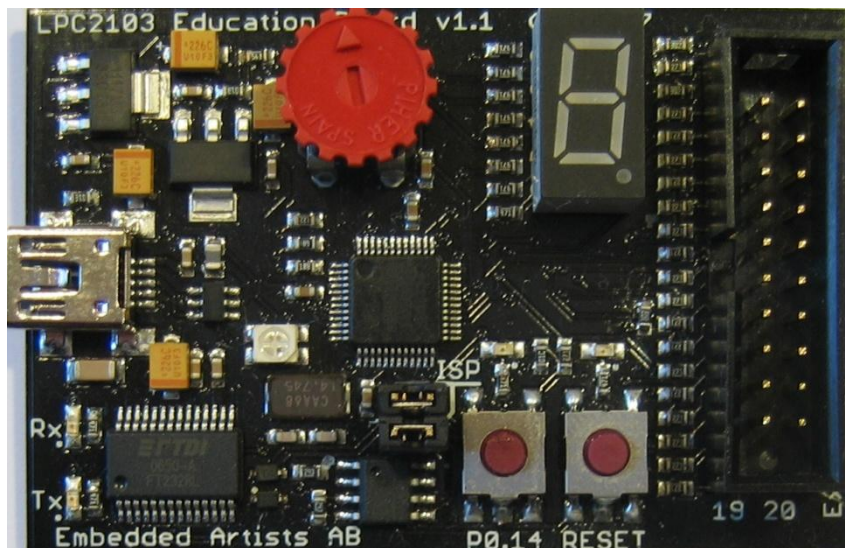


LPC2103 Education Board User's Guide



*Learn everything there is to know about the
new ARM7 32-bit MCU's...*

Start Developing Your Applications On Day 1!

Embedded Artists AB

Davidshallsgatan 16
SE-211 45 Malmö
Sweden

info@EmbeddedArtists.com
<http://www.EmbeddedArtists.com>

Copyright 2005-2012 © Embedded Artists AB. All rights reserved.

No part of this publication may be reproduced, transmitted, transcribed, stored in a retrieval system, or translated into any language or computer language, in any form or by any means, electronic, mechanical, magnetic, optical, chemical, manual or otherwise, without the prior written permission of Embedded Artists AB.

Disclaimer

Embedded Artists AB makes no representation or warranties with respect to the contents hereof and specifically disclaim any implied warranties or merchantability or fitness for any particular purpose. Information in this publication is subject to change without notice and does not represent a commitment on the part of Embedded Artists AB.

Feedback

We appreciate any feedback you may have for improvements on this document. Please send your comments to support@EmbeddedArtists.com.

Trademarks

All brand and product names mentioned herein are trademarks, services marks, registered trademarks, or registered service marks of their respective owners and should be treated as such.

Table of Contents

1	Document Revision History	4
2	Introduction	5
2.1	Contents	5
2.2	Features	5
2.3	Expansion Connector	6
2.4	Experiment Expansion Board	6
2.5	ESD Precaution	6
2.6	General Handling Care	6
2.7	CE Assessment	7
2.8	Other Products from Embedded Artists	7
2.8.1	Design and Production Services	7
2.8.2	OEM / Education / QuickStart Boards and Kits	7
3	Board Design	8
3.1	Board Schematics	8
3.1.1	CPU	8
3.1.2	UART#0 and ISP	8
3.1.3	Expansion Connector	9
3.1.4	LED and Push-button	10
3.1.5	7-segment LED Display	11
3.1.6	RGB-LED	11
3.1.7	Reset Generation and I2C E2PROM	12
3.1.8	Power Supply	12
3.1.9	Analog Input	13
3.2	Jumpers	14
3.3	Connectors	15
3.4	Important Components	16
3.5	JTAG	16
4	Getting Started	17
4.1	Test program	17
4.2	Program Development	17
4.3	Program Download via ISP	17
4.4	FTDI USB Driver	18
4.4.1	USB Driver Behavior	21
5	Further Information	22

1 Document Revision History

<i>Revision</i>	<i>Date</i>	<i>Description</i>
A	2008-01-21	Original release
B	2009-04-25	Update schematic. Grammar and spelling corrections.
C	2012-01-13	Added note about CE marking.

2 Introduction

Thank you for buying Embedded Artists' *LPC2103 Education Board* based on NXP's ARM7TDMI LPC2103 microcontroller.

This document is a User's Guide that describes the *LPC2103 Education Board* hardware design. It also covers some basic software interface principles regarding the hardware. Embedded Artists has also created another document containing many experiments that will guide you through the art of embedded program development.

2.1 Contents

The box received when ordering the *LPC2103 Education Board* contains:

- The *LPC2103 Education Board*
- A 20 pos flat cable for expansion
- A USB cable of type: mini-B-to-A, for powering and communicating with the boards from a PC

2.2 Features

Embedded Artists' *LPC2103 Education Board* with NXP's ARM7TDMI LPC2103 microcontroller lets you get up-and-running quickly. The small form factor board offers unique features that ease your learning curve and speed up your program development. Here are some of the features:

- NXP ARM7TDMI LPC2103 microcontroller with 32 KByte program Flash and 8 KByte SRAM
- 14.7456 MHz crystal for maximum execution speed and standard serial bit rates
- On-board Peripherals
 - UART-to-USB bridge interface on UART #0
 - RGB-LED, each color can be controlled via PWM signal
 - LEDs on P0.14 and Reset signal
 - Pushbutton on P0.14 (interrupt input)
 - Reset button
 - Analog input via a trimmer potentiometer
 - 7-segment LED display
 - 2 Kbit I²C E²PROM
- Connectors
 - Mini-B USB connector to UART#0 UART-to-serial bridge and powering
 - 20 pos expansion connector
- On-board low-dropout voltage and reset generation.
 - Generates +3.3V and 1.95V for powering the LPC2103
 - +3.3V available for external circuits, up to 300 mA
- Powered directly from the mini-B USB connector
- Simple and automatic program download (ISP) via UART-to-serial bridge channel
 - Circuit that automatically controls the bootloader from UART-to-serial bridge channel

- Dimensions: 68 x 42 mm
 - Four layer PCB (FR-4 material) for best noise immunity

2.3 Expansion Connector

A 20 pos expansion connector allows the *LPC2103 Education Board* to be expanded with custom hardware for exciting experiments. The following signals are available on the expansion connector:

- P0.2 - P0.15
- P0.23 - P0.25
- Reset
- Power; VCC (+3.3V) and GND

2.4 Experiment Expansion Board

There is an expansion board called the *Experiment Expansion Board* that can be bought separately for more interesting and useful experiments. For details about the board, see the *Experiment Expansion Board* page on Embedded Artists website. The picture below show how the *LPC2103 Education Board* can be directly connected to the *Experiment Expansion Board* via the expansion connector and a 20 pos flat cable.



Figure 1 - LPC2103 Education Board with Experiment Expansion Board

2.5 ESD Precaution

Please note that the *LPC2103 Education Board* come without any case/box and all components are exposed for finger touches – and therefore extra attention must be paid to ESD (Electro-Static Discharge) precaution.

Make it a habit always to touch the metal surface of the USB connector for a second with both hands before touching any other parts of the boards. That way, you will have the same electrical potential as the board and therefore minimize the risk for ESD.



Note that Embedded Artists does not replace boards that have been damaged by ESD.

2.6 General Handling Care

Handle the *LPC2103 Education Board* with care. The board is not mounted in a protective case/box and is not designed for rough physical handling. Connectors can wear out after excessive use. The board is designed for evaluation and prototyping use, and not for integration into consumer or industrial end-products.

2.7 CE Assessment

The *LPC2103 Education Board* is CE marked. See separate *CE Declaration of Conformity* document.

The *LPC2103 Education Board* is a class B product.

EMC emission test has been performed on the *LPC2103 Education Board*. The USB interface has been in use and also powered the device during the test. General expansion connectors where internal signals are made available (for example processor pins) have been left unconnected. Connecting other devices to the product via the general expansion connectors may alter EMC emission. It is the user's responsibility to make sure EMC emission limits are not exceeded when connecting other devices to the general expansion connectors of the *LPC2103 Education Board*.

Due to the nature of the *LPC2103 Education Board* – an evaluation board not for integration into an end-product – fast transient immunity tests and conducted radio-frequency immunity tests have not been executed. Externally connected cables are assumed to be less than 3 meters. The general expansion connectors where internal signals are made available do not have any other ESD protection than from the chip themselves. Observe ESD precaution.

2.8 Other Products from Embedded Artists

Embedded Artists have a broad range of LPC1000/2000/3000/4000 based boards that are very low cost and developed for prototyping / development as well as for OEM applications. Modifications for OEM applications can be done easily, even for modest production volumes. Contact Embedded Artists for further information about design and production services.

2.8.1 Design and Production Services

Embedded Artists provide design services for custom designs, either completely new or modification to existing boards. Specific peripherals and I/O can be added easily to different designs, for example, communication interfaces, specific analog or digital I/O, and power supplies. Embedded Artists has a broad, and long, experience in designing industrial electronics in general and with NXP's LPC1000/2000/3000/4000 microcontroller families in specific. Our competence also includes wireless and wired communication for embedded systems. For example IEEE802.11b/g (WLAN), Bluetooth™, ZigBee™, ISM RF, Ethernet, CAN, RS485, and Fieldbuses.

2.8.2 OEM / Education / QuickStart Boards and Kits

Visit Embedded Artists' home page, www.EmbeddedArtists.com, for information about other *OEM / Education / QuickStart* boards / kits or contact your local distributor.

3 Board Design

This chapter contains detailed information about the electrical and mechanical design of the *LPC2103 Education Board*. The schematic can be downloaded in pdf format from the support page, and is recommended to have printed out while reading this chapter.

3.1 Board Schematics

The following subsections describe in more detail each part of the design.

3.1.1 CPU

The core part of the design is the NXP LPC2103 microcontroller. It is an ARM7TDMI-S CPU core with many different peripheral units and on-chip memory (32 kByte FLASH and 8 kByte SRAM). There is no external memory bus interface. *Figure 2* below illustrates the CPU section of the design.

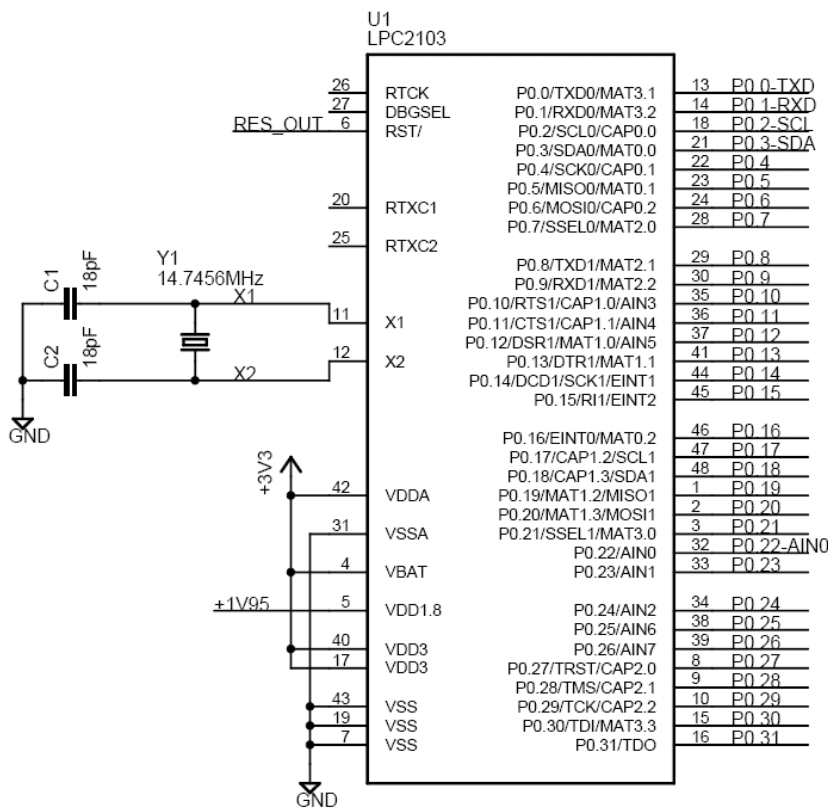


Figure 2 - LPC2103 Education Board Schematic: CPU

The microcontroller crystal frequency is 14.7456 MHz. This frequency has been selected in order to allow close to maximum execution speed ($4 \times 14.7456 \text{ MHz} = 58.9824 \text{ MHz}$) as well as to provide standard serial communication bit rates. The maximum cpu clock frequency is 70 MHz.

The LPC2103 also contains an Analog-to-Digital Converter or ADC for short. The ADC requires a reference voltage, which is supplied via the VDDA and VSSA input pins. For simplicity, the CPU power supply (+3.3V) is used. For an education board like this, the precision of the +3.3V supply is enough.

3.1.2 UART#0 and ISP

UART#0 on the LPC2103 is connected to a USB-to-serial bridge chip (FT232RL from FTDI). The serial interface is not a full interface, only the receive and transmit signals are connected to UART#0. There are two UART channels on the LPC2103 and only channel #1 has all control signals needed for a full

modem implementation. Channel #0 only has got receive and transmit signals. Channel #1 is not used and the signals are available on the expansion connector.

There are two LEDs connected to the USB-to-serial bridge chip. These indicate Rx and Tx activity and can be a good help when determining if a connection with the board is working properly.

There is a special circuit to automate the ISP feature (In-System Programming). With the help of two control signals (RTS and DTR), the processor can be placed in the bootloader mode. The bootloader uses UART#0 for downloading new program images into the processor (either into FLASH or into RAM). DTR controls the processor reset and RTS can pull signal P0.14 low. The signals are pulled low via diodes. If the processor samples P0.14 low after reset the bootloader is entered, or else the application code is executed. The automatic ISP functionality can be disabled by removing the two jumpers on J3. Note that some terminal programs (notably Windows™ Hyperterminal) control the RTS/DTR signals in an unfavorable way so that the board always enters bootloader mode or is always in reset mode. In these cases, the jumpers must be removed.

Note that UART#0 (P0.0 and P0.1) is always connected to the USB-to-serial bridge chip.

Figure 3 below illustrates the USB-to-serial interface and the ISP part of the design.

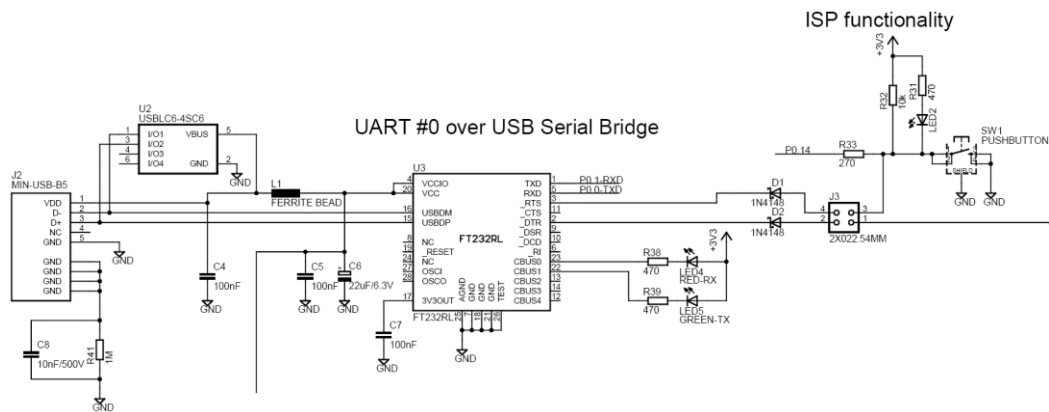


Figure 3 - LPC2103 Education Board Schematic: USB-to-serial and ISP

3.1.3 Expansion Connector

The *LPC2103 Education Board* is not just a monolithic design. Via the expansion connector, it is possible to expand the design. Some of the LPC2103 pins are available on the expansion connector, which is a standard 2x10 shouldered pin list with 100 mil pin spacing. All signals are protected with a 270 ohm series resistor. It is not by far a complete protection of the pins but will give a reasonable protection. Figure 4 below illustrates the expansion connector part of the design. As seen, pins P0.2 – P0.15, P0.23-P0.15, reset and power are available on the connector.

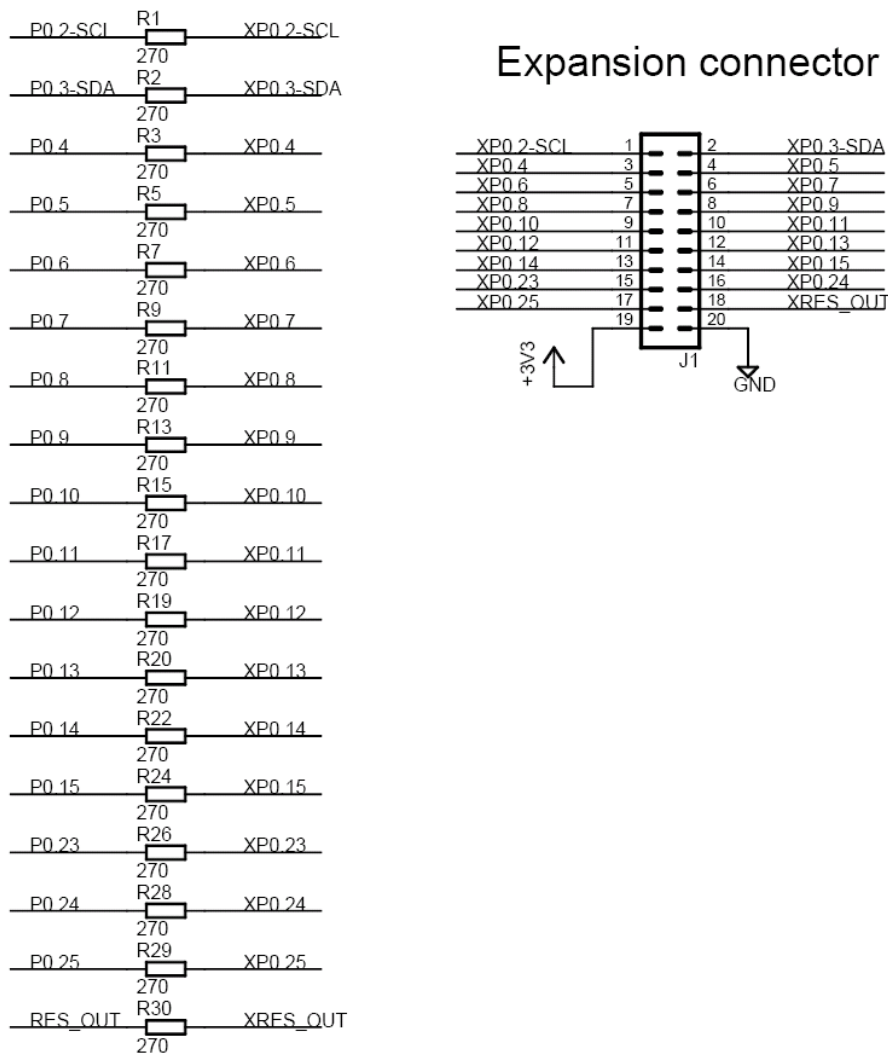


Figure 4 - LPC2103 Education Board Schematic: Expansion Connector

The +3.3V power voltage is available on the expansion connector. Note that the current consumption of external circuitry on the expansion boards should not exceed 300 mA. Since power is drawn from the USB connector, the USB host in the other end will shut down the current delivery completely.

3.1.4 LED and Push-button

Signal P0.14 is connected to a push-button that can pull the signal low. A LED will also light when P0.14 is low. P0.14 has got many functions. Besides being a general purpose i/o-pin, it can be configured as an interrupt input pin on the processor. The signal is also used to enable ISP mode (programming processor flash via UART#0). The signal must be sampled high after reset in order to start normal program execution; or else the internal bootloader will be activated (ISP mode). *Figure 5* below illustrates the circuit around signal P0.14.

ISP functionality

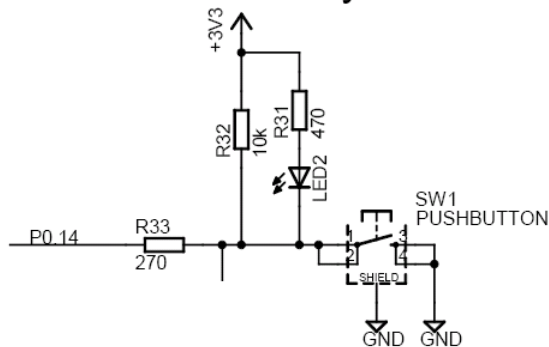


Figure 5 - LPC2103 Education Board Schematic: LED and Push-button

3.1.5 7-segment LED Display

The port pins of the LPC2103 microcontrollers have a 4 mA driving capacity, enough to directly drive the LEDs in a 7-segment display. There are actually 8 LEDs since there is also a dot LED. *Figure 6* below illustrates the 8 LEDs in the design. The LEDs in the display are connected to pin P0.16 - P0.18, P0.26 - P0.30. The 470 ohm resistors limit the current to about 3.5 mA. A low output pin drives current through the LEDs and they will light.

7-segment display

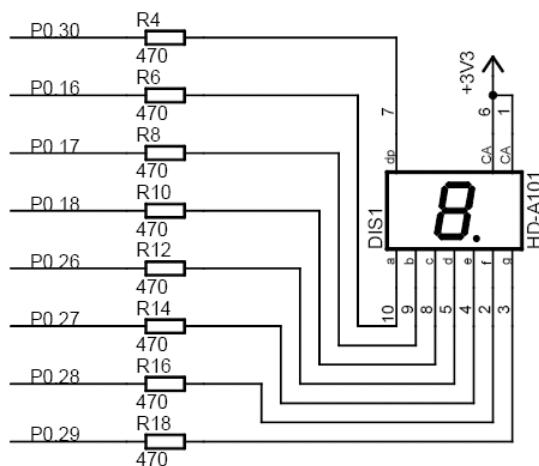


Figure 6 - LPC2103 Education Board Schematic: 7-segment LED Display

3.1.6 RGB-LED

There is a full color RGB-LED that could be controlled by pulse width modulated (PWM) signals. The intensity of each LED can easily be controlled by adjusting the pulse width of the signals. The list below explains the signal connections.

- Red LED, controlled by signal P0.19 – MAT1.2
- Blue LED, controlled by signal P0.20 – MAT1.3
- Green LED, controlled by signal P0.21 – MAT3.0

The MAT signals are available as alternative signals on the pins and are generated from the timer peripheral unit. Both timer 1 and 3 must be used to control all three LEDs. *Figure 7* below illustrates the RGB-LED part of the design.

Note that the LEDs are driven from the +5V power supply. The reason for that is that the forward voltage drop of the blue LED is typically around 3.5V, which is more than the 3.3V power supply for the LPC2103.

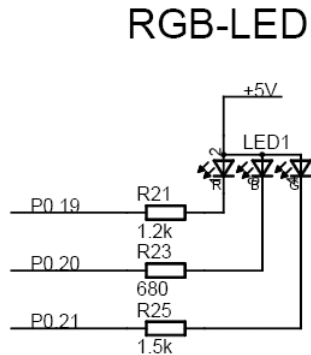


Figure 7 - LPC2103 Education Board Schematic: RGB-LED

3.1.7 Reset Generation and I2C E2PROM

The reset generation is handled by a mixed-signal chip, CAT1025 from Catalyst Semiconductor. The reset signal will be held active (i.e., low) until the supply voltages, +3.3V, is within margins. The reset duration is typically 200 mS (consult the CAT1025 datasheet for exact details). The output reset signal is an open-collector / open-drain output. An external reset source can also control the reset generator. *Figure 8* below illustrates this part of the design. There is a reset push-button (SW2). RES_OUT is available on the expansion connector. Note that an external driver of the RES_OUT signal should be an open-collector / open-drain driver. There is a red LED that lights when the reset signal is active.

I2C-E2PROM and RESET

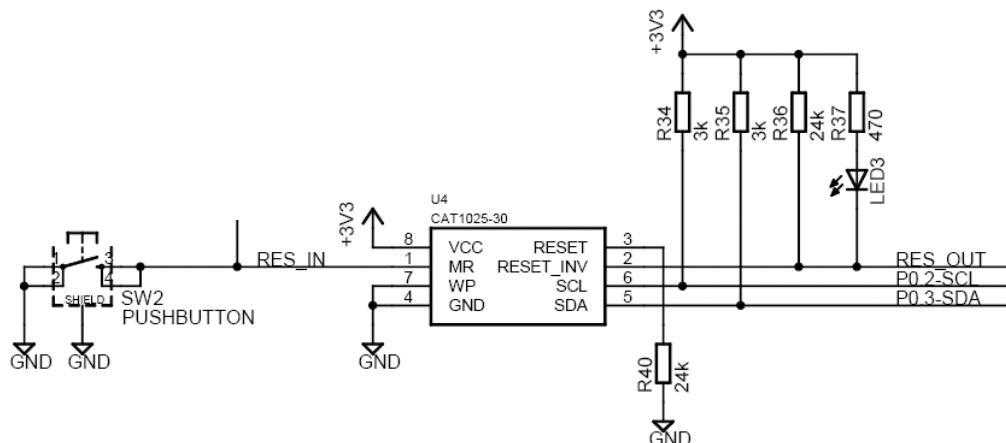


Figure 8 - LPC2103 Education Board Schematic: Reset Generation and I2C E2PROM

The CAT1025 chip also contains a 2kbit E²PROM accessible via the I²C interface. The I²C communication channel can be used to easily connect more peripheral units, just as long as the addresses do not collide. The address of the 2kbit E²PROM is 0xA0.

Note the 3k pull-up resistors, which are always needed on I²C busses.

3.1.8 Power Supply

The power supply uses conventional low-dropout voltage regulators, the Sipex SP1117. The LPC2103 need dual voltages; +3.3V for external i/o and 1.8V for the internal code. Due to an errata on the

LPC2103, the +1.8V voltage has been increased to 1.95V. For a full specification of the SP1117 voltage regulator see the datasheet from Sipex.

Figure 9 below illustrates the voltage regulator part of the design. Power is drawn from the USB connector, which void the need for an external power supply.

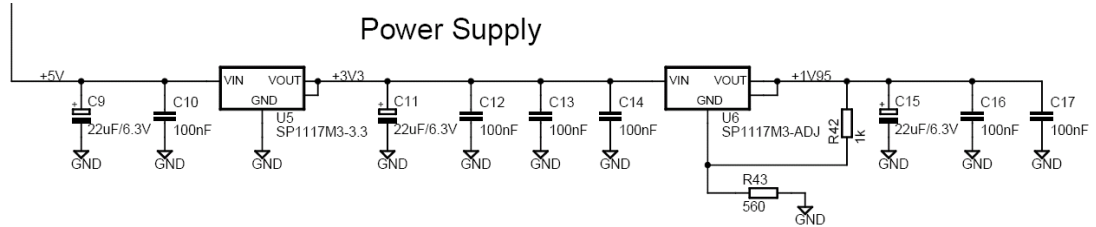


Figure 9 - LPC2103 Education Board Schematic: Power Supply

3.1.9 Analog Input

The LPC2103 has got 8 analog inputs connected to a 10-bit ADC (Analog-to-Digital Converter). The conversion time is as short as 2.44 μ s and the input pins VCCA and VSSA are used as conversion reference. Of the 8 inputs, one is used on-board and three are available on the expansion connector. Figure 10 below illustrates the on-board analog input. As seen, a trim-potentiometer is used to generate a variable voltage to analog input #0 (P0.22).

Analog Input

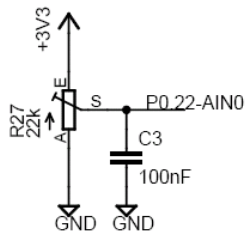


Figure 10 - LPC2103 Education Board Schematic: Analog Input

3.2 Jumpers

The *LPC2103 Education Board* has only got two jumpers. These enable the automatic ISP invocation functionality (i.e., controlling P0.14 and Reset signals from DTR/RTS). *Figure 11* below illustrates where the jumpers can be found.

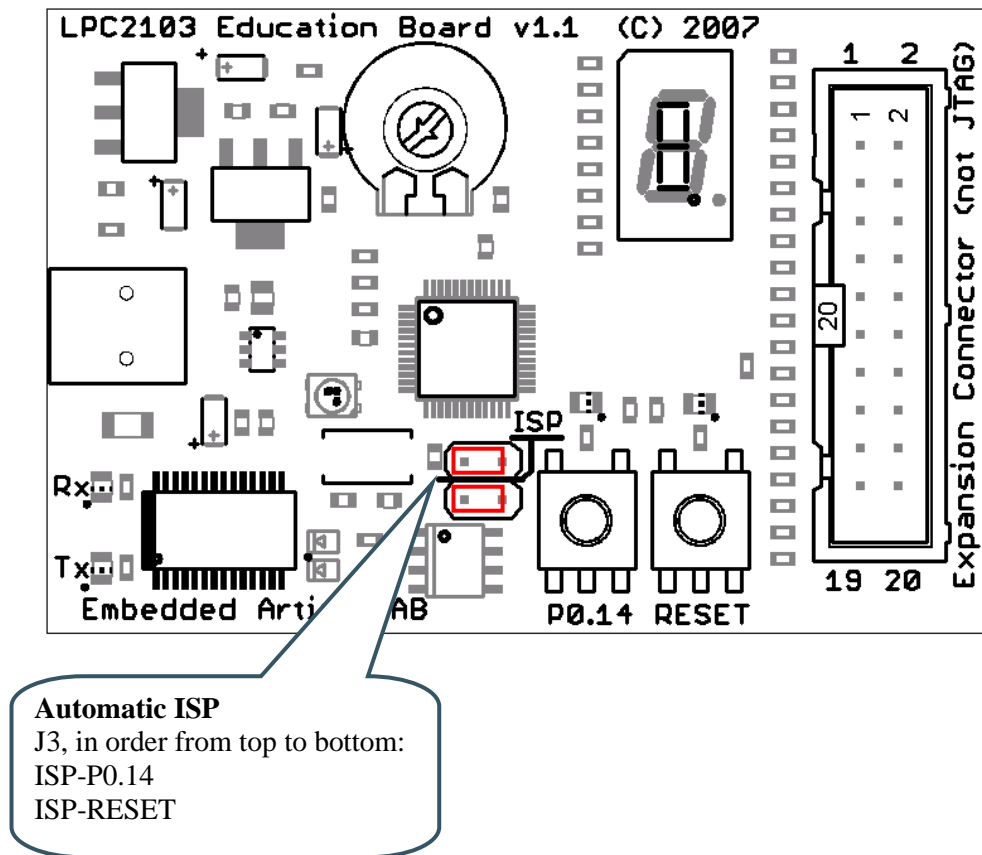


Figure 11 - LPC2103 Education Board Jumpers

3.3 Connectors

Figure 12 illustrate the position of the two external connectors on the LPC2103 Education Board.

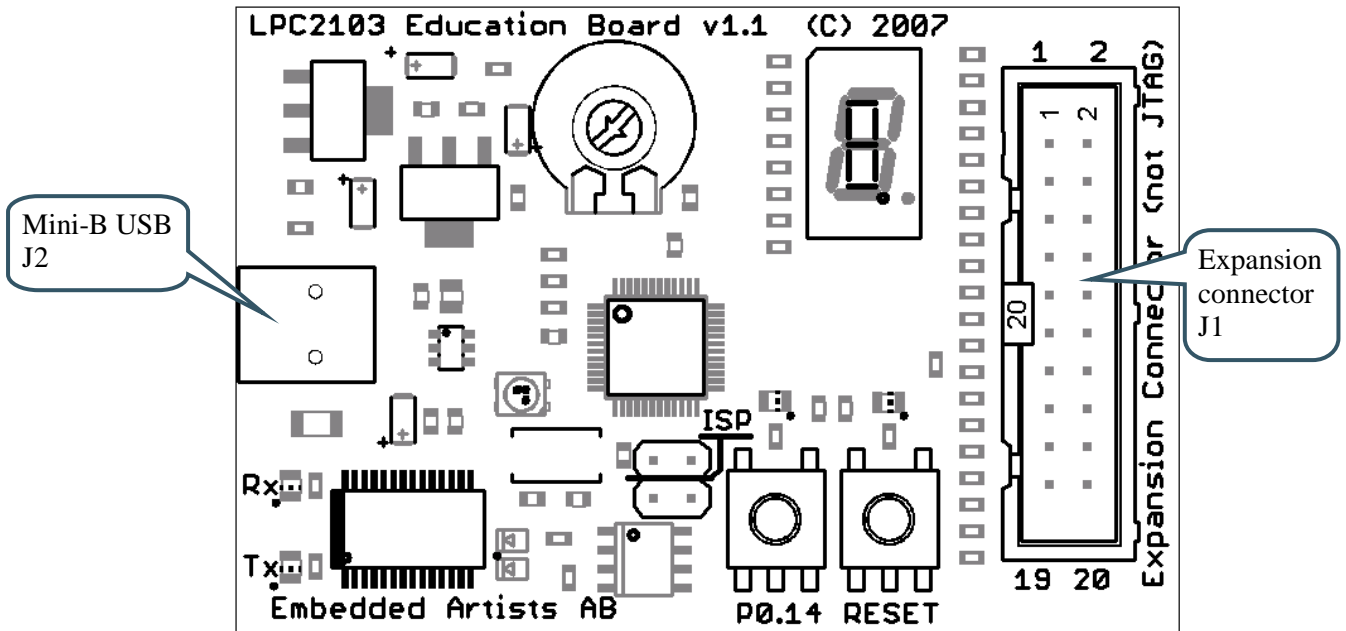


Figure 12 - LPC2103 Education Board External Connectors

3.4 Important Components

Figure 13 illustrates the position on the board for some important components in the design.

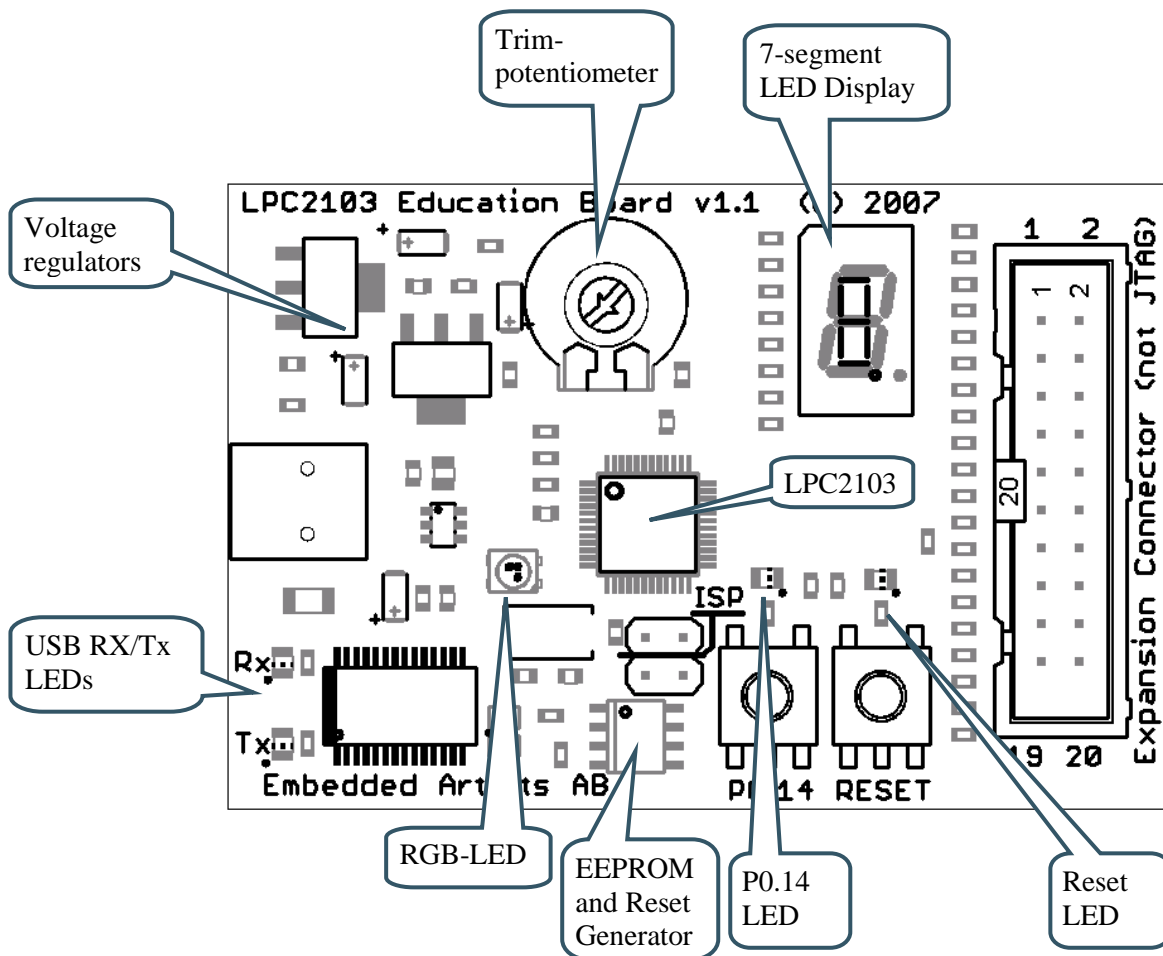


Figure 13 - LPC2103 Education Board Important Components

3.5 JTAG

Note that the JTAG signals are not available on the *LPC2103 Education Board*. The 20 pos expansion connector should **NOT** be mistaken for a JTAG connector.

4 Getting Started

4.1 Test program

The *LPC2103 Education Board* comes preloaded with a test program. This program can be used to verify that the board operates correctly.

- Download the test program (by using the hex-file for the test program)
 - Insert the two jumpers in order to enable automatic ISP activation (during program download)
- Push the reset button and watch the Reset LED light shortly
- Watch the 7-segment display count from 9-8-7-6-5-4-3-2-1-0
- Turn the trim-potentiometer and watch the 7-segment display number change between 0 and 9
- Press the P0.14 push-button. Watch the P0.14 LED light and watch the decimal dot LED on the 7-segment display light
- Watch the RGB-LED flash; red-blue-green-red-blue-green, etc.

A terminal program can be attached to the USB-to-serial mini-B USB connector. The test program will send test information regarding the I²C and E²PROM test over the UART. Also, the UART/USB channel can be tested by typing characters in the terminal program. The settings for the terminal program are: 115.2 kbps, 8 data bits, no parity bits, and one stop bit (i.e., 8N1).

4.2 Program Development

Consult the *QuickStart Program Development User's Manual* for more information about the *QuickStart Build Environment* from Embedded Artists, and program development for the ARM7 in general.

4.3 Program Download via ISP

UART#0 is used to download program code into the internal FLASH of the LPC2103. The ISP (In-System Programming) feature of the LPC2103 is then used. ISP is enabled after reset by pulling pin P0.14 low. In order to enable automated ISP invocation, the *LPC2103 Education Board* allows control of both the reset signal and the P0.14, via the USB-to-serial bridge (FT232RL from FTDI). Reset is controlled by the DTR serial signal and P0.14 via RTS. NXP has released a download program. This program is however no longer supported. Instead there is the open source LPC21ISP program as well as FlashMagic from ES Academy. The latter is the recommended ISP download program to use. This program can be downloaded from: <http://www.flashmagictool.com/>

Figure 14 illustrates the jumper settings when enabling the automatic ISP functionality.

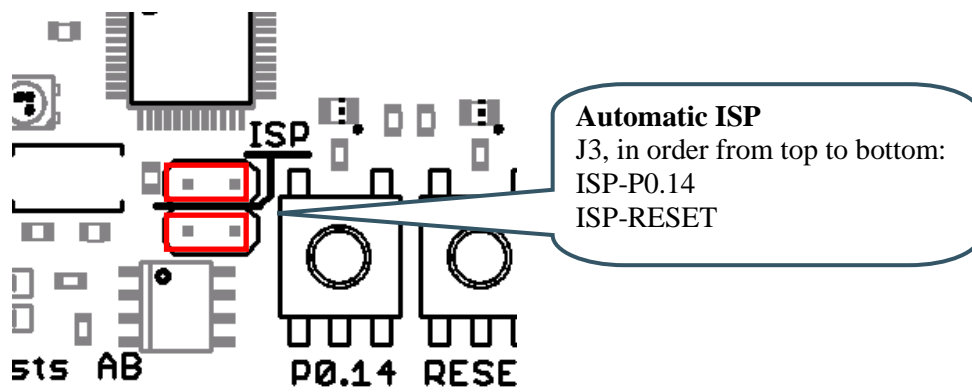


Figure 14 – ISP Jumpers, enable automatic ISP

Some terminal programs can control the DTR/RTS signals when connected to the board so that the board is constantly in reset or always enabling ISP mode. In that case, the automatic ISP functionality must be disabled. *Figure 15* below illustrates the jumper settings when disabling the automatic ISP.

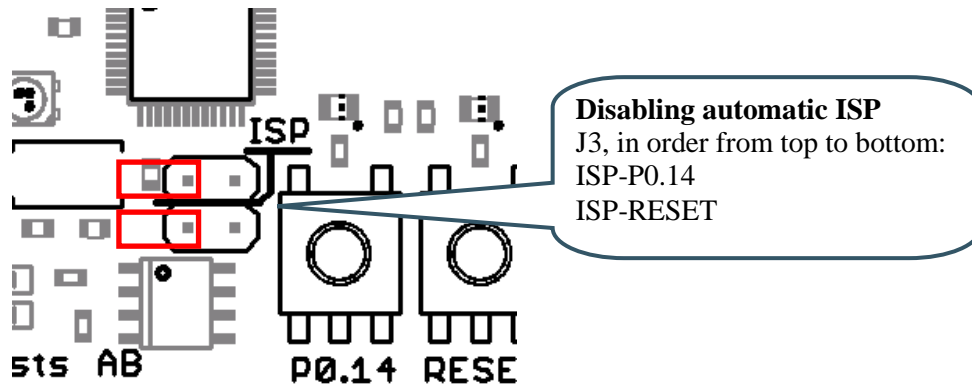


Figure 15 – ISP Jumpers, disable automatic ISP

Note that the USB-to-Serial bridge chip must have its driver installed on the PC (where FlashMagic and the terminal program are running from). *Section 4.4* describes the installation procedure.

4.4 FTDI USB Driver

A USB driver must be installed on your PC computer in order for the USB-to-UART chip (FT232R) to function. Make sure to download the latest version of the driver, which can be found at: <http://www.ftdichip.com/Drivers/VCP.htm> (search for a FT232R driver for your operating system). Latest version of the driver (at the time of writing this document) is 2.02.04.

When the *LPC2103 Education Board* is connected to the PC (via a USB cable) the PC will ask for a driver. Unpack/unzip the downloaded driver file and browse to the position of the driver files. After successful driver installation, a COM port will be created. Before communication with the board can take place the UART settings must be correctly.

The following description is valid for Windows™ XP, but other operating systems have similar dialog windows. See the USB driver documentation for details, if needed.

To change UART settings, first open the System Properties dialog, as illustrated in figure 18.

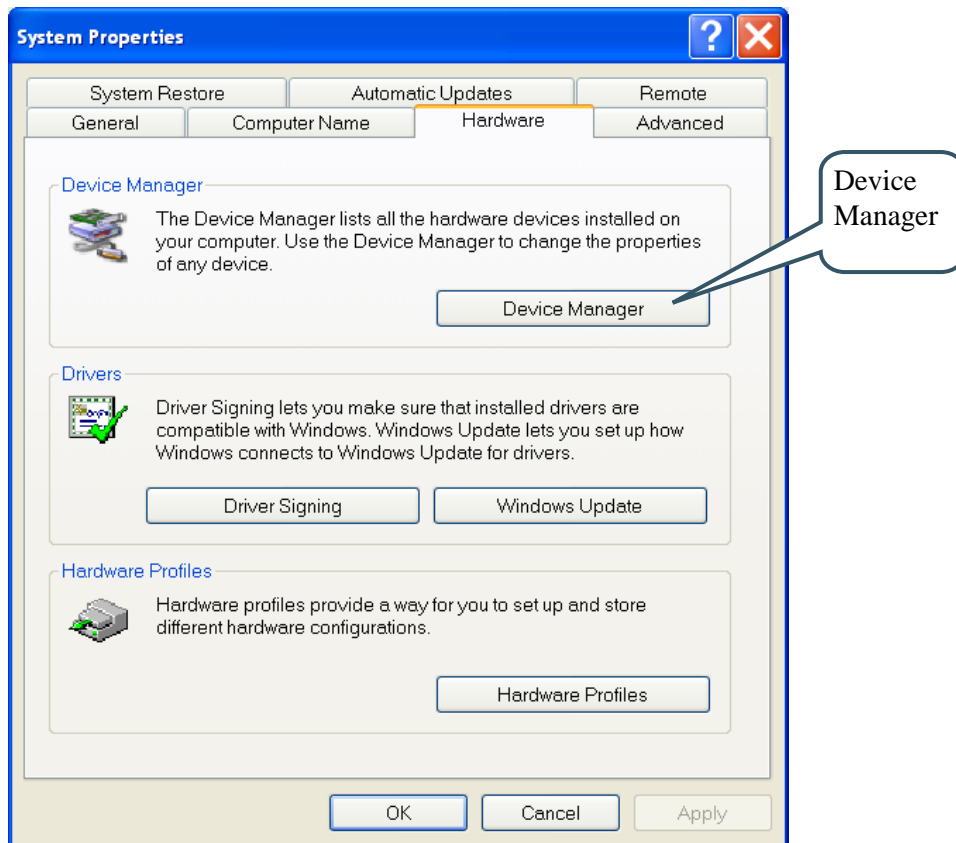


Figure 16 – System Settings Dialog

Then select the *Device Manager* and open the *Ports* list, as illustrated in *Figure 17*.

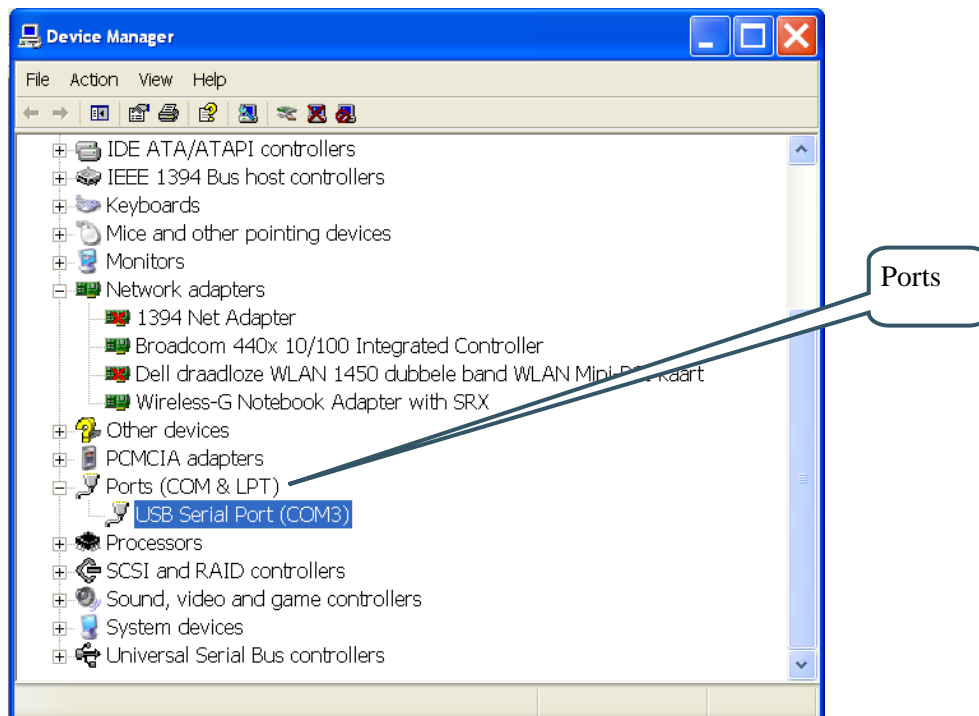


Figure 17 – Device Manager Dialog

The new COM port (USB Serial Port) will be listed under the *Ports* list. Right-click on the new USB Serial Port and select *Properties*, as illustrated in *Figure 18*.

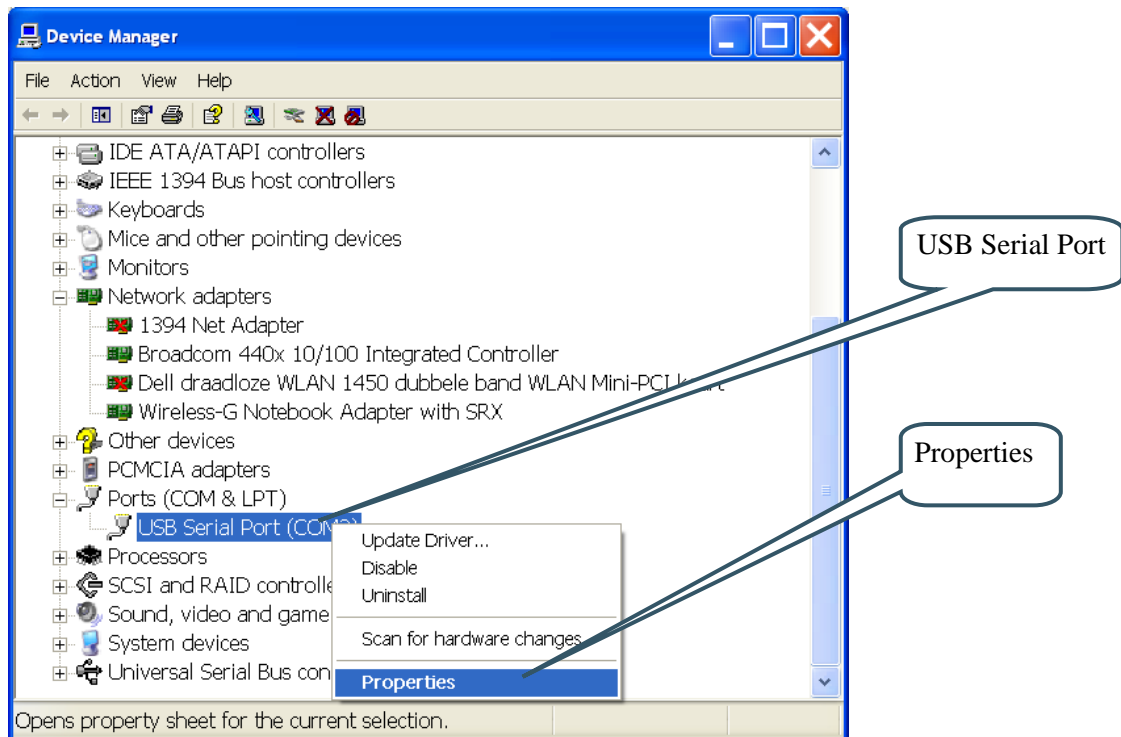


Figure 18 – Device Manager Port Dialog

Set 115200 bits per second, 8 data bits, none parity, 1 stop bit, and none flow control, as illustrated in Figure 19. Select *Advanced* settings.

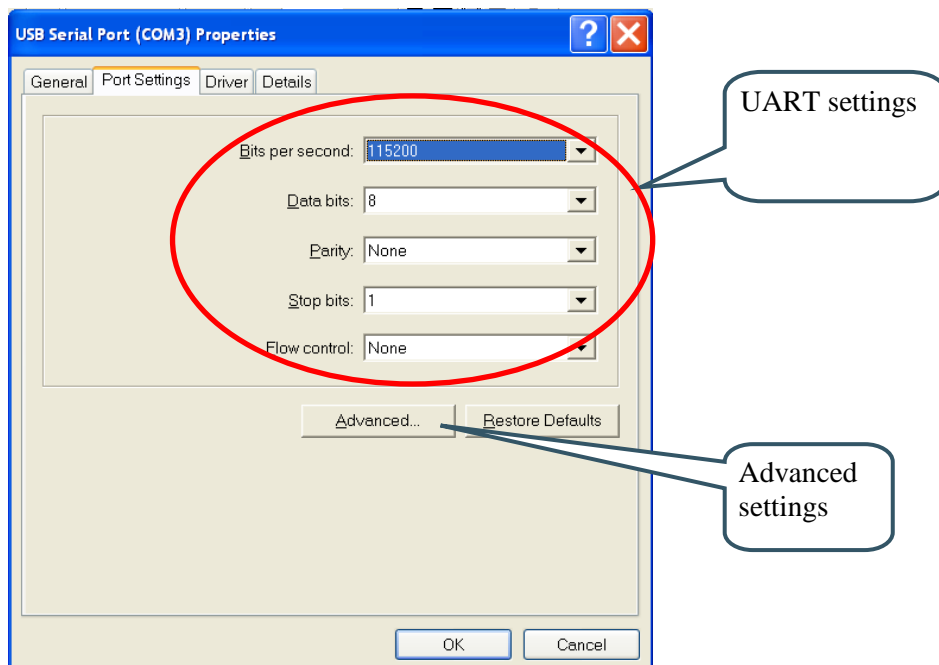


Figure 19 – USB Serial Port Properties Dialog

Set the desired COM port number under the *Advanced* settings dialog. NXP's FLASH Utility program (for ISP program download) needs, for example, a COM port number between 1 and 5. Very often the COM port number selected but the USB Serial Port is higher than that, needs to be changed manually.

It is common that all COM ports with low numbers are listed as occupied, but try to change to a low number anyways. Very often it is no problem at all to do that.

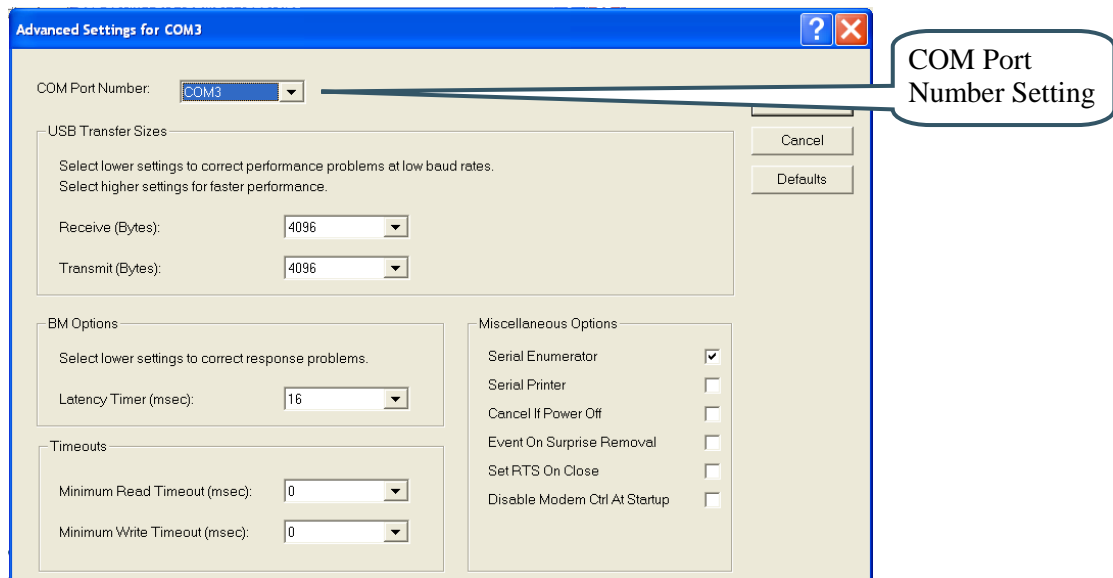


Figure 20 – Advanced USB Serial Port Properties Dialog

Finally it is time to test if the USB Serial Port has been successfully installed and configured. Start a terminal program. Connect to the correct COM port, with 115200 bits per second, 8N1, no flow control. Remember not to have the USB-ISP jumpers inserted.

4.4.1 USB Driver Behavior

Sometimes the USB COM port does not enumerate properly when the board is connected to the PC. This is a known "feature" of the USB driver. If you experience this problem, just unplug the board shortly and then plug it in again. A new COM port that can be accessed properly should be created the second time.

This problem may occur after every time you start (i.e., power cycle) your PC.

If the ISP jumpers are inserted, pressing the reset button is often required in order to startup the board (it can be placed in bootloader mode during startup due to RTS/DTR signal handling by the USB driver during startup).

5 Further Information

The LPC2103 microcontroller is a complex chip and there are a number of other documents with useful information. The following documents are recommended as a complement to this document.

- [1] NXP LPC2103 Datasheet
<http://ics.nxp.com/products/lpc2000/pdf/lpc2101.lpc2102.lpc2103.pdf>
- [2] NXP LPC2103 User's Manual (UM10161)
<http://ics.nxp.com/support/documents/microcontrollers/pdf/user.manual.lpc2101.lpc2102.lpc2103.pdf>
- [3] NXP LPC2103 Errata Sheet
<http://ics.nxp.com/support/documents/microcontrollers/pdf/errata.lpc2103.pdf>
- [4] ARM7TDMI Technical Reference Manual. Document identity: DDI0029G
http://www.arm.com/pdfs/DDI0029G_7TDMI_R3_trm.pdf
- [5] ARM Architecture Reference Manual. Document identity: DDI0100E
Book, Second Edition, edited by David Seal, Addison-Wesley: ISBN 0-201-73719-1
Also available in PDF form on the ARM Technical Publications CD
- [6] ARM System Developer's Guide – Designing and Optimizing System Software, by A.N. Sloss, D Symes, C. Wright. Elsevier: ISBN 1-55860-874-5
- [7] Embedded System Design on a Shoestring, by Lewin Edwards.
Newnes: ISBN 0750676094.
- [8] GNU Manuals
<http://www.gnu.org/manual/>
- [9] GNU ARM tool chain for Cygwin
<http://www.gnuarm.org>
- [10] An Introduction to the GNU Compiler and Linker, by Bill Gatliff
<http://www.billgatliff.com>
- [11] LPC2000 Yahoo Group. A discussion forum dedicated entirely to the NXP LPC2xxx series of microcontrollers.
<http://groups.yahoo.com/group/lpc2000/>
- [12] The Insider's Guide to the NXP ARM7-Based Microcontrollers, by Trevor Martin.
<http://www.hitex.co.uk/arm/lpc2000book/index.html>

Note that there can be newer versions of the documents than the ones linked to here. Always check for the latest information / version.