The GNU configure and build system

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1 Introduction

This document describes the GNU configure and build systems. It describes how autoconf, automake, libtool, and make fit together. It also includes a discussion of the older Cygnus configure system.

This document does not describe in detail how to use each of the tools; see the respective manuals for that. Instead, it describes which files the developer must write, which files are machine generated and how they are generated, and where certain common problems should be addressed.

This document draws on several sources, including the autoconf manual by David MacKenzie (see section "autoconf overview" in *Autoconf*), the automake manual by David MacKenzie and Tom Tromey (see section "automake overview" in *GNU Automake*), the libtool manual by Gordon Matzigkeit (see section "libtool overview" in *GNU libtool*), and the Cygnus configure manual by K. Richard Pixley.

1.1 Goals

The GNU configure and build system has two main goals.

The first is to simplify the development of portable programs. The system permits the developer to concentrate on writing the program, simplifying many details of portability across Unix and even Windows systems, and permitting the developer to describe how to build the program using simple rules rather than complex Makefiles.

The second is to simplify the building of programs distributed as source code. All programs are built using a simple, standardized, two step process. The program builder need not install any special tools in order to build the program.

1.2 Tools

The GNU configure and build system is comprised of several different tools. Program developers must build and install all of these tools.

People who just want to build programs from distributed sources normally do not need any special tools beyond a Unix shell, a make program, and a C compiler.

autoconf
: provides a general portability framework, based on testing the features of the host system at build time.

automake
: a system for describing how to build a program, permitting the developer to write a simplified '`Makefile`'.

libtool
: a standardized approach to building shared libraries.

gettext
: provides a framework for translation of text messages into other languages; not really discussed in this document.

m4
: autoconf requires the GNU version of m4; the standard Unix m4 does not suffice.

perl
: automake requires perl.

1.3 History

This is a very brief and probably inaccurate history.

As the number of Unix variants increased during the 1980s, it became harder to write programs which could run on all variants. While it was often possible to use `#ifdef` to identify particular systems, developers frequently did not have access to every system, and the characteristics of some systems changed from version to version.

By 1992, at least three different approaches had been developed:

- The Metaconfig program, by Larry Wall, Harlan Stenn, and Raphael Manfredi.
- The Cygnus configure script, by K. Richard Pixley, and the gcc configure script, by Richard Stallman. These use essentially the same approach, and the developers communicated regularly.
- The autoconf program, by David MacKenzie.

The Metaconfig program is still used for Perl and a few other programs. It is part of the Dist package. I do not know if it is being developed.

In 1994, David MacKenzie and others modified autoconf to incorporate all the features of Cygnus configure. Since then, there has been a slow but steady conversion of GNU programs from Cygnus configure to autoconf. gcc has been converted, eliminating the gcc configure script.

GNU autoconf was regularly maintained until late 1996. As of this writing in June, 1998, it has no public maintainer.

Most programs are built using the make program, which requires the developer to write Makefiles describing how to build the programs. Since most programs are built in pretty much the same way, this led to a lot of duplication.

The X Window system is built using the imake tool, which uses a database of rules to eliminate the duplication. However, building a tool which was developed using imake requires that the builder have imake installed, violating one of the goals of the GNU system.

The new BSD make provides a standard library of Makefile fragments, which permits developers to write very simple Makefiles. However, this requires that the builder install the new BSD make program.

In 1994, David MacKenzie wrote the first version of automake, which permitted writing a simple build description which was converted into a Makefile which could be used by the standard make program. In 1995, Tom Tromey completely rewrote automake in Perl, and he continues to enhance it.

Various free packages built libraries, and by around 1995 several included support to build shared libraries on various platforms. However, there was no consistent approach. In early 1996, Gordon Matzigkeit began working on libtool, which provided a standardized approach to building shared libraries. This was integrated into automake from the start.

The development of automake and libtool was driven by the GNITS project, a group of GNU maintainers who designed standardized tools to help meet the GNU coding standards.

1.4 Building

Most readers of this document should already know how to build a tool by running ‘`configure`’ and ‘`make`’. This section may serve as a quick introduction or reminder.

Building a tool is normally as simple as running ‘`configure`’ followed by ‘`make`’. You should normally run ‘`configure`’ from an empty directory, using some path to refer to the ‘`configure`’ script in the source directory. The directory in which you run ‘`configure`’ is called the *object directory*.

In order to use a object directory which is different from the source directory, you must be using the GNU version of ‘`make`’, which has the required ‘`VPATH`’ support. Despite this restriction, using a different object directory is highly recommended:

- It keeps the files generated during the build from cluttering up your sources.
- It permits you to remove the built files by simply removing the entire build directory.
- It permits you to build from the same sources with several sets of configure options simultaneously.

If you don't have GNU ‘`make`’, you will have to run ‘`configure`’ in the source directory. All GNU packages should support this; in particular, GNU packages should not assume the presence of GNU ‘`make`’.

After running ‘`configure`’, you can build the tools by running ‘`make`’.

To install the tools, run ‘`make install`’. Installing the tools will copy the programs and any required support files to the *installation directory*. The location of the installation directory is controlled by ‘`configure`’ options, as described below.

In the Cygnus tree at present, the info files are built and installed as a separate step. To build them, run ‘`make info`’. To install them, run ‘`make install-info`’.

All ‘`configure`’ scripts support a wide variety of options. The most interesting ones are ‘`--with`’ and ‘`--enable`’ options which are generally specific to particular tools. You can usually use the ‘`--help`’ option to get a list of interesting options for a particular configure script.

The only generic options you are likely to use are the ‘`--prefix`’ and ‘`--exec-prefix`’ options. These options are used to specify the installation directory.

The directory named by the ‘`--prefix`’ option will hold machine independent files such as info files.

The directory named by the ‘`--exec-prefix`’ option, which is normally a subdirectory of the ‘`--prefix`’ directory, will hold machine dependent files such as executables.

The default for ‘`--prefix`’ is ‘`/usr/local`’. The default for ‘`--exec-prefix`’ is the value used for ‘`--prefix`’.

The convention used in Cygnus releases is to use a ‘`--prefix`’ option of ‘`/usr/cygnus/`*release*’, where *release* is the name of the release, and to use a ‘`--exec-prefix`’ option of ‘`/usr/cygnus/`*release*`/H-`*host*’, where *host* is the configuration name of the host system (see Chapter 4 [Configuration Names], page 20).

Do not use either the source or the object directory as the installation directory. That will just lead to confusion.

2 Getting Started

To start using the GNU configure and build system with your software package, you must write three files, and you must run some tools to manually generate additional files.

2.1 Write configure.in

You must first write the file '`configure.in`'. This is an autoconf input file, and the autoconf manual describes in detail what this file should look like.

You will write tests in your '`configure.in`' file to check for conditions that may change from one system to another, such as the presence of particular header files or functions.

For example, not all systems support the '`gettimeofday`' function. If you want to use the '`gettimeofday`' function when it is available, and to use some other function when it is not, you would check for this by putting '`AC_CHECK_FUNCS(gettimeofday)`' in '`configure.in`'.

When the configure script is run at build time, this will arrange to define the preprocessor macro '`HAVE_GETTIMEOFDAY`' to the value 1 if the '`gettimeofday`' function is available, and to not define the macro at all if the function is not available. Your code can then use '`#ifdef`' to test whether it is safe to call '`gettimeofday`'.

If you have an existing body of code, the '`autoscan`' program may help identify potential portability problems, and hence configure tests that you will want to use. See section "Invoking autoscan" in *the autoconf manual*.

Another handy tool for an existing body of code is '`ifnames`'. This will show you all the preprocessor conditionals that the code already uses. See section "Invoking ifnames" in *the autoconf manual*.

Besides the portability tests which are specific to your particular package, every '`configure.in`' file should contain the following macros.

'`AC_INIT`'
: This macro takes a single argument, which is the name of a file in your package. For example, '`AC_INIT(foo.c)`'.

'`AC_PREREQ(`*VERSION*`)`'
: This macro is optional. It may be used to indicate the version of '`autoconf`' that you are using. This will prevent users from running an earlier version of '`autoconf`' and perhaps getting an invalid '`configure`' script. For example, '`AC_PREREQ(2.12)`'.

'`AM_INIT_AUTOMAKE`'
: This macro takes two arguments: the name of the package, and a version number. For example, '`AM_INIT_AUTOMAKE(foo, 1.0)`'. (This macro is not needed if you are not using automake).

'`AM_CONFIG_HEADER`'
: This macro names the header file which will hold the preprocessor macro definitions at run time. Normally this should be '`config.h`'. Your sources would then use '`#include "config.h"`' to include it.

: This macro may optionally name the input file for that header file; by default, this is '`config.h.in`', but that file name works poorly on DOS filesystems. Therefore, it is often better to name it explicitly as '`config.in`'.

This is what you should normally put in 'configure.in':

```
AM_CONFIG_HEADER(config.h:config.in)
```

(If you are not using automake, use 'AC_CONFIG_HEADER' rather than 'AM_CONFIG_HEADER').

'AM_MAINTAINER_MODE'

This macro always appears in Cygnus configure scripts. Other programs may or may not use it.

If this macro is used, the '--enable-maintainer-mode' option is required to enable automatic rebuilding of generated files used by the configure system. This of course requires that developers be aware of, and use, that option.

If this macro is not used, then the generated files will always be rebuilt automatically. This will cause problems if the wrong versions of autoconf, automake, or others are in the builder's 'PATH'.

(If you are not using automake, you do not need to use this macro).

'AC_EXEEXT'

Either this macro or 'AM_EXEEXT' always appears in Cygnus configure files. Other programs may or may not use one of them.

This macro looks for the executable suffix used on the host system. On Unix systems, this is the empty string. On Windows systems, this is '.exe'. This macro directs automake to use the executable suffix as appropriate when creating programs. This macro does not take any arguments.

The 'AC_EXEEXT' form is new, and is part of a Cygnus patch to autoconf to support compiling with Visual C++. Older programs use 'AM_EXEEXT' instead.

(Programs which do not use automake use neither 'AC_EXEEXT' nor 'AM_EXEEXT').

'AC_PROG_CC'

If you are writing C code, you will normally want to use this macro. It locates the C compiler to use. It does not take any arguments.

However, if this 'configure.in' file is for a library which is to be compiled by a cross compiler which may not fully work, then you will not want to use 'AC_PROG_CC'. Instead, you will want to use a variant which does not call the macro 'AC_PROG_CC_WORKS'. Examples can be found in various 'configure.in' files for libraries that are compiled with cross compilers, such as libiberty or libgloss. This is essentially a bug in autoconf, and there will probably be a better workaround at some point.

'AC_PROG_CXX'

If you are writing C++ code, you will want to use this macro. It locates the C++ compiler to use. It does not take any arguments. The same cross compiler comments apply as for 'AC_PROG_CC'.

'AM_PROG_LIBTOOL'

If you want to build libraries, and you want to permit them to be shared, or you want to link against libraries which were built using libtool, then you will need this macro. This macro is required in order to use libtool.

By default, this will cause all libraries to be built as shared libraries. To prevent this–to change the default–use 'AM_DISABLE_SHARED' before 'AM_PROG_LIBTOOL'.

The configure options '--enable-shared' and '--disable-shared' may be used to override the default at build time.

'AC_DEFINE(_GNU_SOURCE)'
: GNU packages should normally include this line before any other feature tests. This defines the macro '_GNU_SOURCE' when compiling, which directs the libc header files to provide the standard GNU system interfaces including all GNU extensions. If this macro is not defined, certain GNU extensions may not be available.

'AC_OUTPUT'
: This macro takes a list of file names which the configure process should produce. This is normally a list of one or more 'Makefile' files in different directories. If your package lives entirely in a single directory, you would use simply 'AC_OUTPUT(Makefile)'. If you also have, for example, a 'lib' subdirectory, you would use 'AC_OUTPUT(Makefile lib/Makefile)'.

If you want to use locally defined macros in your 'configure.in' file, then you will need to write a 'acinclude.m4' file which defines them (if not using automake, this file is called 'aclocal.m4'). Alternatively, you can put separate macros in an 'm4' subdirectory, and put 'ACLOCAL_AMFLAGS = -I m4' in your 'Makefile.am' file so that the 'aclocal' program will be able to find them.

The different macro prefixes indicate which tool defines the macro. Macros which start with 'AC_' are part of autoconf. Macros which start with 'AM_' are provided by automake or libtool.

2.2 Write Makefile.am

You must write the file 'Makefile.am'. This is an automake input file, and the automake manual describes in detail what this file should look like.

The automake commands in 'Makefile.am' mostly look like variable assignments in a 'Makefile'. automake recognizes special variable names, and automatically add make rules to the output as needed.

There will be one 'Makefile.am' file for each directory in your package. For each directory with subdirectories, the 'Makefile.am' file should contain the line

```
SUBDIRS = dir dir ...
```

where each *dir* is the name of a subdirectory.

For each 'Makefile.am', there should be a corresponding 'Makefile' in the 'AC_OUTPUT' macro in 'configure.in'.

Every 'Makefile.am' written at Cygnus should contain the line

```
AUTOMAKE_OPTIONS = cygnus
```

This puts automake into Cygnus mode. See the automake manual for details.

You may to include the version number of 'automake' that you are using on the 'AUTOMAKE_OPTIONS' line. For example,

```
AUTOMAKE_OPTIONS = cygnus 1.3
```

This will prevent users from running an earlier version of 'automake' and perhaps getting an invalid 'Makefile.in'.

If your package builds a program, then in the directory where that program is built you will normally want a line like

bin_PROGRAMS = *program*

where *program* is the name of the program. You will then want a line like

*program*_SOURCES = *file file* ...

where each *file* is the name of a source file to link into the program (e.g., 'foo.c').

If your package builds a library, and you do not want the library to ever be built as a shared library, then in the directory where that library is built you will normally want a line like

lib_LIBRARIES = lib*name*.a

where 'lib*name*.a' is the name of the library. You will then want a line like

lib*name*_a_SOURCES = *file file* ...

where each *file* is the name of a source file to add to the library.

If your package builds a library, and you want to permit building the library as a shared library, then in the directory where that library is built you will normally want a line like

lib_LTLIBRARIES = lib*name*.la

The use of 'LTLIBRARIES', and the '.la' extension, indicate a library to be built using libtool. As usual, you will then want a line like

lib*name*_la_SOURCES = *file file* ...

The strings 'bin' and 'lib' that appear above in 'bin_PROGRAMS' and 'lib_LIBRARIES' are not arbitrary. They refer to particular directories, which may be set by the '--bindir' and '--libdir' options to 'configure'. If those options are not used, the default values are based on the '--prefix' or '--exec-prefix' options to 'configure'. It is possible to use other names if the program or library should be installed in some other directory.

The 'Makefile.am' file may also contain almost anything that may appear in a normal 'Makefile'. automake also supports many other special variables, as well as conditionals.

See the automake manual for more information.

2.3 Write acconfig.h

If you are generating a portability header file, (i.e., you are using 'AM_CONFIG_HEADER' in 'configure.in'), then you will have to write a 'acconfig.h' file. It will have to contain the following lines.

```
/* Name of package.  */
#undef PACKAGE

/* Version of package.  */
#undef VERSION
```

This requirement is really a bug in the system, and the requirement may be eliminated at some later date.

The 'acconfig.h' file will also similar comment and '#undef' lines for any unusual macros in the 'configure.in' file, including any macro which appears in a 'AC_DEFINE' macro.

In particular, if you are writing a GNU package and therefore include 'AC_DEFINE(_GNU_SOURCE)' in 'configure.in' as suggested above, you will need lines like this in 'acconfig.h':

```
/* Enable GNU extensions.  */
#undef _GNU_SOURCE
```

Normally the 'autoheader' program will inform you of any such requirements by printing an error message when it is run. However, if you do anything particular odd in your 'configure.in' file, you will have to make sure that the right entries appear in 'acconfig.h', since otherwise the results of the tests may not be available in the 'config.h' file which your code will use.

(Thee 'PACKAGE' and 'VERSION' lines are not required if you are not using automake, and in that case you may not need a 'acconfig.h' file at all).

2.4 Generate files

Once you have written 'configure.in', 'Makefile.am', 'acconfig.h', and possibly 'acinclude.m4', you must use autoconf and automake programs to produce the first versions of the generated files. This is done by executing the following sequence of commands.

```
aclocal
autoconf
autoheader
automake
```

The 'aclocal' and 'automake' commands are part of the automake package, and the 'autoconf' and 'autoheader' commands are part of the autoconf package.

If you are using a 'm4' subdirectory for your macros, you will need to use the '-I m4' option when you run 'aclocal'.

If you are not using the Cygnus tree, use the '-a' option when running 'automake' command in order to copy the required support files into your source directory.

If you are using libtool, you must build and install the libtool package with the same '--prefix' and '--exec-prefix' options as you used with the autoconf and automake packages. You must do this before running any of the above commands. If you are not using the Cygnus tree, you will need to run the 'libtoolize' program to copy the libtool support files into your directory.

Once you have managed to run these commands without getting any errors, you should create a new empty directory, and run the 'configure' script which will have been created by 'autoconf' with the '--enable-maintainer-mode' option. This will give you a set of Makefiles which will include rules to automatically rebuild all the generated files.

After doing that, whenever you have changed some of the input files and want to regenerated the other files, go to your object directory and run 'make'. Doing this is more reliable than trying to rebuild the files manually, because there are complex order dependencies and it is easy to forget something.

2.5 Example

Let's consider a trivial example.

Suppose we want to write a simple version of 'touch'. Our program, which we will call 'poke', will take a single file name argument, and use the 'utime' system call to set the modification and access times of the file to the current time. We want this program to be highly portable.

We'll first see what this looks like without using autoconf and automake, and then see what it looks like with them.

2.5.1 First Try

Here is our first try at 'poke.c'. Note that we've written it without ANSI/ISO C prototypes, since we want it to be highly portable.

```
#include <stdio.h>
#include <stdlib.h>
#include <sys/types.h>
#include <utime.h>

int
main (argc, argv)
     int argc;
     char **argv;
{
  if (argc != 2)
    {
      fprintf (stderr, "Usage: poke file\n");
      exit (1);
    }

  if (utime (argv[1], NULL) < 0)
    {
      perror ("utime");
      exit (1);
    }

  exit (0);
}
```

We also write a simple 'Makefile'.

```
CC = gcc
CFLAGS = -g -O2

all: poke

poke: poke.o
$(CC) -o poke $(CFLAGS) $(LDFLAGS) poke.o
```

So far, so good.

Unfortunately, there are a few problems.

On older Unix systems derived from BSD 4.3, the 'utime' system call does not accept a second argument of 'NULL'. On those systems, we need to pass a pointer to 'struct utimbuf' structure. Unfortunately, even older systems don't define that structure; on those systems, we need to pass an array of two 'long' values.

The header file 'stdlib.h' was invented by ANSI C, and older systems don't have a copy. We included it above to get a declaration of 'exit'.

We can find some of these portability problems by running 'autoscan', which will create a 'configure.scan' file which we can use as a prototype for our 'configure.in' file. I won't show the output, but it will notice the potential problems with 'utime' and 'stdlib.h'.

In our 'Makefile', we don't provide any way to install the program. This doesn't matter much for such a simple example, but a real program will need an 'install' target. For that matter, we will also want a 'clean' target.

2.5.2 Second Try

Here is our second try at this program.

We modify 'poke.c' to use preprocessor macros to control what features are available. (I've cheated a bit by using the same macro names which autoconf will use).

```
#include <stdio.h>

#ifdef STDC_HEADERS
#include <stdlib.h>
#endif

#include <sys/types.h>

#ifdef HAVE_UTIME_H
#include <utime.h>
#endif

#ifndef HAVE_UTIME_NULL

#include <time.h>

#ifndef HAVE_STRUCT_UTIMBUF

struct utimbuf
{
  long actime;
  long modtime;
};

#endif

static int
utime_now (file)
```

```
     char *file;
{
  struct utimbuf now;

  now.actime = now.modtime = time (NULL);
  return utime (file, &now);
}

#define utime(f, p) utime_now (f)

#endif /* HAVE_UTIME_NULL  */

int
main (argc, argv)
     int argc;
     char **argv;
{
  if (argc != 2)
    {
      fprintf (stderr, "Usage: poke file\n");
      exit (1);
    }

  if (utime (argv[1], NULL) < 0)
    {
      perror ("utime");
      exit (1);
    }

  exit (0);
}
```

Here is the associated 'Makefile'. We've added support for the preprocessor flags we use. We've also added 'install' and 'clean' targets.

```
# Set this to your installation directory.
bindir = /usr/local/bin

# Uncomment this if you have the standard ANSI/ISO C header files.
# STDC_HDRS = -DSTDC_HEADERS

# Uncomment this if you have utime.h.
# UTIME_H = -DHAVE_UTIME_H

# Uncomment this if utime (FILE, NULL) works on your system.
# UTIME_NULL = -DHAVE_UTIME_NULL

# Uncomment this if struct utimbuf is defined in utime.h.
# UTIMBUF = -DHAVE_STRUCT_UTIMBUF
```

```
CC = gcc
CFLAGS = -g -O2

ALL_CFLAGS = $(STDC_HDRS) $(UTIME_H) $(UTIME_NULL) $(UTIMBUF) $(CFLAGS)

all: poke

poke: poke.o
$(CC) -o poke $(ALL_CFLAGS) $(LDFLAGS) poke.o

.c.o:
$(CC) -c $(ALL_CFLAGS) poke.c

install: poke
cp poke $(bindir)/poke

clean:
rm poke poke.o
```

Some problems with this approach should be clear.

Users who want to compile poke will have to know how 'utime' works on their systems, so that they can uncomment the 'Makefile' correctly.

The installation is done using 'cp', but many systems have an 'install' program which may be used, and which supports optional features such as stripping debugging information out of the installed binary.

The use of 'Makefile' variables like 'CC', 'CFLAGS' and 'LDFLAGS' follows the requirements of the GNU standards. This is convenient for all packages, since it reduces surprises for users. However, it is easy to get the details wrong, and wind up with a slightly nonstandard distribution.

2.5.3 Third Try

For our third try at this program, we will write a 'configure.in' script to discover the configuration features on the host system, rather than requiring the user to edit the 'Makefile'. We will also write a 'Makefile.am' rather than a 'Makefile'.

The only change to 'poke.c' is to add a line at the start of the file:

```
#include "config.h"
```

The new 'configure.in' file is as follows.

```
AC_INIT(poke.c)
AM_INIT_AUTOMAKE(poke, 1.0)
AM_CONFIG_HEADER(config.h:config.in)
AC_PROG_CC
AC_HEADER_STDC
AC_CHECK_HEADERS(utime.h)
AC_EGREP_HEADER(utimbuf, utime.h, AC_DEFINE(HAVE_STRUCT_UTIMBUF))
AC_FUNC_UTIME_NULL
AC_OUTPUT(Makefile)
```

The first four macros in this file, and the last one, were described above; see Section 2.1 [Write configure.in], page 4. If we omit these macros, then when we run 'automake' we will get a reminder that we need them.

The other macros are standard autoconf macros.

'AC_HEADER_STDC'
: Check for standard C headers.

'AC_CHECK_HEADERS'
: Check whether a particular header file exists.

'AC_EGREP_HEADER'
: Check for a particular string in a particular header file, in this case checking for 'utimbuf' in 'utime.h'.

'AC_FUNC_UTIME_NULL'
: Check whether 'utime' accepts a NULL second argument to set the file change time to the current time.

See the autoconf manual for a more complete description.

The new 'Makefile.am' file is as follows. Note how simple this is compared to our earlier 'Makefile'.

```
bin_PROGRAMS = poke

poke_SOURCES = poke.c
```

This means that we should build a single program name 'poke'. It should be installed in the binary directory, which we called 'bindir' earlier. The program 'poke' is built from the source file 'poke.c'.

We must also write a 'acconfig.h' file. Besides 'PACKAGE' and 'VERSION', which must be mentioned for all packages which use automake, we must include 'HAVE_STRUCT_UTIMBUF', since we mentioned it in an 'AC_DEFINE'.

```
/* Name of package.  */
#undef PACKAGE

/* Version of package.  */
#undef VERSION

/* Whether utime.h defines struct utimbuf.  */
#undef HAVE_STRUCT_UTIMBUF
```

2.5.4 Generate Files

We must now generate the other files, using the following commands.

```
aclocal
autoconf
autoheader
automake
```

When we run 'autoheader', it will remind us of any macros we forgot to add to 'acconfig.h'.

When we run 'automake', it will want to add some files to our distribution. It will add them automatically if we use the '--add-missing' option.

By default, 'automake' will run in GNU mode, which means that it will want us to create certain additional files; as of this writing, it will want 'NEWS', 'README', 'AUTHORS', and 'ChangeLog', all of which are files which should appear in a standard GNU distribution. We can either add those files, or run 'automake' with the '--foreign' option.

Running these tools will generate the following files, all of which are described in the next chapter.

- 'aclocal.m4'
- 'configure'
- 'config.in'
- 'Makefile.in'
- 'stamp-h.in'

3 Files

As was seen in the previous chapter, the GNU configure and build system uses a number of different files. The developer must write a few files. The others are generated by various tools.

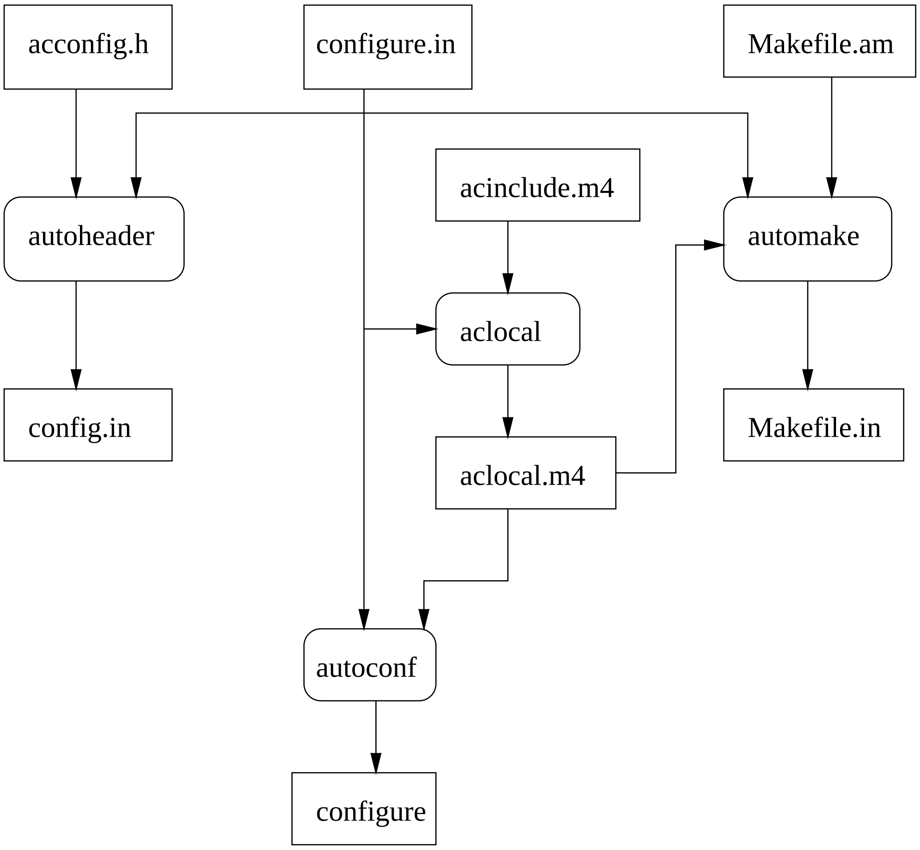
The system is rather flexible, and can be used in many different ways. In describing the files that it uses, I will describe the common case, and mention some other cases that may arise.

3.1 Developer Files

This section describes the files written or generated by the developer of a package.

3.1.1 Developer Files Picture

Here is a picture of the files which are written by the developer, the generated files which would be included with a complete source distribution, and the tools which create those files. The file names are in rectangles with square corners and the tool names are in rectangles with rounded corners (e.g., 'autoheader' is the name of a tool, not the name of a file).



3.1.2 Written Developer Files

The following files would be written by the developer.

'`configure.in`'
: This is the configuration script. This script contains invocations of autoconf macros. It may also contain ordinary shell script code. This file will contain feature tests for portability issues. The last thing in the file will normally be an '`AC_OUTPUT`' macro listing which files to create when the builder runs the configure script. This file is always required when using the GNU configure system. See Section 2.1 [Write configure.in], page 4.

'`Makefile.am`'
: This is the automake input file. It describes how the code should be built. It consists of definitions of automake variables. It may also contain ordinary Makefile targets. This file is only needed when using automake (newer tools normally use automake, but there are still older tools which have not been converted, in which the developer writes '`Makefile.in`' directly). See Section 2.2 [Write Makefile.am], page 6.

'`acconfig.h`'
: When the configure script creates a portability header file, by using '`AM_CONFIG_HEADER`' (or, if not using automake, '`AC_CONFIG_HEADER`'), this file is used to describe macros which are not recognized by the '`autoheader`' command. This is normally a fairly uninteresting file, consisting of a collection of '`#undef`' lines with

comments. Normally any call to 'AC_DEFINE' in 'configure.in' will require a line in this file. See Section 2.3 [Write acconfig.h], page 7.

'acinclude.m4'

This file is not always required. It defines local autoconf macros. These macros may then be used in 'configure.in'. If you don't need any local autoconf macros, then you don't need this file at all. In fact, in general, you never need local autoconf macros, since you can put everything in 'configure.in', but sometimes a local macro is convenient.

Newer tools may omit 'acinclude.m4', and instead use a subdirectory, typically named 'm4', and define 'ACLOCAL_AMFLAGS = -I m4' in 'Makefile.am' to force 'aclocal' to look there for macro definitions. The macro definitions are then placed in separate files in that directory.

The 'acinclude.m4' file is only used when using automake; in older tools, the developer writes 'aclocal.m4' directly, if it is needed.

3.1.3 Generated Developer Files

The following files would be generated by the developer.

When using automake, these files are normally not generated manually after the first time. Instead, the generated 'Makefile' contains rules to automatically rebuild the files as required. When 'AM_MAINTAINER_MODE' is used in 'configure.in' (the normal case in Cygnus code), the automatic rebuilding rules will only be defined if you configure using the '--enable-maintainer-mode' option.

When using automatic rebuilding, it is important to ensure that all the various tools have been built and installed on your 'PATH'. Using automatic rebuilding is highly recommended, so much so that I'm not going to explain what you have to do if you don't use it.

'configure'

This is the configure script which will be run when building the package. This is generated by 'autoconf' from 'configure.in' and 'aclocal.m4'. This is a shell script.

'Makefile.in'

This is the file which the configure script will turn into the 'Makefile' at build time. This file is generated by 'automake' from 'Makefile.am'. If you aren't using automake, you must write this file yourself. This file is pretty much a normal 'Makefile', with some configure substitutions for certain variables.

'aclocal.m4'

This file is created by the 'aclocal' program, based on the contents of 'configure.in' and 'acinclude.m4' (or, as noted in the description of 'acinclude.m4' above, on the contents of an 'm4' subdirectory). This file contains definitions of autoconf macros which 'autoconf' will use when generating the file 'configure'. These autoconf macros may be defined by you in 'acinclude.m4' or they may be defined by other packages such as automake, libtool or gettext. If you aren't using automake, you will normally write this file yourself; in that case, if 'configure.in' uses only standard autoconf macros, this file will not be needed at all.

'config.in'
: This file is created by 'autoheader' based on 'acconfig.h' and 'configure.in'. At build time, the configure script will define some of the macros in it to create 'config.h', which may then be included by your program. This permits your C code to use preprocessor conditionals to change its behaviour based on the characteristics of the host system. This file may also be called 'config.h.in'.

'stamp.h-in'
: This rather uninteresting file, which I omitted from the picture, is generated by 'automake'. It always contains the string 'timestamp'. It is used as a timestamp file indicating whether 'config.in' is up to date. Using a timestamp file means that 'config.in' can be marked as up to date without actually changing its modification time. This is useful since 'config.in' depends upon 'configure.in', but it is easy to change 'configure.in' in a way which does not affect 'config.in'.

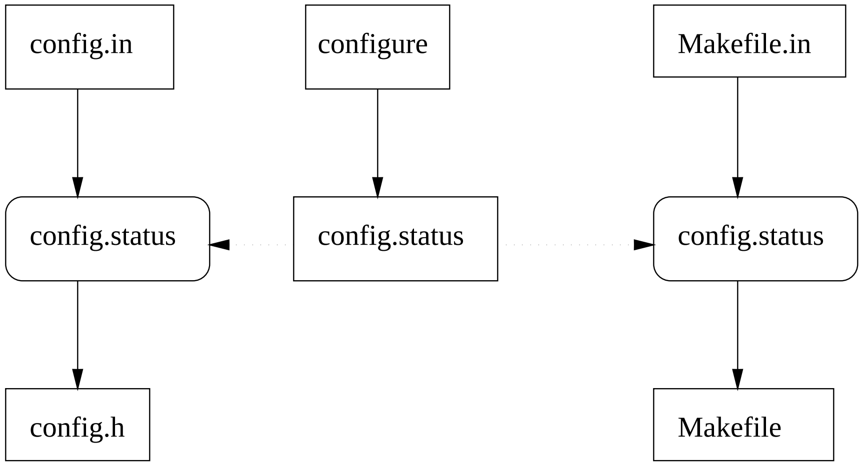
3.2 Build Files

This section describes the files which are created at configure and build time. These are the files which somebody who builds the package will see.

Of course, the developer will also build the package. The distinction between developer files and build files is not that the developer does not see the build files, but that somebody who only builds the package does not have to worry about the developer files.

3.2.1 Build Files Picture

Here is a picture of the files which will be created at build time. 'config.status' is both a created file and a shell script which is run to create other files, and the picture attempts to show that.



3.2.2 Build Files Description

This is a description of the files which are created at build time.

'config.status'
: The first step in building a package is to run the 'configure' script. The 'configure' script will create the file 'config.status', which is itself a shell script. When you first run 'configure', it will automatically run 'config.status'. An 'Makefile' derived from an automake generated 'Makefile.in' will contain rules to automatically run 'config.status' again when necessary to recreate certain files if their inputs change.

'Makefile'
: This is the file which make will read to build the program. The 'config.status' script will transform 'Makefile.in' into 'Makefile'.

'config.h'
: This file defines C preprocessor macros which C code can use to adjust its behaviour on different systems. The 'config.status' script will transform 'config.in' into 'config.h'.

'config.cache'
: This file did not fit neatly into the picture, and I omitted it. It is used by the 'configure' script to cache results between runs. This can be an important speedup. If you modify 'configure.in' in such a way that the results of old tests should change (perhaps you have added a new library to 'LDFLAGS'), then you will have to remove 'config.cache' to force the tests to be rerun.

  The autoconf manual explains how to set up a site specific cache file. This can speed up running 'configure' scripts on your system.

'stamp.h'
: This file, which I omitted from the picture, is similar to 'stamp-h.in'. It is used as a timestamp file indicating whether 'config.h' is up to date. This is useful since 'config.h' depends upon 'config.status', but it is easy for 'config.status' to change in a way which does not affect 'config.h'.

3.3 Support Files

The GNU configure and build system requires several support files to be included with your distribution. You do not normally need to concern yourself with these. If you are using the Cygnus tree, most are already present. Otherwise, they will be installed with your source by 'automake' (with the '--add-missing' option) and 'libtoolize'.

You don't have to put the support files in the top level directory. You can put them in a subdirectory, and use the 'AC_CONFIG_AUX_DIR' macro in 'configure.in' to tell 'automake' and the 'configure' script where they are.

In this section, I describe the support files, so that you can know what they are and why they are there.

'ABOUT-NLS'
: Added by automake if you are using gettext. This is a documentation file about the gettext project.

‘ansi2knr.c’
: Used by an automake generated ‘Makefile’ if you put ‘ansi2knr’ in ‘AUTOMAKE_OPTIONS’ in ‘Makefile.am’. This permits compiling ANSI C code with a K&R C compiler.

‘ansi2knr.1’
: The man page which goes with ‘ansi2knr.c’.

‘config.guess’
: A shell script which determines the configuration name for the system on which it is run.

‘config.sub’
: A shell script which canonicalizes a configuration name entered by a user.

‘elisp-comp’
: Used to compile Emacs LISP files.

‘install-sh’
: A shell script which installs a program. This is used if the configure script can not find an install binary.

‘ltconfig’
: Used by libtool. This is a shell script which configures libtool for the particular system on which it is used.

‘ltmain.sh’
: Used by libtool. This is the actual libtool script which is used, after it is configured by ‘ltconfig’ to build a library.

‘mdate-sh’
: A shell script used by an automake generated ‘Makefile’ to pretty print the modification time of a file. This is used to maintain version numbers for texinfo files.

‘missing’
: A shell script used if some tool is missing entirely. This is used by an automake generated ‘Makefile’ to avoid certain sorts of timestamp problems.

‘mkinstalldirs’
: A shell script which creates a directory, including all parent directories. This is used by an automake generated ‘Makefile’ during installation.

‘texinfo.tex’
: Required if you have any texinfo files. This is used when converting Texinfo files into DVI using ‘texi2dvi’ and $\TeX$.

‘ylwrap’
: A shell script used by an automake generated ‘Makefile’ to run programs like ‘bison’, ‘yacc’, ‘flex’, and ‘lex’. These programs default to producing output files with a fixed name, and the ‘ylwrap’ script runs them in a subdirectory to avoid file name conflicts when using a parallel make program.

4 Configuration Names

The GNU configure system names all systems using a *configuration name*. All such names used to be triplets (they may now contain four parts in certain cases), and the term *configuration triplet* is still seen.

4.1 Configuration Name Definition

This is a string of the form *cpu-manufacturer-operating_system*. In some cases, this is extended to a four part form: *cpu-manufacturer-kernel-operating_system*.

When using a configuration name in a configure option, it is normally not necessary to specify an entire name. In particular, the *manufacturer* field is often omitted, leading to strings such as '`i386-linux`' or '`sparc-sunos`'. The shell script '`config.sub`' will translate these shortened strings into the canonical form. autoconf will arrange for '`config.sub`' to be run automatically when it is needed.

The fields of a configuration name are as follows:

cpu
: The type of processor. This is typically something like '`i386`' or '`sparc`'. More specific variants are used as well, such as '`mipsel`' to indicate a little endian MIPS processor.

manufacturer
: A somewhat freeform field which indicates the manufacturer of the system. This is often simply '`unknown`'. Other common strings are '`pc`' for an IBM PC compatible system, or the name of a workstation vendor, such as '`sun`'.

operating_system
: The name of the operating system which is run on the system. This will be something like '`solaris2.5`' or '`irix6.3`'. There is no particular restriction on the version number, and strings like '`aix4.1.4.0`' are seen. For an embedded system, which has no operating system, this field normally indicates the type of object file format, such as '`elf`' or '`coff`'.

kernel
: This is used mainly for GNU/Linux. A typical GNU/Linux configuration name is '`i586-pc-linux-gnulibc1`'. In this case the kernel, '`linux`', is separated from the operating system, '`gnulibc1`'.

The shell script '`config.guess`' will normally print the correct configuration name for the system on which it is run. It does by running '`uname`' and by examining other characteristics of the system.

Because '`config.guess`' can normally determine the configuration name for a machine, it is normally only necessary to specify a configuration name when building a cross-compiler or when building using a cross-compiler.

4.2 Using Configuration Names

A configure script will sometimes have to make a decision based on a configuration name. You will need to do this if you have to compile code differently based on something which can not be tested using a standard autoconf feature test.

It is normally better to test for particular features, rather than to test for a particular system. This is because as Unix evolves, different systems copy features from one another. Even if you need to determine whether the feature is supported based on a configuration name, you should define a macro which describes the feature, rather than defining a macro which describes the particular system you are on.

Testing for a particular system is normally done using a case statement in 'configure.in'. The case statement might look something like the following, assuming that 'host' is a shell variable holding a canonical configuration name (which will be the case if 'configure.in' uses the 'AC_CANONICAL_HOST' or 'AC_CANONICAL_SYSTEM' macro).

```
case "${host}" in
i[3456]86-*-linux-gnu*) do something ;;
sparc*-sun-solaris2.[56789]*) do something ;;
sparc*-sun-solaris*) do something ;;
mips*-*-elf*) do something ;;
esac
```

It is particularly important to use '*' after the operating system field, in order to match the version number which will be generated by 'config.guess'.

In most cases you must be careful to match a range of processor types. For most processor families, a trailing '*' suffices, as in 'mips*' above. For the i386 family, something along the lines of 'i[3456]86' suffices at present. For the m68k family, you will need something like 'm68*'. Of course, if you do not need to match on the processor, it is simpler to just replace the entire field by a '*', as in '*-*-irix*'.

5 Cross Compilation Tools

The GNU configure and build system can be used to build *cross compilation* tools. A cross compilation tool is a tool which runs on one system and produces code which runs on another system.

5.1 Cross Compilation Concepts

A compiler which produces programs which run on a different system is a cross compilation compiler, or simply a *cross compiler*. Similarly, we speak of cross assemblers, cross linkers, etc.

In the normal case, a compiler produces code which runs on the same system as the one on which the compiler runs. When it is necessary to distinguish this case from the cross compilation case, such a compiler is called a *native compiler*. Similarly, we speak of native assemblers, etc.

Although the debugger is not strictly speaking a compilation tool, it is nevertheless meaningful to speak of a cross debugger: a debugger which is used to debug code which runs on another system. Everything that is said below about configuring cross compilation tools applies to the debugger as well.

5.2 Host and Target

When building cross compilation tools, there are two different systems involved: the system on which the tools will run, and the system for which the tools generate code.

The system on which the tools will run is called the *host* system.

The system for which the tools generate code is called the *target* system.

For example, suppose you have a compiler which runs on a GNU/Linux system and generates ELF programs for a MIPS embedded system. In this case the GNU/Linux system is the host, and the MIPS ELF system is the target. Such a compiler could be called a GNU/Linux cross MIPS ELF compiler, or, equivalently, a '`i386-linux-gnu`' cross '`mips-elf`' compiler.

Naturally, most programs are not cross compilation tools. For those programs, it does not make sense to speak of a target. It only makes sense to speak of a target for tools like '`gcc`' or the '`binutils`' which actually produce running code. For example, it does not make sense to speak of the target of a tool like '`bison`' or '`make`'.

Most cross compilation tools can also serve as native tools. For a native compilation tool, it is still meaningful to speak of a target. For a native tool, the target is the same as the host. For example, for a GNU/Linux native compiler, the host is GNU/Linux, and the target is also GNU/Linux.

5.3 Using the Host Type

In almost all cases the host system is the system on which you run the '`configure`' script, and on which you build the tools (for the case when they differ, see Chapter 6 [Canadian Cross], page 27).

If your configure script needs to know the configuration name of the host system, and the package is not a cross compilation tool and therefore does not have a target, put '`AC_CANONICAL_HOST`' in '`configure.in`'. This macro will arrange to define a few shell variables when the '`configure`' script is run.

'`host`'
: The canonical configuration name of the host. This will normally be determined by running the '`config.guess`' shell script, although the user is permitted to override this by using an explicit '`--host`' option.

'`host_alias`'
: In the unusual case that the user used an explicit '`--host`' option, this will be the argument to '`--host`'. In the normal case, this will be the same as the '`host`' variable.

'`host_cpu`'
'`host_vendor`'
'`host_os`'
: The first three parts of the canonical configuration name.

The shell variables may be used by putting shell code in '`configure.in`'. For an example, see Section 4.2 [Using Configuration Names], page 20.

5.4 Specifying the Target

By default, the 'configure' script will assume that the target is the same as the host. This is the more common case; for example, it leads to a native compiler rather than a cross compiler.

If you want to build a cross compilation tool, you must specify the target explicitly by using the '--target' option when you run 'configure'. The argument to '--target' is the configuration name of the system for which you wish to generate code. See Chapter 4 [Configuration Names], page 20.

For example, to build tools which generate code for a MIPS ELF embedded system, you would use '--target mips-elf'.

5.5 Using the Target Type

When writing 'configure.in' for a cross compilation tool, you will need to use information about the target. To do this, put 'AC_CANONICAL_SYSTEM' in 'configure.in'.

'AC_CANONICAL_SYSTEM' will look for a '--target' option and canonicalize it using the 'config.sub' shell script. It will also run 'AC_CANONICAL_HOST' (see Section 5.3 [Using the Host Type], page 22).

The target type will be recorded in the following shell variables. Note that the host versions of these variables will also be defined by 'AC_CANONICAL_HOST'.

'target'
: The canonical configuration name of the target.

'target_alias'
: The argument to the '--target' option. If the user did not specify a '--target' option, this will be the same as 'host_alias'.

'target_cpu'
'target_vendor'
'target_os'
: The first three parts of the canonical target configuration name.

Note that if 'host' and 'target' are the same string, you can assume a native configuration. If they are different, you can assume a cross configuration.

It is arguably possible for 'host' and 'target' to represent the same system, but for the strings to not be identical. For example, if 'config.guess' returns 'sparc-sun-sunos4.1.4', and somebody configures with '--target sparc-sun-sunos4.1', then the slight differences between the two versions of SunOS may be unimportant for your tool. However, in the general case it can be quite difficult to determine whether the differences between two configuration names are significant or not. Therefore, by convention, if the user specifies a '--target' option without specifying a '--host' option, it is assumed that the user wants to configure a cross compilation tool.

The variables 'target' and 'target_alias' should be handled differently.

In general, whenever the user may actually see a string, 'target_alias' should be used. This includes anything which may appear in the file system, such as a directory name or part of a tool name. It also includes any tool output, unless it is clearly labelled as the canonical target configuration name. This permits the user to use the '--target' option to specify how the tool will appear to the outside world.

On the other hand, when checking for characteristics of the target system, 'target' should be used. This is because a wide variety of '--target' options may map into the same canonical configuration name. You should not attempt to duplicate the canonicalization done by 'config.sub' in your own code.

By convention, cross tools are installed with a prefix of the argument used with the '--target' option, also known as 'target_alias' (see Section 5.5 [Using the Target Type], page 23). If the user does not use the '--target' option, and thus is building a native tool, no prefix is used.

For example, if gcc is configured with '--target mips-elf', then the installed binary will be named 'mips-elf-gcc'. If gcc is configured without a '--target' option, then the installed binary will be named 'gcc'.

The autoconf macro 'AC_ARG_PROGRAM' will handle this for you. If you are using automake, no more need be done; the programs will automatically be installed with the correct prefixes. Otherwise, see the autoconf documentation for 'AC_ARG_PROGRAM'.

5.6 Cross Tools in the Cygnus Tree

The Cygnus tree is used for various packages including gdb, the GNU binutils, and egcs. It is also, of course, used for Cygnus releases.

In the Cygnus tree, the top level 'configure' script uses the old Cygnus configure system, not autoconf. The top level 'Makefile.in' is written to build packages based on what is in the source tree, and supports building a large number of tools in a single 'configure'/'make' step.

The Cygnus tree may be configured with a '--target' option. The '--target' option applies recursively to every subdirectory, and permits building an entire set of cross tools at once.

5.6.1 Host and Target Libraries

The Cygnus tree distinguishes host libraries from target libraries.

Host libraries are built with the compiler used to build the programs which run on the host, which is called the host compiler. This includes libraries such as 'bfd' and 'tcl'. These libraries are built with the host compiler, and are linked into programs like the binutils or gcc which run on the host.

Target libraries are built with the target compiler. If gcc is present in the source tree, then the target compiler is the gcc that is built using the host compiler. Target libraries are libraries such as 'newlib' and 'libstdc++'. These libraries are not linked into the host programs, but are instead made available for use with programs built with the target compiler.

For the rest of this section, assume that gcc is present in the source tree, so that it will be used to build the target libraries.

There is a complication here. The configure process needs to know which compiler you are going to use to build a tool; otherwise, the feature tests will not work correctly. The

Cygnus tree handles this by not configuring the target libraries until the target compiler is built. In order to permit everything to build using a single 'configure'/'make', the configuration of the target libraries is actually triggered during the make step.

When the target libraries are configured, the '--target' option is not used. Instead, the '--host' option is used with the argument of the '--target' option for the overall configuration. If no '--target' option was used for the overall configuration, the '--host' option will be passed with the output of the 'config.guess' shell script. Any '--build' option is passed down unchanged.

This translation of configuration options is done because since the target libraries are compiled with the target compiler, they are being built in order to run on the target of the overall configuration. By the definition of host, this means that their host system is the same as the target system of the overall configuration.

The same process is used for both a native configuration and a cross configuration. Even when using a native configuration, the target libraries will be configured and built using the newly built compiler. This is particularly important for the C++ libraries, since there is no reason to assume that the C++ compiler used to build the host tools (if there even is one) uses the same ABI as the g++ compiler which will be used to build the target libraries.

There is one difference between a native configuration and a cross configuration. In a native configuration, the target libraries are normally configured and built as siblings of the host tools. In a cross configuration, the target libraries are normally built in a subdirectory whose name is the argument to '--target'. This is mainly for historical reasons.

To summarize, running 'configure' in the Cygnus tree configures all the host libraries and tools, but does not configure any of the target libraries. Running 'make' then does the following steps:

- Build the host libraries.
- Build the host programs, including gcc. Note that we call gcc both a host program (since it runs on the host) and a target compiler (since it generates code for the target).
- Using the newly built target compiler, configure the target libraries.
- Build the target libraries.

The steps need not be done in precisely this order, since they are actually controlled by 'Makefile' targets.

5.6.2 Target Library Configure Scripts

There are a few things you must know in order to write a configure script for a target library. This is just a quick sketch, and beginners shouldn't worry if they don't follow everything here.

The target libraries are configured and built using a newly built target compiler. There may not be any startup files or libraries for this target compiler. In fact, those files will probably be built as part of some target library, which naturally means that they will not exist when your target library is configured.

This means that the configure script for a target library may not use any test which requires doing a link. This unfortunately includes many useful autoconf macros, such as ‘AC_CHECK_FUNCS’. autoconf macros which do a compile but not a link, such as ‘AC_CHECK_HEADERS’, may be used.

This is a severe restriction, but normally not a fatal one, as target libraries can often assume the presence of other target libraries, and thus know which functions will be available.

As of this writing, the autoconf macro ‘AC_PROG_CC’ does a link to make sure that the compiler works. This may fail in a target library, so target libraries must use a different set of macros to locate the compiler. See the ‘configure.in’ file in a directory like ‘libiberty’ or ‘libgloss’ for an example.

As noted in the previous section, target libraries are sometimes built in directories which are siblings to the host tools, and are sometimes built in a subdirectory. The ‘--with-target-subdir’ configure option will be passed when the library is configured. Its value will be an empty string if the target library is a sibling. Its value will be the name of the subdirectory if the target library is in a subdirectory.

If the overall build is not a native build (i.e., the overall configure used the ‘--target’ option), then the library will be configured with the ‘--with-cross-host’ option. The value of this option will be the host system of the overall build. Recall that the host system of the library will be the target of the overall build. If the overall build is a native build, the ‘--with-cross-host’ option will not be used.

A library which can be built both standalone and as a target library may want to install itself into different directories depending upon the case. When built standalone, or when built native, the library should be installed in ‘$(libdir)’. When built as a target library which is not native, the library should be installed in ‘$(tooldir)/lib’. The ‘--with-cross-host’ option may be used to distinguish these cases.

This same test of ‘--with-cross-host’ may be used to see whether it is OK to use link tests in the configure script. If the ‘--with-cross-host’ option is not used, then the library is being built either standalone or native, and a link should work.

5.6.3 Make Targets in Cygnus Tree

The top level ‘Makefile’ in the Cygnus tree defines targets for every known subdirectory.

For every subdirectory *dir* which holds a host library or program, the ‘Makefile’ target ‘all-*dir*’ will build that library or program.

There are dependencies among host tools. For example, building gcc requires first building gas, because the gcc build process invokes the target assembler. These dependencies are reflected in the top level ‘Makefile’.

For every subdirectory *dir* which holds a target library, the ‘Makefile’ target ‘configure-target-*dir*’ will configure that library. The ‘Makefile’ target ‘all-target-*dir*’ will build that library.

Every ‘configure-target-*dir*’ target depends upon ‘all-gcc’, since gcc, the target compiler, is required to configure the tool. Every ‘all-target-*dir*’ target depends upon the corresponding ‘configure-target-*dir*’ target.

There are several other targets which may be of interest for each directory: ‘install-*dir*’, ‘clean-*dir*’, and ‘check-*dir*’. There are also corresponding ‘target’ versions of these for the target libraries , such as ‘install-target-*dir*’.

5.6.4 Target libiberty

The '`libiberty`' subdirectory is currently a special case, in that it is the only directory which is built both using the host compiler and using the target compiler.

This is because the files in '`libiberty`' are used when building the host tools, and they are also incorporated into the '`libstdc++`' target library as support code.

This duality does not pose any particular difficulties. It means that there are targets for both '`all-libiberty`' and '`all-target-libiberty`'.

In a native configuration, when target libraries are not built in a subdirectory, the same objects are normally used as both the host build and the target build. This is normally OK, since libiberty contains only C code, and in a native configuration the results of the host compiler and the target compiler are normally interoperable.

Irix 6 is again an exception here, since the SGI native compiler defaults to using the '`O32`' ABI, and gcc defaults to using the '`N32`' ABI. On Irix 6, the target libraries are built in a subdirectory even for a native configuration, avoiding this problem.

There are currently no other libraries built for both the host and the target, but there is no conceptual problem with adding more.

6 Canadian Cross

It is possible to use the GNU configure and build system to build a program which will run on a system which is different from the system on which the tools are built. In other words, it is possible to build programs using a cross compiler.

This is referred to as a *Canadian Cross*.

6.1 Canadian Cross Example

Here is an example of a Canadian Cross.

While running on a GNU/Linux, you can build a program which will run on a Solaris system. You would use a GNU/Linux cross Solaris compiler to build the program.

Of course, you could not run the resulting program on your GNU/Linux system. You would have to copy it over to a Solaris system before you would run it.

Of course, you could also simply build the programs on the Solaris system in the first place. However, perhaps the Solaris system is not available for some reason; perhaps you actually don't have one, but you want to build the tools for somebody else to use. Or perhaps your GNU/Linux system is much faster than your Solaris system.

A Canadian Cross build is most frequently used when building programs to run on a non-Unix system, such as DOS or Windows. It may be simpler to configure and build on a Unix system than to support the configuration machinery on a non-Unix system.

6.2 Canadian Cross Concepts

When building a Canadian Cross, there are at least two different systems involved: the system on which the tools are being built, and the system on which the tools will run.

The system on which the tools are being built is called the *build* system.

The system on which the tools will run is called the host system.

For example, if you are building a Solaris program on a GNU/Linux system, as in the previous section, the build system would be GNU/Linux, and the host system would be Solaris.

It is, of course, possible to build a cross compiler using a Canadian Cross (i.e., build a cross compiler using a cross compiler). In this case, the system for which the resulting cross compiler generates code is called the target system. (For a more complete discussion of host and target systems, see Section 5.2 [Host and Target], page 22).

An example of building a cross compiler using a Canadian Cross would be building a Windows cross MIPS ELF compiler on a GNU/Linux system. In this case the build system would be GNU/Linux, the host system would be Windows, and the target system would be MIPS ELF.

The name Canadian Cross comes from the case when the build, host, and target systems are all different. At the time that these issues were all being hashed out, Canada had three national political parties.

6.3 Build Cross Host Tools

In order to configure a program for a Canadian Cross build, you must first build and install the set of cross tools you will use to build the program.

These tools will be build cross host tools. That is, they will run on the build system, and will produce code that runs on the host system.

It is easy to confuse the meaning of build and host here. Always remember that the build system is where you are doing the build, and the host system is where the resulting program will run. Therefore, you need a build cross host compiler.

In general, you must have a complete cross environment in order to do the build. This normally means a cross compiler, cross assembler, and so forth, as well as libraries and include files for the host system.

6.4 Build and Host Options

When you run '`configure`', you must use both the '`--build`' and '`--host`' options.

The '`--build`' option is used to specify the configuration name of the build system. This can normally be the result of running the '`config.guess`' shell script, and it is reasonable to use '``--build=`config.guess` ``'.

The '`--host`' option is used to specify the configuration name of the host system.

As we explained earlier, '`config.guess`' is used to set the default value for the '`--host`' option (see Section 5.3 [Using the Host Type], page 22). We can now see that since '`config.guess`' returns the type of system on which it is run, it really identifies the build system. Since the host system is normally the same as the build system (i.e., people do not normally build using a cross compiler), it is reasonable to use the result of '`config.guess`' as the default for the host system when the '`--host`' option is not used.

It might seem that if the '`--host`' option were used without the '`--build`' option that the configure script could run '`config.guess`' to determine the build system, and presume a Canadian Cross if the result of '`config.guess`' differed from the '`--host`' option. However, for historical reasons, some configure scripts are routinely run using an explicit '`--host`' option, rather than using the default from '`config.guess`'. As noted earlier, it is difficult or impossible to reliably compare configuration names (see Section 5.5 [Using the Target Type], page 23). Therefore, by convention, if the '`--host`' option is used, but the '`--build`' option is not used, then the build system defaults to the host system.

6.5 Canadian Cross not in Cygnus Tree.

If you are not using the Cygnus tree, you must explicitly specify the cross tools which you want to use to build the program. This is done by setting environment variables before running the '`configure`' script.

You must normally set at least the environment variables '`CC`', '`AR`', and '`RANLIB`' to the cross tools which you want to use to build.

For some programs, you must set additional cross tools as well, such as '`AS`', '`LD`', or '`NM`'.

You would set these environment variables to the build cross tools which you are going to use.

For example, if you are building a Solaris program on a GNU/Linux system, and your GNU/Linux cross Solaris compiler were named '`solaris-gcc`', then you would set the environment variable '`CC`' to '`solaris-gcc`'.

6.6 Canadian Cross in Cygnus Tree

This section describes configuring and building a Canadian Cross when using the Cygnus tree.

6.6.1 Building a Normal Program

When configuring a Canadian Cross in the Cygnus tree, all the appropriate environment variables are automatically set to '*host*-*tool*', where *host* is the value used for the '`--host`' option, and *tool* is the name of the tool (e.g., '`gcc`', '`as`', etc.). These tools must be on your '`PATH`'.

Adding a prefix of *host* will give the usual name for the build cross host tools. To see this, consider that when these cross tools were built, they were configured to run on the build system and to produce code for the host system. That is, they were configured with a '`--target`' option that is the same as the system which we are now calling the host. Recall that the default name for installed cross tools uses the target system as a prefix (see Section 5.5 [Using the Target Type], page 23). Since that is the system which we are now calling the host, *host* is the right prefix to use.

For example, if you configure with '--build=i386-linux-gnu' and '--host=solaris', then the Cygnus tree will automatically default to using the compiler 'solaris-gcc'. You must have previously built and installed this compiler, probably by doing a build with no '--host' option and with a '--target' option of 'solaris'.

6.6.2 Building a Cross Program

There are additional considerations if you want to build a cross compiler, rather than a native compiler, in the Cygnus tree using a Canadian Cross.

When you build a cross compiler using the Cygnus tree, then the target libraries will normally be built with the newly built target compiler (see Section 5.6.1 [Host and Target Libraries], page 24). However, this will not work when building with a Canadian Cross. This is because the newly built target compiler will be a program which runs on the host system, and therefore will not be able to run on the build system.

Therefore, when building a cross compiler with the Cygnus tree, you must first install a set of build cross target tools. These tools will be used when building the target libraries.

Note that this is not a requirement of a Canadian Cross in general. For example, it would be possible to build just the host cross target tools on the build system, to copy the tools to the host system, and to build the target libraries on the host system. The requirement for build cross target tools is imposed by the Cygnus tree, which expects to be able to build both host programs and target libraries in a single 'configure'/'make' step. Because it builds these in a single step, it expects to be able to build the target libraries on the build system, which means that it must use a build cross target toolchain.

For example, suppose you want to build a Windows cross MIPS ELF compiler on a GNU/Linux system. You must have previously installed both a GNU/Linux cross Windows compiler and a GNU/Linux cross MIPS ELF compiler.

In order to build the Windows (configuration name 'i386-cygwin32') cross MIPS ELF (configure name 'mips-elf') compiler, you might execute the following commands (long command lines are broken across lines with a trailing backslash as a continuation character).

```
mkdir linux-x-cygwin32
cd linux-x-cygwin32
srcdir/configure --target i386-cygwin32 --prefix=installdir \
  --exec-prefix=installdir/H-i386-linux
make
make install
cd ..
mkdir linux-x-mips-elf
cd linux-x-mips-elf
srcdir/configure --target mips-elf --prefix=installdir \
  --exec-prefix=installdir/H-i386-linux
make
make install
cd ..
mkdir cygwin32-x-mips-elf
cd cygwin32-x-mips-elf
srcdir/configure --build=i386-linux-gnu --host=i386-cygwin32 \
```

```
    --target=mips-elf --prefix=wininstalldir \
    --exec-prefix=wininstalldir/H-i386-cygwin32
make
make install
```

You would then copy the contents of *wininstalldir* over to the Windows machine, and run the resulting programs.

6.7 Supporting Canadian Cross

If you want to make it possible to build a program you are developing using a Canadian Cross, you must take some care when writing your configure and make rules. Simple cases will normally work correctly. However, it is not hard to write configure and make tests which will fail in a Canadian Cross.

6.7.1 Supporting Canadian Cross in Configure Scripts

In a '`configure.in`' file, after calling '`AC_PROG_CC`', you can find out whether this is a Canadian Cross configure by examining the shell variable '`cross_compiling`'. In a Canadian Cross, which means that the compiler is a cross compiler, '`cross_compiling`' will be '`yes`'. In a normal configuration, '`cross_compiling`' will be '`no`'.

You ordinarily do not need to know the type of the build system in a configure script. However, if you do need that information, you can get it by using the macro '`AC_CANONICAL_SYSTEM`', the same macro that is used to determine the target system. This macro will set the variables '`build`', '`build_alias`', '`build_cpu`', '`build_vendor`', and '`build_os`', which correspond to the similar '`target`' and '`host`' variables, except that they describe the build system.

When writing tests in '`configure.in`', you must remember that you want to test the host environment, not the build environment.

Macros like '`AC_CHECK_FUNCS`' which use the compiler will test the host environment. That is because the tests will be done by running the compiler, which is actually a build cross host compiler. If the compiler can find the function, that means that the function is present in the host environment.

Tests like '`test -f /dev/ptyp0`', on the other hand, will test the build environment. Remember that the configure script is running on the build system, not the host system. If your configure scripts examines files, those files will be on the build system. Whatever you determine based on those files may or may not be the case on the host system.

Most autoconf macros will work correctly for a Canadian Cross. The main exception is '`AC_TRY_RUN`'. This macro tries to compile and run a test program. This will fail in a Canadian Cross, because the program will be compiled for the host system, which means that it will not run on the build system.

The '`AC_TRY_RUN`' macro provides an optional argument to tell the configure script what to do in a Canadian Cross. If that argument is not present, you will get a warning when you run '`autoconf`':

```
warning: AC_TRY_RUN called without default to allow cross compiling
```

This tells you that the resulting '`configure`' script will not work with a Canadian Cross.

In some cases while it may better to perform a test at configure time, it is also possible to perform the test at run time. In such a case you can use the cross compiling argument to 'AC_TRY_RUN' to tell your program that the test could not be performed at configure time.

There are a few other autoconf macros which will not work correctly with a Canadian Cross: a partial list is 'AC_FUNC_GETPGRP', 'AC_FUNC_SETPGRP', 'AC_FUNC_SETVBUF_REVERSED', and 'AC_SYS_RESTARTABLE_SYSCALLS'. The 'AC_CHECK_SIZEOF' macro is generally not very useful with a Canadian Cross; it permits an optional argument indicating the default size, but there is no way to know what the correct default should be.

6.7.2 Supporting Canadian Cross in Makefiles.

The main Canadian Cross issue in a 'Makefile' arises when you want to use a subsidiary program to generate code or data which you will then include in your real program.

If you compile this subsidiary program using '$(CC)' in the usual way, you will not be able to run it. This is because '$(CC)' will build a program for the host system, but the program is being built on the build system.

You must instead use a compiler for the build system, rather than the host system. In the Cygnus tree, this make variable '$(CC_FOR_BUILD)' will hold a compiler for the build system.

Note that you should not include 'config.h' in a file you are compiling with '$(CC_FOR_BUILD)'. The 'configure' script will build 'config.h' with information for the host system. However, you are compiling the file using a compiler for the build system (a native compiler). Subsidiary programs are normally simple filters which do no user interaction, and it is normally possible to write them in a highly portable fashion so that the absence of 'config.h' is not crucial.

The gcc 'Makefile.in' shows a complex situation in which certain files, such as 'rtl.c', must be compiled into both subsidiary programs run on the build system and into the final program. This approach may be of interest for advanced build system hackers. Note that the build system compiler is rather confusingly called 'HOST_CC'.

7 Cygnus Configure

The Cygnus configure script predates autoconf. All of its interesting features have been incorporated into autoconf. No new programs should be written to use the Cygnus configure script.

However, the Cygnus configure script is still used in a few places: at the top of the Cygnus tree and in a few target libraries in the Cygnus tree. Until those uses have been replaced with autoconf, some brief notes are appropriate here. This is not complete documentation, but it should be possible to use this as a guide while examining the scripts themselves.

7.1 Cygnus Configure Basics

Cygnus configure does not use any generated files; there is no program corresponding to 'autoconf'. Instead, there is a single shell script named 'configure' which may be found at the top of the Cygnus tree. This shell script was written by hand; it was not generated by autoconf, and it is incorrect, and indeed harmful, to run 'autoconf' in the top level of a Cygnus tree.

Cygnus configure works in a particular directory by examining the file 'configure.in' in that directory. That file is broken into four separate shell scripts.

The first is the contents of 'configure.in' up to a line that starts with '# per-host:'. This is the common part.

The second is the rest of 'configure.in' up to a line that starts with '# per-target:'. This is the per host part.

The third is the rest of 'configure.in' up to a line that starts with '# post-target:'. This is the per target part.

The fourth is the remainder of 'configure.in'. This is the post target part.

If any of these comment lines are missing, the corresponding shell script is empty.

Cygnus configure will first execute the common part. This must set the shell variable 'srctrigger' to the name of a source file, to confirm that Cygnus configure is looking at the right directory. This may set the shell variables 'package_makefile_frag' and 'package_makefile_rules_frag'.

Cygnus configure will next set the 'build' and 'host' shell variables, and execute the per host part. This may set the shell variable 'host_makefile_frag'.

Cygnus configure will next set the 'target' variable, and execute the per target part. This may set the shell variable 'target_makefile_frag'.

Any of these scripts may set the 'subdirs' shell variable. This variable is a list of subdirectories where a 'Makefile.in' file may be found. Cygnus configure will automatically look for a 'Makefile.in' file in the current directory. The 'subdirs' shell variable is not normally used, and I believe that the only directory which uses it at present is 'newlib'.

For each 'Makefile.in', Cygnus configure will automatically create a 'Makefile' by adding definitions for 'make' variables such as 'host' and 'target', and automatically editing the values of 'make' variables such as 'prefix' if they are present.

Also, if any of the 'makefile_frag' shell variables are set, Cygnus configure will interpret them as file names relative to either the working directory or the source directory, and will read the contents of the file into the generated 'Makefile'. The file contents will be read in after the first line in 'Makefile.in' which starts with '####'.

These 'Makefile' fragments are used to customize behaviour for a particular host or target. They serve to select particular files to compile, and to define particular preprocessor macros by providing values for 'make' variables which are then used during compilation. Cygnus configure, unlike autoconf, normally does not do feature tests, and normally requires support to be added manually for each new host.

The 'Makefile' fragment support is similar to the autoconf 'AC_SUBST_FILE' macro.

After creating each 'Makefile', the post target script will be run (i.e., it may be run several times). This script may further customize the 'Makefile'. When it is run, the shell variable 'Makefile' will hold the name of the 'Makefile', including the appropriate directory component.

Like an autoconf generated 'configure' script, Cygnus configure will create a file named 'config.status' which, when run, will automatically recreate the configuration. The 'config.status' file will simply execute the Cygnus configure script again with the appropriate arguments.

Any of the parts of 'configure.in' may set the shell variables 'files' and 'links'. Cygnus configure will set up symlinks from the names in 'links' to the files named in 'files'. This is similar to the autoconf 'AC_LINK_FILES' macro.

Finally, any of the parts of 'configure.in' may set the shell variable 'configdirs' to a set of subdirectories. If it is set, Cygnus configure will recursively run the configure process in each subdirectory. If the subdirectory uses Cygnus configure, it will contain a 'configure.in' file but no 'configure' file, in which case Cygnus configure will invoke itself recursively. If the subdirectory has a 'configure' file, Cygnus configure assumes that it is an autoconf generated 'configure' script, and simply invokes it directly.

7.2 Cygnus Configure in C++ Libraries

The C++ library configure system, written by Per Bothner, deserves special mention. It uses Cygnus configure, but it does feature testing like that done by autoconf generated 'configure' scripts. This approach is used in the libraries 'libio', 'libstdc++', and 'libg++'.

Most of the 'Makefile' information is written out by the shell script 'libio/config.shared'. Each 'configure.in' file sets certain shell variables, and then invokes 'config.shared' to create two package 'Makefile' fragments. These fragments are then incorporated into the resulting 'Makefile' by the Cygnus configure script.

The file '_G_config.h' is created in the 'libio' object directory by running the shell script 'libio/gen-params'. This shell script uses feature tests to define macros and typedefs in '_G_config.h'.

8 Multilibs

For some targets gcc may have different processor requirements depending upon command line options. An obvious example is the '-msoft-float' option supported on several processors. This option means that the floating point registers are not available, which means that floating point operations must be done by calling an emulation subroutine rather than by using machine instructions.

For such options, gcc is often configured to compile target libraries twice: once with '-msoft-float' and once without. When gcc compiles target libraries more than once, the resulting libraries are called *multilibs*.

Multilibs are not really part of the GNU configure and build system, but we discuss them here since they require support in the 'configure' scripts and 'Makefile''s used for target libraries.

8.1 Multilibs in gcc

In gcc, multilibs are defined by setting the variable '`MULTILIB_OPTIONS`' in the target '`Makefile`' fragment. Several other '`MULTILIB`' variables may also be defined there. See section "The Target Makefile Fragment" in *Using and Porting GNU CC*.

If you have built gcc, you can see what multilibs it uses by running it with the '`-print-multi-lib`' option. The output '`.;`' means that no multilibs are used. In general, the output is a sequence of lines, one per multilib. The first part of each line, up to the '`;`', is the name of the multilib directory. The second part is a list of compiler options separated by '`@`' characters.

Multilibs are built in a tree of directories. The top of the tree, represented by '`.`' in the list of multilib directories, is the default library to use when no special compiler options are used. The subdirectories of the tree hold versions of the library to use when particular compiler options are used.

8.2 Multilibs in Target Libraries

The target libraries in the Cygnus tree are automatically built with multilibs. That means that each library is built multiple times.

This default is set in the top level '`configure.in`' file, by adding '`--enable-multilib`' to the list of arguments passed to configure when it is run for the target libraries (see Section 5.6.1 [Host and Target Libraries], page 24).

Each target library uses the shell script '`config-ml.in`', written by Doug Evans, to prepare to build target libraries. This shell script is invoked after the '`Makefile`' has been created by the '`configure`' script. If multilibs are not enabled, it does nothing, otherwise it modifies the '`Makefile`' to support multilibs.

The '`config-ml.in`' script makes one copy of the '`Makefile`' for each multilib in the appropriate subdirectory. When configuring in the source directory (which is not recommended), it will build a symlink tree of the sources in each subdirectory.

The '`config-ml.in`' script sets several variables in the various '`Makefile`'s. The '`Makefile.in`' must have definitions for these variables already; '`config-ml.in`' simply changes the existing values. The '`Makefile`' should use default values for these variables which will do the right thing in the subdirectories.

'`MULTISRCTOP`'
: '`config-ml.in`' will set this to a sequence of '`../`' strings, where the number of strings is the number of multilib levels in the source tree. The default value should be the empty string.

'`MULTIBUILDTOP`'
: '`config-ml.in`' will set this to a sequence of '`../`' strings, where the number of strings is number of multilib levels in the object directory. The default value should be the empty string. This will differ from '`MULTISRCTOP`' when configuring in the source tree (which is not recommended).

'`MULTIDIRS`'
: In the top level '`Makefile`' only, '`config-ml.in`' will set this to the list of multilib subdirectories. The default value should be the empty string.

'MULTISUBDIR'
: 'config-ml.in' will set this to the installed subdirectory name to use for this subdirectory, with a leading '/'. The default value shold be the empty string.

'MULTIDO'
'MULTICLEAN'
: In the top level 'Makefile' only, 'config-ml.in' will set these variables to commands to use when doing a recursive make. These variables should both default to the string 'true', so that by default nothing happens.

All references to the parent of the source directory should use the variable 'MULTISRCTOP'. Instead of writing '$(srcdir)/..', you must write '$(srcdir)/$(MULTISRCTOP)..'.

Similarly, references to the parent of the object directory should use the variable 'MULTIBUILDTOP'.

In the installation target, the libraries should be installed in the subdirectory 'MULTISUBDIR'. Instead of installing '$(libdir)/libfoo.a', install '$(libdir)$(MULTISUBDIR)/libfoo.a'.

The 'config-ml.in' script also modifies the top level 'Makefile' to add 'multi-do' and 'multi-clean' targets which are used when building multilibs.

The default target of the 'Makefile' should include the following command:

```
@$(MULTIDO) $(FLAGS_TO_PASS) DO=all multi-do
```

This assumes that '$(FLAGS_TO_PASS)' is defined as a set of variables to pass to a recursive invocation of 'make'. This will build all the multilibs. Note that the default value of 'MULTIDO' is 'true', so by default this command will do nothing. It will only do something in the top level 'Makefile' if multilibs were enabled.

The 'install' target of the 'Makefile' should include the following command:

```
@$(MULTIDO) $(FLAGS_TO_PASS) DO=install multi-do
```

In general, any operation, other than clean, which should be performed on all the multilibs should use a '$(MULTIDO)' line, setting the variable 'DO' to the target of each recursive call to 'make'.

The 'clean' targets ('clean', 'mostlyclean', etc.) should use '$(MULTICLEAN)'. For example, the 'clean' target should do this:

```
@$(MULTICLEAN) DO=clean multi-clean
```

9 Frequently Asked Questions

Which do I run first, 'autoconf' or 'automake'?
: Except when you first add autoconf or automake support to a package, you shouldn't run either by hand. Instead, configure with the '--enable-maintainer-mode' option, and let 'make' take care of it.

'autoconf' says something about undefined macros.
: This means that you have macros in your 'configure.in' which are not defined by 'autoconf'. You may be using an old version of 'autoconf'; try building and installing a newer one. Make sure the newly installled 'autoconf' is first on your 'PATH'. Also, see the next question.

My 'configure' script has stuff like 'CY_GNU_GETTEXT' in it.
: This means that you have macros in your 'configure.in' which should be defined in your 'aclocal.m4' file, but aren't. This usually means that 'aclocal' was not able to appropriate definitions of the macros. Make sure that you have installed all the packages you need. In particular, make sure that you have installed libtool (this is where 'AM_PROG_LIBTOOL' is defined) and gettext (this is where 'CY_GNU_GETTEXT' is defined, at least in the Cygnus version of gettext).

My 'Makefile' has '@' characters in it.
: This may mean that you tried to use an autoconf substitution in your 'Makefile.in' without adding the appropriate 'AC_SUBST' call to your 'configure' script. Or it may just mean that you need to rebuild 'Makefile' in your build directory. To rebuild 'Makefile' from 'Makefile.in', run the shell script 'config.status' with no arguments. If you need to force 'configure' to run again, first run 'config.status --recheck'. These runs are normally done automatically by 'Makefile' targets, but if your 'Makefile' has gotten messed up you'll need to help them along.

Why do I have to run both 'config.status --recheck' and 'config.status'?
: Normally, you don't; they will be run automatically by 'Makefile' targets. If you do need to run them, use 'config.status --recheck' to run the 'configure' script again with the same arguments as the first time you ran it. Use 'config.status' (with no arguments) to regenerate all files ('Makefile', 'config.h', etc.) based on the results of the configure script. The two cases are separate because it isn't always necessary to regenerate all the files after running 'config.status --recheck'. The 'Makefile' targets generated by automake will use the environment variables 'CONFIG_FILES' and 'CONFIG_HEADERS' to only regenerate files as they are needed.

What is the Cygnus tree?
: The Cygnus tree is used for various packages including gdb, the GNU binutils, and egcs. It is also, of course, used for Cygnus releases. It is the build system which was developed at Cygnus, using the Cygnus configure script. It permits building many different packages with a single configure and make. The configure scripts in the tree are being converted to autoconf, but the general build structure remains intact.

Why do I have to keep rebuilding and reinstalling the tools?
: I know, it's a pain. Unfortunately, there are bugs in the tools themselves which need to be fixed, and each time that happens everybody who uses the tools need to reinstall new versions of them. I don't know if there is going to be a clever fix until the tools stabilize.

Why not just have a Cygnus tree 'make' target to update the tools?
: The tools unfortunately need to be installed before they can be used. That means that they must be built using an appropriate prefix, and it seems unwise to assume that every configuration uses an appropriate prefix. It might be possible to make them work in place, or it might be possible to install them in some subdirectory; so far these approaches have not been implemented.

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