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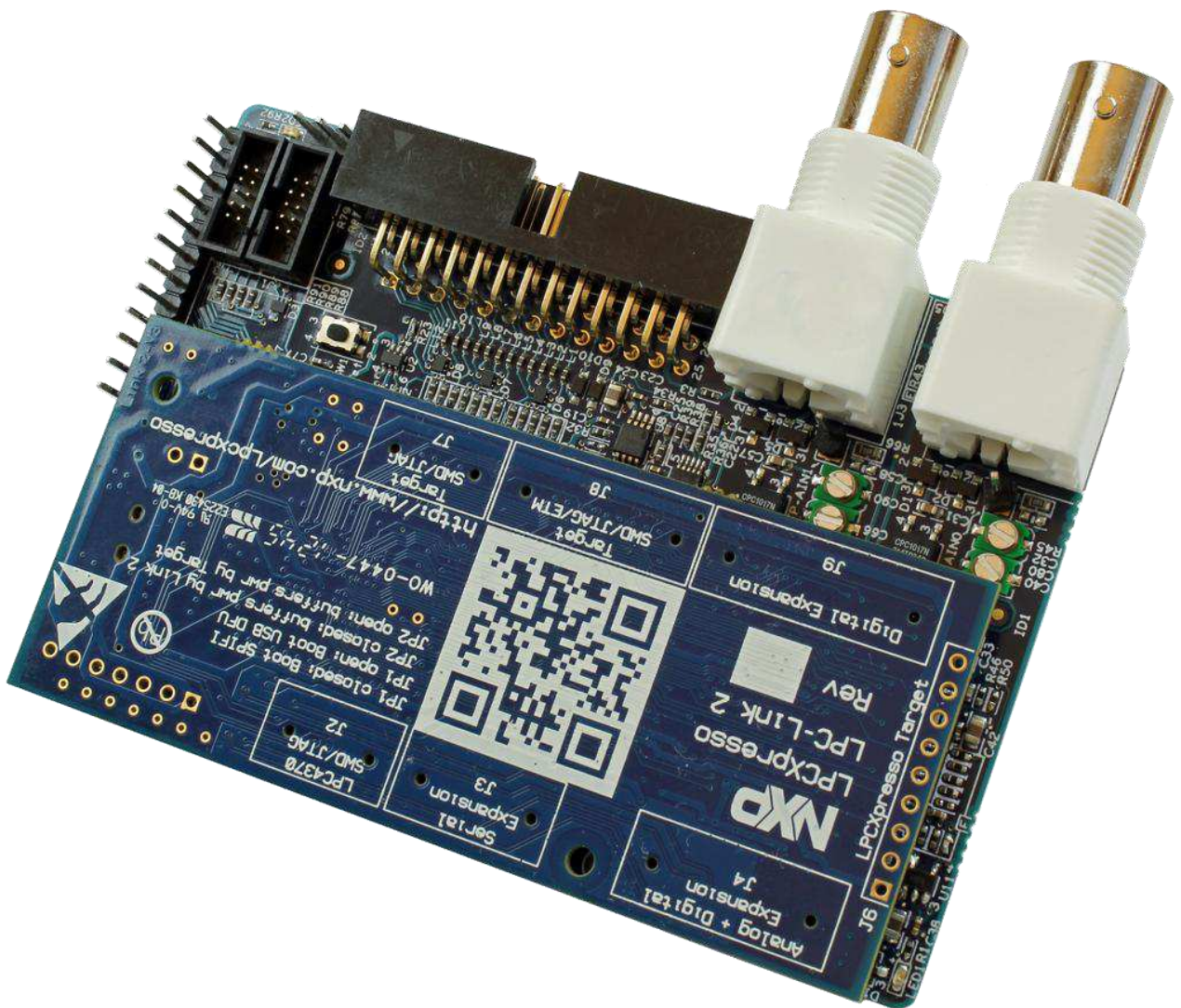
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LabTool User's Guide



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Document Revision History

<i>Revision</i>	<i>Date</i>	<i>Description</i>
PA1	2013-01-03	First version.
PA2	2013-01-07	Updated with continuous sampling, analog triggering and simultaneous analog and digital sampling.
PA3	2013-03-27	Updated for rev PA2 of hardware and updates in GUI.
PA4	2013-05-15	Updated for rev PA3 of hardware and ver 0.8 of installation program. Added step-by-step guide to get started. Added description about cursor functionality.
PA5	2013-10-14	Updated for rev A of hardware. Added more detailed calibration procedure. General update of document.

1 LabTool Introduction

LabTool has been designed to be your best friend on the lab bench!

It is a combination of many instruments packed into a compact unit that fits into your palm.

- 11 channel logic analyzer
- 2 channel oscilloscope
- 11 channel digital signal generator
- 2 channel analog signal generator

Details about the performance (sampling rate, resolution, voltage ranges, etc.) of the LabTool instrument are found in the datasheet on the product page.

The hardware is built around the LPC4370 microcontroller, which is found on the LPC-Link 2 board. The hardware is the combination of an interface board and the LPC-Link 2 board that is mounted on this interface board, see picture below.

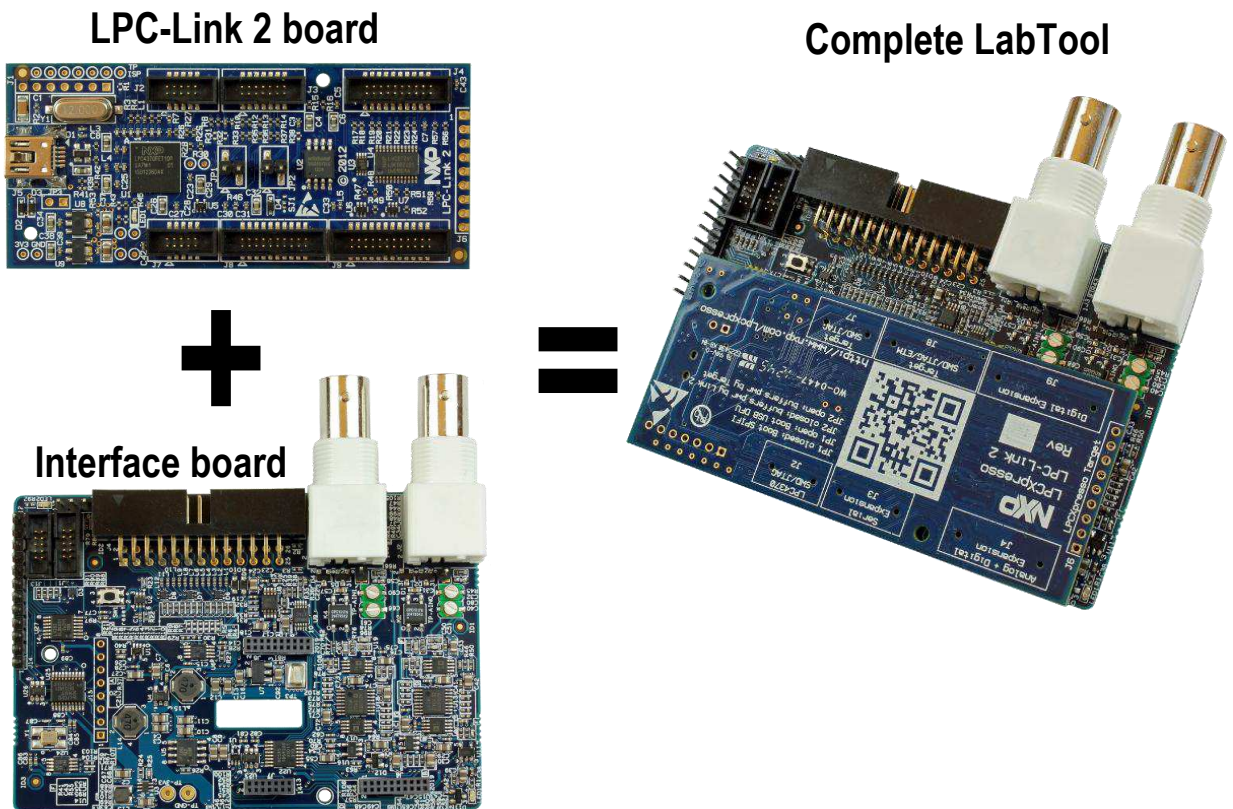


Figure 1 LabTool Board Structure

The user interface for LabTool is software running on a PC. Communication between the hardware and the pc take place over a Hi-Speed (480 Mbps) USB2.0 link.

The user interface is feature rich and supports the user in configuration of the system and presenting the captured signals. Below are some screen shots of the user interface, just to give an idea about how it looks. In this document all details about the user interface will be presented.

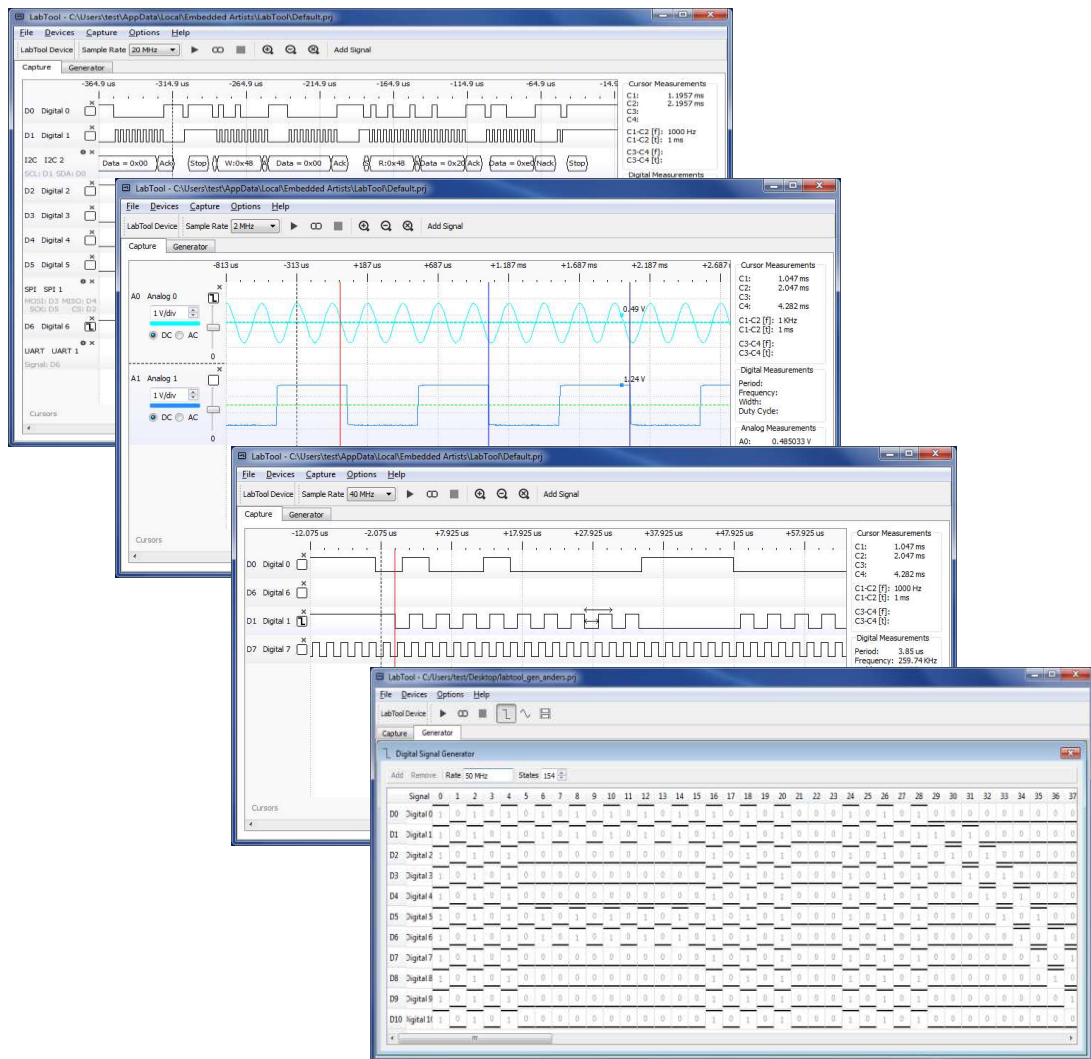


Figure 2 LabTool User Interface Screenshots

As an extra bonus, there are 12 demonstration signals generated by an on-board microcontroller. These are UART, I2C, SPI, PWM and binary counter signals, easily available on 100 mil pitch pin header. The signals can be used to learn how to make full use of the LabTool logic analyzer features and how to work with a logic analyzer in general.

The LPC-Link 2 is a debug interface (Cortex debug) and even though the LPC-Link 2 is mounted in the interface board, creating the LabTool, the Cortex debug interface is available and can be used, see picture below.

The picture below illustrates the external connectors on LabTool.

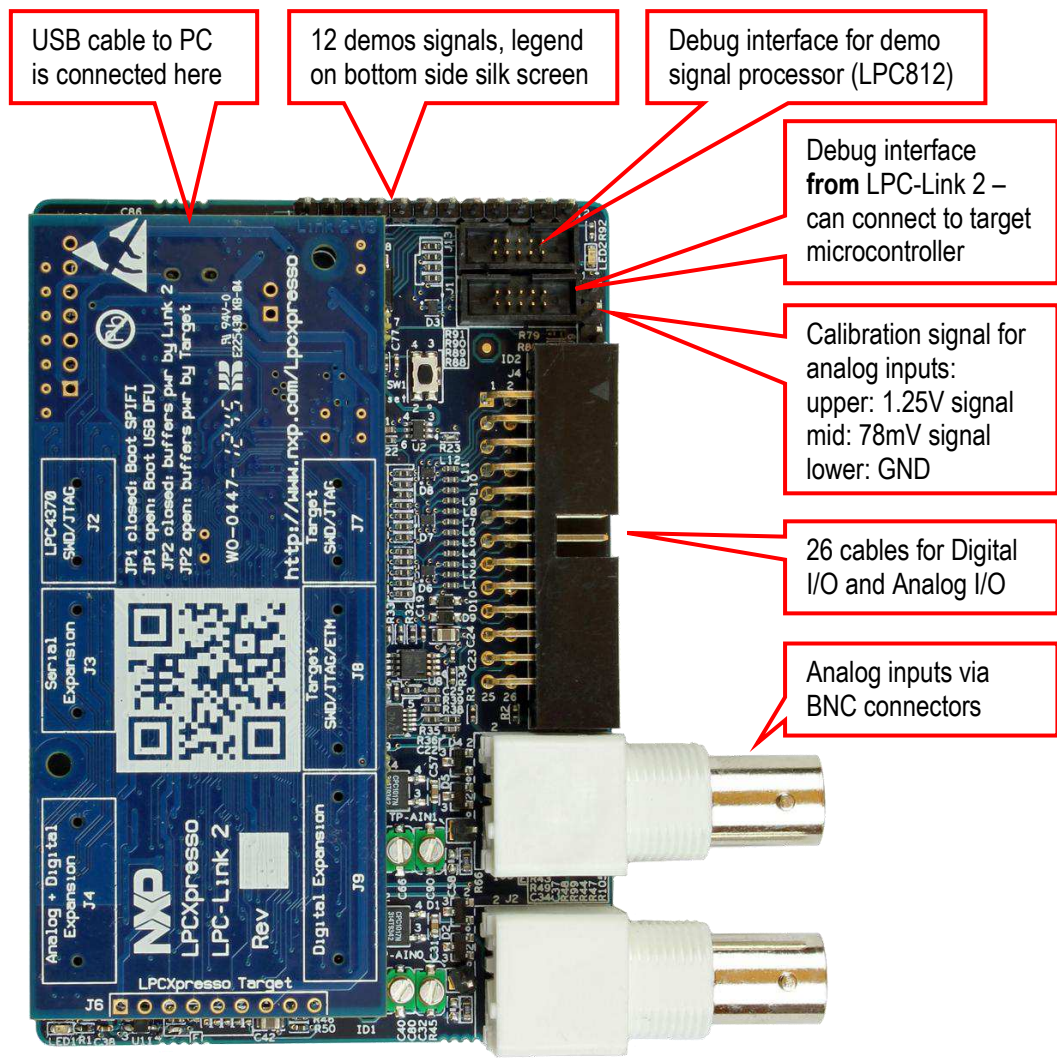


Figure 3 LabTool Connectors and Interfaces

The 26-pos IDC connector carries the following signals.

Pin Number	Pin Name	Cable Color	Description of Demo Signal
1	I2C-SDA	Green	Currently not implemented feature for I2C logging.
2	I2C-SCL	Yellow	Currently not implemented feature for I2C logging.
3	I2C-VCC	Orange	Currently not implemented feature for I2C logging.
4	GND	Red	Ground
5	DIO_VCC	Brown	Can connect to external logic level reference (2.4-5.5V). If left unconnected, the digital I/O voltage reference will be 3.3V.
6	DIO_10	Black	Digital I/O
7	DIO_9	White	Digital I/O

8	DIO_8	Grey	Digital I/O
9	DIO_7	Violet	Digital I/O
10	DIO_6	Blue	Digital I/O
11	DIO_5	Green	Digital I/O
12	DIO_4	Yellow	Digital I/O
13	DIO_3	Orange	Digital I/O
14	DIO_2	Red	Digital I/O
15	DIO_1	Brown	Digital I/O
16	DIO_0	Black	Digital I/O
17	GND	White	Ground
18	AOUT_1	Grey	Analog output #1
19	GND	Violet	Ground
20	AOUT_0	Blue	Analog output #0
21	GND	Green	Ground
22	GND	Yellow	Ground
23	GND	Orange	Ground
24	AIN_1	Red	Analog/Oscilloscope input #1
25	GND	Brown	Ground
26	AIN_0	Black	Analog/Oscilloscope input #0

The signal names are also written in the silkscreen on the bottom side of the pcb. Odd pin numbers are located on the upper row of the 26-pos IDC connector and even numbers are located on the lower row (closest to the pcb).

The use cases for using LabTool in your work are:

- 11 channel logic analyzer, with/without using the demo signals
- 11 channel logic analyzer + 2 channel oscilloscope, with/without using the demo signals
- 11 channel digital signal generator
- 2 channel analog signal generator
- 11 channel digital signal generator + 2 channel analog signal generator
- Cortex Debug interface (SWD) from the functionality of the LPC-Link 2, for example by using the LPCXpresso IDE.

As seen it is not possible to both generate and capture signals.

Last but not least, the **software is released under an open source license**. Anyone can contribute and make the LabTool instrument even better!

2 QuickStart Guide

There is a Cortex-M0+ microcontroller (LPC812) on the LabTool board that generates some sample signals that are very useful to get started and learn about how to use a logic analyzer. In this chapter you will learn how to take a closer look at them using LabTool and at the same time get a quickstart tour on how to work with LabTool.

The guide in this chapter is a quick scratch on the surface to get you started. More complete and detailed information is presented in other chapters.

2.1 Prepare the Hardware

Start by following the preparation steps in section 3.1 (preparing hardware, if needed) and then connect the DIO_x/AIN_0 inputs to the demo signals according to this table:

Input	Cable color	Demo Signal (see legend in silkscreen on bottom of pcb)	Description of Demo Signal
DIO_0	Black	UART-TXD	Asynchronous UART signal transmitting a string at 115.2kbps, 8N1 (8 databits, no parity, one stopbit)
DIO_1	Brown	I2C-SDA	I2C data signal for communicating with a temperature sensor (LM75)
DIO_2	Red	I2C-SCL	I2C clock signal (250kHz) for communicating with a temperature sensor (LM75)
DIO_3	Orange	SPI-SSEL	SPI device select signal for communicating with an SPI E2PROM (25LC040)
DIO_4	Yellow	SPI-MOSI	SPI slave output signal for communicating with an SPI E2PROM (25LC040)
DIO_5	Green	SPI-MISO	SPI master output signal for communicating with an SPI E2PROM (25LC040)
DIO_6	Blue	SPI-SCK	Clock signal (2.1MHz) for communicating with an SPI E2PROM (25LC040)
DIO_7	Violet	CNT-QA	Counter signal, 1MHz
DIO_8	Grey	CNT-QB	Counter signal, 500KHz
DIO_9	White	CNT-QC	Counter signal, 250KHz
DIO_10	Black	PWM-LED	PWM signal (24kHz) that drives the green LED
AIN_0	Black	CNT-QD	Counter signal, 125KHz

2.2 Basic Usage

The next step is installing the LabTool application as described in section 3.2. The LabTool application can be found on the start menu, see Figure 6, or on the desktop if that option was selected during installation.

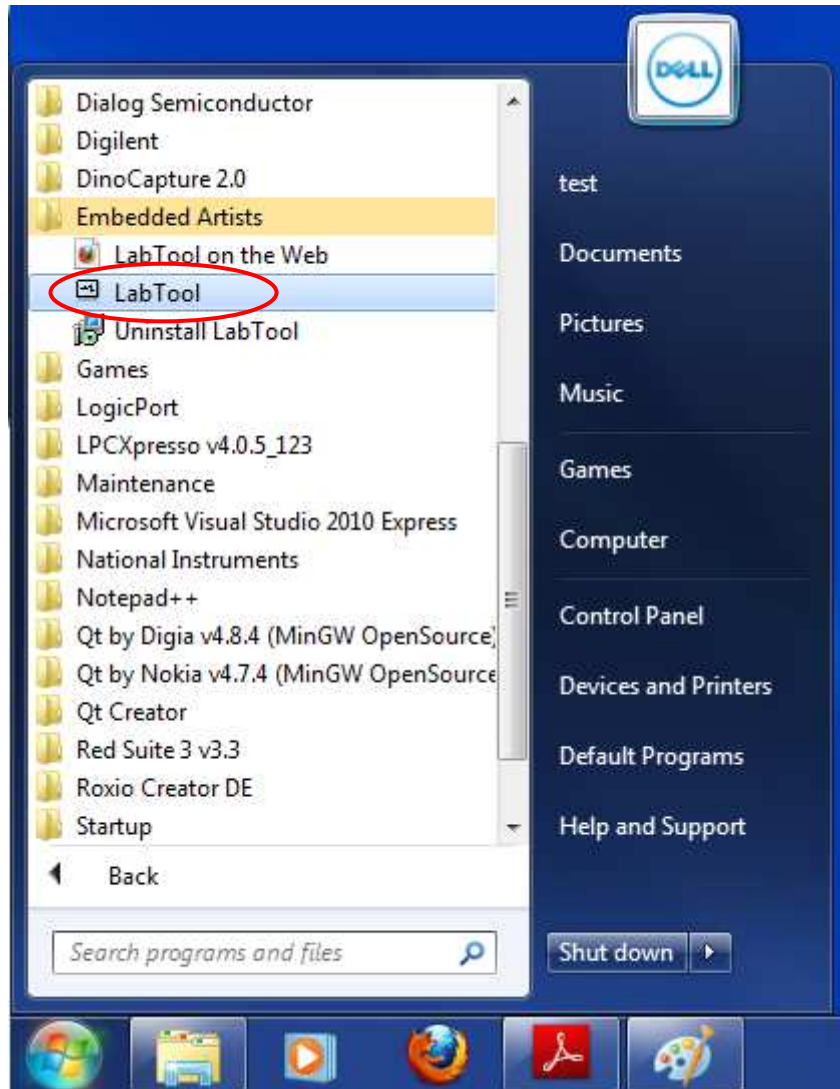


Figure 6 LabTool Application in Start Menu

When the application has started the default screen opens up, as illustrated in Figure 7 below. This window contains a number of areas that are explained below. The left area has a list of the active signals. In the middle area the captured signals are displayed. Between the left and middle areas there is a small area for trigger settings. In the right area the sampled/captured signals are displayed. At the bottom, the cursors are shown and can be manipulated. At the, below the menus, is a toolbar where different settings are controlled, like sample rate, play/capture and time scale adjustment.



Figure 7 LabTool Application Default Screen

A demo project has been installed together with the LabTool application. Select **Open** in the **File** menu and point to the demo.prj file which is located in the same folder as LabTool (typically c:\Program Files\Embedded Artists\LabTool).

When the project has loaded the first thing to do is to create a new copy of it so that the original is not modified if you want to run this demo again. Select **Save As** from the **File** menu as shown in Figure 8.

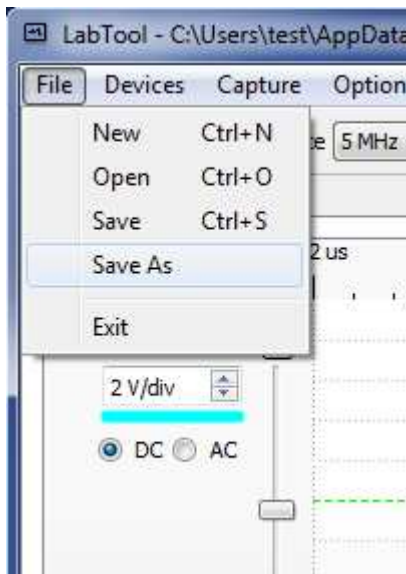


Figure 8 Save Project Settings

The project will be loaded and a number of signals and analyzers will appear, see Figure 9.

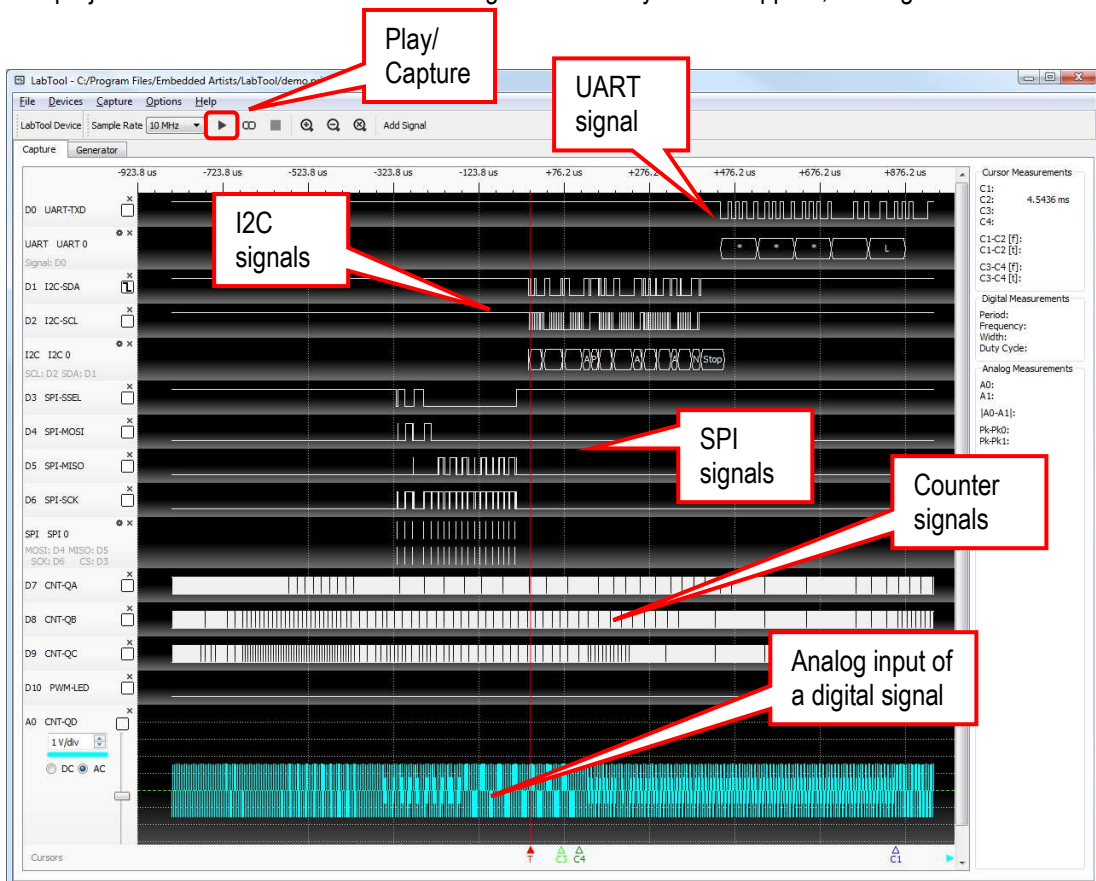


Figure 9 Demo Project Loaded

If the middle area is blank that is because no data has been collected yet. Press the **Play/Capture** button in the toolbar or select **Start** from the **Capture** menu. That will capture a new set of data – one time when the trigger condition is met. Pressing the **Continuous Capture** button (the infinite symbol, just right of the Play/Capture button) will capture data every time the triggering condition is met – not just one time.

The middle area has a dark background here. This can be changed by selecting another color scheme as illustrated in Figure 10 below.

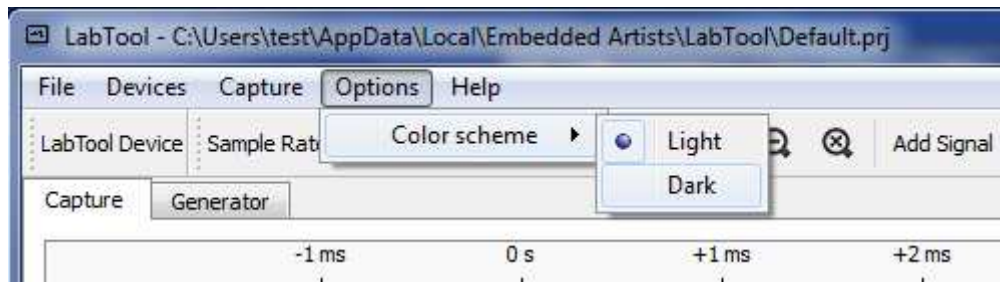


Figure 10 Set Color Scheme

2.3 Interpret Data with Analyzers

Now that the project has been loaded and data has been captured, it is time to take a closer look at the different signals and how to interpret the data with the help of analyzers.

2.3.1 UART

The LPC812 outputs an asynchronous UART signal at 115.2kbps, 8N1 (8 databits, no parity, one stopbit) on the UART-TXD pin, which is connected to the DIO_0. The message that is sent every second is

```
*** LabTool - temp: xx.x deg. C ***
```

where xx.x is the temperature read from the LM75 temperature sensor mounted on the LabTool board.

The default sample rate in the demo is 10MHz which is too high to be able to see the entire signal, see Figure 11 below.

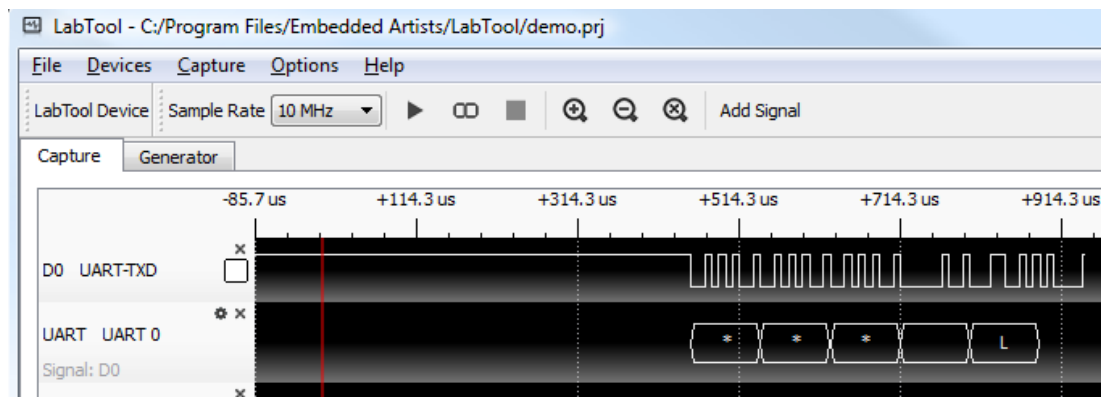


Figure 11 Partial Capture of UART Signal

There are many ways to capture more of the signal:

- 1) Lower the sample rate to e.g. 2MHz. This will allow samples to be taken during the entire 3ms duration of the UART message
- 2) Move the trigger from signal D1/I2C-SDA (default) to D0/UART-TXD
- 3) Remove all unwanted signals. This will allow the D0 signal to use more memory which results in more samples.
- 4) Change the post fill settings in **Trigger Settings** on the **Capture** menu. By increasing post-fill from the default 50% to e.g. 80% more of the data after the trigger will be saved.

2.3.2 SPI

The LPC812 has an SPI channel where it communicates with an SPI-E2PROM. 4 signals are used, SCK (the clock signal), MOSI (the data signal from master to slave - LPC812 to E2PROM), MISO (the data signal from slave to master – E2PROM to LPC812) and SSEL (the chip select signal, active low).

- 5) Zoom-in and measure the clock frequency. It should be 1 MHz. Depending on selected sample rate the (time-) resolution might give another value and it can vary slightly between clock cycles. The higher the sample rate, the better resolution and the less jitter in measurements. Hover the cursor over the captured clock signal and read the measurement in the Digital Measurements area, see 4.4.2 on page 36 for more details.
- 6) It is possible to change settings of an interpreter (reconfigure analyzer) by clicking on the settings icon, see Figure 30 for details where to find it. Experiment with different representation of the data values. **Hex** is selected in the preloaded project. There are also **Decimal** and **Ascii** representation.
- 7) Observe that the SSEL signal goes low in three different periods. These are The clock signal is high between byte transfers within an active transfer (SSEL low) but goes low in-between transfer blocks (when SSEL goes high). Also note that the bytes are not transferred back-to-back. There is a delay between each byte transfer.
Get acquainted with the cursors to measure time periods. Read about how the cursors work and are controlled/manipulated in section 4.4.1 on page 35.

2.3.3 I2C

The LPC812 has an I2C channel where it communicates with a temperature sensor, LM75. 2 signals are used, SCL (the clock signal) and SDA (the bidirectional data signal).

- 8) Zoom-in and measure the clock frequency. It is in the region of 260 kHz.
- 9) Study the I2C-analyzer output and determine the I2C address of the temperature sensor. The I2C communication takes place in two transfers. Decode what is happening with the help of the LM75 datasheet.

2.3.4 Counters

The LPC812 outputs a 2 MHz clock to a 4-bit binary ripple counter. All four signals are available with frequency 1/2, 1/4, 1/8, 1/16 of the input frequency. 3 of them are connected to digital inputs and the lowest frequency signal is connected to analog input #0.

- 10) Measure the three frequencies. Test to trigger on the lowest frequency signal. Test to trigger on the highest frequency signal. Which one is best for stable reasing.

2.3.5 Analog

As presented above, the lowest frequency signal from the ripple counter is connected to the analog input #0.

- 11) Zoom-in and out and determine the frequency of the digital signal.
- 12) Verify that the amplitude of the signal seems correct. It is a 3.3V logic signal. Test to change volts/div setting.
- 13) Test AC coupling of the signal and observe how the signal varies around ground level now.
- 14) Select continuous sampling and change triggering to the analog signal. Adjust triggering level and verify what happens if outside of the signal range. Also verify that the digital signals just randomly flash by now. The only way to get the back into the "area of interest" is to trigger on UART, SPI or I2C communication signals.

2.3.6 PWM

The last demo signal created by the LPC812 is a PWM signal. It controls a green LED on the board.

- 15) Measure the PWM-frequency. It is about 24 kHz. Note that the sample frequency must be high to keep stable triggering is the end points (PWM signal almost always high or almost always low). Trigger on this signal.

3 Installation

This chapter describes the steps needed to prepare the hardware and install the PC application.

3.1 Prepare Hardware

In most cases the hardware is already prepared, looking like the picture below. LabTool can be bought assembled like this. In addition to this, two cables are needed:

- 26-pos cable for external signals. This cable is included when buying LabTool.
- USB cable (mini-B to A). Note that this cable is not included when buying LabTool.

Verify that no jumpers are inserted on the LPC-Link 2 board. These jumpers can possibly be inserted on the bottom side of the LabTool interface board, in the middle hole.

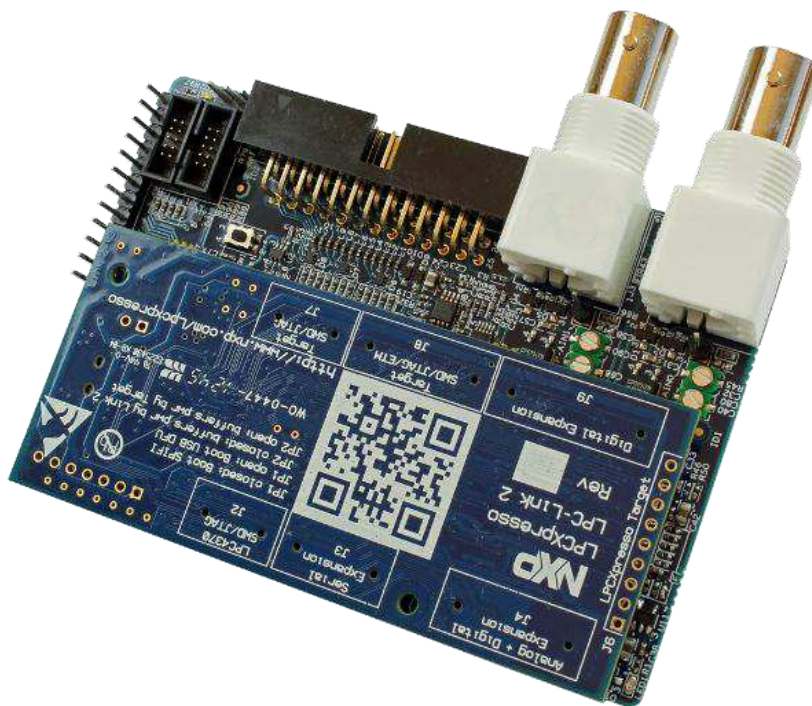


Figure 12 Complete LabTool Board

If LabTool is not assembled like above, some manual work is needed. The following things are needed (one of each):

- LPC-Link 2, rev C board
- LabTool interface board, rev A, with 26-pos cable for external signals.
- Mounting kit
- USB cable (mini-B to A)

Verify that no jumpers are inserted on JP1 or JP2 on the LPC-Link 2 board, see picture below.

LPC-Link 2 board

LabTool interface board

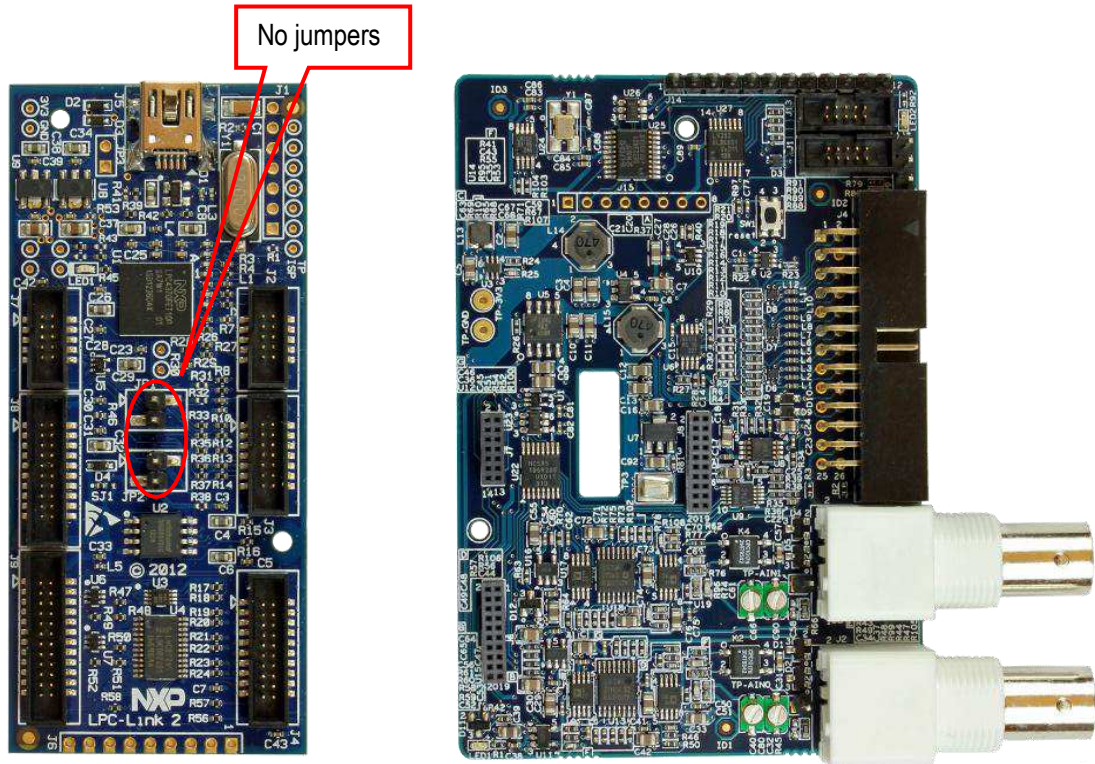


Figure 13 LPC-Link 2 Board and LabTool Interface Board rev A

Place the two boards according to Figure 13 above. Note the board orientations. Place the LPC-Link 2 on top of the LabTool board and press it down – connecting the boards via three connectors. It is possible to mount the two boards slightly misaligned so make sure the connectors on the LPC-Link 2 board are placed symmetrical in the connectors on the LabTool board, see picture below.

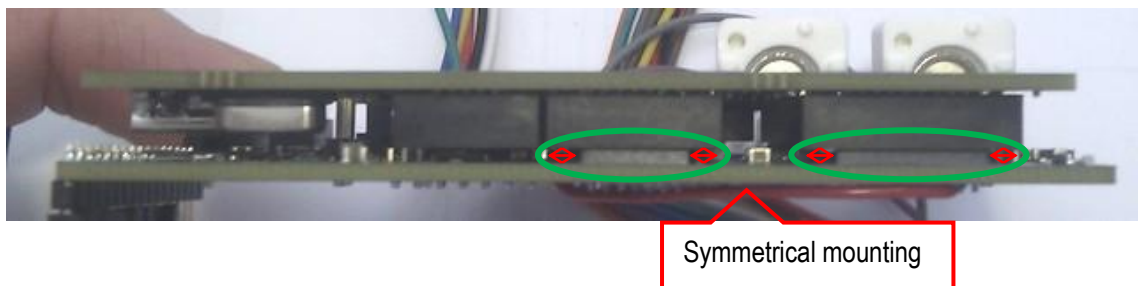


Figure 14 LPC-Link 2 Board and LabTool Board Mounted

When the LPC-Link 2 board has been mounted on the LabTool interface board it will look like on Figure 12 from the top.

3.2 Install PC Application

Uninstall any previous installation of LabTool before starting. Make sure the LPC-Link 2 is not connected to the PC via a USB cable during the installation.

Run the file **Install LabTool vX.Y.exe**, when X.Y is the version number to install the software on the PC.



Figure 15 First Dialog of Installation

Press **Next** button.

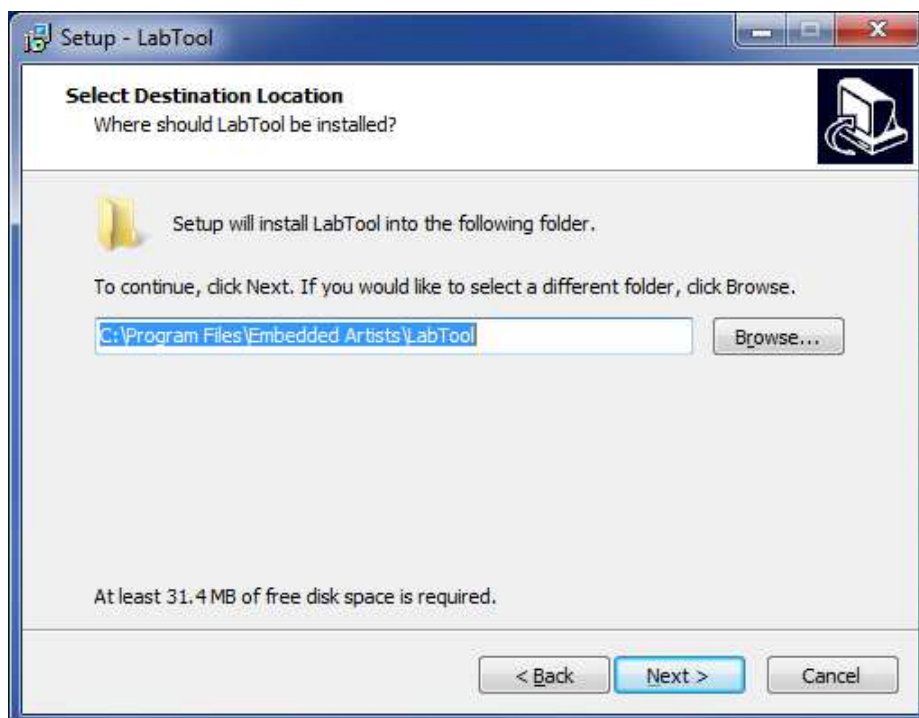


Figure 16 Second Dialog of Installation

Select destination folder and press **Next** button. If possible, keep default folder.

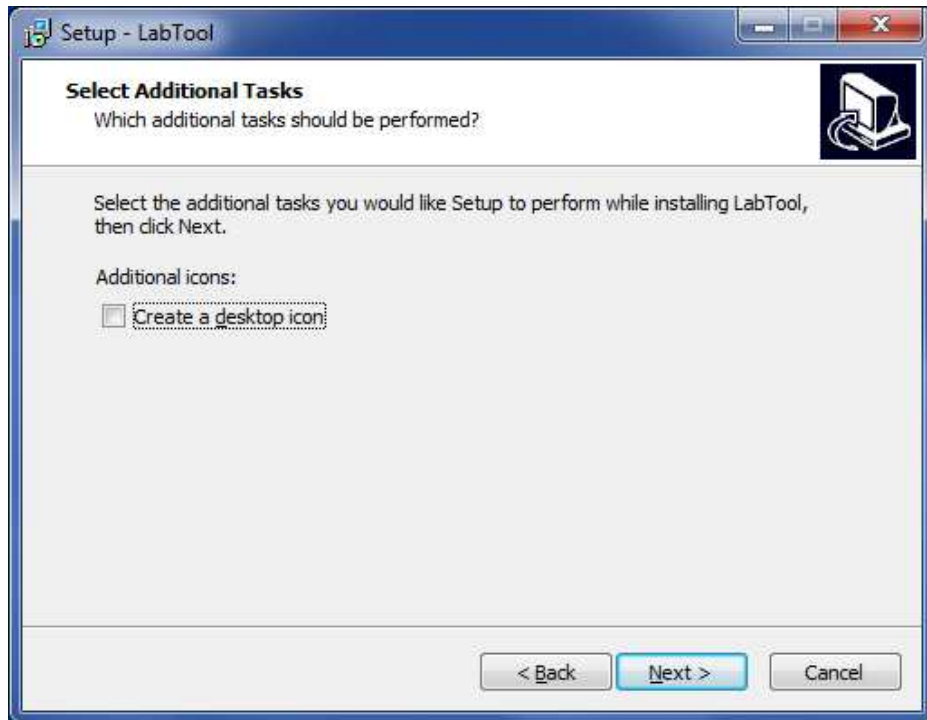


Figure 17 Third Dialog of Installation

Select checkboxes to get a desktop icon and/or Quick Launch icon (not available in all versions of Windows) of the application. Press **Next** button.

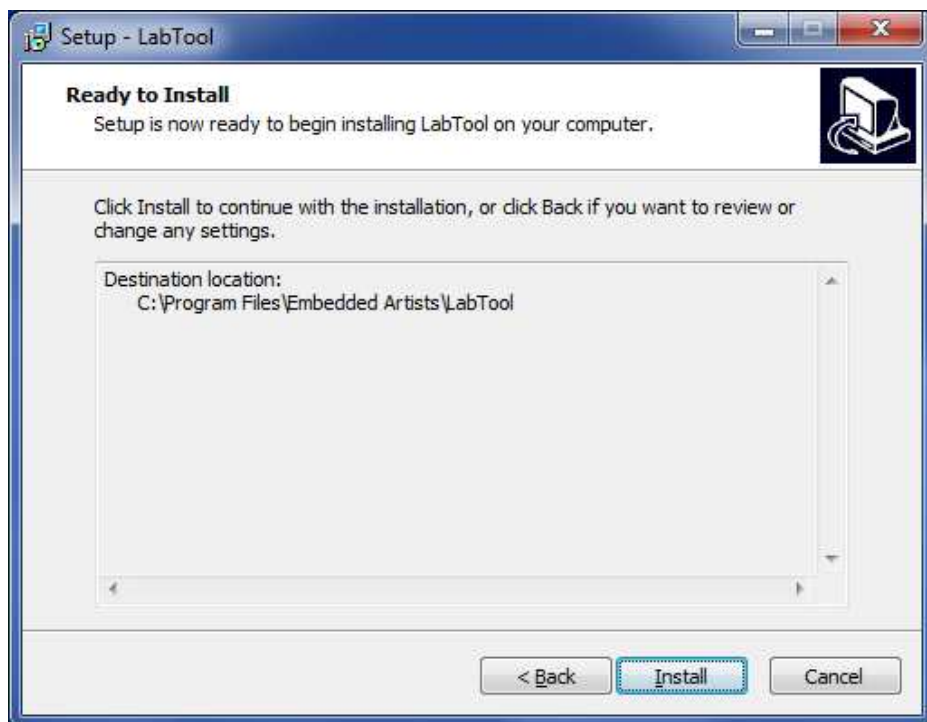


Figure 18 Fourth Dialog of Installation

Press **Install** button and wait while files are installed on the computer.

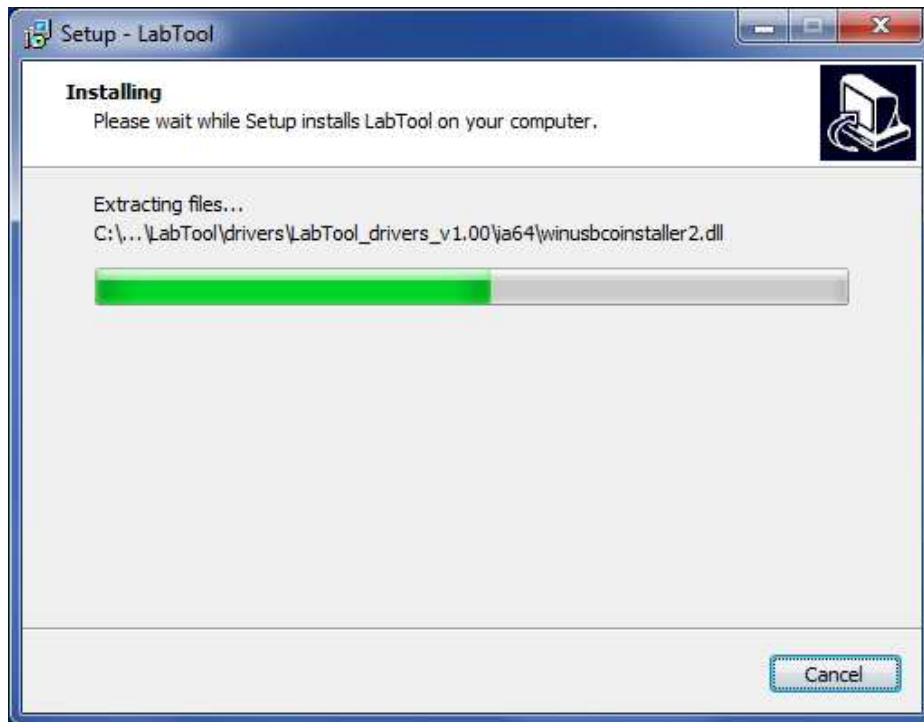


Figure 19 Fifth Dialog of Installation

The USB drivers that are installed have been signed and will likely be installed in the background. However on some versions of Windows two dialogs (one for each driver) may be shown asking for permission to be installed. Permission must be granted otherwise LabTool will not work.

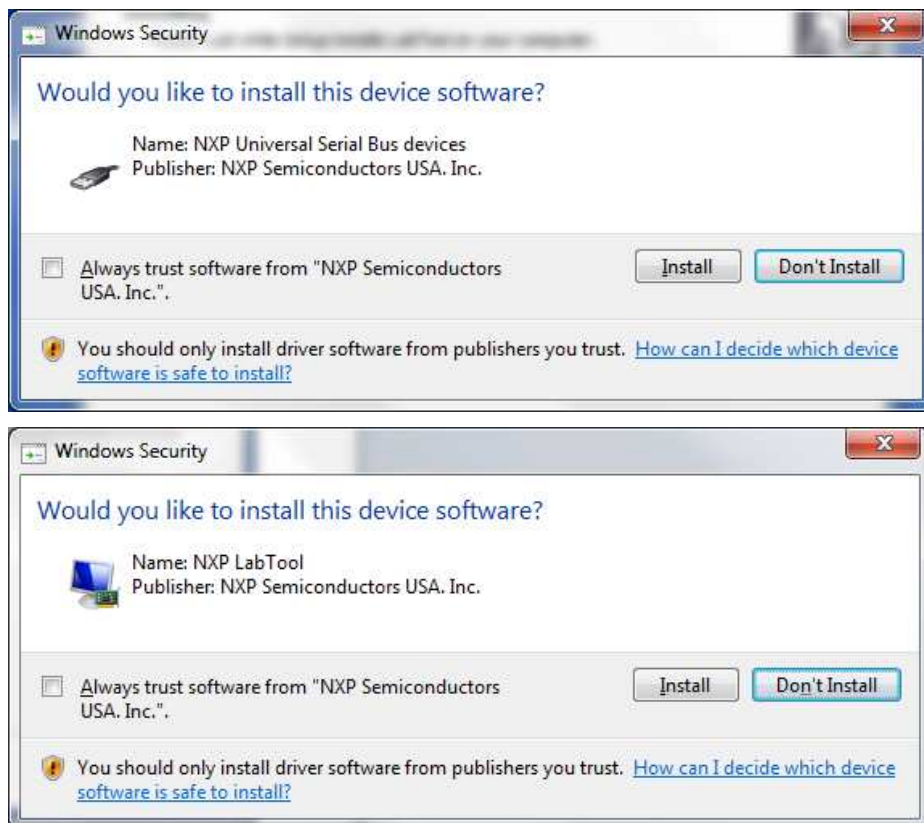


Figure 20 USB Driver Warning Dialogs in Windows 7

After a while (can take several minutes), the final dialog will be displayed, as illustrated below.

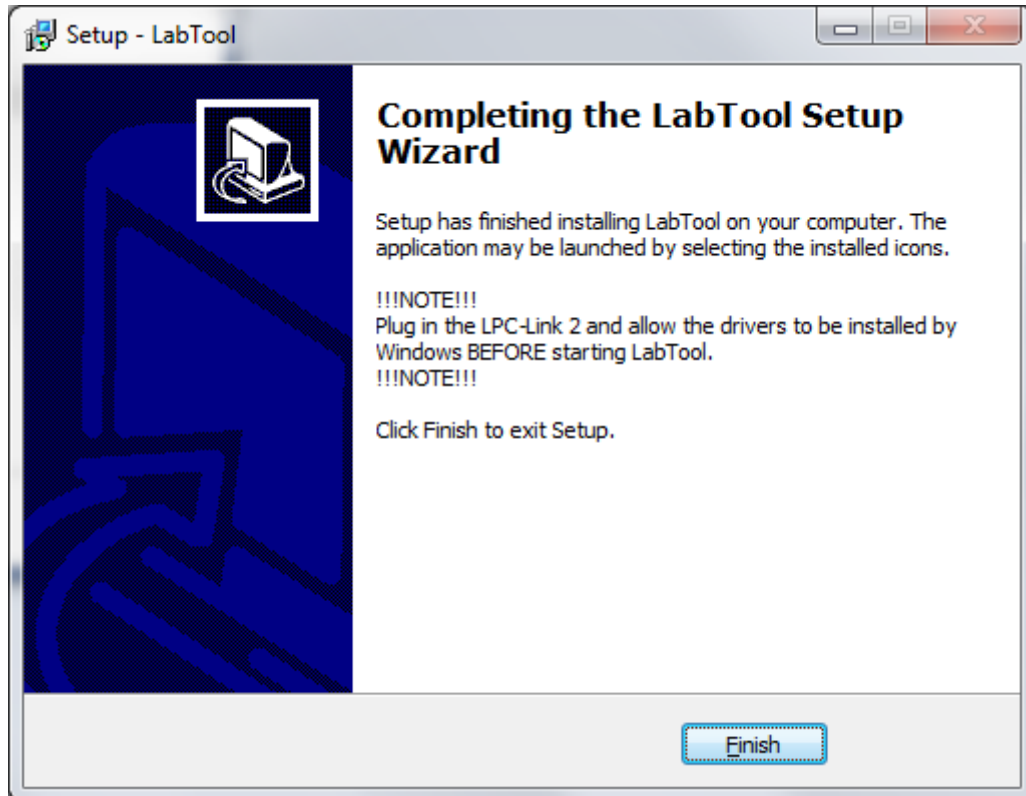


Figure 21 Final Dialog of Installation

Press **Finish** button to complete the installation.

Do not start the LabTool application at this point in time. First connect the LPC-Link 2 to the PC via a USB cable. Wait until the USB drivers have installed. Two windows will appear shortly at the lower right screen of the PC. The process can take several minutes to complete.

4 Using LabTool

This section will describe how to best work with LabTool when using it as a logic analyzer and/or oscilloscope. It is by far the most common use case and gives a nice introduction to the user interface. The other use cases are also presented at the end of the chapter.

There are three steps to follow for successful usage of LabTool as a logic analyzer/oscilloscope:

1. Prepare the measurement

First the signals to measure must be decided, how to trigger that data capture and at what sample rate.

- a. Sometimes the signals have very well-known characteristics and it is easy to set the sample rate. However, sometimes the signals are more unknown and then it is a good start to get familiar with the signal. Set a high sample rate and just take a forced trigger snapshot of the signal. Review the snapshot and adjust sample rate if necessary. Setting sample rate is always a trade-off between level of details in the signals and length of capture. LabTool has a 64 kByte of memory for storing samples. The more signals to capture the shorter the capture length will be. See section 7.3 for more details about how the sample memory is divided.
- b. Sometimes the trigger condition can be difficult to define. LabTool can trigger on any digital signal having a rising or falling edge. If several signals have been selected there is a logical-OR condition between the trigger conditions. Anyone occurs and there will be a trigger to start capture data.
Sometimes the trigger condition is after the time period of interest. In that case pre-fill should be set as high as possible, meaning that most of the captured data is before the triggering point.
Sometimes the trigger condition is before the time period of interest. In that case post-fill should be set as high as possible, meaning that most of the captured data is after the triggering point.
- c. Defining the triggering condition can be difficult. Of a microcontroller is involved it is sometimes possible to let software detect the time period that is of interest, for example an error condition. A GPIO can be manipulated by the microcontroller and this signal can serve as a triggering condition (with suitable pre-/post-fill settings).

2. Capture data

The next step is to capture the actual data. The system that is analyzed should be activated and LabTool shall be started with either a single capture or a continuous capture.

- a. It is not uncommon that several captures have to be taken before a suitable section of the signals has been captured.
- b. Continuous capture is effective for events that do not occur very often in time (not more than once per second). The demo signals, for example, repeat themselves once every second. It is possible to manually analyze such captures on-the-fly.
- c. Continuous capture can sometimes also be effective if there is an error in the system that makes it freeze (or stop working properly). The triggering event stops occurring. Then it is possible to have the capture of the last events that occurred before the error.

3. Interpret captured data

There are four cursors in the graphical user interface that can help measure time between interesting events. There are also interpreters for I2C, SPI and UART that can be activated (before or after) a capture. Any digital signals can be inputs to these interpreters.

- a. Since the LabTool software is open source it is possible to create interpreters for the specific signals you are interested in.

The three steps; **prepare**, **capture** and **analyze** are treated in more details in the following sections.

4.1 Start LabTool Application

The LabTool application can be found on the start menu, see Figure 22, or on the desktop if that option was selected during installation.

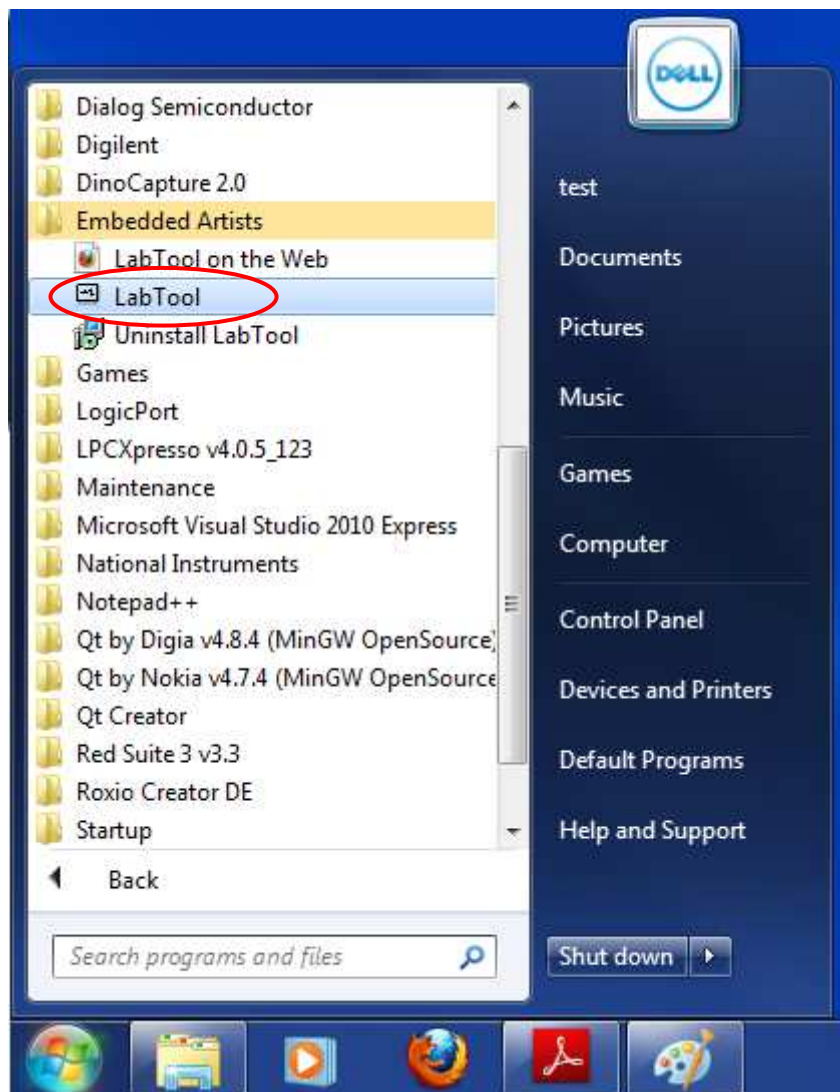


Figure 22 LabTool Application in Start Menu

When the application has started the default screen opens up, as illustrated in Figure 23 below. This window contains a number of areas that are explained below. The left area has a list of the active signals. In the middle area the captured signals are displayed. Between the left and middle areas there is a small area for trigger settings. In the right area the sampled/captured signals are displayed. At the bottom, the cursors are shown and can be manipulated. At the, below the menus, is a toolbar where different settings are controlled, like sample rate, play/capture and time scale adjustment.

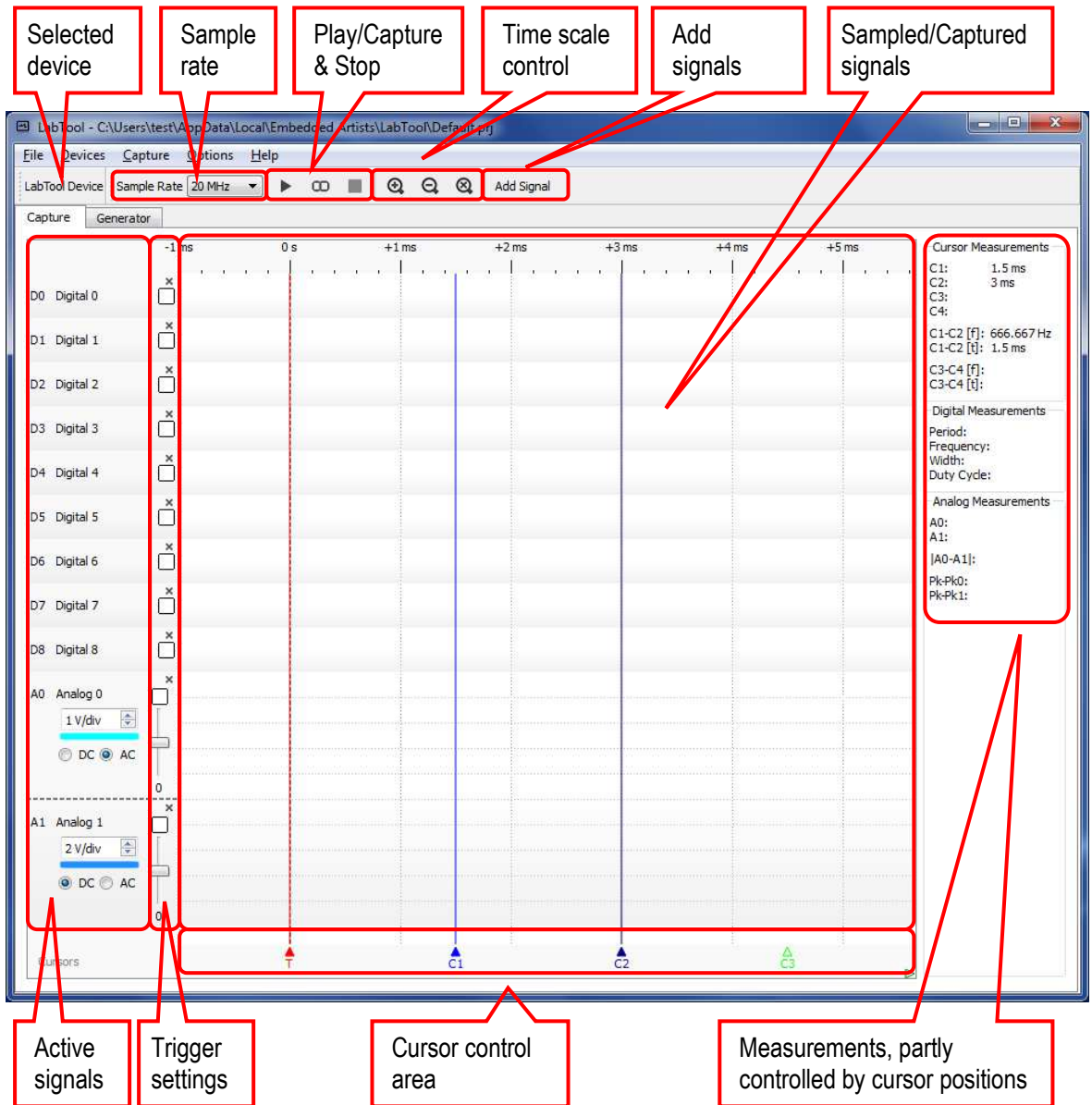


Figure 23 LabTool Application Default Screen

The capture device is selected in the “Devices” menu. When a LabTool device is connected it will show up in the list of selectable devices. The Simulator can always be selected. The status area (see marked area in Figure 24) will indicate which capture device is currently selected. The status text will turn red if the connection to the selected device is lost.