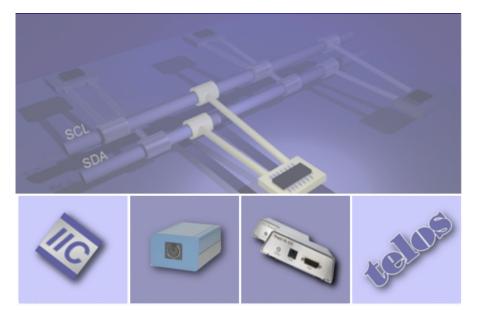
telos I2C Studio 5.15 User Manual



telos Systementwicklung GmbH Kaiser-Wilhelm-Strasse 93, 20355 Hamburg /Germany Phone: +49 (0)40 450 173 61 Mail: tsupport@telos.de Web: www.telos.info

> October 6, 2020 Document Revision: 8960

Contents

1 Terms

Combined Message	A sequence of submessages where only the last submessage is terminated by a STOP condition
telos Connii Interface	USB I2C interface for master operations.
telos Connii MM Interface	USB I2C interface for master and limited tracer operations. Suc-
	cessor of the telos Connii interface.
telos Connii MM 2.0 Interface	USB I2C interface for master and limited tracer operations. Suc-
	cessor of the telos Connii MM interface.
GUI	Graphical User Interface
I2C Interface	Generic term for telos Tracii XL 2.0, telos Tracii XL, telos Connii
	MM 2.0, telos Connii MM, and telos Connii interfaces.
Message	An I2C transfer that begins with a START condition and ends
	with a STOP condition. A message consists of one or more sub-
	messages without a STOP condition in-between.
Submessage	An I2C transfer that begins with a START condition and ends
	with a STOP condition or with a subsequent START condition.
telos Installation CD	CD which is delivered with the product. It contains all software
	and documentation which is needed to use the product.
telos Tracii XL Interface	USB I2C interface for master, tracer, and oscilloscope operations.
telos Tracii XL 2.0 Interface	USB I2C interface for master, tracer, and oscilloscope operations.
	Successor of the telos Tracii XL interface.
USB I2C Interface	I2C interface which is connected to the PC via the Universal Se-
	rial Bus (USB). (The term USB I2C interface applies only to telos
	products.)

2 Introduction

The following sections are an introduction to the application I2C Studio.

2.1 Disclaimer

This product is not designed for use in life support appliances, devices or systems where malfunction of this product can reasonably be expected to result in personal injury.

Customers using or selling this product for use in such applications do so at their own risk and agree to fully indemnify telos for any damages resulting from such improper use or sale.

2.2 Product Outline and Purpose

telos I2C Studio is an easy-to-use integrated I2C development environment to access all features of the I2C interfaces in the telos product chain.

It supports usage of the USB clients telos Tracii XL 2.0, telos Tracii XL, telos Connii MM 2.0, telos Connii MM, and telos Connii.

The installation package contains the following components: I2C Studio, I2C Framework, and I2C Flasher.

2.2.1 I2C Studio

I2C Studio is the GUI to access all features of the I2C interfaces in the telos product chain.

The main functionalities offered by I2C Studio are master, tracer, and negative tester. An additional feature of the tracer is an optional oscilloscope capability to give developers the possibility for watching the analog signal form in parallel to the traced I2C data. I2C Studio also supports scripting in C# for advanced users.

The I2C Studio has integrated an I2C slave, which works as RAM emulation and is only usable with telos Tracii XL 2.0 and telos Tracii XL.

Furthermore, it offers tools for JEDEC SPD RAM support. See chapter ?? for more details.

The telos I2C Studio allows accessing multiple functionalities on a referenced I2C interface at the same time. This means that users can access one I2C interface e.g. as master and tracer at the same time. Thus, it is possible to send and trace I2C messages within one application simultaneously.

The application offers a modern graphical user interface based on the Microsoft .NET technology, which is highly configurable due to the usage of workspaces. Different view modes allow analyzing the traced I2C data regarding different aspects.

A special view model is part of the tracer and allows watching the data on datasheet level. It is called IRD. Instead of working with addresses, offsets and byte values the user is provided with a comprehensive view of device registers, which are given by the names used in the datasheets.

2 Introduction

2.2.2 I2C Framework

The I2C Framework consists of application programming interfaces (APIs) to communicate with telos I2C products within customer applications. The following APIs are part of the framework:

- .NET API
- C++ API
- C API
- Java API
- Labview API
- URT/URD API

2.2.3 I2C Flasher

The I2C flasher is an industrial solution for EEPROM and flash programming needs. It supports a bunch of I2C memories from different vendors as Atmel, Catalyst, Fairchild, ISSI, Microchip, NXP (Philips), Samsung and ST Microelectronics.

3 Installation

The following sections describe the installation of the hardware and the software.

3.1 System Prerequisites

The following preconditions are required for a computer system to install and use I2C Studio:

Memory	Minimum 512 MB RAM, 1 GB are recommended
Processor	1 GHz
OS Platforms	Windows 7 (x86 & x64)
	Windows 8 (x86 & x64)
	Windows 8.1 (x86 & x64)
	Windows 10 (x86 & x64)
Browser	Internet Explorer, version 8 or higher
Software Packages	Microsoft .NET-Framework 4.0

3.2 Software Installation

To start the installation of I2C Studio execute one of the following setup packages, which can be found on the telos setup CD:

- .\software\x86\i2cstudio_setup_x86.exe(x86)
- .\software\x64\i2cstudio_setup_x64.exe(x64)

Please note that administrator rights are required to install the software. The installation wizard leads the user through the installation process. Besides the main application the installation routine also installs the USB device driver for the telos I2C interfaces to the installation directory.

3.3 Driver Installation

After I2C Studio is installed properly, Microsoft Windows has drivers available for all telos I2C USB interfaces.

Now, if a new telos USB I2C interface is plugged into an USB port, the Microsoft Windows hardware wizard comes up and guides the user through a fresh driver installation for this specific device.

The wizard asks whether it should install the driver automatically or manually. Please choose the automatic installation. Now the wizard updates the driver installation with the newly found device. It is ready to use, then.

3 Installation

闄 telos I2C Studio Setup	
Destination Folder Click Next to install to the default folder or click Change to choose another	. IIC
Install telos I2C Studio to:	
C:\Program Files\telos Systementwicklung GmbH\telos I2C Studio\ Change	
Back Next	Cancel

Figure 3.1: I2C Studio Install Wizard



Figure 3.2: New Hardware Wizard

Note: Microsoft Windows also starts the driver installation process, if a telos USB I2C device has formerly been in use on the system but the USB port has changed.

3.4 Mac OS X

There is no native Mac OS X application for interfacing the telos I2C tools. However, telos I2C Studio has been tested to perform well in a virtual machine running Windows 7.

What you need:

- An Intel Mac built 2010 or later earlier models may work but lack performance. I2C Studio will not run on Power PC.
- VM Fusion virtualization software available from:

http://www.vmware.com

- telos I2C Studio
- Microsoft Windows 7 (later versions may work too)

()	/Mware Fusion Ablage B			tuelle Maschine		E O S \$ \$ 100 %	■ Mo. 13:40 Q III
	20 - 200			32 🔲 📖 Imi	🚞 Schreibt	tisch	Speichermedium nicht kor Schließen
	000		FAVORITEN	Name		.▲ Änder	Ausschalten auswerfen.
		 (··) [2] 	💮 AirDrop				
	Anhalten Snapshots						
	🔁 🔜 🤭 🖓 🗢 Dokument - V	NordPad	Dokumente				
	Start Ansicht		Ownloads		VMware Fusion		
	Ausschneiden Calib	ri .	Filme				
	Ch Kopieren	K U abe	J Musik		Wählen Sie, wo Sie telos EDV Systementwicklu	ung	
	r F	K Q abe	Bilder		USB Device anschließen möchten.		
221	Zwischenablage	Schi	GERĂTE				
	3 + 0 + 2 + 0 + 1 + 0 + 2	····1···2	Entfernte		Auswahl speichern und nicht mehr fragen		
		L box Partage	Transc ≜		Verbindung mit Mac herstellen		
		-			Verbindung mit Windows herstellen		
	1	L box of 25 ci	FREIGABEN				
		Box of Partag	382				
		1	apps				
	F	Partagas Prin	carbon				
	F	Romeo y Julii	Cave				
			cdrom				
			com				
			costore				
			🖳 Alle				
			TAGS				
			Rot				
			😑 Orange				
_			Gelb				
			😑 Grün				
			😑 Blau				
			😑 Lila				
-		_	Grau				
Ver	bindung mit Windows I	herstellen	Alle Tags				
	14		2 5 🕑				

Figure 3.3: Mac OS X

Please follow these steps to install your telos I2C interface:

- 1. Install VM Fusion on your Mac.
- 2. Install MS windows by either doing a fresh install or by using the VMWare migration assistant to move your existing installation over to the Mac.
- 3. Please uninstall telos I2C studio, if you migrated an existing windows installation, which had this software installed.
- 4. Do not connect any I2C equipment yet.
- 5. Run the telos I2C Studio setup wizard. You should see the drivers being installed and you should be prompted to confirm the driver installation.
- 6. After the telos I2C Studio setup wizard has completed, connect your telos I2C interface to the USB port of your Mac while Windows is running in VMWare fusion. You should see the dialog shown in figure **??**.

3 Installation

- 7. The dialog prompts you in your localized language to chose between connecting the equipment to the Mac or to your virtual Windows machine. Please chose to connect to the Windows machine and tick the checkbox to make this selection permanent.
- 8. You are done, telos I2C studio should now interact properly with your hardware.

You may use the shared folder facility of VM Fusion to directly store log files created by telos I2C Studio to your native Mac file system. Folder shares are usually placed on your desktop by VMWare.

4 Getting Started

4.1 I2C Studio Overview

Starting telos I2C Studio the first time the user is confronted with a splash screen for a while. Depending on the system speed, it takes a moment until I2C Studio opens up with a blank workspace.



Figure 4.1: I2C Studio Splash Screen

4 Getting Started

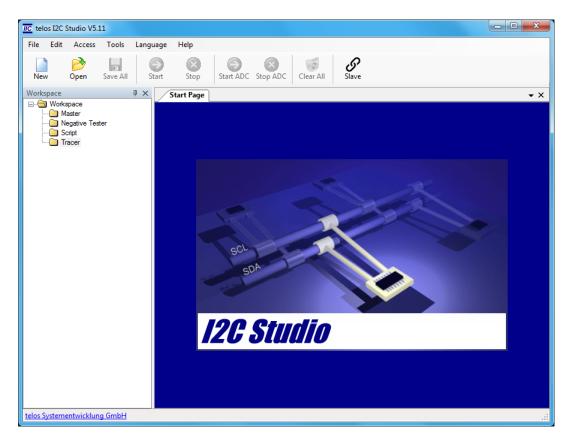


Figure 4.2: I2C Studio after Startup

When starting I2C Studio the first time a nearly blank Workspace on the left side and a so-called start page on the right side is presented.

The applications window top hosts a menu bar and a toolbar with some buttons beneath. Most of the toolbar buttons and parts of the menu bar selections are greyed out at the very first start simply because no function window has been opened in I2C Studio so far.

In this state another component of the application is nearly empty too. The status bar, which resides at the bottom of the application window, is showing only a link to the telos homepage as its default setting.

4.2 Menu and Toolbar

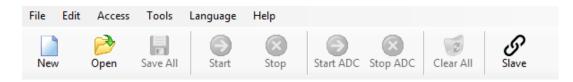


Figure 4.3: I2C Studio Menue and Toolbar after start

The menu allows the access to most of the I2C Studio functions. To ease the access, some of these functions, which are used regularly, have a shortcut by button in the toolbar too.

The menu has a permanent and a dynamic part. Thus some menu items are shown always, while other items are shown only, if the appropriate I2C Interface (Master / Tracer / Negative Tester) is selected in the workspace.

4.2.1 Permanent Menu

As displayed in figure ??, the following menu items are displayed always:

- **File** All file depending activities can be found here. For example a new function window (see section **??** for more details) can be created, stored to disk, loaded from disk etc. The same can be done with the workspace. Additional to that, the License Manager (see chapter **??** for more details) can be found here, to check or renew the service contract of the appropriate telos I2C Interface.
- Edit Descriptions in the Workspace can be copied and pasted.
- Access The remote access can be executed here. See more details in section ??.
- **Tools** Some helpful tools are provided here. See chapter **??** for more details.
- **Language** The telos I2C Studio provides all controls in English and German language. Thus the user can select the preferred language. After selection a restart of the I2C Studio is necessary. If started the first time, I2C Studio will select the language from the culture settings of the computer. Thus if the computer has already German selected as preferred language, I2C Studio will select German too. Otherwise the English setup is used.
- **Help** All necessary information about I2C Studio like content (user manual), I2C-bus helpfile, online manual, contact to the technical support and other information about the I2C Studio are available here.

4.2.2 Dynamic Menu

As mentioned above, the menu provides some dynamic entries. Therefore the menu is changed according to the created and selected device in the Workspace. If the Master is created and selected in the Workspace, the permanent menu gets an additional entry called 'Master'. Thus all Master depending settings can be accessed here. See more details about the Master in chapter **??**.

File Edit Master Access Tools Language He	File	Edit	Master	Access	Tools	Language	Help
---	------	------	--------	--------	-------	----------	------

If the Tracer is created and selected in the Workspace, the permanent menu gets an additional entry called 'Tracer'. If the I2C Interface supports the additional feature of an ADC, the menu gets another additional entry called 'ADC'. See more details about the Tracer in chapter **??** and about the ADC in section **??**.

4 Getting Started

File Edit Tracer ADC Access Tools Language Help

Figure 4.5: I2C Studio Menu - Tracer selected

If a Negative Tester is created and selected in the Workspace, the permanent menu is extended by the item 'Negative Tester'. See more details about the Negative Tester in chapter **??**.

```
File Edit Negative Tester Access Tools Language Help
```

Figure 4.6: I2C Studio Menu - Negative Tester selected

4.2.3 Toolbar

As mentioned before, the Toolbar provides some buttons for frequently used menu functions. Therefore the Toolbar is separated in 5 sections.



Figure 4.7: I2C Studio Toolbar

The first section consists of function support, which can be found in the file menu (New, Open, Save-All).

The second section provides a start and a stop button. These buttons can be used dynamically, depending on the selected interface in the Workspace. Thus the start button can start a Tracer, Master or Negative Tester, according to the pre-selected interface. The stop button can be used to stop a running Tracer or Negative Tester, while the Master typically stops automatically after execution.

The start and stop of the ADC function (see section **??**) can be performed in the third section of the Toolbar. The buttons are only accessible, if the connected I2C Tracer hardware device have a valid ADC license installed.

The clear all button in the fourth section can be used to clear all traced data in the Tracer. Therefore the Tracer must be started and stopped before. Otherwise this function is not available.

The slave button in the fifth section is a shortcut to the menu item Tools ||²C Memory Slave.

4.3 Status Bar

As mentioned above, the status bar can be found at the bottom of the main I2C Studio window. As also mentioned, the status bar shows the link to the telos website after startup only (see figure ??).

If an I2C interface is created in the Workspace, the status bar shows some useful hardware related information, depending on the current selected device in the Workspace.

telos Systementwicklung GmbH

Figure 4.8: I2C Studio Status Bar after start

Figure ?? shows the information of the Dummy-Master, while figure ?? gives some information about the Dummy-Tracer.

Dummy [0x54AC] I2C I2C Vcc: 5,00V 100 Ohm Processed 1/1 message.

Figure 4.9: I2C Studio Status Bar - Master

Dummy [0x54AC] I2C I2C Vcc: 5,00V 100 Ohm Messages: 881

Figure 4.10: I2C Studio Status Bar - Tracer

In case a real hardware is used to create an I2C Interface in the Workspace, the voltage can be selected by user. If no external voltage device is driving the I2C-bus, the internal hardware voltage supply must be set by user. Therefore, the voltage in the status bar is displayed in red (see figure ??), until a voltage is set in the appropriate hardware menu like Tracer|Hardware Options. As a shortcut, the user can also click directly on the (red marked) voltage field of the status bar to open the appropriate hardware dialog.

telos Tracii XL 2.0 [0x4716] I2C I2C Vcc: ~0V 10,90 kOhm Messages: 0

Figure 4.11: I2C Studio Status Bar - Tracer with no power

4.4 Function Windows

To start working with I2C Studio it is necessary to create a function window. I2C Studio knows several different types of function windows: master, tracer, negative tester, and script. Not all I2C interfaces support all types of function windows.

	Master	Tracer	Negative Tester	Script
telos Tracii XL 2.0	Х	Х	-	X
telos Tracii XL	Х	Х	-	Х
telos Connii MM 2.0	Х	Х	-	Х
telos Connii MM	Х	Х	-	Х
telos Connii	Х	-	-	Х
telos I2C Negative Tester	-	-	Х	Х

To create a new function window simply press on the New button. This will open the dialog shown in figure **??**.

4 Getting Started

IIC New	×
Select Type And Module	
Localhost	
ei-telos Tracii XL 2.0 [SN 0x4716] 	
elos Tracii XL 2.0 [SN 0x788B]	
Master	
- Tracer	
All Devices	
I Script	
	K Cancel

Figure 4.12: New Dialog

This dialog contains a tree with three levels. The first level contains the PC, to which the I2C interface is connected. The second level contains the I2C interface. In this example we have two PCs. One real I2C interface is connected to the local PC: a telos Tracii XL with the serial number 0xD4D8. A telos Connii with the serial number 0x1EA5 is connected to the remote PC with the DNS name dyn16-113.telos.de (IP address 194.173.126.113, IP port 3000). The third level of the tree contains the function window types supported by each I2C interface.

To open e.g. a tracer function window on the telos Tracii XL connected to the local PC simply double click on the Tracer line beneath telos Tracii XL. After double clicking a new function window is created. It gets displayed on the right side of I2C Studio.

To close a function window click on the X button on the upper right side of the window.

4.5 Workspace

After creating a new function window an entry is added to the tree of documents in the workspace window on the left side of I2C Studio, see figure **??**.

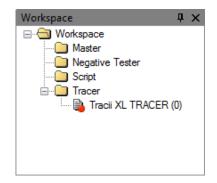


Figure 4.13: Workspace

The tree contains four folders, one for each type of function window supported by I2C Studio. In these folders I2C Studio stores links to opened and closed function windows. The icons in the tree have got the following meaning:

	Folder closed
	Folder opened
Ľ	Function window is closed
×	Function window is closed and cannot be opened
	Function window is opened
B	Function window is opened (stopped state)
Þ	Function window is opened (running state)

The workspace, which is pictured in the example, contains one open function window. It is a function window for the tracer functionality of a telos Tracii XL interface. The tracer is in the stopped state, which can be determined by the icon.

When the user moves the cursor of the mouse over a document in the workspace some information about the document are shown within a tooltip. By double clicking on a closed document, it is possible to open the document.

According to the state of the function window the context menu of a document offers different options:

Open/Close Open or close the appropriate function window file.

Reconnect Associate a new I2C interface with the function window.

Remove From Disk Delete the function window file from disk and its link from the workspace.

Remove From Workspace Delete the function window from Workspace. The file is still available on disk.

Rename Change the name of the function window file.

It is possible to create a new function window not only by using the New button. Another way leads to the context menu of the workspace. Therefore the user simply opens the context menu on one of the folder icons in the tree of the workspace. To create e.g. a master function window, the user opens the context menu on the Master folder and selects New.

The configuration of the workspace is stored in files with the prefix *.i2cw. Workspace files can be created, opened and stored using the items in the File|Workspace menu.

4.6 I2C Scheduler

Figure **??** gives an overview of the I2C Framework and I2C Studio. One central component of the I2C Framework is the I2C scheduler. This component connects the I2C interfaces with the I2C APIs. It is implemented as MS Windows service, which gets started automatically at startup of the PC.

The I2C scheduler acts like a multiplexer/demultiplexer. It makes it possible to communicate simultaneously from several programs with the same I2C interface.

The communication between the I2C scheduler and the I2C APIs uses a TCP/IP channel. Due to this fact it is possible to communicate not only with I2C interface connected to the

4 Getting Started

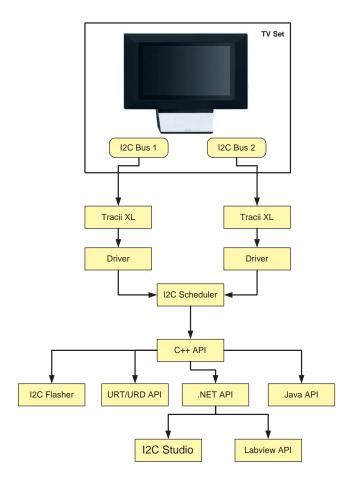


Figure 4.14: I2C Framework

local PC but also with I2C interfaces connected to other PCs in the LAN. This can be useful e.g. for remote diagnostics.

I2C Studio offers a dialog to configure the I2C scheduler running on the local PC and the connection to I2C schedulers running on other PCs. This dialog can be opened by selecting Access |Remote I²C Access in the menu.

The dialog can be divided into two major parts. The upper part serves the configuration of the local I2C scheduler. The Remote Access check box configures whether the local I2C scheduler should accept connection from other PCs in the LAN. The Port input configures the TCP/IP port, on which the I2C scheduler is listing for incoming connections. To prevent a misusage of the local I2C scheduler, it is important to set a secure password.

The second part of the dialog serves the configuration of the connections to I2C schedulers running on remote PCs. To connect to a remote I2C scheduler three parameters are needed: TCP/IP address (DNS name or IP address), TCP/IP port, and password.

In the example, which is shown in figure **??** two remote I2C schedulers have been specified. The Status column of the table shows the current status of the connection. In the example the connection to the first I2C scheduler has been established successfully. The second I2C

IIC Remot	te Access S	ettings						x
- Local I20	Scheduler							
Remo	te Access	Address	moe.telos.de			Pe	ort 3000	-
		Password						
Demote I	2C Schedule							
Status	Remote A	ddress		Port	Passwo	ord		
	194.173.1			3000				
	traciixi.telo	os.de		3000				
Manual	Automatic	1						
	Address				Port	Pag	sword	
	traciid telos de 3000							
Status								
The I2C s	cheduler do	es not respo	nd. Please check, that th	ie I2C scheduler servi	ce is running a	nd no firewalli	ng software	blocks
the TCP/	IP connectio	on to the I2C	scheduler.					
Add/Up	Add/Update Remove Remove All							
					Reset	ОК	Car	icel

Figure 4.15: Remote Access

scheduler cannot be reached by I2C Studio. By selecting one line in the table it is possible to get a detailed description of the reason, why a remote I2C scheduler cannot be contacted.

4.7 Hardware Options

The I2C interfaces offer several hardware and electrical parameters, which can be configured by the software.

Both the master and the tracer function window offer a dialog to configure these parameters. In the master function window this dialog can be opened using the Master|Hardware Options item in the menu. The same dialog can be opened in the tracer function window using Tracer|Hardware Options.

- **Trigger Conditions: Output Testpin** Some I2C interfaces provide an output testpin that can signal certain events. E.g. the I2C interface can trigger this testpin, when it detects a START condition on the I2C-bus.
- **Termination Resistor** Dependent on the bus load the passive termination resistor of the I2C-bus can be adjusted to manipulate the signals slew rate. For long cables and/or

4 Getting Started

IIC Hardware	X
Trigger Conditions: Output Testpin Start Acknowledge Stop Not Acknowledge I2C Protocol Error	Voltage Thresholds Low Level 30 [% VCC]
Termination (Resistor) 10.90 kOhm ▼ SCL 10.90 kOhm ▼ SDA ↓	High Level 70 (% VCC)
Temination (Current Source)	
Termination (Auto Detect) 400 kHz Start	I2C Vcc Supply OFF
Bus Type	Reset OK Cancel

Figure 4.16: Hardware Options

high bitrates it is important to have a sufficient low termination of the I2C-bus.

Termination - Current Source An alternative to control the signals slew rate is to adjust the active current source of the I2C interface. This hardware feature provides a constant current and is therefore independent from voltage deviations, which otherwise have an impact on the current through a passive termination resistor. Therefore the active current source is a more sophisticated possibility to control the rising edges of the I2C-signals. It generates steeper edges with less current than the passive termination.

Remark: Please note, that this feature is only available for telos Tracii XL 2.0 manufactured 2016 or later.

- **Termination (Auto Detect)** Allows to automatically find the optimal termination for the specified bitrate.
- **Voltage Threshold** The voltage thresholds are parameters that define the interpretation of the analog signals. If an I2C-bus signal is high and falls below the low level threshold, it is treated as a high/low transition. If an I2C-bus signal is low and rises above the high level threshold, it is treated as a low/high transition. The default values for an I2C-bus conforming to the I2C specification is a setting of 30%/70%.

Bus Type I2C Studio supports I2C-buses (I2C) and SMBuses (SMB).

I2C Vcc Supply All I2C interfaces have got a I2C Vcc supply pin on their I2C connector. The level on this pin defines the high level of the I2C-bus. Some newer I2C interfaces can generate this voltage internally. The internal supply can be configured using this option.

4.8 I2C Interface "Dummy"

The I2C scheduler does not only communicate with I2C interfaces connected to the local PC, but also implements a virtual I2C interface. This virtual I2C interface can be used e.g. to evaluate I2C Studio without real hardware connected to the PC. Or it can be useful for developing software based on the I2C Framework.

Slave Address	Device
0x0B	Smart Battery: Battery
0x0C	Smart Battery: Charger
0x29	Analog Devices ADM1021A
0x50	256 bytes RAM
0x68	Dallas DS1307

Connected to this virtual I2C interface are five virtual I2C devices:

Some virtual communication between a virtual I2C master and these devices is generated automatically. But it is also possible to communicate with these device manually using e.g. the master function window.

4.9 First Steps Example

To get familiar with the handling of the I2C Studio, the following steps are defined to show an easy example.

• Start the I2C Studio. If no workspace was stored before, an empty workspace will be opened (see figure **??**).

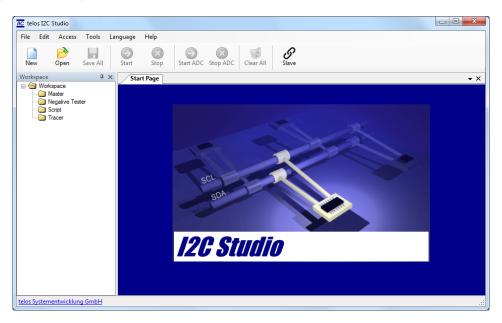


Figure 4.17: I2C Studio with empty Workspace

• Press the New button in the Toolbar or select the File New menu item to open the New Dialog (figure ??)

IIC New
Select Type And Module
Localhost
i⊟ telos Tracii XL 2.0 [SN 0x4716] Master Tracer
i⊟ telos Tracii XL 2.0 [SN 0x788B]
Dummy [SN 0x54AC]
I Tracer
All Devices
OK Cancel

Figure 4.18: New Dialog

- Select for the hardware (telos Tracii XL 2.0 or telos Connii) the desired Mode:
 - Master (continue in chapter ??)
 - Negative Tester (continue in chapter ??)
 - Tracer (continue in chapter ??)

Finally click on the OK button. The Example continues in the chapter of the list above.

To learn more about the I2C Studio features, please read the following chapters.

5 Tracer

5.1 Introduction

One of the function window types, which can be opened in I2C Studio is the tracer window. In contrast to the master window this type of window does not work actively on the I2C-bus. Instead it records the traffic between other I2C masters and slaves on the I2C-bus passively.

Recording the data of an I2C-bus can be useful in different scenarios. E.g. there is an existing system, which does not work as expected. The tracer can then be used as a debugging tool to find e.g. wrong or illegal I2C messages. Another scenario could be the reverse engineering of an existing system, to make e.g. an new system compatible to the existing one.

5.2 Quick Start

To open a new tracer window the developer can use the New button, the File New menu item or the context menu of the workspace.

Note: Not all I2C interfaces can be used as I2C tracer: some I2C interfaces cannot be used as I2C tracer at all, other require a special license.

Figure **??** shows how I2C Studio looks like after opening a new tracer function window. A new item has been added to the workspace. The new tracer function window is displayed on the right side.

5.3 Views

The tracer function window is divided into different views. These views offer different interpretations of the same data traced on an I2C-bus:

- **Time View** Visualizes the data in the time domain. This can be used to detect e.g. stretching on the I2C-bus or to measure the speed of I2C masters on the I2C-bus.
- **Message View** Visualizes the data as a list of I2C messages. This view is useful, when only the transferred data without detailed timing information is of interest. Using this view it is not only possible to see the transferred data bytes, but it is also possible to get an I2C device depended interpretation of the data.
- **Live View** Shows the current value of all registers of the devices connected to the traced I2Cbus.

Statistic View Contains some statistics about the transfers on the I2C-bus.

5 Tracer

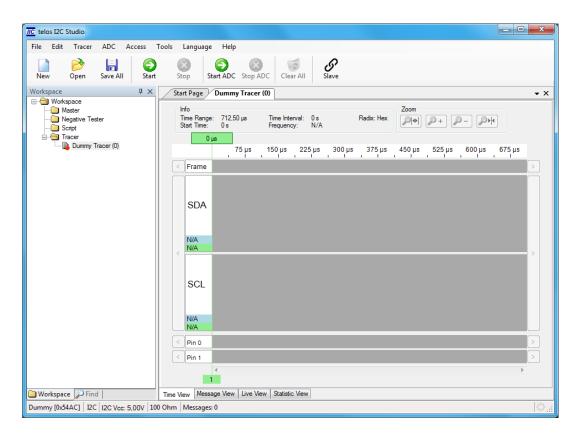


Figure 5.1: New Tracer Window

5.4 Acquire I2C Data

Before it is possible to use any of the views it is necessary to acquire I2C data. The acquisition can be started using the Start button or the menu item Tracer|Start. As soon as the tracer is running the Start button gets greyed out and the Stop button gets enabled.

If there is traffic on the I2C-bus, the "Messages" value in the status bar gets incremented periodically. This value contains the number of I2C messages traced on the I2C-bus. A message starts with a START condition and ends with a STOP condition. This means that combined I2C transfers consisting e.g. of two submessages will be counted as only one I2C message.

The traced I2C data gets streamed to the hard disc, so that the number of I2C messages, which can be traced, is limited only by the space available on the hard disc containing the Windows system directory for temporary files.

While the tracer is running most functions of the tracer function windows can be used in parallel. E.g. it is possible to use the different views to inspect the already traced data. Some functions can be used only while the tracer is in the stopped state.

To finish the acquisition of data the Stop button or the menu item Tracer|Stop can be used.

Restarting the tracer will not delete the already traced data. Instead the new data will be appended to the already acquired data. The deleting of the acquired data can be requested by using the Clear All button, which will also delete some other data, or by the menu item Tracer|Clear.

5.5 Configuration

5.5.1 Tracer Options

Some properties of the tracer function window can be modified using the options dialog of the window. This dialog can be opened using the menu item Tracer |Tracer Options. Figure ?? shows the tracer options dialog.

<u>IIC</u> Tracer		×
Trace Data	I2C Address Filter	
Unlimited	Pass I2C Address Al	lias
Misc		
Trace Input Testpins Auto Scroll	0x0A	ittery
		larger
		Pass All Pass None
	Reset	OK Cancel

Figure 5.2: Tracer Options

In some situations it is necessary to let the tracer run for hours, but only a limited number of messages are of interest to debug a problem. For such situations I2C Studio offers the possibility to limit the data queue to a specific size. This limit can be configured using the slider in the "Trace Data" group box. If the limit is reached, the oldest messages are removed.

If the "Clear At Start" check box is set, the already captured data gets deleted when the tracer is restarted.

Some I2C interfaces have additional digital input lines, whose state can be traced in parallel to the I2C-bus. If the check box "Trace Input Testpins" is set, these lines are traced.

The check box "Auto Scroll" defines, whether the view should jump to the end of the data automatically, when new data arrives. This can be useful especially on an I2C-bus, on which not too many messages are transferred. If this option is enabled, I2C Studio will consume a lot of more resources during tracing. So this option should be used with caution.

Sometimes only messages to specific I2C slaves are of interest. In such situations the I2C address filter can be used. If it has been enabled, only messages to slaves whose I2C addresses are marked as "pass" get recorded. All other messages are not recorded. This means it is not possible to make them visible again at a later time.

5.5.2 IRD & Plug-In Manager

Beside the hardware and the tracer option dialogs there is a third dialog under the Tracer menu item: the "IRD & Plug-In Manager" dialog.

This dialog, which can be seen in figure ??, has got three tasks:

assign alias names to I2C addresses

	fress Scan Scan	Copy Configuration Dummy Tracer (0)			•	Сору
Found	Address	Alias	IRD / Plug-In			Add
	7 0x0B	Battery	SBS Forum: Smart Battery	IRD	X	Clear
	7 0x0C	Charger	SBS Forum: Smart Battery C	IRD	X	Clear
~	7 0x29	ADM 1021 A	Analog Devices: ADM 1021	IRD	X	
V	7 0x68	DS 1307	Maxim: DS 1307	IRD	X	
V	7 0x50		=== Not Mapped ===	IRD	X	

Figure 5.3: IRD & Plug-In Manager

- assign IRD or plug-in files to I2C addresses
- execute a scan for slaves connected to the I2C-bus

Using the **Copy** button it is possible to copy the configuration of another open function window.

Alias Names

For a human being is it always difficult to remember which I2C devices uses which I2C address. So to make it more convenient it is possible to assign an alias name to an I2C address. The tracer function window will show these alias names additionally to the I2C addresses in all places, where I2C addresses are used.

To add a new alias name simply press on the Add button. A new form will be opened asking for the I2C address. After entering the desired I2C address, the user can simply click somewhere outside the form. This will add the I2C address to the table and close the form. In the table the user can click into the "Alias" cell of the new row and enter the desired alias name.

IRD/Plug-Ins

When debugging complex problems it is very time-consuming to compare the transferred raw data with the data-sheets of the used ICs. That is why I2C Studio offers the I2C Register Description (IRD) and the plug-in interface.

Using IRD or the plug-in files I2C Studio can display the raw data in an interpreted format. This higher-level view displays the meaning of the transferred data for an IC. This means that e.g. I2C Studio displays that "20 °C" has been read from the "External Temperature" register of a temperature sensor.

IRD is a XML based file format, which can be used to describe the register and values of an IC. The plug-ins can be written with any programming language supporting Microsoft's .NET framework. I2C Studio comes along with a large number of ready to use IRD and plugin files. In addition the user can write its own files.

To assign an IRD or plug-in file to an I2C address, simply open the "IRD/Plug-In" combo box in the appropriate row of the table and choose the desired IRD or plug-in file. If there is not already a row for the desired I2C address, use the Add button.

User written IRD and plug-in files must be copied to the following folders:

IRD <Documents>\I2C Studio\ird
Plug-In <Documents>\I2c Studio\plugins

I2C Address Scan

When working with an existing system, it is not always known, which I2C addresses are used by the I2C slaves. To examine an I2C-bus an I2C address scan can be started by pressing the **Scan** button.

The address scan tries to read data from each valid I2C address. If the read is answered, this I2C address gets marked as to be in use.

Note: The I2C address scan does not necessarily find all I2C addresses, which are in use. A lot of I2C devices on the market do not comply exactly to the I2C specification. Furthermore the I2C slave can be in a busy state, while the I2C address scan is running.

The result of the I2C address scan is shown in the first column of the table. The icons have got the following meaning:

- ☑ I2C address is in use
- I2C address is not in use or no I2C address scan has been run

5.6 Analog Mode

5.6.1 Introduction

The normal I2C tracer is a great help to debug most of the daily problems when working with I2C-busses. In some cases the digital view of the I2C-bus gives the developer not enough information to fix his problems.

In such situations the analog mode of the tracer comes into play.

Note: Not all I2C interfaces support the analog mode: some I2C interfaces does not support this feature at all, other require a special license.

The analog mode works like a stand alone oscilloscope. The user specifies a trigger condition and some other parameters and starts the analog mode. As soon as the trigger condition gets fulfilled by the data transferred on the I2C-bus, the I2C interface starts to record analog samples of the SCL/SDA lines. Like with a stand alone oscilloscope the sample depth is limited by the sample buffer on the I2C interface:

I2C Interface	Sample Depth
telos Tracii XL	64 kSamples/line
telos Tracii XL 2.0	256 kSamples/line

After the sampling has been completed, the data gets transferred to the PC. When the transfer is completed, the analog mode can be restarted

I2C Studio visualizes the analog data in parallel to the I2C messages and the levels of the input testpins.

5.6.2 Acquire Analog Data

The waiting for the trigger can be activated by using the menu item ADC|Start or by using the Start ADC button in the toolbar. After selecting start the Start ADC button gets greyed out and the Stop ADC button gets enabled.

When the analog mode has found the trigger condition on the I2C-bus and the analog data has been transferred to the PC, the Start ADC button gets activated again.

Starting the acquisition of the analog mode again will not delete the samples of the previous acquisitions. There are two ways to delete the acquired analog data. The Clear All will delete the samples together with the traced I2C messages and the levels of the input testpins. The menu item ADC|Clear will delete only the analog data.

In some situations trigger conditions do not really help to find a problem, e.g. if there the lines of the I2C-bus have not been connected correctly. For such situations I2C Studio offers the manual shot, which can be started using the menu item ADC|Manual Start. This starts the sampling of the analog data immediately.

5.6.3 Configuration

There are a lot of options, which can be configured for the analog mode. The configuration dialog can be opened by clicking on the ADC|Options menu item. Figure ?? shows the configuration dialog.

The following parameters can be configured:

TC ADC	
Event Trigger 12C Events Start Stop Acknowledge Not Acknowledge 12C Protocol Error Testpin Events Input Testpin 0 (Low) Input Testpin 1 (Low)	Sampling Rate 1.00 MHz Pretrigger 4126 (Samples/Channel] 0 ms 4.13 ms 262,14 ms Trigger Selection © Event Message Count Enhanced Miscellaneous Automatic Restart Reset OK Cancel

Figure 5.4: ADC Options: Event Trigger

- **Sampling Rate** Defines how many samples per second get recorded. Because the sample depths of the I2C interfaces are limited, this parameter also defines the length of the shot. Typically the sampling rate should be at least at factor 10 higher than the highest I2C clock rate on the I2C-bus. So if the system under test uses I2C clock rates up to 100 kHz, the sampling rate should be at least 1 MHz to get a good resolution of the recorded signal.
- **Pretrigger** For most scenarios the developer is interested not only in the analog waveform after the trigger condition, but also some samples before the trigger condition are needed. The pretrigger value defines, how many samples should be recorded prior and after the trigger condition.
- **Trigger Selection** I2C Studio offers three groups of ADC trigger conditions. The active one can be selected using this option.
- **Miscellaneous** Normally the ADC module takes only one shot after receiving the trigger condition. If the Automatic Restart switch is enabled, I2C Studio waits automatically for the next trigger after the previous ADC shot has been completed.
 - **Note:** There is always a short time between finishing the sampling of one shot and reactivating the trigger module for the next one. Due to this fact I2C Studio may miss some trigger conditions.

When the user changes the Trigger Selection, the left part of the dialog gets changed.

5 Tracer

Event Trigger

The event trigger group contains very basic trigger conditions. It is possible to trigger on the following I2C events:

- START condition
- STOP condition
- acknowledge
- not acknowledge
- I2C protocol error

If more than one condition is enabled, the ADC shot gets triggered when one of the enabled conditions is fulfilled.

These triggers are very easy to configure and use, but on an I2C-bus with heavy load they are only of limited use, because e.g. normally all I2C messages start with a START condition.

Besides the trigger on I2C events this group also contains triggers for the input testpins. A high-low transition on an input testpin can be used as trigger condition.

Message Trigger

IIC ADC	×
Message Trigger Message Count Trigger n-th Message 10 I2C Events I2C Protocol Error	Sampling Rate 1.00 MHz Pretrigger 4126 [Samples/Channel]
Testpin Events Input Testpin 0 (Low) Input Testpin 1 (Low)	0 ms 4.13 ms 262.14 ms
	Trigger Selection Event Kessage Count Enhanced Miscellaneous Automatic Restart
	Reset OK Cancel

Figure 5.5: ADC Options: Message Trigger

In some cases the developer knows exactly at which position the message of interest is sent. In such a scenario the Message Count Trigger can be used. If this value is set e.g. to "10", the shot is triggered with the 10th message seen on the I2C-bus, after pressing the Start ADC button.

Additional it is possible to trigger on an I2C protocol error and on high-low transitions of the input testpins.

After one of the enabled trigger conditions get fulfilled, the ADC shot is triggered.

Enhanced Trigger

IIC ADC	×
Enhanced Trigger	Sampling Rate
Address	1,00 MHz
V Enable 0x50 7 Bit V V	Pretrigger
Data Bytes	4126 Samples/Channel]
0 XX Hex v 1 XX Hex v 2 XX Hex v 3 XX Hex v	· · · · · · · · · · ·
4 XX Hex 👽 5 XX Hex 👽 6 XX Hex 👽 7 XX Hex 👽	0 ms 4,13 ms 262,14 ms
8 XX Hex 👽 9 XX Hex 👽 10 XX Hex 👽 11 XX Hex 👽	Trigger Selection
12 XX Hex 👽 13 XX Hex 👽 14 XX Hex 👽 15 XX Hex 👽	⊘ Event
16 XX Hex 👽 17 XX Hex 👽 18 XX Hex 👽 19 XX Hex 👽	Message Count Enhanced
20 XX Hex 👽 21 XX Hex 👽 22 XX Hex 👽 23 XX Hex 👽	Miscellaneous
24 XX Hex 👽 25 XX Hex 👽 26 XX Hex 👽 27 XX Hex 👽	Automatic Restart
28 XX Hex 👽 29 XX Hex 👽 30 XX Hex 👽 31 XX Hex 👽	
32 XX Hex 👽 33 XX Hex 👽 34 XX Hex 👽 35 XX Hex 👽	
Clear	
	Reset OK Cancel

Figure 5.6: ADC Options: Enhanced Trigger

On an I2C-bus with several devices connected to complex trigger conditions are needed. In such scenarios the Enhanced Trigger mode could be used, which can be seen in figure ??.

Using the Address field it is possible to trigger on I2C messages, which are sent to a device with the specified slave address. Furthermore it is possible to configure the direction of the transfer to be triggered on:

W The master writes data to the slave.

R The master reads data from the slave.

R/**W** The master reads or writes data from/to the slave.

The Data Bytes field can be used to trigger on specific values for data bytes. E.g. the dialog in figure **??** has been configured to trigger, when the second byte of an I2C submessage equals "0x20" and the lower 4 bits of the third byte equals "0x03".

All values in the Address and the Data Bytes field must be fulfilled in the same I2C submessage to trigger the ADC shot.

To give a small example of the Enhanced Trigger usage lets assume the following setup: there is I2C slave at address 0x30, whose high-level protocol is register-based. The registers are addressed by a 8-bit register pointer. The user wants to get an analog shot of the time when the I2C master reads data from register "0x55".

5 Tracer

For this scenario the user would set the Address field to "0x30" and "W". In the Data Byte field the user would set the first byte to "0x55" and all other bytes to Don't Care (XX).

5.7 Time View

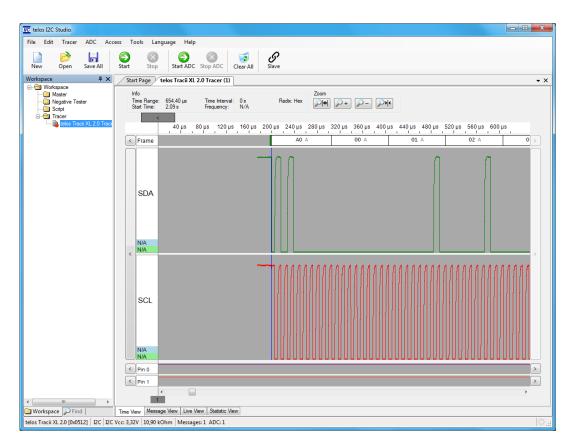


Figure 5.7: Time View

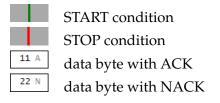
The time view offers a visualization of the traced data in the time domain. Figure **??** shows the time view.

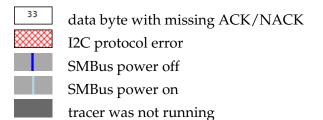
The visualization can be divided into three parts: frame data, analog data, and input testpin data. All parts are synchronized.

Note: The timing information of the I2C interfaces "telos Connii MM" and "telos Connii MM 2.0" are not accurate. Due to this reason the time view gives only a rough information of the timing on the I2C-bus for these I2C interfaces.

5.7.1 Frame Data

The frame data part displays the data, which has been recorded on the I2C-bus. The following symbol are used for the visualization:





Hex Radix 🔹
Virtual Bit Level
Analog •
Testpins +
Zoom Selected
Go To Message Ctrl+G
Message Tool Tips
Copy To Clipboard

Figure 5.8: Time View: Context Menu

It is possible to change the radix of the displayed data bytes using the context menu.

Using the context menu switch Virtual Bit Level (see figure ??) it is possible to enable a second interpretation of the I2C data. This view shows the high/low transitions of the SCL/SDA lines.

Note: The "Virtual Bit Level" view is not based on timing information measured on the I2C-bus. The timing of the real transitions on the I2C-bus may differ from the one in the visualization.

If the option Messages Tool Tips in the context menu is enabled, additional information about an I2C message are shown, when the mouse cursor is moved over the elements of this I2C message.

5.7.2 Analog Data

The analog data part shows the analog electrical levels on the I2C lines SDA and SCL.

During the development process the developer often needs to have a look at the electrical layer of the I2C-bus. The I2C-bus has got several parameters like e.g. the bus termination or the cable capacitance, which the I2C-bus has to fulfil to get a working set-up.

Adjusting these parameters is much easier, if the user has got a view of the electrical levels. Standard digital oscilloscopes come to their limitation, if they are used for the I2C-bus, because most of them cannot trigger on I2C conditions.

The switches in the context menu under Analog can be used to enable or disable the view of the SCL and/or SDA analog data.

The position of the trigger in the analog data gets marked with a blue line.

5.7.3 Digital Input Lines

The transitions on additional digital input lines (input testpins) can be monitored in the third part of the time view.

The number of the available lines depend on the used I2C interface.

If the bus type has been set to SMBus for the tracer function window, the lines get renamed from "Pin 0" to "Alert" and from "Pin 1" to "Suspend". This reflects the special meaning of the lines for the SMBus.

The visualization of the input testpins can be enabled or disabled using the context menu items under **Testpins**.

5.7.4 Navigation

There are various methods to navigate within the time view.

One method is to simply use the vertical scroll bar. With this scroll bar it is possible to move forward and backward in the traced I2C data. This is a good method to navigate within the data bytes of one message, but it can be quite difficult to find e.g. the beginning of the next I2C message.

In such a situation another method comes into play. There are several < and > buttons. They have got the following meaning in the different parts of the time view:

Frame Data Jump to the previous or next START condition.

Analog Data Jump to the previous or next beginning of an analog shot.

Digital Input Lines Jump to the previous or next transition of the line.

IIC Go To Message
Message (054)
26
OK Cancel

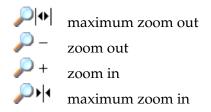
Figure 5.9: Time View: Go To Message

To jump to an I2C message with a known number, the "Go To Message" dialog can be used, which is shown in figure **??**. This dialog can be opened using the context menu item **Go To** Message.

By double-clicking somewhere into the data all other views are synchronized to this time.

5.7.5 Zoom

At the upper right corner of the time view there are four buttons to zoom in the visualization. The buttons have got the following meaning:



There is an additional way to zoom into the data. By holding the left button of the mouse down while moving the mouse over the time view it is possible to select a part of the currently visualized data. Using **Zoom Selected** from the context menu this part can be magnified to the full width of the time view window.

5.7.6 Measuring

The time view offers two cursors, which can be used to measure the signals on the SDA and SCL lines. The cursors can be moved by holding down the left mouse button over one of the cursors.

The upper box of each cursor displays the time difference between the left border of the time view and the cursor. The time corresponds to the time ruler on the upper part of the time view.

If there is analog data available under the current position of the cursor, the corresponding voltages of the SDA and SCL line are displayed on the left side of the time view.

Some more time information can be found in the "Info" box at the upper part of the time view. The values of this box have got the following meaning:

- **Time Range** Describes the length of time of the data currently displayed starting from the left side and ending with the right side of the time view.
- **Start Time** Time of the left edge of the time view measured from the time, when the tracer has been started.
- **Time Interval** The time between the two cursors.
- **Frequency** "Time Interval" converted to a frequency value. This can be used to determine e.g. the frequency of an I2C master by measuring the bits of an analog shot.

Radix Radix currently used by the time view. It can be changed using the context menu.

5.7.7 Export / Copy to Clipboard

The visualization of the time view can be exported to an image. This image can be stored in an external file or in the system's clipboard.

To export the image to a file simply use the menu item File|Trace Data|Export. This opens the wizard for exporting the recorded I2C data. On the first page of the wizard the user must select the type of view which should be exported to the file. After choosing "Time View" a second page gets opened, which is used to configure what data should be exported, see figure ??.

If the image should be used in another MS Windows application, it can be exported directly to the clipboard of the system. This can be done by selecting **Copy to Clipboard** from the context menu of the time view. This opens directly the options page of the export wizard.

IC Export	×
Configurati	ion
Time View	
Format	
Format	Bitmap (*.bmp)
Resolution	1024 v x 266
Optimized For	OFF
Channels Image: Message Image: ADC SDA Image: ADC SCL	Image: Wisc Image: Wisc <
Status 1 image to expo	ort. < Back Next > Cancel

Figure 5.10: Time View: Export

The wizard will export those data, which is currently visible in the time view. If the user wants to export the complete traced data, he must zoom out so that everything is visible in the view and start the wizard.

The option page offers the following parameters, which can be configured:

- **Format** The user can choose between the following three image formats:
 - **Bitmap (*.bmp)** Very common format in the MS Windows world, which is supported by nearly all programs. As these files are not compressed, they get quite large.
 - **Joint Photographic Experts Group (*.jpg)** Format offering a very high, but lossy compression. Has been developed for the storage of photographs, so that it does not offer a really good image quality for I2C Studio's purposes.
 - **Portable Network Graphics (*.png)** Offers a good lossless compression resulting in acceptable file sizes. Very good suitable for files created with I2C Studio.
 - **Tagged Image File Format (*.tif)** Offers a good lossless compression resulting in acceptable file sizes. Very good suitable for files created with I2C Studio.
- **Resolution** Defines the width and the height of the images to be created. The user can only specify the width, the height gets calculated automatically.
- **Optimized For** If the user selects to export several I2C messages at the same time, he will always result into images, whose resolution is too low to see any interesting details. To solve this problem, I2C Studio offers a functionality to split the result into several separate image files.

5 Tracer

This option configures the number of images, which are created. To make the user the decision, how many images are needed, very easy, he can simply specify the needed resolution as frequency.

Let us assume the traced I2C-bus uses a clock rate of 400 kHz. For this set-up the user would simply select an "Optimized For" value of 400 kHz. If there are analog shots of the electrical levels available, typically higher frequencies like e.g. 6 MHz should be selected.

- **Channels** Sometimes the user do not want to export all available parts of the time view. Using these switches the miscellaneous parts can be selected or deselected to be exported.
- **Misc** The "Timescale" options defines, whether a timescale is added to the exported files or not.
- **Status** Displays the number of images, which will be created, when user would export the data with the current settings.

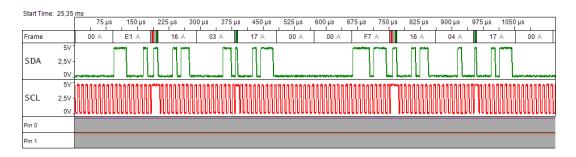


Figure 5.11: Time View: Exported Data

After clicking on Next > the third page of the wizard gets visible. On this page the user must enter the name of the file to be created. A click on the Finish button finally starts the creation of the file(s). Figure **??** shows a typical file, which has been created using the export wizard.

5.8 Message View

Very often during the development process the exact timing information of each byte are not of interest. Instead the developer needs information about the transferred data. This is the domain of the message view in I2C Studio.

There are three different modes in the message view: raw mode, register mode, and value mode. It is possible to switch between these modes by using the toggle buttons at the upper part of the message view.

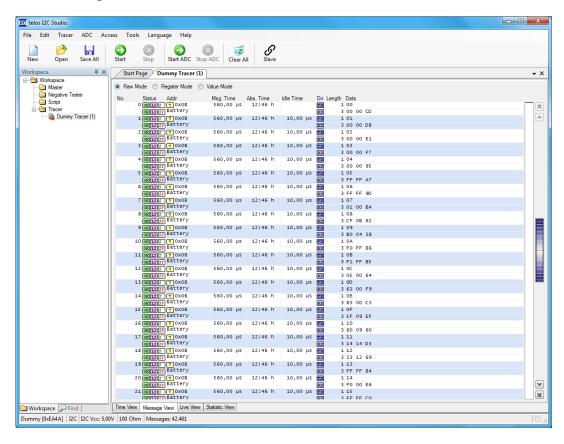


Figure 5.12: Message View: Raw Mode

Figure **??** shows the message view in the raw mode. The I2C data, which has been traced on the I2C-bus, gets displayed as a table.

5.8.1 Navigation

On the right border of the view there are some controls to navigate within the table.

The buttons have got the following functions:

- ス Jump to the first message.
- Jump to the previous message.
- ✓ Jump to the next message.
- \checkmark Jump to the last message.

Another method to navigate in the I2C data is the thumb wheel. By moving the wheel up or down the message view starts to scroll upwards or downwards. After releasing the wheel, the scrolling stops. Scrolling speed is affected by the angle of the wheel.

Next to the buttons and the thumb wheel there is another control, which displays the current position within all I2C messages. This control can be used not only to determine the position but also to jump to a specific position. The user can simply click into the control to define the new position, which should be visualized by the message view.

To jump to an I2C message with a known number, the "Go To Message" dialog can be used, which is shown in figure **??**. This dialog can be opened using the context menu item **Go** to Message.

By double-clicking on a row containing an I2C message all other views get synchronized to this message.

5.8.2 Raw Mode

The raw mode displays the data bytes as they get transmitted on the I2C-bus.

Each row of the table contains one I2C message. If an I2C message consists of several I2C submessages, they are displayed among each other.

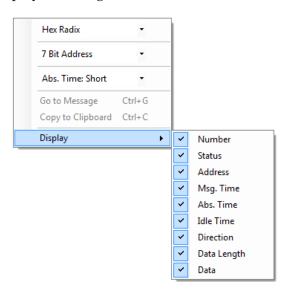


Figure 5.13: Message View: Context Menu

The columns of the table can be enabled or disabled using the context menu items under Display, see figure **??**. They contain the following information:

No Position of the I2C message within the traced messages.

Status The three icons have got the following meaning:

1st lcon Shows whether the I2C messages has been transferred successfully:

0K	no error
00	I2C address has not been acknowledged
Ā	one of the data bytes has not been acknowledged

2nd Icon Shows whether the I2C message has been transferred in the high-speed mode:

- Image: Isolar systemIsolar systemImage: Isolar systemImage: Isola
- **3rd Icon** Shows whether the START and the STOP conditions have been send one the I2C-bus:
 - s only START condition
 - START and STOP condition
 - only STOP condition
- **Addr** Address of the I2C slaves, which has received the I2C message. As default the address gets displayed as a 7-bit addresses with a hexadecimal representation. The numeric format can be changed using the context menu item Hex Radix. Some data sheets specify the I2C addresses in the 8-bit format. This format can be enabled in the message view with the 7 Bit Address switch in the context menu.

The icons can have got the following meaning:

- **7** 7-bit I2C address
- 8 7-bit I2C address (8-bit representation)
- 10-bit I2C address

If an alias name has been registered for the displayed I2C address, this name gets shown in this column.

- **Msg. Time** The message time is measured from the first START condition of the I2C message to the STOP condition.
- **Abs. Time** The absolute time is the time of the first START condition. The user can choose between three different formats using the context menu item Abs. Time: Short. The formats "Short" and "Complete" refer to the real-time clock of the PC. In the format "Relative" the time is relative to the time, when the I2C tracer has been enabled the first time.
- **Idle Time** The idle time is measured from the STOP condition of the previous I2C message to the START condition of the current I2C message.
- **Dir** An I2C message can be transferred into two directions. This column displays, which one has been used:



master transmitter master receiver

- Length Number of data bytes (does not include the bytes of the I2C address).
- **Data** Data bytes (does not include the bytes of the I2C address). Using the context menu it is possible to change the numeric format from hexadecimal to decimal.

5 Tracer

New Open Save All								
	Start Stop	Start ADC Stop	ADC Clear A	All Slave				
orkspace 🛛 🗛 🗙	Start Page	Dummy Tracer (1)						•
- Workspace								
Master	🔘 Raw Mode 🧕) Register Mode 🔘 V	alue Mode					
Negative Tester	No. Status		Msg. Time	Abs. Time	Idle Time	Dir Register	Data	
Script	O OK PEC	<pre>7 0x0B Battery</pre>	560,00 µs	12:46 h		RX Manufacturer Access (0x00)	00 00	
E Tracer	1 OK PEC	7 0x0B Battery	560,00 µs	12:46 h	10,00 µs	RX Remaining Capacity Alarm	00 00	
Dummy Tracer (1)						(0x01)		
		7 0x0B Battery		12:46 h		Remaining Time Alarm (0x02)	00 00	
		7 0x0B Battery		12:46 h		EX Battery Mode (0x03)	00 00	
	4 OK PEC			12:46 h		At Rate (0x04)	00 00	
	5 OK PEC			12:46 h 12:46 h		EX At Rate Time To Full (0x05)	FF FF FF FF	
	0 0K PEC	7 0x0B Battery		12:46 h		RX At Rate Time To Empty (0x06) RX At Rate OK (0x07)	FF FF 01 00	
				12:46 h			CF 0B	
	8 OK PEC			12:46 h		EX Temperature (0x08) EX Voltage (0x09)	B0 04	
	9 OK PEC 10 OK PEC			12:46 h		EX Current (0x0A)	F0 FF	
		7 OXOB Battery		12:46 h		EX Average Current (0x0B)	F1 FF	
	12 OK PEC			12:46 h		RX Max Error (0x0C)	05 00	
		7 0x08 Battery		12:46 h		EX Relative State Of Charge	63 00	
	A DIVIDED	i oxob baccery		12.40 11	20,00 00	(0x0D)	05 00	
		7 0x0B Battery		12:46 h	10,00 µs	Absolute State Of Charge (0x0E)	63 00	
	15 OK PEC			12:46 h		RX Remaining Capacity (0x0F)	5F 09	
	16 OK PEC			12:46 h		EX Full Charge Capacity (0x10)	60 09	
		<pre>? 0x0B Battery</pre>		12:46 h		RX Run Time To Empty (0x11)	14 14	
	18 OK PEC			12:46 h		RX Average Time To Empty (0x12)	23 12	
	19 OK PEC			12:46 h		RX Average Time To Full (0x13)	FF FF	
	2 0 OK PEC			12:46 h		EX Charging Current (0x14)	F0 00	
	21 OK PEC			12:46 h		RX Charging Voltage (0x15)	FF FF	
	2 2 OK PEC			12:46 h		RX Battery Status (0x16)	40 00	
	2 3 OK PEC			12:46 h		EX Cycle Count (0x17)	F6 07	
	24 OK PEC			12:46 h		EX Design Capacity (0x18)	60 09	
	25 OK PEC			12:46 h		EX Design Voltage (0x19)	B0 04	
	2 6 OK PEC			12:46 h		EX Specification Info (0x1A)	31 00	
	27 OK PEC			12:46 h		EX Manufacture Date (0x1B)	91 46	
	2.8 OK PEC	7 0x0B Battery 7 0x0B Battery		12:46 h		EX Serial Number (0x1C)	32 E5 74 65 6C 6F 73	
	29 OK			12:46 h		EX Manufacturer Name (0x20)	74 65 6C 6F 73 53 6D 61 72 74 20 42 61 74 74	
	30 0K	7 OxOB Battery	567,50 µS	12:46 0	2,50 µS	EX Device Name (0x21)	53 6D 61 /2 /4 20 42 61 /4 /4 65 72 79	
	31 OK	7 0x0B Battery	185,00 µs	12:46 h	2,50 µs	RX Device Chemistry (0x22)	4E 69 43 64	
	32 010	7 0x0B Battery		12:46 h		RX Manufacturer Data (0x23)	B5 B9 E4 64 65 E6 4E 62 91 5A	1.1
							BB BE BB BC 23 33 45 AD E8 5D 84 1B E7 33 84 A6 6F AF 17 14 13 07	
	33 OK	7 0x0C Charger	117,50 µs	12:46 h	52,50 µs	RX Charger Spec Info (0x11)	01 00	
	34 016	7 0x0C Charger				TX Charging Current (0x14)	E8 03	
	35 OK	7 0x0C Charger			52,50 µs	TX Charging Voltage (0x15)	FF FF	
	36 01	7 0x0C Charger				TX Alarm Warning (0x16)	00 80	
	37 010	7 0x29 ADM	380,00 µs			RX Status (0x02)	00	
Workspace Dind		ge View Live View S						

Figure 5.14: Message View: Register Mode

5.8.3 Register Mode

If IRD or plug-in files have been registered, the register mode offers a high-level view of the transferred data. The user can see, which data gets read or written from or to a specific register.

Figure **??** shows the register mode. The visualization is based on the same data as the raw mode shown in figure **??**. So e.g. the first I2C message has been converted from transmitting of "0x00" and receiving of "0x00 0x00 0xCD" into reading "0x00 0x00" from the "Manufacturer Access" register.

The columns have got the following meaning:

No See section ??.

Status The two status icons have got the following meaning:

1st lcon Shows whether the I2C messages has been transferred successfully:

- ok no error
- I2C address has not been acknowledged
- one of the data bytes has not been acknowledged

2nd Icon Shows information about the SMBus feature "Packet Error Checking" (PEC):

no PEC checksum available

PEC checksum available and ok

PEC checksum available and wrong

Addr See section ??.

Msg. Time See section ??.

PEC

Ā

Abs. Time See section ??.

Idle Time See section ??.

Dir The data can be read from the register and written to it. This icon specifies the direction:

TX RX

data is written to the register data is read from the register

- **Register** Name of the register. The address pointer value of the register is specified in brackets after the name.
- **Data** Data bytes, which have been read from the register or written to it. Using the context menu it is possible to change the numeric format. The default format is hexadecimal.

5.8.4 Value Mode

Like the register mode the value mode is based on IRD or plug-in files, too. It offers a visualization of the messages one level higher than the visualization offered by the register mode. In most cases one register does not contain exactly one value. E.g. a 8-bit register can contain eight status bits or a 32-bit value is stored in four 8-bit registers.

This mode converts the transferred raw data to their meaning on the value level. Figure **??** shows the message view in the value mode. Lets take message three as an example. The I2C message with the raw data "0x03" and "0x00 0x00 0xF7" has been converted to several values. This transfer reads e.g. "Not Supported" from the "Internal Charge Controller" value of the IC.

The columns of the message view have got the following meaning in this mode:

No See section ??.

Status The two status icons have got the following meaning:

1st lcon Shows whether the I2C messages has been transferred successfully:

- ok no error
- I2C address has not been acknowledged
- one of the data bytes has not been acknowledged

2nd Icon Shows information about the SMBus feature "Packet Error Checking" (PEC):

- no PEC checksum available
- me PEC checksum available and ok
- PEC checksum available and wrong

3rd Icon Shows whether the data is within the allowed range or not:

5 Tracer

-	ess Tools Language Help						
New Open Save All	Start Stop Start ADC Sto	p ADC Clear All	Slave				
orkspace 4 ×	Start Page Dummy Tracer (1)						•
Master	💿 Raw Mode 💿 Register Mode 🧕	Value Mode					
Negative Tester	No. Status Addr	Msg. Time Abs. T	Time Idle Time	Dir Value	Data	Registers	
Cipt	0 OKPECTS 7 OXOB Battery			EX Manufacturer Access		0x00 (0.01.7)	
Dummy Tracer (1)	1 OKPEC<> 7 OXOB Battery			RX Remaining Capacity Alarm	0 mAh @ C/5 (0x0000)	0x01 (0.01.7)	
	2 OKPEC <> 7 OXOB Battery	560,00 µs 12:	:46 h 10,00 µs	RE Remaining Time Alarm	0 min (0x0000)	0x02 (0.01.7)	
	3 OKPECCS 7 OXOB Battery	560,00 µs 12:	:46 h 10,00 µs	EX Internal Charge Controller	Not Supported (0x00)	0x03 (0.0)	
	OK PEC <>			RX Primary Battery Support		0x03 (0.1)	11
	OK PEC <>			EX Condition Flag		0x03 (0.7)	1
	OKPEC			Enabled	Internal Charge Control Disabled (0x00)		
	OKPEC<>			EX Primary Battery	Battery Operating In It Primary Role (0x00)		
	<>33930			EX Alarm Mode	Broadcasts (0x00)	0x03 (1.5)	
	(C2) (334) X0			EX Charger Mode	Enable ChargingVoltage And ChargingCurrent Broadcasts (0x00)		
	OKPEC			RX Capacity Mode	(0x00)	0x03 (1.7)	
	4 OKPECCO 7 OXOB Battery			RX At Rate		0x04 (0.01.7)	
	5 OKPEC<> 7 OXOB Battery			EX At Rate Time To Full	(0xFFFF)	0x05 (0.01.7)	
	6 OKPECKS 7 OXOB Battery			EX At Rate Time To Empty	(0xFFFF)	0x06 (0.01.7)	
	7 OXPECCO 7 OXOB Battery			EX At Rate OK		0x07 (0.01.7)	
	8 OKPEC<> 7 OXOB Battery			EX Temperature		0x08 (0.01.7)	
	9 OKRECS 7 OXOB Battery			ex voltage		0x09 (0.01.7)	
	10 OXPECCS 7 OXOB Battery			Ex Current		OXOA (0.01.7)	
	11 OKPEC<> 7 OXOB Battery			EX Average Current		0x0B (0.01.7)	
	12 OXPECES 7 OXOB Battery			Max Error		0x0C (0.01.7)	
	13 OKPECCO 7 OXOB Battery			EX Relative State Of Charge		0x0D (0.01.7)	
	14 OKPECCO 7 OXOB Battery			EX Absolute State Of Charge		0x0E (0.01.7)	(
	15 OKPECES 7 OXOB Battery			Remaining Capacity		0x0F (0.01.7)	
	16 OXPECCO 7 OXOB Battery			EX Full Charge Capacity		0x10 (0.01.7)	
	17 OKPEC<> 7 OXOB Battery			EX Run Time To Empty		0x11 (0.01.7)	
	18 OK PECKS 7 OXOB	560,00 µs 12:	:46 h 10,00 µs	RX Average Time To Empty	4643 min (0x1223)	0x12 (0.01.7)	

Figure 5.15: Message View: Value Mode

	<	>	
1	<	>	

data is within the range data is out-of-range / invalid

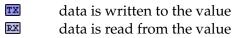
Addr See section ??.

Msg. Time See section ??.

Abs. Time See section ??.

Idle Time See section ??.

Dir The data can be read from the register and written to it. This icon specifies the direction:



Value Name of the value.

Data Data, which has been read from the value or written to it.

Registers Gives detailed information about the registers, which are used to store the data of this value. The register are specified in the format "0xaa (b.c) or "0xaa (b.c..d.e)". "aa" is the address pointer of the register, "b" and "d" are the n-th byte of the register and

"c" and "e" are the n-th bit of this byte. So e.g. "0x10 (0.0..0.7)" stands for the first byte of register "0x10".

essage View				
	ll (*.bd)			✓ ✓
Message Range Start Message	0		End Messa	age 54
Mode Raw View Register View Value View		Message Time 📝 Absolute Time 📝 dle Time	Data Length Co	solute Time Mode

5.8.5 Export / Copy to Clipboard

Figure 5.16: Message View: Export

The traced I2C data can be exported to an external file or to the clipboard using the visualization of the message view. The exporting to a file gets configured using a wizard, which can be started via the File|Trace Data|Export menu item. After selecting "Message View" on the first page of the wizard, the wizard should look like that one, which is shown in figure ??.

To export the data to the system's clipboard, simply select **Copy to Clipboard** in the context menu of the message view.

The option page of the export wizard offers the following options:

Text The user can select between three different formats:

- **ASCII** (*.txt) The data gets exported to a formatted ASCII file. Using the "Line Width" parameter it is possible to configure the width of the created table. This format is humanly readable.
- **Character Separated Values (*.csv)** The CSV format can be imported into a lot of programs like e.g. Microsoft Excel or OpenOffice. Furthermore it is very simply to write own parsers for this format. It conforms to RFC 4180. With the "Separator" switch the user can select, whether the cells in the file should be separated with commas or semicolons.

- **HyperText Markup Language (*.html)** Creates a humanly readable HTML file, which can be viewed with most standard WWW browsers like e.g. Mozilla or the Internet Explorer. It conforms to XHTML 1.0.
- **Compression** If the data is exported to a file, it is possible to compress the data:

Plain Do not use any compression.

- **Zip** Use the ZIP format, which is supported by most compression tools on MS Windows like e.g. WinZip or 7-Zip.
- **GZip** Use the gzip format, which is very common in the Linux world, but also supported by most tools on MS Windows.
- **Message Range** Specifies the messages, which should be exported.
- **Mode** Like in the GUI there are three modes, which can be chosen.
- **Columns** Defines the columns, which should be exported. The available columns depend on the selected mode.
- **Absolute Time Mode** Configures the format of the absolute time column. The user can choose between three different formats. The formats "Short" and "Complete" refer to the real-time clock of the PC. In the format "Relative" the time is relative to the time, when the I2C tracer has been enabled the first time.

c:\te	mp\expo	rt.html - t	elos I20	C Studio -	Mozil	la Firefox				
tei	Bearbeit	en <u>A</u> nsi	cht 🤇	hronik	Lesez	eichen E <u>x</u> tras <u>H</u> i	lfe			
-	i -	@ @		In file	:///C:	/temp/export.html			V Doogle	
	P	-								
Erst	e Schritte	🔂 Aktu	ielle Na	chrichten	₿ Q G	olem.de				
o .	Sub. Msg	Status	PEC	Range	Dir.	Address	Message Time	Value	Data	Register(s)
0	0	OK	OK	OK	RX	0x0B Battery	560,00 µs	Manufacturer Access	0 (0×00)	0x00 (0.01.7
1	0	OK	OK	OK	RX	0x0B Battery	560,00 µs	Remaining Capacity Alarm	0 mAh @ C/5 (0x0000)	0x01 (0.01.7
2	0	OK	ок	OK	RX	0x0B Battery	560,00 µs	Remaining Time Alarm	0 min (0x0000)	0x02 (0.01.7
3	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	Internal Charge Controller	Not Supported (0x00)	0x03 (0.0)
ľ	1	OK	ок	OK	RX	1		Primary Battery Support	Not Supported (0x00)	0x03 (0.1)
	2	OK	ОК	OK	RX			Condition Flag	Battery OK (0x00)	0x03 (0.7)
ſ	3	OK	OK	OK	RX	1		Charge Controller Enabled	Internal Charge Control Disabled (0x00)	0x03 (1.0)
ſ	4	OK	OK	OK	RX	1		Primary Battery	Battery Operating In It Primary Role (0x00)	0x03 (1.1)
ſ	5	OK	OK	OK	RX	1		Alarm Mode	Enable AlarmWarning Broadcasts (0x00)	0x03 (1.5)
Ē	6	OK	ОК	OK	RX	1		Charger Mode	Enable ChargingVoltage And ChargingCurrent Broadcasts (0x00)	0x03 (1.6)
Ē	7	OK	ОК	OK	RX	1		Capacity Mode	Report In mA Or mAh (0x00)	0x03 (1.7)
4	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	At Rate	0 mA (0x0000)	0x04 (0.01.7
5	0	OK	ок	OK	RX	0x0B Battery	560,00 µs	At Rate Time To Full	Not Charged min (0xFFFF)	0x05 (0.01.7
6	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	At Rate Time To Empty	Not Discharged min (0xFFFF)	0x06 (0.01.7
7	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	At Rate OK	False (0x0001)	0x07 (0.01.7
8	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	Temperature	301.70 °K (0x0BC9)	0x08 (0.01.7
9	0	OK	ОК	OK	RX	0x0B Battery	560,00 µs	Voltage	1200 mV (0x04B0)	0x09 (0.01.7
10	0	ОК	ок	OK	RX	0x0B Battery	560,00 µs	Current	-28 mA (0xFFE4)	0x0A (0.01.7)
11	0	ОК	ок	OK	RX	0x0B Battery	560,00 µs	Average Current	-31 mA (0xFFE1)	0x0B (0.01.7)
12	0		ок	OK		0x0B Battery	560,00 µs		5 % (0×0005)	0x0C (0.01.7)
13	0		ок	OK		0x0B Battery		Relative State Of Charge	99 % (0x0063)	0x0D (0.01.7)
14	0		ок	OK		0x0B Battery		Absolute State Of Charge	99 % (0x0063)	0x0E (0.01.7)
15	0		ок	OK		0x0B Battery		Remaining Capacity	2399 mAh (0x095F)	0x0F (0.01.7)
16	0	OK	OK	OK	RX	0x0B Battery	560.00 us	Full Charge Capacity	2400 mAh (0x0960)	0x10 (0.01.7

Figure 5.17: Message View: Exported Data (HTML)

After the configuration has been completed the Next > button opens the third page of the wizard. This page allows the user to specify a file name. The Finish button closes the wizard

and starts the exporting of the data. Figure **??** shows some data, which has been exported to the HTML format.

5.9 Live View

Image Save Al Save Save Bit Save Bit Save Bit Save Bit Save Bit Image Image Bit Save Bit Save Bit Save Bit Save Bit Save Bit Image Image Bit Save Bit Save Bit Save Bit Save Bit Save Bit Image Bit Save Bit Save Bit Save Bit Save Bit Save Bit Save Bit Image Bit Save	ile Edit	Tracer ADC	Access Tools	Languag	e Help		
Workspace Johnson P Martings Charling View Link P Magetive Tetter Social Social Manufacturer Access El O(SoC) P Tracer El Manufacturer Access El O(SoC) Barne Tracer El Manufacturer Access El Manufacturer Access Barne Tracer El Manufacturer Accestatter El Manufacturer Access	New			Stop			
Medater Negative Tetler Status Value Trocor Trocor Bernaining Capacity, Alarm Dinkle (Sci 0000) Remaining Tener (I) Bernaining Tener (I)			Ψ×	Start	Page Dummy Tracer (1)		•
Magnity Tater Manual Status Sopt Sopt Tocor 00 Manufacturer Access 00 Remaining Capacity Alsm 01 Other Access 00 Remaining Capacity Alsm 01 Onther Access 01 Remaining Capacity Alsm 01 Other Access 01 Other Access 01 Other Access 00				[
Statu Value R/W Data Tracer 03 Manufacture Access 00 0(A00) Operating Capacity Atrum 00 Omin (0x000) Operating Capacity Atrum 00 Omin (0x000) Operating Capacity Atrum 00 Omin (0x000) Operating Capacity Atrum 00 Net Supported (0x00) Operating Canadity Flag 00 00 Charge Canadity Flag Operating Canadity Flag 00 00 00 00				0x0B (7 b	it) Battery		
Image: Tracer (1) Mandecture Access Up 0.m/0.00 Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) Image: Tracer (1) <				Chature	Malua	DAM	Data
Durmy Tacer (1) Image Remaining Capacity Marm Image Control Image Remaining Capacity Marm Image Control Image Control Image Remaining Capacity Mark Image Control Image Control Image Remaining Capacity Mark Image Control Image Control Image Remaining Capacity Mark Image Control Image Control Image Control Image Control Image Control Image Control Image Contr							
Image Remaining Time Alarm Image Omit (00000) Interral Charge Controller Not Supported (0x00) Not Supported (0x00) Image Eastery DK (0x00) Eastery DK (0x00) Image Condition Flag Eastery DK (0x00) Image Eastery DK (0x00) Eastery DK (0x00) Image Image Image Image Image Image Image Image Image Image Image Image Image Image Image Image							
Image Internal Charge Controller Not Supported (0x00) Image Image Image		Duniny Hacer (1)				RV	
OPE Primary Estiny Support ED Not Supported (0x00) OPE Condition Flag ED Estary OK (0x00) OPE Condition Flag ED Estary OK (0x00) OPE Alarm Mode ED Estary OK (0x00) OPE Alarm Mode ED Estary OK (0x00) OPE Charge Mode ED Estary OK (0x00) OPE Charge Mode ED Estary OK (0x00) OPE Charge Contin MA Communication (0xFFF) Continue Contin Continue Continue Continue Continue Continue Contin				OK		RO	
Image Condition Fig Control Fig GC Charge Control Fig Perinary Battery Perinary Control Fig Perinary Control Fig GC Alarm Mode Perinary Earley Perinary Control Fig Perinary Control Fig GC Alarm Mode Perinary Earley Perinary Control Fig Perinary Control Fig GC Capacity Mode Perinary Earley Perinary Control Fig Perinary Control Fig GC A Flate Perinary Control Fig Perinary Control Fig Perinary Control Fig GC A Flate Perinary Control Fig Perinary Control Fig Perinary Control Fig GC A Flate OK Perinary Control Fig Perinary Control Fig Perinary Control Fig GC Arrange Control Fig Perinary Control Fig Perinary Control Fig Perinary Control Fig GC Arrange Control Fig Perinary Control Fig Perinary Control Fig Perinary Control Fig GC Arrange Control Fig Perinary Control Fig Perinary Control Fig Perinary Control Fig GC Arrange Control Fig Perinary Control Fig <td></td> <td></td> <td></td> <td>OK</td> <td></td> <td></td> <td></td>				OK			
Image Primary Battery Image Nature Operating In It Primary Role (0x00) Get Alarm Mode Image Nature				OK	Condition Flag	RO	Battery OK (0x00)
Image: Marcian State Algorithmy Arring Droadcasts (0x00) Image: Charger Mode Image: Charger Mode Image: Charger Charger Mode I							
Image: Charger Mode Image: Charging/Value And Charging/Current Broadcasts (0x00) GC Capacity Mode Image: Report In mA (0x000) GC Ar Rate Image: Not Charged min (0xFFFF) GC Ar Rate Time To Enply Image: Not Charged min (0xFFFF) GC Ar Rate Time To Enply Image: Image: Image: GC Ar Rate OK Image: Image: Image: Image: GC Ar Rate OK Image: Image: </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>							
OB Capacity Mode PP Peopt In mA OrmAh (Xx00) W A Rate PD OmA (Xx00) W A Rate Time To Full ED OmA (Xx00) W A Rate Time To Entry ED Not Discharged min (XxFFFF) W A Rate Time To Entry ED Not Discharged min (XxFFFF) W A Rate Time To Entry ED Set 90 ** (Xx0E73) W Voltage ED 20 m/ (Xx04B0) W Voltage ED 20 m/ (Xx04B0) W Voltage ED 38 mA (0xFFFF) W Average Current ED 38 mA (0xFFFF) W Average Time To Finge ED 38 '' (Xx00C2) W Remaining Capacity ED 240 mA (Xx0480) W				OK			
Image At Rate Image At Robins Image At Rate Time To Full ED Not Charged min (0xFFFF) Image At Rate Time To Enpty ED Not Charged min (0xFFFF) Image At Rate OK ED False (0x0001) Image Temperature ED State (0x001) Image ED 1200 mV (0x0E72) Image Current ED State (0x0E72) Image Current ED State (0x0E72) Image Current ED State (0x0E7) Image Current ED State (0x0E7) Image Current ED State (0x0E7) Image Charge ED State (0x0E7)						RW	
Image At Rate Time To Full EDM Not Charged min (0xFFFF) Image At Rate Time To Empty EDM Not Discharged min (0xFFFF) Image At Rate OK EDF False (0x007) Image Image Image							
Image At Rate Time To Empty Res Not Operating Image At Rate OK Emperature Emperature Emperature Image Temperature Emperature Emperature Emperature Image Current Emperature Emperature Emperature Image Average Current Emperature Emperature Emperature Image Emperature							
Image: Section of the sectio				OK			
003 Voltage 001 Voltage 003 Current 00 98 nA (0xFFPF) 003 Average Current 00 97 nA (0xFFPF) 003 Max Error 00 5 % (0x0005) 003 Relative State Of Charge 00 98 % (0x062) 003 Relative State Of Charge 00 98 % (0x062) 003 Relative State Of Charge 00 98 % (0x062) 003 Remaining Capacity 00 98 % (0x062) 003 Remaining Capacity 00 240 mAt (0x0946) 003 Remaining Capacity 00 240 mAt (0x0946) 003 Average Time To Full 00 1453 min (0x050) 003 Average Time To Full 00 240 mAt (0x070) 003 Charging Veltage 00 Charging IN to Longer Detected (0x00) 003 Charging Veltage 00 Charging IN to Longer Detected (0x00) 003 Terminate Discharge Alarm 00 Terminate Discharge Alarm 00 004 Terminate Discharge Ala				UK OK		RU	
003 Voltage 001 Voltage 003 Current 00 98 nA (0xFFPF) 003 Average Current 00 97 nA (0xFFPF) 003 Max Error 00 5 % (0x0005) 003 Relative State Of Charge 00 98 % (0x062) 003 Relative State Of Charge 00 98 % (0x062) 003 Relative State Of Charge 00 98 % (0x062) 003 Remaining Capacity 00 98 % (0x062) 003 Remaining Capacity 00 240 mAt (0x0946) 003 Remaining Capacity 00 240 mAt (0x0946) 003 Average Time To Full 00 1453 min (0x050) 003 Average Time To Full 00 240 mAt (0x070) 003 Charging Veltage 00 Charging IN to Longer Detected (0x00) 003 Charging Veltage 00 Charging IN to Longer Detected (0x00) 003 Terminate Discharge Alarm 00 Terminate Discharge Alarm 00 004 Terminate Discharge Ala						100	
Image: Current Image:						RO	
Image Average Current Image Or An (LoFFPF) IMB Max. Error ED 5 % (0.0005) IMB Relative State Of Charge ED 95 % (0.0005) IMB Aboutos State Of Charge ED 95 % (0.00062) IMB Remaining Capacity ED 95 % (0.00062) IMB Remaining Capacity ED 240 mAh (0.0096) IMB Time To Empty ED 1453 min (0.0050) IMB Average Time To Full ED 1453 min (0.0050) IMB Charging (0.0050) ED 240 mAh (0.0050) IMB Average Time To Full ED 1453 min (0.0050) IMB Charging (0.0050) ED 240 mAh (0.0050) IMB Charging (0.0050) ED ED IMB Charging (0.0050) ED ED IMB Charging (0.0050) ED ED IMB Charging (0.0000) ED ED IMB Temperature Drops thrito Acceptale Range (0.00) ED ED							
Image Max Error Bits Y(x) (c0005) Get Relative State Of Charge Bits Y(x) (c0005) Get Absolute State Of Charge Bits Y(x) (c0005) Get Absolute State Of Charge Bits Y(x) (c0005) Get Absolute State Of Charge Bits Y(x) (c0045) Get Full Charge Capacity Bits Y(x) (c0045) Get Full Charge Capacity Bits Y(x) (c0050) Get Average Time To Entry Bits Y(x) (c0050) Get Average Time To Full Bits Y(x) (c0045) Get Charging Current Bits Y(x) (c0045) Get Charging Current Bits Y(x) (c0050) Get Charging Current Bits Y(x) (c0050) Get Charging Current Bits Y(x) (c0045) Get Charging Current Bits Charging N Longer Detected (0x01) Get Charging Current Bits Charging N Longer Detected (0x01) Get Charging N Longer Detected				OK			
Image: State Of Charge Image: State Of Charge<				OK	Max Error	RO	
OBC Remaining Capacity RE 237 mArk (Xx0346) OPC Full Charge Capacity RE 2400 mArk (Xx0360) OPC Run Time To Empty RE 1443 min (Xx0360) OPC Run Time To Empty RE 1443 min (Xx0360) OPC Average Time To Full Reverage Time To Full Reverage Time To Full OPC Charging Quitage Reverage Time To Full Reverage Time To Full OPC Charging Quitage Reverage Time To Full Reverage Time To Full OPC Charging Quitage Reverage Time To Full Reverage Time To Full OPC Charging Quitage Reverage Time To Fundy Charged Alam Reverage Time To Fundy Charged Alam OPC Terminate Charge Alarm Reverage Time To Fundy Charged Reverage Time To Fundy Charged Reverage Time Alarm' Or "Remaining Capacity Alarm" = 0 (0x00) OPC Terminate Discharge Alarm Reverage Time To Fundy '> "Remaining Time Alarm' = 0 (0x00) OPC Terminate Discharge Alarm Reverage Time To Fundy '> "Remaining Time Alarm' or "Remaining Time Alarm' = 0 (0x00) OPC Remaining Time Alarm Reverage Time To Fundy '> Teremaining Time Alarm' or Teremaining Time Alarm' = 0				OK	Relative State Of Charge	RO	98 % (0x0062)
Image Full Charge Capacity Bit 242 mit (Xx0580) Image Run Time To Empty Bit 1424 mit (Xx0580) Image Run Time To Empty Bit 1424 mit (Xx0580) Image Run Time To Empty Bit Not Charged mit (Xx0580) Image Average Time To Empty Bit Not Charged mit (Xx0580) Image Charging Time To Full Bit Not Charged mit (Xx0570) Image Charging Voltage Bit Charged Should Be Current Source mV (0xFFFF) Image Charged Alarm Bit Charged Should Be Current Source mV (0x070) Image Charged Alarm Bit Charged Should Be Current Source mV (0x070) Image Charged Alarm Bit Charged Should Be Current Source mV (0x070) Image Temperature Drops Into Acceptable Range (0x00) Emperature Drops Into Acceptable Range (0x00) Image Temperature Drops Into Acceptable Range (0x00) Emperature Drops Into Acceptable Range (0x00) Image Temperature Drops Into Acceptable Range (0x00) Emperature Drops Into Acceptable Range (0x00) Image Temperature Drops Into Acceptable Range							
Image Run Time To Empty Image Run Time To Empty Image 000 Average Time To Full Image 1453 min (0x050) 001 Average Time To Full Image 240 mA (0x050) 002 Average Time To Full Image 240 mA (0x050) 003 Charging Ournet Image 240 mA (0x067) 003 Charging Voltage Image Should Be Current Source mV (0xFFFF) 003 Charging Alarm Image Should Be Current Source mV (0xFFFF) 003 Terminate Charge Alarm Image Should Be Current Source mV (0xFFFF) 003 Terminate Charge Alarm Image Should Be Current Source mV (0xFFFF) 004 Terminate Discharge Alarm Image Should Be Current Source mV (0xFFFF) 005 Terminate Discharge Alarm Image Should Be Current Source MAInt Source Cool 006 Terminate Discharge Alarm Image Should Be Current Source MAInt Source Cool 007 Terminate Discharge Alarm Image Should Be Current Source MAInt Source Cool 008 Remaining Time Alarm Image Should Be Current Source MAInt Source Condition Time Alarm Or "Remaining Time Alarm" = 0 (0x00) 008				OK		RO	
Image Average Time To Engly BD Nat Charged Nami (0xC65A) Get Average Time To Engl BD Nat Charged Nami (0xC65A) Get Charging Current BD An (0x00F0) Get Charging Outges BD Charging Solution Get Charging Solution BD Charging Solution Get Over Charged Alarm BD Charging Is No Longer Detected (0x00) Get Over Charged Alarm BD Charging Is No Longer Detected (0x00) Get Over Charged Alarm BD Temperature Drops Into Acceptable Range (0x00) Get Terminate Charge Alarm BD Temperature Drops Into Acceptable Range (0x00) Get Terminate Charge Alarm BD Termaining Capacity Alarm [*] = 0 (0x00) Get Remaining Time Alarm BD Termaining Time Alarm [*] = 0 (0x00) Get Remaining Time Alarm BD Calibration Or Configuration Information Has Beending Time Alarm [*] = 0 (0x00) Get Remaining Time Alarm BD Calibration Configuration Information Has Beending Time Alarm [*] = 0 (0x00) Get Fully Charged <td></td> <td></td> <td></td> <td></td> <td></td> <td>RO</td> <td></td>						RO	
002 Average Time To Full BD Not Charging Output 003 Charging Output BD 240 mA (K0X0F0) 004 Charging Notage BD Charging Notage 005 Charging Notage BD Charging Notage 005 Over Charge Alarm BD Charging IN to Longer Detected (0x00) 005 Terminate Charge Alarm BD Charging IN to Longer Detected (0x00) 006 Terminate Discharge Alarm BD Charging IN to Longer Detected (0x00) 005 Terminate Discharge Alarm BD Temperature Drops thro Acceptable Range (0x00) 006 Terminate Discharge Alarm BD Terminate Discharge Alarm BD 007 Terminate Discharge Alarm BD Termaining Capacity Alarm [*] or Teemaning Time Alarm [*] = 0 (0x00) 008 Remaining Time Alarm BD Termaining Capacity Alarm [*] = 0 (0x00) 008 Remaining Time Alarm BD Calibration Or Configuration Internet Alarm [*] = 0 (0x00) 008 Remaining Time Alarm BD Calibration Or Configuration Internet Alarm [*] or Teemaning Time Alarm [*] = 0 (0x00) 008 Reinaling Time Alarm BD Calibration Or Configuration Internet Alarm [*] or Teemaning Time Alarm [*] = 0 (0x00) 008 Discharging BD Battary Is No Longer Considured							
West Charging Current No							
OPE Charging Voltage EXC Charging Is Voltage Over Charging Is Voltage EXC Charging Is Voltage EXC Over Charge Alarm EXC Charging Is No Longer Detected (0x00) OVER Terminate Charge Alarm EXC Exc (x00) OVER Terminate Discharge Alarm EXC Exc (x00) OVER Terminate Discharge Alarm EXC Exc (x00) OVER Terminate Discharge Alarm EXC Exp (x00) OVER Terminate Discharge Alarm EXC Exp (x00) OVER Terminate Discharge Stand EXC Exp (x00) OVER Terminate Capacity Alarm EXC Exp (x00) OVER Terminating Capacity Alarm EXC Exp (x00) OVER Terminating Time Alarm EXC Exp (x00) OVER Terminating Time Alarm EXC Exit (x00) OVER Terminating Time Alarm				OK			
Oper Charged Alarm BBC Charging Is No Longer Detected (0x00) GE Terminate Charge Alarm BD Charging Is No Longer Detected (0x00) GE Over Term Alarm BD Charging Is No Longer Detected (0x00) GE Over Term Alarm BD Discharge Is No Longer Detected (0x00) GE Terminate Discharge Alarm BD Discharge Is No Longer Detected (0x00) GE Remaining Capacity Alarm BD Terminate Is Discharge Is No Longer Detected (0x00) GE Remaining Time Alarm BD 'Aremaining Capacity Alarm' or 'Remaining Time Alarm' or 'Remaining Time Alarm' == 0 (0x00) GE Remaining Time Alarm BD Calibration Configuration Intermation Has Descuracy Is Significantly Impaired (0x GE Discharging BD Battery Is No Longer Considered In A Full State (0x00) GE Fully Discharged BD Battery Is No Longer '> 20% (0x00) GE Fully Discharged BD Battery Is No Longer Considered In A Full State (0x00) GE Fully Discharged BD Calibration Conger '> 20% (0x00) GE GE Error Codes BD							
OPE Terminate Charge Alarm EDC Charging In No Longer Detected (0x00) OVEr Termy Alarm EDT emperature Drops (Into Accessible Range (x00) OPE Terminate Discharge Alarm EDT emperature Drops (Into Accessible Range (x00) OPE Terminate Discharge Alarm EDT emperature Drops (Into Accessible Range (x00) OPE Terminate Discharge Alarm EDT emaining Tame Alarm' (Dr Remaining Capacity Alarm' em 0 (x00) OPE Remaining Time Alarm EDT 'Accessible To Empery's > "Remaining Time Alarm' Or "Remaining Time Alarm' = 0 (0x00) OPE Relations EDT 'Accessible To Empery's > Termaining Time Alarm' or Termaining Time Alarm' = 0 (0x00) OPE Initialized EDT 'Accessible To Empery's > Termaining Time Alarm' or Termaining Time Alarm' = 0 (0x00) OPE Discharging EDE Alarts (Dot Longer Considered In A Full State (Dot O) OPE Fully Discharged EDE Alarts (Dot Longer Considered In A Full State (Dot O) OPE Fully Discharged ED OY (Cond) ET Cords OPE Coyle Count ED 200 (N/ (X09) ET Cords OPE Design Capacity EDE 200 Cank (K0950) ED 200 Cank (K0950)							
Over Temp Alarm Tem presture Drops Into Acceptable Range (0x00) OPE Termination Elocharge Alarm Termination Scharge Alarm Discharge Is No Longer Detected (0x00) OPE Remaining Capacity Alarm Terminating Capacity Alarm' or Termaining Capacity Alarm' or Termaini							
OPE Terminate Discharge Alarm BDD OPE Remaining Capacity Alarm BD Thermaining Capacity Alarm' or "Remaining Capacity Alarm" or "Remaining Capacity Alarm" are 0 (0x00) OPE Remaining Time Alarm BD "Remaining Capacity Alarm" are 0 (0x00) OPE Remaining Time Alarm BD "Remaining Time Alarm" or "Remaining Time Alarm" are 0 (0x00) OPE Initialized BD Calibration Crossfunction Information Has Even Lest And Accuracy Is Significantly Impaired (0x OPE Discharging BD Battery Is No Longer Considered In A Full State (0x00) OPE Fully Charged BD Battery Is No Longer Considered In A Full State (0x00) OPE Fully Discharged BD Alarwise State (0r Charger > 20% (0x00) OPE Crycle Count BD State (0x00) OPE Opel Count BD 2400 mAh (K0956)							
OBS Remaining Capacity Alarm BB0 Thermaining Capacity Alarm" or Thermaining Capacity Alarm D (0x00) OBS Initialized B00 Thermaining Capacity Alarm" or Thermaining Thermaini							
OBS Remaining Time Alarm BD "Average Time To Egrepty" > "Remaining Time Alarm" == 0 (0x00) OBS Initialized BD Calibration Crossfunction Information Has Even Lest And Accuracy Is Significantly Impaired (0x OBS Discharging BD Battery Is No Longer Considered In A Full State (0x00) OBS Fully Charged BD Battery Is No Longer Considered In A Full State (0x00) OBS Fully Charged BD Battery Is No Longer Considered In A Full State (0x00) OBS Error Codes BD Codes COD (0X00) OBS Cycle Count ED Obs (0x07F) OBS OBS OBS (0x07F) OBS OBS OBS (0x07F) OBS OBS OBS (0x07F) OBS OBS OBS OBS (0							
OPE Discharging EXE Discharging (0x01) OPE Fully Charged EXErus 16 No Longer Considered In A Full State (0x00) OPE Fully Discharged EXErus 16 No Longer Considered In A Full State (0x00) OPE Fully Discharged EXErus 16 No Longer Considered In A Full State (0x00) OPE Error Codes EV Codes OPE Crycle Count EV Codes OPE Design Capetity EX 240 mAh (No096)				OK	Remaining Time Alarm		"Average Time To Empty" > "Remaining Time Alarm" Or "Remaining Time Alarm" == 0 (0x00)
Image Fully Charged Image							Calibration Or Configuration Information Has Been Lost And Accurracy Is Significantly Impaired (0x
IOID Fully Discharged IBO Telative State Of Charge* > 20% (0x00) IOID Error Codes IBO OK (0x00) IOID Cycle Count IBO OK (0x06) IOID Design Capacity IBO 2400 mAh (0x056)						RO	
Image Error Codes Bit O(Kod0) Image Cycle Count Emil 2038 (0x07F6) Image Design Capacity Emil 2400 mAh (0x0560)				OK			
08 Cycle Count IEI 2038 (bx07F6) 08 Design Capacity IEI 2400 mAh (0x0960)							
022 Design Capacity R0 2400 mAh (0x0960)							
Workspace Find Time Vew Message Vew Live Vew Statistic Vew						heal	1200 MV (0X0400)

Figure 5.18: Live View

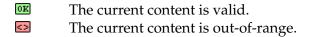
The live view shows the user the content, which is currently stored in the values of the devices on the monitored I2C-bus.

This view is based on the information, which is stored in IRD files. So it can be used only with I2C devices, for which appropriate IRD files are available and have been registered.

When the I2C tracer is running, this view permanently parses the incoming I2C data to monitor any changes of the displayed values. Due to this fact the live view can display only modifications, which have been seen on the I2C-bus. If an I2C device changes e.g. a status value internally and this value is never read by an external I2C master, the view will not update its view of the value to the new content. This limitation is equalized by the fact that the view does not need to send any data actively to the I2C-bus to read out the devices.

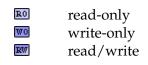
In the upper part of the live view there is a combo box, which can be used to select whose values should be displayed. After one I2C device has been selected, its current values get displayed in the table. The columns of the table have got the following meaning:

Status Shows the status of the value:



Value Name of the value.

R/W Some values are write-only or read-only. This column specifies the allowed directions.



Data Contains the current content of the value. If it is not known, the table shows "Unknown Value".

The lines in the table, whose data have changed a minute ago, are highlighted with a bold face font.

When working with devices, which contain not only a few values but a large quantity of values, it can be difficult to find the needed values in the tables. To make life easier I2C Studio offers a feature called "quick watch". The idea is to add the values of interest into a separate table.

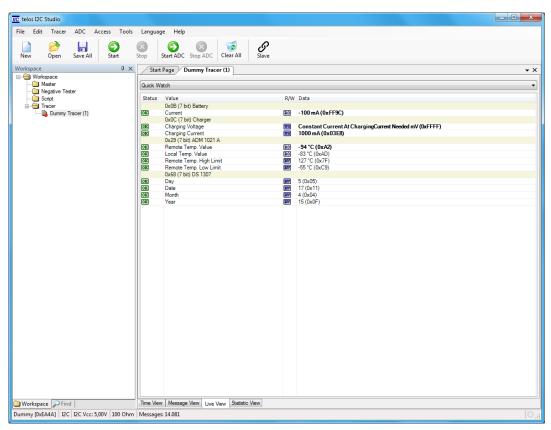


Figure 5.19: Live View: Quick Watch

To add a value to the quick watch simply select the appropriate row in the table and use the context menu item Add To Quick Watch. After the values have been added, the user can change to the quick watch using the same combo box, which is normally used to select the displayed device. Figure **??** shows a quick watch to which some values have been added.

5 Tracer

Values can be removed from the quick watch by the context menu item **Remove From Quick** Watch, which is available in the quick watch window only.

5.10 Statistic View

7 <mark>7</mark> telos 12C Studio. File Edit Tracer ADC Acco	ess Tools Lang	uage Help											×
New Open Save All	Start Stop	Start ADC Ste	op ADC	Clear	All S	9 ave							
Workspace 🛛 🕂 🗙	Start Page	Dummy Tracer (1)										~ >
Workspace Master				Len/Si	ub Messag	e	Time/Byte				Time/Su	b Message	
Negative Tester	Address Errors	SUD Messages	Bytes		Avg. Max	. Min.	Avg.	Max.	Min.	Avg.	Max.	0 200 400 600 800 10	00
Cipt	7 0x08 0		7.476			3 22,50 µs				266,25 µs	767,50 µs		
🗄 😋 Tracer	7 0x0C 0 7 0x29 0		504 840		2,40	3 22,50 µs 1 90.00 µs	22,50 µs	22,50 µs	45,00 µs 182,50 µs	78,75 µs 186,25 µs	92,50 µs 190.00 µs		
🖺 Dummy Tracer (1)	7 0x68 0	672	672 9.492	1	1,00	1 22,50 µs	22,50 µs	22,50 µs	45,00 µs	46,25 μs 210,00 μs	47,50 µs		
	- - - -												
Workspace 🔑 Find	Time View Messag	e View Live View	Statisti	View									
ummy [0x54AC] 12C 12C Vcc: 5.00													1

Figure 5.20: Statistic View

The statistic view displays a statistical analysis of the submessages, which have been traced on the I2C-bus. Using this view the developer gets an overview e.g. which I2C addresses have been accessed how many times or how long is the average submessage to the I2C slave at address 0x50.

Figure **??** shows the statistic view. The table of the view contains a row for each I2C address, to which submessages have been sent. The last row, which is called "All", contains the sum of all rows.

Note: The statistic is based on I2C submessages. If e.g. an I2C message consists of two submessages, these submessages are analysed separately.

5.10.1 Statistic

The columns of the table contain the following statistics:

Address I2C address of the slave.

The icons can have got the following meaning:

- **7** 7-bit I2C address
- 8 7-bit I2C address (8-bit representation)
- 10 10-bit I2C address

In the case of transmission errors, it is possible that the lower part of a 10-bit address is missing. In such cases rows with I2C addresses like "0x0XX" are shown in the table. Beside the normal I2C addresses the following values are possible in this column:

- **Prot. Error** An I2C protocol error can occur e.g. when a STOP condition is not sent after the 9th data bit but after the 2nd.
- SMB Pwr Off The power of a SMBus has been switched off.
- **SMB Pwr On** The power of a SMBus has been switched on.
- **N/A** The I2C address is missing, because e.g. the tracing starts in the middle of an I2C message so that the START condition has not been recorded.

The interpretation of the I2C address can be switched from the default 7-bit mode to the 8-bit mode, which is used by some data-sheets. This is done using the context menu switch Hex Radix. Moreover the user can select a decimal instead of the default hexadecimal interpretation using the 7 Bit Address item.

- **Errors** Contains the number of I2C submessages, which has been transmitted with errors. If the I2C address or one of the data bytes has not been acknowledged, this is counted as error.
- Sub Messages Number of submessages, which have been sent to this I2C address.
- **Bytes** Sum of the data bytes, which have been exchanged with the I2C slave at this address. This value does not include the bytes, which are used to transmit the I2C address on the I2C-bus.
- **Length/Message** Number of data bytes contained in the submessages exchanged with this slave. The minimum, average, and maximum values are shown. This value does not include the bytes, which are used to transmit the I2C address on the I2C-bus.
- **Time/Message** Length of the submessages as time. The measured time starts with the START condition and ends with the STOP condition of the submessage. If the submessage does not contain a STOP condition, because it is part of a combined transfer, the time ends with the acknowledge bit of the last data byte. The minimum, average, and maximum values are shown.
- **Time/Bytes** Length of the bytes in the submessages as time. This value takes into account not only the data bytes but also the bytes, which have been used to transmit the I2C address.

With the context menu of the statistic view, which is shown in figure ??, the user can disable or enable the various columns of the table. Furthermore one value can be chosen, whose result should be visualized with a bargraph. This bargraph displays up to three values with different grey levels: the minimum, average, and maximum.

5.10.2 Export / Copy to Clipboard

The statistic can be exported to a file or to the system's clipboard. The exporting to a file can be started via the menu item File|Trace Data|Export whereas the exporting to the clipboard is started using the context menu item Copy to Clipboard.

In both cases a wizard gets started. Figure ?? shows the options, which can be configured:

Text Three different formats are available:

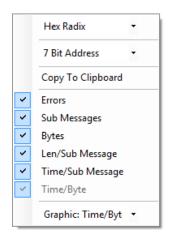


Figure 5.21: Statistic View: Context Menu

C Export	×
Configuration	
Statistic View	
Format	
Text ASCII (*.txt)	
<u> </u>	
Columns	
Text	
Frors	Len/Sub Message
Sub Messages	Time/Sub Message
Ø Bytes	✓ Time/Byte
Graphic	
Time/Byte	▼
	< Back Next > Cancel

Figure 5.22: Statistic View: Export

- **ASCII (*.txt)** The data gets exported to a formatted ASCII file. This format is humanly readable.
- **Character Separated Values (*.csv)** The CSV format can be imported into a lot of programs like e.g. Microsoft Excel or OpenOffice. Furthermore it is very simply to write ones own parsers for this format. It conforms to RFC 4180. With the "Separator" switch the user can select, whether the cells in the file should be seperated with commas or semicolons.
- **HyperText Markup Language (*.html)** Creates a humanly readable HTML file, which can be viewed with most standard WWW browsers like e.g. Mozilla or the Internet Explorer. It conforms to XHTML 1.0.

Columns Defines the statistics to be exported.

5 Tracer

Graphic In some formats it is possible to visualize one of the values with an additional bargraph. This option defines, which value should be exported with a bargraph.

				Daten Eenster 2								_
ነ 🧀 🖬 🔒) # 🖪	🌮 👗 🛍 🛍	🚿 🗠 🗠	- 🍓 Σ 🌬 🛃 🕌	🛍 🚯 100% 👻 🕄 .	Arial 👻	10 - F X U	≣≣≣ ፼%	00 1/8 /第 译 目	🗄 • 🕭 • 🚣 • .		
A1	-	= Address										
A	В	С	D	E	F	G	Н	1	J	K	L	M
Address	Errors	Sub Messages				Length/Message: Max.	Time/Message: Min.		Time/Message: Max.		Time/Byte: Avg.	
0x0B	0				2,76		4 45,00 µs	268,75 µs	790,00 µs	22,50 µs	67,50 µs	92,50 µs
0x0C	0	1.220	2.928	1	2,4		3 45,00 µs	78,75 µs	92,50 µs	22,50 µs	22,50 µs	22,50 µs
0x29	0		4.880	1	1		1 182,50 µs	186,25 µs	190,00 µs	90,00 µs	90,00 µs	92,50 µs
0x68	0	3.904	3.904	1	1		1 45,00 µs	46,25 µs	47,50 µs	22,50 µs	22,50 µs	22,50 µs
All	0	26.108	56.120	1	2,15	3	4 45,00 µs	211,25 µs	790,00 µs	22,50 µs	62,50 µs	92,50 µs
2 3 4 4 7 7												8000

Figure 5.23: Statistics Imported Into MS Excel

Figure ?? shows a CSV file loaded into MS Excel, which has been created by I2C Studio.

5.11 Find

5.11.1 Find Window

I2C Studio offers only an I2C address filter to limit the messages, which get recorded. This can result into a very large number of messages, if there is heavy load on the examined I2C-bus. So in the worst case up to 20,000 messages/sec are recorded on an I2C-bus, whose master work with 400 kHz.

After recording data on such a bus e.g. for one hour, it is nearly impossible to find the interesting messages by hand. That is why I2C Studio comes with a find window allowing to define very complex search criterions.

IIC telos I2C Studio	
File Edit Tracer ADC Access Tools Language Help	
Image: New Open Save All Start Stop Start ADC Stop ADC Stare All	
Find 4 X Start Page telos Tracii XL 2.0 Tracer (3)	• X
Info Info Case 0 Info New Delete New Delete Start Time: 0 s Time Interval: N/A Radix: Hex Zoom Delete	- P
O µs Case 0 0 µs Case 100 µs 200 µs 300 µs 400 µs 500 µs 600 µs 70 µs	800 µs 900 µs
Frame	>
SDA	
SCL N/A N/A	
< Pin 0	>
< Pin 1	>
<< Find C Find >>	Þ
Workspace Find Time View Message View Live View Statistic View	
telos Tracii XL 2.0 [0x4716] I2C I2C Vcc: 3,19V 10,90 kOhm Messages: 0	10

Figure 5.24: Find Window

Figure **??** shows the empty find window. Within this window the user can specify the rules, which should be used to search for the interesting data.

Under "Find Cases" the user can store several collections of find rules, so that he can switch between different rule sets without deleting and entering them again and again. A new collection is started by clicking onto the **New** button. A no longer needed collection can be removed by clicking onto the **Delete** button.

The "Rules" area of the window allows to specify the search criterions for one rule set. The rules are organized in a tree. The icons in the tree have got the following meaning:

\$ ↑	Sequence
AND	Logical AND
0R	Logical OR
XOR	Logical XOR
==	Rule

After the user has entered the rules, the search can be started by clicking onto the Find >> button to search forward and onto the << Find button to search backwards. If the developer has recorded a lot of I2C messages, the search process can take some time. There is a Cancel button to stop a running search process. The current progress of the search gets visualized in a progress bar at the lower part of the window.

5.11.2 Rules

There are three groups of items in the tree of the find window: the sequence, logical operations, and the rules.

The criterions within the sequence must be fulfilled sequentially. So after the first criterion has been matched, the next one must be matched starting from the point where the first has been matched, and so on. The sequence forms the top level of the tree.

Into the sequence the user can add logical operations. All rules and logical operations contained into a logical operation get combined logical.

A rule defines the real search criterion. There are different types of rules, e.g. it is possible to define an address rule.

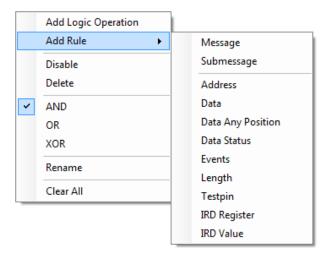


Figure 5.25: Find Window: Context Menu

The tree is modified completely with its context menu, see figure **??**. The context menu knows the following items:

Add Sequence Adds an empty sequence.

Add Logic Operation Adds a logic operation. The results of all children under this operation get combined logically. By default "AND" is used for this combination.

Add Rule Adds a rule.

Disable Disables the item. Its result does not contribute to the search.

Delete Deletes the item permanently.

AND Chooses the kind of used logical operation: AND.

OR Chooses the kind of used logical operation: OR.

XOR Chooses the kind of used logical operation: XOR.

Rename Renames the item.

Clear Removes everything from the tree.

Address Rules

Rule Name Address Rule				
Address	Add	Rules		
0x50 7 Bit 🔹 🗸	Add	Address	Alias	Status
Status	Add All	7 0x50		ACK/NACK
ACK/NACK -	Remove	7 0x52		ACK/NACK
	Remove All			
				d Rules Cance

Figure 5.26: Find Window: Address Rules

This type of rule can be used to search for I2C messages to slaves with specific I2C addresses. Besides the I2C addresses the user can specify the status of the I2C addresses:

Address I2C address to be searched for.

Status Status of the I2C address. The following values are possible:

ACK I2C address has been acknowledged.

NACK I2C address has not been acknowledged.

ACK/NACK I2C address has been or has been not acknowledged.

No confirmation The ACK/NACK bit is missing.

The Add All button inserts all possible 7-bit and 10-bit I2C addresses with status "ACK/NACK" to the list. With the Remove All button all rules can be removed from the table.

The rules shown in figure **??** match all I2C messages, which have been sent to the slaves with the I2C addresses 0x50 and 0x52 and whose ACK/NACK bit is available.

Rule Name				
Data Rule				
Position	Add	Rules		
2	Add	Position	Byte	Don't Care
Byte	Remove	0	0x00	0xFF
22 Hex 🗸	Remove All	1	0x22	0xFF

Figure 5.27: Find Window: Data Rules

Data Rules

The data rules match bits or complete bytes of the data transferred with I2C messages.

To add e.g. a search for I2C messages, which contain 0x10 as the first data byte, enter "0" to the "Position" and "0x10" to the "Byte" field. Afterwards press Add to add the value to the "Rules" table. To add search rules for bits click on the Down button in the "Byte" field.

The rules, which can be seen in figure **??**, match all I2C messages, which have "0x00" as first and "0x22" as second data byte.

Note: The bytes, which are used to transfer the I2C addresses on the I2C-bus, are not counted to the data bytes.

Data Any Pos Rules

IIC Data Any Pos Rules	x
Rule Name	
Data Any Pos Rule	
Data Find Pattern	
23 45	\odot
	Add Rules Cancel

Figure 5.28: Find Window: Data Any Pos Rules

This type of rule is similar to the data rule. It searches for a number of consecutive data bytes. In contrast to the data rule the user cannot specify the position within an I2C message, where the given data byte is expected.

The example in ?? searches of the sequence "0x12, 0x34".

Data Status Rules

This rule can be used to find I2C messages, where the I2C slave has acknowledged or not acknowledged the data bytes. If this rule is set to NACK, all I2C messages will be found

IC Data Status Rules	×
Rule Name	
Data Status Rule	
NACK]
	Add Rules Cancel

Figure 5.29: Find Window: Data Status Rules

where at least one data byte has not been acknowledged.

The example in figure **??** searches for NACK.

Event Rules

IIC Event Rules	X
Rule Name	
Event Rule	
I2C Protocol Error	
	Add Rules Cancel

Figure 5.30: Find Window: Event Rules

I2C Studio displays messages in the tracer window, which are in fact no real I2C messages. Instead they are events. This rule type can be used to search for these events.

One of the following events can be chosen:

I2C Protocol Error A violation of the I2C protocol has been detected, e.g. after five data bits a STOP condition has been sent.

SMBus Power Down The power of a SMBus has been switched off.

SMBus Power Up The power of a SMBus has been switched on.

Tracer Restarted The tracer has been restarted.

The example in figure ?? searches for an I2C protocol error.

Length Rules

To search for I2C messages, whose submessages contain a specific number of data bytes, this rule can be used.

The rule in figure **??** matches I2C messages, whose submessages consist of at least 12 and up to 14 data bytes.

5 Tracer

IC Length Rules	X
Rule Name	
Length Rule	
Min Bytes	Max Bytes
12	
	Add Rules Cancel

Figure 5.31: Find Window: Length Rules

Testpin Rules

IC Testpin Rules	x
Rule Name	
Testpin Rule	
Testpin Testpin 0	State Falling Edge ▼
	Add Rules Cancel

Figure 5.32: Find Window: Testpin Rules

The find rules cannot only be used to search within I2C messages, but also to search for specific states of the input testpins or specific transitions on the input testpins.

Note: There are some limitations in the precision of this rule. It will always match the I2C messages, which has been sent in parallel or before the searched state of the testpin.

The rule shown in figure **??** will match, when a falling edge is detected on the first input testpin line.

Submessage Rules

This rule consists of a combination of some of the previous mentioned rule types and some additional rule types. This rule matches I2C messages, which contain an I2C submessage fulfilling the search criterions specified by this rule.

There are several sub criterions, which can be enabled or disabled using check boxes:

Length Length of the data, see section **??**.

Address I2C address of the slave to which this submessage has been sent, see section ??.

Rule Name					
ubmessage Rule					
.ength					
Min Bytes			Max Byte	es	
15			15		
Address					Discotion
Address		Rules			Direction
	- Add	Address	Alias	Status	
Status	Add All			ACK/NACK	
ACK/NACK	Remove				
	Remove	Ali			
Position 0 Byte	Add Remove	Rules Position Byte		Don't Care	
Position 0 Byte 00 Hex v Pata Bytes Any Positio	Remove Remove All			Don't Care	
Position 0 Byte 00 Hex v	Remove Remove All			Don't Care	
Position 0 Byte 00 Hex Colored Hex Dotata Bytes Any Position	Remove Remove All			Don't Care	
Position Byte 0 Hex Any Position Data Bytes Any Positio Data Find Patter	Remove Remove All			Don't Care	
Position Byte Do Hex Any Positio Data Bytes Any Positio Data Find Patter Data Status	Remove Remove All			Don't Care	
Position Byte 0 Hex Any Position Data Bytes Any Positio Data Find Patter	Remove Remove All			Don't Care	
Position Deta Byte Data Bytes Any Positio Data Find Patter Data Status NACK Byte Time	Remove Remove All	Position Byte		Don't Care	
Position O Byte O Hex O Hex O Data Bytes Any Positio Data Find Patter Data Status NACK Byte Time Time/Byte	Remove Remove All	Position Byte	/Bit		
0 Byte 00 Hex Data Bytes Any Positio Data Find Patter Data Status NACK Byte Time Time/Byte t_min 0 :	Remove All	Position Byte Frequency, 22 f_max [Hz]		Submessage Time	a ms us

Figure 5.33: Find Window: Submessage Rules

- **Direction** If this option is not enabled, the rule will match submessages independent of their transfer direction. The user can enable this option and choose "TX" or "RX" to match only master transmitter or master receiver transfers.
- Data Bytes Matches data bytes at specific positions, see section ??.
- Data Bytes Any Pos Matches a sequence of data bytes, see section ??.
- Data Status Matches submessages with the specified data status ??.
- **Byte Time** Only I2C submessages will match, whose transmission of each data byte has lasted a time within the given time range. The time range can be specific also as fre-

quency. This frequency refers to one bit. A data byte on the I2C-bus consists of eight data bits and the acknowledge bit. This criterion can be used to find I2C submessages, which have been sent with a specific clock rate (SCL) or to find e.g. bus stretching.

Submessage Time The transmission time of the I2C submessage must be within the given time range to match the rule.

The example matches all I2C messages, which contain an master transmitter submessage. This submessage has to be sent to the slave with the address 0x60. It has to contain 15 data bytes and has to be sent with a speed between 100 kHz and 400 kHz.

Message Rules

e Nan sage			
omess - Sub	ages message	85	Position
Ad	d/Chang	ge Remove Remove	All Change 0
Pos	ition	Submessage Rules	
0		TX Rule RX Rule	
ssage	Time		Idle Time
t_m	in 0	: 0 : 0 : 0 : 0	t_min $0: 0: 0: 0: 0$
t_m	ax 0	$\begin{array}{c} \underset{0}{\text{min}} & \underset{0}{\text{s}} & \underset{0}{\text{ms}} & \underset{0}{\text{ms}} \\ \vdots & \underset{0}{\text{o}} & \vdots & \underset{0}{\text{o}} & \vdots & \underset{0}{\text{ms}} \end{array}$	$t_max \boxed{0}: \begin{array}{c} min \\ 0 \end{array}: \begin{array}{c} s \\ 0 \end{array}: \begin{array}{c} ms \\ 0 \end{array}: \begin{array}{c} \mu s \\ 0 \end{array}$
stpins			
Те	estpin		State
Te	stpin 0		Falling Edge

Figure 5.34: Find Window: Message Rules

Using this type of rule it is possible to define search criterions on I2C message level. The following sub criterions can be enabled or disabled using check boxes:

Submessages Contains a number of submessage rules as they have been described in section **??**. A new rule can be added to the list with the help of the Add button. To remove one or all rules the Remove and Remove All buttons can be used.

Each rule is connected with a position in the I2C message. In the example shown in figure **??** each first submessage of an I2C message is compared with the "TX Rule" and each second submessage is compared with the "RX Rule".

The Change button can be used to change the position of a rule.

- **Message Time** The message time is the time from the first START condition of an I2C message to its STOP condition. An I2C message matches this rule, if its message time is within the specified time range.
- **Idle Time** The idle time is the time from the STOP condition of the previous I2C message to the first START condition of the current I2C message.

Testpins Matches the state of one of the input testpins, see section ??.

Figure **??** shows a rule, which will match I2C messages fulfilling the "TX Rule" for their first submessage and the "RX Rule" for the second submessage. Furthermore there must be a falling edge on the first testpin input line.

IRD Register Rules

IIC IRD Register Rules	x
Rule Name	
IRD Register Rule 0	
IRD Alias	
0x0B (7 bit) Smart Battery Data	•
Register	
Voltage	•
Data	Data 2nd
00 00	$\overline{}$
PEC	Direction
PEC is ignored 👻	RX 🔹
	Add Rules Cancel

Figure 5.35: Find Window: IRD Register Rules

If an IRD file has been registered, this type of rule can be used to define search criterions on register level. The following sub criterions can be set:

- **IRD Alias** Selects the I2C slave, which has been addressed by the I2C master. Only I2C slaves are shown here, for which IRD files have been registered (see section **??**).
- **Register** Register of the I2C slave.
- **Data** Data, which has been read from the register or which has been written to the register.
- **Data 2nd** Some registers must be written and read within on I2C message. The data for the write transfer must be specified in the "Data" field and the data for the read transfer must be specified in the "Data 2nd" field.

- **PEC** Some SMBus slaves support "packet error checking". For such slaves this field can be used to search for I2C messages with a specific PEC state.
- **Direction** Specifies the direction of the transfer. If "TX" is specified only transfers to the register are found. If "RX" is specified only transfers from the register are found.

The rule shown in figure **??** will match, when the "Voltage" register of the "Smart Battery Data" device at address "0x0b" is read and the register contains the value "00 00".

IRD Value Rules

Rule Name	
IRD Value Rule 0	
IRD Alias	
0x0B (7 bit) Smart Battery Data	•
Value	
Voltage	•
Minimum	Maximum
0	20
PEC	Direction
PEC is ignored	RX 👻

Figure 5.36: Find Window: IRD Value Rules

If an IRD file has been registered, this type of rule can be used to define search criterions on value level. The following sub criterions can be set:

- **IRD Alias** Selects the I2C slave, which has been addressed by the I2C master. Only I2C slaves are shown here, for which IRD files have been registered (see section **??**).
- Value Value of the I2C slave.
- **Minimum** Minimum for the value, which has been read from the value or which has been written to the value.
- **Maximum** Maximum for the value, which has been read from the value or which has been written to the value.
- **PEC** Some SMBus slaves support "packet error checking". For such slaves this field can be used to search for I2C messages with a specific PEC state.
- **Direction** Specifies the direction of the transfer. If "TX" is specified only transfers to the value are found. If "RX" is specified only transfers from the value are found.

The rule shown in figure **??** will match, when the "Voltage" value of the "Smart Battery Data" device at address "0x0b" is read and the value is between "10" and "20".

5.12 Storage of Trace Data

As we have seen in the previous sections there are several formats, to which the traced data can be exported. I2C Studio only supports exporting the data to these formats. It is not possible to read these files back into I2C Studio.

There are several situations where a developer wants to store the traced data and read it back later into I2C Studio. This can be useful e.g. to pass the data to other developers, when working on a problem caused by the I2C communication.

I2C Studio can save the monitored data (I2C messages, analog shots, and transitions of the input testpins) into a proprietary binary file format, which can also be read back. These files are using the extension *.i2cl. To store the data efficiently these files are compressed.

To create such a file the user simply clicks on the menu item File|Trace Data|Save As. A file selection dialog gets opened, where the user has to specify the name of the file to be created. After a file name has been specified, the saving starts.

Tracii XL 2.0 [0x788B]	12C	I2C Vcc: 5,05V	Saving: 56%	Cancel	Ċ.	.:
------------------------	-----	----------------	-------------	--------	----	----

Figure 5.37: Status Bar: Saving Trace Data

This is done in the background. The current status of the saving is shown in the status bar of I2C Studio, see figure **??**.

The **Cancel** button in the status bar allows the user to cancel the saving process, while it is running.

There are three ways to load an *.i2cl file into I2C Studio. The developer can use the menu item File|Trace Data|Load or he can simply drag and drop the file from an Explorer window to I2C Studio. Furthermore the user can simply double-click onto the file in the Explorer.

5.13 Printing

The data, which has been monitored with I2C Studio, cannot only be written to files but can also be printed.

After some data has been recorded the user can select the menu item File|Print to open the print wizard. This wizard consists of two pages: the first page allows to select and configure the printer, the second page specifies the data to be printed.

5.13.1 Printer Configuration

IC Print			×
Printer			
Name	Microsoft XPS Document Writer		▼ Properties
			Print to File Print Monochrome
Margins		Paper	
Тор	2,60 cm	Size	A4 🔹
Bottom	2,60 cm	Source	Automatically Select
Left	2,60 cm	Orientati	on
Right	2,60 cm	Portra	ait
		Land	scape
			< Back Next > Cancel

Figure 5.38: Print Wizard: Printer Configuration

The first page of the wizard can be seen in figure **??**. The following parameters can be configured by the user:

Name Selects the printer to be used.

- **Properties** This button opens a printer specific dialog, which can be used to configure printer specific options like e.g. the duplexer of the printer.
- **Print to File** Selects whether the data generated by the printer driver is sent directly to the printer or written into a file.

Margins Defines the top, right, bottom, and left margins.

- **Paper Size** Most printers support not only one size of paper but a large quantity of different formats. Selects the format to be used.
- **Paper Source** Larger printer have got more than one paper tray. This option specifies the tray to be used.

Orientation The data can be rendered in the portrait or landscape mode.

After the printer has been configured, the user can jump to the next page of the wizard using the Next > button.

5.13.2 Data Selection

IIC Print	×
Image: Print Time View Print Resolution Optimized For 400 kHz Channels Misc Image: Print Misc Image: Print Image: Print Image: Print Optimized For 400 kHz Image: Print Image: Print Image: Print Image: Print Image: Print Image: Print Print Image: Print Print Image: Print Print Print Image: Print Print Print Print Image: Print	
Status 2 pages	
	< Back Finish Cancel

Figure 5.39: Print Wizard: Data Selection

The second page of the print wizard, which can be seen in figure **??**, can be divided into three major parts.

On the upper left side there is a combo box, which configures the view to be printed. Here the user can select between the time view and the message view.

Under this combo box there are the options, which define the data to be printed.

Finally on the right side there is a preview of the first page to be printed. The preview depends on the currently configured options.

To start the printing the user has to select the Finish button.

Time View

If the user selects to print the time view, all data, which is currently visible in the time view window, gets printed. To print e.g. all traced I2C data, the user has to zoom out completely in the time view window before opening the print wizard.

The following options can be configured when printing the time view:

Optimized For If the user selects to print several I2C messages at the same time, he will always result into print outs, whose resolution is too low to see any interesting details. To solve this problem, I2C Studio offers a functionality to split the data to several pages.

This option configures the number of pages, which are created. To make the user the decision, how many pages are needed, very easy, he can simply specify the needed resolution as frequency.

Let us assume the traced I2C-bus uses a clock rate of 400 kHz. For this set-up the user would simply select an "Optimized For" value of 400 kHz. If there are analog shots of the electrical levels available, typically higher frequencies like e.g. 6 MHz should be selected.

- **Channels** Sometimes the user do not want to print out all available parts of the time view. Using these switches the miscellaneous parts can be selected or deselected to be printed.
- **Info Box** A box containing some information can be added to the beginning of each page. This box includes the absolute time, where the data of this page starts, the time interval of the complete page, the radix, and the time range covered by the page.
- **Legend** A legend describing the possible symbols can be added to the end of each page.
- **Status** Contains the number of pages, which will be created, when the user selects to print with the current configuration.

Message View

- If the user selects to print out the message view, the following options are available:
- Message Range Specifies the I2C messages to be printed out.
- **Mode** Like in the GUI it is possible to choose between three different modes: the raw view, the register view, and the value view.
- **Columns** If the user does not want to print out all possible columns of the table, these switches can be used to disable the appropriate columns.

5.14 Plug-Ins

To get a high-level view of the traced I2C data the user can register IRD files or plug-ins, which convert raw messages to interpreted messages. IRD files, which are based on XML, can be written easily using a normal text editor or the IRD composer of I2C Studio.

They are very good solution for most register based I2C slaves. For more complex I2C high-level protocols there is a better suited solution: the plug-in interface.

Plug-Ins can be written using all programming languages supporting the Microsoft .NET framework. The following example shows how to program a plug-in in C#:

```
using telos.I2cApi.DotNet;
using System;
using System.Collections.Generic;
using System.Text;
public sealed class PlugIn : PlugInInterface
 /// <summarv>
 /// This method describes the IC, whose traffic can be
 /// parsed by the plug-in.
 /// </summary>
 public override PlugInInterface.Device SupportedDevice
 {
   get
   {
    I2cAddressRange address_range;
    List<I2cAddressRange> address_ranges;
    // create I2C address range containing I2C addresses, which are
    // supported by this IC
    address_ranges = new List<I2cAddressRange>();
    address_range = new I2cAddressRange (new I2cAddress (0x40, false),
                                 new I2cAddress (0x4f, false));
    address_ranges.Add (address_range);
    // create an object describing the IC
    return new PlugInInterface.Device
               ("telos",
               "Example Plug-In",
               "This plug-in demonstrates how to use the plug-in interface.",
               address_ranges);
   }
 }
 /// <summary>
 /// Interprets the I2C message with the specified index.
 /// </summary>
```

```
public override string InterpretData (PlugInRawTraceData data, int index)
{
 ParsedTraceData sub_msg
ParsedTraceData result;
                      sub_msg;
  // create object for the result of the parser
  result = new StringBuilder();
  // get the I2C message to be parsed by the plug-in
  msg = data[index];
  // iterate over the submessages of the I2C message
  for (int i=0; i < msg.Length; i++)</pre>
  {
    // new line
    if (i > 0)
      result.Append ("\n");
    // get the submessage
    sub_msg = msg[i];
    // output the direction of the submessage
    switch (sub_msg.Direction)
    {
      case ParsedTraceData.DataDirection.DIRECTION_TX:
        result.Append ("TX: ");
        break;
      case ParsedTraceData.DataDirection.DIRECTION_RX:
        result.Append("RX: ");
        break;
      default:
        continue;
    }
    \ensuremath{{//}} output the data bytes of the submessage
    for (int a=0; a < sub_msg.Data.Length; a++)</pre>
    {
      if (a > 0)
        result.Append (" ");
      result.AppendFormat ("{0:X2}", sub_msg.Data[a]);
    }
  }
  // return result
 return (result.ToString());
}
```

}

A complete documentation of the plug-in interface can be found in the I2C.NET API documentation.

6 Master

6.1 Introduction

Beside the tracer function window there is a second important type of function window in I2C Studio: the master window. This type of window can be used to act actively as an I2C master on an I2C-bus.

An I2C master can write data to I2C slaves and read data from them. Only I2C masters can initiate transfers on an I2C-bus.

6.2 Quick Start

The New button or the File New menu item can be used to open a new master window. Alternatively a new master window can be opened using the context menu of the workspace.

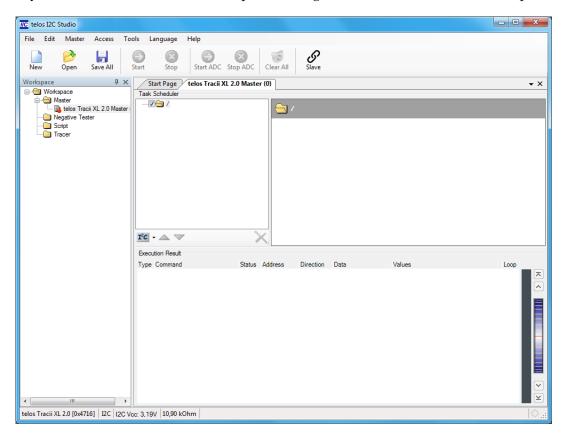


Figure 6.1: New Master Window

Figure ?? shows I2C Studio with a master window, which has just opened.

6 Master

The window is divided into three main areas. On the upper left side there is the command tree. This tree contains all commands, which are executed one by one when the user clicks on the Start button. The upper right side of the window contains detailed information about the command, which is currently selected in the command tree. The remaining space in the lower part of the window is filled out by the result view.

To get familiar with the handling of the Master, the following steps are defined to show an easy example:

• Add a new I2C transfer by clicking on the I2C button. This button is located below the task scheduler (see figure ??).

IC telos I2C Studio	- • ×
File Edit Master Access Tools Language Help	
New Open Save All Start Stop Start ADC Stop ALT Slave	
Workspace I X Start Page telos Tracii XL 2.0 Master (17)	• ×
C StudioWorkspace (i) C Maker Negative Tester Negative Tester Tracer Tack Scheduler Task Sc	
Execution Result	
Type Command Status Address Direction Data Values	Loop
telos Tracii XL 2.0 [0x06CC] 12C 12C Vcc: ~0V 10.90 kOhm	0.:

Figure 6.2: Select I2C Message

- Insert a new TX submessage by clicking on the TX button on the right side of the master window.
- The submessage field appears and the Start button in the main menu gets activated (see figure ??).
- Insert a data byte (e.g. "00") in the data field below the I2C address.
- If a real I2C hardware (e.g. telos Tracii XL 2.0) is used, the following steps have to be performed before the start of a transfer. In case a Dummy interface is used, no action is required.
 - A sufficient supply voltage has to be selected to drive the I2C-bus. Therefore click on the voltage displayed in the Status Bar (see figure ?? | I2C Vcc: ~0V) or select the Master|Hardware Options menu item. If no voltage is selected and the Start button is pressed, an error message will be displayed.

TC telos I2C Studio	x
File Edit Master Access Tools Language Help	
New Open Save All Start Stop Start ADC Stop ADC Clear All Slave	
	×
Task Scheduler	
Sopt Insert Submessage Insert Submessage	\times
Execution Result	
Type Command Status Address Direction Data Values Loop	
	EI.
	✓✓✓
telos Tracii XL 2.0 [0x06CC] 12.C 12.C Vcc: 3.01V 10.90 kOhm	×

Figure 6.3: Select Tx Message

TC telos I2C Studio	
File Edit Master Access Tools Language Help	
New Open Save All Start Stop Start ADC Stop ADC	Clear All Slave
Workspace IX Start Page telos Tracii XL 2.0 Maste	r (0)
Workspace Master Log telos Tracii XL 2.0 Master Log telos Tracii XL 2.0 Master Log telos Tracii XL 2.0 Master	IC I2C Message [1]
- Script	1 TX Insert Submessage: TX EX 🗙
Tracer	I2C Address 0x50 7 Bit V
	Data 00
	Attached File (Type) NONE
	,
Execution Result	
Type Command Status ,	ddress Direction Data Values Loop
telos Tracii XL 2.0 [0x4716] 12C 12C Vcc: ~0V 10,90 kOhm	o

Figure 6.4: Insert Data

telos Tracii XL 2.0 [0x4716] | I2C | I2C Vcc: ~0V | 10,90 kOhm |

Figure 6.5: Statusbar 0V

6 Master

 When the hardware dialog appears, please choose a value from the drop down menu in the section I2C Vcc Supply (e.g. 3.00V) and confirm the new value by pressing the OK button.

IIC Hardware		×
Trigger Condition	ns: Output Testpin	Voltage Thresholds
Start	Acknowledge	Low Level 30 VCC]
Stop	Not Acknowledge	
	I2C Protocol Error	
Termination (Re	sistor)	High Level 70 [% VCC]
10.90 kOhm	scl _	
10.90 kOhm	sda 📕	,
Termination (Cur	rent Source)	
OFF	- SCL -	
OFF	sda 🚽	
- Termination (Aut	o Detect)	I2C Vcc Supply
400 kHz	▼ Start	3.00 V 🔹
Bus Type		
I2C	•	
		Reset OK Cancel

Figure 6.6: Select Master Voltage

- The new voltage appears in the Status Bar at the bottom of the I2C Studio window (see figure ??).

telos Tracii XL 2.0 [0x4716] | I2C | I2C Vcc: 3,08V | 10,90 kOhm |

Figure 6.7: Statusbar 3V

• Click the Start button in the Toolbar (see figure ??).



Figure 6.8: Toolbar

• If a real hardware Master is used, the execution result window below the task scheduler shows an error by displaying the red error sign (see figure ??). Additional to that, the message "there is no slave responsible for this I2C address" is displayed.

File Edit Master Access Tools Language Help New Open Save All Stat Stop Stat ADC Stop ADC Stat Stop Stat ADC Stop ADC Swe changed ZC documents and workspace configuration Workspace Workspace Stat Scheduler Polios Track Z 20 Mater South Take Scheduler Polios Track Z 20 Mater Polios Track 20 Mater Polios Tra	IIC telos I2C :	Studio											_ 0 <mark>_ X</mark>
New Open Size All Size Size All Size Size </th <th>_</th> <th></th> <th>Access</th> <th>Tools</th> <th>Language</th> <th>Help</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	_		Access	Tools	Language	Help							
New Open Sire All Start Stop Start ADC Stop ADC Clear All Save Sore Save changed I2C documents and workspace configuration Image: Sore Changed I2C documents and workspace configuration Task Scheduler Task Scheduler Task Scheduler Task Scheduler Image: Sore Changed I2C Message II Image: Sore Changed III Imag	The Luit			-	Language	Theip	-	1					
Image: Scheduler Image: Scheduler Imag	New		Save All	Start				Clear A	All Slave	e			
Image: Scheduler Image: Scheduler Imag	Workspace		Save chang	ged I2C do	ocuments an	d workspace c	onfiguratio	0)					• X
Internet Track 12.20 Masses Contraction Contractio				Task	Scheduler								
Scipt Tracer Insert Submessage: Insert Submessage:	👔	telos Trad				Message [1]		I ² C D	2C Message	[1]			
International and the second secon	— 🔁 S	ript						1 11				Insert Submessag	e: TX RX 🗙
Attached File (Type) NONE Insert Submessage: IP Insert Submessage: IP Insert Submessage: IP Insert Submessage: IP Image: Insert Submessage: IP Image: Insert Submessage: Insert Submessage: Image: Insert Submessage: Image: Insert Submessage: Image: Insert Submessage: Image: I	 Ir	acer						I2C Add	ress	0x50			7 Bit 🔻 🗸
Insert Submessage: TR R Execution Result Type Command Status Address Direction Data Values Loop TR 12C Message [1] TOXSO TR Data 00 Length 0/1 Bytes Error There is no slave responsible for this 12C address.													$\overline{\mathbf{v}}$
III b								Attache	d File (Type)	NONE			•
IIII P												Insert Submessag	e: TX RX 📉
Type Command Status Address Direction Data 00 0 Image: Status Image: Statu				_			×						
<pre> IZC Message [1] IZ Dotso IZ Data 00 Length 0/1 Bytes Error There is no slave rasponsible for this IZC address. (III F</pre>													
Length 0/1 Bytes Error There is no slave responsible for this I2C address. (III)						ae [1]							
<pre>responsible for this I2C address. </pre>							ك			Length	0/1 Bytes		
< m +										Error	responsible		
	•		,										
elos Tracii XL 2.0 [0x4716] 12C 12C Vcc: 3,08V 10,90 kOhm	telos Tracii XI	. 2.0 [0x47:	L6] 12C 12	C Vcc: 3,0	08V 10,90 k	Ohm							0.

Figure 6.9: Master on real Hardware with no Slave

• If a Dummy device is used instead, a valid transfer is displayed (see figure ??).

<mark>C</mark> telos I2C Studio File Edit Master Access T					
File Edit Master Access T	Start Start Help Start Stop Start ADC Stop ADC	Clear All Slave)		
Workspace 4 × Workspace Master Dummy Master (0)	Start Page Dummy Master (0) Task Scheduler Task 200 J Task 200	I ² C 12C Message	: [1]		• ×
Negative Tester Script Tracer		1 TX I2C Address Data	0x50	Inser	t Submessage: 👿 💌 🗡 7 Bit 🔍 🗸
		Attached File (Type)	NONE	Inser	▼ t Submessage: IX IX
	IC - A V X				
	Type Command Status Ad	Idress Direction	Data Data Length	Values 00 1/1 Bytes	
ummy [0x54AC] I2C I2C Vcc: 5,00	V 100 Ohm				0

Figure 6.10: Master on Dummy with no Slave

- Because no real I2C transfer is performed using the Dummy Master, this setup is able to simulate a receiving device, thus a I2C Slave. Therefore no error occurs using a Dummy Master.
- However, to get a valid I2C transfer without an error message using a real hardware device, the internal Slave device must be enabled or a hardware slave device must be connected to the Master. To activate the internal I2C Studio Slave, the following steps have to be performed:
 - Click on the Slave button in the Toolbar (see figure ??). The I2C Memory Slave dialog will be opened.
 - Enable the Slave by activating the appropriate check box in slave configuration section and confirm this setting with CLOSE (see figure ??).

I2C Memo	-						X
telos Tra	cii XL 2.0 [SN 0x4	716]					
Slave Config	uration						
🗸 Enable	All I2C Addresses	I2C Address	0x50 7 Bit	-			
	✓ Auto Increment	Memory Size	256	-	Timeout [ms]	Disabled	~
Data							
00 00 00 00	00 00 00 00 00 00 00 00 00 00	0 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00	00 00	Get	Set
					_		
							Close

Figure 6.11: Slave Activation

- Run the master transfer again by clicking on the Start button in the Toolbar.
- The I2C transfer should be valid now. Thus the status of the transfer should be indicated with a green OK sign in the result window (see figure **??**).

6.3 Creation of Messages

6.3.1 Command Tree

After opening a new master window the developer has to define the messages, which should be transferred over the I2C-bus.

Figure **??** shows a command tree, which contains five commands grouped into two folders. The first folder contains four commands, which are used to initialize a TV tuner and the second folder contains one command, which changes the currently active TV channel.

Each line in the command tree starts with a check box. If this box is checked, the command or rather the content of the folder is going to be executed when the user clicks on the Start button. Items, whose boxes are not checked, are not going to be executed. This feature can be useful, if the developer wants to deactivate some commands temporarily without deleting them completely from the tree.

The check box is followed by one of the following icons:

6.3 Creation of Messages

IIC telos I2C Studio		
File Edit Master Access Tools Langu	age Help	
New Open Save All	top Start ADC Stop ADC Clear All Slave	
Workspace I X Start Pag	e telos Tracii XL 2.0 Master (1)	▼ X
Workspace Task Schedu Aster	ler	
Externa Travel VI 2 0 Marter	I2C Message [1]	1]
Cript	1 TX	Insert Submessage: 🖽 💌 🗙
Tracer	I2C Address	0x50 7 Bit 👻 😪
	Data	00
	Attached File (Type)	NONE
		Insert Submessage: 🎞 🖭 📉
<u>r</u> c	~ X	
Execution Re		
Type Comm Intel I2C M		Data Values Loop
10 120 0	lessage [1] 0X 70x50 TX	Length 1/1 Buter
۲۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰		

Figure 6.12: Master on real Hardware with Slave

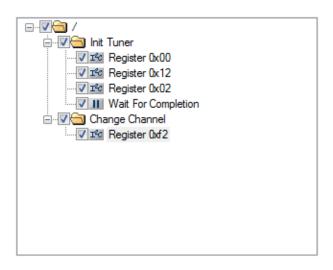


Figure 6.13: Command Tree

- folder (opened)
- folder (closed)
- 12C command
- SMBus command
- IRD command
- pause command
- input testpins command
- output testpins command

The last element in each line is a text, which can be entered by the user to identify a command.

There are several different ways, how to fill and modify the command tree. Below the command tree there are four buttons, which can be used for this purpose. They have got the following meaning:

I ² C	Adds an I2C command to the command tree. There is a drop-down list on the right side of the button, which can be used to change the type of command. Figure ?? shows
	be used to change the type of command. Figure ?? shows this list.

- Moves the selected item upwards in the tree. \bigtriangledown
 - Moves the selected item downwards in the tree.

Deletes the selected item from the tree

	Folder
I ² C	12C
SMB	SMB
IRD	IRD
П	Pause
0	Output
I	Input

Figure 6.14: Drop-Down List for Changing the Type of the Command

Instead of the buttons the developer can use the context menu of the command tree. This menu is shown in figure ??.

6.3.2 I2C

An I2C command sends an I2C message to an I2C-bus. Such an I2C message consists of one or more submessages. The I2C command shown in figure ?? consists of two submessages: a master transmitter submessage followed by a master receiver submessage.

The submessages get numbered serially. The number can be found on the left side of each submessage. This number is followed by one of the following icons:

- TΧ master transmitter submessage $\mathbf{R}\mathbf{X}$
 - master receiver submessage

On the right side there are three buttons before and after each submessage:

	New Folder
1 ² C	New I2C Message
SNB	New SMB Command
IRD	New IRD Command
Ш	New Pause
0	New Testpin Output
I	New Testpin Condition
	Сору
	Paste Into
	Paster After This
\times	Delete
	Select All
	Unselect All
	Rename

Figure 6.15: Context Menu

I ² C I2C Messa	ge [1]	
1 TX	Insert Submessage: 🖭 🔀	-
I2C Address	0x50 7 Bit 🔻 😪	
Data	30	
Attached File (Type)	NONE	
2 RX	Insert Submessage: 🎞 🗵 🗙	
I2C Address	0x50 7 Bit 💌 😪	
Requested Bytes	Þ	
	Insert Submessage: 🎞 💌	
		Ļ

Figure 6.16: I2C Command

TΧ	
RX	
X	

insert a master receiver submessage

insert a master transmitter submessage

delete this submessage

The submessages contains the following entries:

I2C address I2C address of the slave.

Data Data bytes to be sent to the slave (master transmitter only).

Attached File (Type) This can be set to "NONE", "ASCII HEX", "INTEL HEX", and "BI-NARY". If it is set to a value unequal "NONE", data gets read from an external file. This data gets sent after the data, which has been specified in the "data" field. This option specifies the format of the external file (master transmitter only).

Attached File (Name) Path of the external file (master transmitter only).

Requested Bytes Number of bytes to be read from the slave (master receiver only).

By clicking into the grey headline, it is possible to change the alias name of the command. This feature is not only supported by I2C commands, but by all other commands.

6.3.3 SMBus

SMB SMB N	lessage [1]	
Block Write 👻		-
Address	0x50 7 Bit 👻	
Command Byte	20 Hex 🗸	
PEC	Enabled	
Data	22 22 E3 41 41 23 13 22 02	

Figure 6.17: SMBus Command

While the I2C specification allows I2C messages with an arbitrary number of submessages and arbitrary length of the submessages, the SMBus specification defines a limited set of message types:

- Quick Command
- Send/Receive Byte
- Write/Read Byte
- Write/Read Word
- Write/Read 32
- Write/Read 64
- Process Call
- Write/Read Block
- Block Write Block Read Process Call

Note: The SMBus command is not supported by all I2C interfaces.

The first step after the creation of an empty SMBus command is the selection of the message type. Afterwards the command has to be configured. Depending on the chosen message type some of the following inputs are displayed:

I2C address I2C address of the slave.

- **Direction** Specifies the direction of the transfer. "TX" sends data to the slave, "RX" reads data from the slave.
- **Command Byte** Specifies a command. This informs the slave how to process the received data or which data has been requested by the master respectively.

Data (Byte/Word) Data to be sent to the slave.

PEC Enables or disables the "packet error checking" (PEC) of the SMBus. PEC adds a CRC8 to each transfer to detect transmission errors.

Figure **??** shows the SMBus command mask. In this example the message type has been set to "Block Write". The message gets sent to the slave with the address "0x50". Packet error checking has been enabled. The data bytes, which gets transmitted to the slave, are "22 22 E3 41 41 23 13 22 02".

Note: There are some ICs on the market, whose PEC implementation does not conform to the SMBus specification.

6.3.4 IRD

IRD ADM 1021 A [0x50 (7 b	it)] <configuration (mask)=""></configuration>	
ADM 1021 A: Configuration (Mas	k), <set> ▼</set>	
Configuration (Mask) (Name)	ALERT Enabled	
Configuration (Mask) (Numeric)	1	
Configuration (Run/Stop) (Name)	Run 🔻	
Configuration (Run/Stop) (Numeric)	0	
		III
		Ŧ

Figure 6.18: IRD Command

While the I2C and SMBus commands allow to create messages on a very low level, the IRD commands offer a higher abstraction. The I2C Register Description (IRD) defines a file format, which allows to describe the register and values of ICs.

Note: The IRD feature is not supported by all I2C interfaces.

Before an IRD command can be created, it is necessary to use the "IRD & Plug-In Manager", see section **??**. In this manager the developer can specify the IRD files, which should be used for the slaves connected to the I2C-bus.

After the slave addresses have been registered, the slave and the value to be read or written can be selected. This is done using the drop-down list at the upper part of the IRD command editor. Figure **??** shows this editor. In this example the user has selected "ADM 1021 A: Configuration (Mask), <Set>". "ADM 1021 A" is the alias name of the slave, which has been specified in the "IRD & Plug-In Manager". "Configuration (Mask)" is the name of the value to be modified. The direction of the command is specified by "<Set>"."

If the user has selected to set a value in the IC, the value to be set must be defined in the next step. In this example the value "Configuration (Mask)" will be set to "ALERT Enabled". The content can be specified numerically or by name.

Very often it is not possible to set values separately. Instead a whole group of values must be modified at once. This is caused by the fact that the values are stored in registers. Very often a register stores the content of several values. In this example "Configuration (Run/Stop)" must be set besides "Configuration (Mask)".

The value, which has initially been selected in the drop-down list, gets underlined.

6.3.5 Pause

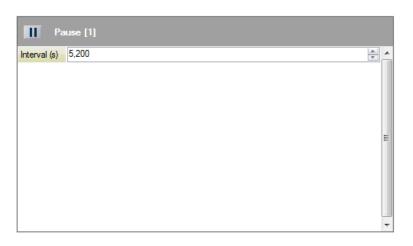


Figure 6.19: Pause Command

There are some situations, where the user does not want to send all specified messages as soon as possible to the I2C-bus. An example for such a situation are EEPROM or flash ICs. After transferring some data to such an IC, the device needs some time to copy the data from its internal cache to the EEPROM or flash cells.

A pause command tells I2C Studio to wait the specified time before going on with the next command in the tree.

Figure **??** shows the editor for pause commands. In this example the interval of the pause has been set to 5.2 seconds.

Note: The precision of the interval is limited. It is guaranteed that the interval is not shorter than the specified time, but it can be longer. This is not a problem for the typical usage of this feature.

6.3.6 Input Testpins

I Testpin Co	ndition [1]	
Testpin Condition 0:	L	*
Timeout	Disabled	
Interval (s)	0,000	
Testpin Condition 1:	Н	
Timeout	Enabled	
Interval (s)	3,000	E
		Ŧ

Figure 6.20: Input Testpins Command

All I2C interfaces have got a number of digital input lines. This command type can be used to wait for certain levels on one or more lines.

The editor for the input testpins command is shown in figure **??**. For each available line there are three parameters:

Testpin Condition Defines the level to be expected:

L	low level
Η	high level
Х	don't care

Timeout Specifies whether to use a timeout or not.

Interval (s) If the timeout has been enabled, this parameter defines how long I2C Studio waits for the expected level. If the expected level is not seen within this interval, I2C Studio simply continues.

6.3.7 Output Testpins

With the output testpins command the user can set the level of the digital output lines of an I2C interface. All I2C interfaces have got at least one digital output line.

For each available output testpin there is a line in the output testpins command editor. The I2C interface used for the example in figure **??** has got two digital output lines. The user can select one of three possible values for each line:

L	low level
Н	high level
Х	don't care

In the shown example the level of testpin 0 is set to don't care. So I2C Studio will not change the level of this testpin. Testpin 1 will be set to high level.

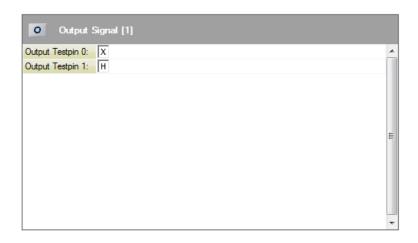


Figure 6.21: Output Testpins Command

6.4 Results

After the user has started the master, the results are displayed in the result view. There is one entry for each command, which has been defined by the user.

The result view consists of a number of columns, which contain the following content:

Type Type of the command.

Command Name The user can assign a name to each command. This name typically describes the purpose of the command.

Status Signals the status of the command. The icons have got the following meaning:

- ok no error
- I2C address has not been acknowledged
- one of the data bytes has not been acknowledged
- Err error
- PEC (packet error checking) error [SMBus only]
- **Addr** Address of the I2C slave, which has been addressed. The icons have got the following meaning:

7	7-bit I2C address
10	10-bit I2C address

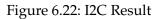
If an alias name has been registered for the displayed I2C address, this name gets shown in this column.

- **Flags** An I2C message can be transferred into two directions. This column displays which one has been used:
 - 📧 master transmitter
 - master receiver
 - master transmitter / master receiver

- **Data/Values** These columns describe the transferred data. The content of both columns is different from command type to command type.
- **Loop** The loop counter shows how often the command has been transferred. The counting starts when the user starts the master e.g. by clicking on the Start button. It ends when the user stops the master e.g. by clicking on the Stop button.

Туре	e Command Name	Status	Address	Flags	Data	Values	Loop
E ² C	Tuner: Ch=1	OK	7 0x50		Data	11	1
					Length	1/1 Bytes	
			7 0x50	RX	Data	00	
					Length	1/1 Bytes	
E ² C	Audio: Vol=50%	00	7 0x51	TX	Data	22	0
					Length	0/1 Bytes	
							_

6.4.1 I2C



The Data/Values columns contain the following entries:

- **Data** Data bytes, which have been exchanged with the I2C slave. Data bytes, which have been specified by the user for the master transmitter case and which have not been accepted by the I2C slave, are marked with red color.
- **Length** The first value indicates the number of bytes, which have been exchanged actually with the I2C slave. The second value indicates the number of bytes, which have been specified by the user. If the transfer was successful, both values should be the same.

The example in figure **??** shows two I2C messages. The first message consists of two submessages: a master transmitter submessage containing the data byte "0x11" and a master receiver submessage requesting one data byte. The message has been exchanged with the I2C slave on address "0x50". No error has occurred during the transfer.

The second message is a master transmitter message containing the data byte "0x22". The transfer of this message was not successful, because no I2C slave was responsible for the address "0x51".

6.4.2 SMBus

The Data/Values columns contain the following entries:

Type Type of the SMBus transfer (e.g. "Block Read").

- **PEC** Defines whether the SMBus message has been transferred with or without "packet error checking".
- **Command** Command byte, which has been sent to the SMBus slave.

6 Master

Exect	ution Result							
Туре	Command Name	Status	Address	Flags	Data	Values	Loop	
SNB	SMB: Block Read	PEC	7 0x50	RX	Туре	Block Read	0	
					PEC	Enabled		
					Command	00		
					Data			
SNB	SMB: Write/Read PC	0K	7 0x50	TR	Туре	Block Write - Block Read Process Call	1	
					PEC	Disabled		
					Command	00		
					TX Data	11 22		
					RX Data	44 00 00 04 00 00 00 22 00 00 00 00 04 00 20 00 00 00 00 00 02 00 00 00 C0 00 02 03 10 10 00 10		
								Ľ

Figure 6.23: SMBus Result

(TX/RX) Data Data bytes, which have been exchanged with the SMBus slave. Data bytes, which have been specified by the user for the master transmitter case and which have not been accepted by the SMBus slave, are marked with red color.

Figure **??** shows the result of two SMBus messages. A message of the "Block Read" type has been transferred as first. The transfer of this message failed, because PEC had been enabled and the PEC checksum has been wrong.

The second SMBus message has been transferred successfully. It was of the "Block Write -Block Read Process Call" type. PEC has been disabled. I2C Studio has sent the command byte "0x00" and the data bytes "0x11 0x22". The SMBus slave answered the request with several data bytes.

6.4.3 IRD

Execu	tion Result						
Туре	Command Name	Status	Address	Flags	Data	Values	Loop
IRD	Configuration (Mask)	OK	70x50 ADM 1021 A		Configuration (Mask)	ALERT Enabled	1
					Configuration (Run/Stop)	Run	
IRD	Local Temp. Value	OK	70x50 ADM 1021 A		Local Temp. Value	2 °C	1
IRD	Manufacturer Device ID	OK	70x50 ADM 1021 A		Manufacturer Device ID	16	1
							×

Figure 6.24: IRD Result

For IRD message the Data column contains the name of the IRD values. The Values column contains the values of the IRD values.

The example in figure **??** contains the results for three IRD messages. All messages have been exchanged with an ADM1021A device, which is listening to address "0x50".

The first message sets the values "Configuration (Mask)" to "ALERT Enabled" and "Configuration (Run/Stop)" to "Run". The second message reads the "Local Temp. Value" from the device, which is "2 °C". The last message reads out the "Manufacturer Device ID" of the IC, which is "16".

6.4.4 Pause

Execution Result					
Type Command Name	Status Ad	dress Flags		Values	Loop
II Pause [1]	OK		Interval	5200 ms/5200 ms	1

Figure 6.25: Pause Result

The Data/Values columns contain the following entry:

Interval The first value indicates the time in milliseconds, which has already elapsed. The second value indicates the time, which has been specified by the user.

The example in figure **??** shows a pause command. The user has specified an interval of "5200 ms". Since the pause has already been completed, both values are "5200 ms".

6.4.5 Input Testpins

	/pe Command Name	Status	Address F	Flags	Data	Values	Loop
Testpin 1 🔣						H	
		_			Testpin 1		
					Timeout		

Figure 6.26: Input Testpins Result

The Data/Values columns contain the following entries:

Testpin (x) Level of the input testpin. The following icons are possible:

- H high level expected & found
- L low level expected & found
- H high level expected, low level found
- Iow level expected, high level found
- **Timeout** The first value indicates the time of the timeout, which has already elapsed. The second values indicates the timeout, which has been specified by the user. Both values are given in milliseconds.

6 Master

The example shown in figure **??** contains the result of one input testpins command. The user has specified an input testpins command, which has expected high-levels on testpin 0 and testpin 1. A timeout of "12 s" has been specified. Both testpin had the expected level, when the master was started.

6.4.6 Output Testpins

Execution Result					
Type Command Name		Address		Values	Loop
	0K		Testpin 1	H	1
O TP 0: LOW	0K		Testpin O	L	1

Figure 6.27: Output Testpins Result

The Data/Values columns contain the following entries:

Testpin (x) Level to which the output testpin has been set by the master. The following icons are possible:

Image: Image with the second second

The result view in figure **??** contains the results of two output testpins commands. Both have been transferred successfully. The first command sets testpin 1 to high level. The second command sets testpin 0 to low level.

6.5 Configuration

6.5.1 Master Options

The master function window can be configurated with its options dialog. The menu item Master Master Options opens this dialog.

The following parameters can be configured using the master options dialog:

Bitrate Defines the I2C bitrate (SCL) to be used by the master.

- **Low/Full Speed** Configures the low/full-speed bitrate. Some I2C interfaces allow to set I2C bitrates, which do not conform to the values defined by the I2C specification.
- **High Speed** If this value is set, the master sends the messages using the high-speed mode of I2C. This mode is supported only by a few I2C devices on the market. SMBus devices do not support this mode. The high-speed token gets sent with the "Low/Full Speed" bitrate.

IIC Master
Bitrate
100,00 kHz Low/Full Speed
High Speed Enabled
2.00 MHz High Speed Ox08 Master Code
Settings
Stop Transmission On Error
Stop Transmission On Arbitration Lost
Send Loop
Reset OK Cancel

Figure 6.28: Master Options

- **Master Code** Configures the master code to be used in I2C high-speed mode. If more than one I2C master talks to the I2C-bus, the master code defines the priority during the bus arbitration.
- **Stop Transmission On Error** If this check box is set and an error occurs, the master function window goes to the stop state.
- **Stop Transmission On Arbitration Lost** If this check box is set and an arbitration error occurs, the master function window goes to the stop state.
- **Send Loop** Normally the master function window sends each message on time. After sending all messages having been defined by the user, the master goes into the stop state. If this check box is set, the master continues sending the messages until the user stops the master manually.
 - **Note:** The I2C high-speed mode is only available for I2C interfaces with a high-speed license.

6.5.2 IRD & Plug-In Manager

The "IRD & Plug-In Manager" dialog gets described in section ??.

7 Negative Tester

7.1 Introduction

The most common use of an I2C interface's master functionality is to send and receive data in compliance with the I2C-Bus Specification. This implies that the device we are talking to is known to conform to the I2C standard, as well.

However, there are situations in which this particular aspect of a device is to be tested, i.e. where the goal is to determine whether or not a device is fully compliant with the I2C-Bus Specification and how this device behaves in case of ill-formed signals.

IIC telos	I2C Studio				-	o ×
File Ec	lit Negat	ive Tester	Acces	s Tools Language	Help	
New	📂 Open	Save All		tart Stop Start	and the state of t	
Workspac		Ę	×	Start Page NegTes	stCaseMasterData telos Tracii XL 2.0 Tracer (6)	+ ×
⊡- ⊡ W	orkspace Master			Master Slave		
ė- 6	Negative T			Testcases	Current Testcase	
		stCaseMaster stCaseMaster		Master Data	Testcase Message Configuration	
	Script			Master Speed		
	Tracer	acii XL 2.0 Ti	racer	Master Clock [
		001712 2.0 1		Master Termin	Start (Bytes) 1 👻 The "master data" test transfers I2C messages with different lengths to the I2C bus.	
				Master Spike	Stop (Bytes) 1 Amaster receiver transfer with a length of zero bytes works only with special I2C slaves	ves. Most otł
				Master Triling	Step (Bytes) 1 Summarted Directions: TX RX	
					Rest Defa.k Message Defa + + 0 1000p Addr Dirlen Sendlen Recbata Send 0 17,0050 EZ 1	60µs
				< >		× ¥
				1°C · 🛆 🗢 🗙		>
				Results Evaluation		
					t TypeResult Speed Cond Addr Dir Length Data	x
				15 Master Stop Master Master Stop Master Master Stop Master 16 Master Stop Master	r Stop 008 EE E 7 0x50 TX 100 r Stop Fer IZC Protocol Error r Stop Fer 0 0	^
				Master Stop Master	r Stop tra I2C Protocol Error	~
				Master Stop Master	r Stop 🗤 💿 0	¥
<			>	<		>
talas To 1		71.71				

Figure ?? shows an example of the Negative Tester function window.

Figure 7.1: Example of Negative Tester Function Window

The Negative Tester is designed to fulfill all requirements introduced by this kind of application. It is capable of acting as master or as slave. In both roles it allows to control all relevant low-level aspects of bus communication, in particular it provides functionality to define the timing for each and every bit.

It is also possible to send out patterns which violate the standard, e.g. make a "byte" six bits long. In slave mode the Negative Tester permits to stretch the clock at any time. The user has full control over arbitration handling in master mode.

Furthermore, independent configurable output signals can be used to trigger external events or to flag certain states in real time.

7 Negative Tester

In the master mode several testcases are available (refer to chapter ??) that can be executed sequential. In the Slave Mode the slave buffer data can be defined.

7.2 Quick Start

A Negative Tester function window can be opened by clicking on the New button and selecting a Negative Tester. Another way is to click on the File|New menu item. Beside this it is possible to open a new window using the context menu of the workspace. Figure **??** shows the I2C Studio after the Negative Tester function window has just opened.

IIC telos I2C Studio		- 0	×
File Edit Negative Tester Access Tools La	anguage Help		
New Open Save All		Se an	
Workspace # X	Start Page telos Tracii XL 2.0 Negativ	e Tes	▼×
Workspace Waster	Master Slave		
🖃 😁 Negative Tester	Testcase	Current Testcase	
	ZSI Master Data (0)	Testcase Message Configuration	
🗀 Tracer		Enabled Name Master Data [0] Type Data ~	
		Start (Bytes) 1 The "imaster data" test transfers 12C messages with different lengths to the 12C bus.	
		Stop (bytes)	
		Step (bytes) 1 +	
			- 1
			- 1
		Reset Default	
		Meesage Data	
		اماني -ني +ني	
		No.Loop Addr Dir en Send en Recipata Send Og +20µ5 +40µ5 +60µ5 +80µ5 +100µ5 +120µ5 +140µ5 +140µ5 +140µ5 +210µ5 +2100 +210µ5 +210µ5 +2100 +2100 +2100 +21000 +21000 +21000 +21000 +21000 +21000 +21000000 +210000000000	
			() (
			~
		Nessages: 2	×
		¢	>
	Results Evaluation		
			×
			^
			¥
	¢		>
			Later

Figure 7.2: New Negative Tester Function Window

Note: The Negative Tester function window is only available, if a Negative Tester interface is connected to the local or a remote PC. Besides the telos Negative Tester a telos Tracii XL or telos Tracii XL 2.0 with a tracer license is needed to use the full set of features of the Negative Tester. See figure **??**

The Negative Tester and the telos Tracii XL / telos Tracii XL 2.0 must be connected to the same I2C-Bus. The Negative Tester acts as a pattern generator and the telos Tracii XL / telos Tracii XL 2.0 with a tracer license as an I2C-Bus tracer.

7.3 Negative Tester Window

The Negative Tester supports two different roles. It can work as an I2C master or as an I2C slave. To select these modes, please click on one of the two tabs at the top of the the Negative Tester window (refer to figure ??).



Figure 7.3: Negative Tester and telos Tracii XL 2.0

To navigate directly to the appropriate chapter, please click on one of the following items:

- **??** (refer to chapter **??**)
- ?? (refer to chapter ??)

For both modes the result (refer to chapter ??) is displayed at the bottom of the window.

The following chapters present a detailed description of all important Negative Tester functions and features. Please refer to Figure **??** which shows the Negative Tester Window with the names of the sub windows and tabs.

7.4 Master

After the activation of the Master Tab (refer to figure ??) the I2C Studio acts as a master. This mode can be used to test I2C slaves by sending and receiving data. One or more testcases can be defined and executed sequentially.

To start and stop the sending process, use the menu item Negative Tester|Start (F5)/Stop (F6) or the corresponding buttons in the toolbar. Figure **??** shows the Master Tab, which has just opened.

The left side of the Master Tab contains the **??** (refer to chapter **??**) and the right side shows the current selected testcase in the **??** (refer to chapter **??**).

7 Negative Tester

Master Tab	Testçase W	/indow						
Slave Tab			Testcase Parameter Ta					
Testc	ase Selectio	n Window	Testcase Message					
	ase Selectio		Testcase Config	guration lab				
Master Slave								
Testcases	Current Testcase							
Master Data	Testcase Messag	ge Configuration						
· 기호 Master Stop · 기호 Master Speed · 기호 Master Clock [· 기호 Master Stress · 기호 Master Termin, · 기호 Master Spike	Enabled	Name	Master Data	Туре	Data			
	Start (Bytes)		The "master data" test transfers I2C messages with different lengths to the I2 Warning:					
	Stop (Bytes) 1 A master receiver transfer with a length of zero bytes works only with special I2C slav							
	Step (Bytes)							
< >>	Reset Default Message Data +		Len RecData Send CA Messages: 2	05 +80µ5 SDA MM SCL 111111111111111111111111111111111111	+200µs +360µs 101	× ¥		
12 - 🗆 🗻 🗙	<		Messages, 2			>		
Results Evaluation								
No Text Name Test 15 Master Stop Master Master Stop Master Master Stop Master 16 Master Stop Master Master Stop Master Master Stop Naster	Stop Err Stop OK LS Stop Err	d Cond Addr D © 7 0x50 0 © 7 0x50 0 P	1 00 I2C Protocol Error 0	Data		× ×		
<						>		
Resu	lt Tab Evalu	uation Tab	Message Data Wind	dow				

Figure 7.4: Negative Tester Window

7.4.1 Testcase Selection Window

Figure **??** shows this window (with the default testcase) as it exists after opening a new function window. This window provides a tree view that is used to define the sequence of the master testcases.

Each new testcase is placed in a selection tree. With this feature it is possible, to add several different testcases to the tree. If the same testcase should be performed more than once, it can be added several times to the tree. Each test (no matter if the type is the same or not) can consist of individual parameters (e.g. bitrate, messages data, ..) This provides a freedom of choice on a high level in the use of the testcases.

The data for the current selected testcase is displayed and can be changed in the window at the right side of the tree (refer to chapter **??**).

Each testcase can be enabled/disabled for execution (checkbox). To add, remove and move the testcases use the buttons at the bottom of this window or the context.

case	Current Testcase							
⊠i≊d Master Data [0]	Testcase Message Config	uration						
	Enabled Name	Master Data [0]	Туре	Data	~			
	Start (Bytes) 1 Stop (Bytes) 1 Step (Bytes) 1	The "master data" test transfers 12 Warning: A master receiver transfer with a le			Nost other I2C slaves will hol	d the SDA line low after this	lest.	
		T						
	Reset Default Message Data							
	No Loop Addr Dir Len	Send Len Rec Data Send	os	+20µs +40µs	+60µs +80µs	+100µs +120µs	+140µs +160µs	+180µs +20
	0 1 7 0X50 7X	1 00						
	1 1 7 0050 22	0 1	SDA SCL					
\sim	× <			Messages: 2				
Evaluation								

Figure 7.5: Master Tab

Testcases	
Master Data	
I ² C - 🛆 🔽	\mathbf{x}

Figure 7.6: Testcase Selection Window

The testcases are automatically named and individually numbered to ensure a valid operation. However, the user can choose a more significant name, if necessary. If the default

7 Negative Tester

testcase name in the selection window should be changed, this can be done by a single click to the testcase in the via ?? (see chapter ??) or via ?? (see page ??).

Buttons

The following buttons as part of the Testcase Selection Window are available:

1 ² C -	New Testcase (select same type as current)
1²C 🕤	New Testcase (select type via testcase list)
	Move Testcase Upwards
\bigtriangledown	Move Testcase Downwards
\sim	Delete Testcase

The user can choose whether to select the same type of testcase selected lastly by clicking directly on the New Testcase button, or select a new testcase by clicking on the arrow button next to the New Testcase. Figure **??** shows the list with the testcase types (refer to chapter **??**).

Testcases						
√ I ² C	Master Data					
	Master Stop					
I 20	Master Speed					
I ² C	Master Clock Diversifying					
	Master Stress					
2	Master Data					
	Master Expert					
	Master Expert					
	Master Stop					
	Master Speed					
·····12	Master Spike					
	Master Stress					
	Master Termination					
I ² C	Master Timing					

Figure 7.7: Add New Testcase Menu

Context Menu

Additional to the buttons mentioned above it is possible to use the Context Menu to edit the testcase tree in the selection window. While a testcase is selected by a single click of the left mouse button, the right mouse button can be used to activate the Context Menu (see figure ?? and ??). This menu provides the button actions described in section (??) and also some additional operation features like copy, paste and rename.

Thus it is possible to copy a testcase and paste it at a defined position in the testcase tree. It can be decided whether to paste the copied testcase above or below the current selected testcase. The menu entries are dynamically switched on or off depending on the current testcase tree composition and the pre-selected menu function. E.g. the **Paste** option is available earliest after the **Copy** function was selected (see figure **??**).

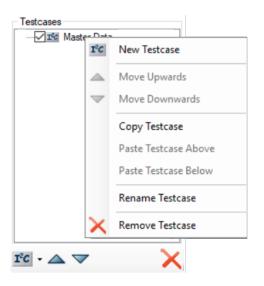


Figure 7.8: Negative Tester - Context Menu (partly activated)

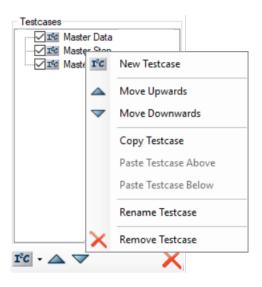


Figure 7.9: Negative Tester - Context Menu (fully activated)

7.4.2 Testcase Window

This window (see figure ??) shows the data of the currently selected testcase in the ?? (see ??). It is used to enable/disable the testcase for execution, set the type (refer to chapter ??) and the parameters for this testcase. Figure ?? shows an example of the Testcase Window (selected testcase: ??).

7 Negative Tester

estcase Message	Configuration											
Enabled	Name	Master Data [0]	Туре	Data	~							
Start (Bytes)		The "master data" test transfers I Waming:	I2C messages with different	lengths to the I2C bus.								
Stop (Bytes) 1		A master receiver transfer with a l	length of zero bytes works o	only with special I2C slav	es. Most other I2C	slaves will hold	the SDA line l	ow after this te	st.			
Step (Bytes)	÷											
Reset Default												
ssage Data												
)+ <u>P</u> - ,				+2007 +400	15 +50115	+8000	+1000	+12014	+14005	+150 18	-1500	+200
)+ 🔎- ,		n RecData Send	05	+20µs +40	us +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
)+ <u>P</u> - ,	r Len Send Le	n RecData Send	SDA	+20µs +40	ıs +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le			+20µs +40	us +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
2+ - , Loop Addr Di 1 70x50 72	r Len Send Le		SDA	+20µs +40	us teopus	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le	00		+20µs +40	из +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le	00		+20µs +40	μs +60μs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
2+ - , Loop Addr Di 1 70x50 72	r Len Send Le	00		+20µs +40	из +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+150µs	
2+ - , Loop Addr Di 1 70x50 72	r Len Send Le	00		+20µs +40	из +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le	00		+20µs +40	из тбоµз	+80µs	+100µs	+120µs	+140µs	+160µs	+180µ5	+200
Loop Addr Di	r Len Send Le	00		*20µs +40	us +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le	00		+20µ5 +400	из +60µs	+80µs	+100µs	+120µs	+140µs	+160µs	+180µs	+200
Loop Addr Di	r Len Send Le	00		+20µs +40	15 +60µ5	+80µ5	+100µs	+120µs	+140µs	+160µs	+180µs	+2000

Figure 7.10: Testcase Window

The window shows the I2C-Bus messages that will be sent with the current configuration. For each message a graphical visualization of the SDA/SCL signals is available. Direct after the changes of a parameter the data will be updated automatically in the **??**. Thus the user can easily understand the function of the parameters by watching the changes in the **Messages** Data frame (refer to figure **??**).

The Testcase Window is divided in the following sub windows:

- Current Testcase (see ??) to define the testcase data
- Message Data (see ??) to show the I2C-Bus data

7.4.3 Testcase Parameter Window

This window is used to define the message data for the testcases. Figure **??** shows an example of the **??** testcase.

The following tab pages are available:

Testcase ?? - to define of the the testcase parameters

Message ?? - to define of the the message data (like address, send, receive, ...)

Configuration ?? - to define of the the configuration (like bitrate, timing, ...)

Each testcase type (defined in ??) provides a number of Special Parameters which are valid only for this testcase. They can be set in the ??. The **Poset** button sets the default values for all parameter of the current selected tob page.

The Reset button sets the default values for all parameter of the current selected tab page.

The **Common Parameters** in the **??** and **??** are available for several testcase types. For some testcases some common parameter are omitted because there is a conflict with the special parameter.

Testcase Parameter Tab

This tab page is used to set the type (refer to chapter ??), the user name and the testcase parameter. A description of the testcase function and the parameters appear in the text field next to the parameter. Figure ?? shows an example of the ?? testcase.

Testcase	Message	Configuration	
🗹 Enable	ed	Name	Master Data Type Data ~
Start (B		1	The "master data" test transfers I2C messages with different lengths to the I2C bus. Warning:
Stop (B	lytes)	1 😫	A master receiver transfer with a length of zero bytes works only with special I2C slaves. Most other I2C
Step (B	lytes)	1 🛓	Supported Directions: TX_RX
Reset D	efault		

Figure 7.11: Testcase Parameter Page

The following elements are available:

Enabled Enable/Disable the testcase for the execution

Name Individual name of the testcase given by the user (appears in the tree)

Type Selected testcase type (refer to chapter **??**)

Testcase Parameter Parameter of the testcase (refer to chapter **??** for a detailed description)

Reset default Set the default values

Testcase Message Tab

The **??** testcase provides additional functions. Thus two types of the Testcase Message Tab pages exist:

- ??
- ??

Testcase Message Tab (Standard Testcases)

This tab page is used to define the message data for the all testcases (except **??** testcase). The **Negative Tester** can work as a master transmitter and/or as a master receiver. This tab page is

7 Negative Tester

used to set the address, to enable the send/receive function and to define the messages data. Figure **??** shows an example of the Testcase Message Tab.

Testcase Message	Configuration
I2C Addresse	0x50 7 Bit v
Transmitter	
Address Pointer	
Data	CA FF EE
Receiver	
Address Pointer	00
Length	10 Expected Data Check 12 34
Reset Default	

Figure 7.12: Testcase Message Tab Page

The following elements are available:

I2C Address I2C address (7/10 bit) of the slave device, which should be tested by the testcases

Transmitter all settings regarding the transmitter function

Checkbox Enable/Disable data transmitter

Address Pointer Sub Address of the slave device

Data Data to be transmitted

Receiver all settings regarding the receiver function

Checkbox Enable/Disable data receiver
Address Pointer Sub Address of the slave device
Length Number of received bytes from the device
Expected Data - Checkbox Enable/Disable compare function
Expected Data -Data Field Compare data for received data

Transmitter and receiver are enabled by default and can be individually disabled using the appropriate checkbox. The transmitter provides a **data** preset (0x00 - 0xFF) which are sent to the I2C slave address. The additional field **Address Pointer** can be used to set the sub address. This is the first data byte after the address. It specifies an internal address of the slave device. Thus, with this pointer it can be specified, to which internal memory address the transmitted data should be stored or from which memory address data should be received.

The Expected Data will be compared to the received data in the **??**. To enable this function set the Check checkbox. The Length field is used to set the length of the data to be received. If the length is greater than the number of expected data, the test will fail. If the length of received data is smaller, than the expected data of the remaining bytes are ignored. If the length of the compare data is smaller than the defined length, the compare function will be started at the first byte of defined data.

Testcase Message Tab (Expert Testcase only)

This tab page is used to define the message data for the **??** testcase. In the expert mode it is possible to define each kind of messages in and outside the **I2C-Bus Specification**. The entries of bit/condition can be changed, added and removed to create each kind of **invalid** i2c-bus message. Be aware that there are no fields to define the address or the read/write direction. Thus the user has to take care that the message starts/ends with a start/stop condition and that the first byte is a valid address with R/W bit.

The GUI differs from the other testcases. The upper area is used to define the message data. In the upper left window the user can select the bytes/condition data and the upper right area is used to show and to edit the selected data. To store the changed data the Update button must be pressed, otherwise the data is lost.

The lower area shows all messages as they will be send on the i2c-bus in graphical format with the byte and bit/condition data. With the horizontal and vertical scroll bar the user can scroll through the message data.

With the context menu in the lower window it is possible to show/hide the data and conditions text in graphic, and to set the option "7/8 Bit" and the "Hex/Radix". The log of the ??) can be deleted as well. These settings are valid for all elements of the control. E.g. if the "Radix" option is set, all values are displayed in the decimal format and each user input is interpreted as decimal value.

Figure **??** shows an example of the messages of the **??** tab page.

estcase	Message	Config	guration														
Data	Byt	e O	Bit/Con	ndition	n								Current Byte: 1 (0x01)				
Addi	r Dir	Length	Data										\mathbf{x}	Hex	A0		_
70x050			000:	s	A0.NA	CA.NA	s	AO.NA	98.NA	EE.NA	EE.NA		^	Die	10100	0 0 0 NACK	_
			008:	23.NA	31.NA	40.NA	OF.NA	04.NA	05.NA	06.NA	07.NA			Bin	10100	UUUNACK	_
			010:	08.NA	09.NA	OA.NA	58.NA	CA.NA	00.NA	00.NA	00.NA						
			018:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA						
	0 TX	73	020:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA						
			028:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA		~				
			030:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA		¥				
Reset		• ⊲	►	~ ~									×				
essage D D +	lata P -																
	dr Dir	r Lengti	n (50µs	+100µ	s +1	50µs	+200µ	s +2	50µs	+300µs	+350µ	+400	15 +45	0µs +500µ	.s
Ad							. NA		5 A0.	ALA.		98.NA		EE.NA		EE.NA	
	50 TX	7	3	5 AO.NA								98.NA					
	50 TX	7		S AO. NA		nnn		010	51(000				
70x0			³ SCL SDA			0 1		010	ווינים ו חרוחו	100	000		000	1 1 1 EE.NA	0111	0 1 1 1 EE.NA	
70x0		7.	³ SCL SDA SCL	51010		0 1 CA	1001	010	51(0 1 0 0 NA	000	10011	000		01110		
Ad 7 0x0 7 0x0 7 0x0	50 TX		³ SCL SDA SCL SDA	5 1 0 1 0 5 AO.NA		0 1 CA	1 0 0 1 . NA	010	5 1 (5 A0	0 1 0 0 NA		1 0 0 1 1 98. NA	<u>1</u> ГП П Г		01110	EE.NA	

Figure 7.13: Testcase Message Tab (Expert Testcase)

To get a description of the byte and bit condition text, please refer to ??.

Each combination of bits, conditions and acknowledge can be defined for the Transmitter mode. If the defined byte ends with a "NACK" and no slave responses, the transmission will be terminated after this byte. To proceed the transmission in any case, the entry "NACK (ignore)" must be used. If a "1" will be sent and another device stretches the bus, the transmission will be terminated as well.

One or more complete receive bytes (bit 0..7) can be defined for the **Receiver**. It is not possible to receive less than eight bits. The data in the **Byte** (Hex) is displayed as "??", if the received data bits are unknown.

Two views are available to add and change the data of the message. It can be changed via options buttons at the top of the window:

- Byte: ??
- Bit/Condition: ??

Each view has a common and a special function only for this view.

In the upper left area for both views a table with the following columns exists:

- **Addr** Field contains the address of the I2C slave, which has been addressed by the master. The icons have got the following meaning:
 - 7-bit I2C Address10-bit I2C Address

Dir Direction of the message (Transmit/Receive)



Master Transmitter Master Receiver

Length Length of the message

Data This column shows the data in different views.

The following buttons are available for both views:

- Add new: data byte / bit/condition
- Move current data byte / bit/condition upwards
- Move selected data byte / bit/condition downwards
- Move current selected data byte / bit/condition line upwards (only bytes)
- Move selected data byte / bit/condition line downwards (only bytes)
- X Delete: data byte / bit/condition

Testcase Master Expert Message: Change Byte

In this view the message data is displayed in a table. The data is displayed in the byte format (column: Data). Each line starts with the address of the data and contains eight data bytes. The data element is a data byte with the acknowledge or the condition (**??** tab page).

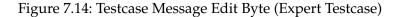
If the **Byte** representation is selected, the following data is visible at the right area of the screen:

- Current Byte: [AddressByte] in decimal (0x[AddressByte] in hex)
- Hex/Dec: data in hex/decimal format
- Bin: data in binary format

In the "Bin" field the bits/condition of the data byte can be set (please refer to: **??**). After the data is changed the associated values in the hex/bin box and in the table will be updated.

Figure ?? shows an example of the messages of the ?? tab page.

estcase	Message	Config	guration											
Data	Byte	0	Bit/Cond	lition									Current B	lyte: 1 (0x01)
Add	r Dir L	ength	Data									×	Hex	A0
			000:	s	AO.NA	CA.NA	s	AO.NA	98.NA	EE.NA	EE.NA	^		
			008:	23.NA	31.NA	40.NA	OF.NA	04.NA	05.NA	06.NA	07.NA		Bin	1010000NACK
			010:	08.NA	09.NA	OA.NA	58.NA	CA.NA	00.NA	00.NA	00.NA			
			018:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA			
7 0x05	0 1979	73	020:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA			
		13	028:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	~		
			030:	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	00.NA	¥		



The following buttons are available for this view:

- Add data byte (Write Data)
- \bigcirc Use the arrow to add one of the the following data:
 - Byte (write): add write byte
 - Start Condition (S): add start condition
 - Stop Condition (P): add stop condition
 - Byte (read): add read byte
- X Delete data byte

Testcase Master Expert Message: Change Bits/Conditions

In this view the message data is displayed in a table. The data is available in the byte and bit/condition format, which is displayed in the graphical visualization of the SCL/SDA signals (?? tab page). The bits and condition can be selected directly in the graphic (left area). The selected data can be changed in the edit fields in the right area.

The horizontal scroll bar can be used to show all bytes and bits of the message.

If the Bit/Condition mode is selected, the following data fields are visible at the right area of the screen:

- Current Byte: [AddressByte] in decimal (0x[AddressByte] in hex)
- Hex/Dec: data in hex/decimal format
- Current Bit/Condition: [AddressBit] in the byte
- Bin: available data in the list box

If the "update" button is pressed the associated value will be updated in the hex field and in the SCL/SDA graphical representation.

Figure **??** shows an example of the messages of the **??** tab page.

Current Testcase	
Testcase Message Configuration	
Data O Byte Bit/Condition	Current Byte: 1 (0x01)
	Hex A0
Addr Dir Length 0s +20µs +40µs +60µs +80µs +100µs	Current Bit/Condition: 3
SDA AO. NA CA. NA 73 SCL 1 0 0 0 0 NACK 1	Bin S P 1
	0 NACK NACK_I
< >	

Figure 7.15: Testcase Message Edit Bit (Expert Testcase)

The following buttons are available for this view:

È

₿⊙

Add data byte (Write Data)

Use the arrow to add one of the the following data:

- 0: add low bit
- 1: add high bit
- NACK: add acknowledge (checked)
- NACK_I: add acknowledge (checked ignore)
- Start Condition (S): add start condition
- Stop Condition (P): add stop condition



Delete data bit/condition

Testcase Master Expert Message: Byte and Bits Condition Text

The data bytes provide the following available condition text:

Text	Direction	Description
S	send	start condition
Р	send	stop condition
(0FF) NA	send	data byte (hex) with an acknowledge (checks acknowledge)
(0FF) NAI	send	data byte (hex) with an acknowledge (ignores acknowl-
		edge)
(0FF) NA ??	send	data byte (hex) with an acknowledge (checks acknowledge)
		with additional (invalid) bits/conditions
??/[data]	receive	receive data is always unknown
АСК	receive	send an ACK for the slave (expects more data)
NACK	receive	send a NACK for the slave (last byte)

Table 7.1: Negative Tester Master Byte Text

The data bits provide the following available condition text:

Text	Direction	Description
0	send	low value
1	send	high value
S	send	start condition
Р	send	stop condition
NACK	send	acknowledge (high value) - transmission terminated if the
		slave does not generate the acknowledge
NACK.I	send	acknowledge (high value) - ignores the acknowledge from
		the slave
NACK	receive	send a NACK for the slave (last byte)
NACK.I	receive	send a NACK for the slave (last byte)

Table 7.2: Negative Tester Master Bit Text

Testcase Master Expert Message: Time Cursor

In the visualization of the graphic signals two cursors are available to show the current time and the delta time between the cursors.

Double click on the scale with the left mouse button to enable the cursor that shows the time of the current position. Then click on the scale to set the cursor to each position. To set the second cursor hold the shift key during the click with the left mouse key.

Figure ?? shows an example of the messages of the cursor functions.

Data (Byt	te 💿	Bit/Condition			
<i>></i> +	<u> </u>					
Addr	Dir	Length	2ms +50µs +100µs	2,22ms 5 +	200µ <mark>∆ 84,70µs</mark> 0µs	x
70x050 T	X	73	DA 00.NA 00.	. NA	00. NA	^
<						¥
Reset		i • «	▶ <u>→</u> <u>→</u>			\times

Figure 7.16: Testcase Expert: Time Cursor

Testcase Configuration Tab

This tab page is used to set the bitrate, timing and other behavior of the I2C-Bus. Most messages will be transferred using the default timing according to the bitrate as defined in the I2C-Bus Specification. Figure **??** shows the tab page with bitrate setting (Time Configuration not set).

Testcase Message Configu	ation	
Bitrate (Hz)	Enable Value	Timing Configuration
Low-Speed	100,000	
High-Speed	1.000,000 🚖	
Options		
Ignore Stretching		
Ignore Arbitration Lost		
NACK Behaviour	Generate STOP \checkmark	
Reset Default		

Figure 7.17: Testcase Configuration Tab Page

The following elements are available:

Bitrate (Hz) Select the bitrate in [Hz]

Low-Speed Low-Speed bitrate of the message

High-Speed High-Speed bitrate of the message (use Checkbox to enable)

Options Set options

Ignore Stretching Enable Checkbox to ignores the bus stretching Ignore Arbitration Lost Set Checkbox to ignores the loss of arbitration on SDA NACK Behaviour Select behaviour of the test if a NACK occurs Release SCL/SDA Release SCL and SDA immediately Generate STOP Generate a STOP condition (default) Restart Script Restart the test

Timing Configuration Enable Checkbox to show timing fields (refer to ??)

Button: Reset default Set the default values

Some testcases provide the option Time Configuration to change the timing of I2C-Bus messages (refer to chapter ??). If this option is enabled the bitrate can not be set. Thus the bitrate fields show not available (n.a.). A help text always appears for the timing field that has the focus. Additional to that the area in the SDA/SCL signals for time parameter is emphasized (only for low speed). Figure ?? shows the tab page with the set option Time Configuration.

Most messages will be transferred using the default bitrate which is already set. Only some testcases, which are testing the bitrate itself, may use other bitrates. For this testcases the bitrate field is not available (n.a.). If a high-speed operation is requested, it can be enabled and its bitrate can be adjusted too. In high-speed mode the master code gets transmitted using the standard bitrate. The remaining message gets transferred using the high-speed bitrate. The

Current Teacoase									
Testcase Message Configura	stion								
Btrate (Hz)	Enable Value	Timing Config	guration						
Low-Speed	n.a.	Data			Clock				The hold time START
High-Speed	n.a.	Time/ns	Time (LS)	Time (HS)	Time/ns	Time (LS)	Time (HS)		condition'(t_HD; STA) as described in
Options		Start: Hold	4000	• 160	Clock: Befor	e 2640	\$ 560	•	the I2C specification.
Ignore Stretching		RepStart: Setup	4720	• 320	Clock	4680	• 320	*	
Ignore Arbitration Lost		Stop: Setup	4000	320	Clock: After	2680	120		
NACK Behaviour	Generate STOP ~								
		Buff	4720	×					~
Reset Default		Reset Default							

Figure 7.18: New Negative Tester Window

I2C high-speed mode requires compatible I2C slaves. This mode should not be used with standard I2C slaves.

The option Ignore Stretching forces SCL to the other required bitrate. It may lead to an incorrect data transmission if enabled (e.g. due to short SCL high times). The option Ignore Arbitration Lost ignores the loss of arbitration on SDA e.g. in a multimaster system. This case usually leads to faulty data. If this option is disabled the Negative Tester stops after the loss of arbitration is detected (recommended setting). The option "NACK Behaviour: Restart test" could be useful if a slave sends a NACK to its address while the slave is busy (e.g. if an EEPROM is performing an internal write operation). Be aware that can cause the test to run forever if there is no slave!

7.4.4 Message Data Window

This window shows a graphical visualization of the SDA/SCL signals (I2C-Bus data and clock) that will be sent using the current configuration. According to the parameters for the testcases a number of read/write messages appear in this window.

It can be used to understand the functionality of different parameters settings by watching the changes in the graphical message representation. A zoom and scroll function for the signal is available to have a detailed look to each bit. After a change of one parameter in the **??** the data will be immediately updated. Figure **??** shows the Message Data Window.

Loop Addr Dir Len Send Len Rec Data Send	05 +20	µs +40µs +6	0µs +80µs	+100µs	+120µs	+140µs +16	0µs +180µs	+200
1 7 0X50 72 1 00								
1 7 0X50 RX 0 1	SDA							
	CC1							
	SCL							
	SCL							
	SCL							
	SCL							

Figure 7.19: Message Data Window

The columns have got the following meaning:

No Number (index) of the message

Loop The number of repetitions of the message

Addr This field contains the address of the I2C slave, which has been addressed. The icons have got the following meaning:

7-bit I2C address10-bit I2C address

Dir Direction of the message (Transmit/Receive)

TX	master transmitter
RX	master receiver
TR	master transmitter / master receiver

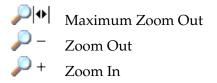
Len Send Number of bytes sent to the slave device

Len Rec Number of bytes received from the slave device

Data Send Data sent to the slave device

Signals SCL/SDA signal of the I2C-Bus message

The following buttons are available:



Note: For the received data the SDA signals appear always as high in the graphic.

7.4.5 Message Timing

Normally the message timing will be set according to the bitrate (refer to chapter ??). For some timings please refer to the I2C-Bus Specification (Rev. 6 4 April 2014) (https://www.nxp. com/docs/en/user-guide/UM10204.pdf). The value can be changed from the standard value. Be aware that the bitrate may be changed if you set the values.

Table **??** contains the name of the field in the dialog (column: Field) and the name of the time in the I2C-Bus Specification. The following columns show if this value is available for low speed and high speed (LS/HS). In the last column (Description) the description of the timing is visible.

Field	Time	LS	HS	Description
Start: Hold (ls)	$t_{HD;STA}$	x		The hold time START condition
Start: Hold (hs)	$t_{HD;STA}$		x	The hold time START condition
RepStart: Hold (ls)	$t_{SU;STA}$	X		The setup time repeated START condition
RepStart: Hold (hs)	$t_{SU;STA}$		x	The setup time repeated START condition
Stop Setup (ls)	$t_{SU;STO}$	x		The setup time for STOP condition
Stop: Setup (hs)	$t_{SU;STO}$		x	The setup time for STOP condition
Clock: Before (ls)	t_{LOW}	X		The LOW period of the SCL clock before the
				high clock
Clock: Before (hs)	t_{LOW}		x	The LOW period of the SCL clock before the
				high clock
Clock: After (ls)	t_{LOW}	X		The LOW period of the SCL clock after the high
				clock
Clock: After (hs)	t_{LOW}		x	The LOW period of the SCL clock after the high
				clock
Clock (ls)	t_{HIGH}	x		The HIGH period of the SCL clock
Clock (hs)	t_{HIGH}		x	The HIGH period of the SCL clock
Buff	t_{BUF}	X	x	The bus free time between a STOP and START
				condition (graphic shows the time $/2$).

Table 7.3: Message Timing

7.4.6 Master Testcase Types

Table **??** shows the available testcases for the master:

Testcase Type	Transmiter	Receiver	Time
??	Х	Х	Х
??	Х	Х	
??	Х	Х	
??	X	Х	
??	Х		
??	Х	Х	
??	Х	Х	
??	X	Х	Х
??	Х	Х	

Table 7.4: Master Testcase Types

Not all options are available for all testcases. Table **??** shows which testcase can be used to send/receive data (column: Transmitter/Receiver). Additional to that, some testcases provide the option to set the message timing (column: Time).

Note: If the message timing is enabled, the real average bitrate cannot calculated in the evaluation window.

Master Data

This testcase sends messages with different lengths via I2C-Bus. The length of the first message, which gets transferred, is specified by Start (bytes). The length of the following messages get periodically incremented, defined by Step (bytes). If the length exceeds the value specified by Stop (bytes), the test stops.

Note: A master transfer with a length of zero bytes works only with special I2C slaves. Other I2C slaves can hold the SDA line low after this test has been executed.

Master Expert

This testcase is used to send each combination of bits and conditions inside and outside the I2C-Bus Specification.

Each bit and condition of the byte can be set. Therefore an enhanced dialog for the message data exists (refer to **??**).

E.g. it is possible to:

- Send messages without start/stop conditions.
- Send start/stop conditions inside a message byte.
- Send bytes longer or shorter than 8 bits.

For this testcase the user must be familiar with the specification (7/10 bit addresses, sub addresses, ...) to make sure that messages will send correctly.

The number of send message can be defined in the field **Cycles**. The data of the messages are the same for each cycle.

Master Clock Diversifying

This testcase transfers I2C messages via the I2C-Bus, which contain longer pauses between some of the bits. With this test it is possible to check, whether a slave works correctly with an asynchronous clock. These pauses are added between different positions of the bits.

The length of the pauses can be configured by the user. The first message uses the pauses specified by Start (ms). The pauses of the next messages are periodically incremented by Step (ms). The test stops, after the length is reached, which is specified in Stop (ms). All values are specified in milliseconds.

Master Stress

A lot of problems will only occur, if there is a lot of traffic on the I2C-Bus and the I2C slave, which is tested, has to handle a lot of requests within a short time.

This testcase is used to emulate this situation. During the time, which is specified by the Time (s) value, the I2C-Bus load is nearly 100%. Even the time between two consecutive I2C messages is very short, because the complete message generation is handled in the Negative Tester interface. So the PC does not add any latency.

Master Stop

This testcase transfers I2C messages via the I2C-Bus, which contain STOP conditions at illegal positions. E.g. a message with less than 1 data byte like [START, ADDR, 5 Data Bits, STOP] is created. The purpose of this test is to verify that an I2C slave resets its internal state machine correctly after receiving a STOP condition.

Message lengths within the range specified by Start (bytes) and Stop (bytes) are tested. The length gets periodically incremented by Step (bytes).

For each defined message length, which should be tested, eight transfers are created. Each transfer places the STOP condition at a different bit position. Thus the first transfer contains the STOP condition after the first bit of the last byte, the second transfer contains the STOP condition after the second bit of the last byte and so on.

Master Timing

This testcase transfers an I2C message via the I2C-Bus with different timings. Several combinations of $[t_{HD;DAT}]$, $[t_{SU;DAT}]$, and $[t_{HIGH}]$ are tested. The tested minimum and maximum values are conform to the value specified for standard- and fast-mode devices. The values for fast-mode plus devices are specified in the I2C-Bus Specification And User Manual.

By setting the appropriate checkboxes it is possible to execute this test only for the selected requirements of standard-mode, fast-mode or fast-mode plus, or for all modes.

Note: For this test the signal slope on SCL and SDA is important, because otherwise it cannot be guaranteed that the Negative Tester can create the requested timings on the I2C-Bus. Due to this fact it is important to use a strong termination on the I2C-Bus and to prevent long cables.

Master Speed

This testcase transfers an I2C message with different bitrates. The purpose of this test is to verify that an I2C slave supports the specified bitrates.

The first message uses a bitrate specified by Start (Hz). Messages are using a bitrate, which is periodically incremented by Step (Hz). This testcase ends when the bitrate has reached the limit value given by Stop (Hz).

Master Termination

This testcase transfers an I2C message with different values for the I2C bus termination (SCL / SDA). The purpose of this test is to verify that an I2C slave works correctly with different types of slopes.

The first message uses a termination specified by Start (Ohm). The following messages are using the next values from the list of possible terminations. This testcase ends if the termination, specified by Stop (Ohm), is reached.

Master Spike

This testcase adds spikes to the transferred I2C message. Conforming to the I2C-Bus Specification an I2C slave has to suppress spikes of up to $[t_{SP}]$. The spike length can be configured

in three steps from 40 ns to 120 ns. Usually 40 ns should be used, but depending on the bus capacitances, longer spikes (e.g. 80 ns) could be used to see an appropriate effect. A spike length of 120 ns is only necessary for very special setups and leads to an error in most cases.

Note: For this test the signal slope on SCL and SDA is important, because otherwise it cannot be guaranteed that the **Negative Tester** can create the requested timings on the I2C-Bus. Due to this fact it is important to use a strong termination on the I2C-Bus and to prevent long cables.

7.5 Slave

After the activation of the Slave Tab (refer to figure ??) the I2C Studio acts as a slave. In this mode it can be used to test I2C masters.

To start/stop (activate/deactivate device) the slave mode use the menu item Negative Tester|Start (F5) / Stop (F6) or the corresponding buttons in the toolbar. Figure **??** shows the Slave Tab window.

Master Slave		
Testcase Message		
Stretch To Time (ns) 500 NACK After Last Byte	The "slave" test emulates an I2C slave. The "Stretch To Time" value specifies the time in which the slave stretches the low level of the clock. If the master e.g. sends with 400 kHz, a value of 5000 ns will slow down the transfer to 100 kHz. Usually the slave receiver will accept more data bytes than have been specified. If the "NACK After Last Byte" option has been enabled, the slave receiver sends a NACK after receiving the next byte.	^
	Press Start-Button to start and Stop-Button to end the test.	~

Figure 7.20: Negative Tester - Slave Tab

It contains the following sub windows:

- Testcase (??) Define parameter data
- Message (??) Define message (buffer) data

Testcase Slave Tab

This tab page is used to set options for the slave mode. A description of the parameters appears in the text field next to the parameter. Figure **??** shows the testcase slave tab.

Te	stcase Message				
	Stretch To Time (ns)	500	-		~
	NACK After Last Byte			The "Stretch To Time" value specifies the time in which the slave stretches the low level of the clock. If the master e.g. sends with 400 kHz, a value of 5000 ns will slow down the transfer to 100 kHz.	
				Usually the slave receiver will accept more data bytes than have been specified. If the "NACK After Last Byte" option has been	~

Figure 7.21: Testcase Slave Tab

The following elements are available:

- Stretch To Time (ns): Set to stretch time for the low level of the clock
- NACK After Last Byte: Set to send NACK after receiving the next byte

The Stretch To Time option specifies the time how long the slave stretches the low level of the clock. If the master e.g. sends with 400 kHz, a value of 5000 ns will slow down the transfer to 100 kHz. So this option can be useful to test, whether the I2C master's stretching detection works correctly.

Usually the slave receiver will accept more data bytes than have been specified. If the NACK After Last Byte option has been enabled, the slave receiver sends a NACK after receiving the next byte.

Testcase Slave Message Tab

This tab page is used to set the address, to enable the buffer data. The Expected Data will be compared to the received data in the **??**. To enable this function set the Check checkbox. The Length field is used to set the length of the data to be compared.

Master Slave	
Testcase Messag	e
I2C Addresse	0x50 7 Bit V
Transmitter	
Data	CA FF EE
Receiver	
Length	1 😫 Expected Data 🗋 Check CA FF EE

Figure 7.22: Testcase Slave Message Tab

The following elements are available:

I2C Address Address, which the emulated I2C slave in the Negative Tester is listening to

Transmitter all settings regarding the transmitter function

Checkbox Enables/Disables the function to send message data for this address

Data Data that will be sent after a data request from this device

Receiver All settings regarding the receiver function

Checkbox Enables/Disables the function to receive message data for this address

Length Length of expected data to be compared to the received data

Expected Data The data to be received

Checkbox Enables/Disables the compare function

Data Data that will be compared to the received data

If the length is greater than the number of expected data, the test will fail. If the length of received data is smaller, than the expected data the remaining bytes are ignored. If the length of defined compare data is smaller than the defined length, the compare function will be started at the first byte of defined data.

Note: It is not possible to disable the Transmitter and the Receiver function.

7.6 Results

The log output (I2C-Bus messages) of the **??** and **??** operation is displayed at the bottom of the **??**.

Therefore two tab pages are available:

- ??: Transmitted messages and their status
- ??: HTML Page with a more detailed data evaluation (visible after the send process)

Additional to that, the status bar shows the number of sent/received messages and their status.

7.6.1 Results Tab

The Results Window shows the log output of the parsed I2C-Bus messages and the appropriate message status. The message data is displayed in a byte representation of the parsed messages. These messages should be similar to the sent data which is presented in the graphical view of the **??**. Figure **??** shows this window.

0	Test Name	Test	Type Result	t Speed	Cond	Addr Di	r Length								Dat	ta.									
	Master Stop [1]		Stop Err				12	C Protoco	1 Error																
	Master Stop [1]		Stop Err		2		0																		
	Master Stop [1]		Stop ox	1.0		7 0x50 TX																			
	Master Stop [1]		Stop 🖬				12	C Protoco	1 Error																
	Master Stop [1]		Stop try				0																		
	Master Stop [1]		Stop OK	LS		7 0x50 TX																			
	Master Stop [1]		Stop [m				12	C Protoco	1 Error																
	Master Stop [1]		Stop [22		2		0																		
	Master Stop [1]		Stop OK	13	2	2 0x50 TX																			
	Master Stop [1]		Stop (17				12	C Protoco	1 Error																
	Master Stop [1]		Stop 🗰	_	2		0																		
	Master Stop [1]		Stop OK	12		7 0x50 🛣																			
	Master Stop [1]		Stop [11		_		12	C Protoco	1 Error																
	Master Stop [1]		Stop Err	_	2		0																		
	ock Diversifying [2] Master				22 22 22 22 22 22 22 22 22 22 22	7 0×50 TX	256 00	01 02 03				08 OC	OD OE	0F 10	11 12	13 14	15 1	6 17 1	18 19	1A 18	1C 10	1E 3	F 20	21 22	23
	ock Diversifying [2] Master			13	22	7 0x50 BX	10 00	01 02 03																	
	ock Diversifying [2] Master			13	2	🔽 0x50 🕅		01 02 03				OB OC	OD OE	0F 10	11 12	13 14	15 1	6 17 1	18 19	1A 1B	1C 10	16 1	F 20	21 22	23
	ock Diversifying [2] Master			L3	<u>8</u>	7 0x50 RX	10 00	01 02 03																	_
	ock Diversifying [2] Master			13	22	7 0x50 TX	256 00	01 02 03				08 OC	OD OE	0F 10	11 12	13 14	15 1	6 17 1	18 19	1A 1B	1C 10	16 3	F 20	21 22	23
	ock Diversifying [2] Master			13	122	7 0×50 RX	10 00	01 02 03																	
	ock Diversifying [2] Master			LS		7 0x50 TX		01 02 03				OB OC	OD OE	0F 10	11 12	13 14	+ 15 1	.6 17 1	18 19	1A 1B	1C 10	/ 1E 1	LF 20	21 22	23
Master CI	ock Diversifying [2] Master	CTOCK DIVERSIT	rying ok	13	SP	7 0x50 🕅	10 00	01 02 03	04 05 0	5 07 08	09														

Figure 7.23: Result Window

The columns have got the following meaning:

No Number (index) of the messages

Test Name Test name as defined by the user

Test Type Type of the testcase

Result Result/Status of the test execution. The icons have got the following meaning:

0K	No Error
00	I2C address

I2C address has not been acknowledged

- One of the data bytes has not been acknowledged
- Error Error

Speed Speed of the testcase

III I2C Normal-Speed

I2C High-Speed

Cond Shows whether the START and the STOP conditions have been sent one the I2C-Bus:

- S Only START Condition
- START and STOP Condition
- Only STOP Condition
- **Addr** Field contains the address of the I2C slave, which has been addressed by the master. The icons have got the following meaning:

7	7-bit I2C Address
10	10-bit I2C Address

Dir Direction of the message (Transmit/Receive)

TX	Master Transmitter
RX	Master Receiver
TR	Master Transmitter/Receiver

Length Length of the message

Data Data of the message/error messages if an error occurred

7.6.2 Evaluation Tab

The Evaluation Window shows the log output with the I2C-Bus messages and the evaluation of the transmission. This window is available when the run is complete, thus all tests have finished. Figure **??** and **??** show two examples.

This viewer window is HTML-based and therefore provides a web-page like look. The report consists of several files, which are connected by links. By clicking on the links it is possible to navigate to the different files. The context menu item **Back** navigates back to the previously viewed file.

For each testcase one report file is created. Figure ?? and ?? show the result for the "Master Speed" testcase.

The setup part of the report gives some details about the configuration. In this example e.g. the Negative Tester and the tracer have both been configured to a termination of "10.900 Ohm" and level thresholds of "30/70%". The tested I2C slave uses the I2C address "0x50".

The result part of the report provides web-page related links (marked as 'X') to the following files:

Input Pattern (SVG) Pattern loaded into the Negative Tester. This file uses the SVG vector graphics format.

- **VHDL Stimuli (VHD)** Stimuli file for VHDL, which uses the same transitions and timings as generated by the Negative Tester. This can be used to reproduce errors with a VHDL simulator.
- **Trace Data (HTML)** I2C messages, which have been traced on the I2C-Bus during the test run. This file uses the HTML format.
- **ADC Data (SVG)** Analogue shot of the I2C lines, which has been captured during the test run. This file uses the SVG vector graphics format.
 - **Note:** The ADC Data option is only available, if the telos Tracer consists of an additional ADC license!
- **Trace/ADC Data (I2CL)** Contains the same data as "Trace Data (HTML)" and "ADC Data (SVG)". The telos I2C Studio's own log file format I2CL is used to store this data.

The last column of the table contains the results of the test run. The given example figure ?? shows the result OK in each row while in figure ?? the I2C device has failed to communicate at a speed of 1 MHz.

The expected bitrate is shown in the table and additional to that, the approximate average of the real bitrate is calculated and also given in an additional column. The real bitrate can be equal or lower than the expected bitrate. If the deviation between the real bitrate and the expected bitrate is greater than 10%, the average bitrate cell is marked in orange (see figure ??).

	peed							
fest Typ	e: Master	Speed					Test Results	<u>s</u> > Master
Setup								
·								
Negative								
Terminatio			1.376 / 1.376 Ohm					
Level Thre	sholds		30 / 70 %					
Tracer								
Terminatio	n	1	10.900 / 10.900 Ohm					
Level Thre	sholds	3	30 / 70 %					
Test Con	figuration							
I2C Addres	s (Tested Sla	ave)	0x50 (7 bit)					
NACK Beh	aviour		NACK_GENERAT	TE_STOP				
NACK Beh	aviour		NACK_GENERAT	TE_STOP				
NACK Beh Results	aviour		NACK_GENERAT	TE_STOP				
	aviour		NACK_GENERAT	re_stop				
Results	Pitrata	Real average Bitrate (Hz)	Input Pattern (SVG)	VHDL Stimuli (VHD)	Trace Data (HTML)	ADC Data (SVG)	Trace/ADC Data (I2CL)	Result
Results Direction	Bitrate		Input Pattern (SVG)	VHDL Stimuli				Result Ok
Results Direction	Bitrate (Hz)	Bitrate (Hz)	Input Pattern (SVG)	VHDL Stimuli		(SVG)		
Results Direction TX RX	Bitrate (Hz) 400.000	Bitrate (Hz) 394.700	Input Pattern (SVG)	VHDL Stimuli		(SVG)		Ok
	Bitrate (Hz) 400.000 400.000	Bitrate (Hz) 394.700 398.200	Input Pattern (SVG) X X	VHDL Stimuli		(SVG) X X	(I2CL) X X	Ok Ok
Results Direction TX RX TX RX	Bitrate (Hz) 400.000 600.000	Bitrate (Hz) 394.700 398.200 562.500	Input Pattern (SVG) X X X	VHDL Stimuli (VHD) X X X		(SVG) X X X X	(12CL) X X X X	Ok Ok Ok Ok Ok
Results Direction TX RX TX	Bitrate (Hz) 400.000 600.000 600.000	Bitrate (Hz) 394.700 398.200 562.500 562.500	Input Pattern (SVG) X X X X X	VHDL Stimuli (VHD) X X X		(SVG) X X X X X X	(12CL) X X X X X	Ok Ok Ok Ok
Results Direction TX RX TX RX TX TX	Bitrate (Hz) 400.000 400.000 600.000 600.000 800.000	Bitrate (Hz) 394.700 398.200 562.500 562.500 703.100	Input Pattern (SVG) X X X X X X X	VHDL Stimuli (VHD) X X X		(SVG) X X X X X X X X X X X	(12CL) X X X X X X X	Ok Ok Ok Ok Ok

Figure 7.24: Negative Tester Result - Master Speed Test - OK

Results Evaluation

est Typ	e: Mastei	Speed					į	<u>Test Results</u> > Maste
Setup								
Negative	Tester				_			
Terminatio	n		1.534 / 1.534 O	ım				
Level Thre	sholds		30 / 70 %					
Tracer								
Terminatio	n		10.900 / 10.900 Oh	ım				
Level Thre	sholds		30 / 70 %					
Test Con	figuration							
I2C Addres	s (Tested Sl	ave)	0x50 (7 bit)					
Ignore Stre	etching		Enabled					
NACK Beh	aviour		NACK_GENE	RATE_STOP				
Results								
toouno								
Counto								
	Bitrate (Hz)	Real average Bitrate (Hz)	Input Pattern (SVG)	VHDL Stimuli (VHD)	Trace Data (HTML)	ADC Data (SVG)	Trace/ADC Data (I2CL)	Result
Direction								Result Ok
Direction	(Hz)	Bitrate (Hz)	(SVG)		(HTML)		(I2CL)	Result
Direction TX RX	(Hz) 400.000	Bitrate (Hz) 394.700	(SVG)		(HTML) X		(I2CL) X	Ok
Direction TX RX TX	(Hz) 400.000 400.000	Bitrate (Hz) 394.700 394.700	(SVG) X X	(VHD) ≚ ≚	(HTML) X X	(SVG) X X	(I2CL) X X	Ok Ok
Direction TX RX TX TX RX TX	(Hz) 400.000 400.000 600.000	Bitrate (Hz) 394.700 394.700 592.100	(SVG) X X	(VHD) ≚ ≚	(HTML) X X X	(SVG) X X	(I2CL) X X X	Result Ok Ok Ok Ok Ok
Direction TX RX TX RX	(Hz) 400.000 400.000 600.000 600.000	Bitrate (Hz) 394.700 394.700 592.100 592.100	(SVG) X X X X X	(VHD) X X X X X X	(HTML) X X X X	(SVG) X X X X X X X	(12CL) <u>×</u> × × × × ×	Result Ok Ok Ok Ok
Direction TX RX TX TX RX TX	(Hz) 400.000 400.000 600.000 600.000 800.000	Bitrate (Hz) 394.700 394.700 592.100 592.100 775.900	(SVG) X X X X X X	(VHD) X X X X X X	(HTML) X X X X X X X	(SVG) X X X X X X X X X	(I2CL) X X X X X X X	Result Ok Ok Ok Ok Ok

Figure 7.25: Negative Tester Result - Master Speed Test - Not OK

7.7 Options

Figure ?? shows the "Options" dialog for the Negative Tester.

IIC Negative	Tester		×
Common			
Report Directo	bry		
C:\Users\jp\[locuments\I2C Studio\negative_tester_report		Browse
Tracer Select I2C Int			
telos Tra	cii XL 2.0 [SN 0x788B]		~
Master			
Master High-S	ipeed		
Master Code	0x08		~
		Reset OK	Cancel

Figure 7.26: Negative Tester Options

This dialog can be opened using the Negative Tester |Negative Tester Options menu item.

The following options can be configured within this dialog:

- **Report Directory** During the test run a test report in the HTML format gets generated. This parameter specifies the directory, into which this report gets written.
- **Select I2C Interface** The telos Negative Tester interface itself works only as an I2C master or I2C slave on the bus. To use the Negative Tester with the telos I2C Studio, a telos Tracii XL or telos Tracii XL 2.0 interface with a valid tracer license is needed additionally. This interface has to be connected to the same bus like the Negative Tester. In this case all connected tracer interfaces are displayed in this menu and can be selected.
- **Master High Speed** In I2C high-speed mode each message starts with a master code. This option configures the master code to be used.

8 Scripting

8.1 Introduction

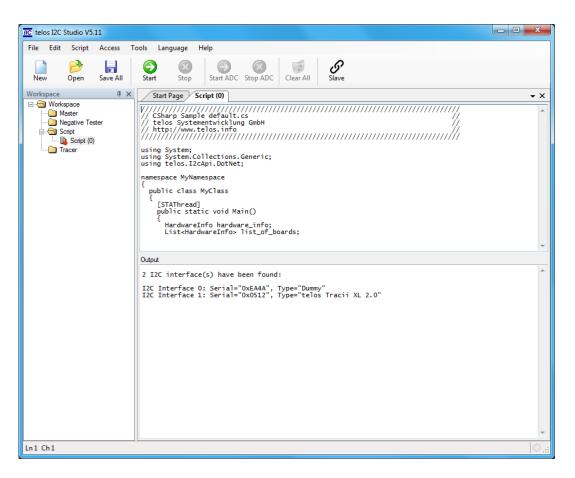


Figure 8.1: Script Window

The master and the tracer windows provide a powerful and convenient way to use the I2C interfaces from telos. But sometimes users need a more flexible way to access the I2C interfaces. Therefor I2C Studio offers the script window.

A new script window can be created using the New button, the menu item File|New or the context menu item New from the workspace. In contrast to the other window types a script window is never associated to a certain I2C interface. The user has to set up an interface connection manually by calling the appropriate functions from I2C.NET API.

The script window consists of two text boxes. The upper text box allows to enter the script. The lower text box receives error messages from the compiler and the output generated by the script.

8 Scripting

The programming language supported by the script window is C#. Two frameworks are available in the script window: .NET 4.0 and the I2C.NET API. The user can add additional libraries, which are based on .NET 4.0.

The programming language C# is defined in ECMA-334, which can be downloaded from here:

```
http://www.ecma-international.org/publications/standards/Ecma-334.
htm
```

The documentation for the I2C.NET API is part of the I2C Studio setup package. It can be opened by the menu item Help|I2C Api Documentation.

I2C Studio comes with APIs for several other languages:

- C++
- .NET (e.g. C#, Visual Basic, and Delphi)
- C
- Labview
- NXP (formerly Philips Semiconductors) URT and URD

These APIs cannot be used directly in I2C Studio. Instead the programmer can use them within the normal development environments.

8.2 Example

The following C# source code can be used to demonstrate the script window:

```
// CSharp Sample default.cs
                                                     11
                                                     //
// telos Systementwicklung GmbH
// http://www.telos.info
                                                     11
using System;
using System.Collections.Generic;
using telos.I2cApi.DotNet;
namespace MyNamespace
{
 public class MyClass
 {
  [STAThread]
  public static void Main()
    HardwareInfo hardware_info;
   List<HardwareInfo> list_of_boards;
    try
    {
```

```
using (Board board = new Board())
    {
      list_of_boards = board.ListOfBoards;
      Console.WriteLine();
      Console.WriteLine("{0} I2C interface(s) have been found:", list_of_boards.Count);
      Console.WriteLine();
      for (int i = 0; i < list_of_boards.Count; i++)</pre>
        hardware_info = list_of_boards[i];
        Console.WriteLine("I2C Interface {0}: Serial=\"0x{1:X4}\", Type=\"{2}\"",
                           i,
                          hardware_info.SerialNumber,
                           HardwareInfo.GetBoardTypeAsString(hardware_info.BoardType));
      }
      11
      // TODO: Add your script code
      11
    }
  }
  catch (System.Exception ex)
  {
    Console.WriteLine("Error: " + ex.Message);
  }
}
```

This program establishes a connection to the I2C scheduler and outputs a list of the I2C interfaces, which are currently connected to the local PC.

After a script has been entered, it can be started using the Start button or the menu item Script|Start.

While a script is running, its output is redirected to the output text box.

Note: More examples for several programming languages can be found in the examples folder of the installation path of I2C Studio (see section **??** for more details).

8.3 Configuration

}

Like the other function windows the script window has got a configuration dialog, see figure **??**. This dialog can be opened using the menu item Script|Script Options.

The dialog offers the following options:

- **Main Class** Defines the name of the class, which contains the "Main" method. If the source code uses a namespace, this has to be specified, too. For the example the correct value would be "MyNamespace.MyClass".
- **Referenced Assemblies** Contains a list of .NET assemblies, which should be linked to the executable. To communicate with the I2C interfaces the i2capi_dotnet_net40.dll is needed.

C Script	×
Main Class	
MyNamespace.MyClass	
Referenced Assemblies	
[i2capi_dotnet_net40.dll	
	Add Remove
	Reset OK Cancel

Figure 8.2: Script Window: Options Dialog

Assemblies can be added by using the Add button and removed by using the Remove button.

8.4 Development Environment

While writing scripts like mentioned above, it could be helpful to use a more sophisticated development environment like Microsoft Visual Studio. E.g. if step by step debugging is necessary to be used while development. Therefore the given examples (see ??) written in C#.NET, which can be found in the installation folder <code>examples\dotnet</code>, provide a project [*.csproj] file. This can be loaded into Microsoft Visual Studio to take advantage of this development environment and to extend or vary the examples for individual purposes.

8.5 Advanced Examples

The setup package of I2C Studio contains some advanced examples, which demonstrate the features of the I2C.NET API. They are located in the installation directory of I2C Studio in examples\dotnet\.

The available examples are:

- **AdcExample.cs** Demonstrates the usage of the module, which can create analog shots of the I2C lines SCL and SDA.
- **InputTestpinsExample.cs** Demonstrates the module, which can monitor the transitions of the input testpins.

MasterExample.cs Demonstrates how to send messages on the I2C-bus.

NegativeTesterExample.cs Demonstrates the Negative Tester interface.

PluginExample.cs Demonstrate the writing of plug-ins for I2C Studio.

TracerExample.cs Demonstrate how to record the messages, which have been sent on the I2C-bus.

8.6 I2C.NET API (IRD)

Communicating with I2C slaves from a script can be exhausting, because the device specific high-level protocols must be implemented by hand using the data sheets of the devices.

To make life easier I2C Studio comes with the i2capi_dotnet_ird.dll assembly. It has been created using the IRD compiler, which is described in section **??**.

All IRD files of I2C Studio have been converted to .NET classes. These classes allow a type-safe access to the registers and values of several widely used I2C slaves.

The following example demonstrates how to use one of theses classes to read out the Maxim DS 1307, which is connected to the virtual I2C-bus of the Dummy I2C interface. The emulated I2C slave uses address 0x68.

```
using System;
using System.Collections.Generic;
using System.Text;
using telos.I2cApi.DotNet;
using telos.Ird.Maxim;
namespace Test
{
  class Program
  {
   static void Main(string[] args)
    {
      Board board;
      Ds1307 clock;
      board = new Board();
      try
      {
        // open Dummy
        board.Open (board.ListOfBoards[0]);
        // create DS 1307 wrapper for address 0x68
        clock = new Ds1307(board, new I2cAddress(0x68, false), "..\\ird");
        // read out date/time every 500 ms
        while(true)
        {
          Console.WriteLine ((clock.Year+2000).ToString().PadLeft(4) + "/" +
                             clock.Month.ToString("D2") + "/" +
                             clock.Date.ToString("D2") + " " +
```

8 Scripting

```
clock.Hours.ToString().PadLeft(2) + ":" +
clock.Minutes.ToString("D2") + ":" +
clock.Seconds.ToString("D2"));
System.Threading.Thread.Sleep(500);
}
finally
{
board.Dispose();
}
}
```

To execute this script in the script window it is necessary to add two .NET assemblies to the options dialog: i2capi_dotnet_net40.dll and i2capi_dotnet_ird.dll. The example reads out the data and time from the DS 1307 every 500 ms.

9 Tools

9.1 I2C Memory Slave

The I2C interface types telos Tracii XL and telos Tracii XL 2.0 can be configured to act as a slave on the I2C-bus. This slave behaves like a standard I2C RAM with a capacity of 256 bytes. A description of the high-level I2C protocol used by such RAMs can be found e.g. in the data-sheet of the NXP PCF8570 IC:

```
http://www.nxp.com/products/interface_and_connectivity/i2c/i2c_serial_
eeprom_ram/series/PCF8570.html
```

The slave in telos Tracii XL 2.0 supports 7-bit and 10-bit I2C addresses. It also supports the I2C high-speed mode.

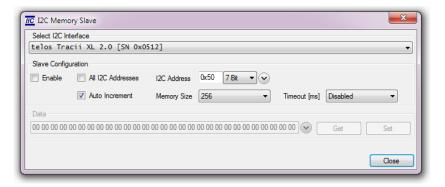


Figure 9.1: I2C Memory Slave

The configuration dialog (see figure **??**) for the slave mode is opened by the menu item Tools|I2C Memory Slave or by pressing the Slave button on the toolbar (see section **??**).



Figure 9.2: Toolbar Slave Button

Within this dialog the following options can be configured:

Select I2C Interface This combo box contains a list of I2C interfaces, which can be used as I2C slaves. The configuration shown under "Slave Configuration" refers to the I2C interface selected in this combo box.

Enable If this check box is set, the slave emulation is running.

- All I2C Addresses If this check box is set, the emulated RAM listens on all possible 7-bit or 10-bit I2C addresses.
- **I2C Address** Specifies the I2C slave address of the emulated RAM. All I2C requests sent on the I2C-bus to this address will be answered by the I2C interface.
- **Memory Size** Configures the size of the emulated I2C slave.
- **Auto Increment** Enables/disables auto incrementing of the address pointer in the emulated I2C slave.

Timeout Configures the timeout of the emulated I2C slave.

Data Gets/sets the data of the emulated RAM.

Note: telos Tracii XL2.0 can operate as I2C master and I2C slave in parallel. While the RAM slave emulation is running, an I2C message can be sent by master from the same I2C interface.

If the user has enabled the slave using the configuration dialog, it stays enabled while I2C Studio is running. Even closing the configuration dialog will not stop the slave emulation. An enabled slave will be notified by a green slave button (see figure ??).



Figure 9.3: Toolbar Slave Button enabled

9.2 JEDEC SPD

There is an important field, where I2C EEPROMs are used in the PC industry: memory modules. All memory modules sold today contain an EEPROM, which describes the timing parameters needed by the module so that the user must not enter these parameters manually. The JEDEC standards and specifications can be downloaded from the JEDEC WWW page at:

```
http://www.jedec.org/
```

Figure **??** shows the dialog, which has been opened by clicking onto the menu item **Tools**|JEDEC SPD.

There are **Read** and Write buttons to exchange the configuration with an appropriate EEP-ROM connected to the I2C-bus of the selected I2C interface. The I2C address of the EEPROM is not fix. The user has to specify the I2C address he wants to exchange the data with.

Moreover there are Import and Export buttons, which export the content as an image to a file and reimport it.

All other fields of the dialog serve the modification of the content to be stored in the JEDEC image.

Number of Bytes (Utilized by Manufacturer) All All Total Bytes 128 Bytes Total Bytes 256 Bytes SPD Revision Rev 1.0 Manufacturer Data Manufacturer Data Manufacturing Date 01/2000 Serial Number 00 00 00 00 00 Gustomer Data 00 00 00 00 00 Bemertary Module Data 00 00 00 00 00 Rows (Bank 1) 1 Rows (Bank 1) 1 Columns (Bank 2) No 2nd Asymmetr	Select I2C Interface telos Tracii XL 2.0 RAM Type DDR SDRAM	0 [SN 0x0512]	← Addr: 0x50 ▼ Read Write
DIMM Banks 1	All General Number Bytes SPD Revision Manufacturer Data Manufacturer Data Manufacturer Part Number Revision Code Manufacturing Date Serial Number Manufacturing Date Serial Number Manufacturer Data Customer Data Elementary Module Data Rows (Bank 1) Rows (Bank 1) Columns (Bank 2)	128 Bytes 256 Bytes Rev 1.0 AMD 0 00 00 01/2000 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1 No 2nd Asymmetr	128 Bytes Description: This field specifies the total number of bytes used by the module manufacturer (SPD data/optional specific supplier). Defined in: JEDEC Standard No. 21-C - 4.1.2.4 (Appendix D) Rev. 1.0

Figure 9.4: JEDEC SPD

9.3 SMBus Address Resolution Protocol

The SMBus specification version 2.0 describes in section 5.6 an "Address Resolution Protocol" (ARP). Using this protocol a SMBus ARP master can determine the slave address of SMBus ARP slaves, which are using a fix address. Furthermore the master can assign an address to slaves using dynamic addresses during runtime. With the help of this protocol the master can also get some information about the slaves, e.g. the vendor and device IDs.

I2C Studio contains a SMBus ARP dialog, which implements an ARP master. This dialog, opened by the menu item Tools SMB ARP, is shown in figure ??.

Normally the ARP process does not need any interactions of the user. It is simply started by clicking onto the Start button. Afterwards the "Devices" table contains a list of all found devices, which support SMBus ARP. The first column of the table contains the "Unique Device Identifier" (UDID), the second the I2C address used by this device.

The UDID contains some information about the device. An interpreted view of this value can be viewed by selecting a row in the table and clicking onto the **Device Info** button. A new dialog opens, which is shown in figure **??**.

When developing a new SMBus slave device, it can be useful to execute the ARP process step by step. For this purpose there is an advanced ARP dialog, which can be opened using the Advanced button. The advanced ARP dialog is shown in figure ??.

The meaning of the ARP commands, which can be triggered with the buttons of this dialog, are described in the SMBus specification.

 Image: SMBus ARP

 Select I2C Interface

 tellos Tracii XL 2.0 [SN 0x0512]

 Devices

 UDID

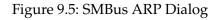
 I2C Address

 Device Info.

 Advanced.

 Status

 SMBus ARP master is ready.



Device Info from UDID		Advanced De	vice Info from IRD	
Device Capabilities	Dynamic and volatile address device (0x0)	Manufacturer	n.a.	
UDID Version	UDID version 1, SMBus 2.0 release (0x1)	Name	n.a.	
Silicon Revision	0x0	Device Type	n.a.	
SMBus Version	SMBus 2.0 (0x4)	Description	n.a.	
Vendor ID	0x1131			
Device ID	0x0001			
Subsystem Vendor ID	0x0000			
Subsystem Device ID	0x0000			
Vendor Specific ID	0x12345678			
PEC Support	Yes			
ZONE Support	No			
IPMI Support	No			
ASF Support	No			
OEM Support	No			Close

Figure 9.6: SMBus ARP Dialog: Device Info

Note: At the moment there are not a lot of SMBus devices on the market supporting SMBus ARP. Even these devices does not work correctly, because their algorithm to calculate the "Packet Error Checking" (PEC) does not conform to the SMBus specification.

Besides the SMBus ARP dialog I2C Studio also supports ARP in the tracer function window. Using a supplied IRD file, which must be registered to the I2C address 0x61, the ARP communication between the SMBus ARP master and the ARP slaves can be viewed.

9.4 IRD Compiler

IRD files are used by I2C Studio to describe the registers and values of an I2C device. This file format is based on XML. I2C Studio comes with a lot of ready to use IRD files for widely used I2C slaves. The user has also the possibility to write its own IRD files.

C SMBus ARP: Advanced	Device Info
	Device into
Commands General	
Prepare To Arp Reset All	Get UDID
Directed	
I2C Address 0x7F 7 Bit V	
Assign Address Reset Device	Get UDID
Status	
	Close

Figure 9.7: SMBus ARP Dialog: Advanced

IC IRE) Compiler	x
- Input		
File	C:\Program Files\telos Systementwicklung GmbH\telos I2C Studio\ird\analog\adm1021a.ird	Change
Outpu	t.	
File	C:\temp\adm1021a.cs	Change
🔽 Ci	reate DLL	
	Cancel	ок

Figure 9.8: IRD Compiler Dialog

Using the IRD compiler it is possible to convert an IRD file to a C# source code file. Such a source code file contains one class, which offers a type-safe access to the registers/values of a device via the I2C-bus.

Using such a class communicating with an I2C slave from a script or one's own .NET program becomes a lot of easier. It is no longer necessary to calculate the data bytes to be sent to the I2C slave from its data-sheet. Instead, the developer can simply assign the needed value to a property of the created class.

This dialog offers the following options:

Input File Contains the name of the IRD file, which should be converted.

Output File The C# source code file gets written to a file with this name.

Create DLL If this box is checked, the C# source code gets compiled to a .NET assembly DLL, which can be used from all programming languages which come with .NET support.

The conversion is started by clicking onto the OK button.

9 Tools

The .NET assembly i2capi_dotnet_ird.dll contains the classes for all IRD files which come with I2C Studio. It can be found in the installation directory of I2C Studio in the subdirectory lib\.

	Format		TX Register	RX Register	Name	POR	ID
•	Byte			0	Local Temp, Value	128	local temp value
	Byte	-		1	Remote Temp. Value High Byte	128	remote temp_value_high
	Byte	-		2	Status		status
	Byte	-	9	3	Configuration	0	configuration
	Byte	-	10	4	Conversion Rate	2	conversion_rate
	Byte	-	11	5	Local Temp. High Limit	127	local_temp_high_limit
	Byte	-	12	6	Local Temp. Low Limit	201	local_temp_low_limit
	Byte	-	13	7	Remote Temp. High Limit High Byte	127	remote_temp_high_limit_high
	Byte	-	14	8	Remote Temp. Low Limit High Byte	201	remote_temp_low_limit_high
	Empty	-	15		One-Shot		one_shot
	Byte	-		16	Remote Temp. Value Low Byte	0	remote_temp_value_low
	Byte	-	17	17	Remote Temp. Offset High Byte	0	remote_temp_offset_high
	Byte	-	18	18	Remote Temp. Offset Low Byte	0	remote_temp_offset_low
	Byte	-	19	19	Remote Temp. High Limit Low Byte	0	remote_temp_high_limit_low
	Byte	-	20	20	Remote Temp. Low Limit Low Byte	0	remote_temp_low_limit_low
	Byte	-		254	Manufacturer Device ID	65	manufacturer_id
	Byte	-		255	Die Revision Code		device_revision_id
*		-					
*		-					

9.5 IRD Composer

Figure 9.9: IRD Composer Dialog

I2C Studio comes with a large collection of IRD files for all common I2C devices. However, there will be always I2C devices for which there are no ready-to-use IRD files. In such a situation the user has two possibilities for writing his own IRD files: he can write the IRD files, which are in fact XML files, by hand using the "IRD User Manual" and a text editor. Or he can use the IRD Composer to create the IRD files.

Figure **??** shows the IRD Composer, which can be opened using the menu item Tools|IRD Composer. This dialog offers a graphical user interface for creating IRD files.

It consists of a collection of tab pages, which contain input masks for defining general information, registers, types, and values. The exact meanings of all these fields are not covered by this manual. They are described in the "IRD User Manual".

After all information for one I2C device has been entered, the Save button can be used to create an IRD file. This file uses, like all IRD files created by the user, the suffix *.xml instead of *.ird.

The Load button loads an IRD file, which has been created by the user, into the dialog. It is not possible to load IRD files into this dialog, which are part of I2C Studio.

10 License & Support

10.1 License Management

10.1.1 Service Contracts

Each I2C interface bought from telos has got a service contract. This service contract is valid for 12 months. During this time the user gets free software updates of I2C Studio and free support.

To benefit from new features in future release or make use of the support after these 12 months, the service contract can be extended or renewed. To get prices please visit the telos home page or get in contact with our sales department:

http://www.telos.info/shop/service-contracts/

Service contract extensions are delivered in the form of registration codes.

10.1.2 Upgrade Features

Some I2C interfaces like e.g. telos Tracii XL 2.0 have got several features, which can be bought separately. If the user e.g. owns a basic telos Tracii XL 2.0, he can buy the "Tracer Option" at a later time.

To get this new feature, it is not necessary to send the I2C interface back to telos. Instead the user simply gets a registration code, which will enable the feature in the I2C interface.

10.1.3 Registration Dialog

The License Manager has got two purposes. It can be used to view the currently available features and the service contracts of an I2C interface. Furthermore the user can enter registration codes, which have be purchased from telos, to extend the service contracts or to enable new features.

The file menu item File|Registration is used to open this dialog. The dialog can be divided into the following parts:

Select Board Contains a list of all I2C interfaces, which are currently visible for I2C Studio. The user has to select the I2C interface, whose licenses should be viewed or modified.

Licenses This table contains the licenses, which are currently stored in the selected I2C interface:

Status Indicates, whether this feature can be used with this version of I2C Studio.

- ☑ license available
- Iicense not available

License Service Contract Until Image: Master High-Speed 31.08.2019 Image: Master High-Speed 31.08.2019 Image: Tracer 31.08.2019 Image: ADC ADC Image: ADC ADC	Len	os Tracii XL 2.0	[SN 0X4716]
Master 31.08.2019 Master High-Speed 31.08.2019 Tracer 31.08.2019 ADC 31.08.2019 ADC 31.08.2019 Negative Tester Feature not available Labview Feature not available Needed License Eature not available This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@etelos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	Lice	nse	
Master High-Speed 31.08.2019 Image: Tracer 31.08.2019 ADC 31.08.2019 Negative Tester Feature not available Labview Feature not available Needed License Image: This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@telos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard		License	Service Contract Until
▼ Tracer 31.08.2019 ▲ DC 31.08.2019 ▲ DC 31.08.2019 ▲ Negative Tester Feature not available ▲ Labview Feature not available Needed License Environmentation of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@telos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	~	Master	31.08.2019
▼ Tracer 31.08.2019 ▲ DC 31.08.2019 ▲ DC 31.08.2019 ▲ Negative Tester Feature not available ▲ Labview Feature not available Needed License Environmentation of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@telos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	~	Master High-Speed	31.08.2019
Negative Tester Feature not available Labview Feature not available Needed License Feature not available This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@etelos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	~	Tracer	31.08.2019
Negative Tester Feature not available Labview Feature not available Needed License Feature not available This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@etelos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	~	ADC	31.08.2019
Needed License This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@telos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09 Set Paste from Clipboard	/	Negative Tester	Feature not available
This version of telos I2C Studio requires a service contract until at least: 31.03.2016 License-Key The registration code can be used to unlock features of an I2C interface. For more information please contact telos sales department [sales@telos.info]. AA BB CC DD EE FF 01 02 03 04 05 06 07 08 09	/	Labview	Feature not available
	This Licer The For	version of telos I2C Stud nse-Key registration code can be more information please	used to unlock features of an I2C interface. contact telos sales department [sales@telos.info].
Close	This Licer The For	version of telos I2C Stud nse-Key registration code can be more information please	used to unlock features of an I2C interface. contact telos sales department [sales@telos.info].
	This Licer The For	version of telos I2C Stud nse-Key registration code can be more information please BB CC DD EE FF 0:	used to unlock features of an I2C interface. contact telos sales department [sales@telos.info].

Figure 10.1: License Manager

License Name of the feature.

- **Service Contract Until** This feature can be used with all I2C Studio versions, which have been release not later than this date. The I2C interface shown in figure **??** can be used with all I2C Studio versions released not later than 2008/09/30.
- **Required License** Shows the date, when the currently running version of I2C Studio has been released.
- **Registration Code** One or more registration codes can be entered in this field to enable new features or to renew the service contracts. When a registration code is set using the Set button, the updated license information is stored in the I2C interface itself. So afterwards the registration code is no longer needed.
 - **Note:** If the user buys some additional features or a service contract extension together with the basic hardware, all needed license information is already stored in the I2C interface. So the user does not have to enter any registration codes.

10.2 Support

telos offers support for its products by e-mail or phone. We do our best to solve any problem within one working day.

To get into contact with the telos product support:

telos Systementwicklung GmbH Kaiser-Wilhelm-Strasse 93 20355 Hamburg Germany

Phone: +49 (0)40 450173 61 Fax: +49 (0)40 450173 99 E-Mail: tsupport@telos.de Web: www.telos.info

Build Information Us Module Information	ed Libraries Info				
Windows 7 6.1.7	7601.65536, Se	rvice Pack 1 (:	x64)		-
PC Information	() Core(TM) i7	-3770 CPU @ 3.4	40GHz		
Product Informa Product Name	ation: e: telos I2C S	tudio		-	
				Þ	
Logfile Contents					
					^
4				4	Ŧ
Current O Pre-	vious		Submit	Copy To Clipboa	ard

Figure 10.2: About Dialog

Please always add the type and the serial number of your I2C interface to your e-mails. The easiest way to get this information is to use the "About" dialog, which can be opened using Help|About. With the Copy to Clipboard button all needed information is copied to the MS Windows clipboard. Alternatively the Submit button can be used to mail all this information directly to the product support.

11 Redistribution

11.1 Overview

Sometimes a user wants to distribute an application, which has been written using one of the I2C APIs, to other users. Therefore it is necessary to redistribute the infrastructure to these users, which is needed to communicate with the I2C interfaces from telos.

If the redistribution of the complete I2C Studio is not the desired solution, it is possible to include only the really needed files into the user's own setup package. telos does not offer any support for such setups.

Normally three components are needed: the driver, the I2C scheduler, and the API itself.

11.2 Driver

The driver can be found in the installation directory:

```
<install dir>\drivers
```

If the tools, which are used to create the setup package, do not support the installation of drivers by itself, telos recommends to use the "Driver Install Frameworks (DIFx)" from Microsoft, which is part of the WDK.

11.3 I2C Scheduler

The I2C Scheduler is located in the following executable:

```
<install dir>\bin\tracii_scheduler.exe
```

This executable must be registered as Windows Service during the installation of the setup package. Before a setup package gets deinstalled the Windows Service must be deregistered. The I2C scheduler offers some command line options to register and deregister itself:

```
tracii_scheduler.exe <option>
    /install_2000 register the I2C scheduler (>= Win2k)
    /remove_2000 deregister the I2C scheduler (>= Win2k)
```

After a successful registration the I2C Scheduler can be found in the Services dialog of the Administrative Tools (see figure ??).

11.4 API

Depending on the used API different files must be included into the user's own setup package.

11 Redistribution

File Action View Help	D				
	4				
Name	Description	Status	Startup Type	Log On As	
Group Policy Client	The service is responsible for applying settings configur	Started	Automatic	Local System	
Health Key and Certificate Management	Provides X.509 certificate and key management services		Manual	Local System	
🐍 Human Interface Device Access	Enables generic input access to Human Interface Devic		Manual	Local System	
L2C Scheduler	telos' I2C Scheduler (http://www.telos.info/)	Started	Automatic	Local System	
🛸 IKE and AuthIP IPsec Keying Modules	The IKEEXT service hosts the Internet Key Exchange (IKE	Started	Automatic	Local System	
🖓 Infrared monitor service	Detects other Infrared devices that are in range and lau	Started	Automatic	Local System	
Interactive Services Detection	Enables user notification of user input for interactive ser		Manual	Local System	
🕼 Internet Connection Sharing (ICS)	Provides network address translation, addressing, name		Disabled	Local System	
🕼 IP Helper	Provides automatic IPv6 connectivity over an IPv4 netw	Started	Automatic	Local System	
🕼 IPsec Policy Agent	Internet Protocol security (IPsec) supports network-leve	Started	Automatic	Network Service	
🔆 KtmRm for Distributed Transaction Coordinator	Coordinates transactions between MSDTC and the Kern	Started	Automatic (D	Network Service	
🛸 Link-Layer Topology Discovery Mapper	Creates a Network Map, consisting of PC and device to		Manual	Local Service	
🗟 Lookout Citadel Server	Historical data logging database service used for Looko	Started	Automatic	Local System	
Microsoft .NET Framework NGEN v2.0.50727_X64	Microsoft .NET Framework NGEN		Manual	Local System	
Microsoft .NET Framework NGEN v2.0.50727_X86	Microsoft .NET Framework NGEN		Manual	Local System	
🖳 Microsoft iSCSI Initiator Service	Manages Internet SCSI (iSCSI) sessions from this compu		Manual	Local System	
🛸 Microsoft Software Shadow Copy Provider	Manages software-based volume shadow copies taken		Manual	Local System	
🖗 Multimedia Class Scheduler	Enables relative prioritization of work based on system	Started	Automatic	Local System	
🖓 National Instruments Domain Service	Provides a domain server for NI security.	Started	Automatic	Local System	
🔍 National Instruments PSP Server Locator	Locates PSP servers at the request of PSP clients.	Started	Automatic	Local System	
🛸 National Instruments Time Synchronization	Allows this machine to keep its time synchronized with	Started	Automatic	Local System	
🔍 Net.Tcp Port Sharing Service	Provides ability to share TCP ports over the net.tcp prot		Disabled	Local Service	

Figure 11.1: Control Panel\Administrative Tools\Services

11.4.1 C

The I2C.C API is located in the following files:

```
<windows dir>\SysWOW64\i2capi_c.dll
<windows dir>\System32\i2capi_c.dll
```

11.4.2 C++

As the I2C.C++ API gets linked statically to the user's application; no additional files must be included into the setup package.

11.4.3 .NET

The I2C.NET API can be found in the following directory:

<install dir>\lib\dotnet

There are two subdirectories, which contain the 32-bit and the 64-bit versions of the I2C.NET assembly. The interface of both assemblies is compatible.

11.4.4 Java

The JAR file and the DLLs of the I2C.Java API can be found in the following directory:

<install dir>\java

11.4.5 Labview

For the I2C.Labview API some more files are needed. At first two .NET assemblies are needed: the I2C.NET API and i2capi_dotnet_labview.dll. The second assembly can be found in the Assembly Cache of Windows, which can be accessed using the following virtual directories:

```
<windows dir>\assembly(.NET 2.0)
<windows dir>\Microsoft.NET\assembly\GAC_MSIL\i2capi_dotnet_labview\<version>
(.NET 4.0)
```

In addition to these assemblies it is necessary to add all used I2C VIs to the Labview project or setup package. These VIs can be found in the following directory:

<install dir>\labview

The VIs support Labview starting with version 2014. Older versions for Labview 8.2 are still available from our support.

If a package or project dependency cannot be resolved on loading then just point the environment to the proper directory.

There are two sample Labview projects delivered with I2C Studio for an I2C Master Transmitter and Tracer. They can be found in <install dir>\examples\labview.

The Labview projects provide predefined build targets which require write access to the <install dir>\examples\labview\Example[Master|Tracer] directory. If the build process does not complete because of missing file permissions the directories <install dir>\examples\labview and <install dir>\labview can be copied to a different location with proper file permissions. This probably requires the resolution of missing dependencies.