

SoftGenLock Manual: Software Active Stereo and Genlock for Linux

netjuggler.sourceforge.net

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1 Introduction

Active stereo rendering requires multi display systems to have their different video outputs genlocked, i.e. to have their different video retrace signals synchronized. Active stereo also requires quad buffering and left/right eye buffer flipping synchronized with the video retrace.

Except for some high end cards, off-the-shelf graphics cards do not support genlock. Especially for Linux, today's graphics card drivers generally do not enable quad buffer page flipped stereo.

The SoftGenLock library provides a software solution to genlock and active stereo that does not require specific hardware or access to the driver source code.

SoftGenLock can be used for:

- active stereo viewing on a single display,
- genlocking several displays driven by different computers,
- active stereo viewing on a multi display system driven by several computers (a Cave like environment driven by a PC cluster for example).

SoftGenLock is currently available for Linux. There is no plan to port SoftGenLock for Windows now. It should work with any graphics cards having VGA registers. It was successfully tested with NVIDIA and Voodoo cards.

SoftGenLock was originally designed to be used with Net Juggler, a software harness to run VR Juggler on clusters (See netjuggler.sourceforge.net). But it is totally independent from Net Juggler and thus it should be possible to associated it with any 3D environment.

How SoftGenLock basically works :

- It uses the VGA registers to flip the image displayed (right/left eye).
- It uses the VGA registers to slow down the retrace by adding extra invisible pixels. This is the way we achieve genlocking.
- It uses the parallel port or the VGA port for NIVIDA card to send the sync signal to the glasses.
- It uses the parallel port to execute a synchronization barrier to measure how late ("out of genlock") a machine is. Based on this data a machine can decide to slow down its video retrace. When you launch SoftGenLock you see a black line going from the bottom to the top of the screen: this is the convergence phase of the algorithm.
- It uses the VGA registers to know when the vertical no retrace occurs.
- It runs as a real time kernel module so it can wake up right when the vertical no retrace occurs (in fact a fixed number of micro seconds before the end of the vertical no retrace). Such precision can only be acheived with a hard real time system. SoftGenLock supports two of them : RT Linux and RTAI.

2 Software and Hardware Requirements

The main components required to install and run SoftGenLock are, of course, shutter glasses (Elsa Revelator 3D or StereoGraphics CrystalEyes glasses for example), but also a real time Linux kernel and a fast synchronization network.

2.1 X and 3D application setup

SoftGenLock switches between the left and right eye images displayed side by side on a virtual display twice as large as the actual display resolution. If your actual display resolution is 1024x768, then edit the `/etc/X11/XF86Config-4` file and add :

```
Virtual 2048 768
```

in the `Screen` section. Launch X. Configure the 3D application to draw the 1024x768 left eye image from the coordinate (0,0) of the virtual display and the 1024x768 right eye image from the (1024,0) coordinate.

Instead of modifying `XF86Config-4`, you can copy it in `/etc/X11/XF86Config-4.stereo` and apply the required modifications to this file. To force XFree to use the stereo enabled configuration file uses :

```
startx -- -xf86config XF86Config-4.stereo
```

2.2 Real Time Linux

SoftGenLock must be triggered at regular time intervals (each video retrace) and its execution should not be interrupted. This is achieved using a real time Linux kernel. SoftGenLock supports RT Linux (fsmllabs.com) and RTAI (www.aero.polimi.it/projects/rtai/). Both systems requires to patch and recompile the Linux kernel.

2.2.1 RT Linux

Add in the section of the patched kernel for RTLINUX in `/etc/lilo.conf` file the line :

```
append="nmi_watchdog=0"
```

and run `lilo` to update your system.

This option is forwarded to the kernel to disable NMI watchdogs. If activated these watchdogs can crash your system when SoftGenLock is running.

To start RT Linux (you must be super user) once the machine booted with the patched kernel (check with `uname -a`):

```
rtlinux start
```

To stop RT Linux :

```
rtlinux stop
```

2.2.2 RTAI

Add in the section of the patched kernel for RTAI in `/etc/lilo.conf` file the line :

```
append="nmi_watchdog=0"
```

To start RTAI (you must be super user) once the machine booted with the patched kernel (check with `uname -a`):

```
ldmod
```

To stop RTAI :

```
remmod
```

2.3 PC to Shutter Glasses Cable

SoftGenLock supports two ways to send the synchronization signal to shutter glasses

2.3.1 NVIDIA graphics cards

SoftGenLock is able to send the sync signal on the pin 12 of the VGA connector when using NVIDIA cards. Shutter glasses, like Elsa Revelator 3D or Stereo-Graphics CrystalEyes glasses for example, are sold with a special connector to forward this signal to the shutter glasses.

2.4 Parallel port

On other way is to send the synchronization signal to shutter glasses through the parallel port. Such cable is not available on the market so you have to prepare one by your own. We propose two solutions depending if you use SoftGenLock with a single or multiple displays. We assume you have shutter glasses with a mini-din 3 VESA connector.

If you use SoftGenLock with a single display only, build a cable having on one side a male parallel port connector and a mini-din 3 connector on the other side. Connect the pin 3 (stereo sync signal), 4 (power) and 18 (ground) of the parallel connector with the pins 1,3,2 respectively of the mini-din 3 connector (Table 2.4).

If you use SoftGenLock with multiple displays refer to section 2.5.1.

Table 1: The male parallel port connector and the female mini-din 3 connector.

2.5 Synchronization network

If you only want to use SoftGenLock with a single display skip this section.

SoftGenLock algorithm uses a fast synchronization barrier to genlock the video signals. We propose two solutions using parallel port based synchronization networks. Note that because SoftGenLock is run as a real time kernel module, it can only access a very limited set of devices. In particular, it cannot access a classical network cards (Ethernet or Myrinet for example). Thus, even if such networks could be fast enough, their use is not possible with SoftGenLock.

2.5.1 ParaCable

This is a simple solution that does not require any skill other than thread soldering. The network is a modified parallel cable (ParaCable) with one master and 5 slaves. It is also possible to integrate a mini-din 3 in the design to send the sync signal to the shutter glasses. Here is the wiring diagram of this cable :

The pins 2 to 6 correspond to the bit 0 to 4 of the data register of the parallel port (output bits), while the pins 15,13,12,10,11 correspond to the bits 3,4,5,6 and 7 (inverted) of the status register (input bits). For more details about the parallel port see www.beyondlogic.org/spp/parallel.htm.

One possible design consists in plugging 6 female DB25 connectors and one mini-din 3 female connector on one board (Fig 1). Connect them as described in the diagram (table 2.5.1). Each PC connects on the board with a classical parallel port cable (IEEE 1284) with 2 DB5 male connectors. The IR emitter of the shutter glasses connect on the mini-din.

With such a network, it is possible to synchronise the 6 machines in about 6 μ s.

If you want to genlock only 2 machines and do not need the mini-din 3 connector on the cable you can use a simple laplink parallel cable.

Master Node	Slave 1	Slave 2	Slave 3	Slave4	Slave 5
Pin 2	Pin 15				
Pin 3		Pin 15			
Pin 4			Pin 15		
Pin 5				Pin 15	
Pin 6					Pin 15
Pin 15	Pin 2				
Pin 13		Pin 2			
Pin 12			Pin 2		
Pin 10				Pin 2	
Pin 11					Pin 2
Pin 18	Pin 25				
Pin 19		Pin 25			
Pin 20			Pin 25		
Pin 21				Pin 25	
Pin 22					Pin 25

Mini Din 3	Slave 1
Pin 1	Pin 3
Pin 3	Pin 4
Pin 2	Pin 18

Table 2: The ParaCable wiring diagram

Figure 1: A board for the SoftGenlock synchronisation network. Six DB35 connector are soldered on a copper board. The master connector is on the right hand side. Below the first slave (left-hand side), we can distinguish the mini-din 3 connector for the IR emitter of the shutter glasses.

It is probably not too difficult to connect more than 6 PCs using several Paracable but we did not explore in detail such a solution.

2.5.2 TTL_PAPERS Synchronization Network

A highly scalable synchronization network is obtained with a TTL_PAPERS like synchronization network (www.aggregate.org). PCs are connected to a PAPERS box through parallel port cables. A PAPERS box can typically accept up to 4 PCs. Several boxes can be tree assembled to connect an arbitrary large number of nodes. A 4 PC synchronization takes only about 4 μ s. Each extra tree level adds about a hundred of nano-seconds.

TTL_PAPERS like networks are not commercially available. You thus have to build your own. Even if it is not really difficult you should better have some skills

in electronics. Reserve this solution if scalability is critical for your project.

3 NVIDIA Graphics cards

To enable SoftGenLock with NVIDIA graphics cards page flipping must be disabled. Edit the `/etc/X11/XF86Config-4` file (or `XF86Config-4.stereo`) and add :

```
Option "PageFlip" "0"
```

in the `Screen` section of the `nv` driver.

3.1 Ge force / quadro 4

The Ge force/ quadro 4 cards have 2 video outputs. Softgenlock works properly with only one of these output (the addresses of the vga registers of the other output are not available). On the Ge force 4 SoftGenLock requires to use the DVI ouptut.

4 Compiling SoftGenLock

Download the SoftGenLock distribution (`net.juggler.sourceforge.net`).
unzip and untar it:

```
gunzip softgenlock-version.tar.gz  
tar -xf softgenlock-version.tar
```

The two main files you may have to edit to customize SoftGenLock are `Makefile` and `sgen_param.h`

4.1 Makefile

SoftGenLock configuration is controled by commenting in or out the following variables in the `Makefile` :

- `USE_FLIP`: Enable left/right image flipping
- `USE_GLASSES`: Enable Stereo sync signal generation. By default the signal is sent to the parallel port.

- `USE_NVIDIA`: Send the stereo sync signal to the VGA DCC bit for NVIDIA graphics cards.
- `USE_GENLOCK`: Enable genlock.
- `USE_MPI`: Use a MPI synchronization barrier. for genlocking. Cannot be used with a Real Time system.
- `USE_PARBOX`: Use a TTL_PAPERS like synchronization network.
- `USE_PARCABLE`: Use the modified parallel cable ParaCable.
- `USE_RT LINUX`: Use RT Linux (by default SoftGenLock is compiled as a classical linux user proram)
- `RTLDIR=/usr/rtlinux`: Installation directory of RT Linux.
- `USE_RT AI`: Use RTAI (by default SoftGenLock is compiled as a classical linux user proram)
- `TOPDIR=/usr/src/rtai`: Installation directory of RTAI.
- `LINUXDIR=/usr/src/linux`: Directory of the linux kernel sources patched for RTAI.
- `DEBUG`: Verbose SoftGenLock for debugging.

4.2 `sgen_param.h`

SoftGenLock adjusts automatically most of the parameters required for the algorithm. However some still need manual tuning. Only 3 parameters may require adjustments for a normal use of SoftGenLock: `HSIZE`, `GLASS_LATENCY` and `GENLOCK` :

- `HSIZE (1024 * 2)`: Horizontal resolution. If display resolution is 1024*768*32 then `HSIZE` must be set to 1024 * 4 (32 bits == 4 bytes).
- `STARTWORK_BEFORE_VNEND`: How long before `VNEND` (vertical no retrace end) occur SoftGenLock should start to work.
- `WRITE_REGISTERS_BEFORE_VNEND`: How long before `VNEND` Soft-GenLock should write the VGA card registers.

- **GLASS_LATENCY:** Shutter glasses latency (time required to flip the shutters). If the top lines of your display are kind of blurry there is good chance this value is not high enough.
- **GENLOCK:** Minimum time required to have the genlocking algorithm working properly. GENLOCK should be long enough so SoftGenLock has some time left before VNEND to detect when small modifications of the video signal (not detected by the screen) are required. If your image seems unstable there is a chance this value is not large enough.
- **GENLOCK_TOLERANCE:** How accurate genlocking should be. If you put here $10 \mu s$, SoftGenLock will make everything possible so that all video retraces start in a range of $10 \mu s$.

4.3 Ready ?

Did you modify the Makefile ? Did you adjust the value of HSIZE ? Did you boot your system with a linux kernel patched for RTAI or RTLinux (check with `uname -a`) ? Ok you can compile SoftGenLock :

```
make all
```

5 Running SoftGenLock

Did you started the real time system ? Did you plug your glasses and the sync network , Did you launch X with the double horizontal resolution ? Are you super user ? Ok you can launch SoftGenLock.

5.1 First Test

For a first test put an Xterm window on the left side of the virtual screen and nothing on the right side. Start SoftGenLock and put the shutter glasses. Close the left eye. You should not see the Xterm window. Congratulation, you successfully installed SoftGenLock.

5.2 Single Display

You just have to load the SoftGenLock module :

```
insmod softgenlock.o
```

To stop SoftGenLock unload the module:

```
rmmmod softgenlock
```

5.3 Multiple Displays

5.3.1 TTL_PAPERS network

On each machine load the SoftGenLock module:

```
insmod softgenlock.o
```

To stop SoftGenLock unload the module on each machine.

```
rmmmod softgenlock
```

Note that once a machine stopped SoftGenLock the other machines will wait for a while (few seconds) and stop SoftGenLock, but the module is still loaded.

5.3.2 ParaCable

It is important to identify each machine according to its role in the parallel cable :

- Master : node 0
- Slave 1 : node 1
- Slave 2 : node 2
- Slave 3 : node 3
- Slave 4 : node 4
- Slave 5 : node 5

On each machine load the SoftGenLock module with the rank of the node and the total number of machine involved (counting the master). For exemple if you want to use 3 machines load the module on the :

- master: `insmod softgenlock.o size=3 rank=0`
- slave 1: `insmod softgenlock.o size=3 rank=1`
- slave 2: `insmod softgenlock.o size=3 rank=2`

To stop SoftGenLock unload the module on each machine.

```
rmmod softgenlock
```

Note that once a machine stopped SoftGenLock the other machines will wait for a while (few seconds) and stop SoftGenLock, but the module is still loaded.

5.4 SoftGenLock Refuse to Start

Stereo is not activated right after SoftGenLock is started, because SoftGenLock first takes time to measure some internal parameteres and sync itself with the vertical retrace. This step may take few seconds. In the case you are using multiple displays it may stop itself during or after this calibration step. This is a side-effect of a watchdog mechanism we integrated in SoftGenLock to avoid locking the kernel while waiting in an endless synchronisation barrier. If you are experiencing this problem increase the value of the variable `SGEN_COMM_EXIT_BARRIER_TIME` in the `Comm/comm.h` file.

5.5 Controlling Genlock Quality

Once SoftGenLock is working, wear the shutter glasses. If a black line appears on one screen the genlock is not perfect yet. But it may take some time for SoftGenLock to converge to a genlocked state. As SoftGenLock progress, you should see this black line progressively going up or down the screen and then disappear. If the top lines of your display(s) are kind of blurry there is good chance the latency of your glasses is higher than what you put in the `sgen_param.h` file. Increase the value of `GLASS_LATENCY`. If your image seems unstable (image flipping occurs after the video retrace started) try to increase the value of `GENLOCK` in `sgen_param.h`.

5.6 Launch the 3D Application First

SoftGenLock must be launched after the 3D application. Doing the opposite, SoftGenLock may fail to properly display in stereo or genlock the displays. When launched, SoftGenLock first starts to measure some parameters of the video signal (retrace time for exemple). These parameteres may change when you start X or a 3D application. SoftGenLock is not (yet) able to detect these changes and recalibrate itself.

6 Installing SoftGenLock

We detail in the following how to install the SoftGenLock module with the other Linux kernel modules. This install eases starting/stopping SoftGenLock.

For each machine edit the `/etc/modules.conf` file and add the following line with the correct values for the `size` and `rank` options :

```
options softgenlock size=3 rank=1
```

Copy `softgenlock.o` into the `/lib/modules/<kernel-version>/misc` directory

```
cp softgenlock.o /lib/modules/<kernel-version>/misc/.
```

Execute the `thedepmod` command. This command identifies all other modules required to load `softgenlock` (in particular the modules of the real time system).

Now to start SoftGenLock with the correct options and the real time system you just have to type in:

```
modprobe softgenlock
```

To stop SoftGenLock and to unload all modules that become useless (the modules of the real time system):

```
modprobe -r softgenlock
```

7 SoftGenLock without Real Time System

Up to now we did not speak about using SoftGenLock without a real time kernel. This is possible. You just have to select the good configuration in your Makefile. But because strong restrictions apply to this configuration we reserve it for a first test only.

When compiling SoftGenLock without a real time system, SoftGenLock is a simple user program. Linux does not guarantee SoftGenLock has access to the CPU when required, i.e. during the vertical retrace, so flickers may affect the stereo effect especially if the CPU has other programs to run. In this case to run SoftGenLock just launch the program (you need to be super user only if you use the parallel port):

- `softgenlock` for a single display
- `softgenlock` on each machine for multiple displays and a TTL_PAPERS network

- `softgenlock size=... rank=...` on each machine for multiple displays and ParaCable.
- `mpirun -np ... softgenlock` on one machine for multiple displays and MPI. **NOTE: we do not support MPI any more.** This solution requires MPI to be installed. Note that MPI cannot be used with a real time kernel (real time modules have very limited I/O accesses).

8 SoftGenLock Directory Organization

Each component of SoftGenLock corresponds to a directory and each subdirectory to an implementation. Place your custom code on a subdirectory and reference it in the Makefile, and it should work... The required functions to implement are documented in the .h header file in each directory.

- `Algorithm`: main SoftGenLock algorithm. This should not need modifications other than bug correction or performance improvements.
- `Comm`: communication system
 - `Comm/ParaBox`: parallel port synchronization network
 - `Comm/ParaCable`: parallel cable
 - `Comm/MPI`: use `MPI_BARRIER` for synchronization.
- `Doc`: Documentation
- `Glasses`: stereo sync signal for shutter glasses
 - `Glasses/DDC`: SVGA DCC SDA pin 12 connector (using functions in `Graph/VGA`).
 - `Glasses/ParallelPort`: parallel port access.
- `Graph`: graphics card
 - `Graph/VGA`: vga compatible cards (with NVIDIA extension support).
- `Main`: main program
 - `Main/RTAI`: RTAI module

- Main/RTLinux: RTLinux module
- Main/Standard: User level program
- MyTime: timer
 - MyTime/i586: i586 cycle counter register.
 - MyTime/None: no timer (this should not be used).
 - MyTime/Posix: standard gettimeofday unix function.
 - MyTime/RTLINUX: RT Linux timer.
 - MyTime/RTAI: RTAI Timer.
- ParallelPort: parallel port access
 - ParallelPort/Kernel: IO perms for kernel level programs
 - ParallelPort/User: IO perms for user level programs

9 The SoftGenLock Team

The SoftGenLock team includes Jérémie Allard (the main programmer), Valérie Gouranton, Loïck Lecointre, Sébastien Limet, Souley Madougou, Emmanuel Melin, Olivier Riffaut, Laboratoire d'Informatique Fondamentale d'Orléans, France, and Bruno Raffin, Laboratoire Informatique et Distribution, Grenoble, France.

10 Problems and Feedback

For problems and feedbacks use the SoftGenLock mailing lists (see `net.juggler.sourceforge.`