# RS-232 Serial Interface Waveform

## Introduction

In this lab you will generate an RS-232 waveform that transmits your name and BCIT ID.

A diagram of the equipment is shown below. The waveform is generated by the Arbitrary Waveform Generator (AWG) from samples loaded into it from a file. The AWG output is connected to a PC serial port (on the back of the PC) through a cable. A "terminal emulator" program running on the PC displays the characters received over the serial port and this confirms that you created a valid RS-232 signal.
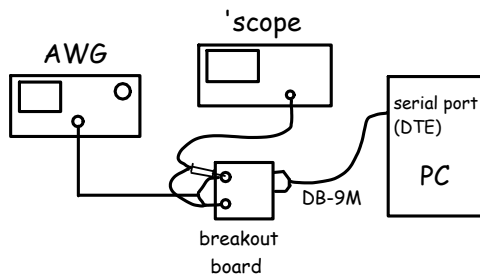


## Software

You will use the following software to complete this lab:

- `tcc`, `notepad++` and the command prompt: these are the same tools used in a previous lab. Your C program will generate samples of an RS-232 waveform and save them to a `.RAF`-format file that the AWG can read.
- TeraTerm: an application called a "terminal emulator". This application displays ASCII-encoded characters received on the PC's serial port. You will use it to verify that you've generated the correct waveform.
- Hexedit, Audacity: as in the previous lab, these programs may help you spot errors by displaying the bytes and waveform in the `RAF` file.

## Write the Software

Modify your previous C program, or write a new one, to generate a waveform that is the sequence of 8-bit RS-232 characters corresponding to your full name and BCIT ID. The characters should be preceded by 10 bit periods of mark (low). This will allow the receiver to synchronize to the first start bit. The characters should be followed by a line feed and a carriage return character at the end of the string (you can use the `\r` and `\n` escape sequences in your string). Use one start bit, 8 data bits and one stop bit. Generate 8 samples per bit.

You can work from the sample code placed on the course web site but it contains several errors and you will have to fix these for it work.

The diagram below shows the structure of the output your program must generate. The string is composed of several characters, the last two being CR and LF. Each character is composed of a start bit, several data bits and a stop bit. Each bit is composed of a number of samples.
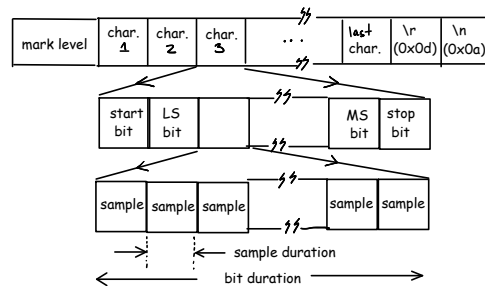


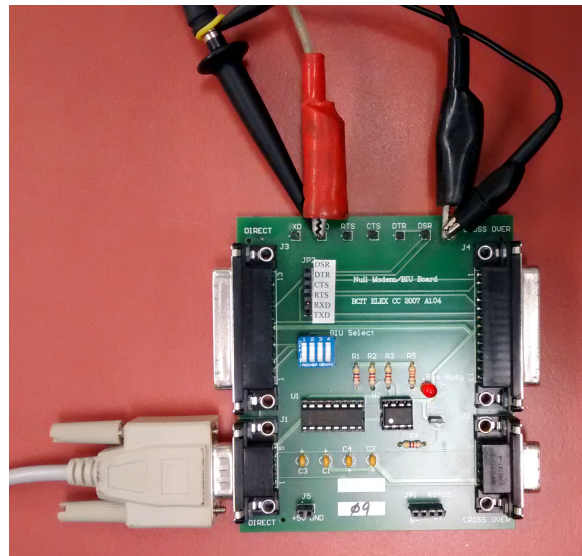A diagram summarizing the format of the RS-232 waveform for one character is shown below.

It will not be practical to "hard-code" the values for all of the bits in each character of your name and ID. Instead, your program will have to determine the values of the individual bits using bitwise logical C operators. Hint: to test the value of the $n$'th bit of the character `c` we can use the expression `c & (1<<n)`.

Some other hints that might help you write the program:
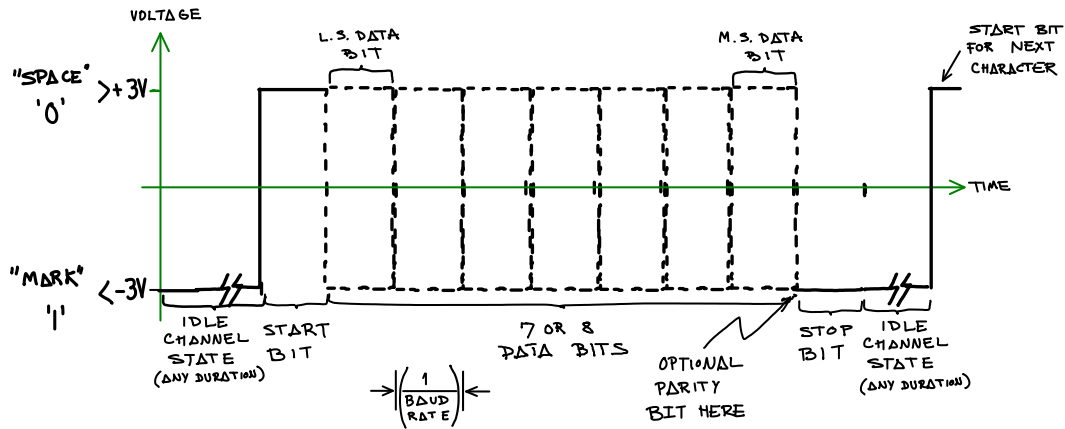
- *Design* your solution "top-down" by decomposing the problem into smaller parts (for example: output a string by outputting one character at a time, output a character by outputting one bit at a time, output a bit by ..., output a sample by ...). Sketch out your solution as "pseudo-code" before trying to write the C code.
- *Implement* your solution "bottom-up" by writing and testing one part at a time. The smaller you make each part the easier it will be to find and fix errors. While testing you can output visible characters (say '+' and '-' or '0' and '1') instead of the sample values.
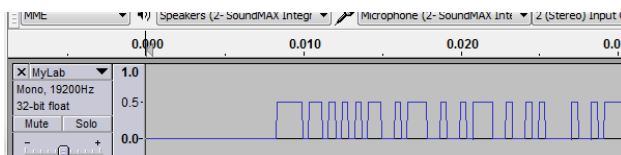
## Procedure

### Generate and Check RAF File

Run your program to generate the .RAF file. Then use hexedit and Audacity as in the previous lab to make sure it contains the correct values.

In Audacity you should see something similar to:



### Generate and Check Waveform

Connect the AWG output to the appropriate pins of the DB-9 breakout board (you will have figured out the appropriate pins in the Pre-Lab). Connect the 'scope to the same pins. Then connect the 9-pin serial cable connector from the PC to the DIRECT connector on the "breakout board" as shown below:



Copy your .RAF file to your USB flash drive and load it into the AWG using the instructions in the previous lab. Use the oscilloscope to check for a ±5 V waveform on the AWG output. Capture a sufficiently-long portion of the waveform and examine it.

Use the Decode menu on the 'scope to set up protocol decoding. Select the appropriate input channel for RX decoding and the appropriate settings for the RS-232 signal you generated (polarity, endianness, baud rate and character format). The 'scope screen captures below shows the configuration and an example of a decoded string.
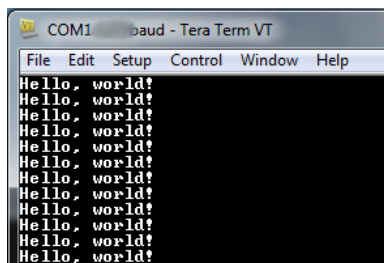
2
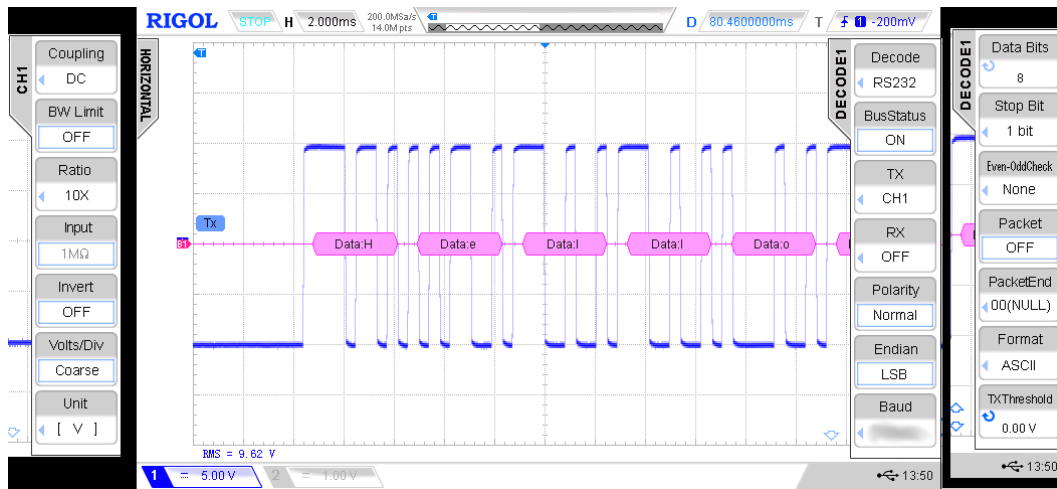
## Display Characters

Run Teraterm. Select serial port input using COM1 when the program starts. Select Setup->Serial Port and *set the COM1 settings for the correct baud rate, number of data bits, parity, and stop bits*[1]. Set flow control to none.
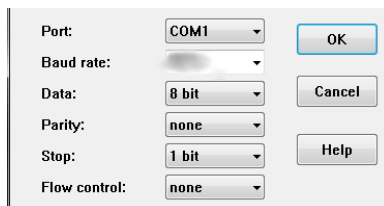


If you've done everything correctly you should now see your name displayed repeatedly on the terminal:



Show your result to the instructor to get credit for completing the lab.

Make sure you save a copy of your working C code, a screen capture showing the Teraterm output and a screen capture of the 'scope display showing the initial portion of the decoded serial waveform.

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[1]Hint: Do this step carefully. A significant number of students mis-configure the software and then waste time tracking down non-existent problems elsewhere.

## Pre-Lab Assignment

Write a C program the meets the above requirements. You will not have enough time to write the program in the lab. Do not use someone else's program. The instructor will likely be able to tell – even if he can't prove it.

Answer the following questions:

1. What range of values can you configure for the high- and low AWG output levels so that the output conforms to the RS-232 specification?
2. If the PC's connector is a DTE, to which RS-232 pin do you need to connect the AWG's output?
3. What should you configure as the PC's serial port baud rate assuming 8 samples per bit and that the AWG sample rate is set according to the table below?
4. How many characters are in your string (including CR and LF)? What is the duration of the waveform (including the 10 trailing mark bits) in units of bit periods? What is the duration in milliseconds? What is the size of your .RAF file in bytes?

| Last digit of your ID | sample rate (Hz) |
|---|---|
| 0,1,4,7 | 38400 |
| 2,5,8 | 76800 |
| 3,6,9 | 153600 |

Use this sample rate in your lab.

Create a PDF file containing the answers to the above questions and the source code of your C program. Submit your pre-lab report *before the start of*

*your lab* using the appropriate dropbox on the course web site.

## Lab Report

Create a report in PDF format containing the identification information requested in Lab 1, a screen capture showing the Teraterm window with your name displayed, the 'scope screen capture and a copy of your code including any changes you made during the lab. Submit your lab report using the appropriate dropbox on the course web site.