Lab 3 Report - Serial
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ECE 3710
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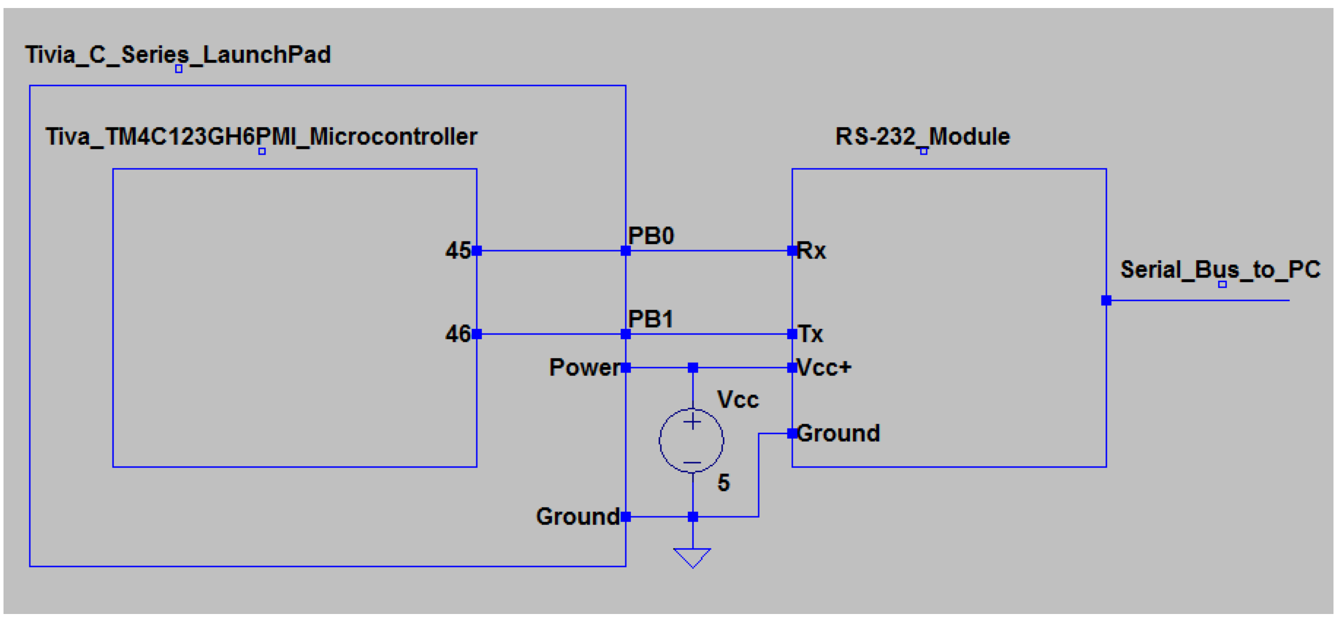
Overview:

The microcontroller was configured to send data to and from the PC using UART via RS-232. Upon input from the microcontroller or the PC, a message is sent to the PC to display. For hardware, this project requires

- A 5V voltage source (DC)
- A UART to RS-232 module
- A serial cable
- The microcontroller
- A 3.3V voltage source (optional, but recommended)

Hardware Details:

Using UART module 1 and the alternative function of GPIO pins PB[0:1], the microcontroller is connected to the RS-232 module. The microcontroller is powered by the 5V voltage source and the RS-232 module is powered by the 3.3V voltage source (alternatively, this could be powered from the microcontroller or the same 5V source). The RS-232 module is in turn connected to the PC via a serial cable. See schematic below:



Software Details:

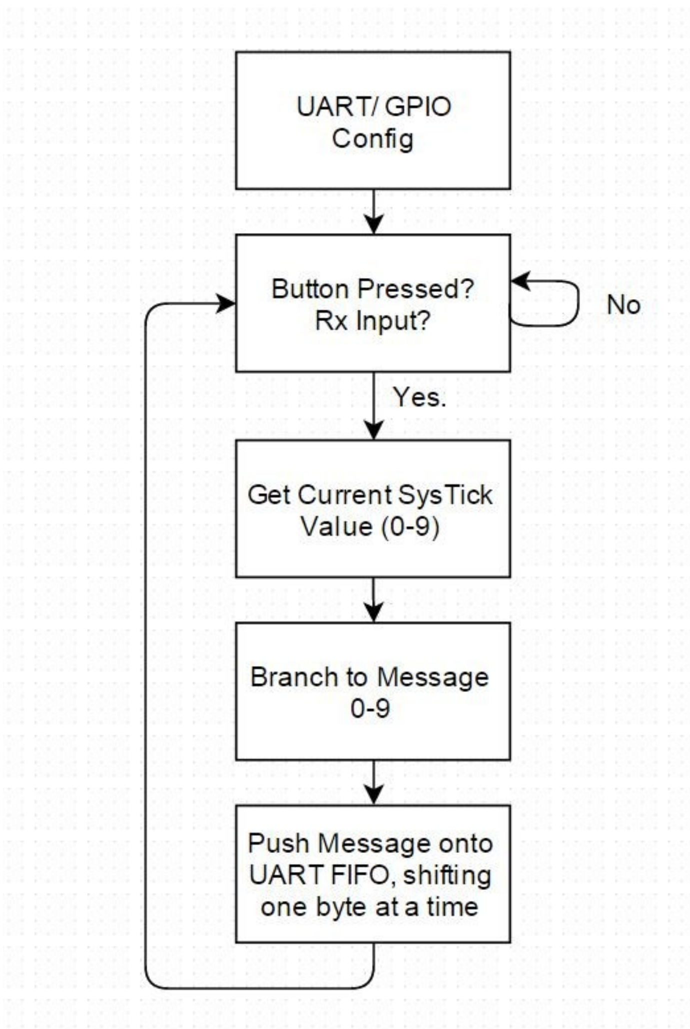
The microcontroller is configured to await input from the user in either of two forms, a button on the microcontroller (PF0) or data from the PC via the UART module (Rx – PB0). Upon either input, the microcontroller sends one of ten messages to the PC. To prevent multiple messages being sent upon a single input, the microcontroller first checks to see if the input is default, and then awaits the user. This was a very concise and efficient method. The not concise part was sending ten different hexadecimal strings, and resulted in the program being the absolute maximum size allowed.

Randomness:

To arbitrarily choose between any of ten strings, Systick was utilized to always be running and to count down from ten. When a value was needed, Systick was sampled and that value determined which string to send to the PC.

Switch Statements:

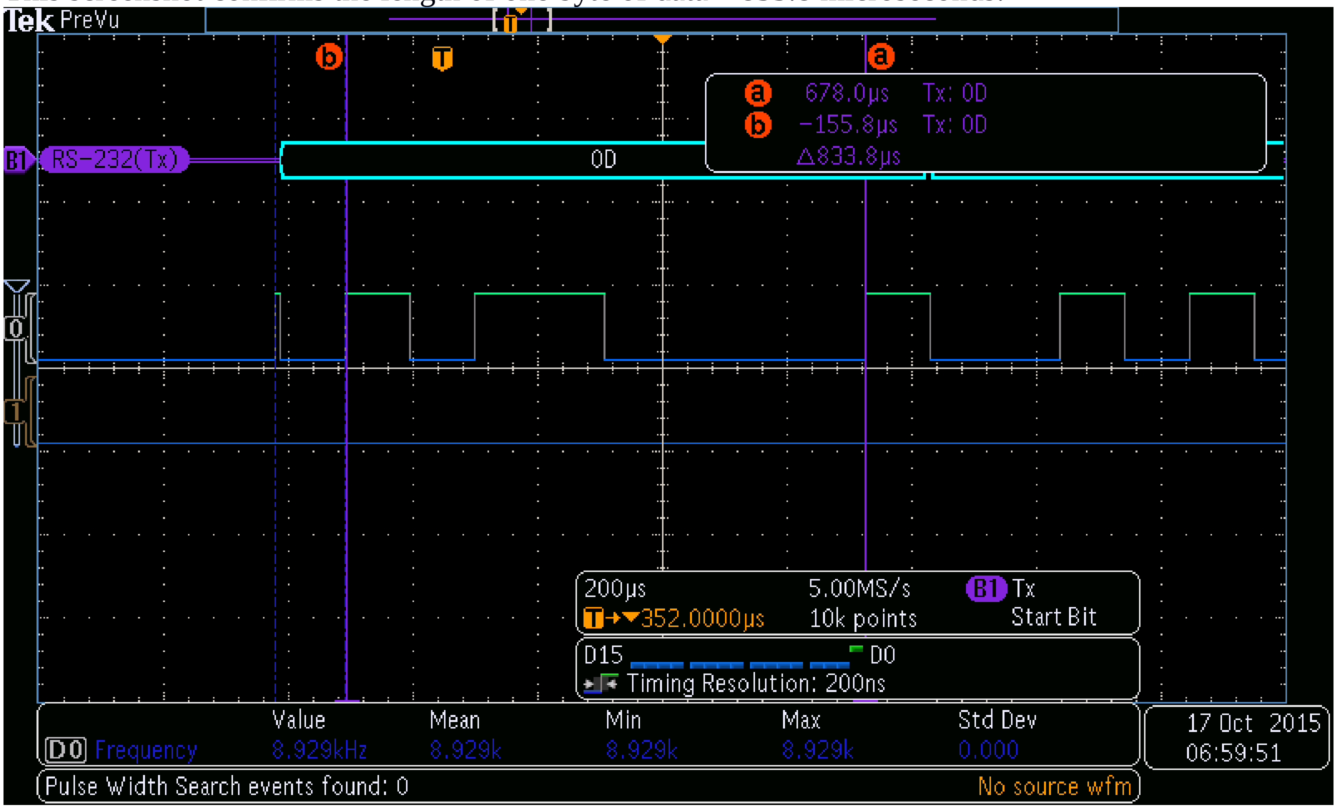
Gathering a random value is one thing, it is quite another to execute entirely different code based on that value. Rather than a very long if-else statement, an effective jump table was used to decide where to go. To accomplish this, the Program Counter was read, and added to the Systick value multiplied by 2 (the length of each instruction, in this case), with a little bit accounted for offsets and the like. This value was then loaded into the link register, and then a simple “BX LR” (return to value in link register) accomplished a jump to a list of branches to appropriate functions. A misuse of the link register to be sure, but it worked perfectly. Code is given at the end. Here is a flowchart of the software logic:



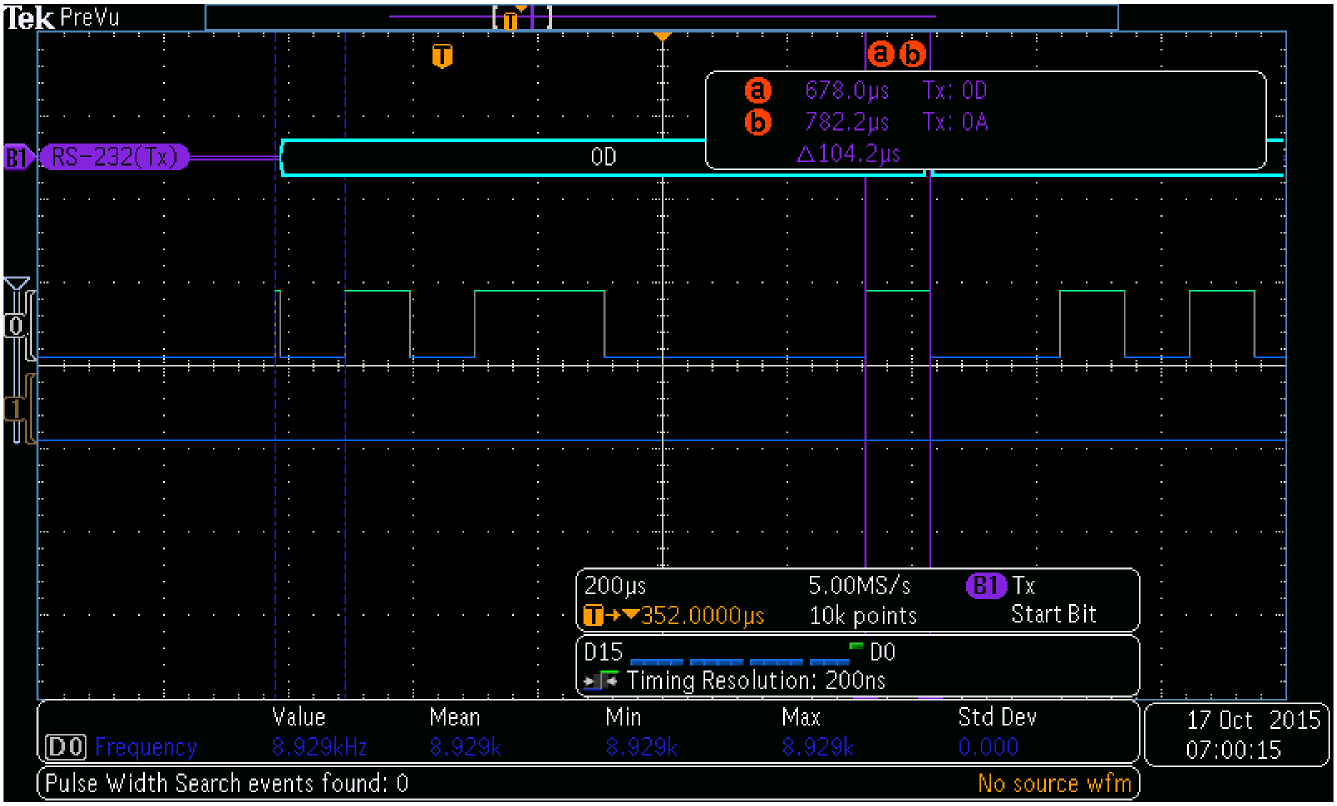
UART:

The UART module was configured to use both trnasmit and receive simultaneously using the FIFO buffer. For a 9600 baud rate, the BRDI was set to 104 (16MHz / (16 * 9600) = 104.166667) and the BRDF was set to 11 (.16667 * 64 + .5 = 11.16667). Using this configuration with GPIO port B, the data was sent and received to and from the PC. Screenshots from the logic analyzer are given below:

This screenshot confirms the length of one byte of data – 833.8 microseconds:



This screenshot confirms the length of the start bit – 104.2 microseconds:



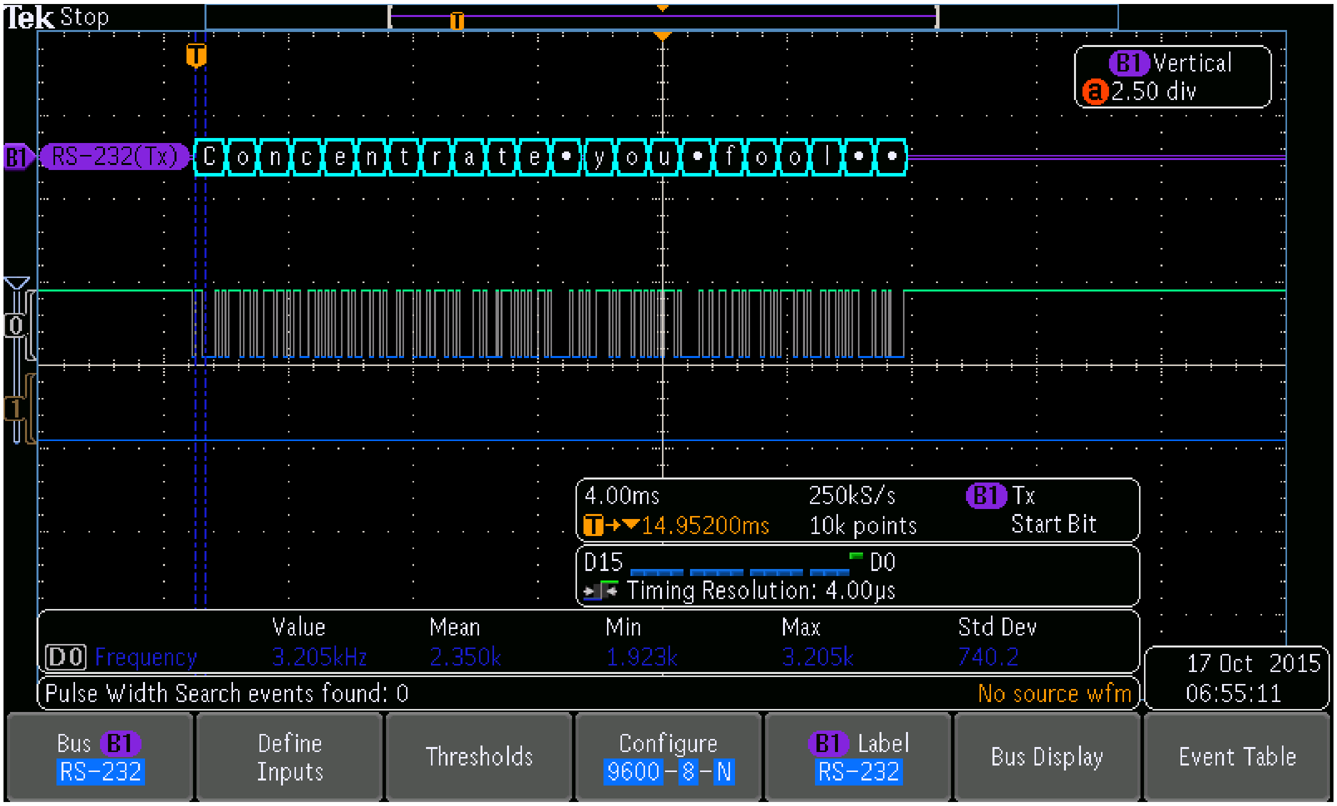
Messages:

Depending on the random value generated, one of ten messages is sent to the PC. The possible messages are given below:

-Nope
-You are doomed
-Concentrate you fool
-What a rubbish question
-Only in your dreams
-Yes now leave me alone
-Heh you wish
-Oh yeah that will happen
-Stop bothering me
-Not if you were the last person on earth

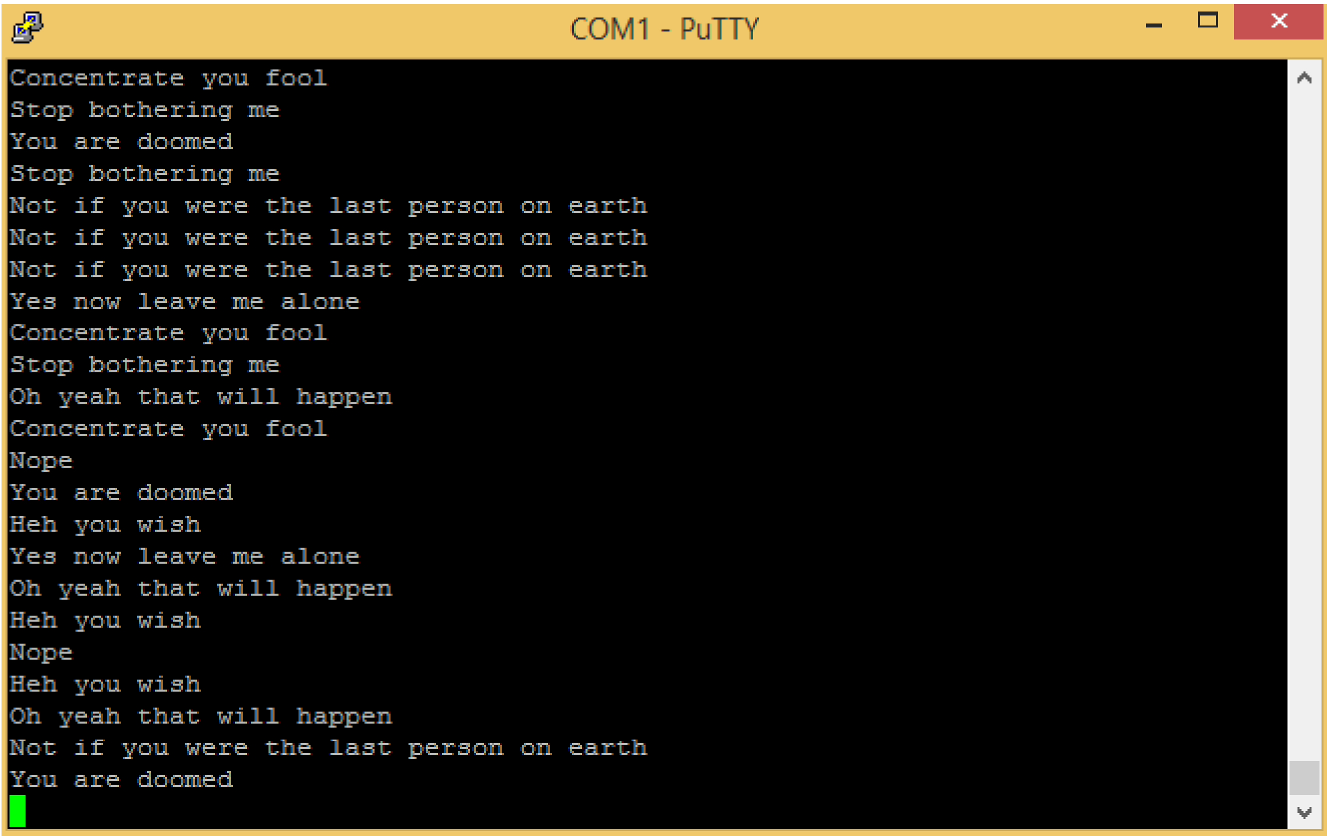
Although the program is fully capable of generating any of these ten strings as verified by the logic analyzer, only the one given below is provided for this report.

This screenshot verifies the output of the data as being one of the messages:

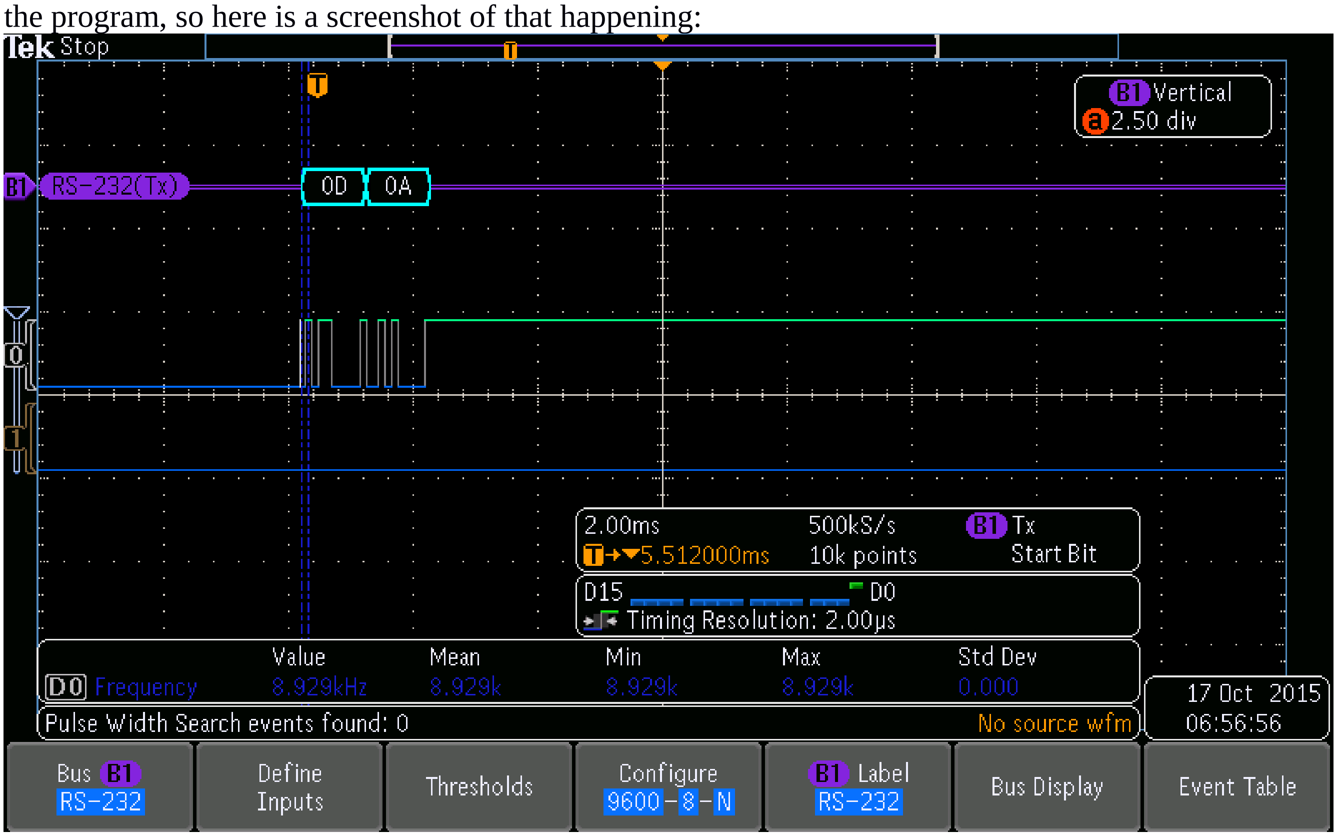


User Input:

The microcontroller reliably responded to both types of user input and sent appropriate messages to the screen. Given restrictions on the software of the PC used to interface with the microcontroller, the user input does not appear on the screen, only the messages. Below is a screenshot of the PC displaying the appropriate messages.



Also, the requirements dictated that a carriage return and a new line be transmitted at the beginning of the program, so here is a screenshot of that happening:



And here is a screenshot of the event table after a message was sent:

The rest of this document only contains code. Here it is:

```
; main.s

       THUMB
       AREA    |.text|, CODE, READONLY, ALIGN=2
       EXPORT  Start

; timer vars
UART1 EQU 0x4000D000                       ;UART1 base
UART2 EQU 0x4000E000                       ;UART2 base
UART3 EQU 0x4000F000                       ; UART3 base
PA EQU 0x40004000                           ;GPIO Port A (APB): 0x4000.4000
PB EQU 0x40005000                          ;GPIO Port B (APB): 0x4000.5000
PCBASE EQU 0x40006000                      ;GPIO Port C (APB): 0x4000.6000
PD EQU 0x40007000                          ;GPIO Port D (APB): 0x4000.7000
PE EQU 0x40024000                          ;GPIO Port E (APB): 0x4002.4000
PF EQU 0x40025000                          ; GPIO Port F (APB): 0x4002.5000
;RCGC2 EQU 0x400FE608                      ; GPIO clock
ST EQU 0xE000E000                          ; systick timer base address
TM0 EQU 0x40030000                ; GPTM0
TM1 EQU 0x40031000                ; GPTM1
TM2 EQU 0x40032000                ; GPTM2
RCGC EQU 0x400FE000                        ; Timer clock

Start
  ldr R1,=RCGC

  ; 1. enable clock: uart then port
  mov R0,#0x2
  str R0,[R1,#0x618] ;uart1            ;Note 0x104 is for Legacy suppory only 618
  MOV R0, #0x22
  str R0,[R1,#0x608] ;portb, portF     ;Note, 0x108 for Legacy support only 608
  nop
  nop

  ; 2. PD enable alt. func. and pin
  ldr R1,=PB
;  MOV32 R0, #0x4C4F434B                                  ; GPIO Unlock code.
;  STR R0, [R1,#0x520]                             ; unlock GPIOD_LOCK
;  MOV R0, #0x80
;  STR R0, [R1,#0x524]                 ; GPIOCR unlock pin PD7
  mov R0,#0xFF
  str R0,[R1,#0x420] ;AFSEL
  str R0,[R1,#0x51C] ;DEN
  STR R0, [R1, #0x514] ;pull down PD[6:7]
  MOV R0, #0x11
  STR R0, [R1, #0x52C]        ; GPIOPCTL in conjunction with GPIOAFSEL offset 0x52C
;  STR R0, [R1, #0x400] ; PD[6:7] OUTPUT
```

```
;Config port F for sw2
LDR R1, =PF
MOV32 R0, #0x4C4F434B                    ; GPIO Unlock code.
STR R0, [R1,#0x520]                 ; unlock GPIOF_LOCK
MOV R0, #0x00                       ; set PF as input
STR R0, [R1, #0x400]
MOV R0, #0x01
STR R0, [R1,#0x524]         ; GPIOCR unlock pin PF0
MOV R0, #0x1                        ; set pull up PF0
STR R0, [R1, #0x510]
; enable PF0
STR R0, [R1, #0x51C]            ; GPIODEN

; 3. disable uart1
ldr R1,=UART1
mov R0,#0x0
str R0,[R1,#0x30]

; 4. set baudrate divisor
; BRD = 16e6/(16*9600)= 104.16
; integer portion: int(104.16)=104
mov R0,#0x68
str R0,[R1,#0x24]
; fractional portion: int(0.16*2^6+0.5)=11
mov R0,#0xB
str R0,[R1,#0x28]

; 5. set serial parameters: No pairity, enable fifo, WL = 1 byte
mov R0,#0x70 ;0b01110000
str R0,[R1,#0x2C]

; 6. enable tx, rx, and uart
mov R0,#0x301 ;0b0110000001
str R0,[R1,#0x30]
;three delays  before any uart registers accessed

MOV R0, #0x0d0a
BL writeRZeroToUARTTwoByte

LDR R1, =ST

;disable systick
MOV R2, #0x1                                        ; disable SYSTICK
STR R2, [R1, #0x10]                 ; SYSTICK Control STCTRL offset 0x010
;enable systick, load 9
MOV R0, #0x9
STR R0, [R1, #0x14]                 ; SYSTICK Reload STRELOAD
;Start SysTick
```

```
        MOV R0, #0x5
        STR R0, [R1, #0x10]                     ; SYSTICK Control STCTRL offset 0x010
        ;Note: offset 0x18 holds SysTick current value

Begin
        LDR R1, =PF
        LDR R0, [R1, #0x3FC]
        CMP R0, #0x0
        BEQ Begin

        LDR R1,=UART1
        LDR R0,[R1,#0x018]          ; Read UART flag register
        ANDS R0,#0x10
        BEQ Begin                           ; If receiver is NOT empty, Send

delay1
        LDR R1, =PF
        ;Check for sw2 press (check PF0)
        LDR R0,[R1,#0x3FC]                  ; If sw2 pressed, R0 == 0
        CMP R0,#0x0
        BEQ Send                            ; If Button pressed, Send
        ;Check for request from Computer (check Rx of UART1, PB1)
        LDR R1,=UART1
        LDR R0,[R1,#0x018]          ; Read UART flag register
        ANDS R0,#0x10
        BNE delay1; If receiver is NOT empty, Send

Send
        LDR R1,=ST
        LDR R0,[R1,#0x18]           ; Read SysTick (a 0-9 value)
        LDR R1, =UART1
        BL waitLoop
        MOV R4, #0x2
        MUL R6, R4, R0
        MOV R4, PC
        ADD R4, R6, R4
        ADD R2, R4, #0x9
        MOV LR, R2
        BX LR

        B message0
        B message1
        B message2
        B message3
        B message4
        B message5
        B message6
        B message7
        B message8
```

```
        B message9

message0
        MOV32 R0, #0x4e6f7065
        BL writeRZeroToUART

        MOV R0, #0x0d0a
        BL writeRZeroToUARTTwoByte

        B Begin

message1
        MOV32 R0, #0x596f7520
        BL writeRZeroToUART

        MOV32 R0, #0x61726520
        BL writeRZeroToUART

        MOV32 R0, #0x646f6f6d
        BL writeRZeroToUART

        MOV32 R0, #0x65640d0a
        BL writeRZeroToUART

        B Begin

message2
        MOV32 R0, #0x436f6e63
        BL writeRZeroToUART

        MOV32 R0, #0x656e7472
        BL writeRZeroToUART

        MOV32 R0, #0x61746520
        BL writeRZeroToUART

        MOV32 R0, #0x796f7520
        BL writeRZeroToUART

        BL waitLoop

        MOV32 R0, #0x666f6f6c
        BL writeRZeroToUART

        MOV R0, #0x0d0a
        BL writeRZeroToUARTTwoByte

        B Begin
```

```
message3
	MOV32 R0, #0x57686174
	BL writeRZeroToUART

	MOV32 R0, #0x20612072
	BL writeRZeroToUART

	MOV32 R0, #0x75626269
	BL writeRZeroToUART

	MOV32 R0, #0x73682071
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x75657374
	BL writeRZeroToUART

	MOV32 R0, #0x696f6e0d
	BL writeRZeroToUART

	MOV R0, #0x0a
	STR R0, [R1]

	B Begin

message4
	MOV32 R0, #0x4f6e6c79
	BL writeRZeroToUART

	MOV32 R0, #0x20696e20
	BL writeRZeroToUART

	MOV32 R0, #0x796f7572
	BL writeRZeroToUART

	MOV32 R0, #0x20647265
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x616d730d
	BL writeRZeroToUART

	MOV R0, #0x0a
	STR R0, [R1]

	B Begin
```

```
message5
	MOV32 R0, #0x59657320
	BL writeRZeroToUART

	MOV32 R0, #0x6e6f7720
	BL writeRZeroToUART

	MOV32 R0, #0x6c656176
	BL writeRZeroToUART

	MOV32 R0, #0x65206d65
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x20616c6f
	BL writeRZeroToUART

	MOV32 R0, #0x6e650d0a
	BL writeRZeroToUART

	B Begin

message6
	MOV32 R0, #0x48656820
	BL writeRZeroToUART

	MOV32 R0, #0x796f7520
	BL writeRZeroToUART

	MOV32 R0, #0x77697368
	BL writeRZeroToUART

	MOV R0, #0x0d0a
	BL writeRZeroToUARTTwoByte

	B Begin

message7
	MOV32 R0, #0x4f682079
	BL writeRZeroToUART

	MOV32 R0, #0x65616820
	BL writeRZeroToUART

	MOV32 R0, #0x74686174
	BL writeRZeroToUART

	MOV32 R0, #0x2077696c
```

```
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x6c206861
	BL writeRZeroToUART

	MOV32 R0, #0x7070656e
	BL writeRZeroToUART

	MOV R0, #0x0d0a
	BL writeRZeroToUARTTwoByte

	B Begin

message8
	MOV32 R0, #0x53746f70
	BL writeRZeroToUART

	MOV32 R0, #0x20626f74
	BL writeRZeroToUART

	MOV32 R0, #0x68657269
	BL writeRZeroToUART

	MOV32 R0, #0x6e67206d
	BL writeRZeroToUART

	BL waitLoop

	MOV R0, #0x65
	STR R0, [R1]
	MOV R0, #0x0d0a
	ROR R0, #8
	STR R0, [R1]
	ROR R0, #24
	STR R0, [R1]

	B Begin

message9
	MOV32 R0, #0x4e6f7420
	BL writeRZeroToUART
	MOV32 R0, #0x69662079
	BL writeRZeroToUART

	MOV32 R0, #0x6f752077
	BL writeRZeroToUART
```

```
	MOV32 R0, #0x65726520
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x74686520
	BL writeRZeroToUART

	MOV32 R0, #0x6c617374
	BL writeRZeroToUART

	MOV32 R0, #0x20706572
	BL writeRZeroToUART

	BL waitLoop

	MOV32 R0, #0x736f6e20
	BL writeRZeroToUART

	MOV32 R0, #0x6f6e2065
	BL writeRZeroToUART

	MOV32 R0, #0x61727468
	BL writeRZeroToUART

	MOV32 R0, #0x0d0a
	BL writeRZeroToUARTTwoByte

	B Begin

writeRZeroToUARTTwoByte
	ROR R0, #8
	STR R0, [R1]
	ROR R0, #24
	STR R0, [R1]
	BX LR

; assumes R1 is set to base address of UART
writeRZeroToUART
	ROR R0, #24
	STR R0, [R1]
	ROR R0, #24
	STR R0, [R1]
	ROR R0, #24
	STR R0, [R1]
	ROR R0, #24
	STR R0, [R1]
	BX LR
```

```
waitLoop
        ldr R2,[R1,#0x18]
        ands R2,#0x80 ;0b100000 (set Z=1 if result is 0)
        BEQ waitLoop
        BX LR

    ALIGN
    END
```