University of Colorado Denver, Fall 2020

Special Topics Course: Autonomous Vehicle Design

Homework 2: Serial Communication - Arduino and pySerial

Total Points Possible: Undergraduate(46), Graduate(66)

**Submission Instructions**: For questions not requiring programming source code, submit a pdf document with your answers. The answers may be hand-written or typed. Clearly label your work and the question being answered. Upload your source-code and pdf to Canvas. It is preferable to submit all work in a single zip file with a .zip extension. That file may include sub-folders to more easily organize your work.

Programming:

* Arduino source code will be graded with an Arduino Uno or Nano (they both have the same atmega328p)
* Python source code will be graded with python3.

**Lesson 1 Questions**

1. The Arduino variable count is declared as data type ***byte***. When the count value reaches 255 and it is incremented by 1, the value of count becomes 0. Explain why. (2 points)
2. The Arduino variable count is declared as data type ***byte***. List the ASCII characters that the Arduino programming statement Serial.println(count) function transmits and the total number of bytes transmitted for each of the following. (3 points)
   1. 3
   2. 53
   3. 107

**Lesson 2 Questions**

1. In lesson 2b, the Arduino count variable’s data type is unsigned int. The form of the Serial.write function is Serial.write(buf, len) versus the form Serial.write(val) used in lesson 2a. (5 points)
   1. Why does lesson 2b use an array to transmit the count value?
   2. Is it possible to write the Arduino sketch in a way to use the Serial.write(val) form to transmit the count value? If so, rewrite the Arduino sketch to accomplish the same task and still work with the lesson 2b python program. Include your Arduino program with this assignment. Name the file lesson2q3.
2. If lesson2b Arduino count variable’s data type was int, (7 points)
   1. What is the ***sizeof*** the Arduino Nano’s (same as Uno) int type? In other words, how many bytes of memory? Explain how you determined this.
   2. What range of values does the Arduino int data type represent?
   3. When the Arduino count value is 32767 and 1 is added to it, what are the decimal and hexadecimal values of the updated count value?
   4. Are any changes needed to the lesson2b python program to read and interpret the serial data received? If so, what are the changes and why are they needed? If not, why not?

**Design Questions**

For each of the problems below, assume

* one bit per baud, i.e. baud rate is equivalent to bits per second.
* one start bit, 8 data bits, no parity, and one stop bit for each byte.

***Show your work where appropriate.***

1. What is the Arduino worst-case transmission time for a 20-element array of four-byte unsigned integers? Assume the baud rate is 115200. (5 points)
   1. Transmitted using serial.println().
   2. Transmitted using serial.write(buf,len)
2. Suppose a sensor’s measurement rate can be set at 5, 10, 25, or 75 Hz. Each set of sensor measurements contains 382 bytes. When the sensor rate is set to 5 Hz, the sensor produces 5 sets of measurements each second. (8 points)
   1. What is the minimum allowable baud rate that allows a sensor to transmit measurements at a rate of 75 Hz?
   2. If the only serial transmission rate available is 57600 baud, what is the maximum sensor rate setting to ensure complete transmission of all data in one second?
3. Use the ATMega data sheet (USART section) and Arduino Nano schematic to answer the questions b and c. (5 points)
   1. What is the Arduino Nano’s external crystal oscillator frequency? (1 point)
   2. What is the ATMega328p maximum receiver baud rate error for normal speed mode? (2 points)
      1. D = 8 ? (D is the sum of the character size (data bits) and parity size (bits).
      2. D = 9 ?
   3. What baud rate settings are less than the recommended baud rate error for D = 8, normal speed mode for the Arduino Nano? (2 points)

**Lesson 5 Questions**

1. Modify the Lesson 5 Arduino example to transmit binary values of x and y. You may only use Arduino Serial.write functions for transmission (no print, println functions). Modify the python program to receive the binary data. The python program should print the received x, y values as it does in lesson 5. (11 points)
   1. Name the Arduino program lesson5q9.ino and the python program lesson5q9.py.

**Graduate Students are required to complete the following problem. Undergraduates are not required to complete the problem but may do so as a learning experience.**

1. Timing serial data transmission (20 points)

Compare the performance of binary versus ASCII character serial transmission using the Serial write, print functions. Write an Arduino program that serially transmits the range of values from 0 to 2^16-2 to a python program.

* 1. What is the total transmission time for write versus print for the range of values 0 to 2^16-2?

The following pseudocode provides an example of the timing and transmission logic

* + 1. Set count to 0
    2. Start timer
    3. While count < 2^16-1
       1. Transmit count
       2. Increment count
    4. Stop timer
  1. Compare total number of bytes transmitted for the range 0 to 2^16-2.
  2. Submit a brief written explanation/analysis of your methodology and results. Include all source code used to obtain the results.