MECH 345

MODERN INSTRUMENTATION AND EXPERIMENTATION

DESIGN OF EXPERIMENT

LAB REPORT #2

- **Saravana Kumar Phillip Nagarajan**

1. Factorial design:

The experiment which allows the investigator to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable, is known as factorial design of experiment.

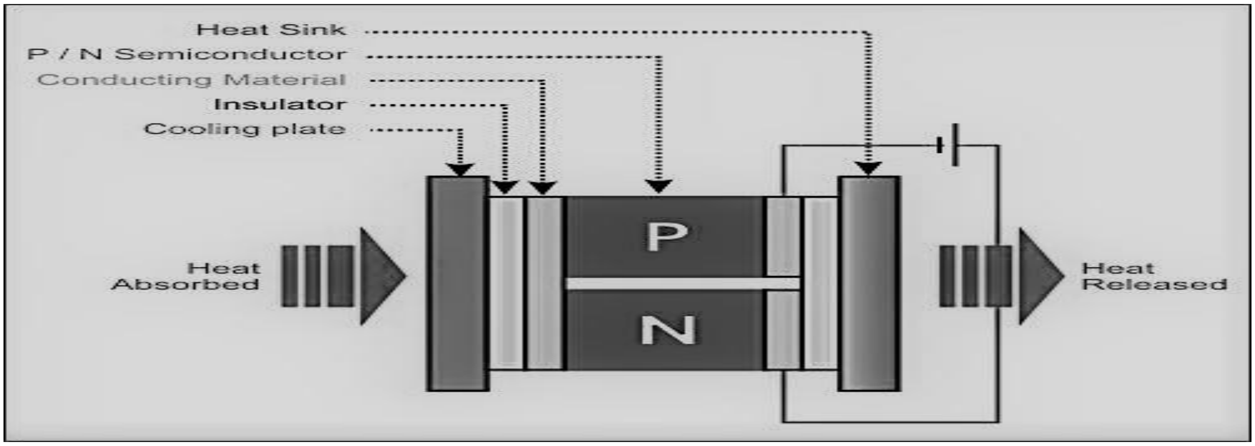
Factorial designs allow the effects of a factor to be estimated at several levels of the other factors, yielding conclusions that are valid over a range of experimental conditions.

Table 1- Types of modules & High and Low values of the variables

Test Number	Variable A	Variable B	Variable C	(Variable A) x (Variable B)
1.	**-1**	**-1**	**-1**	**1**
2.	-1	-1	1	1
3	**-1**	**1**	**1**	**-1**
4.	-1	1	-1	-1
5.	**1**	**1**	**-1**	**1**
6.	1	-1	-1	-1
7.	1	1	1	1
8.	**1**	**-1**	**1**	**-1**

1.1 Peltier effect and setup:

The Peltier effect is the phenomenon that a potential difference applied across a thermocouple causes a temperature difference between the junctions of the different materials in the thermocouple.



2. **Fractional factorial design:**

Fractional factorial designs are experimental designs consisting of a carefully chosen subset (fraction) of the experimental runs of a full factorial design.

Thus, from the factorial design table the test number 1, 3, 5, and 8 has been chosen to carry out the test. Only these four test has been selected, because when comparing the variable C and variable A x variable B, we have to select the test numbers of either the same sign or opposite sign. In this case, we have selected the opposite signs when comparing.

2.1 Summary:

- Factorial design ------ Fractional Factorial design

  (8 experiment)   (4 experiment)(test number 1, 3, 5, and 8)

- We named two peltier module as Alpha and Bravo.

  [Peltier module 1 - Alpha - Test #1,3]

  [Peltier module 2 - Bravo - Test #5,8]

Test Number	Type of Peltier module (A)	Current value (B)	Fan voltage (C)
1	Alpha	1 A	7 V
3	Alpha	2 A	10 V
5	Bravo	2 A	7 V
8	Bravo	1 A	10 V

Table 2: The four test that needs to be performed

3. Procedure of the experiment:

- The DC fan must be connected to BK Precision DC Power supply, and the Peltier module should be connected to one of the Agilent power supplies.
- A Peltier module is sandwiched between two aluminium blocks, which can be disassembled to insert thermocouples.

3.1 For Peltier module 1:

- The cold side is placed on one side (top) and the hot side is placed on other side (bottom), as there is heat sink and fan are present at the bottom. This setup is carried out for first two tests.

- Set the current value and fan voltage in the DC supply.
- For the first test, Current value = 1 A

  Fan voltage = 7 V
- For the second test, Current value = 2 A

  Fan voltage = 10 V
- After thermal equilibrium is attained, the total power is obtained by the summation of fan power and cooler power that obtained in the graph.

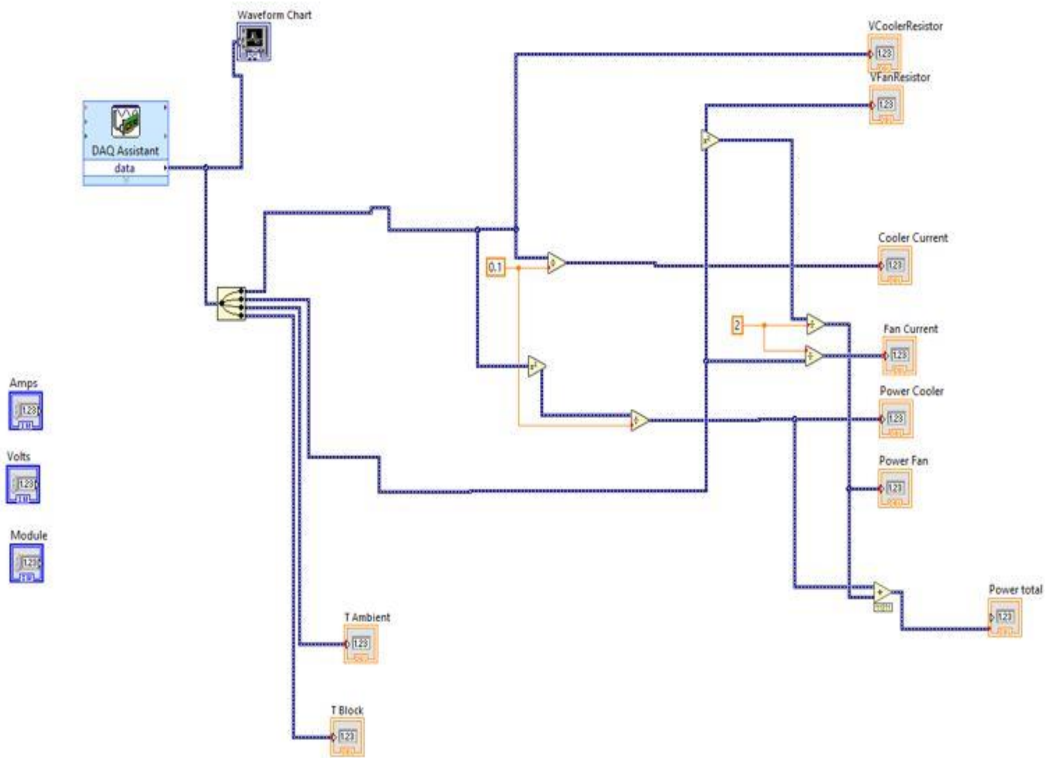
3.2 For Peltier module 2:

- Here, the peltier module is placed in opposite way i.e. now the cold side is placed at the bottom and the hot side is placed at the top.
- Set the current value and fan voltage in the DC supply.
- For the first test, Current value = 2 A

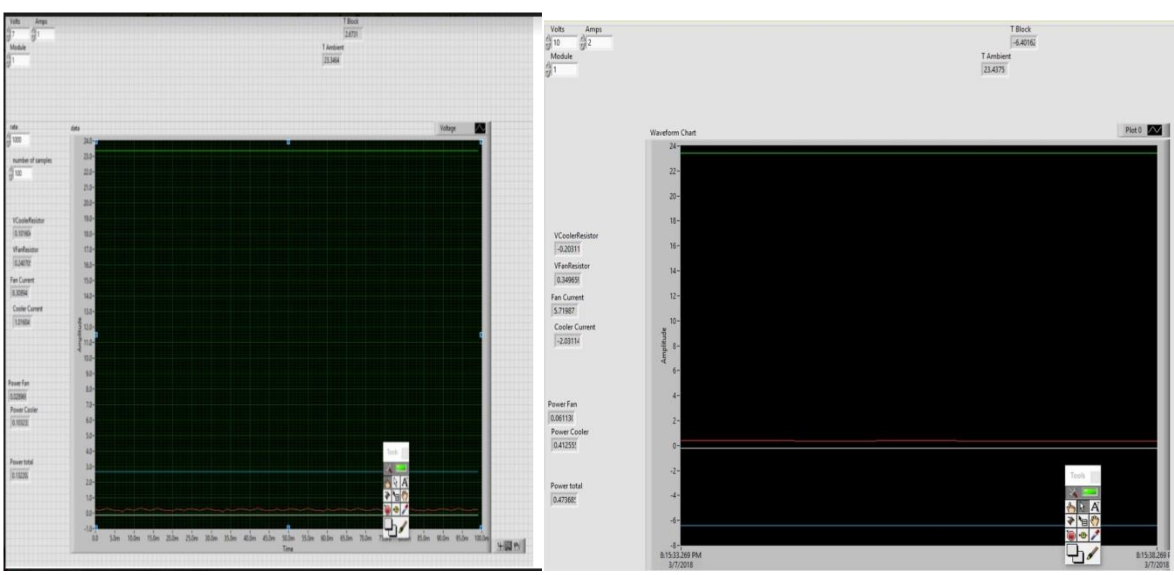
  Fan voltage = 7 V
- For the second test, Current value = 1 A

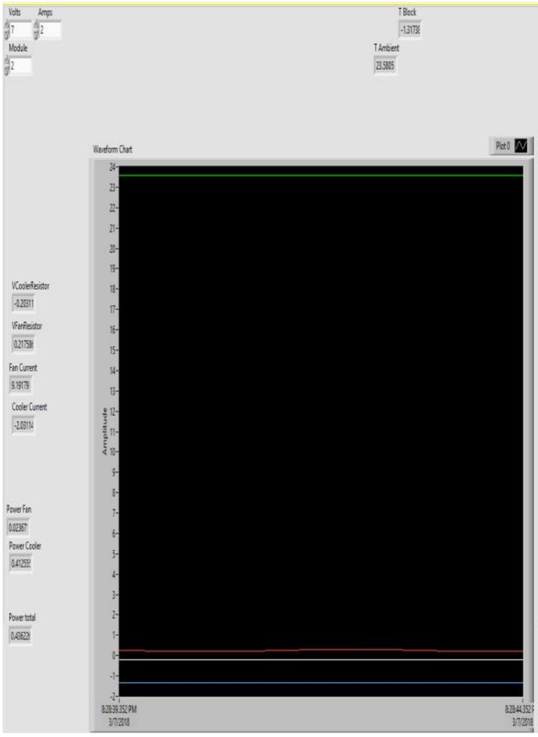
  Fan voltage = 10 V
- After thermal equilibrium is attained, the total power is obtained by the summation of fan power and cooler power that obtained in the graph.

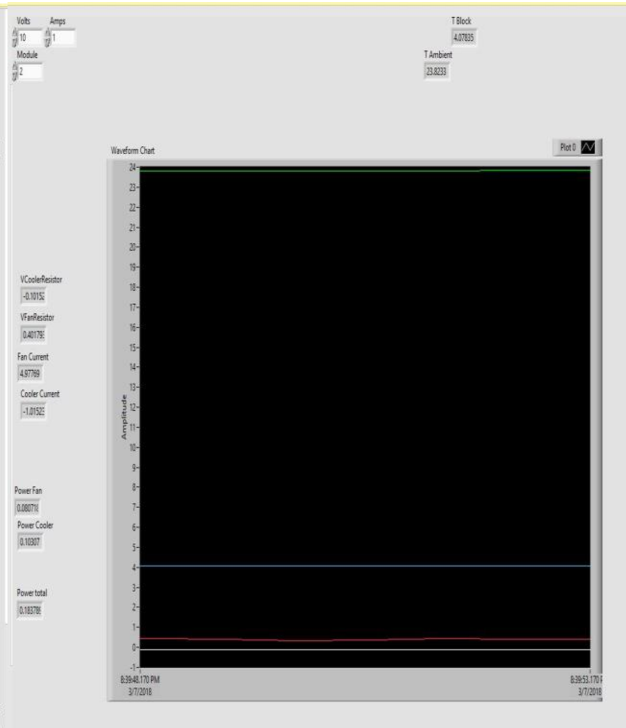
4. LabView circuit:



5. Waveform graph generated:







6. **Equation to estimate power consumption and temperature:**

$$y_{power} = y_0 + y_A x_{Module} + y_B x_{Current} + y_C x_{Voltage.fan}$$
$$z_{Temperature} = z_0 + z_A x_{Module} + z_B x_{Current} + z_C x_{Voltage.fan}$$

6.1 For Power consumption,

$\mathbf{Y_{P1} = Y_0 + Y_A (-1) + Y_B(-1) + Y_C(-1)}$

$\mathbf{Y_{P2} = Y_0 + Y_A (-1) + Y_B(1) + Y_C(1)}$

$\mathbf{Y_{P3} = Y_0 + Y_A (1) + Y_B(1) + Y_C(-1)}$

$\mathbf{Y_{P4} = Y_0 + Y_A (1) + Y_B(-1) + Y_C(1)}$

$$\begin{bmatrix} Y_{P1} \\ Y_{P2} \\ Y_{P3} \\ Y_{P4} \end{bmatrix} = \begin{bmatrix} 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix} \begin{bmatrix} Y_0 \\ Y_A \\ Y_B \\ Y_C \end{bmatrix}$$

$$\begin{bmatrix} 0.13 \\ 0.47 \\ 0.44 \\ 0.18 \end{bmatrix} = \begin{bmatrix} 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix} \begin{bmatrix} Y_0 \\ Y_A \\ Y_B \\ Y_C \end{bmatrix}$$

$$\begin{bmatrix} Y_0 \\ Y_A \\ Y_B \\ Y_C \end{bmatrix} = \begin{bmatrix} 2.67 \\ -6.40 \\ -1.32 \\ 4.07 \end{bmatrix}$$

6.2) For temperature,

$$Z_{T1} = Z_0 + Z_A\,(-1) + Z_B\,(-1) + Z_C\,(-1)$$

$$Z_{T2} = Z_0 + Z_A\,(-1) + Z_B\,(1) + Z_C\,(1)$$

$$Z_{T3} = Z_0 + Z_A\,(1) + Z_B\,(1) + Z_C\,(-1)$$

$$Z_{T4} = Z_0 + Z_A\,(1) + Z_B\,(-1) + Z_C\,(1)$$

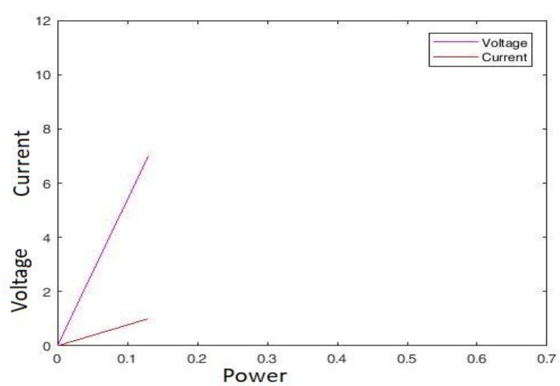
$$\begin{bmatrix} Z_{T1} \\ Z_{T2} \\ Z_{T3} \\ Z_{T4} \end{bmatrix} = \begin{bmatrix} 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix} \begin{bmatrix} Z_A \\ Z_B \\ Z_C \\ Z_D \end{bmatrix}$$

$$\begin{bmatrix} 0.305 \\ 0.005 \\ 0.150 \\ 0.199 \end{bmatrix} = \begin{bmatrix} 1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix} \begin{bmatrix} Z_A \\ Z_B \\ Z_C \\ Z_D \end{bmatrix}$$

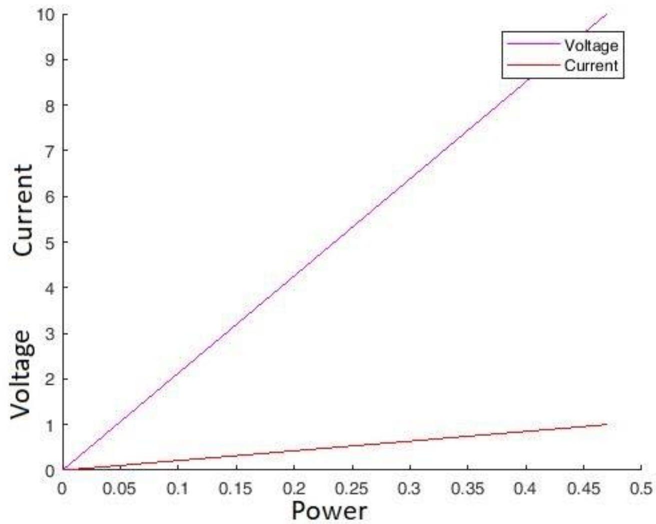
$$\begin{bmatrix} Z_A \\ Z_B \\ Z_C \\ Z_D \end{bmatrix} = \begin{bmatrix} -0.245 \\ 1.620 \\ -3.615 \\ -0.919 \end{bmatrix}$$

7. **Graph: Power vs Current and Voltage fan**

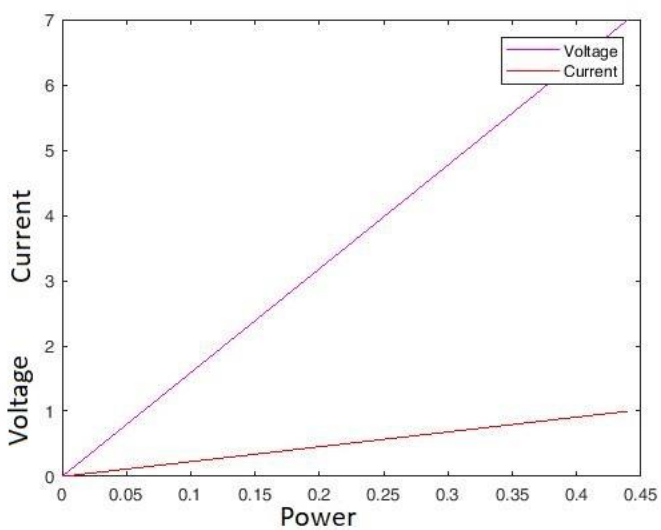
Test 1:



Test 2:


Voltage
Current
Voltage Current
Power
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
1
2
3
4
5
6
7
8
9
10

Test 3:


Voltage
Current
Voltage Current
Power
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0
1
2
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4
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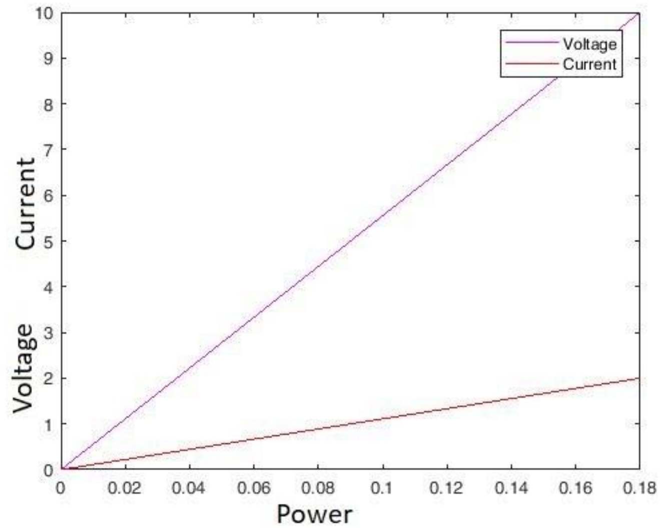
6
7

Test 4:



7.1 Summary:

Test Number	Type of Peltier module (A)	Current value (B)	Fan voltage (C)	Power (W)	Temperature (°C)
1	Alpha	1 A	7 V	0.13	2.67
3	Alpha	2 A	10 V	0.47	-6.40
5	Bravo	2 A	7 V	0.44	-1.32
8	Bravo	1 A	10 V	0.18	4.07

Conclusion:

Based on the results obtained, the **test number 1** is the best estimate of the module which has lower power consumption, while the temperature is less than 5°C. Because while comparing power consumption of all the 4 test, Test number #1 has the lower power consumption 0.13 W where the corresponding temperature is 2.67°C (<5°C). So, the test number 1 is the best solution to perform.