Name:_____

EE 107: Midterm

Spring 2019
May 15, 2019

Time: 50 minutes

Information

· This exam is closed book/notes. Use of any printed material, electronic devices or any other aid will be treated as a violation of the Stanford Honor Code.
· This question-cum-answer booklet has a total of 10 pages (including the cover page and two blank pages).
· The exam consists of 4 questions totaling 100 points. You have 50 minutes to complete the exam.

Instructions

· Write your solutions neatly and legibly in the space provided for each question. If you need more space, use the last pages.
· Write your name in the space provided on each sheet.
· The reverse side of each sheet is your scratch space. We will **NOT** grade anything written on the reverse side.

Name:_____ SUNet _____

ID:_____@stanford.edu

In accordance with both the letter and the spirit of the Stanford Honor Code, I declare that I neither received nor provided any assistance on this exam.

Signature: _____

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Problem	**1**	**2**	**3**	**4**	**Total**
Score					

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GPIO [20 Points]

[10 pts] 1. Following is the Pin Configuration Summary table from SAMD21 datasheet. How would you configure a GPIO pin that is used to communicate with another MCU (without damaging GPIO port)? Write down values for DIR / INEN / PULLEN and explain your choice.

Table 23-2. Pin Configurations Summary

DIR	INEN	PULLEN	OUT	Configuration
0	0	0	X	Reset or analog I/O: all digital disabled
0	0	1	0	Pull-down; input disabled
0	0	1	1	Pull-up; input disabled
0	1	0	X	Input
0	1	1	0	Input with pull-down
0	1	1	1	Input with pull-up
1	0	X	X	Output; input disabled
1	1	X	X	Output; input enabled

We should configure it as bidirectional port.
DIR=0
INEN=1
PULLEN=1

OUT could be either 0 or 1. Set DIR=1 may damage port.

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[10 pts] 2. Following is part of the GPIO characteristics taken from SAMD21 datasheet. Now we want to control an LED with a forward voltage drop of 2.1V. How would you configure the PORT.PINCFG.DRVSTR register so the LED has the maximum brightness? Also calculate value of the resistor in series with the LED so the current value does not exceed limits shown in the following table. The supply voltage (VDD) for the MCU is 3.3V.

I_{OL}	Output low-level current	V_{DD}=1.62V-3V, PORT.PINCFG.DRVSTR=0	-	-	1	mA
		V_{DD}=3V-3.63V, PORT.PINCFG.DRVSTR=0	-	-	2.5	
		V_{DD}=1.62V-3V, PORT.PINCFG.DRVSTR=1	-	-	3	
		V_{DD}=3V-3.63V, PORT.PINCFG.DRVSTR=1	-	-	10	
I_{OH}	Output high-level current	V_{DD}=1.62V-3V, PORT.PINCFG.DRVSTR=0	-	-	0.70	
		V_{DD}=3V-3.63V, PORT.PINCFG.DRVSTR=0	-	-	2	
		V_{DD}=1.62V-3V, PORT.PINCFG.DRVSTR=1	-	-	2	
		V_{DD}=3V-3.63V, PORT.PINCFG.DRVSTR=1	-	-	7	

Set PORT.PINCFG.DRVSTR=1 to max drive current.
We could connect the LED as: VCC->resistor->LED->GPIO. LED will be turned on when output low. The max current is 10mA. The resistor value is (3.3V-2.1V)/10mA=120Ohm.

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Serial Buses [20 Points]

[10 pts] 1.Which of the following bus has the highest data throughput: UART/I2C/SPI? Can you explain why it is faster than the other two?

SPI has the highest data throughput.
SPI is faster than UART because SPI receiver do not have to infer the clock (receiver side has to oversample by 8x or 16x), also the efficiency of UART is 80%.
SPI is faster than I2C because the bus speed of I2C is limited by the pull up resistor and line capacitance. Also the efficiency of I2C is ~40%.

[10 pts] 2.Thinking that you have a MCU, 3 I2C sensors (each has a different address) and 2 SPI sensors. What's the minimal IO pins needed to connect them together?

7. 2 pins for I2C, 5 pins for SPI (2 CS, one SCLK/MISO/MOSI).

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Wireless [20 Points]

[10 points] 1. In what application scenarios would you choose Bluetooth over WiFi? Explain your choice in terms of speed, range and power consumption.

I would choose Bluetooth over WiFi if I do not need speed higher than 1Mbps, OK with a range of several meters and requires power consumption lower than 10mA.

[10 points] 2. What is the difference between digital wireless communication and analog wireless communication? Can you explain why people are moving towards digital wireless communication?

Digital wireless communication transmits discrete values (usually 0 or 1s) while analog communication transmit continuous values. Digital communication is more robust to noise and is possible to send message in a lossless way.

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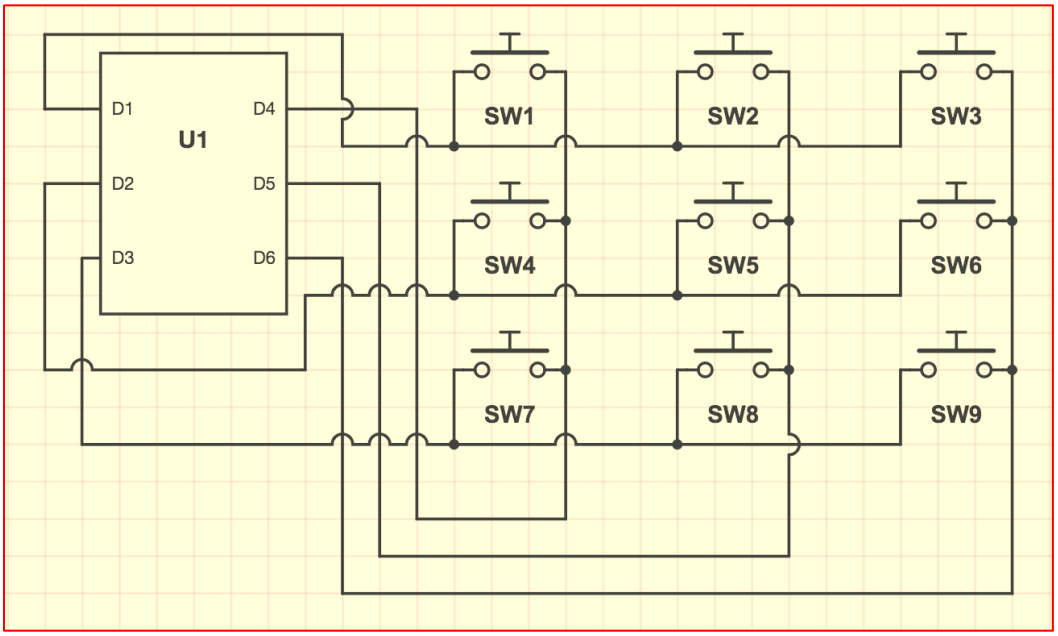
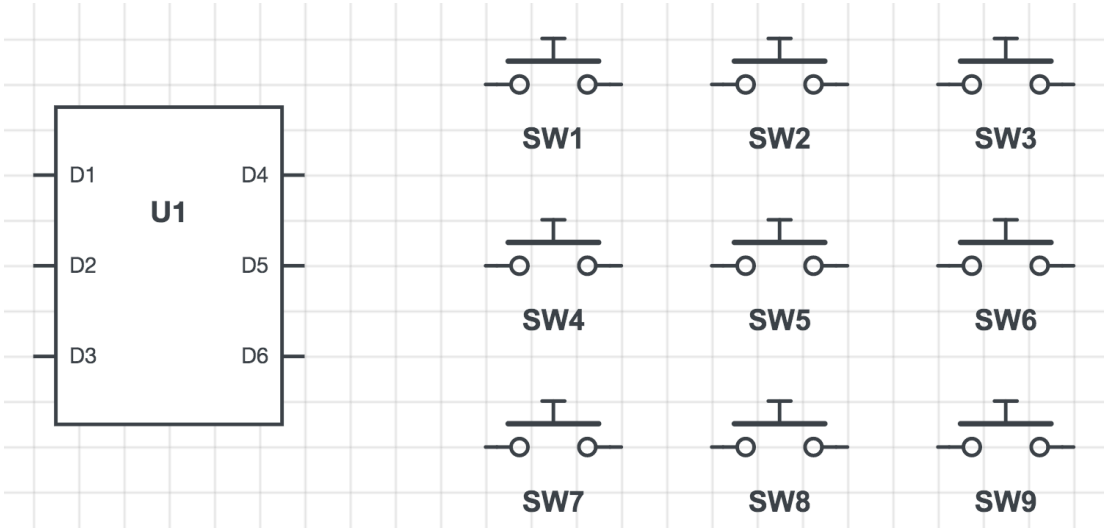
System design [40 Points]

[10pts] 1.You're asked to build a 9-key keypad with Arduino zero using only 6 GPIOs rather than 9. **Assuming that only one key will be pressed at a given time**. Try to connect each switch to the MCU in the following figure:

(Bottom one is the original one)



(If you screwed up with the drawing above, use the backup figure below. This is the last one.)



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[20pts] 2.Write a driver for the keypad in the loop() function below.
Focus on the function – we will not deduct points for minor grammar issues.
Here are some useful references:
pinMode: pinMode(1, INPUT), pinMode(1, INPUT_PULLDOWN), pinMode(1, OUTPUT)
digitalRead: val = digitalRead(1); // return val as HIGH or LOW
digitalWrite: digitalWrite(1, HIGH), digitalWrite(1, LOW)
delay: delay(100); // delay 100ms

```
int val = 0; // 0 means no key has been pressed
void setup(){
} // leave setup empty

void loop(){
// begin of your code
// the solution is deliberately written in a verbose way to help understanding
int key_val=0;

// check first row
// set D1 output HIGH, D2/D3 as input
pinMode(1, OUTPUT); digitalWrite(1, HIGH);
pinMode(2, INPUT); pinMode(3, INPUT);
// set D4/D5/D6 to input with pull_down resistor, and read the value
for(int i=4;i<7;i++){
  pinMode(i, INPUT_PULLDOWN);
  key_val = digitalRead(i);
  if(key_val == HIGH){val=i-3;}
}

// check second row
pinMode(2, OUTPUT); digitalWrite(2, HIGH);
pinMode(1, INPUT); pinMode(3, INPUT);
for(int i=4;i<7;i++){
  pinMode(i, INPUT_PULLDOWN);
  key_val = digitalRead(i);
  if(key_val == HIGH){val=i;}
}

// check third row
pinMode(2, OUTPUT); digitalWrite(2, HIGH);
pinMode(1, INPUT); pinMode(3, INPUT);
for(int i=4;i<7;i++){
  pinMode(i, INPUT_PULLDOWN);
  key_val = digitalRead(i);
  if(key_val == HIGH){val=i+3;}
}
delay(100);
// end of your code
}
```

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[10pts] 3.Describe at least two methods to optimized the power consumption of keypad driver in the previous section.

Put the MCU in sleep mode periodically (replace delay(100) with LowPower.sleep(100))
Use external interrupt triggered by the button
Reduce MCU clock speed

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