RTAI-Lab tutorial: Scilab, Comedi, and real-time control

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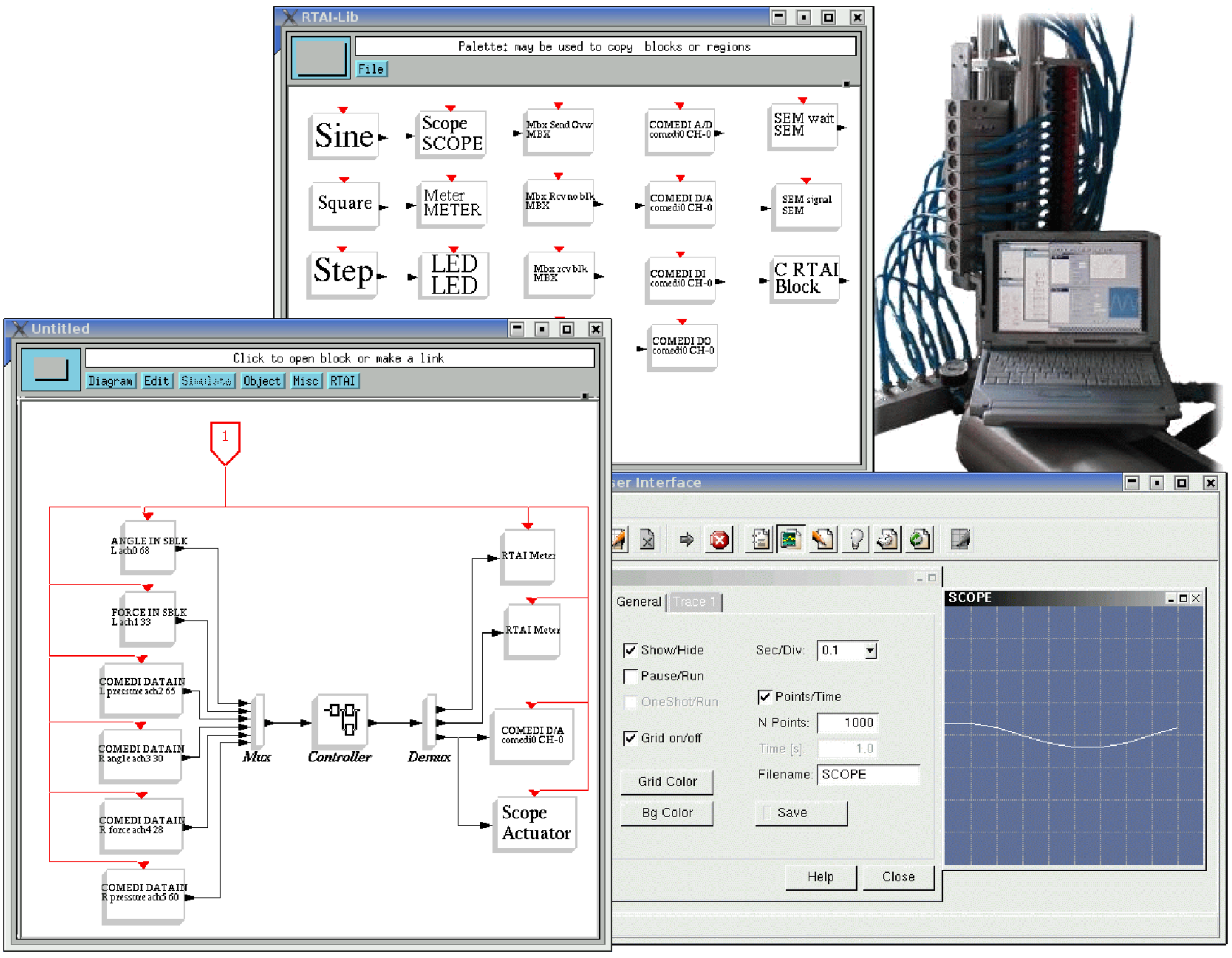
Summary

RTAI-Lab is a tool chain for real-time software and control system development. This tutorial shows how to install the various components: the RTAI real-time Linux kernel, the Comedi interface for control and measurement hardware, the Scilab/Scicos GUI-based CACSD modeling software and associated RTAI-Lab blocks, and the xrtailab interactive oscilloscope. RTAI-Lab's Scicos blocks are detailed and examples show how to develop elementary block diagrams, automatically generate real-time executables, and add custom elements.



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Filename: SCOPE

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Note: Because of frequent updates, this document may not be mirrored on any server apart from www.rtai.org

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1 Introduction

This tutorial shows how to install, use, and customize, a free[1], open-source, Computer Aided Control System Design (CACSD) and real-time control tool-chain called RTAI-Lab.
Apart from being a tool to develop real-time control systems, RTAI-Lab also lets you integrate real-time controllers and simulators generated by Mathworks' Matlab®/Simulink®/Real-Time Workshop® and/or the open source Scilab/Scicos/CodeGen CACSD software suite.
Furthermore, RTAI-Lab lets you:

- Develop and execute real-time software in a local/remote/distributed way,
- Monitor a controller's local/remote/distributed execution,
- Change a controller's parameters on the fly.

1.1 RTAI-Lab tool chain

The RTAI-Lab tool-chain is based on:

- **Scilab/Scicos**. Scilab is an open source CACSD software for numerical computation. Scilab includes Scicos, a block diagram editor that can be used to create simulations and automatically generate and compile code. See www.scilab.org and www.scicos.org
- **Comedi.** Comedi provides the drivers, library functions, and an API to interact with signal acquisition hardware. Hundreds of devices are supported. See www.comedi.org
- **RTAI**. The Real-Time Application Interface (RTAI) is distributed as a package with a patch to apply to the Linux kernel. RTAI inserts a sub-kernel where prioritized, hard real-time tasks can run. FIFOs and shared memory can be used to transfer data between real-time and user space processes. See www.rtai.org
- **RTAI-Lib**. RTAI-Lib is a palette of Scicos blocks that let you design block diagrams with sensors and actuators. It provides an interface to RTAI and signal acquisition hardware. Block diagrams that use RTAI-Lib can be compiled into RTAI execuatble software. It is included in the RTAI package.
- **xrtailab**. xrtailab is an oscilloscope-like software that can connect to your real-time executables. It lets you visually monitor signals and real-time events using gauge, scope, and LED mock-ups. xrtailab also lets you adjust parameters of the real-time executable while it runs. It is also part of RTAI.

1.2 Commercial software

All software used for RTAI-Lab is free and Open Source. The RTAI-Lab tool chain represents an alternative to the commercial software listed below:

- Scilab/Scicos → Mathworks' Matlab®/Simulink®
- Comedi → drivers supplied by signal acquisition hardware vendors, but most vendors don't supply Linux drivers
- RTAI → LynxOS® from Lynuxworks®, MontaVista Linux®, QNX®, VxWorks®, etc.
- RTAI-Lib → Mathworks' Real-Time Workshop®
- xrtailab → LabView®

Note that you can still use commercial software and use RTAI/RTAI-Lab as a target (see RTAI-Target-HOWTO and RTAI-UbuntuGutsy-Matlab in Appendix D). If you think you have sufficient funds to purchase commercial software, you will then buy a better GUI, better documentation, support that you can pay for, and the possibility to consult with the vendor in case of problems (especially if you work for a large company). On the other hand, upgrades with bug fixes are expensive, should be budgeted, and included in your real-time

[1] No purchase cost. See licenses in Appendix C.3, page 46

software's multi-year maintenance and extension plan. These costs represent a financial burden even for companies with a few hundred employees and only a few licenses. The advantage of using exclusively Open Source software in the RTAI-Lab tool chain is that you or a subcontractor can customize it. You probably already know that. That's why softwares that constitute the RTAI-Lab tool chain are developed.

2 Installation

The full installation requires several software packages to be downloaded from their development servers and compiled from source. Since RTAI, RTAI-Lab, and Comedi are undergoing strong development we recommend that you do not rely on precompiled packages provided by Linux distributions.
The following sections provide detailed instructions to install (order is important and must be followed). If you are installing on an Ubuntu-based distribution you may also refer to www.rtai.org/RTAILAB/RTAI-UbuntuGutsy-Matlab.txt

- The Mesa 3D graphical library. http://www.mesa3d.org
- The EFLTK graphic widgets library. equinox-project.org
- A new Linux kernel that will be patched with RTAI code
- The Comedilib data acquisition device interface library
- The RTAI real-time modules
- The Comedi data acquisition device modules
- The Scilab/Scicos Computer Aided Control System Design (CACSD) software

Note: The next sections list commands where software minor versions are indicated with "x.x". Make sure to replace the "x" with version numbers that correspond to your downloads.

2.1 Requirements

2.1.1 Hardware requirements

Most PCs can run a Linux kernel patched with RTAI. Some hardware configurations deserve a specific comment.
Comedi support. Before starting the installation, first check that your data acquisition card or external hardware is supported by Comedi. See (this page may be out of date) http://www.comedi.org/hardware.html. If you don't see your hardware listed then download Comedi anyway (see section 2.5) and look/`grep` into `/usr/local/src/comedi/comedi/drivers`
PCMCIA. Our PCMCIA card was not detected with some Linux kernels 2.6.13.xx, 2.6.14.xx, 2.6.19 (see note in Sec. 2.4).
Laptops & PCI sharing. We have experienced incompatibilities with some Toshiba Satellite laptops. If you use a data acquisition card that plugs into the PCMCIA/CardBus slot of a Toshiba Satellite laptop you might see warning messages about PCI devices sharing the same IRQ when loading Comedi modules. RTAI+Comedi might not work, but give it a try anyway. If you know of other laptops that have this problem, or know how to solve the problem, please notify us.
A quick way to test whether your computer will easily work with RTAI is to download an ISO image from issaris.homelinux.org/ takis/projects/rtai/livecd and conduct some latency tests. Note that failing to boot the CD or run the tests does not necessarily mean your computer cannot run RTAI.

2.1.2 Software requirements

We assume that your Linux system is based on one of the available distributions such as Debian, Fedora, Mandriva, Red Hat, Slackware, Suse, Ubuntu, etc., and that you have suitable software development libraries installed to compile a Linux kernel, as well as graphical development libraries.
Your working environment and list of packages should enable you to compile and install software as `root`.
Ensure that your distribution is up to date with the latest versions of development software such as
`automake > 1.7, autoconf, libtool, bison`, and `doxygen`.
Important: we recommend that `gcc -v` and `g77 -v` show a version lower than 4.0. For example `gcc/g++/cpp` version 3.4.6 works. In the following, make sure your replace the version numbers that contain "x" with the versions you downloaded!

2.2 Mesa library

Make a new installation of Mesa even if your distribution already includes it. Mesa is needed to compile EFLTK. You will need development packages such as xlibs-dev,...,x11proto-xext-dev,...

1. Become root
2. `cd /usr/local/src`
3. Visit `http://www.mesa3d.org` or `http://sourceforge.net/projects/mesa3d` and download MesaLib-6.x.x.tar.bz2
4. `tar jxvf MesaLib-7.x.x.tar.bz2`
5. `cd Mesa-7.x.x`
6. `make realclean`
7. `make linux-x86` or `make linux-x86-static`
   Note that `linux-dri` configurations are listed in the `configs` subdirectory.
   See also `http://dri.freedesktop.org/wiki/`
8. `make install`
   This queries whether to accept the default installation directories: `/usr/local/include` and `/usr/local/lib`.
   Note that some Linux distributions may require installation in `/usr/X11R6/include` and `/usr/X11R6/lib`.

2.3 EFLTK library

EFLTK is needed by `xrtailab`. EFLTK is part of the EDE project ede.sourceforge.net. You will need packages gettext, flex, and svn.

1.
   ```
   cd /usr/local/src
   svn co https://ede.svn.sourceforge.net/svnroot/ede/trunk/efltk
   svn co https://ede.svn.sourceforge.net/svnroot/ede/trunk/ede
   ```

2.
   ```
   cd efltk
   autoconf
   ./configure --disable-mysql --disable-unixODBC
   ./emake
   ./emake install
   ```

3. Edit `/etc/ld.so.conf` and add a line with the path `/usr/local/lib` on a line.

4. Execute `/sbin/ldconfig` to update the library database

2.4 Linux kernel and RTAI patch

- `cd /usr/src`
- Download RTAI (at least version 3.5) of either:
  - Stable (numbered): `http://www.rtai.org` (e.g. `rtai-3.3.tar.bz2`)
    ```
    tar xjvf rtai-3.3.tar.bz2
    ln -s /usr/src/rtai-3.3 rtai
    ```
  - Experimental (hot stuff, beware): `cvs -d:pserver:anonymous@cvs.gna.org:/cvs/rtai co magma`
    (see also `https://gna.org/cvs/?group=rtai`)
- Check kernel version numbers of available RTAI patches:
  `ls /usr/src/rtai/base/arch/i386/patches/`
  and look for kernel version numbers in: `hal-linux-<kernel-version>.patch`
- Carefully read `/usr/src/rtai/base/arch/i386/patches/README` as it might request that you edit some files *after* you have configured your kernel.
- Decide what kernel version you will use: 2.4.xx or a 2.6.xx
  Note: If you use a PCMCIA card, we recommend kernels up to 2.6.12.6 or 2.6.17 and above. For kernels upwards of 2.6.13.xx we have experienced “Oops” when inserting Comedi’s pcmcia module (including kernel 2.6.16.15).
  2007-05-22: There have also been difficulties with some kernel 2.6.17.xx (2.6.17.4 is said to work, though) and kernels $\geq$ 2.6.19. When compiling Comedi, one should therefore add the option `--disable-pcmcia`.

- **Kernel 2.4.xx.** The latest RTAI v.3.5 supports kernels 2.4.30 to 2.4.32 with ”hal-linux-2.4.xx-i386.patch”.
    1. Download a ”vanilla” linux-2.4.x.tar.bz2 from `http://www.kernel.org`
    2. Unpack the kernel: `tar xjvf linux-2.4.30.tar.bz2`
       `mv /usr/src/linux-2.4.30 /usr/src/linux-2.4.30-rtai`
       `ln -s /usr/src/linux-2.4.30-rtai linux`
    3. Patch the kernel:
       `cd /usr/src/linux`
       `patch -p1 < <rtaidir>/base/arch/i386/patches/<kernel-version>.patch`
       for example:
       `patch -p1 < /usr/src/rtai/base/arch/i386/patches/hal-linux-2.4.30-i386.patch`
    4. `make xconfig` or `make menuconfig`
    5. Configure the kernel. See details in Appendix A.
    6. Possibly do edits requested in `/usr/src/rtai/base/arch/i386/patches/README`
    7. `make`
    8. `make modules_install`
    9. `make install`
- **Kernel 2.6.xx.** The latest RTAI v.3.3 supports kernel 2.6.10 and upwards with ”hal-linux-2.6.xx-i386-xxx.patch”
  WARNING: Some Linux distributions include the new *udev* platform. That can induce problems if the new inodes are not registered (see Section A.3).
    1. Download a ”vanilla” linux-2.6.xx.xx.tar.bz2 from `http://www.kernel.org`
    2. Unpack the kernel: `tar xjvf linux-2.6.23.14.tar.bz2`
       `mv /usr/src/linux-2.6.23.14 /usr/src/linux-2.6.23.14-rtai`
       `ln -s /usr/src/linux-2.6.23.14-rtai linux`
    3. Patch the kernel:
       `cd /usr/src/linux`
       `patch -p1 < <rtaidir>/base/arch/i386/patches/<kernel-version>.patch`
       for example:
       `patch -p1 < /usr/src/rtai/base/arch/i386/patches/hal-linux-2.6.23.14-i386-r12.patch`
    4. `make xconfig` or `make menuconfig`
    5. Configure the kernel. See details in Appendix A
    6. Possibly do edits requested in `/usr/src/rtai/base/arch/i386/patches/README`
    7. `make`
    8. `make modules_install`
    9. `make install`
- **Update your boot loader** (either `lilo` or `grub`):
    - Lilo: edit `/etc/lilo.conf`, and execute `lilo`
    - Grub: edit `/boot/grub/menu.lst` (Debian) or `/etc/grub.conf` (Fedora, see Appendix B)
- Add module names to `/etc/modules` (Debian), e.g. `pcmcia` if you use a laptop with a signal acquisition card and execute `update-modules` (Debian)
- **Reboot computer into newly compiled kernel**

2.5 Comedilib

1. `cd /usr/local/src`
2. `cvs -d :pserver:anonymous@cvs.comedi.org:/cvs/comedi login`
   `cvs -d :pserver:anonymous@cvs.comedi.org:/cvs/comedi co comedi`
   `cvs -d :pserver:anonymous@cvs.comedi.org:/cvs/comedi co comedilib`
3. `cd comedilib`
4. Read software installation requirements in `README.CVS` and verify that your packages (automake etc.) are up to date with `automake --version`
5. `sh autogen.sh`
   Note: you may ignore warnings and reminders
6. `./configure −−sysconfdir=/etc`
   Note: pay attention to warnings and possibly remedy to these by installing extra software/packages
7. `make` and `make install`
   Note: installation places `comedi.h` and `comedilib.h` in `/usr/local/include`. You will later have to overwrite these header files with those from Comedi (see Sec. 2.8).
8. `make dev`
   This step creates the `/dev/comedi`[0-3] device inodes.
9. Optional calibration tool: `comedi_calibrate`
   Install packages from your favourite Linux distribution: `libboost-program-options-dev` and `libgsl0-dev`
   See also RTAI manual Sec. 4.7-8.

2.6 RTAI (1st pass)

This is usually straightforward. For more details download a draft of the RTAI User Manual Racciu and Mantegazza [2006]. You will need packages libxmu-dev and libxi-dev.

1. `cd /usr/src/rtai`)
2. `make xconfig` or `make menuconfig`
3. Menu General: verify default directories:
   - Installation directory `/usr/realtime`
   - Kernel source directory `/usr/src/linux`
4. Menu General: optionally select RTAI Documentation (HTML, PDF,...)
5. Menu Machine (x86): adjust Number of CPUs (default = 2)
6. Exit xconfig/menuconfig and save configuration
7. `make` and `make install`
8. **IMPORTANT:** Add `/usr/realtime/bin` to the PATH variable in /etc/profile or your home directory's `.bashrc`.

2.7 RTAI tests

Load RTAI-related modules (Section 2.13, `insmod` modules `rtai_hal` to `rtai_fifos`). You should measure your system's latency to real-time interrupts:

```
cd /usr/realtime/testsuite/kern/latency
./run
```

This launches a periodic task. The default period of 100000 ns is defined by `DEFAULT_PERIOD` in `/usr/src/rtai/testsuite/kern/latency/latency-module.c` and can be redefined upon module insertion (see below). Watch *lat min* (ns) and *overruns*. Load your computer's CPU, e.g. use multimedia applications. If *overruns* becomes greater than zero then you might try to lenghten the period:

- Type `ctrl-c` to stop execution
- `insmod` modules of Section 2.13 from `rtai_hal.ko` to `rtai_fifos.ko`

- `insmod /usr/realtime/modules/rtai_lxrt.ko`
  `insmod latency_rt.ko period=1000000`
  `./display`
  Overruns should either remain at zero or increase much more slowly. If they are still increasing then stop execution and reload `latency_rt.ko` with a longer period.

Stop execution: `ctrl-c`
`rmmod latency_rt`
You may compare your latency results with those published at issaris.org/˜ takis/projects/rtai → Benchmarks.

2.8 Comedi

In case of difficulties, please refer to the INSTALL file in the `comedi` directory and to the documentation at www.comedi.org.
IMPORTANT: Make any edits that may be requested in `/usr/src/rtai/base/arch/i386/patches/README`, especially if they apply to the Linux kernel's `.config` because it is read by Comedi's `configure` script. See also earlier note in Sec. 2.4 if you use a PCMCIA card.

1. `cd /usr/local/src/comedi`
2. `sh autogen.sh`
3. `./configure` or possibly:
   `./configure --with-linuxdir=/usr/src/linux --with-rtaidir=/usr/realtime`
   or: `./configure --with-linuxdir=/usr/src/linux --with-rtaidir=/usr/realtime --enable-kbuild`
   with PCMCIA acquisition card: `./configure --with-linuxdir=/usr/src/linux --with-rtaidir=/usr/realtime --enable-pcmcia`
   Note: Towards the end of the output pay attention that either CONFIG_IPIPE, CONFIG_RTHAL, or CONFIG_ADEOS is set to "yes". This reflects what is set in `/usr/src/linux/.config`
4. `make`
5. `make install` (installs the comedi kernel modules)
6. `make dev`
7. `cp include/linux/comedi.h include/linux/comedilib.h /usr/include/`
   `cp include/linux/comedi.h include/linux/comedilib.h /usr/local/include/`
8. `ln -s /usr/include/comedi.h /usr/include/linux/comedi.h`
   `ln -s /usr/include/comedilib.h /usr/include/linux/comedilib.h`
9. Load RTAI and Comedi modules (Section 2.13)
10. Configure Comedi to work with you data acquisition hardware (section 2 of Comedi documentation www.comedi.org/doc). The Comedi manual and `man comedi_config` show how to associate a particular driver and hardware device to one of the `/dev/comedi` device files. For example, to configure a National Instruments 6024E PCMCIA card, type:
    `comedi_config -v /dev/comedi0 ni_mio_cs`
    and the output is:
    `configuring driver=ni_mio_cs 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,`
    WARNING: with the new *udev* platform there are some problems if the new inodes are not registered (see Section A.3).

2.9 RTAI (2nd pass)

1. `cd /usr/src/rtai`
2. `make xconfig` or `make menuconfig`
3. Menu Add-ons:
   - Select COMEDI support over LXRT
   - Specify COMEDI installation directory (`/usr/local` or `/usr`). The directory should contain `lib/libcomedi.a`, `include/comedi.h` and `include/comedilib.h`

4. Menu RTAI Lab:
   - Select RTAI Lab
   - Adjust EFLTK installation directory (default is `/usr/local`)
5. Exit xconfig/menuconfig and save configuration
6. `make` and `make install`

2.10 Scilab/Scicos

1. `cd /usr/local`
2. Download the latest version of Scilab source code from www.scilab.org
3. It sometimes happens that the latest version requires a patch to be downloaded. Check www.scicos.org
4. `tar xzvf scilab-4.X.X-src.tar.gz`
5. Ensure that your Linux system has the following packages installed: g77, sablotron, tcl8.4-dev, tk8.4-dev, xaw3dg, xaw3dg-dev, libpvm3, pvm-dev, and optionally the set of development packages associated with gtk-2.0.
6. `cd scilab-4.X.X`
7. Depending on your Linux distribution you may try either:
   `./configure`
   Debian:
   `./configure --without-java --with-tcl-library=/usr/lib --with-tcl-include=/usr/include/tcl8.4`
   Fedora Core: `./configure --without-java`
8. `make all`
   Note: DO NOT make install
9. `ln -s /usr/local/scilab-4.x.x/bin/scilab /usr/local/bin/scilab`
10. In a terminal, as normal user, type: `scilab`. Then type `quit` at Scilab's prompt. If Scilab did not start, see end of Section 2.12.

2.11 RTAI-Lab add-ons to Scilab

1. `cd /usr/local`
2. Download the files for Scilab-4.1.2 from web.dti.supsi.ch/ bucher/scilab.html
3. `tar zxvf scilab-4.1.2-rtailab.tgz`
4. `cd scilab-4.1.2-rtailab/macros`
5. `make install`
6. `exit` and then, as normal user: `make user`

2.12 User configuration

Every RTAI-Lab user must edit `${HOME}/.Scilab/scilab-4.X.X/.scilab` with:

```
load('SCI/macros/RTAI/lib')
%scicos_menu($+1)=['RTAI','RTAI CodeGen','Set Target']
scicos_pal($+1,:)=['RTAI-Lib','SCI/macros/RTAI/RTAI-Lib.cosf']
```

These lines add:

- Menu RTAI to the Scicos diagram editor with items →CodeGen and →Set Target
- Palette RTAI-Lib to menu Edit→Palettes

To add Scilab to the executable path you must either:

```
cd /usr/local/bin
ln -s /usr/local/scilab-4.x.x/bin/scilab scilab
```

or add `/usr/local/src/scilab-4.x.x/bin` to the PATH variable in your `.bash_profile and/or .bashrc` or relevant shell start-up file.

2.13 Load the modules

To compile and execute real-time RTAI-Lab programs you must boot the Linux-RTAI kernel. If all goes well your acquisition hardware will be detected (try `cardctl info` for kernels less that 2.6.13 or `pccardctl info` otherwise). You then load RTAI- and hardware-related modules. Note that which modules to load depends on your RTAI kernel configuration.
We recommend to initially load the modules manually, and possibly later configure your system to load these modules at boot time using system files or commands (depending on your Linux distribution and hardware) such as `/etc/modules, update-modules, /etc/modutils/..., /etc/hotplug/ or /etc/udev` and/or a manually launched script.
To manually load the modules, you will have to be root or use `sudo`. You can check the progress by issuing `dmesg` commands or `tail -f /var/log/messages`. For example, on a laptop with a National Instruments DAQCard-6024E PCMCIA card (see hardware-specific comments indicated by # signs below), here's how to load the modules:

```
modprobe rsrc_nonstatic                         # PCMCIA-related
modprobe i82092                                 # PCMCIA-related
modprobe yenta_socket                           # PCMCIA-related
insmod /usr/realtime/modules/rtai_hal.ko
insmod /usr/realtime/modules/rtai_up.ko         # or rtai_lxrt.ko
insmod /usr/realtime/modules/rtai_fifos.ko
insmod /usr/realtime/modules/rtai_sem.ko
insmod /usr/realtime/modules/rtai_mbx.ko
insmod /usr/realtime/modules/rtai_msg.ko
insmod /usr/realtime/modules/rtai_netrpc.ko  ThisNode="127.0.0.1"
insmod /usr/realtime/modules/rtai_shm.ko
insmod /usr/realtime/modules/rtai_signal.ko
insmod /usr/realtime/modules/rtai_tasklets.ko
modprobe comedi
modprobe kcomedilib
modprobe comedi_fc
modprobe 8255                                   # acq. card hardware-specific
modprobe ni_mio_cs                              # acq. card hardware-specific
insmod /usr/realtime/modules/rtai_comedi.ko
/etc/init.d/pcmciautils restart                 # from pcmciautils package
                                                # or pcmcia restart (kernel < 2.6.13)
```

Note that you may have to load more modules in `/usr/realtime/modules/` depending on what blocks you use in your application. It may be useful to write a shell script to load these modules after you boot RTAI.

3 Development with RTAI-Lab

Real-time software development with the RTAI-Lab tool chain is done with the Scilab/Scicos block diagram editor and associated palettes of blocks, including the RTAI-Lib palette.. Some testing of the real-time executable can be done with `xrtailab`. New Scicos blocks may be programmed using the Scilab language, and their executable component programmed in C (see section 5).

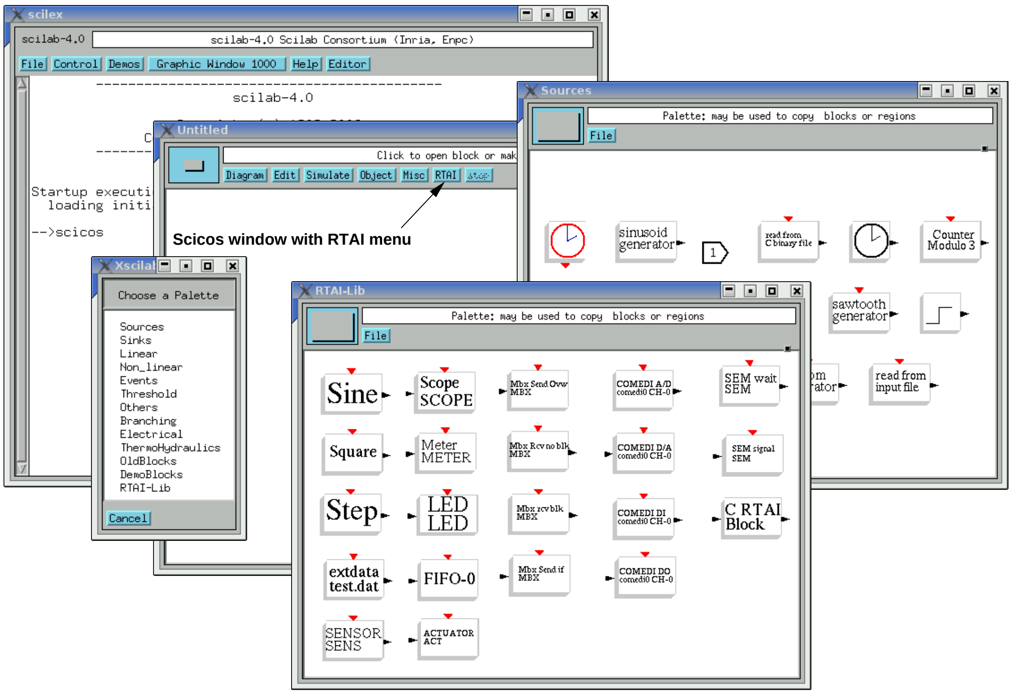


Figure 1: Scilab, Scicos, and 2 palettes (Sources and RTAI-Lib). Note the addition of the RTAI drop-down menu button to the standard Scicos window. The most important block in the Sources palette is the red clock.

3.1 Boot Linux-RTAI

Boot Linux-RTAI. Load associated modules (section 2.13).

3.2 Start Scicos

To launch Scilab, type at a shell's command prompt: `scilab`
At Scilab's prompt type: `scicos`
This opens the Scicos window in which you will draw block diagrams. For a tutorial on Scicos check http://www.scicos.org/TUTORIAL/tutorial.html
RTAI-Lab modifies 2 aspects of Scicos (Fig.1):

- There is an RTAI menu towards the right of the Scicos window
- There is an RTAI-Lib palette

3.3 RTAI-Lib palette

RTAI-Lab provides the Scicos RTAI-Lib palette (Fig. 2). To display the palette from Scicos click on menu Edit → Palettes, a pop-up opens, then click on RTAI-Lib which should be listed at the bottom of the pop-up.

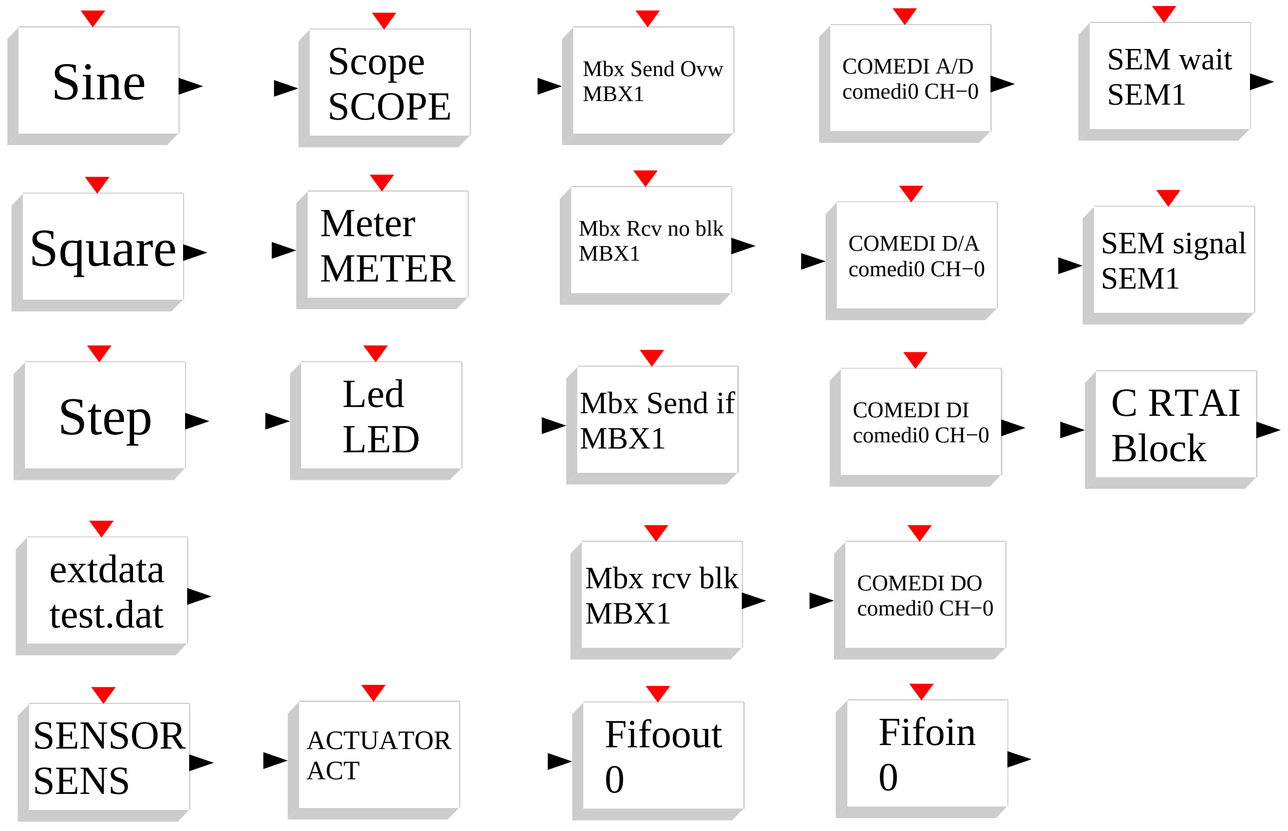


Figure 2: The RTAI-Lib palette featuring (from left to right columns) inputs, outputs, mailboxes, hardware interfaces, and semaphores.

The blocks are (more or less) arranged in thematic columns:

1. **Inputs:** function generators (sine, square, step), read data file, programmable generic sensor
2. **Outputs:** displays (oscilloscope, meter, LED), programmable generic actuator
3. **Mailboxes:** send message and overwrite, receive without blocking task, receive unconditionally, send message if task timing permits, and FIFO boxes
4. **Comedi hardware drivers:** A/D, D/A, digital input, digital output
5. **Semaphores and more:** wait, signal, programmable generic C block

If you have correctly installed RTAI-Lab you can find the source code for the blocks in `/usr/local/scilab-4.x.x/macros/RTAI`. In any case the original blocks provided with the RTAI distribution are in `/usr/src/rtai/rtai-lab/scilab/macros/RTAI`. Most of these blocks call up RTAI-Lab functions written in C and compiled into the library `/usr/realtime/lib/libsciblk.a`. The source code of the C functions is in `/usr/src/rtai/rtai-lab/scilab/devices`. If you look at the source code of the RTAI-Lab functions, you will see how RTAI API functions are called. These RTAI API functions are documented in HTML and other formats in `/usr/src/rtai/doc/generated` if you specified that documentation be generated during RTAI installation (section 2.6).
A detailed review of RTAI-Lib blocks follows. Default values are indicated in brackets.

1. **Inputs:**
   - **Sine.** Real-time sinewave generator. The Sine block lets you adjust amplitude [1], frequency [1] (Hz), phase [0], bias [0], and delay [0]. Furthermore, you can adjust these parameters from xrtailab or an external program while the real-time executable is running.
   - **Square.** Real-time square waveform. The Square block lets you adjust amplitude [1], period [4] (s), pulse width [2] (s), bias [0], and delay [0] (s). You can also adjust parameters from xrtailab or other programs during real-time execution.
   - **Step.** Step function. The Step block lets you adjust amplitude [1] and delay [0] (s).
   - **extdata.** Load data from a file. The file [test.dat] must contain a single column with ASCII values at each sampling time [1000 points].
   - **SENSOR.** Generic sensor input. You can adjust the number of outputs [1] and an identifier [SENS]. Following that another dialog box opens where you can enter C code. This code is compiled and linked after clicking on `OK`. Although the dialog box has basic editing functions similar to Emacs, we recommend that you edit your code in a separate editor and then copy-paste it into the dialox box.
2. **Outputs:**
   Scope, Meter, and LED are output blocks that send data to `xrtailab` displays.
   - **Scope.** `xrtailab` multichannel oscilloscope. You can adjust the number of inputs [1] and the scope's name [SCOPE].
   - **Meter.** `xrtailab` single channel meter. You can adjust the meter's name [METER].
   - **LED.** `xrtailab` multichannel multi-LED block. Each LED switches ON if the input is positive. You can adjust the number of inputs/LEDs [1] and the LED block's name [LED].
   - **ACTUATOR.** Generic actuator output. This block is similar to the SENSOR block. You can adjust the number of inputs [1] and an identifier [ACT].
3. **Mailboxes:**
   Mailboxes let real-time tasks exchange arbitrarily-seized messages. Their advantage is that there is no need to size mailbox buffers to cater for unusually large messages. Message passing may be interrupted by real-time constraints. See /usr/src/rtai/doc/generated/html/api/group__mbx.html and [Sarolahti, 2001]
   Local task blocking may occur when exchanging a packet between a local host and a mailbox on a remote host. Furthermore, packet transmission to a mailbox on a remote host is currently limited by the UDP packet size ($\approx$ 1500 bytes).
   - **Mbx Send Ovw.** Sends a message to a mailbox, possibly overwriting what is already in the mailbox. You can adjust the number of message input ports [1], mailbox name [MBX], and mailbox IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_mbx_ovrwr_send`.
   - **Mbx Rcv no blk.** Receives a message only if the whole message can be passed without blocking the calling task. However, if the mailbox is on a remote host, the calling task may be blocked. You can adjust the number of message output ports [1], mailbox name [MBX], and mailbox IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_mbx_receive_if`.
   - **Mbx Rcv blk.** Receives a message. The calling task will be blocked until all bytes of the message arrive or an error occurs. You can adjust the number of message output ports [1], mailbox name [MBX], and mailbox IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_mbx_receive`.
   - **Mbx Send if.** Sends a message only if the whole message can be passed without blocking the calling task. However, if the mailbox is on a remote host, the calling task may be blocked. You can adjust the number of message input ports [1], mailbox name [MBX], and mailbox IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_mbx_send_if`.
   - **FIFOout and FIFOin.** Multichannel FIFO. You can adjust the number of inputs [1], the FIFO's number [0], and the FIFO's Dimension [50000] (in bytes).

4. **Comedi hardware drivers:**

   - **Comedi A/D.** Comedi supported Analog Input. You can select your acquisition card's analog input channel [0], the device if you have several acquisition cards [comedi0], the range number as specified in your acquisition hardware's manual [0] (warning: the value to enter is not expressed in volts), and the type of voltage reference [0], e.g. nonreferenced single ended, referenced single ended, and differential. See also Comedi API `comedi_data_read`.
   - **Comedi D/A.** Comedi supported Analog Output. The parameters are similar to Comedi A/D. See also Comedi API `comedi_data_write`.
   - **Comedi DI.** Comedi supported Digital Input. You can select the channel [0] and device [comedi0]. See also Comedi API `comedi_dio_read`.
   - **Comedi DO.** Comedi supported Digital Output. You can select the channel [0], device [comedi0], and threshold [1]. If the data input to the block is greater than the threshold value, then a single bit will be output by your hardware. See also Comedi API `comedi_dio_write`.

5. **Semaphores and more:**
   Semaphores can be used to synchronize real-time tasks. Similarly to mailboxes, caution is needed with respect to blocking when exchanging a semaphore between a local and a remote host.

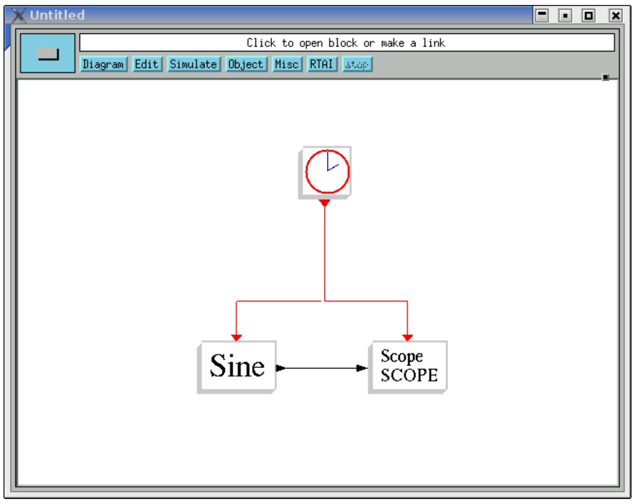
   - **SEM wait.** Decrement a semaphore's value and wait for a signal event. The caller task is blocked and queued up as long as the semaphore's value is negative. You can adjust the semaphore's name [SEM] and IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_sem_wait`.
   - **SEM signal.** Increment a semaphore's value. If the resulting value is not positive then the first task in the semaphore's waiting queue is allowed to run. You can adjust the semaphore's name [SEM] and IP address [127.0.0.1] (localhost). See also RTAI API documentation for function `rt_sem_signal`.
   - **C RTAI.** This is a generic block that lets you edit C code. It is based on Scilab's C-Block2 found in the "Others" palette. When you click on the C RTAI Block a dialog window opens where you can edit block parameters such as the name of the main function that it will contain, the number of inputs and outputs for data and events, and various parameters (see section 5.10 and also [Campbell, Chancelier, and Nikoukhah, 2006], section 9.5). After clicking on OK a second window opens with a code skeleton to edit. It is best to copy-paste code from your favorite editor into this window. When you click on OK the code is compiled and linked. If your code is relatively large we recommend that you program your own block instead of using C RTAI Block (see section 5).

3.4 Real-time sinewave: step by step

In this example you use Scilab/Scicos to draw a block diagram that generates a sinewave. You automatically generate and compile a real-time executable. You test the program and visualize the sinewave with `xrtailab`.

3.4.1 Create block diagram

Let's create the preliminary Sinewave diagram shown in figure 3.
Select palettes. Start Scicos. Open the Sources palette: click on menu Edit → Palettes and select Sources at the top of the pop-up window. Open the RTAI-Lib palette in a similar way (figure 1).
Keyboard shortcuts. Note that by default, Scicos has a few customizable keyboard shortcuts, list them with menu Misc → Shortcuts.
Select blocks. From the Sources palette, left-click on the red clock. Move your mouse to the main Scicos window. You should see the block's contour being dragged as your mouse cursor enters the main Scicos window. Left-click again to place the clock in the main Scicos window, somewhere towards the upper center of the window. You may also right-click to cancel block placement during the drag.
From the RTAI-Lib palette, left-click on the Sine block and place it towards the lower left of the main Scicos window. Place also a Scope block towards the lower right.
Align blocks. Scicos does not currently feature a block placement grid so blocks are not perfectly aligned to make a nice diagram. Two methods can help block alignment:



Click to open block or make a link

Figure 3: Preliminary RTAI-Lib block diagram with real-time sinewave generator and xrtailab scope blocks.

- Use Scicos's Align function: menu Edit $\rightarrow$ Align. Click on the Sine block's *data output port* (the black triangle to the right of the block) and then on the Scope's *data input port*. One of the blocks will then be shifted so that both blocks' ports are aligned. A faster way to align blocks using keyboard shortcuts is to place the mouse over a block's port (input or output), then use keyboard shortcut "a", then click on the port of the block to be aligned.
- Adjust mouse acceleration so that motion increments are more discretized: type `xset m 4 1` in a terminal/shell window. The drawback is that your mouse might move too fast for comfort.

Link blocks. Menu Edit $\rightarrow$ Link. Click on Sine's output port. Click on Scope's input port. A link is drawn from Sine to Scope. Click on the clock's *event output port* (the red triangle below the clock). Then draw an S-shaped link to the Sine block by clicking below the clock's port, once more above the Sine's event port, and finally directly onto the Sine's event port. A red link is drawn from the clock to the Sine. Draw another event link by clicking onto the red line, then click above the Scope, and click again onto the Scope's event port.
Set block parameters. Click on the clock. You may adjust period and initialization times (values are in seconds). Click on Sine, adjust parameters accordingly, then click on OK. You may also edit the Scope's name and notice that it may actually have more than one data input. In any case, it is necessary that Scicos *evaluate* all blocks. This is done when you click on a block, adjust its parameters, and then click on OK. A general way to have all blocks *evaluated* is to select menu Simulate $\rightarrow$ Eval. You must do this Eval operation every time you add a block to a diagram and omit inspecting its internal parameters.
Create super block. Menu Diagram $\rightarrow$ Region to Super Block. You must draw an elastic frame around the Sine and Scope blocks, excluding the Clock (figure 4, left). First click above-left of the Sine block, then click again below-right of the Scope block. The region then becomes a Super Block (Fig. 4, right).

3.4.2 Compile

Set target. You may optionally click on menu RTAI $\rightarrow$ Set Target and then click on the Super Block to compile. A dialog box opens where you may modify:

- **Target.** This is the Makefile's basename. See description below.
- **Ode function.** This is one of the ordinary differential equation functions available in Scilab. The default is `ode4`. Possible values are:
  - **ode1.** Uses Euler's method (RK1)
  - **ode2.** Uses Heun's method (RK2), also known as the Improved Euler method.
  - **ode4.** Uses a 4th order Runge-Kutta formula (RK4).

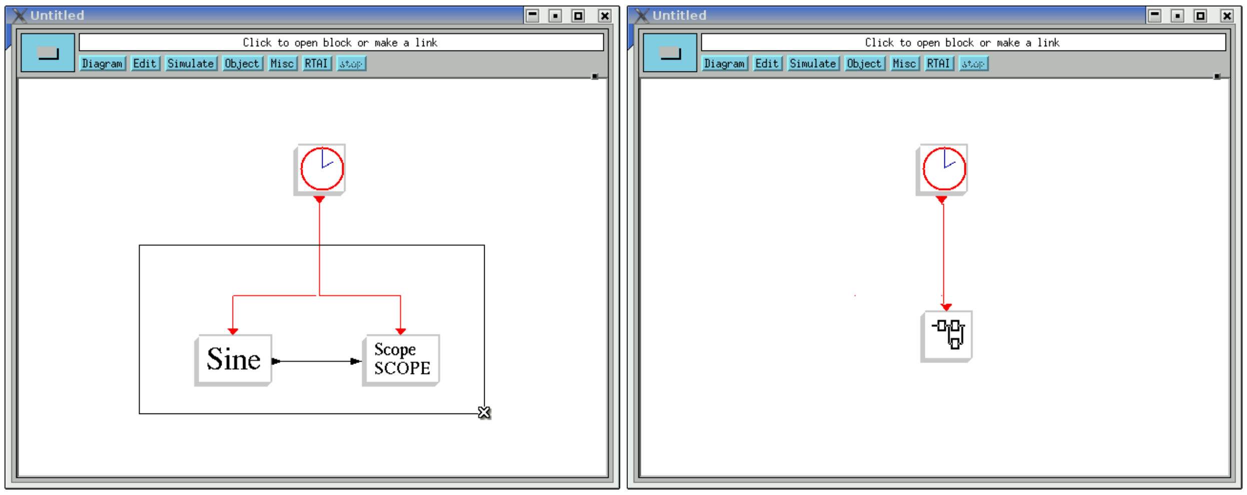
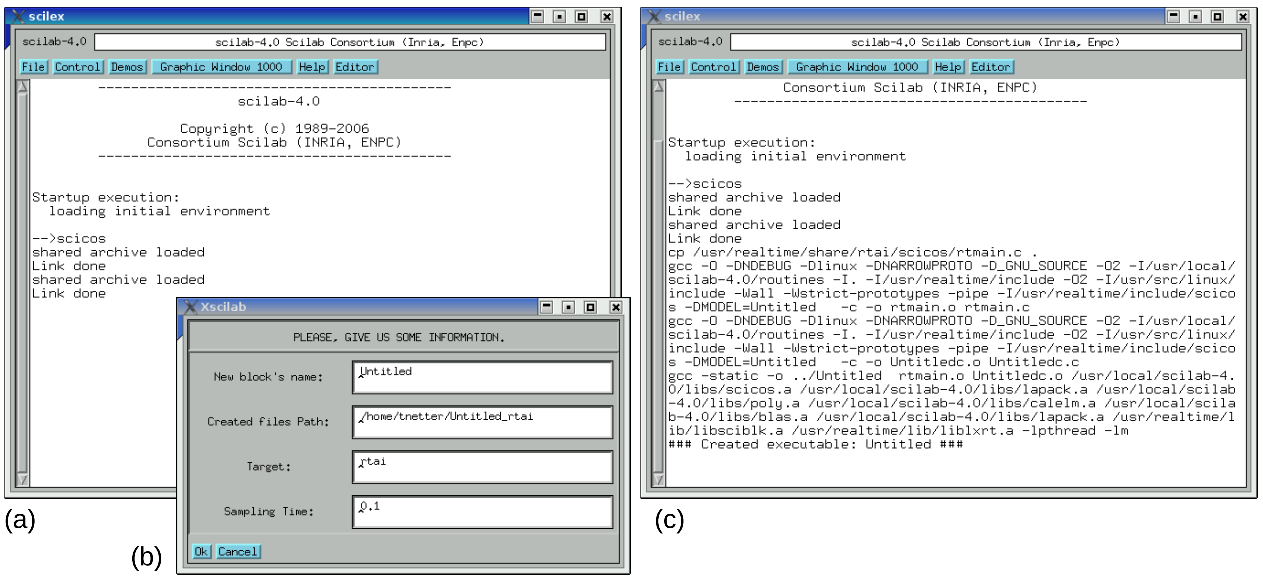

Untitled
Click to open block or make a link
Diagram Edit Simulate Object Misc RTAI stop
Sine
Scope
SCOPE
Untitled
Click to open block or make a link
Diagram Edit Simulate Object Misc RTAI stop

Figure 4: **Left:** preliminary RTAI-Lib block diagram during Region to Super Block framing. All blocks except the clock should be contained in the region. **Right:** resulting Super Block.

The source code for these functions is available in `$SCILAB/macros/RTAI/RTAICodeGen_.sci`. Scilab's ODE functions are detailed in section 3.2 of [Campbell et al., 2006] and also in [Sallet, 2004].

- **Step between sampling.** Indicates the number of computational sub-sampling points used for various functions such as ODE functions. The default is 10.


(a)
scilex
scilab-4.0
scilab-4.0 Scilab Consortium (Inria, Enpc)
File Control Demos Graphic Window 1000 Help Editor
(b)
Xscilab
Ok Cancel
(c)
scilex
scilab-4.0
scilab-4.0 Scilab Consortium (Inria, Enpc)
File Control Demos Graphic Window 1000 Help Editor

```
        -------------------------------------------
                          scilab-4.0

                  Copyright (c) 1989-2006
              Consortium Scilab (INRIA, ENPC)
        -------------------------------------------


Startup execution:
  loading initial environment

-->scicos
shared archive loaded
Link done
shared archive loaded
Link done
```

```
PLEASE, GIVE US SOME INFORMATION.

New block's name:     Untitled
Created files Path:   /home/tnetter/Untitled_rtai
Target:               rtai
Sampling Time:        0.1
```

```
              Consortium Scilab (INRIA, ENPC)
        -------------------------------------------


Startup execution:
  loading initial environment

-->scicos
shared archive loaded
Link done
shared archive loaded
Link done
cp /usr/realtime/share/rtai/scicos/rtmain.c .
gcc -O -DNDEBUG -Dlinux -DNARROWPROTO -D_GNU_SOURCE -O2 -I/usr/local/
scilab-4.0/routines -I. -I/usr/realtime/include -O2 -I/usr/src/linux/
include -Wall -Wstrict-prototypes -pipe -I/usr/realtime/include/scico
s -DMODEL=Untitled   -c -o rtmain.o rtmain.c
gcc -O -DNDEBUG -Dlinux -DNARROWPROTO -D_GNU_SOURCE -O2 -I/usr/local/
scilab-4.0/routines -I. -I/usr/realtime/include -O2 -I/usr/src/linux/
include -Wall -Wstrict-prototypes -pipe -I/usr/realtime/include/scico
s -DMODEL=Untitled   -c -o Untitledc.o Untitledc.c
gcc -static -o ../Untitled  rtmain.o Untitledc.o /usr/local/scilab-4.
0/libs/scicos.a /usr/local/scilab-4.0/libs/lapack.a /usr/local/scilab
-4.0/libs/poly.a /usr/local/scilab-4.0/libs/calelm.a /usr/local/scila
b-4.0/libs/blas.a /usr/local/scilab-4.0/libs/lapack.a /usr/realtime/l
ib/libsciblk.a /usr/realtime/lib/liblxrt.a -lpthread -lm
### Created executable: Untitled ###
```

Figure 5: Block diagram: code generation and compilation. **(a)**: Scicos window after code generation. **(b)**: Dialog box to adjust generated filenames, makefile, and clock period. **(c)**: Text output after compilation.

Compile block diagram. Menu RTAI → RTAI CodeGen. Then click on the Super Block. At this point Scilab converts your block diagram into C code. For each block inside the Super Block two lines are output in the Scicos window (Fig. 5a):

```
shared archive loaded
Link done
```

A dialog then opens (Fig. 5b shows the dialog with default values) where you may modify:

- **New block's name.** This will be the name of the final executable. It will be saved in what Scilab thinks is your current directory. The default is `Untitled`.

- **Created files Path.** This is the directory where the generated C files are saved along with a Makefile. This is also the directory where compilation occurs.
- **Target.** This is the Makefile's basename. It will be copied to the generated files directory and used for compilation. The default value `rtai` corresponds to the file `$SCILAB/macros/RTAI/RT_templates/rtai.mak`
- **Sampling Time.** This corresponds to the Period value set in the Clock block parameters, i.e. you can adjust the clock here.

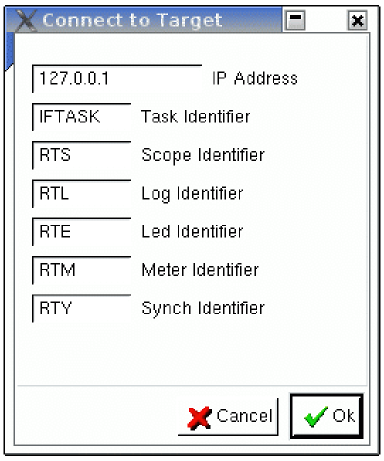
Click on OK and the compilation starts. Steps in the compilation can be monitored in the Scilab window (Fig. 5c). In case the compilation fails (this can happen for example when you develop your own custom blocks, see section 5.2), you can still start the compilation manually by typing `make` in the directory where C files were generated. This provides more debugging output that what is printed in the Scilab window.
If you kept the default values you should find an executable file called `Untitled` in your current directory.

3.4.3 Execute

Open two terminal shells.
Real-time executable. In the first terminal type: `Untitled -u`
This provides usage instructions as a list of command line options.
To start the real-time executable with verbose output type: `Untitled -v`
xrtailab. Note that `xrtailab` only executes when an RTAI Linux kernel is running. `xrtailab` will generate a segmentation fault if started over a standard Linux kernel.
In the second terminal type:

```
xrtailab -h
xrtailab
```

Select menu File → Connect... (keyboard shortcut: alt-c) then Click on OK (Fig. 6).



127.0.0.1	IP Address
IFTASK	Task Identifier
RTS	Scope Identifier
RTL	Log Identifier
RTE	Led Identifier
RTM	Meter Identifier
RTY	Synch Identifier

Figure 6: `xrtailab`'s connect dialog box.
IP Address is that of the host where the real-time task is executing. Identifiers IFTASK, RTS, RTL, RTE, RTM, and RTY are predefined in `rtmain.c`, in the directory that contains the generated source code. If several real-time tasks must run in parallel, a real-time task's identifiers may be set via the command line options (execute the task with option `-u` to list command line options) and by adjusting values in the "Connect to Target" dialog. Note that you may even edit `rtmain.c` to change the real time task's predefined identifiers.

`xrtailab`'s row of buttons (Fig. 7) lets you start and stop the real-time executable and open various displays such as scopes, meters, and LEDs. At the time this tutorial is written, not all buttons are fully functional. Some may find it more convenient to use the View menu and associated keyboard shortcuts.
Open a scope manager window by either clicking on the Scope button or selecting it in the View menu (shortcut: alt-s). Then click on the Show/Hide checkbox to display the scope. You should see a 1 Hz sinewave snaking smoothly in the scope.
Note that the Scope Manager lets you modify display properties such as the number of grid division (Sec/-Div), colors, and filename. You can save data points (default: 1000) to a file (default filename: SCOPE). You may also pause the display. Each trace's properties can also be adjusted via the Trace tab. The trace can be hidden, its offset shifted, and its color changed. You may also adjust the number of units per vertical division.

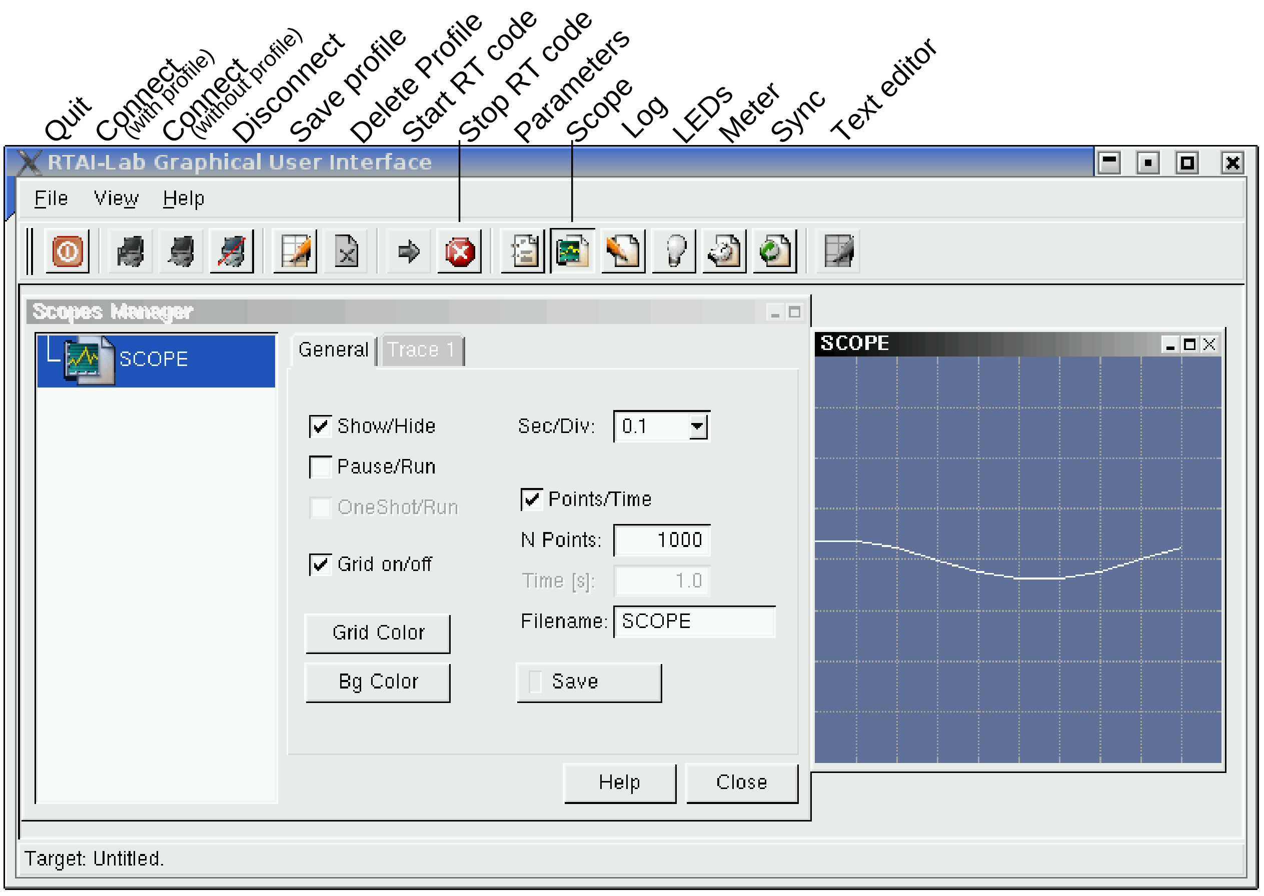


Figure 7: `xrtailab` with scope manager window and a scope displaying a 1 Hz sinewave. Most functions of the row of buttons are duplicated in the drop-down menus. Keyboard shortcuts are also available.

3.4.4 Change parameters

`xrtailab` lets you change “on the fly” the parameters that were defined in the Scicos block diagram. For example, the Sine block has 5 parameters: amplitude (Value[0]), frequency (Value[1]), phase (Value[2]), bias (Value[3]), and delay (Value[4]).
Click on the Parameters button. The Parameters Manager window opens. You might have to resize `xrtailab`’s window and reposition the Parameters Manager window to obtain a convenient layout similar to that shown in figure 8. Change Value[0] to 3 and press the Enter key. The sinewave’s amplitude will increase accordingly. Change Value[1] to 2. This will double the sinewave’s frequency to 2 Hz and you will notice that the wave lost its smoothness. This is an undersampling effect induced by the fact that the clock’s period, as defined in the Scicos block diagram, is only of 0.1 s or 10 Hz.
Note that the Parameters Manager also lets you download block parameters from real-time tasks running on remote hosts and upload them back after modification.

3.4.5 Stop executable

Click on the Stop hexagonal icon to disconnect `xrtailab` from the real-time target and terminate it. Note that it is possible to only disconnect `xrtailab` from a target (alt-d) and leave it running. You can re-connect to it later. Finally, you may also interrupt the real-time executable directly at the terminal where you launched its execution: type ctrl-c.

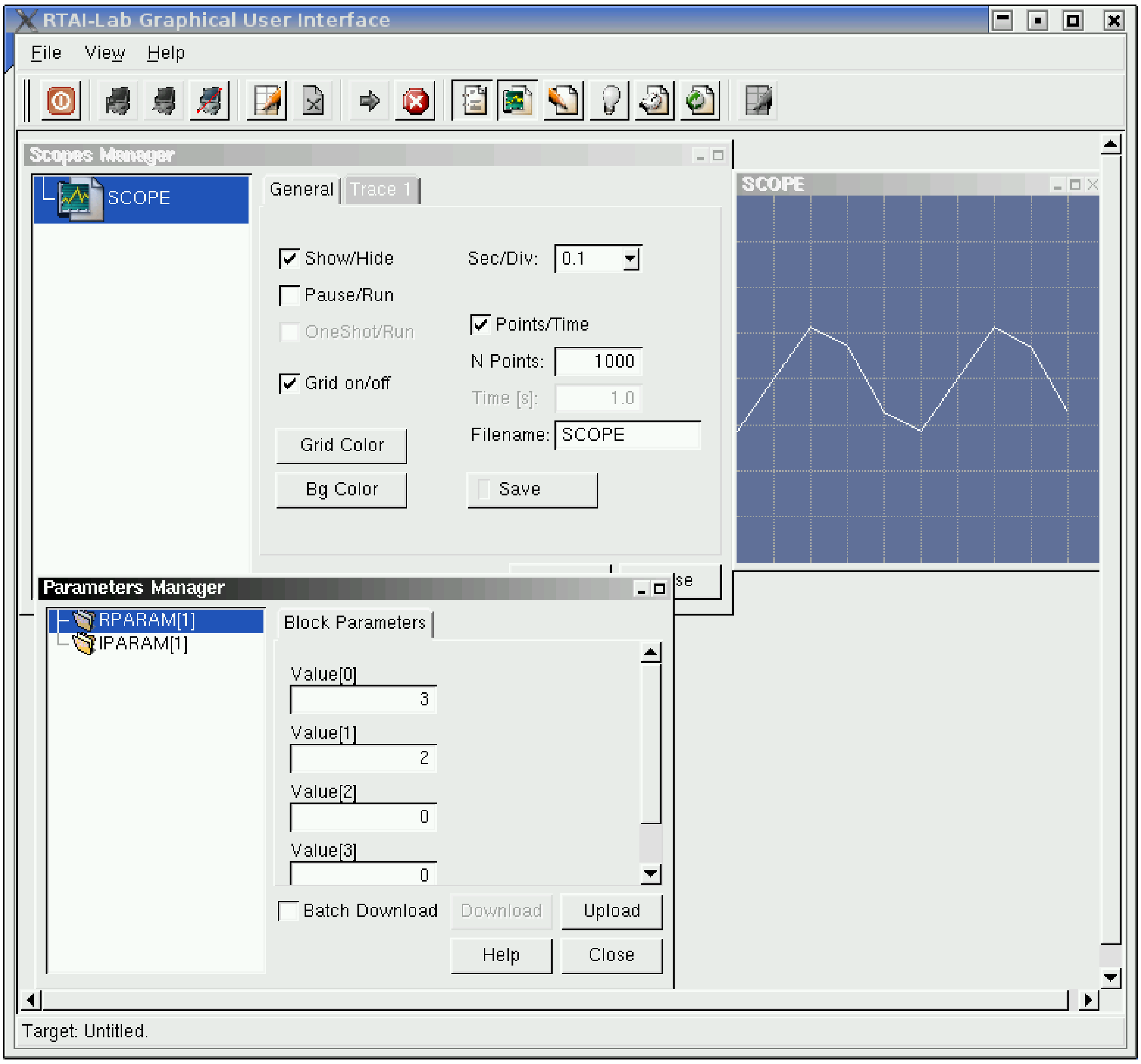


Figure 8: `xrtailab` with Parameters Manager window. Parameters that have been changed are sinewave amplitude (Value[0]) from 1 to 3 and frequency (Value[1]) from 1 to 2 Hz. The scope reveals an undersampled sinewave that results from the real-time executable's clock being set to only 10 Hz.

4 Examples

In this section we provide a few basic examples that show how to:

- Use FIFOs
- Use semaphores
- Represent a continuous-time plant as a discrete-time model

4.1 FIFOs

FIFOs provide a way of passing data to other tasks and programs. Design the diagram of figure 9a.

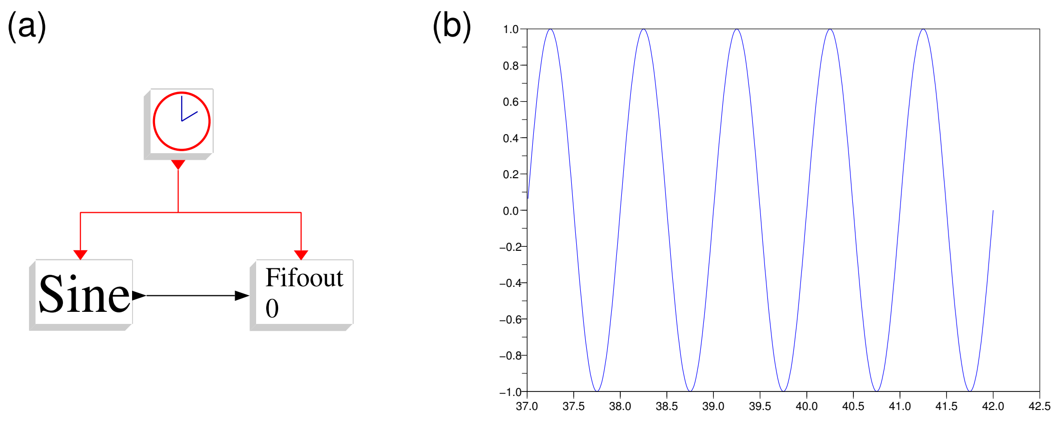


Figure 9: Preliminary diagram of a task that outputs sinewave data to a FIFO. An external program is then used to read the data from `/def/rtf0`

- Click on Simulate → Eval to ensure all blocks are registered. You may change parameters in the Sine block.
- Set clock period to 0.01
- Frame a Superblock around Sine and FIFOout
- Open the Superblock and click menu Diagram → Rename. Replace `Untitled` with `fifo1`
- Close the Superblock's window
- Diagram → Save As: `fifo1.cos`
- Menu RTAI → RTAI CodeGen and click on the superblock to generate code and compile it to produce the executable `fifo1`

Now copy the program `readfifo.c` and compile it with: `gcc -o readfifo readfifo.c`

```
/* readfifo.c -- Read a FIFO and print its data */
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <fcntl.h>
#include <signal.h>

static int end;
```

```
struct data{
     float t;
     float u[1];
};

static void do_end(int dummy) { end = 1; }

int main (void)
{
     int fifo;
     struct data val;

     if ((fifo = open("/dev/rtf0", O_RDONLY)) < 0) {
          fprintf(stderr, "Error opening /dev/rtf0\n");
          exit(1);
     }
     signal(SIGINT, do_end);
     while (!end) {
          read(fifo, &val, sizeof(val));
          printf("%f\t%f\n", val.t, val.u[0]);
     }
     return 0;
}
```

- In a terminal type: `./fifo1 -v`
- In a second terminal type: `./readfifo`
  Two columns of data should start printing. Interrupt the program by typing ctrl-c.
- In the second terminal now type: `./readfifo > fifo.dat`
  Interrupt the program after 3 to 10 seconds by typing ctrl-c.
- In Scicos, menu Diagram → Quit
- In Scilab's scilex window, type "n" and then type at Scilab's "-->" command prompt to produce the plot in Fig. 9b:

```
    -->x = read('fifo.dat', -1, 2);
    -->plot(x(:,1), x(:,2))
```

4.2 Semaphores

Semaphores are used as a signalling method between tasks. Design the diagram of figure 10.

- Open the SEM signal block and ensure that IP addr is 127.0.0.1
- Open the SEM wait block and ensure that IP addr is 0
- Open the left LED block and call it LED1
- Frame a Superblock on the left side around blocks Sine, SEM signal, and LED. Frame a Superblock on the right side around blocks SEM wait, LED, Sine, and Scope.
- Set each clock to a Period of 0.001
- Simulate → Eval

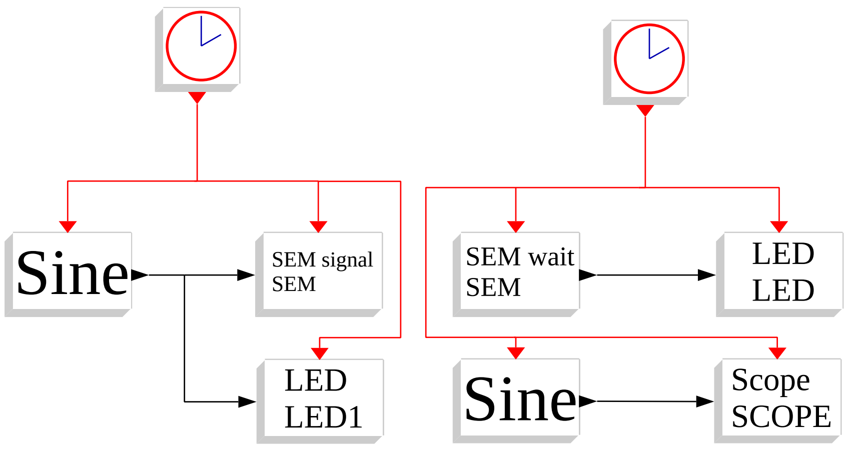
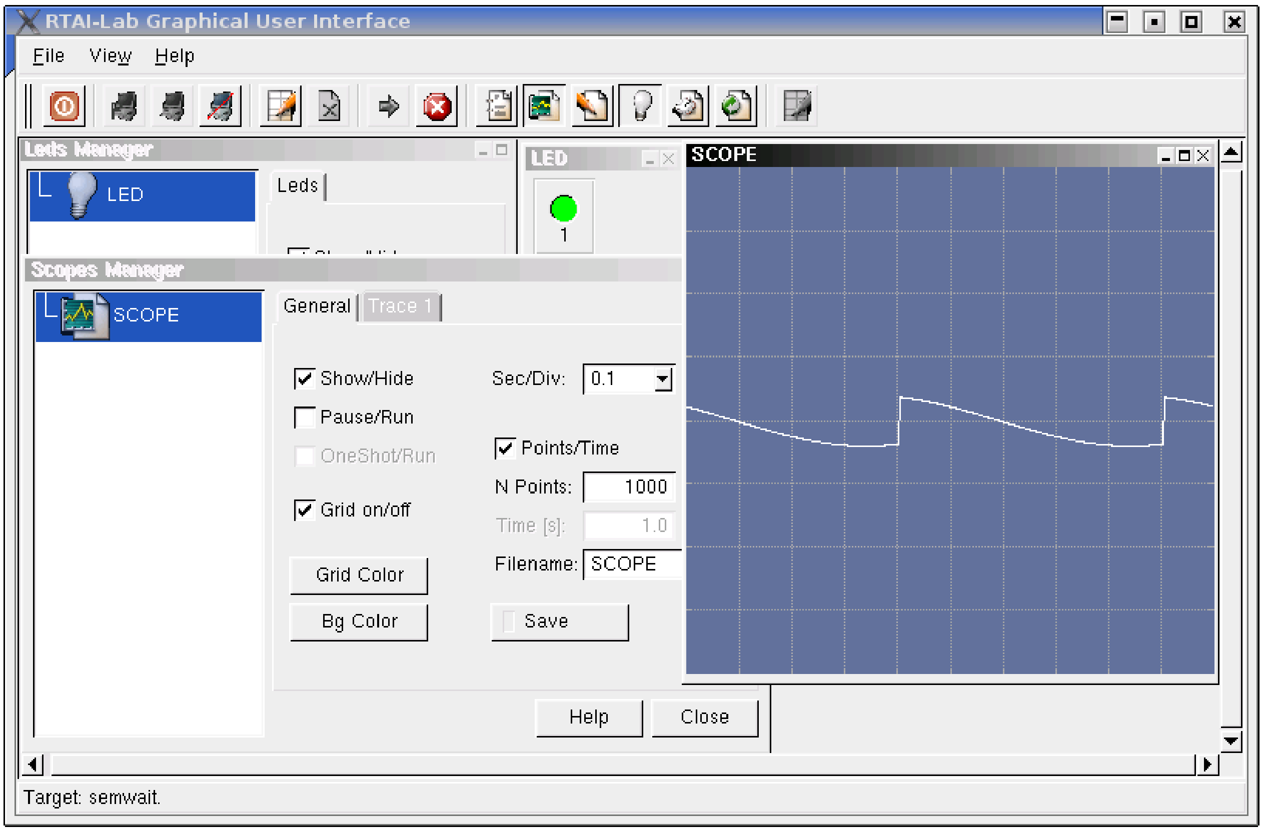


Figure 10: Preliminary diagram of two tasks that use semaphores. Left: the signalling task uses a sinewave to increment a semaphore. Right: the waiting task reads the semaphore and produces an output only when the sinewave in the signalling task is positive.

- Open the left Superblock and Diagram → Rename it to `semsig`. Note: you might have to Diagram → Replot to recenter the diagram. Warning: do not put a dash "-" in the name of a block, RTAI CodeGen has problems with that. Close the window.
- Put a name tag under the Superblock: Object → Identification, click on the left Superblock and set ID to `semsig`
- Open the right Superblock and rename it to semwait. Close the window.
- Save the diagram to sem.cos
- RTAI → RTAI CodeGen the left Superblock
- RTAI → RTAI CodeGen the right Superblock
- In a terminal type: `semsig -v -n IFTASL -d LED`
- In a second terminal type: `semwait -v -e`
- In a third terminal type: `xrtailab -v`
- In `xrtailab`:
  - Connect to `semwait`: type alt-c and set the "Led identifier" field to `LED`
  - Open and display an LED: click on the light bulb button then check Show/Hide. The *signalling task*'s LED should blink every second
  - Open and display a scope. You should see the *waiting task*'s truncated sinewave scrolling in a jerky manner every second (Fig.11).
  - Disconnect from `semwait`: type alt-d
  - Connect to `semsig`: type alt-c. In the Task Identifier field type: `IFTASL` and click on the OK button.
  - Open and display an LED. LED1 should blink at 1 Hz.
  - Open the "parameters manager": type alt-p. Increase Value[1] of RPARAM[1] from 1 to 2 and press Enter. By doing this you have increased semsig's Sine frequency from 1 to 2 Hz. LED1 should now blink at 2 Hz.
  - Disconnect from `semsig`: type alt-d
  - Connect again to `semwait`: type alt-c. Set Task Identifier to `IFTASK`
  - Open again an LED and a scope. The LED now blinks at 2 Hz and the sinewave has twice as many kinks.



Show/Hide [✓]
Pause/Run [ ]
OneShot/Run [ ]
Grid on/off [✓]
Grid Color
Bg Color
Sec/Div: 0.1
Points/Time [✓]
N Points: 1000
Time [s]: 1.0
Filename: SCOPE
Save

Target: semwait.

Figure 11: `xrtailab` scope display of the sinewave generated by the semwait Superblock (the waiting task). The green LED reflects the state of the LED block in the semsig Superblock (the signalling task). The waiting task operates only when the “SEM wait” semaphore is positive (light green LED). The result is a jerky sinewave synchronized to the semsig task’s semaphore.

4.3 From continuous- to discrete-time

4.3.1 Discretize the system

Say a continuous-time feedback system includes a plant modeled by the transfer function:

$$G(s) = \frac{20}{s^2 + 4s}.$$

Use Scilab to discretize the system with a sampling time of 1 ms.

```
-->s = poly(0,'s');
-->G = [20/(s^2 + 4*s)]
 G  =
      20
    ------
          2
    4s + s
-->Gc = syslin('c',G);
-->T = 0.001;
-->Gd = ss2tf(dscr(tf2ss(Gc),T))
 Gd  =
     0.0000100 + 0.0000100z
    ------------------------
                            2
    0.9960080 - 1.996008z + z
```

The system's discrete-time transfer function is therefore:

$$G(z) = 10^{-6} \frac{10z + 10}{z^2 - 1.996z + 0.996}.$$

4.3.2 Block diagram and simulation

Replicate the block diagram of figure 12 (you will use palettes Sources, Sinks, Linear, and Branching).

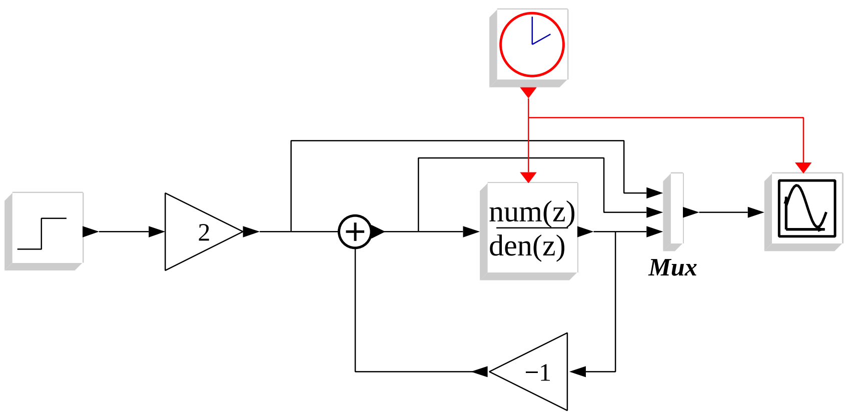


Figure 12: Scicos block diagram to simulate the step response of a discretized plant.

- **Clock block:** set Period = 0.001, Init time = 0
- **Step block:** set step time = 1, Initial value = 0, Final value = 1.
- **Gain block:** set gain to 2

- **Discrete SISO transfer function:** set numerator to: `0.00001 + 0.00001*z`
  set denominator to: `0.996008 - 1.996008*z + z^2`
- **Feedback gain block:** set gain to -1
- **Scope block:** set Ymin = -1, Ymax = 3, Refresh period = 5, Buffer size = 20
- **Menu Simulate → Setup:** set Final integration time = 5
- **Menu Simulate → Eval**

Use Scicos to visualize the system's response to a square signal: menu Simulate → Run produces the plot of figure 13.

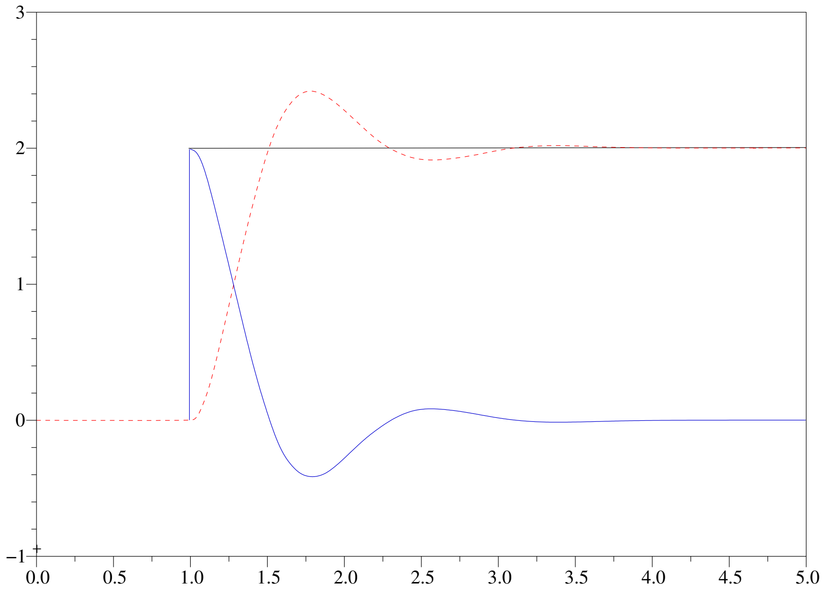


Figure 13: Step response (dashed red line) of block diagram shown in Fig. 12

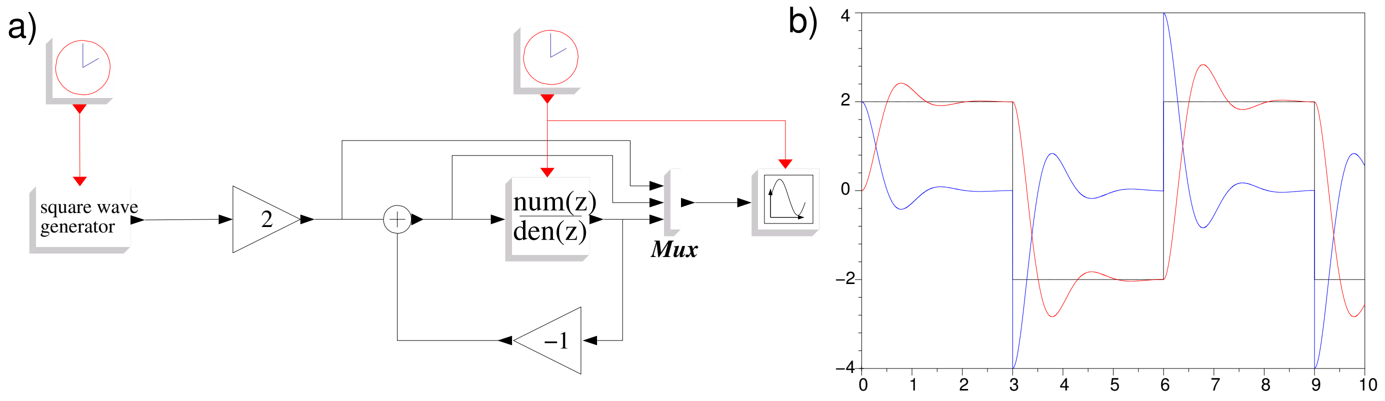


Figure 14: a) Block diagram of Fig. 12 modified to display the response to a square wave. b) Resulting plot showing square wave and step response (red line). Note: This figure was assembled by exporting the block diagram to Postscript and converting it with `pstoedit -f fig`. The plot was directly exported to `Xfig` format. Both figures were then merged using `Xfig` and the numbering on the axes was enlarged using `Xfig`'s "Update" button.

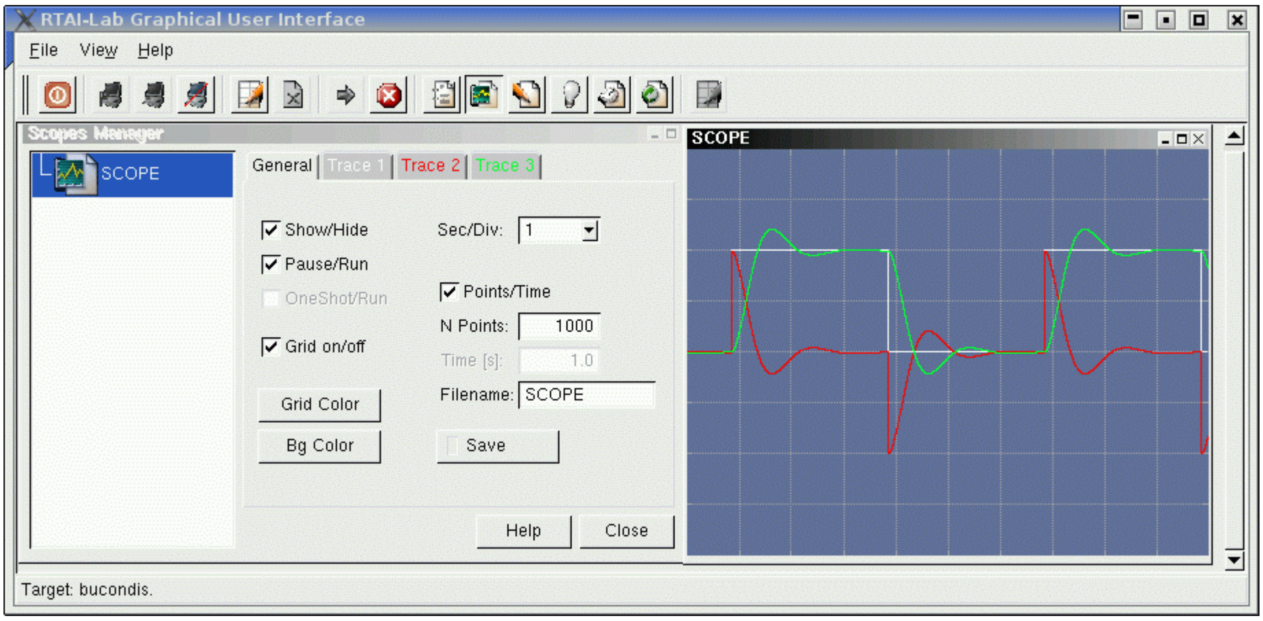
Modify the block diagram so as to simulate the response to a square wave input (Fig. 14a):

- **Left clock:** Period = 3, Init time = 0
- **Square wave generator:** Amplitude = 1
- **Scope:** Ymin = -4, Ymax = 4, Refresh period = 10, Buffer size = 20
- **Menu Simulate** → **Eval** generates Fig. 14b.

4.3.3 Real-time model and simulation

Modify again the block diagram using blocks from the RTAI-Lib palette (Fig. 14a):

- Replace the left clock and square wave generator with an RTAI-Lib Square block. Set Square block parameters: Amplitude = 1, Period = 6, Impulse width = 3, Bias = 0, Delay = 0
- Replace the multiplexer and scope with an RTAI-Lib Scope block. Set input ports = 3
- **Menu Diagram** → **Region to Super Block:** frame all blocks except the clock. You then obtain Fig. 14b
- Open Super Block. Menu Diagram → Rename and set diagram name to `rtex3`. Close Super Block window.
- **Menu RTAI** → **RTAI CodeGen** and compile
- In a terminal type: `./rtex3 -v`
- In another terminal type: `xrtailab`
- In xrtailab: connect to target (alt-c), open the scope manager and show the scope. In the Scopes Manager you can click on Trace tabs to adjust each trace's color (Fig. 15).



☑ Show/Hide
☑ Pause/Run
☐ OneShot/Run
☑ Grid on/off
Sec/Div: 1
☑ Points/Time
N Points: 1000
Time [s]: 1.0
Filename: SCOPE
Target: bucondis.

Figure 15: `xrtailab` Scopes Manager and scope displaying real-time plots of the block diagram shown in Fig. 14a

4.4 DC Motor control

In this example we show how to adapt a Simulink block diagram to Scicos and RTAI. This example is based on the Control Tutorials for Matlab® and Simulink®, hosted at Carnegie Mellon University and University of Michigan [Messner and Tilbury, 1998]: www.library.cmu.edu/ctms. Please refer to the "DC Motor position modeling in Simulink" example. Sections 7.2 and 10.2 of [Campbell et al., 2006] also provide in-depth information on using Scicos for control.

4.4.1 Motor position model

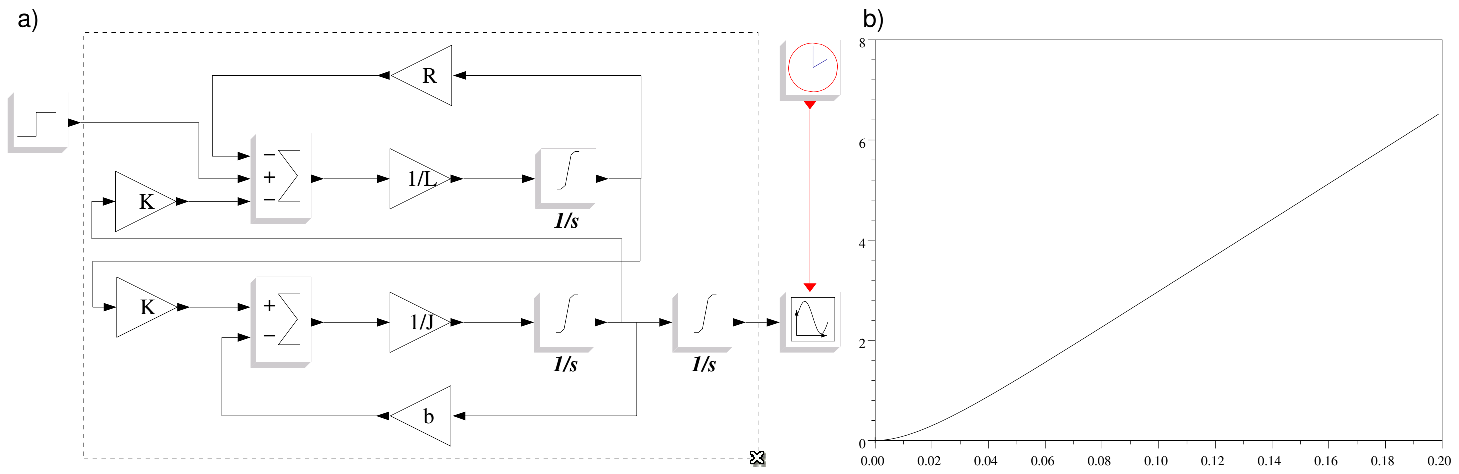
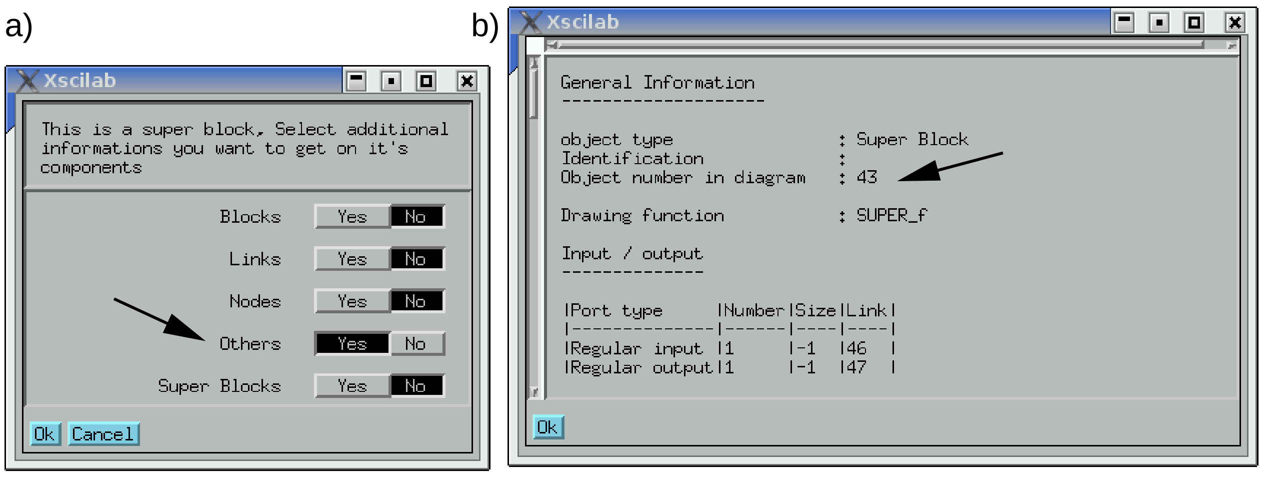


Figure 16: a) Continuous time model of DC motor position as described at www.library.cmu.edu/ctms. b) Open-loop step response of DC motor.

- Replicate the model of Fig. 16a
- Menu Edit → Context: enter values for constants:
  `J = 3.2284E-6; b = 3.5077E-6; K = 0.0274;`
  `R = 4; L = 2.75E-6`
- Menu Simulate → Setup: Final integration time = 0.2
- Step block: Step time = 0, Initial value = 0, Final value = 1
- Clock block: Period = 0.001, Init time = 0
- Scope block: Ymin = 0, Ymax = 8, Refresh period = 0.2
- Menu Simulate → Eval
- Menu Simulate → Run: produces the plot of Fig. 16b

4.4.2 Digital model

- Menu Diagram → Region to Super Block: draw a frame around the computational blocks as shown in Fig. 17a. You then obtain a superblock.
- Menu Diagram → Save As: save to dcmot-model.cos
- Menu Object → Get Info, then click on the superblock. A window opens, select "Others [Yes]" and click on OK (Fig.17a). A second window opens, remember the superblock's object number (here 43, Fig. 17b) and click on OK
- Menu Diagram → Quit to exit Scicos, then type "n" to get past the junk in the Scilab window.


a)

This is a super block, Select additional informations you want to get on it's components

Blocks	Yes [✓ No]
Links	Yes [✓ No]
Nodes	Yes [✓ No]
Others	[✓ Yes] No
Super Blocks	Yes [✓ No]

b)

```
General Information
-------------------

object type              : Super Block
Identification           :
Object number in diagram : 43

Drawing function         : SUPER_f

Input / output
--------------

|Port type      |Number|Size|Link|
|---------------|------|----|----|
|Regular input  |1     |-1  |46  |
|Regular output |1     |-1  |47  |
```

Figure 17: How to obtain information about a superblock prior to its discretization: menu Object → Get Info then a) select Others [Yes] and b) remember block's object number (43)

- In Scilab type:
  (replace the "43" in the 3rd line with your superblock's object number):

```
load dcmot-model.cos
J = 3.2284e-6; b = 3.5077e-6; k = 0.0274; R = 4; L = 2.75e-6
scs_m = scs_m.objs(43).model.rpar
sys = lincos(scs_m);
dtf = ss2tf(dscr(sys,0.001))
```

  You then obtain the discrete-time transfer function from voltage input to motor position output:

```
dtf  =

                                    2
 9.454E-10 + 0.0010214z + 0.0010389z
 -----------------------------------

                            2    3
     0.9424937z - 1.9424937z + z
```

  which after simplification and reordering corresponds to:

$$\frac{0.001z + 0.001}{z^2 - 1.9425z + 0.9425}.$$

  You can recover the transfer function's plot of Fig. 16b with:

```
td = 0:T:0.2
u = ones(1, size(td,2));
plot2d([td'],[(dsimul(tf2ss(dtf),u))']);
```

4.4.3 Digital control

Build upon the superblock resulting from the block diagram of Fig. 16a and generate the diagram of Fig. 18a:

- Left clock: Period = 0.1, Init time = 0
- Square wave generator: Amplitude = 1

- Discrete transfer function num(z)/den(z):
  Numerator(z) = `450*(z-0.85)*(z-0.85)`
  Denominator(z) = `(z+0.98)*(z-0.7)`
- Scope block: Ymin = -1.5, Ymax = 1.5, Refresh period = 0.2
- Menu Simulate → Setup: Final integration time = 0.2
- Menu Simulate → Eval
- Menu Simulate → Run: produces the animated plot of Fig. 18b

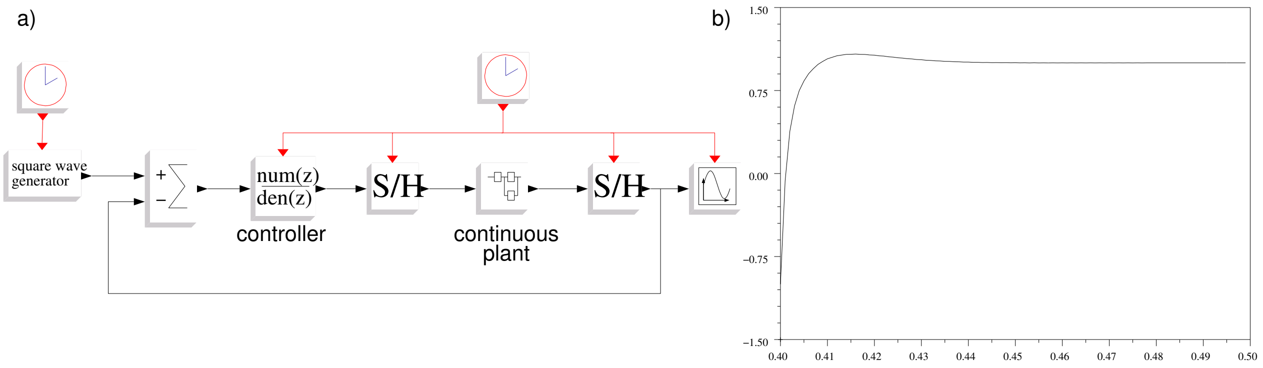


Figure 18: a) Closed-loop system with digital controller. b) Step response

4.4.4 RTAI-Lab controller

In its current version, RTAI-Lab requires the block diagram to be simplified (Fig.19).

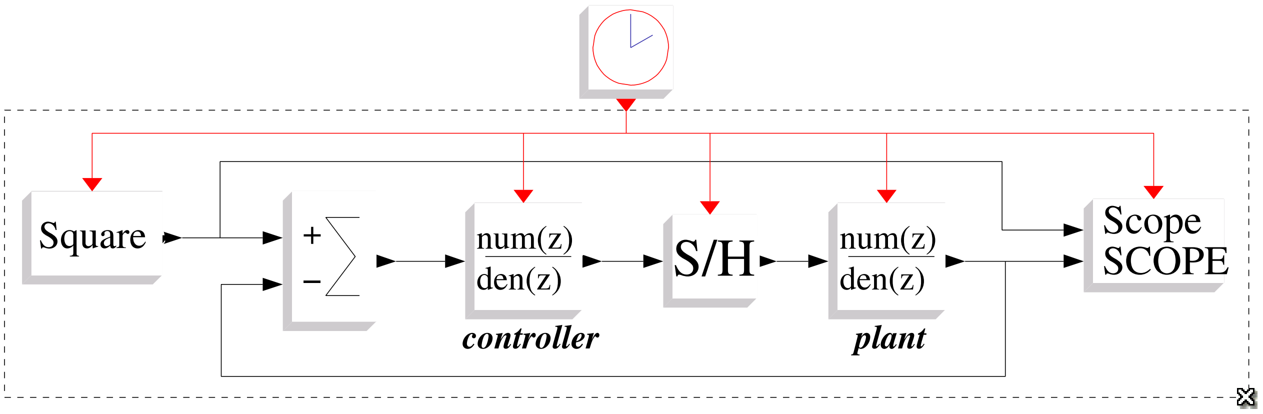


Figure 19: Simplified DC motor control loop.

You will have to:

- Clock Period = 0.001
- Replace Scicos's square wave generator with RTAI-Lab's real-time Square block
- Unfactorize the controller's transfer function with:
  Numerator(z) = `450*z^2 - 765*z + 325.125`
  Denominator(z) = `z^2 + 0.28*z - 0.686`
- Replace the plant's continuous model by a discretized model:
  Numerator(z) = `0.001*z + 0.001`
  Denominator(z) = `z^2 - 1.9425*z + 0.9425`

- Replace Scicos's scope by RTAI-Lab's real-time scope: input ports = 2
- Menu Diagram → Region to Super Block: frame all blocks except the clock
- Open superblock and Menu Diagram → Rename: dcmot
- Menu RTAI → RTAI CodeGen
- In a terminal type: `dcmot -v`
- In another terminal type: `xrtailab`
- In xrtailab: connect to target (alt-c), open the scope manager and show the scope. In the Scopes Manager you can click on Trace tabs to adjust each trace's color (Fig. 20).
- Disconnect and stop the real-time task by clicking on the red button.

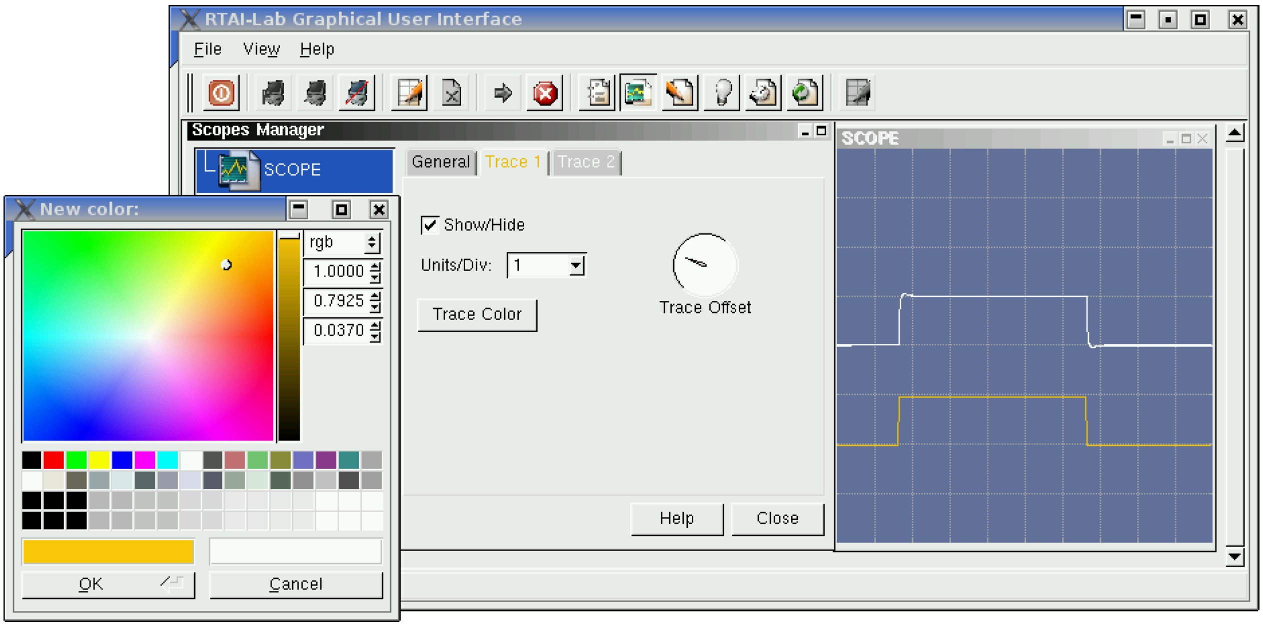
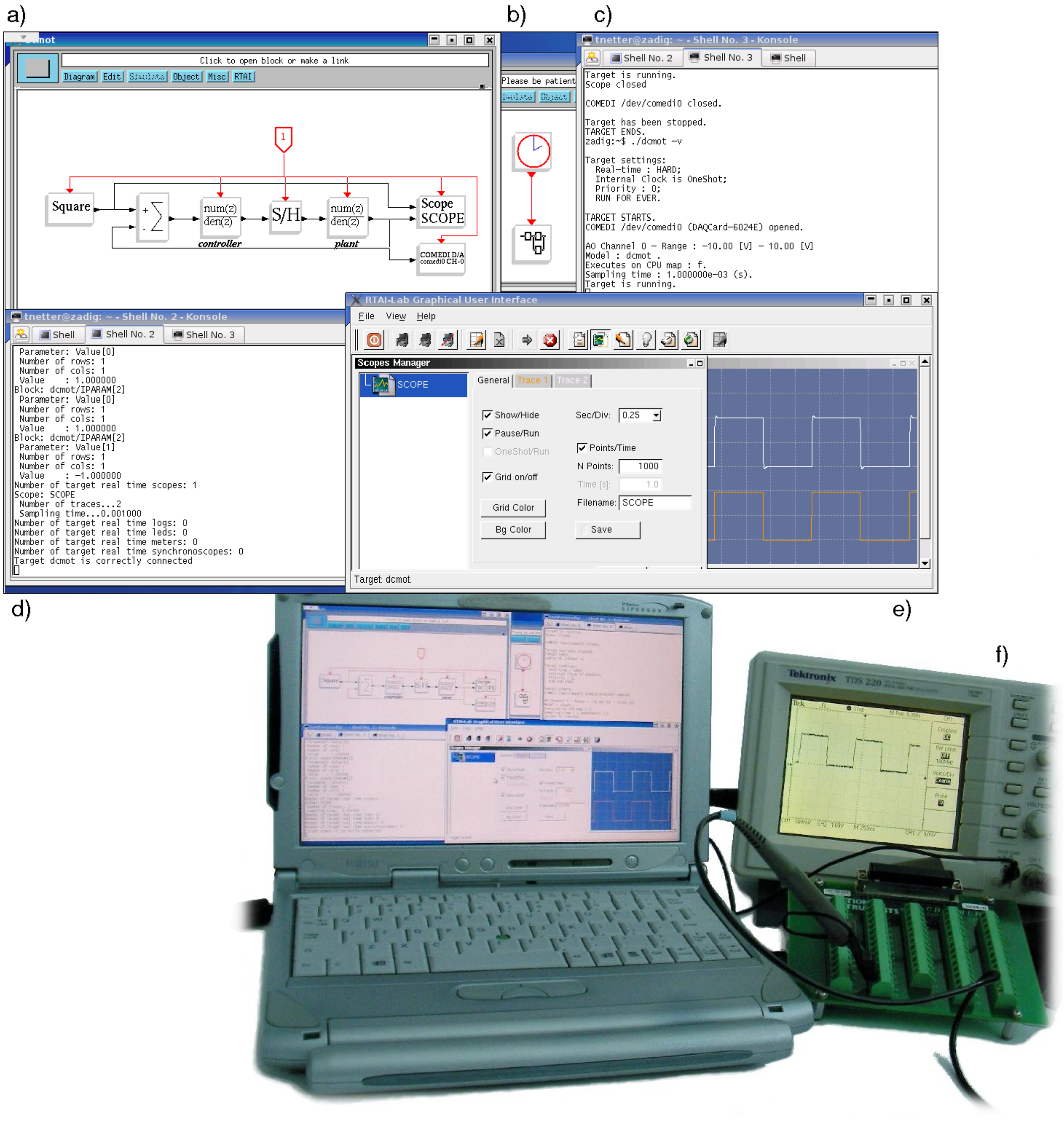


Figure 20: `xrtailab` lets you adjust trace offset and color as well as units/division. Here the square wave input is set to orange. The output signal (white) features a slight overshoot.

- Finally, return to the block diagram, open the superblock, add a Comedi D/A block under the Scope, and connect it similarly (Fig. 21a).
- Close the window and RTAI CodeGen the superblock.
- Connect the analog output and analog ground of your signal acquisition and generation hardware to a real oscilloscope. For example with the National Instruments PCMCIA DAQcard 6024E, connect pins 22 (DAC0OUT) and 55 (AOGND).
- In one terminal (Fig. 21c): `xrtailab -v`
- In another terminal (Fig. 21d): `dcmot -v`
- You should now see something that looks like a square wave on your oscilloscope. Settings: vertical: 500mV/div, horizontal: 250ms/div.
- In `xrtailab`: connect, open the scope, adjust visualization parameters in a similar manner to the oscilloscope. You can grab the scope's window corner to enlarge the display.



```
Target is running.
Scope closed

COMEDI /dev/comedi0 closed.

Target has been stopped.
TARGET ENDS.
zadig:~$ ./dcmot -v

Target settings:
  Real-time : HARD;
  Internal Clock is OneShot;
  Priority : 0;
  RUN FOR EVER.

TARGET STARTS.
COMEDI /dev/comedi0 (DAQCard-6024E) opened.

AO Channel 0 - Range : -10.00 [V] - 10.00 [V]
Model : dcmot .
Executes on CPU map : f.
Sampling time : 1.000000e-03 (s).
Target is running.
```

```
 Parameter: Value[0]
 Number of rows: 1
 Number of cols: 1
 Value    : 1.000000
Block: dcmot/IPARAM[2]
 Parameter: Value[0]
 Number of rows: 1
 Number of cols: 1
 Value    : 1.000000
Block: dcmot/IPARAM[2]
 Parameter: Value[1]
 Number of rows: 1
 Number of cols: 1
 Value    : -1.000000
Number of target real time scopes: 1
Scope: SCOPE
 Number of traces...2
 Sampling time...0.001000
Number of target real time logs: 0
Number of target real time leds: 0
Number of target real time meters: 0
Number of target real time synchronoscopes: 0
Target dcmot is correctly connected
```

Show/Hide ✓
Pause/Run ✓
Grid on/off ✓
Sec/Div: 0.25
Points/Time ✓
N Points: 1000
Time [s]: 1.0
Filename: SCOPE
Target: dcmot

Figure 21: Signal generation and visualization on an oscilloscope. a) Add a Comedi A/D block and connect it. Close the window. b) RTAI CodeGen on the Super Block. c) Execute the real-time task: `dcmot -v`. d) `xrtailab -v`. e) `xrtailab`: adjust units/div and sec/div. f) Visualize the signal on an oscilloscope (ensure all grounds are well connected). The laptop is a Fujitsu P-2040 featuring a Transmeta Crusoe TM-5800 CPU. Data acquisition hardware: National Instruments PCMCIA DAQCard-6024E.

4.5 Hardware example: parallel port LED blinker

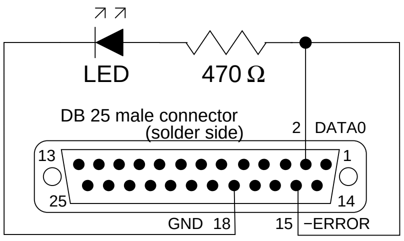
This example uses the parallel port to output and input a bit that will blink an LED.
The example shows how to:

- Build the circuit
- Program Scicos blocks
- Produce C code to access the parallel port

4.5.1 Parallel port + LED circuit

Build a circuit with:

- a DB-25 male connector
- an LED
- a 470 Ω resistor



Check your BIOS settings for parallel port mode and address. The safest choice is SPP (Standard Parallel Port) and base address 0x378 (other valid addresses are 0x278 or 0x3BC). This example outputs to pin 2/DATA0 (base address, bit 0) and inputs from pin 15/-ERROR (base+1, Bit 3). Parallel port pinout addresses are detailed in Appendix B if you wish to extend this example.

- `cd /usr/src/rtai/rtai-lab/scilab/macros/RTAI`
- Copy the code for `rtai_DirOutBit.sci` and `rtai_DirInpBit.sci`
- Edit `Makefile` and add to the MACROS list `rtai_DirOutBit.sci` and `rtai_DirInpBit.sci`
- `cd ..`
- `make`

4.5.2 C code for the parallel port device

RTAI-Lab provides the `/usr/realtime/bin/gen_dev` script to:

- Generate a C skeleton for new RTAI-Lab devices
- Append `/usr/realtime/include/scicos/devices.h` with corresponding ANSI C function prototypes (see function headers in DirOutBit.c and DirInpBit.c).

To produce the new RTAI-Lab devices for output and input:

- Become root
- `cd /usr/src/rtai/rtai-lab/scilab/devices`
- Choose names for the new RTAI-Lab output devices, e.g. *DirOutBit* and *DirInpBit*
- `../utility/gen_dev DirOutBit; ../utility/gen_dev DirInpBit`
- Edit `GNUmakefile.am` and append to `libsciblk_a_SOURCES` file names of the new devices: `DirOutBit.c DirInpBit.c`
- `mv GNUmakefile.in GNUmakefile.in-old; mv GNUmakefile GNUmakefile-old`
- `cd /usr/src/rtai/`
- Optional step: `aclocal`
- `automake`
- `make menuconfig` and exit/save configuration
- `make; make install`
- Edit `DirOutBit.c` and `DirInpBit.c` (listing on page 34)
- `make; make install`

You may now start Scilab/Scicos and use the new blocks via menu Edit → Add New Block and enter `rtai_DirOutBit` or `rtai_DirInpBit` in the pop-up window (see also section 5.8, page 40).

rtai_DirOutBit.sci

```
function [x, y, typ] = rtai_DirOutBit(job, arg1, arg2)
x = []; y = []; typ = [];
select job
case 'plot' then
  exprs = arg1.graphics.exprs;  // grab graphic parameters
  paddr = exprs(1)
  standard_draw(arg1)
case 'getinputs' then
  [x, y, typ] = standard_inputs(arg1)
case 'getoutputs' then
  [x, y, typ] = standard_outputs(arg1)
case 'getorigin' then
  [x, y] = standard_origin(arg1)
case 'set' then
  x = arg1;
  model = arg1.model; graphics = arg1.graphics;
  exprs = graphics.exprs;
  while %t do
    [ok, paddr, exprs] =.. // acquire parameters in dialog box
        getvalue('Set parallel port block parameters',..
        ['Port Address:'], list('str',1), exprs)
    if ~ok then break, end
    if exists('inport') then
      in = ones(inport,1), out = []
    else
      in = 1, out = []
    end

    [model, graphics, ok] = check_io(model, graphics, in, out, 1, [])
    if ok then
      graphics.exprs = exprs;
      model.rpar = [] // rpar can be passed on to xrtailab
      model.ipar = [hex2dec(strsubst(paddr,'0x',''))];
      model.dstate = [1];
      x.graphics = graphics;
      x.model = model
      break
    end
  end
case 'define' then // initialize parameters
  paddr = '0x378'
  model = scicos_model()
  model.sim = list('rt_DirOutBit', 4)
  if exists('inport') then
    model.in = ones(inport,1); model.out = []
  else
    model.in = 1; model.out = []
  end
  model.evtin = 1
  model.rpar=[]
  model.ipar=[hex2dec(strsubst(paddr,'0x',''))]
  model.dstate=[1];
  model.blocktype='d'
  model.dep_ut=[%t %f]
  label=list([sci2exp(in),name],[])
  exprs=[paddr]
  // this will be used as the command to draw the block
  gr_i = ['xstringb(orig(1), orig(2), [''PPORT''; ''output''; paddr], sz(1), sz(2), ''fill'');']
  x = standard_define([3 2], model, exprs, gr_i)
end
endfunction
```

rtai_DirInpBit.sci

```
function [x, y, typ] = rtai_DirInpBit(job, arg1, arg2)
x = []; y = []; typ = [];
select job
case 'plot' then
  exprs = arg1.graphics.exprs;  // grab graphic parameters
  paddr = exprs(1)
  standard_draw(arg1)
case 'getinputs' then
  [x, y, typ] = standard_inputs(arg1)
case 'getoutputs' then
  [x, y, typ] = standard_outputs(arg1)
case 'getorigin' then
  [x, y] = standard_origin(arg1)
case 'set' then
  x = arg1;
  model = arg1.model; graphics = arg1.graphics;
  exprs = graphics.exprs;
  while %t do
    [ok, paddr, exprs] =.. // acquire parameters in dialog box
        getvalue('Set parallel port block parameters',..
        ['Port Address:'], list('str',1), exprs)
    if ~ok then break, end
    if exists('outport') then
      out = ones(outport,1), in = []
    else
      out = 1, in = []
    end

    [model, graphics, ok] = check_io(model, graphics, in, out, 1, [])
    if ok then
      graphics.exprs=exprs;
      model.rpar = [] // rpar can be passed on to xrtailab
      model.ipar = [hex2dec(strsubst(paddr,'0x',''))];
      model.dstate = [1];
      x.graphics = graphics;
      x.model = model
      break
    end
  end
case 'define' then // initialize parameters
  paddr = '0x378'
  model = scicos_model()
  model.sim = list('rt_DirInpBit', 4)
  if exists('outport') then
    model.in = []; model.out = ones(outport, 1)
  else
    model.in = []; model.out = 1
  end
  model.evtin = 1
  model.rpar = []
  model.ipar = [hex2dec(strsubst(paddr, '0x', ''))]
  model.dstate = [1];
  model.blocktype = 'd'
  model.dep_ut = [%t %f]
  exprs=[paddr]

  // this will be used as the command to draw the block
  gr_i=['xstringb(orig(1), orig(2),..
  [''PPORT''; ''input''; paddr], sz(1), sz(2), ''fill'');']
  x = standard_define([3 2], model, exprs, gr_i)
end
endfunction
```

DirOutBit.c

```
#include <machine.h>
#include <scicos_block.h>
#include <asm/io.h>

static void init(scicos_block *block)
{
  outb(0x00, block->ipar[0]);
}

static void inout(scicos_block *block)
{
  if ((int) block->inptr[0][0] > 0)
       outb(0x01, block->ipar[0]);
  else
       outb(0x00, block->ipar[0]);
}

static void end(scicos_block *block)
{
  outb(0x00, block->ipar[0]);
}

void rt_DirOutBit(scicos_block *block, int flag)
{
     if (flag == 1) {          /* set output */
          inout(block);
     }
     if (flag == 2) {          /* get input */
          inout(block);
     }
     else if (flag == 5) {     /* termination */
          end(block);
     }
     else if (flag == 4) {    /* initialisation */
          init(block);
     }
}
```

DirInpBit.c

```
#include <machine.h>
#include <scicos_block.h>
#include <asm/io.h>

static void init(scicos_block *block)
{
     block->outptr[0][0] = 0.0;
}

static void inout(scicos_block *block)
{
     if (inb(block->ipar[0]) > 0)
          block->outptr[0][0] = 1.0;
     else
          block->outptr[0][0] = 0.0;
}

static void end(scicos_block *block)
{
     block->outptr[0][0] = 0.0;
}

void rt_DirInpBit(scicos_block *block, int flag)
{
     if (flag == 1) {          /* set output */
          inout(block);
     }
     if (flag == 2) {          /* get input */
          inout(block);
     }
     else if (flag == 5) {     /* termination */
          end(block);
     }
     else if (flag == 4) {    /* initialisation */
          init(block);
     }
}
```

5 Custom blocks

Custom Scicos blocks can be programmed, added to palettes, and used to generate real-time code.
In section 4.5 we presented an example where part of the code is generated from templates. In section 5.2 we show how to create blocks from scratch, and add them to the Scilab + RTAI-Lab installation to use them either in your home directory (Section 5.6) or install them for system-wide usage (Section 5.7). Finally, we explain how palettes are created.
Note that Chapter 9.5 of [Campbell et al., 2006] provides much information on Scicos blocks.
See www.scicos.org

5.1 Overview of Scicos blocks

A Scicos block is defined by two functions:

- A Scicos *interfacing function*. It is coded in Scilab language and compiled. A block's code specifies:
  - The block's graphical appearance
  - The number of data inputs and outputs
  - The number of event inputs and outputs
  - Dialog windows to adjust appearance, inputs and outputs, and computation parameters
- A *computational function*. It is coded in a separate C file (it used to be enclosed with in a dedicated `getCode` function after the Scicos interfacing function). It is this code that is compiled and executed for simulations or even used for "Hardware in the loop (HIL)" tests (see www.scicos.org. This code may also call external C libraries.

  The C code is segmented according to a flag's value, thereby defining the job type such as [Campbell et al., 2006; Nikoukhah and Steer, 1998]:
  - Initialization (flag = 4)
  - Output update (flag = 1)
  - State update (flag = 2)
  - Integrator calls (flag = 0)
  - Mode and zero-crossing (flag = 9)
  - Event scheduler (flag = 3)
  - Ending (flag = 5)

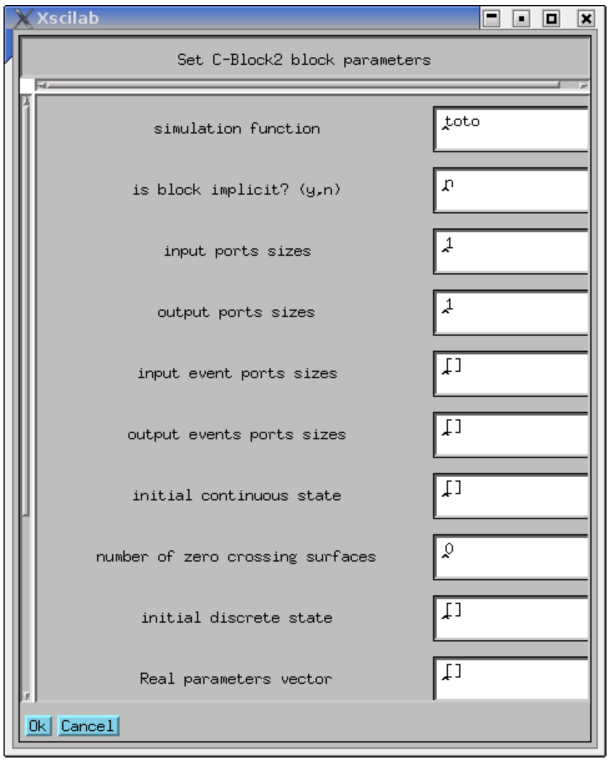
Source code for Scicos and RTAI-Lab blocks may provide useful guidance and is available in the `.sci` files in directories: `SCILAB_DIR/macros/scicos_blocks` and `SCILAB_DIR/macros/RTAI`

5.2 Program a Scicos custom block

The Scilab code that follows implements a typical input-output Scicos block that calls up external precompiled functions. A block's code is usually segmented by `case` selections depending on actions within the Scicos window:

- `plot, getinputs, getoutputs, getorigin`
- `set`, where a block's variables (inputs, outputs, etc.) are set and can be edited via a custom dialog window
- `define`, where a block's variables are defined and initialized

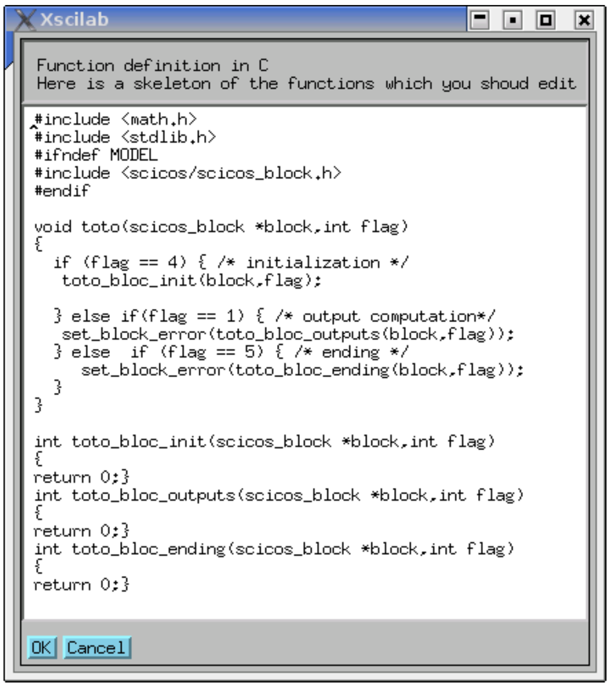
As mentioned in Section 5.1, a block's code may also contain a `getCode` function (see second column on page 37). The `getCode` function is programmed as text strings that will print a C code skeleton with an Xscilab editor window. Note that the `getCode` method is becoming obsolete so we recommend that you replicate what is shown on page 34.
After loading the block into Scicos (see section 5.8), left-clicking on the new block lets you adjust the block's parameters in the dialog window (Fig. 22(a)) and, after clicking [Ok], edit the `getCode` C code within an Xscilab editor window (Fig. 22(b)). Click [Ok] in the editor window and the code is compiled and linked.



Set C-Block2 block parameters

simulation function	toto
is block implicit? (y,n)	n
input ports sizes	1
output ports sizes	1
input event ports sizes	[]
output events ports sizes	[]
initial continuous state	[]
number of zero crossing surfaces	0
initial discrete state	[]
Real parameters vector	[]

(a) 1st window where block parameters can be adjusted



Function definition in C
Here is a skeleton of the functions which you shoud edit

```
#include <math.h>
#include <stdlib.h>
#ifndef MODEL
#include <scicos/scicos_block.h>
#endif

void toto(scicos_block *block,int flag)
{
  if (flag == 4) { /* initialization */
   toto_bloc_init(block,flag);

  } else if(flag == 1) { /* output computation*/
   set_block_error(toto_bloc_outputs(block,flag));
  } else  if (flag == 5) { /* ending */
     set_block_error(toto_bloc_ending(block,flag));
  }
}

int toto_bloc_init(scicos_block *block,int flag)
{
return 0;}
int toto_bloc_outputs(scicos_block *block,int flag)
{
return 0;}
int toto_bloc_ending(scicos_block *block,int flag)
{
return 0;}
```

(b) 2nd window where the block's `getCode` can be edited

Figure 22: Parameter and code editing windows of CBlock2

rtai_generic_proc.sci

```
function [x, y, typ] = rtai_generic_proc(job, arg1, arg2)
//
// (c) <roberto.bucher at supsi.ch> & Thomas Netter <tnetter at ailab.ch>
x = []; y = []; typ = [];
select job
case ’plot’ then
  graphics = arg1.graphics;
  label = graphics.exprs;
  name1 = label(1)(3); // text that appears inside the block
  name2 = label(1)(4);
  standard_draw(arg1)
case ’getinputs’ then
  [x, y, typ] = standard_inputs(arg1)
case ’getoutputs’ then
  [x, y, typ] = standard_outputs(arg1)
case ’getorigin’ then
  [x, y] = standard_origin(arg1)
case ’set’ then
  x = arg1
  model = arg1.model;
  graphics = arg1.graphics; // see SCI/man/eng/scicos/scicos_block.htm
  label = graphics.exprs;
  while %t do
    // acquire parameters from dialog window
    [ok, nin, nout, name1, name2, lab]=..
        getvalue(’Set RTAI generic input block parameters’,..
        [’input ports’; ’output ports’; ’1st name’; ’2nd name’],..
         list(’vec’,-1, ’vec’,-1, ’str’,1, ’str’,1), label(1))
    if ~ok then break, end

    label(1) = lab
    funam = ’generic_proc_’ + name2; // function name in generated C code
    xx = []; // set block-to-block polyline to 0
    ng = [];  // number of zero-crossing surfaces
    z = 0; // vector of size nz: discrete-time state
    nz = 0; // size of the discrete-time state
    nx = 0;  // size of the continuous-time state

    i = ones(nin, 1); // input data vector
    o = ones(nout, 1); // output data vector

    ci = 1; // number of input events
    co = []; // number of output events
    funtyp=2004;
    depu = %t; // direct feed-thru?: [t]rue/[f]alse
    dept = %f; // time dependence?
    dep_ut = [depu dept];

    tt = label(2);
    [ok, tt] = getCode(funam, tt) // see function below
    if ~ok then break, end

    // check that ports match connections, see SCI/macros/scicos/check_io.sci
    [model, graphics, ok] = check_io(model, graphics, i, o, ci, co)
    if ok then // see SCI/man/eng/scicos/scicos_block.htm
      model.sim = list(funam, funtyp)
      model.in = i
      model.out = o
      model.evtin = ci
      model.evtout = []
      model.state = []
      model.dstate = 0
      model.rpar = []
      model.ipar = []
      model.firing = []
      model.dep_ut = dep_ut
      model.nzcross = 0
      label(2) = tt
      x.model = model
      graphics.exprs = label
      x.graphics = graphics
      break
    end
  end
case ’define’ then
  insz = 1 // number of block inputs
  outsz = 1 // number of block outputs
  name1 = ’Blkname1’// text that appears inside the block
  name2 = ’Blkname2’

  model = scicos_model() // see SCI/man/eng/scicos/scicos_block.htm
  model.sim = list(’ ’,2004)
  model.in = insz
  model.out = outsz
  model.evtin = 1
  model.evtout = []
  model.state = []
  model.dstate = []
  model.rpar = []
  model.ipar = []
  model.blocktype = ’c’
  model.firing = []
  model.dep_ut = [%t %f]
  model.nzcross = 0

  label = list([sci2exp(insz), sci2exp(outsz), name1, name2], [])

  // this will be used as the command to draw the block
  gr_i = [’xstringb(orig(1), orig(2), [name1; name2], sz(1), sz(2), ’’fill’’);’]
  x = standard_define([3 2], model, label, gr_i)

end
endfunction
```

```
// here is the C code presented to the user in a dialog
function [ok,tt] = getCode(funam, tt)
if tt==[] then
   textmp=[
          ’#ifndef MODEL’
          ’#include <math.h>’;
          ’#include <stdlib.h>’;
          ’#include <scicos/scicos_block.h>’;
          ’#endif’
          ’’;
          ’void ’+funam+’(scicos_block *block,int flag)’;
         ];
  textmp($+1)=’{’
  textmp($+1)=’#ifdef MODEL’
  textmp($+1)=’int i;’
  textmp($+1)=’static int port;’
  textmp($+1)=’double y[’ + string(nout) + ’];’
  textmp($+1)=’double t = get_scicos_time();’
  textmp($+1)=’  switch(flag) {’
  textmp($+1)=’  case 4: /* initialize block states, etc. */’
  textmp($+1)=’    port = userfunc_init(""’ + name2 + ’"");’
  textmp($+1)=’    break;’;
  textmp($+1)=’  case 1: /* compute outputs */’
  textmp($+1)=’    for (i = 0; i <’ + string(nout) + ’; i++) {’
  textmp($+1)=’    /* here we call an external precompiled function */’
  textmp($+1)=’      block->outptr[i][0] = userfunc_output(port, y[i], t);’
  textmp($+1)=’    }’
  textmp($+1)=’    break;’
  textmp($+1)=’  case 2: /* update states, react to zero-crossings */’
  textmp($+1)=’    for (i = 0; i <’ + string(nin) + ’; i++) {’
  textmp($+1)=’      u[i] = block->inptr[i][0];’
  textmp($+1)=’    /* here we call an external precompiled function */’
  textmp($+1)=’      y[i] = userfunc_update(port, u[i], t);’
  textmp($+1)=’    }’
  textmp($+1)=’    break;’
  textmp($+1)=’  case 5: /* terminate execution */’
  textmp($+1)=’    userfunc_end(port);’
  textmp($+1)=’    break;’
  textmp($+1)=’  }’
  textmp($+1)=’#endif’
  textmp($+1)=’}’
else
  textmp = tt;
end

while 1==1 // display the dialog box with C code inside
  [txt] = x_dialog([’Function definition in C’;
  ’Code skeleton to edit’],..
 textmp);

  if txt <> [] then
    tt = txt
    [ok] = scicos_block_link(funam, tt, ’c’) // compile & link the C code
    if ok then
      textmp = txt;
    end
    break;
  else
    ok = %f;
    break;
  end
end

endfunction
```

5.3 Generate a Scicos library of custom blocks

You must now compile your custom Scicos block(s) and archive them into a library so that they can be loaded by Scilab/Scicos.
After programming your Scicos block (e.g. in the previous section `${HOME}/scilab-usr/blocks/rtai_generic_proc.sci`):

- Save the Makefile below as `${HOME}/scilab-usr/blocks/Makefile`
- Possibly add filenames to the `MACROS` line
- `make` (this generates `lib`, your library of custom blocks)
- Add to `${HOME}/.Scilab/scilab-4.0/.scilab`:
  `load(home+'/scilab-usr/blocks/lib')`

The next time you start Scilab, your new library will be loaded. You may also execute this last command at the Scilab prompt (you will have to halt your current Scicos session to do that).

Makefile to generate a library of Scicos blocks

```
# Makefile to compile scilab/scicos blocks into Scilab libraries
# Based on SCI/macros/Make.lib

MACROS = rtai_generic_proc.sci
NAME = userlib

RLMAKE = /usr/src/rtai/rtai-lab/scilab/macros/Makefile
SCIDIREV := eval grep \"SCILAB_DIR \=\" $(RLMAKE) | sed s/"SCILAB_DIR = "//
SCIDIR = $(shell $(SCIDIREV))
#SCIDIR = /usr/lib/scilab-3.1.1

OBJ = $(MACROS:.sci=.bin)
MACROSN = $(MACROS:.sci=)
NAM = $(CURDIR)

.SUFFIXES: .sci .bin $(SUFFIXES)

all :: genlib names lib
```

```
.sci.bin:
        @SCI = $(SCIDIR); \
export SCI; \
$(SCIDIR)/bin/scilab -comp  $*.sci

lib  :   $(MACROS)
@echo $? > tmp_comp ;$(SCIDIR)/macros/Lib Xtmp_comp; $(RM) tmp_comp
@$(RM) ‘cat tmp_Bin‘
@echo Starting Compilation...
@if ( $(SCIDIR)/util/scibatch $(SCIDIR) tmp_Macros ) ; \
then echo Generating lib and names...; \
$(SCIDIR)/util/scibatch $(SCIDIR) genlib ;\
else echo "Compilation failed";$(RM) ‘cat tmp_Bin‘ ;exit 1; \
fi
@echo End of compilation

names genlib :  $(MACROS) Makefile
@echo $(NAM) > tmp_comp ;
@echo $(NAME) >> tmp_comp ;
@echo $(MACROS) >> tmp_comp ;
@$(SCIDIR)/macros/Name Xtmp_comp; $(RM) tmp_comp
```

5.4 Program the external C functions

In `rtai_generic_proc.sci` (page 37) note that the C code skeleton in the `getCode` function is segmented by `case` selections. In our example function, each `case` calls the external precompiled C functions `userfunc_init`, `userfunc_output`, and `userfunc_update` respectively. See also `DirOutBit.c` and `DirInpBit.c` on page 34 to program the `case` selections in separate `.c` files rather than in a (now obsolete) `getCode` function.
These C functions can be coded normally. They must however be compiled and archived into a library. This library will be called by Scilab/Scicos when it converts your block diagram into C code and compiles and links the resulting functions.

5.5 Compile your C functions and generate a library

The `Makefile` below is an example to compile C functions contained in `userfunc.c` (e.g. `userfunc_init`, `userfunc_output`, and `userfunc_update`) into the library `libuser.a`.

```
SRC = userfunc.c
LIB = libuser.a
OBJ = $(SRC:.c=.o)
RTAIDIR = $(shell rtai-config --prefix)

all: $(LIB)

CC_FLAGS = -c $(DBG) -I. -O2

%.o: %.c
cc $(CC_FLAGS) $<

$(LIB): $(OBJ)
ar -r $(LIB) $(OBJ)
        cp $(LIB) ../lib

clean:
rm -f $(LIB) $(OBJ)
```

5.6 Home directory installation

You may install custom blocks within your home directory (most convenient) or within the Scilab directory for system-wide access by other users (see next section). Home directory installation is possible since RTAI-3.5 (if you use an older version you should update files RTAICodeGen_.sci and SetTarget_.sci with those found in RTAI-3.5).
As a normal user you must then in your home directory:

- `mkdir scilab-usr`
- `cd scilab-usr`
- `mkdir blocks lib src templates`
- `cp SCI/macros/RTAI/RT_templates/rtai.gen templates/user.gen`
- `cp SCI/macros/RTAI/RT_templates/rtai.mak templates/user.mak`
- `cp SCI/macros/RTAI/RT_templates/standalone.cmd templates`

The file `templates/user.gen` specifies which files are used to generate a target. Edit `templates/user.gen` so it becomes:

```
user.mak
standalone.cmd
```

where:

- `user.mak` is the target's makefile
- `standalone.mak` specifies the generation sequence

In `user.mak` add your custom C libraries to the `ULIBRARY` variable, e.g.:

```
ULIBRARY = $(RTAIDIR)/lib/libsciblk.a $(RTAIDIR)/lib/liblxrt.a $(HOME)/scilab-usr/lib/libuser.a
```

Create `blocks/Makefile` and `src/Makefile`:

blocks/Makefile

```
SHELL = /bin/sh

SCIDIR=/usr/local/scilab-4.0

include $(SCIDIR)/Makefile.incl

.SUFFIXES: .sci .bin $(SUFFIXES)

NAME = userlib
NAM = $(PWD)

MACROS = $(wildcard *.sci)

include $(SCIDIR)/macros/Make.lib

cleanpwd:
        rm -f *.bin names lib tmp_Bin tmp_Macros genlib *~
```

src/Makefile

```
LIB = libuser.a
all: $(LIB)

RTAIDIR = $(shell rtai-config --prefix)

SRC = $(wildcard *.c)

OBJ = $(SRC:.c=.o)
DBG =

CC_FLAGS = -c $(DBG) -I. -I$(RTAIDIR)/include -O2

%.o: %.c
     cc $(CC_FLAGS) $<

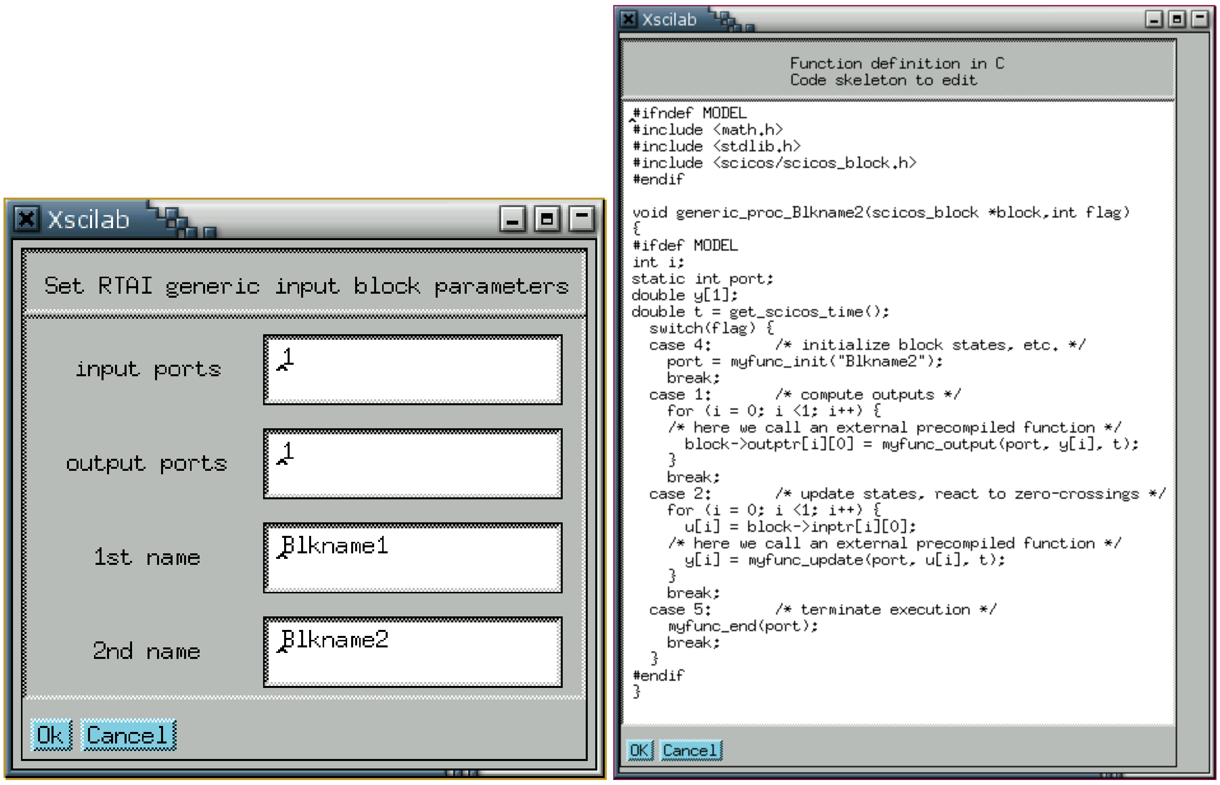
$(LIB): $(OBJ)
        ar -r $(LIB) $(OBJ)

install:
cp $(LIB) ../lib

clean:
rm -f $(LIB) $(OBJ)
```

Finally, add the path of your target directory to `${HOME}/.Scilab/scilab-4.0/.scilab`:

```
TARGET_DIR = getenv('HOME')+'/scilab-usr/target'
```



Set RTAI generic input block parameters

input ports	1
output ports	1
1st name	Blkname1
2nd name	Blkname2

Function definition in C
Code skeleton to edit

```
#ifndef MODEL
#include <math.h>
#include <stdlib.h>
#include <scicos/scicos_block.h>
#endif

void generic_proc_Blkname2(scicos_block *block,int flag)
{
#ifdef MODEL
int i;
static int port;
double y[1];
double t = get_scicos_time();
  switch(flag) {
  case 4:       /* initialize block states, etc. */
    port = myfunc_init("Blkname2");
    break;
  case 1:       /* compute outputs */
    for (i = 0; i <1; i++) {
    /* here we call an external precompiled function */
      block->outptr[i][0] = myfunc_output(port, y[i], t);
    }
    break;
  case 2:       /* update states, react to zero-crossings */
    for (i = 0; i <1; i++) {
      u[i] = block->inptr[i][0];
    /* here we call an external precompiled function */
      y[i] = myfunc_update(port, u[i], t);
    }
    break;
  case 5:       /* terminate execution */
    myfunc_end(port);
    break;
  }
#endif
}
```

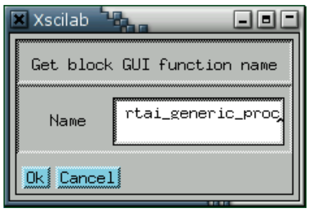
Figure 23: Parameter and code editing windows of rtai_generic_proc

5.7 System-wide installation

After doing the steps for home directory installation you might want to install your new blocks for system-wide usage. As system administrator you must then:

1. `mkdir SCI/macros/USER`
2. Copy the block's Scilab `.sci` file to `SCI/macros/USER`
3. `cd SCI/macros/USER`
4. `make` (this will compile the `.sci` files)
5. Copy the `libuser.a` library to `/usr/realtime/lib`
6. Copy `user.gen` and `user.mak` to `SCI/macros/RTAI/RT_templates`
7. Edit `SCI/macros/RTAI/RT_templates/user.mak` and append `$(RTAIDIR)/lib/libuser.a` to the `ULIBRARY` line

5.8 Use the block



Get block GUI function name

Name	rtai_generic_proc

To insert a new block into a Scicos diagram use menu Edit → Add New Block. A dialog box then opens asking for the name of the Scilab function that defines the block, e.g. `rtai_generic_proc`. You can then open the block to edit its parameters and adjust its `getCode` C function (Fig. 23).

5.9 Create a Scicos palette

Create a new diagram with Diagram → New. Load new blocks into this diagram with Edit → Add New Block. You may also slide blocks from pre-existing palettes into this new diagram. Then save your diagram with Diagram → Save as Palette. You can later reload this palette with Diagram → Load as Palette.

5.10 Scicos C block data structure

When a block is linked to another in the Scicos GUI, the link allows data to be passed from one block to its successor. When a block diagram is converted to C code, the block's data-passing scheme along with some parameters are represented in C by the `block` data structure of type `scicos_block` (see `SCI/routines/scicos/scicos_block.h`). See usage examples in the `.c` files in `SCI/routines/scicos` and in the RTAI-Lab `.sci` files in `SCI/macros/RTAI`. [Campbell et al., 2006] gives more details on how to use this structure.
Members of the `block` structure are listed below:

```
  int block->nevprt; /* binary coding of activation inputs, */
   /* -1 if internally activated  */
  int block->nz; /* size of the discrete time state */
  double* block->z; /* vector of size nz: discrete-time state */
  int block->nx; /* size of the continuous-time state */
  double* block->x; /* vector of size nx: continuous-time */
  double* block->xd; /* vector of size nx: derivative of */
/* continuous-time state */
  double* block->res; /* vector of size nx: only used for */
/* internally implicit blocks */
  int block->nin; /* number of inputs */
  int *block->insz; /* input sizes */
  double **block->inptr; /* table of pointers to inputs */
  int block->nout; /* number of outputs */
  int *block->outsz; /* output sizes */
  double **block->outptr; /* table of pointers to outputs */
  int block->nevout; /* number of activation output ports */
  int block->nrpar; /* number of real parameters */
  double *block->rpar; /* real parameters of size nrpar */
  int block->nipar; /* number of integer parameters */
  int *block->ipar; /* integer parameters of size nipar */
  int block->ng; /* number of zero-crossing surfaces */
  double *block->g; /* zero-crossing surfaces */
  int *block->jroot;
  char block->label[41];
```

A Notes on Linux configuration and installation

This appendix details how to configure a new RTAI kernel that you will boot as an alternative to your standard Linux kernel. In other words, you should not use RTAI as the only kernel on you system. You should use your computer's boot menu (Lilo or Grub) to select either your current Linux kernel, RTAI-Linux kernel, or other operating system.

A.1 Kernel configuration

As a first try, you should configure a minimum RTAI kernel. You may then add hardware drivers (CD, sound, etc.) after some testing. For help on configuring a kernel see:

- www.linuxdocs.org/HOWTOs/Kernel-HOWTO.html
- www.linuxheadquarters.com/howto/tuning/kernelconfig.shtml

Note that a convenient starting point if you have already compiled a Linux kernel of a similar 2.x generation is to copy the `.config` to the new linux-2.x.xx-rtai directory and type `make oldconfig`.
The following guidelines are for a 2.6.x kernel. Now launch the configuration tool (`make xconfig` or `make menuconfig`).

- `cd /usr/src/linux-2.x.xx-rtai`
- `make xconfig` or `make menuconfig`
- **General setup:** select "Prompt for development..."
- **General setup:** set "Local version" to `-rtai`
- **Enable loadable module support:** select "Enable module support", "Module unloading", and "Automatic module loading". Deselect "Module versioning support"; RTAI modules are not version dependent.
- **Processor type and features:** Select your Subarchitecture Type (PC-Compatible) and Processor family. Select "Preemption Model (Preemptible kernel (Low-Latency Desktop))". You might need "High Memory Support (4GB)" if you use a PCMCIA data acquisition card. Deselect "Use register arguments (EXPERIMENTAL)". Possibly deselect "Local APIC support on uniprocessors".
- **Power Management options:** Select ACPI Support and features relevant to your hardware. Leave APM deselected. Leave CPU Frequency scaling unselected. Warning: ACPI support may be a problem on laptops that use the "screen closed" button to put the computer into sleep or standby modes.
- **Bus options:** Leave the default. Check the support for your hardware. Laptops need PCCARD (PCMCIA/CardBus) support and PC-card bridges. e.g. CardBus yenta-compatible bridge support
- **Device Drivers:**
  - **Generic driver options:** keep default
  - **Memory Technology Devices (MTD):** not needed
  - **Parallel port support:** unselect Parallel port support. The standard parallel port is a useful device for realtime debugging and experimenting. You must leave it unselected so that Comedi's drivers can directly access the port.
  - **Plug and Play support:** keep default
  - **Block devices:** select your devices. Fedora Core III needs Ram Disk Support and Initial RAM Disk (initrd) to boot.
  - **ATA/ATAPI/MFM/RLL Support:** select the main item "ATA/ATAPI/MFM/RLL support" and all items relevant to your system.
  - **SCSI device support:** select "SCSI device support" and keep the default selections according to your computer's SCSI devices.
  - **Multi-device support (RAID and LVM):** only needed in special cases. For Fedora Core III default installation you need this option enabled with LVM (Device Mapper) enabled too.

  - **Network device support:** keep defaults. Explore the devices submenu until you find your network interface. The command `lspci` may reveal the name of your ethernet controller.
  - **Amateur Radio, Irda, Bluetooth, ISDN subsystem, and Telephony support:** Leave disabled. You may enable these later.
  - **Input device support:** Ensure that Mouse is selected.
  - **Character devices:** Ensure "/dev/agpart AGP Support" and "Direct Rendering Manager (XFree 4.1.0 and higher DRI support)" are selected. See coments below about video card selection.
  - **I2C support:** keep unselected; there are reports of difficulties when used with RTAI
  - **Multimedia devices:** keep unselected. You may enable these later
  - **Graphics support:** keep unselected, possibly enabling later. With this option you can use the advanced features of your video card, but sometimes this creates compatibility problems.
  - **Sound:** preferably enable as module and select suitable drivers.
  - **USB Support:** preferably enable as module.
- **File Systems:**
  - **Second extended fs support:** select
  - **Ext3 journalling file system support:** select it and "Ext3 extended attributes"
  - **Reiserfs support:** the Suse distribution uses it, maybe your Linux distribution doesn't need it
  - **CD/ROM-DVD Filesystems:** select "ISO 9660..." and sub-items
  - **DOS/FAT/NT Filesystems:** select as needed

  Keep other default selections

A.2 Configuring the GRUB boot manager

This section gives an example to configure the GRUB boot manager's configuration file usually located in `/etc/grub.conf` (Fedora Core II distribution) or /etc/grub/grub.conf (Debian distribution).
See also www.gnu.org/software/grub

```
# grub.conf
# Note that you do not have to rerun grub after making changes to this file
# NOTICE:  You have a /boot partition.  This means that
#          all kernel and initrd paths are relative to /boot/, e.g.:
#          root (hd0,1)
#          kernel /vmlinuz-version ro root=/dev/hda3
#          initrd /initrd-version.img
#          boot=/dev/hda
default=2
timeout=10
splashimage=(hd0,1)/grub/splash.xpm.gz
# The original F.C. II Generic-Modular Non-Realtime Kernel
title Fedora Core (2.6.5-1.358)
        root (hd0,1)
        kernel /vmlinuz-2.6.5-1.358 ro root=LABEL=/ rhgb quiet
        initrd /initrd-2.6.5-1.358.img
# RTAI patched Kernel
title Linux (2.6.23.14-RTAI-3.3)
        root (hd0,1)
        kernel /vmlinux-2.6.23.14-rtai
# VERY useful memory tester program
title Memtest86
        root (hd0,1)
        kernel /memtest86+-1.11
#
title Windows XP-Home
        rootnoverify (hd0,0)
        chainloader +1
```

A.3 *udev* and RTAI

udev is a dynamic device detection scheme (see www.kernel.org/pub/linux/utils/kernel/hotplug/udev.html) that is used by several Linux distributions and works with the 2.6 Linux kernel.
udev automatically creates device inodes in the `/dev` directory upon device detection. It later deletes those inodes as the devices are unused.
RTAI uses inodes in `/dev` for FIFOs, message passing between user and kernel space, and to interact with data acquisition hardware. It is therefore necessary to create persistent inodes. You can for example launch the script below prior to loading RTAI and Comedi modules (make it executable with `chmod 777 rtai-inode`):

```
# rtai-inode: RTAI inode creation for UDEV systems, creates /dev/rtf(n)

rm -f /dev/comedi* /dev/rtf* /dev/rtai_shm

for n in ‘seq 0 9‘; \
do \
        rm -f /dev/rtf$n; \
mknod -m 666 /dev/rtf$n c 150 $$n; \
done ; \

# create shared memory inode
mknod -m 666 /dev/rtai_shm c 10 254

# create Comedi inodes
for i in ‘seq 0 15‘;
do \
        rm -f /dev/comedi$i; \
        mknod -m 666 /dev/comedi$i c 98 $i ; \
done;
```

Basically, *udev* has an init script that reinstalls all devices in `/dev`. A user can create devices in `/lib/udev/devices` and the init script will copy them into `/dev` at boot time. The above script can be modified to create devices under `/lib/udev/devices`.

B Reference: standard parallel port

```
DB-25 Pin allocation.
Pin     Name           Func.    Register      Hardware Inverted
-----|--------------|----------|-----------|----------------------
1       nStrobe        In/Out   Control       Yes
2       Data 0         Out      Data
3       Data 1         Out      Data
4       Data 2         Out      Data
5       Data 3         Out      Data
6       Data 4         Out      Data
7       Data 5         Out      Data
8       Data 6         Out      Data
9       Data 7         Out      Data
10      nAck           In       Status
11      Busy           In       Status        Yes
12      P_Out/_End     In       Status
13      Select         In       Status
14      nAuto          In/Out   Control       Yes
15      Error          In       Status
16      nInit          In/Out   Control
17      nSelect        In/Out   Control       Yes
18-25   Ground         Gnd
-------------------------------------------------------------------
In/Out: TTL level input / Open Collector output
Out   : TTL level output
In    : TTL level input

Hardware Inverter: the in/out voltage level is inverted respect to
                   normal logic.
```

```
I/O BASE valid address: 0x378 - 0x278 - 0x3BC
-------------------------------------------------------------------
BASE+0 : Data Register
Bit     Pin     Name            Fun.    Register
-----|-------|-------------|----------|---------
0       2       Data 0          Out     Data
1       3       Data 1          Out     Data
2       4       Data 2          Out     Data
3       5       Data 3          Out     Data
4       6       Data 4          Out     Data
5       7       Data 5          Out     Data
6       8       Data 6          Out     Data
7       9       Data 7          Out     Data
--------------------------------------------------------------------

BASE+1 : Status Register
Bit     Pin     Name            Fun.    Register   Hardware Inverted
-----|-------|-------------|----------|----------|---------------------
0               Reserved
1               Reserved
2               Reserved
3       15      Error           In      Status
4       13      Select          In      Status
5       12      P-Out/-End      In      Status
6       10      nAck            In      Status
7       1       Busy            In      Status          Yes
-----------------------------------------------------------------------

BASE+2 : Control
Bit    Pin      Name          Fun      Register   Hardware Inverted
-----|-------|-------------|---------|---------|---------------------
0       1       nStrobe       In/Out   Control         Yes
1       14      nAuto         In/Out   Control         Yes
2       16      nInit         In/Out   Control
3       17      nSelect       In/Out   Control         Yes
4               En_IRQ(nACK)
5               En_DATA_READ
6               unused
7               unuded
```

References

Stephen L. Campbell, Jean-Philippe Chancelier, and Ramine Nikoukhah. *Modeling and Simulation in Scilab/Scicos*. Springer, Berlin, Germany, 2006. URL `www.scicos.org`.

Gene F. Franklin, J. David Powell, and Michael L. Workman. *Digital control of dynamic systems*. Addison Wesley Longman, Reading, MA, 1998.

Bill Messner and Dawn Tilbury. *Control tutorials for MATLAB and Simulink*, 1998. URL `www.library.cmu.edu/ctms`.

Ramine Nikoukhah and Serge Steer. *SCICOS - A Dynamic System Builder and Simulator, User's Guide*, 1998. URL `scilabsoft.inria.fr/doc/scicos/scicos.html`. Also as: scilabsoft.inria.fr/doc/scicos/scicos.pdf.

Giovanni Racciu and Paolo Mantegazza. *RTAI 3.3 User Manual*, 2006. URL `www.rtai.org`. in Documentation → Reference Documents.

G. Sallet. *Ordinary differential equations with Scilab*. Université de Saint-Louis / INRIA Lorraine, Université de Metz, 2004. URL `www.math.univ-metz.fr/~sallet/ODE_Scilab.pdf`.

Pasi Sarolahti. Real-time application interface. Technical report, University of Helsinki, Dept. of Comp. Sci., 2001. URL `www.cs.helsinki.fi/u/sarolaht/papers/rtai.pdf`.

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  title =   {RTAI-Lab tutorial: Scilab, Comedi, and real-time control},
  author =  {Roberto Bucher and Simone Mannori and Thomas Netter},
  year =  2006,
  url =  {www.rtai.org/RTAILAB}
}
```

C About this document / Bug reports

This tutorial and associated source code can be downloaded in PDF and HTML from
`https://www.rtai.org/RTAILAB`
This tutorial should be considered "work in progress" and subject to frequent updates, we therefore request that you do not make it available on other web sites.

The first edition (June 14, 2006) of this document was written and tested with: Linux 2.6.12.6 patched with RTAI 3.3, Scilab/Scicos 4.0, Comedi CVS downloaded 2006-06-09.
This 3rd edition (Mar. 14, May 23, 2007, Feb. 2008) was updated to RTAI-3.5 and partly tested with: Linux 2.6.23.14 patched with RTAI 3.6, Scilab/Scicos 4.1.2, Comedi CVS, gcc-4.1.3, Mesa 7.0.2, efltk 2.0.7.

C.1 About the authors

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C.2 Bug reports, suggestions

RTAI-Lab queries: If you notice software bugs, have questions, wish to suggest improvements to RTAI-Lab such as submit new blocks for the RTAI-Lib palette, contact the main developer:
`<roberto.bucher at supsi.ch>`.
For bug reports please provide Linux kernel version, RTAI version, RTAI patch number, CPU type, data acqusition hardware type, Scilab version, gcc/g++/cpp versions, the block diagram that may cause the bug (`.cos` file), outputs using verbose option "-v", and possibly kernel logs resulting from `tail -f /var/log/syslog`.
RTAI-Lab tutorial queries: If you notice typos, errors, omissions, or have contributions to make to this tutorial, contact the author of this tutorial: Thomas Netter `<tnetter at ifi.unizh.ch>`
RTAI queries: Check `www.rtai.org` and its associated mailing-list
Scilab/Scicos queries: Check `www.scilab.org`, `www.scicos.org`, and the newsgroup
`comp.soft-sys.math.scilab`

C.3 Software licenses

RTAI-Lab, RTAI, and xrtailab are subject to the GNU Lesser General Public License.
Comedi is subject to the GNU General Public License.
Scilab and Scicos are subject to a specific license. See scilabsoft.inria.fr/legal/license.html

C.4 Acknowledgements

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D Useful files and links

- **RTAI-Lab** www.rtai.org/RTAILAB and `www.dti.supsi.ch/~bucher`
  - Pre-installation source of RTAI-Lab Scicos blocks: `/usr/src/rtai/rtai-lab/scilab/macros/RTAI`
  - Makefile to compile Scicos RTAI-Lab blocks: `/usr/src/rtai/rtai-lab/scilab/macros/RTAI/Makefile`
  - Post-installation location of RTAI-Lab Scicos blocks: `/usr/local/scilab-4.0/macros/RTAI`
  - RTAI-Lib Scicos blocks contain C code that make calls to C functions located in: `/usr/src/rtai/rtai-lab/scilab/devices/`.
    C prototypes are in `devices.h`. Associated C library is `libsciblk.a`, installed in `/usr/realtime/lib/`.
  - Install on Ubuntu + Matlab (by Arno Stienen): www.rtai.org/RTAILAB/RTAI-UbuntuGutsy-Matlab.txt
  - Use Windows + Matlab/Simulink/RTW for design and RTAI/RTAI-Lab as a target (by Giampiero Campa): www.rtai.org/RTAILAB/RTAI-TARGET-HOWTO.txt
- **Scilab/Scicos** www.scilab.org / www.scicos.org
  - Tutorials:
    www.wolffdata.se/scilab.htm
    www.scicos.org/TUTORIAL/tutorial.html
  - French publications: www.saphir-control.fr/articles
  - Scilab start-up file that includes a pointer to RTAI-Lib palette: `$HOME/.Scilab/scilab-4.0/.scilab`
  - Scilab installation: `/usr/local/scilab-4.0`
  - Code of standard Scicos blocks: `/usr/local/scilab-4.0/macros/scicos_blocks/`
- **Comedi** www.comedi.org
  - Code of acquisition card drivers: `/usr/local/src/comedi/comedi/drivers`
- **RTAI** www.rtai.org
  - Draft of RTAI User Manual www.rtai.org → Documentation → Reference Documents
  - www.rtai.dk (somewhat outdated but useful stuff)
  - Hannes “Captain” Mayer’s notes: www.captain.at/rtai.php
  - Real-Time Linux tutorial (based on RTAI): www.isd.mel.nist.gov/projects/rtlinux
  - Links to several articles describing RTAI projects: pramode.net
  - RTAI internals: `www.aero.polimi.it/~rtai/documentation/articles/paolo-dissecting.html`
  - RTAI history: www.rtai.org → Documentation → Articles → RTAI History
  - Documentation: `/usr/realtime/share/doc/rtai-3.3`
  - Loadable modules are in: `/usr/realtime/modules`
- **Automatic control**
  - PI control with RTAI: linuxgazette.net/118/sreejith.html
  - Control tutorials for Matlab® and Simulink®: www.library.cmu.edu/ctms
    Hint: It would be great if someone wrote a Scilab/Scicos version
  - Matlab files associated to the book Digital control of dynamic systems [Franklin et al., 1998]: www.mathworks.com/support/books/book1464.html
    Hint: It would be fantastic if someone translated the book’s m-files to Scilab/Scicos
- **Miscellaneous links**
  - RTAI-XML project to monitor RTAI tasks from various OS’s: artist.dsi.unifi.it/rtaixml
  - Moodss graphical monitoring application: moodss.sourceforge.net
    Note: it would be interesting to adapt Moodss to work with RTAI
  - Matplotlib python 2D plotting library: matplotlib.sourceforge.net
  - Qt interface to Matlab/Scilab/Octave: chainlink.sf.net