

Serial Port Signals

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Introduction

This document explains data signals I encountered looking at my PC's serial port. Serial (or RS-232) ports were common some years ago, but they are scarce on today's computers. Instead one needs to use an USB-to-serial converter either as a separate device or built into the target circuit.

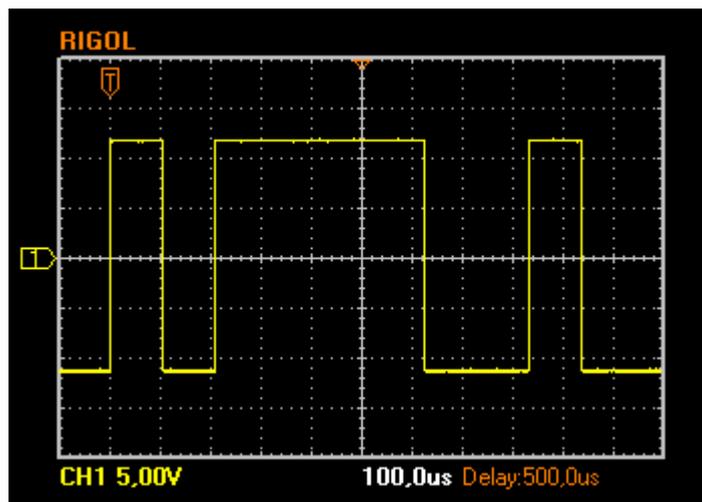
A good introduction into RS-232 is on Wikipedia. The TIA RS-232 standard itself is not freely available.

Signal levels

The following diagrams were taken with my Rigol oscilloscope measuring different computers and RS-232 converters I use. Unless noted otherwise they show the character 'a' (dec. 97) sent at a speed of 9600 baud 8N1 (8 data bits, no parity, one stop bit). Time starts on the left side of a diagram.

RS-232 port on desktop computer

The following figure shows the signals levels on my desktop computers which has a serial port header connector on its motherboard.



Signal levels are about $\pm 11V$. As the signal is of RS-232 type, a logical '0' is at +11V while a logical '1' is at -11V. This is also called 'Non-Return-to-Zero' encoding.

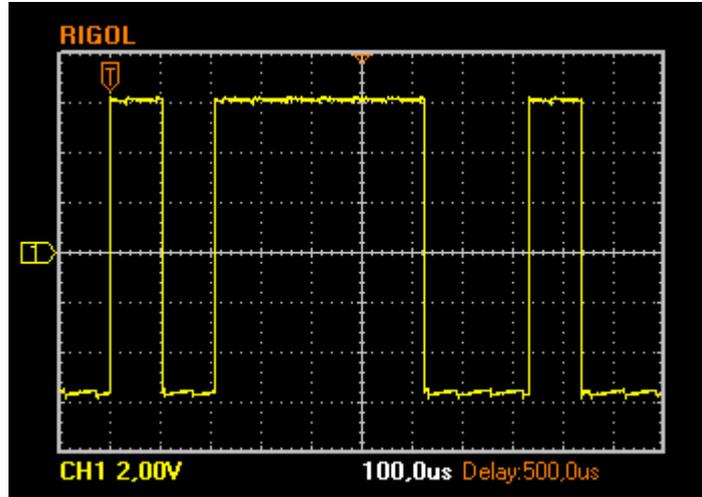
The following bits can be detected:

- Start bit (0)

- Data bits (1000 0110, LSB sent first)
- Stop bit (1)

RS-232 port on my laptop computer

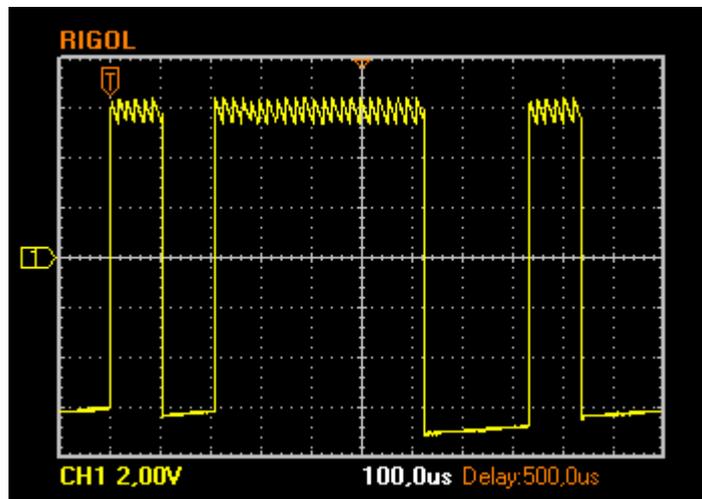
The following picture shows the same signal on the RS-232 port of my laptop computer:



Signal levels are about $\pm 6V$ with $-6V$ showing a little sawtooth pattern. This indicates the use of an internal voltage inverter.

USB to RS-232 converter

The next picture shows the signal levels generated by an USB to UART converter that uses a FTDI FT232 bridge chip and a level shifter to produce RS-232 level signals:

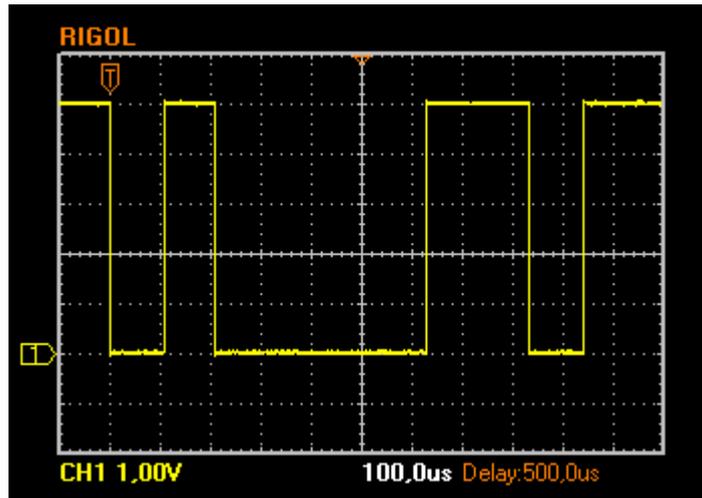


Again, the signal levels are about $\pm 6V$. This time the $+6V$ level shows a distinct sawtooth pattern.

Serial TTL with MAX232 level shifter

The RS-232 signal levels cannot be used with micro-controllers or other logic chips due to the negative voltage and the high positive voltage levels. Instead the signals must be converted by a level shifter to signal levels that can be used with logic chips (0V and +5V).

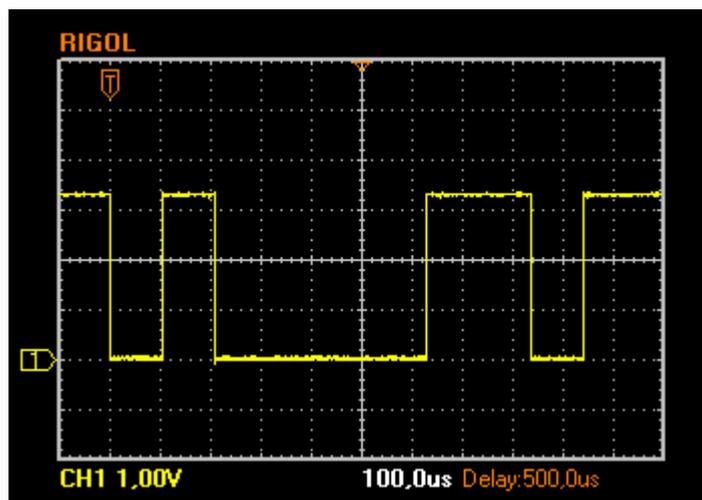
The following picture shows the waveform produced by a MAX232 level shifter by passing it a signal from the previous section:



Signal levels are now 0V for logic '0' and +5V for logic '1'.

Serial data with CP2102

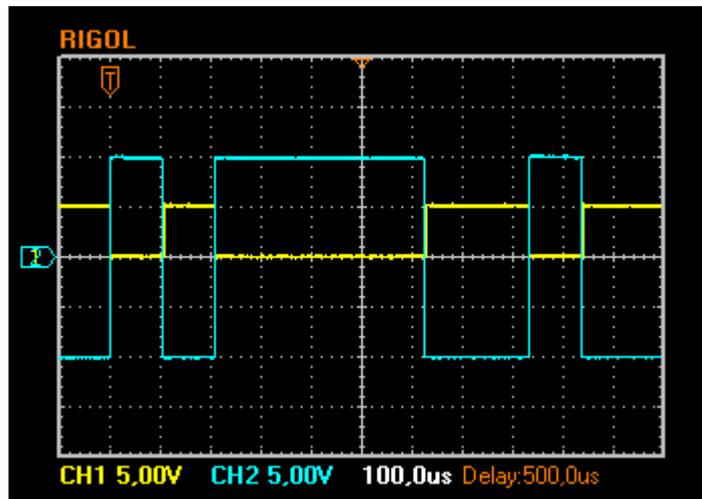
Instead of using a RS-232 port on a computer and passing its signal through a level shifter, an USB to UART converter that outputs TTL-type levels can be used directly. The following picture shows the output from a Silicon Labs CP2102 bridge chip.



This chip uses 0V for logic '0' and +3.3V for logic '1'.

Comparing RS-232 and TTL level serial signals

The next pictures shows a RS-232 level signal (blue line) and the TTL level signal for the same bits (yellow line).



The different voltage levels are summarized by the following table:

Bit value (logical)	Name as in RS-232	RS-232 voltage level	TTL voltage level
0	Space	+11 V	0 V
1	Mark	-11V	+5 V