RABID MANTIS

Isolated USB-UART

Galvanically isolated USB to UART converter.

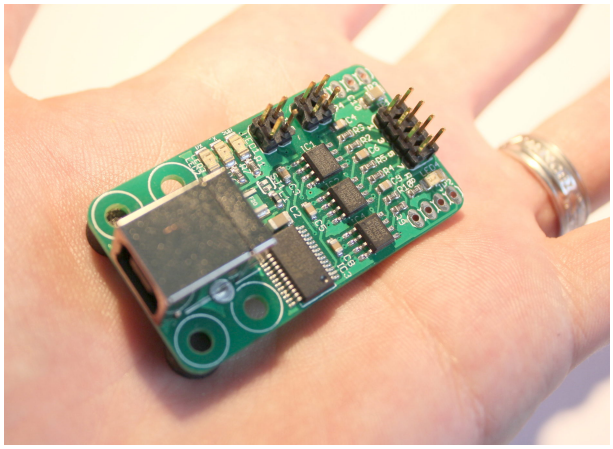
Features

Isolated transfer of RX, TX, RTS, CTS, DTR, and DSR signals.
Up to 3Mbaud operation.
1131V isolation per the IEC 60950-1 standard.
560V isolation per the DIN V VDE V 0884-10 standard.
Breadboard-friendly pin headers.
2.7V to 5.5V output voltage range.
Optional non-isolated mode, USB 5V supply powers load.

Description

Isolated USB-UART is a galvanically isolated USB to UART converter. It is based on the FT232R and ADuM1201 IC's and offers speeds up to 3Mbaud[a] with support for up to three data transfer pairs, RX/TX, RTS/CTS, and DSR/DTR, controllable by component mounting choices. Galvanic isolation of up to 1131V is achievable as per the IEC 60950-1 standard, making mains isolation easily achievable. A 2.7V to 5.5V output voltage range allows for communication with most devices. An optional mode supplies the load with 5V from the USB bus, though without any isolation.

[a] 1Mbaud with the default components.



Contents

Copyright Notice

Hardware Revision History

1.0.2 Output ferrite added, reduces LC-ringing on hotplugging.

1.0.1 Minor silkscreen updates.

1.0.0 Initial version.

Documentation Revision History

1.0.1 Update documentation to match hardware revision 1.0.2.

1.0.0 Initial version, applies to hardware revision 1.0.1.

Absolute Maximum Ratings

PARAMETER	RATING
Load-side supply voltage V_{DD}	-0.5V to 7.0V
Load-side logic input voltages	-0.5V to V_{DD}+0.5V
Load-side logic short to GND or V_{DD}	Infinite

Assembly

Isolated USB-UART is relatively easy to assembly, consisting of mostly surface mount components and some through-hole components for input and output connections. Though there are surface mount components, these are relatively easy to handle and can be soldered with a basic fine-point soldering iron (the smallest package is IC3, a 28-pin SSOP package with 0.65mm pin spacing). See Bill of materials for components to use and figure 4 for their positions. See Pin Description for a description of all I/O connections, and Operation for a description of the signal flow in the device.

Depending on the desired usage case, there are a few different ways to populate the board, which are described below and summarized in table 1.

Shorting SJ1 results in needing to mount fewer components and reducing costs. This results in not needing C1,F1, and L1, but violates the USB specification. Usually this is safe, but there is an increased risk of brown-outs on the USB bus when connecting the device (as C2 is large and temporarily brings down the USB 5V rail on connection), an increased risk of EMI (which would otherwise be blocked/absorbed by L1), as well as relying on the PTC fuses in the host device in the event of a short-circuit (rather than F1, which is designed to trigger before the host device fuse). **The recommended setting is NOT to short SJ1 and to mount C1,F1, and L1. If this mode is used it is strongly recommended to disable the USB powered load functionality.**

The number of data channels can be adjusted by selectively not mounting IC1, IC2, IC4, and their associated protection resistors and decoupling capacitors in any combination. Each of these IC and resistor groups handle RX/TX, RTS/CTS, and DTR/DSR respectively. For example, for applications where no hardware flow control or carrier signals are needed it is sufficient to just mount IC1, R2, R3, C3, and C4. (Leaving IC2, R4, R5, C3, C4, IC4, R9, R10, C5, and C6 unmounted).

Breadboard pins can be left unmounted if the device is not going to be attached to a breadboard. In this case do not mount JP2 and JP3.

USB powered load functionality can be permanently disabled by not mounting JP4 and JP5. This makes it difficult to inadvertently power the external load with the USB power source (which is otherwise done by connecting JP4 and JP5). This is recommended when SJ1 is shorted.

Table 1: Population configurations.

MODE	LEAVE UNMOUNTED
SJ1 shorted	C1,F1,L1
RX/TX not used	IC1,R2,R3,C3,C4
RTS/CTS not used	IC2,R4,R5,C5,C6
DTR/DSR not used	IC4,R9,R10,C8,C9
Breadboard pins not used	JP2,JP3
USB-powered load not used	JP4,JP5
Status LEDs not used	LED1,R1,LED2,R6,LED3,R7,LED4,R8

High speed functionality can be achieved by mounting higher grade components for IC1,IC2, and IC4. The default component choices (ADuM1201A grade) will allow data rates of up to 1MBaud, for rates of up to 3MBaud use the ADuM1201B or ADuM1201C grade IC.

After populating the board, the unit can be tested by connecting it to a PC, enabling USB powered load mode, and connecting the TX and RX pins on JP1 together. Start a terminal application on the host PC, connect to the device, and send some characters to it. When this is done any characters sent to the unit will echo back, in other words, transmitting "`Hello World`" will result in receiving "`Hello World`".

Pin Description

All connections through pin-headers and contacts are listed below. All signals on JP1 are identical (and electrically connected) to their equivalents on JP2 and JP3.

HEADER	PIN	DESCRIPTION
USB	-	Host USB connection (type B connector).
JP1	1	External load ground connection.
	2	External load positive voltage (V_{DD}). This supplies the digital isolators and sets the voltage from the isolator's outputs.
	3	RX (input). Connect to output from external load.
	4	TX (output). Connect to input on external load.
	5	CTS (input). Connect to output from external load.
	6	RTS (output). Connect to input on external load.
	7	DSR (input). Connect to output from external load.
	8	DTR (output). Connect to input on external load.
JP2	1	External load ground connection.
	2	RX (input). Connect to output from external load.
	3	CTS (input). Connect to output from external load.
	4	DSR (input). Connect to output from external load.
JP3	1	External load positive voltage (V_{DD}). This supplies the digital isolators and sets the voltage from the isolator's outputs.
	2	TX (output). Connect to input on external load.
	3	RTS (output). Connect to input on external load.
	4	DTR (output). Connect to input on external load.
JP4	1,3	External load positive voltage (V_{DD}). Connect to JP5 pins 1,3 to power load from the USB bus.
	2,4	External load ground. Connect to JP5 pins 2,4 to power load from the USB bus.
JP5	1,3	USB bus positive voltage (V_{USB}). Connect to JP4 pins 1,3 to power load from the USB bus.
	2,4	USB bus ground. Connect to JP4 pins 2,4 to power load from the USB bus.

Usage

At it's simplest, connect a USB cable to Isolated USB-UART, connect the external device's ground to pin 1 on JP1, a logic level supply voltage (2.7-5.5V) to pin 2, the TX output from the external device to the RX input of Isolated USB-UART on pin 3, and the TX output from Isolated USB-UART to the RX input of the external device on pin 4. At this time the status indicators LED1 and LED4 should light up, signaling USB and external device power respectively. Open a terminal on the PC connected to Isolated USB-UART and start communicating with the external device!

Be sure to respect the maximum isolation voltage (1131V per the IEC 60950-1 standard, 560V per the DIN V VDE V 0884-10), and be sure not to reverse the input power connections.

The device will be damaged if the ground and logic supply pins on the load side are reversed! (IE. if JP1 pin 1 (ground) and pin 2 (logic supply) or JP2 pin 1 (ground) and JP3 pin 1 (logic supply) are reversed).

Isolated USB-UART is quite simple, and offers two modes of operation. In the primary mode there is complete isolation between the host PC and the external device. In this mode the external device must supply power to the isolators in the device. In the secondary operation mode the USB bus voltage V_{USB} drives the isolators and the load, though without any isolation. **Again, there is no isolation in this secondary mode.**

See Assembly for assembly instructions and Pin Description for a list of all connectors. As the device has no high-power components there are no parts that become significantly warm or require heat sinking. There are no specific cabling requirements, though try to keep connections from Isolated USB-UART to the external device relatively short, on the order of a few meters at most for higher data rates.

Isolated mode usage guidelines

The primary mode of operation, this gives full electrical isolation between the host PC and the external device. Depending on the number of components mounted the outputs from Isolated USB-UART may include RX/TX, CTS/RTS, and DTR/DSR. For most applications only RX and TX are used. CTS/RTS are hardware flow control pins that allow for controlling data flow, and DTR/DSR are typically user-configurable pins that can be used for many different purposes (but are not very often used).

In this mode the external device must supply 2.7-5.5V to Isolated USB-UART, which drives the isolators and determines the voltage levels of their outputs. Note that there are protection resistors on all logic inputs and outputs, making it safe to for example inadvertently connect two outputs together. However, there is no protection against incorrectly powering the isolators — **the device will be damaged if $V_{DD} > 7.0$V or if the input power is reversed.**

Powered load usage guidelines

In this axillary **non-isolated** mode, the USB bus voltage V_{USB} (nominally 5V), supplies the external load through JP1 Pin 2 / JP3 Pin 1 and JP1 Pin 1 / JP2 Pin 1. This is useful for small applications where current consumption is low (<200mA) and there is no dedicated power supply for the external device. Enable this mode by connecting pins 1,3 on JP4 to pins 1,3 on JP5, as well as 2,4 on JP4 to 2,4 on JP5. Again, **keep in mind that there is no isolation in this secondary mode.** If SJ1 is not shorted (and L1,F1,C1 are mounted) there is an integrated PTC fuse that can deliver approximately 200mA to the load before tripping.

PC connection guide

In order to use the device, a PC and serial terminal software is required. IC3, an FT232R, handles all USB support, and has driver support in most operating systems (Windows 98 to Windows 7, Mac OSX, and Linux 2.4 and greater). In order to use the device connect it to the host PC and check which terminal device it is registered as. (Such as COM1 on Windows or /dev/ttyUSB0 on Linux). Start a serial terminal application (such as hyperterm or putty on Windows or minicom, putty, or cutecom on Linux) and connect to the serial device using the desired baud rate, flow control, parity, and so on.

Maximum allowable isolation voltage

The ADuM1201 IC's (IC1,IC2,IC4) specify a varying maximum isolation voltage dependent on conditions and chosen standard. The IEC 60950-1 standard specifies a maximum isolation voltage of 1131V, while the DIN V VDE 0884-10 standard only allows an isolation of 560V. Depending on the intended region of use it is important to determine the standard to follow.

However, in most cases the peak voltage differential would be caused by rectified line-to-line mains voltage, giving a worst-case value of $230 \cdot \sqrt{2} \cdot \sqrt{3} V \approx 563 V$, which virtually lies within even the most stringent standard. *In other words, when working with voltage up to and including rectified line-to-line levels the isolators operate within a safe region and the device will function as intended.*

Always keep in mind that line level voltages are potentially lethal! Be sure to follow reasonable safety precautions and shield line-level devices and conductors from inadvertent contact!

Bill of materials

Note; A value of 4n7 corresponds to a value of 4.7n, and in the case of a capacitor corresponds to 4.7nF. The suggested part number is only that — a suggestion — and may be replaced with any other equivalent matching the specifications listed under value, rating, and type.

Component name	Value	Rating	Type	Suggested Part No.
C1,C3,C4,C5, C6,C7,C8,C9	1uF	16V	SMD 0603, X5R	GRM188R61C105KA93D
C2,C10	10uF	16V	SMD 1206, X5R	C3216X5R1C106M160AA
F1	Input PTC fuse	30V, $I_{Hold} \geq$ 200mA,$I_{Trip} \leq$ 400mA	SMD 1210	MC36208
IC1,IC2,IC4	ADuM1201	See Operation for grade.	SMD SO8	ADUM1201ARZ
IC3	FT232RL		SMD SSSOP-28	FT232RL
L1,L2	EMI ferrite bead	DC current $\geq$ 400mA, $Z \geq 100\Omega@100MHz$	SMD 0603	MMZ1608B601C
LED1,LED4	Generic LED (power status)	>5mA	SMD 1206	KPT-3216SGC
LED2	Generic LED (Transmit)	>5mA	SMD 1206	KPT-3216SURCK
LED3	Generic LED (Receive)	>5mA	SMD 1206	KPT-3216SYCK
R1,R2,R3,R4, R5,R6,R7,R8, R9,R10	1k	5%, 100mW	SMD 0603 thick film resistor	CRCW06031K00JNEA
X1	USB-B connector	Lumberg 2411 03	Through hole right angle	Lumberg 2411 03
JP1	8 way, 2 row header	2.54mm pitch	Through hole vertical	M20-9980845
JP2,JP3	4 way, 1 row header	2.54mm pitch	Through hole vertical	M20-9990445
JP4,JP5	4 way, 2 row header	2.54mm pitch	Through hole vertical	M20-9980445

Mechanical Description

Isolated USB-UART consists of a PCB and associated components, with a finished size of 50mm by 27.94mm and a build height limited by the USB connector, giving a total height of 14mm. Keep in mind that if JP2 and JP3 are mounted the total height increases to 20mm. No components require heat-sinking, however care must be taken when working with high voltage differentials, both for the safety of the device and user. Be sure to shield the device sufficiently when working with high voltage differentials, for example by placing the device in a non-conductive enclosure.

The PCB is relatively simple to manufacture and should should be able to be fabricated at nearly any PCB house; see table 4 for the minimum requirements. See table 5 and figure 1 for mounting hole locations and the mounting hole reference frame.

Table 4: PCB manufacturing requirements.

PARAMETER	REQUIREMENT	UNIT
PCB thickness	Any (nominal 1.6)	mm
PCB layers	2	-
Copper fill thickness/density (tested)	35/1	µm / oz/ft^2
Trace isolation (minimum)	0.2032/8	mm/mil
Trace width (minimum)	0.254/10	mm/mil
Trace to board edge (minimum)	0.25	mm
Drill to board edge (minimum)	0.254	mm
Drill diameter (minimum)	0.3	mm
Via annular ring (minimum)	0.2032/8	mm/mil

Table 5: Mounting hole locations.

HOLE DIAMETER [mm]	POSITION X [mm]	POSITION Y [mm]
3.2	3.81	3.81
3.2	3.81	12.7
3.2	24.13	3.81
3.2	24.13	12.7

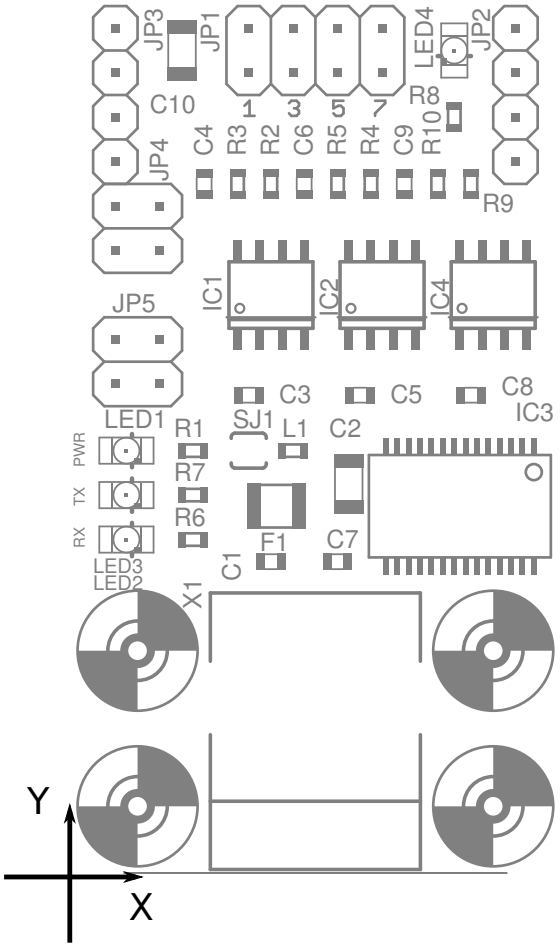


Figure 1: Coordinate system for mounting holes.

Electrical Characteristics

Assuming $R_{out} = 1k\Omega$, $V_{DD} = 5V$ unless otherwise noted.

PARAMETER	SYMBOL	TEST CONDITIONS/COMMENTS	MIN	TYP	MAX	UNIT
Input Characteristics						
Supply voltage	V_{DD}	Only applicable when in isolated mode[1].	2.7		5.5	V
Supply current	I_S	If three isolators mounted[2], DC to 2Mbaud.		5.7	6.6	mA
Input current			-10	0.1	10	μA
Input low voltage					$0.3 \cdot V_{DD}$	V
Input high voltage			$0.7 \cdot V_{DD}$			V
Output Characteristics						
Output impedance	R_{out}	Controllable by component choice[3].		1		kΩ
Output low voltage		With high-impedance load			0.1	V
Output high voltage		With high-impedance load	$V_{DD} - 0.1$			V
Operational output current	$I_{out,hold}$	When operating in powered load mode, powering load	200			mA
Fusing output current	$I_{out,trip}$	When operating in powered load mode, powering load			400	mA
Dynamic behavior						
Data output rate		With ADuM1201 A-grade components mounted	1			MBaud
Data output rate		With ADuM1201 B/C-grade components mounted	3			MBaud

[1] Powered load mode drives VDD to the USB bus voltage, typically 5V.
[2] Reduces to 2.1mA (typ), 2.55mA (max) when LED4 not mounted.
[3] See Operation for possible choices.

Operation

Isolated USB-UART has two types of active components — the USB to UART converter (IC3), and the digital isolators (IC1, IC2, IC4) — which are supported with various passive components. The entire device is electrically separated into two halves referred to as the USB side (which is electrically biased around the USB bus voltage) and the load side (which is electrically biased around the external load voltage). See figure 2 for the device's schematic, figure 3 for the PCB layout, and figure 4 for the component positions.

The USB connector (X1) supplies power to the USB side of the device. The 5V USB supply bus is decoupled, low-pass filtered, protected with a PTC fuse, and drives the USB power status indicator (C1,F1,L1,C2,LED1,R1) while also supplying the USB handling circuit (IC3). An optional mounting choice removes the need to mount C1,F1 and L1 by shorting SJ1, at cost of not following USB specifications. Keep in mind this choice removes the PTC fuse, relying on the PTC fuse higher up in the USB bus in the event of a short circuit or other failure mode, as well as potentially causing a brown-out on the USB bus on connection/removal of Isolated USB-UART.

IC3 handles all USB-related data conversion and outputs the RS232 signals used (TX, RX, CTS, RTS, DTR, DSR), as well as status indicators for data transmission (LED2, R6, LED3, R7). C7 decouples the internal 3.3V regulator which is otherwise unused.z

Each input/output signal pair — RX/TX, CTS/RTS, DTR/CSR — is fed to one of three identical isolation stages, each of which use a ADuM1201 digital isolator IC. Each stage is individually and globally decoupled on both sides of the isolation barrier; for example, IC1 is decoupled with C3 and C1 on the USB side and C4 and C10 on the load side[4]. The digital isolators are bi-directional, with one data link in each direction. The input and output from each stage on the load side of the isolation barrier is connected in series with a resistor (nominally $1k\Omega$), which limits the input current when the load side is unpowered and protects the device if the output is short-circuited. This output is sent both to JP1, which is intended to be used for cable/jumper connections, as well as JP2 and JP3, which is intended to be used when attached to a breadboard.

The logic power and ground signals on the USB side of the isolation barrier are present on JP3, and their equivalent levels on the load side of the isolation barrier are present on JP4. These headers are placed near each other, making it possible to deliver the USB bus voltage to the isolators and the load by connecting the ground pins of JP3 and JP4 together and the logic power pins of JP3 and JP4 together. This, of course, removes all isolation between the USB bus and the load.

[4] Note the existence of the ferrite bead L2. This inhibits excessive LC ringing that may otherwise appear when connecting Isolated USB-UART to a powered load (caused by the parasitic inductance of the connection leads and the ceramic decoupling capacitors on the board).

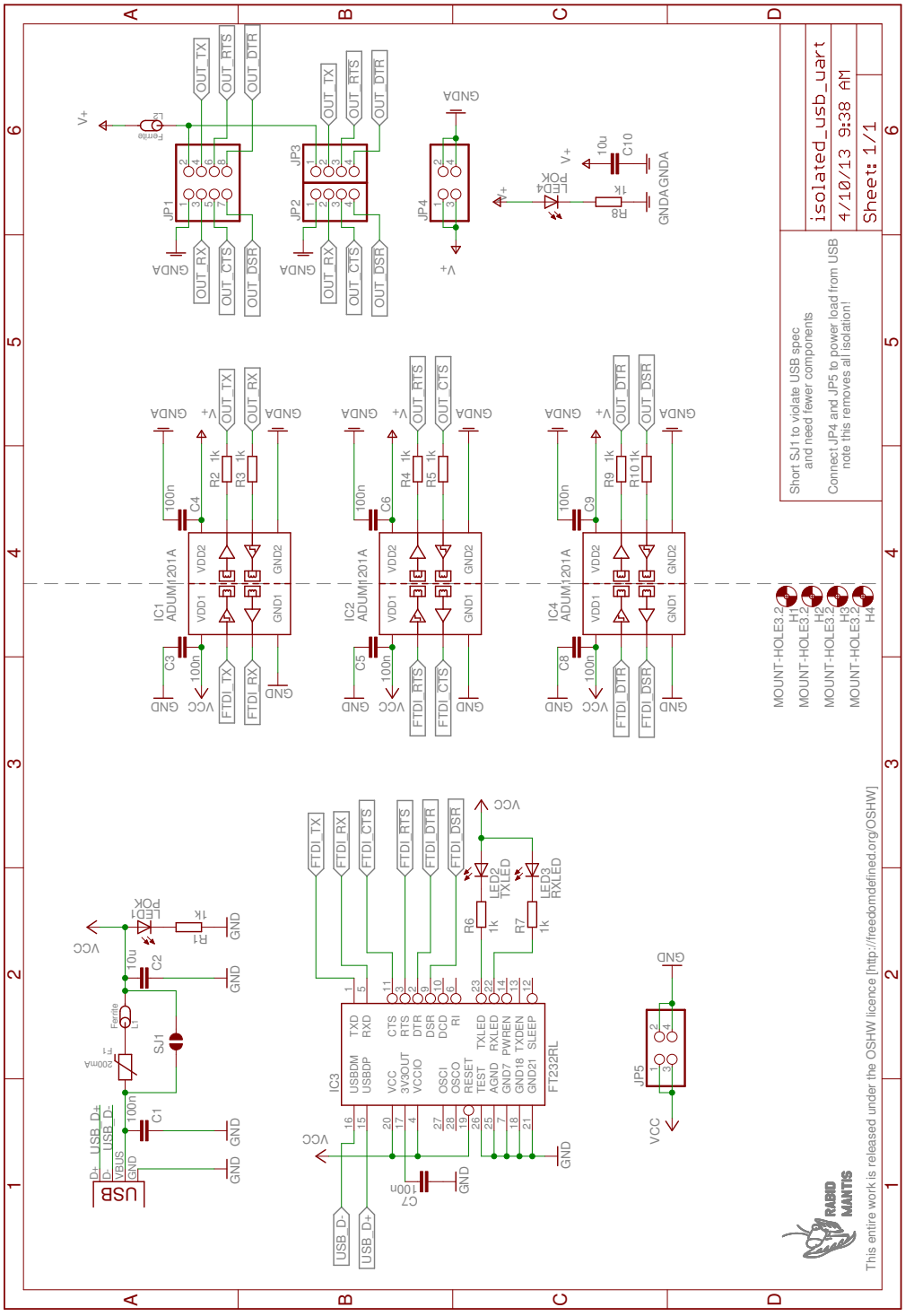
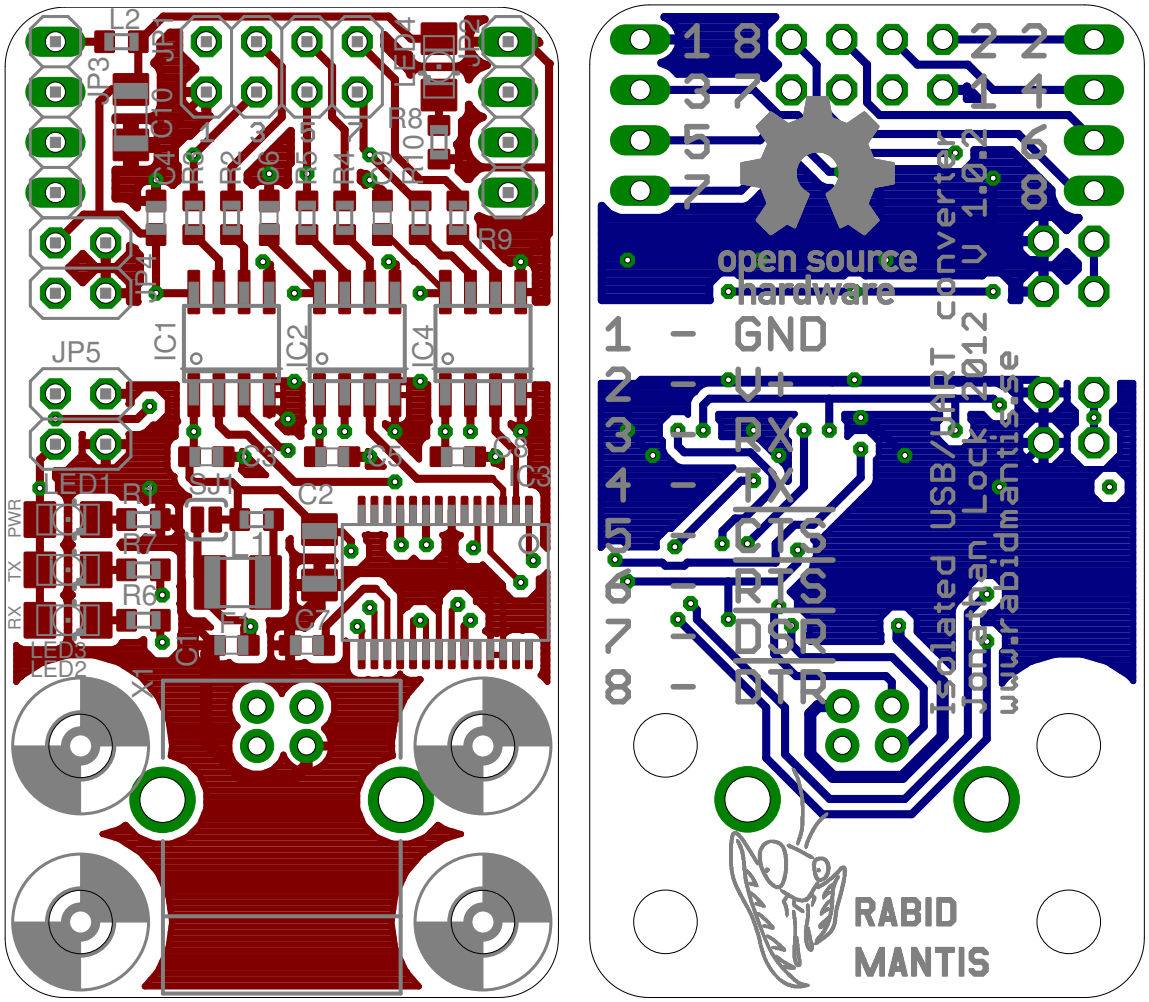


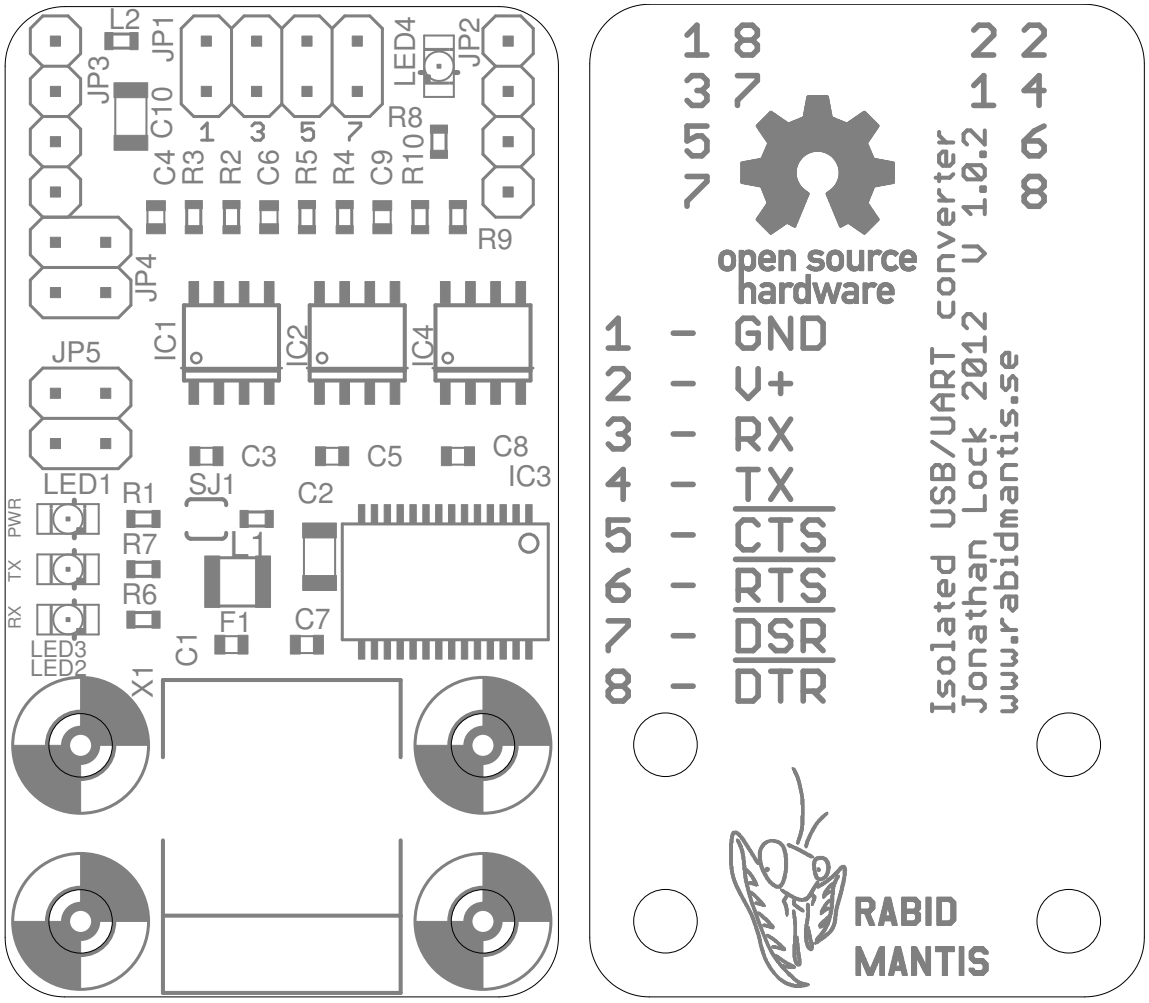
Figure 2: Isolated USB-UART schematic.



(a) Complete top layer as seen from above.

(b) Complete bottom layer as seen from below.

Figure 3: PCB details.



(a) Top layer component outline as seen from above. (b) Bottom layer component outline as seen from below.

Figure 4: Component placement details.