

# **sysmocom**

sysmocom - s.f.m.c. GmbH



## **osmocom**

### **icE1usb User Manual**

by Harald Welte

Copyright © 2020-2022 sysmocom - s.f.m.c. GmbH

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.3 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

The Asciidoc source code of this manual can be found at <http://git.osmocom.org/osmo-gsm-manuals/>

| HISTORY |                   |   |      |
|---------|-------------------|---|------|
| NUMBER  | DATE              | DESCRIPTION   | NAME |
| 2       | January 17, 2022  | Update documentation to firmware 0.2 (GPS-DO, second E1 port) | HW   |
| 1       | December 13, 2020 | Initial version.  | HW   |

# Contents

|          |                                      |          |
|----------|--------------------------------------|----------|
| <b>1</b> | <b>Foreword</b>                      | <b>1</b> |
| 1.1      | Acknowledgements                     | 1        |
| 1.2      | Endorsements                         | 2        |
| <b>2</b> | <b>Preface</b>                       | <b>2</b> |
| 2.1      | FOSS lives by contribution!          | 2        |
| 2.2      | Osmocom and sysmocom                 | 3        |
| 2.3      | Corrections                          | 3        |
| 2.4      | Legal disclaimers                    | 3        |
| 2.4.1    | Spectrum License                     | 3        |
| 2.4.2    | Software License                     | 3        |
| 2.4.3    | Trademarks                           | 3        |
| 2.4.4    | Liability                            | 4        |
| 2.4.5    | Documentation License                | 4        |
| <b>3</b> | <b>Introduction</b>                  | <b>4</b> |
| 3.1      | Required Skills                      | 4        |
| 3.2      | Getting assistance                   | 5        |
| <b>4</b> | <b>icE1usb Hardware</b>              | <b>5</b> |
| 4.1      | Schematics                           | 5        |
| 4.2      | Connectors on E1 side                | 6        |
| 4.2.1    | X5A and X5B: E1 Interface Connectors | 6        |
| 4.2.2    | Switching between TE/NT mode         | 7        |
| 4.3      | Connectors on USB side               | 8        |
| 4.3.1    | X4: USB Connector                    | 8        |
| 4.3.2    | X2: Serial Console Connector         | 8        |
| 4.3.3    | X1: GPS Antenna Connector            | 9        |
| 4.3.4    | X3: GPIO / Extension Connector       | 9        |
| 4.4      | Pushbutton                           | 9        |
| 4.5      | Multi-Color LED                      | 9        |
| <b>5</b> | <b>icE1usb Gateware</b>              | <b>9</b> |

|          |  |           |
|----------|--|-----------|
| <b>6</b> | <b>icE1usb Firmware</b>                              | <b>9</b>  |
| 6.1      | Firmware Upgrade (DFU)                               | 10        |
| 6.1.1    | Obtaining firmware upgrades                          | 10        |
| 6.1.2    | Upgrading the FPGA gateway                           | 10        |
| 6.1.3    | Upgrading the picoRISCV firmware                     | 11        |
| 6.2      | Use of the E1 Interface LEDs                         | 11        |
| 6.3      | Use of the Multi-Color RGB LED                       | 12        |
| 6.4      | Firmware ↔ USB Host Interface                        | 12        |
| 6.4.1    | E1 ports   | 12        |
| 6.4.2    | CDC-ACM with GPS NMEA                                | 13        |
| 6.4.3    | DFU (Device Firmware Upgrade)                        | 13        |
| <b>7</b> | <b>Host Software</b>                                 | <b>13</b> |
| 7.1      | osmo-e1d   | 13        |
| 7.2      | DAHDI driver   | 13        |
| 7.2.1    | Installing DAHDI driver                              | 14        |
| 7.3      | Other software                                       | 14        |
| <b>A</b> | <b>GNU Free Documentation License</b>                | <b>14</b> |
| A.1      | PREAMBLE   | 15        |
| A.2      | APPLICABILITY AND DEFINITIONS                        | 15        |
| A.3      | VERBATIM COPYING                                     | 16        |
| A.4      | COPYING IN QUANTITY                                  | 16        |
| A.5      | MODIFICATIONS  | 16        |
| A.6      | COMBINING DOCUMENTS                                  | 17        |
| A.7      | COLLECTIONS OF DOCUMENTS                             | 18        |
| A.8      | AGGREGATION WITH INDEPENDENT WORKS                   | 18        |
| A.9      | TRANSLATION  | 18        |
| A.10     | TERMINATION  | 18        |
| A.11     | FUTURE REVISIONS OF THIS LICENSE                     | 19        |
| A.12     | RELICENSING  | 19        |
| A.13     | ADDENDUM: How to use this License for your documents | 19        |

# 1 Foreword

Digital cellular networks based on the GSM specification were designed in the late 1980s and first deployed in the early 1990s in Europe. Over the last 25 years, hundreds of networks were established globally and billions of subscribers have joined the associated networks.

The technological foundation of GSM was based on multi-vendor interoperable standards, first created by government bodies within CEPT, then handed over to ETSI, and now in the hands of 3GPP. Nevertheless, for the first 17 years of GSM technology, the associated protocol stacks and network elements have only existed in proprietary *black-box* implementations and not as Free Software.

In 2008 Dieter Spaar and I started to experiment with inexpensive end-of-life surplus Siemens GSM BTSs. We learned about the A-bis protocol specifications, reviewed protocol traces and started to implement the BSC-side of the A-bis protocol as something originally called `bs11-abis`. All of this was *just for fun*, in order to learn more and to boldly go where no Free Software developer has gone before. The goal was to learn and to bring Free Software into a domain that despite its ubiquity, had not yet seen any Free / Open Source software implementations.

`bs11-abis` quickly turned into `bsc-hack`, then *OpenBSC* and its *OsmoNITB* variant: A minimal implementation of all the required functionality of an entire GSM network, exposing A-bis towards the BTS. The project attracted more interested developers, and surprisingly quickly also commercial interest, contribution and adoption. This allowed adding support for more BTS models.

After having implemented the network-side GSM protocol stack in 2008 and 2009, in 2010 the same group of people set out to create a telephone-side implementation of the GSM protocol stack. This established the creation of the Osmocom umbrella project, under which OpenBSC and the OsmocomBB projects were hosted.

Meanwhile, more interesting telecom standards were discovered and implemented, including TETRA professional mobile radio, DECT cordless telephony, GMR satellite telephony, some SDR hardware, a SIM card protocol tracer and many others.

Increasing commercial interest particularly in the BSS and core network components has lead the way to 3G support in Osmocom, as well as the split of the minimal *OsmoNITB* implementation into separate and fully featured network components: OsmoBSC, OsmoMSC, OsmoHLR, OsmoMGW and OsmoSTP (among others), which allow seamless scaling from a simple "Network In The Box" to a distributed installation for serious load.

It has been a most exciting ride during the last eight-odd years. I would not have wanted to miss it under any circumstances.

— Harald Welte, Osmocom.org and OpenBSC founder, December 2017.

## 1.1 Acknowledgements

My deep thanks to everyone who has contributed to Osmocom. The list of contributors is too long to mention here, but I'd like to call out the following key individuals and organizations, in no particular order:

- Dieter Spaar for being the most amazing reverse engineer I've met in my career
- Holger Freyther for his many code contributions and for shouldering a lot of the maintenance work, setting up Jenkins - and being crazy enough to co-start sysmocom as a company with me ;)
- Andreas Eversberg for taking care of Layer2 and Layer3 of OsmocomBB, and for his work on OsmoBTS and OsmoPCU
- Sylvain Munaut for always tackling the hardest problems, particularly when it comes closer to the physical layer
- Chaos Computer Club for providing us a chance to run real-world deployments with tens of thousands of subscribers every year
- Bernd Schneider of Netzing AG for funding early ip.access nanoBTS support
- On-Waves ehf for being one of the early adopters of OpenBSC and funding a never ending list of features, fixes and general improvement of pretty much all of our GSM network element implementations
- sysmocom, for hosting and funding a lot of Osmocom development, the annual Osmocom Developer Conference and releasing this manual.

- Jan Luebbe, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer, Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov
- NLnet Foundation, for providing funding for a number of individual work items within the Osmocom universe, such as LTE support in OsmoCBC or GPRS/EGPRS support for Ericsson RBS6000.
- WaveMobile Ltd, for many years of sponsoring.

May the source be with you!

— Harald Welte, Osmocom.org and OpenBSC founder, January 2016.

## 1.2 Endorsements

This version of the manual is endorsed by Harald Welte as the official version of the manual.

While the GFDL license (see [Appendix A](#)) permits anyone to create and distribute modified versions of this manual, such modified versions must remove the above endorsement.

## 2 Preface

First of all, we appreciate your interest in Osmocom software.

Osmocom is a Free and Open Source Software (FOSS) community that develops and maintains a variety of software (and partially also hardware) projects related to mobile communications.

Founded by people with decades of experience in community-driven FOSS projects like the Linux kernel, this community is built on a strong belief in FOSS methodology, open standards and vendor neutrality.

### 2.1 FOSS lives by contribution!

If you are new to FOSS, please try to understand that this development model is not primarily about “free of cost to the GSM network operator”, but it is about a collaborative, open development model. It is about sharing ideas and code, but also about sharing the effort of software development and maintenance.

If your organization is benefiting from using Osmocom software, please consider ways how you can contribute back to that community. Such contributions can be many-fold, for example

- sharing your experience about using the software on the public mailing lists, helping to establish best practises in using/operating it,
- providing qualified bug reports, workarounds
- sharing any modifications to the software you may have made, whether bug fixes or new features, even experimental ones
- providing review of patches
- testing new versions of the related software, either in its current “master” branch or even more experimental feature branches
- sharing your part of the maintenance and/or development work, either by donating developer resources or by (partially) funding those people in the community who do.

We’re looking forward to receiving your contributions.

## 2.2 Osmocom and sysmocom

Some of the founders of the Osmocom project have established *sysmocom - systems for mobile communications GmbH* as a company to provide products and services related to Osmocom.

sysmocom and its staff have contributed by far the largest part of development and maintenance to the Osmocom mobile network infrastructure projects.

As part of this work, sysmocom has also created the manual you are reading.

At sysmocom, we draw a clear line between what is the Osmocom FOSS project, and what is sysmocom as a commercial entity. Under no circumstances does participation in the FOSS projects require any commercial relationship with sysmocom as a company.

## 2.3 Corrections

We have prepared this manual in the hope that it will guide you through the process of installing, configuring and debugging your deployment of cellular network infrastructure elements using Osmocom software. If you do find errors, typos and/or omissions, or have any suggestions on missing topics, please do take the extra time and let us know.

## 2.4 Legal disclaimers

### 2.4.1 Spectrum License

As GSM and UMTS operate in licensed spectrum, please always double-check that you have all required licenses and that you do not transmit on any ARFCN or UARFCN that is not explicitly allocated to you by the applicable regulatory authority in your country.



#### Warning

Depending on your jurisdiction, operating a radio transmitter without a proper license may be considered a felony under criminal law!

---

### 2.4.2 Software License

The software developed by the Osmocom project and described in this manual is Free / Open Source Software (FOSS) and subject to so-called *copyleft* licensing.

Copyleft licensing is a legal instrument to ensure that this software and any modifications, extensions or derivative versions will always be publicly available to anyone, for any purpose, under the same terms as the original program as developed by Osmocom.

This means that you are free to use the software for whatever purpose, make copies and distribute them - just as long as you ensure to always provide/release the *complete and corresponding* source code.

Every Osmocom software includes a file called `COPYING` in its source code repository which explains the details of the license. The majority of programs is released under GNU Affero General Public License, Version 3 (AGPLv3).

If you have any questions about licensing, don't hesitate to contact the Osmocom community. We're more than happy to clarify if your intended use case is compliant with the software licenses.

### 2.4.3 Trademarks

All trademarks, service marks, trade names, trade dress, product names and logos appearing in this manual are the property of their respective owners. All rights not expressly granted herein are reserved.

For your convenience we have listed below some of the registered trademarks referenced herein. This is not a definitive or complete list of the trademarks used.

*Osmocom*® and *OpenBSC*® are registered trademarks of Holger Freyther and Harald Welte.

*sysmocom*® and *sysmoBTS*® are registered trademarks of *sysmocom - systems for mobile communications GmbH*.

*ip.access*® and *nanoBTS*® are registered trademarks of *ip.access Ltd*.

#### 2.4.4 Liability

The software is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the License text included with the software for more details.

#### 2.4.5 Documentation License

Please see Appendix A for further information.

## 3 Introduction

### 3.1 Required Skills

Please note that even while the capital expenses of running mobile networks has decreased significantly due to Osmocom software and associated hardware like sysmoBTS, GSM networks are still primarily operated by large GSM operators.

Neither the GSM specification nor the GSM equipment was ever designed for networks to be installed and configured by anyone but professional GSM engineers, specialized in their respective area like radio planning, radio access network, back-haul or core network.

If you do not share an existing background in GSM network architecture and GSM protocols, correctly installing, configuring and optimizing your GSM network will be tough, irrespective whether you use products with Osmocom software or those of traditional telecom suppliers.

GSM knowledge has many different fields, from radio planning through site installation to core network configuration/administration.

The detailed skills required will depend on the type of installation and/or deployment that you are planning, as well as its associated network architecture. A small laboratory deployment for research at a university is something else than a rural network for a given village with a handful of cells, which is again entirely different from an urban network in a dense city.

Some of the useful skills we recommend are:

- general understanding about RF propagation and path loss in order to estimate coverage of your cells and do RF network planning.
- general understanding about GSM network architecture, its network elements and key transactions on the Layer 3 protocol
- general understanding about voice telephony, particularly those of ISDN heritage (Q.931 call control)
- understanding of GNU/Linux system administration and working on the shell
- understanding of TCP/IP networks and network administration, including tcpdump, tshark, wireshark protocol analyzers.
- ability to work with text based configuration files and command-line based interfaces such as the VTY of the Osmocom network elements



## 3.2 Getting assistance

If you do have a support package / contract with sysmocom (or want to get one), please contact [support@sysmocom.de](mailto:support@sysmocom.de) with any issues you may have.

If you don't have a support package / contract, you have the option of using the resources put together by the Osmocom community at <https://projects.osmocom.org/>, checking out the wiki and the mailing-list for community-based assistance. Please always remember, though: The community has no obligation to help you, and you should address your requests politely to them. The information (and software) provided at osmocom.org is put together by volunteers for free. Treat them like a friend whom you're asking for help, not like a supplier from whom you have bought a service.

If you would like to obtain professional/commercial support on Osmocom CNI, you can always reach out to [sales@sysmocom.de](mailto:sales@sysmocom.de) to discuss your support needs. Purchasing support from sysmocom helps to cover the ongoing maintenance of the Osmocom CNI software stack.

## 4 icE1usb Hardware

The icE1usb Hardware consists of a single circuit board (in an optional enclosure).

It's main building blocks are:

- an iCE40 FPGA
- Two E1 line interface (transformers, biasing networks and ESD protection) <sup>1</sup>
- a GPS receiver module with 1PPS output to the FPGA <sup>2</sup>

### 4.1 Schematics

As icE1usb is an OSHW (Open Source Hardware) project, the full schematics and design files are publicly available.

The design files in KiCAD format are available at <https://git.osmocom.org/osmo-e1-hardware/tree/hardware/icE1usb>

PDF rendered schematics are available at <https://git.osmocom.org/osmo-e1-hardware/plain/hardware/icE1usb/r1.0/icE1usb.pdf>

---

<sup>1</sup>Second interface requires firmware >= 0.2 and OHCI/OHCI/EHCI host controller

<sup>2</sup>Requires firmware >= 0.2

## 4.2 Connectors on E1 side



Figure 1: E1 side of icE1usb

From left to right, there are the following connectors:

- X5A: Primary E1 Port
- X5B: Secondary E1 Port

### 4.2.1 X5A and X5B: E1 Interface Connectors

On one side of the PCB there are two RJ45 connectors next to each other.

Those are the two E1 line interfaces. The interfaces are of symmetric 120 Ohms type.

Assuming the board is oriented with the tab of the RJ45 connectors facing up:

- Interface 0 is on the right side
- Interface 1 is on the left side (next to the button)

The pin-out of the connectors can be swapped between TE and NT mode using the J4 and J5 jumper blocks on the circuit board.

The factory default setting of the jumpers is TE-mode.

In case you're using the icE1usb with user-side equipment such as a GSM BTS, a PBX, a Router or the like which traditionally was attached to the public network, those devices all implement TE mode. In such situations you need to either switch the icE1usb to NT mode (and use straight wiring), or use an E1 cross-over cable.

Table 1: Pin-out of RJ45 E1 connectors

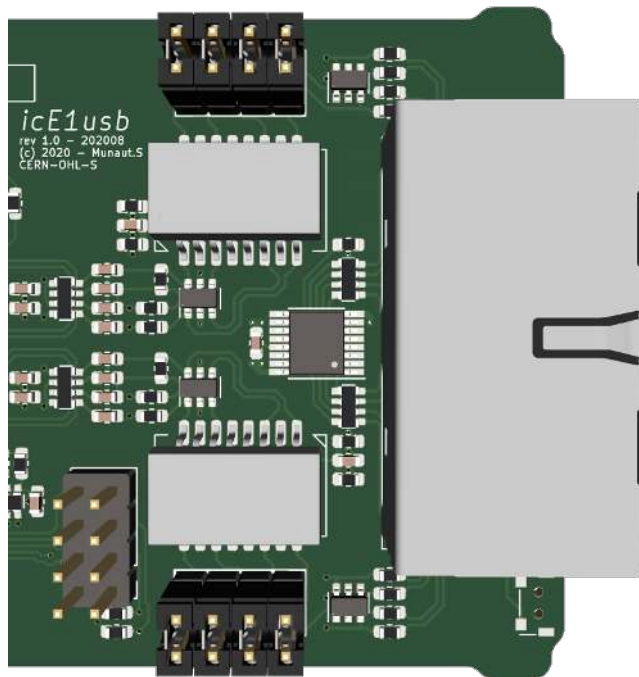
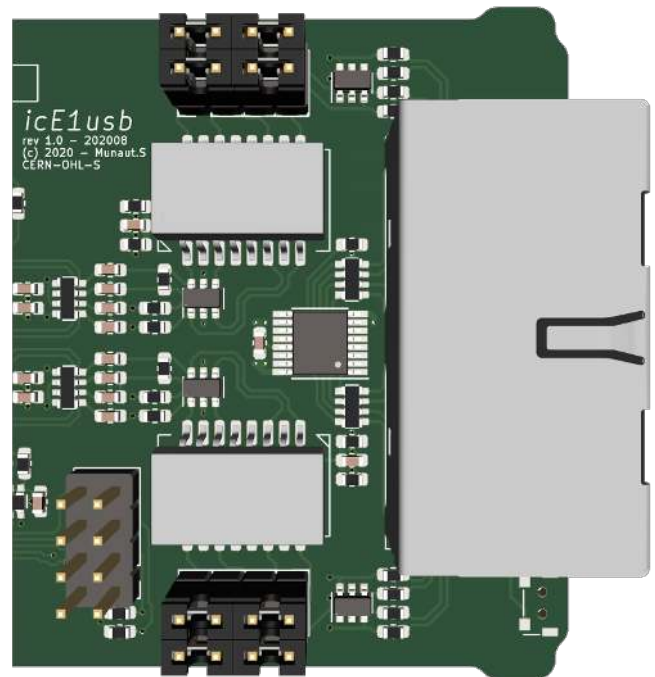
| Pin | Function (TE) | Function (NT Mode) |
|-----|---------------|--------------------|
| 1   | Rx            | Tx                 |
| 2   | Rx            | Tx                 |
| 3   | not used      | not used           |
| 4   | Tx            | Rx                 |
| 5   | Tx            | Rx                 |
| 7   | not used      | not used           |
| 8   | not used      | not used           |

**Note**

E1 cables use RJ45 like Ethernet, but Ethernet cables have a different pin-out. Particularly, you cannot use an Ethernet cross-over cable as an E1 cross-over!

**4.2.2 Switching between TE/NT mode**

To change the mode, unscrew the 2 PH0 screws on the side with the 2 RJ45 jacks. You'll also need to unscrew the nut on the SMA jack on the other side. After that, the cover plate and rubber gasket around the 2 RJ45 jacks can be removed. The PCB can be slid out of the case.

**TE mode (default)****NT mode**

Each 2x4 jumper block is connected to the nearest RJ45 connector.

### 4.3 Connectors on USB side



Figure 2: USB side of icE1usb

From left to right, there are the following connectors:

- X1: GPS Antenna Connector
- X2: Serial Console Connector
- X4: USB Connector
- X3: GPIO / Extension Connector

#### 4.3.1 X4: USB Connector

The USB connector is a USB Type C connector. However, it only carries USB 1.1 full-speed signals. 5V DC power is also sourced from this connector.

#### 4.3.2 X2: Serial Console Connector

The serial console is used for development and debugging. It uses an Osmocom-style 2.5mm stereo TRS jack.

The serial console uses 3.3V CMOS logic levels

The serial console uses a rate of 1000000 bps.

The pin-out is as follows:

- Tip: Tx output from PC (Rx input of icE1usb)
- Ring: Rx input of PC (Tx output of icE1usb)
- Shield: GND

A compatible cable can be sourced from the sysmocom web-shop at <http://shop.sysmocom.de/>.

#### 4.3.3 X1: GPS Antenna Connector

The GPS antenna connector is a female SMA connector.

You can connect most standard active GPS antennas with built-in LNA.

icE1usb provide phantom voltage.

The use of a GPS antenna is only required when you need a high precision clock reference for the 2.048 MHz E1 bit clock, e.g. to provide a clock reference to a cellular base station on the A-bis interface.

#### 4.3.4 X3: GPIO / Extension Connector

This is a RJ45 connector adjacent to the USB connector.

It is currently unused and reserved for future use.

### 4.4 Pushbutton

This is a push-button next to the *E1 interface 'I'*. It is recessed to protect against accidental use. You will need to use a paper clip, pen tip or other similar object to push it.

The button can be used to force booting into the DFU loader in order to recover from a broken firmware installation.

### 4.5 Multi-Color LED

Above the USB-C connector, there is a multi-color RGB LED.

This LED is used by the firmware to indicate a variety of status information. Please see the firmware documentation in [\[firmware\]](#).

## 5 icE1usb Gateway

The icE1usb *gateway* is where pretty much everything happens, from the E1 Line Interface Unit to the E1 Framer/Deframer, the picoRISCv soft-core running the as well as the USB device peripheral talking to the host PC.

The gateway is stored in binary form on the device-internal non-volatile memory (SPI flash). It is field-upgradeable via USB.

As an OSHW project, all of it is available in source code format at <https://git.osmocom.org/osmo-e1-hardware/tree/gateway/-icE1usb>

Please use `git clone --recursive` when cloning the git repository so you get all of the sub-modules for the various soft-cores.

## 6 icE1usb Firmware

The icE1usb *firmware* is a small amount of bare-iron software running on the picoRISCv soft-core of the *gateway*.

It mainly consists of drivers for the no2e1 E1 Framer IP core and the no2usb USB Device IP core which are part of the gateway described in Section 5.

## 6.1 Firmware Upgrade (DFU)

icE1usb contains support for the USB DFU (Device Firmware Upgrade) standard.

As such, you can use any USB DFU compliant utility to upgrade the firmware of the icE1usb device.

DFU mode can be entered in two ways:

1. by performing a DFU detach from the normal application firmware (obviously that requires a [still] working firmware present on the device). To do so, please use `dfu-util -e`
2. by pushing the push-button (see Section 4.4) during power-up. Simply disconnect the USB cable, then push that button and keep it pushed while re-attaching the USB cable.

The icE1usb boot loader enumerates as VID:PID 1d50 : 6144, while the normal application firmware enumerates as 1d50 : 6145,

You can for example use `lsusb` to check the VID:PID:

```
$ lsusb -d 1d50:
Bus 001 Device 042: ID 1d50:6145❶ OpenMoko, Inc. icE1usb
$ sudo dfu-util -d 1d50:6145 -e ❷
...
$ lsusb -d 1d50:
Bus 001 Device 043: ID 1d50:6144❸ OpenMoko, Inc. icE1usb (DFU)
```

- ❶ initially the device is in normal runtime mode
- ❷ we use `dfu-util -e` to switch to DFU mode
- ❸ we can see, the device is now in DFU mode

### 6.1.1 Obtaining firmware upgrades

The latest firmware can be found at <https://ftp.osmocom.org/binaries/icE1usb/firmware/latest/> a backlog of earlier builds can be found at <https://ftp.osmocom.org/binaries/icE1usb/firmware/all/>

The latest gateway can currently only be found at the personal developer directory of tnt at <https://people.osmocom.org/tnt/-/icE1usb/icE1usb-202010-bd399e96.bin> A more official download location for the gateway will be provided shortly.

### 6.1.2 Upgrading the FPGA gateway

Gateway files are called `icE1usb-*.bin`. (without *fw* in the name)

The gateway can be upgraded by accessing the DFU *altsetting 0* using `dfu-util -a 0`

Assuming you already are in DFU mode, you would typically use a command like `dfu-util -d 1d50:6144 -a 0 -D icE1usb-202010-bd399e96.bin -R` to perform the upgrade.

---

#### Note

The `-R` will switch the device back to runtime mode after the upgrade. If you want to upgrade the firmware in the same session, skip the `-R` in the above command.

---

### 6.1.3 Upgrading the picoRISCV firmware

Firmware files are called `icE1usb-fw*.bin`.

The firmware can be upgraded by accessing the DFU *altsetting 1* using `dfu-util -a 1`

Assuming you already are in DFU mode, you would typically use a command like `dfu-util -d 1d50:6144 -a 1 -D fw_app-202011-4d9a04e2.bin -R` to perform the upgrade.

#### Typical output during upgrade of the firmware

```
$ sudo dfu-util -d 1d50:6144 -a 1 -D ./fw_app.bin -R
dfu-util 0.9

Copyright 2005-2009 Weston Schmidt, Harald Welte and OpenMoko Inc.
Copyright 2010-2016 Tormod Volden and Stefan Schmidt
This program is Free Software and has ABSOLUTELY NO WARRANTY
Please report bugs to http://sourceforge.net/p/dfu-util/tickets/

dfu-util: Invalid DFU suffix signature
dfu-util: A valid DFU suffix will be required in a future dfu-util release!!!
Opening DFU capable USB device...
ID 1d50:6144
Run-time device DFU version 0101
Claiming USB DFU Interface...
Setting Alternate Setting #1 ...
Determining device status: state = dfuIDLE, status = 0
dfuIDLE, continuing
DFU mode device DFU version 0101
Device returned transfer size 4096
Copying data from PC to DFU device
Download      [=====] 100%          11256 bytes
Download done.
state(2) = dfuIDLE, status(0) = No error condition is present
Done!
Resetting USB to switch back to runtime mode
```

As the `-R` option was used, the device will reset and re-enumerate in the newly programmed firmware.

You can verify this as follows:

```
$ lsusb -d 1d50:
Bus 001 Device 042: ID 1d50:6145 OpenMoko, Inc. icE1usb
```

or alternatively:

```
$ dfu-util -l -d 1d50:
dfu-util 0.9

Copyright 2005-2009 Weston Schmidt, Harald Welte and OpenMoko Inc.
Copyright 2010-2016 Tormod Volden and Stefan Schmidt
This program is Free Software and has ABSOLUTELY NO WARRANTY
Please report bugs to http://sourceforge.net/p/dfu-util/tickets/

Found Runtime: [1d50:6145] ver=0003, devnum=44, cfg=1, intf=1, path="1-2", alt=0, name="DFU ←
runtime", serial="dc697407e7881531"
```

## 6.2 Use of the E1 Interface LEDs

Each E1 interface has two LEDs integrated into the RJ45 connector. They are (starting to get) used by the firmware to indicate status information to the user.

| Color | Pattern         | Meaning                         |
|-------|-----------------|---------------------------------|
| Green | Blinking (slow) | E1 Receiver attempting to align |
| Green | On              | E1 Receiver fully aligned       |

### 6.3 Use of the Multi-Color RGB LED

FIXME: describe how it is used.

### 6.4 Firmware ↔ USB Host Interface

The icE1usb firmware provides a USB 1.1 full-speed (FS) device with

- one configuration
- 5 interfaces
  - E1 port 0
  - E1 port 1
  - CDC-ACM (control + data)
  - DFU (device firmware upgrade)

The interfaces have self-explanatory string descriptors like

```
iInterface      6 E1 port 0
iInterface      8 E1 port 1
iInterface      9 GPS (CDC control)
iInterface     10 GPS (CDC data)
iInterface     11 DFU runtime
```

#### 6.4.1 E1 ports

There are two physical E1 ports in the icE1usb. Each is exposed via its own USB *interface*.

Each port (USB *interface*) contains two *altsettings*:

- one altsetting with no data endpoints (E1 disabled, this is the default)
- one altsetting with isochronous IN/OUT endpoints (E1 enabled)

In order to activate one E1 port, the driver must perform a USB standard request to activate the *enabled* altsetting.

#### NOTE

Please note that on many XHCI host controllers there seem to be implementation flaws in the XHCI host controller firmware preventing the activation of both icE1usb ports simultaneously. The XHCI controller firmware erroneously claims that there is insufficient bus bandwidth. However, the same icE1usb hardware/firmware works perfectly fine with OHCI, UHCI and EHCI host controllers. See [https://osmocom.org/projects/e1-t1-adapter/wiki/Isochronous\\_USB\\_Issues](https://osmocom.org/projects/e1-t1-adapter/wiki/Isochronous_USB_Issues) for a user-maintained list of USB hosts / controllers and whether or not they work with two E1 ports.

As most modern [PC] hardware has XHCI host controllers, you need to choose your hardware carefully if concurrent operation of both icE1usb ports is required in your application.



### 6.4.2 CDC-ACM with GPS NMEA

There's a CDC-ACM (virtual com port) interface available in the icE1usb. This will be supported by the standard `cdc_acm` driver of your operating system, and will expose a `/dev/ttyACMx` device on Linux.

The port provides read-only access to the GPS receiver on-board the icE1usb. You can use this to

- determine the GPS fix (and hence 1PPS frequency reference) availability
- obtain the GPS position of the device

#### NOTE

Write access to the GPS receiver is not permitted as the icE1usb firmware needs to control the GPS receiver for frequency reference purposes.

### 6.4.3 DFU (Device Firmware Upgrade)

There's a DFU interface available in order to update the icE1usb gateway and firmware. For more information, see [above](#).

## 7 Host Software

Host Software is software running on the USB host computer to which the icE1usb is attached.

At the time of this writing, there are two options for icE1usb driver interfaces: `osmo-e1d` and DAHDI.

### 7.1 osmo-e1d

`osmo-e1d` is a pure user-space driver, not requiring any specific Linux kernel, kernel patches or out-of-tree kernel modules. It utilizes `libusb` to talk to the icE1usb hardware and offers a unix domain socket based interface to application software.

In theory, `osmo-e1d` should work on any operating system with `libusb` support for isochronous transfers. However, official support is limited to GNU/Linux at this point.

Software such as `osmo-bsc` and `osmo-mgw` can interface `osmo-e1d` via the `libosmo-abis` support for `osmo-e1d`.

More information about `osmo-e1d` can be found at its homepage <https://osmocom.org/projects/osmo-e1d/wiki>

### 7.2 DAHDI driver

DAHDI (Digium Asterisk Hardware Driver Interface) is an extremely popular driver for a variety of POTS/PSTN and also TDM interface boards by originally Zaptel, later Digium and now most recently Sangoma.

DAHDI is available only for Linux, and is provided as source code for a set of out-of-tree kernel modules. You must compile those modules for each specific Linux kernel version you are using. Keep this in mind when performing kernel upgrades and the like.

DAHDI is supported by a wide range of open source PBX / softswitch software, including Asterisk, FreeSWITCH and yate.

There is a DAHDI driver for the icE1usb available from the `laforge/icE1usb` branch of the <https://github.com/osmocom/-dahdi-linux> git repository.

When using that DAHDI Linux kernel driver, there is no need for `osmo-e1d`. The USB interface is directly managed inside the kernel.

### 7.2.1 Installing DAHDI driver

Example installation steps, tested on Debian 11, for installing DAHDI Linux & DAHDI Tools. Note: Plugging in the device prior to installing may lead to issues.

```
$ sudo apt-get install -y linux-headers-`uname -r` git dfu-util make gcc autoconf libtool ↵
libnewt-dev
$ git clone https://git.osmocom.org/dahdi-linux/
$ git clone https://github.com/asterisk/dahdi-tools
$ cd dahdi-linux
$ sudo make install
$ cd ../dahdi-tools
$ sudo autoreconf -i
$ ./configure
$ sudo make install
$ sudo make install-config
$ sudo modprobe icE1usb
$ sudo /etc/init.d/dahdi start
```

At this point you can plug in the icE1usb, which

- should make the icE1usb enumerate on USB (dmesg, lsusb)
- should and scan for it with `sudo dahdi_scan` which should list the two E1 ports on the icE1usb.
- see a `/proc/dahdi/N` file (with N being the span number, typically 1 unless you have other spans)
- see the device listed in `dahdi_scan` or `dahdi_tool`

#### Example dmesg output when icE1usb is plugged in

```
usb 2-1: new full-speed USB device number 5 using xhci_hcd
usb 2-1: New USB device found, idVendor=1d50, idProduct=6145, bcdDevice= 0.03
usb 2-1: New USB device strings: Mfr=2, Product=3, SerialNumber=1
usb 2-1: Product: icE1usb
usb 2-1: Manufacturer: osmocom
usb 2-1: SerialNumber: dc697407e7682731
```

#### Example lsusb output after icE1usb is plugged in

```
$ lsusb -d 1d50:
Bus 002 Device 005: ID 1d50:6145 OpenMoko, Inc. icE1usb
```

## 7.3 Other software

you can interface 3rd party applications with osmo-e1d in the following ways:

- by adding support for osmo-e1d, e.g. via `libosmo-e1d` to the respective application
- by directly implementing the USB interface exposed by icE1usb in your software

Should you require any related development/porting services, please do not hesitate to reach out to sysmocom.

## A GNU Free Documentation License

Version 1.3, 3 November 2008

Copyright © 2000, 2001, 2002, 2007, 2008 Free Software Foundation, Inc. <http://fsf.org/>

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

## A.1 PREAMBLE

The purpose of this License is to make a manual, textbook, or other functional and useful document “free” in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of “copyleft”, which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

## A.2 APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The “Document”, below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as “you”. You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A “Modified Version” of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A “Secondary Section” is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document’s overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a [Secondary Section](#) may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The “Invariant Sections” are certain [Secondary Section](#) whose titles are designated, as being those of [Invariant Sections](#), in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero [Invariant Sections](#). If the Document does not identify any Invariant Sections then there are none.

The “Cover Texts” are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A “Transparent” copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise [Transparent](#) file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not [Transparent](#). An image format is not [Transparent](#) if used for any substantial amount of text. A copy that is not [Transparent](#) is called “Opaque”.

Examples of suitable formats for [Transparent](#) copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The “Title Page” means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, [Title Page](#) means the text near the most prominent appearance of the work’s title, preceding the beginning of the body of the text.

The “publisher” means any person or entity that distributes copies of the Document to the public.

A section “Entitled XYZ” means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as “Acknowledgements”, “Dedications”, “Endorsements”, or “History”.) To “Preserve the Title” of such a section when you modify the Document means that it remains a section “Entitled XYZ” according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

### A.3 VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section Section A.4.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

### A.4 COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document’s license notice requires [Cover Texts](#), you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable [Transparent](#) copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete [Transparent](#) copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this [Transparent](#) copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

### A.5 MODIFICATIONS

You may copy and distribute a [Modified Version](#) of the Document under the conditions of sections 2 and 3 above, provided that you release the [Modified Version](#) under precisely this License, with the [Modified Version](#) filling the role of the Document, thus licensing distribution and modification of the [Modified Version](#) to whoever possesses a copy of it. In addition, you must do these things in the [Modified Version](#):

- a. Use in the [Title Page](#) (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- b. List on the [Title Page](#), as authors, one or more persons or entities responsible for authorship of the modifications in the [Modified Version](#), together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.

- c. State on the [Title Page](#) the name of the publisher of the [Modified Version](#), as the publisher.
- d. Preserve all the copyright notices of the Document.
- e. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- f. Include, immediately after the copyright notices, a license notice giving the public permission to use the [Modified Version](#) under the terms of this License, in the form shown in the Addendum below.
- g. Preserve in that license notice the full lists of [Invariant Sections](#) and required [Cover Texts](#) given in the Document's license notice.
- h. Include an unaltered copy of this License.
- i. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the [Modified Version](#) as given on the [Title Page](#). If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its [Title Page](#), then add an item describing the [Modified Version](#) as stated in the previous sentence.
- j. Preserve the network location, if any, given in the Document for public access to a [Transparent](#) copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
- k. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- l. Preserve all the [Invariant Sections](#) of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- m. Delete any section Entitled "Endorsements". Such a section may not be included in the [Modified Version](#).
- n. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any [Invariant Sections](#).
- o. Preserve any Warranty Disclaimers.

If the [Modified Version](#) includes new front-matter sections or appendices that qualify as [Secondary Section](#) and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of [Invariant Sections](#) in the [Modified Version](#)'s license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your [Modified Version](#) by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of [Cover Texts](#) in the [Modified Version](#). Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any [Modified Version](#).

## A.6 COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the [Invariant Sections](#) of all of the original documents, unmodified, and list them all as [Invariant Sections](#) of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical [Invariant Sections](#) may be replaced with a single copy. If there are multiple [Invariant Sections](#) with the same name but different contents, make the title of each such

section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of [Invariant Sections](#) in the license notice of the combined work.

In the combination, you must combine any sections Entitled “History” in the various original documents, forming one section Entitled “History”; likewise combine any sections Entitled “Acknowledgements”, and any sections Entitled “Dedications”. You must delete all sections Entitled “Endorsements”.

## A.7 COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

## A.8 AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an “aggregate” if the copyright resulting from the compilation is not used to limit the legal rights of the compilation’s users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document’s [Cover Texts](#) may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

## A.9 TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing [Invariant Sections](#) with translations requires special permission from their copyright holders, but you may include translations of some or all [Invariant Sections](#) in addition to the original versions of these [Invariant Sections](#). You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled “Acknowledgements”, “Dedications”, or “History”, the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

## A.10 TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense, or distribute it is void, and will automatically terminate your rights under this License.

However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, receipt of a copy of some or all of the same material does not give you any rights to use it.



## A.11 FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <http://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License “or any later version” applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation. If the Document specifies that a proxy can decide which future versions of this License can be used, that proxy’s public statement of acceptance of a version permanently authorizes you to choose that version for the Document.

## A.12 RELICENSING

“Massive Multiauthor Collaboration Site” (or “MMC Site”) means any World Wide Web server that publishes copyrightable works and also provides prominent facilities for anybody to edit those works. A public wiki that anybody can edit is an example of such a server. A “Massive Multiauthor Collaboration” (or “MMC”) contained in the site means any set of copyrightable works thus published on the MMC site.

“CC-BY-SA” means the Creative Commons Attribution-Share Alike 3.0 license published by Creative Commons Corporation, a not-for-profit corporation with a principal place of business in San Francisco, California, as well as future copyleft versions of that license published by that same organization.

“Incorporate” means to publish or republish a Document, in whole or in part, as part of another Document.

An MMC is “eligible for relicensing” if it is licensed under this License, and if all works that were first published under this License somewhere other than this MMC, and subsequently incorporated in whole or in part into the MMC, (1) had no cover texts or invariant sections, and (2) were thus incorporated prior to November 1, 2008.

The operator of an MMC Site may republish an MMC contained in the site under CC-BY-SA on the same site at any time before August 1, 2009, provided the MMC is eligible for relicensing.

## A.13 ADDENDUM: How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

```
Copyright (c) YEAR YOUR NAME.
Permission is granted to copy, distribute and/or modify this document
under the terms of the GNU Free Documentation License, Version 1.3
or any later version published by the Free Software Foundation;
with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts.
A copy of the license is included in the section entitled ``GNU
Free Documentation License''.
```

If you have [Invariant Sections](#), [Front-Cover Texts](#) and [Back-Cover Texts](#), replace the “with... Texts.” line with this:

```
with the Invariant Sections being LIST THEIR TITLES, with the
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have [Invariant Sections](#) without [Cover Texts](#), or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.