Biomedical Instrumentation, ECE 396 Final-Exam Total Grade=50 Points January 12th, 2018

Mansoura University	Faculty of Engineering	Biomedical Engineering (BME) Program
		Time allowed: **120** min, Exam is **Five** pages
		OPEN HAND WRITTEN NOTES EXAM
		QUESTIONS ARE INDEPENDENT
		Assume any missing data, use clear assumptions

To design a medical care system for the Egyptian army, you are asked to acquire and control the electrocardiogram (ECG) signal from the soldier using the block diagram shown in **Fig.** 1. The system is put in the soldiers' room, monitor their heart on daily basis, and send an alarm to a doctor if heart rate is abnormal. Answer questions below:

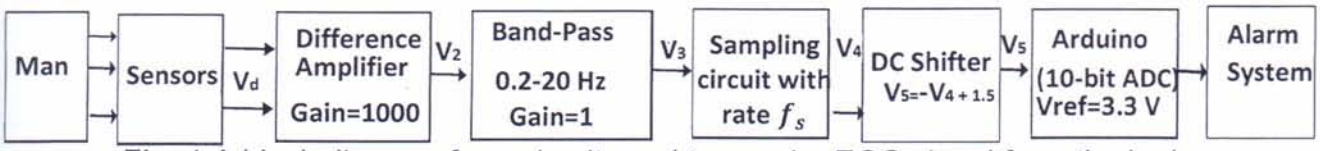


Fig. 1 A block diagram for a circuit used to acquire ECG signal from the body

1. On cell basis, a bioelectrical signal (action potential) leads to heart muscle contraction and expansion. Answer the following: **[5 points]**

- Sketch the signal: (3 points)

- Which part of the signal correspond to muscle contraction? (1 point)

  .....

- How the action potential of cells propagate in heart? (1 point)

  .....

2. For the sensors used, answer the following: **[5 points]**

- Type of sensor used: (1 point)

  .....

- Sketch sensor structure: (2 points)

- Where the three inputs to the sensors connected to body? (1 point)

  .....

- Sensor chemical equations: (1 points)

  .....

  .....

3. For a normal heart rate of 70 beat per minute. Answer the following: **[5 points]**

- Sketch ECG signal: (3 points)

- Determine RR interval : (1 points)

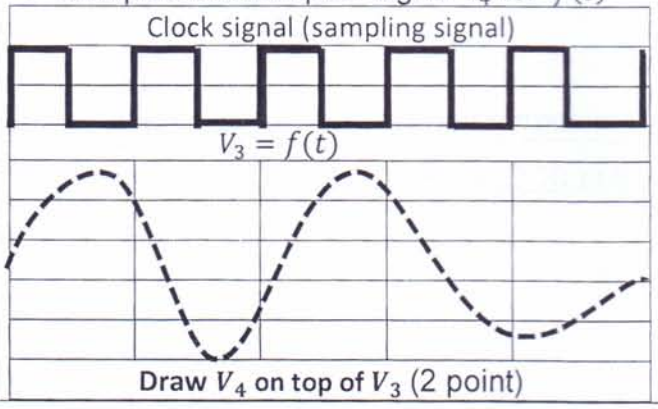
RR interval =.....

- Part of ECG corresponding to: (1 point)
  - **Ventricular expansion is** .....
  - **Atrial contraction is** .....

4. Design the difference amplifier of gain=1000 using an instrumentation amplifier with discrete elements. Explain why it is better to use integrated circuit (IC) **[5 points]**

5. Design the sample and hold circuit and answer the following: **[5 points]**

- Circuit design (1 points)
- Circuit output equation (1 points)
- Sampling rate according to sampling theory is..... (1 point)
- Compute the sampled signal V_4 for $f(t)$



6. Sensor output V_d is between -1.5 to 1.5mV. Design a DC shifter **[$V_{out}=V_5=-V4+1.5$]**, to enter only positive voltages to Arduino. Use a summing amplifier **[5 points]**

- Design: (4 points)

- Output of summing amplifier is between ..... and ..... (1 point)

7. To replace the Arduino board with the programming IC (to minimize circuit cost). You need to design an ADC. Answer the following: **[5 points]**

- Design a successive approximation ADC if V_5 is between 0 to 3V (use **Vref=3.3V**) and the maximum allowable quantization error (step size) is 0.5 V. (4 points)

- Determine the output code for three sequence samples of 1.5V, 1.9V, and 3.1V

  Output code is ..... (1 point)

8. An Arduino with 10 bit internal ADC with Vref=3.3V is used to record ECG, measure heart rate, and activate an alarm system if the heart rate is abnormal (below 60 bpm or above 100 bpm). **Write a code to measure heart rate (bpm)** **[5 points]**

Let Sensor output V_d is between -1.5 to 1.5mV.

Let a practical sampling rate is selected as f_s=100 sample/sec.

- Arduino take a reading every 10 ms
- Whenever v_d just exceed 1 mV (two samples with a separation 10 ms: one is below 1mV and the next is above 1mV), a peak is found
- Heart rate cycle duration is measured as the duration between two peaks
- Use the instruction $float$ **time1** $= millis()$ to return the number of milliseconds since the Arduino board began running the current program
- Note that **V_5 is connected to Arduino PIN 3 (an analog PIN)**.

- Resolution of the internal ADC of Arduino= ..... (1 point)
- **Code for heart rate** (4 points)

```
// Add comments whenever applicable

void setup() {




}
void loop() {




}
```

9. Design an alarm circuit to be connected to Arduino **PIN 12** (a digital PIN) such that a **LED is** flashing (ON with a delay of 1 sec then OFF with delay 0.5 sec) whenever the heart rate is abnormal (below 60 bpm or above 100 bpm). A LED to be ON needs **2V** across its terminals and consumes around **2mA**. Write the code **[5 points]**

Alarm Circuit	Arduino Code

• Note that Arduino Vref=3.3V	// Add comments whenever applicable
	
	void setup() {
	float heart_rate; // heart rate is already stored in this variable
	
	}
	void loop() {
	
	}
	
	}

10. Apply a moving average filter with length=3 on the heart rate signal x(n): **[5 points]**

$$x(n) = [66\ ,\quad 69\ ,\quad 73\ ,\quad 69\ ,\quad 63\ ,\quad 66, \ldots\ldots\ldots\ldots]$$

- Signal after moving average filter =[.....,.....,.....,.....] (4 points)

- Job of the moving average filter is ..... (1 points)

Code appendix: pinMode(pin , mode); digitalWrite(pin , value); digitalRead(pin); analogRead(pin); analogWrite(pin , value); delay(time in ms); int x = digitalRead(pin, value) If (condition) {expression 1;} else {expression 2)}; int reading 1=millis()

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