# Lab 5 - RS-232 Serial Interface Waveform

Introduction

In this lab you will generate a waveform representing an RS-232 serial data signal representing the characters of your name and BCIT ID. You will test that your waveform is correct by connecting it to a PC's serial port and displaying the characters received by the PC.

A diagram of the hardware to be used in this lab is shown below. As in a previous lab, the waveform is generated by Audacity from samples stored in a file. It is amplified to RS-232-compatible levels by an op-amp circuit built on your prototyping board. The output of the amplifier is connected to a "DB-9" serial connector using a "breakout box." A cable connects the RS-232 signal to the serial port on the back of the PC. A "terminal emulator" program running on the PC while Audacity is generating the waveform will display the characters received over the serial port and thus confirm that your software and hardware are working correctly.
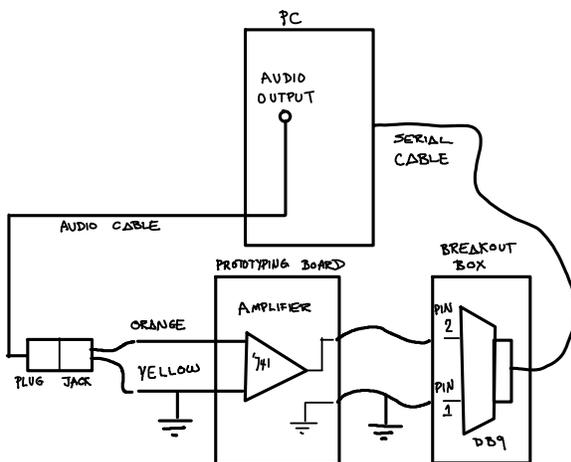
Software Tools

You will use the following applications to complete this lab:

- `tcc`, `notepad++`, the command prompt and `audacity`: these are the same tools you used in a previous lab. Your C program will generate a sampled RS-232 serial waveform that Audacity will "play" to generate the ASCII-encoded characters of your name and ID.
- 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.

All of these applications are free and may be installed on other computers.

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 rather than just one character. Output line feed and a carriage return characters at the end of your string (you can use the C \r and \n escape sequences in strings or character constants). Use one start bit, 8 data bits and *one* stop bit. As before, generate 8 samples per bit period.

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).
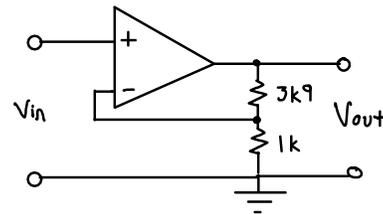
Some other hints that should help write the program:

- Design your solution 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 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
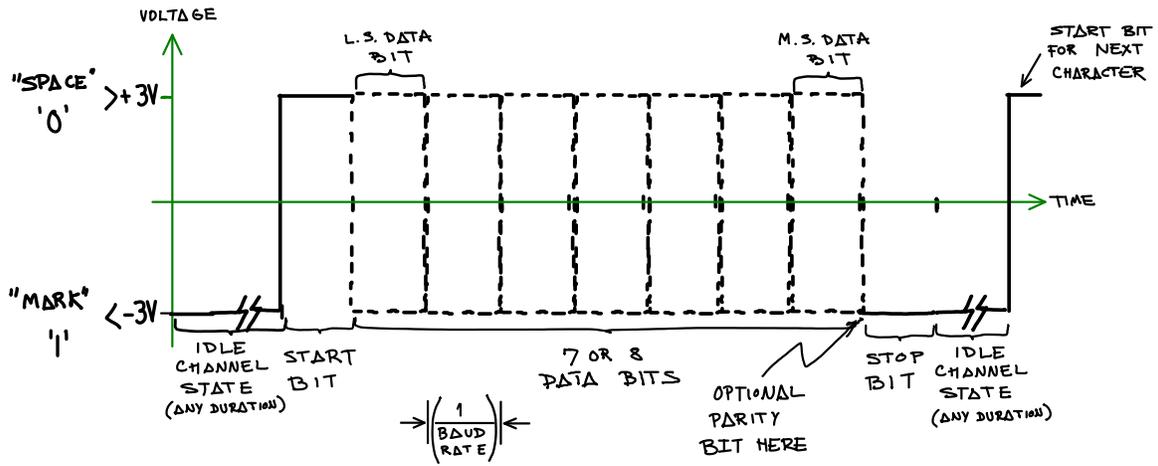
you can output visible characters (say '+' and '-' or '0' and '1') instead of the sample values.

A summary of the format the RS-232 waveform for each character is given above.
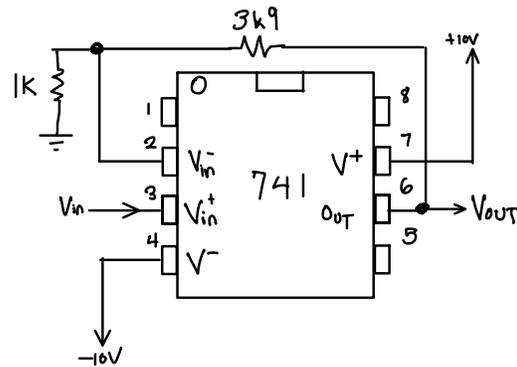
Check Waveform

Plug an audio cable into the audio output port (green) on the front of the PC.

Run Audacity. Select File->Import->Raw Data and select the waveform samples file. Select a sample rate of 19200 Hz so you get a data rate of 2400 bits per second. Select Transport->Loop Play to repeatedly output the waveform from the PC's audio output port. Set the volume slider to maximum.

Use the oscilloscope to check for a waveform of about ±1.5 V on the connector at the end of the audio cable. The yellow wire is connected to ground and the other wires to the non-inverted left and right audio signals.

Build the Amplifier

Since RS-232 serial ports require voltages of at least ±3 V, we need to build an amplifier to increase the voltage swing of the signal. Use a 741 op-amp in a simple non-inverting amplifier configuration. The schematic is:

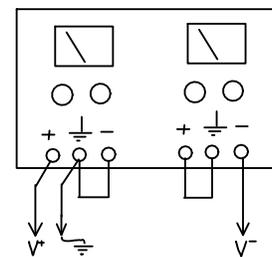and the pin-out of the 741 and the connections for this circuit are:

Build the amplifier circuit on your prototyping board using the components supplied in the lab.

The lab supplies have floating outputs. In order to get positive and negative supplies you will need to connect one supply's positive terminal to ground and the other's negative terminal to ground:

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Double-check your circuit. Check it again. Set the power supply voltages before connecting them to your circuit. Make sure the voltages are not being limited by the current limiting controls, if any.

Use the connector supplied in the lab to connect the end of the audio cable to the amplifier input. Check the output of your amplifier for an appropriate waveform of the right level.

Connect the 9-pin serial cable connector from the PC to a BRK9MF "breakout box" to access the following RS-232 signals:

- terminal 1 of the terminal strip corresponds to pin 1 of the 9-pin connector and is the RS-232 signal ground
- terminal 2 of the terminal strip corresponds to pin 2 of the 9-pin connector and is the RS-232 receive data signal (PCs are wired as DTEs)

Connect terminal 1 to ground on the amplifier. Connect terminal 2 to the output of the amplifier.

Check Data

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.

If you don't get the expected results use the oscilloscope to check the bit period and the waveform voltages. Check the Teraterm settings for the COM1 serial port. If these are correct, check to see that the waveform shown in Audacity corresponds to what you expected (check for the presence and polarity of start and stop bits, and verify that the bit order is correct).

For troubleshooting or to examine the waveform in detail you may find it easier to "play" your waveform once and examine the stored waveform. You can click on the Horizontal scale knob to switch between normal and "zoomed" views of the waveform.

Use the Decode menu on the 'scope to set up protocol decoding. Select the appropriate input channel for

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[1]Warning: a significant number of students misconfigure the software and then waste time tracking down a non-existent problem in their software or hardware.

RX decoding and the appropriate settings for the RS-232 signal you generated (polarity, endianness, baud rate and character format). Use Bus Status to turn the decoding on or off. You should see a display of the decoded data corresponding to the characters of the string being output by your program.

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 (a portion of) the decoded serial waveform.

Pre-Lab Assignment

Write a C program the meets the above requirements. Do not modify 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 would you need to set as the PC's serial port baud rate if your program wrote 6 samples per bit and the audio waveform's sample rate was 57.6 kHz?
2. Assuming an ideal op-amp, what is the voltage difference between the inverting and non-inverting inputs of the op-amp? For the non-inverting amplifier used in this lab, what is the ratio of the voltage at the output of the op-amp to the voltage at the inverting input of the op-amp? What is the gain of the amplifier? If the input levels were ± 3 V, what levels would you expect at the output of your amplifier?

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 Lab 5 Pre-Lab 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 with any additional changes you made during the lab. Submit your lab report using the Lab 5 Report dropbox on the course web site.