Embedded Systems Design
Modules Reference Manual

ICOM4217

Electrical & Computer Engineering Department
University of Puerto Rico at Mayagüez
Mayagüez, PR 00681-9000

Danilo Rojas Manuel Jiménez

2016

Electrical and Computer Engineering Department
University of Puerto Rico at Mayagüez

ACKNOWLEDGMENT

The authors would like to thank Cesar A. Aceros, for his help creating the Latex template for the manual.

DISCLAIMER

Table Of Contents

Module 1

Basic I/O Module

1.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 1.1.

Table 1.1: Boom of materials Module 1

Item	Qty	Description	P/N reference	Supplier
1	4	Pushbutton Case	SW259-ND	DIGI-KEY
2	4	Jumper x5	970	POLOLU
3	2	Piezoelectric Buzzer	810-PS1240P02CT3	MOUSER
4	1	0.1uF Tantalum	581-TAP104K035SCS	MOUSER
5	1	1x40 Male Header	965	POLOLU
6	1	2x40 Male Header	966	POLOLU
7	1	Diode 1N4004	512-1N4004	MOUSER
8	1	Display LCD 2x16	932-MIKROE-55	MOUSER
9	1	Green LED 5mm	67-1098-ND	DIGI-KEY
10	1	Yellow LED 5mm	67-1111-ND	DIGI-KEY
11	2	Red LED 5mm	67-1105-ND	DIGI-KEY
12	1	10K Round Pot	652-3319P-1-103	MOUSER
13	1	1k Ohm Resistor	660-MF1/4LCT52R102J	MOUSER
14	1	2.2k Ohm Resistor	660-MF1/4LCT52R222J	MOUSER
15	1	510 Ohm Resistor	660-MF1/4LCT52R511J	MOUSER
16	2	4.7k Ohm Resistor	660-MF1/4LCT52R472J	MOUSER
17	4	330 Ohm Resistor	660-MF1/4LCT52R331J	MOUSER
18	4	Pusbutton	653-B3F-4050	MOUSER
19	1	2N3904 NPN Transistor	512-2N3904BU	MOUSER

1.2 Description

The basic I/O module is composed of 4 main blocks. It provides access to the most common electronic peripherals such as pushbuttons, LEDS, display LCD, and Buzzer. Figure 1.1 shows the block diagram of the basic I/O module and its four blocks (16x2 LCD display, 4 LEDS, 4 Pushbuttons, and Buzzer). This module is intended to work with either 3.3V and 5V microcontrollers and it is also designed to allow direct interfacing to the MCU with no intermediate components.

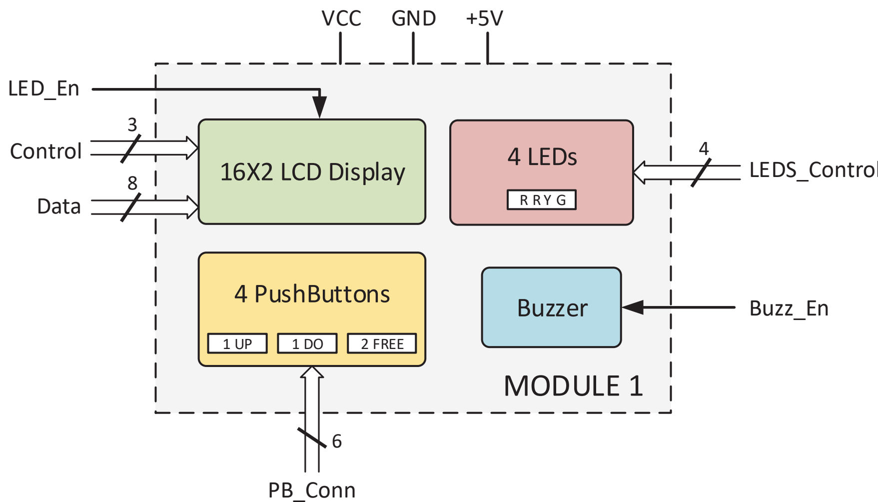

Figure 1.1: Module 1 Block diagram

The schematic of the module is illustrated in Figure 1.7 where all the connections between the different electronics components are depicted. In addition the board layout, divided into components layer, top layer, and bottom layer, can be observed in Figure 1.8, Figure 1.9, and Figure 1.10 respectively. Finally, a real board representation of the EM is presented in Figure 1.11. This representation shows the real board to be used in the development of the laboratory experiments.

1.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must take into account the operation voltage of your MCU. Although some components in the module were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. If your MCU works at 3.3V, you must connect all the power supply pins labeled on the board: 5V, VCC, and GND (using 3.3V for VCC). Also, the jumper in pinheader JP6 must be removed. But, if you are using a 5V microcontroller, you only need to connect one of the two power supply pins (5V or VCC) and put a jumper in pinheader JP6. The power supply pins are highlighted in Figure 1.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

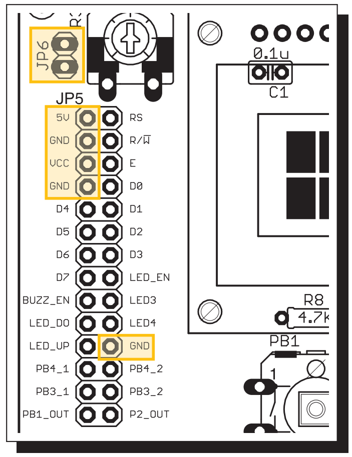

Figure 1.2: Module 1 Power supply pins

1.2.2 16X2 LCD Display

This block is provided with a removable LCD screen (2 lines x 16 characters), 1 10KΩ potentiometer, and a 2N3904 NPN transistor as depicted in Figure 1.3.

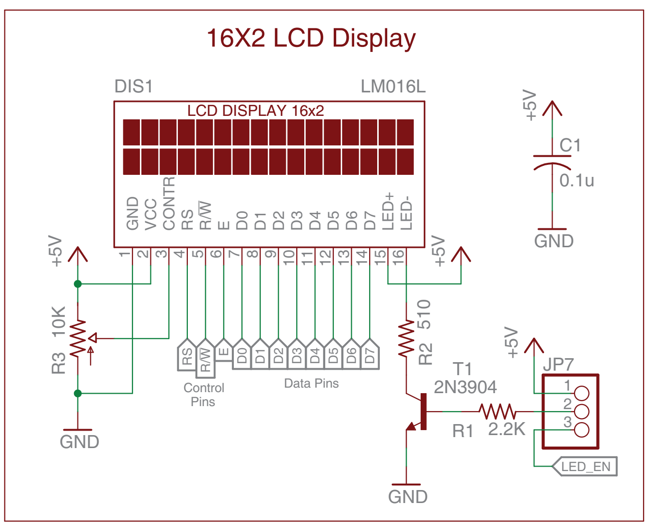

Figure 1.3: 16X2 LCD Display Schematic

To use this block, you need to adjust the LCD's brightness, define the desired operation of the LCD (4-bits or 8-bits), and determine if you want to control the LCD's back-light operation. Follow the steps outlined below to setup this block:

1. To adjust the LCD brightness, you must turn-right or turn-left the potentiometer R3.

2. To define the operation of the back-light, you need to put a jumper between 2 of the three pins on the pinheader JP7. If you put the jumper between the middle pin and the 5V pin, the back-light will permanently be On. But, if you insert the jumper between the middle pin and the LED_EN pin, it will provide you control to the turn On/Off operation. This turn On/Off operation is carried out by a 2N3904 NPN transistor (T1) and a 510Ω resistor (R2). This interface allows to turn-On the back-light with a logic 1 and turn it Off with a logic 0, through the LED_EN pin.

3. To control the LCD display, you must define the desired operating mode. If you want to use the 4-bit mode you must connect the control lines (RS, R/$\overline{\text{W}}$ and E) and the four higher Data lines (D4-D7) to your MCU. But, if you want to use the 8-bit mode you must connect the control lines and all Data lines. The pinheader JP5 allow the connection between the LCD pins and your MCU pins (see Figure 1.7).

1.2.3 4 LEDs

This block provides access to 4 LEDs, two in fixed configuration and two in re-configurable configuration, as depicted in Figure 1.4.

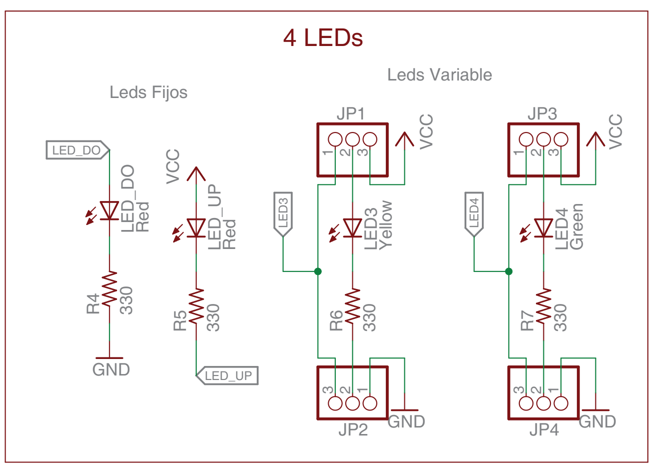

Figure 1.4: 4 LEDs Schematic

To use this module you need to connect your MCU to all the LEDs and set the operating mode of the two re-configurable LEDs. Follow the steps outline below to setup this block:

1. To use the fixed LEDs you must connect your MCU to the pins LED_DO and LED_UP located in pinheader JP5. The LED1 is wired in a pull-down

configuration meaning that it needs a logic 1 to turn it On and logic 0 to turn it Off. On the other hand, LED2 is wired in a pull-up configuration meaning that it needs a logic 0 to turn it On and logic 1 to turn it Off.

2. To setup the re-configurable LED3 you need to insert jumpers in pinheaders JP1 & JP2 and insert jumpers in JP3 & JP4 to setup the LED4. If you want to use the LED3 in pull-down mode, you need to put a jumper between the middle pin and the LED3 pin in pinheader JP1 and a jumper between the middle pin and the GND pin in pinheader JP2. But, if you want to use the LED in pull-up mode, you need to insert a jumper between the middle pin and the VCC pin in JP1 and a jumper between the middle pin and LED3 pin in JP2. To setup the LED4 you have to perform the same procedure outlined to setup the LED3. Remember that the LED4 uses the pinheader JP3 and JP4 in instead of JP1 and JP2.

1.2.4 4 Pushbuttons

This block provides access to 4 pushbuttons, two in fixed configuration and two in free configuration, as depicted in Figure 1.5.

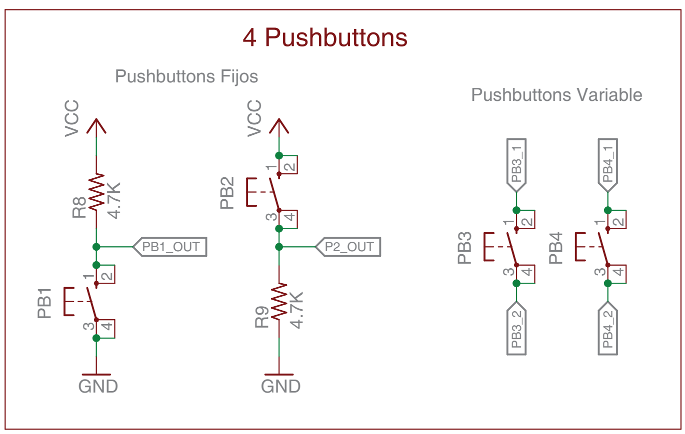

Figure 1.5: 4 Pushbuttons Schematic

To use this module, you need to connect your MCU to all the pushbuttons and set the configuration for the two free pushbuttons. Follow the steps outline below to setup this block:

1. To use the fixed pushbuttons (PBs) you must connect your MCU to the pins PB1_OUT and PB2_OUT in pinheader JP5. The S1 is a PB with a pull-up resistor that constantly sends a logic 1 when it is not depressed and a logic 0

when it is depressed. The output signal can be read in pin PB1_Out. On the other hand, the S2 is a PB with a pull-down resistor meaning that it constantly sends a logic 0 when it is not depressed and a logic 1 when it is depressed. The output signal can be read through pin PB2_out.

2. The two remaining PBs are in free configuration, which means you have to provide external components to use them. The connections pins for each PB are located in JP7. The S3 uses pins PB3_1 and PB3_2 and the S4 uses pins PB4_1 and the PB4_2 for their connections.

1.2.5 Buzzer

This block provides access to a buzzer as depicted in Figure 1.6.

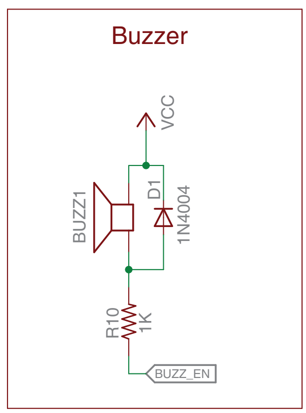

Figure 1.6: BUZZER Schematic

To use this module, you need to connect a pin of your MCU to the BUZZ_EN pin in pinheader JP7, to drive the buzzer. The buzzer needs a sequence of pulses to produce an audible sound. The VCC pin needs to be at the same voltage level of your MCU's operating voltage.

1.3 Schematic

The Figure 1.7 shows the complete schematic of the module were all the connections are described.

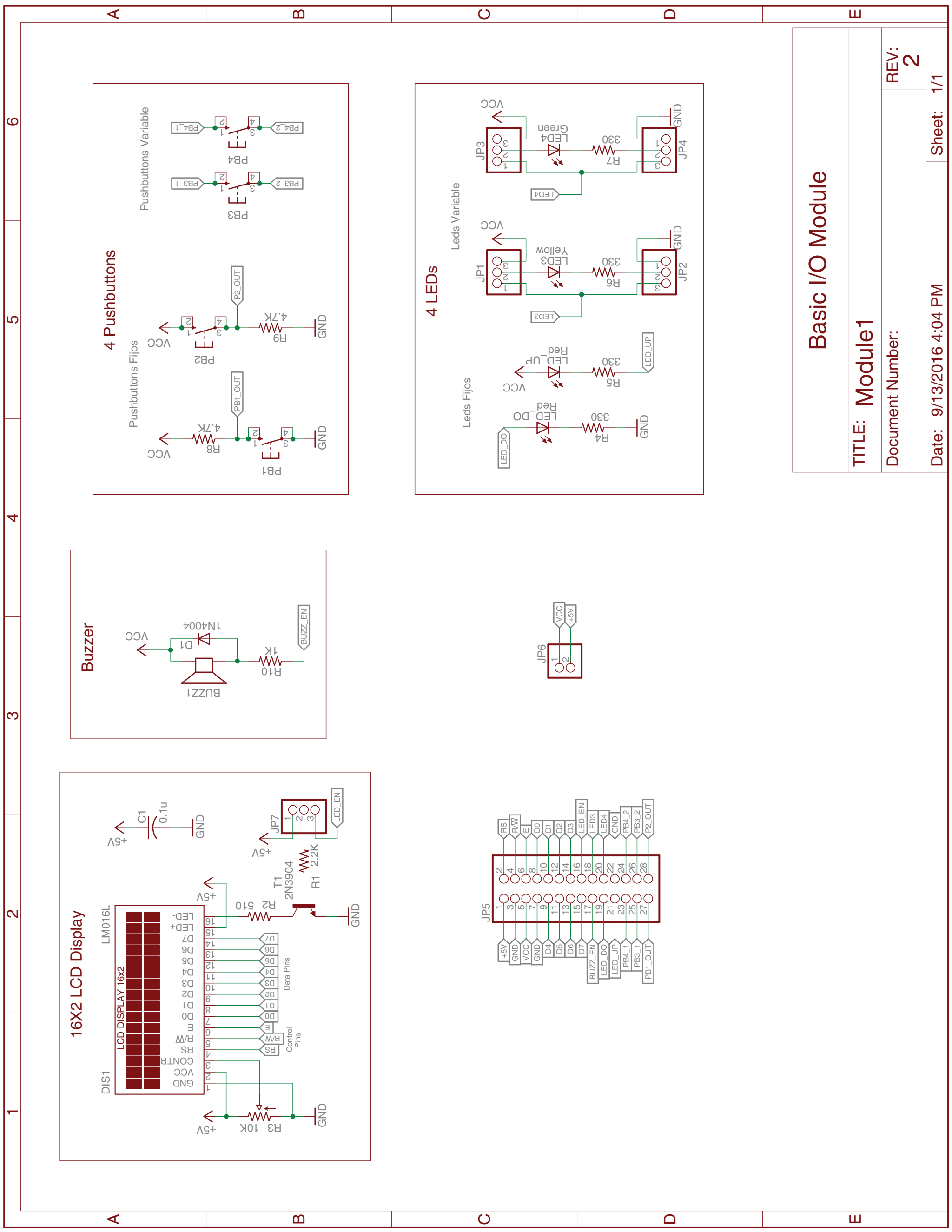

Figure 1.7: Module 1 Schematic

1.4 Board

The Figure 1.8 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

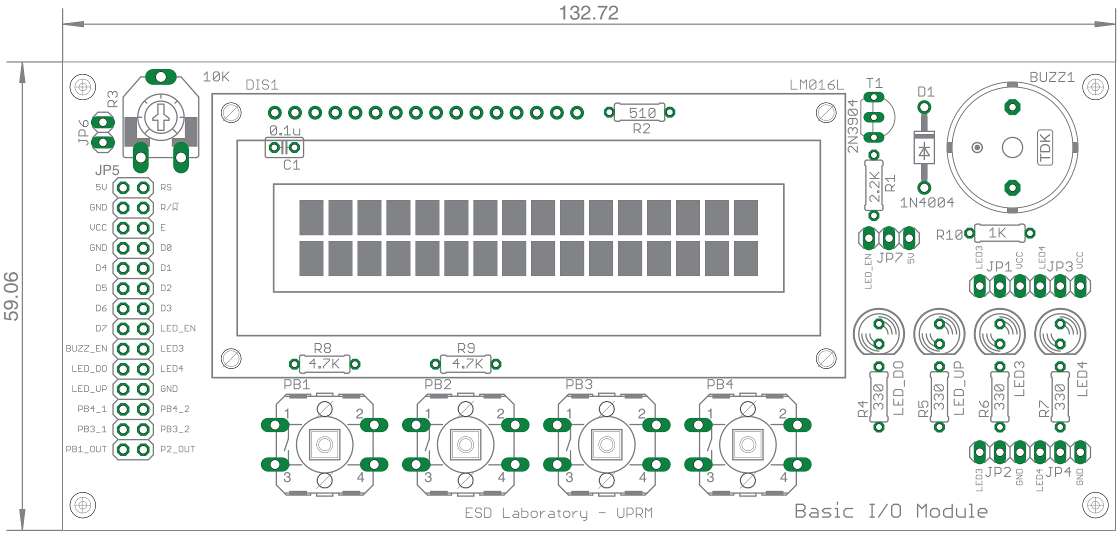

Figure 1.8: Module 1 board - components layer

The Figure 1.9 and Figure 1.10 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

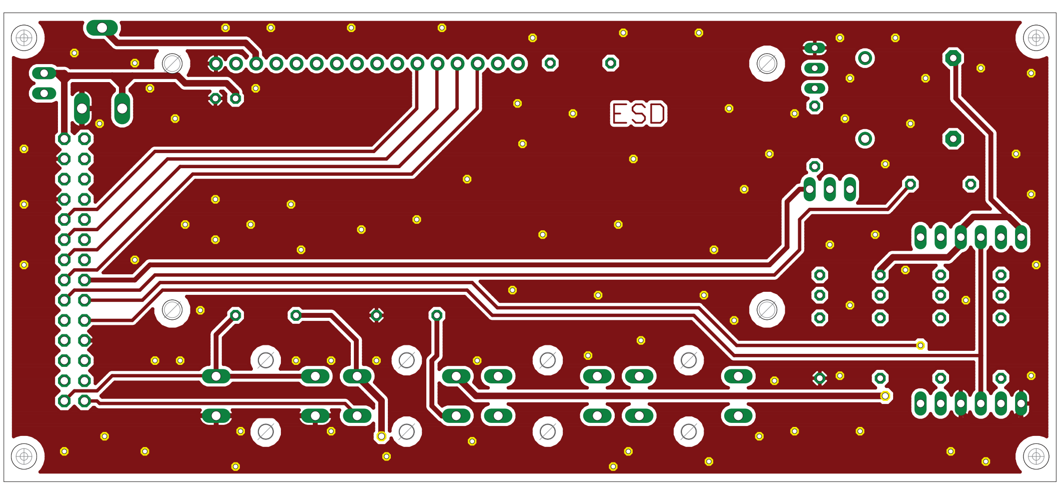

Figure 1.9: Module 1 board - top layer

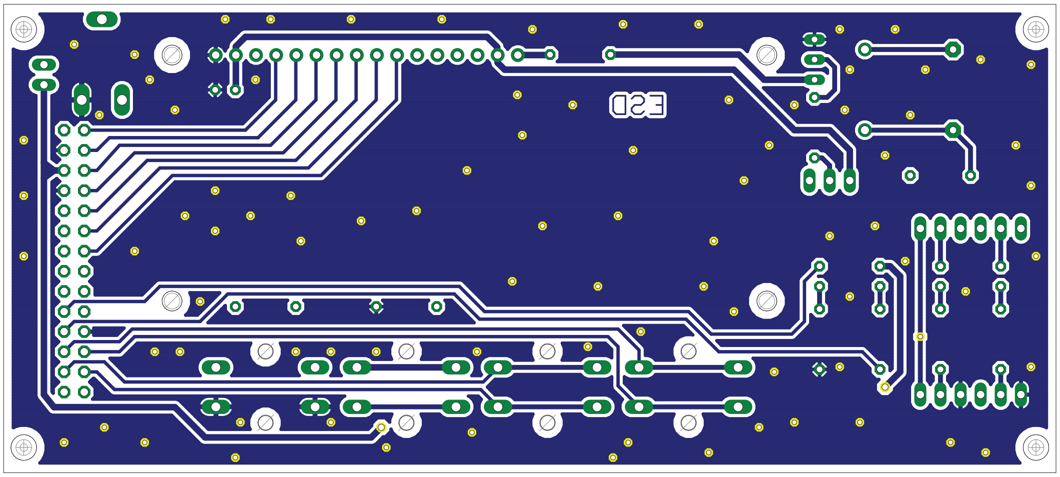

Figure 1.10: Module 1 board - bottom layer

The Figure 1.11 illustrate a real representation of the module's PCB.

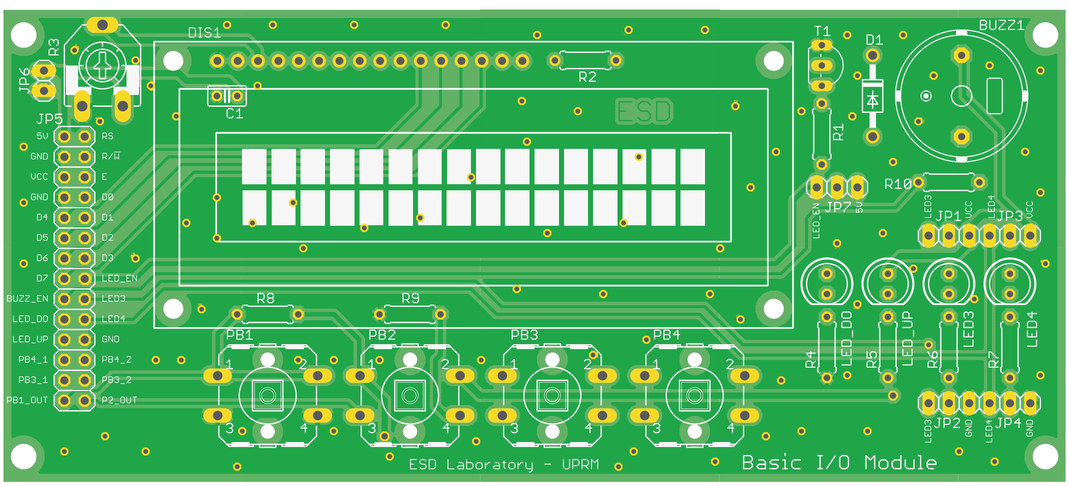

Figure 1.11: Module 1 board

Module 2

Keypad Module

2.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 2.1.

Table 2.1: Boom of materials Module 2

Item	Qty	Description	P/N reference	Supplier
1	1	Jumper x5	970	POLOLU
2	1	1x40 Male Header	965	POLOLU
3	1	1x7 Female Header	1017	POLOLU
4	4	Diode 1N4004	512-1N4004	MOUSER
5	3	4.7K Ohm Resistor	660-MF1/4LCT52R472J	MOUSER
6	1	3x4 Button Keypad	KP-22	All Electronics

2.2 Description

The 3X4 keypad module is composed of 1 main block. It provides access to a one key matrix (keypad). Figure 2.1 shows the block diagram of 3X4 keypad module. This module is intended to work with either 3.3V and 5V microcontrollers and it is also designed to allow direct interfacing to the MCU with no intermediate components.

The schematic of the module is illustrated in Figure 2.4 where all the connections between the different electronics components are depicted. In addition the board layout, divided into components layer, top layer, and bottom layer, can be observed in Figure 2.5, Figure 2.6, and Figure 2.7 respectively. Finally, a real board representation of the EM is presented in Figure 2.8. This representation shows the real board to be used in the development of the laboratory experiments.

2.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must have into account the operation voltage of your MCU. Although some compo-

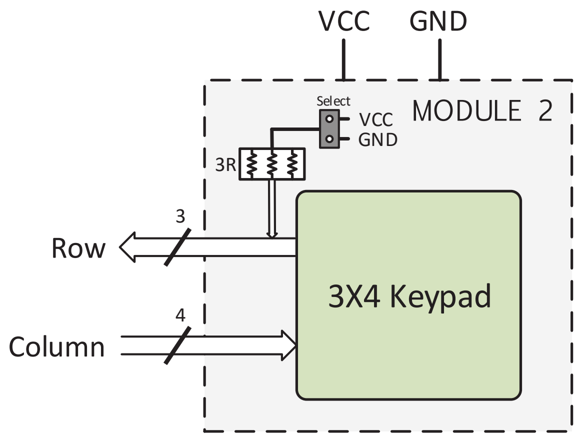

Figure 2.1: Module 2 Block Diagram

nents in the module were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. If your MCU works at 3.3V or 5V, you must connect all the power supply pins labeled on the board: VVC and GND (using the operation voltage of your MCU in VCC). The power supply pins are highlighted in Figure 2.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

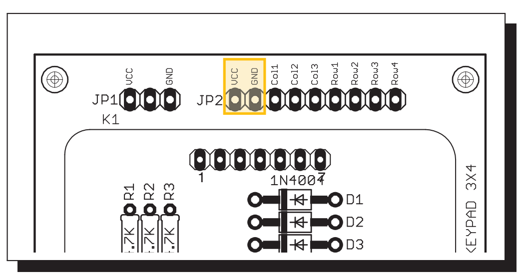

Figure 2.2: Module 2 Power supply pins

2.2.2 3x4 Keypad

This block is provided with a removable 3X4 keypad with 3 pull-up/down resistors, and 4 protection diodes as depicted in Figure 2.3.

To use this block, you need to connect your MCU to all the rows and column pins and select the desired operation for the pull-up/down resistors. To define the operation mode of the resistors, you need to insert a jumper between 2 of the three pins on the pinheader JP1. If you put the jumper between the middle pin and the VCC pin,

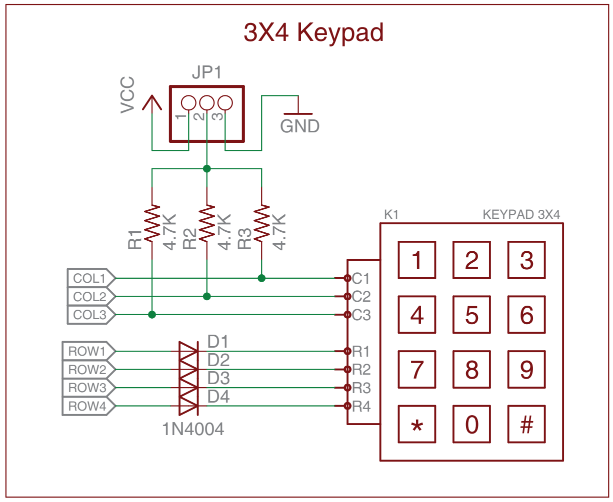

Figure 2.3: 3x4 Keypad Schematic

the resistors will work as pull-up resistors. But, if you insert the jumper between the middle pin and the GND pin, they will work as a pull-down.

Due the configuration of the keypad, if you want to use the resistor in pull-up mode, the diodes (D1 to D4) need to be replaced by shortcuts in their terminals.

2.3 Schematic

The Figure 2.4 shows the complete schematic of the module were all the connections are described.

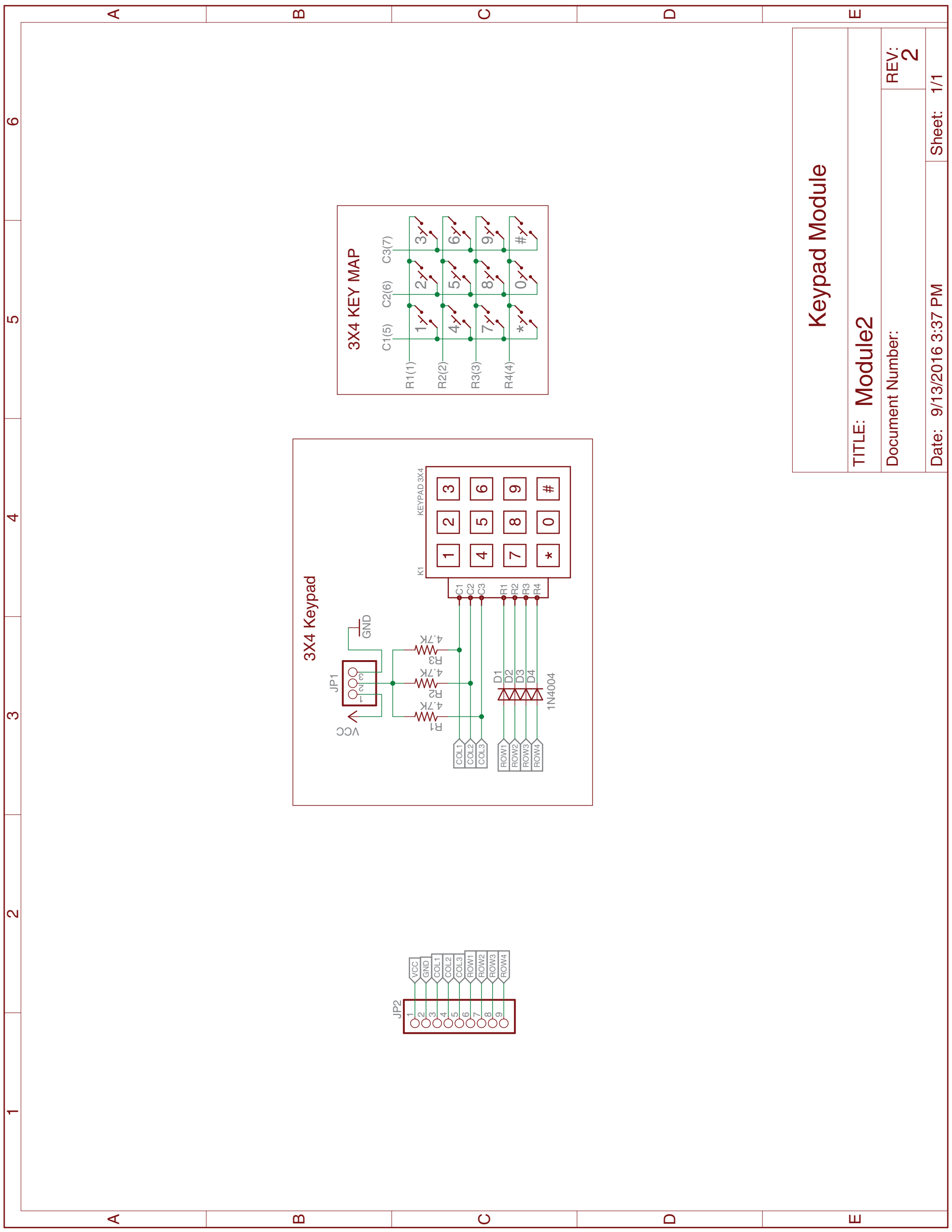

Figure 2.4: Module 2 Schematic

2.4 Board

The Figure 2.5 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

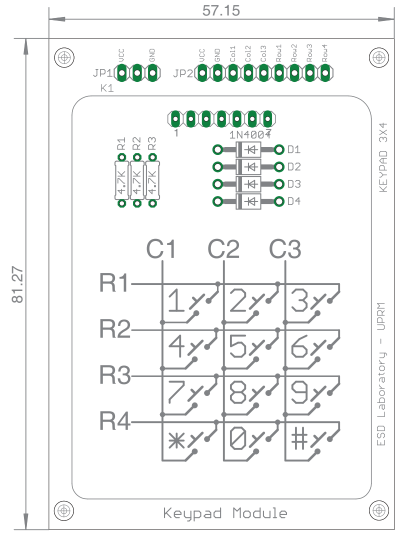

Figure 2.5: Module 2 board - components layer

The Figure 2.6 and Figure 2.7 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

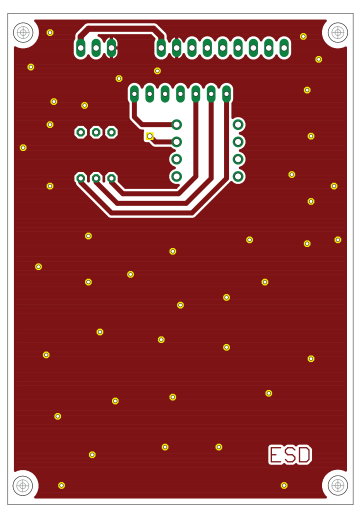

Figure 2.6: Module 2 board - top layer

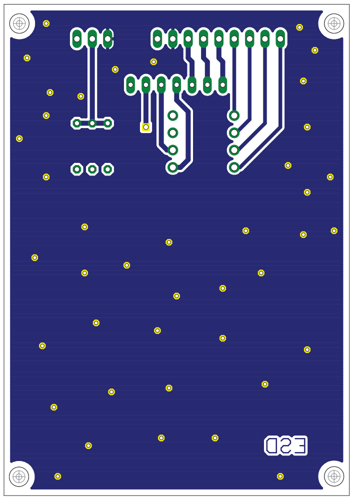

Figure 2.7: Module 2 board - bottom layer

The Figure 2.8 illustrate a real representation of the module's PCB.

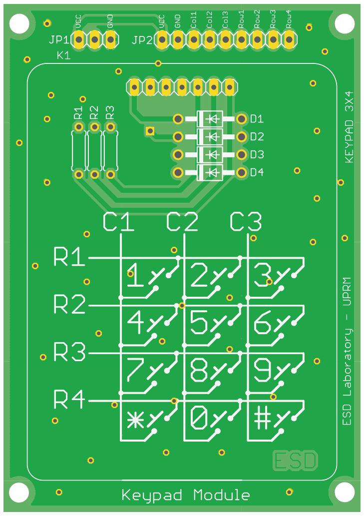

Figure 2.8: Module 2 board

Module 3

Seven Segment Module

3.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 3.1.

Table 3.1: Boom of materials Module 3

Item	Qty	Description	P/N reference	Supplier
1	1	Jumper x5	970	POLOLU
2	1	1x40 Male Header	965	POLOLU
3	1	2x40 Male Header	966	POLOLU
4	1	1x2 Female Header	1012	POLOLU
5	1	1x9 Female Header	1019	POLOLU
6	1	Double 7-Segment	604-DC56-11EWA	MOUSER
7	1	RGB LED 5mm	604-WP154A4SUREQBFZW	MOUSER
8	1	Green LED 3mm	1497-1022-ND	DIGI-KEY
9	1	RPR-220 Optoswitch	755-RPR-220	MOUSER
10	1	12K Ohm Resistor	660-MF1/4LCT52R123J	MOUSER
11	2	220 Ohm Resistor	660-MF1/4LCT52R221J	MOUSER
12	2	1k Ohm Resistor	660-MF1/4LCT52R102J	MOUSER
13	3	510 Ohm Resistor	660-MF1/4LCT52R511J	MOUSER
14	9	330 Ohm Resistor	660-MF1/4LCT52R331J	MOUSER
15	2	2N3906 PNP Transistor	512-2N3906BU	MOUSER

3.2 Description

The seven-segment module is composed of 3 main blocks. It provides access to opto-electronic peripherals such as 7-segment displays, RGB LED, and opto-switches. Figure 3.1 shows the block diagram of the seven-segment module and its three blocks (Dual 7-SEGMENT display, RGB LED, and OptoSwitch). This module is intended to work with either 3.3V and 5V microcontrollers and it is also designed to allow direct interfacing to the MCU with no intermediate components.

The schematic of the module is illustrated in Figure 3.6 where all the connections

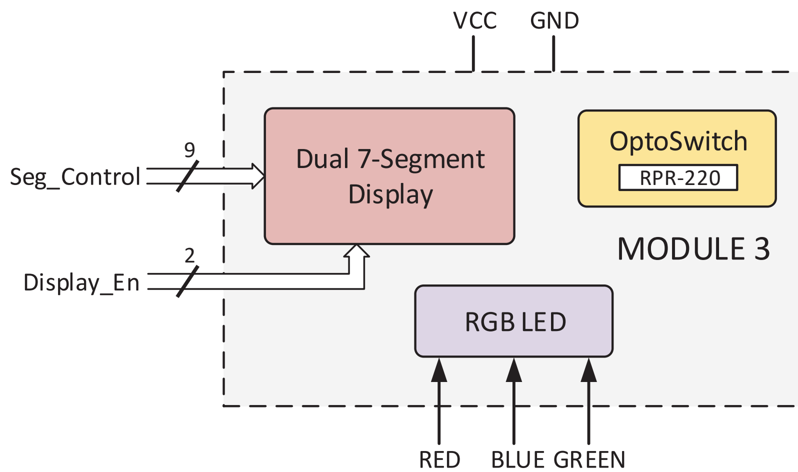

Figure 3.1: Module 3 Block Diagram

between the different electronics components are depicted. In addition the board layout divided into components layer, top layer, and bottom layer, can be observed in Figure 3.7, Figure 3.8, and Figure 3.9 respectively. Finally, a real board representation of the EM is presented in Figure 3.10. This representation shows the real board to be used in the development of the laboratory experiments.

3.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must have into account the operation voltage of your MCU. Although some components in the module were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. If your MCU works at 3.3V or 5V, you must connect all the power supply pins labeled on the board: VVC and GND (using the operation voltage of your MCU in VCC). The power supply pins to be used are highlighted in Figure 3.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

3.2.2 Dual 7-Segment Display

This block is provided with a double 7-segment display, nine limiting current resistors, and two 2N3906 PNP transistor as depicted in Figure 3.3.

To use this block you need to connect your MCU to all the 7-segment segments and determine if you want to control the turn On/Off operation of both 7-segment displays. Follow the steps outlined below to setup this block:

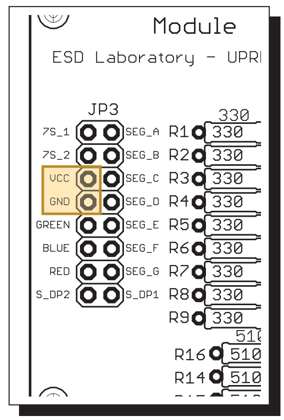

Figure 3.2: Module 3 Power supply pins

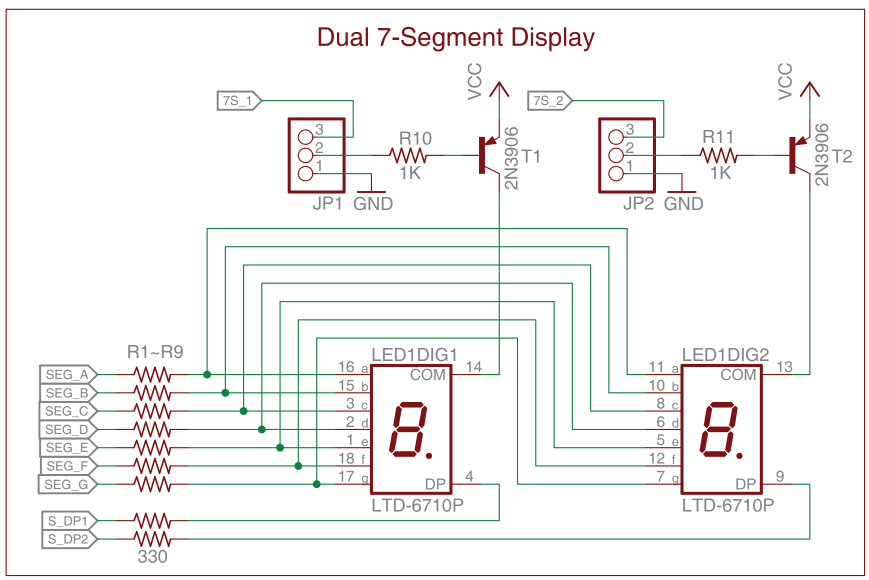

Figure 3.3: Dual 7-Segment Display Schematic

1. To control the displays turn On/Off process, you need to put a jumper between 2 of the three pins in pinheader JP1 for the first display (LED1DIG1) and JP2 for the second display (LED1DIG2). In the case of the LED1DIG1, if you insert the jumper between the middle pin and the GND pin, the display will permanently be On. But, if you insert the jumper between the middle pin and the 7S_1 pin, it will provide you control to the turn On/Off operation. This turn On/Off operation is carried out by a 2N3906 PNP transistors (T1) and a 1 KΩ resistor (R10). This interface allows to turn-On the display with a logic 0 and turn it Off with a logic 1, through the 7S_1 pin. To setup the display LED1DIG2 you need to perform the same procedure used to setup the

LED1DIG1.

2. To activate the segments in both displays you must connect your MCC to the segment pins in the pinheader JP3. The 7-segments displays are common anodes that need a logic 0 to turn On a segment and a logical 1 to turn it Off. The segments between the two displays are connected with the exception of the DP segments pins (S_DP1 and S_DP2).

3.2.3 RGB LED

This block provides access to an RGB (RED-GREEN-BLUE) LED with three limiting current resistors as depicted in Figure ??.

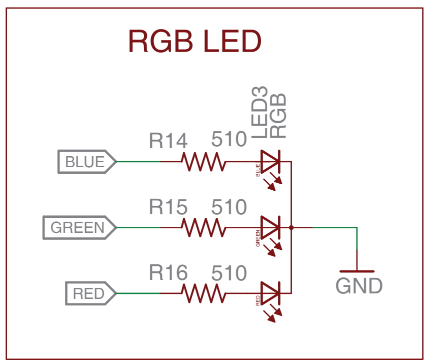

Figure 3.4: RGB Schematic

To use this block you need to connect your MCU to the color control pins BLUE, GREEN, and RED in the pinheader JP3, to drive the RGB LED. The RGB LED is made of common cathode LEDs that needs a logic 1 in one of the three pins to turn-On a particular color and a logic 0 to turn it Off.

3.2.4 OptoSwitch

This block provides access to a standalone RPR-220 optoswitch with a 12KΩ resistor, 330Ω resistor, and a 3mm LED as depicted in Figure 3.5.

This block is used only for demonstrate how the RPR-220 works with the presences of a black or white color object. The RPR-220 has in the transistor collector pin an LED that will turn-On when the sensor detects a white color, otherwise, the LED will turn it Off.

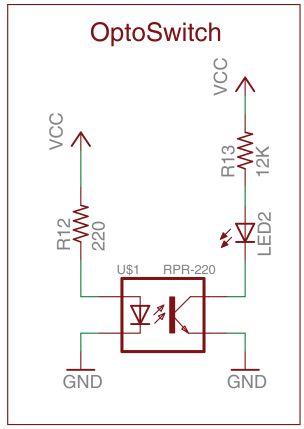

Figure 3.5: Optoswitch Schematic

3.3 Schematic

The Figure 3.6 shows the complete schematic of the module were all the connections are described.

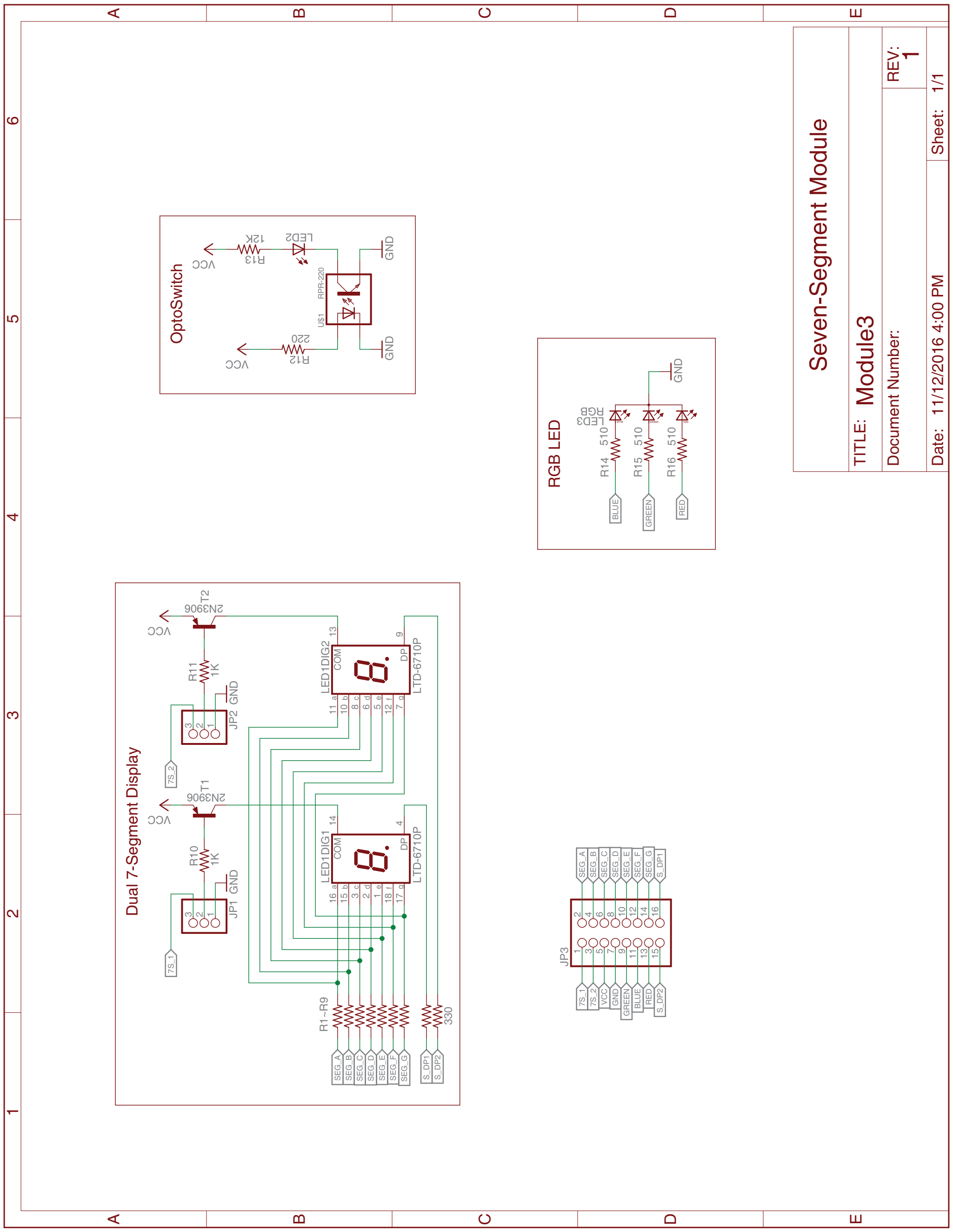

Figure 3.6: Module 3 Schematic

3.4 Board

The Figure 3.7 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

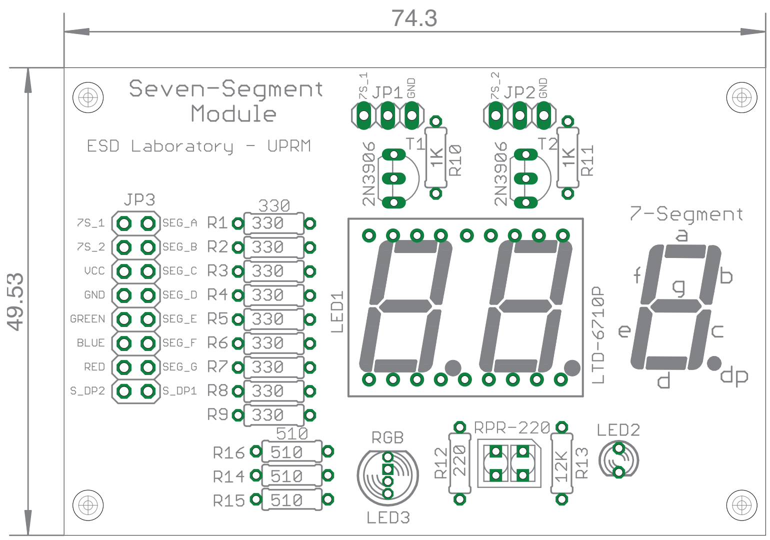

Figure 3.7: Module 3 board - components layer

The Figure 3.8 and Figure 3.9 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

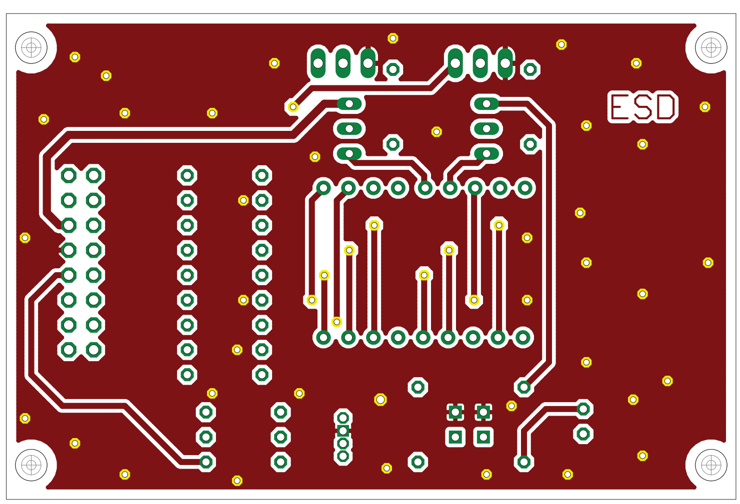

Figure 3.8: Module 3 board - top layer

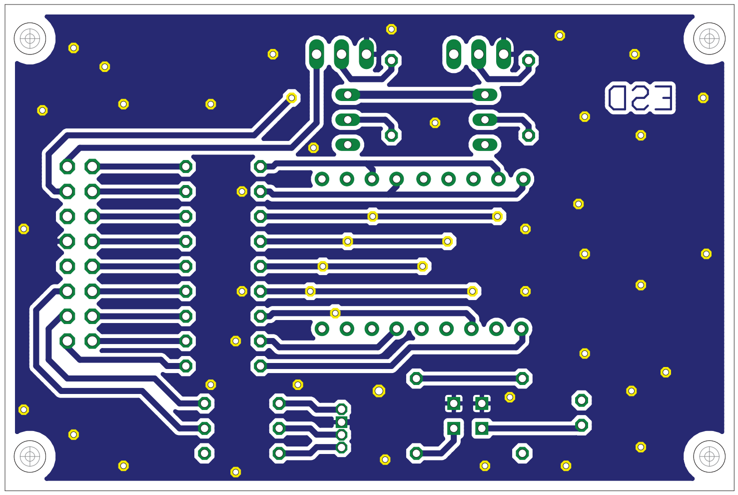

Figure 3.9: Module 3 board - bottom layer

The Figure 3.10 illustrate a real representation of the module's PCB.

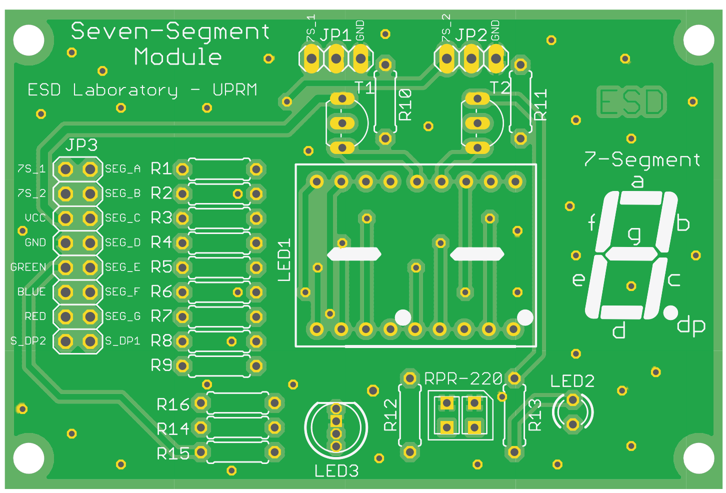

Figure 3.10: Module 3 board

Module 4

Motor Interface Module

4.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 4.1.

Table 4.1: Boom of materials Module 4

Item	Qty	Description	P/N reference	Supplier
1	1	Jumper x5	970	POLOLU
2	1	0.1uF Tantalum Cap.	581-TAP104K035SCS	MOUSER
3	1	2Pins Screw Con.	571-1776493-2	MOUSER
4	1	3Pins Screw Con.	ED1976-ND	DIGI-KEY
5	1	Fuse Holder	693-0031.8201	MOUSER
6	1	1x40 Male Header	965	POLOLU
7	1	Dip16 IC Base	AE9992-ND	DIGI-KEY
8	1	Dip18 IC Base	AE9995-ND	DIGI-KEY
9	1	Dip6 IC Base	AE1485-ND	DIGI-KEY
10	5	Diode 1N4004	512-1N4004	MOUSER
11	1	1.5 Amp Fuse	504-BK/GMC-1.5-R	MOUSER
12	1	L293D Motor Driver	595-L293DNE	MOUSER
13	1	ULN2803 Darlington Array	511-ULN2803A	MOUSER
14	5	RED LED 3mm	754-1604-ND	DIGI-KEY
15	1	DC Motor	1528-1150-ND	DIGI-KEY
16	1	Servomotor	900-00005-ND	DIGI-KEY
17	1	Stepper Motor	1528-1367-ND	DIGI-KEY
18	2	4N25 Optocoupler	78-4N25	MOUSER
19	1	5V Relay	653-G5LE-14-DC5	MOUSER
20	1	1k Ohm Resistor	660-MF1/4LCT52R102J	MOUSER
21	1	4.7K Ohm Resistor	660-MF1/4LCT52R472J	MOUSER
22	2	22 Ohm Resistor	660-MF1/4LCT52R220J	MOUSER
23	2	330 Ohm Resistor	660-MF1/4LCT52R331J	MOUSER
24	5	2.2k Ohm Resistor	660-MF1/4LCT52R222J	MOUSER
25	1	2N3904 NPN Transistor	512-2N3904BU	MOUSER
26	2	MPSA42 NPN Transistor	512-MPSA42	MOUSER
27	2	MPSA92 PNP Transistor	610-MPSA92	MOUSER

4.2 Description

The motor interface module is composed of 4 main blocks. It provides access to standard motor drivers such as H-bridges, relays, and stepper motor controller. Figure 4.1 shows the block diagram of the motor interface module and its four blocks (H-bridge transistor, IC motor driver, relay, and stepper driver). This module is intended to work with either 3.3V and 5V microcontroller and it is also designed to allow direct interfacing to the MCU with no intermediate components.

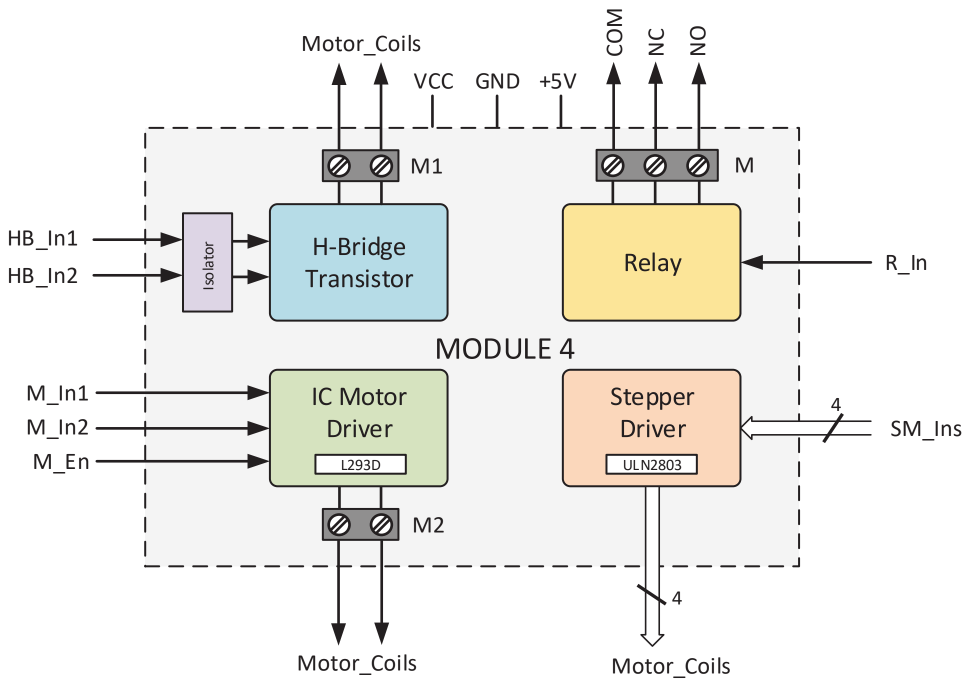

Figure 4.1: Module 4 Block diagram

The schematic of the module is illustrated in Figure 4.7 where all the connection between the different electronics components are depicted. In addition the board layout divided into components layer, top layer, and bottom layer, can be observed in Figure 4.8. Figure 4.9, and Figure 4.10 respectively. Finally, a real board representation of the EM is presented in Figure 4.11. This representation shows the real board to be used in the development of the laboratory experiments.

4.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must have into account the operation voltage of your MCU, motors, and IC drivers.

Although some components in the modules were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. In this module, the most quantity of connections are data signals and motor operating voltages. If your MCU works at 3.3V or 5V, you must connect all the power supply pins labeled on the board: 5V and GND (connect the voltages only when they are required). The power supply pins are highlighted in Figure 4.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

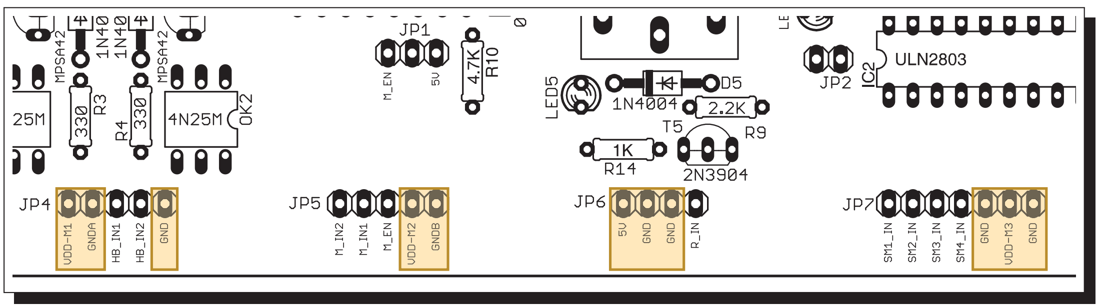

Figure 4.2: Module 4 Power supply pins

4.2.2 H-Bridge Transistor

This block is provide with 2 MPS42 NPN transistors, 2 MPS92 PNP transistors, 4 1N4004 Diodes, 2 4N25 optocouplers, 2 330Ω resistors, 2 22Ω resistors, and a 500mA fuse as depicted in Figure 4.3.

To use this block you need to connect all the voltages requires and insert the fuse into the fuse holder. The motor voltage needed will depend on of the specification of you DC motor, and it will be connected in the pins VDD-M1 and GNDA in pinheader JP4. Remember do not use a dc motor that could exceed the transistor's maximum current. The control signals that comes from your MCU must be connected to the pins HB_IN1 and HB_IN2 in pinheader JP4. Also a ground connection between your MCU and the block need to be carried out through the GND pin in the same pinheader. The control inputs in this block are isolated to prevent noise problems.

4.2.3 IC Motor Driver

This block provides access to a L293D dc motor driver with 4.7 KΩ resistor as depicted in Figure 4.4.

To use this block you need to connect all the controls signals, determine if you want

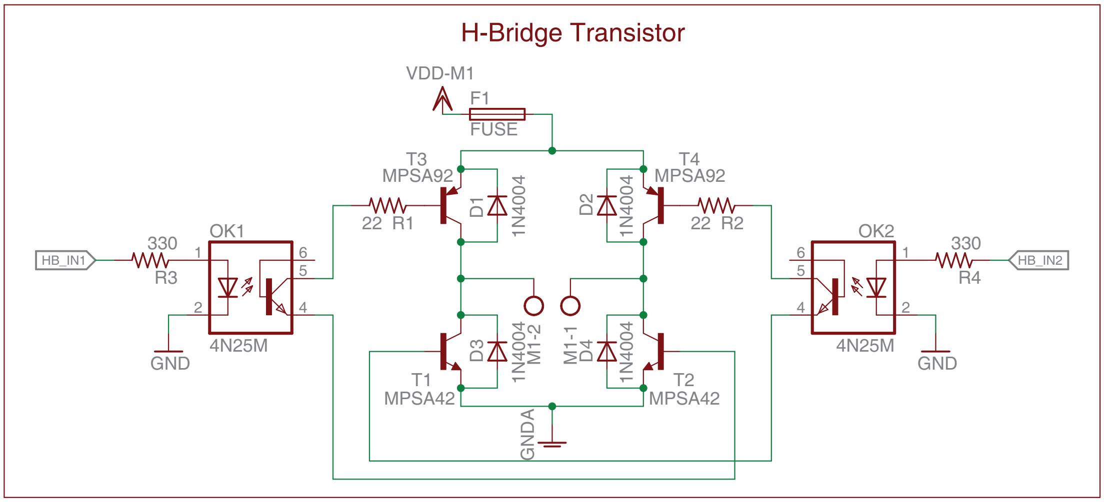

Figure 4.3: H-Bridge Transistor Schematic

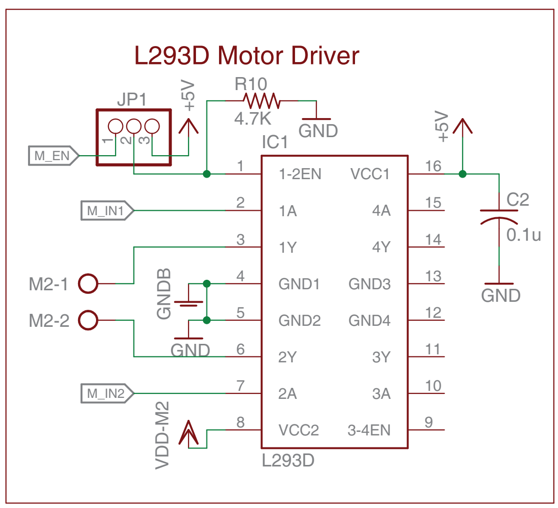

Figure 4.4: IC Motor Driver Schematic

to control the driver enable pin, and connect the power supply to the module. Follow the steps outlined below to setup this block:

1. To setup the power supply, you need to connect the motor voltage in the pins VDD-M2 and GNDB in pinheader JP5, and connect the IC power supply in the pins 5V and GND in pinheader JP6.

2. To define the operation of the enable pin you need to insert a jumper between 2 of the three pins on the pinheader JP1. If you put the jumper between the

middle pin and the 5V pin, the motor driver will permanently be enabled and whatever change presented in the inputs will be reflected on the outputs. But, if you insert the jumper between the middle pin and the M_En pin, it will provide you control to the enable or disable the operation of the motor driver. It will allow you to determine when the inputs will affect the outputs.

3. To control the rotation direction of the DC motor, you need to connect your MCU to the M_IN1 and M_IN2 pins in pinheader JP5 and sends the appropriate sequence of signals.

4.2.4 Relay

This block is provided with a 5V coil relay, 1 1N4004 diode, 1 1KΩ resistor, 1 2.2KΩ resistor, 1 2N3904 NPN transistor, and a 3mm RED LED as depicted in Figure 4.5.

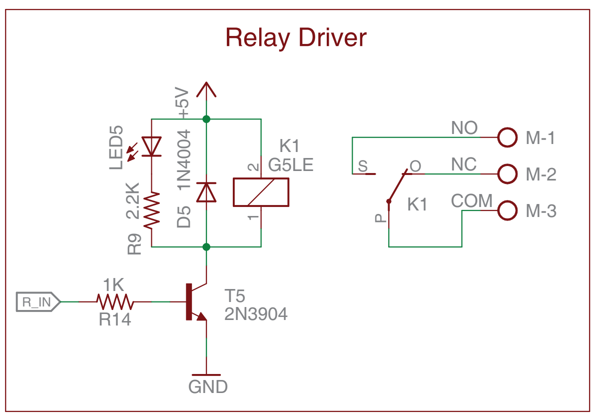

Figure 4.5: Relay Schematic

To use this block, you need to connect the power supply in the pins 5V and GND in the pinheader JP6. Also, you need to connect the control signal that comes from your MCU in the pin R_IN in pinheader JP6. This signal will turn On or Off the relay. The turn On/Off process is carried out by a 2N3904 NPN transistor and a 1KΩ resistor. This interface allows to turn-On the relay with a logic 1 and turn it Off when receives a logic 0. The 3mm LED will be On when the relay is activated.

4.2.5 Stepper Driver

This block is provided with a Darlington transistor array UNL2803, 4 3mm LEDs, and 4 2.2KΩ resistors as depicted in Figure 4.6.

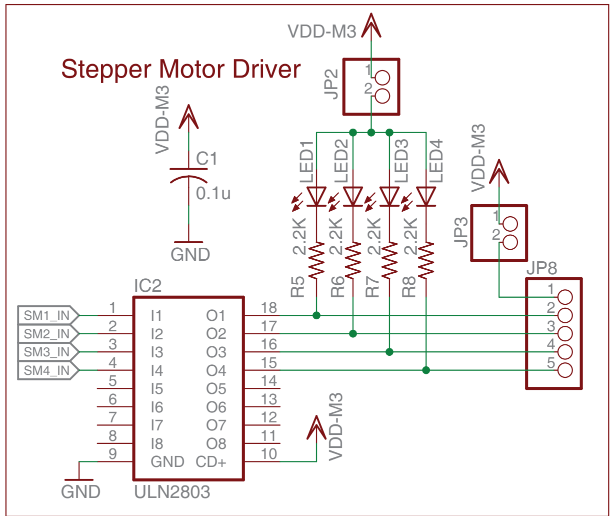

Figure 4.6: Stepper Driver block Schematic

To use this block, you need to connect the motor voltage in the pins VDD-M3 and GND in the pinheader JP7. The motor voltage required will depend on of your stepper motor specifications. To control the stepper motor, you need to connect all the control signals in pins SM1_IN, SM2_IN, SM3_IN, and SM4_IN in pinheader JP7. If you want to enable the turn On/Off process of the LEDs, you need to put a jumper in pinheader JP2. To enable the stepper motor, you need to insert a jumper in pinheader JP3. Each output of the driver will be in high impedance state while the inputs are receiving a logic 0 and they will be at ground when the inputs receive a logic 1.

4.3 Schematic

The Figure 4.7 shows the complete schematic of the module were all the connections are described.

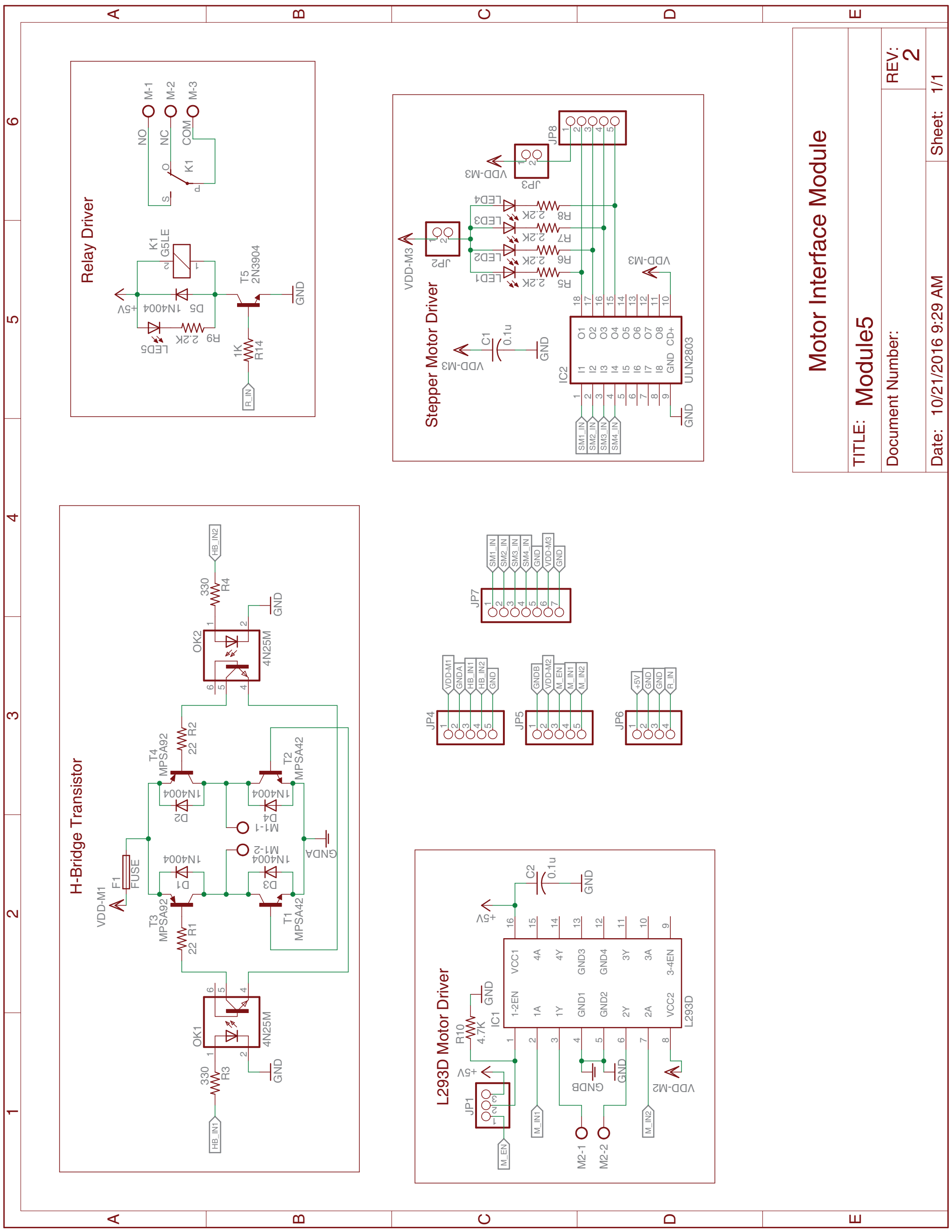

Figure 4.7: Module 4 Schematic

4.4 Board

The Figure 4.8 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

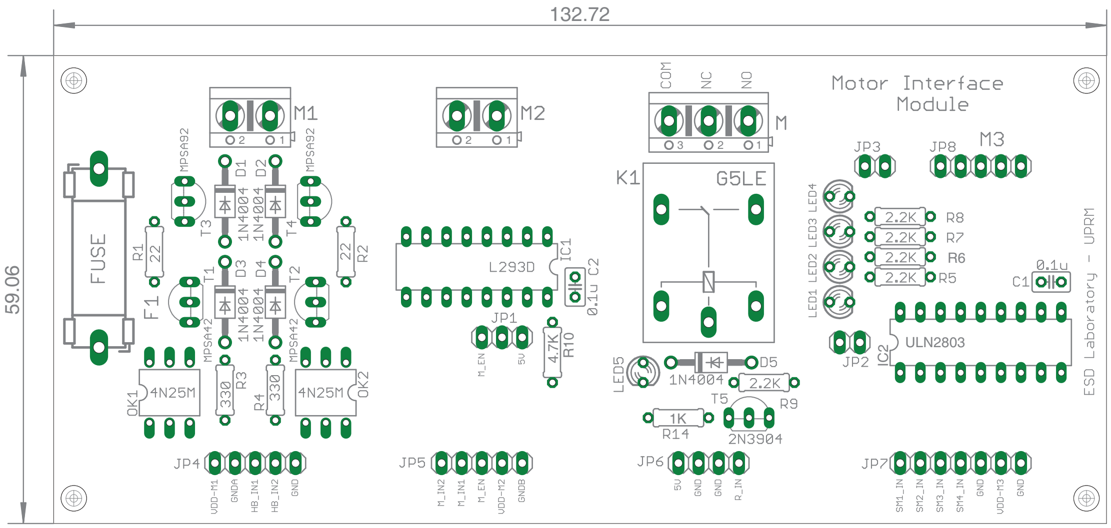

Figure 4.8: Module 4 board - components layer

The Figure 4.9 and Figure 4.10 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

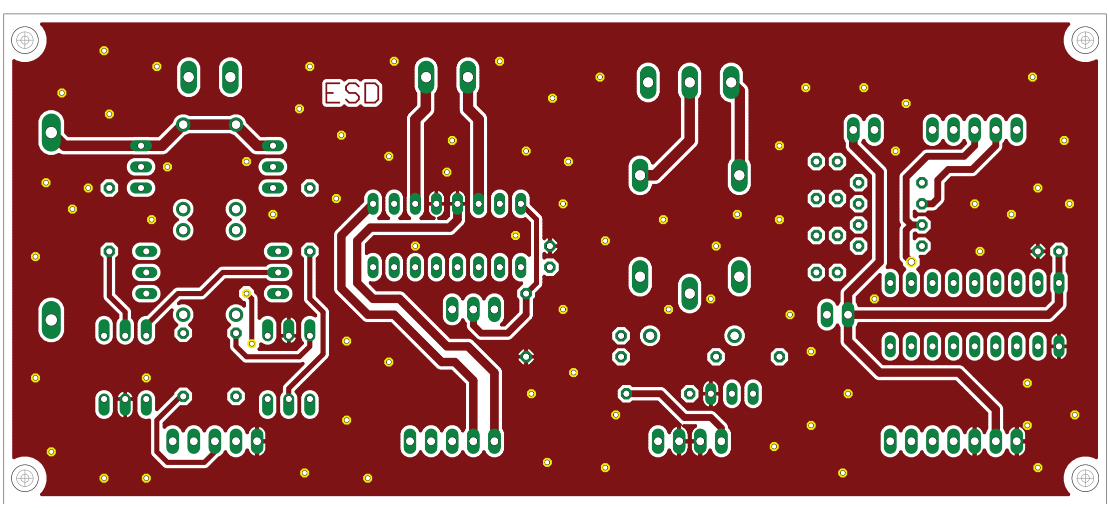

Figure 4.9: Module 4 board - top layer

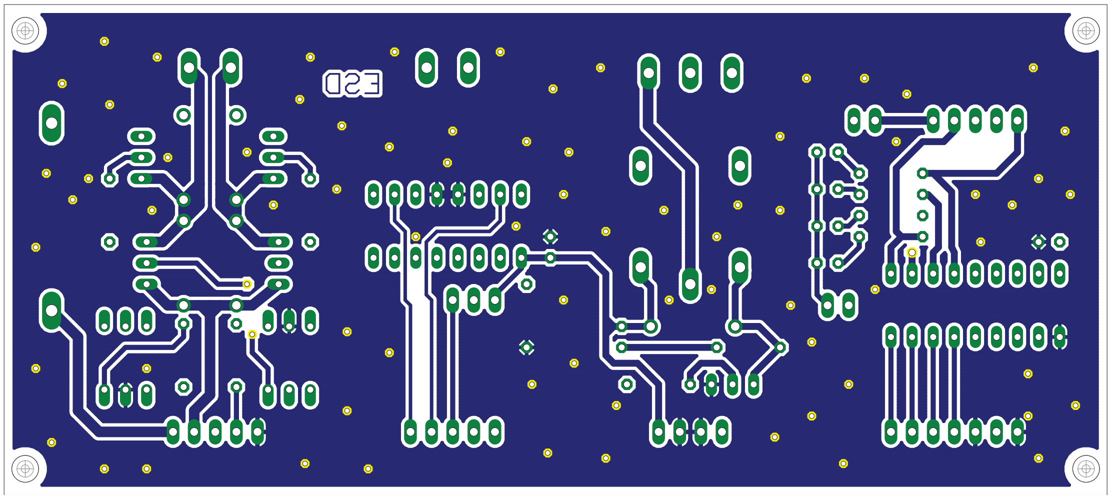

Figure 4.10: Module 4 board - bottom layer

The Figure 4.11 illustrate a real representation of the module's PCB.

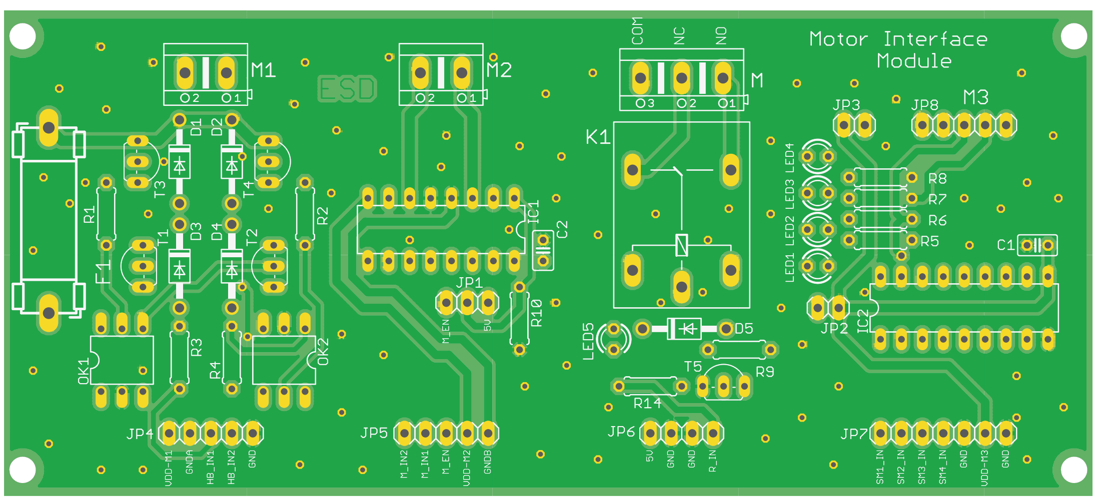

Figure 4.11: Module 4 board

Module 5

Serial Communications Module

5.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 5.1.

Table 5.1: Boom of materials Module 5

Item	Qty	Description	P/N reference	Supplier
1	1	Jumper x5	970	POLOLU
2	1	3V Battery cr2032	P189-ND	DIGI-KEY
3	1	0.1uF Tantalum Cap.	581-TAP104K035SCS	MOUSER
4	3	0.47uF Capacitor	647-UHE1HR47MDD	MOUSER
5	1	0.1uF Capacitor	647-UVR1H0R1MDD	MOUSER
6	1	Female DB9 Connector	AE10921-ND	DIGI-KEY
7	1	1x40 Male Header	965	POLOLU
8	1	Battery Holder	BS-3-ND	DIGI-KEY
9	1	Dip16 IC base	AE9992-ND	DIGI-KEY
10	1	Dip8 IC base	AE9986-ND	DIGI-KEY
11	1	32.768KHz Crystal	732-C004R32.76K-APB	MOUSER
12	1	Real-Time Clock DS1307	700-DS1307	MOUSER
13	1	MAX3232 RS-232 Transceiver	700-MAX3232CPE	MOUSER
14	2	RED LED 3mm	754-1604-ND	DIGI-KEY
15	2	1k Ohm Resistor	660-MF1/4LCT52R102J	MOUSER
16	3	4.7K Ohm Resistor	660-MF1/4LCT52R472J	MOUSER

5.2 Description

The serial communications module is composed of 2 main blocks. It provides access to devices that use serial communication protocols such as RS232 and I^2C. Figure 5.1 shows the block diagram of the serial communication module and its two blocks (Serial-to-RS232 converter and Real-Time clock). This module is intended to work with either 3.3V and 5V microcontrollers and it is also designed to allow direct interfacing to the MCU with no intermediate components.

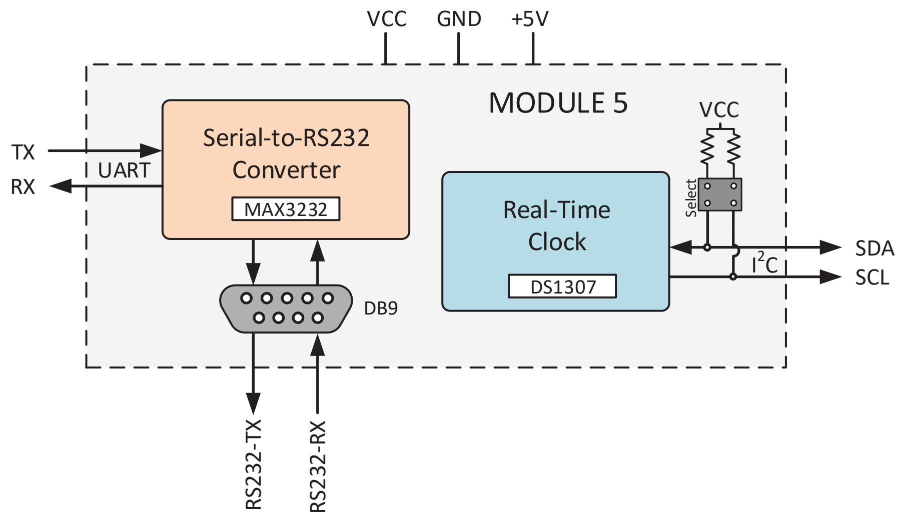

Figure 5.1: Module 5 Block Diagram

The schematic of the module is illustrated in Figure 5.5 where all the connection between the different electronics components are depicted. In addition the board layout divided into components layer, top layer, and bottom layer, can be observed in Figure 5.6. Figure 5.7, and Figure 5.8 respectively. Finally, a real board representation of the EM is presented in Figure 5.9. This representation shows the real board to be used in the development of the laboratory experiments.

5.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must take into account the operation voltage of your MCU. Although some components in the module were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. If your MCU works at 3.3V, you must connect all the power supply pins labeled on the board: 5V, VCC, and GND (using 3.3V for VCC). Also, the jumper in pinheader JP3 must be removed. But, if you are using a 5V microcontroller, you only need to connect one of the two power supply pins (5V or VCC) and put a jumper in pinheader JP3. The power supply pins to be used are highlighted in Figure 5.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

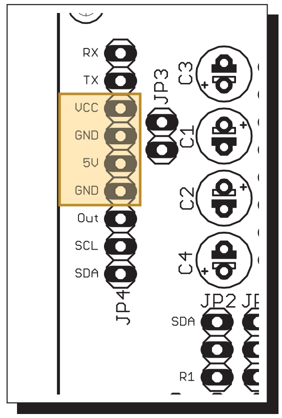

Figure 5.2: Module 5 Power supply pins

5.2.2 Serial-To-RS232 Converter

This block is provided with a MAX3232, 1 0.47uF electrolytic capacitor, 3 0.1uF electrolytic capacitor, 2 1KΩ resistor, 2 3mm LEDs, and a DB9 connector as depicted in Figure 5.3.

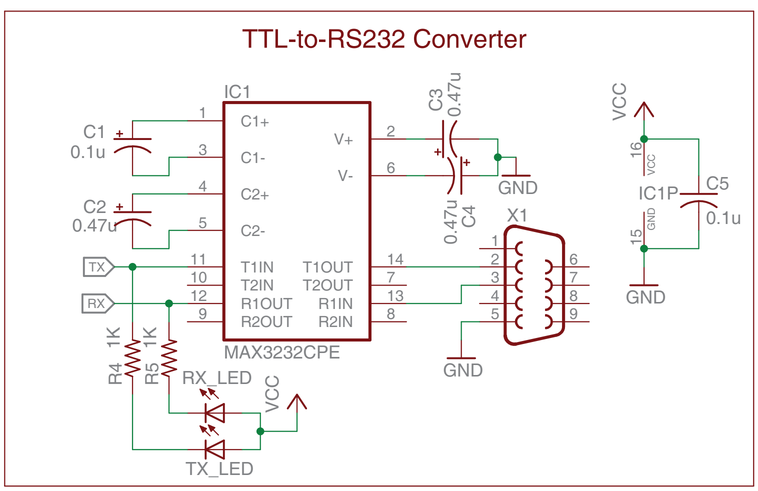

Figure 5.3: Serial-To-RS232 Converter Schematic

To use this block, you need to connect the RX and TX pins of your MCU to the RX and TX pins in pinheader JP4. Also, you need to plug in an RS232-to-USB cable converter in the DB9 connector X1 to start the communication process between your MCU and the PC. Internally, the driver (MAX3232) do the respective conversions between the TTL logic levels and RS232 logic levels.

5.2.3 Real-Time Clock

This block provides access to a real-time clock DS1307 with a 32.768 KHz crystal, three 3KΩ pull-up resistors, and a 3V lithium battery backup as depicted in Figure 5.4.

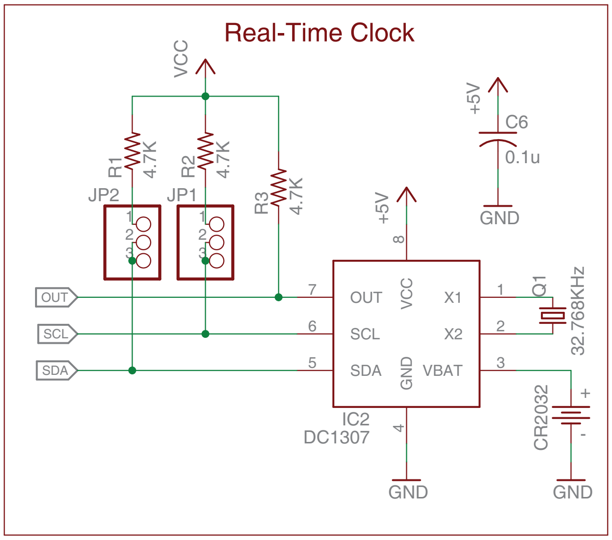

Figure 5.4: Serial-To-RS232 Converter Schematic

To use this block you need to connect the SDA and SCL pins of your MCU to the module pins, determine the use or not of the pull-up resistors, and configure DS1307's OUT signal. Follow the steps outline below to setup this block:

1. The SCL and SDA pins of your MCU needs to be connected to SCL and SDA pins in pinheader JP4 of the module. These pins will be used for establishing the I^2 communication between the devices. The OUT signal in the block is an extra feature that can be activated or not on the DS1307 by configuring its internal registers.

2. To setup the pull-up resistor for the I^2C bus, you need to put jumpers in pinheaders JP1 and JP2. If you want to use the pull-up resistor, for SDA line, you need to insert a jumper between the middle pin and the R1 pin in pinheader JP2. But, if you desired not use the pull-up resistor, you need to insert the jumper between the middle pin and the SDA pin in pinheader JP2 and provide an external pull-up resistor attached to the operation voltage of your MCU. To setup the another pull-up resistor you have to perform the same procedure outlined to setup the SDA line.

5.3 Schematic

The Figure 5.5 shows the complete schematic of the module were all the connections are described.

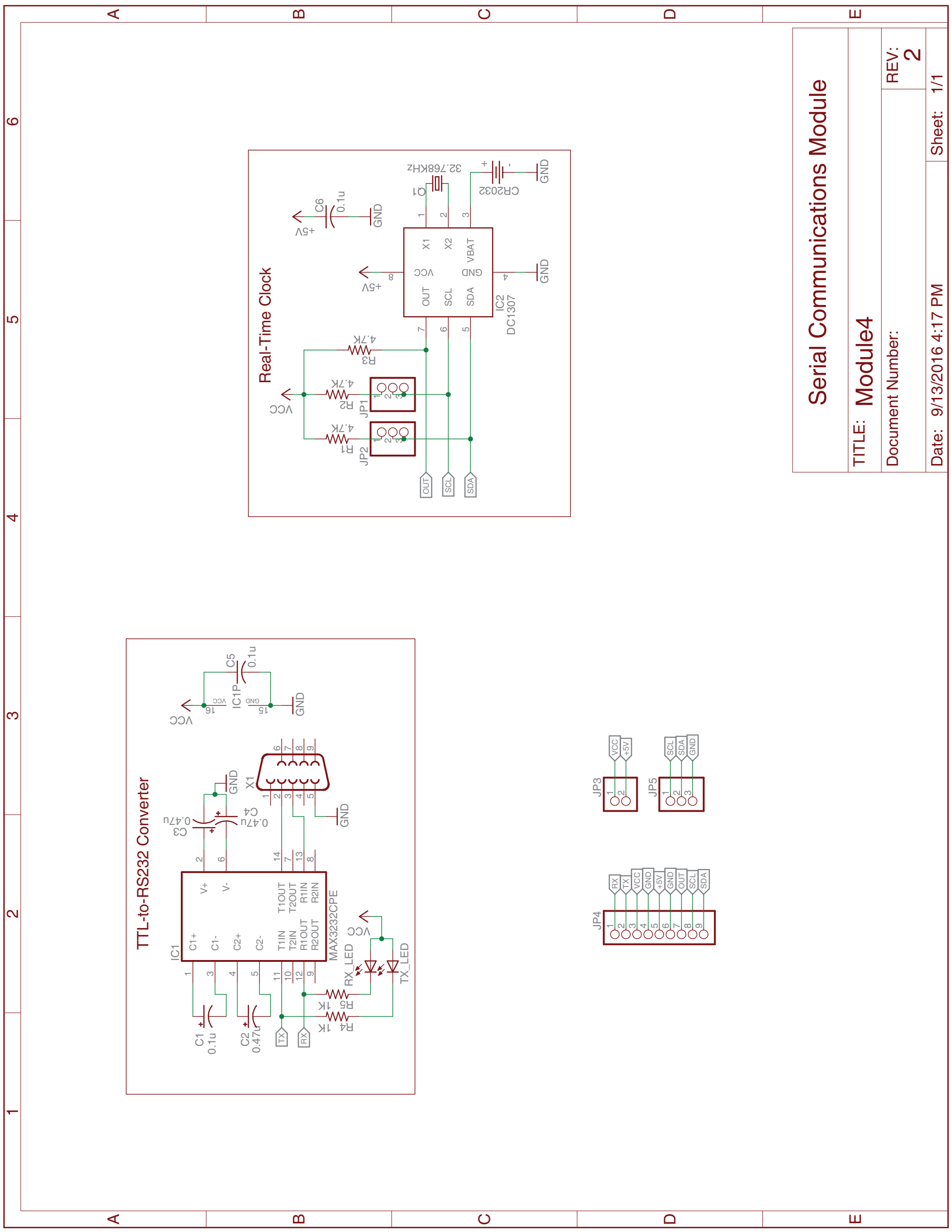

Figure 5.5: Module 5 Schematic

5.4 Board

The Figure 5.6 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

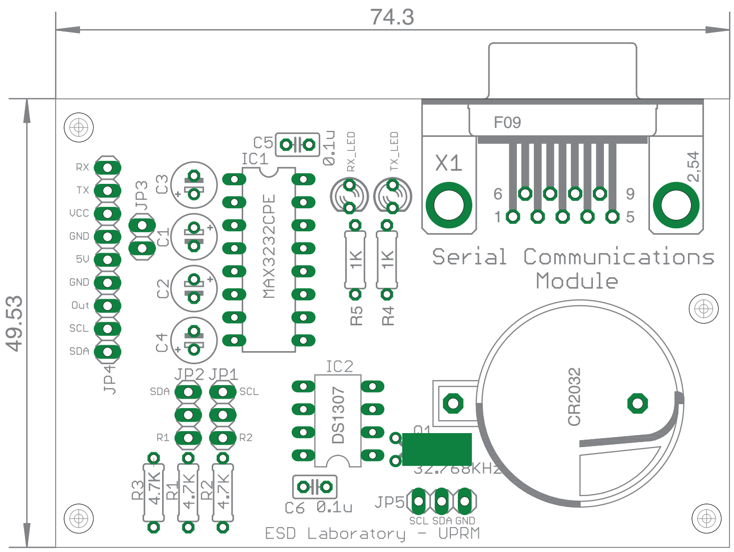

Figure 5.6: Module 5 board - components layer

The Figure 5.7 and Figure 5.8 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

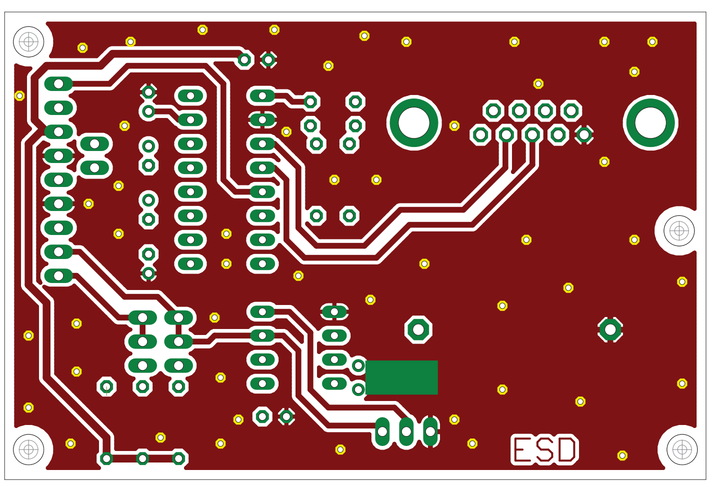

Figure 5.7: Module 5 board - top layer

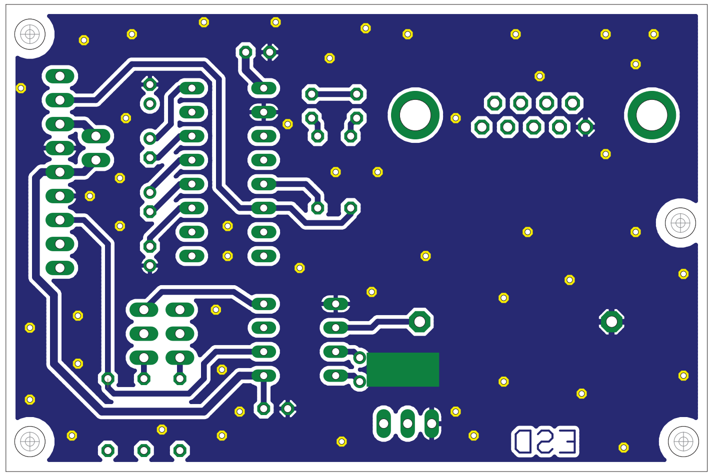

Figure 5.8: Module 5 board - bottom layer

The Figure 5.9 illustrate a real representation of the module's PCB.

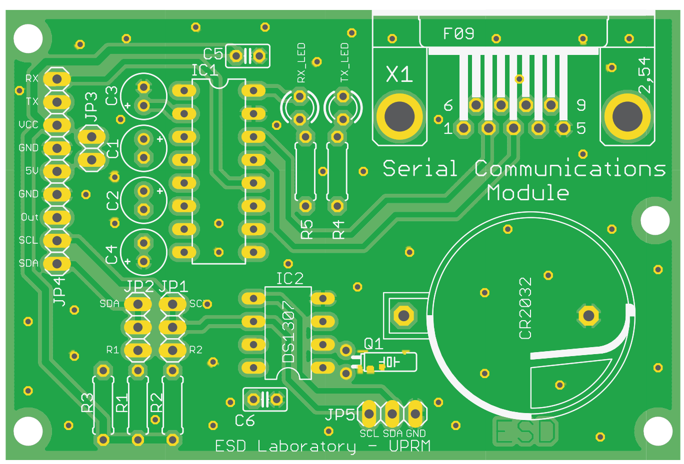

Figure 5.9: Module 5 board

Module 6

Data Converters Module

6.1 Materials

The materials needed to assembly the Data Converters module is listed in Table 6.1.

Table 6.1: Boom of materials Module 6

Item	Qty	Description	P/N reference	Supplier
1	1	0.1uF Tantalum	581-TAP104K035SC	MOUSER
2	1	0.1uF Ceramic	594-D101K20Y5PL63L6R	MOUSER
3	1	1x40 Male Header	965	POLOLU
4	1	2x40 Male Header	966	POLOLU
5	1	Dip16	AE9992-ND	DIGI-KEY
6	1	Dip8	AE9986-ND	DIGI-KEY
7	1	DAC0808	926-DAC0808LCN/NOPB	MOUSER
8	1	LM35	926-LM35DZ/NOPB	MOUSER
9	1	LM358	595-LM358P	MOUSER
10	1	10k Ohm pot	688-RK09K1130AH1	MOUSER
11	1	10k Ohm Prec. Pot	72-T18-10K	MOUSER
12	4	2.4k Ohm	660-MF1/4LCT52R242J	MOUSER

6.2 Description

The data converters module is composed of 3 main blocks. It provides access to common analog devices and digital-to-analog converters. Figure 6.1 shows the block diagram of the data converter module and its three blocks (Digital-To-Analog Converter, Temperature Sensor, and Potentiometers). This module is intended to work with either 3.3V and 5V microcontroller and it is also designed to allow direct interfacing to the MCU with no intermediate components.

The schematic of the module is illustrated in Figure 6.6 where all the connection between the different electronics components are depicted. In addition, the board layout divided into components layer, top layer, and bottom layer, can be observed

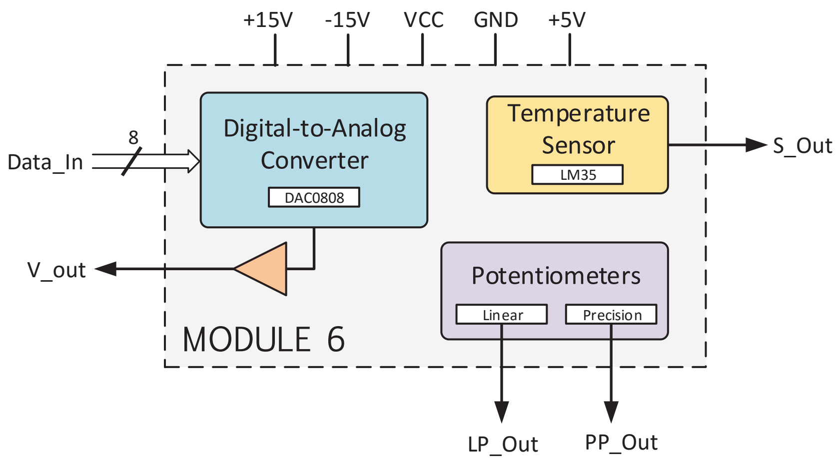

Figure 6.1: Module 6 Block diagram

in Figure 6.7. Figure 6.8, and Figure 6.9 respectively. Finally, a real board representation of the EM is presented in Figure 6.10. This representation shows the real board to be used in the development of the laboratory experiments.

6.2.1 Power Supply Setup

To setup the different voltages needed for the proper operation of the system, you must take into account the operation voltage of your MCU. Although some components in the module were chosen to work with both 3.3V and 5V microcontrollers, some of them require a 5V power supply. If your MCU works at 3.3V, you must connect all the power supply pins labeled on the board: 5V, VCC, and GND (using 3.3V for VCC). Also, the jumper in pinheader JP6 must be removed. But, if you are using a 5V microcontroller, you only need to connect one of the two power supply pins (5V or VCC), and put a jumper in pinheader JP3. The power supply pins to are highlighted in Figure 6.2. Remember to connect the GND, of your MCU, to the GND in the module to establish the same reference voltage for the entire system.

6.2.2 Digital-To-Analog Converter

This block is provided with a DAC0808 digital-to-analog converter, 1 LM358 operational amplifier, 4 2.4KΩ resistors, and a 0.1nF ceramic capacitor as depicted in Figure 6.3.

To use this block you need to connect all the voltages requires by the ICs (+15V, -15V, 5V, and VCC) in pinheader JP2 and JP1. Also, the data signals that comes

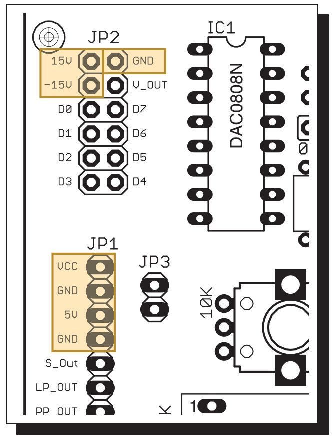

Figure 6.2: Module 6 Power supply pins

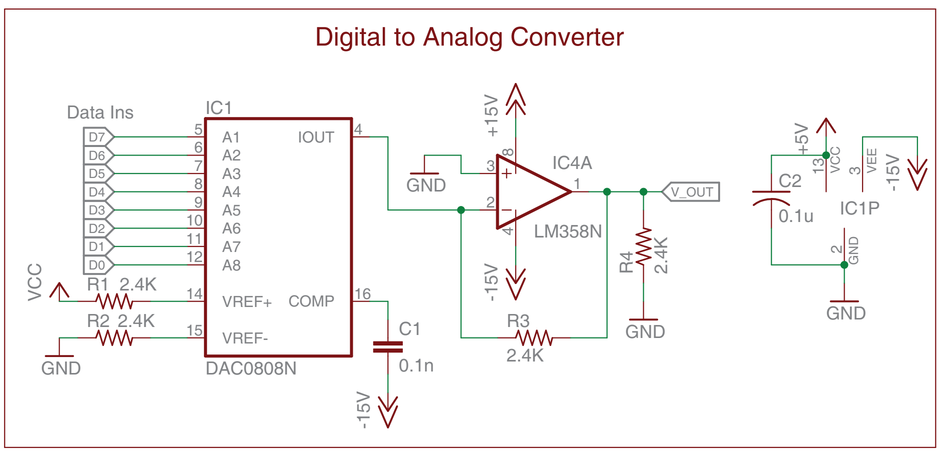

Figure 6.3: Digital-To-Analog Converter Schematic

from your MCU must be connected to D0 to D7 pins in pinheader JP2. The DAC0808 is a data converter of 8 bits that uses the D0 for the LSB and D7 for the MSB. The output voltage could be measured in the V_OUT pin. The reference voltage for the conversion could be the same of your MCU operation voltage but if you need to select another voltage, connect the voltage to the VCC pin and remove the jumper in pinheader JP3. Be sure that the reference voltage needed do not exceed 10V DC.

6.2.3 Temperature Sensor

This block provides access to an LM35 analog temperature sensor as depicted in Figure 6.4.

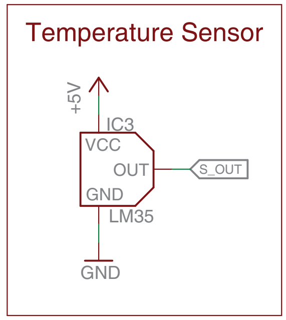

Figure 6.4: Temperature Sensor Schematic

To use this block you only need to connect the power supply to the 5V pin in pinheader JP1 and measure the analog output voltage in the pin S_Out. The sensor has a conversion factor of 10mV for each 1°C of temperature.

6.2.4 Potentiometers

This block provides access to a single turn potentiometer R5 (Linear) and an multi-turn potentiometer R6 (Precision) as depicted in Figure 6.5.

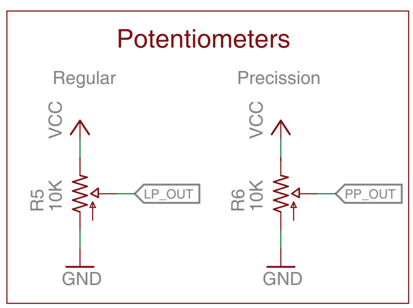

Figure 6.5: Potentiometers Schematic

To use use this block you only need to connect the power supply to the VCC pin in pinheader JP1 and measure the desired potentiometer output in LP_OUT for the R5 potentiometer or PP_OUT for the R6 potentiometer. Be sure to use the same operation voltage of your MCU or a voltage that is acceptable for the ADC module of your MCU. Any other voltage could potentially damage your MCU.

6.3 Schematic

The Figure 6.6 shows the complete schematic of the module were all the connections are described.

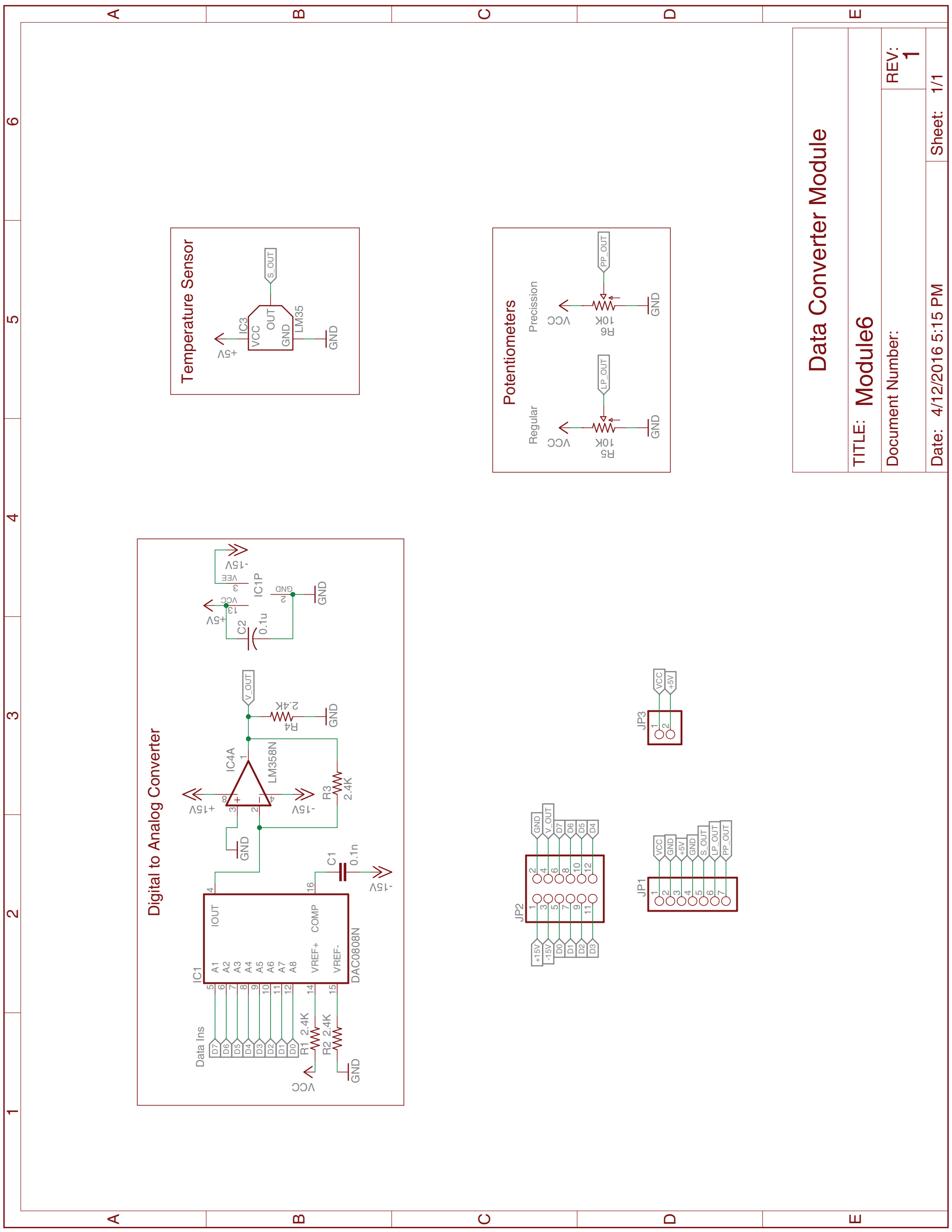

Figure 6.6: Module 6 Schematic

6.4 Board

The Figure 6.7 represent the component layer of the module. This Figure shows how the different elements are arranged on the PCB. The measures are in millimeters.

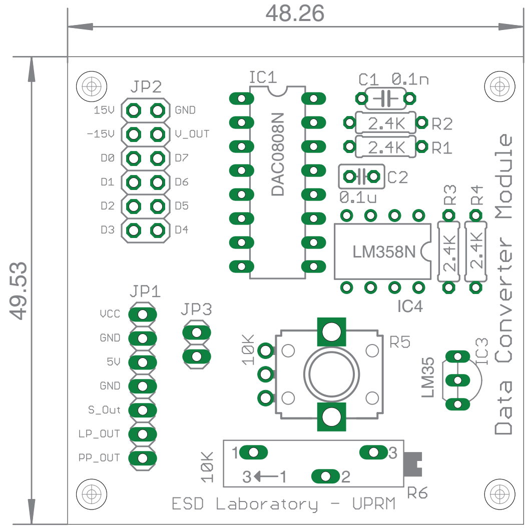

Figure 6.7: Module 6 board - components layer

The Figure 6.8 and Figure 6.9 represents the Top and Bottom layer of the module respectively. These images show the different physical connections between the different components in the module.

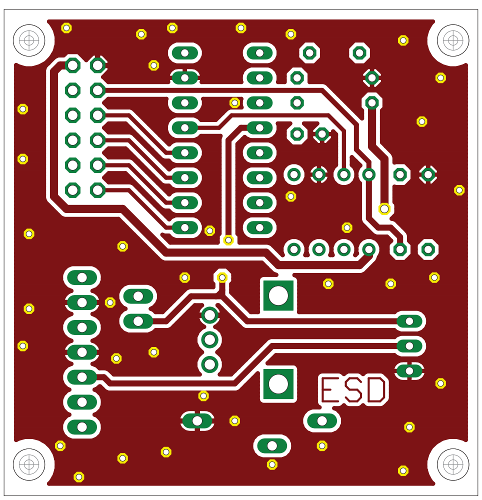

Figure 6.8: Module 6 board - top layer

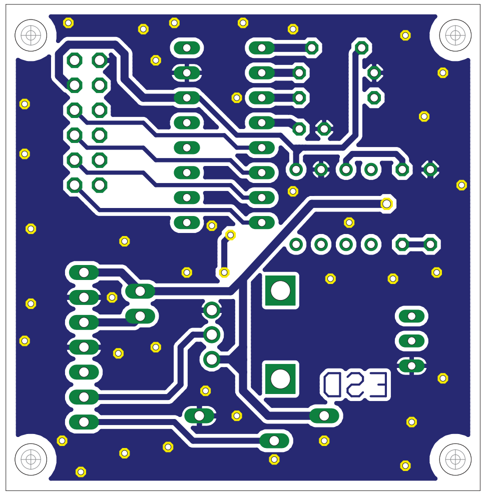

Figure 6.9: Module 6 board - bottom layer

The Figure 6.10 illustrate a real representation of the module's PCB.

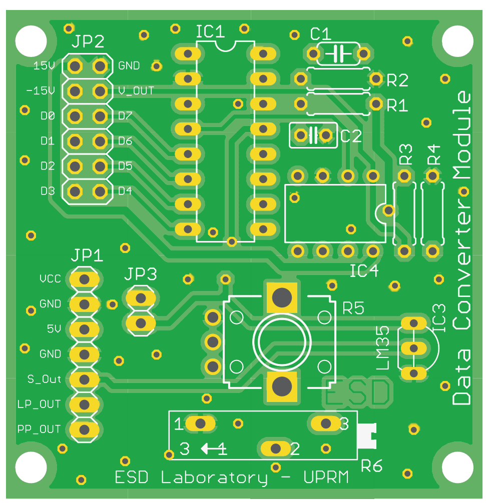

Figure 6.10: Module 6 board

Bibliography

[1] Hd44780u (lcd-ii). HITACHI. https://www.sparkfun.com/datasheets/LCD/HD44780.pdf. Accessed: 2016-03-25.

[2] Lcd 16x2 (wh1602b2-tm1-et#). http://www.mouser.com/ds/2/272/-364177.pdf. Accessed: 2016-03-25.

[3] Ps1240p02ct3. TDK. https://product.tdk.com/info/en/catalog/datasheets/ef532_ps.pdf. Accessed: 2016-03-25.

[4] Dc56-11ewa. KINGBRIGHT. http://www.us.kingbright.com/images/catalog/spec/DC56-11EWA.pdf. Accessed: 2016-03-25.

[5] Wp154a4sureqbfzw. KINGBRIGHT. https://www.kingbrightusa.com/images/catalog/spec/WP154A4SUREQBFZGW.pdf. Accessed: 2016-03-25.

[6] Rpr-220. ROHM. http://rohmfs.rohm.com/en/products/databook/datasheet/opto/optical_sensor/photosensor/rpr-220.pdf. Accessed: 2016-03-25.

[7] Ds1307. MAXIM INTEGRATED. http://datasheets.maximintegrated.com/en/ds/DS1307.pdf. Accessed: 2016-03-25.

[8] Max3232. MAXIM INTEGRATED. http://pdfserv.maximintegrated.com/en/ds/MAX3222-MAX3241.pdf. Accessed: 2016-03-25.

[9] Parallax standard servo (#900-00005). PARALLAX. https://www.parallax.com/sites/default/files/downloads/900-00005-Standard-Servo-Product-Documentation-v2.2.pdf. Accessed: 2016-03-25.

[10] L293d. TEXAS INSTRUMENTS. http://www.mouser.pr/ProductDetail/Texas-Instruments/L293DNE/?qs=sGAEpiMZZMtYFXwiBRPs0wSafWlCmJbc. Accessed: 2016-03-25.

[11] Dac0808. TEXAS INSTRUMENTS. http://www.ti.com/lit/ds/symlink/dac0808.pdf. Accessed: 2016-03-25.

[12] Lm35. TEXAS INSTRUMENTS. http://www.ti.com/lit/ds/symlink/lm35.pdf. Accessed: 2016-03-25.