

# EU068-MCTRIPSP0CZ

Motor Control Kit with RX13T and IPS2200

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## 1. Introduction

The Y-MotorControl\_RX13T kit is a design and evaluation system based on the RX13T device of the 32-bit RX microcontroller family.

The kit enables engineers to test and evaluate the performance of the RX13T in a laboratory environment where the IPS2200 sensor device is used for sending position feedback from the rotor of any 3-phase Permanent Magnet Synchronous Motor (for example, DC Brushless Motor).

The board is designed to be as small as possible, eventually allowing to use in a customer's target system. All BoM, Schematics and Gerber collaterals are part of the kit package.

The Graphical User Interface (GUI) gives real time access to key motor performance parameters and provides a unique motor auto-tuning facility. The on-board buttons are used in standalone operation without the GUI control.

The power supply of the board allows input voltages between 12V and 36V DC, with 5A maximum DC current.

The included Nanotech BLDC motor requires a sufficient 24V 2A DC power supply for operation.

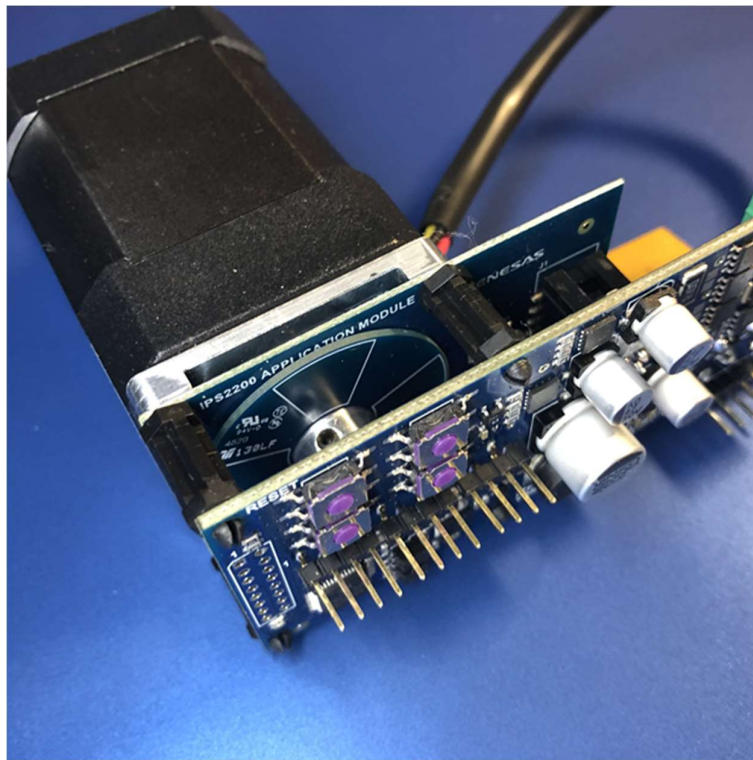


Figure 1. Y-MotorControl-RX13T

## 2. EU068 Motorcontrol Kit RX13T and IPS2200 – Hardware Overview

### 2.1 MCU

The MCU used on the board has the following parts:

- RX13T (ordering part name: R5F513T5ADFL)
- RX100 RXV1 Core derivate device with FPU running at maximum 32MHz clock frequency

The part used has the following features:

- 128KB Flash
- 12KB RAM
- 4KB Data Flash Memory to store the motor control settings
- 48-pin LFQFP package

For more information visit [www.renesas.com/RX13T](http://www.renesas.com/RX13T).

### 2.2 Inductive Position Sensor

The IPS2200 (ordering part name: IPS2200BI1W) is an Inductive Position Sensor for High-Speed Motor Commutation. The sensor is configured using a digital SPI or I2C interface to the RX13T and provides rotor angle feedback over an analog high-speed Sine and Cosine voltage output.

For more information visit [www.renesas.com/IPS2200](http://www.renesas.com/IPS2200).

### 2.3 Connectivity

External control of the board is achieved via an isolated USB-to-Serial interface connecting to a standard GUI, obtained with the RL78/G1C device (ordering part name: R5F10JBCANA). This part allows full control of a UART port from the USB input.

For more information visit [www.renesas.com/RL78G1C](http://www.renesas.com/RL78G1C).

The galvanic isolation between the board and a controlling MS Windows™ PC is achieved with two high speed (15Mbps) optocouplers (ordering part name: RV1S9160A) on the Tx and Rx lines of the RX13T MCU.

For more information visit [www.renesas.com/RV1S9160A](http://www.renesas.com/RV1S9160A).

### 2.4 Half-Bridge Mosfet Drivers

The PWM outputs from the RX13T device are adjusted to the correct control voltages for the Mosfets with three HIP2211 MOSFET drivers (ordering part name: HIP2211FRTZ).

For more information visit [www.renesas.com/HIP2211](http://www.renesas.com/HIP2211).

### 2.5 Mosfets

The controlling Mosfets are 6 x N-channel single power, maximum voltage is 60V at 30A (ordering part name: RJK0654DPB). The LPAK device package allows a small PCB footprint while enabling heat transportation and dissipation via the PCB layers.

For more information visit [www.renesas.com/RJK0654DPB](http://www.renesas.com/RJK0654DPB).

### 2.6 Power Supply

Note: the board works with the Nanotech DB42M03 24V BLDC motor, therefore the DC power input cannot exceed 24V.

The board contains a DCDC step down device (allowing an input voltage between 3.5V and 40V) to provide an

intermediate voltage of 10V powering the half bridge drivers (ordering part name: ISL85413FRTZ-T). The DCDC can only work with an input voltage between ~11V to 40V<sub>max</sub>.

For more information visit [www.renesas.com/ISL85413](http://www.renesas.com/ISL85413).

The MCU and the position sensor are powered at 5V DC, this is achieved with a low I<sub>q</sub> LDO (ordering part name: RAA214220)

For more information visit [www.renesas.com/RAA214220](http://www.renesas.com/RAA214220).

## 2.7 Push Buttons

The following buttons are used on the device:

- Three general purpose push button connected to the RX13T
- RX13T MCU reset button

## 2.8 Indicator LEDs

The following LEDs are used on the device:

- Green LED on the motor control board driven by a GPIO on the microcontroller. It shows the correct functioning of the RX13T firmware.
- Green power LED on the sensor board.

### 3. EU068 Motor Control Kit Content

The motor controller kit is delivered pre-assembled with the RX13T motor controller board, inductive position sensor board, and sensor target that is mounted on the BLDC motor.

Items included in the EU068 motor control kit:

- RX13T motor control board
- IPS2200 inductive position sensor board
- Inductive position sensor target mounted on a target holder
- Nanotech DB42S03 BLDC motor

Required items not included in the kit:

- 24V power supply
- Micro USB cable

Optional items not included in the kit:

- E1 or compatible debugger
- Potentiometer for stand-alone speed control
- IPS communication board for sensor demonstration

## 4. Quick Start Guide

The board is delivered with a factory default firmware tuned to the connected Nanotech motor, and a tuned IPS2200 inductive position sensor offset. The default setting can be launched to spin the motor by connecting a 24V DC power supply and pressing the push buttons on the board.

### 4.1 Using Buttons

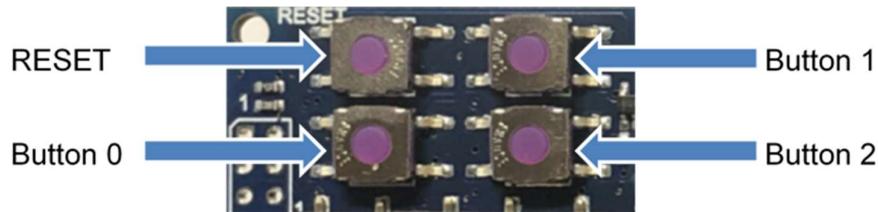


Figure 2: board detail with buttons

After connecting the external power supply, select one of the following options by pressing the relevant button:

- Button 0: starts/stops the spinning of the motor in the following sequence (see Figure 3):
  1. Enables the spinning of the motor with position feedback from the IPS2200.  
The RPM of the motor can be increased/decreased by Button 1 and 2.
  2. Stops the motor.
  3. Enable the spinning of the motor without position feedback from the IPS2200.  
In Sensorless mode, the RPM of the motor can be increased/decreased by Button 1 and 2.
  4. Stops the motor.
  5. Enables the spinning of the motor with position feedback from the IPS2200.  
The RPM of the motor can be increased/decreased by Button 1 and 2.
- Button 1: increases the requested RPM in steps up to the maximum RPM (set via the GUI).
- Button 2: decreases the RPM, passing through 0RPM increases the speed in the other direction.

Note that in Sensorless mode, the minimum RPM is 150. It is possible to run at 10RPM with IPS2200 support.

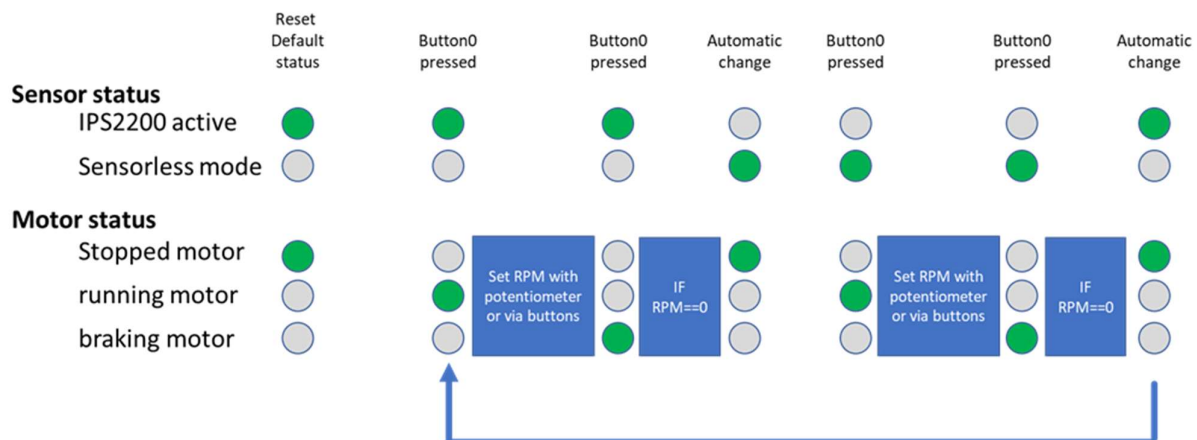


Figure 3: Detail of the Sequence of Button 0



## 4.2 Using Potentiometer

To set the board to potentiometer use, hold Button 1 while pressing the Reset button shortly.

In potentiometer use, the potentiometer or an DC voltage between 0 and 5V is connected on Pin 2 of connector J5, Pins 2 and 3 of connector J4 must be bridged by a jumper.



**Figure 4: board detail, potentiometer connection**

Button 0 starts/stops the spinning of the motor in the following sequence:

1. Enables the spinning of the motor with position feedback from the IPS2200.  
The RPM of the motor can be controlled by moving the slider of the potentiometer as the following:
  - Middle setting (approximately 2.5V on Pin 2 of J5) is 0 RPM
  - Moving the slider to either end spins the rotor at the maximum speed
  - Direction is set by the direction of the slider (0V is max left, 5V is max right).
2. Stops the motor.
3. Enable the spinning of the motor without position feedback from the IPS2200.  
In Sensorless mode, the RPM of the motor can be controlled by moving the slider of the potentiometer.
4. Stops the motor.
5. Enables the spinning of the motor with position feedback from the IPS2200.  
The RPM of the motor can be controlled by moving the slider of the potentiometer.

Note that in Sensorless mode, the minimum RPM is 150. It is possible to run at 10RPM with IPS2200 support.

## 4.3 Using GUI

Additional setting of the device can be done on the GUI, which can be downloaded from the [YROTATE-IT-RX23T PC Control GUI](#) site. Note: the INI file required to this board must be stored in the same directory as the 'MotorController.exe' file.

To set the board to GUI use, hold Button 1 and 2 while pressing the Reset button shortly. The Mode (parameter 0 in the GUI) is now set to '1' and allows the GUI to connect to the board as described below.

Follow these steps to operate the board using the GUI:

1. Connect power (24V) via the barrel connector to the board.  
The green LED on the MCU board lights up, indicating that the RX13T Microcontroller has booted successfully.  
The green LED on the Sensor board lights up.
2. Connect the USB cable to a free PC USB port.  
The PC connects to the RL78/G1C.  
If required, download the MS Windows™ driver files for this USB device from the [USB Drivers | Renesas](#) site.

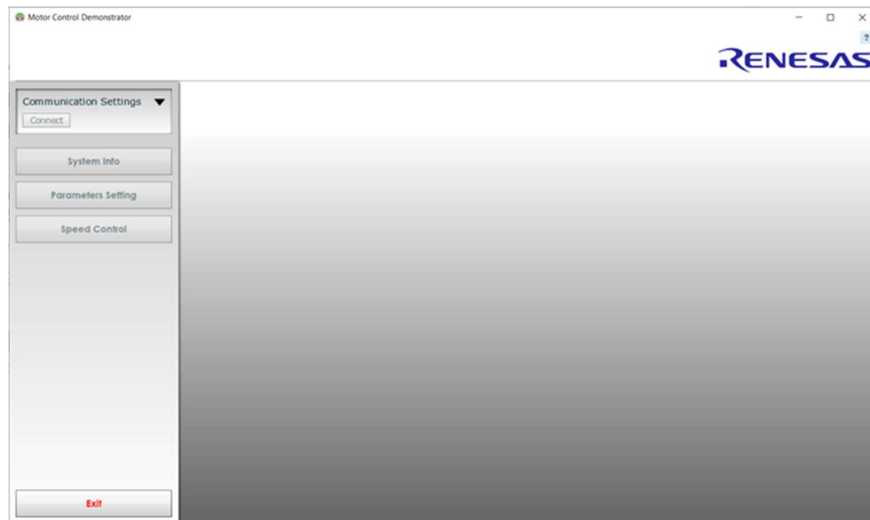


Figure 5. GUI Startup Screen

3. Start the GUI in MS Windows™ Administrator mode.
4. Open the 'Communication Settings' drop-down list.
5. Select "RX13T\_IPS2200" for the control settings.
6. Select "Auto Detect" for the COMx port.

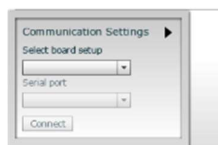


Figure 6. Communication Settings (1)



Figure 7. Communication Settings (2)

7. Click 'Connect'.
8. If necessary, click 'Parameter Setting' and edit values.  
The default system settings allows an immediate use of the board.

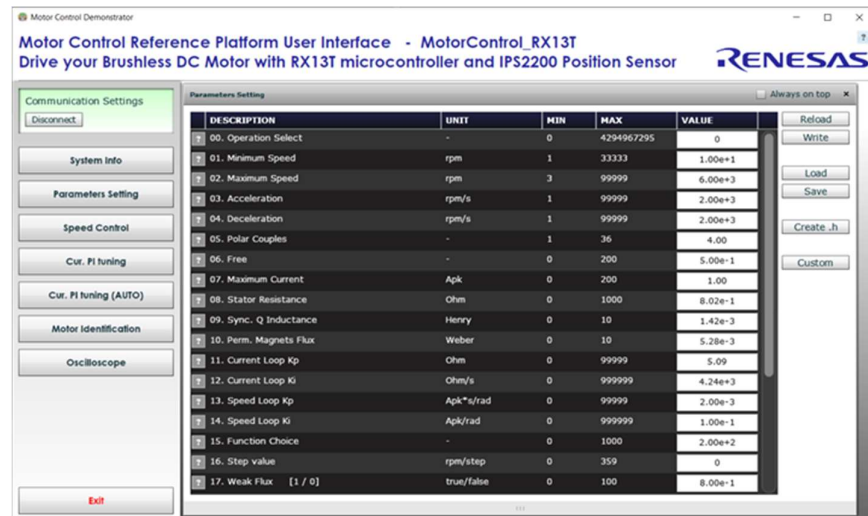


Figure 8. Parameter Settings Screen

## Important Notes:

- If the mechanical connection of the rotating IPS2200 reflector board is changed, run 'motor identification' command again to checks the sensor encoder offset on the rotor. Neglecting this can result in damage of the system, as the rotary field/current is not in sync with the actual position of the rotor.
- Enabling the GUI activity from the factory default button control stores '1' in parameter 00. To lock setting to GUI, program a '0' in this parameter first.  
When keeping '1' in parameter 00, the motor control setting is 'Sensorless'. To enable IPS2200 support, Parameter 00 must be '0'.  
Return to button control by programming '22' into parameter 00.

9. Run the motor.

10. Click 'Speed Control'.

The Speed Control screen appears, see Figure 9.

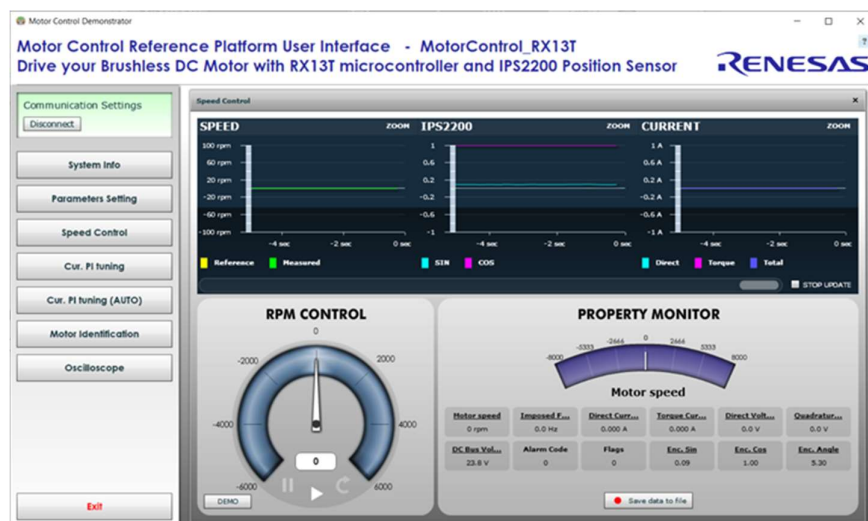


Figure 9. Speed Control Screen

11. Enter the desired value into the 'RPM control' and press the Tab button on the keyboard.  
The rotor starts turning and the feedback values are showing the measured and set data from the RX13T firmware.

Values for sine/cosine are showed both in the graph output for IPS2200 and in the value outputs 'Enc.Sin' and 'Enc.Cos' fields. The rotor position value is shown in the 'Enc.Angle' field.

Note: manually slowing the rotor results in increased current to keep the torque/position on the rotor as the system maintains the set RPM speed.

Output values of the IPS2200 screen that look like sine/cosine curves are achieved with very few RPM speeds, as the data update repetition rate needs to correlate with the measurement trigger speed.

Figure 10 shows an example for RPM speeds that show sine/cosine values using the factory default motor and firmware, running at 4495RPM.

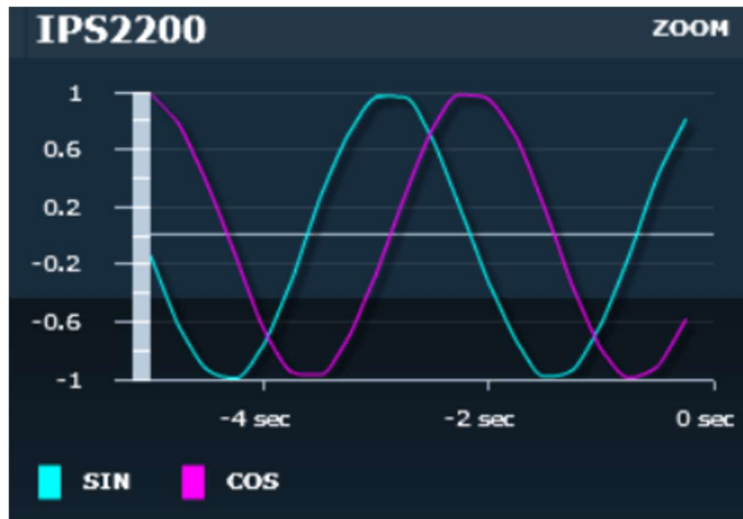


Figure 10: Sine/Cosine output from IPS2200

#### 4.3.1. Additional GUI Options

The default settings (stored in the RX13T\_IPS2200.ini file) can be edited according to the customer needs. To set additional options, follow these steps:

1. Open the GUI.  
For more information on initial GUI launch and communication settings, see section 4.3.
2. Select "Parameters Settings" (see Figure 5).  
A parameter list opens on the main screen.
3. Set the relevant values to the parameters and select an option by clicking on either of the following buttons:
  - Reload: get the latest values from the RX13T dataflash into the display.
  - Write: store the display settings into the RX13T dataflash.
  - Create .h: create and store a C-source header file with the settings. The file can be added to the project at compile time for fixing settings of the customer specific motor.
  - Custom: Reload/Write system parameters from specific address

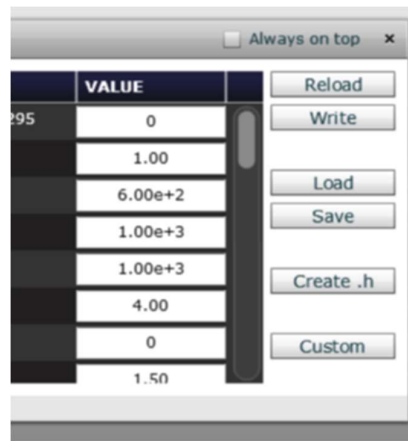


Figure 11: parameter options

**Important note:** the value for “21. Encoder Offset” parameter is detected during the self-tuning of the kit. If the connection of the rotating board (with the 2 HEX (Allen) screws) is modified, the Encoder Offset needs to be readjusted by clicking the “Motor Identification” (see Figure 5). It checks the motor parameters and recalculates the IPS2200 position sensor offset (in full degrees).



Figure 12: motor tuning button, on main control screen

Make sure to click the “Write Values in EEPROM” (dataflash), otherwise the value is not considered when turning the motor.

For more information on settings, controls, and mathematical background of the system refer to the *YROTATE-IT-RX23T User Manual* document.

## 4.4 Operation Modes

To allow specific test sequences with the RX13T board, a set of functions are included into the default RX13T firmware. These functions can be initiated using ‘operation mode numbers’ to be programmed via the GUI in parameter 00.

The mode number control sequence allows data output without the graphical GUI interface. There is a basic ‘fall back’ mechanism built into the system that allows an easy return control back to the GUI and reprogram specific motor settings of the system. For further details, refer to section 4.

## 4.5 Factory Default Setting

Upon delivery the GUI parameter 00 setting is “22”, which allows control of the board by using buttons. Alternative output settings are described in Table 1.

Table 1. Mode Settings Overview

| Parameter 00 value | Action                                                                            | Output to GUI<br>19200Bd | Output to Terminal<br>5600Bd |
|--------------------|-----------------------------------------------------------------------------------|--------------------------|------------------------------|
| 0                  | Full control by GUI                                                               | Yes                      | No                           |
| 1                  | Full control by GUI, allows reprogramming default value into parameter 00 setting | Yes                      | No                           |
| 10                 | Potentiometer control, bidirectional:<br>▪ 0%: maximum RPM counter-clockwise      | Yes                      | No                           |
| 20                 | ▪ 50%: stopped motor                                                              | No                       | Yes                          |

| Parameter 00 value            | Action                                                                                                                                                                                       | Output to GUI<br>19200Bd | Output to Terminal<br>5600Bd |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------|
|                               | <ul style="list-style-type: none"> <li>100%: maximum RPM clockwise</li> </ul>                                                                                                                |                          |                              |
| 11                            | Potentiometer control, one direction:                                                                                                                                                        | Yes                      | No                           |
| 21                            | <ul style="list-style-type: none"> <li>speed 0%~100% is 0RPM to max RPM</li> <li>direction change is done with Button 1</li> </ul>                                                           | No                       | Yes                          |
| 12                            | Button control:                                                                                                                                                                              | Yes                      | No                           |
| 22<br>Default factory setting | <ul style="list-style-type: none"> <li>speed clockwise with Button 1 decrease and Button 2 increase</li> <li>speed counterclockwise, with Button 1 increase and Button 2 decrease</li> </ul> | No                       | Yes                          |

When NOT in GUI mode, starting/stopping the motor is always done with Button 0, see sections 4.1 and 4.2 for details.

Switching between the different modes (see Table 1) without permanently changing the setting via the GUI can be achieved with button combinations. See

Table 2 for the button combinations while cycling RESET.

**Table 2. Button Combinations for Switching Control Options**

| Button 0    | Button 1    | Button 2    | Results in Parameter 00 Setting:            |
|-------------|-------------|-------------|---------------------------------------------|
| Pressed     | Not pressed | Not pressed | 21                                          |
| Not pressed | Pressed     | Not pressed | 20                                          |
| Not pressed | Not pressed | Pressed     | 22                                          |
| Not pressed | Pressed     | pressed     | 1 (return to GUI control)                   |
| Not pressed | Not pressed | Not pressed | Original programmed value from parameter 00 |

## 4.6 Terminal Data Output

Setting “2x” to Parameter 00 outputs board data to a simple terminal (Tera Term terminal or similar) with 57600Baud. Note that this is transmit to the terminal only, it is not possible to control the board in these modes.

When sending board data to the terminal, one data package is sent every 100ms, using semicolon between reported data. Table 3 shows the data output to the terminal, packet end is a '\$' sign, all values are in ASCII as readable form.

**Table 3. Data Packet Detail**

| Data Value         | Explanation                                                                                           |
|--------------------|-------------------------------------------------------------------------------------------------------|
| Counter            | Timer tick, counts up in 100ms intervals                                                              |
| Board control mode | Active mode value from parameter 00                                                                   |
| Sensor mode        | 0: Sensorless mode<br>1: IPS2200 active                                                               |
| Motor status       | 0: stopped motor<br>1: running enabled (RPM setting via potentiometer or buttons)<br>2: braking motor |
| Rotor direction    | -1: counterclockwise rotation<br>+1: clockwise rotation                                               |
| RPM setting        | Induced rotor speed                                                                                   |
| RPM actual         | Measured rotor speed                                                                                  |
| PWM frequency      | Frequency of the 3-phase voltage signal to the motor                                                  |
| Direct current     | Id (in mA)                                                                                            |
| Quad current       | Iq (in mA)                                                                                            |
| Direct voltage     | Vd (in mV)                                                                                            |

| Data Value     | Explanation                                       |
|----------------|---------------------------------------------------|
| Quad voltage   | Vq (in mV)                                        |
| Board voltage  | Vb (in Volt)                                      |
| IPS2200 sine   | Measured IPS2200 sine value (multiplied by 100)   |
| IPS2200 cosine | Measured IPS2200 cosine value (multiplied by 100) |
| \$             | Packet terminator                                 |

## 4.7 Default GUI Settings

The default settings are chosen to allow an effortless use of the system. Note that the boards have been reset at factory, storing the IPS2200 position offset into data flash (at position 21).

When a system data reset is invoked, the position 21 value is reset to '0' (zero). Readjustment of the offset is done using the 'Motor Identification' menu, see Figure 9.

Table 4 shows the default settings of the GUI controlled RX13T firmware, running with the IPS2200 as position sensing system and the Nanotech DB42S03 motor.

**Table 4. Default Firmware Settings**

| Name                         | Unit      | Min | Max    | Default <sup>[1]</sup> | Description                                                     | Type   | Decimal |
|------------------------------|-----------|-----|--------|------------------------|-----------------------------------------------------------------|--------|---------|
| 00. Operation select         | n/a       | 0   | 32768  | 0                      | Special operating modes selection                               | UInt32 | 0       |
| 01. Minimum speed            | rpm       | 1   | 3000   | 10                     | Minimum allowable speed                                         | Float  | 0       |
| 02. Maximum speed            | rpm       | 100 | 100000 | 7000                   | Maximum allowable speed                                         | Float  | 0       |
| 03. Acceleration             | rpm/s     | 1   | 10000  | 2000                   | Speed increasing ratio                                          | Float  | 0       |
| 04. Deceleration             | rpm/s     | 1   | 10000  | 2000                   | Speed decreasing ratio                                          | Float  | 0       |
| 05. Polar couples            | n/a       | 1   | 24     | 4                      | Number of motor pole pairs                                      | Float  | 0       |
| 06. Startup current          | n/a       | 0   | 10     | 0.5                    | Startup current at speed = 0 RPM                                |        |         |
| 07. Maximum current          | Apk       | 0   | 10     | 1                      | Maximum allowable current                                       | Float  | 3       |
| 08. Stator resistance        | Ohm       | 0   | 30000  | 0.803                  | Stator resistance                                               | Float  | 3       |
| 09. Synchronous Q inductance | Henry     | 0   | 30000  | 0.001426               | Synchronous inductance (q axis)                                 | Float  | 6       |
| 10. Permanent magnets flux   | Weber     | 0   | 30000  | 0.005283               | Permanent magnets flux vector amplitude                         | Float  | 6       |
| 11. Current loop Kp          | Ohm       | 0   | 30000  | 5.090                  | Current PI control loop proportional constant                   | Float  | 3       |
| 12. Current loop Ki          | Ohm/s     | 0   | 30000  | 4242.022               | Current PI control loop integral constant                       | Float  | 3       |
| 13. Speed loop Kp            | Apk*s/rad | 0   | 30000  | 0.002                  | Speed PI control loop proportional constant                     | Float  | 3       |
| 14. Speed loop Ki            | Apk/rad   | 0   | 30000  | 0.1                    | Speed PI control loop integral constant                         | Float  | 3       |
| 15. Flux feedback gain       | n/a       | 0   | 1000   | 200                    | Feedback gain for the integration of the flux estimation method | Float  | 0       |
| 16. Free                     | n/a       |     |        |                        |                                                                 |        |         |
| 17. Weak flux                | n/a       | 0   | 1      | 0                      | Setup countermeasure for weak flux                              | Float  | 1       |

| Name                        | Unit   | Min  | Max   | Default <sup>[1]</sup> | Description                                        | Type  | Decimal |
|-----------------------------|--------|------|-------|------------------------|----------------------------------------------------|-------|---------|
| 18. Free                    | n/a    |      |       |                        |                                                    |       |         |
| 19. Sampling frequency      | Hz     | 4000 | 16000 | 8000                   | Sampling frequency                                 | Float | 0       |
| 20. PWM/SAM frequency ratio | n/a    | 1    | 4     | 1                      | Ratio between PWM frequency and sampling frequency | Float | 0       |
| 21. Encoder offset          | degree | 0    | 360   | 0 <sup>[2]</sup>       | Encoder offset angle                               | Float | 1       |
| 22. Encoder direction       | n/a    | 0    | 1     | 0                      | Encoder offset angle direction                     | Float | 0       |
| 23. Free                    | n/a    |      |       |                        |                                                    |       |         |
| 24. Reserved                | n/a    | 0    | 256   |                        |                                                    | Float | 0       |
| 25. Free                    | n/a    |      |       |                        |                                                    |       |         |

1. Values are specific for the Nanotech DB42S03 BLDC motor
2. Offset value from the IPS2200 is evaluated using the 'Motor Identification' from the GUI and set when running the 'autotune' by the GUI.



## 5. Component Layout Map

### 5.1 MCU PCB

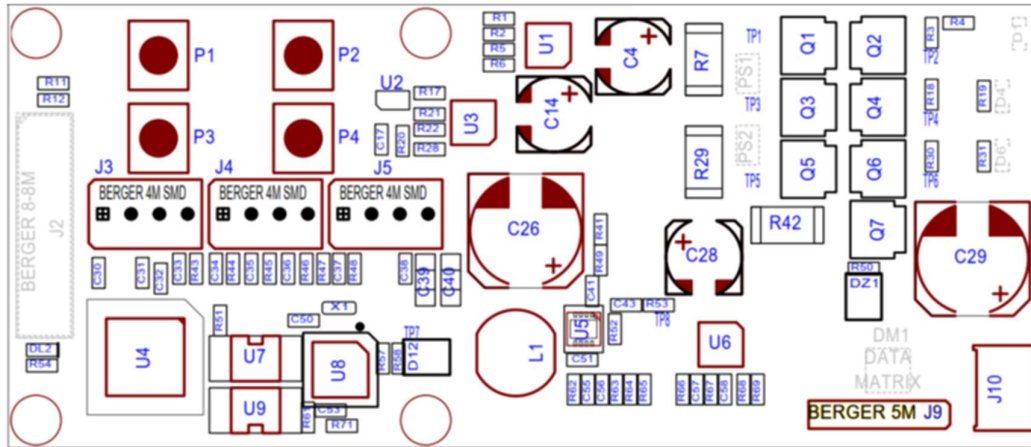


Figure 13. Top Side MCU PCB Assembly

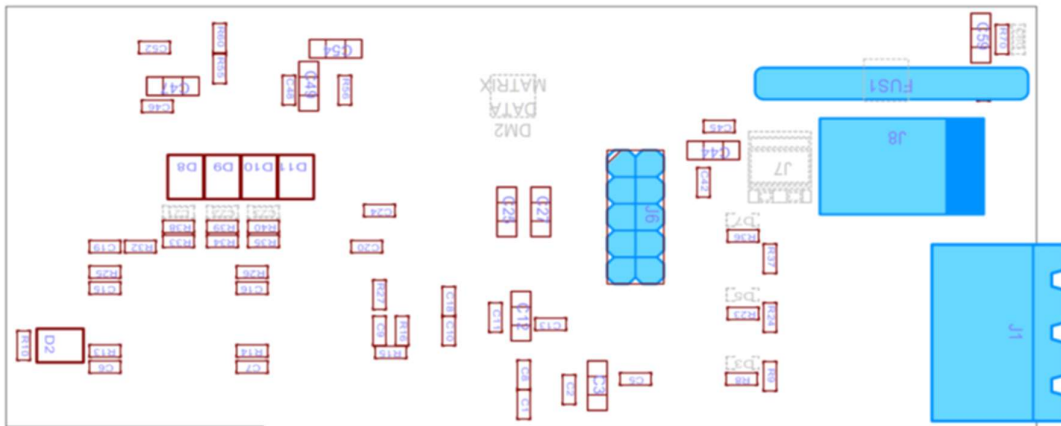


Figure 14. Bottom Side MCU PCB Assembly

Table 5. Board Connector Descriptions

|    |                         |    |                                                |
|----|-------------------------|----|------------------------------------------------|
| U1 | Half bridge HIP2211 (U) | J2 | Auxiliary connector (spare GPIO)               |
| U2 | Dual diode              | J3 | Debug RX13T                                    |
| U3 | Half bridge HIP2211 (V) | J4 | Jumper analog In or IPS Differential COS Input |
| U4 | RX13T                   | J5 | Potentiometer connector                        |
| U5 | DCDC power supply       | J6 | IPS2200 sensor connector                       |
| U6 | Half bridge HIP2211 (W) | J7 | Direct power connection                        |

|       |                        |
|-------|------------------------|
| U7/U9 | Optocoupler            |
| U8    | USB-to-Serial RL78/G1C |
| J1    | Motor connector        |

|     |                               |
|-----|-------------------------------|
| J8  | Power supply barrel connector |
| J9  | Debug RL78/G1C                |
| J10 | USB connector                 |

## 5.2 IPS2200 Sensor Board

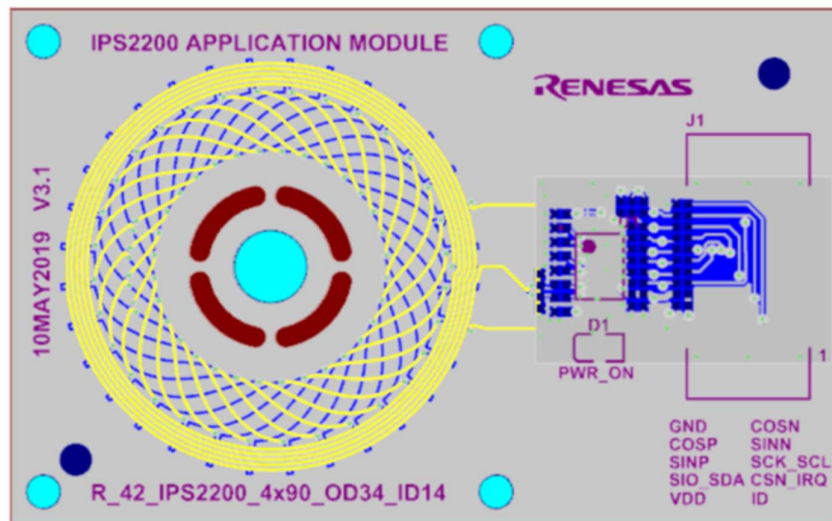


Figure 15. IPS2200 Sensor Board

Table 6. IPS2200 Board Contentions

|    |                |
|----|----------------|
| U1 | IPS2200 device |
| D1 | Power LED      |

|    |                         |
|----|-------------------------|
| J1 | Connection to MCU board |
|----|-------------------------|

## 6. Boards Overview

### 6.1 Schematics

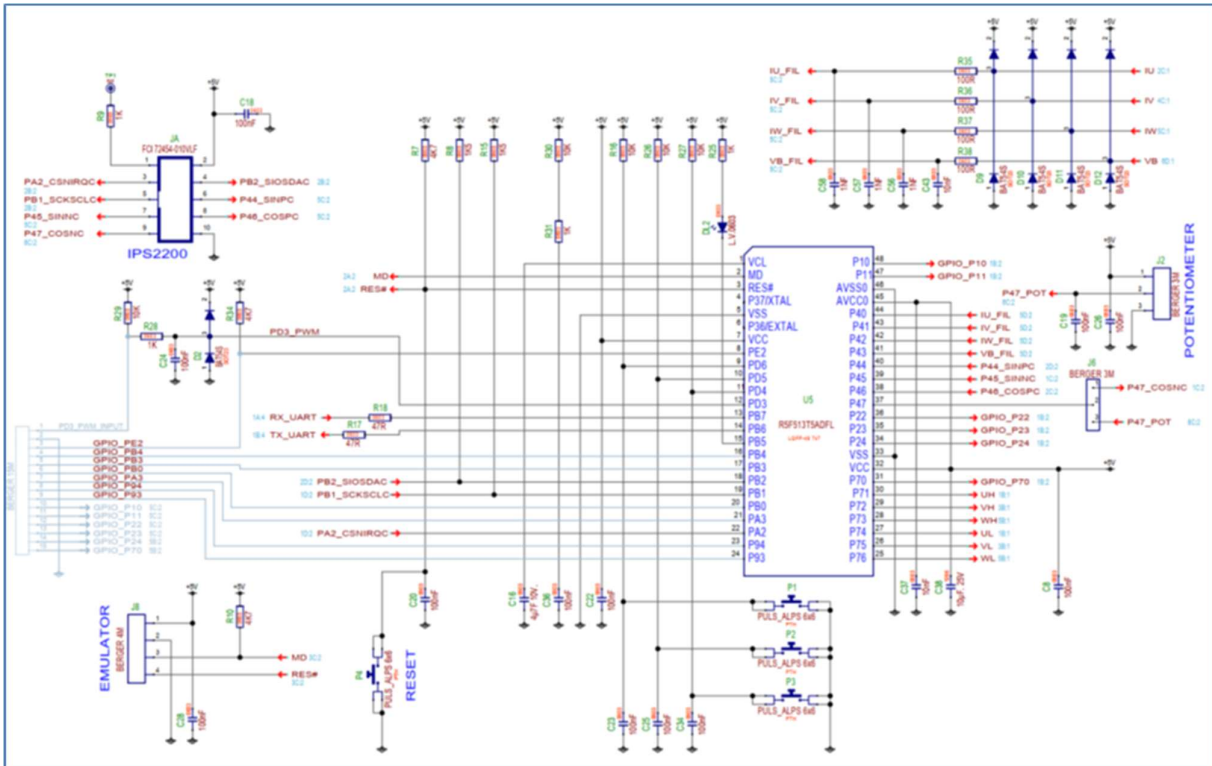


Figure 16. MCU

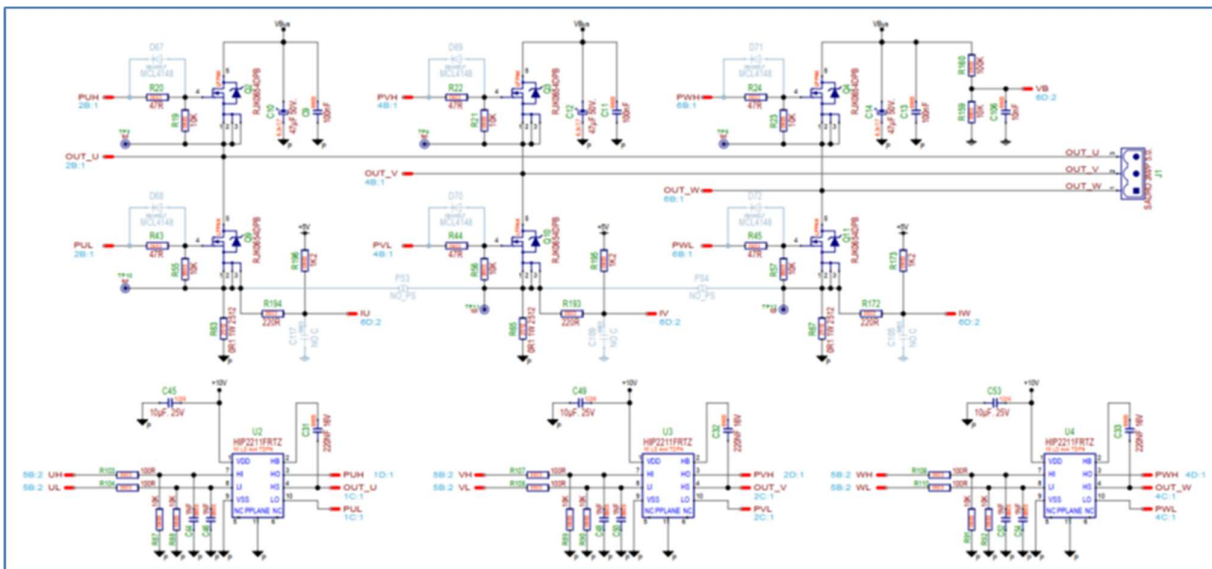


Figure 17. Power Stage

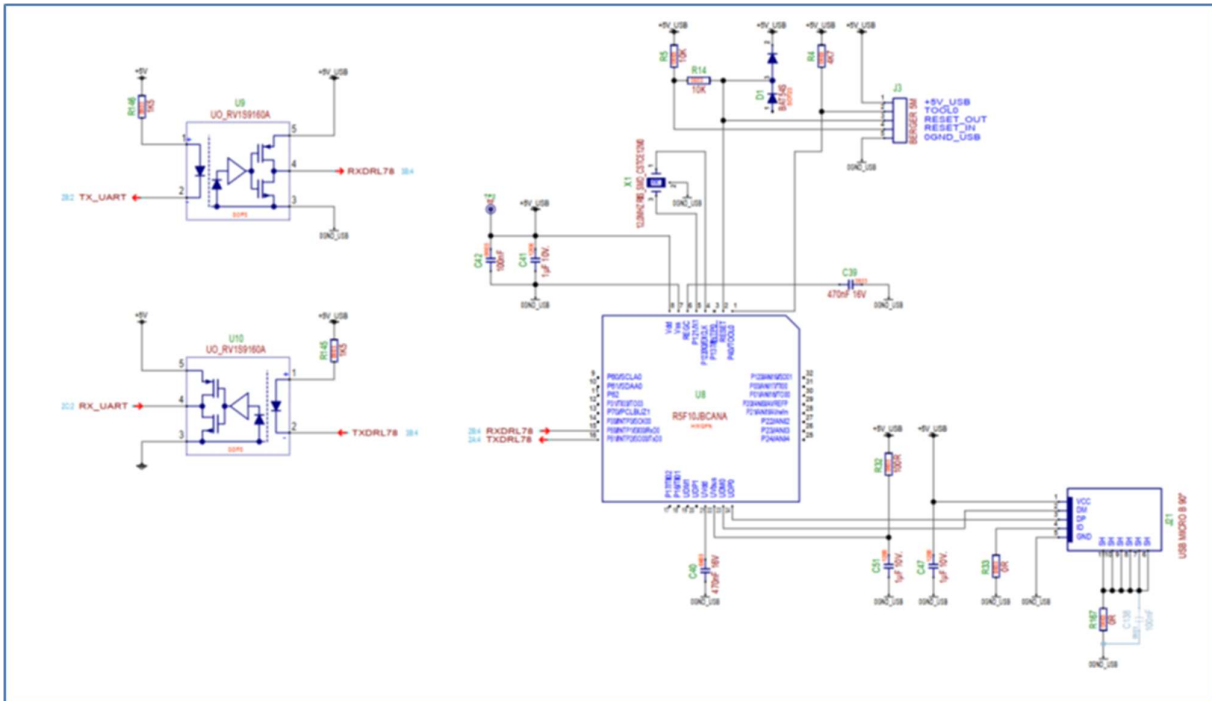


Figure 18. USB-to-Serial

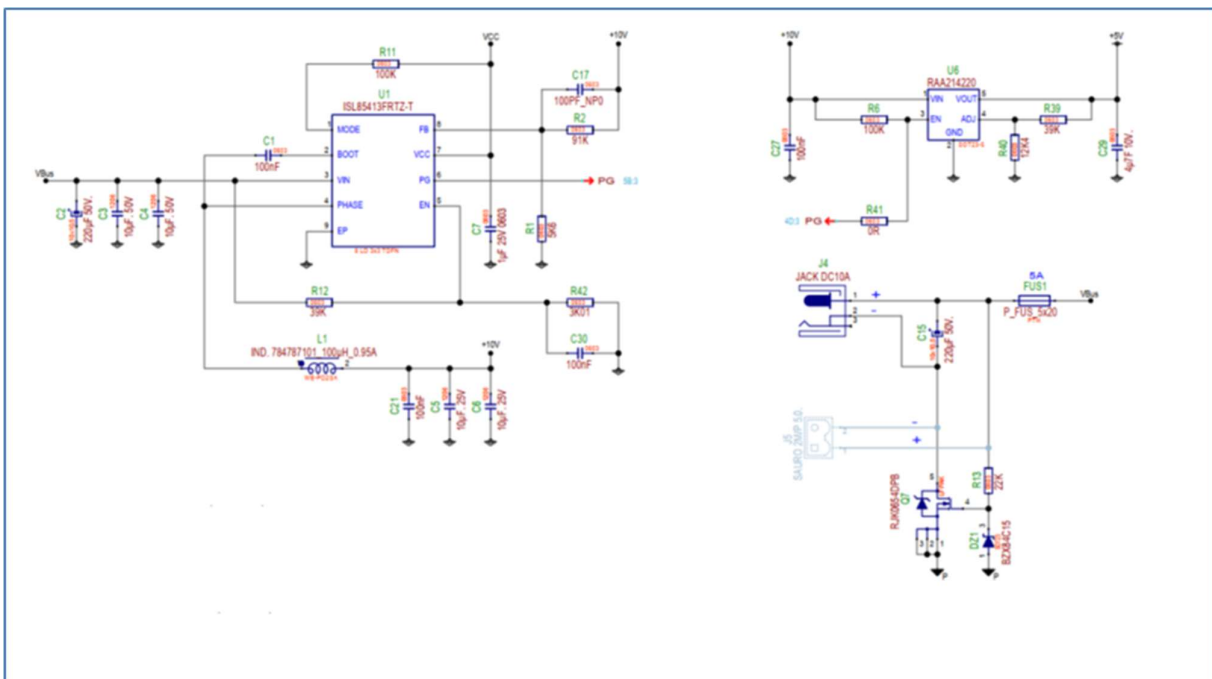


Figure 19. Power Supply

## 6.2 Microcontroller and motor driver board

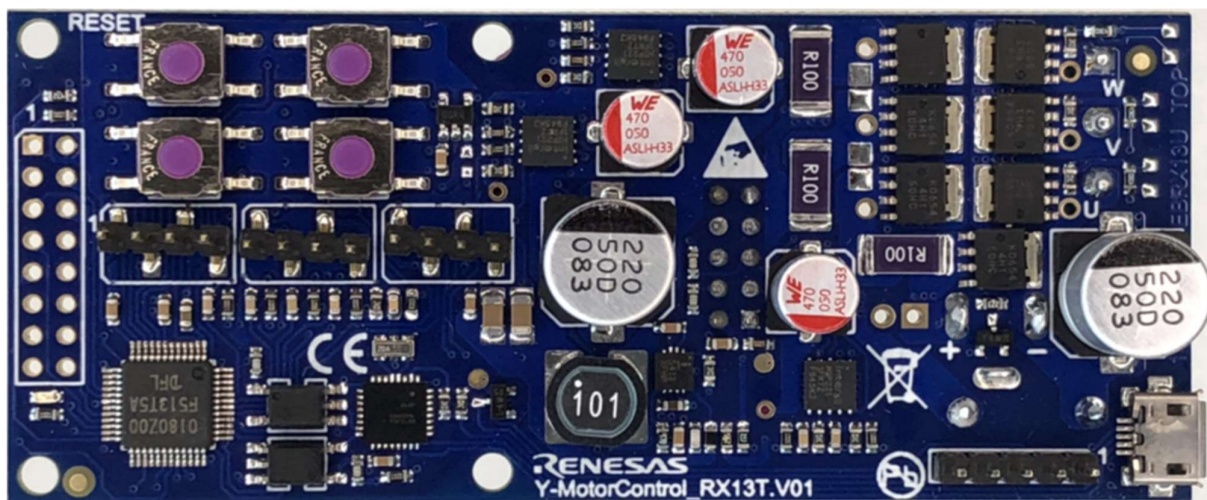


Figure 20. Microcontroller Board (Top Side)

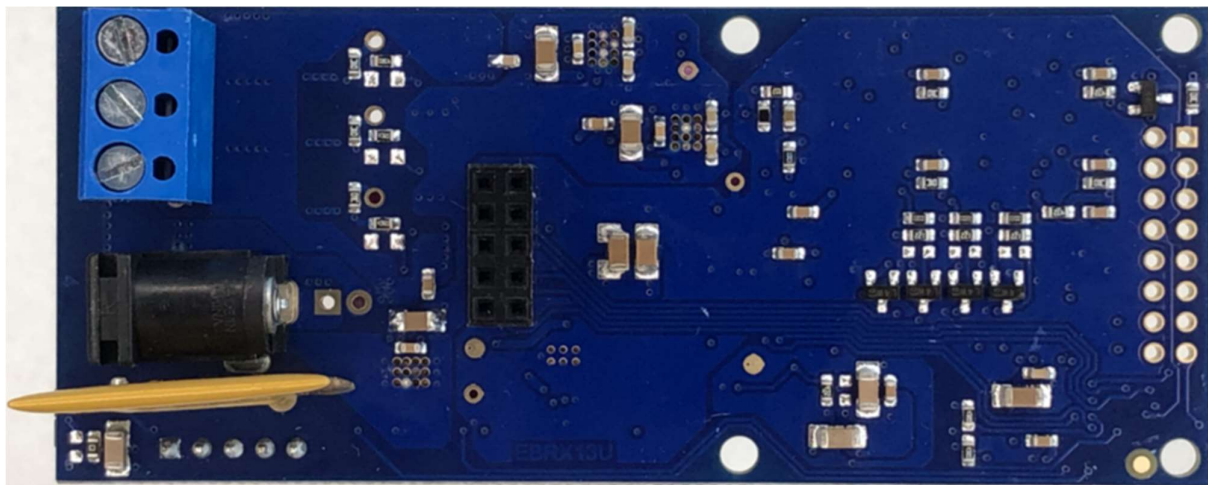


Figure 21. Microcontroller Board (Bottom Side)



## 6.3 Sensor Board

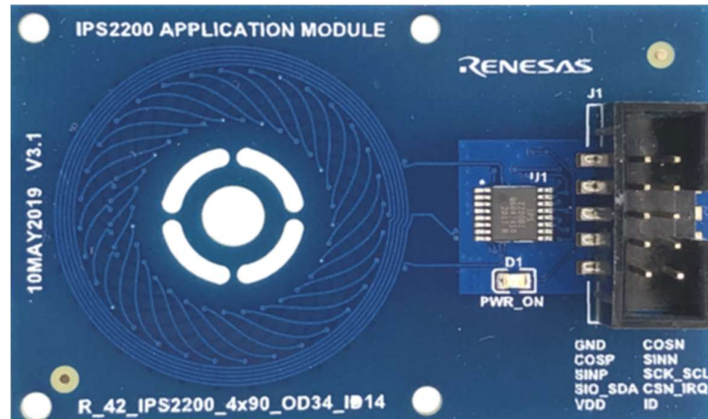


Figure 22. IPS2200 Sensor Board

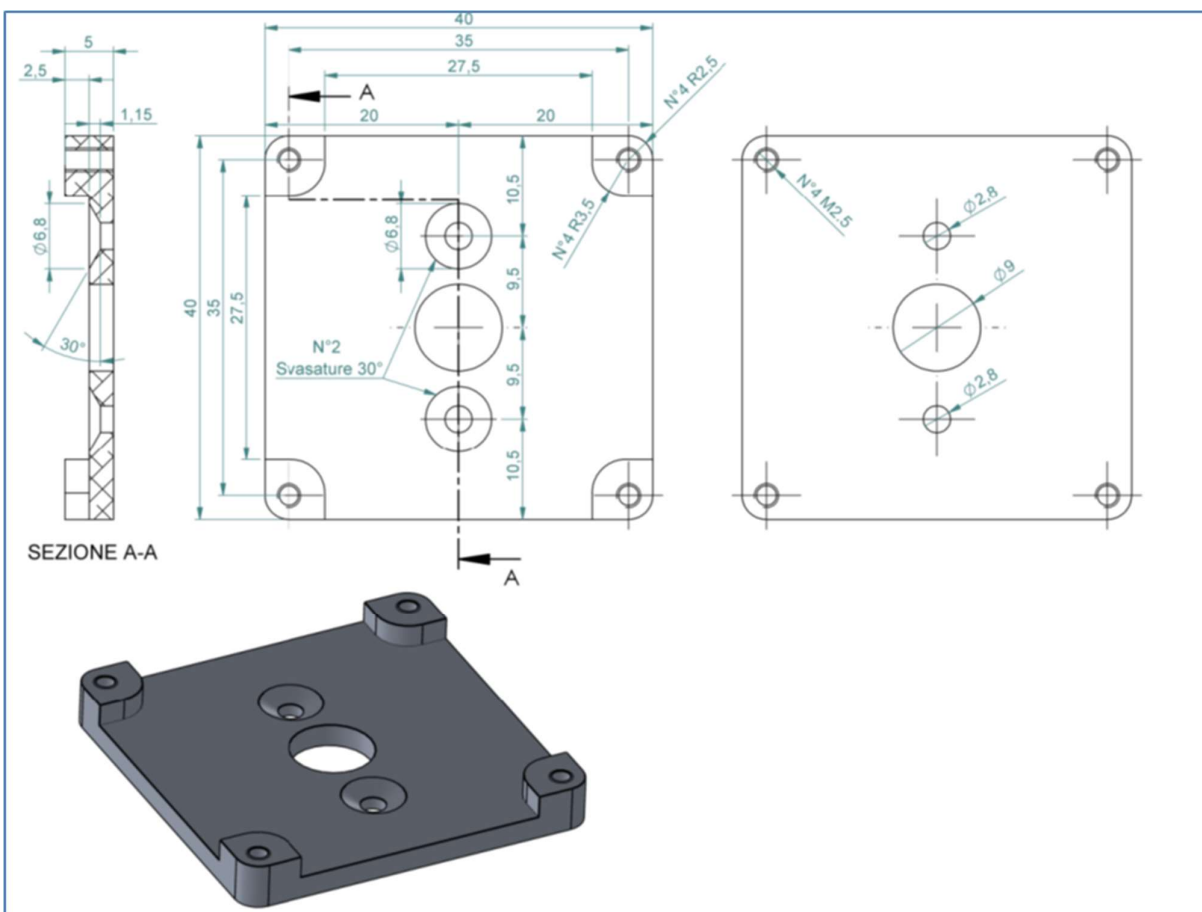


Figure 23. Reflector Board, Mounted onto Rotor

## 6.4 Mechanical Construction

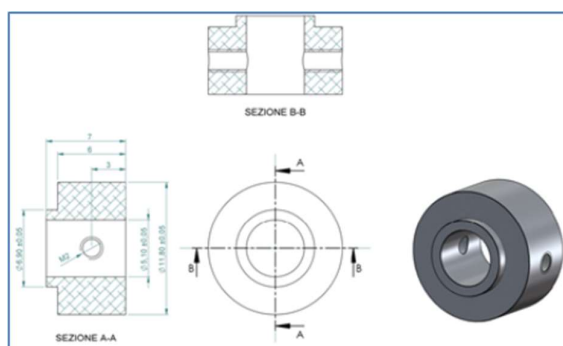
A mechanical construction is designed to allow relative closeness of the (rotating) disc to the IPS2200 coils. The minimum system allows to remove the IPS2200 board to the motor housing and the disc to the rotor.

When using distance holders, the MCU board can also be mounted to this construction, allowing a fixed connection (connector J6, on the backside of the MCU PCB) between the sensor board and MCU transmitting the IPS2200 signals.



### Figure 24. PCB Holder Mechanics

The middle screws fit to prepared holes in the backside of the Nanotech motor, while the holes on the corners are threaded and allow fixing of the sensor board with M2.5 screws.



**Figure 25. Reflector Holder, Fits on the Rotor**

## 7. RX13T Connections

The MotorControl-RX13T kit is a single board inverter, based on the 48pin RX13T. The hardware includes a low-voltage MOSFETs power stage, a communication section to a PC GUI, and an alternative speed control inputs independent of the GUI.

To obtain the maximum flexibility, the PoC board includes:

- A complete 3-phase inverter on-board with a low voltage motor to allow testing the several available algorithms on the RX13T.
- USB communication with the PC via a RL78/G1C microcontroller. The Rx and Tx lines to the RX13T are optically/galvanically isolated.
- IPS2200 device for position sensing

Further input signals are the 3 general purpose buttons, analog input/potentiometer speed control, and PWM input for speed control. Spare GPIO pins are available on connector J2.

Debugging is possible via a 4-pin connection to E1/E2 emulator.

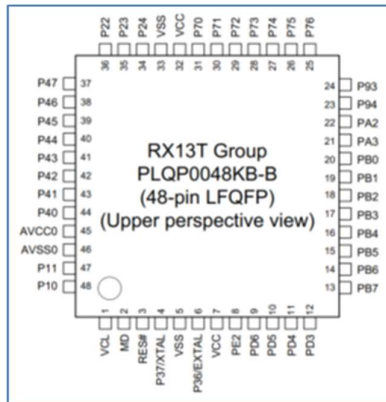


Figure 26. RX13T - 48pin Layout

Table 7 shows the RX13T pin layout matching the usage on the board.

Table 7. RX13T Pin Layout

| Pin No. | Pin Name | I/O Port        | Timers (MTU, POE, CAC)              | Communications (SCI,IIC) | Board Use                    |
|---------|----------|-----------------|-------------------------------------|--------------------------|------------------------------|
| 1       | VCL      |                 |                                     |                          |                              |
| 2       | MD       | FINED           |                                     |                          | EML mode pin                 |
| 3       | RES#     |                 |                                     |                          | EML RESET pin / reset Button |
| 4       | XTAL     | P37             |                                     |                          | NC                           |
| 5       | VSS      |                 |                                     |                          | GND                          |
| 6       | EXTAL    | P36             |                                     |                          | NC                           |
| 7       | VCC      |                 |                                     |                          | VCC                          |
| 8       | PE2      | POE10#          | NMI/IRQ0                            |                          | J2 - pin 3                   |
| 9       | PD6      | MTIOC0D         | CTS1#/RTS1#/SS1#                    | IRQ5/ADST0               | Button 2                     |
| 10      | PD5      | MTIOC0C         | RXD1/SMISO1/SSCL1                   | IRQ3                     | Button 1                     |
| 11      | PD4      | MTIOC0B         | SCK1                                | IRQ2                     | Button 3                     |
| 12      | PD3      | MTIOC0A         | TXD1/SMOS11/SSDA1                   |                          | J2 - pin 1 - PWM in          |
| 13      | PB7      | MTIOC3C/MTCLKD  | RXD1/SMISO1/SSCL1/RXD5/SMISO5/SSCL5 | IRQ5                     | UART Rx                      |
| 14      | PB6      | MTIOC1B/MTIOC3A | TXD1/SMOS11/SSDA1/TXD5/SMOS15/SSDA5 |                          | UART Tx                      |



| Pin No. | Pin Name | I/O Port               | Timers<br>(MTU, POE, CAC)             | Communications<br>(SCI,IIC) | Board Use                         |
|---------|----------|------------------------|---------------------------------------|-----------------------------|-----------------------------------|
| 15      | PB5      | ADTRG0#                |                                       |                             | Green LED DL2                     |
| 16      | PB4      | POE8#                  | IRQ3                                  |                             | J2 - pin 4                        |
| 17      | PB3      | MTIOC0A/CACREF         | SCK5/SCK12                            |                             | J2 - pin 5                        |
| 18      | PB2      | MTIOC0B/MTCLKC/ADSM0   | TXD5/ <b>SMOSI5</b> /SSDA5/SDA0       |                             | IPS2200 SIOSDAC                   |
| 19      | PB1      | MTIOC0C/MTIC5W/MTCLKA  | RXD5/ <b>SMISO5</b> /SSCL5/SCL0       | IRQ2                        | IPS2200 SCKSCLC                   |
| 20      | PB0      | MTIOC0D/MTIOC2A/MTCLKB | TXD12/TXD12/SIOX12/<br>SMOSI12/SSDA12 |                             | J2 - pin 6                        |
| 21      | PA3      | MTIOC1B/MTIOC2A        | CTS12#/RTS12#/SS12#                   |                             | J2 - pin 7                        |
| 22      | PA2      | MTIOC1A/MTIOC2B        | CTS5#/RTS5#/SS5#                      | IRQ4                        | IPS2200 CSNIRQC                   |
| 23      | P94      | MTIOC2B/MTIC5U/MTCLKA  | RXD12/RXD12/SMISO12/<br>SSCL12        | IRQ1                        | J2 - pin 8                        |
| 24      | P93      | MTIOC1A/MTIC5V         | SCK5/SCK12                            | IRQ0/ADTRG0#                | J2 - pin 9                        |
| 25      | P76      | MTIOC4D                |                                       |                             | HIP2211 - WL                      |
| 26      | P75      | MTIOC4C                |                                       |                             | HIP2211 - VL                      |
| 27      | P74      | MTIOC3D                |                                       |                             | HIP2211 - UL                      |
| 28      | P73      | MTIOC4B                |                                       |                             | HIP2211 - WH                      |
| 29      | P72      | MTIOC4A                |                                       |                             | HIP2211 - VH                      |
| 30      | P71      | MTIOC3B                |                                       |                             | HIP2211 - UH                      |
| 31      | P70      | POE0#                  | IRQ5                                  |                             | J2 - pin 15                       |
| 32      | VCC      |                        |                                       |                             | VCC                               |
| 33      | VSS      |                        |                                       |                             | GND                               |
| 34      | P24      | MTIC5U                 | RXD5/SMISO5/SSCL5                     | IRQ3/COMP0                  | J2 - pin 14                       |
| 35      | P23      | MTIC5V/CACREF          | TXD5/SMOSI5/SSDA5                     | IRQ4/COMP1                  | J2 - pin 13                       |
| 36      | P22      | MTIC5W                 | IRQ2/COMP2                            |                             | J2 - pin 12                       |
| 37      | P47*1    | <b>AN007</b> /CMPC13   |                                       |                             | J4 - pin 2<br>(pot/IPS2200 COSNC) |
| 38      | P46*1    | <b>AN006</b> /CMPC03   |                                       |                             | IPS2200 COSPC                     |
| 39      | P45*1    | <b>AN005</b> /CMPC22   |                                       |                             | IPS2200 SINNC                     |
| 40      | P44*1    | <b>AN004</b> /CMPC12   |                                       |                             | IPS2200 SINPC                     |
| 41      | P43*1    | <b>AN003</b> /CMPC02   |                                       |                             | High Voltage Ref                  |
| 42      | P42*1    | <b>AN002</b> /CMPC20   |                                       |                             | Shunt W                           |
| 43      | P41*1    | <b>AN001</b> /CMPC10   |                                       |                             | Shunt V                           |
| 44      | P40*1    | <b>AN000</b> /CMPC00   |                                       |                             | Shunt U                           |
| 45      | AVCC0    |                        |                                       |                             | VCC                               |
| 46      | AVSS0    |                        |                                       |                             | GND                               |
| 47      | P11      | MTIOC3A/MTCLKA/POE8#   | IRQ1/CVREFC0                          |                             | J2 - pin 11                       |
| 48      | P10      | MTCLKB                 | IRQ0                                  |                             | J2 - pin 10                       |

## 8. Board Connections

The MCU board has several connections to communicate with the environment.

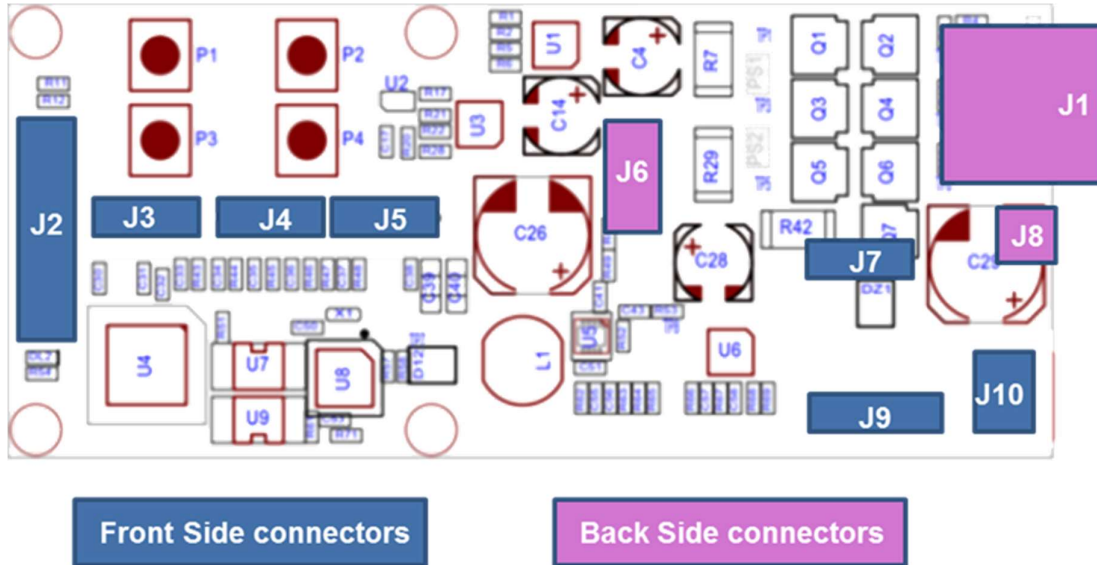


Figure 27. Position of Connectors

### 8.1 J1 3 Pin Motor Connector

The 3 pin motor connector allows to transport up to 5A.

### 8.2 J2 Auxiliary Connector (Spare GPIO)

The spare pins from the RX13T are available on J2 connector.

Table 8. Auxiliary Connector

| J2 | RX13T Pin No. | Pin Name |
|----|---------------|----------|
| 1  | 12            | PD3      |
| 2  | 5             | GND      |
| 3  | 8             | PE2      |
| 4  | 16            | PB4      |
| 5  | 17            | PB3      |
| 6  | 20            | PB0      |
| 7  | 21            | PA3      |
| 8  | 23            | P94      |
| 9  | 24            | P93      |
| 10 | 48            | P10      |
| 11 | 47            | P11      |
| 12 | 36            | P22      |
| 13 | 35            | P23      |
| 14 | 34            | P24      |
| 15 | 31            | P70      |
| 16 |               | NC       |

### 8.3 J3 Debug RX13T

Connector J3 allows connection to an E1/E2 emulator.

Note that the emulator cannot be used either during programming of the flash memory or to power the board. The system is safe to connect 24V on the barrel connector to program or to debug code on the RX13T device.

**Table 9. Debug Connector**

| J3 | RX13T Pin No. | Pin Name  | E1 Pin Connection |
|----|---------------|-----------|-------------------|
| 1  | 7             | Vcc (+5V) | 8 - 9             |
| 2  | 5             | GND       | 2 – 12 - 14       |
| 3  | 2             | MD        | 7                 |
| 4  | 3             | Reset     | 13                |

### 8.4 J4 Jumper Analog IN / IPS Differential COSN Input

The RX13T has only 7 ADC channels available (the factory default firmware uses single ended input only). The IPS2200 can only be used in single ended mode if the motor speed is set with an external potentiometer or analog DC voltage in non-GUI control.

**Table 10. AN7 Analog IN**

| J4 | Connection    |
|----|---------------|
| 1  | IPS2200 COSCN |
| 2  | RX13T pin37   |
| 3  | ANALOG IN     |
| 4  | Not connected |

When using the IPS2200 in differential mode, ensure to connect pins 1 and 2. When connecting a potentiometer or provide the board with an external DC control voltage, ensure to connect pins 2 and 3.

### 8.5 J5 Potentiometer Connector

When using an external analog DC voltage, the external control voltage must be connected to pin 2 of J5. When using a potentiometer, connect the slider to pin 2, while the outer pins must be connected to pins 1 and 3. Note that the used potentiometer must be >10kOhm.

**Table 11. Analog Speed Control**

| J5 | Connection                       |
|----|----------------------------------|
| 1  | Board +5V                        |
| 2  | Analog IN (potentiometer slider) |
| 3  | Board GND                        |
| 4  | Not connected                    |

## 8.6 J6 IPS2200 Sensor Connector

The IPS2200 connects directly to the MCU board via J6. All pins of the device are wired to the connector.

Table 12. IPS2200 Connection

| J6 | IPS2200 Signal Name | RX13T Connection Name |
|----|---------------------|-----------------------|
| 1  | Test point TP8      | Not connected         |
| 2  | Board +5V           | N/A                   |
| 3  | CSN IRQ             | PA2                   |
| 4  | Serial SDA          | PB2                   |
| 5  | Serial SCL          | PB1                   |
| 6  | SIN P signal        | P44                   |
| 7  | SIN N signal        | P45                   |
| 8  | COS P signal        | P46                   |
| 9  | COS N signal        | P47 (via J4 pin 1)    |
| 10 | Board GND           | N/A                   |

## 8.7 J7 Direct Power Connection

The board allows to use a wired 24V connection (without using the barrel connector) with the following restrictions:

- Voltage Rating: 12VDC to 36VDC
- Power Rating: 5A<sub>max</sub>

Table 13. External Power

| J7 | Connection |
|----|------------|
| 1  | + 24V DC   |
| 2  | Board GND  |

## 8.8 J8 Power Supply Barrel Connector (24V / maximum 36V)

Do not exceed 3A when using the barrel connector from the power supply. Use the power connectors on the board when using the board to the maximum current.

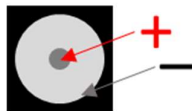


Figure 28: Barrel Connector

Power supply restrictions:

- Board voltage Rating: 12VDC to 36VDC
- Barrel connector current rating: 3A<sub>max</sub>

## 8.9 J9 Debug RL78/G1C

The board has a debug connector to program the RL78/G1C device (USB 2 serial) – **RL78/G1C device is factory programmed and does not need debugging or reprogramming.**

## 8.10 J10 USB Connector

The USB connector on the board allows to connect to a controlling MS Windows™ environment. When using the GUI, the control signals are transferred here. When using non-GUI mode, the firmware feedback is sent to a terminal by using a 115kBaud transfer rate.

## 9. System BOM List

Table 14. System Bill of Material

| Quantity | Manufacturer     | MFR Part Number | Description                                                                         | Component Names                                                                            |
|----------|------------------|-----------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| 1        | Würth Elektronik | 694106301002    | CONN. JACK 5A 2,1mm DC-10A 5A 12VDC                                                 | J8                                                                                         |
| 1        | NAC              | 2CSI9M03        | C.SAURO CIM/9P-03 M.POL.90GR.                                                       | J1                                                                                         |
| 1        | STP F DP 5-5     | 2CV00149        | STP F DP 5+5 H8.5 P.2,54 SS14S(F1593490)                                            | J6                                                                                         |
| 1        | BERGER 5M        | 2CV00165        | STRIP 5P.M.VERT.p.2,54mm                                                            | J9                                                                                         |
| 3        | Harwin           | M20-8770442R    | ST.4M p2.54 h9.65 M20-8770442R                                                      | J3, J4, J5                                                                                 |
| 1        | Würth Elektronik | 629105150921    | USB MICRO B 90°                                                                     | J10                                                                                        |
| 4        | PULS_KSEM31G LFS | 4AAP0040        | KSEM31G LFS - Interruttore Tattile, Non Illuminato, 32 V, 50 mA, 1.5 N, SMD         | P1, P2, P3, P4                                                                             |
| 1        | Würth Elektronik | 784787101       | 784787101 (SMD) AEC-Q200 100µH 950mA Schermato 870mA WE-PD2SA Series                | L1                                                                                         |
| 1        | Würth Elektronik | 885012006057    | COND. SMD 50V 0603 NP0 "100pF"                                                      | C56                                                                                        |
| 9        | Würth Elektronik | 885012206083    | COND. SMD 50V 0603 X7R "1nF"                                                        | C1, C8, C10, C18, C33, C34, C35, C57, C58                                                  |
| 3        | Würth Elektronik | 885012206089    | COND. SMD 50V 0603 X7R "10nF"                                                       | C36, C37, C46                                                                              |
| 19       | Würth Elektronik | 885012206095    | COND. SMD 50V 0603 X7R "100nF"                                                      | C5, C6, C7, C13, C15, C16, C17, C19, C20, C24, C30, C31, C38, C41, C42, C43, C48, C52, C55 |
| 3        | Würth Elektronik | 885012206048    | COND. SMD 16V X7RK 0603 "220nF"                                                     | C2, C11, C45                                                                               |
| 2        | Würth Elektronik | 885012206050    | COND. SMD 16V 0603 X7R "470nF"                                                      | C50, C53                                                                                   |
| 3        | Würth Elektronik | 885012208093    | COND. SMD 1µF 50V X7R 1206                                                          | C49, C54, C59                                                                              |
| 1        | Würth Elektronik | 885012106022    | C.SMD 1µF 25V 0603 X5R                                                              | C51                                                                                        |
| 2        | Würth Elektronik | 885012106012    | C.SMD 4.7µF 10V 0603 X5R                                                            | C9, C32                                                                                    |
| 6        | Würth Elektronik | 885012208069    | COND. SMD 10µF 25V X7R (Package 1206)                                               | C3, C12, C39, C40, C44, C47                                                                |
| 2        | Würth Elektronik | 885012108022    | C.SMD 10µF 50V X5R 1206                                                             | C25, C27                                                                                   |
| 3        | Würth Elektronik | 865060645008    | COND. SMD ELETTR. 47µF 50V                                                          | C4, C14, C28                                                                               |
| 2        | Würth Elektronik | 865060657012    | COND. SMD ELETTR. 220µF 50V                                                         | C26, C29                                                                                   |
| 6        | Onsemi           | BAT54S          | D.SMD BAT54S 200mA 30V SCHOTTKY SOT-23                                              | D2, D8, D9, D10, D11, D12                                                                  |
| 2        | Renesas          | RV1S9160A       | OPT. RV1S9160A SOP-5 CMOS                                                           | U7, U9                                                                                     |
| 3        | Renesas          | HIP2211FRTZ     | C.I.SMD HIP2211FRTZ 100V 3A 10DFN 4X4                                               | U1, U3, U6                                                                                 |
| 1        | Renesas          | ISL85413FRTZ-T  | ISL85413FRTZ-T Integrated FET Regulators Wide Vin, 300mA Synchronous Buck Regulator | U5                                                                                         |
| 1        | Renesas          | RAA214220       | RAA214220 150mA 20V Wide Input Voltage Range LDO Linear Regulator                   | U2                                                                                         |

| Quantity | Manufacturer | MFR Part Number  | Description                                                 | Component Names                                                                           |
|----------|--------------|------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 1        | Renesas      | R5F10JBCANA      | R5F10JBCANA RL78 Microcontroller for USB to UART Conversion | U8                                                                                        |
| 1        | Renesas      | R5F513T5ADFL     | R5F513T5ADFL RX Family RX13T Group Microcontrollers         | U4                                                                                        |
| 1        | DIALIGHT     | 4ALV0603         | LED.SMD VERDE 0603 DIALIGHT                                 | DL2                                                                                       |
| 7        | Renesas      | RJK0654DPB       | MOSFET RJK0654DPB LFPK 60V 30A Rds=6.5mOhm                  | Q1, Q2, Q3, Q4, Q5, Q6, Q7                                                                |
| 1        | Murata       | CSTCE12M0G52A-R0 | RIS.CER.SMD CSTCE12M0G52A-R0 12.0Mhz MURATA-AVX AUTOMOTIVE  | X1                                                                                        |
| 3        | 0R           | 4AR00006         | RESIST.SMD 0603 "0R 1%"                                     | R20, R59, R70                                                                             |
| 3        | 0R1 1W 2512  | 4AR00125         | RESIST.SMD 2512 "0R1" 1% 200V 100PPM/°C                     | R7, R29, R42                                                                              |
| 8        | 47R          | 4AR04706         | RESIST.SMD 0603 "47R 1%"                                    | R4, R8, R19, R23, R31, R36, R55, R60                                                      |
| 11       | 100R         | 4AR11006         | RESIST.SMD 0603 "100R 1%"                                   | R2, R5, R21, R22, R43, R44, R45, R46, R66, R69, R71                                       |
| 3        | 220R         | 4AR12006         | RESIST.SMD 0603 "220R 1%"                                   | R33, R34, R35                                                                             |
| 3        | 1K           | 4AR21006         | RESIST.SMD 0603 "1K 1%"                                     | R12, R53, R54                                                                             |
| 3        | 1K2          | 4AR21206         | RESIST.SMD 0603 "1K2 1%"                                    | R38, R39, R40                                                                             |
| 4        | 1K5          | 4AR21506         | RESIST.SMD 0603 "1K5 1%"                                    | R41, R49, R51, R61                                                                        |
| 1        | 3K01         | 4AR23316         | R.SMD 3K01 0603 1% 100PPM                                   | R62                                                                                       |
| 4        | 4K7          | 4AR24706         | RESIST.SMD 0603 "4K7 1%"                                    | R11, R13, R32, R56                                                                        |
| 1        | 5K6          | 4AR25606         | RESIST.SMD 0603 "5K6 1%"                                    | R64                                                                                       |
| 19       | 10K          | 4AR31006         | RESIST.SMD 0603 "10K 1%"                                    | R1, R3, R6, R9, R10, R14, R17, R18, R24, R25, R26, R28, R30, R37, R47, R57, R58, R67, R68 |
| 1        | 12K4         | 4AR31246         | R.SMD 12K4 0603 1% 100PPM                                   | R16                                                                                       |
| 1        | 22K          | 4AR32206         | RESIST.SMD 0603 "22K 1%"                                    | R50                                                                                       |
| 2        | 39K          | 4AR33906         | RESIST.SMD 0603 "39K 1%"                                    | R15, R65                                                                                  |
| 1        | 91K          | 4AR39106         | RESIST.SMD 0603 "91K 1%"                                    | R63                                                                                       |
| 3        | 100K         | 4AR41006         | RESIST.SMD 0603 "100K 1%"                                   | R27, R48, R52                                                                             |
| 1        | Onsemi       | BZX84C15         | D. ZENER 15V 350mW SOT-23                                   | DZ1                                                                                       |
| 1        | Bourns       | MF-R800          | PTC Bourns MF-R800_0_99 8A/16A multifuse                    | FUS1                                                                                      |

## 10. Operation Modes

To allow specific test sequences with the RX13T board, a set of functions are included into the default RX13T firmware. These functions can be initiated using 'operation mode numbers' to be programmed via the GUI in parameter 00, see section 4.5 for details.

The mode number control sequence allows data output without the graphical GUI interface. There is a basic 'fall back' mechanism built into the system that allows an easy return control back to the GUI and reprogram specific motor settings of the system. For further details, refer to section 4.

## 11. Certifications

The EU068 Motorcontrol Kit RX13T & IPS2200 Kit complies with the laws and regulations described below.

## 12. References

- [1] RX13T Group User's Manual: Hardware RENESAS 32-Bit MCU RX Family/RX100 Series
- [2] IPS2200 Inductive Position Sensor IC, Datasheet
- [3] RL78/G1C User's Manual: Hardware Rev.1.21 Dec 2020 16 16-Bit Single-Chip Microcontrollers
- [4] RV1S9160A, 15Mbps CMOS OUTPUT, 5-PIN SOP PHOTOCOUPLER, Datasheet
- [5] HIP2210, HIP2211 100V, 3A Source, 4A Sink, High Frequency Half-Bridge Drivers, Datasheet
- [6] RJK0654DPB 60V, 30A, Silicon N Channel Power MOS FET, Datasheet
- [7] ISL85413 Wide VIN 300mA Synchronous Buck Regulator, Datasheet
- [8] RAA214220 150mA 20V Wide Input Voltage Range LDO Linear Regulator, Datasheet
- [9] Renesas Electronics, "E1/E20/E2 Emulator, E2 Emulator Lite - Additional Document for User's Manual - (Notes on Connection for RL78)", Jul. 2020 - R20UT1994EJ0702.
- [10] Renesas Electronics, "YROTATE-IT-RX23T User Manual" Oct. 2015, UM-YROTATE-IT-RX23T



## 13. Glossary

| Term | Description                                 |
|------|---------------------------------------------|
| BOM  | Bill of Material                            |
| DC   | Direct Current                              |
| EML  | Emulator                                    |
| GPIO | General Purpose Input Output                |
| GUI  | Graphical User Interface                    |
| I2C  | Inter Integrated Circuit Interface          |
| LDO  | Low Dropout (voltage regulator)             |
| MCU  | Microcontroller Unit                        |
| PCB  | Printed Circuit Board                       |
| PI   | Proportional Integral (control loop)        |
| PoC  | Proof of Concept                            |
| PWM  | Pulse Width Modulation                      |
| RMP  | Ramp Up                                     |
| SAM  | Sampling Frequency                          |
| SCL  | Serial Clock Line                           |
| SDA  | Serial Data Line                            |
| SPI  | Serial Peripheral Interface                 |
| UART | Universal Asynchronous Receiver Transmitter |

## 14. Revision History

| Revision | Date         | Description      |
|----------|--------------|------------------|
| 1.0      | Oct 18, 2021 | Initial release. |