# Feasibility Report on LED Array Configurations

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ENG 1002 - ENGINEERING DESIGN: CLEANER, SAFER, SMARTER


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## Executive Summary

This report describes the result of the analysis on several light-emitting diodes lighting array configurations and the recommendations made for a new lighting array design. The aim of the report is to design a multipurpose light-emitting diode to be used by the company in developing communities. The analysis of the three configurations was made using Ohm’s Law and simple arithmetic. The result obtained from the analysis was that configuration A was deemed to be unfeasible. Both configurations B and C were deemed to be feasible.

The total cost for small-scale prototyping of configuration B and configuration C would be RM 8.63 and RM 7.29 respectively. For large-scale production of the circuit, configuration B and C would cost RM 5.35 and RM 5.17 respectively assuming that each component is bought at a quantity larger than 1000. Essentially, the proposed design of the light-emitting diodes circuit was based on configuration B as all of the criteria were met without the risk of electrical failure unlike the other configurations analyzed.

The proposed design would consist of 8 light-emitting diodes and 8 resistors accompanied by a 5V voltage source. Each unit of the circuit would cost RM 14.56. If the production of scale is achieved, each unit would cost RM 9.60. The proposed design would be instrumental in delivering low-cost lighting solutions to the community sector.

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## 1. Introduction

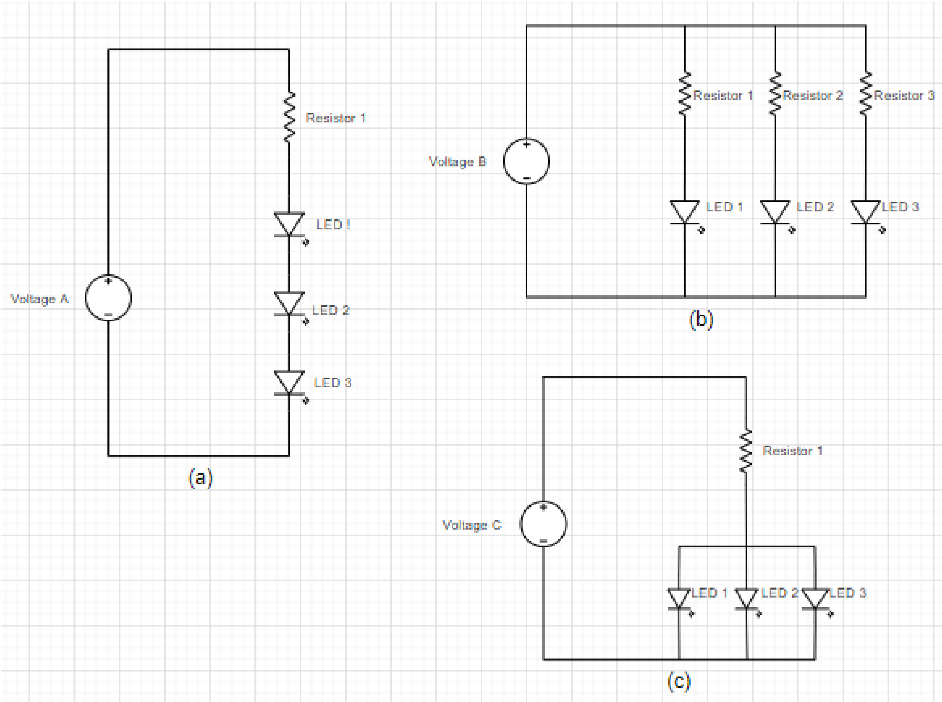


Fig. 2: LED array configurations to be analysed in the report. (a) Configuration A. (b) Configuration B. (C) Configuration C

Low-income families in impoverished communities have historically faced a lack of access to light. As a team of graduate engineers at “LED There Be Light Pty Ltd", our team has been tasked to solve this problem by utilizing our knowledge in electrical engineering and circuitry tinkering to develop sustainable and low-cost lighting for the community. The feasibility report will focus on developing communities by conducting analyses on several LED lighting array configurations, determining the suitable configuration to be implemented in the proposed design and designing a multipurpose light-emitting-diode (LED) array to be used by the company in a variety of projects. The aim of this report is to design a circuit that requires minimal cost in order to deliver low-cost lighting solutions to the community sector.

## 2. Discussions on LED array configurations

2.1. Assumptions Made :

- The source voltage (Vs) is 5V.
- The values of the resistors in the design comes from the E12 range of values
- The resistors of different resistance values have the same cost.
- The turn-on voltage(Vd, on) for LEDs is 2V and operates best when Id is 18mA.
- The margin of error for the LEDs is none existent.
- If the current through a LED exceeds 20mA, the LED has a 50% chance of electrical failure.
- If power absorbed by a resistor exceeds 250mW, the resistor has a 20% chance of failure.
- Power will not be lost by any external factors and the efficiency of power transfer to the LEDs is assumed to be 100%.
- The “failure” of a component leads to it becoming an open circuit.
- The LEDs are all the same which is the white LED.
- The cost of the wire is deemed to be redundant (RM 0.04) [3]

2.2. Configuration A

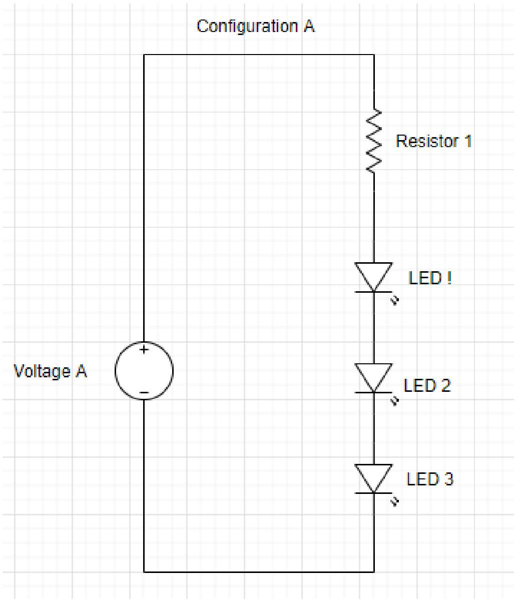


Fig. 2: Configuration A

In configuration A, a resistor and three LEDs are connected in series as shown in the figure above. The current will be the same throughout a series circuit, however, to calculate the voltage, we must add all the voltages of the elements. The turn-on voltage of the LED is 2V, however, there are 3 LEDs in the circuit which equals 6V. This exceeds the source voltage of 5V, therefore, making the current a negative value due to the negative voltage of the resistor and as a result, has a negative power consumption of the LEDs. Hence, the circuit will still not be feasible and robust with any value of the resistor used. For this circuit to be feasible, we would need to increase the source voltage or reduce the number of LEDs used. The calculation working is shown in the appendix.

2.3. Configuration B

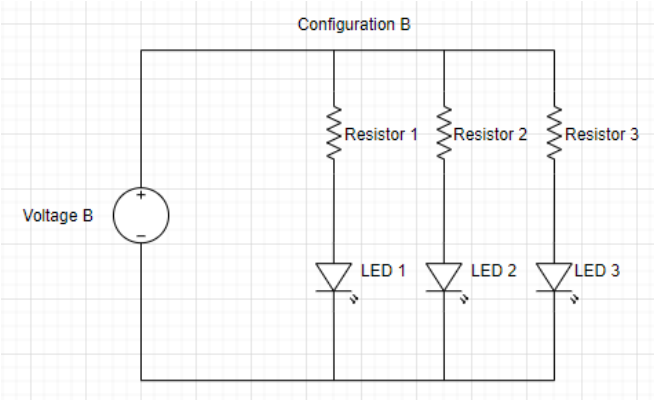


Fig. 3 Configuration B

In configuration B, three resistors together with three LEDs are connected in parallel, with each resistor connected in series with each LED. The three resistors have the same value of resistance. In a parallel circuit, the voltage drop across each branch would be the same but the total current would be equal to the sum of the three branches, each containing a resistor and a LED. By analyzing one of the branches, the voltage drop across the LED is 2V which is less than the source voltage (5V). In this configuration, the LED will light up indefinitely. The resistor will provide a safe forward current as not to damage the LED as the excessive current will cause excessive heating.

The value of the resistor can be estimated using Ohm's Law which is given by equation (1)

$$V = IR \tag{1}$$

As the result of the calculation, the resistor value would be 180 Ohm based on the "E12" range of resistor values and the total LED output electrical power would be 0.10 W in this circuit.

The power consumption of each of the resistor could be estimated by using equation (2)

$$P_R = \quad V_R^2/R \tag{2}$$

The calculation process is shown in the appendix.

The power consumption of the resistor $P_{R_B}$ is about 50mW which is smaller than the maximum power absorption of the resistor. Thus, configuration B is a feasible and robust circuit, in which all criteria are met with minimal risk of electrical failure.

2.4. Configuration C

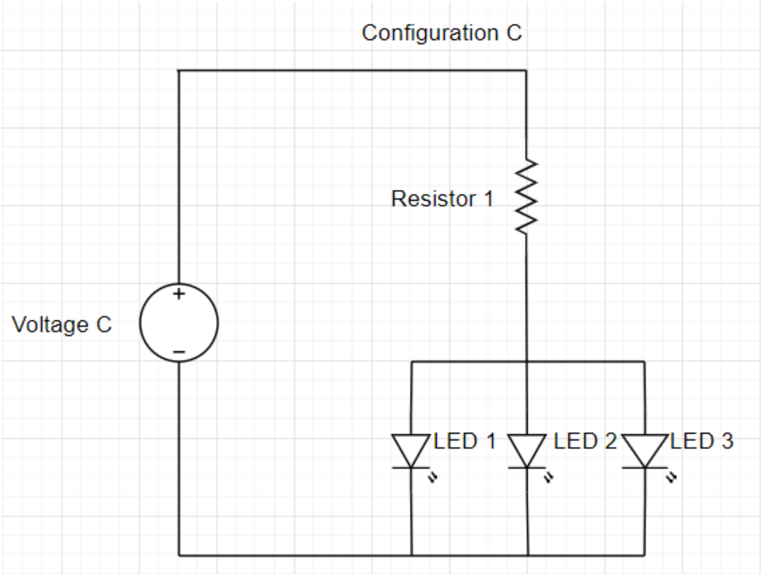


Fig.4: Configuration C

In configuration C, there are three LEDs in parallel and one resistor connected in series with the LEDs as shown in the figure above. The value of the voltage drop across the three LEDs is taken from the assumption which is 2V and the total current would be the sum of the current from each of the branches. The 5V source voltage is greater than the turn-on voltage of the LEDs. As the result of the calculation, the resistor value would be 56 Ohm based on the "E12" range of resistor values and the total LED output electrical power would be 0.12 W in this circuit. The calculation process is shown in the appendix.

If the resistor absorbs more than 250mW, the resistor will have a 20% chance of failure. The power consumption of the resistor $P_{R_c}$ is about 160.71mW smaller than the maximum power absorption of the resistor. Thus, configuration C is a feasible and robust circuit, in which all criteria are met with minimal risk of electrical failure.

2.5. Summary

Table I: Results Of Analysis

| LED Configuration | | A | B | C |
|---|---|---|---|---|
| Does it work? | | No. This configuration does not work. | Yes. This configuration works. | Yes. This configuration works. |
| Chosen resistor value (Ω) | | None | 180.00 | 56.00 |
| Power consumption of | each resistor (mW) | None | 50.00 | 160.71 |
| | each LED (mW) | None | 36.00 | 36.00 |
| | the entire array (mW) | None | 258.00 | 268.71 |
| Cost of | small scale/prototyping (RM) | 7.21 | 8.63 | 7.29 |
| | large scale/production (RM) | 5.17 | 5.35 | 5.17 |
| Robustness | | This configuration is not a robust circuit | This configuration is a robust circuit. | This configuration may not be as robust as configuration B. |

2.6. Proposed Design

Based on the analysis of the previous configurations, configuration B would be our team's choice for a feasible circuit. The LEDs are all connected in the parallel circuit with a resistor connected in series in each branch. The performance of a LED will not be affected by other LEDs. It means that even if one of the LEDs is broken or could not work properly, the rest of the LEDs are still able to perform normally. As a result, the risk of electrical failure will be minimized in this configuration. A 5.0 V source voltage supply has been used in the designed array as stated in the assumption in section 2.1. In our proposed design, the resistor value with the E12 value would be 180 Ohms. By using the resistor with 180 Ohms of E12 value, the current generated for each branch of the circuit is about 16.67 mA which is closer to the ideal current as mentioned in the assumption in section 2.1. As a result, the LED output electrical power would be 0.03 mW. Based on the requirement of 0.24 W as the minimum of total LED output electrical power, the array design should add 5 more LEDs which are all connected in parallel. According to the diagram of the designed circuit in figure(1), the current in each branch of the circuit will produce about 33.34mW for each of the LEDs. As a result,  the total LED output electrical power would be 0.27W which is larger than 0.24W. The limitations of this proposed design would be that the design requires the use of large quantities of wires and the power dissipated by each resistor would be higher. The calculation process is shown in the appendix.

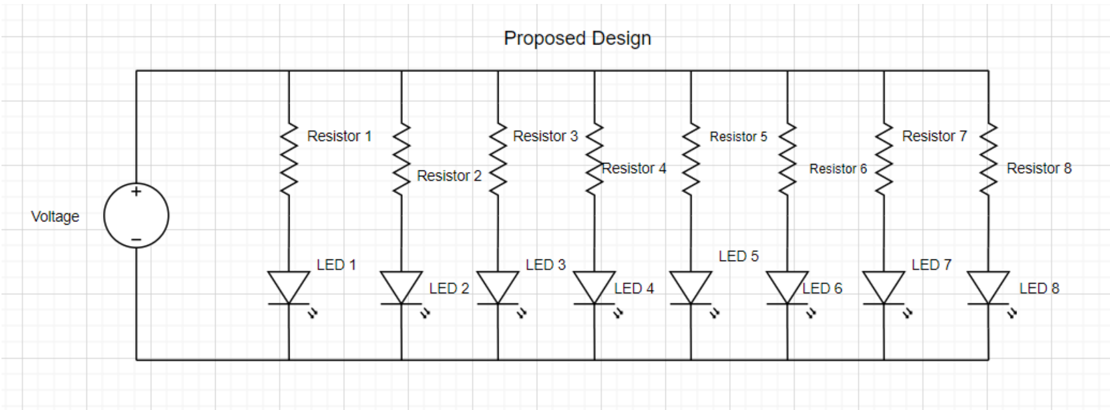


Fig. 5: Proposed Configuration

Table II: Summary of the Proposed Design

| Chosen Resistor Value (Ω) | Power Consumptions of | | | Small Scale/ Prototyping (RM) | Large Scale/ Prototyping (RM) |
|---|---|---|---|---|---|
| | Each resistor (mW) | Each LED (mW) | The entire array (W) | | |
| 180.00 | 50.00 | 33.34 | 0.42 | 14.56 | 9.60 |

## 3. Conclusion

In conclusion, configuration B is the most feasible and robust configuration to be used in the proposed design. The proposed design that consists of multiple resistors in parallel and LEDs which are in series with the resistors (configuration B) would achieve the aim of the feasibility report as the proposed design is more economical compared to other forms of lighting currently in use. The limitations of this proposed design would be that the design requires the use of large quantities of wires. The power dissipated by each resistor would also be higher. Overall, the sustainable and low-cost multipurpose LED designed by our team is suitable and affordable for low-income families.

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## 5 .Appendices

### Appendix A: Calculation

### Calculation of the Configuration A

The voltage of the resistor is calculated as follows

$$V_{RB} = 5 - (2 \times 3)$$

$$V_{RB} = 5 - 6$$

$$V_{RB} = -1V$$

The circuit is not feasible with any value of the resistor used because of the negative voltage value of the resistor.

### Calculation of the Configuration B

The voltage of the resistor divided in the branch

$$V_{RB} = 5 - 2$$

$$V_{RB} = 3V$$

The ideal power consumption of the LED can be calculated by using equation (2).

$$P = VI \tag{2}$$

$$P = \frac{V^2}{R}$$

where:

P = Power,

V = Voltage ,

I = Current

$$P_{LED} = V_{LED} \times I_{Ideal}$$

$$P_{LED} = (5 - 3) \times 18 \times 10^{-3}$$

$$P_{LED} = 0.036W$$

Power consumption of the resistor in ideal value can be calculated by using equation (2)

$$P_{R_B} = V_{RB} \times I_{Ideal}$$

$$P_{R_B} = 3 \times 18 \times 10^{-3}$$

$$P_{R_B} = 0.054W$$

$$P_{R_B} = 54mW$$

The value of the resistor can be estimated using Ohm's Law which is given by equation (1)

$$V = IR \tag{1}$$

where:

V = Voltage ,

I = Current ,

R = Resistance

$$R_B = V_{RB} \div I_{Ideal}$$

$$R_B = 3 \div (18 \times 10^{-3})$$

$$R_B = 166.67\Omega$$

From the "E12" range of resistor values, 180 Ohms is the closest value obtainable and the current made in the assumption with 180 Ohms can be determined using Ohm's Law which is given by the equation (2)

$$I \quad = V_{R_B} \div R_B$$

$$I \quad = 3 \div 180$$

$$I \quad = 16.67mA$$

The power consumption of the resistor can then be calculated using equation (2)

$$P_{RB} = V_{RB}^2 \div R_B$$

$$P_{RB} = 3^2 \div 180$$

$$P_{RB} = 50mW$$

The LED output electrical power could be calculated using Ohm's Law which is given by equation (1)

$$P_{LED} = V_{LED} \times I$$

$$P_{LED} = 2 \times 16.67 \times 10^{-3}$$

$$P_{LED} = 33.34mW$$

Hence the total LED output electrical power can be estimated.

$$P_{LED} \times 3$$

$$= 33.34 \times 10^{-3} \times 3$$

$$= 0.10W$$

**Calculation of the Configuration C**

As the voltage across the LEDs in parallel is the same, the voltage absorbed by the resistor will be 3V.

$$V_{R_C} = 5 - 2$$

$$V_{R_C} = 3V$$

Since the ideal current for each of the LEDs is 18mA, each of the branches will have 18mA. There are a total of 3 branches in the circuit, which equates to 54mA.

$$I_{Total} = 3 \times 18 \times 10^{-3}$$

$$I_{Total} = 54mA$$

By applying the assumption that each of the LEDs will operate the best at 18mA and Ohm's law which is given by equation (1). The ideal value of Rc can be calculated.

$$R_c = V_{R_c} \div I_{Total}$$

$$R_c = 3 \div (54 \times 10^{-3})$$

$$R_c = 55.56\Omega$$

From the “E12” range of resistor values, 56 Ohms is the closest value obtainable.

The current made in the assumption with 180 Ohms can be determined using Ohm’s Law which is given by the equation (1)

$$I \quad = V_{R_B} \div R_B$$

$$I \quad = 3 \div 56$$

$$I \quad = 53.57mA$$

The current made on the circuit of each LED

$$I \div 3$$

$$= (53.57 \times 10^{-3}) \div 3$$

$$= 17.86mA$$

The power consumption of the resistor can then be calculated using equation (2)

$$P_{R_C} = V_{R_C}^2 \div R_C$$

$$P_{R_C} = 3^2 \div 56$$

$$P_{R_C} = 160.71mW$$

The LED output electrical power could be calculated by using equation (2)

$$P_{LED} = V_{LED} \times I$$

$$P_{LED} = 2 \times 17.86 \times 10^{-3}$$

$$P_{LED} = 35.75mW$$

The total LED output electrical power

$$P_{LED} \times 3$$

$$= 35.75 \times 10^{-3} \times 3$$

$$= 0.12mW$$

**Calculation of the Proposed Design**

The resistor values in each branch of the circuit are designed to be 180 Ohm.

The voltage of the LEDs is designed to be 2V.

The voltage of the resistor divided in the branch

$$V_R = 5 - 2$$

$$V_R = 3V$$

The power consumption of each of the resistor could be estimated by using equation (2)

$$P_R = V_R^2/R$$

$$P_R = 3^2/180$$

$$P_R = 50mW$$

The current for each branch of the circuit would be calculated using Ohm's Law

which is given by the equation (1)

$$I = V_{RB}/R$$

$$I = 3/180$$

$$I = 16.67mA$$

The power consumption of each LED in the circuit could be determined by using the equation (2)

$$P_{LED} = V_{LED} \times I$$

$$P_{LED} = 2 \times 16.67$$

$$P_{LED} = 33.34mW$$

The total LED output electrical power would be 8 times the power for one branch of the circuit.

$$P_{LED_s} = 33.34m \times 8$$

$$P_{LED_s} = 33.34m \times 8$$

$$P_{LED_s} \approx 0.27W$$

**Appendix B: Cost**

Configuration A (Small Scale Prototyping)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM3.50 | [5] |
| 1 resistor | RM0.71 | [1] |
| 3 LEDs | RM1 * 3 = RM3 | [2] |
| Total Cost | RM 7.21 | - |

Configuration A (Large Scale Prototyping)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM2.80 | [5] (50 + Quantity) |
| 3 resistor | RM0.09 | [6] |
| 3 LEDs | RM0.76 * 3 = RM2.28 | [2] |
| Total Cost | RM 5.17 | - |

Configuration B (Small Scale Prototyping)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM3.50 | [5] |
| 3 resistor | RM0.71 * 3 = RM2.13 | [1] |
| 3 LEDs | RM1 * 3 = RM3 | [2] |
| Total Cost | RM 8.63 | - |

Configuration B (Large Scale Prototyping)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM2.80 | [5] (50 + Quantity) |
| 3 resistor | RM0.09 * 3 = RM0.27 | [6] |
| 3 LEDs | RM0.76 * 3 = RM2.28 | [2] |
| Total Cost | RM 5.35 | - |

Configuration C  (Small Scale Prototyping)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM3.50 | [5] |
| 1 resistor | RM0.79 | [1] |
| 3 LEDs | RM1*3 = RM 3 | [2] |

| | | |
|---|---|---|
| Total | RM 7.29 | - |

Configuration C (Large Scale Prototype)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM2.80 | [5] (50 + Quantity) |
| 1 resistor | RM0.09 | [6] |
| 3 LEDs | RM0.76 * 3 = RM2.28 | [2] (1000+ Quantity) |
| Total | RM 5.17 | - |

Proposed Design Cost (Small Scale Prototype)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM2.80 | [5] (50 + Quantity) |
| 1 resistor | RM0.71 * 8 = RM 5.68 | [6] |
| 3 LEDs | RM0.76 * 8 = RM 6.08 | [2] (1000+ Quantity) |
| Total | RM 14.56 | - |

Proposed Design Cost (Large Scale Prototype)

| Name of components | Cost (MYR) | Source |
|---|---|---|
| 1 Power supply (5V) | RM2.80 | [5] (50 + Quantity) |
| 1 resistor | RM0.09 * 8 = RM 0.72 | [6] |

| | | |
|---|---|---|
| 3 LEDs | RM0.76 * 8 = RM 6.08 | [2] (1000+ Quantity) |
| Total | RM 9.60 | - |