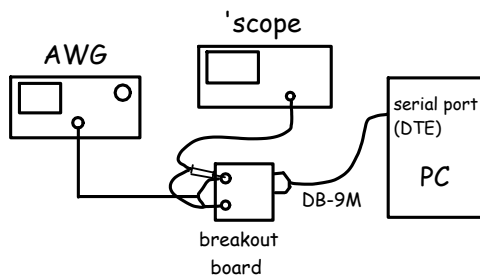


RS-232 Serial Interface Waveform

Introduction

In this lab you will generate an RS-232 waveform that transmits your name and BCIT ID. You will test your waveform by feeding it into a PC's serial port and displaying the characters received by the PC.

A diagram of the equipment setup 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: this program may help you spot errors by displaying the values in the RAF file.

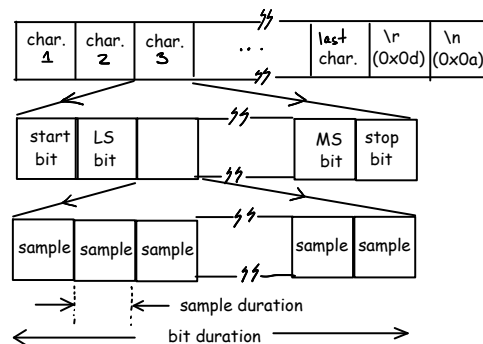
- Audacity: this waveform editor will also help debug your code by showing you the waveform stored in an RAF file.

Write the Software

Modify your previous C program, or write a new one, to generate a waveform corresponding to the sequence of 8-bit RS-232 characters corresponding to your full name and student number. Output a line feed and a carriage return character at the end of your string (you can use the C `\r` and `\n` escape sequences). Use one start bit, 8 data bits and *one* stop bit. As before, generate 8 samples per bit.

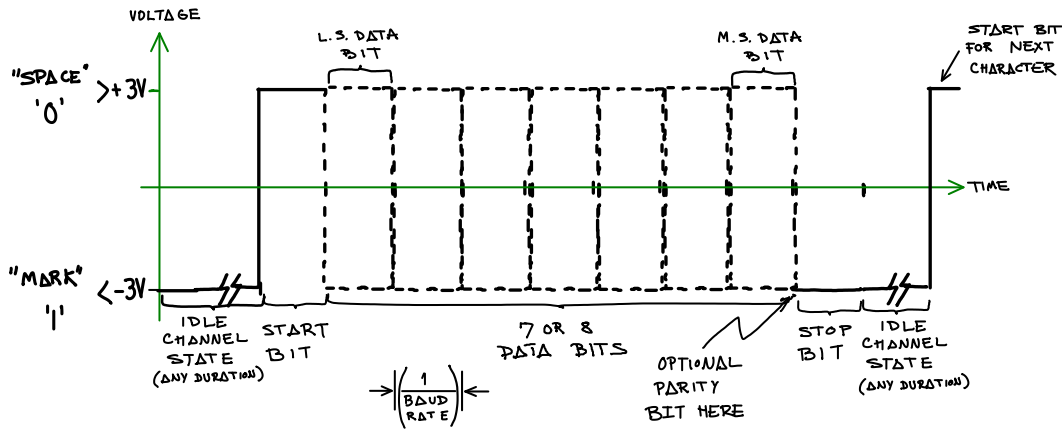
You can work from the sample code placed on the course web site but it contains various errors and you will have to make changes to it for it work.

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.

We need to write the sample values to a file in a format that the AWG can read. The Rigol DG1000Z AWG can read binary files in the `.RAF` (Rigol AWG File) format documented on page 2-75 of the user manual.



The RAF file consists of a sequence of 16-bit sample values in little-endian byte order. Each sample value must be an unsigned integer between 0 and 16383 ($2^{14} - 1$). The value 0 corresponds to the low level configured manually into the AWG and 16383 corresponds to the configured high level.

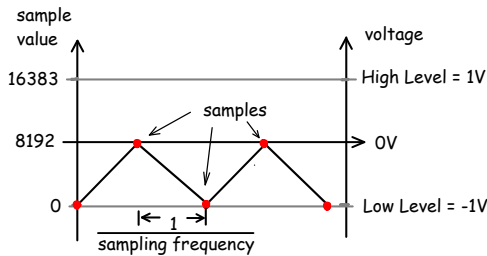
For example, if the AWG was configured for a low level of -1 V and a high level of +1 V and the RAF file contained values alternating between 0 and 8192 (half-way between the minimum and maximum values):

```

00: 00 00 00 20 00 00 00 20
10: 00 00 00 20 00 00 00 20

```

then the output would be a triangle (or square) wave with levels of -1V and 0V:



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 $c \& (1 \ll n)$.

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” or as a flowchart 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

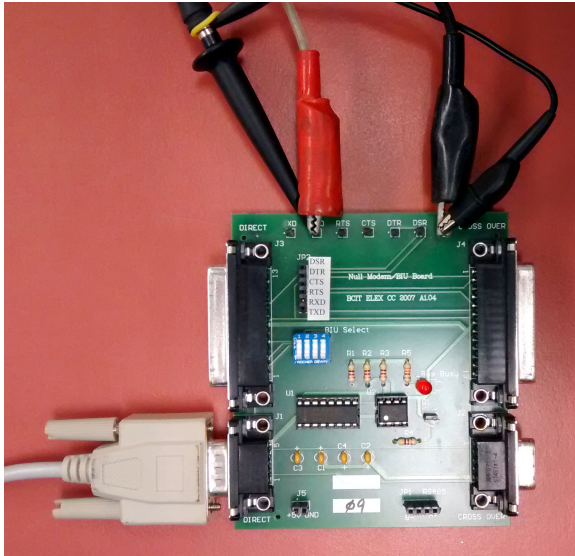
Run your program to generate the RAF file. Check the RAF file with hexedit to make sure it contains the correct values (the sequence 0x00 0x00 for a low voltage sample and the byte pair 0xFF 0x3F for the high values).

Load your waveform into Audacity. Use File / Import / Raw Data for one channel of 16-bit unsigned values in little-endian format at the appropriate sample rate. You should see something like:



Generate and Check Waveform

Connect the AWG output to the appropriate pins of the DB-9 breakout board. 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:



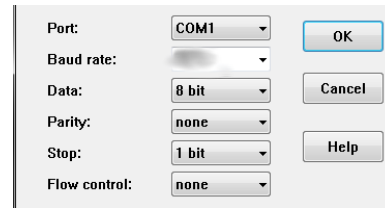
Copy your .RAF file to your USB flash drive and load it into the AWG using the instructions in Appendix A below. Use the oscilloscope to check for a ± 10 V waveform on the AWG output. Capture a sufficiently-long portion of the waveform and examine it.

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.

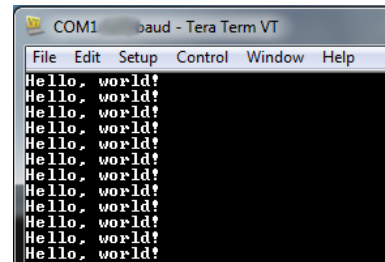
Display Characters

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 bits¹. Set flow control to none.

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



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.

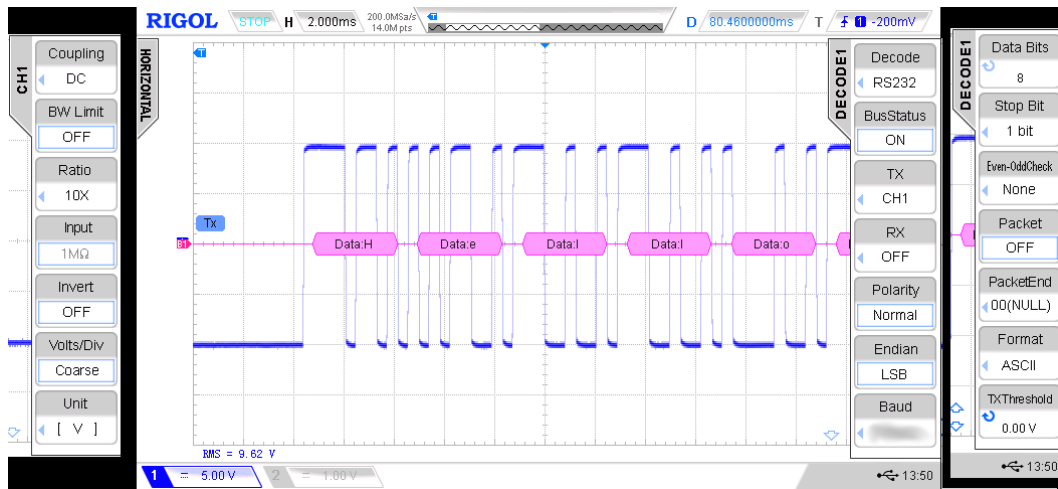
Make sure you save a copy of your working C code, a screen capture showing the Teraterm output and a screen capture of the 'scope display showing the initial portion of the decoded serial waveform.

Pre-Lab Assignment

Write a C program that 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 there in the string you are generating? What is the size of your .RAF file (in bytes)? What is the duration of your waveform (in ms)?



Last digit of your ID	sample rate (Hz)
0,1,4,7	19200
2,5,8	38400
3,6,9	76800

Use this sample rate and baud rate in your lab.


Create a PDF file containing the answers to the above questions and your C file. 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.

Appendix A - Configuring The AWG

- Press **Utility** **Set To Default** **OK** to reset the AWG to it's default settings.
- Press **Arb** to select **Arbitrary** waveform output.
- Press **Arb Mode** until **SRate** (sample rate mode) is selected. Note: to access this and some of the following buttons you may need to press **▽** (gray key on the bottom) to toggle between two sets of menus.

- Plug your USB drive into the USB socket on the front of the AWG. You should see the message **USB device detected** and the USB icon () will appear on the display.
- Press **Select Waveform** **Stored Wforms**.
- Press **File Type** **Arb File**
- Press **Browser** until **Dir** is selected.
- Use the knob to highlight drive **D:** (the USB drive).
- Press **Browser** until **File** is selected.
- Use the knob to highlight your **.RAF** file.
- Press **Read** and you should see the message **Completed! Arb Wave data have been read.**
- Press **Arb** to return to the Arb menu.
- Press **Srate** and enter the sample rate on the keyboard.
- Press **Ampl** until **HiLevel** is highlighted.
- Enter the voltage that should be output for the maximum sample value.
- Press **Offset** until **LoLevel** is highlighted.
- Enter the voltage that should be output for the minimum sample value.
- Press **Output1** to turn on the Channel 1 output.