



## Exam March 2017, answers

Introduction To Mechatronics Systems Design (Nanyang Technological University)

**MA2012 – Introduction to Mechatronics Systems Design**

**AY1314**

3.

a) Stroke = 140 mm, because total required stroke is  $55+60 = 115\text{mm}$ .

Gear Reduction Ratio = 35:1, because 50 N is sufficient for the heavier box weighing 3 kg.

Controller type = Type P, because feedback potentiometer is needed to move the tray to exactly -55 and +60 mm.

(3 marks)

b) Range of potentiometer output,  $V_{out} = 5-0 = 5\text{ V}$

At midpoint, i.e.  $d = 70\text{mm}$ ,  $V_{out} = 5/2 = 2.5\text{ V}$

At position A,  $V_{out} = 2.5\text{V} - 55\text{mm} / 140\text{mm} \times 5\text{V} = 0.536\text{ V}$

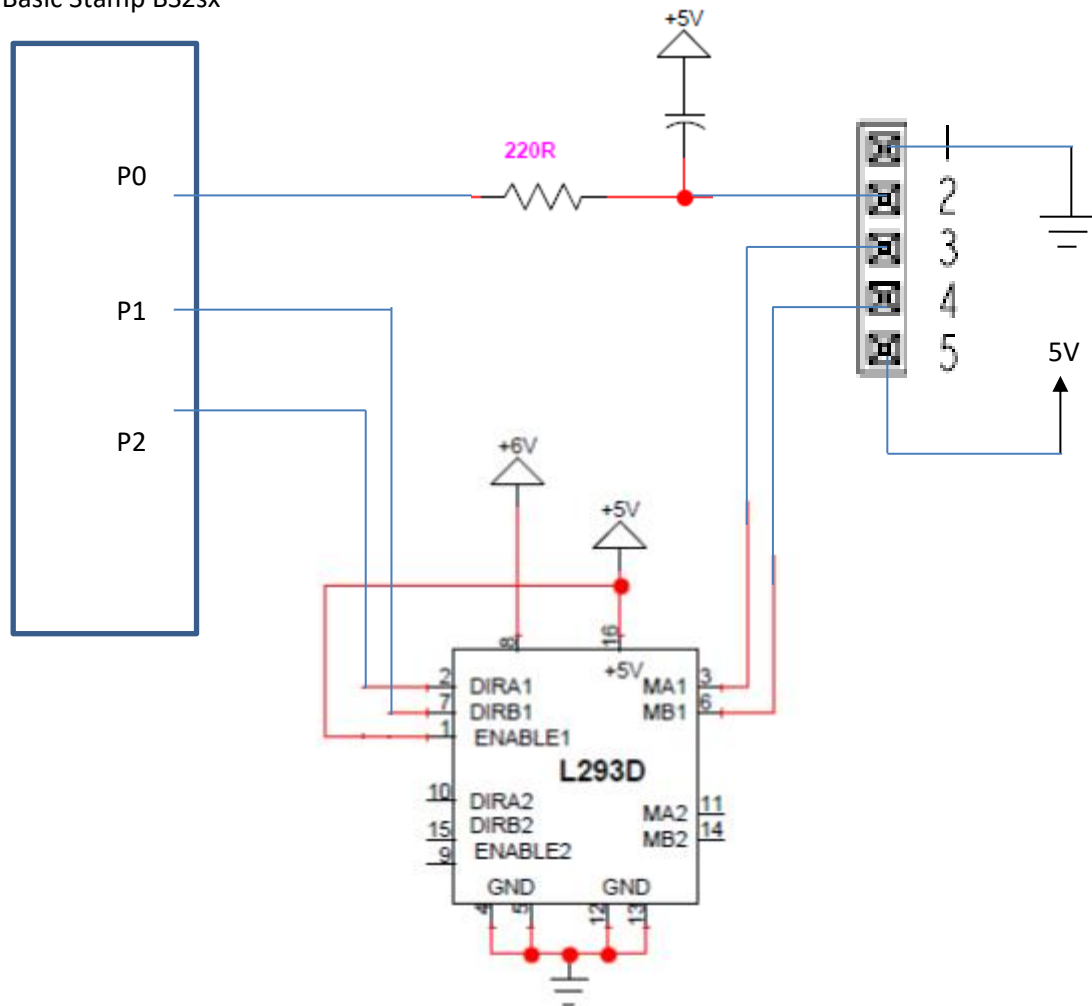
At Position B,  $V_{out} = 2.5\text{V} + 60\text{mm} / 140\text{mm} \times 5\text{V} = 4.643\text{ V}$

(6 marks)

d)

- 1 (orange) – Feedback Potentiometer negative reference rail
- 2 (purple) – Feedback Potentiometer wiper
- 3 (red) – Actuator Motor Power
- 4 (black) – Actuator Motor Power
- 5 (yellow) – Feedback Potentiometer positive reference rail

Basic Stamp BS2sx



(10 marks)

Q1.

a) Conditional and unconditional transfer.

(1 mark)

b)

i) When a person enters a toilet, MCU switches on the lights.

(A) Infrared motion sensor / Proximity sensor.

(B) No signal conditioning element needed for interfacing with MCU, because output of sensor is in digital form, i.e. TTL 5V (HIGH) and 0V (LOW).

(C) A power transistor to switch ON/OFF the lights.

(D) No signal conditioning element is needed for interfacing with MCU, because a power transistor is a digital device that can be driven by the output pin of a MCU.

(6 marks)

ii) When a car hits an obstacle, MCU activates an airbag.

(A) Accelerometer.

(B) ADC.

(C) A solenoid valve.

(D) A power transistor.

(6 marks)

iii) When a car is caught moving too fast, MCU triggers a camera to take pictures.

(A) Infrared speed sensor.

(B) ADC.

(C) Power transistor to trigger camera.

(D) No signal conditioning element is needed for interfacing with MCU, because a power transistor is a digital device that can be driven by the output pin of a MCU.

(6 marks)

iv) When a kettle of water boils, MCU cuts off the power.

(A) Temperature sensor.

(B) ADC.

(C) A power transistor.

(D) No signal conditioning element is needed for interfacing with MCU, because a power transistor is a digital device that can be driven by the output pin of a MCU.

(6 marks)

Q4.

a)  $X_{\text{FILT}}$  &  $Y_{\text{FILT}}$  are analog output;  $X_{\text{OUT}}$  &  $Y_{\text{OUT}}$  are digital output.

(2 marks)

b)

(i)  $X_{\text{FILT}} = Y_{\text{FILT}} = 2.5\text{V}$

(3 marks)

(ii)  $X_{\text{OUT}} = Y_{\text{OUT}} = \text{T1}$

$$\text{T2} = 125\text{k}\Omega / 125\text{M}\Omega = 1\text{ms}$$

$$\text{T1}/\text{T2} = 50\% \text{ duty cycle}$$

$$\text{T1} = 0.5\text{ms}$$

(5 marks)

c)

(i)  $X_{\text{FILT}} = 0 \text{ g} = 2.5\text{V}$

$$Y \text{ acceleration} = g \sin 30^\circ = 0.5 \text{ g}$$

$$\text{Sensitivity} = 312 \text{ mV/g}$$

$$Y_{\text{FILT}} = 2.5 + 0.5 \times 0.312 \text{ V} = 2.656 \text{ V}$$

(5 marks)

(ii)  $X_{\text{OUT}} = 0.05\text{s}$

$$Y \text{ acceleration} = g \sin 30^\circ = 0.5 \text{ g}$$

$$\text{Sensitivity} = 12.5\%/g$$

$$\text{T1}/\text{T2} = 50\% + 0.5 \times 12.5\% = 56.25\% \text{ duty cycle}$$

$$Y_{\text{OUT}} = 0.5625 \times 1\text{ms} = 0.5625\text{ms}$$

(5 marks)

d) Cut-off frequency,  $F_{-3\text{dB}} = 5 \text{ uF} / C_{X,Y}$

$$15 \text{ Hz} = 5\text{uF} / C_{X,Y}$$

$$C_{X,Y} = 5 \text{ uF} / 15 = 0.33 \text{ uF}$$

(5 marks)

## AY1516

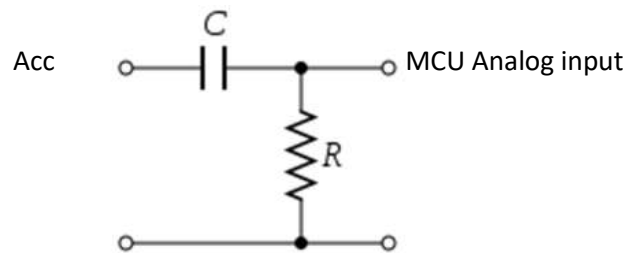
Q1.

- a) Any two of the following 3 reasons:
- Digital-to-Analog conversion
  - To amplify signal (power, current, voltage, etc.)
  - To improve noise immunization

(4 marks)

- b) [1] To differentiate the accelerometer signal of a smart wristband worn by someone walking down a flight of stairs from someone taking an escalator down.

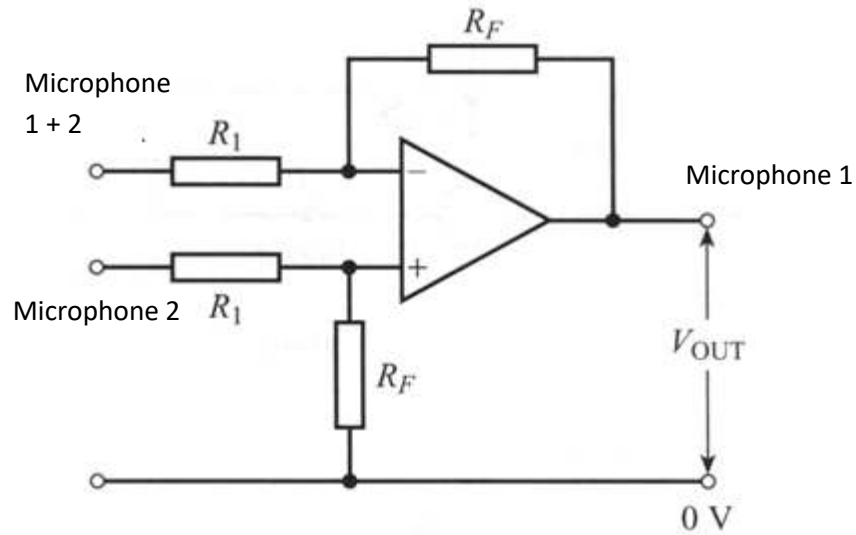
- A high-pass filter
- To filter out the low frequency signal of taking escalator.
- 



(7 marks)

- [2] To eliminate ambient noise detected by a microphone from the music played from a headphone.

- A differential op-amp
- To perform common mode rejection of the ambient noise.
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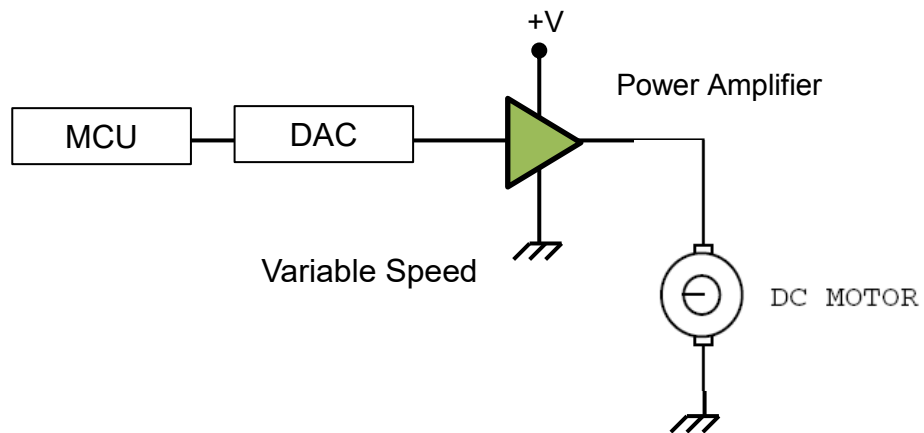
(7 marks)

[3] To control the speed of a conveyor belt driven by a DC motor.

(I) DAC and power amplifier

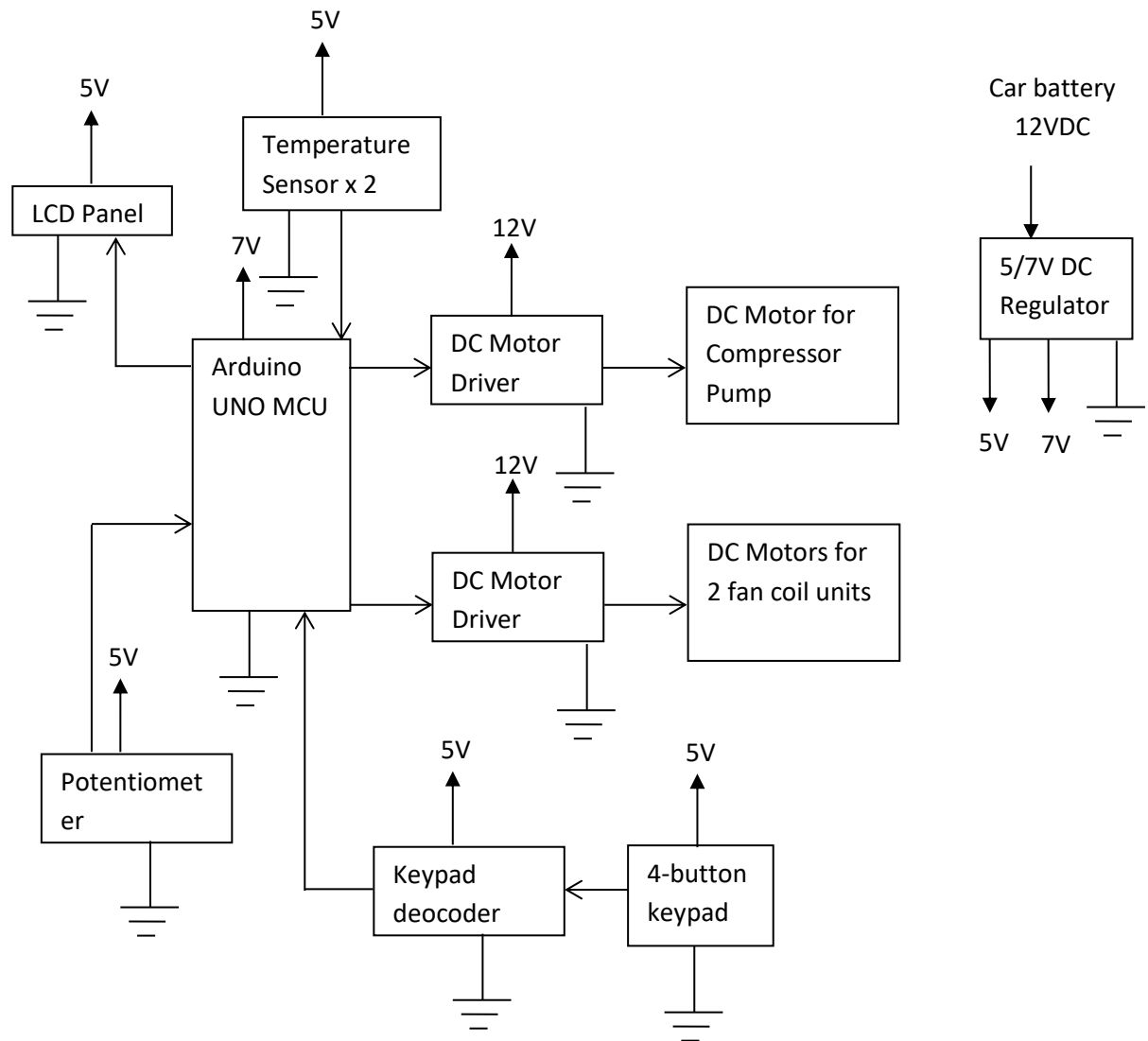
(II) Because output of MCU is digital and output of DAC is usually only up to 5VDC.

(III)



(7 marks)

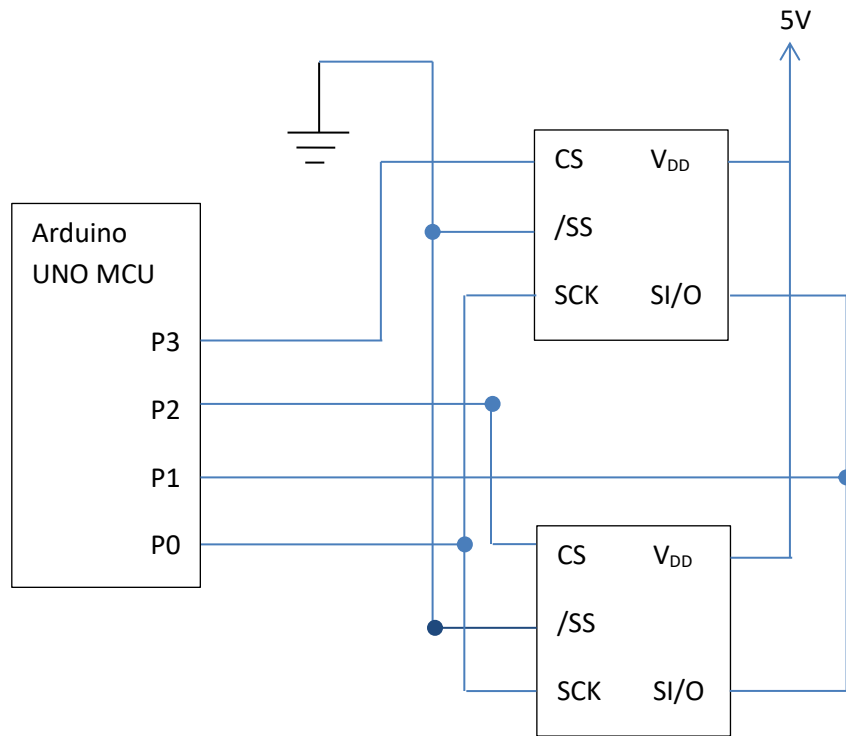
Q3.



(25 marks)



Q4.  
a)



(10 marks)

a) No.

(1 marks)

b) 0.0625 degree per bit

(2 marks)

c) 2 bytes

(2 marks)

d)  $30 \text{ deg}/0.0625 = 480 \text{ bits} = 0 \ 0001 \ 1110 \ 0000$

(4 marks)

e) Continuous Conversion mode is appropriate as there is no power consumption limitation when the car's engine is on.

(3 marks)

f) 0000

(3 marks)

**AY16/17**

**Q2)**

- a) This fluctuation is caused by random or white noise.

(2 mark)

- b) 12 bit is equivalent to  $2^{12} = 4096$  levels

Temperature range =  $90 - 10 = 80^{\circ}\text{C}$

Resolution =  $80 / 4,096 = 0.02^{\circ}\text{C}$

The 5 possible temperatures to be displayed are 29.96, 29.98, 30.00, 30.02 & 30.04.

(9 marks)

- c) Any 3 of the following:

v) Use a lowpass filter

vi) Perform a moving average

vii) Display only 1 decimal point

viii) Update display every minute (or any time period significantly longer than sampling period)

(6 marks)

- d) To use a lowpass filter with a cut-off frequency between 10-40 Hz.

Or to use a bandstop filter centered at 50Hz.

(3 marks)

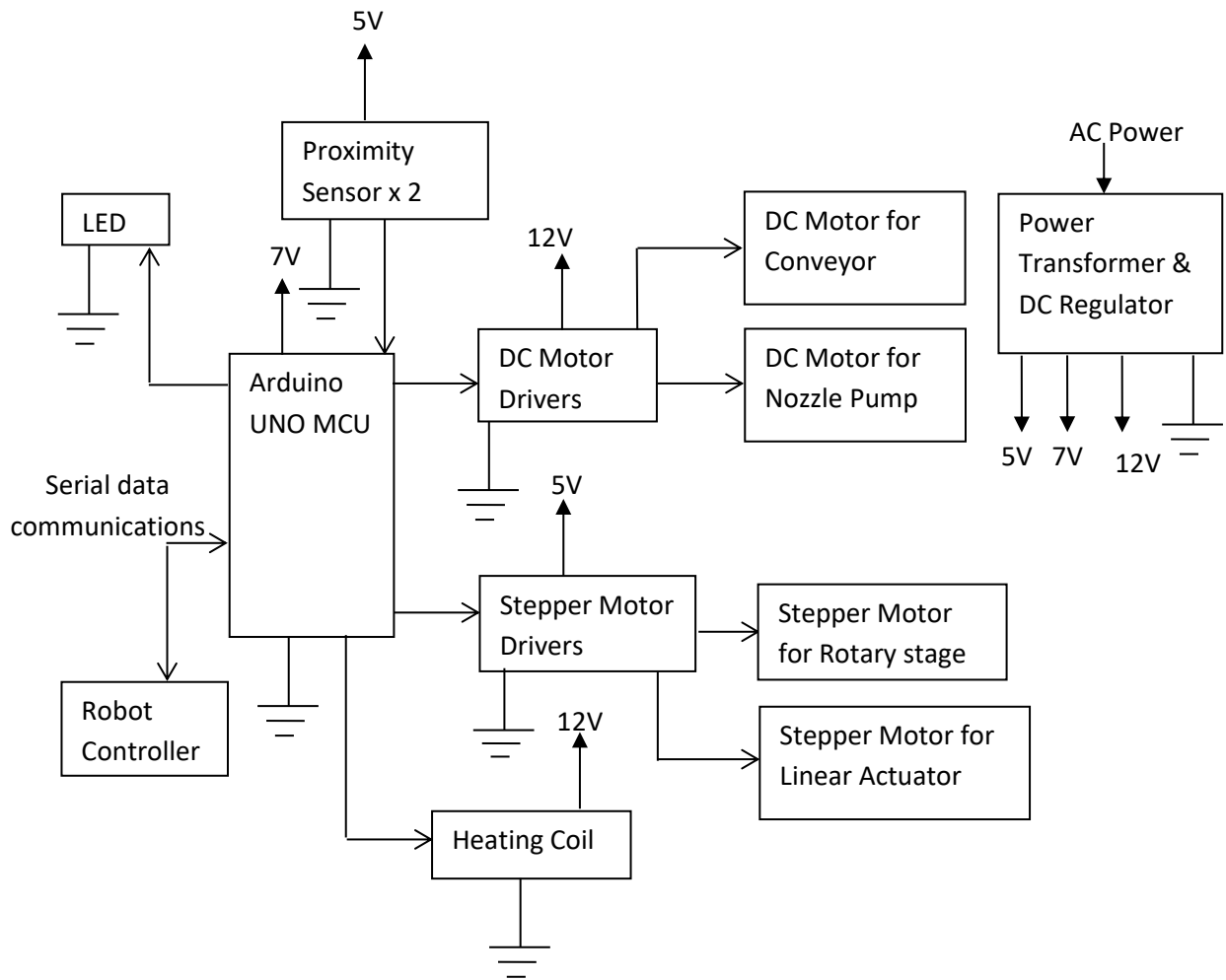
- e) Because the sampling frequency is lower than the Nyquist frequency to sense the 50 Hz powerline hum.

(3 marks)

- f) Yes.

(2 marks)

Q3.



(25 marks)