Exam 1

Date: Oct 4, 2017

UT EID: ____________________________ Professor: Valvano

Printed Name: ____ ____
Last, First

Your signature is your promise that you have not cheated and will not cheat on this exam, nor will you help others to cheat on this exam:

Signature: ____

Instructions:

- Closed book and closed notes. No books, no papers, no data sheets (other than the last two pages of this Exam)
- No devices other than pencil, pen, eraser (no calculators, no electronic devices), please turn cell phones off.
- Please be sure that your answers to all questions (and all supporting work that is required) are contained in the space (boxes) provided. *Anything outside the boxes/blanks will be ignored in grading*. You may use the back of the sheets for scratch work.
- You have 75 minutes, so allocate your time accordingly.
- For all questions, unless otherwise stated, find the most efficient (time, resources) solution.
- Unless otherwise stated, make all I/O accesses friendly.
- *Please read the entire exam before starting.*

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Total	100	

(12) Question 1. Short answers.

(2) Part a) What are the two output states of open collector logic?

Low and off

(2) Part b) Does the equation **power = voltage*current** apply to both resistors and LEDs? Answer yes or no.

Yes, this is true for all electrical devices

(2) Part c) What does nonvolatile mean (in context of computer memory?

Information is not lost, it is retained, if power is removed and then restored

(2) Part d) Under what conditions does this code branch?

```
ORRS R0,R0,#4
BNE  FunTimes
```

It always branches; all values of R0 will branch; ORR sets bit 2, so it will be nonzero

(2) Part e) Considering R0 as input and R1 as output, what is the mathematically relation between R1 and R0?

```
LSL R1,R0,#4
SUB R1,R1,R0
```

(R1 is 16*R0)
R1 is 15*R0

(2) Part f) If you add an *n*-bit signed number to an *m*-bit signed number, what is the maximum number of bits in the sum? Assume $n \geq m$.

n+1; think of example 63+15 = 78, 6bit+4bit => 7bit

(8) Question 2. Assume the value is 8 bits. The binary is 10010010.
What is the value as unsigned hexadecimal?

0x92

What is the value as unsigned decimal?

9*16+2 = 146
128+16+2 = 146

What is the value as signed decimal?

-128+16+2 = -110

(10) Question 3 Assume **`Data`** is an 8-bit unsigned variable in RAM.

```
uint8_t Data;
```

Write assembly code that performs the following C code (no function, just assembly code),

```
 if(Data >= 32){
   Data = 255; // ceiling
 }else{
   Data = Data<<3;
 }
```

```
    LDR  R1,=Data
    LDRB R0,[R1]
    CMP  R0,#32 ;8*32 would have been 256, causing overflow
    BLO  ok
    MOV  R0,#255  ; ceiling
    B    set
ok  LSL  R0,R0,#3 ; unsigned
set STRB R0,[R1]

     LDR  R1,=Data
     LDRB R0,[R1]
     CMP  R0,#32 ;8*32 would have been 256, causing overflow
     BHS  ceil
ok   LSL  R0,R0,#3 ; unsigned
     B    set
ceil MOV  R0,#255  ; ceiling
set  STRB R0,[R1]
```

(15) Question 4. Consider the following C function with two inputs and one output.

```
uint32_t x;
uint32_t func(uint32_t in1, uint32_t in2){
  uint32_t out;
  out = 1;
  while(in1 >=  in2){
    out = out*in2;
    in2 = in2 + 1;
  }
  return out;
}
```

(5) Part a) If we were to execute `x=func(6,4);` what would be the value of x?

x = 4*5*6=120

(10) Part b) Write `func` in assembly using AAPCS

```
// AAPCS: inputs in R0,R1
func MOV R3,#1    ;R3 is out
loop CMP R0,R1    ;R0 is in1, R1 is in2
// while loop has test first
     BLO done
     MUL R3,R3,R1 ;out=out*in2
     ADD R1,R1,#1 ;in2=in2+1
     B   loop
done MOV R0,R3
// AAPCS: output in R0
     BX  LR
```

(10) Question 5. Consider initialization code for a regular GPIO pin PE0:
Consider the following shorthand codes for 5 bits needed during initialization

```
Clk = SYSCTL_RCGCGPIO_R (bit 4)
Dir = GPIO_PORTE_DIR_R (bit 0)
Pur = GPIO_PORTE_PUR_R (bit 0)
Pdr = GPIO_PORTE_PDR_R (bit 0)
Den = GPIO_PORTE_DEN_R (bit 0)
```

<Hint: work backwards. What bits do you use if regular input?>

For each of the following cases, choose the description that best fits

A) PE0 cannot be used for input or output
B) PE0 is an output
C) PE0 is a regular input
D) PE0 is an input used with a negative logic switch and no external resistor
E) PE0 is an input used with a positive logic switch and no external resistor

Clk	Dir	Pur	Pdr	Den	Place A,B,C,D,or E
0	0	0	0	1	A
1	0	0	0	1	C
1	0	0	0	0	A
1	1	0	0	1	B
1	1	0	0	0	A
0	1	0	0	1	A
1	0	1	0	1	D
1	0	0	1	0	A
1	0	0	1	1	E
1	0	1	1	0	A

(15) Question 6. Assume the value of the Stack pointer (SP) is **`0x20000FF8`** when the following code sequence starts execution (i.e., **`PC=0x00001000`**). The initial stack contents are given on the right. When drawing the stack contents, you need only to show numbers on the stack that represents valid data.

```
0x00001000        POP {R0,R1}
0x00001004        ADD R2,R0,R1
0x00001008        BL   Func        <-- B
0x0000100C        ...
...
0x00002000 Func   PUSH {R2,LR}     <-- A
0x00002004        MOV  R2,R1
0x00002008        MUL  R0,R2
0x0000200C        ADD  R0,R1
0x00002010        POP {R2,PC}
```

0x20000FF4	1
0x20000FF8	2
0x20000FFC	3
0x20001000	4
0x20001004	5
0x20001008	6
0x2000100C	7

(6) Part a) Give the state of the stack (SP and contents) after executing of the **`PUSH`** instruction, as shown by arrow A: **`pop (R0,R1}`**causes R0=2, R1=3, SP = 0x20001000

`Add R2,R0,R1` causes R2 = 5

`BL` causes LR = 0x0000100D

`Push R2,LR`

0x20000FF4	
0x20000FF8	5
0x20000FFC	0x0000100D
0x20001000	4
0x20001004	5
0x20001008	6
0x2000100C	7

SP = **`0x20000FF8`**

We give full credit for 0x0000100C. On the ARM/Thumb processors, the PC is 32 bits with bit 0 always clear. The processor uses this bit to specify if the destination code is ARM (0) or Thumb (1). For EE319K this bit will always be 1 for Thumb.

(10) Part b) Give the state of the stack (SP and contents) while executing the instruction at memory location 0x0000100C as shown by the arrow B and the values stored in R0, R1, and R2.

`mov r2,r1` causes r2=3

`mul r0,r2` causes r0 = 2*3=6

`add r0,r1` causes r0 = 6+3 = 9

`POP {R2,PC}`restores R2 = 7, SP to 0x20001000

0x20000FF4	
0x20000FF8	
0x20000FFC	
0x20001000	4
0x20001004	5
0x20001008	6
0x2000100C	7

SP = 0x20001000

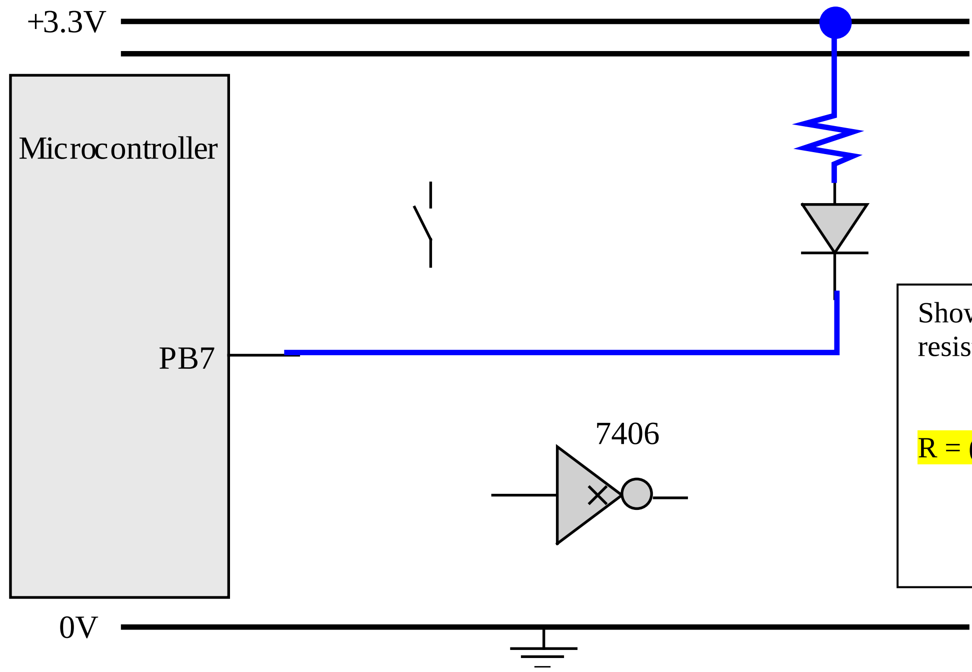
R0 = 9

R1 = 3

R2 = 5

(20) Question 7. Assume the microcontroller's output voltage high is 3.3V. Assume the microcontroller's output voltage low is 0V. The V_{OL} for the 7406 driver is 0.5V. Pick resistors appropriately and assume you have 5V, 3.3V, and ground to which you can connect your components. The symbols for each part are given below for your convenience – *use the minimum number of parts to construct the interface*.

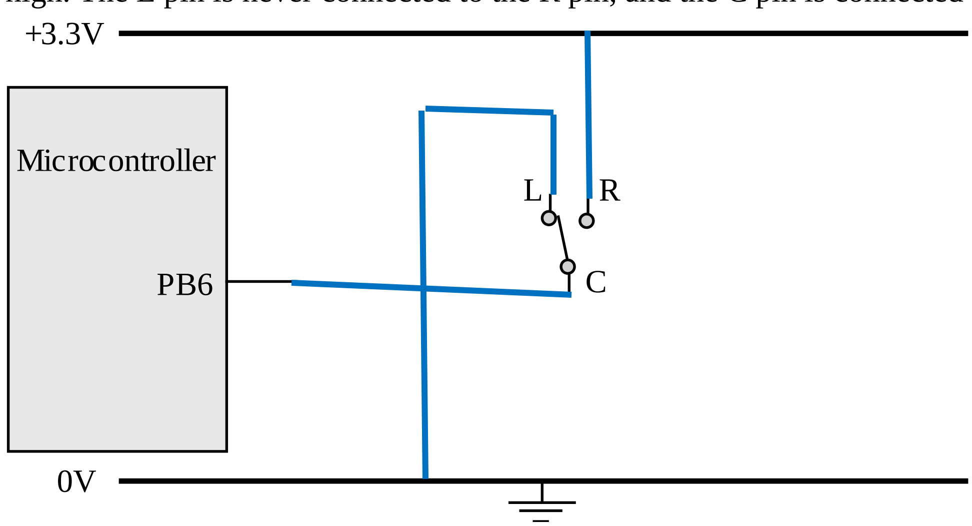
Part a) Interface the LED to Port B bit 7 (PB7) using negative logic (means low => LED on). The LED operating point is 2.3V at 2mA. 2mA<8mA so no 7406 needed



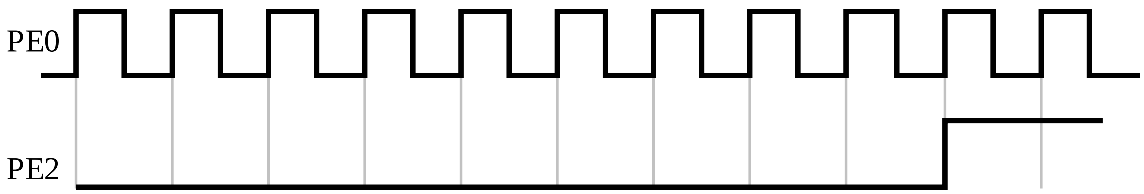
Show calculations for selecting resistor value(s)

R = (3.3-2.3)/2mA = 500 ohms

Part b) Interface this single pole double throw switch to the microcontroller PB6 input. The switch has two possibilities. The first case is the C pin is connected to the L pin. For this case, make PB6 low. The second case is the C pin is connected to the R pin. For this case, make PB6 high. The L pin is never connected to the R pin, and the C pin is connected to either L or R.



(10) Question 8. You may assume the **`PortE_Init`** function initializes PE1-PE0 as inputs, and initializes PE3-PE2 as outputs. Write the C code for this main program that performs these two tasks over and over indefinitely.
Task 1: if PE1 equals PE0 then set PE3 high, otherwise set PE3 low.
Task 2: A trigger event is defined as the rising edge of PE0 (last time it was low, this time it is high). On the 10th trigger event, set PE2 high. Once PE2 is high it will remain high. Perform friendly output on Port E. You may assume the time PE0 is low and the time it is high is long compared to the time it takes the software to execute the loop once.



You may add local variables, and you may execute code before the **while(1)** statement. You will read and write to the Port E data register **GPIO_PORTE_DATA_R**.

```
int main(void){
  uint32_t pe0,pe1,last,count;
  PortE_Init(); // you do not need to write this
  last = GPIO_PORTE_DATA_R&0x01;
  count = 0;
  while(1){
// to properly detect edges, read PE0 once per loop
    pe0 = GPIO_PORTE_DATA_R&0x01;
    pe1 = (GPIO_PORTE_DATA_R&0x02)>>1;
    if(pe0 == pe1){
      GPIO_PORTE_DATA_R |= 0x08;
    }else{
      GPIO_PORTE_DATA_R &= ~0x08;
    }
    if((last==0)&&(pe0==1)){
      if(count<10){
        count++;
        if(count == 10){
          GPIO_PORTE_DATA_R |= 0x04;
        }
      }
    }
    last = pe0;
  }
}
```

Memory access instructions

```
LDR    Rd, [Rn]        ; load 32-bit number at [Rn] to Rd
LDR    Rd, [Rn,#off]   ; load 32-bit number at [Rn+off] to Rd
LDR    Rd, =value      ; set Rd equal to any 32-bit value (PC rel)
LDRH   Rd, [Rn]        ; load unsigned 16-bit at [Rn] to Rd
LDRH   Rd, [Rn,#off]   ; load unsigned 16-bit at [Rn+off] to Rd
LDRSH  Rd, [Rn]        ; load signed 16-bit at [Rn] to Rd
LDRSH  Rd, [Rn,#off]   ; load signed 16-bit at [Rn+off] to Rd
LDRB   Rd, [Rn]        ; load unsigned 8-bit at [Rn] to Rd
LDRB   Rd, [Rn,#off]   ; load unsigned 8-bit at [Rn+off] to Rd
LDRSB  Rd, [Rn]        ; load signed 8-bit at [Rn] to Rd
LDRSB  Rd, [Rn,#off]   ; load signed 8-bit at [Rn+off] to Rd
STR    Rt, [Rn]        ; store 32-bit Rt to [Rn]
STR    Rt, [Rn,#off]   ; store 32-bit Rt to [Rn+off]
STRH   Rt, [Rn]        ; store least sig. 16-bit Rt to [Rn]
STRH   Rt, [Rn,#off]   ; store least sig. 16-bit Rt to [Rn+off]
STRB   Rt, [Rn]        ; store least sig. 8-bit Rt to [Rn]
STRB   Rt, [Rn,#off]   ; store least sig. 8-bit Rt to [Rn+off]
PUSH   {Rt}            ; push 32-bit Rt onto stack
POP    {Rd}            ; pop 32-bit number from stack into Rd
ADR    Rd, label       ; set Rd equal to the address at label
MOV{S} Rd, <op2>       ; set Rd equal to op2
MOV    Rd, #im16       ; set Rd equal to im16, im16 is 0 to 65535
MVN{S} Rd, <op2>       ; set Rd equal to -op2
```

Branch instructions

```
B    label   ; branch to label    Always
BEQ  label   ; branch if Z == 1   Equal
BNE  label   ; branch if Z == 0   Not equal
BCS  label   ; branch if C == 1   Higher or same, unsigned ≥
BHS  label   ; branch if C == 1   Higher or same, unsigned ≥
BCC  label   ; branch if C == 0   Lower, unsigned <
BLO  label   ; branch if C == 0   Lower, unsigned <
BMI  label   ; branch if N == 1   Negative
BPL  label   ; branch if N == 0   Positive or zero
BVS  label   ; branch if V == 1   Overflow
BVC  label   ; branch if V == 0   No overflow
BHI  label   ; branch if C==1 and Z==0  Higher, unsigned >
BLS  label   ; branch if C==0 or  Z==1  Lower or same, unsigned ≤
BGE  label   ; branch if N == V   Greater than or equal, signed ≥
BLT  label   ; branch if N != V   Less than, signed <
BGT  label   ; branch if Z==0 and N==V  Greater than, signed >
BLE  label   ; branch if Z==1 or N!=V  Less than or equal, signed ≤
BX   Rm      ; branch indirect to location specified by Rm
BL   label   ; branch to subroutine at label, return address in LR
BLX  Rm      ; branch to subroutine indirect specified by Rm
```

Interrupt instructions

```
CPSIE  I               ; enable interrupts  (I=0)
CPSID  I               ; disable interrupts (I=1)
```

Logical instructions

```
AND{S} {Rd,} Rn, <op2> ; Rd=Rn&op2    (op2 is 32 bits)
ORR{S} {Rd,} Rn, <op2> ; Rd=Rn|op2    (op2 is 32 bits)
EOR{S} {Rd,} Rn, <op2> ; Rd=Rn^op2    (op2 is 32 bits)
BIC{S} {Rd,} Rn, <op2> ; Rd=Rn&(~op2) (op2 is 32 bits)
ORN{S} {Rd,} Rn, <op2> ; Rd=Rn|(~op2) (op2 is 32 bits)
LSR{S} Rd, Rm, Rs      ; logical shift right Rd=Rm>>Rs  (unsigned)
LSR{S} Rd, Rm, #n      ; logical shift right Rd=Rm>>n   (unsigned)
```

```
   ASR{S} Rd, Rm, Rs      ; arithmetic shift right Rd=Rm>>Rs (signed)
   ASR{S} Rd, Rm, #n      ; arithmetic shift right Rd=Rm>>n  (signed)
   LSL{S} Rd, Rm, Rs      ; shift left Rd=Rm<<Rs (signed, unsigned)
   LSL{S} Rd, Rm, #n      ; shift left Rd=Rm<<n  (signed, unsigned)
```

Arithmetic instructions

```
   ADD{S} {Rd,} Rn, <op2> ; Rd = Rn + op2
   ADD{S} {Rd,} Rn, #im12 ; Rd = Rn + im12, im12 is 0 to 4095
   SUB{S} {Rd,} Rn, <op2> ; Rd = Rn - op2
   SUB{S} {Rd,} Rn, #im12 ; Rd = Rn - im12, im12 is 0 to 4095
   RSB{S} {Rd,} Rn, <op2> ; Rd = op2 - Rn
   RSB{S} {Rd,} Rn, #im12 ; Rd = im12 – Rn
   CMP    Rn, <op2>       ; Rn – op2      sets the NZVC bits
   CMN    Rn, <op2>       ; Rn - (-op2)   sets the NZVC bits
   MUL{S} {Rd,} Rn, Rm    ; Rd = Rn * Rm       signed or unsigned
   MLA    Rd, Rn, Rm, Ra  ; Rd = Ra + Rn*Rm    signed or unsigned
   MLS    Rd, Rn, Rm, Ra  ; Rd = Ra - Rn*Rm    signed or unsigned
   UDIV   {Rd,} Rn, Rm    ; Rd = Rn/Rm         unsigned
   SDIV   {Rd,} Rn, Rm    ; Rd = Rn/Rm         signed
```

Notes `Ra Rd Rm Rn Rt represent 32-bit registers`

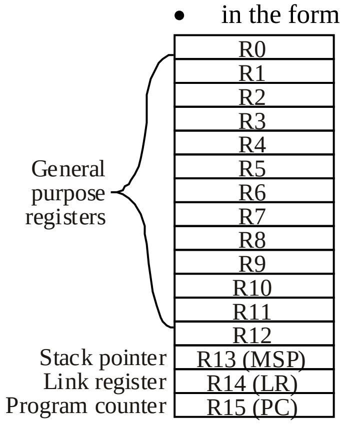
```
     value   any 32-bit value: signed, unsigned, or address
     {S}     if S is present, instruction will set condition codes
     #im12   any value from 0 to 4095
     #im16   any value from 0 to 65535
     {Rd,}   if Rd is present Rd is destination, otherwise Rn
     #n      any value from 0 to 31
     #off    any value from -255 to 4095
     label   any address within the ROM of the microcontroller
     op2     the value generated by <op2>
```

Examples of flexible operand **`<op2>`** creating the 32-bit number. E.g., **`Rd = Rn+op2`**

```
   ADD Rd, Rn, Rm         ; op2 = Rm
   ADD Rd, Rn, Rm, LSL #n ; op2 = Rm<<n  Rm is signed, unsigned
   ADD Rd, Rn, Rm, LSR #n ; op2 = Rm>>n  Rm is unsigned
   ADD Rd, Rn, Rm, ASR #n ; op2 = Rm>>n  Rm is signed
   ADD Rd, Rn, #constant  ; op2 = constant
```

, where **X** and **Y** are hexadecimal digits:

- produced by shifting an 8-bit unsigned value left by any number of bits
- in the form **0x00XY00XY**
- in the form **0xXY00XY00**
- in the form **0xXYXYXYXY**



Condition code bits

N negative
Z zero
V signed overflow
C carry or unsigned overflow