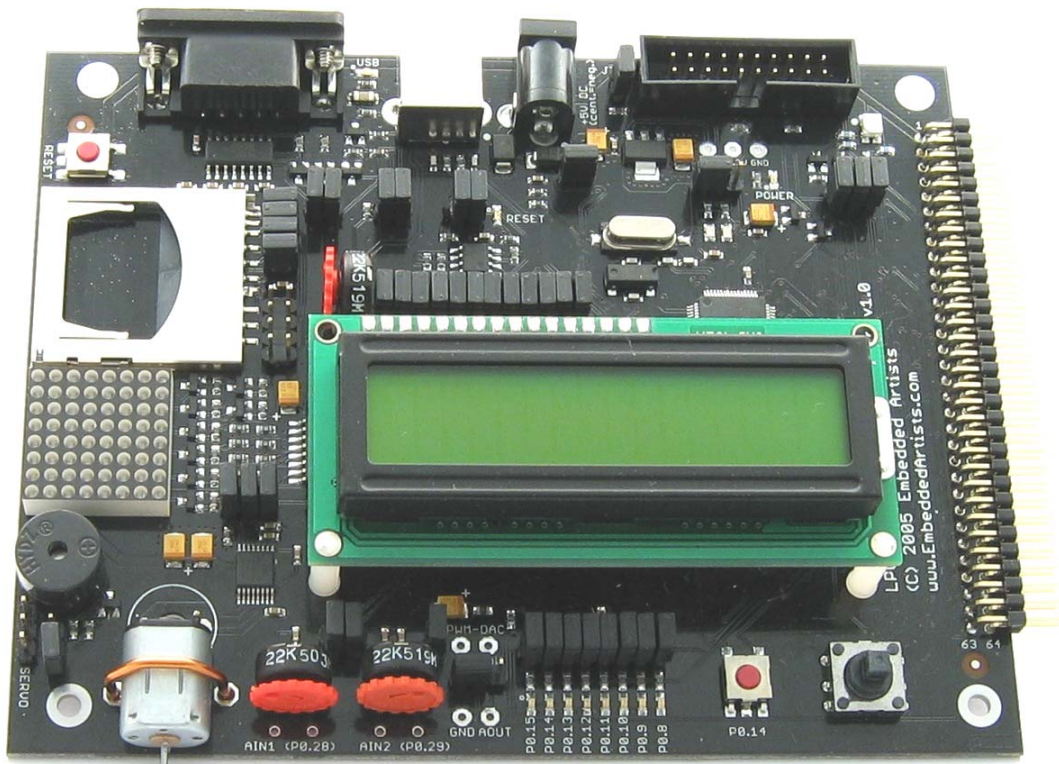


LPC2148 Education Board User's Guide



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

Start Developing Your Applications On Day 1!

Embedded Artists AB

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1 Introduction

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

This document is a User's Guide that describes the *LPC2148 Education Board* hardware design and some basic software interface principles with the hardware. There is a separate document describing program development that also includes a lot of experiments that will guide you through the art of embedded program development.

1.1 Contents

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

- The *LPC2148 Education Board*.
- A modem serial cable, DB9-male to DB9-female (DB9M-DM9F), for connecting the *LPC2148 Education Board* to a PC.
- A USB cable of type: B-to-A, for powering the boards from a PC.
- CD-ROM with additional material and programs, including complete and evaluation versions of different development environments.

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.

1.2 Features

Embedded Artists' *LPC2148 Education Board* with Philips 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.

- Philips 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
 - RS232 interface on UART #0
 - USB 2.0 device interface
 - RGB-LED, each color can be controlled via PWM signal
 - 8 LEDs
 - Pushbutton on P0.14 (interrupt input)
 - 8x8 LED matrix, controlled via shift registers in the SPI bus
 - MMC/SD memory card interface
 - Brushless DC motor control
 - Piezoelectric buzzer

- Servo interface (3-pole)
- 2 Analog inputs
- Low-pass filtering of PWM signal
- 1 Analog output
- Reset button
- Connectors
 - RS232, female DSUB-9 (ESD protected)
 - USB, type B connector
 - MMC/SD memory card connector
 - Servo (3-pin) connector
 - JTAG
 - 64 pin expansion connector, all 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 from a +5V supply
 - +3.3V available for external circuits, up to 300 mA
- Power supply
 - 4.5-6 VDC, ≥150 mA, either from USB connector or 2.1 mm power connector
- Simple and automatic program download (ISP) via RS232 channel
 - Circuit that automatically controls the bootloader from RS232 channel
- Dimensions: 139 x 110 mm
 - Four layer PCB (FR-4 material) for best noise immunity

1.3 Expansion Boards

The 64 pin expansion connector, with all LPC2148 I/O pins available, allows the *LPC2148 Education Board* to be expanded with new and exciting hardware. The experiments can be more advanced and complex by using the expansion boards. The list below presents the first set of available expansion boards. As seen, many of the boards are communication oriented.

- Ethernet board (10Mbps) with SPI interface
- Bluetooth™ board with UART interface
- ZigBee™ board with SPI interface
- MP3 decoder board with SPI interface
- Graphical monochrome LCD (240x128 pixels) with parallel interface
- Modem (UART#1) and RS485 board
- Prototype board

More boards are in preparation, for example:

- GSM/GPRS modem board
- GPS board
- WLAN (IEEE802.11) board

...and many more to come!

1.4 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.

1.4.1 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 Philips 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.

1.4.2 LPC2xxx QuickStart Boards and Kits

Visit Embedded Artists' home page, www.EmbeddedArtists.com, for information about other *QuickStart* 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*.

2.1 Board Schematics

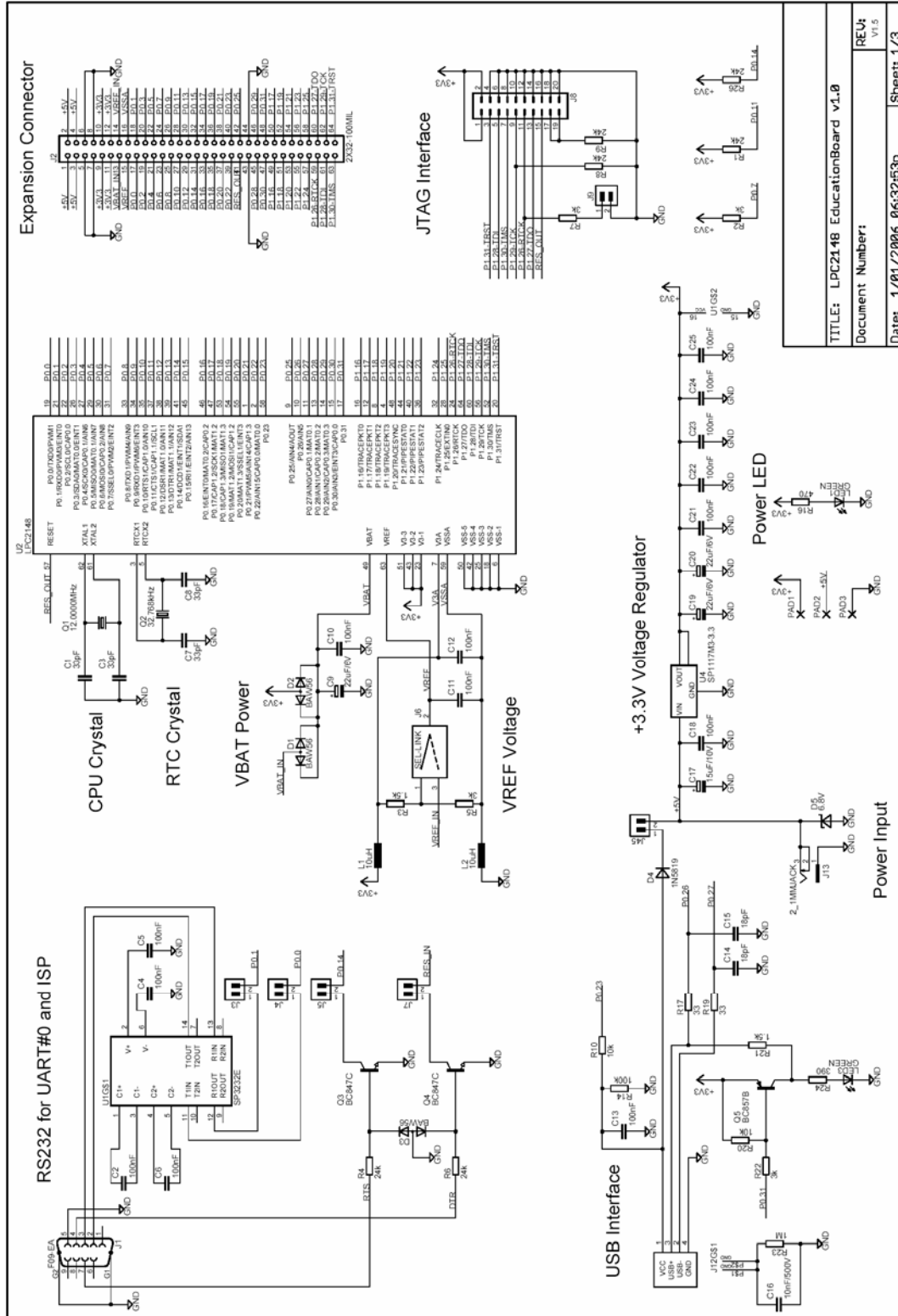


Figure 1 - LPC2148 Education Board Schematic, page 1

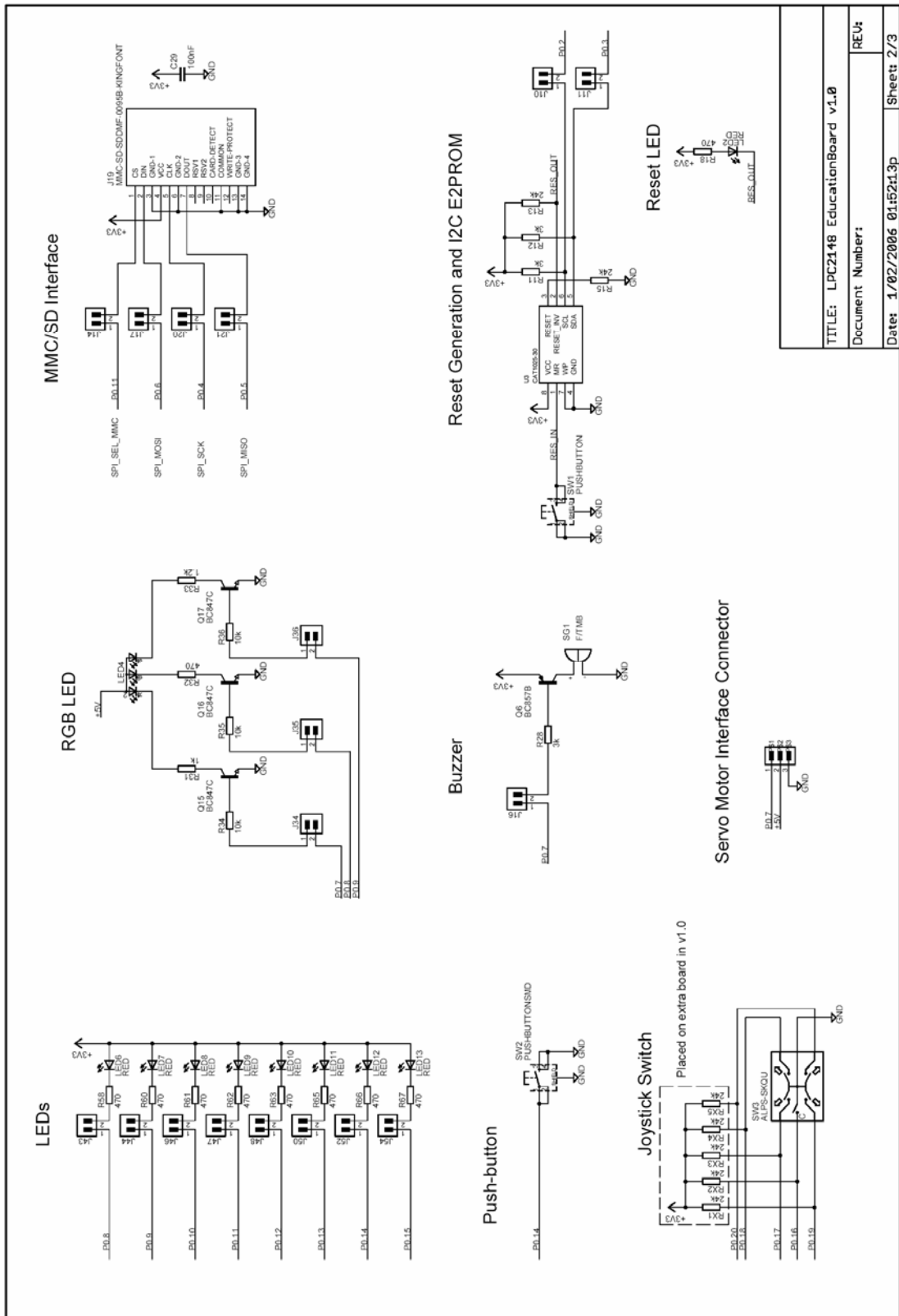


Figure 2 - LPC2148 Education Board Schematic, page 2

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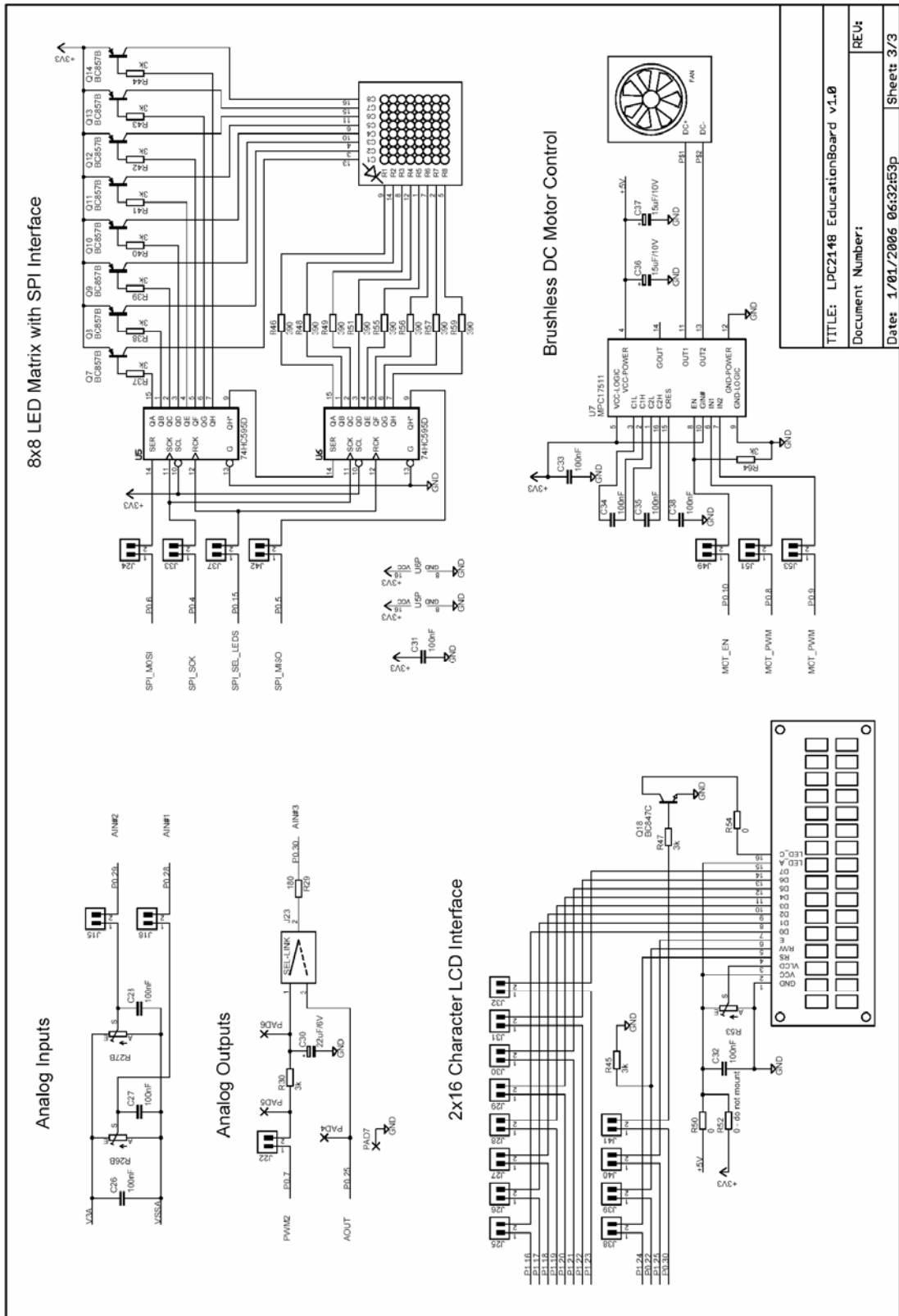


Figure 3 - LPC2148 Education Board Schematic, page 3

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

2.1.1 Page 1: CPU

The core part of the design is the Philips 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 4* below illustrates the CPU section of the design.

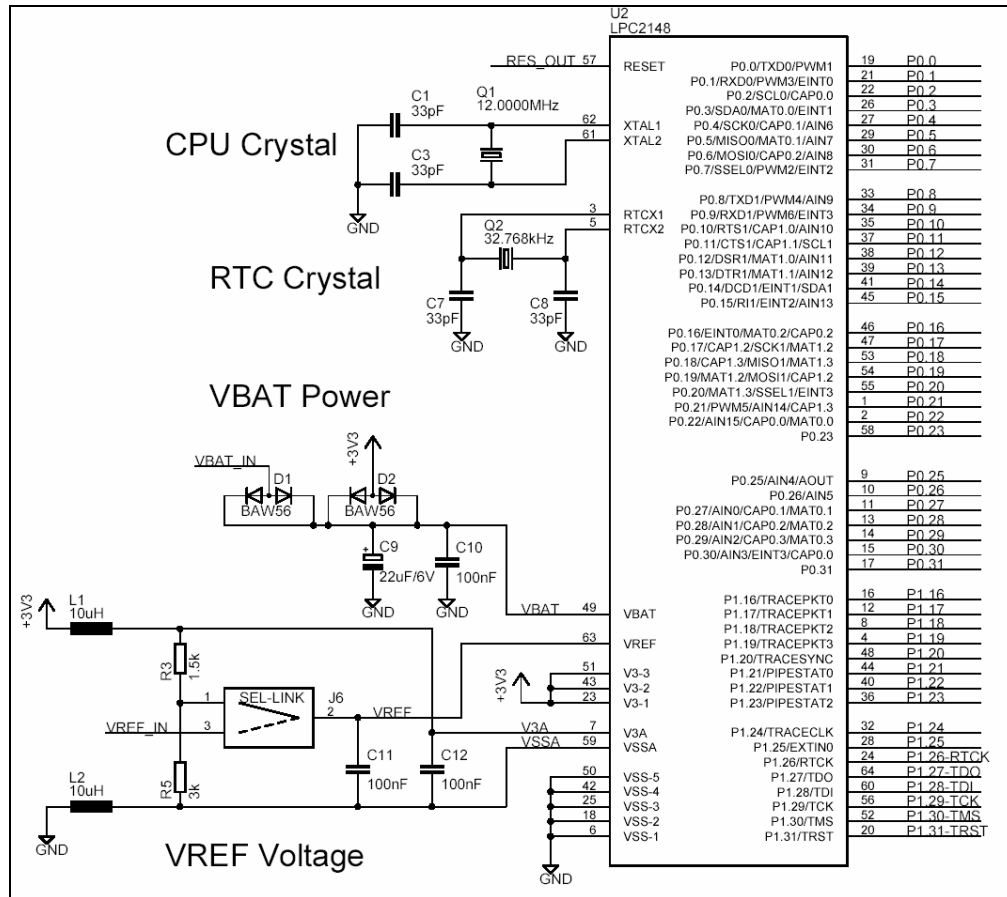


Figure 4 - LPC2148 Education Board Schematic, page 1: CPU

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 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 J6 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 1: Power Supply

The power supply uses a conventional low-dropout voltage regulator, 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 (also included on the CD-ROM).

Figure 5 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 USB connector. Diode D4 keeps the USB interface 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 ($\geq 500\text{mA}$).

A transient suppression diode (D5) protects the board from power surges via the power input.

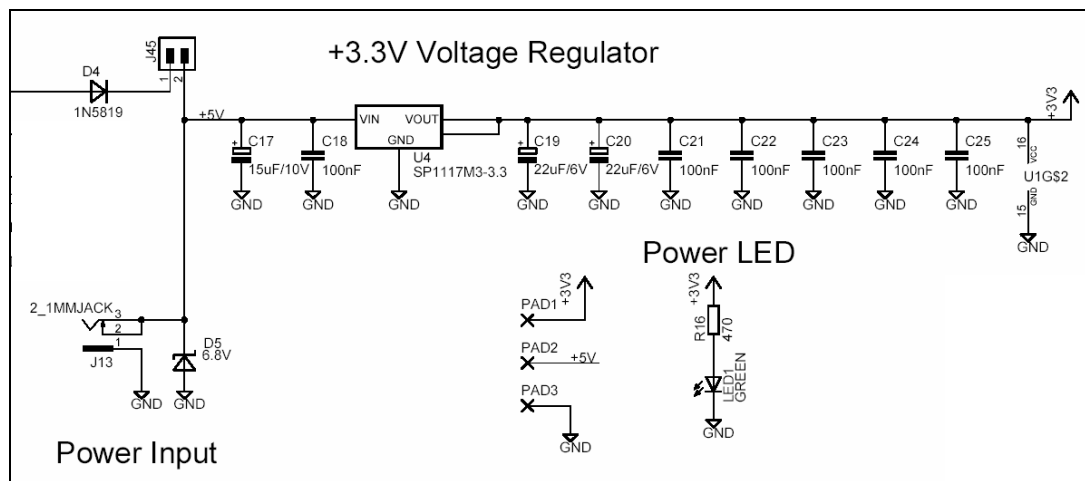


Figure 5 - LPC2148 Education Board Schematic, page 1: Power Supply

There are three pads to ease measurements of the incoming (+5V) voltage and the generated (+3.3V) voltage, see PAD1 – PAD3. When ON, a small green LED indicates the presence of +3.3V voltage. See Figure 26 on page 27 for a description where the pads and the green LED are placed on the PCB.

2.1.3 Page 1: RS232 and ISP

UART#0 on the LPC2148 is connected to a RS232 interface via a Sipex SP3232E standard RS232 interface chip. It's a 3.3V powered chip with integrated ESD protection in order to minimize the risk of damaging the interface. The RS232 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.

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 jumper J3 and J4, in case an external 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 jumpers J5 and J7. 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 6 below illustrates the RS232 and ISP part of the design.

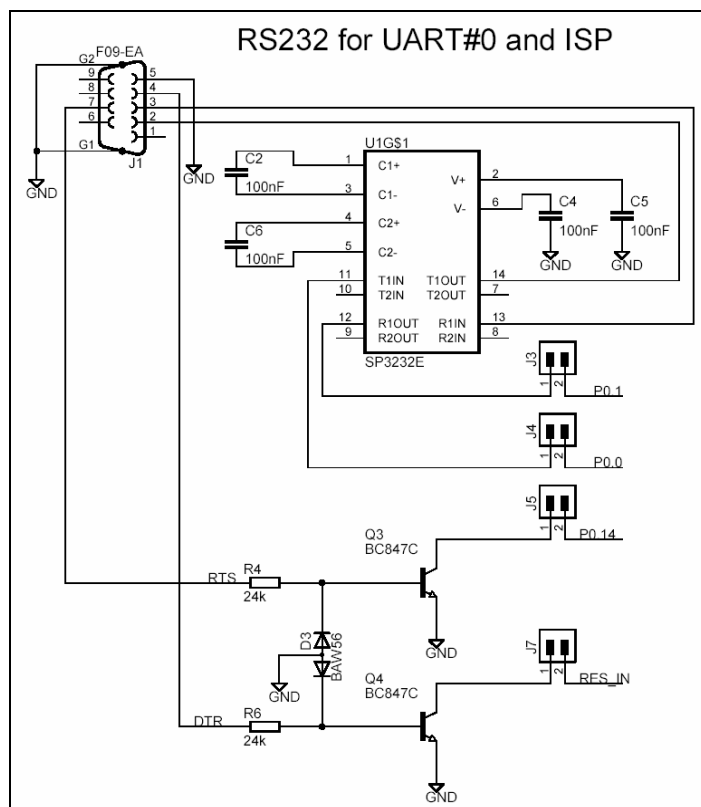


Figure 6 - LPC2148 Education Board Schematic, page 1: RS232 and ISP

2.1.4 Page 1: USB

The LPC2148 also contains a USB 2.0 device interface as one of its peripheral units. Figure 7 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.

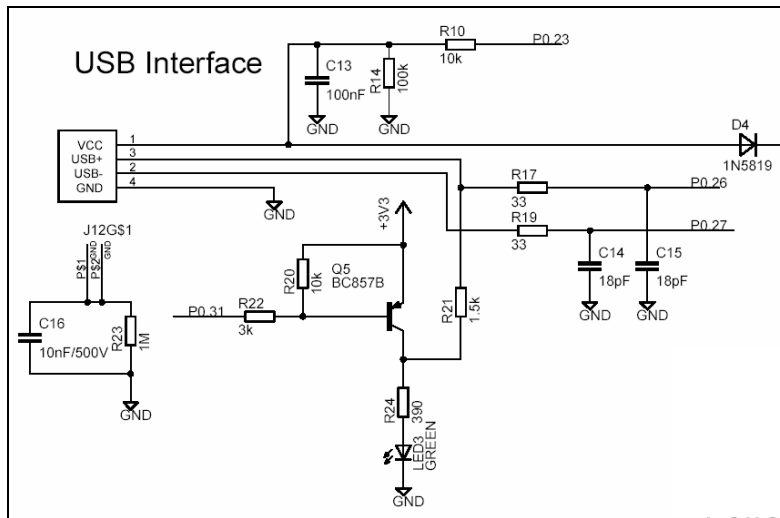


Figure 7 - LPC2148 Education Board Schematic, page 1: USB

2.1.5 Page 1: 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 J9, 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 8* below illustrates the JTAG part of the schematics.

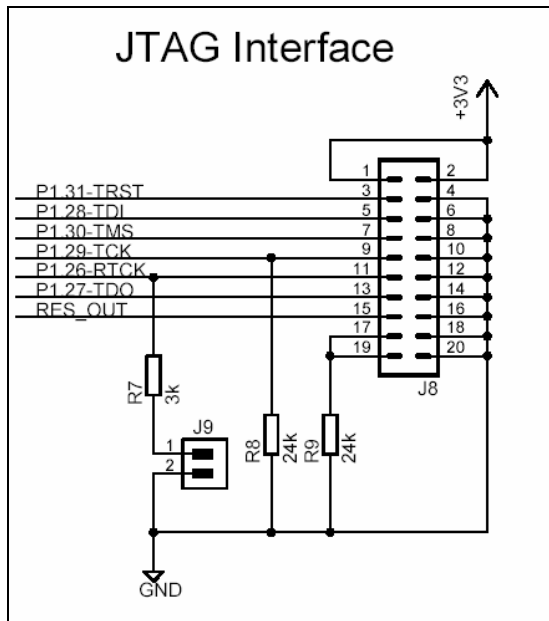


Figure 8 - LPC2148 Education Board Schematic, page 1: JTAG

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.

2.1.6 Page 1: Expansion Connector

The *LPC2148 Education Board* is not just a monolithic design. Via the expansion connector, it's possible to expand the design. All LPC2148 pins are available on the expansion connector, which is a standard 2x32 pin list with 100 mil pin spacing. *Figure 9* below illustrates the expansion connector part of the design.

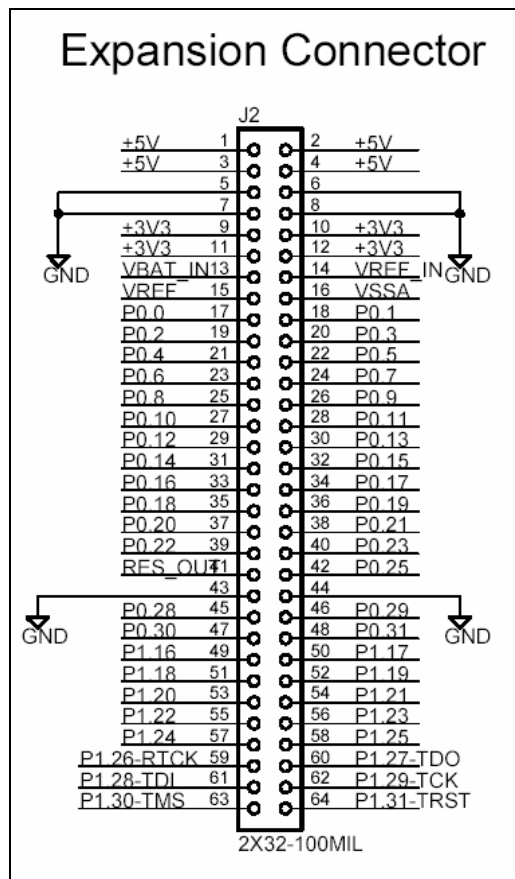


Figure 9 - LPC2148 Education Board Schematic, page 1: Expansion Connector

The power voltages, +5V 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 the +5V power supply 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.

2.1.7 Page 2: LEDs

The port pins of the LPC2148 microcontrollers have a 4 mA driving capacity, just enough to directly drive LEDs. *Figure 10* below illustrates the 8 LEDs in the design. The LEDs are connected to pin P0.8 – P0.15 and are red. The 470 ohm resistors limit the current to about 4 mA. A low output pin drives current through the LEDs and they will light. Each LED can be individually enabled or disabled via jumpers:

- J43 – P0.8
- J44 – P0.9
- J46 – P0.10
- J47 – P0.11
- J48 – P0.12
- J50 – P0.13
- J52 – P0.14
- J54 – P0.15

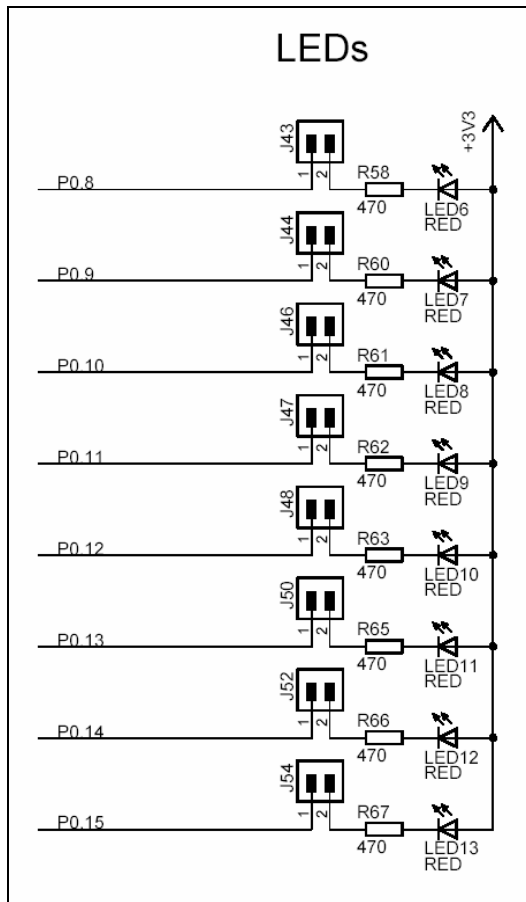


Figure 10 - LPC2148 Education Board Schematic, page 2: LEDs

2.1.8 Page 2: 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 (24 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 11* below illustrates the push-button part of the design.

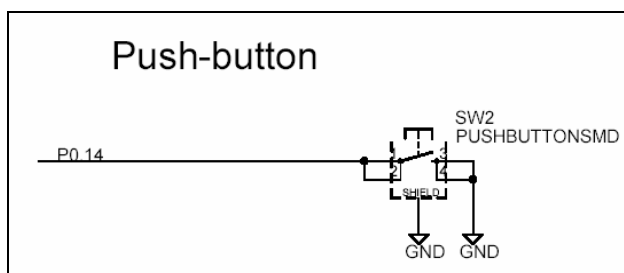


Figure 11 - LPC2148 Education Board Schematic, page 2: Push-button

2.1.9 Page 2: Joystick-switch

There is a joystick-switch on the board and *Figure 12* below illustrates this part of the design. The switch has five internal switches, one for the four directions and one center, push-down switch. Note that the five pull-up resistors are missing on the main board for version 1.0. Instead these are placed on a small expansion board that is shipped with all version 1.0 *LPC2148 Education Boards*. 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.

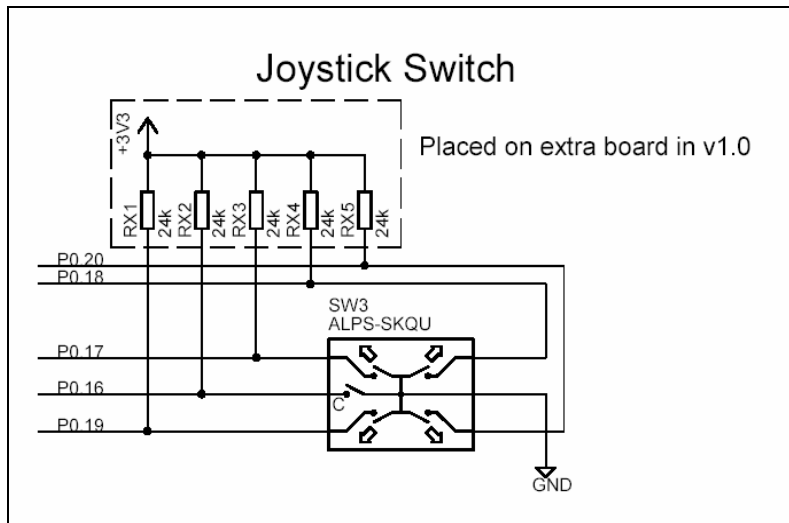


Figure 12 - LPC2148 Education Board Schematic, page 2: Joystick-switch

2.1.10 Page 2: 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 13* 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 LCP2148.

The RGB-LED can be disconnected by removing jumpers J34, J35, and J36. 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, the servo motor interface (P0.7), as well as for the individual LEDs (see *Figure 10*).

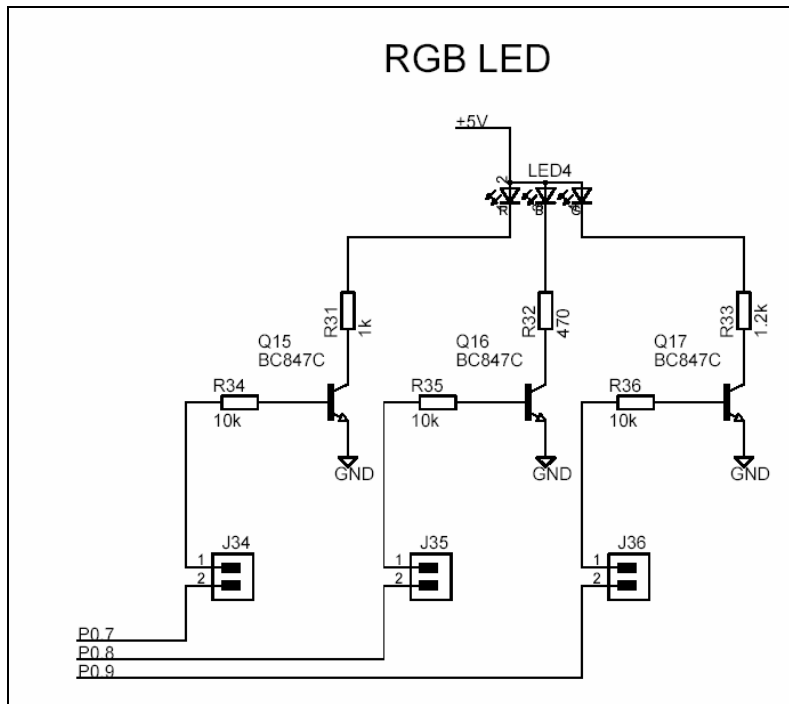


Figure 13 - LPC2148 Education Board Schematic, page 2: RGB-LED

2.1.11 Page 2: Buzzer

There is also a small piezoelectric buzzer on the *LPC2148 Education Board*. *Figure 14* below illustrate the buzzer part of the design. By pulling pin P0.7 low, current will flow through the buzzer and a relatively sharp, single-tone frequency will be heard.

The alternative PWM feature of pin P0.7 (the PWM2 signal) can be used to modulate the buzzer to oscillate around different frequencies. It's not the pulse width feature that is used to change the frequency. Only the volume of the sound will be changed by alternating the pulse width. Instead, it's possible to change the frequency of the PWM signal, and this will also change the frequency of with the buzzer oscillate.

The buzzer can be disconnected by removing jumper J16, and this is also the default position for this jumper since the buzzer sound can be quite annoying if always left on.

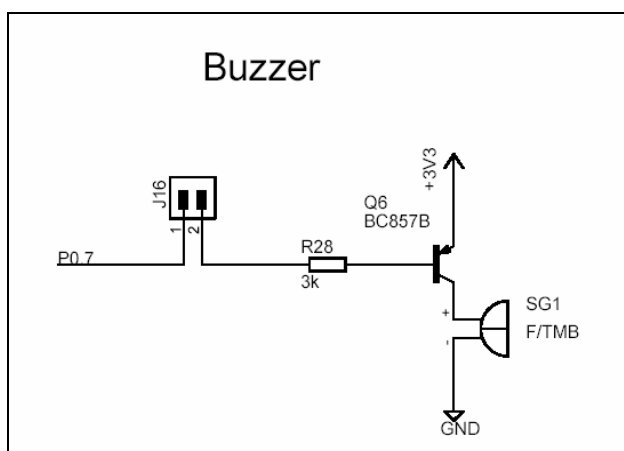


Figure 14 - LPC2148 Education Board Schematic, page 2: Buzzer

Note that signal P0.7 is shared with several other parts of the design, for example the motor control, the red LED in the RGB-LED, servo motor interface, analog output, and the individual LEDs (see *Figure 10*).

2.1.12 Page 2: Servo Motor Interface

Figure 15 below illustrates the servo motor interface part of the design. As seen the interface is as simple as it gets. Only a three position connector that is standard for servo motors. The servo is powered from the +5V power supply. Also this part of the design uses the PWM2 signal available on pin P0.7. The servo position is controlled by altering the pulse width of the PWM signal.

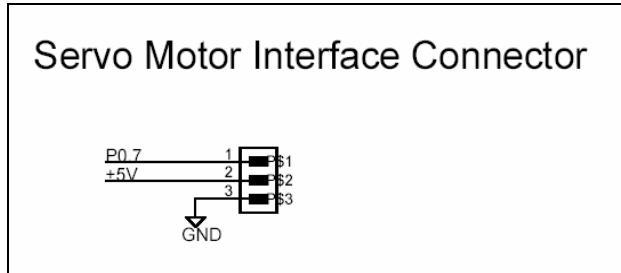


Figure 15 - LPC2148 Education Board Schematic, page 2: Servo Motor Interface

Note that signal P0.7 is shared with several other parts of the design, for example the motor control, the buzzer, analog output, the red LED in the RGB-LED, and the individual LEDs (see Figure 10).

2.1.13 Page 2: 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. Philips 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 16 below illustrates the MMC/SD interface part of the design.

The interface can be disconnected from the LCP2148 by removing jumpers J14, J17, J20, and J21. Also note that jumper J42 on 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 jumper J42 installed so this is normally not a problem.

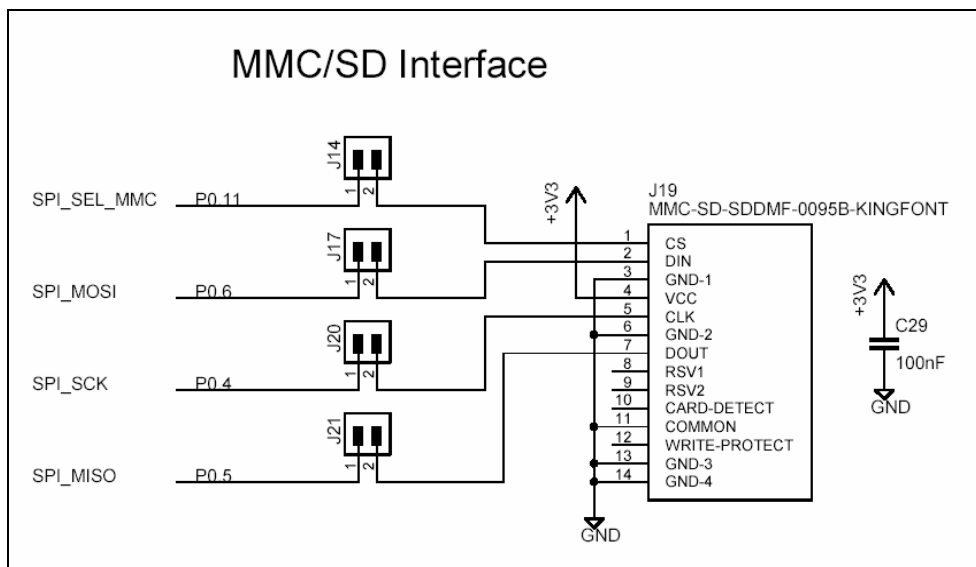


Figure 16 - LPC2148 Education Board Schematic, page 2: MMC/SD Interface

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

2.1.14 Page 2: 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, also included on the CD-ROM). The output reset signal is an open-collector / open-drain output. An external reset source can also control the reset generator. *Figure 17* 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.

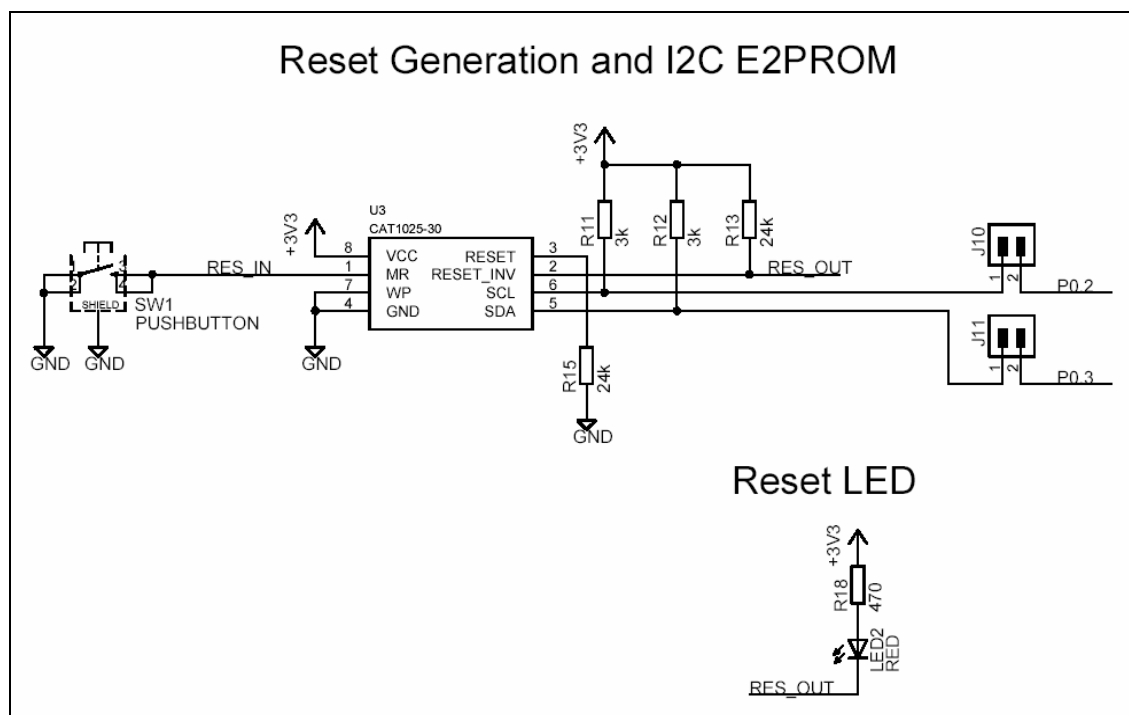


Figure 17 - LPC2148 Education Board Schematic, page 2: Reset Generation and I2C E2PROM

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 J10 and J11.

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*.

2.1.15 Page 3: 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 us and the input pins VREF and

VSSA are used as conversion reference. *Figure 19* 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 jumpers J15 and J18.

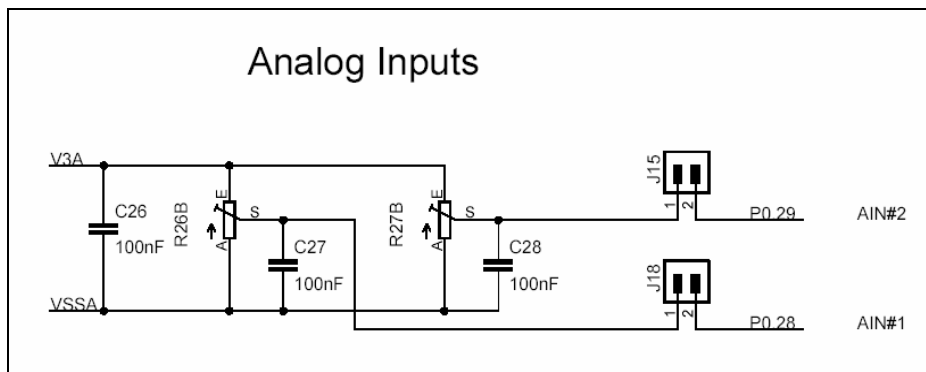


Figure 18 - LPC2148 Education Board Schematic, page 3: Analog Inputs

2.1.16 Page 3: Analog Outputs

The LPC2148 has one analog output, available as an alternative function on pin P0.25. *Figure 19* below illustrate the analog output part of the design. Via jumper J23 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 (PAD4 and PAD7).

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.

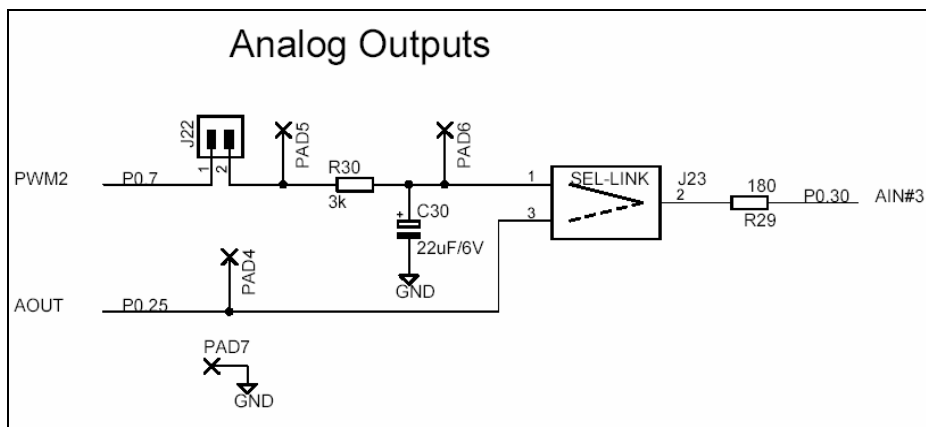


Figure 19 - LPC2148 Education Board Schematic, page 3: Analog Outputs

2.1.17 Page 3: 2x16 Character LCD

The *LPC2148 Education Board* also contains a small 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 20 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 J25 – J32 and J38 – J41. The LCD is powered from the +5V power supply but there is an option to power it from the +3.3V power supply. +5V power is no problem since all pins on the LPC2148 are +5V tolerant and a high logic level from the CPU (powered by +3.3V) is also interpreted as a high logic level by the LCD. Display contrast is adjusted via trim-potentiometer R53.

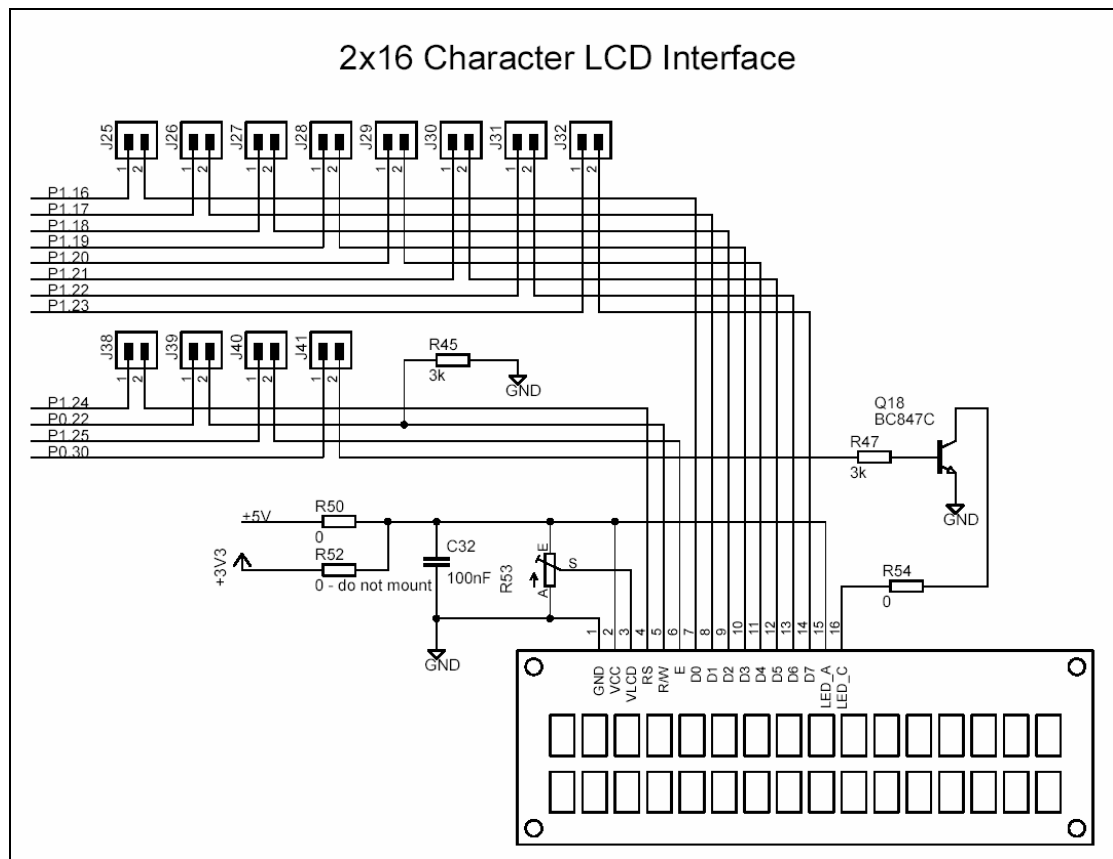


Figure 20 - LPC2148 Education Board Schematic, page 3: 2x16 Character LCD

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 (R45) and jumper J38 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.

2.1.18 Page 3: 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 21 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.

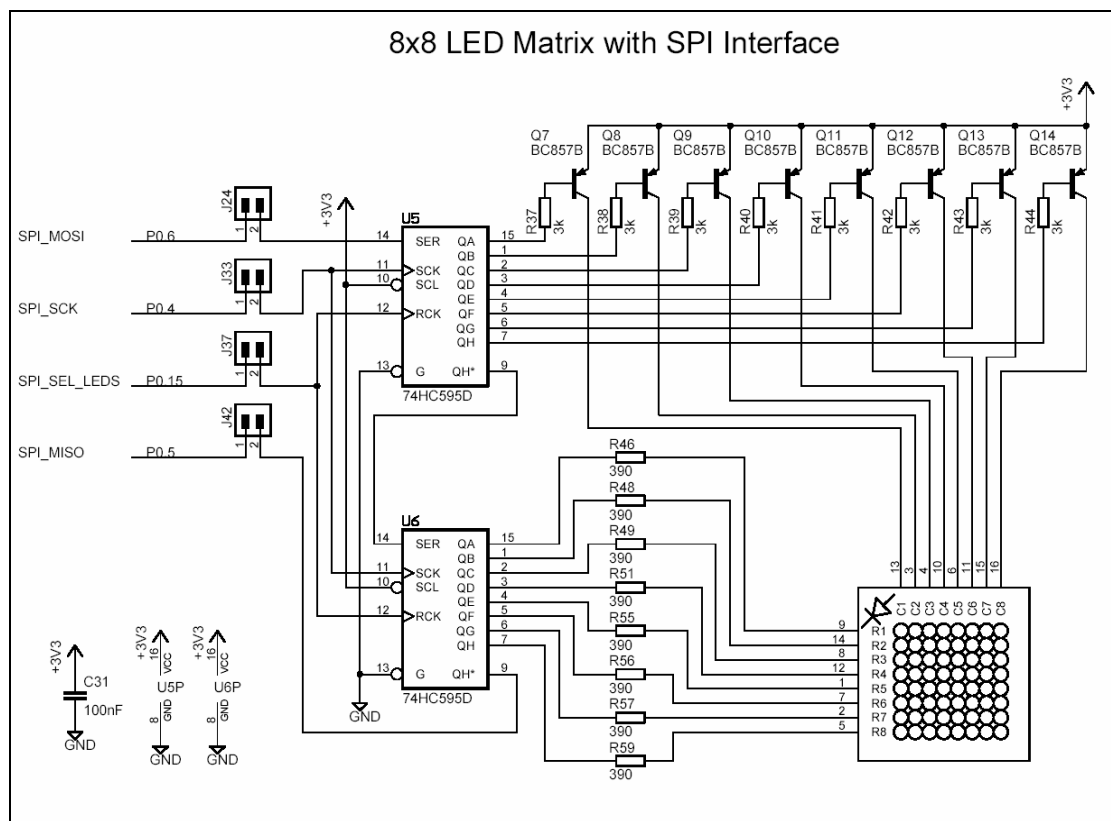


Figure 21 - LPC2148 Education Board Schematic, page 3: 8x8 LED Matrix with SPI Interface

The 8x8 LED matrix circuit can be disconnected from SPI channel #0 by removing jumpers J24, J33, J37, and J42. Normally, jumper J42 should not be inserted since the output from U6 is not three-states when the shift registers are not enabled by device select signal P0.15. If inserted, the output from U6 will collide with the data output (DOUT) from the MMC/SD interface. The only reason to have jumper J4 inserted would be to read back the last two bytes shifted into the shift registers (and there is no typical reason to do this).

2.1.19 Page 3: Brushless DC Motor Control

The final part of the LPC2148 Education Board is the Brushless DC motor control. The control chip MPC17511 from Freescale is used. See the datasheet for details about the controller (included on the CD-ROM). The interface principles are really easy. An enable signal exists and is controlled by signal P0.10. The motor controller is enabled when P0.10 is high. Two other input signals control the speed and direction of the motor rotation. These signals are PWM signals and the duty cycle controls the speed of the motor. Signal P0.8 is used to rotate to motor in one direction and P0.9 is used for the other direction. When a signal is not used it should be help low. *Figure 22* below illustrates the brushless DC motor control part of the design.

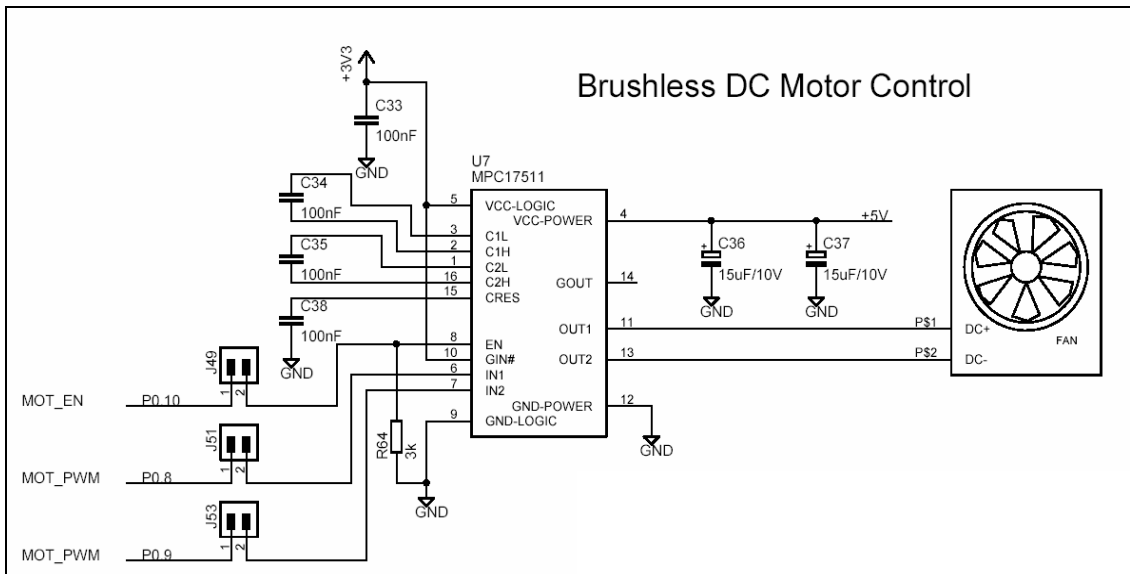


Figure 22 - LPC2148 Education Board Schematic, page 3: Brushless DC Motor Control

Note that the motor controller can draw a lot of power from the +5V power supply. This will happen if the signals P0.8, P0.9 are high at the same time as signal P0.10. This unfortunately happens when the processor is in reset state. Therefore, jumper J49 should normally not be inserted, unless the motor controller is used.

The motor has a limited operation area when it comes to rotation speed. The diagram below, in *Figure 23*, illustrates the area. The motor does not rotate all the way from zero speed up to full speed. A certain DC-level must be applied over the motor before it starts rotating. This level is about 35-40% duty cycle. When the motor rotates it can keep rotating at slightly lower speed than the 'start-rotating' speed.

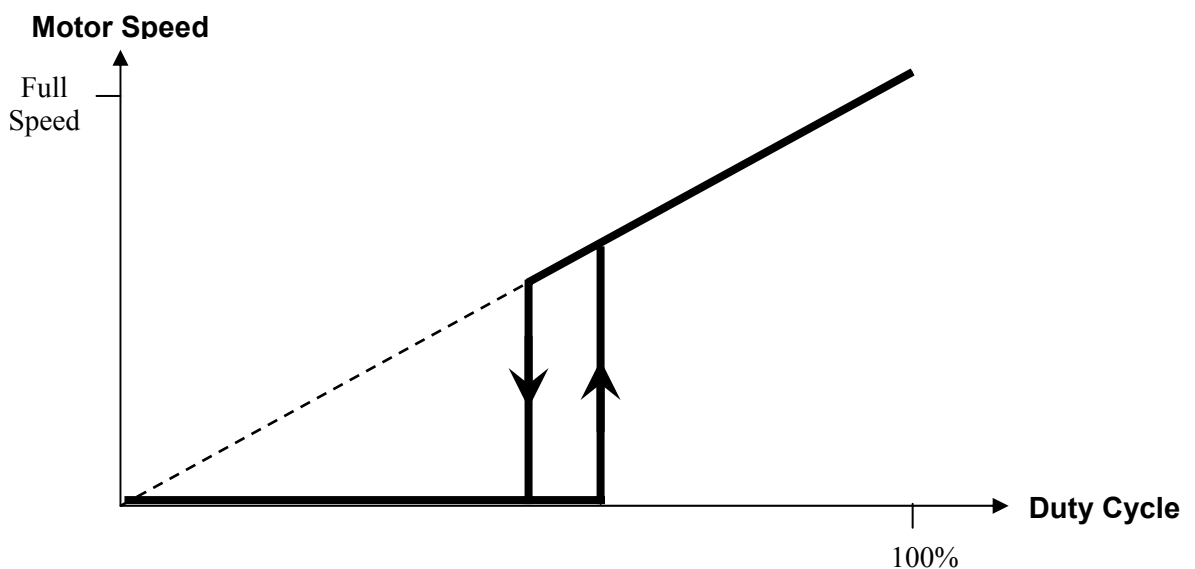


Figure 23 - Brushless DC Motor Operation Area

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 24* below illustrates all jumpers and explains to what part of the design they belong.

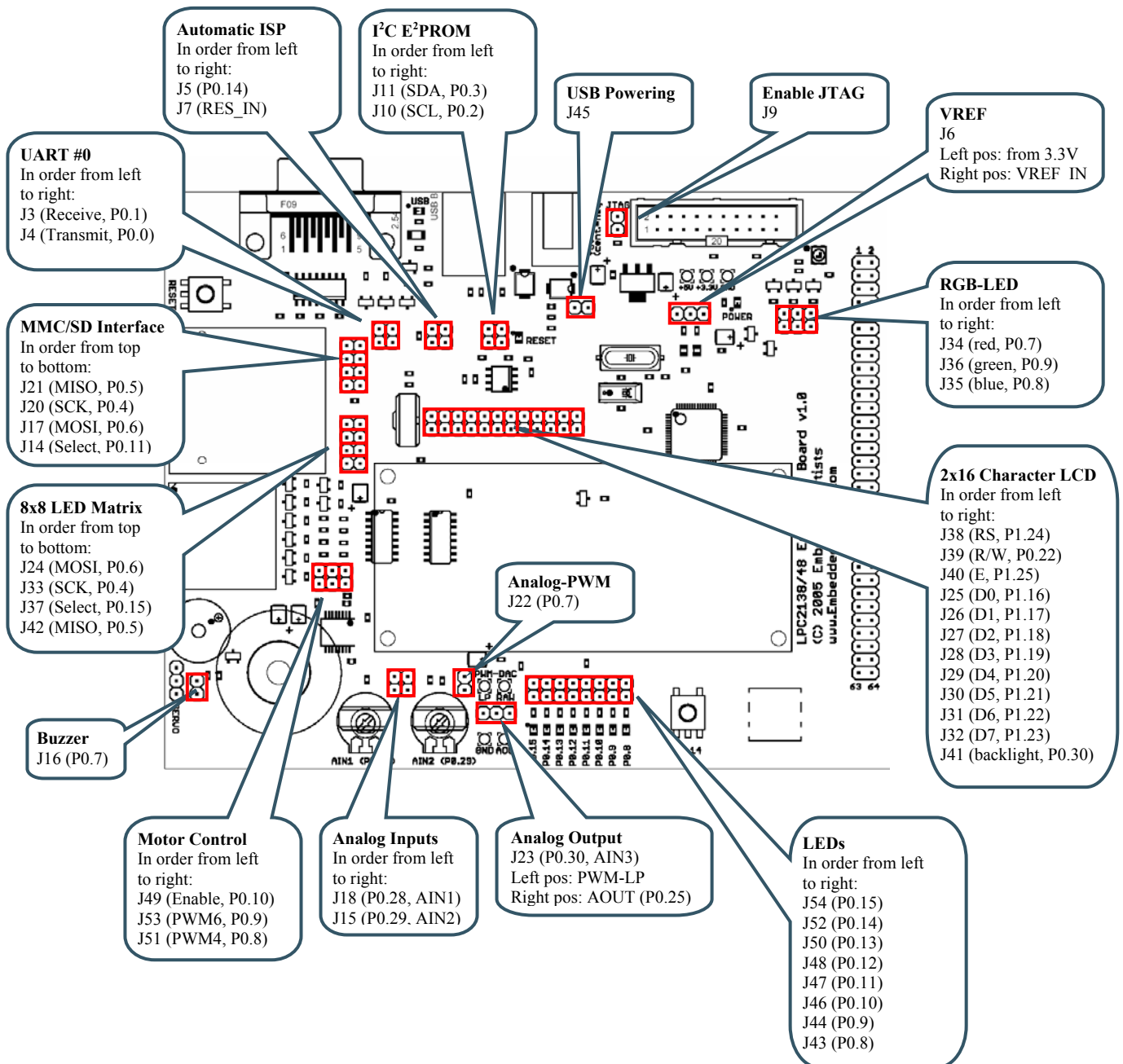


Figure 24 - LPC2148 Education Board Jumpers

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 jumper J42 inserted simultaneously as the MMC/SD interface is used. See explanation in *section 2.1.13*
- P0.7 is a commonly used signal that is used for the buzzer, motor control, the red LED in the RGB-LED, individual LED, and the servo motor interface.

- 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 25 below illustrate the position of all external connectors on the *LPC2148 Education Board*.

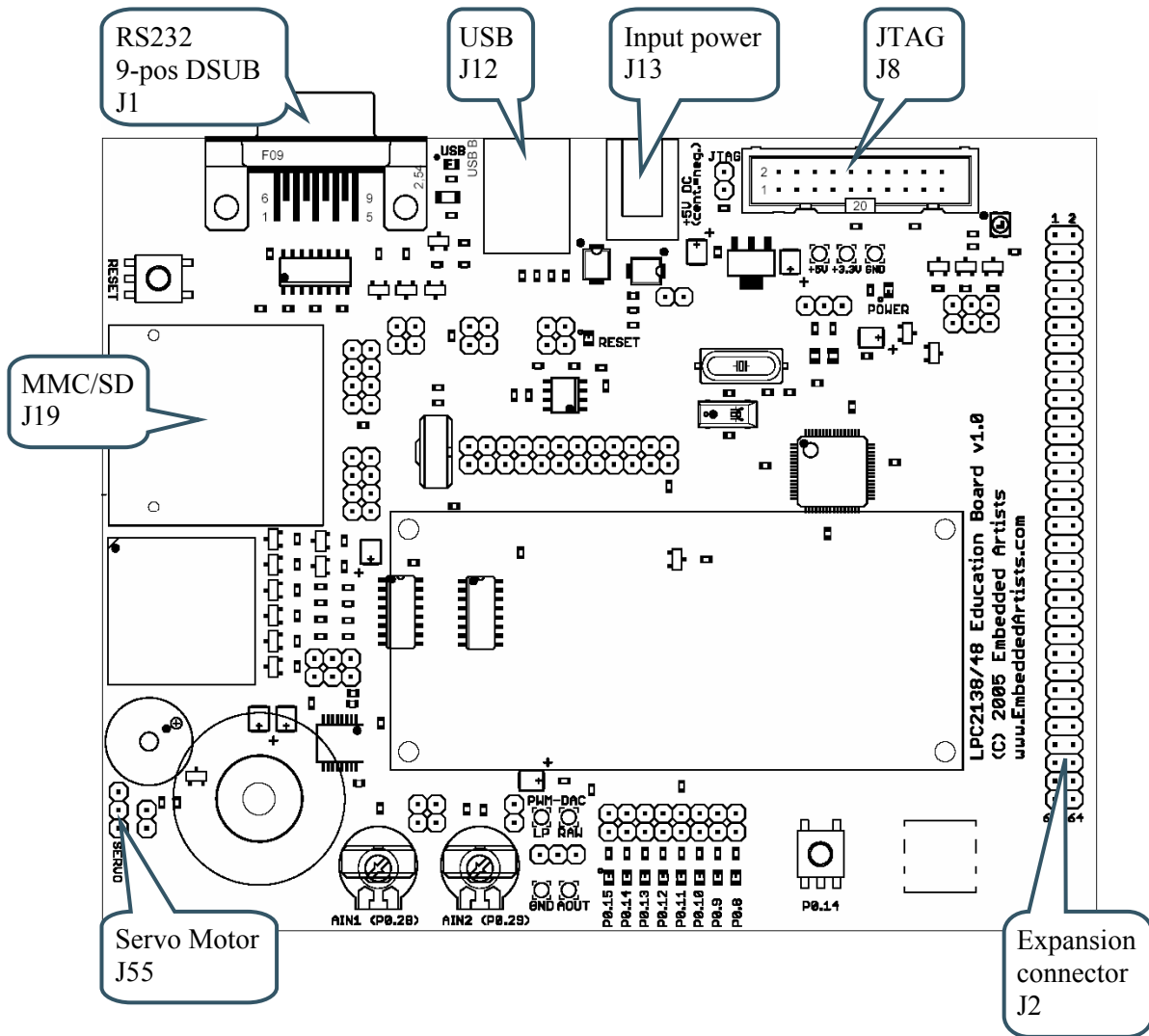


Figure 25 - LPC2148 Education Board External Connectors

2.4 Important Components

Figure 26 below illustrates the position on the board for some important components in the design.

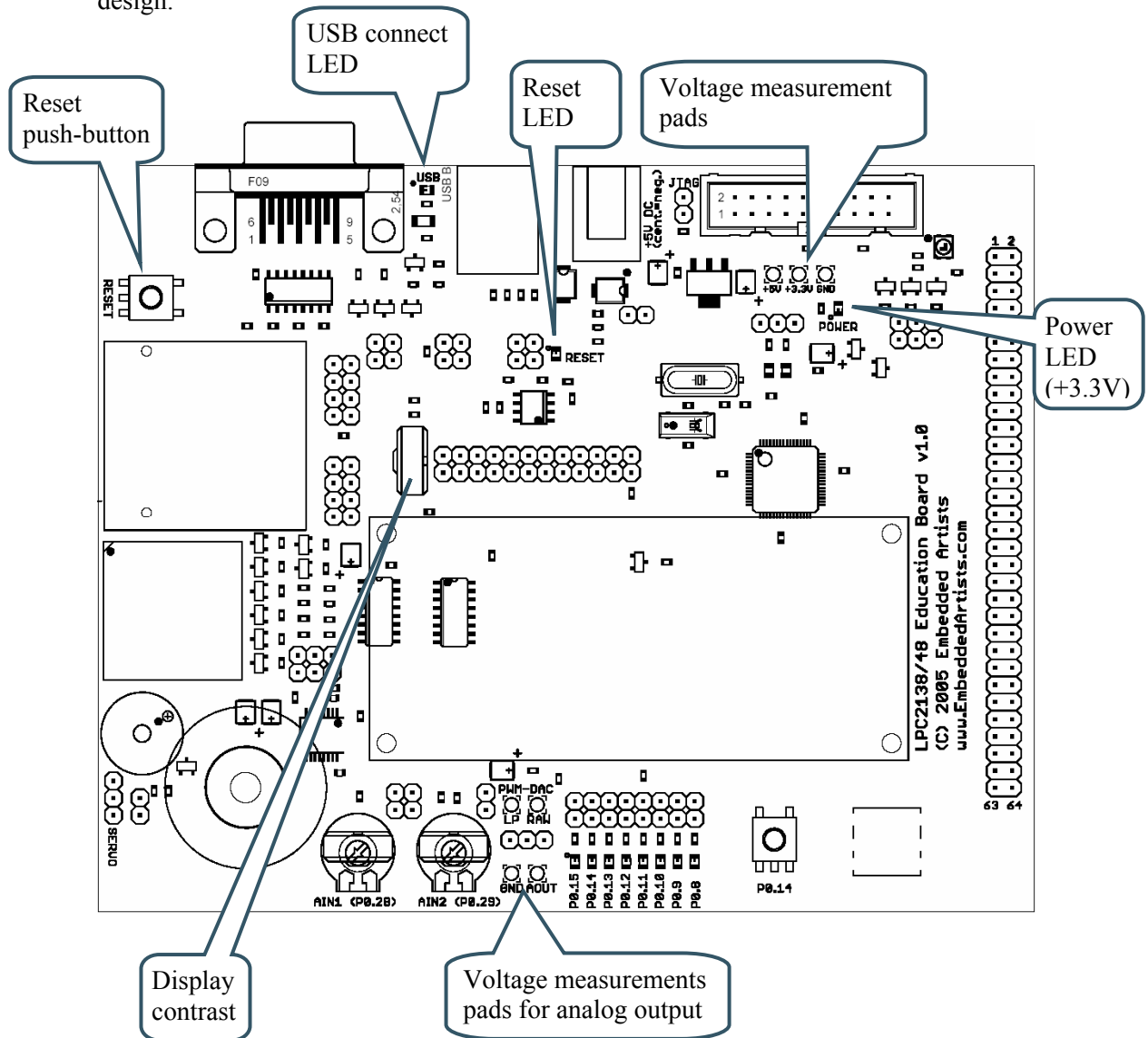


Figure 26 - LPC2148 Education Board Important Components

2.5 Mechanical Dimensions

Figure 27 below contains a drawing of the board that includes mechanical measures. As seen, the board is 139 x 110 mm large with mounting holes 125 x 98 mm apart.

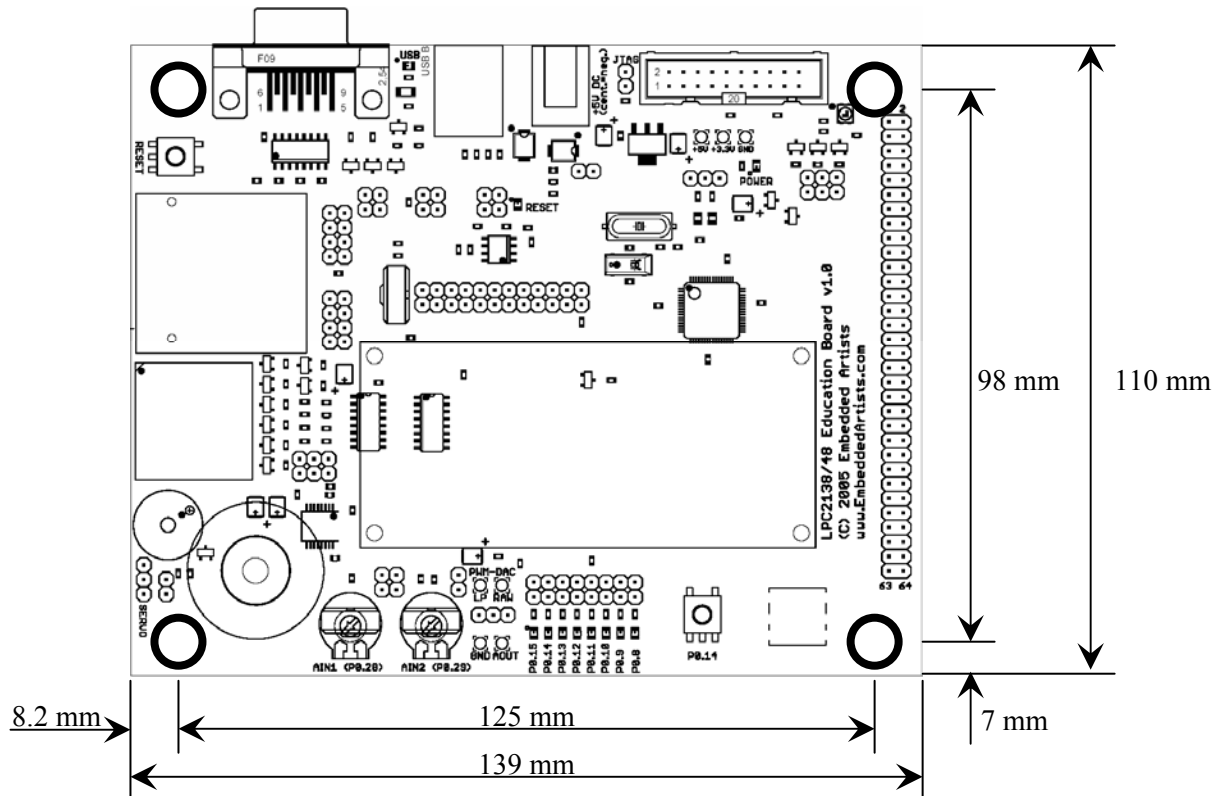


Figure 27 - LPC2148 Education Board Mechanical Dimensions

2.6 JTAG Interface and Reset Control Issue

An external JTAG controller can control the reset signal to the LPC2148. Some JTAG controllers will start sending JTAG commands to the internal TAP controller in the LPC2148 immediately after de-asserting the reset signal in the JTAG interface. Others will wait a short while before start sending commands. Note that the behavior can be different for different firmware versions of the JTAG controllers.

The reset system of the *LPC2148 Education Board* will keep the reset signal to the LPC2148 asserted for up to 270 ms (typically 200 ms) after the reset signal is de-asserted from the JTAG interface. This design will guarantee that short reset pulses will not put the LPC2148 in an undefined state. Proper reset pulses will always be generated to the LPC2148. For some JTAG controllers this may however be a problem. Some versions of ULINK from Keil are known to have this problem. Ask Keil for available firmware updates.

If you experience problem you might lift pin 2 of U3 (the combined reset controller and E²PROM). This will reconnect the reset controller from the reset signal. See *Figure 2* on page 9 for details about the reset controller. This solution is possible if it is acceptable to control the reset signal from the JTAG controller.

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 except J42
- Push the reset button
- Watch the running-one on the individual LEDs, except for P0.10. After a few rounds, LED P0.10 will flash alone.
- Also watch the printed information on the terminal (se 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 motor forward and backward

A terminal program should be attached to the RS232 DSUB-9 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/RS232 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.

4 CD-ROM and Product Registration

The accompanying CD-ROM contains a lot of information and programs that will ease your program development! Note that there may be newer versions of different documents and programs available than the ones on the CD-ROM. See *Section 4.2* for information about the product registration process, which allows you to always have access to the latest versions.

4.1 CD-ROM

The following is included on the CD-ROM:

- The preloaded test program as a HEX-file.
- The two different ISP download programs.
- Datasheets of all circuits on the *LPC2148 Education Board*.
- *QuickStart Build Environment* from Embedded Artists, which contains a complete setup of a build environment for GCC.
- A complete development environment: Rowley Associates CrossWorks for ARM, 30-day evaluation version.
- A complete development environment: IAR Embedded Workbench for ARM, Kickstart Edition with 32 Kbyte program size limit.
- Another complete development environment: GCC, GNUARM distribution, including compiler, linker, make, and debugger.
- The program Programmers Notepad, which is a very good program development editor and project manager.
- The Eclipse development environment including the CDT (C/C++ Development Tools) project.

4.2 Product Registration

By registering as a customer of Embedded Artists you will get access to more valuable material that will get you up-and-running instantly:

- Access to a Real-Time Operating System (RTOS), in the form of a library that can be used for non-commercial applications.
- Access to a number of sample applications that demonstrated different (peripheral) functions in the LPC2148 processor.
- Access to the latest versions of all information and programs on the CD-ROM.

Registering is easy and done quickly.

- 1) Go to <http://www.EmbeddedArtists.com>, select *Support* and then *Register*.
- 2) Type in the products serial number (can be found on the *LPC2148 Education Board* or on the package carrying the board) along with your personal information.

5 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] Philips LPC2148 Datasheet
http://www.semiconductors.philips.com/acrobat/datasheets/LPC2141_42_44_46_48_1.pdf
- [2] Philips LPC2148 User's Manual
http://www.semiconductors.philips.com/acrobat/usermanuals/UM10139_1.pdf
- [3] Philips LPC2148 Errata Sheet
<http://www.semiconductors.philips.com/acrobat/erratasheets/2148.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 Philips LPC2xxx series of microcontrollers.
<http://groups.yahoo.com/group/lpc2000/>
- [12] The Insider's Guide to the Philips ARM7-Based Microcontrollers, by Trevor Martin.
<http://www.hitex.co.uk/arm/lpc2000book/index.html>

Especially 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.

Datasheets for all circuits on the *LPC2148 Education Board* are included on the accompanying CD-ROM.

6 App.A – 10M Ethernet Expansion Board

This chapter contains detailed information about the electrical design of the board.

6.1 Board Schematics

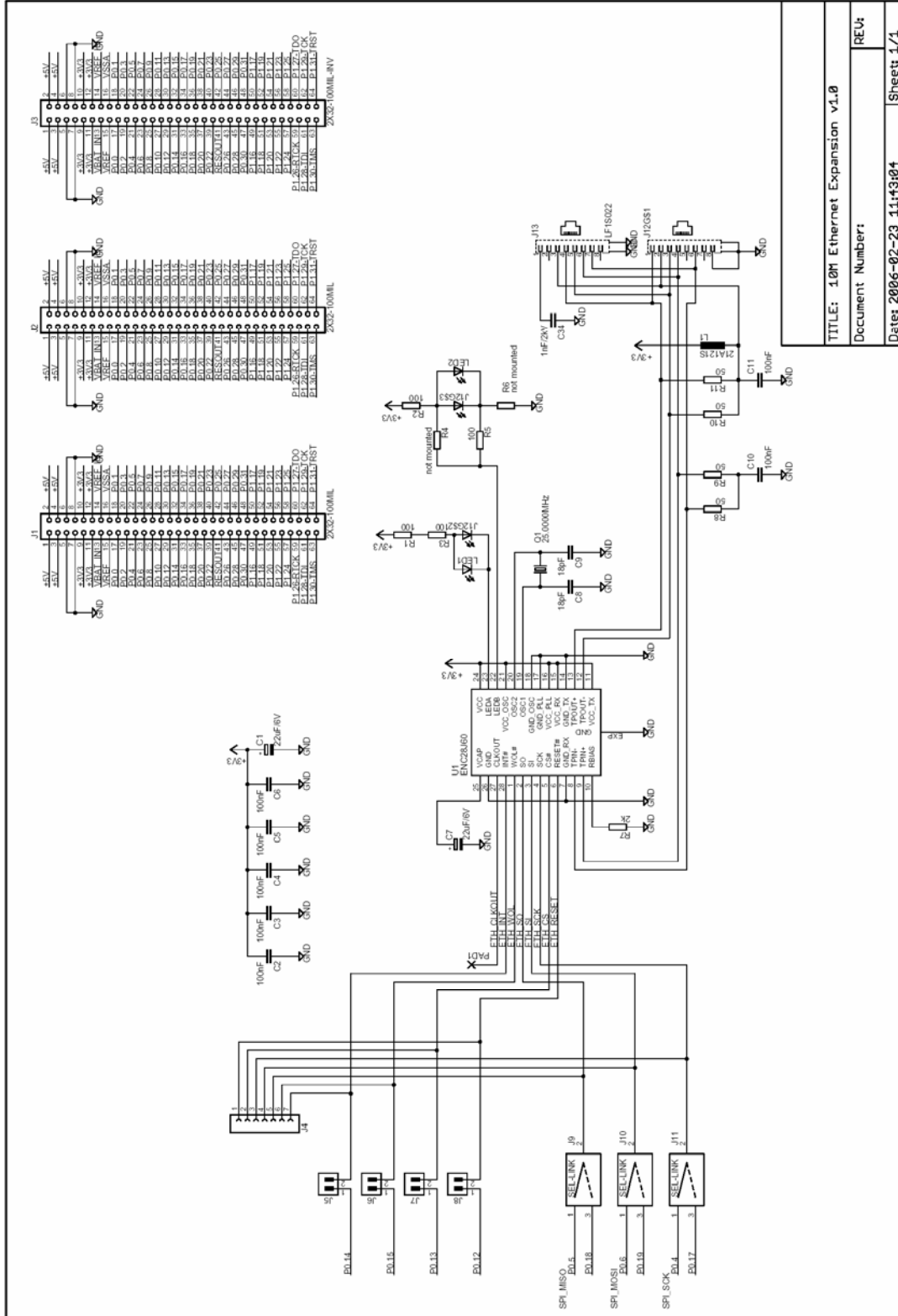


Figure 28 – 10M Ethernet Expansion Board Schematic

The design is centered on the ENC28J60 Ethernet controller from Microchip. It's a very nice chip with SPI interface. Only 6 signals are needed (4 for SPI channel, reset and interrupt). The datasheet of the chip explain all details. Especially note the errata sheet that indicates a minimum SPI clock frequency of 8 MHz. This is not possible to achieve with SPI channel #0, but luckily it is with the SSP channel (also commonly referred to as SPI channel #1). If SPI channel #0 is used it is alternatively possible to create a software workaround for the problem (simple read the PHY-registers after a write operation – rewrite the value if not correct).

It is possible to select with jumpers which SPI channel to connect the ENC28J60 to, see picture below.

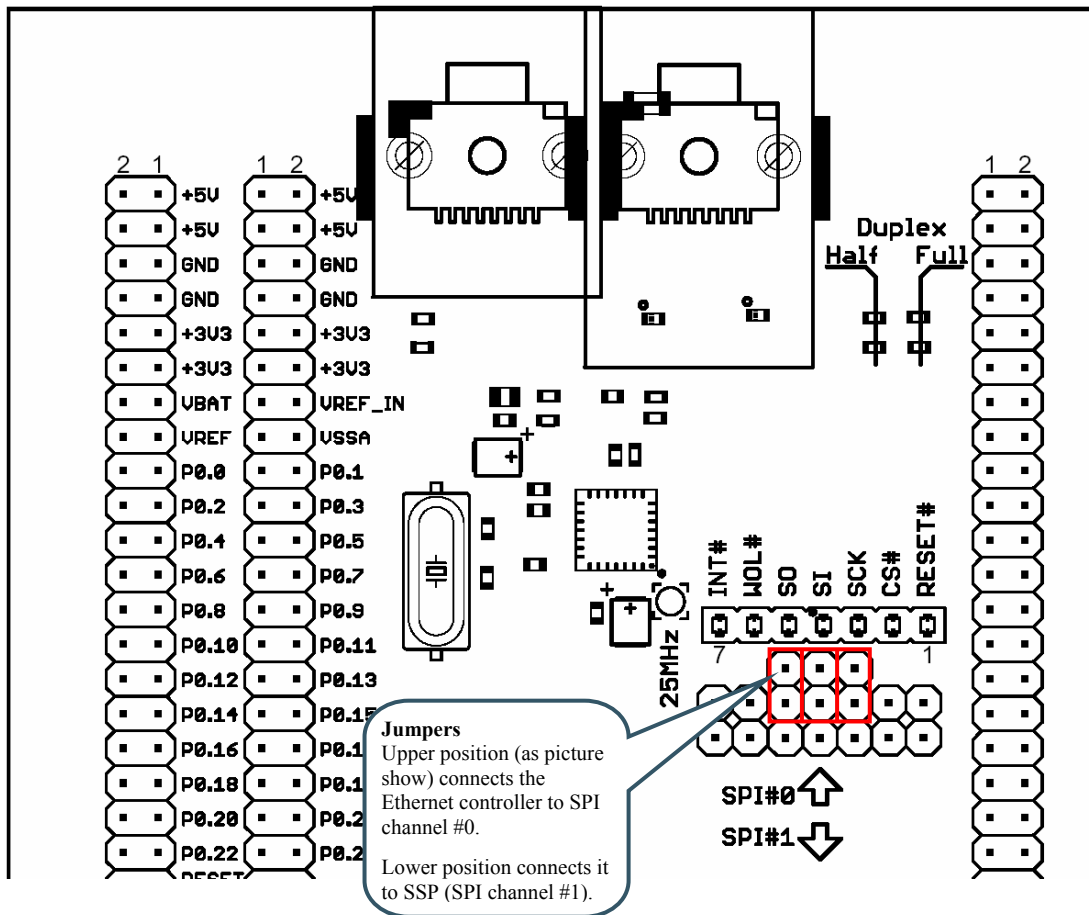


Figure 29 – 10M Ethernet Expansion Board Jumpers

The *10M Ethernet Expansion Board* power consumption is low enough to let the USB power (of the *LPC2148 Education Board*) also feed this expansion board, i.e., no external power supply is needed for this board.

7 App.B – Bluetooth Expansion Board

This chapter contains detailed information about the electrical design of the board.

7.1 Board Schematics

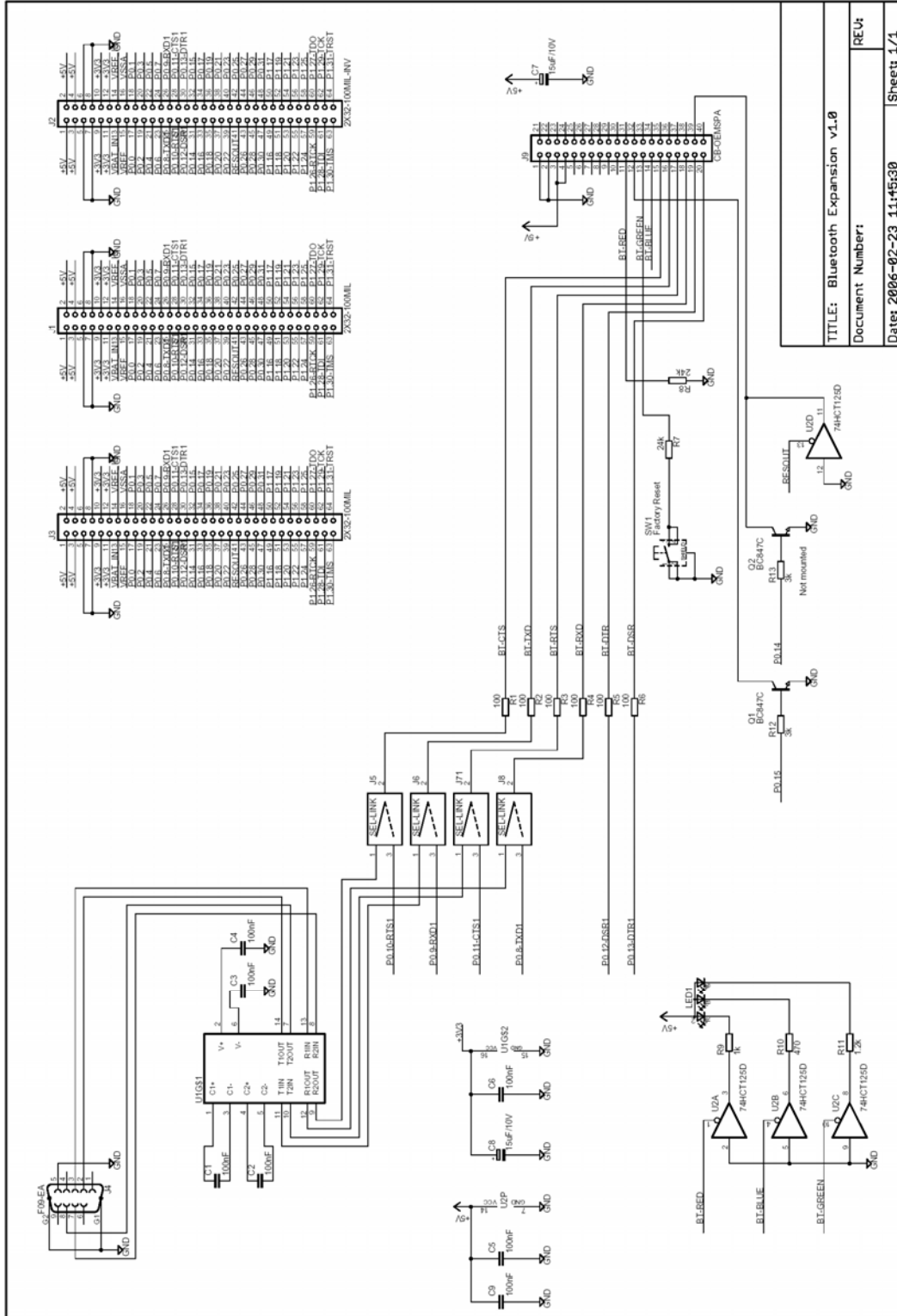


Figure 30 – Bluetooth Expansion Board Schematic

The main part of the design is to interface the *LPC2148 Education Board* to the Bluetooth module from connectBlue. The Bluetooth module is unique in the sense that it is a complete product that is Bluetooth qualified (all Bluetooth products on the market must be certified to the Bluetooth standard, and this is called Bluetooth qualification). Products based on these modules from connectBlue do not require any further Bluetooth qualification.

Download product documentation from connectBlue's homepage for details about the Bluetooth modules, <http://www.connectblue.com>.

Two different Bluetooth module series can be used; OEMSPA1x/3x or OEMSPA31x/33x. The *Bluetooth Expansion Board* is delivered with either OEMSPA13i or OEMSPA31i. They are compatible in most aspects.

The *LPC2148 Education Board* communicates with the Bluetooth module via UART #1. Some of the modem signals can be used but are not required. The serial interface to the modules is programmable. The default is to use RTS/CTS flow control but this can be disabled by software.

It is possible to communicate directly with the Bluetooth module via the on-board RS232 interface. Communication can take place via a simple terminal program or via an external application program. The default communication setting is 57.6 kbps, 8N1, RTS/CTS flow control. Note that the Bluetooth module will get default values (i.e., factory reset values) by pressing the switch during power-up of the module.

When placing the four jumpers to the DSUB side, the module's serial channel is connected to the on-board RS232 serial interface (i.e., the DSUB). When the jumpers are to the module's side, the serial channel is connected to the LPC2148's UART #1. See picture below for details.

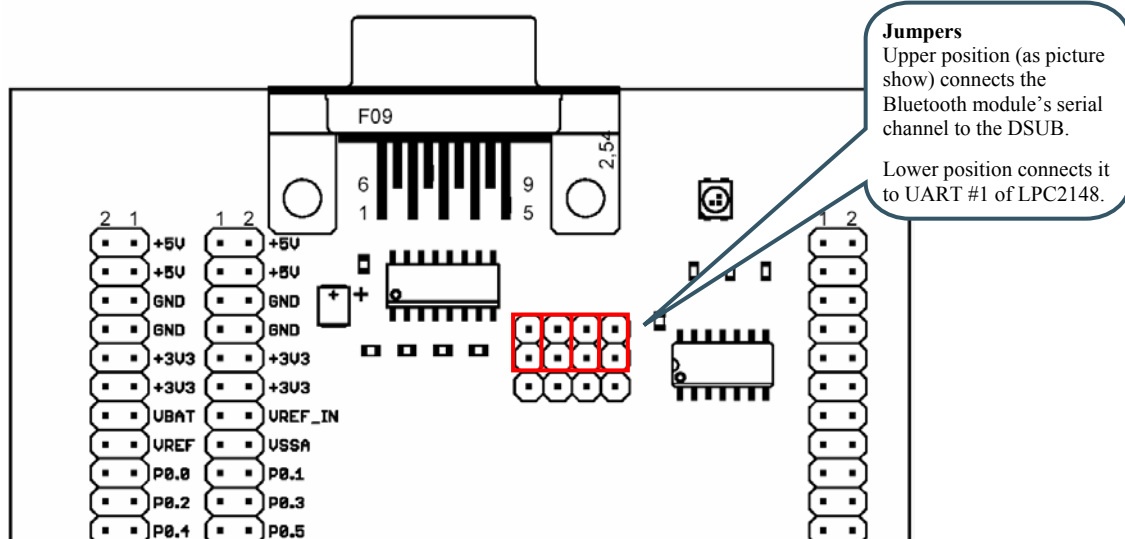


Figure 31 – Bluetooth Expansion Board Jumpers

Note that the rest control of P0-.14 is not active. The transistor base resistor is not mounted.

Communication status is indicated via a RGB-LED. See the module's documentation for details.

The Bluetooth module is powered with +3.3V from the *LPC2148 Education Board*. USB powering (of the *LPC2148 Education Board*) is typically possible since the peak current consumption of the Bluetooth module is 150 mA (peak current is 70 mA for OEMSPA311i).

8 App.C – Graphical LCD Expansion Board

This chapter contains detailed information about the electrical design of the board.

8.1 Board Schematics

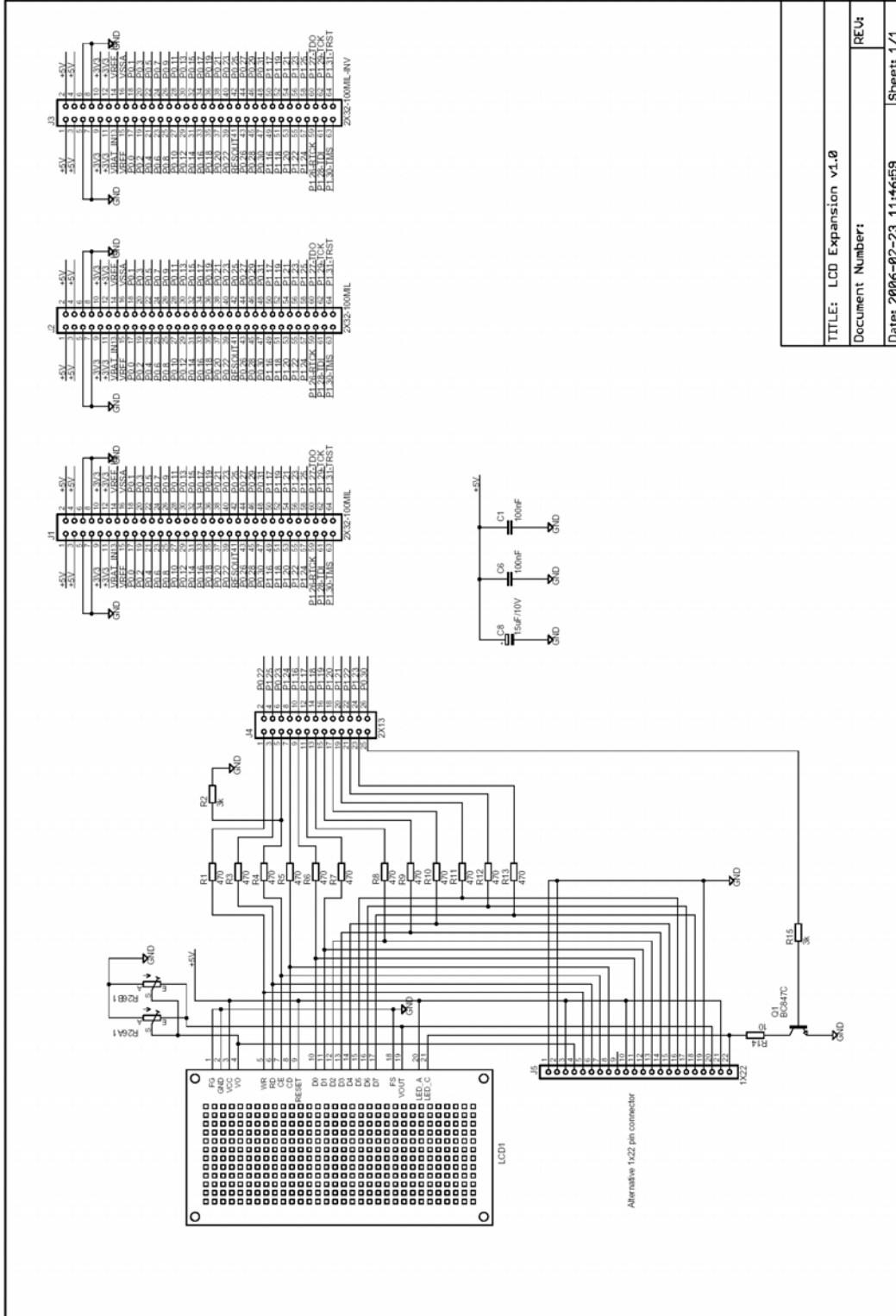


Figure 32 – Graphical Expansion Board Schematic

The graphical monochrome display has 240x128 pixels and contains an on-board LCD controller based on T6963C from Toshiba. The controller has a standard 8-bit parallel MCU interface. The LPC2148 must simulate this interface since it has no external address/databus.

13 pins are needed to create an 8-bit interface; 8 data bits (D0-D7), 1 address bit (CD), 1 read signal (RD), 1 write signal (WE), and 1 chip enable signal (CE). It's also possible to control the backlight via signal P0.30. All pins can be disconnected from the LPC2148 pins, if needed, by removing the jumpers.

The pins used for this interface are the same as for creating the bus interface to the 16x2 character LCD on the *LPC2148 Education Board*. Therefore it is important to note that all jumpers for the LCD interface on the *LPC2148 Education Board* must be removed before the *LCD Expansion Board* is connected. See picture below.

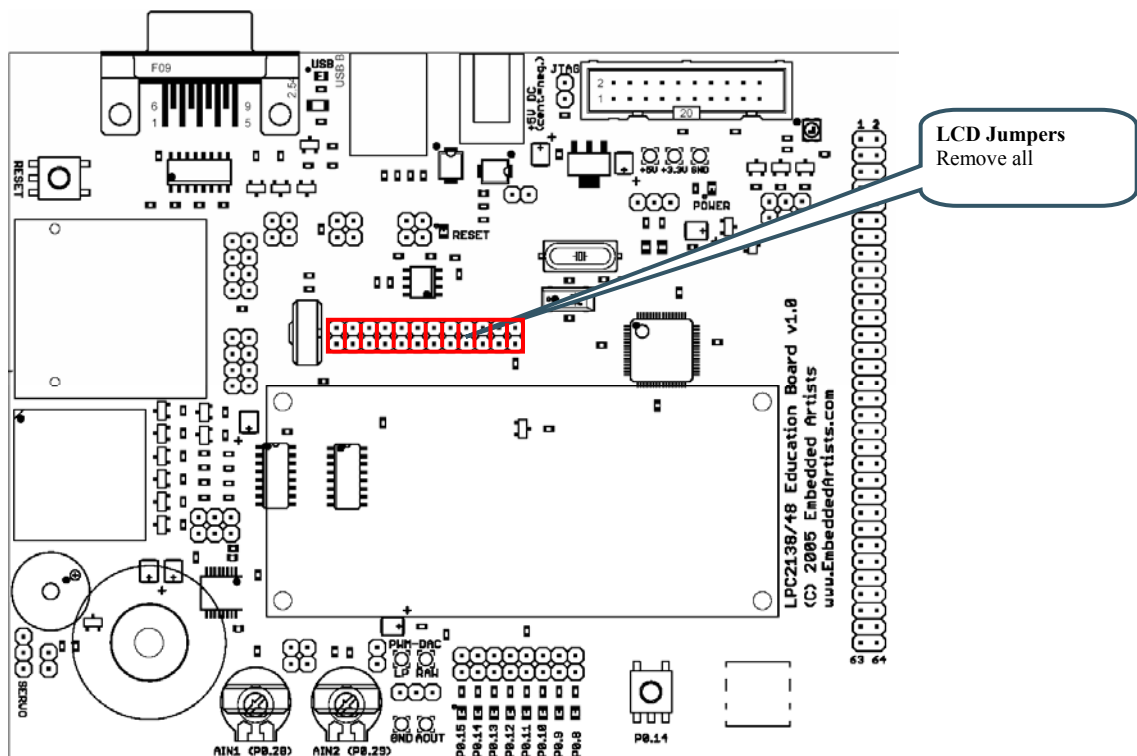


Figure 33 – LCD Jumpers on LPC2148 Education Board

It's possible to adjust the display contrast with a small trim-potentiometer on the *LCD Expansion Board*.

The LCD is powered from the +5V power supply. +5V power is no problem since all pins on the LPC2148 are +5V tolerant and a high logic level from the CPU (powered by +3.3V) is also interpreted as a high logic level by the LCD. Display contrast is adjusted via trim-potentiometer R53.

There are two different connectors for the display on the LCD Expansion Board. One has 21 pins and the other has 22 pins. This is just for allowing more options when selecting the LCD. The currently used display is the 240 x 128 pixel monochrome graphical LCD SMG210128A from Sunman.

9 App.D – UART & RS485 Expansion Board

This chapter contains detailed information about the electrical design of the board.

9.1 Board Schematics

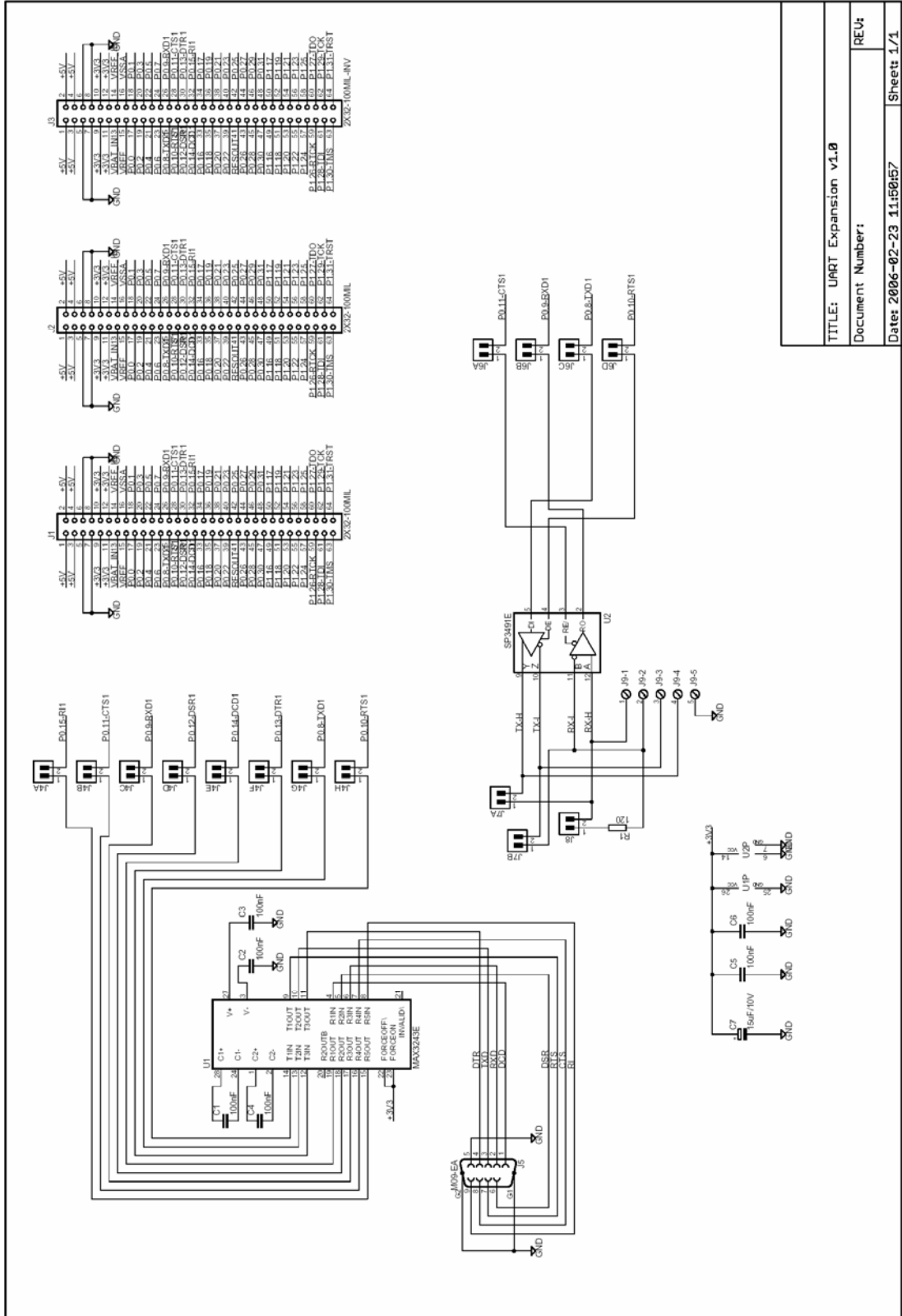


Figure 34 – UART & RS485 Expansion Board Schematic

The *UART & RS485 Expansion Board* contains the SP3243E full modem RS232 interface and the SP3491E RS422/485 interface from Sipex. Both interfaces include on-chip ESD protection.

The LPC2148 communicates with the *UART & RS485 Expansion Board* via UART channel #1. Note that both interfaces cannot be used at the same time since UART #1 is used by both interfaces. All signals in UART #1 (i.e., P0.8 – P0.15) can be disconnected by removing jumpers.

The RS232 interface contains control for all signals. The DSUB is a male connector.

The RS485 interface can actually be used as either a RS422 or RS485 interface. If jumpers J7A/B are inserted the Rx and Tx lines are connected and the interface is a RS485 interface (i.e., a half-duplex two-wire interface). If the jumpers are removed the Rx and Tx signals are separated (i.e., a full-duplex 4-wire interface).

With jumper J8 it is possible to add a 120 ohm termination resistor, which some applications need.

The interface circuits are powered with +3.3V from the *LPC2148 Education Board*.

10 App.E – MP3 Decoder Expansion Board

This chapter contains detailed information about the electrical design of the board.

10.1 Board Schematics

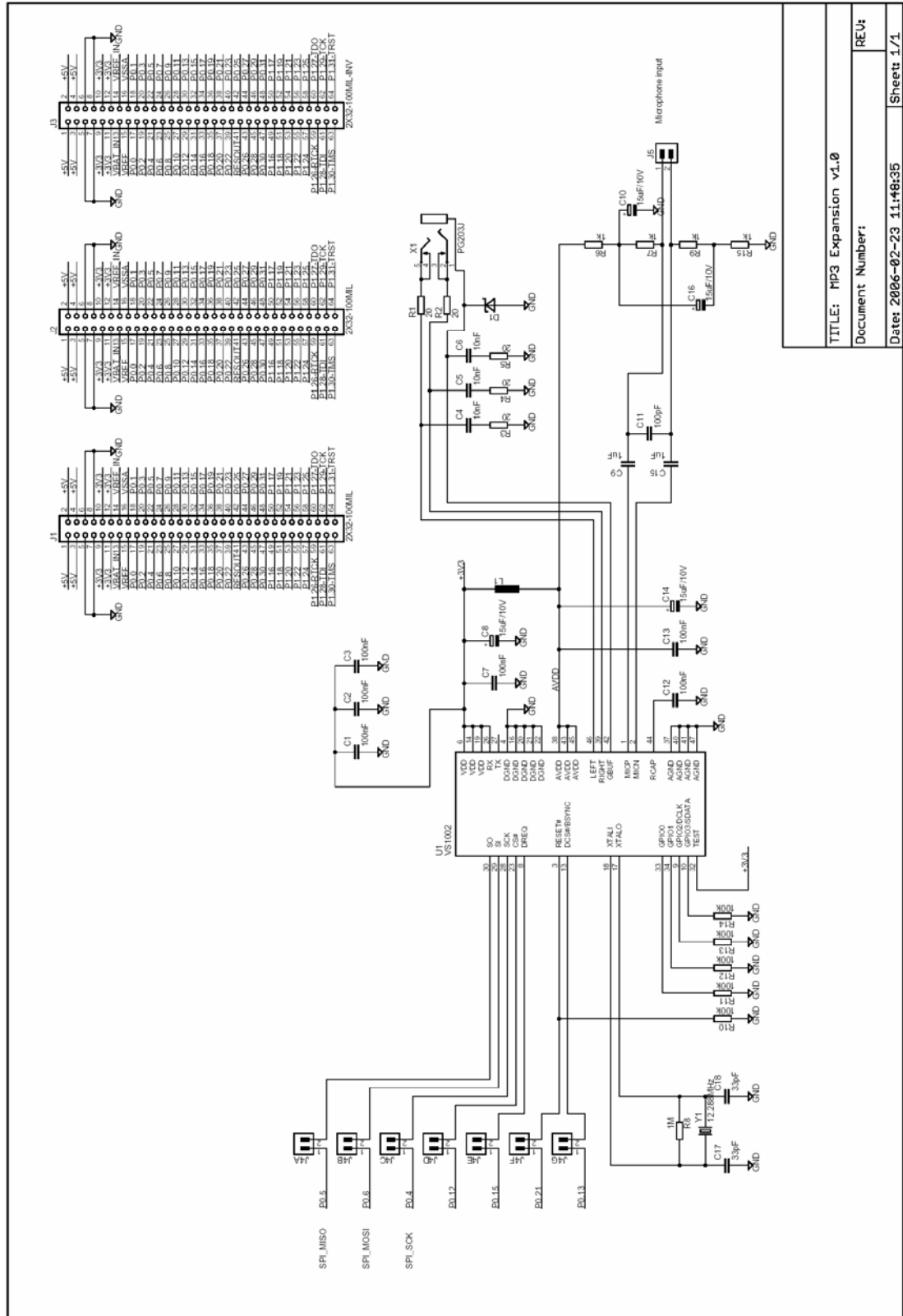


Figure 35 – MP3 Decoder Expansion Board Schematic

TITLE: MP3 Expansion v1.0
 Document Number:
 Date: 2006-02-23 11:48:35
 REV:
 Sheet 1/1

The *MP3 Decoder Expansion Board* is based on the well-known MP3 decoder chip vs1002 from VLSI (<http://www.vlsi.fi>). The LPC2148 communicates with the vs1002 decoder chip module via SPI channel #0. Four other signals (other than the three SPI signals) are needed for the interface. See the vs1002 datasheet for details about the interface.

The audio is available via a 3.5mm headphone connector. No external amplifier is needed for small headphones. A microphone input is also available (note that microphone is not included) for recording audio. The circuit is powered with +3.3V from the *LPC2148 Education Base Board*.

11 App.F – ZigBee Expansion Board

This chapter contains detailed information about the electrical design of the board.

11.1 Board Schematics

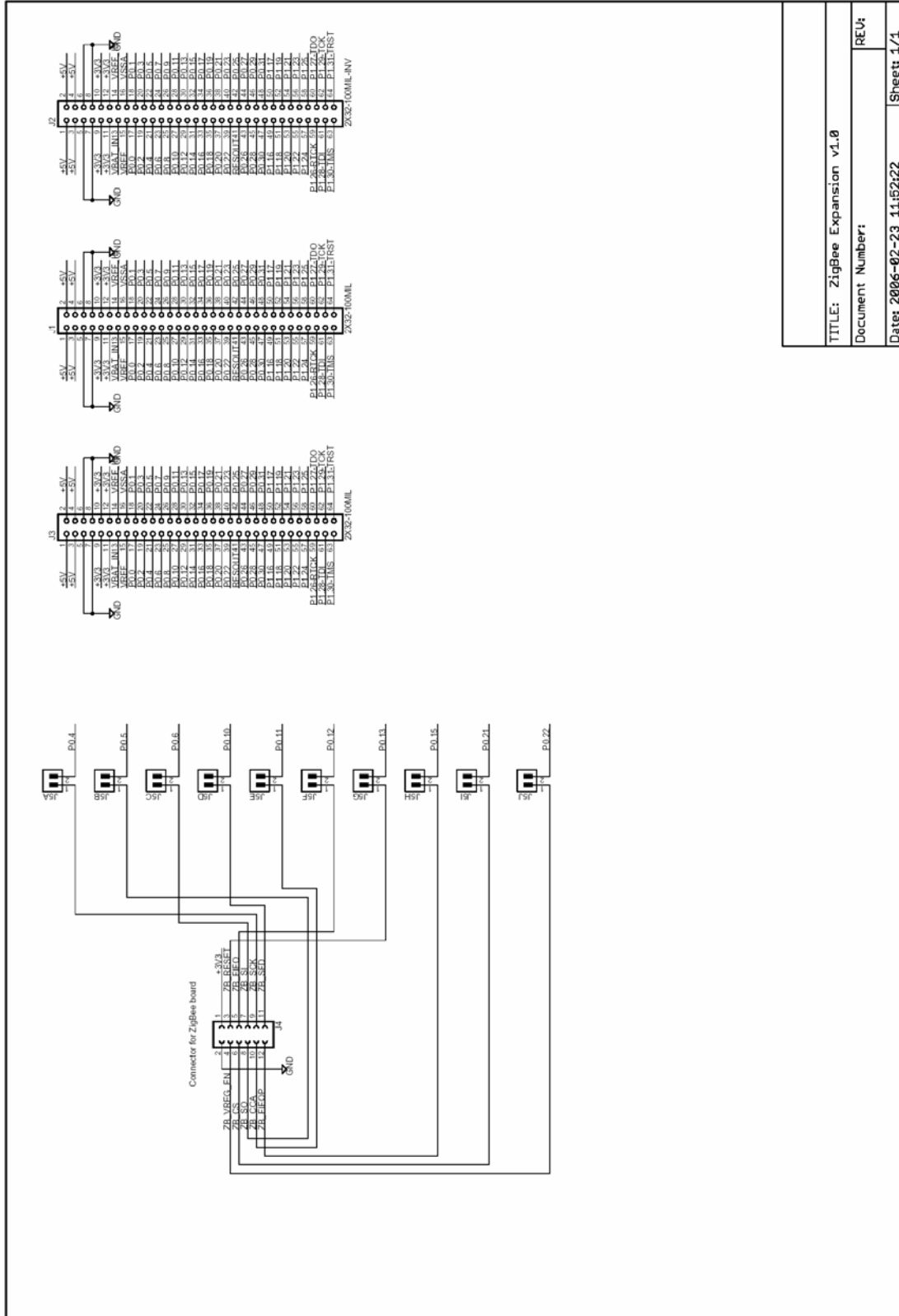


Figure 36 – ZigBee Expansion Board Schematic

The *ZigBee Expansion Board* is based on the well-known RF-circuit CC2420 from Chipcon/Texas Instruments (<http://www.chipcon.no>). The LPC2148 communicates with the ZigBee interface via SPI channel #0. The interface is 10 signals in total. See the CC2420 datasheet for details about the interface.

The CC2420 and all RF parts of the design are placed on a separate board (2.4GHz RF card AC163027-2 from Microchip). The schematic above only illustrates the signals to the connector to the RF board. Detailed schematic for the RF board is delivered when purchasing the *ZigBee Expansion Board*.

The circuit is powered with +3.3V from the *LPC2148 Education Base Board*.

12 App.G – Prototype Expansion Board

This chapter contains detailed information about the electrical design of the board.

12.1 Board Schematics

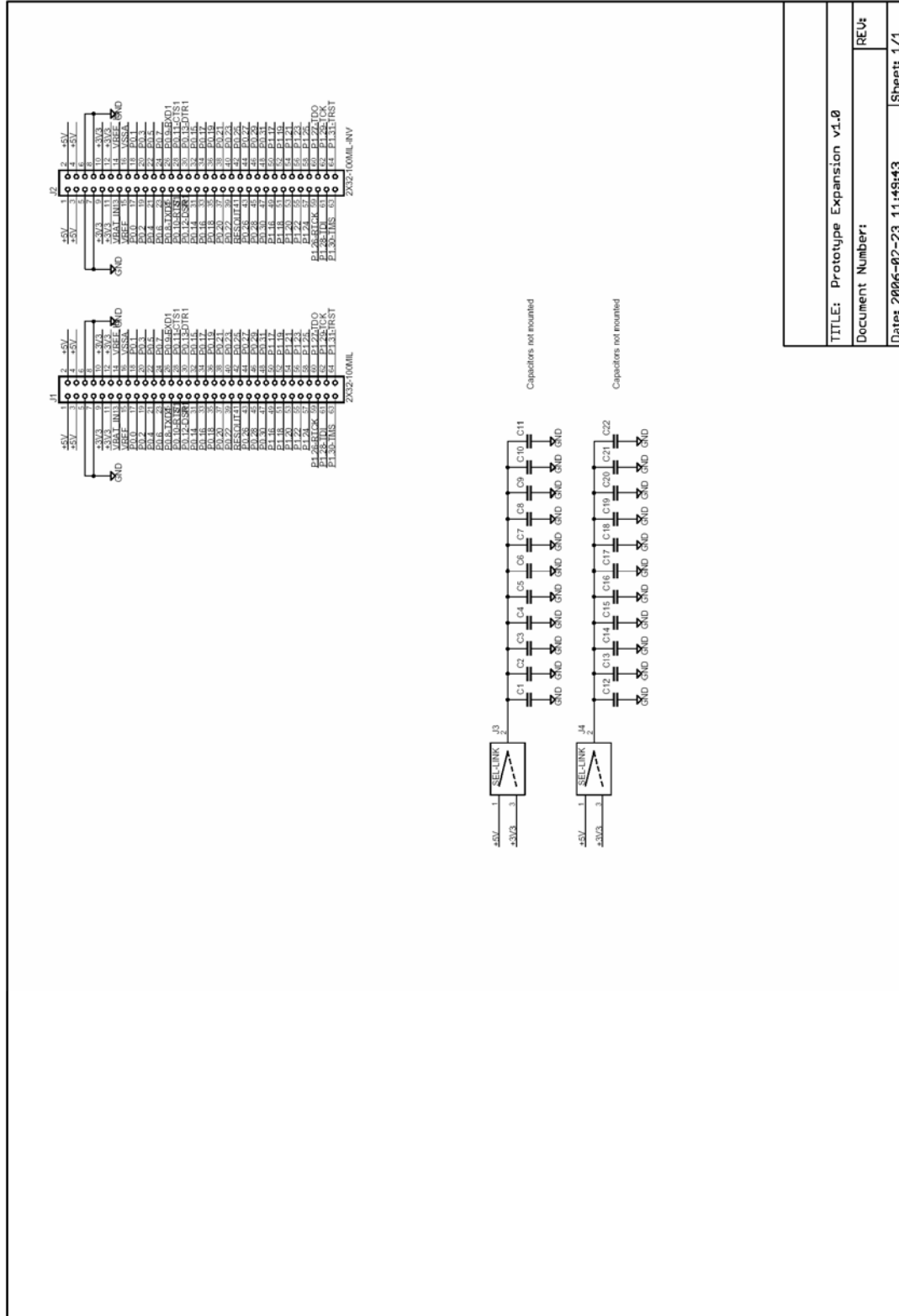


Figure 37 – Prototype Expansion Board Schematic

The *Prototype Expansion Board* allows you to build your own design and interface it to the *LPC2148 Education Board*. All signals on the expansion connector can easily be accessed.

The board contains a large 100 mil prototype area, a smaller 50 mil prototype area, two 50 mil areas for SOIC chips, and a 0.65 mm area for SSOP chips.

Solder pads for bypass capacitors are placed between the solder pad rows for the SOIC areas. It is possible to feed these bypass capacitors with either +3.3V or +5V, selectable via two jumpers. See electrical schematic above.