

The ERC32 GNU Cross-Compiler System

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The ERC32 GNU cross-compiler system

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1 Introduction

1.1 General

This document describes the ERC32 GNU cross-compiler system version 1.3. Discussions are provided for the following topics:

- contents and directory structure of ERC32CCS
- compiling and linking ERC32 applications
- usage of SIS and MKPROM
- debugging ERC32 application with GDB/SIS

The ERC32 GNU cross-compiler system is a multi-platform development system based on the GNU family of freely available tools with additional 'point' tools developed by Cygnus, OAR and ESTEC. The ERC32CCS consists of the following packages:

- EGCS/GCC C/C++ compiler
- GNAT Ada95 compiler
- GNU binary utilities
- RTEMS C/C++ real-time kernel
- Newlib standalone C-library
- SIS ERC32 simulator
- GDB debugger with ERC32 remote debugging monitor (rdbmon)
- DDD graphical front-end for GDB
- MKPROM boot-prom builder

1.2 News in version 1.3.2

This version of ERC32CCS contains the following changes with respect to 1.3:

- DDD version 3.0
- Mprom version 1.2
- Egcs-1.0 C/C++ compiler
- RTEMS 4.0 beta release with simplified compile procedure
- Experimental Ada95 compiler based on gnat-3.10 and rtems-4.0
- Re-compiled floating-point library (libm.a) to incorporate the FPU fixes
- GDB version 4.17 with gnat support
- SIS version 3.0

2 Installation and directory structure

2.1 Obtaining ERC32CCS

ERC32CCS is only distributed via anonymous ftp. The primary home of ERC32CCS is the ESTEC ftp-server at <ftp://ftp.estec.esa.nl/pub/ws/wsd/erc32/erc32ccs>. Two platforms are supported: SUN Sparcstaion (SunOS & Solaris) and PC/Linux. Sources for rdbmon and mkprom are provided with ERC32CCS, the remaining sources can be found at the usual GNU sites.

2.2 Installation

The ERC32CCS directory tree is compiled to reside in `/usr/local/erc32`. After obtaining the compressed tar-file with the binary distribution, un-compress and un-tar it in a suitable location - if this is not `/usr/local/erc32` then a link have to be created to point to the location of the ERC32CCS directory. The distribution can be installed with the following command:

```
gunzip -c erc32ccs-1.3.2.tar.gz | tar xf -
```

This will create the `erc32` directory in the current directory. The `erc32` contains the following sub-directories:

<code>bin</code>	<code>executables</code>
<code>doc</code>	<code>documentation</code>
<code>include</code>	<code>host includes</code>
<code>lib</code>	<code>host libraries</code>
<code>man</code>	<code>man pages</code>
<code>rtems</code>	<code>rtems libraries</code>
<code>rtemsnp</code>	<code>rtems libraries (no posix)</code>
<code>sparc-rtems</code>	<code>target libraries (ERC32)</code>
<code>src</code>	<code>various sources</code>

Documentation for the various packages can be found in `doc`, while unix-style man-pages are in `man`.

2.3 Environment

ERC32CCS does not longer require any environment variables to be set; just add `/usr/local/erc32/bin` to your search path.

2.4 Support

For technical support regarding GNU tools, contact Cygnus at <http://www.cygnus.com/>. For RTEMS support contact OAR at <http://www.oarcorp.com/>. For SIS and MkProm support, contact J.Gaisler (ESTEC) at jgais@ws.estec.esa.nl.

3 Using ERC32CCS

3.1 ERC32CCS tools

The following tools are included in ERC32CCS:

ddd	graphic X11 front-end to GDB
fcheck	utility to check for FPU rev.B bugs
mkprom	boot-prom builder
protoize	GNU protoize utility
sis	ERC32 simulator
sis64	ERC32 simulator (with 64-bit time)
sparc-rtems-ar	library archiver
sparc-rtems-as	modified cross-assembler (FPU rev.B fixes)
sparc-rtems-c++	C++ cross-compiler
sparc-rtems-c++filt	utility to demangle C++ symbols
sparc-rtems-g++	same as sparc-rtems-c++
sparc-rtems-gasp	assembler pre-processor
sparc-rtems-gcc	C/C++ cross-compiler
sparc-rtems-gdb	debugger with ERC32 simulator and remote target interface
sparc-rtems-gdb64	debugger with ERC32 simulator (64-bit time)
sparc-rtems-gnatcmd	Utility to print all GNAT command switches
sparc-rtems-gnatmake	Ada make utility
sparc-rtems-gnatbind	Ada binder
sparc-rtems-gnatf	Ada syntax checker and cross-reference generator
sparc-rtems-gnatprep	Ada pre-processor
sparc-rtems-gnatbl	Ada bind and link
sparc-rtems-gnatkr	Ada file name cruncher
sparc-rtems-gnatpsta	Utility to print the <i>Standard</i> package
sparc-rtems-gnat Chop	Ada source code splitter
sparc-rtems-gnatlink	Ada linker
sparc-rtems-gnatpsys	Utility to display the <i>System</i> package
sparc-rtems-gnat Chp	Ada source code splitter
sparc-rtems-gnatls	Ada library lister
sparc-rtems-ld	GNU linker
sparc-rtems-nm	utility to print symbol table
sparc-rtems-objcopy	utility to convert between binary formats
sparc-rtems-objdump	utility to dump various parts of executables
sparc-rtems-ranlib	library sorter
sparc-rtems-size	utility to display segment sizes
sparc-rtems-strings	utility to dump strings from executables
sparc-rtems-strip	utility to remove symbol table
unprotoize	GNU unprotoize utility

3.2 Documentation

An extensive set of documentation for all tools can be found in `doc` and `man`. The following documents are provided:

<code>as.bdf</code>	Using as - the GNU assembler
<code>bfd.pdf</code>	Libbfd - the binary file description
<code>binutils.pdf</code>	The GNU binary utilities
<code>cpp.pdf</code>	The C Preprocessor
<code>ddd.pdf</code>	DDD - The Data Display Debugger
<code>gcc.pdf</code>	Using and porting GCC
<code>gdb.pdf</code>	Debugging with GDB
<code>gnat_rm.pdf</code>	GNAT reference manual
<code>gnat_ug.pdf</code>	GNAT User's guide
<code>ld.pdf</code>	Using ld - the GNU linker
<code>mkprom.pdf</code>	Mprom manual page
<code>rtems_dev.pdf</code>	RTEMS Development environment guide
<code>rtems_relnotes.pdf</code>	RTEMS Release notes
<code>rtems_sparc.pdf</code>	RTEMS SPARC Applications supplement
<code>rtems_user.pdf</code>	RTEMS C User's manual (this is the one you want!)
<code>sis.pdf</code>	SIS - SPARC instruction set simulator manual
<code>sparcv7.pdf</code>	SPARC V7 Instruction set manual

Data sheets for the ERC32 chip-set are also provided:

<code>mecspec.pdf</code>	MEC rev.A Device specification
<code>tsc961e.pdf</code>	TSC961 Integer Unit User's manual
<code>tsc962e.pdf</code>	TSC962 Floating-point Unit user's manual
<code>sysover.pdf</code>	ERC32 System overview

The documents are all provided in PDF format, with searchable indexes. The GNU documents have embedded hyper-links and searchable document text. A free PDF viewer ('acrobat') can be downloaded from Adobe (<http://www.adobe.com/>).

3.3 Development flow

The compilation and debugging of an ERC32-based applications is done in the following steps:

1. Compile and link program with `gcc`
2. Debug program in standalone simulator (SIS) or with `gdb`
3. Debug program on remote target with `gdb`
4. Create boot-prom for a standalone application

The ERC32CCS-1.3.2 supports three types of applications; ordinary sequential C-programs, multi-tasking real-time C--programs based on the RTEMS kernel, and Ada-95 programs. Compiling and linking is done in much the same manner as with the host-based `gcc` and `GNAT`.

3.4 RTEMS applications

The primary application type for ERC32CCS is now RTEMS programs. As of ERC32CCS-1.3, compiling and linking of RTEMS applications is greatly simplified. The usage of a RTEMS specific makefile is no longer required, the gcc compiler driver supplies all necessary paths and libraries. To compile and link a RTEMS application, use 'sparc-rtems-gcc':

```
sparc-rtems-gcc -g -O3 rtems-hello.c -o rtems-hello.exe
```

The various compilation switches are explained in the gcc manual (gcc.pdf) and the man-pages. RTEMS is provided in two versions; with and without POSIX threads interface. If applications are written with the POSIX interface, add the -posix switch during compilation and linking:

```
sparc-rtems-gcc -posix -g -O3 posix-app.c -o posix-app.exe
```

The default load address is start of RAM, i.e. 0x2000000. Any load address can be specified through the -Ttext option (see gcc manual).

Extensive documentation is provided on RTEMS in doc/rtems_user.pdf.

3.5 Compiling sequential C-programs

Ordinary sequential C programs are still supported by providing the -nortems switch to the compiler driver:

```
sparc-rtems-gcc -nortems -g -O2 hello.c -o hello.exe
```

3.6 Compiling Ada95 programs

Compiling and linking an Ada95 program is easiest done through gnatmake:

```
sparc-rtems-gnatmake -g -O3 -gnatp dais.adb
```

Individual units can be compiled through gcc:

```
sparc-rtems-gcc -c -g -O3 -gnatp dais.adb
```

If linking is done through gnatbl, the -posix and -qgnat flags has to be added:

```
sparc-rtems-gnatbl -posix -qgnat -g -O3 -gnatp dais.adb
```

For details on how to use gnat, see the GNAT User's Manual (gnat_us.pdf) and GNAT Reference Manual (gnat_rm.pdf). NOTE: the gnat compiler is only provided for testing purposes, and is not by any means validated or guaranteed. A commercial, validated version is available from Ada Core Technology (<http://www.gnat.com/>).

The gnat compiler is configured for a maximum of 20 tasks and 30 mutexes. If you need a different configuration, go to the erc32/src/libio directory, edit gnatinit.c and do a 'make install'.

3.7 Making boot-proms

Both sequential C-programs and RTEMS applications are linked to run from beginning of ram at address 0x2000000. To make a boot-prom that will run on a standalone target, use the mkprom utility. This will create a compressed boot image that will load the application to the beginning of ram, initiate various MEC register, and finally start the application. mkprom will set all target dependent

parameters, such as memory sizes, number of memory banks, waitstates, baudrate, and system clock. The applications do not set these parameters themselves, and thus do not need to be relinked for different board architectures. The example below creates a boot-prom for a system with 1 Mbyte RAM, one waitstate during write, 3 waitstates for rom access, and 12 MHz system clock. For more details see the `mkprom` manual

```
mkprom -ramsz 0x100000 -ramws 1 -romws 3 hello.exe -freq 12 hello.srec
```

To let the real-time clock generate the correct time base, the loader passes board frequency to the program via the memory location at `%tbr[0x7e0]`. When running programs on top of `sparcmon` without using `mkprom`, this is not done and the default frequency of 14 MHz is assumed. This can be changed by setting the first word in trap `0x7e` to the value of the clock frequency (in MHz) after the program has been loaded but before it is started. This needs to be done only to get the time correct, the run-time system will not modify the UART baudrate if it already has been set. The example below sets the clock frequency to 10 MHz for a program that is linked to run from address `0x2020000`:

```
monitor> ex -l 20207e0
0x020207e0: 0x91d02000 ? a
```

3.8 Simple examples

Following example compiles the famous 'hello world' program and creates a boot-prom in SRECORD format:

```
tellus > sparc-rtems-gcc -nortems -g -O2 hello.c -o hello
tellus > mkprom hello -o hello.exe
tellus> sparc-rtems-objcopy -v -O srec hello.exe hello.srec
copy from prom.out(a.out-sunos-big) to hello.srec(srec)
tellus>
```

An Ada application compiled through `gnatmake`:

```
tellus > sparc-rtems-gnatmake -g -O3 -gnatp dais.adb
sparc-rtems-gcc -c -g -O3 -gnatp dais.adb
sparc-rtems-gnatbind -a0./ -I- -r -x dais.ali
sparc-rtems-gnatlink -g -posix -qgnat dais.ali
tellus > sparc-rtems-size dais
text    data    bss     dec      hex      filename
204720  6392     32268   243380   3b6b4    dais
```

Several example C, C++ and Ada program can be found in `src/examples`. The RTEMS validation tests can be found in `src/examples/RTEMS`.

3.9 FPU rev.B bugs

The FPU rev.B have a bug that will make certain `lddf/stdf` sequences fail. The compiler only rarely emits these sequences. The occurrence of such sequence can be check with the provided `fcheck` program. A modified assembler is also provided which will automatically insert NOPs in the failing sequences to correct this problem. The modified assembler also emits NOPs between `ldf/fpop` sequences with dependencies to circumvent a second FPU bug which is only occur if waitstates are used.

4 Execution and debugging

The applications built by ERC32CCS can be executed in four different ways; on the standalone simulator, on gdb with integrated simulator, on a remote target connected to gdb and on a standalone target board from prom.

4.1 Standalone simulator

The standalone simulator can run both application produced by the compiler and srecord images produced by MkProm. The following example shows how the 'hello world' program is run:

```
tellus > sis hello
```

```
SIS - SPARC instruction simulator 2.7.6,  copyright Jiri Gaisler 1995-1998
Bug-reports to jgais@ws.estec.esa.nl
```

```
loading hello:
```

```
section .text at 0x02000000 (26032 bytes)
section .data at 0x020065b0 (1304 bytes)
section .bss at 0x02006ac8 (40 bytes)(not loaded)
serial port A on stdin/stdout
sis> go
Hello world
IU in error mode (257)
    2567  02000800  91d02000  ta  0
sis>
```

Note that the program was started from address 0x2000000, the default start address. Programs always halt the IU after they have terminated, that is why the IU goes into error mode. The boot-prom image can also be simulated:

```
tellus > sparc-rtems-sis hello.srec
```

```
SIS - SPARC instruction simulator 2.7.6,  copyright Jiri Gaisler 1995-1998
Bug-reports to jgais@ws.estec.esa.nl
```

```
loading hello.srec:
```

```
section .secl at 0x00000000 (16784 bytes)
serial port A on stdin/stdout
sis> run
ERC32 boot loader v1.0
```

```
  initialising RAM
  decompressing .text
  decompressing .data
```

```
starting hello
```

```
Hello world!
IU in error mode (257)
sis>
```

4.2 GDB with simulator

To do symbolic debugging of both C and Ada applications, use `gdb`. After `gdb` is started, the simulator has to be attached and the program loaded. It is important that the applications have been compiled with the `-g` switch. Below is a sample session:

```
tellus > sparc-rtems-gdb hello
(gdb)tar sim

  SIS - SPARC instruction simulator 2.7.6
  Bug-reports to Jiri Gaisler ESA/ESTEC (jgais@ws.estec.esa.nl)
  serial port A on stdin/stdout
  Connected to the simulator.
(gdb)
(gdb) load
(gdb) break main
Breakpoint 1 at 0x20014e4: file hello.c, line 4.
(gdb) run
Starting program: /home/jgais/erc32/src/examples/hello

Breakpoint 1, main () at hello.c:4
4          printf("Hello world!\n");
(gdb) cont
Continuing.
Hello world!

Program exited normally.
(gdb)
```

4.3 GDB with remote target

To attach `gdb` to a remote target similar to attaching to the simulator. The baud rate for the serial port has to be specified and the remote target monitor has to run on the target. Also, a tip window should be connected to UART A to see the application output. Below is a sample session with a remote target:

```
tellus> xterm -e tip -38400 /dev/ttya &
[234]
tellus > sparc-rtems-gdb hello
(gdb) set remotebaud 38400
(gdb) tar erc32 /dev/ttyb
Remote debugging using /dev/ttyb
0x2000000 in trap_table ()
(gdb) lo
Loading section .text, size 0x65e8 vma 0x2000000
Loading section .data, size 0x4d0 vma 0x20065e8
(gdb) bre main
Breakpoint 1 at 0x20014e4: file hello.c, line 3.
(gdb) run
Starting program: /home/jgais/erc32/src/examples/hello
main () at hello.c:4
```

```
3          printf("Hello world!\n");
(gdb) cont
Continuing.
```

```
Program exited with code 03.
(gdb)
```

Note that the program has to be loaded each time before it is started with 'run'. This is to initialise the data segment to the proper start values. It is possible to switch between several targets (real or simulated) in the same GDB session. Use the GDB command **detach** to disconnect from the present target before attaching a new one.

4.4 Using DDD

DDD is a graphical front-end to gdb, and can be used regardless of target. To start DDD with the debugger use:

```
ddd --debugger sparc-rtems-gdb --attach-window
```

A small script, `ddd.x`, is provided to start DDD in this configuration. You might need the full path in front of DDD if you already have a version of ddd installed. To get the source code displayed in the ddd window, click on **locate()**. The required gdb commands to connect to a target can be entered in the command window. See the GDB and DDD manuals for how to set the default settings. If you have problems with getting DDD to run, run it with `--check-configuration` to probe for necessary libraries etc. DDD has many advanced features, see the manual in `erc32/doc(ddd.pdf)` or the on-line manual under the 'Help' menu.

4.5 Remote target monitor

The directory `src/rdbmon` contains the remote monitor which needs to be running on the target board to allow remote target debugging with gdb. The monitor supports 'break-in' into a running program by pressing Ctrl-C in GDB or **interrupt** in DDD. The two timers are stopped during monitor operation to preserve the notion of time for the application. Note that the remote debugger monitor only works with programs compiled with ERC32CCS, and thus NOT with programs compiled with Aonix Ada, VxWorks or similar.

Type `make` to build the monitor. Depending on desired baudrate type either 'make m38k4', 'make m19k2' or 'make m9k6'. Program the resulting *.srec file to you boot-prom. The remote debugger will be attached via UART B, console is on UART A. The maximum baudrate depends on the system clock of the target, 38K4 has been successfully used with a zero-waitstate ERC32 system running at 10 MHz. The monitor installs it self into the top 32K of ram. It therefore needs to know how large the ram is. The default ram size for the monitor is 2 Mbyte, adjust the Makefile if your system has different size.

5 Internals (sequential C-programs)

Below is some information you might need if you wish to modify the way sequential C-programs are built.

5.1 Memory allocation

The resulting executables are in a.out format and has three segments; text, data and bss. The text segment is at address 0x2000000, followed immediately by the data and bss segments. The stack starts at top-of-ram and extends downwards.

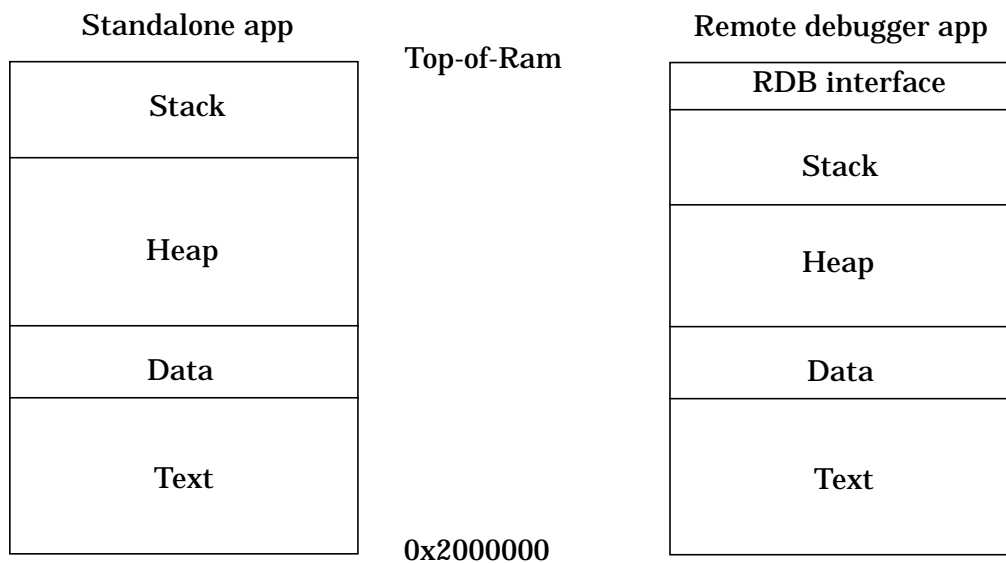


Figure 1: ERC32CCS applications memory map

The link script ram.M in `erc32/share/sparc-erc32-aout/lib` contains the setting for the available memory. The default setting is 2Mbyte. The applications are not compiled for a specific ram size, the initialisation sequence in the boot-prom (or remote target monitor) will set the top of stack to the highest available memory. The area between the data segment and the stack is used for the heap.

5.2 Libraries

A posix compatible C-library and math library is provided with ERC32CCS. However, no file or other I/O related functions will work, with the exception of I/O to stdin/stdout. Stdin/stdout are mapped on UART A, accessible via the usual stdio functions. UART B can be accessed via file handle 3 (input) or 4 (output). The following function call will write `size` character from `buf` to UART B:

```
write(4,buf,size);
```

At startup of a program, the MEC real-time counter is programmed to increment one per microsecond. The function `clock()` will return the value of the counter. The sources to the board-specific part of the C-library is provided in `erc32/src/libio`. A user can modify the I/O functions according to his needs and install them into the C-library location (`erc32/sparc-rtems/lib`).