Userial USB to I^{2}C/SPI/GPIO Bridge

User Manual

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Chapter 1. Introduction to *userial*

userial is an Open Source USB to I^2C/SPI/GPIO bridge. The board uses an ATMEL [http://www.atmel.com] AT90USB647 chip and provides the following interfaces:

- 1 × USB interface (serial emulation, to the PC)
- 1 × JTAG port
- 1 × I^2C port
- 1 × SPI port
- 8 × General purpose digital I/O (GPIO) lines
- 4 × Analog to Digital (ADC) converters

The board communicates with the host computer using a CDC (USB communications device class). This makes it easy to use *userial* without installing a device driver or special libraries. Under Windows it is necessary to install a `.inf` file while Linux and Mac OS will recognise the device correctly as serial port without particular configuration. Due to the ASCII based command interface it is easy to control devices manually with just a terminal emulation. This makes it easy to obtain quick results, to configure devices on-the-fly or to control prototyping boards in a straight-forward way.

Schematics and firmware are available to the public. The firmware is released under the terms of the MIT license [http://opensource.org/licenses/mit-license.php] and the hardware is released under the terms of the Creative Commons Attribution-Share Alike 3.0 Unported License [https://creativecommons.org/licenses/by-sa/3.0/].

userial is based on Dean Camera's LUFA [http://www.fourwalledcubicle.com/LUFA.php] (Lightweight USB Framework for AVRs) library.

Chapter 2. Installation

The *userial* board is a USB communications device class (CDC) device and is visible as a virtual COM port to the user. Most Operating Systems already include drivers for this kind of device.

The serial settings are not important for the USB communication. The values of 115200 bps, 8 data bits, no parity, 1 stop bit are a safe choice. Hardware handshake should be turned off.

Installation on Linux, BSD, OS X

Virtually all UNIX systems include an ACM driver already in their kernel. Under Linux this device is accessible as a `/dev/ttyACMx` device file. The device can be opened using a serial terminal such as miniterm or cutecom.

Driver installation on Microsoft Windows

Users of Microsoft Windows need to install the file `userial.inf` when the Hardware Wizard searches for new devices. There are many serial terminals for Windows out there to access the userial device. Some of them are: Hyperterm, TeraTerm or Br@y terminal.

Chapter 3. Protocol Description

The *userial* protocol is ASCII based, in order to make it easy to insert commands and to read the replies in a serial terminal emulation. In the following examples, lines starting with a less-than character (<) are commands sent to *userial*; lines with a greater-than character (>) are replies.

All commands are case insensitive, though the replies are always uppercase. It is possible to specify ASCII characters instead of hex numbers. Those characters must be escaped by a backslash.

Example 3.1. Alternative data formats

```
< IS12W303132P
< is12w303132p
< IS12W\0\1\2P
```

A line must end with a carreage return '**\r**' or a newline '**\n**' or any combination of those two.

Firmware Version request

The software version can be queried with the '**V**' command.

Example 3.2. Requesting the firmware version

```
< V
> V1.9
```

I²C Protocol

I²C Configuration

The only I²C configuration parameter so far is the clock rate. It is changed by using the '**I**' command, followed by the '**C**' character and the clock rate in kHz, expressed as a hexadecimal number. The reply to the configuration command is the clock rate effectively set in hardware.

To query the current configuration, just send the command '**IC**'. The description of a I²C configuration command is:

```
IC[<dd>]
```

`IC` Start of a I²C configuration command.

`<dd>` The frequency of the I²C clock rate in kHz, expressed as a hexadecimal number.

The following example sets the I²C master clock frequency to 100kHz (0x64 in hexadecimal).

Example 3.3. Setting the I²C clock rate to 100kHz

```
< IC64
> IC0064
```

I²C Reads and Writes

A complete I²C transaction is written entirely on one line. It starts with '**IS**' (start) and ends with '**P**' (stop) and may contain zero or more repeated start commands ('**S**') in between. The general form of a I²C read/write command is as follows:

```
IS<aa>(R|W)<dd>[S<aa>(R|W)<dd>…]P
```

`IS` I²C Start Command.

The reply to '**IS**' is '**IS**'.

`<aa>` The I²C slave address in a left-aligned form. The last bit of the address must match the Read/Write operation: 1 for a Read and 0 for a Write operation

The reply to '<aa>' is '**A**' for an Acknowledge or '**N**' for a Nack.

`(R|W)` One character, either '**R**' or '**W**' for a Read or a Write operation.

`<dd>` The operation payload of byte count. On a Read operation this number indicates the number of bytes to read from the slave. On a Write operation this is a sequence of hexadecimal 8-bit values: the payload to write to the slave.

The reply to a Write command is one '**A**' for each byte written to the slave in case of success. If the slave Nacks one byte, the transaction will be stopped (a Stop condition is put on the bus) and a '**N**' is sent to the user.

The reply to a Read command is the data read from the slave device.

`S` Repeated Start Condition. This command can be added to a command, resulting in a repeated start condition.

The reply to '**S**' is always '**S**'. This helps to distinguish between data bytes from different transactions.

`P` Stop Condition.

The reply to '**P**' is always '**P**'.

In order to illustrate the command structure, let's write down a simple Read operation:

```
IS<aa>R<dd>P
```

and a simple Write operation:

```
IS<aa>W<dd>P
```

The following examples show the use of the commands.

Example 3.4. Writing 3 bytes to a slave

```
< IS12W010203P
> ISAAAAP
```

Example 3.5. Reading 5 bytes from a slave

```
< IS21R05P
> ISA3132333435P
```

Example 3.6. Combining write and read into one transaction

```
< IS12W010203S21R05P
> ISAAAASA3132333435P
```

I²C Bus Clear

If the data line (SDA) is stuck LOW, the master should send 9 clock pulses. The device that held the bus LOW should release it sometime within those 9 clocks.

In *userial*, this operation is currently implemented as Start condition, followed by a general call address and a Stop condition.

```
IX
```

`IX` The I²C bus clear command. This command has no parameters. The reply to a '**IX**' command is always **IX**.

Example 3.7. I²C bus clear

```
< IX
> IX
```

I²C Slave Reset

The I²C specification defines a slave reset command. This reset consists of a General Call, followed by the byte 0x06. *userial* does not provide a specific command for it, because the following command can be used to achieve the same effect:

Example 3.8. I²C slave reset

```
< IS00W06P
> ISAAP
```

GPIO Protocol

GPIO Configuration

With the GPIO configuration command it is possible to specify the I/O direction of each pin of the I/O port individually.

```
GC<p><dddddddd>[<p><dddddddd>…]
```

`GC` Start of a GPIO configuration command.

`<p>` The port name. On the *userial* board, ports '**A**' and '**B**' are supported.

`<dddddddd>` The direction of the pins: '**I**' for input or '**O**' for output. The first character corresponds to bit 7, the last character corresponds to bit 0.

userial replies to a GPIO command with the configuration that has been actuated.

The following command configures the port B with pins 7,6,3,2 and inputs and pins 5,4,1,0 as outputs.

Example 3.9. GPIO port B configuration

```
< GCBIIOOIIOO
> GCBIIOOIIOO
```

GPIO Read

The read-back of ports is simple. The port names are listed after the '**GR**' command. The data is returned in hexadecimal format.

```
GR<p>[<p>…]
```

`GR` Start of a GPIO read command.

`<p>` The port name.

userial replies to a GPIO command with the port number, followed by the logical value of the IO lines.

For example, to read port B and A back (in this order):

Example 3.10. GPIO bit read

```
< GRBA
> GRB24A02
```

GPIO Bit Set

Individual bits can be set using the '**GB**' command.

```
GB<p><dddddddd>[<p><dddddddd>…]
```

`GB` Start of a GPIO set command.

`<p>` The port name.

`<dddddddd>` The data of each pin: '**1**', '**0**', to set and reset a pin, '**F**' to flip the value of a bit, '**X**' to leave the value of a bit unchanged.

userial replies to a GPIO set command with the data read from the port, as a bit field.

For example, to write data to port A and B:

Example 3.11. GPIO bit set

```
< GBA010000xxBFF00xx11
> GBA01000001B10000011
```

This command can also be used to read back the current value of a port, in a binary format:

Example 3.12. GPIO bit set, binary read back

```
< GBAxxxxxxxxBxxxxxxxx
> GBA01000001B10000011
```

SPI Protocol

SPI Configuration

The SPI configuration command can set a series of parameters: the operation mode, the data order and the clock frequency.

```
SC<m><o><dd>
```

`SC` Start of a SPI configuration command.

`<m>` The SPI mode. See Table 3.1, “SPI mode” for possible values of this parameter.

Table 3.1. SPI mode

SPI Mode	Shift SCK-edge	Capture SCK-edge
0	Falling	Rising
1	Rising	Falling
2	Rising	Falling
3	Falling	Rising

`<o>` When this value is set to '**L**', the LSB of the data word is transmitted first. When this value is set to '**M**', the MSB of the data word is transmitted first.

`<dd>` The frequency of the SPI clock rate in kHz, expressed as a hexadecimal number.

The reply to this command is the effective setting of the SPI interface.

Example 3.13. SPI configuration

```
< SC0L1007
> SC0L1000
```

SPI Reads and Writes

Data are written to the SPI bus with the write command. It has the following form: the operation mode, the data order and the clock frequency.

```
SW[H|L]<dd>[<dd>…]
```

`SW` Start of a SPI transfer command.

`[H|L]` One optional character, either '**H**' or '**L**'. This parameter indicates if the SPI Slave Select line must be toggled during the transfer. If '**H**', the SS line will be held high during the transfer, if '**L**', the SS line will be held low. Specify nothing if the SS line should not be changed.

`<dd>[<dd>…]` One or more bytes of data to be written to the SPI slave.

The reply to this command is the data read during the transfer.

Example 3.14. SPI read and write, with SS line active

```
< SWH01020304
> SWA1B2C3D4
```

Example 3.15. SPI read and write, without changing the SS line

```
< SW01020304
> SWA1B2C3D4
```

ADC Protocol

ADC Configuration

The ADC device can be configured to use the internal reference voltage, or one of the external voltages on AVcc or AREF. At startup, *userial* uses the internal reference, 2.56V.

To query the current configuration, send the command '**AC**'. The description of a ADC configuration command is:

```
AC[<t><v.vv>]
```

`AC` ADC config command.

`<t>` The type of voltage reference:

Table 3.2. ADC voltage reference type

Type	Description
'**I**'	Internal 2.56V Voltage Reference with external capacitor on AREF pin
'**C**'	AVcc with external capacitor on AREF pin

Type	Description
'**F**'	AREF, Internal Vref turned off

`<v.vv>` The actual voltage reference. This value is used to calculate the voltage for the '**AV**' command.

The reply to this command is the string "AC", followed by the ADC configuration.

Example 3.16. ADC configuration to AREF reference, 3.3V

```
< ACF3.30
> ACF3.30
```

ADC Readback

The ADC peripheral can be used directly without initialisation. The only parameter the

```
AR<c>
```

`AR` Start of an ADC read command.

`<c>` The ADC channel.

The reply to this command is the string "AR", followed by the ADC value in headecimal format.

Example 3.17. ADC read from channel 0

```
< ADR0
> AR0167
```

ADC Readback in Volts

This command is actually the same as the previous ADC read command. The result is given as using the reference voltage given in the ADC config.

```
AV<c>
```

`AV` Start of an ADC Voltage read command.

`<c>` The ADC channel.

The reply to this command is the string "AV", followed by the voltage in decimal.

Example 3.18. ADC read Voltage from channel 0

```
< ADV0
> AV1.1569
```

Comments

Lines that start with '#' are comments and all characters until the end of line are ignored. This is useful when working with batch files that are sent to *userial*.

Chapter 4. Firmware upgrade

Recompiling the Firmware

The *userial* firmware is pre-compiled for the ATMEL AT90USB647 chip. The software can be compiled using AVR-GCC [https://gcc.gnu.org] under Linux, *BSD and Mac OS, or WinAVR [http://winavr.sourceforge.net] under Windows. Just type **make** on the command line prompt.

Alternative target or frequency can conveniently be set by overriding the **MCU** and **F_CPU** variables in the project `Makefile`. Alternatively, the variables can be specified on the command line, as in the following example:

```
make MCU=at90usb162 F_CPU=8000000UL
```

The file `version.h` allows to selectively disable some features in the firmware. These compile switched all start with the prefix **FEATURE_**. A value of **1** enables the feature, a **0** disables it.

Firmware upgrade using FLIP

ATMEL ships the chip with a pre-programmed boot loader. This makes it possible to update the *userial* firmware with just a USB cable. All that's needed is a USB cable, a jumper and ATMEL's FLIP [http://www.atmel.com/tools/FLIP.aspx] boot loader. Follow this list for an update of the firmware:

1. Power down the *userial* board
2. Close the jumper JP4
3. Power up the *userial* board by connecting it to the PC
4. Launch FLIP boot loader and update the firmware
5. Power down the *userial* board
6. Remove jumper JP4

An alternative to FLIP, especially for Linux and OS X is dfu-programmer [https://dfu-programmer.github.io].

Firmware upgrade using ButtLoad

Since ATMEL's FLIP boot loader is not Open Source and the protocol is not published, people have written alternative boot loaders. One very good boot loader is Dean Camera's ButtLoad [http://www.fourwalledcubicle.com/ButtLoad.php], that is also included in the LUFA [http://www.fourwalledcubicle.com/LUFA.php] library. This boot loader uses a protocol documented in the application note AVR109 [http://www.atmel.com/Images/doc1644.pdf]: Self Programming.

Firmware upgrades are performed as in the section called “Firmware upgrade using FLIP”, with the only variation in the download procedure. The following example used *avrdude* to download the firmware, but alternative clients, include AVR Studio, can be used instead.

```
avrdude -p at90usb647 -P /dev/ttyACM0 -c avr109 -U flash:w:userial.hex
```

Upgrading the boot loader

The boot loader itself can not be upgraded using a boot loader. It must be downloaded using the JTAG interface.

Chapter 5. Hardware Description

Jumpers and Connectors

Table 5.1. Jumpers

Jumper	Position	Default	Function
JP1	C5	closed	Pull-up resistor on SCL line. If open, the pull-up resistor is disconnected.
JP2	C5	closed	Pull-up resistor on SDA line. If open, the pull-up resistor is disconnected.
JP3	C6	1-2 closed	Power selector for SCL and SDA pull-ups. In position 1-2 the pull-ups are connected to +3V3, in position 2-3 the pull-ups are connected to +5V. If no jumper is set, both pull-ups are disabled.
JP4	D5	open	Boot loader enable. When this jumper is closed the controller runs the boot loader code instead of the application code. Used for firmware upgrades.
JP5	B6	open	For testing purposes. If closed, the AVR micro will source power to the circuit. This jumper must be left open all the time.
JP6	A6	1-2 closed	Power selector for SPI interface. In position 1-2 the SPI power is +3V3, in position 2-3 the power is +5V.
JP7	D1	closed	Power switch. When this jumper is open the micro controller is disconnected from the power supply.

Table 5.2. I^2C connector, SV7

Pin	Function
1	SDA
2	VCC
3	SCL
4	GND

Table 5.3. SPI connector, SV3

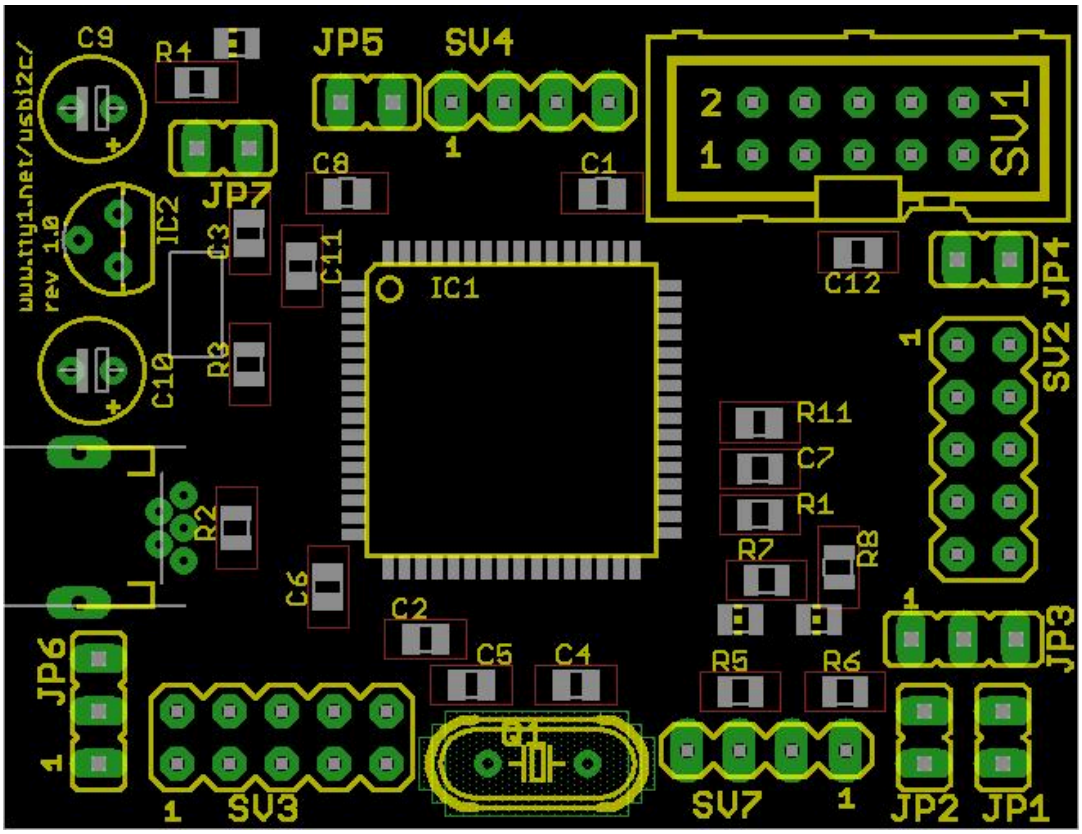
Pin	Function
1	MOSI
2	NC
3	MISO
4	NC
5	SS
6	NC
7	SCK
8	NC
9	VCC
10	GND

Table 5.4. JTAG connector, SV1

Pin	Function
1	TCK
2	GND
3	TDO
4	+3.3V
5	TMS
6	!RESET
7	+3.3V
8	NC
9	TDI
10	GND

Board

Figure 5.1. *userial* board



Schematic

Figure 5.2. *userial* schematic