `getpwent/getgrent` at all.

**all**  The opposite. Enumerates accounts from all known sources, including all trusted domains.

**cache**  Enumerate all accounts currently cached in memory.

**builtin**  Enumerate the predefined built-in accounts for backward compatibility. These are five passwd accounts (SYSTEM, LocalService, NetworkService, Administrators, TrustedInstaller) and two group accounts (SYSTEM and TrustedInstaller).

**files**  Enumerate the accounts from `/etc/passwd` or `/etc/group`.

**local**  Enumerate all accounts from the local SAM.

**primary**  Enumerate all accounts from the primary domain.

**alltrusted**  Enumerate all accounts from all trusted domains.

**some.domain**  Enumerate all accounts from the trusted domain `some.domain`. The trusted domain can be given as Netbios flat name (MY_DOMAIN) or as dns domain name (my_domain.corp). In contrast to the aforementioned fixed source keywords, distinct domain names are case-insensitive. Only domains which are actually trusted domains are enumerated. Unknown domains are simply ignored.

Please note that `getpwent/getgrent` do not test if an account was already listed from another source, so an account can easily show up twice or three times. Such a test would be rather tricky, nor does the Linux implementation perform such test. Here are a few examples for `/etc/nsswitch.conf`:

```
db_enum: none
```

No output from `getpwent/getgrent` at all. The first call to the function immediately returns a NULL pointer.

```
db_enum: cache files
```

Enumerate all accounts cached by the current process, plus all entries from either the `/etc/passwd` or `/etc/group` file.

```
db_enum: cache local primary
```

Enumerate all accounts cached by the current process, all accounts from the SAM of the local machine, and all accounts from the primary domain of the machine.

```
db_enum: local primary alltrusted
```

Enumerate the accounts from the machine’s SAM, from the primary domain of the machine, and from all trusted domains.

```
db_enum: primary domain1.corp sub.domain.corp domain2.net
```

Enumerate the accounts from the primary domain and from the domains domain1.corp, sub.domain.corp and domain2.net.

```
db_enum: all
```

Enumerate everything and the kitchen sink.
3.6.2.4.4 Settings defining how to create the passwd entry

/etc/nsswitch.conf supports three settings to configure where to get the pw_dir, pw_shell, and pw_gecos content of a passwd entry from:

```
db_home: schema...  # Define how to fetch the pw_dir entry.
db_shell: schema... # Define how to fetch the pw_shell entry.
db_gecos: schema... # Define how to fetch the pw_gecos entry.
```

"schema..." is a list of up to four space-separated schemata:

```
db_FOO: schema1 schema2 ...
```

When generating a passwd entry, Cygwin tries the schemata in order. If the first schema returns an empty string, it skips to the second, and so on. Schemata only supported on AD are silently skipped for SAM accounts and on non-AD machines.

Four schemata are predefined, two schemata are variable. The predefined schemata are the following:

- **windows** Utilizes typical Windows settings. Supported for AD and SAM accounts.
- **cygwin** Utilizes the cygwinUser AD schema extension. This schema extension is available via a schema extension file `/usr/share/cygwin/cygwin.ldif`. See Section 3.6.2.4.8 for more information.
- **unix** Utilizes the posixAccount schema attributes per RFC 2307. The posixAccount schema is available by default in Windows Server, but typically only utilized when installing the Active Directory "Server for NIS" feature (which is deprecated since Server 2012 R2). See also Section 3.6.2.4.9.
- **desc** Utilizes XML-style attributes in the description attribute. Supported for AD and SAM accounts. See Section 3.6.2.4.10 for a more detailed description.

The variable schemata are as follows. Note that the leading characters (@ and /) are an integral part of the definition.

- **@ad_attribute** `ad_attribute` is any arbitrary AD attribute name which should (ideally) be available in the User class or in any attached auxiliary class. It’s always treated as a single string argument. Only the first string of a multi-string attributes will be read.

- **/path** An arbitrary string, typically a path. The leading slash is required. Given that a single, fixed path for all users only makes marginal sense, the /path schema supports wildcards. A wildcard is a per-cent (%) character, followed by another character giving the meaning. The supported wildcard characters are:

  - %u The Cygwin username (that’s lowercase u).
  - %U The Windows username (that’s uppercase U).
  - %D Windows domain in NetBIOS style.
  - %H Windows home directory in POSIX style. Note that, for the `db_home:` setting, this only makes sense right after the preceeding slash, as in

    ```
    db_home: /%H/cygwin
    ```

  - %__ Since space and TAB characters are used to separate the schemata, a space in the filename has to be given as %__ (that’s an underscore).
  - %%% A per-cent character.
  - Any other %X expression is treated as if the character X has been given alone.

The exact meaning of a schema depends on the setting it’s used for. The following sections explain the settings in detail.
3.6.2.4.5 The db_home: setting

The db_home: setting defines how Cygwin fetches the user’s home directory, or, more precise, the content of the pw_dir member of the user’s passwd entry. The following list describes the meaning of each schema when used with db_home:

windows The user’s home directory is set to the same directory which is used as Windows home directory. This is the home Directory AD attribute. For SAM accounts, this is equivalent to the "Home folder" setting in SAM. If both attributes are unset, Cygwin falls back to the user’s local profile directory, typically something along the lines of C:\Users\$USERNAME. Of course, the Windows directory is converted to POSIX-style by Cygwin.

cygwin AD only: The user’s home directory is set to the POSIX path given in the cygwinHome attribute from the cygwinUser auxiliary class. See also Section 3.6.2.4.8.

unix AD only: The user’s home directory is set to the POSIX path given in the unixHomeDirectory attribute from the posixAccount auxiliary class. See also Section 3.6.2.4.9.

desc The user’s home directory is set to the POSIX path given in the home="..." XML-alike setting in the user’s description attribute in SAM or AD. See Section 3.6.2.4.10 for a detailed description.

@ad_attribute AD only: The user’s home directory is set to the path given in the ad_attribute attribute. The path can be given as Windows or POSIX path.

/path The user’s home directory is set to the given POSIX path. Remember the wildcards described in Section 3.6.2.4.4.

Fallback If none of the schemes given for db_home: define a non-empty directory, the user’s home directory is set to /home/$USERNAME.

As has been briefly mentioned before, the default setting for db_home: is

db_home: /home/%U

So by default, Cygwin just sets the home dir to /home/$USERNAME.

3.6.2.4.6 The db_shell: setting

The db_shell: setting defines how Cygwin fetches the user’s login shell, the content of the pw_shell member of the user’s passwd entry. The following list describes the meaning of each schema when used with db_shell:

windows The windows schema is ignored for now. The logical choice would be CMD, but that introduces some problems, for instance the fact that CMD has no concept of running as login shell. This may change in future.

cygwin AD only: The user’s home directory is set to the POSIX path given in the cygwinShell attribute from the cygwinUser auxiliary class. See also Section 3.6.2.4.8.

unix AD only: The user’s login shell is set to the POSIX path given in the loginShell attribute from the posixAccount auxiliary class. See also Section 3.6.2.4.9.

desc The user’s login shell is set to the POSIX path given in the shell="..." XML-alike setting in the user’s description attribute in SAM or AD. See Section 3.6.2.4.10 for a detailed description.

@ad_attribute AD only: The user’s login shell is set to the path given in the ad_attribute attribute. The path can be given as Windows or POSIX path.

/path The user’s login shell is set to the given POSIX path. Albeit not being as important here, the wildcards described in Section 3.6.2.4.4 are also available for specifying a login shell path.

Fallback If none of the schemes given for db_shell: define a non-empty pathname, the user’s login shell is set to /bin/bash.

As for db_home:, the default setting for db_shell: is pretty much a constant

db_shell: /bin/bash
### 3.6.2.4.7 The `db_gecos:` setting

The `db_gecos:` setting defines how to fetch additional content for the `pw_gecos` member of the user’s `passwd` entry. There’s always a fixed, Cygwin-specific part in the `pw_gecos` field for identifying the account. However, an administrator might want to add informative content like, for instance, the user’s full name. That’s what the `db_gecos:` setting is for. The following list describes the meaning of each schema when used with `db_gecos`:

- **windows** Add the AD `displayName` attribute or, for SAM accounts, the “Full name” entry to the `pw_gecos` field.
- **cygwin** AD only: The content of the `cygwinGecos` attribute from the `cygwinUser` auxiliary class is added to `pw_gecos`. See also Section 3.6.2.4.8.
- **unix** AD only: The content of the `gecos` attribute from the `posixAccount` auxiliary class is added to `pw_gecos`. See also Section 3.6.2.4.9.
- **desc** The content of the `gecos="..."` XML-alike setting in the user’s `description` attribute in SAM or AD is added to `pw_gecos`. See Section 3.6.2.4.10 for a detailed description.
- **@ad_attribute** AD only: The content of the `ad_attribute` attribute is added to `pw_gecos`.
- **/path** The string following the slash is added to `pw_gecos`. Here, the wildcards described in Section 3.6.2.4.4 may come in handy.

**Fallback** If none of the schemes given for `db_gecos:` define a non-empty pathname, nothing is added to `pw_gecos`.

The default setting for `db_gecos:` is the empty string.

### 3.6.2.4.8 The `cygwin` schema

The `cygwin` schema is based on a Cygwin-specific Active Directory schema extension. Using this schema extension allows to maintain Cygwin-specific settings entirely within AD, without colliding with any other schema.

The `cygwin` schema extension is available in a default Cygwin installation in the file `/usr/share/cygwin/cygwin.ldif`. To install the schema extension, you have to be schema admin, and you have to run the `ldifde` command on the schema master.

The installation itself is rather simple. Assuming you’re schema admin and running a shell with administrative privileges:

```
$ cd /usr/share/cygwin
$ ldifde -i -f cygwin.ldif -k -c "CN=schema,CN=Configuration,DC=X" #schemaNamingContext
```

Afterwards, the auxiliary class `cygwinUser` is attached to the class `User`, and the auxiliary class `cygwinGroup` is attached to the class `Group`. The new attributes can be immediately edited using ADSI Edit.

At the time of writing the following attributes are utilized by Cygwin:

- `:cygwinHome`, Used as Cygwin home directory with `db_home:cygwin`. See Section 3.6.2.4.5.
- `:cygwinShell`, Used as Cygwin login shell with `db_shell:cygwin`. See Section 3.6.2.4.6.
- `:cygwinGecos`, Content will be added to the `pw_gecos` field with `db_gecos:cygwin`. See Section 3.6.2.4.7.

### 3.6.2.4.9 The `unix` schema

The `unix` schema utilizes the `posixAccount` attribute extension. This is one of two schema extensions which are connected to AD accounts, available by default. They are usually **not set**, unless used by the Active Directory Server for NIS feature (deprecated since Server 2012 R2). Two schemata are interesting for Cygwin, `posixAccount`, connected to user accounts, and `posixGroup`, connected to group accounts. Both follow the description of RFC 2307, an Approach for Using LDAP as a Network Information Service. The user attributes utilized by Cygwin are:

- `:unixHomeDirectory`, Used as Cygwin home directory with `db_home:unix`. See Section 3.6.2.4.5.
- `:loginShell`, Used as Cygwin login shell with `db_shell:unix`. See Section 3.6.2.4.6.
- `::gecos`, Content will be added to the `pw_gecos` field with `db_gecos:unix`. See Section 3.6.2.4.7.
- `:uidNumber`, See Section 3.6.2.5 and Section 3.6.2.6.
The group attributes utilized by Cygwin are:

:\*gidNumber. : See Section 3.6.2.5 and Section 3.6.2.6.

Apart from power shell scripting or inventing new CLI tools, these attributes can be changed using the Attribute Editor tab in the user properties dialog of the Active Directory Users and Computers MMC snap-in. Alternatively, if the Server for NIS administration feature has been installed, there will be a UNIX Attributes tab which contains the required fields, except for the gecos field. Last resort is ADSI Edit.

### 3.6.2.4.10 The desc schema

When using user accounts from the local account database, the SAM, there are only a very limited number of settings available. In contrast to Active Directory there’s no way to add fields to a user’s entry. You have to make do with the fields available. The method to utilize the description field has been mainly introduced for those accounts, usually the only ones a home user has. However, for symmetry, and because there may be a reason to use this in an AD environment, this schema is also supported for AD users.

---

**Note**

The presentation of local user account settings on Windows is confusing, to say the least. The description field is not visible at all in the user settings available via the User Accounts control settings. And while it’s called Description in the Local Users and Groups MMC snap-in (available, for instance, via the Computer Management GUI), in the command line tool net user the same field is called comment. The latter is especially confusing for AD admins, because the comment attribute in AD is called usercomment on the command line. Confused? Never mind, you’re not the only one...

---

Fortunately you can utilize the description field even if you’re running a "home edition” of Windows, by using the command line. The net user command allows to set all values in the SAM, even if the GUI is crippled.

A Cygwin SAM comment entry looks like this:

```
<cygwin key="value" key="value" [...] />
```

The supported keys are:

:\*home="value". : Sets the Cygwin home dir to value.
:\*shell="value". : Sets the Cygwin login shell to value.
:\*gecos="value". : Adds the string value to the user’s gecos field.

The next two settings are only supported for SAM accounts.

:\*group="value". : Sets the Cygwin primary group of the account to value, provided that the user is already a member of that group. This allows to override the default None primary group for local accounts. One nice idea here is, for instance, group="Users".
:\*unix="value". : Sets the NFS/Samba uid of the user to the decimal value. See Section 3.6.2.5 and Section 3.6.2.6.

The `<cygwin .../>` string can start at any point in the comment, but you have to follow the rules:

- It starts with "<cygwin " and ends with "/>".
- The "cygwin" string and the key names have to be lowercase.
- No spaces between key and "value", just the equal sign.
- The value must be placed within double quotes and it must not contain a double quote itself. The double quotes are required for the decimal values as well!

---

**Note**

There’s also a length restriction imposed by Windows. The description entry has a maximum length of 1023 characters.

---

CMD example:
net user corinna /comment:"<cygwin home="/"/home/foo"/">"

Bash example (use single quotes):

net user corinna /comment:'<cygwin home="/"/home/foo"/>'

For changing group comments, use the `net localgroup` command. The supported key/value pair for SAM groups are:

: unix="value":. Sets the NFS/Samba gid of the group to the decimal value. See Section 3.6.2.5 and Section 3.6.2.6.

3.6.2.5  NFS account mapping

Microsoft’s NFS client does not map the uid/gid values on the NFS shares to SIDs. There’s no such thing as a (fake) security descriptor returned to the application. Rather, via an undocumented API an application can fetch RFC 1813 compatible NFSv3 stat information from the share. This is what Cygwin is using to show stat information for files on NFS shares.

The problem is, while all other information in this stat record, like timestamps, file size etc., can be used by Cygwin, Cygwin had no way to map the values of the st_uid and st_gid members to a Windows SID for a long time. So it just faked the file owner info and claimed that it’s you.

However, SFU has, over time, developed multiple methods to map UNIX uid/gid values on NFS shares to Windows SIDs. You’ll find the full documentation of the mapping methods in NFS Identity Mapping in Windows Server 2012.

Cygwin now utilizes the RFC 2307 mapping for this purpose. This is most of the time provided by an AD domain, but it could also be a standalone LDAP mapping server. Per RFC 2307, the uid is in the attribute uidNumber. For groups, the gid is in the gidNumber attribute. See Section 3.6.2.4.9.

When Cygwin stat()s files on an NFS share, it asks the mapping server via LDAP in two different ways, depending on the role of the mapping server.

• If the server is an AD domain controller, it asks for an account with uidNumber attribute == st_uid field of the stat record returned by NFS. If an account matches, AD returns the Windows SID, so we have an immediate mapping from UNIX uid to a Windows SID, if the user account has a valid uidNumber attribute. For groups, the method is the same, just that Cygwin asks for a group with gidNumber attribute == st_gid field of the stat record.

• If the server is a standalone LDAP mapping server Cygwin asks for the same uidNumber/gidNumber attributes, but it can’t expect that the LDAP server knows anything about Windows SIDs. Rather, the mapping server returns the account name. Cygwin then asks the DC for an account with this name, and if that succeeds, we have a mapping between UNIX uid/gid and Windows SIDs.

The mapping will be cached for the lifetime of the process, and inherited by child processes.

3.6.2.6  Samba account mapping

A fully set up Samba file server with domain integration is running winbindd to map Windows SIDs to artificially created UNIX uids and gids, and this mapping is transparent within the domain, so Cygwin doesn’t have to do anything special.

However, setting up winbindd isn’t for everybody, and it fails to map Windows accounts to already existing UNIX users or groups. In contrast to NFS, Samba returns security descriptors, but unmapped UNIX accounts get special SIDs:

• A UNIX user account with uid X is mapped to the Windows SID S-1-22-1-X.
• A UNIX group account with gid X is mapped to SID S-1-22-2-X.

As you can see, even though we have SIDs, they just reflect the actual uid/gid values on the UNIX box in the RID value. It’s only marginally different from the NFS method, so why not just use the same method as for NFS?

That’s what Cygwin will do. If it encounters a S-1-22-x-y SID, it will perform the same RFC 2307 mapping as for NFS shares.
For home users without any Windows domain or LDAP server per RFC 2307, but with a Linux machine running Samba, just add this information to your SAM account. Assuming the uid of your Linux user account is 505 and the gid of your primary group is, say, 100, just add the values to your SAM user and group accounts. The following example assumes you didn’t already add something else to the comment field.

To your user’s SAM comment (remember: called Description in the GUI), add:

```xml
<cygwin group="Users" unix="505"/>
```

To the Users group SAM comment add:

```xml
<cygwin unix="100"/>
```

This should be sufficient to work on your Samba share and to see all files owned by your Linux user account as your files.

### 3.6.3 File permissions

On NTFS and if the noacl mount option is not specified for a mount point, Cygwin sets file permissions as on POSIX systems. Basically this is done by defining a Security Descriptor with the matching owner and group SIDs, and a DACL which contains ACEs for the owner, the group and for "Everyone", which represents what POSIX calls "others".

There’s just one problem when trying to map the POSIX permission model onto the Windows permission model.

There’s a leak in the definition of a "correct" ACL which disallows a certain POSIX permission setting. The official documentation explains in short the following:

- The requested permissions are checked against all ACEs of the user as well as all groups the user is member of. The permissions given in these user and groups access allowed ACEs are accumulated and the resulting set is the set of permissions of that user given for that object.
- The order of ACEs is important. The system reads them in sequence until either any single requested permission is denied or all requested permissions are granted. Reading stops when this condition is met. Later ACEs are not taken into account.
- All access denied ACEs should precede any access allowed ACE. ACLs following this rule are called "canonical".

Note that the last rule is a preference or a definition of correctness. It’s not an absolute requirement. All Windows kernels will correctly deal with the ACL regardless of the order of allow and deny ACEs. The second rule is not modified to get the ACEs in the preferred order.

Unfortunately the security tab in the file properties dialog of the Windows Explorer insists to rearrange the order of the ACEs to canonical order before you can read them. Thank God, the sort order remains unchanged if one presses the Cancel button. But don’t even think of pressing OK...

Canonical ACLs are unable to reflect each possible combination of POSIX permissions. Example:

```
-rw-r-xrw-
```

Ok, so here’s the first try to create a matching ACL, assuming the Windows permissions only have three bits, as their POSIX counterpart:

- UserAllow: 110
- GroupAllow: 101
- OthersAllow: 110

Hmm, because of the accumulation of allow rights the user may execute because the group may execute.

Second try:

- UserDeny: 001
- GroupAllow: 101
- OthersAllow: 110
Now the user may read and write but not execute. Better? No! Unfortunately the group may write now because others may write.

Third try:

<table>
<thead>
<tr>
<th>Access Type</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>UserDeny</td>
<td>001</td>
</tr>
<tr>
<td>GroupDeny</td>
<td>010</td>
</tr>
<tr>
<td>GroupAllow</td>
<td>001</td>
</tr>
<tr>
<td>OthersAllow</td>
<td>110</td>
</tr>
</tbody>
</table>

Now the group may not write as intended but unfortunately the user may not write anymore, either. How should this problem be solved? According to the canonical order a UserAllow has to follow the GroupDeny but it’s easy to see that this can never be solved that way.

The only chance:

<table>
<thead>
<tr>
<th>Access Type</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>UserDeny</td>
<td>001</td>
</tr>
<tr>
<td>UserAllow</td>
<td>010</td>
</tr>
<tr>
<td>GroupDeny</td>
<td>010</td>
</tr>
<tr>
<td>GroupAllow</td>
<td>001</td>
</tr>
<tr>
<td>OthersAllow</td>
<td>110</td>
</tr>
</tbody>
</table>

Again: This works on all supported versions of Windows. Only the GUIs aren’t able (or willing) to deal with that order.

### 3.6.4 Switching the user context

Windows users have been accustomed to the "Switch User" feature, which switches the entire desktop to another user while leaving the original user’s desktop "suspended". Another Windows feature is the "Run as..." context menu entry, which allows you to start an application using another user account when right-clicking on applications and shortcuts.

On POSIX systems, this operation can be performed by processes running under the privileged user accounts (usually the "root" user account) on a per-process basis. This is called "switching the user context" for that process, and is performed using the POSIX `setuid` and `seteuid` system calls.

While this sort of feature is available on Windows as well, Windows does not support the concept of these calls in a simple fashion. Switching the user context in Windows is generally a tricky process with lots of "behind the scenes" magic involved.

Windows uses so-called `access tokens` to identify a user and its permissions. Usually the access token is created at logon time and then it’s attached to the starting process. Every new process within a session inherits the access token from its parent process. Every thread can get its own access token, which allows, for instance, to define threads with restricted permissions.

#### 3.6.4.1 Switching the user context with password authentication

To switch the user context, the process has to request such an access token for the new user. This is typically done by calling the Win32 API function `LogonUser` with the user name and the user’s cleartext password as arguments. If the user exists and the password was specified correctly, the access token is returned and either used in `ImpersonateLoggedOnUser` to change the user context of the current thread, or in `CreateProcessAsUser` to change the user context of a spawned child process.

Later versions of Windows define new functions in this context and there are also functions to manipulate existing access tokens (usually only to restrict them). Windows Vista also adds subtokens which are attached to other access tokens which plays an important role in the UAC (User Access Control) facility of Vista and later. However, none of these extensions to the original concept are important for this documentation.

Back to this logon with password, how can this be used to implement set(e)uid? Well, it requires modification of the calling application. Two Cygwin functions have been introduced to support porting `setuid` applications which only require login with passwords. You only give Cygwin the right access token and then you can call `seteuid` or `setuid` as usual in POSIX applications.

Porting such a `setuid` application is illustrated by a short example:

```c
/* First include all needed cygwin stuff. */
#ifdef __CYGWIN__
#include <windows.h>
#endif
```
3.6.4.2 Switching the user context without password, Method 1: Kerberos/MsV1_0 S4U authentication

An unfortunate aspect of the implementation of \texttt{set(e)uid} is the fact that the calling process requires the password of the user to switch to. Applications such as \texttt{sshd} wishing to switch the user context after a successful public key authentication, or the \texttt{cron} application which, again, wants to switch the user without any authentication are stuck here. But there are other ways to get new user tokens.

Starting with Cygwin 3.0, Cygwin tries to create a token by using Windows S4U authentication by default. For a quick description, see this blog posting. Cygwin versions prior to 3.0 tried to create a user token from scratch using an officially undocumented function \texttt{NtCreateToken} which is now disabled.

So we just start the servers which have to switch the user context (\texttt{sshd, inetd, cron, ...}) as Windows services under the \texttt{SYSTEM} (or \texttt{LocalSystem} in the GUI) account and everything just works. Unfortunately that’s too simple. Using S4U has a drawback.

Annoyingly, you don’t have the usual comfortable access to network shares. The reason is that the token has been created without knowing the password. The password are your credentials necessary for network access. Thus, if you logon with a password, the password is stored hidden as "token credentials" within the access token and used as default logon to access network resources. Since these credentials are missing from the token created with S4U or \texttt{NtCreateToken}, you only can access network shares from the new user’s process tree by using explicit authentication, on the command line for instance:
bash$ net use '\server\share' /user:DOMAIN\my_user my_user_password

Note that, on some systems, you can’t even define a drive letter to access the share, and under some circumstances the drive letter you choose collides with a drive letter already used in another session. Therefore it’s better to get used to accessing these shares using the UNC path as in

bash$ grep foo //server/share/foofile

3.6.4.3 Switching the user context without password, Method 2: With password

Not being able to access network shares without having to specify a cleartext password on the command line or in a script is a harsh problem for automated logons for testing purposes and similar stuff.

Fortunately there is a solution, but it has its own drawbacks. But, first things first, how does it work? The title of this section says it all. Instead of trying to logon without password, we just logon with password. The password gets stored two-way encrypted in a hidden, obfuscated area of the registry, the LSA private registry area. This part of the registry contains, for instance, the passwords of the Windows services which run under some non-default user account.

So what we do is to utilize this registry area for the purpose of set(e)uid. The Cygwin command passwd -R allows a user to specify his/her password for storage in this registry area. When this user tries to login using ssh with public key authentication, Cygwin’s set(e)uid examines the LSA private registry area and searches for a Cygwin specific key which contains the password. If it finds it, it calls LogonUser under the hood, using this password. If that works, LogonUser returns an access token with all credentials necessary for network access.

For good measure, and since this way to implement set(e)uid is not only used by Cygwin but also by Microsoft’s SFU (Services for Unix), we also look for a key stored by SFU (using the SFU command regpwd) and use that if it’s available.

We got it. A full access token with its own logon session, with all network credentials. Hmm, that’s heaven...

Back on earth, what about the drawbacks?

First, adding a password to the LSA private registry area requires administrative access. So calling passwd -R as a normal user will fail! Cygwin provides a workaround for this. If cygserver is started as a service running under the SYSTEM account (which is the default way to run cygserver) you can use passwd -R as normal, non-privileged user as well.

Second, as aforementioned, the password is two-way encrypted in a hidden, obfuscated registry area. Only SYSTEM has access to this area for listing purposes, so, even as an administrator, you can’t examine this area with regedit. Right? No. Every administrator can start regedit as SYSTEM user, the Internet is your friend here.

Additionally, if an administrator knows under which name the private key is stored (which is well-known since the algorithms used to create the Cygwin and SFU keys are no secret), every administrator can access the password of all keys stored this way in the registry.

Conclusion: If your system is used exclusively by you, and if you’re also the only administrator of your system, and if your system is adequately locked down to prevent malicious access, you can safely use this method. If your machine is part of a network which has dedicated administrators, and you’re not one of these administrators, but you (think you) can trust your administrators, you can probably safely use this method.

In all other cases, don’t use this method. You have been warned.

3.6.4.4 Switching the user context, how does it all fit together?

Now we learned about three different ways to switch the user context using the set(e)uid system call, but how does set(e)uid really work? Which method does it use now?

The answer is, all three of them. So here’s a brief overview what set(e)uid does under the hood:

- When set(e)uid is called, it tests if the user context had been switched by an earlier call already, and if the new user account is the privileged user account under which the process had been started originally. If so, it just switches to the original access token of the process it had been started with.
• Next, it tests if an access token has been stored by an earlier call to `cygwin_set_impersonation_token`. If so, it tests if that token matches the requested user account. If so, the stored token is used for the user context switch. If not, there’s no predefined token which can just be used for the user context switch, so we have to create a new token. The order is as follows.

• Check if the user has stored the logon password in the LSA private registry area, either under a Cygwin key, or under a SFU key. If so, use this to call `LogonUser`. If this succeeds, we use the resulting token for the user context switch.

• Otherwise, use the default S4U authentication to create a token.

• Older systems, like WOW64 under Windows 7 64 bit, don’t support S4U authentication for local machine accounts. On these systems Cygwin falls back to an old and otherwise deprecated method to create a user token from scratch. The underlying system call is undocumented and has an unfortunate requirement: We have to create a special account with dangerous permissions to perform this action. Therefore this is only enabled on affected systems.

• If all of the above fails, our process has insufficient privileges to switch the user context at all, so `set(e)uid` fails and returns -1, setting errno to EPERM.

### 3.7 Cygserver

#### 3.7.1 What is Cygserver?

Cygserver is a program which is designed to run as a background service. It provides Cygwin applications with services which require security arbitration or which need to persist while no other cygwin application is running.

The implemented services so far are:

• XSI IPC Message Queues.
• XSI IPC Semaphores.
• XSI IPC Shared Memory.

• Allows non-privileged users to store obfuscated passwords in the registry to be used by `setuid` and `seteuid` calls to create user tokens with network credentials. This service is used by `passwd -R`. Using the stored passwords in `set(e)uid` does not require running Cygserver. For details, see Section 3.6.4.

#### 3.7.2 Cygserver command line options

Options to Cygserver take the normal UNIX-style `-X` or `--longoption` form. Nearly all options have a counterpart in the configuration file (see below) so setting them on the command line isn’t really necessary. Command line options override settings from the Cygserver configuration file.

The one-character options are prepended by a single dash, the long variants are prepended with two dashes. Arguments to options are marked in angle brackets below. These are not part of the actual syntax but are used only to denote the arguments. Note that all arguments are required. Cygserver has no options with optional arguments.

The recognized options are:

• `-f, --config-file <file>`

  Use `<file>` as configuration file instead of the default configuration line. The default configuration file is `/etc/cygserver.conf`. The --help and --version options will print the default configuration pathname.

  This option has no counterpart in the configuration file, for obvious reasons.

• `-c, --cleanup-threads <num>`

  Number of threads started to perform cleanup tasks. Default is 2. Configuration file option: kern.srv.cleanup_threads
• `-r, --request-threads <num>`

Number of threads started to serve application requests. Default is 10. The `-c` and `-r` options can be used to play with Cygserver’s performance under heavy load conditions or on slow machines. Configuration file option: kern.srv.request_threads

• `-d, --debug`

Log debug messages to stderr. These will clutter your stderr output with a lot of information, typically only useful to developers.

• `-e, --stderr`

Force logging to stderr. This is the default if stderr is connected to a tty. Otherwise, the default is logging to the system log. By using the `-e`, `-E`, `-y`, `-Y` options (or the appropriate settings in the configuration file), you can explicitly set the logging output as you like, even to both, stderr and syslog. Configuration file option: kern.log.stderr

• `-E, --no-stderr`

Don’t log to stderr. Configuration file option: kern.log.stderr

• `-y, --syslog`

Force logging to the system log. This is the default, if stderr is not connected to a tty, e.g. redirected to a file. Configuration file option: kern.log.syslog

• `-Y, --no-syslog`

Don’t log to syslog. Configuration file option: kern.log.syslog

• `-l, --log-level <level>`

Set the verbosity level of the logging output. Valid values are between 1 and 7. The default level is 6, which is relatively chatty. If you set it to 1, you will get only messages which are printed under severe conditions, which will result in stopping Cygserver itself. Configuration file option: kern.log.level

• `-m, --no-sharedmem`

Don’t start XSI IPC Shared Memory support. If you don’t need XSI IPC Shared Memory support, you can switch it off here. Configuration file option: kern.srv.sharedmem

• `-q, --no-msgqueues`

Don’t start XSI IPC Message Queues. Configuration file option: kern.srv.msgqueues

• `-s, --no-semaphores`

Don’t start XSI IPC Semaphores. Configuration file option: kern.srv.semaphores

• `-S, --shutdown`

Shutdown a running daemon and exit. Other methods are sending a SIGHUP to the Cygserver PID or, if running as service, calling `net stop cygserver` or `cygrunsrv -E cygserver`.

• `-h, --help`

Output usage information and exit.

• `-V, --version`

Output version information and exit.
3.7.3 How to install Cygserver

Cygserver is part of the base cygwin package. Therefore, whenever Cygwin is installed, so is Cygserver.
You may want to install Cygserver as a service. See Section 3.7.4.

3.7.4 How to start Cygserver

Before you run Cygserver for the first time, you should run the /usr/bin/cygserver-config script once. It creates the default configuration file and, upon request, installs Cygserver as service. The script only performs a default install, with no further options given to Cygserver when running as service. Due to the wide configurability by changing the configuration file, that’s typically not necessary.

You should always run Cygserver as a service under LocalSystem account. This is the way it is installed for you by the /usr/bin/cygserver-config script.

3.7.5 The Cygserver configuration file

Cygserver has many options, which allow you to customize the server to your needs. Customization is accomplished by editing the configuration file, which is by default /etc/cygserver.conf. This file is only read once, at startup of Cygserver. There’s no option to re-read the file at runtime by, say, sending a signal to Cygserver.

The configuration file determines how Cygserver operates. There are options which set the number of threads running in parallel, options for setting how and what to log and options to set various maximum values for the IPC services.

The default configuration file delivered with Cygserver is installed to /etc/defaults/etc. The /usr/bin/cygserver-config script copies it to /etc, giving you the option to overwrite an already existing file or to leave it alone. Therefore, the /etc file is safe to be changed by you, since it will not be overwritten by a later update installation.

The default configuration file contains many comments which describe everything needed to understand the settings. A comment at the start of the file describes the syntax rules for the file. The default options are shown in the file but are commented out.

It is generally a good idea to uncomment only options which you intend to change from the default values. Since reading the options file on Cygserver startup doesn’t take much time, it’s also considered good practice to keep all other comments in the file. This keeps you from searching for clues in other sources.

3.8 Cygwin Utilities

Cygwin comes with a number of command-line utilities that are used to manage the UNIX emulation portion of the Cygwin environment. While many of these reflect their UNIX counterparts, each was written specifically for Cygwin. You may use the long or short option names interchangeably; for example, --help and -h function identically. All of the Cygwin command-line utilities support the --help and --version options.

3.8.1 chattr

chattr — Change file attributes

Synopsis

    chattr [-RVfh] [+-=mode]... [file]...
Options

- `R`, `--recursive` recursively list attributes of directories and their contents
- `V`, `--verbose` Be verbose during operation
- `f`, `--force` suppress error messages
- `h`, `--help` this help text
- `v`, `--version` display the program version

Description

The `chattr` program allows to change file attributes, namely DOS attributes, as well as making files sparse, encrypt or compress them on FS level, or setting directories’ case sensitivity.

The format of ’mode’ is {+-=}[acCehnrsSt]

The operator '+' causes the selected attributes to be added to the existing attributes of the files; '-' causes them to be removed; and '=' causes them to be the only attributes that the files have.

Supported attributes:

- 'r', 'Readonly': file is read-only
- 'h', 'Hidden': file or directory is hidden
- 's', 'System': file or directory that the operating system uses
- 'a', 'Archive': file or directory has the archive marker set
- 't', 'Temporary': file is being used for temporary storage
- 'S', 'Sparse': file is sparse
- 'c', 'Compressed': file or directory is compressed
- 'n', 'Notindexed': file or directory is not to be indexed by the content indexing service
- 'e', 'Encrypted': file is encrypted
- 'C', 'Casesensitive': directory is handled case sensitive
  (Windows 10 1803 or later, local NTFS only, WSL must be installed)

3.8.2 cygcheck

cygcheck — List system information, check installed packages, or query package database

Synopsis

cygcheck [-v] [-h] PROGRAM
  cygcheck -c [-d] [PACKAGE]
  cygcheck -s [-r] [-v] [-h]
  cygcheck -k
  cygcheck -f FILE [FILE]...
  cygcheck -l [PACKAGE]...
  cygcheck -p REGEXP
  cygcheck --delete-orphaned-installation-keys
  cygcheck -h

Options
At least one command option or a PROGRAM is required, as shown above.

<table>
<thead>
<tr>
<th>OPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-c, --check-setup</td>
<td>show installed version of PACKAGE and verify integrity (or for all installed packages if none specified)</td>
</tr>
<tr>
<td>-d, --dump-only</td>
<td>just list packages, do not verify (with -c)</td>
</tr>
<tr>
<td>-s, --sysinfo</td>
<td>produce diagnostic system information (implies -c -d)</td>
</tr>
<tr>
<td>-r, --registry</td>
<td>also scan registry for Cygwin settings (with -s)</td>
</tr>
<tr>
<td>-k, --keycheck</td>
<td>perform a keyboard check session (must be run from a plain console only, not from a pty/rxvt/xterm)</td>
</tr>
<tr>
<td>-f, --find-package</td>
<td>find the package to which FILE belongs</td>
</tr>
<tr>
<td>-l, --list-package</td>
<td>list contents of PACKAGE (or all packages if none given)</td>
</tr>
<tr>
<td>-p, --package-query</td>
<td>search for REGEXP in the entire cygwin.com package repository (requires internet connectivity)</td>
</tr>
<tr>
<td>--delete-orphaned-installation-keys</td>
<td>Delete installation keys of old, now unused installations from the registry. Requires the right to change the registry.</td>
</tr>
<tr>
<td>-v, --verbose</td>
<td>produce more verbose output</td>
</tr>
<tr>
<td>-h, --help</td>
<td>annotate output with explanatory comments when given with another command, otherwise print this help</td>
</tr>
<tr>
<td>-V, --version</td>
<td>print the version of cygcheck and exit</td>
</tr>
</tbody>
</table>

Note: -c, -f, and -l only report on packages that are currently installed. To search all official Cygwin packages use -p instead. The -p REGEXP matches package names, descriptions, and names of files/paths within all packages.

Description

The cygcheck program is a diagnostic utility for dealing with Cygwin programs. If you are familiar with dpkg or rpm, cygcheck is similar in many ways. (The major difference is that setup.exe handles installing and uninstalling packages; see Section 2.1 for more information.)

The -c option checks the version and status of installed Cygwin packages. If you specify one or more package names, cygcheck will limit its output to those packages, or with no arguments it lists all packages. A package will be marked Incomplete if files originally installed are no longer present. The best thing to do in that situation is reinstall the package with setup.exe. To see which files are missing, use the -v option. If you do not need to know the status of each package and want cygcheck to run faster, add the -d option and cygcheck will only output the name and version for each package.

If you list one or more programs on the command line, cygcheck will diagnose the runtime environment of that program or programs, providing the names of DLL files on which the program depends. If you specify the -s option, cygcheck will give general system information. If you list one or more programs on the command line and specify -s, cygcheck will report on both.

The -f option helps you to track down which package a file came from, and -l lists all files in a package. For example, to find out about /usr/bin/less and its package:

Example 3.3 Example cygcheck usage

$ cygcheck -f /usr/bin/less
less-381-1

$ cygcheck -l less
/usr/bin/less.exe
/usr/bin/lessecho.exe
/usr/bin/lesskey.exe
/usr/man/man1/less.1
/usr/man/man1/lesskey.1
The \(-h\) option prints additional helpful messages in the report, at the beginning of each section. It also adds table column headings. While this is useful information, it also adds some to the size of the report, so if you want a compact report or if you know what everything is already, just leave this out.

The \(-v\) option causes the output to be more verbose. What this means is that additional information will be reported which is usually not interesting, such as the internal version numbers of DLLs, additional information about recursive DLL usage, and if a file in one directory in the \PATH\ also occurs in other directories on the \PATH\.

The \(-r\) option causes \texttt{cygcheck} to search your registry for information that is relevant to Cygwin programs. These registry entries are the ones that have "Cygwin" in the name. If you are paranoid about privacy, you may remove information from this report, but please keep in mind that doing so makes it harder to diagnose your problems.

In contrast to the other options that search the packages that are installed on your local system, the \(-p\) option can be used to search the entire official Cygwin package repository. It takes as argument a Perl-compatible regular expression which is used to match package names, package descriptions, and path/filenames of the contents of packages. This feature requires an active internet connection, since it must query the \cygwin.com\ web site. In fact, it is equivalent to the search that is available on the Cygwin package listing page.

For example, perhaps you are getting an error because you are missing a certain DLL and you want to know which package includes that file:

\textbf{Example 3.4 Searching all packages for a file}

```
$ cygcheck -p 'cygintl-2\ dll'
  Found 1 matches for 'cygintl-2\ dll'.
libintl2-0.12.1-3 GNU Internationalization runtime library

$ cygcheck -p 'libexpat.*\ a'
  Found 2 matches for 'libexpat.*\ a'.
expat-1.95.7-1 XML parser library written in C
expat-1.95.8-1 XML parser library written in C

$ cygcheck -p '/ls\. exe'
  Found 2 matches for '/ls\. exe'.
coreutils-5.2.1-5 GNU core utilities (includes fileutils, sh-utils and textutils)
coreutils-5.3.0-6 GNU core utilities (includes fileutils, sh-utils and textutils)
```

Note that this option takes a regular expression, not a glob or wildcard. This means that you need to use . * if you want something similar to the wildcard * commonly used in filename globbing. Similarly, to match the period character you should use \. since the . character in a regexp is a metacharacter that will match any character. Also be aware that the characters such as \ and * are shell metacharacters, so they must be either escaped or quoted, as in the example above.

The third example above illustrates that if you want to match a whole filename, you should include the / path separator. In the given example this ensures that filenames that happen to end in \ls\.exe such as ncftp\ls\.exe are not shown. Note that this use does not mean "look for packages with \ls\ in the root directory," since the / can match anywhere in the path. It's just there to anchor the match so that it matches a full filename.

By default the matching is case-sensitive. To get a case insensitive match, begin your regexp with (?i) which is a PCRE-specific feature. For complete documentation on Perl-compatible regular expression syntax and options, read the \texttt{perlre}\ manpage, or one of many websites such as \texttt{perldoc.com}\ that document the Perl language.

The \texttt{cygcheck}\ program should be used to send information about your system for troubleshooting when requested. When asked to run this command save the output so that you can email it, for example:

```
$ cygcheck -s -v -r -h > cygcheck_output.txt
```

Each Cygwin DLL stores its path and installation key in the registry. This allows troubleshooting of problems which could be a result of having multiple concurrent Cygwin installations. However, if you’re experimenting a lot with different Cygwin installation paths, your registry could accumulate a lot of old Cygwin installation entries for which the installation doesn’t exist anymore. To get rid of these orphaned registry entries, use the \texttt{cygcheck --delete-orphaned-installation-keys}\ command.
3.8.3 cygpath

cygpath — Convert Unix and Windows format paths, or output system path information

Synopsis

cygpath (-d|-m|-u|-w|-t TYPE) [-f FILE] [OPTION]... NAME...
cygpath [-c HANDLE]
cygpath [-ADHOPSW]
cygpath [-F ID]

Options

Output type options:

- d, --dos       print DOS (short) form of NAMEs (C:\PROGRA~1\)
- m, --mixed    like --windows, but with regular slashes (C:/WINNT)
- M, --mode     report on mode of file (currently binmode or textmode)
- u, --unix     (default) print Unix form of NAMEs (/cygdrive/c/winnt)
- w, --windows  print Windows form of NAMEs (C:\WINNT)
- t, --type TYPE print TYPE form: 'dos', 'mixed', 'unix', or 'windows'

Path conversion options:

- a, --absolute output absolute path
- l, --long-name print Windows long form of NAMEs (with -w, -m only)
- p, --path     NAME is a PATH list (i.e., '/bin:/usr/bin')
- U, --proc-cygdrive Emit /proc/cygdrive path instead of cygdrive prefix when converting Windows path to UNIX path.
- s, --short-name print DOS (short) form of NAMEs (with -w, -m only)
- C, --codepage CP print DOS, Windows, or mixed pathname in Windows codepage CP. CP can be a numeric codepage identifier, or one of the reserved words ANSI, OEM, or UTF8. If this option is missing, cygpath defaults to the character set defined by the current locale.

System information:

- A, --allusers use ‘All Users’ instead of current user for -D, -P
- D, --desktop output ‘Desktop’ directory and exit
- H, --homeroot output ‘Profiles’ directory (home root) and exit
- O, --mydocs  output ‘My Documents’ directory and exit
- P, --smprograms output Start Menu ‘Programs’ directory and exit
- S, --sysdir   output system directory and exit
- W, --windir   output ‘Windows’ directory and exit
- F, --folder ID output special folder with numeric ID and exit

Other options:

- f, --file FILE read FILE for input; use - to read from STDIN
- o, --option read options from FILE as well (for use with --file)
- c, --close HANDLE close HANDLE (for use in captured process)
- i, --ignore ignore missing argument
- h, --help output usage information and exit
- V, --version output version information and exit
Description

The **cygpath** program is a utility that converts Windows native filenames to Cygwin POSIX-style pathnames and vice versa. It can be used when a Cygwin program needs to pass a file name to a native Windows program, or expects to get a file name from a native Windows program. Alternatively, **cygpath** can output information about the location of important system directories in either format.

The `-u` and `-w` options indicate whether you want a conversion to UNIX (POSIX) format (`-u`) or to Windows format (`-w`). Use the `-d` to get DOS-style (8.3) file and path names. The `-m` option will output Windows-style format but with forward slashes instead of backslashes. This option is especially useful in shell scripts, which use backslashes as an escape character.

In combination with the `-w` option, you can use the `-l` and `-s` options to use normal (long) or DOS-style (short) form. The `-d` option is identical to `-w` and `-s` together.

The `-C` option allows to specify a Windows codepage to print DOS and Windows paths created with one of the `-d`, `-m`, or `-w` options. The default is to use the character set of the current locale defined by one of the internationalization environment variables `LC_ALL`, `LC_CTYPE`, or `LANG`, see Section 2.4. This is sometimes not sufficient for interaction with native Windows tools, which might expect native, non-ASCII characters in a specific Windows codepage. Console tools, for instance, might expect pathnames in the current OEM codepage, while graphical tools like Windows Explorer might expect pathnames in the current ANSI codepage.

The `-U` option allows to use cygpath to create unambiguous Unix paths pointing outside the Cygwin tree and thus having no explicit POSIX path. Those paths usually use the cygdrive prefix. However, the cygdrive prefix can be changed by the user, so symbolic links created using the cygdrive prefix are not foolproof. With `-U` cygpath will generate such paths prepended by the virtual `/proc/cygdrive` symbolic link, which will never change, so the created path is safe against changing the cygdrive prefix.

The `-C` option takes a single parameter:

- **ANSI**, to specify the current ANSI codepage
- **OEM**, to specify the current OEM (console) codepage
- **UTF8**, to specify UTF-8.
- A numerical, decimal codepage number, for instance 936 for GBK, 28593 for ISO-8859-3, etc. A full list of supported codepages is listed on the Microsoft MSDN page Code Page Identifiers. A codepage of 0 is the same as if the `-C` hasn’t been specified at all.

The `-p` option means that you want to convert a path-style string rather than a single filename. For example, the `PATH` environment variable is semicolon-delimited in Windows, but colon-delimited in UNIX. By giving `-p` you are instructing **cygpath** to convert between these formats.

The `-i` option suppresses the print out of the usage message if no filename argument was given. It can be used in make file rules converting variables that may be omitted to a proper format. Note that **cygpath** output may contain spaces (C:\Program Files) so should be enclosed in quotes.

### Example 3.5 Example cygpath usage

```bash
#!/bin/sh
if [ "$1" = "" ];
  then
    XPATH=".";
  else
    XPATH="$(cygpath -C ANSI -w "$1")";
  fi
explorer $XPATH &
```

The capital options `-D`, `-H`, `-P`, `-S`, and `-W` output directories used by Windows that are not the same on all systems, for example `-S` might output `C:\WINNT\system32` or `C:\Windows\System32`. The `-H` shows the Windows profiles directory that can be used
as root of home. The \texttt{-A} option forces use of the "All Users" directories instead of the current user for the \texttt{-D, -O} and \texttt{-P} options. The \texttt{-F} outputs other special folders specified by their internal numeric code (decimal or 0x-prefixed hex). For valid codes and symbolic names, see the CSIDL_* definitions in the include file /usr/include/w32api/shlobj.h from package w32api. The current valid range of codes for folders is 0 (Desktop) to 59 (CDBurn area). By default the output is in UNIX (POSIX) format; use the \texttt{-w} or \texttt{-d} options to get other formats.

3.8.4 dumper

dumper — Dump core from WIN32PID to FILENAME.core

Synopsis

dumper [OPTION] FILENAME WIN32PID

Options

\texttt{-d, \textasciitilde d} \hspace{1em} \texttt{--verbose} \hspace{1em} be verbose while dumping

\texttt{-h, \textasciitilde h} \hspace{1em} \texttt{--help} \hspace{1em} output help information and exit

\texttt{-q, \textasciitilde q} \hspace{1em} \texttt{--quiet} \hspace{1em} be quiet while dumping (default)

\texttt{-V, \textasciitilde V} \hspace{1em} \texttt{--version} \hspace{1em} output version information and exit

Description

The \texttt{dumper} utility can be used to create a core dump of running Windows process. This core dump can be later loaded to \texttt{gdb} and analyzed. One common way to use \texttt{dumper} is to plug it into cygwin’s Just-In-Time debugging facility by adding

\begin{verbatim}
error_start=x:\path\to\dumper.exe
\end{verbatim}

to the \texttt{CYGWIN} environment variable. Please note that \texttt{x:\path\to\dumper.exe} is Windows-style and not cygwin path. If \texttt{error_start} is set this way, then dumper will be started whenever some program encounters a fatal error.

\texttt{dumper} can be also be started from the command line to create a core dump of any running process. Unfortunately, because of a Windows API limitation, when a core dump is created and \texttt{dumper} exits, the target process is terminated too.

To save space in the core dump, \texttt{dumper} doesn’t write those portions of target process’ memory space that are loaded from executable and dll files and are unchangeable, such as program code and debug info. Instead, \texttt{dumper} saves paths to files which contain that data. When a core dump is loaded into \texttt{gdb}, it uses these paths to load appropriate files. That means that if you create a core dump on one machine and try to debug it on another, you’ll need to place identical copies of the executable and dlls in the same directories as on the machine where the core dump was created.

3.8.5 getconf

getconf — Get configuration values

Synopsis

getconf \texttt{[\texttt{-v specification}] variable_name [pathname]}
getconf \texttt{\textasciitilde a [pathname]}
### Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-v</td>
<td>Indicate specific version for which configuration values shall be fetched.</td>
</tr>
<tr>
<td>-a, --all</td>
<td>Print all known configuration values</td>
</tr>
</tbody>
</table>

**Other options:**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>This text</td>
</tr>
<tr>
<td>-V, --version</td>
<td>Print program version and exit</td>
</tr>
</tbody>
</table>

### Description

The `getconf` utility prints the value of the configuration variable specified by `variable_name`. If no `pathname` is given, `getconf` serves as a wrapper for the `confstr` and `sysconf` functions, supporting the symbolic constants defined in the `limits.h` and `unistd.h` headers, without their respective `_CS_` or `_SC_` prefixes.

If `pathname` is given, `getconf` prints the value of the configuration variable for the specified `pathname`. In this form, `getconf` serves as a wrapper for the `pathconf` function, supporting the symbolic constants defined in the `unistd.h` header, without the `_PC_` prefix.

If you specify the `-v` option, the parameter denotes a specification for which the value of the configuration variable should be printed. Note that the only specifications supported by Cygwin are `POSIX_V7_ILP32_OFFBIG` and the legacy `POSIX_V6_ILP32_OFFBIG` and `XBS5_ILP32_OFFBIG` equivalents.

Use the `-a` option to print a list of all available configuration variables for the system, or given `pathname`, and their values.

### 3.8.6 getfacl

**getfacl — Display file and directory access control lists (ACLs)**

**Synopsis**

```
getfacl [-adceEn] FILE [FILE2...]
```

**Options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-a, --access</td>
<td>display the file access control list only</td>
</tr>
<tr>
<td>-d, --default</td>
<td>display the default access control list only</td>
</tr>
<tr>
<td>-c, --omit-header</td>
<td>do not display the comment header</td>
</tr>
<tr>
<td>-e, --all-effective</td>
<td>print all effective rights</td>
</tr>
<tr>
<td>-E, --no-effective</td>
<td>print no effective rights</td>
</tr>
<tr>
<td>-n, --numeric</td>
<td>print numeric user/group identifiers</td>
</tr>
<tr>
<td>-V, --version</td>
<td>print version and exit</td>
</tr>
<tr>
<td>-h, --help</td>
<td>this help text</td>
</tr>
</tbody>
</table>

When multiple files are specified on the command line, a blank line separates the ACLs for each file.

**Description**

For each argument that is a regular file, special file or directory, `getfacl` displays the owner, the group, and the ACL. For directories `getfacl` displays additionally the default ACL. With no options specified, `getfacl` displays the filename, the owner, the group, the setuid (s), setgid (s), and sticky (t) bits if available, and both the ACL and the default ACL, if it exists. For more information on Cygwin and Windows ACLs, see Section 3.6 in the Cygwin User’s Guide. The format for ACL output is as follows:
# file: filename
# owner: name or uid
# group: name or uid
# flags: sst
# user::perm
# user:name or uid:perm
# group::perm
# group:name or gid:perm
# mask:perm
# other:perm
# default: user::perm
# default: user:name or uid:perm
# default: group::perm
# default: group:name or gid:perm
# default: mask:perm
# default: other:perm

## 3.8.7 kill

kill — Send signals to processes

### Synopsis

```bash
kill [-f] [-signal] [-s signal] pid1 [pid2 ...]
kill -l [signal]
```

### Options

- `-f`, `--force` force, using win32 interface if necessary
- `-l`, `--list` print a list of signal names
- `-s`, `--signal` send signal (use kill --list for a list)
- `-W`, `--winpid` specified pids are windows PIDs, not Cygwin PIDs
- `-h`, `--help` output usage information and exit
- `-V`, `--version` output version information and exit

### Description

The `kill` program allows you to send arbitrary signals to other Cygwin programs. The usual purpose is to end a running program from some other window when 'C won’t work, but you can also send program-specified signals such as SIGUSR1 to trigger actions within the program, like enabling debugging or re-opening log files. Each program defines the signals they understand.

You may need to specify the full path to use `kill` from within some shells, including `bash`, the default Cygwin shell. This is because `bash` defines a `kill` builtin function; see the `bash` man page under `BUILTIN COMMANDS` for more information. To make sure you are using the Cygwin version, try

```
$ /bin/kill --version
```

which should give the Cygwin `kill` version number and copyright information.

The `-f` option uses Windows functions to terminate processes forcefully. Use `-f` to terminate native Windows processes not started by Cygwin processes. `-f` can also be useful to terminate Cygwin processes not answering to SIGKILL.

Unless you specify the `-W` option, the “pid” values used by `kill` are the Cygwin pids, not the Windows pids. To get a list of running programs and their Cygwin pids, use the Cygwin `ps` program. `ps -W` will display all windows pids.
The `kill -l` option prints the name of the given signal, or a list of all signal names if no signal is given.

To send a specific signal, use the `-signN` option, either with a signal number or a signal name (minus the "SIG" part), as shown in these examples:

**Example 3.6 Using the kill command**

```bash
$ kill 123
$ kill -1 123
$ kill -HUP 123
$ kill -f 123
```

Here is a list of available signals, their numbers, and some commentary on them, from the file `<sys/signal.h>`, which should be considered the official source of this information.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGHUP</td>
<td>1</td>
<td>hangup</td>
</tr>
<tr>
<td>SIGINT</td>
<td>2</td>
<td>interrupt</td>
</tr>
<tr>
<td>SIGQUIT</td>
<td>3</td>
<td>quit</td>
</tr>
<tr>
<td>SIGILL</td>
<td>4</td>
<td>illegal instruction (not reset when caught)</td>
</tr>
<tr>
<td>SIGTRAP</td>
<td>5</td>
<td>trace trap (not reset when caught)</td>
</tr>
<tr>
<td>SIGABRT</td>
<td>6</td>
<td>used by abort</td>
</tr>
<tr>
<td>SIGIOT</td>
<td>6</td>
<td>another name for SIGABRT</td>
</tr>
<tr>
<td>SIGEMT</td>
<td>7</td>
<td>EMT instruction</td>
</tr>
<tr>
<td>SIGFPE</td>
<td>8</td>
<td>floating point exception</td>
</tr>
<tr>
<td>SIGKILL</td>
<td>9</td>
<td>kill (cannot be caught or ignored)</td>
</tr>
<tr>
<td>SIGBUS</td>
<td>10</td>
<td>bus error</td>
</tr>
<tr>
<td>SIGSEGV</td>
<td>11</td>
<td>segmentation violation</td>
</tr>
<tr>
<td>SIGSYS</td>
<td>12</td>
<td>bad argument to system call</td>
</tr>
<tr>
<td>SIGPIPE</td>
<td>13</td>
<td>write on a pipe with no one to read it</td>
</tr>
<tr>
<td>SIGALRM</td>
<td>14</td>
<td>alarm clock</td>
</tr>
<tr>
<td>SIGTERM</td>
<td>15</td>
<td>software termination signal from kill</td>
</tr>
<tr>
<td>SIGSTOP</td>
<td>16</td>
<td>urgent condition on IO channel</td>
</tr>
<tr>
<td>SIGCONT</td>
<td>17</td>
<td>sendable stop signal not from tty</td>
</tr>
<tr>
<td>SIGTSTP</td>
<td>18</td>
<td>stop signal from tty</td>
</tr>
<tr>
<td>SIGCHLD</td>
<td>19</td>
<td>continue a stopped process</td>
</tr>
<tr>
<td>SIGTTIN</td>
<td>21</td>
<td>to readers pgrp upon background tty read</td>
</tr>
<tr>
<td>SIGTTOU</td>
<td>22</td>
<td>like TTIN for output if (tp-&gt;t_local&amp;LTOSTOP)</td>
</tr>
<tr>
<td>SIGIO</td>
<td>23</td>
<td>input/output possible</td>
</tr>
<tr>
<td>SIGPOLL</td>
<td>23</td>
<td>System V name for SIGIO</td>
</tr>
<tr>
<td>SIGXCPU</td>
<td>24</td>
<td>exceeded CPU time limit</td>
</tr>
<tr>
<td>SIGXFSZ</td>
<td>25</td>
<td>exceeded file size limit</td>
</tr>
<tr>
<td>SIGVTALRM</td>
<td>26</td>
<td>virtual time alarm</td>
</tr>
<tr>
<td>SIGPROF</td>
<td>27</td>
<td>profiling time alarm</td>
</tr>
<tr>
<td>SIGWINCH</td>
<td>28</td>
<td>window changed</td>
</tr>
<tr>
<td>SIGLOST</td>
<td>29</td>
<td>resource lost (eg, record-lock lost)</td>
</tr>
<tr>
<td>SIGPWR</td>
<td>29</td>
<td>power failure</td>
</tr>
<tr>
<td>SIGUSR1</td>
<td>30</td>
<td>user defined signal 1</td>
</tr>
<tr>
<td>SIGUSR2</td>
<td>31</td>
<td>user defined signal 2</td>
</tr>
</tbody>
</table>

### 3.8.8 ldd

**ldd** — Print shared library dependencies

**Synopsis**

```bash
ldd [OPTION]... FILE...
```
Options

- `h`, --help  print this help and exit
- `V`, --version  print version information and exit
- `r`, --function-relocs  process data and function relocations
  (currently unimplemented)
- `u`, --unused  print unused direct dependencies
  (currently unimplemented)
- `v`, --verbose  print all information
  (currently unimplemented)

Description

**ldd** prints the shared libraries (DLLs) loaded when running an executable or DLL.

Security

**ldd** invokes the Windows loader on the file specified, then uses the Windows debugging interface to report DLLs loaded, and (for executables) to attempt to stop execution before the entrypoint. Thus, you should never use ldd on an untrusted file.

3.8.9 locale

locale — Get locale-specific information

Synopsis

locale [-amvhV]
locale [-ck] NAME
locale [-iusfnU]

Options

System information:

- `a`, --all-locales  List all available supported locales
- `m`, --charmaps  List all available character maps
- `v`, --verbose  More verbose output

Modify output format:

- `c`, --category-name  List information about given category NAME
- `k`, --keyword-name  Print information about given keyword NAME

Default locale information:

- `i`, --input  Print current input locale
- `u`, --user  Print locale of user’s default UI language
- `s`, --system  Print locale of system default UI language
- `f`, --format  Print locale of user’s regional format settings
  (time, numeric & monetary)
- `n`, --no-unicode  Print system default locale for non-Unicode programs
- `U`, --utf  Attach ".UTF-8\" to the result

Other options:
-h, --help
-h, --help
-V, --version
-V, --version

This text
Print program version and exit

Description

locale without parameters prints information about the current locale environment settings.

The -i, -u, -s, -f, and -n options can be used to request the various Windows locale settings. The purpose is to use this command in scripts to set the POSIX locale variables.

The -i option prints the current input language. This is called the "Input language" and basically equivalent to the current keyboard layout setting.

The -u option prints the current user’s Windows UI locale to stdout. In Windows this setting is called the "Display Language".

The -s option prints the systems default instead.

The -f option prints the user’s setting for time, date, number and currency. That’s equivalent to the setting in the "Formats" or "Regional Options" tab in the "Region and Language" or "Regional and Language Options" dialog.

The -n option prints the system’s default language used for applications which don’t support Unicode.

With the -U option locale appends the string ".UTF-8" to enforce using UTF-8. Using UTF-8 as codeset is recommended.

Usage example:

bash$ export LANG=$(locale -uU)
bash$ echo $LANG
en_US.UTF-8
bash$ export LC_TIME=$(locale -fU)
bash$ echo $LC_TIME
de_DE.UTF-8

The -a option is helpful to learn which locales are supported by your Windows machine. It prints all available locales and the allowed modifiers. Example:

bash$ locale -a
c
C.utf8
POSIX
af_ZA
af_ZA.utf8
am_ET
am_ET.utf8
...
be_BY
be_BY.utf8
be_BY@latin
...
ca_ES
can ES.utf8
can_ES@euro
catalan
...

The -v option prints more detailed information about each available locale. Example:

bash$ locale -av
locale: af_ZA archive: /cygdrive/c/Windows/system32/kernel32.dll
language: Afrikaans
territory: South Africa
codeset: ISO-8859-1
The `-m` option prints the names of the available charmaps supported by Cygwin to stdout.

Otherwise, if arguments are given, `locale` prints the values assigned to these arguments. Arguments can be names of locale categories (for instance: `LC_CTYPE`, `LC_MONETARY`), or names of keywords supported in the locale categories (for instance: `thousands_sep`, `charmap`). The `-c` option prints additionally the name of the category. The `-k` option prints additionally the name of the keyword. Example:

```bash
bash$ locale -ck LC_MESSAGES
LC_MESSAGES
yesexpr="^[yY]"
noexpr="^[nN]"
yesstr="yes"
nostr="no"
messages-codeset="UTF-8"
bash$ locale noexpr
^[nN]
```

### 3.8.10 lsattr

**lsattr** — List file attributes

**Synopsis**

```bash
lsattr [-RVadhln] [file]...
```

**Options**

- `-R, --recursive` recursively list attributes of directories and their contents
- `-V, --version` display the program version
- `-a, --all` list all files in directories, including files that start with ‘.’
- `-d, --directory` list directories like other files, rather than listing their contents.
The `lsattr` program allows to list file attributes, namely DOS attributes, file sparseness, FS level encryption and compression state, as well as directories’ case sensitivity setting.

Supported attributes:

- `'r', 'Readonly'`: file is read-only, directory is system-marked
- `'h', 'Hidden'`: file or directory is hidden
- `'s', 'System'`: file or directory that the operating system uses
- `'a', 'Archive'`: file or directory has the archive marker set
- `'t', 'Temporary'`: file is being used for temporary storage
- `'S', 'Sparse'`: file is sparse
- `'r', 'Reparse'`: file or directory that has a reparse point
- `'c', 'Compressed'`: file or directory is compressed
- `'o', 'Offline'`: the data of a file is moved to offline storage
- `'n', 'Notindexed'`: file or directory is not to be indexed by the content indexing service
- `'e', 'Encrypted'`: file is encrypted
- `'C', 'Casesensitive'`: directory is handled case sensitive

(Windows 10 1803 or later, local NTFS only, WSL must be installed)

### 3.8.11 minidumper

**minidumper** — Write minidump from WIN32PID to FILENAME.dmp

**Synopsis**

```sh
minidumper [OPTION] FILENAME WIN32PID
```

**Options**

- `-t, --type` minidump type flags
- `-n, --nokill` don’t terminate the dumped process
- `-d, --verbose` be verbose while dumping
- `-h, --help` output help information and exit
- `-q, --quiet` be quiet while dumping (default)
- `-V, --version` output version information and exit

**Description**

The `minidumper` utility can be used to create a minidump of a running Windows process. This minidump can be later analysed using breakpad or Windows debugging tools.

`minidumper` can be used with cygwin’s Just-In-Time debugging facility in exactly the same way as `dumper` (See `dumper(1)`).

`minidumper` can also be started from the command line to create a minidump of any running process. For compatibility with `dumper` the target process is terminated after dumping unless the `-n` option is given.
3.8.12 mkgroup

mkgroup — Write /etc/group-like output to stdout

Synopsis

mkgroup [OPTION]...

Options

Options:

- l, --local [machine]  Print local group accounts of "machine",
  from local machine if no machine specified.
- L, --Local machine    Ditto, but generate groupname with machine prefix.
- d, --domain [domain]  Print domain groups,
  from current domain if no domain specified.
- c, --current          Print current group.
- S, --separator char   For -L use character char as domain\group
  separator in groupname instead of default ‘+’.
- o, --id-offset offset  Change the default offset (0x10000) added to gids
- g, --group groupname  Only return information for the specified group.
- b, --no-builtin       Don’t print BUILTIN groups.
- U, --unix grouplist   Print UNIX groups when using -l on a UNIX Samba
  server. Grouplist is a comma-separated list of
  groupnames or gid ranges (root,-25,50-100).
- h, --help             Print this message.
- v, --version          Print version information and exit.

Default is to print local groups on stand-alone machines, plus domain
groups on domain controllers and domain member machines.

Description

Don’t use this command to generate a local /etc/group file, unless you really need one. See the Cygwin User’s Guide for more information.

The mkgroup program can be used to create a local /etc/group file. Cygwin doesn’t need this file, because it reads group information from the Windows account databases, but you can add an /etc/group file for instance, if your machine is often disconnected from its domain controller.

Note that this information is static, in contrast to the information automatically gathered by Cygwin from the Windows account databases. If you change the group information on your system, you’ll need to regenerate the group file for it to have the new information.

By default, the information generated by mkgroup is equivalent to the information generated by Cygwin itself. The -d and -l/-L options allow you to specify where the information comes from, some domain, or the local SAM of a machine. Note that you can only enumerate accounts from trusted domains. Any non-trusted domain will be ignored. Access-restrictions of your current account apply. The -l/-L when used with a machine name, tries to contact that machine to enumerate local groups of other machines, typically outside of domains. This scenario cannot be covered by Cygwin’s account automatism. If you want to use the -L option, but you don’t like the default domain/group separator from /etc/nsswitch.conf, you can specify another separator using the -S option, for instance:
Example 3.7 Setting up group entry for current user with different domain/group separator

$ mkgroup -L server1 -S= > /etc/group

For very simple needs, an entry for the current user’s group can be created by using the option \( -c \).

The \( -o \) option allows for (unlikely) special cases with multiple machines where the GIDs might match otherwise. The \( -g \) option only prints the information for one group. The \( -U \) option allows you to enumerate the standard UNIX groups on a Samba machine. It’s used together with \( -l \) \( \text{samba-server} \) or \( -L \) \( \text{samba-server} \). The normal UNIX groups are usually not enumerated, but they can show up as a group in \texttt{ls -l} output.

### 3.8.13 mkpasswd

mkpasswd — Write /etc/passwd-like output to stdout

#### Synopsis

mkpasswd [OPTIONS]...

#### Options

-\( -l \),--local [machine] Print local user accounts of \"machine\", from local machine if no machine specified. Automatically adding machine prefix for local machine depends on settings in \texttt{/etc/nsswitch.conf}.
-\( -L \),--Local machine Ditto, but generate username with machine prefix.
-\( -d \),--domain [domain] Print domain accounts, from current domain if no domain specified.
-\( -c \),--current Print current user.
-\( -S \),--separator char For \( -L \) use character char as domain\user separator in username instead of the default \( '+' \).
-\( -o \),--id-offset offset Change the default offset (0x10000) added to uids of foreign local machine accounts. Use with \( -l/-L \).
-\( -u \),--username username Only return information for the specified user. One of \( -l, -d \) must be specified, too
-\( -b \),--no-builtin Don’t print BUILTIN users.
-\( -p \),--path-to-home path Use specified path instead of user account home dir or \texttt{/home} prefix.
-\( -U \),--unix userlist Print UNIX users when using \( -l \) on a UNIX Samba server. Userlist is a comma-separated list of usernames or uid ranges (root, -25, 50-100). Enumerating large ranges can take a long time!
-\( -h \),--help Displays this message.
-\( -V \),--version Version information and exit.

Default is to print local accounts on stand-alone machines, domain accounts on domain controllers and domain member machines.

#### Description

Don’t use this command to generate a local \texttt{/etc/passwd} file, unless you really need one. See the Cygwin User’s Guide for more information.
The `mkpasswd` program can be used to create a `/etc/passwd` file. Cygwin doesn’t need this file, because it reads user information from the Windows account databases, but you can add an `/etc/passwd` file, for instance if your machine is often disconnected from its domain controller.

Note that this information is static, in contrast to the information automatically gathered by Cygwin from the Windows account databases. If you change the user information on your system, you’ll need to regenerate the passwd file for it to have the new information.

By default, the information generated by `mkpasswd` is equivalent to the information generated by Cygwin itself. The `-d` and `-l/-L` options allow you to specify where the information comes from, some domain, or the local SAM of a machine. Note that you can only enumerate accounts from trusted domains. Any non-trusted domain will be ignored. Access-restrictions of your current account apply. The `-l/-L` when used with a machine name, tries to contact that machine to enumerate local groups of other machines, typically outside of domains. This scenario cannot be covered by Cygwin’s account automatism. If you want to use the `-L` option, but you don’t like the default domain/group separator from `/etc/nsswitch.conf`, you can specify another separator using the `-S` option, analog to `mkgroup`.

For very simple needs, an entry for the current user can be created by using the option `-c`.

The `-o` option allows for special cases (such as multiple domains) where the UIDs might match otherwise. The `-p` option causes `mkpasswd` to use the specified prefix instead of the account home dir or `/home/`. For example, this command:

```
Example 3.8 Using an alternate home root
$ mkpasswd -l -p "$(cygpath -H)" > /etc/passwd
```

would put local users’ home directories in the Windows ‘Profiles’ directory. The `-u` option creates just an entry for the specified user. The `-U` option allows you to enumerate the standard UNIX users on a Samba machine. It’s used together with `-l samba-server` or `-L samba-server`. The normal UNIX users are usually not enumerated, but they can show up as file owners in `ls -l` output.

### 3.8.14 mount

`mount` — Display information about mounted filesystems, or mount a filesystem

**Synopsis**

```
mount [OPTION] [<win32path> <posixpath>]
mount -a
mount <posixpath>
```

**Options**

```
-a, --all
-c, --change-cygdrive-prefix [posixpath]
-f, --force
-h, --help
-m, --mount-entries
-o, --options X[,X...]
-p, --show-cygdrive-prefix
-V, --version
```

mount all filesystems mentioned in fstab
change the cygdrive path prefix to `<posixpath>`
force mount, don’t warn about missing mount point directories
output usage information and exit
write fstab entries to replicate mount points and cygdrive prefixes
specify mount options
show user and/or system cygdrive path prefix
output version information and exit
Description

The `mount` program is used to map your drives and shares onto Cygwin’s simulated POSIX directory tree, much like as is done by mount commands on typical UNIX systems. However, in contrast to mount points given in `/etc/fstab`, mount points created or changed with `mount` are not persistent. They disappear immediately after the last process of the current user exited. Please see Section 3.1.2 for more information on the concepts behind the Cygwin POSIX file system and strategies for using mounts. To remove mounts temporarily, use `umount`.

Using mount

If you just type `mount` with no parameters, it will display the current mount table for you.

**Example 3.9** Displaying the current set of mount points

```bash
$ mount
C:/cygwin/bin on /usr/bin type ntfs (binary)
C:/cygwin/lib on /usr/lib type ntfs (binary)
C:/cygwin on / type ntfs (binary)
C: on /mnt/c type ntfs (binary,user,noumount)
D: on /mnt/d type fat (binary,user,noumount)
```

In this example, c:/cygwin is the POSIX root and the D drive is mapped to /mnt/d. Note that in this case, the root mount is a system-wide mount point that is visible to all users running Cygwin programs, whereas the /mnt/d mount is only visible to the current user.

The `mount` utility is also the mechanism for adding new mounts to the mount table in memory. The following example demonstrates how to mount the directory `//pollux/home/joe/data` to `/data` for the duration of the current session.

**Example 3.10** Adding mount points

```bash
$ ls /data
ls: /data: No such file or directory
$ mount //pollux/home/joe/data /data
mount: warning - /data does not exist!
$ mount
//pollux/home/joe/data on /data type smbfs (binary)
C:/cygwin/bin on /usr/bin type ntfs (binary)
C:/cygwin/lib on /usr/lib type ntfs (binary)
C:/cygwin on / type ntfs (binary)
C: on /c type ntfs (binary,user,noumount)
D: on /d type fat (binary,user,noumount)
```

A given POSIX path may only exist once in the mount table. Attempts to replace the mount will fail with a busy error. The `-f` (force) option causes the old mount to be silently replaced with the new one, provided the old mount point was a user mount point. It's not valid to replace system-wide mount points. Additionally, the `-f` option will silence warnings about the non-existence of directories at the Win32 path location.

The `-o` option is the method via which various options about the mount point may be recorded. The following options are available (note that most of the options are duplicates of other mount flags):

- **acl** - Use the filesystem’s access control lists (ACLs) to implement real POSIX permissions (default).
- **binary** - Files default to binary mode (default).
- **bind** - Allows to remount part of the file hierarchy somewhere else. Different from other mount calls, the first argument specifies an absolute POSIX path, rather than a Win32 path. This POSIX path is remounted to the POSIX path specified as the second parameter. The conversion to a Win32 path is done within Cygwin immediately at the time of the call. Note that symlinks are ignored while performing this path conversion.
cygexec - Treat all files below mount point as cygwin executables.
dos - Always convert leading spaces and trailing dots and spaces to characters in the UNICODE private use area. This allows to use broken filesystems which only allow DOS filenames, even if they are not recognized as such by Cygwin.
exec - Treat all files below mount point as executable.
lihash - Always fake inode numbers rather than using the ones returned by the filesystem. This allows to use broken filesystems which don’t return unambiguous inode numbers, even if they are not recognized as such by Cygwin.
noacl - Ignore ACLs and fake POSIX permissions.
nosuid - No suid files are allowed (currently unimplemented).
notexec - Treat all files below mount point as not executable.
override - Override immutable mount points.
posix=0 - Switch off case sensitivity for paths under this mount point.
posix=1 - Switch on case sensitivity for paths under this mount point (default).
sparse - Switch on support for sparse files. This option only makes sense on NTFS and then only if you really need sparse files.
text - Files default to CRLF text mode line endings.

For a more complete description of the mount options and the /etc/fstab file, see Section 3.1.2.

Note that all mount points added with mount are user mount points. System mount points can only be specified in the /etc/ fstab file.

If you added mount points to /etc/fstab or your /etc/fstab.d/<username> file, you can add these mount points to your current user session using the -a/--all option, or by specifying the posix path alone on the command line. As an example, consider you added a mount point with the POSIX path /my/mount. You can add this mount point with either one of the following two commands to your current user session.

$ mount /my/mount
$ mount -a

The first command just adds the /my/mount mount point to your current session, the mount -a adds all new mount points to your user session.

If you change a mount point to point to another native path, or if you changed the flags of a mount point, you have to umount the mount point first, before you can add it again. Please note that all such added mount points are added as user mount points, and that the rule that system mount points can’t be removed or replaced in a running session still applies.

To bind a POSIX path to another POSIX path, use the bind mount flag.

$ mount -o bind /var /usr/var

This command makes the file hierarchy under /var additionally available under /usr/var.

The -m option causes the mount utility to output the current mount table in a series of fstab entries. You can save this output as a backup when experimenting with the mount table. Copy the output to /etc/fstab to restore the old state. It also makes moving your settings to a different machine much easier.

Cygdrive mount points

Whenever Cygwin cannot use any of the existing mounts to convert from a particular Win32 path to a POSIX one, Cygwin will, instead, convert to a POSIX path using a default mount point: /cygdrive. For example, if Cygwin accesses z:\foo and the z drive is not currently in the mount table, then z:\ will be accessible as /cygdrive/z. The mount utility can be used to change this default automount prefix through the use of the "--change-cygdrive-prefix" option. In the following example, we will set the automount prefix to /mnt:
Example 3.11 Changing the default prefix

$ mount --change-cygdrive-prefix /mnt

Note that the cygdrive prefix can be set both per-user and system-wide, and that as with all mounts, a user-specific mount takes precedence over the system-wide setting. The `mount` utility creates system-wide mounts by default if you do not specify a type. You can always see the user and system cygdrive prefixes with the `-p` option. Using the `--options` flag with `--change-cygdrive-prefix` makes all new automounted filesystems default to this set of options. For instance (using the short form of the command line flags)

Example 3.12 Changing the default prefix with specific mount options

$ mount -c /mnt -o binary,noacl

Limitations

Limitations: there is a hard-coded limit of 64 mount points. Also, although you can mount to pathnames that do not start with "/", there is no way to make use of such mount points.

Normally the POSIX mount point in Cygwin is an existing empty directory, as in standard UNIX. If this is the case, or if there is a place-holder for the mount point (such as a file, a symbolic link pointing anywhere, or a non-empty directory), you will get the expected behavior. Files present in a mount point directory before the mount become invisible to Cygwin programs.

It is sometimes desirable to mount to a non-existent directory, for example to avoid cluttering the root directory with names such as `a`, `b`, `c` pointing to disks. Although `mount` will give you a warning, most everything will work properly when you refer to the mount point explicitly. Some strange effects can occur however. For example if your current working directory is `/dir`, say, and `/dir/mtpt` is a mount point, then `mtpt` will not show up in an `ls` or `echo *` command and `find .` will not find `mtpt`.

3.8.15 passwd

`passwd` — Change USER’s password or password attributes.

Synopsis

```
passwd [OPTION] [USER]
```

Options

User operations:
- `-l`, `--lock` — lock USER’s account.
- `-u`, `--unlock` — unlock USER’s account.
- `-c`, `--cannot-change` — USER can’t change password.
- `-C`, `--can-change` — USER can change password.
- `-e`, `--never-expires` — USER’s password never expires.
- `-E`, `--expires` — USER’s password expires according to system’s password aging rule.
- `-p`, `--pwd-not-required` — no password required for USER.
- `-P`, `--pwd-required` — password is required for USER.
- `-R`, `--reg-store-pwd` — enter password to store it in the registry for later usage by services to be able to switch to this user context with network credentials.

System operations:
- `-i`, `--inactive NUM` — set NUM of days before inactive accounts are disabled
(inactive accounts are those with expired passwords).

-\n, \--minage MINDAYS set system minimum password age to MINDAYS days.
-\x, \--maxage MAXDAYS set system maximum password age to MAXDAYS days.
-\L, \--length LEN set system minimum password length to LEN.

Other options:

-\d, \--logonserver SERVER connect to SERVER (e.g. domain controller).
Usually not required.
-\S, \--status display password status for USER (locked, expired,
etc.) plus global system password settings.
-\h, \--help output usage information and exit.
-\V, \--version output version information and exit.

If no option is given, change USER’s password. If no user name is given,
operate on current user. System operations must not be mixed with user
operations. Don’t specify a USER when triggering a system operation.

Don’t specify a user or any other option together with the \-R option.
Non-Admin users can only store their password if cygserver is running.
Note that storing even obfuscated passwords in the registry is not overly
secure. Use this feature only if the machine is adequately locked down.
Don’t use this feature if you don’t need network access within a remote
session. You can delete your stored password by using ‘passwd \-R’ and
specifying an empty password.

Description

passwd changes passwords for user accounts. A normal user may only change the password for their own account, but admin-
istrators may change passwords on any account. passwd also changes account information, such as password expiry dates and
intervals.

For password changes, the user is first prompted for their old password, if one is present. This password is then encrypted and
compared against the stored password. The user has only one chance to enter the correct password. The administrators are
permitted to bypass this step so that forgotten passwords may be changed.

The user is then prompted for a replacement password. passwd will prompt twice for this replacement and compare the second
entry against the first. Both entries are required to match in order for the password to be changed.

After the password has been entered, password aging information is checked to see if the user is permitted to change their
password at this time. If not, passwd refuses to change the password and exits.

To get current password status information, use the \-S option. Administrators can use passwd to perform several account
maintenance functions (users may perform some of these functions on their own accounts). Accounts may be locked with the \-\l flag and unlocked with the \-u flag. Similarly, \-c disables a user’s ability to change passwords, and \-C allows a user to change
passwords. For password expiry, the \-e option disables expiration, while the \-E option causes the password to expire according
to the system’s normal aging rules. Use \-p to disable the password requirement for a user, or \-P to require a password.

Administrators can also use passwd to change system-wide password expiry and length requirements with the \-i, \-n, \-x, and
\-L options. The \-i option is used to disable an account after the password has been expired for a number of days. After a user
account has had an expired password for NUM days, the user may no longer sign on to the account. The \-n option is used to
set the minimum number of days before a password may be changed. The user will not be permitted to change the password
until MINDAYS days have elapsed. The \-x option is used to set the maximum number of days a password remains valid. After
MAXDAYS days, the password is required to be changed. Allowed values for the above options are 0 to 999. The \-L option sets
the minimum length of allowed passwords for users who don’t belong to the administrators group to LEN characters. Allowed
values for the minimum password length are 0 to 14. In any of the above cases, a value of 0 means `no restrictions’.

All operations affecting the current user are by default run against the logon server of the current user (taken from the environment
variable LOGONSERVER. When password or account information of other users should be changed, the logon server is evaluated
automatically. In rare cases, it might be necessary to switch to another domain controller to perform the action. In this case,
use the \-d option to specify the machine to run the command against. Note that the current user must have account operator
permissions to perform user account changes in a domain.
Users can use the **passwd -R** to enter a password which then gets stored in a special area of the registry on the local system, which is also used by Windows to store passwords of accounts running Windows services. When a privileged Cygwin application calls the **set{e}uid(user_id)** system call, Cygwin checks if a password for that user has been stored in this registry area. If so, it uses this password to switch to this user account using that password. This allows you to logon through, for instance, **ssh** with public key authentication and get a full qualified user token with all credentials for network access. However, the method has some drawbacks security-wise. This is explained in more detail in Section 3.6.

Please note that storing passwords in that registry area is a privileged operation which only administrative accounts are allowed to do. Administrators can enter the password for other user accounts into the registry by specifying the username on the commandline. If normal, non-admin users should be allowed to enter their passwords using **passwd -R**, it’s required to run **cygserver** as a service under the LocalSystem account before running **passwd -R**. This only affects storing passwords. Using passwords in privileged processes does not require **cygserver** to run.

Limitations: Users may not be able to change their password on some systems.

### 3.8.16 pldd

**pldd** — List dynamic shared objects loaded into a process

**Synopsis**

```
pldd [OPTION...] PID
```

**Options**

- `-?`, `--help`  
  Give this help list
- `--usage`  
  Give a short usage message
- `-V`, `--version`  
  Print program version

**Description**

`pldd` prints the shared libraries (DLLs) loaded by the process with the given PID.

### 3.8.17 ps

**ps** — Report process status

**Synopsis**

```
ps [-aefls] [-u UID]
```

**Options**

- `-a`, `--all`  
  show processes of all users
- `-e`, `--everyone`  
  show processes of all users
- `-f`, `--full`  
  show process uids, ppids
- `-h`, `--help`  
  output usage information and exit
- `-l`, `--long`  
  show process uids, ppids, pgids, winpids
- `-p`, `--process`  
  show information for specified PID
- `-s`, `--summary`  
  show process summary
- `-u`, `--user`  
  list processes owned by UID
- `-V`, `--version`  
  output version information and exit
- `-W`, `--windows`  
  show windows as well as cygwin processes

With no options, **ps** outputs the long format by default.
Description

The `ps` program gives the status of all the Cygwin processes running on the system (ps = "process status"). Due to the limitations of simulating a POSIX environment under Windows, there is little information to give.

The PID column is the process ID you need to give to the `kill` command. The PPID is the parent process ID, and PGID is the process group ID. The WINPID column is the process ID displayed by NT's Task Manager program. The TTY column gives which pseudo-terminal a process is running on, or a ‘?’ for services. The UID column shows which user owns each process. STIME is the time the process was started, and COMMAND gives the name of the program running. Listings may also have a status flag in column zero; S means stopped or suspended (in other words, in the background), I means waiting for input or interactive (foreground), and O means waiting to output.

By default, `ps` will only show processes owned by the current user. With either the `-a` or `-e` option, all user’s processes (and system processes) are listed. There are historical UNIX reasons for the synonymous options, which are functionally identical. The `-f` option outputs a "full" listing with usernames for UIDs. The `-l` option is the default display mode, showing a "long" listing with all the above columns. The other display option is `-s`, which outputs a shorter listing of just PID, TTY, STIME, and COMMAND. The `-u` option allows you to show only processes owned by a specific user. The `-p` option allows you to show information for only the process with the specified PID. The `-W` option causes `ps` show non-Cygwin Windows processes as well as Cygwin processes. The WINPID is also the PID, and they can be killed with the Cygwin `kill` command’s `-f` option.

3.8.18 regtool

regtool — View or edit the Windows registry

Synopsis

```
regtool [OPTION] (add|check|get|list|remove|unset|load|unload|save) KEY
```

Options

Actions:

- `add KEY\SUBKEY` add new SUBKEY
- `check KEY` exit 0 if KEY exists, 1 if not
- `get KEY\VALUE` prints VALUE to stdout
- `list KEY` list SUBKEYs and VALUES
- `remove KEY` remove KEY
- `set KEY\VALUE [data ...]` set VALUE
- `unset KEY\VALUE` removes VALUE from KEY
- `load KEY\SUBKEY PATH` load hive from PATH into new SUBKEY
- `unload KEY\SUBKEY` unload hive and remove SUBKEY
- `save KEY\SUBKEY PATH` save SUBKEY into new file PATH
- `restore KEY\SUBKEY PATH` restore SUBKEY from file PATH

Options for ‘list’ Action:

- `-k, --keys` print only KEYS
- `-l, --list` print only VALUES
- `-p, --postfix` like ls -p, appends ‘\’ postfix to KEY names

Options for ‘get’ Action:

- `-b, --binary` print REG_BINARY data as hex bytes
- `-n, --none` print data as stream of bytes as stored in registry
- `-x, --hex` print numerical data as hex numbers

Options for ‘set’ Action:
The `regtool` program allows shell scripts to access and modify the Windows registry. Note that modifying the Windows registry is dangerous, and carelessness here can result in an unusable system. Be careful.

The `-v` option means "verbose". For most commands, this causes additional or lengthier messages to be printed. Conversely, the `-q` option suppresses error messages, so you can use the exit status of the program to detect if a key exists or not (for example).

The `-w` option allows you to access the 64 bit view of the registry. Several subkeys exist in a 32 bit and a 64 bit version when running on Windows 64. Since Cygwin is running in 32 bit mode, it only has access to the 32 bit view of these registry keys. When using the `-w` switch, the 64 bit view is used and `regtool` can access the entire registry. This option is simply ignored when running on 32 bit Windows versions.

The `-W` option allows you to access the 32 bit view on the registry. The purpose of this option is mainly for symmetry. It permits creation of OS agnostic scripts which would also work in a hypothetical 64 bit version of Cygwin.

You must provide `regtool` with an action following options (if any). Currently, the action must be `add`, `set`, `check`, `get`, `list`, `remove`, `set`, or `unset`.

The `add` action adds a new key. The `check` action checks to see if a key exists (the exit code of the program is zero if it does, nonzero if it does not). The `get` action gets the value of a key, and prints it (and nothing else) to stdout. Note: if the value doesn’t
exist, an error message is printed and the program returns a non-zero exit code. If you give `-q`, it doesn’t print the message but does return the non-zero exit code.

The `list` action lists the subkeys and values belonging to the given key. With `list`, the `-k` option instructs `regtool` to print only KEYs, and the `-l` option to print only VALUEs. The `-p` option postfixes a `/` to each KEY, but leave VALUEs with no postfix. The `remove` action removes a key. Note that you may need to remove everything in the key before you may remove it, but don’t rely on this stopping you from accidentally removing too much.

The `get` action prints a value within a key. With the `-b` option, data is printed as hex bytes. `-n` allows to print the data as a typeless stream of bytes. Integer values (REG_DWORD, REG_QWORD) are usually printed as decimal values. The `-x` option allows to print the numbers as hexadecimal values.

The `set` action sets a value within a key. `-b` means it’s binary data (REG_BINARY). The binary values are specified as hex bytes in the argument list. If the argument is `-`, binary data is read from stdin instead. `-d` or `-i` means the value is a 32 bit integer value (REG_DWORD). `-D` means the value is a 32 bit integer value in Big Endian representation (REG_DWORD_BIG_ENDIAN). `-q` means the value is a 64 bit integer value (REG_QWORD). `-s` means the value is a string (REG_SZ). `-e` means it’s an expanding string (REG_EXPAND_SZ) that contains embedded environment variables. `-m` means it’s a multi-string (REG_MULTI_SZ). If you don’t specify one of these, `regtool` tries to guess the type based on the value you give. If it looks like a number, it’s a DWORD, unless it’s value doesn’t fit into 32 bit, in which case it’s a QWORD. If it starts with a percent, it’s an expanding string. If you give multiple values, it’s a multi-string. Else, it’s a regular string.

The `unset` action removes a value from a key.

The `load` action adds a new subkey and loads the contents of a registry hive into it. The parent key must be HKEY_LOCAL_MACHINE or HKEY_USERS. The `unload` action unloads the file and removes the subkey.

The `save` action saves a subkey into a registry file. Ideally you append the suffix `.reg` to the file so it gets automatically recognized as registry file by Windows Explorer.

The `restore` action restores a registry subkey from a file saved via the aforementioned save action.

By default, the last "\" or "/" is assumed to be the separator between the key and the value. You can use the `-K` option to provide an alternate key/value separator character.

### 3.8.19 setfacl

**setfacl — Modify file and directory access control lists (ACLs)**

**Synopsis**

```
setfacl [-n] {-f ACL_FILE | -s acl_entries} FILE...
setfacl [-n] {-b|-k|-x acl_entries} {-m acl_entries} FILE...
```

**Options**

- `-b, --remove-all` remove all extended ACL entries
- `-x, --delete` delete one or more specified ACL entries
- `-f, --set-file` set ACL entries for FILE to ACL entries read
- `-k, --remove-default` remove all default ACL entries
- `-m, --modify` modify one or more specified ACL entries
- `-n, --no-mask` don’t recalculate the effective rights mask
- `-s, --set` set specified ACL entries on FILE
- `-V, --version` print version and exit
- `-h, --help` this help text

At least one of `-b`, `-x`, `-f`, `-k`, `-m`, `-s` must be specified

Description

For each file given as parameter, `setfacl` will either replace its complete ACL (-s, -f), or it will add, modify, or delete ACL entries. For more information on Cygwin and Windows ACLs, see Section 3.6 in the Cygwin User’s Guide.

Acl_entries are one or more comma-separated ACL entries from the following list:

<table>
<thead>
<tr>
<th>Entry Type</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>u[ser]:perm</td>
</tr>
<tr>
<td>User</td>
<td>u[ser]:uid:perm</td>
</tr>
<tr>
<td>Group</td>
<td>g[roup]:perm</td>
</tr>
<tr>
<td>Group</td>
<td>g[roup]:gid:perm</td>
</tr>
<tr>
<td>Mask</td>
<td>m[ask]:perm</td>
</tr>
<tr>
<td>Others</td>
<td>o[ther]:perm</td>
</tr>
</tbody>
</table>

Default entries are like the above with the additional default identifier. For example:

<table>
<thead>
<tr>
<th>Entry Type</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>d[efault]:u[ser]:uid:perm</td>
</tr>
</tbody>
</table>

`perm` is either a 3-char permissions string in the form "rwx" with the character ‘-’ for no permission or it is the octal representation of the permissions, a value from 0 (equivalent to "---") to 7 ("rwx"). `uid` is a user name or a numerical uid. `gid` is a group name or a numerical gid.

The following options are supported:

- `-b, --remove-all` Remove all extended ACL entries. The base ACL entries of the owner, group and others are retained. This option can be combined with the `-k, --remove-default` option to delete all non-standard POSIX permissions.

- `-x, --delete` Delete one or more specified entries from the file’s ACL. The owner, group and others entries must not be deleted. Acl_entries to be deleted should be specified without permissions, as in the following list:

<table>
<thead>
<tr>
<th>Entry Type</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>u[ser]:uid[: ]</td>
</tr>
<tr>
<td>Group</td>
<td>g[roup]:gid[: ]</td>
</tr>
<tr>
<td>Mask</td>
<td>m[ask][: ]</td>
</tr>
<tr>
<td>Default</td>
<td>d[efault]:u[ser][:uid]</td>
</tr>
<tr>
<td>Default</td>
<td>d[efault]:g[roup][:gid]</td>
</tr>
<tr>
<td>Default</td>
<td>d[efault]:m[ask][: ]</td>
</tr>
<tr>
<td>Default</td>
<td>d[efault]:o[ther][: ]</td>
</tr>
</tbody>
</table>

- `-f, --set-file` Take the Acl_entries from ACL_FILE one per line. Whitespace characters are ignored, and the character "#" may be used to start a comment. The special filename "-" indicates reading from stdin. Note that you can use this with `getfacl` and `setfacl` to copy ACLs from one file to another:

```bash
$ getfacl source_file | setfacl -f - target_file
```

Required entries are: one user entry for the owner of the file, one group entry for the group of the file, and one other entry.

If additional user and group entries are given: a mask entry for the file group class of the file, and no duplicate user or group entries with the same uid/ gid.

If it is a directory: one default user entry for the owner of the file, one default group entry for the group of the file, one default mask entry for the file group class, and one default other entry.

- `-k, --remove-default` Remove all default ACL entries. If no default ACL entries exist, no warnings are issued. This option can be combined with the `-b, --remove-all` option to delete all non-standard POSIX permissions.

- `-m, --modify` Add or modify one or more specified ACL entries. Acl_entries is a comma-separated list of entries from the same list as above.

- `-n, --no-mask` Valid in conjunction with `-m`. Do not recalculate the effective rights mask. The default behavior of `setfacl` is to recalculate the ACL mask entry, unless a mask entry was explicitly given. The mask entry is set to the union of all permissions of the owning group, and all named user and group entries. (These are exactly the entries affected by the mask entry).

- `--mask` Valid in conjunction with `-m`. Do recalculate the effective rights mask, even if an ACL mask entry was explicitly given. (See the `-n` option.)
Like `-f`, but set the file’s ACL with Acl_entries specified in a comma-separated list on the command line.

While the `-x` and `-m` options may be used in the same command, the `-f` and `-s` options may be used only exclusively.

Directories may contain default ACL entries. Files created in a directory that contains default ACL entries will have permissions according to the combination of the current umask, the explicit permissions requested and the default ACL entries.

### 3.8.20 setmetamode

**setmetamode** — Get or set keyboard meta mode

**Synopsis**

```
setmetamode [metabit|escprefix]
```

**Options**

Without argument, it shows the current meta key mode.

- `metabit|meta|bit` The meta key sets the top bit of the character.
- `escprefix|esc|prefix` The meta key sends an escape prefix.

Other options:

- `-h, --help` This text
- `-V, --version` Print program version and exit

**Description**

`setmetamode` can be used to determine and set the key code sent by the meta (aka Alt) key.

### 3.8.21 ssp

**ssp** — Single-step profile COMMAND

**Synopsis**

```
ssp [options] low_pc high_pc command...
```

**Options**

- `-c, --console-trace` trace every EIP value to the console. *Lots* slower.
- `-d, --disable` disable single-stepping by default; use `OutputDebugString ("ssp on")` to enable stepping
- `-e, --enable` enable single-stepping by default; use `OutputDebugString ("ssp off")` to disable stepping
- `-h, --help` output usage information and exit
- `-l, --dll` enable dll profiling. A chart of relative DLL usage is produced after the run.
- `-s, --sub-threads` trace sub-threads too. Dangerous if you have race conditions.
- `-t, --trace-eip` trace every EIP value to a file TRACE.SSP. This
Description

SSP - The Single Step Profiler

Original Author: DJ Delorie

The SSP is a program that uses the Win32 debug API to run a program one ASM instruction at a time. It records the location of each instruction used, how many times that instruction is used, and all function calls. The results are saved in a format that is usable by the profiling program gprof, although gprof will claim the values are seconds, they really are instruction counts. More on that later.

Because the SSP was originally designed to profile the Cygwin DLL, it does not automatically select a block of code to report statistics on. You must specify the range of memory addresses to keep track of manually, but it’s not hard to figure out what to specify. Use the "objdump" program to determine the bounds of the target’s ".text" section. Let’s say we’re profiling cygwin1.dll. Make sure you’ve built it with debug symbols (else gprof won’t run) and run objdump like this:

```
$ objdump -h cygwin1.dll
```

It will print a report like this:

```
cygwin1.dll: file format pei-i386
Sections:
  Idx Name Size  VMA      LMA      File off  Algn
 0 .text 007ea00 61001000 61001000 00000400 2\*\*2
     CONTENTS, ALLOC, LOAD, READONLY, CODE, DATA
 1 .data 008000 61080000 61080000 007ea00 2\*\*2
     CONTENTS, ALLOC, LOAD, DATA
...
```

The only information we’re concerned with are the VMA of the .text section and the VMA of the section after it (sections are usually contiguous; you can also add the Size to the VMA to get the end address). In this case, the VMA is 0x61001000 and the ending address is either 0x61080000 (start of .data method) or 0x0x6107fa00 (VMA+Size method).

There are two basic ways to use SSP - either profiling a whole program, or selectively profiling parts of the program.

To profile a whole program, just run ssp without options. By default, it will step the whole program. Here’s a simple example, using the numbers above:

```
$ ssp 0x61001000 0x61080000 hello.exe
```

This will step the whole program. It will take at least 8 minutes on a PII/300 (yes, really). When it’s done, it will create a file called "gmon.out". You can turn this data file into a readable report with gprof:

```
$ gprof -b cygwin1.dll
```

The "-b" means 'skip the help pages'. You can omit this until you’re familiar with the report layout. The gprof documentation explains a lot about this report, but ssp changes a few things. For example, the first part of the report reports the amount of time spent in each function, like this:

```
Each sample counts as 0.01 seconds.
% cumulative  self   self    total
  time seconds  seconds  calls  ms/call  ms/call   name
10.02  231.22   72.43    46  1574.57  1574.57  strcspn
  7.95  288.70   57.48   130  442.15   442.15  strncasematch
```

The "seconds" columns are really CPU opcodes, 1/100 second per opcode. So, "231.22" above means 23,122 opcodes. The ms/call values are 10x too big; 1574.57 means 157.457 opcodes per call. Similar adjustments need to be made for the "self" and "children" columns in the second part of the report.

OK, so now we’ve got a huge report that took a long time to generate, and we’ve identified a spot we want to work on optimizing. Let’s say it’s the time() function. We can use SSP to selectively profile this function by using OutputDebugString() to control SSP from within the program. Here’s a sample program:

```c
#include <windows.h>
main()
{
    time_t t;
    OutputDebugString("ssp on");
    time(&t);
    OutputDebugString("ssp off");
}
```

Then, add the -d option to ssp to default to *disabling* profiling. The program will run at full speed until the first OutputDebugString, then step until the second. You can then use gprof (as usual) to see the performance profile for just that portion of the program’s execution.

There are many options to ssp. Since step-profiling makes your program run about 1,000 times slower than normal, it’s best to understand all the options so that you can narrow down the parts of your program you need to single-step.

-`v` - verbose. This prints messages about threads starting and stopping, OutputDebugString calls, DLLs loading, etc.

-`t` and `-c` - tracing. With `-t`, *every* step’s address is written to the file "trace.ssp". This can be used to help debug functions, since it can trace multiple threads. Clever use of scripts can match addresses with disassembled opcodes if needed. Warning: creates huge files, very quickly. `-c` prints each address to the console, useful for debugging key chunks of assembler. Use add r2line -C -f -s -e foo.exe < trace.ssp > lines.ssp and then perl cvttrace to convert to symbolic traces.

-`s` - subthreads. Usually, you only need to trace the main thread, but sometimes you need to trace all threads, so this enables that. It’s also needed when you want to profile a function that only a subthread calls. However, using OutputDebugString automatically enables profiling on the thread that called it, not the main thread.

-`-l` - dll profiling. Generates a pretty table of how much time was spent in each dll the program used. No sense optimizing a function in your program if most of the time is spent in the DLL. I usually use the `v`, `s`, and `-l` options:

```
$ ssp -v -s -l -d 0x61001000 0x61080000 hello.exe
```

### 3.8.22 strace

`strace` — Trace system calls and signals

**Synopsis**

```
strace [OPTIONS] <command-line>
strace [OPTIONS] -p <pid>
```

**Options**

- `-b`, `--buffer-size=SIZE` set size of output file buffer
- `-d`, `--no-delta` don’t display the delta-t microsecond timestamp
- `-e`, `--events` log all Windows DEBUG_EVENTS (toggle - default true)
- `-f`, `--trace-children` trace child processes (toggle - default true)
- `-h`, `--help` output usage information and exit
- `-m`, `--mask=MASK` set message filter mask
- `-t`, `--no-delta`
-n, --crack-error-numbers output descriptive text instead of error numbers for Windows errors
-o, --output=FILENAME set output file to FILENAME
-p, --pid=n attach to executing program with cygwin pid n
-q, --quiet toggle "quiet" flag. Defaults to on if "-p", off otherwise.
-S, --flush-period=PERIOD flush buffered strace output every PERIOD secs
-t, --timestamp use an absolute hh:mm:ss timestamp insted of the default microsecond timestamp. Implies -d
-T, --toggle toggle tracing in a process already being traced. Requires -p <pid>
-u, --usecs toggle printing of microseconds timestamp
-V, --version output version information and exit
-w, --new-window spawn program under test in a new window

MASK can be any combination of the following mnemonics and/or hex values (0x is optional). Combine masks with ‘+’ or ‘,’ like so:

--mask=wm+system,malloc+0x00800

Mnemonic Hex Corresponding Def Description
=========================================================================
all 0x000001 (_STRACE_ALL) All strace messages.
flush 0x000002 (_STRACE_FLUSH) Flush output buffer after each message.
inherit 0x000004 (_STRACE_INHERIT) Children inherit mask from parent.
uhoh 0x000008 (_STRACE_UHOH) Unusual or weird phenomenon.
syscall 0x000010 (_STRACE_SYSCALL) System calls.
startup 0x000020 (_STRACE_STARTUP) argc/envp printout at startup.
debug 0x000040 (_STRACE_DEBUG) Info to help debugging.
paranoid 0x000080 (_STRACE_PARANOID) Paranoid info.
termios 0x000100 (_STRACE_TERMIOS) Info for debugging termios stuff.
select 0x000200 (_STRACE_SELECT) Info on ugly select internals.
wm 0x000400 (_STRACE_WM) Trace Windows msgs (enable _strace_wm).
sigp 0x000800 (_STRACE_SIGP) Trace signal and process handling.
minimal 0x001000 (_STRACE_MINIMAL) Very minimal strace output.
pthread 0x002000 (_STRACE_PTHREAD) Pthread calls.
extdump 0x004000 (_STRACE_EXITDUMP) Dump strace cache on exit.
system 0x008000 (_STRACE_SYSTEM) Serious error; goes to console and log.
nomutex 0x010000 (_STRACE_NOMUXTEX) Don’t use mutex for synchronization.
malloc 0x020000 (_STRACE_MALLOC) Trace malloc calls.
thread 0x040000 (_STRACE_THREAD) Thread-locking calls.
special 0x100000 (_STRACE_SPECIAL) Special debugging printfs for non-checked-in code

Description

The strace program executes a program, and optionally the children of the program, reporting any Cygwin DLL output from the program(s) to stdout, or to a file with the -o option. With the -w option, you can start an strace session in a new window, for example:

```
$ strace -o tracing_output -w sh -c 'while true; do echo "tracing..."; done' &
```

This is particularly useful for strace sessions that take a long time to complete.

Note that strace is a standalone Windows program and so does not rely on the Cygwin DLL itself (you can verify this with cygcheck). As a result it does not understand symlinks. This program is mainly useful for debugging the Cygwin DLL itself.

3.8.23 tzset

tzset — Print POSIX-compatible timezone ID from current Windows timezone setting
**Synopsis**

tzset [OPTION]

**Options**

Options:
- `-h, --help` output usage information and exit.
- `-V, --version` output version information and exit.

**Description**

Use tzset to set your TZ variable. In POSIX-compatible shells like bash, dash, mksh, or zsh:

```bash
export TZ=$(tzset)
```

In csh-compatible shells like tcsh:

```bash
setenv TZ 'tzset'
```

The `tzset` tool reads the current timezone from Windows and generates a POSIX-compatible timezone information for the TZ environment variable from that information. That’s all there is to it. For the way how to use it, see the above usage information.

### 3.8.24 umount

** Synopsis **

umount — Unmount filesystems

** Synopsis **

umount [OPTION] [<posixpath>]

**Options**

Options:
- `-h, --help` output usage information and exit
- `-U, --remove-user-mounts` remove all user mounts
- `-V, --version` output version information and exit

**Description**

The `umount` program removes mounts from the mount table in the current session. If you specify a POSIX path that corresponds to a current mount point, `umount` will remove it from the current mount table. Note that you can only remove user mount points. The `-U` flag may be used to specify removing all user mount points from the current user session.

See Section 3.1.2 for more information on the mount table.
3.9 Using Cygwin effectively with Windows

Cygwin is not a full operating system, and so must rely on Windows for accomplishing some tasks. For example, Cygwin provides a POSIX view of the Windows filesystem, but does not provide filesystem drivers of its own. Therefore part of using Cygwin effectively is learning to use Windows effectively. Many Windows utilities provide a good way to interact with Cygwin's predominately command-line environment. For example, `ipconfig.exe` provides information about network configuration, and `net.exe` views and configures network file and printer resources. Most of these tools support the `/?` switch to display usage information.

Unfortunately, no standard set of tools included with all versions of Windows exists. Generally, the younger the Windows version, the more complete are the on-board tools. Additionally, many independent sites such as download.com, simtel.net, and Microsoft's own Sysinternals provide quite useful command-line utilities, as far as they are not already provided by Cygwin. A few Windows tools, such as `find.exe`, `link.exe`, and `sort.exe`, may conflict with the Cygwin versions make sure that you use the full path (`/usr/bin/find`) or that your Cygwin `bin` directory comes first in your `PATH`.

3.9.1 Pathnames

Windows programs do not understand POSIX pathnames, so any arguments that reference the filesystem must be in Windows (or DOS) format or translated. Cygwin provides the `cygpath` utility for converting between Windows and POSIX paths. A complete description of its options and examples of its usage are in `cygpath(1)`, including a shell script for starting Windows Explorer in any directory. The same format works for most Windows programs, for example:

```
notepad.exe "$(cygpath -aw "Desktop/Phone Numbers.txt")"
```

A few programs require a Windows-style, semicolon-delimited path list, which `cygpath` can translate from a POSIX path with the `-p` option. For example, a Java compilation from `bash` might look like this:

```
javac -cp "$(cygpath -pw "$CLASSPATH")" hello.java
```

Since using quoting and subshells is somewhat awkward, it is often preferable to use `cygpath` in shell scripts.

3.9.2 Cygwin and Windows Networking

Many popular Cygwin packages, such as `ncftp`, `lynx`, and `wget`, require a network connection. Since Cygwin relies on Windows for connectivity, if one of these tools is not working as expected you may need to troubleshoot using Windows tools. The first test is to see if you can reach the URL's host with `ping.exe`, one of the few utilities included with every Windows version since Windows 95. If you chose to install the `inetutils` package, you may have both Windows and Cygwin versions of utilities such as `ftp` and `telnet`. If you are having problems using one of these programs, see if the alternate one works as expected.

There are a variety of other programs available for specific situations. If your system does not have an always-on network connection, you may be interested in `rasdial.exe` for automating dialup connections. Users who frequently change their network configuration can script these changes with `netsh.exe`. For proxy users, the open source NTLM Authorization Proxy Server or the no-charge Hummingbird SOCKS Proxy may allow you to use Cygwin network programs in your environment.

3.9.3 Creating shortcuts

By default, Cygwin does not create symlinks as .lnk files, but there’s an option to do that, see Section 3.5. These symlink .lnk files are compatible with Windows-created .lnk files, but they are still different. They do not include much of the information that is available in a standard Microsoft shortcut, such as the working directory, an icon, etc. The `cygutils` package includes a `mkshortcut` utility for creating standard native Microsoft .lnk files from the command line.

But here’s the problem. If Cygwin handled these native shortcuts like any other symlink, you could not archive Microsoft .lnk files into `tar` archives and keep all the information in them. After unpacking, these shortcuts would have lost all the extra information and would be no different than standard Cygwin symlinks. Therefore these two types of links are treated differently. Unfortunately, this means that the usual Unix way of creating and using symlinks does not work with native Windows shortcuts.
3.9.4 Printing

There are several options for printing from Cygwin, including the `lpr` found in cygutils-extra (not to be confused with the native Windows `lpr.exe`). The easiest way to use cygutils-extra’s `lpr` is to specify a default device name in the PRINTER environment variable. You may also specify a device on the command line with the `-d` or `-P` options, which will override the environment variable setting.

A device name may be a UNC path (`\server_name\printer_name`), a reserved DOS device name (`prn`, `lpt1`), or a local port name that is mapped to a printer share. Note that forward slashes may be used in a UNC path (`//server_name/printer_name`), which is helpful when using `lpr` from a shell that uses the backslash as an escape character.

`lpr` sends raw data to the printer; no formatting is done. Many, but not all, printers accept plain text as input. If your printer supports PostScript, packages such as `a2ps` and `enscript` can prepare text files for printing. The `ghostscript` package also provides some translation from PostScript to various native printer languages. Additionally, a native Windows application for printing PostScript, `gsprint`, is available from the Ghostscript website.
Chapter 4

Programming with Cygwin

4.1 Using GCC with Cygwin

4.1.1 Standard Usage

Use gcc to compile, just like under UNIX. Refer to the GCC User’s Guide for information on standard usage and options. Here’s a simple example:

Example 4.1 Building Hello World with GCC

```
bash$ gcc hello.c -o hello.exe
bash$ hello.exe
Hello, World
bash$
```

4.1.2 Building applications for 64 bit Cygwin

The 64 bit Cygwin toolchain uses the Microsoft x64 calling convention by default, so you can create applications using the Win32 API just as with the 32 bit Cygwin toolchain.

There’s just one important difference. The 64 bit Cygwin compilers use a different data model than the Mingw and Microsoft compilers. For reference, see the Wikipedia entry on 64-bit computing.

While the Mingw and Microsoft compilers use the LLP64 data model, Cygwin compilers use the LP64 data model, just like Linux. This affects the size of the type long. In the LLP64 model preferred by Microsoft, sizeof(long) is 4. This applies for the related Win32 types like LONG, ULONG, DWORD, etc., too.

In the LP64 model used by Cygwin, sizeof(long) is 8, just like the size of pointers or the types size_t/ssize_t. This simplifies porting Linux applications to 64 bit Cygwin, but it requires due diligence when calling Windows functions taking LONG, ULONG, DWORD, or any other equivalent type. This is especially important in conjunction with pointers.

Here’s an example. The Win32 function ReadFile returns the number of read bytes via a pointer to a DWORD variable:

```
BOOL WINAPI ReadFile (HANDLE, PVOID, DWORD, PDWORD, LPOVERLAPPED);
```

Note that the forth parameter is a pointer to a DWORD, thus it’s a pointer to a 4 byte type, on 32 as well as on 64 bit Windows. Now we write our own my_read function using ReadFile:
Example 4.2 64bit-programming, Using ReadFile, 1st try

```c
ssize_t
my_read (int fd, void *buffer, size_t bytes_to_read)
{
    HANDLE fh = _get_osfhandle (fd);
    ssize_t bytes_read;

    if (ReadFile (fh, buffer, bytes_to_read, (PDWORD) &bytes_read, NULL))
        return bytes_read;
    set_errno_from_get_last_error ();
    return -1;
}
```

While this example code works fine on 32 bit Windows, it has in fact a bad bug. The assumption that the size of ssize_t is the same as the size of DWORD is wrong for 64 bit. In fact, since sizeof(ssize_t) is 8. ReadFile will write the number of read bytes into the lower 4 bytes of the variable bytes_read, while the upper 4 bytes will contain an undefined value. my_read will very likely return the wrong number of read bytes to the caller.

Here’s the fixed version of my_read:

Example 4.3 64bit-programming, Using ReadFile, 2nd try

```c
ssize_t
my_read (int fd, void *buffer, size_t bytes_to_read)
{
    HANDLE fh = _get_osfhandle (fd);
    DWORD bytes_read;

    if (ReadFile (fh, buffer, bytes_to_read, &bytes_read, NULL))
        return (ssize_t) bytes_read;
    set_errno_from_get_last_error ();
    return -1;
}
```

4.1.3 GUI Mode Applications

Cygwin comes with an X server, so usually you should compile your GUI applications as X applications to allow better interopera-

Other than that, Cygwin allows you to build programs with full access to the standard Windows API, including the GUI functions as defined in any Microsoft or off-the-shelf publication.

The build process is similar to any other build process. The only difference is that you use `gcc -mwindows` to link your program into a GUI application instead of a command-line application. Here’s an example Makefile:

```makefile
myapp.exe : myapp.o myapp.res
    gcc -mwindows myapp.o myapp.res -o $@

myapp.res : myapp.rc resource.h
    windres $< -O coff -o $@
```

Note the use of `windres` to compile the Windows resources into a COFF-format .res file. That will include all the bitmaps, icons, and other resources you need, into one handy object file. For more information on `windres`, consult the Binutils manual.
4.2 Debugging Cygwin Programs

When your program doesn’t work right, it usually has a "bug" in it, meaning there’s something wrong with the program itself that is causing unexpected results or crashes. Diagnosing these bugs and fixing them is made easy by special tools called debuggers.

In the case of Cygwin, the debugger is GDB, which stands for "GNU DeBugger". This tool lets you run your program in a controlled environment where you can investigate the state of your program while it is running or after it crashes. Crashing programs sometimes create "core" files. In Cygwin these are regular text files that cannot be used directly by GDB.

Before you can debug your program, you need to prepare your program for debugging. What you need to do is add \(-g\) to all the other flags you use when compiling your sources to objects.

Example 4.4 Compiling with -g

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bash$ gcc -g -O2 -c myapp.c</td>
<td>Compiles with debugging information</td>
</tr>
<tr>
<td>bash$ gcc -g myapp.c -o myapp</td>
<td>Builds the executable with debugging information</td>
</tr>
</tbody>
</table>

What this does is add extra information to the objects (they get much bigger too) that tell the debugger about line numbers, variable names, and other useful things. These extra symbols and debugging information give your program enough information about the original sources so that the debugger can make debugging much easier for you.

To invoke GDB, simply type \(gdb\ myapp.exe\) at the command prompt. It will display some text telling you about itself, then \((gdb)\) will appear to prompt you to enter commands. Whenever you see this prompt, it means that gdb is waiting for you to type in a command, like \(run\) or \(help\). Oh :-( type \(help\) to get help on the commands you can type in, or read the \([?]\) for a complete description of GDB and how to use it.

If your program crashes and you’re trying to figure out why it crashed, the best thing to do is type \(run\) and let your program run. After it crashes, you can type \(where\) to find out where it crashed, or \(info locals\) to see the values of all the local variables. There’s also a \(print\) that lets you look at individual variables or what pointers point to.

If your program is doing something unexpected, you can use the \(break\) command to tell gdb to stop your program when it gets to a specific function or line number:

Example 4.5 "break" in gdb

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(gdb) break my_function</td>
<td>Stops at the my_function function</td>
</tr>
<tr>
<td>(gdb) break 47</td>
<td>Stops at line 47</td>
</tr>
</tbody>
</table>

Now, when you type \(run\) your program will stop at that "breakpoint" and you can use the other gdb commands to look at the state of your program at that point, modify variables, and \(step\) through your program’s statements one at a time.

Note that you may specify additional arguments to the \(run\) command to provide command-line arguments to your program. These two cases are the same as far as your program is concerned:

Example 4.6 Debugging with command line arguments

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bash$ myprog -t foo --queue 47</td>
<td>Debugging with command line arguments</td>
</tr>
<tr>
<td>bash$ gdb myprog</td>
<td>Starts gdb with the command line arguments</td>
</tr>
<tr>
<td>(gdb) run -t foo --queue 47</td>
<td>Starts your program with command line arguments</td>
</tr>
</tbody>
</table>

4.3 Building and Using DLLs

DLLs are Dynamic Link Libraries, which means that they’re linked into your program at run time instead of build time. There are three parts to a DLL:

- the exports
- the code and data
• the import library

The code and data are the parts you write - functions, variables, etc. All these are merged together, like if you were building one big object files, and put into the dll. They are not put into your .exe at all.

The exports contains a list of functions and variables that the dll makes available to other programs. Think of this as the list of "global" symbols, the rest being hidden. Normally, you’d create this list by hand with a text editor, but it’s possible to do it automatically from the list of functions in your code. The dlltool program creates the exports section of the dll from your text file of exported symbols.

The import library is a regular UNIX-like .a library, but it only contains the tiny bit of information needed to tell the OS how your program interacts with ("imports") the dll. This information is linked into your .exe. This is also generated by dlltool.

4.3.1 Building DLLs

This page gives only a few simple examples of gcc’s DLL-building capabilities. To begin an exploration of the many additional options, see the gcc documentation and website, currently at http://gcc.gnu.org/

Let’s go through a simple example of how to build a dll. For this example, we’ll use a single file myprog.c for the program (myprog.exe) and a single file mydll.c for the contents of the dll (mydll.dll).

Fortunately, with the latest gcc and binutils the process for building a dll is now pretty simple. Say you want to build this minimal function in mydll.c:

```c
#include <stdio.h>

int
hello()
{
    printf ("Hello World!\n");
}
```

First compile mydll.c to object code:

```bash
gcc -c mydll.c
```

Then, tell gcc that it is building a shared library:

```bash
gcc -shared -o mydll.dll mydll.o
```

That’s it! To finish up the example, you can now link to the dll with a simple program:

```c
int
main ()
{
    hello ();
}
```

Then link to your dll with a command like:

```bash
gcc -o myprog myprog.c -L/ -lmydll
```

However, if you are building a dll as an export library, you will probably want to use the complete syntax:

```bash
gcc -shared -o cyg${module}.dll \
    -Wl,--out-implib=lib${module}.dll.a \
    -Wl,--export-all-symbols \
    -Wl,--enable-auto-import \
    -Wl,--whole-archive ${old_libs} \
    -Wl,--no-whole-archive ${dependency_libs}
```

The name of your library is ${module}, prefixed with cyg for the DLL and lib for the import library. Cygwin DLLs use the cyg prefix to differentiate them from native-Windows MinGW DLLs, see the MinGW website for more details. ${old_libs} are all your object files, bundled together in static libs or single object files and the ${dependency_libs} are import libs you need to link against, e.g ‘-lpng -lz -L/usr/local/special -lmyspeciallib’.
4.3.2 Linking Against DLLs

If you have an existing DLL already, you need to build a Cygwin-compatible import library. If you have the source to compile the DLL, see Section 4.3.1 for details on having gcc build one for you. If you do not have the source or a supplied working import library, you can get most of the way by creating a .def file with these commands (you might need to do this in bash for the quoting to work correctly):

```bash
echo EXPORTS > foo.def
nm foo.dll | grep ' T _' | sed 's/.* T _//' >> foo.def
```

Note that this will only work if the DLL is not stripped. Otherwise you will get an error message: "No symbols in foo.dll".

Once you have the .def file, you can create an import library from it like this:

```bash
dlltool --def foo.def --dllname foo.dll --output-lib foo.a
```

4.4 Defining Windows Resources

windres reads a Windows resource file (*.rc) and converts it to a res or coff file. The syntax and semantics of the input file are the same as for any other resource compiler, so please refer to any publication describing the Windows resource format for details. Also, the windres program itself is fully documented in the Binutils manual. Here’s an example of using it in a project:

```bash
myapp.exe : myapp.o myapp.res
  gcc -mwindows myapp.o myapp.res -o $@

myapp.res : myapp.rc resource.h
  windres $< -O coff -o $@
```

What follows is a quick-reference to the syntax windres supports.

```plaintext
id ACCELERATORS suboptions
  BEG
  "c" 12
  "0" 12
  65 12
  65 12, VIRTKEY ASCII NOINVERT SHIFT CONTROL ALT
  65 12, VIRTKEY, ASCII, NOINVERT, SHIFT, CONTROL, ALT
  (12 is an acc_id)
  END

SHIFT, CONTROL, ALT require VIRTKEY

id BITMAP memflags "filename"
  memflags defaults to MOVEABLE

id CURSOR memflags "filename"
  memflags defaults to MOVEABLE,DISCARDABLE

id DIALOG memflags exstyle x,y,width,height styles BEG controls END
id DIALOGEX memflags exstyle x,y,width,height styles BEG controls END
id DIALOGEX memflags exstyle x,y,width,height,helpid styles BEG controls END

memflags defaults to MOVEABLE
```
exstyle may be EXSTYLE=number
styles: CAPTION "string"
  CLASS id
  STYLE FOO | NOT FOO | {12}
  EXSTYLE number
  FONT number, "name"
  FONT number, "name", weight, italic
  MENU id
  CHARACTERISTICS number
  LANGUAGE number, number
  VERSIONK number
controls:
  AUTO3STATE params
  AUTOCHECKBOX params
  AUTORADIOBUTTON params
  BEDIT params
  CHECKBOX params
  COMBOBOX params
  CONTROL ["name",] id, class, style, x, y, w, h [,exstyle] [data]
  CONTROL ["name",] id, class, style, x, y, w, h, exstyle, helpid [data]
  CTEXT params
  DEFPUSHBUTTON params
  EDITTEXT params
  GROUPBOX params
  HEDIT params
  ICON ["name",] id, x, y [data]
  ICON ["name",] id, x, y, w, h, style, exstyle [data]
  ICON ["name",] id, x, y, w, h, style, exstyle, helpid [data]
  IEDIT params
  LISTBOX params
  LTEXT params
  PBUTTON params
  PUSHBOX params
  PUSHBUTTON params
  RADIOBUTTON params
  RTEXT params
  SCROLLBAR params
  STATE3 params
  USERBUTTON "string", id, x, y, w, h, style, exstyle
  params:
    ["name",] id, x, y, w, h, [data]
    ["name",] id, x, y, w, h, style [,exstyle] [data]
    ["name",] id, x, y, w, h, style, exstyle, helpid [data]
  [data] is optional BEG (string|number) [,,(string|number)] (etc) END

id FONT memflags "filename"
memflags defaults to MOVEABLE|DISCARDABLE

id ICON memflags "filename"
memflags defaults to MOVEABLE|DISCARDABLE

LANGUAGE num, num

id MENU options BEG items END
items:
  "string", id, flags
  SEPARATOR
  POPUP "string" flags BEG menuitems END
flags:
  CHECKED
  GRAYED
4.5 Profiling Cygwin Programs

4.5.1 Introduction

Profiling is a way to analyze your program to find out where it is spending its time. You might need to do this if it seems your program is taking more time to do its job than you think it should. It is always preferable to profile your program than to just guess where the time is being spent; even expert programmers are known to guess badly at this.
In Cygwin, you enable profiling with a compiler flag and you display the resulting profiling data with gprof. Read on to find out how.

To enable profiling of your program, first compile it with an additional gcc flag: `-pg`. That flag should be used when compiling every source file of the program. If your program has a Makefile, you would add the flag to all gcc compilation commands or to the CFLAGS= setting. A manual compilation that enables profiling looks like this:

```
bash$ gcc -pg -g -o myapp myapp.c
```

The `-pg` flag causes gcc to do two additional things as it compiles your program. First, a small bit of code is added to the beginning of each function that records its address and the address it was called from at run time. gprof uses this data to generate a call graph. Second, gcc arranges to have a special "front end" added to the beginning of your program. The front end starts a recurring timer and every time the timer fires, 100 times per second, the currently executing address is saved. gprof uses this data to generate a "flat profile" showing where your program is spending its time.

After compiling your program (and linking it, if you do that as a separate step), you are ready to profile it. Just run it as you normally would. If there are specific code paths you want to profile, take the actions that would exercise those code paths. When your program exits, you will have an additional file in the current directory: gmon.out. That file contains the profiling data gprof processes and displays.

gprof has many flags to control its operation. The `?` details everything gprof can do. We will only use a few of gprof’s flags here. You launch gprof as follows:

```
bash$ gprof [flags] appname [datafile]...
```

If you don’t specify any flags, gprof operates as if you gave it flags `-p` `-q` which means: generate a flat profile with descriptive text and generate a call graph with more descriptive text. In the examples below we will give specific flags to gprof to demonstrate specific displays. We’ll also use flag `-b` which means: be brief, i.e. don’t display the descriptive text. You can also specify a trailing list of one or more profiling data files. If you don’t, gprof assumes gmon.out is the only file to process and display.

### 4.5.2 Examples

#### Example 4.7 Flat profile

```
bash$ gprof -b -p myapp
Flat profile:
```

<table>
<thead>
<tr>
<th>% sample</th>
<th>cumulative</th>
<th>self</th>
<th>self</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>seconds</td>
<td>seconds</td>
<td>calls</td>
<td>s/call</td>
</tr>
<tr>
<td>25.11</td>
<td>13.34</td>
<td>13.34</td>
<td>1</td>
<td>13.34</td>
</tr>
<tr>
<td>25.00</td>
<td>26.62</td>
<td>13.28</td>
<td>1</td>
<td>13.28</td>
</tr>
<tr>
<td>25.00</td>
<td>39.90</td>
<td>13.28</td>
<td>1</td>
<td>13.28</td>
</tr>
<tr>
<td>24.89</td>
<td>53.12</td>
<td>13.22</td>
<td>1</td>
<td>13.22</td>
</tr>
</tbody>
</table>

#### Example 4.8 Call graph

```
bash$ gprof -b -q myapp
Call graph
```

granularity: each sample hit covers 4 byte(s) for 0.02% of 53.12 seconds

<table>
<thead>
<tr>
<th>index</th>
<th>% time</th>
<th>self</th>
<th>children</th>
<th>called</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>100.0</td>
<td>0.00</td>
<td>53.12</td>
<td></td>
<td>&lt;spontaneous&gt;</td>
</tr>
<tr>
<td></td>
<td>13.34</td>
<td>0.00</td>
<td>1/1</td>
<td>1/1</td>
<td>func0    [2]</td>
</tr>
<tr>
<td></td>
<td>13.28</td>
<td>0.00</td>
<td>1/1</td>
<td>1/1</td>
<td>func1    [3]</td>
</tr>
<tr>
<td></td>
<td>13.28</td>
<td>0.00</td>
<td>1/1</td>
<td>1/1</td>
<td>func3    [4]</td>
</tr>
</tbody>
</table>
### Example 4.9 Source line profile

bash$ gprof -b -l myapp

Flat profile:

<table>
<thead>
<tr>
<th>time</th>
<th>% cumulative</th>
<th>self</th>
<th>seconds</th>
<th>calls</th>
<th>s/call</th>
<th>self</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.11</td>
<td>13.34</td>
<td>0.00</td>
<td>1/1</td>
<td>1</td>
<td>13.34</td>
<td>13.34</td>
<td>func0 (myapp.c:9 @ 1004010e0)</td>
</tr>
<tr>
<td>25.00</td>
<td>26.62</td>
<td>13.28</td>
<td>1/1</td>
<td>1</td>
<td>13.28</td>
<td>13.28</td>
<td>func1 (myapp.c:10 @ 10040111a)</td>
</tr>
<tr>
<td>25.00</td>
<td>39.90</td>
<td>13.28</td>
<td>1/1</td>
<td>1</td>
<td>13.28</td>
<td>13.28</td>
<td>func3 (myapp.c:12 @ 10040118e)</td>
</tr>
<tr>
<td>24.89</td>
<td>53.12</td>
<td>13.22</td>
<td>1/1</td>
<td>1</td>
<td>13.22</td>
<td>13.22</td>
<td>func2 (myapp.c:11 @ 100401154)</td>
</tr>
</tbody>
</table>

Call graph

Granularity: each sample hit covers 4 byte(s) for 0.02% of 53.12 seconds

<table>
<thead>
<tr>
<th>index</th>
<th>% time</th>
<th>self</th>
<th>children</th>
<th>called</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>[2]</td>
<td>25.1</td>
<td>13.34</td>
<td>0.00</td>
<td>1/1</td>
<td>main (myapp.c:26 @ 10040123c) [1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>func0 (myapp.c:9 @ 1004010e0) [2]</td>
</tr>
<tr>
<td>[3]</td>
<td>25.0</td>
<td>13.28</td>
<td>0.00</td>
<td>1/1</td>
<td>main (myapp.c:26 @ 10040123c) [1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>func1 (myapp.c:10 @ 10040111a) [3]</td>
</tr>
<tr>
<td>[4]</td>
<td>25.0</td>
<td>13.28</td>
<td>0.00</td>
<td>1/1</td>
<td>main (myapp.c:28 @ 100401246) [5]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>func3 (myapp.c:12 @ 10040118e) [4]</td>
</tr>
<tr>
<td>[6]</td>
<td>24.9</td>
<td>13.22</td>
<td>0.00</td>
<td>1/1</td>
<td>main (myapp.c:27 @ 100401241) [7]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>func2 (myapp.c:11 @ 100401154) [6]</td>
</tr>
</tbody>
</table>

Index by function name

[2] func0 (myapp.c:9 @ 1004010e0) [6] func2 (myapp.c:11 @ 100401154)

[3] func1 (myapp.c:10 @ 10040111a) [4] func3 (myapp.c:12 @ 10040118e)
4.5.3 Special situations

4.5.3.1 Profiling multi-threaded programs

Multi-threaded programs are profiled just like single-threaded programs. There is no mechanism to turn profiling on or off for specific threads. gprof combines the data for all threads when generating its displays.

4.5.3.2 Profiling programs that fork

Programs that fork, i.e., use the fork() system call with or without using exec() afterwards, require special care. Since there is only one gmon.out file, profiling data from the parent process might get overwritten by the child process, or vice-versa, after a fork(). You can avoid this by setting the environment variable GMON_OUT_PREFIX before running your program. If the variable is non-empty, its contents will be used as a prefix to name the profiling data files. Here’s an example:

```
bash$ export GMON_OUT_PREFIX=myapp.out
bash$ ./myapp -fork
bash$ ls myapp.out*
myapp.out.2728 myapp.out.3224
bash$ gprof -bp myapp myapp.out.2728
Flat profile:

Each sample counts as 0.01 seconds.

<table>
<thead>
<tr>
<th>% cumulative</th>
<th>self</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>seconds</td>
<td>seconds</td>
</tr>
<tr>
<td>50.25</td>
<td>30.28</td>
<td>30.28</td>
</tr>
<tr>
<td>24.99</td>
<td>45.34</td>
<td>15.06</td>
</tr>
<tr>
<td>24.76</td>
<td>60.26</td>
<td>14.92</td>
</tr>
</tbody>
</table>
```

```
bash$ gprof -bp myapp myapp.out.3224
Flat profile:

Each sample counts as 0.01 seconds.

<table>
<thead>
<tr>
<th>% cumulative</th>
<th>self</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>seconds</td>
<td>seconds</td>
</tr>
<tr>
<td>49.25</td>
<td>29.36</td>
<td>29.36</td>
</tr>
<tr>
<td>25.43</td>
<td>44.52</td>
<td>15.16</td>
</tr>
<tr>
<td>25.33</td>
<td>59.62</td>
<td>15.10</td>
</tr>
</tbody>
</table>
```

```
bash$ gprof -bp myapp myapp.out*
Flat profile:

Each sample counts as 0.01 seconds.

<table>
<thead>
<tr>
<th>% cumulative</th>
<th>self</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>seconds</td>
<td>seconds</td>
</tr>
<tr>
<td>49.75</td>
<td>59.64</td>
<td>59.64</td>
</tr>
<tr>
<td>25.21</td>
<td>89.86</td>
<td>30.22</td>
</tr>
<tr>
<td>25.04</td>
<td>119.88</td>
<td>30.02</td>
</tr>
</tbody>
</table>
```

As the last gprof command above shows, gprof can combine the data from a selection of profiling data files to generate its displays. Just list the names of those files at the end of the gprof command; you can use a wildcard here. NOTE: If you update your program, remember to remove stale profiling data files before profiling your program again. If you aren’t careful about this, gprof could combine data from your most recent version with stale data from prior versions, possibly giving misleading displays.

4.5.3.3 Getting better profiling resolution

To get better resolution (i.e., more data points) when profiling your program, try running it multiple times with the environment variable GMON_OUT_PREFIX set, as described in the previous situation. There will be multiple profiling data files generated...
and you can have gprof combine the data from all of them into one display.

4.5.3.4 Profiling programs with their libraries

At the time of this writing Cygwin’s profiling support only allows for one range of addresses per program. It is hard-wired to be the range covering the .text segment of your program, which is where your code resides. If you build your program with static libraries (e.g., libfoo.a), the code from those libraries is linked into your program’s .text segment so will be included when profiling. But dynamic libraries (e.g., libfoo.dll) reside in other address ranges and code within them won’t be included.

4.5.3.5 Profiling Cygwin itself

Due to the issue mentioned in the previous situation and other issues, at the time of this writing there is no support for profiling Cygwin itself.