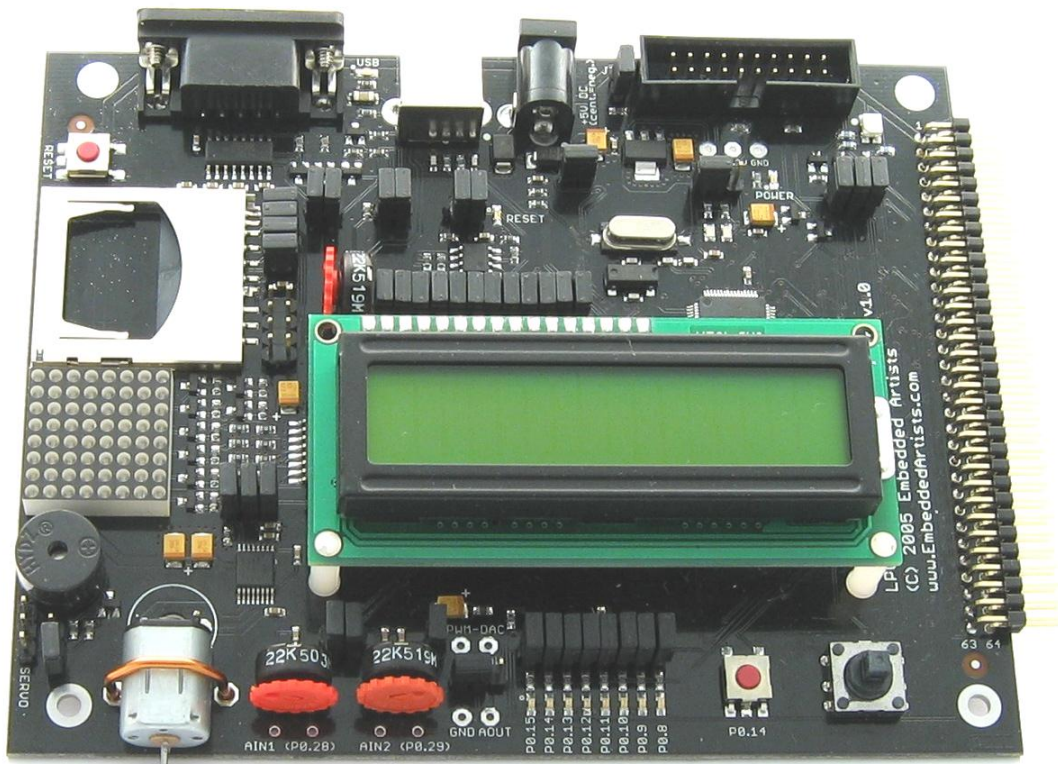


LPC2148 Education Board (version 3) User's Guide



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

Start Developing Your Applications On Day 1!

Embedded Artists AB

Södra Promenaden 51
SE-211 38 Malmö
Sweden

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

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1 Introduction

Thank you for buying Embedded Artists' *LPC2148 Education Board* based on NXP's ARM7TDMI LPC2148 microcontroller.

This document is a User's Guide that describes the *LPC2148 Education Board* hardware design. There is a separate document describing program development for the LPC2xxx series in general with Embedded Artists QuickStart Build Environment.

1.1 Board Version

Note that this manual is only for version 3 of the *LPC2148 Education Board*. There are other manuals for the older versions of the board (v1 and v2).

Note that all pictures of the board in this manual has been taken from the older versions on the board but it's basically only the expansion connector that has changed. On the old boards there was a 64 pin expansion (open) pin list. On the new v3 board this has changed to a 50 pos shouldered pin list for flat cable connection.

1.2 Contents

The box received when ordering the *LPC2148 Education Board* contains the following:

- The *LPC2148 Education Board*.
- A USB cable of type: mini-B-to-A, for powering and communicating with the boards from a PC.
- 50 pos flat cable for expansion connector.

An optional JTAG interface can be used for debugging during program development. The interface is not strictly needed but can be needed for more advanced debugging.

1.3 Features

Embedded Artists *LPC2148 Education Board* with NXP's ARM7TDMI LPC2148 microcontroller lets you get up-and-running quickly. The small form factor board offers many unique features that ease your learning curve and program development.

- NXP ARM7TDMI LPC2148 microcontroller with 512 KByte program Flash and 32+8 KByte SRAM
- 12.0000 MHz crystal for maximum execution speed and standard serial bit rates
 - Phase-locked loop (PLL) multiplies frequency with five; $5 \times 12 \text{ MHz} = 60 \text{ MHz}$
- 32.768kHz RTC crystal
- Onboard Peripherals
 - 2x16 character LCD with background light
 - Joystick switch
 - UART-to-USB bridge interface on UART #0
 - USB 2.0 device interface (on the LPC2148)
 - RGB-LED, each color can be controlled via PWM signal
 - 8 LEDs
 - Temperature sensor (LM75) on I²C bus

- Pushbutton on P0.14 (interrupt input)
- 8x8 LED matrix, controlled via shift registers in the SPI bus
- MMC/SD memory card interface
- Step motor (bipolar driving)
- Interface to Max Stream XBee™ module (note that XBee module is not included)
- Speaker on analog output (P0.25)
- 2 Analog inputs
- Low-pass filtering of PWM signal
- 1 Analog output
- Reset button
- Connectors
 - Mini-B USB connector to UART#0 UART-to-serial bridge)
 - Mini-B USB connector to LPC2148 device interface
 - MMC/SD memory card connector
 - JTAG
 - 50 pin expansion connector, most LPC2148 I/O pins are available on connector
 - 2.1 mm power supply connector
- 2 Kbit I²C E²PROM for storing non-volatile parameters
- Onboard low-dropout voltage and reset generation.
 - Generates +3.3V (and +5V if 9-15VDC is used to power the board)
 - +3.3V available for external circuits, up to 300 mA
- Power supply
 - 9-15 VDC, ≥200 mA from 2.1 mm power connector
 - Can also be powered directly from any of mini-B USB connectors
- 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: 156 x 110 mm
 - Four layer PCB (FR-4 material) for best noise immunity

1.4 Expansion Connector

The 50 pin expansion connector, with most LPC2148 I/O pins available, allows the *LPC2148 Education Board* to be expanded with new and exciting hardware. The following signals are available on the expansion connector:

- P0.0 - P0.23, P0.25, P0.28-P0.31
- P1.16 - P1.25
- Reset

- Vref
- Vbat
- Power; VCC (+3.3V), GND, and Vin (+5V)

There is a board that is sold separately, called the *Experiment Expansion Board*, that can be used for additional interesting and useful experiments. The picture below show the *LPC2148 Education Board* connected to the *Experiment Expansion Board* via the 50 pos flat cable.



Figure 1 - LPC2148 Education Board with Experiment Expansion Board

1.5 ESD Precaution

Please note that the *LPC2148 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 to always first touch the metal surface of one of the USB connectors or MMC/SD connector for a few seconds with both hands before touching any other parts of the boards. That way, you will have the same 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.

1.6 Other Products from Embedded Artists

Embedded Artists have a broad range of LPC2xxx 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.

1.6.1 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 LPC2xxx microcontroller family, 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.

1.6.2 LPC2xxx OEM / Education / QuickStart Boards and Kits

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

2 Board Design

This chapter contains detailed information about the electrical and mechanical design of the *LPC2148 Education Board*, version 3.

2.1 Board Schematics


<p>Page 2 CPU, USB interface, Expansion connector, JTAG interface and USB-UART interface</p> <p>Page 3 8LEDs, RGB-LED, SD/MMC memory card interface joystick, temperature sensor, RF-module interface</p> <p>Page 4 i2C-e2prom with reset generation, 8x8 LED matrix, Step motor and power supply</p> <p>Page 5 Analog inputs/output, 2x16 character LCD and audio output with speaker</p>	<p>Rev 3.0 Replaced expansion connector to 50-pos with shoulder. Added 270 ohm series resistors for exp. conn. Replaced buzzer with audio output with speaker.</p> <p>Rev 2.1 Added +5V voltage regulator (U15, D10, C41-42)</p> <p>Rev 2.0 Changed RS232 UART interface to USB-UART interface Replaced DC-motor with step motor, added RF-module if.</p> <p>Rev 1.1 Added pullups on joystick pins Possible to select SPI0/1 for SD memory card interface</p> <p>Rev 1.0 Original revision</p> <p style="text-align: center;"> (C) Embedded Artists AB</p> <p>TITLE: LPC2148 Education Board v3.0 Document Number: REU: Date: 2009-08-18 19:08:00 Sheet: 1/5</p> <p>UL = UnLoaded = normally not mounted component. Default jumper settings are indicated in the schematic. However, always check jumper positions on actual boards since there is no guarantee that all jumpers are in default place.</p>
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Figure 2 - LPC2148 Education Board Schematic v3.0, page 1

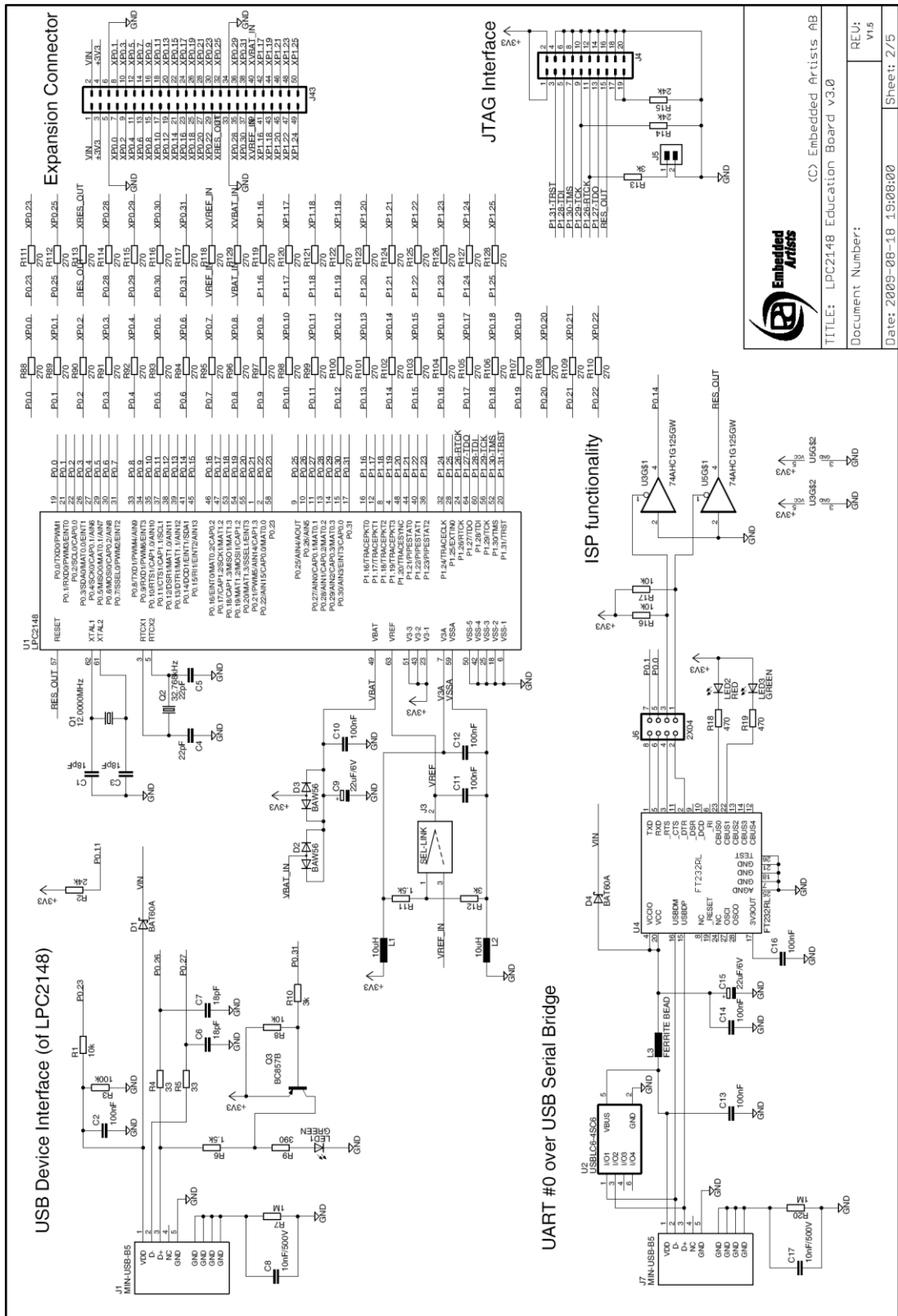


Figure 3 - LPC2148 Education Board Schematic v3.0, page 2

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 TITLE: LPC2148 Education Board v3.0
 Document Number:
 REU: V1.5
 Date: 2009-08-18 19:08:00 Sheet: 2/5

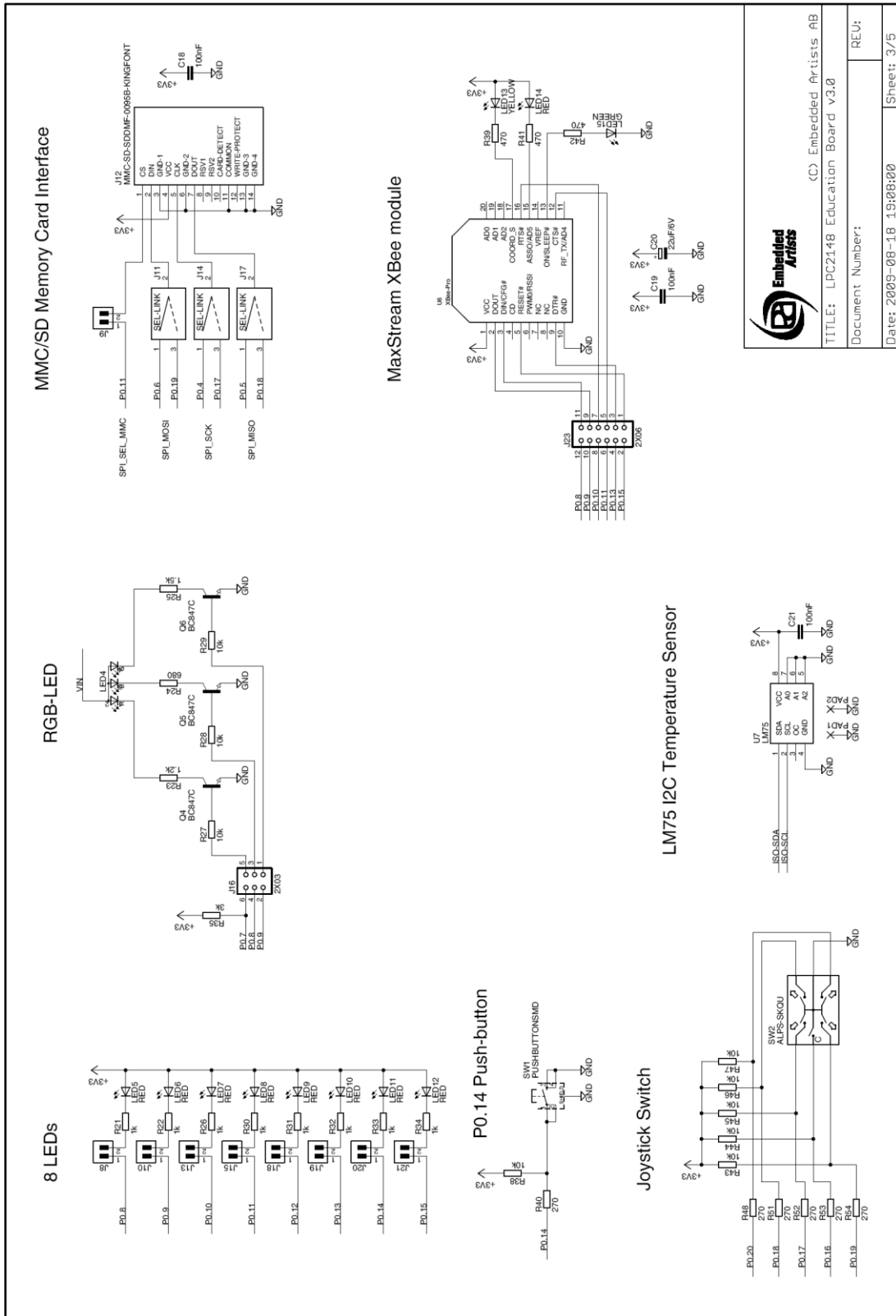


Figure 4 - LPC2148 Education Board Schematic v3.0, page 3

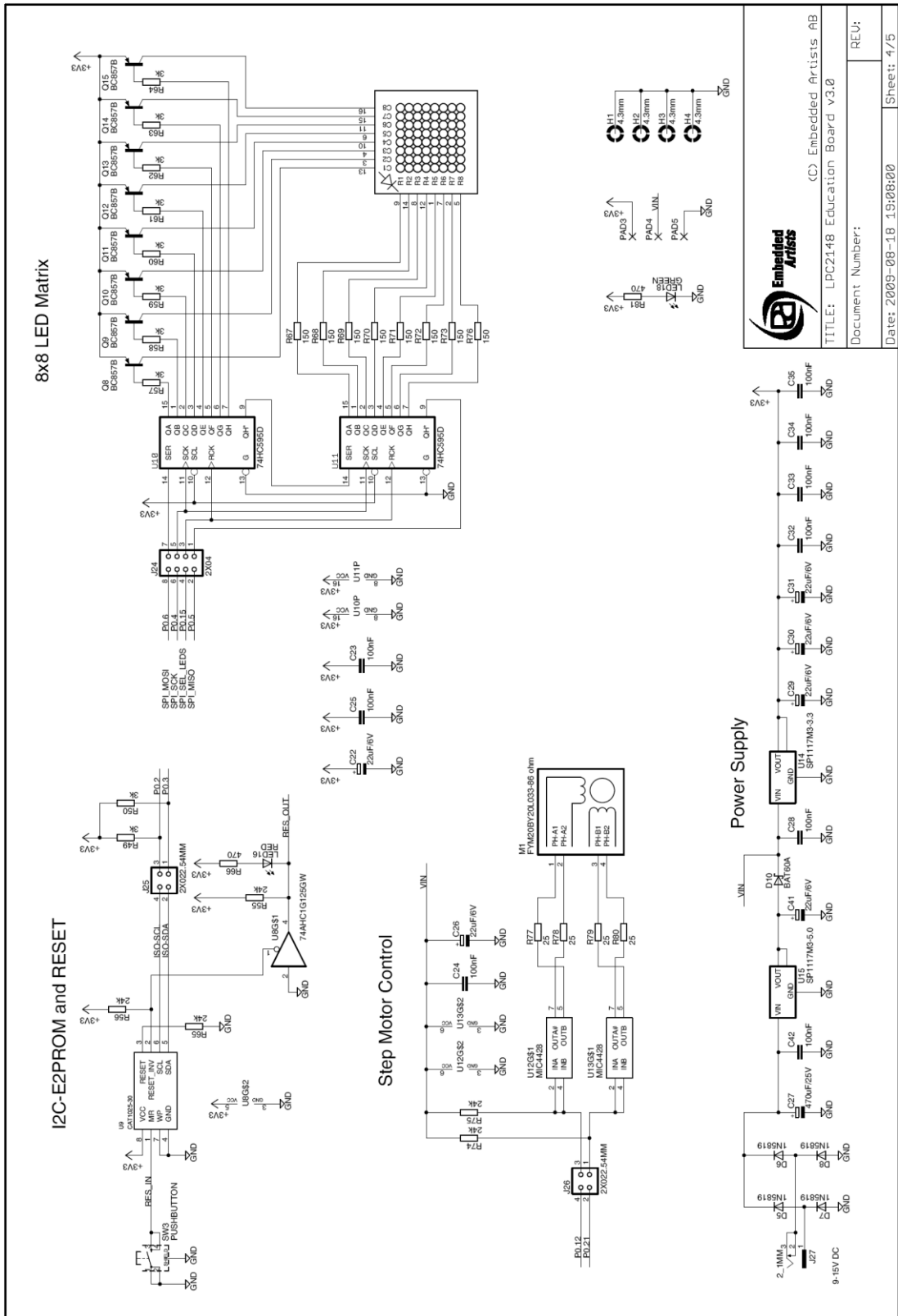
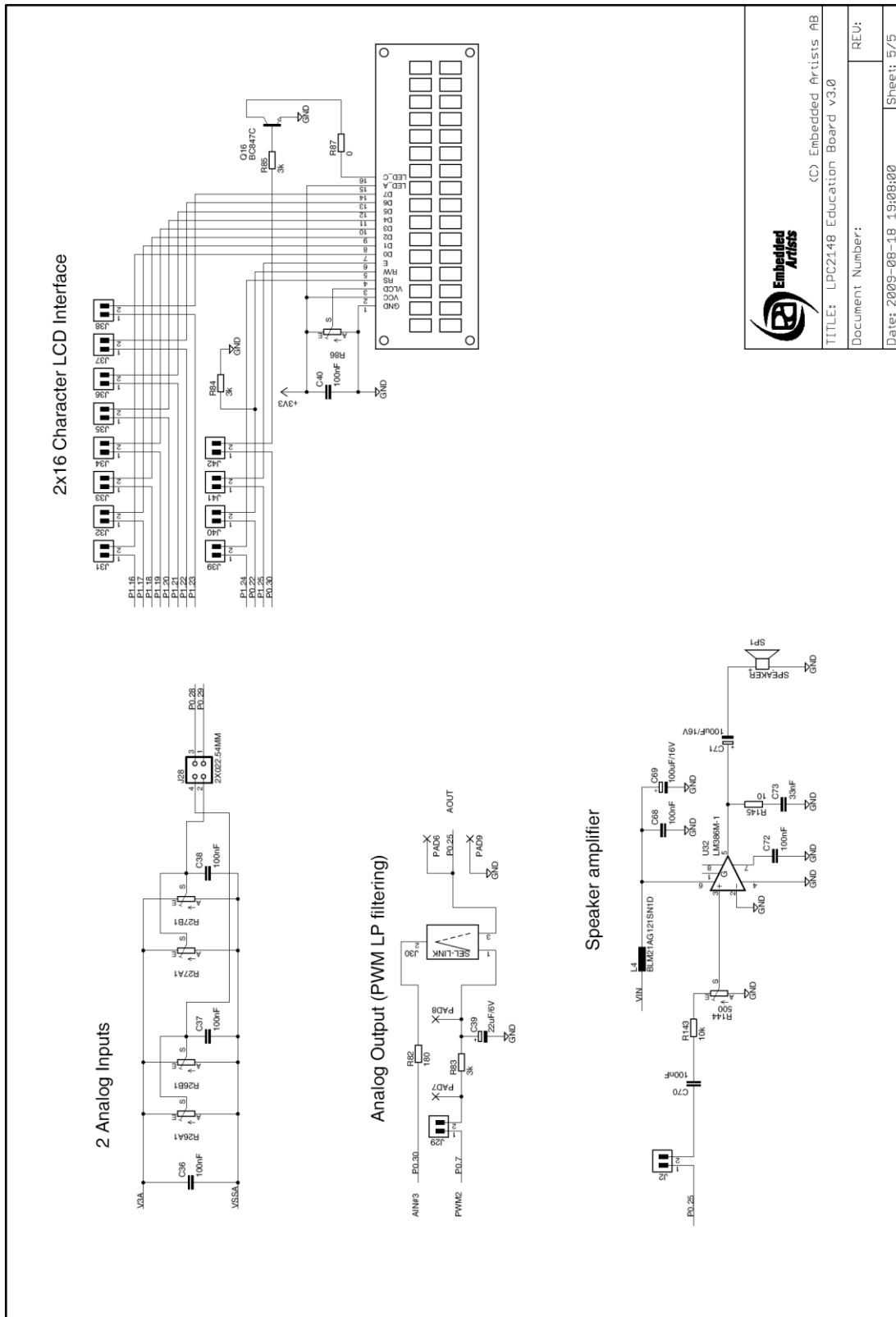


Figure 5 - LPC2148 Education Board Schematic v3.0, page 4

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 Document Number: REU:
 Date: 2009-08-18 19:08:00
 Sheet: 4/5



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TITLE: LPC2148 Education Board v3.0
Document Number: REU:
Date: 2009-08-18 19:08:00 Sheet: 5/5

Figure 6 - LPC2148 Education Board Schematic v3.0, page 5

The following subsections describe in more detail each part of the design. Each schematic page is described in turn.

2.1.1 Page 2: CPU

The core part of the design is the NXP LPC2148 microcontroller. It's an ARM7TDMI-S CPU core with a lot of different peripheral units and on-chip memory (512 kByte FLASH and 32-8 kByte SRAM). There is no external memory bus interface. *Figure 7* below illustrates the CPU section of the design.

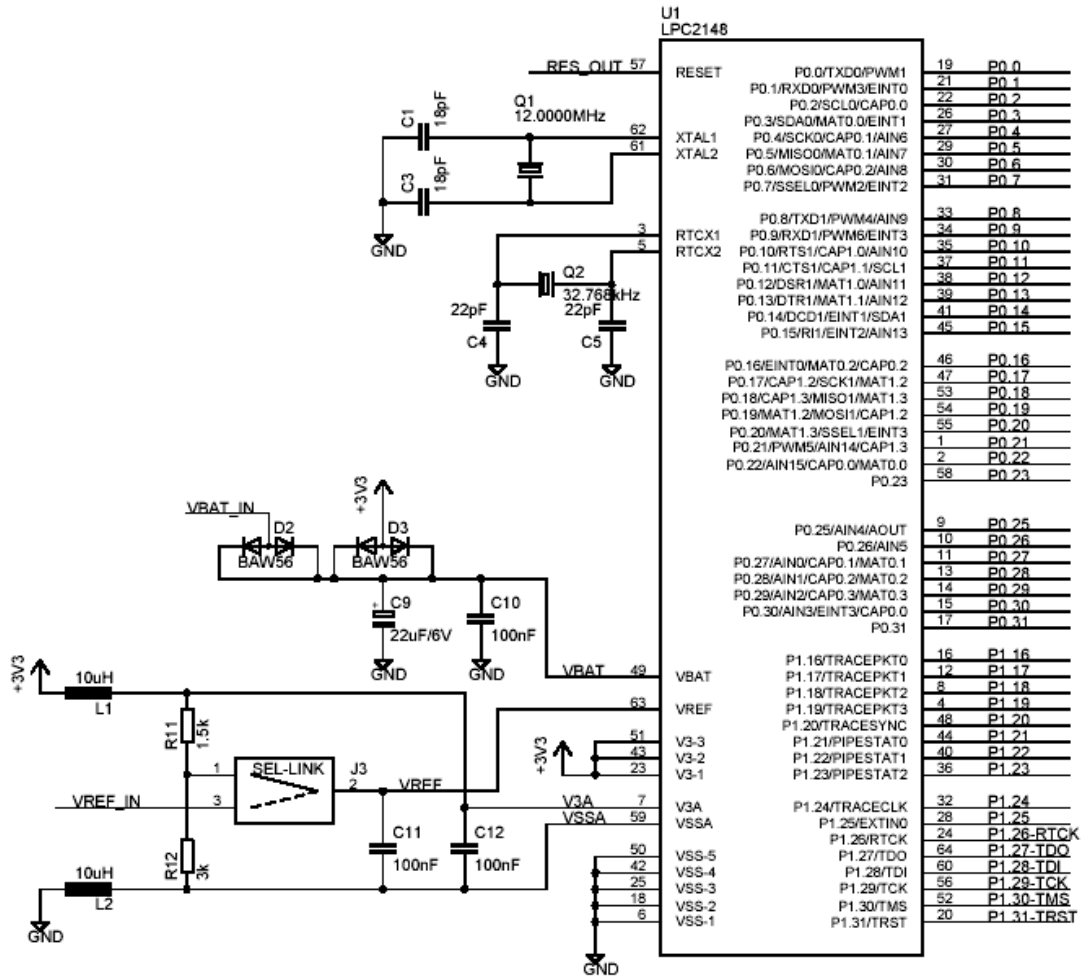


Figure 7 - LPC2148 Education Board Schematic, page 1: CPU

The microcontroller crystal frequency is 12.0000 MHz. This frequency has been selected in order to allow maximum execution speed (5 x 12 MHz = 60 MHz, which is the maximum frequency). The on-chip UART peripheral includes a fractional baud rate generator that allow standard baud rates to be generated from the 60 MHz base clock. The USB clock (48 MHz) is also generated from the 60 MHz clock without any problems.

There is also a 32.768 kHz crystal clock for the on-chip real-time clock peripheral unit or RTC for short. The microcontroller can be placed in a very low power mode while the RTC operates and keeps track of time. Power for the RTC (during these low power modes) comes from the VBAT input pin. Power is sourced either from the +3.3V power supply or the external VBAT_IN signal (available on the expansion connector), depending on which one have highest voltage.

The LPC2148 also contains an Analog-to-Digital Converter or ADC for short, as well as a Digital-to-Analog Converter (DAC). These two peripheral units need a reference voltage, which is supplied from the VREF input pin.

Jumper J3 selects two different sources for VREF. The CPU power supply (+3.3V) is used and divided by 3/2. The power supply is low-pass filtered for noise immunity. The precision of the power supply is 1%. Alternatively an external precision voltage is used, the VREF_IN pin on the expansion connector.

2.1.2 Page 2: UART#0 and ISP

UART#0 on the LPC2148 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 LPC2148 and only channel #1 has all control signals needed for a full modem implementation. Channel #0 only has receive and transmit signals. Channel #1 is free and used by some of the expansion boards.

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.

Even though the CPU clock crystal is 12.000 MHz, any standard baud rate can be generated since both UART channels have a fractional baud rate generator. 'Fractional' means that the clock frequency does not have to be divided by an even integer value. It can also be divided by a fractional value, which means that a lot more baud rates can be achieved from basically any clock crystal frequency. There is even an *autobauding* capability, meaning that basically any baud rate can be detected. Read more about this functionality in the LPC2148 datasheet.

The interface can be disconnected by removing the jumpers on J6, in case an external UART interface is to be designed (for example on a prototype board).

Finally 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. If the processor samples P0.14 low after reset the bootloader is entered, else the application code is executed. The automatic ISP functionality can be disabled by removing the two bottom jumpers on J6. 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 more. In these cases, the jumpers must be removed or a serial cable with only receive and transmit signals must be used.

Figure 8 below illustrates the USB-to-serial interface and ISP part of the design.

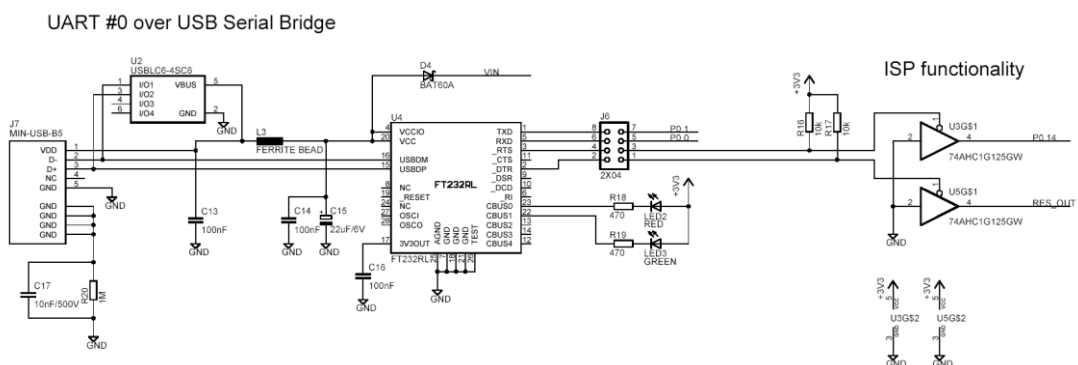


Figure 8 - LPC2148 Education Board Schematic, page 2: USB-to-serial and ISP

2.1.3 Page 2: USB

The LPC2148 also contains a USB 2.0 device interface as one of its peripheral units. Figure 9 below illustrate the USB part of the design. Low-pass filtering is added for noise immunity. The USB interface supports the Soft Connect functionality and voltage sense (see

LPC2148 User's Manual for more information about these functions). The Soft Connect feature is controlled by IO-pin P0.31 and is activated by placing a 1.5 kohm resistor between the D+ signal and +3.3V. A green LED also is on when the resistor is present. The voltage sense feature is handled by IO-pin P0.23, which is connected to VCC of the USB interface.

USB Device Interface (of LPC2148)

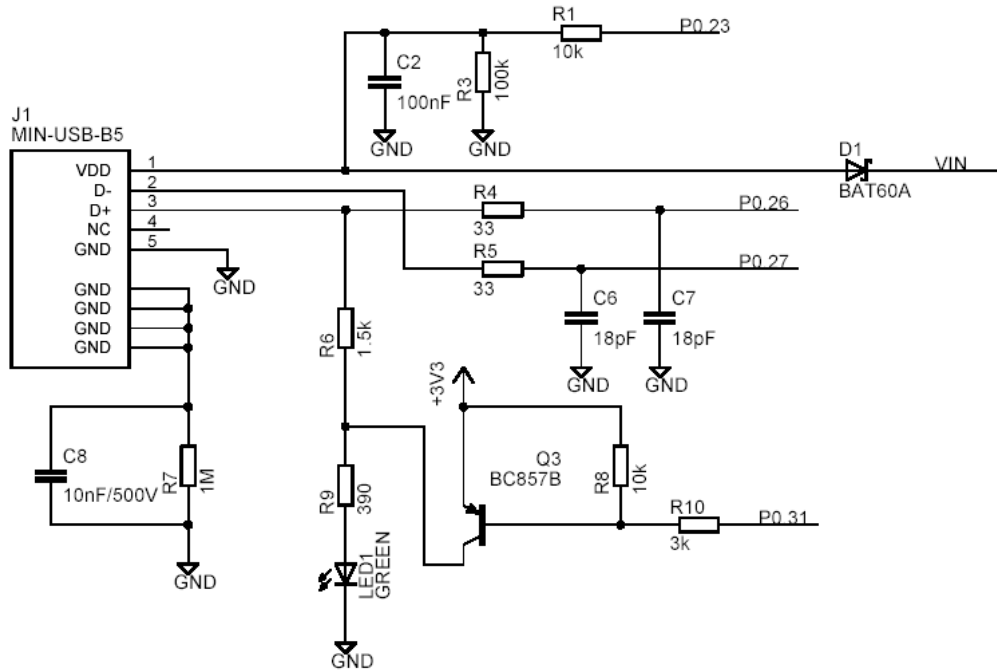


Figure 9 - LPC2148 Education Board Schematic, page 2: USB

2.1.4 Page 2: JTAG

The JTAG interface is a standard 20-pin (2x10) connector with shoulders – ‘standard’, at least in the ARM world. The JTAG interface shares 6 general IO-pins (GPIOs) and is enabled by shorting jumper J5, i.e., pulling P1.26 low during reset. When the JTAG interface is enabled, the 6 IO-pins cannot be used for other purposes than the JTAG interface. *Figure 10* below illustrates the JTAG part of the schematics.

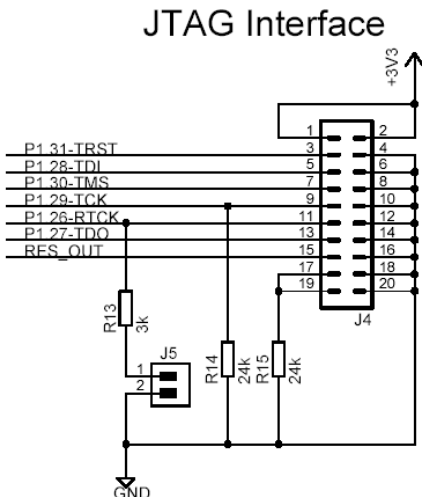


Figure 10 - LPC2148 Education Board Schematic, page 2: JTAG

To use the JTAG interface of the *LPC2148 Education Board* a special JTAG interface pod must be used. This pod must be integrated with a debugger in order to do anything useful with it. There exist many different manufacturers of JTAG interface pods.

2.1.5 Page 2: Expansion Connector

The *LPC2148 Education Board* is not just a monolithic design. Via the expansion connector, it's possible to expand the design. Most LPC2148 pins are available on the expansion connector, which is a standard 50 pcs (2x25) shouldered pin list with 100 mil pin spacing. All cpu signals available on the expansion connector are protected with 270 ohm series resistors. It's not a foolproof protection but will at least reduce the risk for shortcut and ESD damages on the board. *Figure 11* below illustrates the expansion connector part of the design.

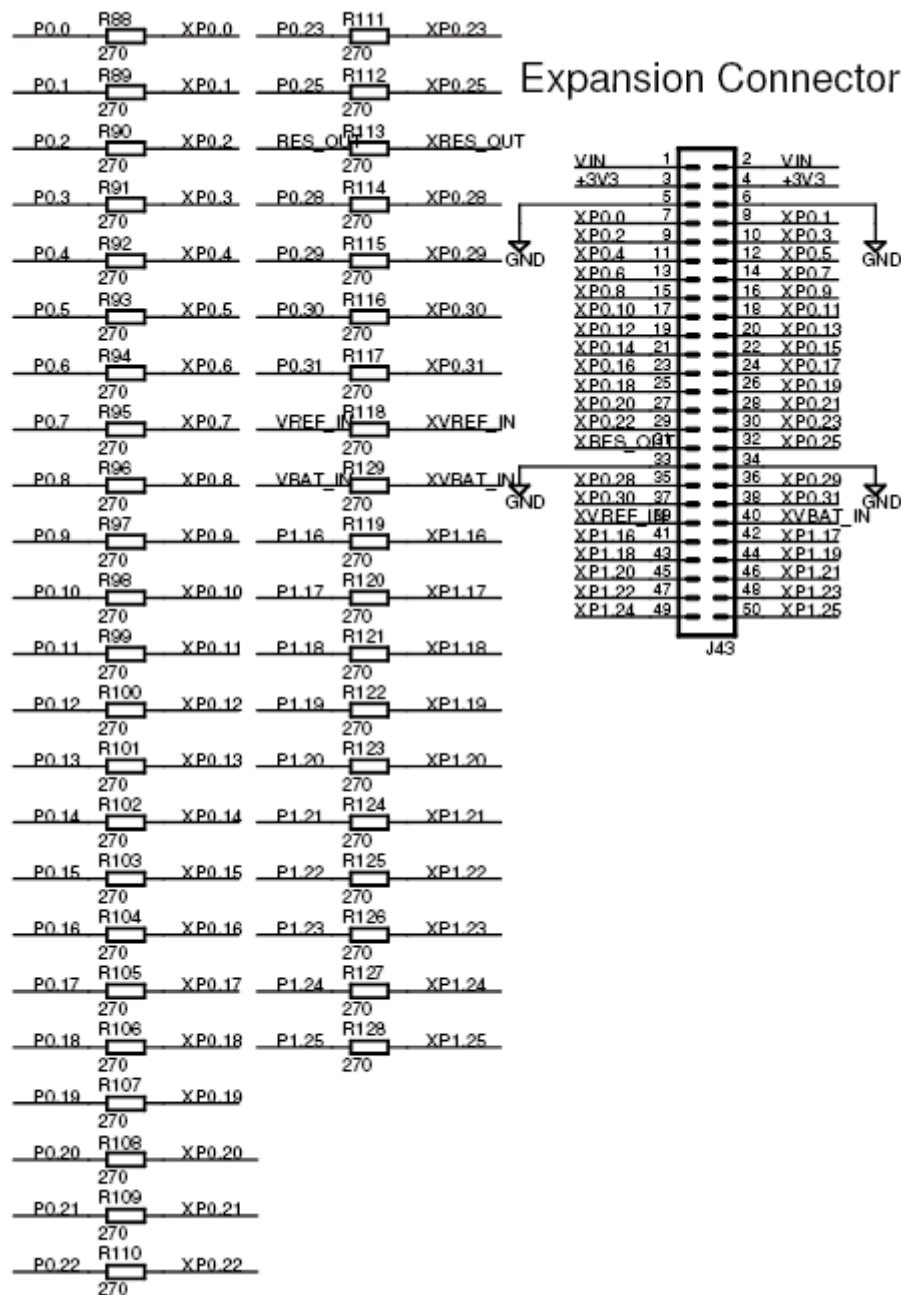


Figure 11 - LPC2148 Education Board Schematic, page 2: Expansion Connector

The power voltages, +5V (VIN) and +3.3V, are available on the expansion connector. Note that the current consumption of external circuitry on the expansion boards must be low. The on-board +3.3V voltage regulator can only supply up to 300 mA to external circuits. Note also that an external power supply (+9-15 VDC) must be able to deliver all needed current. In the case that the USB port is used to power the board, the total current consumption must be less than 500 mA. Else the USB host in the other end will shut down current delivery completely.

2.1.6 Page 3: LEDs

The port pins of the LPC2148 microcontrollers have a 4 mA driving capacity, enough to directly drive LEDs. *Figure 12* below illustrates the 8 LEDs in the design. The LEDs are connected to pin P0.8 – P0.15 and are red. The 1kohm resistors limit the current to about 2 mA. A low output pin drives current through the LEDs and they will light. Each LED can be individually enabled or disabled via jumpers: J8 (P0.8), J10 (P0.9), J13 (P0.10), J15 (P0.11), J18 (P0.12), J19 (P0.13), J20 (P0.14), J21 (P0.15).

8 LEDs

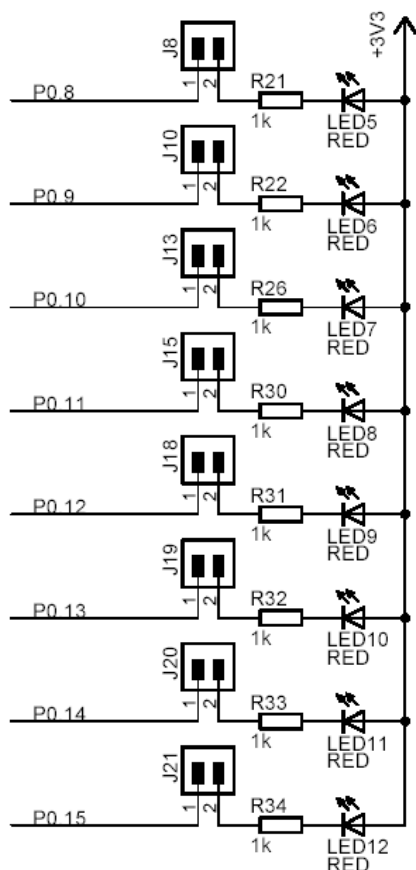


Figure 12 - LPC2148 Education Board Schematic, page 3: LEDs

2.1.7 Page 3: Push-button

The signal P0.14 can be configured as an interrupt input pin on the processor. A push-button is connected to this signal so it's possible to pull the signal low. There is a pull-up resistor (10 kohm) on the signal, which is also needed for the ISP feature. The signal P0.14 must be sampled high after reset in order to start normal program execution; else the internal bootloader will be activated. *Figure 13* below illustrates the push-button part of the design.

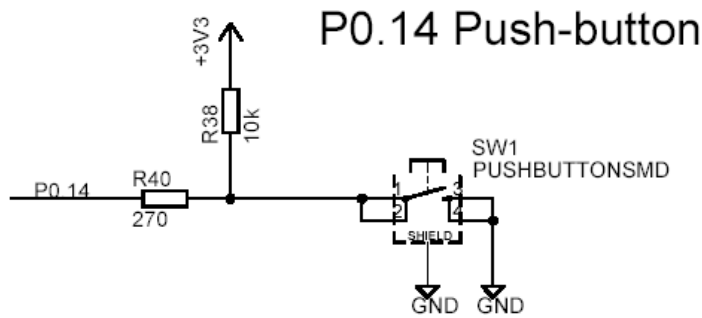


Figure 13 - LPC2148 Education Board Schematic, page 3: Push-button

2.1.8 Page 3: Joystick-switch

There is a joystick-switch on the board and *Figure 14* below illustrates this part of the design. The switch has five internal switches, one for the four directions and one center, push-down switch. All of the input pins (P0.16 – P0.20) can be programmed as interrupt inputs, either directly as an EINTx-pin or via a CAPture-pin, which in turn can generate an interrupt.

Joystick Switch

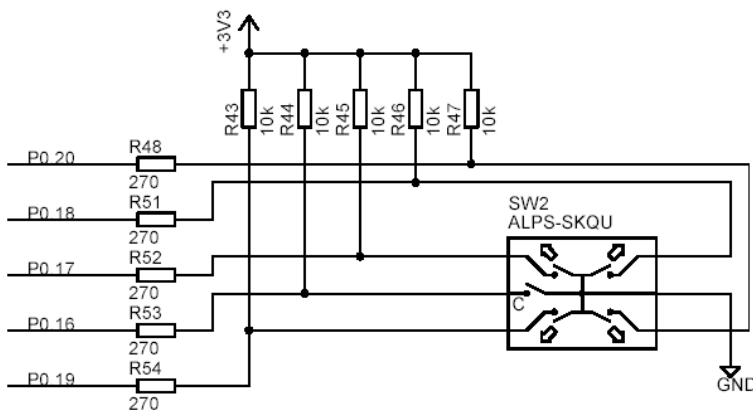


Figure 14 - LPC2148 Education Board Schematic, page 3: Joystick-switch

2.1.9 Page 3: RGB-LED

There is a full color RGB-LED that can be controlled by PWM (Pulse Width Modulated) 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 P0.7 – PWM2
- Blue LED, controlled by signal P0.8 – PWM4
- Green LED, controlled by signal P0.9 – PWM6

The PWM signals are available as alternative signals on the pins and are generated from the PWM peripheral unit. *Figure 15* below illustrates the RGB-LED part of the design.

Note that the LEDs are driven from the +5V power supply. This is because the forward voltage drop of the blue LED is typically around 3.5V, which is more than the 3.3V power supply for the LPC2148.

The RGB-LED can be disconnected by removing the three jumpers on J16. Also note that the signals P0.8 – P0.10 are used for other parts of the design also, for example for controlling the buzzer, the motor control, analog output, as well as for the individual LEDs (see *Figure 12*).

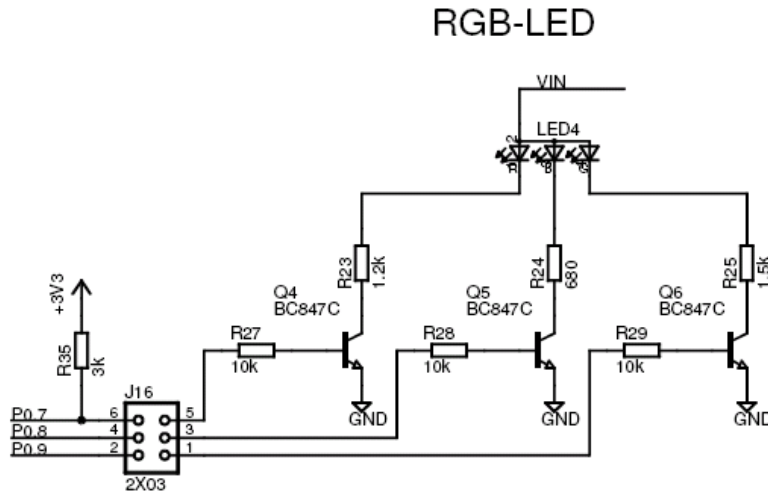


Figure 15 - LPC2148 Education Board Schematic, page 3: RGB-LED

Note that signal P0.7 is shared with several other parts of the design, and requires a pull-up for some functionality.

2.1.10 Page 3: Temperature Sensor

Figure 16 below illustrates the temperature sensor part of the design. The interface is very simple; a LM75 temperature sensor is connected to the I²C interface. Note that the jumpers on J25 (see reset and I2C-E2PROM part) must be mounted to connect the I2C interface with the LPC2148.

The address of the LM75 is 0x90. Consult the LM75 datasheet for details about how to read the temperature.

LM75 I2C Temperature Sensor

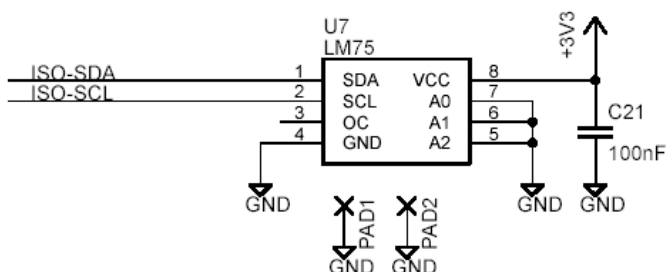


Figure 16 - LPC2148 Education Board Schematic, page 3: Temperature Sensor

2.1.11 Page 3: MMC/SD Interface

The SPI bus of the LPC2148 can be used to interface a MMC/SD memory card, when operating in the simpler MMC mode. Pin/signal P0.11 is used as device select. NXP has published an application note describing how to implement the low-level interface (reading

and writing sectors on the memory card). See *AN10406: Accessing SD/MMC card using SPI on LPC2000* for details. *Figure 17* below illustrates the MMC/SD interface part of the design.

The interface can be disconnected from the LPC2148 by removing jumpers J9, J11, J14, and J17. Also note that bottom jumper on J24 (SPI_MISO to P0.5 the SPI interface for the 8x8 LED matrix) should not be installed since this output is not a three-state output and will hence collide with the MISO signal (DOUT on the MMC/SD interface). There is also no typical need to have this jumper installed so this is normally not a problem.

It's possible to change if SPI channel #0 or #1 is connected to the MMC/SD memory card interface, by changing jumpers J11, J14 and J17. The default is SPI channel #0.

MMC/SD Memory Card Interface

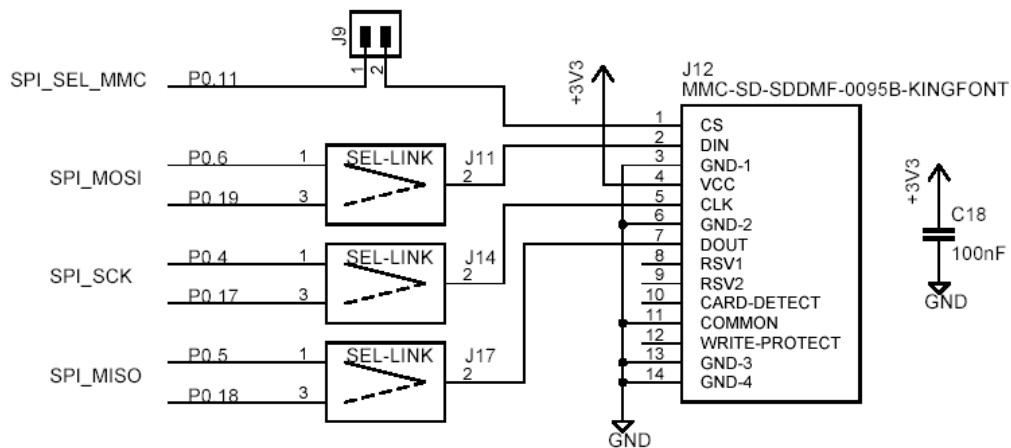


Figure 17 - LPC2148 Education Board Schematic, page 3: MMC/SD Interface

Note that the switches for 'card detect' and 'write protect' are not connected at all in this design.

2.1.12 Page 3: MaxStream XBee Interface

There is a connector for MaxStream's XBee modules. Both XBee and XBee Pro modules can be used. Note that the XBee module is not included and must be purchased separately. The module is connected to UART channel #1. Up to four control signals can be used to control the interface (can be selected with jumpers on J23). Three LEDs indicate status of the module.

MaxStream XBee module

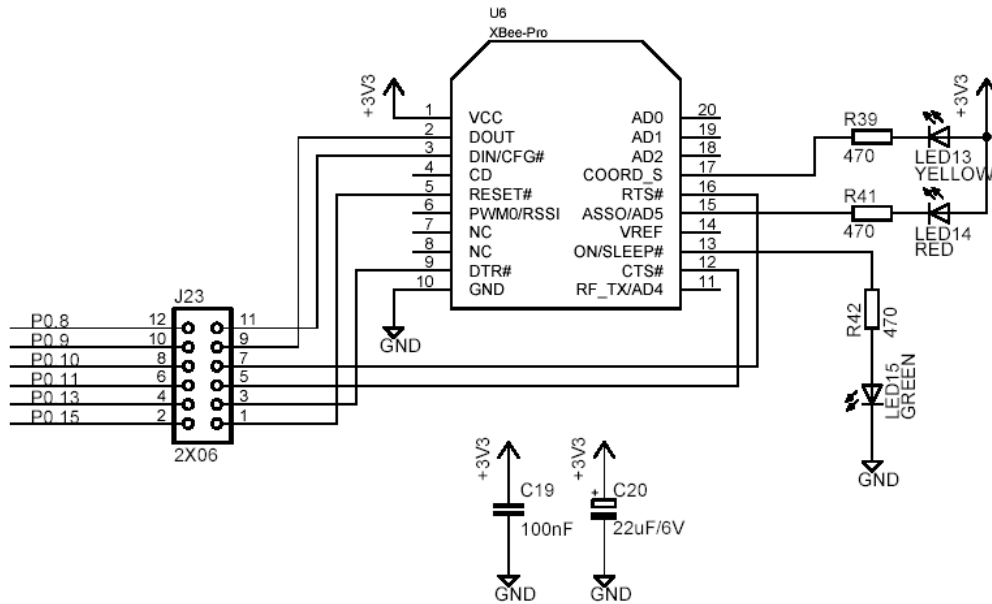


Figure 18 - LPC2148 Education Board Schematic, page 3: XBee interface

2.1.13 Page 4: 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 19* below illustrates this part of the design. There is also a reset push-button (SW1) and both the signals RES_IN and RES_OUT are available on the expansion connector. Note that an external driver of these signals should be an open-collector / open-drain driver. There is also a red LED that lights when the reset signal is active.

I2C-E2PROM and RESET

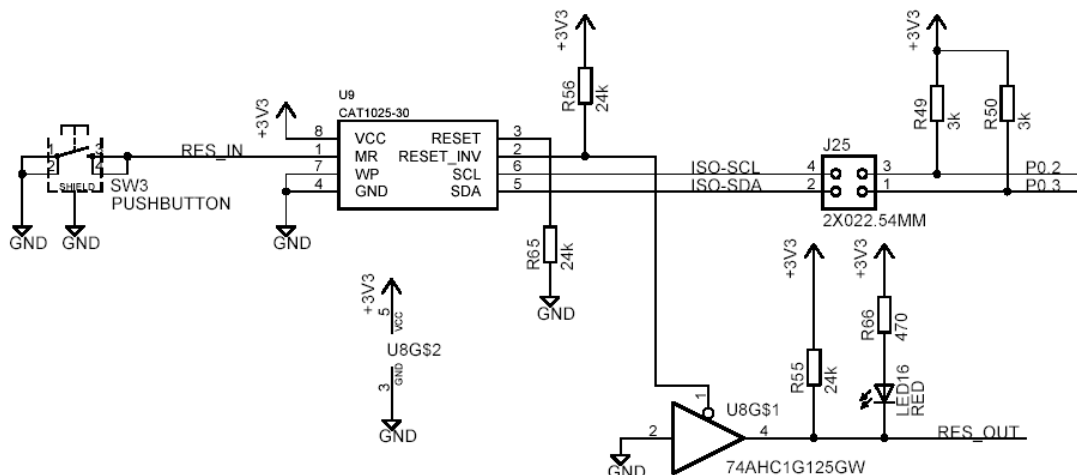


Figure 19 - LPC2148 Education Board Schematic, page 4: Reset Generation and I2C E2PROM

The CAT1025 chip also contains a 2kbit E²PROM accessible via the I²C interface. The LPC2148 microcontroller has two on-chip I²C communication channels. Channel #0 is used for communicating with the E²PROM. The other channel can optionally be used on an expansion board. More peripheral units are easily connected to the two-wire I²C bus, just as long as the addresses do not collide. The address of the 2kbit E²PROM is 0xA0. The I²C interface to the CAT1025 can be disconnected from the LPC2148 by removing jumpers on J25.

Note that the pull-up resistors (which are always needed on I²C busses) are included on the board. These pull-up resistors are 3000 ohm each. If using the second I²C channel do not forget to connect pull-up resistors to these signals also. Note that this must be done even if the I²C functionality is not used/enabled. Pins P0.11 and P0.14 are open-drain I/Os and must have pull-up resistors when configured as outputs. This is unfortunately easy to forget, but they are included on the *LPC2148 Education Board*.

2.1.14 Page 4: 8x8 LED Matrix with SPI Interface

The 8x8 LED matrix is the most advanced circuit on the board, at least when it comes to controlling it. *Figure 20* below illustrate the 8x8 LED matrix part of the design. Two shift registers (serial-input, parallel-output), 74HC595, are used to control the eight columns and rows respectively. 16 bits must be shifted (= 2 bytes) in order to update the two shift registers. The first byte sent controls the rows and the second byte the columns. A zero bit in the first byte will light LEDs for the corresponding row and a zero bit in the second byte will light LEDs for the corresponding column. In order to display arbitrary patterns on the display a time-multiplexing mechanism must be implemented where each column (or row) is updated one at a time in a circular pattern. The update frequency must be higher than 100 Hz in order not to see flickering on the LEDs.

The LPC2148 microcontroller has two on-chip SPI serial communication channels. The shift registers are accessed via the SPI bus, channel #0, and signal P0.15 is used as device select pin. SPI mode 0 can be used to shift data into the shift registers. SPI channel #0 is also shared with the MMC/SD interface.

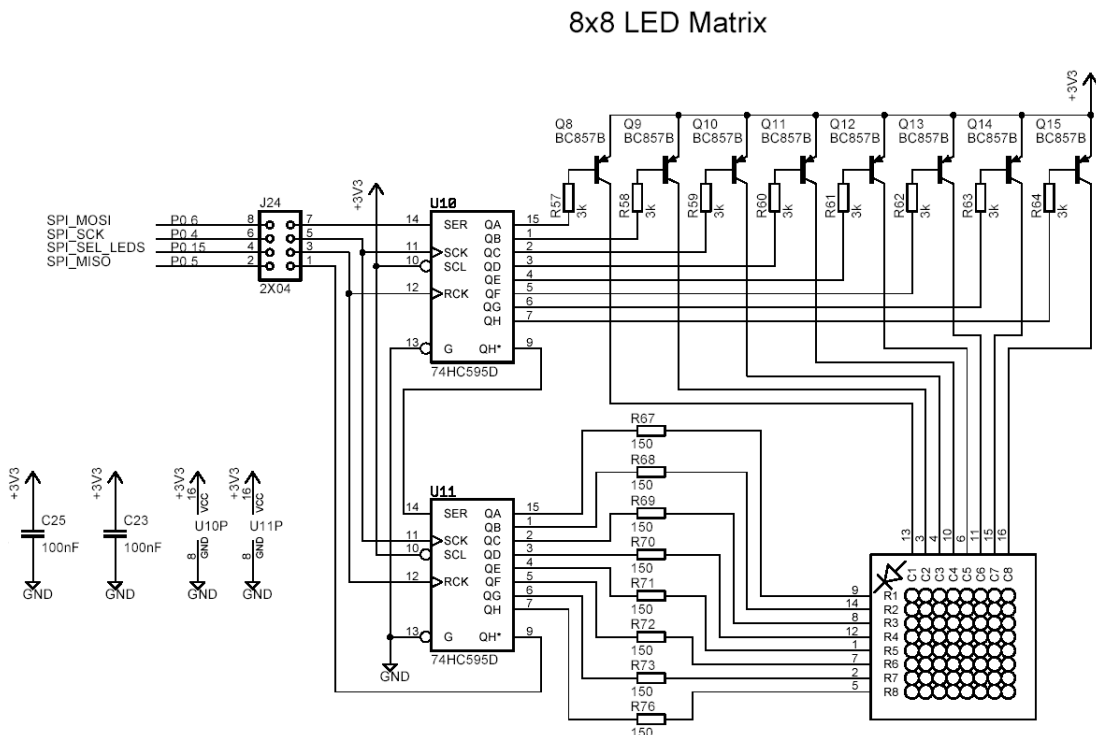


Figure 20 - LPC2148 Education Board Schematic, page 4: 8x8 LED Matrix with SPI Interface

The 8x8 LED matrix circuit can be disconnected from SPI channel #0 by removing the jumpers on J24. Normally, the bottom jumper on J24 (SPI_MISO on P0.5) should not be inserted since the output from U11 is not three-states when the shift registers are not enabled by device select signal P0.15. If inserted, the output from U11 will collide with the data output (DOUT) from the MMC/SD interface. The only reason to have this jumper inserted would be to read back the last two bytes shifted into the shift registers (and there is no typical reason to do this).

2.1.15 Page 4: Step Motor Control

The board includes a small bipolar step motor with a propeller mounted so movements can easily be observed. Signals P0.12 and P0.21 are used to control the movement of the step motor. Bipolar control of a step motor means that the current must flow in one (of two possible) directions through the windings. Two output buffers (4428-type drivers) make sure the motor windings are driven correctly. To rotate the axis one of the following two output patterns must be used.

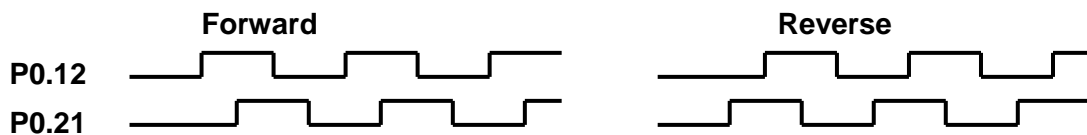


Figure 21 below illustrates the step motor control part of the design.

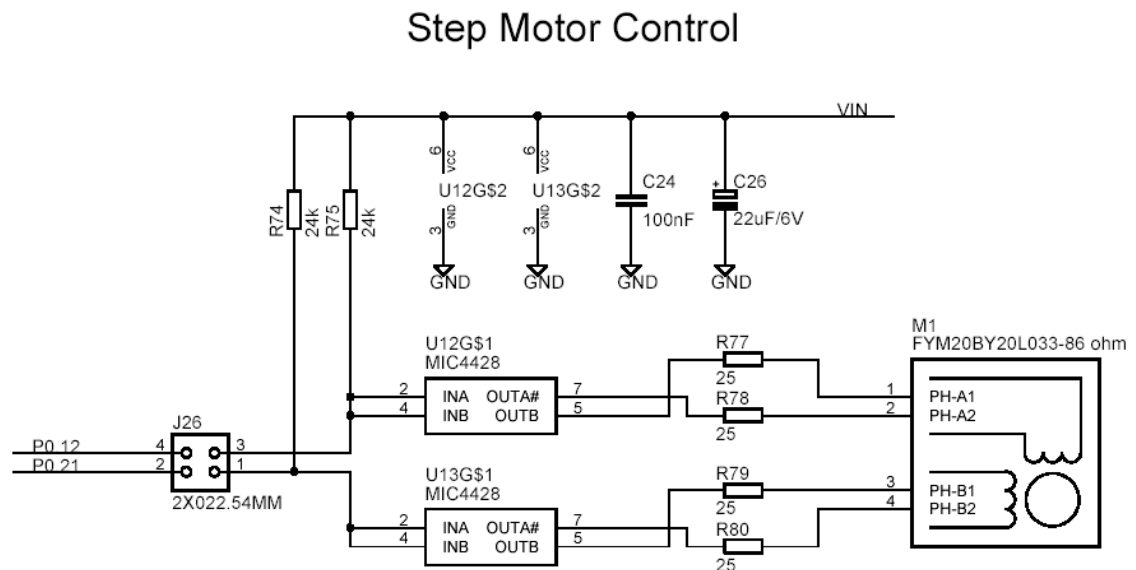


Figure 21 - LPC2148 Education Board Schematic, page 4: Step Motor Control

2.1.16 Page 4: Power Supply

The power supply uses conventional low-dropout voltage regulators, the Sipex SP1117. The LPC2148 need only a single +3.3V voltage and has an internal 1.8V regulator for powering the core. Some other processors in the LPC2xxx series require both a +3.3V and a +1.8V voltage. For a full specification of the SP1117 voltage regulator see the datasheet from Sipex.

Figure 22 below illustrates the voltage regulator part of the design. As seen, power can come from either an external power adapter via a standard 2.1 mm power connector or from the two USB connectors (see schematic page #1 for details). Diode D10 and the diodes on the USB interfaces feeds the VIN power signal. The diodes are needed in order for any power

supply input to feed the power and for blocking the USB interfaces from being reverse-fed. Normally, power is taken from the USB connector, but in some cases the 2.1 mm connector can be used, for example when the power need for expansion boards is high and the USB cannot supply the needed current ($\geq 500\text{mA}$).

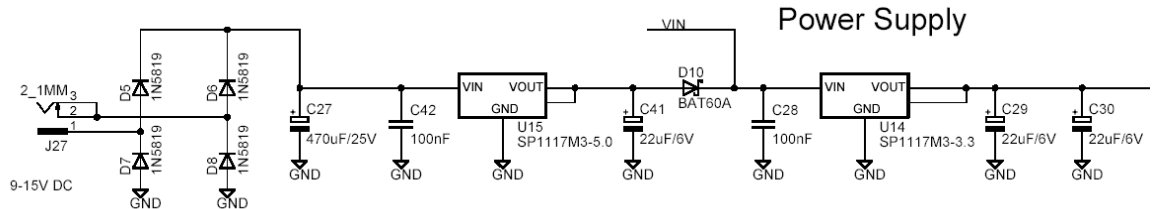


Figure 22 - LPC2148 Education Board Schematic, page 4: Power Supply

There are three pads to ease measurements of the incoming (+5V) voltage and the generated (+3.3V) voltage, see PAD3 – PAD5. A green LED indicates the presence of +3.3V voltage.

2.1.17 Page 5: Analog Inputs

The LPC2148 has 14 analog inputs connected to two different 10-bit ADC (Analog-to-Digital Converter). The conversion time is as short as 2.44 μs and the input pins VREF and VSSA are used as conversion reference. *Figure 24* below illustrates the analog input part of the design. As seen, two trim-potentiometers are used to generate a variable voltage to analog input #1 (P0.28) and #2 (P0.29). Note that the analog inputs are counted from analog input #0, but this input is not used in this design.

The signals P0.28 and P0.29 can be used as general purpose pins if the analog inputs are not used and in this case the analog voltages can easily be removed by removing the two jumpers on J28.

2 Analog Inputs

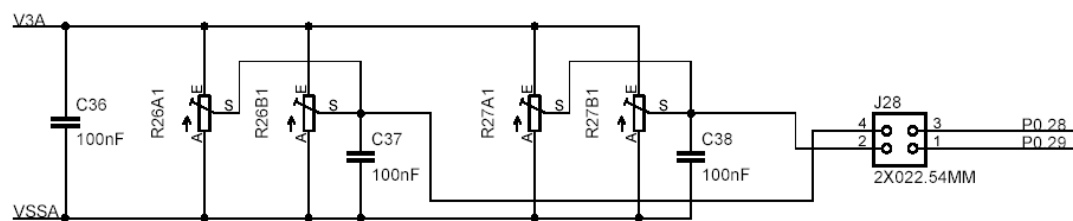


Figure 23 - LPC2148 Education Board Schematic, page 5: Analog Inputs

2.1.18 Page 5: Analog Outputs

The LPC2148 has one analog output, available as an alternative function on pin P0.25. *Figure 24* below illustrate the analog output part of the design. Via jumper J29 it is possible to connect the analog input to analog input #3 (P0.30). There are also special pads to make it easier to measure the analog voltage (PAD6 and PAD9).

It's also possible to generate an analog output voltage by filtering a PWM signal. Also in this case, the alternative PWM2 signal on P0.7 is used and low-pass filtered. It's possible to measure the result with analog input #3. An oscilloscope can with advantage be used to measure the PWM signal before and after the low-pass filtering. The cut-off frequency is $1 / (2\pi RC) = \text{about } 2 \text{ Hz}$, which means that any PWM signal with a reasonable high frequency will be adequately low-pass filtered. It's also possible to measure if the remaining ripple is what can be expected from a simple 1-pole low-pass filter like this.

Analog Output (PWM LP filtering)

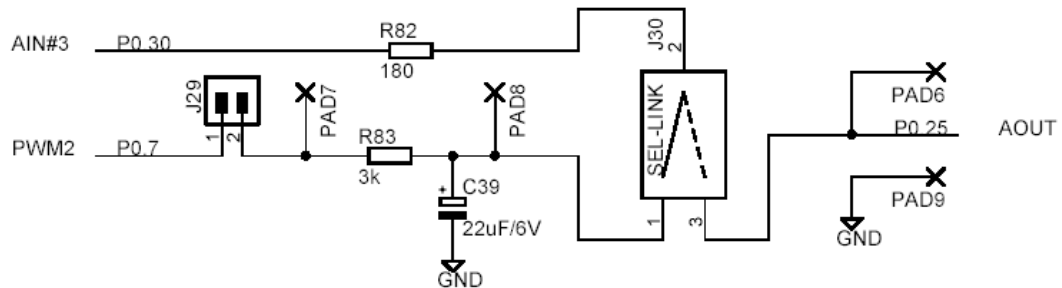


Figure 24 - LPC2148 Education Board Schematic, page 5: Analog Outputs

2.1.19 Page 5: Speaker

The analog output of the LPC2148, available as an alternative function on pin P0.25, can also be connected to a speaker (with associated amplifier) via jumper connector J2. Volume can be adjusted via a trim potentiometer. The amplifier is powered from +5V (VIN).

Speaker amplifier

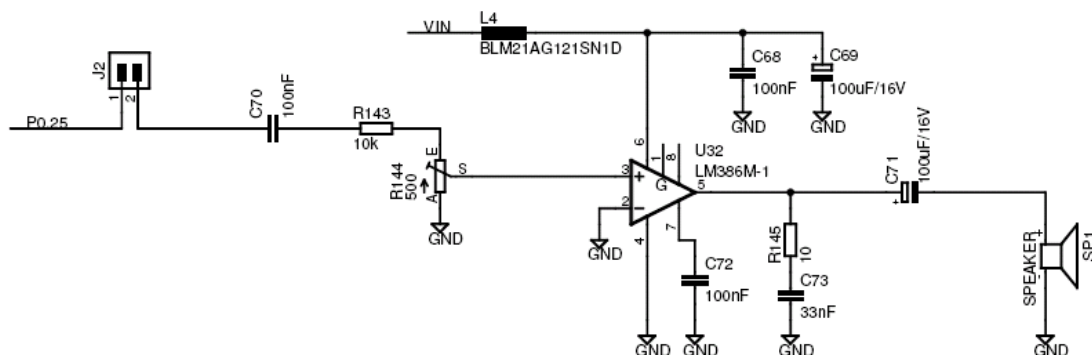


Figure 25 - LPC2148 Education Board Schematic, page 5: Speaker

2.1.20 Page 5: 2x16 Character LCD

The final part of the LPC2148 Education Board is the 2x16 character LCD. The interface to the LCD is a simulated memory bus. 11 pins are needed to create an 8-bit interface; 8 data bits (D0-D7), 1 address bit (RS), 1 read/write bit (R/W), and one control signal (E). It's also possible to control the backlight via signal P0.30. The LCD controller is a standard KS0070B or equivalent, which is a very well-known interface for smaller character based LCDs.

Figure 26 below illustrate the LCD part of the design and which pins are used for the interface. All pins can be disconnected from the interface if needed, via jumpers J31 – J42. The LCD is powered from the +3.3V power supply. The display contrast adjustment (via R86) is not mounted since the currently used LCD does not need adjusted.

2x16 Character LCD Interface

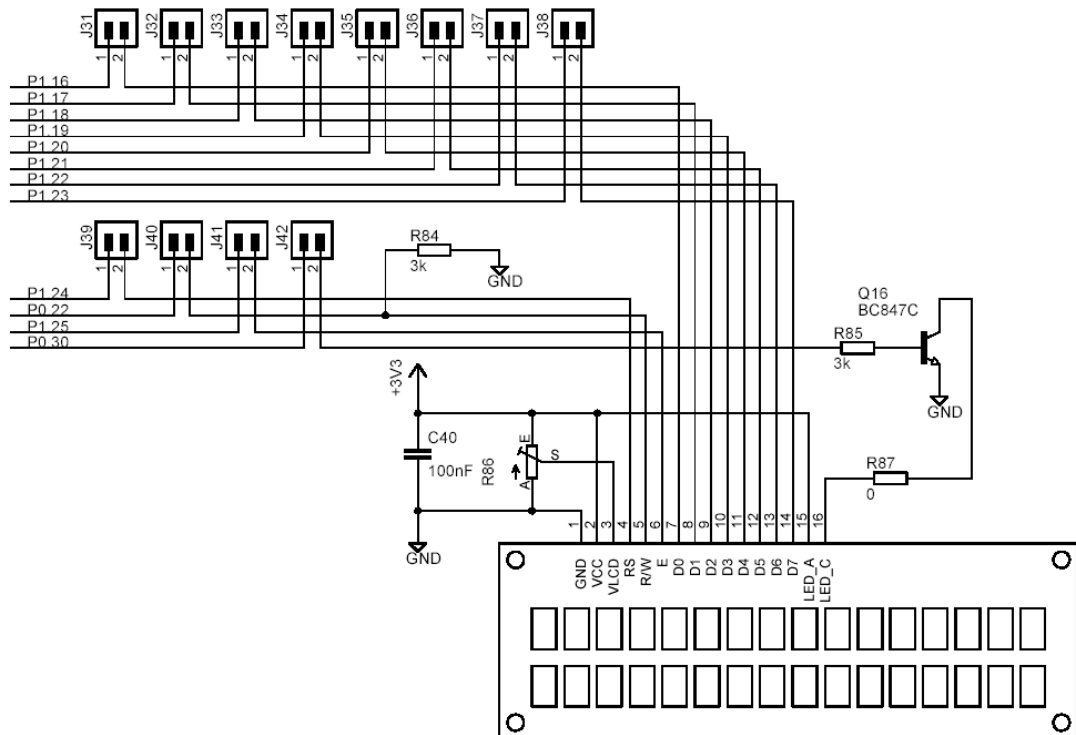


Figure 26 - LPC2148 Education Board Schematic, page 5: 2x16 Character LCD

There are two options to reduce the number of pins used for the interface.

- Do not use the R/W pin and save one pin (P0.22). Normally, there is only a need to write to the display controller. In this case, the R/W signal can be tied low permanently (R84) and jumper J40 is removed.
- Use the 4-bit interface instead of the 8-bit interface. The LCD controller can operate from a 4-bit interface. In this case, data bus pins D4 – D7 are just used. In this case 4 pins will be free (P1.16 – P1.19) for other use. If combined with the option above, five pins will be freed.

2.2 Jumpers

The LPC2148 Education Board is full of jumpers in order to be able to connect/disconnect all different parts of the external circuits. *Figure 27* below illustrates all jumpers and explains to what part of the design they belong. The picture below also illustrates the default positions for all jumpers.

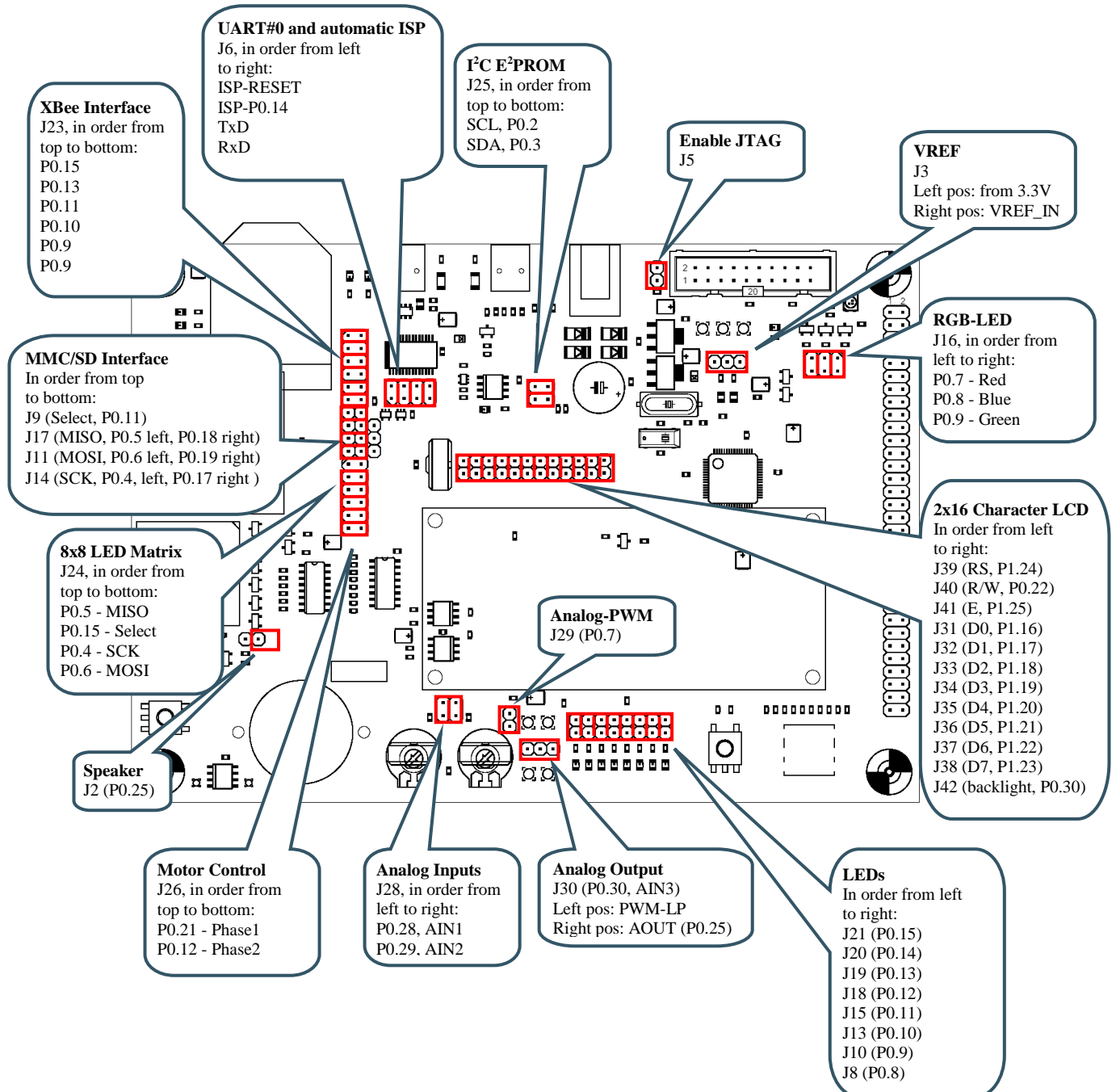


Figure 27 - LPC2148 Education Board Jumpers

2.2.1 Illegal Jumper Combinations

Note that some jumpers are mutual exclusive and should not be inserted simultaneously.

- MISO signal (P0.5) on SPI channel #0. Do not have bottom jumper on J24 inserted simultaneously as the MMC/SD interface is used. See explanation in *section 2.1.11*
- Many of the signals for the individual LEDs (P0.8 – P0.15) are also used for other parts of the design. It does not damage the electronics if the LEDs are connected, and in some cases it might even be useful to have LED indicators for some signals.

2.3 Connectors

Figure 28 below illustrate the position of all external connectors on the *LPC2148 Education Board*.

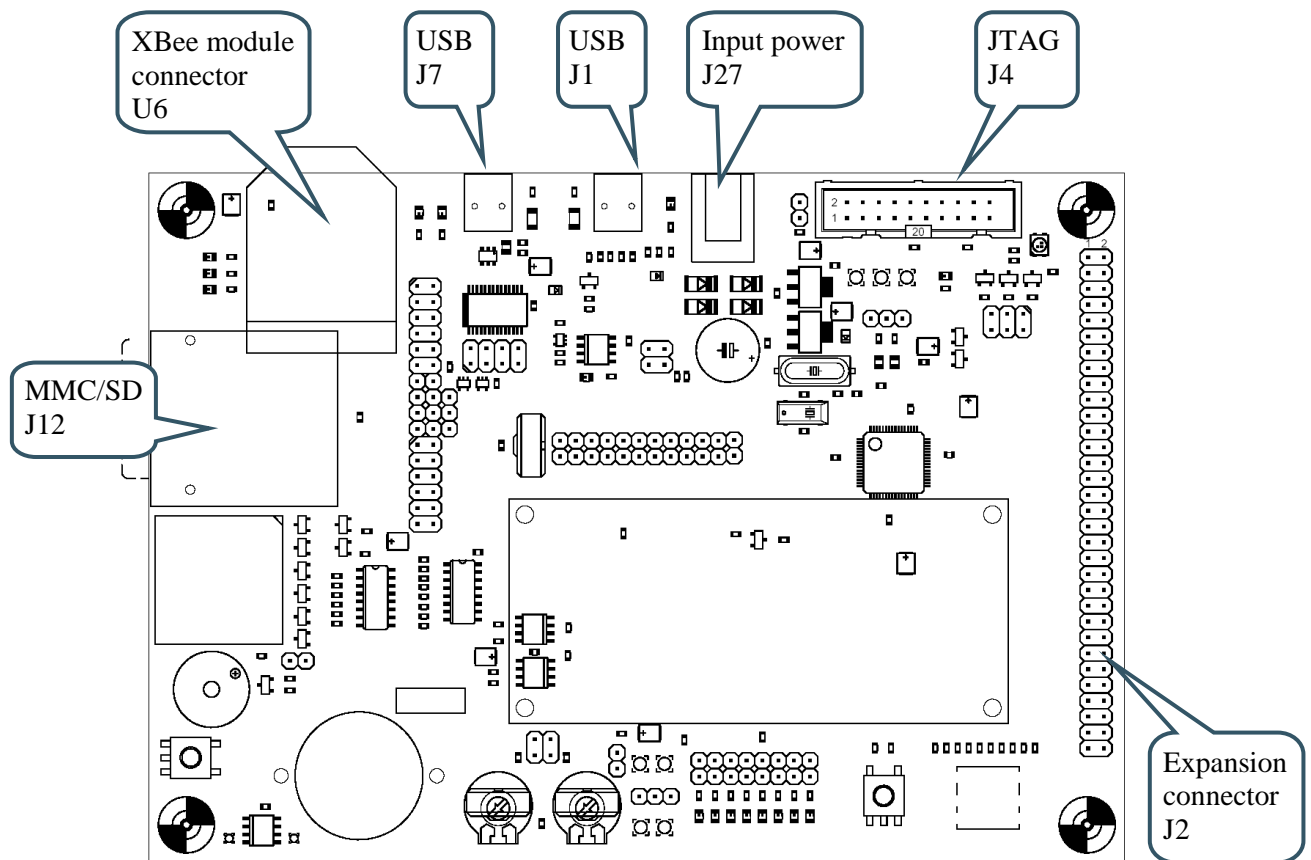


Figure 28 - LPC2148 Education Board External Connectors

2.4 Important Components

Figure 29 below illustrates the position on the board for some important components in the design.

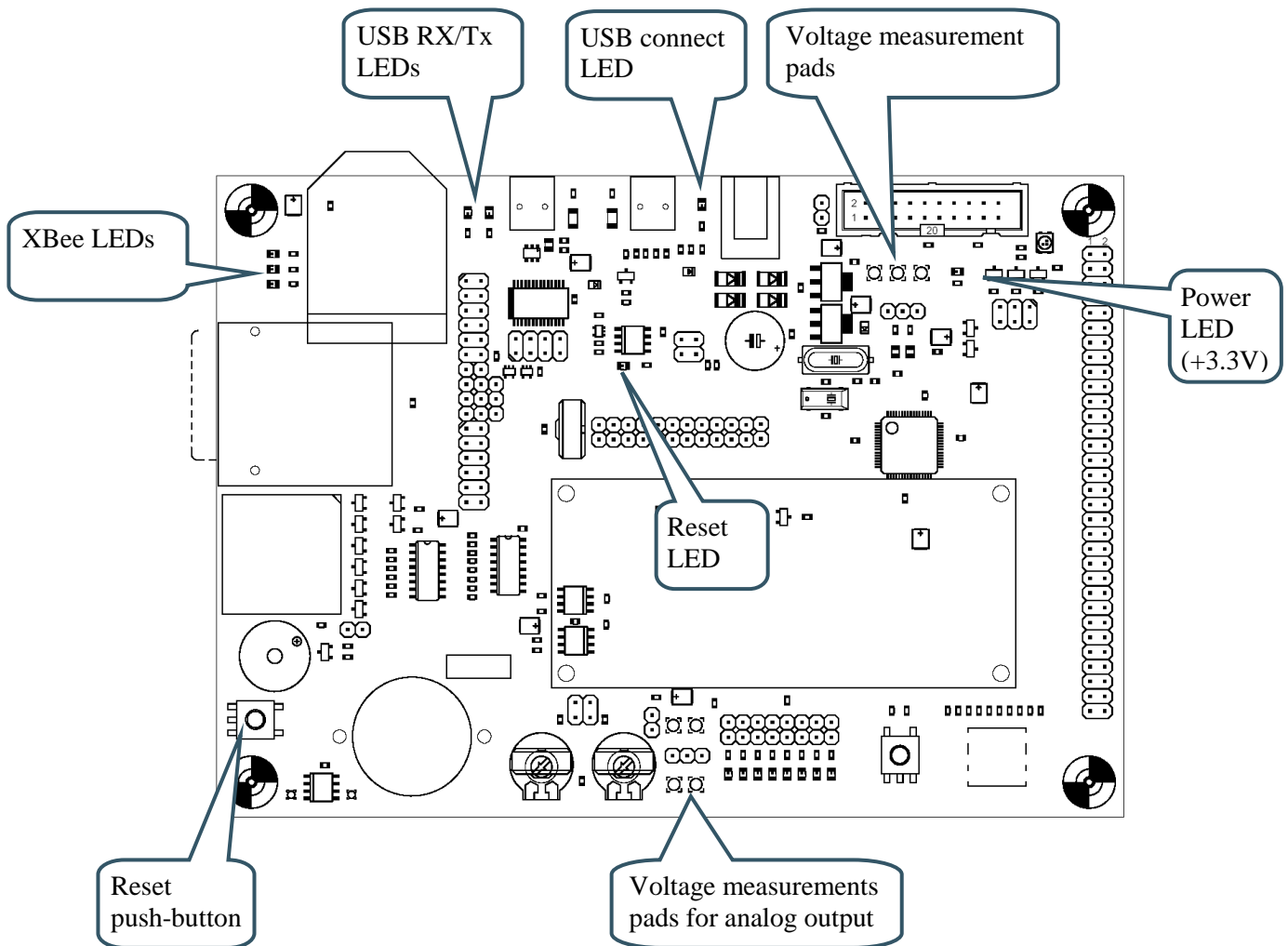


Figure 29 - LPC2148 Education Board Important Components

2.5 Mechanical Dimensions

Figure 30 below contains a drawing of the board that includes mechanical measures. As seen, the board is 156 x 110 mm large with mounting holes 144 x 98 mm apart.

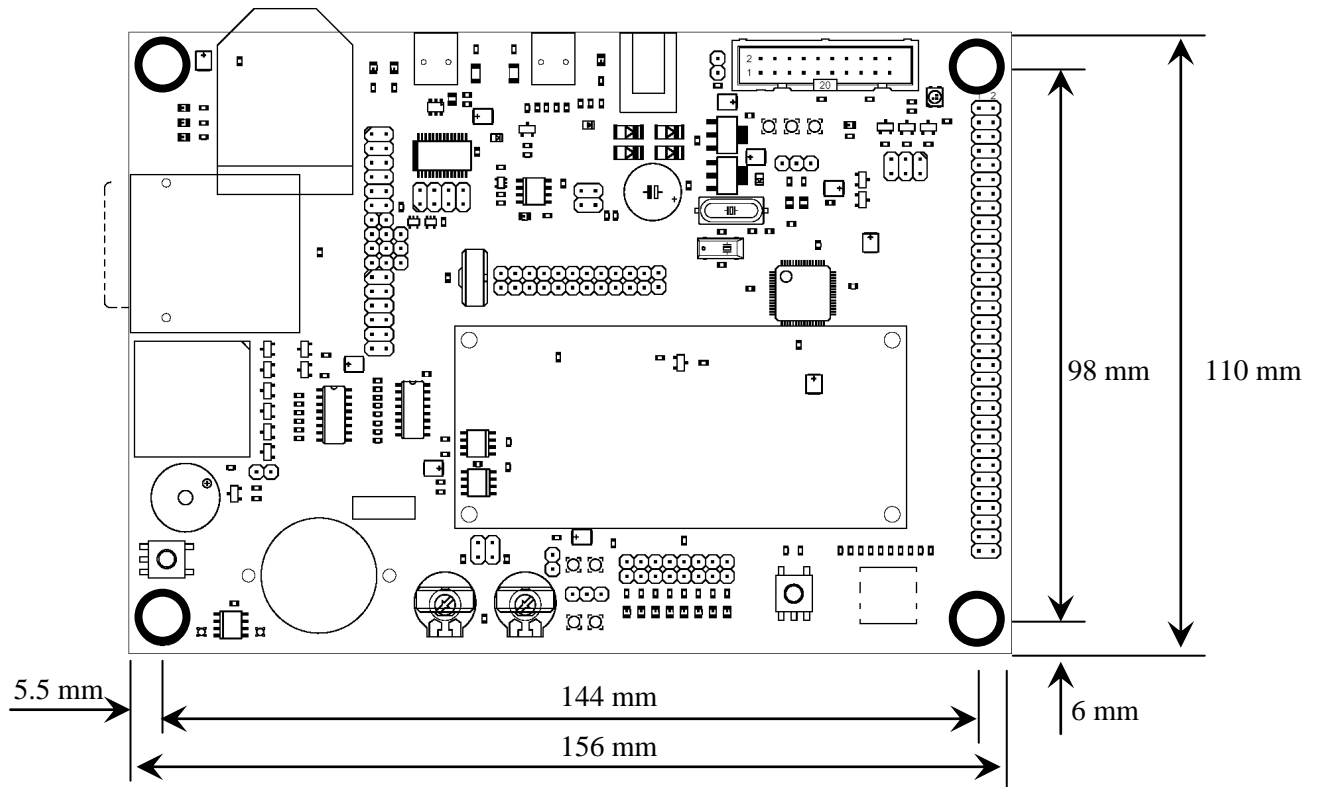


Figure 30 - LPC2148 Education Board Mechanical Dimensions

3 Getting Started

3.1 Test program

The *LPC2148 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 all jumpers according to default positions
- Push the reset button
- Hear the startup sound from the speaker (adjust volume control just beside the speaker if a sound is not heard).
- Watch the running-one on the individual LEDs.
- Also watch the printed information on the terminal (see explanation below)
- After that a test loop is entered:
 - Printed message on the LCD and flashing of backlight
 - Scrolled message on 8x8 LED matrix
 - PC-mouse emulation over USB and joystick-switch
 - Dimming of RGB-LEDs
 - Running the step motor forward and backward

A terminal program should be attached to the USB-to-serial mini-B USB connector. The test program will output test information regarding the I²C and E²PROM test, MMC/SD test, as well as the RTC crystal test. Also, the UART/USB channel can be tested by typing characters in the terminal program. The settings for the terminal program are: 38.4 kbps, 8 data bits, no parity bits, and one stop bit (i.e., 8N1).

3.2 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.

3.3 Program Download via ISP

UART#0 can be used to download program code into the internal FLASH of the LPC2148. The ISP (In-System Programming) feature of the LPC2148 is then used. ISP is enabled after reset by pulling pin P0.14 low. In order to enable automated ISP invocation, the *LPC2148 Education Board* allows control of both the reset signal and 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 release a download program (no longer supported) and there is also the open source LPC21ISP program. FlashMagic from ES Academy is however the recommended ISP download program to use. The program can be downloaded from:
<http://www.flashmagictool.com/>

Figure 31 below illustrates the jumper settings when enabling the automatic ISP functionality.

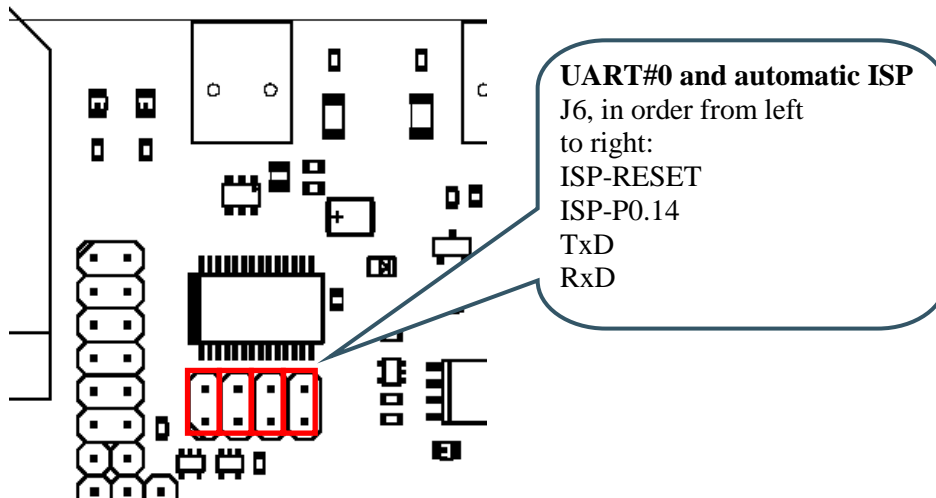


Figure 31 – ISP Jumpers, enable automatic ISP

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 32* below illustrates the jumper settings then disabling the automatic ISP.

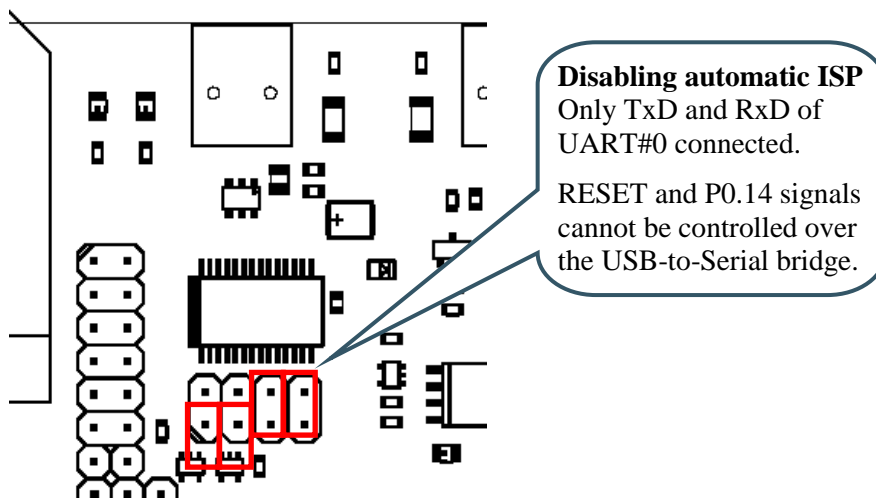


Figure 32 – ISP Jumpers, disable automatic ISP

Note that the USB-to-Serial bridge chip must have its driver installed on the PC FlashMagic and the terminal program is running from. *Section 3.4* below describes the installation procedure.

3.4 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 the following URL: <http://www.ftdichip.com/Drivers/VCP.htm> (search for a FT232R driver for your operating system).

When the *LPC2148 Education Board* is connected to the PC (via an 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 set. 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 the figure below.

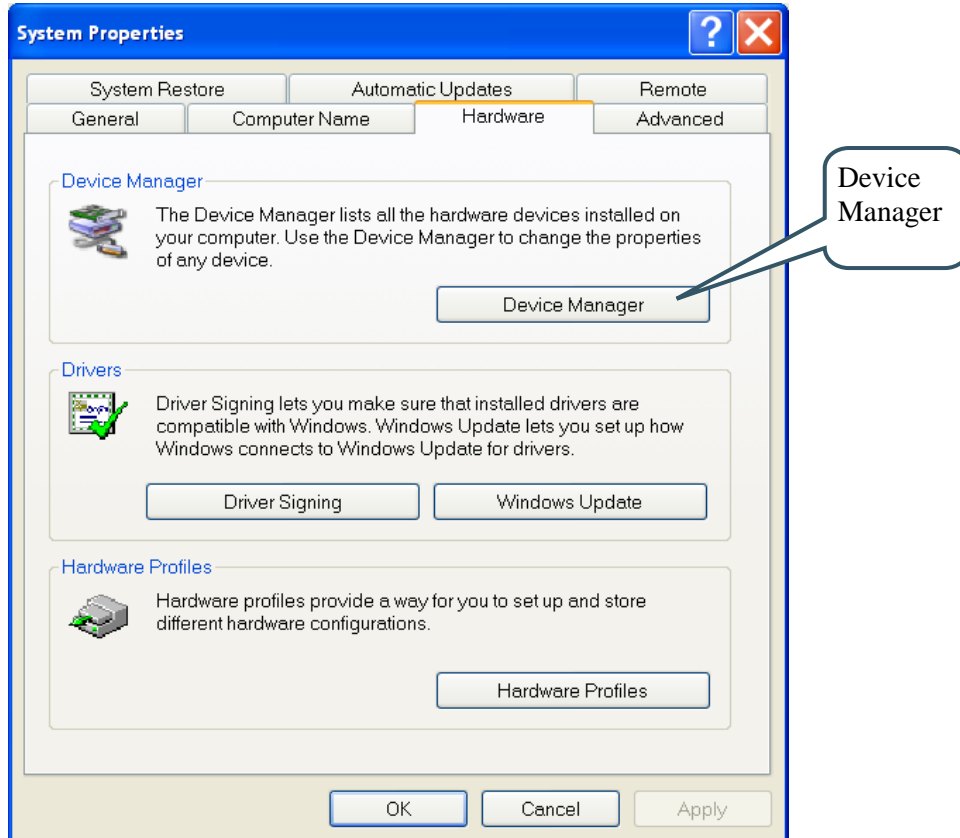


Figure 33 – System Settings Dialog

Then select the *Device Manager* and then open the *Ports* list, as illustrated in *Figure 34* below.

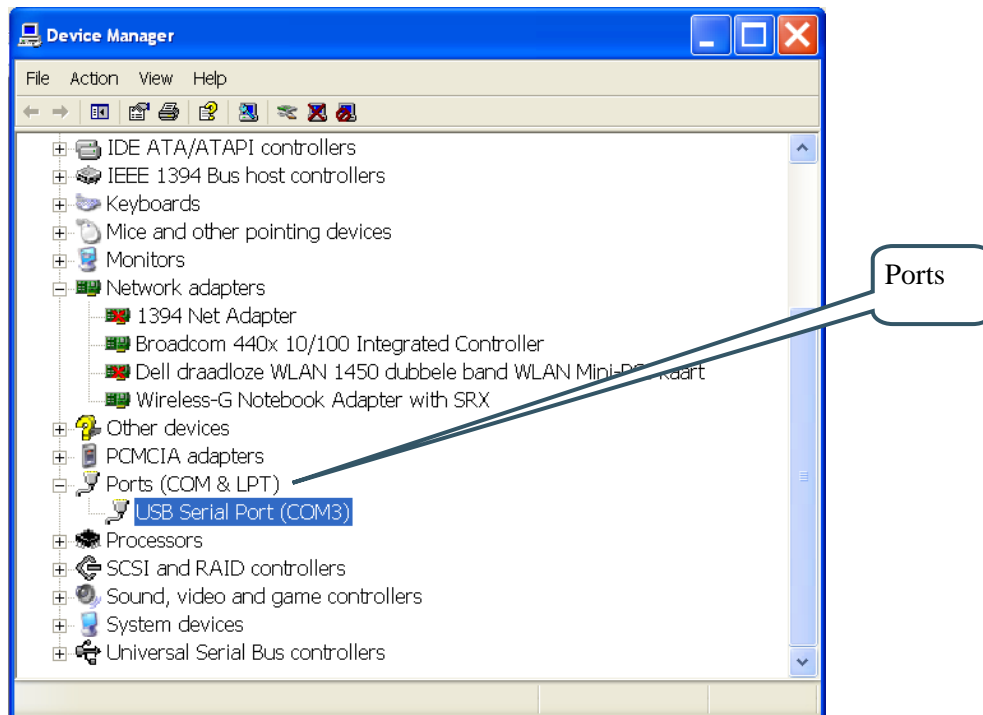


Figure 34 – Device Manager Dialog

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 35* below.

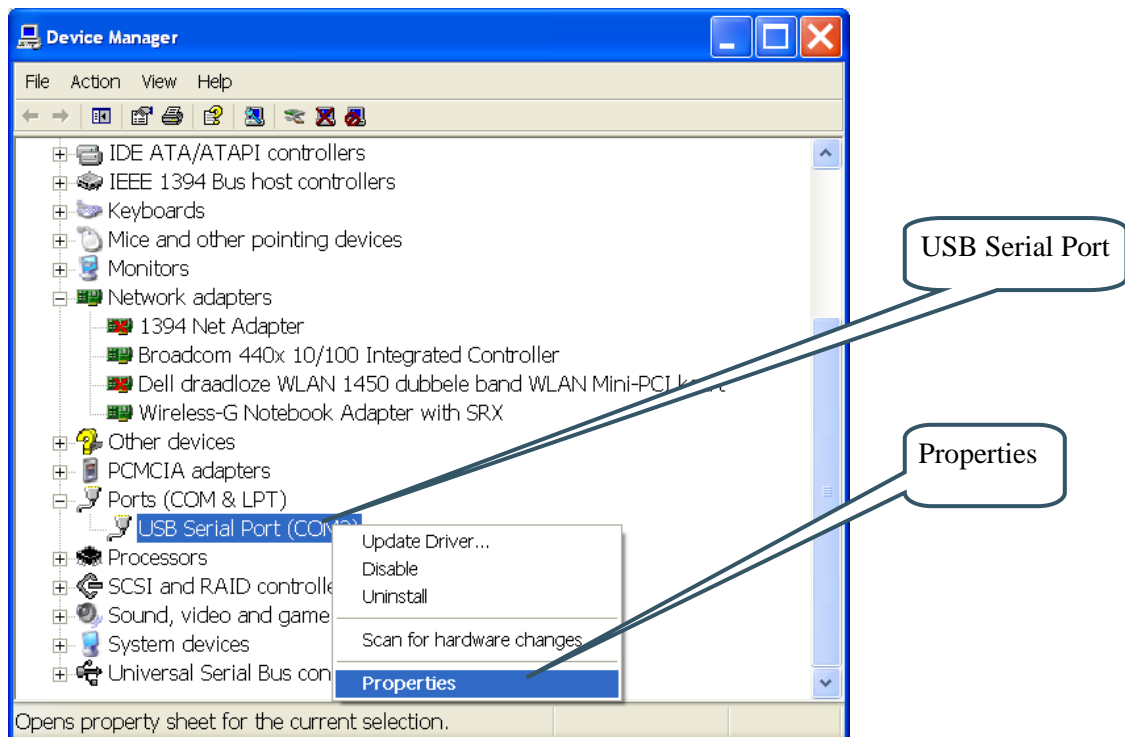


Figure 35 – Device Manager Port Dialog

Set 38400 bits per second, 8 data bits, none parity, 1 stop bit, and none flow control, as illustrated in *Figure 36* below. Then select *Advanced* settings.

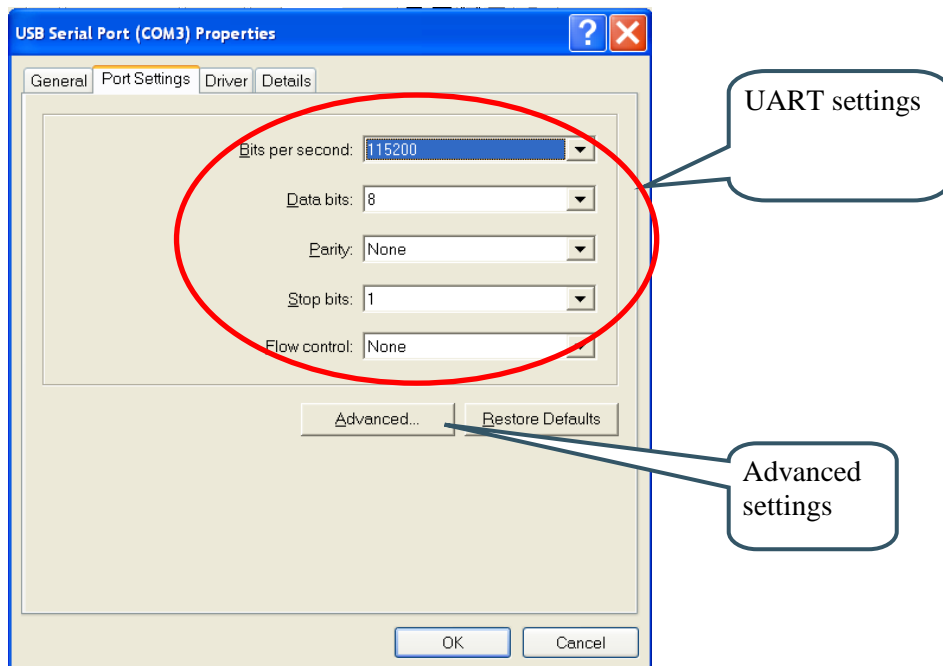


Figure 36 – USB Serial Port Properties Dialog

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 this, so this needs to be changed manually.

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

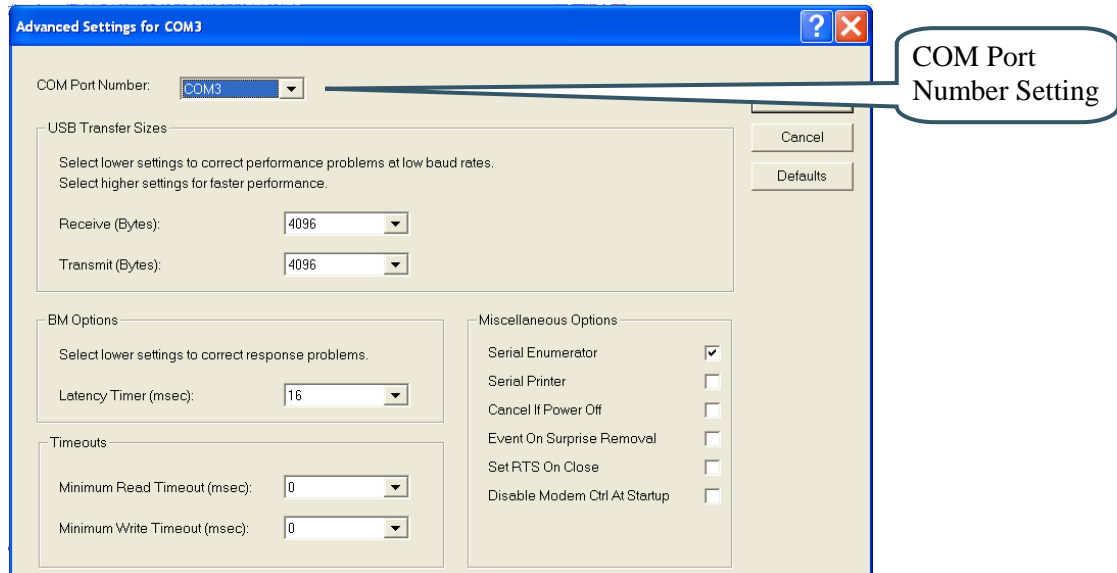


Figure 37 – Advanced USB Serial Port Properties Dialog

Finally it's time to test if you have successfully installed and configured the USB Serial Port. Start a terminal program. Connect to the correct COM port, with 38400 bits per second, 8N1, no flow control. Remember to not have the USB-ISP jumpers inserted.

3.4.1 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 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).

4 Further Information

The LPC2148 microcontroller is a complex circuit and there exist a number of other documents with a lot more information. The following documents are recommended as a complement to this document.

- [1] NXP LPC2148 Datasheet
<http://www.standardics.nxp.com/support/documents/microcontrollers/pdf/user.manual.lpc2141.lpc2142.lpc2144.lpc2146.lpc2148.pdf>
- [2] NXP LPC2148 User's Manual
<http://www.standardics.nxp.com/products/lpc2000/pdf/lpc2141.lpc2142.lpc2144.lpc2146.lpc2148.pdf>
- [3] NXP LPC2148 Errata Sheet
<http://www.standardics.nxp.com/support/documents/microcontrollers/pdf/errata.lpc2148.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.com>
- [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 document [3]. There exist a number of bugs in the processor that is important to be aware of.

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