This manual, written on 7 June 2004 by Pierre Pomiers <pierre@robosoft.fr> is version 1.0. It contains Robosoft Development Toolchain features and howto's.

Robosoft Development Toolchain

Pierre Pomiers

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Robosoft Development Toolchain: An Introduction

Robosoft distributes its products with both MPC555 and Intel x86 based architectures. This document aims to present all features of the Robosoft Development Toolchain and give users enough practical keys for using it efficiently. You will also find here several related links to follow for obtaining additional information about tools our distribution is relying on.

1 Hardware

Both Robosoft control system and development platform are based on a fully distributed architectures. Such architectures are composed with computing units, linked together over a communication media network. Supported computing units are:

- x86 familly processors (normally Intel processors from 80386 to recent P4 and others AMD or Cyrix clones are supported)
- Motorola MPC555 [See 'doc/MPC555/MPC555UM/START.pdf'] Robosoft control boards

While, supported communication media are:

- Ethernet for communication between PC computers
- CAN bus for communication between both MPC555 boards and also between MPC555 and PC.

IMPORTANT! ! !... Only Philips SJA1000 [See 'doc/CAN/SJA1000_3.pdf'] -based CAN bus devices are supported. Please use devices of the following references:

- PCI 7841 [See 'doc/CAN/PCI7841 Manual.PDF'] ADLINK Dual CAN ports
- CAN Dongle [See 'doc/CAN/MANUAL_CANDongleV160a-1.pdf'] for ECP/EPP

PCI 7841 [See 'doc/CAN/PCI7841 Manual.PDF'] reference can only be used on PC with, at least one half PCI port on the backplane. While, CAN Dongle [See 'doc/CAN/MANUAL_CANDongleV160a-1.pdf'] interface could be used on any PC equipped with a parallel port (with EPP/ECP [See 'doc/ECP/ecp_reg.pdf'] capabilities).

2 Requirements

Here is the list of software taht needs to be installed on your Robosoft product system. You will also find links to related web site and download pages. Required for realtime support under PC:

- Linux kernel version 2.4.22 (download here)
- RTAI distribution version 24.1.12 (download here)

Required for developping applications for MPC555 (needed to build the cross compiler):

- GNU binutils version 2.14: providing linker `ld`, assembler `as` and many other utils (download sources here and read documentation here)
- GNU gcc core version gcc-3.3.2 (download sources here and read documentation here)
- newlib version 1.12.0 (download sources and read documentation here)
- fdlibm version 5.2 (download sources and read documentation here)

Required for designing heterogeneous and distributed applications:

- SynDEx CAD version 6.7.0 (download sources here and read documentation here)
- SynDEx macros for:
  - Robosoft control board
  - Motorola MPC555 microcontroller
  - x86 PC running under Linux/RTAI
  - CAN bus media

3 Installation

All installation procedure shown here assume your development tools directory is organized as follow (e.g. here user home directory is '`/home/pierre`' and developments done under '`last`' directory):

```
/home/pierre/syndex/current/last
-- appsv5
   |-- robucarAna18-0.9
   |-- test-0.0-flash
   |-- test-0.1
   |-- test-0.2
   `-- test-0.4
-- appsv6
   |-- Base128v6-0.1
   |-- floatv6-0.1
   |-- floatv6-0.2
   |-- linuxIOv6-0.1
   |-- linuxIOv6-0.2
   |-- linuxIOv6-0.3
   |-- linuxIOv6-0.4
   |-- linuxIOv6-0.5
   |-- robucarAna18-1.0-v6.6.8
   |-- robucarAna18-1.0-v6.6.8_2RD_lo
   |-- robucarAna18-1.0-v6.7.0
   |-- robucarAna18-1.0-v6.7.0-flash
   |-- robucarAna30-0.9-v6.6.8
   |-- robucarAna30-0.9-v6.6.8-flash
   |-- robucarPWM30-0.9
   |-- robucarPWM30-1.0-v6.7.0
   |-- robuter-0.10
   |-- robuter-0.11
   |-- robuter-0.12
   |-- robuter-0.12f
   |-- robuter-1.0f
   |-- robuter-1.1f
   |-- robuter-1.2f
   |-- robuter-1.3f
   |-- swissknife-0.1
   |-- swissknife-0.2
   |-- swissknife-0.3
   |-- testv6-0.1
   |-- testv6-0.2
   |-- testv6-0.3
   |-- testv6-0.4
   |-- testv6-0.5
   `-- testv6-0.6
-- crossgcc
   |-- bin
   |-- fdlibm
   |-- include
   |-- info
   |-- lib
   |-- man
   |-- ppc-elf32
   `-- share
-- doc
   |-- CAN
```

```
   |-- ECP
   |-- FDLIBM
   |-- MPC555
   |-- ROBO
   |-- SDX
   |-- pic
   `-- texi
-- ldscripts
-- macrosv5
   `-- draft
-- macrosv6
   `-- draft
-- mini-crossgcc
   |-- bin
   |-- fdlibm
   |-- include
   |-- lib
   `-- ppc-elf32
-- rtai
   `-- rtai-24.1.13 -> /usr/local/rtai-24.1.13
`-- utils
    |-- app2flash
    |-- bin2rtfifo
    |-- bootapp
    |-- bootloader
    |-- dwnbin
    |-- elf2sdxbin
    `-- sdx2img

79 directories
```

The tree given above is organized the same way that the one you will find on the product cdrom. This will help you to recover a new clean development directory in case of problem. Let us note that all tarball required for installation procedures (described in the sections below) are located under the '`required`' directory.

```
/home/pierre/syndex/current/required
-- crossgcc
   |-- binutils-2.14.tar.bz2
   |-- fdlibm-5.2.tar.bz2
   |-- gcc-core-3.3.2.tar.bz2
   `-- newlib-1.12.0.tar.gz
-- linux
   `-- linux-2.4.22.tar.bz2
-- rtai
   `-- rtai-24.1.13.tgz
`-- syndex
    |-- syndex-6.7.0-linux.tgz
    `-- syndex52linux.tgz

4 directories, 8 files
```

3.1 Installing CAN hardware

Robosoft development toolchain support two types of CAN device for handling communications between MPC555 boards and PC:

- PCI 7841 ADLINK Dual CAN ports (based on two Philips SJA1000)
- CAN Dongle (based on one Philips SJA1000)

Developping and running applications for Robosoft platforms requires to install only one of these two devices: this means that user receives his platform with the convinient device (either a PCI 7841 board or a CAN Dongle).

3.1.1 General purpose remarks

Support for the mentionned CAN devices is not done by classical drivers. The required pieces of software are generated automatically and included into the application binaries. This means that user do not have to install any additional software on his PC. Thus, most user are not concerned by the two subsections below.

Instead, advanced users wanting to build their own system, has to respect the following recommendations, depending on the choice of device they made.

3.1.2 Installing the PCI 7841 board

In order to ensure the support of the PCI 7841 board under realtime constraints, you have to be sure the PCI board does not share its interrupt with any other device (ie. there is no IRQ conflict). To check this point, you should display information about the PCI resources. Use the `lspci` command from the shell command line as shown below:

```
[root@localhost root]# lspci -v

00:00.0 Host bridge: Intel Corp. 82845 845 (Brookdale)
        Chipset Host Bridge (rev 11)
        Subsystem: Intel Corp. 82845 845 (Brookdale) Chipset Host Bridge
        Flags: bus master, fast devsel, latency 0
        Memory at e0000000 (32-bit, prefetchable) [size=64M]
        Capabilities: [e4] #09 [a104]
        Capabilities: [a0] AGP version 2.0

00:01.0 PCI bridge: Intel Corp. 82845 845 (Brookdale)
        Chipset AGP Bridge (rev 11) (prog-if 00 [Normal decode])
        Flags: bus master, 66Mhz, fast devsel, latency 64
        Bus: primary=00, secondary=01, subordinate=01, sec-latency=32
        I/O behind bridge: 00009000-00009fff
        Memory behind bridge: e4000000-e6ffffff

00:1e.0 PCI bridge: Intel Corp. 82801BA/CA/DB
        PCI Bridge (rev 05) (prog-if 00 [Normal decode])
        Flags: bus master, fast devsel, latency 0
        Bus: primary=00, secondary=02, subordinate=02, sec-latency=32
        I/O behind bridge: 0000a000-0000afff
        Memory behind bridge: e7000000-e8ffffff

00:1f.0 ISA bridge: Intel Corp. 82801BA ISA Bridge (LPC) (rev 05)
        Flags: bus master, medium devsel, latency 0

00:1f.1 IDE interface: Intel Corp. 82801BA
        IDE U100 (rev 05) (prog-if 80 [Master])
        Subsystem: Intel Corp.: Unknown device 2442
        Flags: bus master, medium devsel, latency 0
        I/O ports at f000 [size=16]

01:00.0 VGA compatible controller: ATI Technologies Inc
        Rage Mobility P/M AGP 2x (rev 64) (prog-if 00 [VGA])
        Subsystem: ATI Technologies Inc Rage Mobility P/M AGP 2x
        Flags: bus master, stepping, medium devsel, latency 32, IRQ 9
```

```
        Memory at e4000000 (32-bit, non-prefetchable) [size=16M]
        I/O ports at 9000 [size=256]
        Memory at e6000000 (32-bit, non-prefetchable) [size=4K]
        Expansion ROM at <unassigned> [disabled] [size=128K]
        Capabilities: [50] AGP version 1.0
        Capabilities: [5c] Power Management version 1

02:09.0 Network controller: Adlink Technology PCI-7841 (rev 02)
        Subsystem: Adlink Technology PCI-7841
        Flags: medium devsel, IRQ 5
        I/O ports at a000 [size=128]
        I/O ports at a400 [size=256]
        I/O ports at a800 [size=256]

02:0a.0 Ethernet controller: 3Com Corporation 3c905C-TX/TX-M [Tornado] (rev 74)
        Subsystem: 3Com Corporation
        3C905C-TX Fast Etherlink for PC Management NIC
        Flags: bus master, medium devsel, latency 32, IRQ 11
        I/O ports at ac00 [size=128]
        Memory at e8000000 (32-bit, non-prefetchable) [size=128]
        Expansion ROM at <unassigned> [disabled] [size=128K]
        Capabilities: [dc] Power Management version 2

[root@localhost root]#
```

This list reports that the PCI-7841 subsystem uses IRQ 5. This IRQ number appears nowhere else in the list, indicating this IRQ is not shared with any other devices. Thus, the reported installation is correct: there is no IRQ conflict.

In case the IRQ number appears twice or more in the `lspci` report, you should find and affect a free IRQ to the CAN board. To do this, you have two solutions:

- your PC is equiped with a BIOS allowing to configure PCI slots, then you can affect the IRQ number you desire (in our case an unused one).
- your PC does not have such a BIOS, only remains the possibility to move the CAN board to another PCI slot, until `lspci` reports no IRQ conflict.

NOTE FOR DEVELOPERS: Do not forget to specify the CAN speed you want to use for your application. For instance, if you intend to use a 800 Kbps CAN baudrate add the following line to your application dependent '`.m4x`' file:

```
define('CAN_speed_',800Kbps)
```

3.1.3 Installing the CAN Dongle

Configuring your PC for the CAN Dongle support is easier. This device uses the parallel port for driver the SJA1000 chipset. Hence, just be sure your parallel port is configure in ECP or EPP mode (to be done from the PC BIOS) and verify that, at boot time, the Linux kernel returns you the following display:

```
...
parport0: PC-style at 0x378 (0x778) [PCSPP,TRISTATE]
parport0: irq 7 detected
...
```

If your display is too fast, you can also check it after logging in by using `dmesg` from the command line:

```
[root@localhost root]# dmesg
...
EXT3 FS 2.4-0.9.19, 19 August 2002 on ide0(3,6), internal journal
EXT3-fs: mounted filesystem with ordered data mode.
SCSI subsystem driver Revision: 1.00
hdc: attached ide-scsi driver.
scsi0 : SCSI host adapter emulation for IDE ATAPI devices
  Vendor: MATSHITA  Model: UJDA730 DVD/CDRW  Rev: 1.02
  Type:   CD-ROM                             ANSI SCSI revision: 02
parport0: PC-style at 0x378 (0x778) [PCSPP,TRISTATE]
parport0: irq 7 detected
Attached scsi CD-ROM sr0 at scsi0, channel 0, id 0, lun 0
sr0: scsi3-mmc drive: 24x/24x writer cd/rw xa/form2 cdda tray
Uniform CD-ROM driver Revision: 3.12
...
```

If you do not get the right information in this display and you are sure your PC is equipped with a parallel port (remember that a DB25 connector could also be attached to a serial line), you will have to configure it manually. You have two solutions: doing it using directly kernel modules or using `kmod`. Please for more advanced use refer to '`/usr/src/linux/Documentation/parport.txt`' and '`/usr/src/linux/Documentation/parport-lowlevel.txt`'

3.1.3.1 Using `parport` as modules

If you load the parport code as a module, say:

```
# insmod parport
```

to load the generic parport code. You then must load the architecture-dependent code with (for example):

```
# insmod parport_pc io=0x3bc,0x378,0x278 irq=none,7,auto
```

to tell the parport code that you want three PC-style ports, one at 0x3bc with no IRQ, one at 0x378 using IRQ 7, and one at 0x278 with an auto-detected IRQ. Currently, PC-style (parport_pc), Sun 'bpp', Amiga, Atari, and MFC3 hardware is supported.

PCI parallel I/O card support comes from parport_pc. Base I/O addresses should not be specified for supported PCI cards since they are automatically detected.

3.1.3.2 Using `kmod`

If you use kmod, you will find it useful to edit /etc/modules.conf. Here is an example of the lines that need to be added:

```
alias parport_lowlevel parport_pc
options parport_pc io=0x378,0x278 irq=7,auto
```

KMod will then automatically load parport_pc (with the options `"io=0x378,0x278 irq=7,auto"`) whenever a parallel port device driver (such as lp) is loaded.

Note that these are example lines only! Generally, you shouldn't need to specify any options to parport_pc in order to be able to use a parallel port.

NOTE FOR DEVELOPERS: by default, when using the CAN dongle, SynDEx kernel macros assume that the dongle IRQ is 0x7 (which is the case on most computers). If it is not your case,

do not forget to add the convenient line to your application dependent '`.m4x`' file. For instance if your parallel port IRQ is 0x5 add this:

```
define(‘ECP_IRQ’,‘0x5’)
```

Moreover, as mentionned previously (See Section 3.1.2 [Installing the PCI 7841 board], page 6.) do not forget to specify the CAN speed you want to use for your application. For instance, if you intend to use a 800 Kbps CAN baudrate add the following line to your application dependent '`.m4x`' file:

```
define(‘CAN_speed_’,800Kbps)
```

3.2 Preparing Linux kernel for RTAI installation

First of all, for these operations, log as root. Get Linux kernel sources from the '`required`' directory and move it under the '`/usr/src`' directory. Get also RTAI sources from the '`required`' directory and move it under your development tree (e.g. '`syndex/[...]/last`').

```
...
cd required
cp linux/linux-2.4.xx.tar.bz2 /usr/src
cp rtai/rtai-24.1.xx.tgz syndex/[...]/last/rtai/
```

Unpack RTAI sources:

```
cd syndex/[...]/last/rtai/
tar zxvf rtai-24.1.xx.tgz
```

Unpack the Linux kernel sources:

```
cd /usr/src
tar --bzip2 -xvf linux-2.4.xx.tar.bz2
```

or

```
tar -xzvf linux-2.4.xx.tar.gz
```

Apply the ADEOS patch for this kernel. The names of the patches are in the form '`patch-2.4.xx-adeos-rx`', where '`2.4.xx`' is the kernel version the patch applies to, and the final Ids are the interface and version number for the patch. Interface numbers are changed when there is an incompatible change made to the patch, and the version letter is changed whenever a bugfix is made.

Apply the patch. Taken that '`$RTAIDIR`' is the directory where you have extracted your RTAI sources:

```
patch -p1 < $RTAIDIR/rtai-24.1.9/patches/patch-2.4.xx-adeos-rx
```

Configure the kernel. For an ADEOS patched one enable ADEOS in the "General setup" menu. You can have ADEOS either as a module or native within the Linux kernel. ADEOS mutex support can be enabled also but it does not affect RTAI. Under X11, command to this is:

```
make xconfig
```

See the README in the kernel source, in the section "Configuring the kernel" for additional information.

One easy way to configure a kernel is to start from the configuration of a previous kernel. Copy the configuration file (typically found in '`/boot`') to '`.config`', and then run `make oldconfig`.

Be carefull to:

- disable "Set version information on all module symbols" under the "Loadable module support" kernel configuration paragraph, to avoid missing links when you'll use RTAI
- disable The kernel APM option (that is known to be suspicious)

Then, compile modules, the kernel and install:

```
make dep; make modules; make modules_install; make bzImage; make install
```

Let us note that bootloader (grub) is updated automatically. Now reboot the system with this new kernel.

3.3 Installing and testing RTAI kernel

Change directories to the RTAI source tree (e.g. '`syndex/[...]/last/rtai/rtai-24.1.xx`'), and configure RTAI using:

```
make config
```

or:

```
make menuconfig
```

This will ask you the location of the ADEOS/RTHAL-enabled kernel source that you just compiled, and then ask a bunch of configuration questions. The default answers are almost always the best selection for beginning users.

If you want to trust the configuration already found in the distribution and thus avoid answering any configuration question, simply type:

```
make oldconfig
```

Clearly the above command can be used any time you want to configure RTAI using any configuration already available, i.e. when you already have an RTAI '`.config`' file you like.

Compile RTAI using:

```
make dep; make
```

Install RTAI using (as root):

```
make install
make dev
```

This will install the compiled RTAI modules into the '`/lib/modules`' directory, so that they can be loaded using `modprobe`.

For administrators intending to make the robotics systems available for non-root users, it is possible to tune '`sudo`'. '`sudo`' is used for executing a command as another user. Typically, we

will use 'sudo' to allow a permitted user to execute a command as the superuser, as specified in the sudoers file. For allowing RTAI use you just need to set access to 'sh', 'insmod', 'rmmod' and 'lsmod'. This configuration is done by editing '/etc/sudoers' file. For this, use 'visudo' as root from the command line. Here is a copy of a sample '/etc/sudoers' configuration that tunes 'sh', 'insmod', 'rmmod' and 'lsmod' access for user 'guest':

```
# sudoers file.
#
# This file MUST be edited with the 'visudo' command as root.
#
# See the sudoers man page for the details on how to write a sudoers file.
#

# Host alias specification

# User alias specification

# Cmnd alias specification

# Defaults specification

# User privilege specification
root    ALL=(ALL) ALL
guest  ALL=/bin/sh,/sbin/insmod,/sbin/rmmod,/sbin/lsmod

# Uncomment to allow people in group wheel to run all commands
# %wheel        ALL=(ALL)       ALL

# Same thing without a password
# %wheel        ALL=(ALL)       NOPASSWD: ALL

# Samples
# %users  ALL=/sbin/mount /cdrom,/sbin/umount /cdrom
# %users  localhost=/sbin/shutdown -h now
```

Once configured, you can test your 'sudo' config. First, logon as user 'guest'. For testing 'lsmod' command execution right, type:

```
[guest@localhost guest]$ sudo /sbin/lsmod
```

Now, 'sudo' will ask for a password. So, if user 'guest' password is GuEsT1234, give 'sudo' GuEsT1234 as a password. Then, you will get the displays returned by /sbin/lsmod command:

```
[guest@localhost guest]$ sudo /sbin/lsmod
Password:

Module                  Size  Used by    Not tainted
trident                34228   0  (autoclean)
ac97_codec             16776   0  (autoclean) [trident]
pcigame                 2824   0  (autoclean) [trident]
gameport                2980   0  (autoclean) [pcigame]
soundcore               5860   2  (autoclean) [trident]
radeon                 88824   1
agpgart                47808   3
appletalk              27044  12  (autoclean)
binfmt_misc             7464   1
```

```
parport_pc             19012   1  (autoclean)
lp                      8996   0  (autoclean)
parport                34528   1  (autoclean) [parport_pc lp]
8139too                18472   1
mii                     3700   0  [8139too]
crc32                   3592   0  [8139too]
sg                     36844   0  (autoclean)
sr_mod                 18168   0  (autoclean)
ide-scsi               12240   0
scsi_mod              106644   3  [sg sr_mod ide-scsi]
ide-cd                 35776   0
cdrom                  32960   0  [sr_mod ide-cd]
nls_iso8859-1           3516   1  (autoclean)
nls_cp437               5148   1  (autoclean)
vfat                   12812   1  (autoclean)
fat                    37752   0  (autoclean) [vfat]
keybdev                 2944   0  (unused)
mousedev                5556   1
hid                    24676   0  (unused)
input                   5312   0  [keybdev mousedev hid]
usb-ohci               21768   0  (unused)
usbcore                76288   1  [hid usb-ohci]
ext3                   71012   3
jbd                    49856   3  [ext3]

[guest@localhost guest]$
```

If you prefer user '`guest`' to access these commands without confirming his password, you can just add a `NOPASSWD` flag in the related '`sudoers`' line:

```
guest  ALL=NOPASSWD:/bin/sh,/sbin/insmod,/sbin/rmmod,/sbin/lsmod
```

For further information about '`sudo`' configuration, please refer to '`sudoers`', '`sudo`' and '`visudo`' man pages.

3.4 Installing the MPC555 cross compiler

If you need to re-install the cross compiler we gave you, please copy back the content of the '`crossgcc`' directory into your development tree. If for any reason, you need to recompile the cross compiler, please follow directives given below.

First, delete the content of the '`crossgcc`' directory located under your development tree:

```
rm -rf crossgcc/*
```

Now, copy back all compiler related files and extract them into this '`crossgcc`' directory:

```
...
cd crosgcc
cp ../../required/crossgcc/* ./
tar jxvf binutils-x.xx.tar.bz2
tar jxvf gcc-core-x.x.x.tar.bz2
tar zxvf newlib-x.xx.x.tar.gz
```

Then, create build directories under the '`crossgcc`' directory:

```
...
cd crossgcc
mkdir build-binutils build-gcc build-newlib
```

Now compile binutils:

```
cd build-binutils
CC=gcc
../binutils-x.xx/configure --target=ppc-elf32
                           --prefix=/home/pierre/[...]/last/crossgcc/
                           --with-newlib
make all install
```

Add binutils binary location to your `PATH`:

```
PATH=$PATH:/home/pierre/syndex/[...]/last/crossgcc/bin/
```

... more details on '`binutils2.14/binutils/README`' file.

Now compile GCC:

```
cd ../build-gcc
../gcc-x.x.x/configure --target=ppc-elf32
                       --prefix=/home/pierre/[...]/last/crossgcc/
                       --with-newlib
make all install
```

... more details under '`gcc-gcc-3.3.2/INSTALL`' directory.

Now compile newlib:

```
cd ../build-newlib
../newlib-x.xx.x/configure --target=ppc-elf32
                           --prefix=/home/pierre/[...]/last/crossgcc/
make all install
```

Precious information about building cross compiler could be found at the following addresses:

- http://www.sthoward.com/CrossGCC/
- http://www.kegel.com/crosstool/
- http://billgatliff.com/twiki/bin/view/Crossgcc/WebHome.
- http://ecos.sourceware.org/build-toolchain.html

3.5 Installing the C math library support

The math library support we use rely on fdlibm version 5.2, developed at SunSoft (a Sun Microsystems, Inc. business.).

FDLIBM is intended to provide a reasonably portable (see assumptions below), reference quality (below one ulp for major functions like sin,cos,exp,log) math library (libm.a). For a copy of FDLIBM, please see: http://www.netlib.org/fdlibm/ or http://www.validlab.com/software/

If you need to re-install the C math library support we gave you, please copy back the content of the '`crossgcc`' directory into your development tree. If for any reason, you need to recompile the C math library support, please follow directives given below.

First, copy back the C math library sources archive under the '`crossgcc`' directory, located under your development tree, and unpack it:

```
...
cd crossgcc
cp ../../required/crossgcc/fdlibm-x.x.tar.bz2 .
tar jxvf fdlibm-x.x.tar.bz2
```

Change to '`fdlibm`' directory and compile sources:

```
...
cd fdlibm
make "CFLAGS = -D_IEEE_LIBM"
```

Now, clean your C math library directory:

```
rm -f *.c *.o makefile index*
```

3.6 Installing SynDEx CAD

SynDEx is a system level CAD software based on the "algorithm-architecture adequation" (AAA) methodology, for rapid prototyping and optimizing the implementation of distributed real-time embedded applications onto multicomponent" architectures. It has been designed and developed at INRIA in the Rocquencourt Research Unit France, by the OSTRE team. The SynDEx distribution on which is based our development toolchain is version 5.2. If you need to re-install the SynDEx CAD software, please copy the archive located under '`required/syndex`' directory. Place the copy where are your other home applications (e.g. under '`~/bin`') and unpack it:

```
...
cd required/syndex
cp syndex-x.x.x-linux.tgz ~/bin
cd ~/bin
tar zxvf syndex-x.x.x-linux.tgz
```

This will create in the current directory the SynDEx subdirectory containing all the distributed files. Read the '`README`' file to complete the installation, and to start SynDEx.

If you experience any installation problem (and the answer is not in the '`README`' file or in the FAQ), please send by e-mail, to SynDEx staff, a description of the problem, with enough informations to let them a chance to resolve it.

3.7 Development tree organisation

Once all software installations, mentioned above, are completed, only remains to build (or recover) a clean development tree. It is very IMPORTANT to note that the various toolchains utils, Makefiles and scripts rely on a tree dependent organisation: thus we highly encourage to respect the tree shape we describe here.

```
/home/pierre/syndex/current/last
-- appsv5
-- appsv6
-- crossgcc
-- doc
-- ldscripts
-- macrosv5
-- macrosv6
-- macrosv6-20041220.tgz
```

```
-- mini-crossgcc
-- rtai
`-- utils

10 directories, 1 file
```

First, let us define all directories:

- '`appsv5`': contains old applications developed with SynDEx V5 distributions. This directory should only be used for maintaining old applications, but not to create new ones, as SynDEx V5 is no more supported by OSTRE team.
- '`appsv6`': contains applications developed with the newly supported SynDEx V6 distribution.
- '`crossgcc`': contains the cross MPC555 compiler tools (refer to previous sections for details).
- '`doc`': contains all documents related to the development environment (datasheets, specifications, user guides, etc...). It also contains the documentation you are reading now. Please, leave the '`doc`' directory arranged this way if you want to keep benefits of dynamical links that exist between them.
- '`ldscripts`': contains the linker scripts used by the cross compiler when producing MPC555 binaries. This files includes comments that may give you deep information on the MPC555 boards memory mapping and binary sections.
- '`macrosv5`': contains the last SynDEx macros developed for V5 distributions
- '`macrosv6`': contains the last SynDEx macros developed for V6 distributions
- '`rtai`': contains the RTAI distribution (or at least a symbolic link pointing toward the directory where it is installed). Please, refer to previous sections for details.
- '`utils`': contains a set of tools, developed by Robosoft, required for generating binaries, generating SynDEx bootloaders for MPC555, downloading applications and also preparing applications for being transfered into MPC555 internal flash memory.

As mentionned above, '`macrosv5`' and '`macrosv6`' directories contain the last macros developed for respective versions of SynDEx distributions. This mean that SynDEx macros, either for V5 or V6, provide programmers with exactely the same functionalities. Main SynDEx macros features, common to all supported processors, are documented over the dedicated SynDEx documentation web site.

Apart from this, a huge set of advanced macros has been developed for handling all MPC555 features. These macros are fully documented into The 555.m4x and RSB.m4x SynDEx Macro-Executives [See '`doc/ROBO/555macros/555macros.pdf`'] document.

Another, macro has been developed for PCs running RTAI/Linux. It aims to provide Linux users with a C/C++ programming interface, for accessing hardware resources handled by SynDEx. This macro, named `linuxIO_`, is documented into The SynDEx "linuxIO_" Macro: An Easy C/C++ Linux User's Application Interface [See '`doc/ROBO/linuxIO_/linuxIO_.pdf`'] .

4 Setting toolchain variables

Right after installing all the Robosoft development toolchain, remains few setting to be done. After this step, the toolchain will be fully functional and ready to be used for developing applications.

4.1 Bash environment variables

First, we recommend user to add the few lines into your '`~/.bashrc`' file. Let assume you installed SynDEx CAD under your '`~/bin`' directory. If you are using SynDEx CAD version V5 insert this:

```
alias syndex52='$HOME/bin/syndex52/syndex5'
SYNDEX5=$HOME/bin/syndex52
export SYNDEX5
```

If you are using SynDEx CAD version V6 just insert this:

```
alias syndex-6.6.8='$HOME/bin/syndex-6.6.8/syndex-6.6.8'
```

If you intend to use both version at the same time, insert all these lines.

4.2 Application makefile rules

Each developed application, should include under its directory and application dependent makefile named '`GNUmakefile`'. Let us focus on the '`robucar`' application.

```
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$ pwd
/home/guest/syndex/last/appsv6/robucarAna30-0.9-v6.6.7
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$ ll
total 56
-rw-rw-r--    1 guest   guest       3860 Jan 26 17:30 f555.m4
-rw-------    1 guest   guest       2523 Feb 20 14:28 GNUmakefile
-rw-rw-r--    1 guest   guest       7739 Jan 26 17:30 r555.m4
-rw-rw-r--    1 guest   guest        290 Jan 26 17:30 robucar.m4
-rw-------    1 guest   guest      11333 Apr  6 18:00 robucar.m4x
-rw-------    1 guest   guest      14362 Jan 26 17:03 robucar.sdx
-rw-rw-r--    1 guest   guest       2008 Jan 26 17:30 root.m4
-rw-r--r--    1 guest   guest         78 Feb  5 18:00 User.mk
[guest@localhost robucarAna30-0.9-v6.6.7]$
```

'`GNUmakefile`' contains a set of rules, required for compiling application correctly, and also, a set of variables related to your toolchain installation. Let us comment the '`GNUmakefile`' content step by step.

4.2.1 Linux paths

```
# $(LINUX_SRC) is the path to the Linux home directory
# $(LINUX_LIB) is the path to the Linux library files
LINUX_HOME = /usr/src/linux-2.4.22
LINUX_LIB = /usr/lib
```

Here you should indicate where to find the Linux sources and libraries (corresponding to the currently running kernel).

4.2.2 RTAI paths

```
# $(RTAI_HOME) is the path to the RTAI home directory
# If you change this path, don't forget to change the one in the "run" script !
RTAI_HOME = ../../rtai/rtai-24.1.12
```

Here you should indicate the path of RTAI installation. Note that you can either locate this directory with an absolute path ('`RTAI_HOME = /home/guest/syndex/last/rtai/rtai-24.1.12`') or, as set above, a relative path ('`RTAI_HOME = ../../rtai/rtai-24.1.12`').

4.2.3 Toolchain macros, compiler and utils paths

```
export Macros_Path  = ../../macrosv6
export M4PATH       = $(Macros_Path)
export LDSCRIPTPATH = ../../ldscripts
export CROSSGCCBIN  = ../../crossgcc/bin
export CROSSGCCLIB  = ../../crossgcc/ppc-elf32/lib
export CROSSGCCINC  = ../../crossgcc/ppc-elf32/include
export FDLIBM       = ../../crossgcc/fdlibm
export UTILSPATH    = ../../utils
M4=m4
STARTPRG = $(UTILSPATH)/bin2rtfifo/bin2rtfifo
```

Here are comments about these variables:

- `Macros_Path` indicate the path where SynDEx macros may be found.
- `M4PATH`: here nothing to be done. This variable exists for backward compatibility with SynDEx V5 distributions.
- `LDSCRIPTPATH` indicate the path where linker scripts are located
- `CROSSGCCBIN` indicate the path where to find cross-compiler tools
- `CROSSGCCLIB` indicate the path where to find cross-compiler libraries
- `CROSSGCCINS` indicate the path where to find cross-compiler header files
- `FDLIBM` indicate the path where to find the mathematical library
- `UTILSPATH` indicate the path where to find the Robosoft development toolchain utilities
- `M4` indicate which macroprocessor is installed on your development workstation: here it is `m4`, but it could be `gm4` depending on your Linux installation.
- `STARTPRG` indicate which utility is used for passing application executives to the download sequence (at boot time, ie. when starting application)

4.2.4 Application name variable

```
A = robucar
```

Here user just need to mention the application name. In this particular case, the application graphes have been stored under '`robucar.sdx`', thus the corresponding application name is `robucar`.

4.2.5 Application specific dependencies

```
# application specific dependents:

P0.libs = myLib.555
```

This type of rule aim to give operators access to separately compiled sets of functions (also called libraries). For each operator (that belong to the main architecture description), exists a '`GNUmakefile`' variable which name is the operator name followed by `.libs` extension.

In this example, we indicate that object file '`myLib.555`' contains functions that may be called by operator `P0`. Such function calls are usually done using SynDEx macro `Ccall_`. For advanced information about `Ccall_` SynDEx macro, please refer to SynDEx online documentations and to the Robosoft document titled "The 555.m4x and RSB.m4x SynDEx Macro-Executives [See '`doc/ROBO/555macros/555macros.pdf`'] ".

Note that an example of use is given farther to illustrate mathematical function calls. See Section 5.3 [About FDLIBM the C math library support], page 25.

4.2.6 Additional makefile rules

If for any reason (external function calls, separate compilation, etc...) user need to add his own extra makefile rules, he should include them into the local '`User.mk`' file.

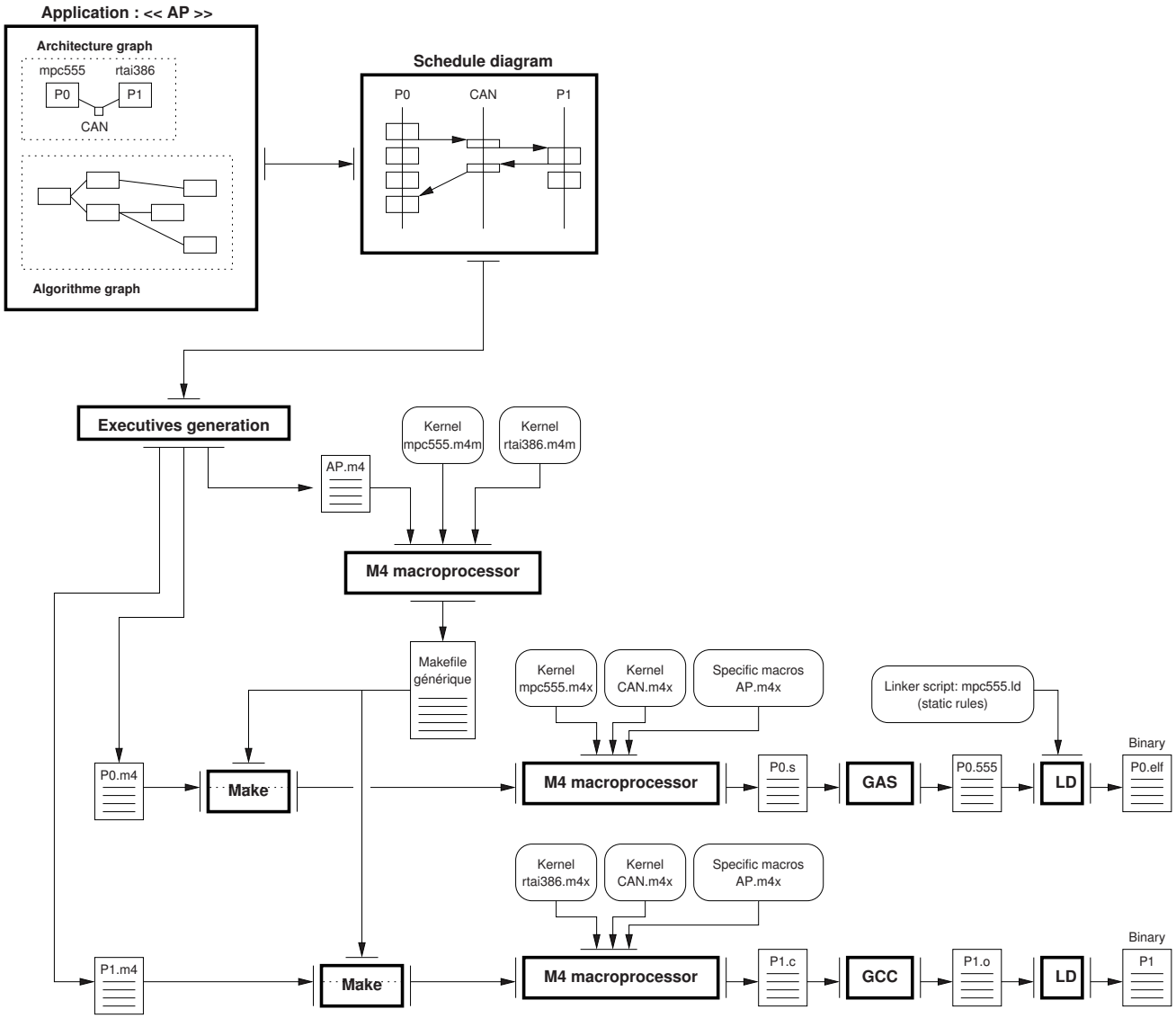
By default, this file contains a rule needed for preparing standalone flash images (named `flash_image`): this rule should NEVER be modified nor deleted! ! !... Thus additional rules should be added at the end of the file.

```
[guest@localhost robucarAna30-0.9-v6.6.7]$ cat User.mk
flash_image: $($(A).root)
        make $(A).mk
        $(UTILSPATH)/sdx2img/sdx2img $? > $@

myLib.555 : myLib.c

[guest@localhost robucarAna30-0.9-v6.6.7]$
```

For instance, here the added rule allow to compile '`myLib.c`' into an object file. This object file '`myLib.555`' contains functions used as processor `P0` library in the subsection above (ie. `P0.libs = myLib.555`).

5 Developping applications

5.1 Reminder: the SynDEx compilation sequence



The figure above depicts the full compilation sequence following the SynDEx executives generation. You can see here the way GNU development utilities (macroprocessor, compiler, ...) are run for producing binaries. In our particular case, this sequence produce PowerPC ELF 32-bits binaries for MPC555 operators and kernel modules for PC operators (running RTI/Linux).

The Robosoft development toolchain utilities, we describe below, make use of the generated PowerPC ELF 32-bits binaries, for achieving various type of work.

5.2 About Robosoft development toolchain utilities

The Robosoft development toolchain contains a set of utilities, required for downloading applications, manipulating PowerPC ELF 32-bits binaries and preparing images for flashed applications. Here is the directory tree you can find under '`.../last/utils`':

```
/home/pierre/syndex/current/last/utils
-- app2flash
-- bin2rtfifo
```

```
-- bootapp
-- bootloader
-- dwnbin
-- elf2sdxbin
`-- sdx2img

7 directories, 0 files
```

Let us browse and describe utilities features.

5.2.1 SynDEx download tools: the 'elf2sdxbin' and 'bin2rtfifo' utilities

IMPORTANT!... These tools are fully linked to the SynDEx download procedure: thus, they are not intended to be run directly by users. The following explainations just aim to familiarize users with SynDEx environment.

We recommend user to read about SynDEx download procedure. The following documents cover this topic: "SynDEx v5 Downloader Specification" [See 'doc/SDX/Dwnspec.pdf'] and "CAN Boot-Loader and Downloader Specification" [See 'doc/SDX/CANboot.pdf'] that is more specifically focused on the way a PC (running RTAI and Linux) should boot a set of MPC555 operators.

The 'elf2sdxbin' and 'bin2rtfifo' utilities are involved in download process right after the MPC555 executives compilation. At that step, one PowerPC ELF (32-bits) binary exists for each MPC555 operator of the main architecture. Refering the SynDEx download specifications (mentionned above), these ELF binaries should be converted into a SynDEx-download compatible format; this first step is done by 'elf2sdxbin'.

Once converted, the SynDEx-download compatible binaries are forwarded to the main PC operator in order to be passed to the main download sequence. To this aim, the binary files (locally stored on the PC hard drive) are read and written sequencially to an RTAI realtime fifo. The second end of this fifo is handled by the main operator communication thread, in order to pass the received binaries to the loadDnto_ sequence. This forwarding operation is done by 'bin2rtfifo'.

5.2.2 Another download tool: the 'dwnbin' utility

For users intending to download executives into MPC555 boards without using the SynDEx automatic download sequence, we developped the 'dwnbin' utility.

This utility should be run by user logged as root (or with root privileges). It is executed from the shell command line with the following syntax:

```
./dwnbinecp BAUDRATE FILE0 SID0 FILE1 SID1 ... FILEn SIDn
```

where:

- BAUDRATE is used for passing CAN baudrate to be used for download; possible values are 800, 500 or 250 respectively for 800 Kbps, 500 Kbps or 250 Kbps.
- FILE is the name of a SynDEx binary file user want to download: WARNING! DO NOT FORGET that such a file should result from an elf2sdxbin conversion.
- SID is the identifier of the station where code is supposed to be downloaded.

Here is an example of use: here, we download the bianry file 'P0' into the MPC555 board of Id. 0x4000 and the bianry file 'P1' into the MPC555 board of Id. 0x4001. CAN baudrate during download operation is set to 250 Kbps.

```
[root@localhost dwnbin]# ./dwnbinecp 250 P0 0x4000 P1 0x4001

SynDEx binary file name: P0
Target station ID: 0x4000... loaded.
```

```
SynDEx binary file name: P1
Target station ID: 0x4001... loaded.
[root@localhost dwnbin]#
```

If the user forget an argument, he will get the following display:

```
[root@localhost dwnbin]# ./dwnbinecp P0 0x4000 P1 0x4001

ERROR: bad arguments number

USAGE: ./dwnbinecp BAUDRATE FILE0 SID0 FILE1 SID1 ... FILEn SIDn

BAUDRATE possible values are 800, 500 or 250 resp. for 800 Kbps, 500  Kbps
         or 250 Kbps CAN baudrate
FILE is expected to be a SynDEx downloader format file
SID is the identifier of the station where code is supposed to be loaded.

[root@localhost dwnbin]#
```

If the user specify an invalid baudrate, he will get the following display:

```
[root@localhost dwnbin]# ./dwnbinecp 150 P0 0x4000 P1 0x4001

ERROR: bad baudrate

USAGE: pass 800, 500 or 250 resp. for 800 Kbps, 500 Kbps or 250 Kbps
settings! ! !...

[root@localhost dwnbin]#
```

If '`dwnbinecp`' does not manage to download the boards (because of a broken CAN cable or a missing power supply), it will return the following display:

```
[root@localhost dwnbin]# ./dwnbinecp 250 P0 0x4000 P1 0x4001

SynDEx binary file name: P0
Target station ID: 0x4000
WARNING! ! ! Time out has expired...

SynDEx binary file name: P1
Target station ID: 0x4001
WARNING! ! ! Time out has expired...
[root@localhost dwnbin]#
```

IMPORTANT REMARK: each time the download sequence fails, do not forget to reset the MPC555 boards by turning the off, waiting few seconds and turning them on back again. This way, you will be sure bootloaders are in a correct execution state.

'`dwnbinecp`' implement the download sequence in relation with the SynDEx download procedure. We recommend advanced user to read about SynDEx download procedure. The following documents cover this topic: "SynDEx v5 Downloader Specification" [See '`doc/SDX/Dwnspec.pdf`'] and "CAN Boot-Loader and Downloader Specification" [See '`doc/SDX/CANboot.pdf`'] . Implementation comments could also be found in the '`dwnbinecp`' source code (located under the '`dwnbin`' directory). We advise users that Robosoft is not responsible for the consequences of any change into the source code.

5.2.3 Bootloader tools: the 'bootloader' utility

Bootloader tool aim to prepare binary images to be flashed into MPC555, in order to make the MPC555 boards bootable through the CAN bus interface. These binaries consist of very small codes implementing the minimal board initialisations to make the SynDEx download sequence be possible.

What caracterise a bootloader are:

- its identifier (a 32-bits interger value chosen by the application developer),
- and its CAN baudrate (indicating the CAN comminucations speed during the SynDEx download sequence)

Preparing a bootloader is rather simple. First, move to the 'bootloader' utility directory.

```
[guest@Gromit bootloader]$ pwd
/home/guest/syndex/last/utils/bootloader
[guest@localhost bootloader]$ ll
total 40
-rw-r--r--    1 guest   guest       4242 Feb 20 16:56 bootloader-1.0.ld
-rw-r--r--    1 guest   guest      24241 Feb  5 09:47 bootloader-1.0.s
-rw-r--r--    1 guest   guest       1218 Feb 20 17:01 Makefile
-rw-rw-r--    1 guest   guest        169 Feb  5 17:32 README
[guest@localhost bootloader]$
```

This directory contains the bootloader assembly sources (with `.s` extension), the related linker script (with `.ld` extension), a '`README`' file (showing basic usage) and the '`Makefile`'. This '`Makefile`' is used for passing bootloader appropriate parameters (identifier and CAN baudrate). Let us show how to use it over an example. Here is the command line a user should execute for generating a bootloader which identifier is 0x4000 and CAN baudrate is 800 Kbps:

```
make PROCID=0x4000 KBPS=800
```

Where:

- PROCID corresponds to the identifier 32-bits HEXADECIMAL integer value
- KBPS corresponds to bootloader CAN baudrate

IMPORTANT REMARK: Available CAN baudrates are 800 Kbps, 500 Kbps and 250Kbps. Passing other values will not returns error messages but will generate erroneous flash images.

On success, the following message will be displayed:

```
# ------------------------------------------------------------------
#
# Output file is: bootloader-1.0-0x4000-800.s19
#
# ------------------------------------------------------------------
```

It indicates user that the bootloader flash image has been written into an S19 file, named '`bootloader-1.0-0x4000-800.s19`'.

```
[guest@localhost bootloader]$ ll
total 68
-rwxrwxr-x    1 guest   guest      25894 Apr  8 10:05 bootloader-1.0-0x4000-800.s19
-rw-r--r--    1 guest   guest       4242 Feb 20 16:56 bootloader-1.0.ld
-rw-r--r--    1 guest   guest      24241 Feb  5 09:47 bootloader-1.0.s
-rw-r--r--    1 guest   guest       1218 Feb 20 17:01 Makefile
-rw-rw-r--    1 guest   guest        169 Feb  5 17:32 README
[guest@localhost bootloader]$
```

Now, only remains to program the MPC555 target board.

The S19 file, obtained above, is ready to be transfered to the flash memory of the main MPC555 microcontroller. Commercial tool allow to do this: for instance Raven or Blackbird BDM devices from Macraigor Systems. More information about these products could be found at the Macraigor Systems website.

At that step, programming MPC555 microcontroller flash memory is very hardware dependent. So please refer to the documentation of the BDM device you chose and follow instructions.

5.2.4 Flash tools: the 'app2flash', 'bootapp' and 'sdx2img' utilities

Flash tools aim to prepare binary images to be flashed into MPC555, for standalone applications (ie. running without PC). Generated images respect the convenient file format, in order to be compatible with commercial flash programmer.

Preparing such a standalone application (for MPC555 only) falls into the following steps:

5.2.4.1 To be done from SynDEx CAD

When designing your application with SynDEx CAD, you will have to specify the hardware architecture. For standalone application, the hardware architecture will be composed of one MPC555, or a set of MPC555 boards communicating over a CAN bus. The board (if alone), or one of the boards has to be declared as the main operator (the "root" operator in version V5 of SynDEx CAD). This means that, at boot time, this main operator will be used for downloading the other boards of the architecture. At that step, nothing else is required.

5.2.4.2 The standalone application basic principle

In a standalone application, the download sequence is handled by the main MPC555 board. To this aim, the main operator flash memory contains both executives to be downloaded and operators identifiers. At boot time, main operator reads executives from a dedicated section of its flash memory and sequencially download all operators of the architecture. Once all operator are loaded, main operator sends a null synchronization frame on the CAN bus for starting application execution.

IMPORTANT REMARK: in such standalone architecture, only the main MPC555 board embeds an application dependent flash memory image. All other operators contain classical SynDEx bootloaders. This property is quite useful, as for changing an application, you only need to change the main operator flash memory image (instead of reprogramming all operators flash memories).

5.2.4.3 Generating the application image

Let us show how to generate the main operator flash image over an example. Let us assume that a user guest is developing a standalone application named "robucar" with two MPC555 boards.

```
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$ pwd
/home/guest/syndex/last/appsv6/robucarAna30-0.9-v6.6.7-flash
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$ ll
total 52
-rw-rw-r--    1 guest   guest       3747 Feb  5 17:42 f555.m4
-rw-------    1 guest   guest       2506 Feb 20 14:29 GNUmakefile
-rw-rw-r--    1 guest   guest       6888 Feb  5 17:42 r555.m4
-rw-rw-r--    1 guest   guest        236 Feb  5 17:42 robucar.m4
-rw-------    1 guest   guest      11623 Apr  6 18:02 robucar.m4x
-rw-------    1 guest   guest      13522 Jan 30 10:05 robucar.sdx
-rw-r--r--    1 guest   guest         78 Feb  5 18:00 User.mk
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$
```

This application is designed with two operators named respectively "r555" and "f555"; with "r555" as the main operator. Moreover, let us assume that user affects 0x4000 as an identifier for "r555" and 0x4001 for "f555". Let us also consider that the chosen CAN baudrate for this application is 250 Kbps. Before generating the "r555" flash image, user has to check if the '`User.mk`' exists in the local application directory: this file contains a part of makefile required for the generation.

```
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$ cat User.mk
flash_image: $($(A).root)
        make $(A).mk
        $(UTILSPATH)/sdx2img/sdx2img $? > $@
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$
```

Now, everything is ready. Let us move to the '`app2flash`' utility directory.

```
[guest@localhost robucarAna30-0.9-v6.6.7-flash]$ cd ../../utils/app2flash/
[guest@localhost app2flash]$ ll
total 8
-rw-r--r--    1 guest   guest        936 Feb 13 11:04 Makefile
-rw-rw-r--    1 guest   guest        286 Feb  5 17:53 README
[guest@localhost app2flash]$
```

All the flash image generation procedure is launched by the local '`Makefile`'. The '`README`' file contains instructions on how to use it. For compiling a bootable version of the user application located under '`robucarAna30-0.9-v6.6.7-flash`' directory, user just have to type the following command line:

```
make APPSPATH=../../appsv6 APP=robucarAna30-0.9-v6.6.7-flash ROOTID=0x4000 KBPS=250
```

where:

- `APPSPATH` argument corresponds to the directory where applications are located: in our case, the '`appsv6`' directory
- `APP` argument corresponds to the name of the application directory: in our case, the '`robucarAna30-0.9-v6.6.7-flash`' directory
- `ROOTID` argument corresponds to the main operator identifier: in our case, 0x4000 (as previously mentionned). The main operator identifier should be passed as an HEXADECIMAL 32-bits integer.
- and `KBPS` argument corresponds to the chosen CAN baudrate: in our case, 250 Kbps (as previously mentionned).

IMPORTANT REMARK: Available CAN baudrates are 800 Kbps, 500 Kbps and 250Kbps. Passing other values will not returns error messages but will generate erroneous flash images.

Once run, the Makefile will call other utilities: '`bootapp`' and '`sdx2img`'. These utilities should not be used alone, they are only expected to be called by the '`app2flash`' Makefile. On success, the following message will be displayed:

```
# ----------------------------------------------------------------------
#
# Output file is: robucarAna30-0.9-v6.6.7-flash.s19
#
# ----------------------------------------------------------------------
```

It indicates user that the main operator flash image has been written into an S19 file, named '`robucarAna30-0.9-v6.6.7-flash.s19`'.

```
[guest@localhost app2flash]$ ll
total 208
-rw-r--r--    1 guest   guest        936 Apr  7 17:21 Makefile
-rw-rw-r--    1 guest   guest        286 Apr  7 17:21 README
-rwxrwxr-x    1 guest   guest     197370 Apr  7 17:39 robucarAna30-0.9-v6.6.7-flash.s19
[guest@localhost app2flash]$
```

5.2.4.4 Flashing the application image

The S19 file, obtained above, is ready to be transfered to the flash memory of the main MPC555 microcontroller. Commercial tool allow to do this: for instance Raven or Blackbird BDM devices from Macraigor Systems. More information about these products could be found at the Macraigor Systems website.

At that step, programming MPC555 microcontroller flash memory is very hardware dependent. So please refer to the documentation of the BDM device you chose and follow instructions.

5.3 About FDLIBM the C math library support

The math library support we use rely on fdlibm version 5.2, developed at SunSoft (a Sun Microsystems, Inc. business.).

FDLIBM (Freely Distributable LIBM) is a C math library for machines that support IEEE 754 floating-point arithmetic. In this release, only double precision is supported. It provides user with ANSI POSIX functions, which documentations you can find below.

At the end of this section, an example of use is given to illustrate how to call mathematical functions from a user defined SynDEx macro.

5.3.1 double acosh (double);

```
ACOSH(3)                    Linux Programmer's Manual                    ACOSH(3)



NAME
       acosh - inverse hyperbolic cosine function

SYNOPSIS
       #include <math.h>

       double acosh(double x);

DESCRIPTION
       The  acosh()  function  calculates  the inverse hyperbolic cosine of x;
       that is the value whose hyperbolic cosine is x.  If x is less than 1.0,
       acosh() returns not-a-number (NaN) and errno is set.

ERRORS
       EDOM   x is out of range.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       asinh(3), atanh(3), cosh(3), sinh(3), tanh(3)
```

1993-06-13 ACOSH(3)

5.3.2 double acos (double);

ACOS(3) Linux Programmer's Manual ACOS(3)

NAME
acos - arc cosine function

SYNOPSIS
#include <math.h>

double acos(double x);

DESCRIPTION
The acos() function calculates the arc cosine of x; that is the value whose cosine is x. If x falls outside the range -1 to 1, acos() fails and errno is set.

RETURN VALUE
The acos() function returns the arc cosine in radians and the value is mathematically defined to be between 0 and PI (inclusive).

ERRORS
EDOM x is out of range.

CONFORMING TO
SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
asin(3), atan(3), atan2(3), cos(3), sin(3), tan(3)

1993-06-08 ACOS(3)

5.3.3 double asinh (double);

ASINH(3) Linux Programmer's Manual ASINH(3)

NAME
asinh - inverse hyperbolic sine function

SYNOPSIS
#include <math.h>

double asinh(double x);

DESCRIPTION
The asinh() function calculates the inverse hyperbolic sine of x; that is the value whose hyperbolic sine is x.

```
CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acosh(3), atanh(3), cosh(3), sinh(3), tanh(3)



                                  1993-06-13                            ASINH(3)
```

5.3.4 double asin (double);

```
ASIN(3)                    Linux Programmer's Manual                    ASIN(3)



NAME
       asin - arc sine function

SYNOPSIS
       #include <math.h>

       double asin(double x);

DESCRIPTION
       The  asin()  function  calculates  the arc sine of x; that is the value
       whose sine is x.  If x falls outside the range -1 to  1,  asin()  fails
       and errno is set.

RETURN VALUE
       The  asin()  function  returns the arc sine in radians and the value is
       mathematically defined to be between -PI/2 and PI/2 (inclusive).

ERRORS
       EDOM   x is out of range.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acos(3), atan(3), atan2(3), cos(3), sin(3), tan(3)



                                  1993-06-08                             ASIN(3)
```

5.3.5 double atan2 (double, double);

```
ATAN2(3)                   Linux Programmer's Manual                   ATAN2(3)



NAME
       atan2 - arc tangent function of two variables

SYNOPSIS
       #include <math.h>
```

```
       double atan2(double y, double x);

DESCRIPTION
       The  atan2() function calculates the arc tangent of the two variables x
       and y.  It is similar to calculating the arc tangent of y /  x,  except
       that  the signs of both arguments are used to determine the quadrant of
       the result.

RETURN VALUE
       The atan2() function returns the result in radians,  which  is  between
       -PI and PI (inclusive).

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acos(3), asin(3), atan(3), cos(3), sin(3), tan(3)



                                    1993-06-08                          ATAN2(3)
```

5.3.6 double atanh (double);

```
ATANH(3)                   Linux Programmer's Manual                   ATANH(3)



NAME
       atanh - inverse hyperbolic tangent function

SYNOPSIS
       #include <math.h>

       double atanh(double x);

DESCRIPTION
       The  atanh()  function  calculates the inverse hyperbolic tangent of x;
       that is the value whose hyperbolic tangent is x.  If the absolute value
       of  x is greater than 1.0, acosh() returns not-a-number (NaN) and errno
       is set.

ERRORS
       EDOM   x is out of range.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       asinh(3), acosh(3), cosh(3), sinh(3), tanh(3)



                                    1993-06-13                          ATANH(3)
```

5.3.7 double atan (double);

```
ATAN(3)                    Linux Programmer's Manual                    ATAN(3)



NAME
       atan - arc tangent function

SYNOPSIS
       #include <math.h>

       double atan(double x);

DESCRIPTION
       The  atan() function calculates the arc tangent of x; that is the value
       whose tangent is x.

RETURN VALUE
       The atan() function returns the arc tangent in radians and the value is
       mathematically defined to be between -PI/2 and PI/2 (inclusive).

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acos(3), asin(3), atan2(3), cos(3), sin(3), tan(3)



                                  1993-06-08                            ATAN(3)
```

5.3.8 double cbrt (double);

```
CBRT(3)                    Linux Programmer's Manual                    CBRT(3)



NAME
       cbrt - cube root function

SYNOPSIS
       #include <math.h>

       double cbrt(double x);

DESCRIPTION
       The  cbrt()  function returns the cube root of x.  This function cannot
       fail; every representable real value  has  a  representable  real  cube
       root.

CONFORMING TO
       cbrt is a GNU extension.

SEE ALSO
       sqrt(3), pow(3)
```

1995-09-16 CBRT(3)

5.3.9 double ceil (double);

```
CEIL(3)                    Linux Programmer's Manual                    CEIL(3)



NAME
       ceil, ceilf, ceill - ceiling function: smallest integral value not less
       than argument

SYNOPSIS
       #include <math.h>

       double ceil(double x);
       float ceilf(float x);
       long double ceill(long double x);

DESCRIPTION
       These functions round x up to the nearest integer.

RETURN VALUE
       The rounded integer value. If x is integral or infinite,  x  itself  is
       returned.

ERRORS
       No  errors other than EDOM and ERANGE can occur.  If x is NaN, then NaN
       is returned and errno may be set to EDOM.

NOTES
       SUSv2 and POSIX 1003.1-2001 contain text about  overflow  (which  might
       set  errno  to ERANGE, or raise an exception).  In practice, the result
       cannot overflow on any current machine, so this error-handling stuff is
       just nonsense.  (More precisely, overflow can happen only when the max-
       imum value of the exponent is smaller than the number of mantissa bits.
       For  the IEEE-754 standard 32-bit and 64-bit floating point numbers the
       maximum value of the exponent is 128 (resp. 1024), and  the  number  of
       mantissa bits is 24 (resp. 53).)

CONFORMING TO
       The  ceil() function conforms to SVID 3, POSIX, BSD 4.3, ISO 9899.  The
       other functions are from C99.

SEE ALSO
       floor(3), lrint(3), nearbyint(3), rint(3), round(3), trunc(3)



                                  2001-05-31                         CEIL(3)
```

5.3.10 double cosh (double);

```
COSH(3)                    Linux Programmer's Manual                    COSH(3)
```

```
NAME
       cosh - hyperbolic cosine function

SYNOPSIS
       #include <math.h>

       double cosh(double x);

DESCRIPTION
       The  cosh()  function  returns  the  hyperbolic  cosine  of x, which is
       defined mathematically as (exp(x) + exp(-x)) / 2.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899 (C99)

SEE ALSO
       acosh(3), asinh(3), atanh(3), sinh(3), tanh(3)



                                    1993-06-13                          COSH(3)
```

5.3.11 double cos (double);

```
COS(3)                     Linux Programmer's Manual                     COS(3)



NAME
       cos - cosine function

SYNOPSIS
       #include <math.h>

       double cos(double x);

DESCRIPTION
       The  cos()  function returns the cosine of x, where x is given in radi-
       ans.

RETURN VALUE
       The cos() function returns a value between -1 and 1.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acos(3), asin(3), atan(3), atan2(3), sin(3), tan(3)



                                    1993-06-08                          COS(3)
```

5.3.12 double erf (double);

```
ERF(3)                     Linux Programmer's Manual                     ERF(3)
```

```
NAME
       erf, erfc - error function and complementary error function

SYNOPSIS
       #include <math.h>

       double erf(double x);

       double erfc(double x);

DESCRIPTION
       The erf() function returns the error function of x; defined as

       erf(x) = 2/sqrt(pi)* integral from 0 to x of exp(-t*t) dt

       The erfc() function returns the complementary error function of x, that
       is 1.0 - erf(x).

CONFORMING TO
       SVID 3, BSD 4.3

SEE ALSO
       exp(3)



BSD                                1993-06-25                                ERF(3)
```

5.3.13 double erfc (double);

See Section 5.3.12 [erf], page 31.

5.3.14 double exp (double);

```
EXP(3)                     Linux Programmer's Manual                     EXP(3)



NAME
       exp, log, log10, pow - exponential, logarithmic and power functions

SYNOPSIS
       #include <math.h>

       double exp(double x);

       double log(double x);

       double log10(double x);

       double pow(double x, double y);

DESCRIPTION
       The  exp()  function  returns the value of e (the base of natural loga-
```

```
       rithms) raised to the power of x.

       The log() function returns the natural logarithm of x.

       The log10() function returns the base-10 logarithm of x.

       The pow() function  returns the value of x raised to the power of y.

ERRORS
       The log() and log10() functions can return the following errors:

       EDOM   The argument x is negative.

       ERANGE The argument x is zero.  The log of zero is not defined.

       The pow() function can return the following error:

       EDOM   The argument x is negative and y is not an integral value.  This
              would result in a complex number.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       sqrt(3), cbrt(3)



GNU                                1993-06-16                                EXP(3)
```

5.3.15 double fabs (double);

```
FABS(3)                    Linux Programmer's Manual                    FABS(3)



NAME
       fabs, fabsf, fabsl - absolute value of floating-point number

SYNOPSIS
       #include <math.h>

       double fabs(double x);
       float fabsf(float x);
       long double fabsl(long double x);

DESCRIPTION
       The fabs functions return the absolute value of the floating-point num-
       ber x.

ERRORS
       No errors can occur.

CONFORMING TO
       The fabs() function conforms to SVID 3, POSIX, BSD 4.3, ISO 9899.   The
       other functions are from C99.
```

```
SEE ALSO
       abs(3), ceil(3), floor(3), labs(3), rint(3)


                                  2001-06-07                          FABS(3)
```

5.3.16 int finite (double);

See Section 5.3.22 [isnan], page 37.

5.3.17 double floor (double);

```
FLOOR(3)                  Linux Programmer's Manual                  FLOOR(3)



NAME
       floor,  floorf,  floorl - largest integral value not greater than argu-
       ment

SYNOPSIS
       #include <math.h>

       double floor(double x);
       float floorf(float x);
       long double floorl(long double x);

DESCRIPTION
       These functions round x down to the nearest integer.

RETURN VALUE
       The rounded integer value. If x is integral or infinite,  x  itself  is
       returned.

ERRORS
       No  errors other than EDOM and ERANGE can occur.  If x is NaN, then NaN
       is returned and errno may be set to EDOM.

NOTES
       SUSv2 and POSIX 1003.1-2001 contain text about  overflow  (which  might
       set  errno  to ERANGE, or raise an exception).  In practice, the result
       cannot overflow on any current machine, so this error-handling stuff is
       just nonsense.  (More precisely, overflow can happen only when the max-
       imum value of the exponent is smaller than the number of mantissa bits.
       For  the IEEE-754 standard 32-bit and 64-bit floating point numbers the
       maximum value of the exponent is 128 (resp. 1024), and  the  number  of
       mantissa bits is 24 (resp. 53).)

CONFORMING TO
       The floor() function conforms to SVID 3, POSIX, BSD 4.3, ISO 9899.  The
       other functions are from C99.

SEE ALSO
       ceil(3), lrint(3), nearbyint(3), rint(3), round(3), trunc(3)
```

2001-05-31 FLOOR(3)

5.3.18 double fmod (double, double);

FMOD(3) Linux Programmer's Manual FMOD(3)

NAME
fmod - floating-point remainder function

SYNOPSIS
#include <math.h>

double fmod(double x, double y);

DESCRIPTION
The fmod() function computes the remainder of dividing x by y. The return value is x - n * y, where n is the quotient of x / y, rounded towards zero to an integer.

RETURN VALUE
The fmod() function returns the remainder, unless y is zero, when the function fails and errno is set.

ERRORS
EDOM The denominator y is zero.

CONFORMING TO
SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
drem(3)

1993-06-06 FMOD(3)

5.3.19 double frexp (double, int *);

FREXP(3) Linux Programmer's Manual FREXP(3)

NAME
frexp - convert floating-point number to fractional and integral components

SYNOPSIS
#include <math.h>

double frexp(double x, int *exp);

DESCRIPTION
The frexp() function is used to split the number x into a normalized fraction and an exponent which is stored in exp.

```
RETURN VALUE
       The  frexp() function returns the normalized fraction.  If the argument
       x is not zero, the normalized fraction is x times a power of  two,  and
       is always in the range 1/2 (inclusive) to 1 (exclusive).  If x is zero,
       then the normalized fraction is zero and zero is stored in exp.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       ldexp(3), modf(3)



GNU                                1993-06-06                            FREXP(3)
```

5.3.20 double gamma (double);

```
GAMMA(3)                      libc math functions                      GAMMA(3)



NAME
       gamma - logarithm of the gamma function

SYNOPSIS
       #include <math.h>

       double gamma (double x);

       float gammaf (float x);

       long double gammal (long double x);


DESCRIPTION
       The gamma() functions exist for compatibility reasons.  They are equiv-
       alent to lgamma() etc. Use these. Use of the name gamma() is confusing,
       since  these functions do not compute the Gamma function, but the natu-
       ral logarithm of the Gamma function.

CONFORMING TO
       Nonstandard. Compatible with previous mistakes.

SEE ALSO
       lgamma(3), signgam(3), tgamma(3)



GNU                                2002-08-10                            GAMMA(3)
```

5.3.21 double hypot (double, double);

```
HYPOT(3)                    Linux Programmer's Manual                  HYPOT(3)
```

```
NAME
       hypot - Euclidean distance function

SYNOPSIS
       #include <math.h>

       double hypot(double x, double y);

DESCRIPTION
       The  hypot()  function returns the sqrt(x*x + y*y).  This is the length
       of the hypotenuse of a right-angle triangle with sides of length x  and
       y, or the distance of the point (x, y) from the origin.

CONFORMING TO
       SVID 3, BSD 4.3

SEE ALSO
       sqrt(3)



                                    1993-06-25                          HYPOT(3)
```

5.3.22 int isnan (double);

```
ISINF(3)                  Linux Programmer's Manual                  ISINF(3)



NAME
       isinf, isnan, finite - test for infinity or not-a-number (NaN)

SYNOPSIS
       #include <math.h>

       int isinf(double value);

       int isnan(double value);

       int finite(double value);

DESCRIPTION
       The  isinf() function returns -1 if value represents negative infinity,
       1 if value represents positive infinity, and 0 otherwise.

       The isnan() function returns a non-zero value if value  is  "not-a-num-
       ber" (NaN), and 0 otherwise.

       The  finite()  function  returns  a  non-zero value if value is neither
       infinite nor a "not-a-number" (NaN) value, and 0 otherwise.

CONFORMING TO
       BSD 4.3
```

```
GNU                                1993-06-02                          ISINF(3)
```

5.3.23 double j0 (double);

```
J0(3)                      Linux Programmer's Manual                      J0(3)
```

```
NAME
       j0,  j0f,  j0l, j1, j1f, j1l, jn, jnf, jnl, y0, y0f, y0l, y1, y1f, y1l,
       yn, ynf, ynl - Bessel functions

SYNOPSIS
       #include <math.h>

       double j0(double x);
       double j1(double x);
       double jn(int n, double x);
       double y0(double x);
       double y1(double x);
       double yn(int n, double x);

       float j0f(float x);
       float j1f(float x);
       float jnf(int n, float x);
       float y0f(float x);
       float y1f(float x);
       float ynf(int n, float x);

       long double j0l(long double x);
       long double j1l(long double x);
       long double jnl(int n, long double x);
       long double y0l(long double x);
       long double y1l(long double x);
       long double ynl(int n, long double x);

DESCRIPTION
       The j0() and j1() functions return Bessel functions of x of  the  first
       kind  of  orders  0 and 1, respectively.  The jn() function returns the
       Bessel function of x of the first kind of order n.

       The y0() and y1() functions return Bessel functions of x of the  second
       kind  of  orders  0 and 1, respectively.  The yn() function returns the
       Bessel function of x of the second kind of order n.

       For the functions y0(), y1() and yn(), the value of x must be positive.
       For negative values of x, these functions return -HUGE_VAL.

       The  j0f()  etc.  and  j0l()  etc. functions are versions that take and
       return float and long double values, respectively.

CONFORMING TO
       The functions returning double conform to SVID 3, BSD 4.3, XPG4,  POSIX
       1003.1-2001. The other functions exist by analogy, and exist on several
       platforms.

BUGS
```

```
       There are errors of up to 2e-16 in the values returned  by  j0(),  j1()
       and jn() for values of x between -8 and 8.


                                    2002-08-25                          J0(3)
```

5.3.24 double j1 (double);

See Section 5.3.23 [j0], page 38.

5.3.25 double jn (int, double);

See Section 5.3.23 [j0], page 38.

5.3.26 double ldexp (double, int);

```
LDEXP(3)                  Linux Programmer's Manual                 LDEXP(3)



NAME
       ldexp - multiply floating-point number by integral power of 2

SYNOPSIS
       #include <math.h>

       double ldexp(double x, int exp);

DESCRIPTION
       The  ldexp()  function  returns the result of multiplying the floating-
       point number x by 2 raised to the power exp.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       frexp(3), modf(3)



BSD                               1993-06-06                          LDEXP(3)
```

5.3.27 double lgamma (double);

```
LGAMMA(3)                 Linux Programmer's Manual                 LGAMMA(3)



NAME
       lgamma - log gamma function

SYNOPSIS
       #include <math.h>

       double lgamma(double x);
       float lgammaf(float x);
       long double lgammal(long double x);
```

```
       double lgamma_r(double x, int *signp);
       float lgammaf_r(float x, int *signp);
       long double lgammal_r(long double x, int *signp);

DESCRIPTION
       The Gamma function is defined by

        Gamma(x) = integral from 0 to infinity of t^(x-1) e^-t dt

       It  is  defined  for every real number except for nonpositive integers.
       For nonnegative integral m one has

        Gamma(m+1) = m!

       and, more generally, for all x:

        Gamma(x+1) = x * Gamma(x)

       For x < 0.5 one can use

        Gamma(x) * Gamma(1-x) = PI/sin(PI*x)

       The lgamma() function returns the natural  logarithm  of  the  absolute
       value  of  the  Gamma  function.  The  sign  of  the Gamma function is
       returned in the external integer signgam declared in <math.h>.  It is 1
       when the Gamma function is positive or zero, -1 when it is negative.

       Since  using  a constant location signgam is not thread-safe, the func-
       tions lgamma_r() etc. have been introduced; they return this  sign  via
       the parameter signp.

       For  nonpositive  integer  values of x, lgamma() returns HUGE_VAL, sets
       errno to ERANGE and raises  the  zero  divide  exception.  (Similarly,
       lgammaf() returns HUGE_VALF and lgammal() returns HUGE_VALL.)

ERRORS
       An  application  wishing to check for error situations should set errno
       to zero and  call  feclearexcept(FE_ALL_EXCEPT)  before  calling  these
       functions. On return, if errno is non-zero or fetestexcept(FE_INVALID |
       FE_DIVBYZERO | FE_OVERFLOW | FE_UNDERFLOW) is non-zero,  an  error  has
       occurred.

       ERANGE Invalid argument - nonpositive integer value of x.

CONFORMING TO
       C99, SVID 3, BSD 4.3

SEE ALSO
       tgamma(3)
```

5.3.28 double log (double);

See Section 5.3.14 [exp], page 32.

5.3.29 double log10 (double);

See Section 5.3.14 [exp], page 32.

5.3.30 double modf (double, double *);

```
MODF(3)                    Linux Programmer's Manual                    MODF(3)



NAME
       modf  -  extract  signed  integral and fractional values from floating-
       point number

SYNOPSIS
       #include <math.h>

       double modf(double x, double *iptr);

DESCRIPTION
       The modf() function breaks the argument x into an integral part  and  a
       fractional  part,  each  of which has the same sign as x.  The integral
       part is stored in iptr.

RETURN VALUE
       The modf() function returns the fractional part of x.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       frexp(3), ldexp(3)



                                  1993-06-06                          MODF(3)
```

5.3.31 double nextafter (double, double);

```
NEXTAFTER(3)                libc math functions                NEXTAFTER(3)



NAME
       nextafter, nexttoward - floating point number manipulation

SYNOPSIS
       #include <math.h>

       double nextafter(double x, double y);
       float nextafterf(float x, float y);
       long double nextafterl(long double x, long double y);

       double nexttoward(double x, long double y);
```

```
       float nexttowardf(float x, long double y);
       long double nexttowardl(long double x, long double y);

DESCRIPTION
       The  nextafter()  functions return the next representable neighbor of x
       in the direction towards y.  The size of the step  between  x  and  the
       result depends on the type of the result.  If x = y the function simply
       returns y.  If either value is NaN, then NaN is returned.  Otherwise  a
       value  corresponding  to  the value of the least significant bit in the
       mantissa is added or subtracted, depending on the direction.

       The nexttoward() functions do the same as  the  nextafter()  functions,
       except that they have a long double second argument.

       These  functions  will  signal overflow or underflow if the result goes
       outside of the range of normalized numbers.

CONFORMING TO
       C99. This function is defined in IEC 559 (and the appendix with  recom-
       mended functions in IEEE 754/IEEE 854).

SEE ALSO
       nearbyint(3)



GNU                               2002-08-10                       NEXTAFTER(3)
```

5.3.32 double pow (double, double);

See Section 5.3.14 [exp], page 32.

5.3.33 double sinh (double);

```
SINH(3)                    Linux Programmer's Manual                    SINH(3)



NAME
       sinh - hyperbolic sine function

SYNOPSIS
       #include <math.h>

       double sinh(double x);

DESCRIPTION
       The  sinh() function returns the hyperbolic sine of x, which is defined
       mathematically as (exp(x) - exp(-x)) / 2.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899 (C99)

SEE ALSO
       acosh(3), asinh(3), atanh(3), cosh(3), tanh(3)
```

```
                                1993-06-13                              SINH(3)
```

5.3.34 double sin (double);

```
SIN(3)                    Linux Programmer's Manual                    SIN(3)



NAME
       sin - sine function

SYNOPSIS
       #include <math.h>

       double sin(double x);

DESCRIPTION
       The  sin() function returns the sine of x, where x is given in radians.

RETURN VALUE
       The sin() function returns a value between -1 and 1.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
       acos(3), asin(3), atan(3), atan2(3), cos(3), tan(3)



                                1993-06-08                               SIN(3)
```

5.3.35 double sqrt (double);

```
SQRT(3)                   Linux Programmer's Manual                   SQRT(3)



NAME
       sqrt - square root function

SYNOPSIS
       #include <math.h>

       double sqrt(double x);

DESCRIPTION
       The  sqrt()  function  returns  the  non-negative square root of x.  It
       fails and sets errno to EDOM, if x is negative.

ERRORS
       EDOM   x is negative.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899
```

```
SEE ALSO
       hypot(3)



                                  1993-06-21                            SQRT(3)
```

5.3.36 double tanh (double);

```
TANH(3)                   Linux Programmer's Manual                   TANH(3)



NAME
       tanh - hyperbolic tangent function

SYNOPSIS
       #include <math.h>

       double tanh(double x);

DESCRIPTION
       The  tanh()  function  returns  the  hyperbolic  tangent of x, which is
       defined mathematically as sinh(x) / cosh(x).

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899 (C99)

SEE ALSO
       acosh(3), asinh(3), atanh(3), cosh(3), sinh(3)



                                  1993-06-13                            TANH(3)
```

5.3.37 double tan (double);

```
TAN(3)                    Linux Programmer's Manual                    TAN(3)



NAME
       tan - tangent function

SYNOPSIS
       #include <math.h>

       double tan(double x);

DESCRIPTION
       The  tan() function returns the tangent of x, where x is given in radi-
       ans.

CONFORMING TO
       SVID 3, POSIX, BSD 4.3, ISO 9899

SEE ALSO
```

```
       acos(3), asin(3), atan(3), atan2(3), cos(3), sin(3)


                                  1993-06-08                                TAN(3)
```

5.3.38 double y0 (double);

See Section 5.3.23 [j0], page 38.

5.3.39 double y1 (double);

See Section 5.3.23 [j0], page 38.

5.3.40 double yn (int, double);

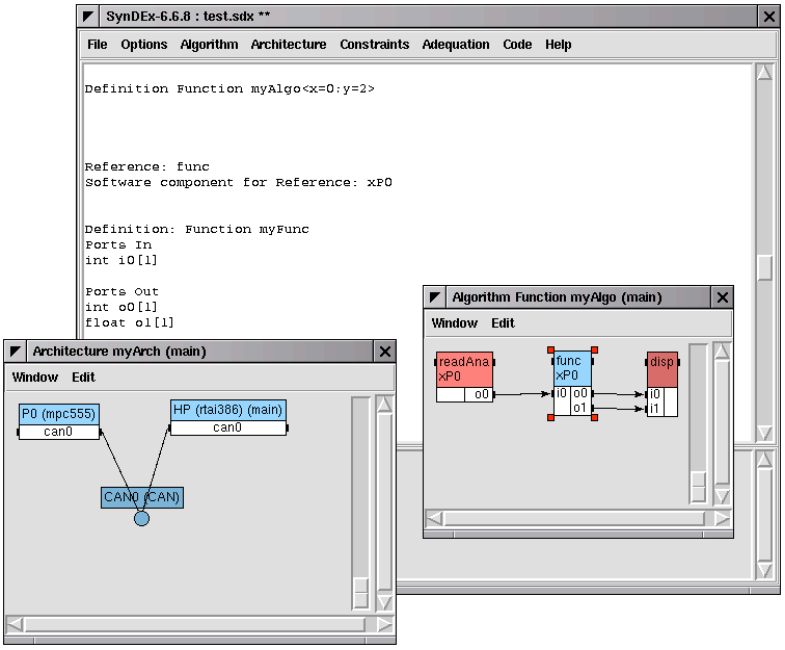
See Section 5.3.23 [j0], page 38.

5.3.41 Sample application

Let us illustrate how to use FDLIBM features over a very simple application example. You will find this example on the Robosoft development toolchain under the '`appsv6/floatv6-0.1/`' directory:

```
[guest@localhost appsv6]$
[guest@localhost appsv6]$ pwd
/home/guest/syndex/last/appsv6
[guest@localhost appsv6]$
[guest@localhost appsv6]$
[guest@localhost appsv6]$ cd floatv6-0.1/
[guest@localhost floatv6-0.1]$
[guest@localhost floatv6-0.1]$ ll
total 32
-rw-r--r--    1 guest   guest       2542 Apr  8 12:34 GNUmakefile
-rw-rw-r--    1 guest   guest       1018 Feb 19 18:10 HP.m4
-rw-rw-r--    1 guest   guest        156 Feb 20 14:34 myLib.c
-rw-rw-r--    1 guest   guest       1063 Feb 19 18:10 P0.m4
-rw-rw-r--    1 guest   guest        209 Feb 19 18:10 test.m4
-rw-r--r--    1 guest   guest        671 Apr  6 18:03 test.m4x
-rw-r--r--    1 guest   guest       1445 Feb 19 18:10 test.sdx
-rw-r--r--    1 guest   guest        101 Apr  8 12:34 User.mk
[guest@localhost floatv6-0.1]$
```

Here is a screen capture, from the SynDEx CAD session, showing the sample application.



The hardware architecture is compose of one MPC555 operator (named `P0`) and a PC operator (running RTAI/Linux, named `HP`). The designed algorithm implements a short sequence:

- read an analog port on P0 (that performs an analog to digital conversion)
- use the result of the conversion (a 32-bits integer) as input for function `func` (running on `P0`). `func` calls a separately compiled C function (we will define farther) and produces two values: a 32-bits integer (passed through output `o0`) and a floating point value (passed through output `o1`).
- send these two values (through the CAN bus) to operator `HP`, for being displayed.

We can see in the SynDEx CAD main window that `func` is a function of type `myFunc`. `myFunc` macro is defined by user into the file '`test.m4x`'.

```
[guest@localhost floatv6-0.1]$
[guest@localhost floatv6-0.1]$ cat test.m4x
divert(-1)
define(‘NOTRACEDEF’)

define(‘ECP_IRQ’,‘0x5’)
define(‘CAN_speed_’,800Kbps)
define(‘loop_period’,‘10000000’)

# Robosoft MPC555 boards Serial Number (used by the download process)
define(‘P0_CANID_’,0x4000)

# PP: Fix IT timer period to 156/15625=10ms (refer to 555.m4x comments).
dnl define(‘PITCOUNTER’, 1562)

# --------------
# myFunc()
#
define(‘myFunc’, ‘ifelse(dnl
MGC,‘LOOP’,‘Ccall_(void, ‘myCall’, int $1, int *$2, float *$3)’)’)

# --------------
```

```
# display()
#
define(‘display’, ‘ifelse(MGC,‘LOOP’,‘dnl
{
  int f = 0;
  f = (int)(*$1 + *$2);
  rt_printk("Sum of input values is %5d.\n", f);
}’)’)

divert‘’dnl
[guest@localhost floatv6-0.1]$
```

The user macro `myFunc` appears to be defined as a call to the `myCall` function (separately compile). This is done using the `Ccall_` macro. For advanced information about `Ccall_` SynDEx macro, please refer to SynDEx online documentations and to the Robosoft document titled The 555.m4x and RSB.m4x SynDEx Macro-Executives [See ‘`doc/ROBO/555macros/555macros.pdf`’]
.

The `myCall` function is declared in the local file ‘`myLib.c`’. Remark, that the function prototype must fit the prototype declaration passed to `Ccall_` during the `myFunc` macro definition:

```
[guest@localhost floatv6-0.1]$
[guest@localhost floatv6-0.1]$ cat myLib.c
#include "fdlibm.h"

void myCall (int in, int *iout, float *fout)
{
  double f = 0.75;

  *iout = (int)(100 * sin(f));
  *fout = (float)(sin(in / 100.));
}
[pierre@Gromit floatv6-0.1]$
```

Now, just remains to add the appropriate makefile rules to the local ‘`GNUmakefile`’ and ‘`User.mk`’, in order to launch ‘`myLib.c`’ compilation automatically. ‘`myLib.c`’ should be compile to produce an object file named ‘`myLib.555`’. Hence, called functions will be copied from ‘`myLib.555`’ and included into `P0` operator object file. At final compilation step, the composed `P0` operator object file will be linked to produce the PowerPC ELF 32-bits executable binary.

To do so, we have to declare the object file ‘`myLib.555`’ as a valid library for `P0` operator. This is done by setting the following variable into the local ‘`GNUmakefile`’:

```
P0.libs = myLib.555
```

Then, we have to give the makefile rule needed for producing ‘`myLib.555`’. This is done by adding the following line to the local ‘`User.mk`’:

```
myLib.555 : myLib.c
```

In fact, this rule only sets a dependency between ‘`myLib.555`’ and ‘`myLib.c`’. This meeans, that for compiling ‘`myLib.c`’ an implicit rule will be applied. This implicit rule corresponds to the one already defined by the ‘`mpc555.m4m`’ SynDEx kernel macros. If user has any specific needs for compilation, he can write the convenient rule instead. For instance:

```
myLib.555 : myLib.c
        ../../crossgcc/bin/ppc-elf32-gcc -o myLib.555 -mcpu=powerpc\
```

```
-mhard-float -I../../crossgcc/fdlibm -O2 -c myLib.c
```

Now, user can simply start application by executing `make` from the shell command line. '`myLib.c`' compilation will be automatically done before producing '`P0`'.

6 Launching applications

In this section we give a brief summary of files you will require to generate and compile your executive. Code generation principles will be detailed in next sections. Files required are :

- One '`processorName.m4`' file for each processor specified in your main architecture, including '`root.m4`' (generally the file generated for the main operator). These files are generated by SynDEx during the executive generation step;
- '`applicationName.m4m`';
- '`applicationName.m4x`', which may be empty, but which generally contains the application dependent macros (written by the application programmer);
- '`GNUmakefile`' application dependent top makefile rules;
- '`User.mk`' another application dependent set of makefile rules;

For the files which are not generated by SynDEx, most of the time you can simply copy existing ones (for instance from the example directory) and make modifications explained in the comments of these files.

Once you gathered all these files, type '`make`' in your shell. This will compile, download and execute your application over the hardware architecture. You can also clean your directory by typing '`make clean`'.

For instance, if user guest want to execute the '`robucar`', he will have to execute the following commands from the shell command line:

```
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$ ll
total 56
-rw-rw-r--    1 guest   guest       3860 Jan 26 17:30 f555.m4
-rw-------    1 guest   guest       2523 Feb 20 14:28 GNUmakefile
-rw-rw-r--    1 guest   guest       7739 Jan 26 17:30 r555.m4
-rw-rw-r--    1 guest   guest        290 Jan 26 17:30 robucar.m4
-rw-------    1 guest   guest      11333 Apr  6 18:00 robucar.m4x
-rw-------    1 guest   guest      14362 Jan 26 17:03 robucar.sdx
-rw-rw-r--    1 guest   guest       2008 Jan 26 17:30 root.m4
-rw-r--r--    1 guest   guest         78 Feb  5 18:00 User.mk
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$ make clean
GNUmakefile:64: robucar.mk: No such file or directory
m4 robucar.m4  >robucar.mk
rm -f robucar.mk *~ *.o *.a
rm -f root root.map root.o root.c run *~
rm -f f555 f555.elf f555.555 f555.s f555.elf.map
rm -f r555 r555.elf r555.555 r555.s r555.elf.map
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$
[guest@localhost robucarAna30-0.9-v6.6.7]$ make
```

On success, the following message will be displayed:

```
==== RT memory manager v1.3 Loaded. ====


***** STARTING THE UP REAL TIME SCHEDULER WITH LINUX *****
***** FP SUPPORT AND READY FOR A PERIODIC TIMER *****
***<> LINUX TICK AT 100 (HZ) <>***
***<> CALIBRATED CPU FREQUENCY 233871000 (HZ) <>***
***<> CALIBRATED TIMER-INTERRUPT-TO-SCHEDULER LATENCY 2689 (ns) <>***
```

```
***<> CALIBRATED ONE SHOT SETUP TIME 2009 (ns) <>***

Probed CAN base address: 0xE000
Probed CAN IRQ: 0xB

Downloading processor ID 0x4000 station!... loaded.
Downloading processor ID 0x4001 station!... loaded.

Download complete... application is running.
--------------------------------------------------------------------------
```

If a problem occurs during the download sequence, the following message will be displayed:

```
==========================================================================
Downloading processor ID 0x4001 station!

Download failed. Please try again:
  1) make stop
  2) reset MPC555 stations
  3) make
--------------------------------------------------------------------------
[guest@localhost robucarAna30-0.9-v6.6.7]$
```

It indicates the procedure to follow for trying to download again, ie.

- executing `make stop`
- resetting MPC555 boards
- executing `make` one more time

Last, for stopping a running application, user just has to execute:

```
[guest@localhost robucarAna30-0.9-v6.6.7]$ make stop
```

What will displays:

```
[guest@localhost robucarAna30-0.9-v6.6.7]$ make stop
sync
../../rtai/rtai-24.1.12/scripts/rt_rmmod root
using sudo
sudo sh -c "/sbin/rmmod -r root"
rmmod: module root not loaded
../../rtai/rtai-24.1.12/scripts/rt_rmmod rtai_shm
using sudo
sudo sh -c "/sbin/rmmod -r rtai_shm"
rmmod: module rtai_shm not loaded
../../rtai/rtai-24.1.12/scripts/rt_rmmod rtai_fifos
using sudo
sudo sh -c "/sbin/rmmod -r rtai_fifos"
rmmod: module rtai_fifos not loaded
../../rtai/rtai-24.1.12/scripts/rt_rmmod rtai_sched_up
using sudo
sudo sh -c "/sbin/rmmod -r rtai_sched_up"
rmmod: module rtai_sched_up not loaded
../../rtai/rtai-24.1.12/scripts/rt_rmmod rtai
using sudo
sudo sh -c "/sbin/rmmod -r rtai"
```

```
rmmod: module rtai not loaded
==== RT memory manager max allocated: 4016 bytes.
==== RT memory manager kernel kmalloc()'s:   4
==== RT memory manager kernel kfree()'s:     4
==== RT memory manager overhead:      0 bytes.
==== RT memory manager leaks:         0 bytes.


==== RT memory manager v1.3 Unloaded. ====


***** THE UP REAL TIME SCHEDULER HAS BEEN REMOVED *****



ADEOS: Domain RTAI unregistered.
RTAI/Adeos unmounted.

[pierre@Gromit robucarAna30-0.9-v6.6.7]$
```

IMPORTANT REMARK: depending on the the shell environment your are working on, the mentionned messages may not appear on the screen... In this case, use the commands `dmesg` or `tail -f /var/log/messages` for displaying them.

Document Index

This is an alphabetical listing of all the commands, variables, and topics discussed in this document.

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