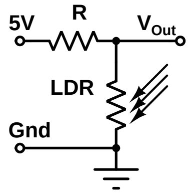
Solution to EE-Quiz 2
MS-101 Makerspace
Spring Semester 2022-23

Answer the following in the space provided with the questions.
Steps for arriving at numerical answers must be shown.
Numerical answers must be accurate to within 0.1%

Q–1 We use a circuit as shown on the right to detect light using a light dependent resistor (LDR). The resistance of LDR in dark is 100 kΩ. Its resistance when exposed to the brightest light to be measured is 5 kΩ.



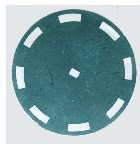
a) What should be the value of the series resistor R such that the output voltage V_{Out} is 2.0 V in dark?

$$V_{out} = 2 = \frac{5}{R + 10^5}\, 10^5 \quad \text{so} \quad \frac{5}{2} = 1 + \frac{R}{10^5}$$

$$\text{Therefore } R = \frac{3}{2}\, 10^5 = 150 \text{ k}\Omega$$

No partial marking. 2 marks for answer (within ±0.1%)	**Answer:** <u>150 kΩ</u>

b) If we use a 25 kΩ resistor for R and a rotating wheel with slots to periodically interrupt the brightest light (for which the LDR resistance is 5 kΩ), what will be the peak to peak voltage at the output (V_{Out})?



In dark, the output is:

$$\frac{5.0}{(25 + 100) \times 10^3} \times 10^5 = \frac{500}{125} = 4 \text{ V}$$

When the LDR is lit, its resistance is 5kΩ. Then the output is:

$$\frac{5.0}{(25 + 5) \times 10^3} \times 5 \times 10^3 = \frac{25}{30} = 0.833 \text{ V}$$

So the peak to peak amplitude is $4.0 - 0.833 = 3.167$ V

Answer: <u>3.167 V</u>

1 mark each for dark and light outputs.
1 mark for method: compute dark, light then diff.
1 mark for V_{p-p} in the range 3.16 to 3.17.
Total 4 marks.

c) The rotating wheel used to chop light has 8 slots with equal spacing as shown in part b) above. If the wheel rotates at a constant speed of 150 revolutions per minute, what will be the time period of the periodic signal observed at V_{Out}?

150 rev. per minute ⇒ 150/60 = 2.5 rev. per second.
⇒ 8 × 2.5 = 20 sectors pass in a second. Hence the time period is 1/20 s = 50 ms.

Method: 2 marks, Result: 1 mark, total 3 marks.	**Answer:** <u>50 ms</u>

Q–2 The voltage output from a sensor ranges between 0 V and 2.0 V. This is to be measured using the in-built 10 bit ADC in Arduino. To maximize resolution of the measurement, we want to use an externally supplied reference voltage of 2.0 V to the ADC.

a) To which pin of Arduino should we connect the reference voltage of 2.0 V?

2 marks for correct answer.

Answer: Aref pin.

b) Which library function should we call and with what argument, so that this reference voltage is used for A to D conversion?

1 mark for function, 1 for argument

Answer: analogReference(EXTERNAL)

c) What precaution should we take while writing a sketch using an external reference voltage?

3 marks. No partial marking.

Answer: The call to analogReference should be made *before* any analogRead call, otherwise the internal and external references will be shorted.

Q–3 We want to construct a toy car controlled by an Arduino board which can carry out the following four commands:

i) **F** (Move Forward), ii) **B** (Move backwards), iii) **R** (Turn right) and iv) **L** (Turn Left).

Rather than using 4 port pins from Arduino, we want to use just two port pins (D2 and D3) and generate the four commands by decoding the outputs using a digital logic circuit.

The commands are encoded as shown below:

D2	D3	Command
0	0	**F**: Forward
0	1	**B**: Backwards
1	0	**R**: Turn Right
1	1	**L**: Turn Left

a) Express each of these commands as a logic function of D2, D3 and their complements.

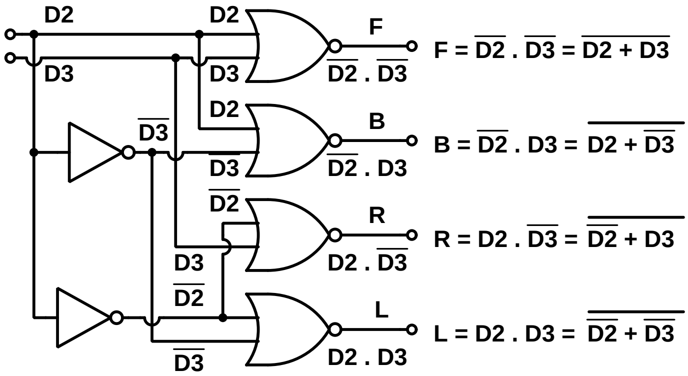
Answer: $\mathbf{F} = \overline{\mathbf{D2}} \cdot \overline{\mathbf{D3}}$, $\mathbf{B} = \overline{\mathbf{D2}} \cdot \mathbf{D3}$, $\mathbf{R} = \mathbf{D2} \cdot \overline{\mathbf{D3}}$, $\mathbf{L} = \mathbf{D2} \cdot \mathbf{D3}$.

$\mathbf{4 \times 0.5 = 2}$**marks**

b) We want to generate the decoded commands **F, B, R** and **L** as positive TRUE signals derived from the digital outputs at pins D2 and D3 using **no more than 2 inverters and four 2-input NOR gates** for decoding all commands.

Provide a logic diagram for decoding the four commands from the two digital inputs (D2 and D3) with this constraint.

Answer:



$\boxed{\mathbf{4 \times 1 = 4\ marks}}$

Q–4 What will be the value returned by the library function "map" if it is called as: **map(95, 50, 1000, 0, 250)**?

($x = 50$) maps to ($y = 0$) and ($x = 1000$) maps to ($y = 250$) in linear mapping as $y = mx + c$. So $m = \Delta y/\Delta x = (250 - 0)/(1000 - 50) = 5/19$ and $c = -250/19$.
Thus, for $x = 95$, $y = 95 * 5/19 - 250/19 = (475 - 250)/19 = 225/19 = 11.8421$.
map function returns only the integer part of the result, so it will return **11**.

Linear mapping: 2 marks, Numerical answer: 2 marks.
1 mark for numerical answer if reported as ≈ 11.84 or 12.

Answer: 11

Q–5 The library function "attachInterrupt( )" is used for setting up interrupts in an Arduino card. Consider a call to this function as:
attachInterrupt(digitalPinToInterrupt(2), handler, CHANGE);

Subsequent to executing this call,

a) What kind of signal will result in an interrupt?

Answer: A signal which goes from 0 to 1 or from 1 to 0.

3 marks, no partial marking.

b) On which pin should this signal occur in order to cause an interrupt?

2marks, no partial marking

Answer: On Digital pin no. 2

c) Which function will be run when an interrupt occurs? Specify its return and argument types.

fn. name: 2, types 2, total 4 marks

Answer: void handler(void);

Q–6 Arduino library provides two functions for measuring pulse width: "pulseIn( )" and "pulseInLong( )".

a) Why should interrupts be disabled for an accurate measurement of pulse width if we use the function "pulseIn( )"?

Answer: "pulseIn" measures the time interval between edges of a pulse using a software loop. The loop will stop incrementing when the interrupt handler runs (if an interrupt occurs while it is counting), so the result will be inaccurate.

No partial marking. 3 marks.

b) Why should interrupts be enabled if we use the function “pulseInLong( )” for pulse width measurement?

Answer: “pulseInLong( )” uses hardware timers with interrupts to make pulse width measurements. Therefore interrupts must be enabled before calling this function.

No partial marking. 3 marks.

Paper Ends

Just for fun:

For an LDR with dark resistance R_D and lit resistance R_L, what value of the series resistor R will maximize the peak to peak output voltage?

$$V_{p-p} = 5.0\left(\frac{R_D}{R+R_D} - \frac{R_L}{R+R_L}\right) = 5.0\left(\frac{R_D(R+R_L) - R_L(R+R_D)}{(R+R_D)(R+R_L)}\right)$$

$$\text{This gives } V_{p-p} = 5(R_D - R_L)\frac{R}{(R+R_D)(R+R_L)}$$

Since R_D and R_L are given constants, V_{p-p} will be maximum when $R/\left((R+R_D)(R+R_L)\right)$ is maximum.

$$\text{Let } y \equiv \frac{R}{((R+R_D)(R+R_L))} \quad \text{then } \ln y = \ln R - \ln(R+R_D) - \ln(R+R_L)$$

Taking derivative with respect to R and setting it to 0 gives

$$\frac{1}{R} = \frac{1}{R+R_D} + \frac{1}{R+R_L} = \frac{2R+R_D+R_L}{(R+R_D)(R+R_L)}$$

Cross multiplication gives

$$2R^2 + R(R_D+R_L) = R^2 + R(R_D+R_L) + R_D R_L \quad \text{Therefore, } R^2 = R_D R_L$$

Thus the optimum value of R is the geometric mean of R_D and R_L.