

The Teach Brunel Project: Learning electronics with the use of MATLAB®

Nadarajah Manivannan¹, Mina Nasiri² and Numan Celik³

Design¹ / Mechanical Engineering² / Electrical and Electronic Engineering Department³

INTRODUCTION

Brunel BA design undergraduate students do not necessarily have electronics/physics/mathematics background, though they will benefit from electronics knowledge they gain from the electronics module they are taught in early years of their course. Learning electronics in a conventional method can be ineffective due to the contents of mathematics or theory of physics/electronics and can lead to poor performance and frustration among the students. MATLAB® is a software, which has evolved over the years and becomes one of the best software for engineering/mathematics applications due to its excellent user-friendliness and simple and reliable built-in functions and routines [1-2].

MATLAB® is relatively inexpensive and widely available across the Universities and other educational institutions. Introducing MATLAB® to BA design students to learn electronics will definitely make the learning experience effective as well as enjoyable. The successful learning of electronics gives great confidence to the learners and can carry forward into their further education or employment [3]. It is very evident from literature that MATLAB® has been heavily used in teaching for many engineering disciplines. Ibrahim has looked into various simulation environments (MATLAB®) in engineering education as a virtual engineering laboratories [4]. In particular, the use of the MATLAB® in engineering education was presented using an important experiment taken from the field of electrical and electronic engineering. The worked shown that how a tuned resistor-inductor-capacitor (RLC) circuit can easily be modelled and simulated using the MATLAB® engineering simulation and analysis package, without having to use real expensive RLC components, oscilloscopes, and power supplies [4]. Another work published by Fauda et al., MATLAB® was used to analyse a square wave generator based on Operational amplifier [5]. They concluded that MATLAB® helped them logical thinking in solving matrix operations and numerical analysis [5]. Song et al. used MATLAB® based exercising for assessing an electronic engineering course for active concept learning [6] and they claimed that their work was the first detailed investigation of an online course using MATLAB®. It is very clear from literature that using MATLAB® in teaching electronics for BA design students in Brunel have a number of direct advantages explained by the authors [4-6]; user-

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friendliness, solving mathematical equations, e-learning and assessing and in-direct benefits such as enhanced learning experience, confidence building and added skill set.

This paper describes the project, which was aimed at investigating the effectiveness of the MATLAB®-based electronic learning as a part of BA Design course; the project was funded by TeachBrunel initiative of Brunel University. An electronic problem was developed with a team of academics, graduate teaching assistants (GTAs) and student partners and evaluated by a group of six volunteers from first year design BA cohort with mixed ability. Finally, a feedback was obtained from the volunteers through a set of questions discussed in this paper.

The objective of the project was to understand the impact of using MATLAB® in teaching electronics to BA design students in terms of leaning experience, confidence building in electronics learning and successful learning.

The success of the project can lead to the real implementation of MATLAB®-based electronics teaching to BA Design students. This would result in producing design graduates with an excellent electronic background and hence increase the employability of the Brunel graduates.

One electronic problem with MATLAB® was developed and assigned to a group of six volunteer students to solve problems with and without the use of MATLAB®; the volunteer students were also asked to give feedback in terms of easiness and learning experience. Finally, the students' feedback was analysed and a number of key findings were established.

The paper is structured in the following way. Section 2 describes the project in details and the methodology adapted in the implementation of the project is presented in Section 3. Results and Discussion is given in section 4. Finally, conclusions are drawn in Section 5. A number of supplementary materials are given in a number of appendices to support the main paper.

THE PROJECT DETAILS

It was intended to include students' participation in order to improve the project objectives. There were two categories of student participation.

- (1) Student partners: Two final year BA students were recruited to support in the development of the MATLAB® based electronics problem (MEP), solution and evaluation criteria and also to assist the evaluation sessions.

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(2) Students for evaluating the electronic problem: Six BA first year students were recruited on a volunteer basis to participate in the evaluation of the MEP and to provide their feedback on various aspects related to MEP.

PROJECT STAGES

There were a number of different stages identified and successfully implemented throughout the project:

Stage 1: Recruitment of GTAs - Two GTAs (Graduate Teaching Assistants, who were PhD students and have completed Apex 1) were employed on part-time basis to support the investigators in the development of the MATLAB® based electronics problems (MEP), solution and evaluation criteria. The recruited GTAs were Numan Celik (a final year PhD student from ECE) and Mina Nasiri (a third year PhD student from MACE). Numan was with the team till Sept 2017; he attended and contributed in the team meetings and developed the required MATLAB® code for the chosen MEP (stage 4). Mina worked till end of the project and mainly contributed in the electronic circuit development and testing.

Stage 2: Recruitment of student partners - Two student partners were recruited to be part of the project throughout the project period. These students were recruited on a volunteer basis and from the final year BA design cohort; the recruited students were S Bowlers, A Galton and J Khan. S Bowlers and A Galton were only stayed in the first half of the project. J Khan joined in the second half of the project and assisted till last stage of the project; in particular he contributed in the recruitment of volunteer students (stage 4), preparation of the certificate of the participation and MEP evaluation and feedback in the lab. These students were appreciated with lunch vouchers.

Stage 3: Development MATLAB® based electronics problem (MEP) – The project team researched, identified and developed an electronic problem within the syllabus of first year BA electronic course (DM1313). This problem should also involves a certain degree of mathematic contents as to assess the effectiveness of MATLAB® in electronic learning. Fig. 1 shows a photo taken during the physical construction and testing of the chosen electronic circuit.

Stage 4: Recruitment of volunteer first year BA students – a set of six BA first year students was recruited on volunteer basis to evaluate an MEP and give feedback. Since these students were in the first year, there memories of electronic learning were very fresh and hence able to express their challenges in an effective way. Lunch vouchers worth of £20 for each participant were awarded as the appreciation for their time and effort. They were also awarded with certificate of participation, which was signed by the PI of the project and Head of the Design department.

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Stage 5: Students working on the MEPs and Feedback - The first year volunteer first year BA students worked on an MEP in the electronic lab where they evaluated the electronic circuit and MATLAB® code in pair and gave their feedback by answering the questionnaire, made by the project team.

Step 6: Dissemination: Production of final report which included the results, analysis and findings.

The project team (here after referred as the team) consisted of Dr N. Manivannan (PI), Prof David Harrison (CI), Dr Dr Richard Rakowski (CI), Numan Celik (GTA), Mina.S.M. Nasiri (GTA), S Bowlers (3^{ed} year BA Industrial Design – student partner) and A Galton (3^{ed} year BA Industrial Design, student partner) and J Khan (3^{ed} year BA Industrial Design, student partner).



Fig. 1: Physical construction and Testing of the chosen temperature sensing circuit with MATLAB® in Brunel electronic lab (TOWB 303) by GTAs (Mina and Numan) and PI (Dr N Manivannan).

METHODOLOGY

As mentioned previously in this paper, the project was implemented with a development of MEP followed by evaluation by six first year BA Design students. The students experience and opinions were also captured via a feedback questionnaire.

Electronic Circuit for evaluating the concept

The important factors in choosing an appropriate MEP were

- (i) within context of the syllabus of the BA electronic curriculum
- (ii) a real word application
- (iii) easy to work with to evaluate the concept of using MATLAB® and
- (iv) involve a significant contents of mathematics

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Having researched across the literature [2, 4, 5] and a number of the team discussions, the following two circuits were identified as the possible circuits to implement in this project:

- (1) Radio receiver – A circuit that is tuned a frequency so that a single radio channel can be implemented.
- (2) Temperature or light sensor – A circuit which can used to control an electrical appliance based on the temperature/light at a specific point.

Both circuits are examples of real world applications, involve a significant degree of mathematics and the use of MATLAB® makes the learning a real difference. The main difference between these two circuits is that radio receive circuit uses Resistor-Inductor-Capacitor circuit which is not in the actual curriculum of the BA electronic curriculum, whereas the temperature/light sensor circuit uses a transistor, resistor and thermistor/Light dependent resistor, which are part of the respective curriculum. Hence a temperature sensor circuit was chosen to implement in the project. The full circuit description, MATLAB® program and lab instructions are presented in Appendix II.

Questionnaire for Feedback

There were seven question selected to get the feedback from the volunteer students; these questions can be classified to fall into four sets as described below.

The following two questions were used to evaluate how the volunteers view electronics in terms of liking and in their career in electronics design:

Question 1: Do you like electronics in general?

Question 2: Do you think that you will progress your career in electronics design?

The following two questions were related to the electronic exercise they worked in this project.

Their views on the experiences and usefulness were gathered from these questions:

Question 3: How did you find today's exercise?

Question 4: Do you think that learning these kind of electronic circuits is useful for your career?

The following two questions were aimed at getting feedback on MATLAB® experiences:

Question 5: Have you used MATLAB® before?

Question 6: Do you think that the use of MATLAB® has helped you to learn the temperature sensing circuit better?

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This final question is a summary question for the overall evaluation of the exercise, in terms of recommending MATLAB® based electronic learning:

Question 7: Will you recommend us to teach the basic MATLAB® programming in DM1313 (electronics) module?

RESULTS AND DISCUSSION

On 22nd March 2018, six volunteer Design students {five first year BA and one second year BA (replacement for a non-attendance)} attended a lab session in two sets which was scheduled with following items:

- (1) A brief about the whole project and details of their tasks was first given by PI (see the appendix III for the power point slides used)
- (2) Circuit evaluation – worked in pair and one of the student partner and an academic assisted the volunteers in building the circuit and testing with the MATLAB® Program. A printed instructions sheet were delivered to the volunteer participants.
- (3) Feedback – after the circuit evaluation, the volunteer students were given questionnaire to fill in (see Appendix IV the exact format of the questionnaire).

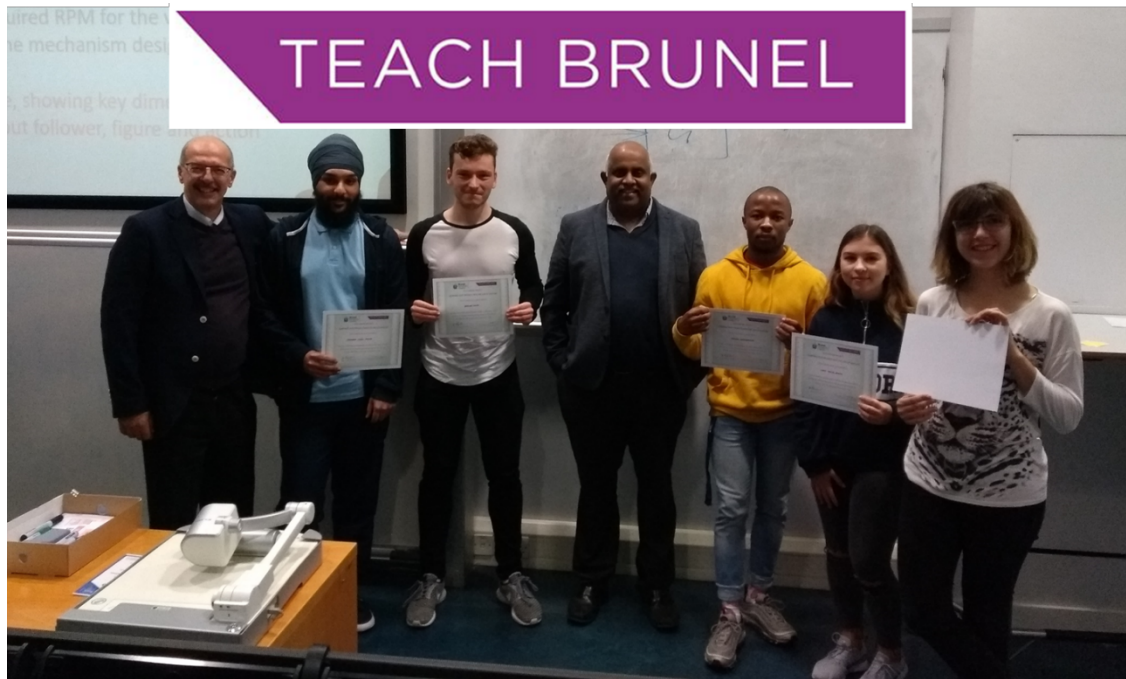
The volunteer students were happy about their participation. The results of the feedback are given in the next section. Figure 2 shows the volunteer students after evaluation sessions and the certificate presentation.



The volunteer students after evaluating the Electronic circuit (MEP) with Dr Manivannan (PI) and one of the student partners (J Khan).

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Certificate presented by Dr R Rakwoski (CI) and Dr N Maivananan (PI)

Fig. 2: Volunteer students after evaluation of the MEP and Certificate presentation

FEEDBACK AND DISCUSSION

Based on their answers to the feedback questions as mentioned in the previous questions the following results were obtained. The results are presented in a form of bar chart in Fig. 3 to Fig. 6. As shown in Fig. 3a and Fig. 3b, though most of the students liked electronics, only one student may consider career in electronics design. These results show there is less awareness/understanding how electronics can be used in design arena, though it is very evident that electronics is everywhere in the modern world.

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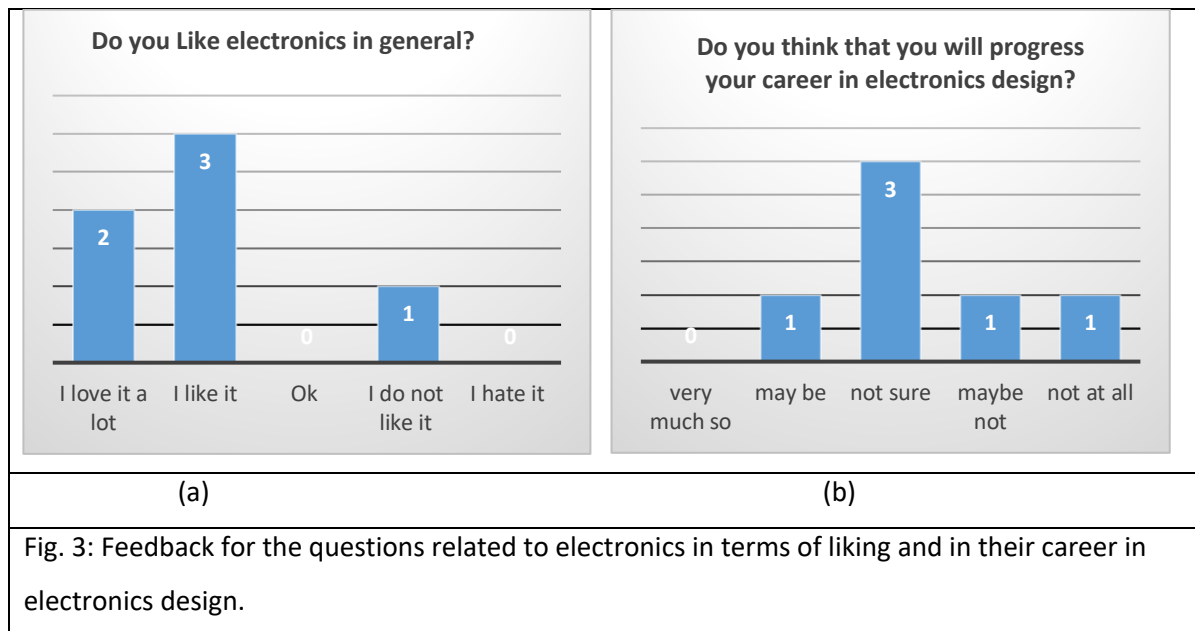
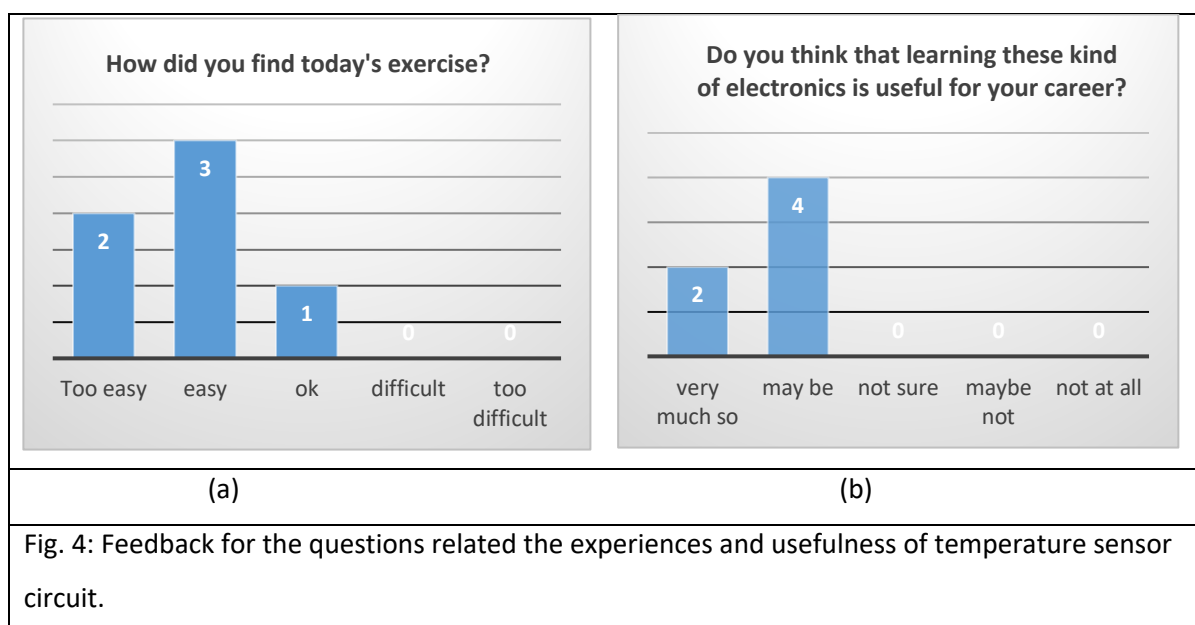


Fig 4a clearly shows that the students enjoyed today's exercise; five students gave positive response and one gave a negative response. The results in Fig 4b suggests that students think that learning circuits like temperature sensor will be useful in their career, though in Q2 (Fig. 3b), they said they will not choose a career in electronic design. These two results are bit confusing and probably need further exploration.

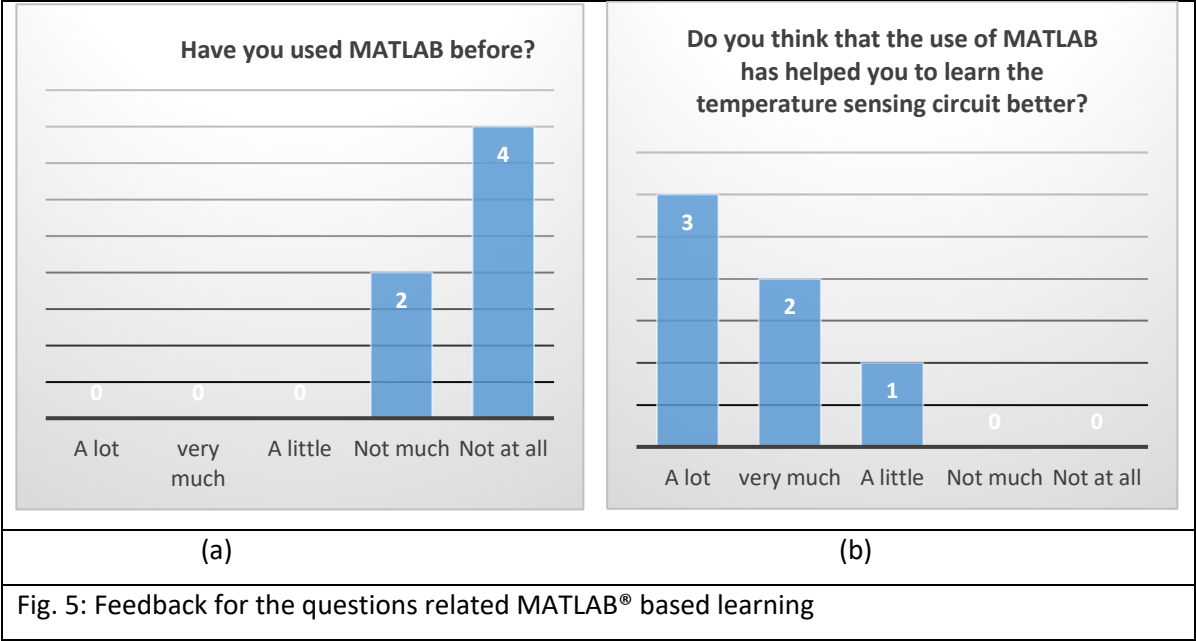


The feedback for the questions about the MATLAB® based learning is presented in Fig. 5. Fig. 5a is clearly shows that none of the volunteer students had used MATLAB® before, indicates the learning

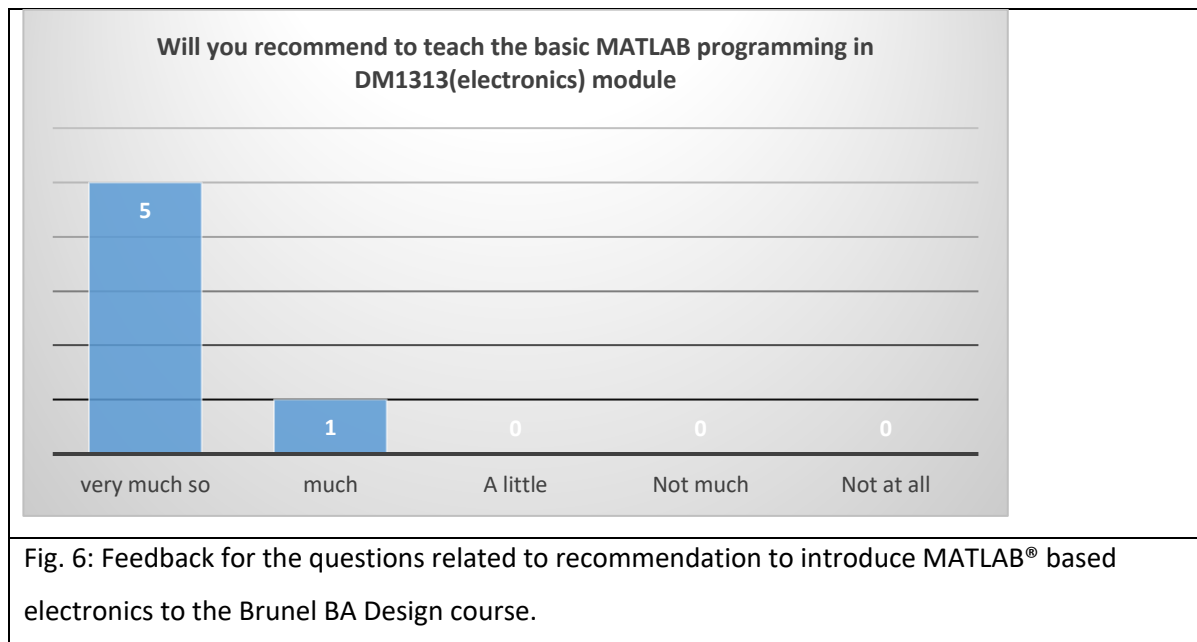
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materials prepared by the team was very good for the students to perform the tasks successfully. As shown in Fig 5b, most of the students think that use of MATLAB® had helped them learning the electronics better, which is a positive response and agrees the expectation proposed in the project.



The final question was about the recommendation to introduce MATLAB® based electronics and the feedback is presented in Fig 6. As shown in this figure, all the students thinks that introduction MATLAB® would enhance learning experience of electronics. Though this is a small sample size, these positive responses is really encouraging in taking the project further.



CONCLUSIONS

The project was successfully carried out as planned, though there were few delays in certain tasks: for example, recruiting the student partners and volunteer students took longer time and effort than expected.

The student partners contributed in a number of ways, including volunteer students recruitment, contributing in deciding of the MEPs, created art work for the certificate of participation and finally assisting in the lab during the evaluation.

The students were able to solve a complex mathematical problem that was associated with electronic circuits with the use of MATLAB® – problem based learning is an effective ways of learning, especially in electronics. The students found the learning much more fun.

Although the number of students participants was small in compare with the whole BA design cohort, this activity showed that helping students to experience harder subjects in practical way, using available software (MATLAB®) would help them to have better understanding of the concept and also be able to get benefit from available resources in their fields. The enthusiasm showed by the participants was really encouraging, though it was quite challenging to come up with a final conclusion from the feedback and the comments from the other academics in the team. However,

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the investigators are interested to expand the project with a larger number of participants in order to make conclusive directions in terms of implementing MATLAB® based teaching in the curriculum of BA Design.

ACKNOWLEDGEMENTS

The academic con-investigators (Prof D Harrison and Dr R Rakowski) were very critical in a positive sense and shared their valuable experiences with the Design department in making the project tasks and MEPs successful. Authors wish to extend their sincere thanks to them. Authors also want to acknowledge the financial support provided by the TeachBrunel scheme, in particular thank Professor William Leahy for his valuable time and effort to consider and approve the revised application in the first place.

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APPENDIX 1

The following flyer used for the recruitment of volunteer students



**Learning electronics with the use MATLAB
BA (Design) First Year Student
Volunteers wanted**

- **SIX BA FIRST YEAR STUDENTS**
- **TO ASSESS AN ELECTRONIC CIRCUIT AND MATLAB PROGRAM**
- **THREE HOURS IN TERM 2**
- **FREE LUNCH VOUCHERS AND CERTIFICATION OF PARTICIPATION**

Deadline for the application – 16 Feb 2018

Interested students Contact:

Dr N Manivannan (Mani) - emsrnm@brunel.ac.uk

Sophie Bowers (Student) <1404528@brunel.ac.uk> (Student Partner, 3rd Year BA Student)

Jahanzeb Khan <1207913@brunel.ac.uk> (Student Partner, 3rd Year BA Student -

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APPENDIX II

A. Electronic circuit for temperature Measurement

In this circuit it was intended to look at how external variation in temperature can be converted into an electrical signal and be processed using a simple MATLAB® Program.

Components:

- 10 K Ω potentiometer
- 10 K Ω Thermistor (B57861S0103F040)
- Transistor (IRLU2703)
- 3.3 K Ω resistor
- LED

The thermistor is a two leaded component that changes its resistance responds to a change in temperature. The symbol for a thermistor is shown below:

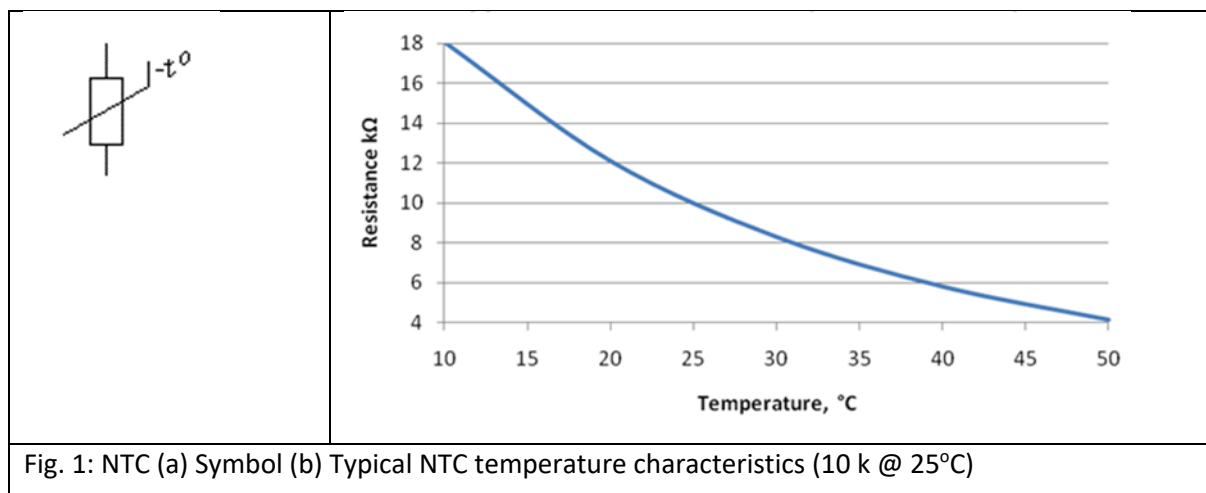
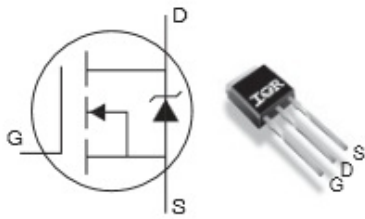


Fig. 1: NTC (a) Symbol (b) Typical NTC temperature characteristics (10 k @ 25°C)

The '-t°' alongside the symbol indicates that this is a negative temperature coefficient (or n.t.c.) thermistor, which simply means that the resistance of the thermistor decreases as temperature increases.

The characteristic curve for a thermistor is shown in Fig. 1 (b). As shown, as temperature increases, the resistance of the thermistor goes down.

The thermistor is used as part of a voltage divider circuit together with a potentiometer. The output of the voltage divider is used to switch on a MOSFET, which has an LED as its load. As soon as MOSFET switch on, LED will light up.



MOSFET transistor: MOSFET can act as a switching device in electronic circuits. Below picture shows the image and symbol of transistor in this lab.

In order to have transistor in on mode, Voltage at gate should be above a threshold voltage (can be found in Datasheet). As soon as the voltage gate reaches the limit transistor switch on and current can flow between drain

and source. Having a load at drain (for example a LED), when transistor is in switching mode and on, LED will light up.

We are using this feature in the following circuit to have LED on when we are measuring voltage (V pot) and resistance of potentiometer. Then we will use these measurements to calculate resistance of thermistor and find the temperature.

Below is the complete circuit diagram to sense temperature.

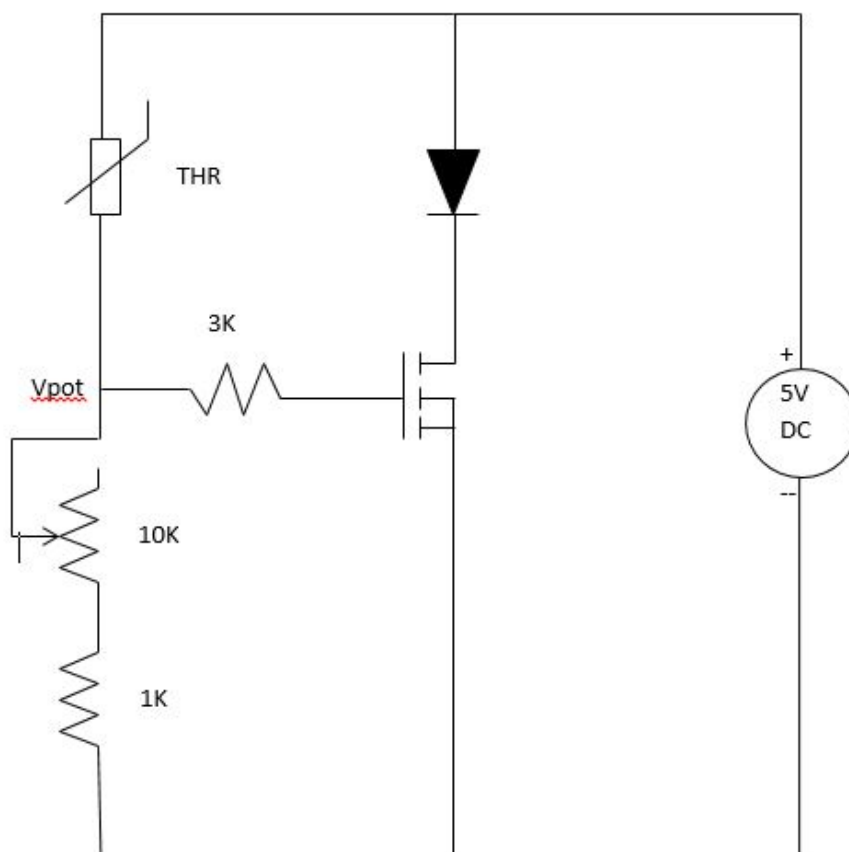


Fig. 4 : Temperature Sensing Circuit

Task1: Measuring ambient temperature

In this task we measure the ambient temperature. Set up the circuit as it shows in fig 4. Pay attentions to components values and voltage source.

By changing the variable resistor (potentiometer) the position of potentiometer in which the LED is on. Measure the voltage at V_{pot} and record it. Then measure the resistance of potentiometer.

Task 2: Measuring your body temperature

Follow the circuit diagram in Task 1. Make sure you set the potentiometer on minimum value (Tuning clockwise to the end limit). To be able to see significant change in temperature, you can warm up your hands. Touch the head of potentiometer and tune the potentiometer until LED is on. Measure V_{pot} and resistance of potentiometer and record them. Then follow the MATLAB® instructions to find your body temperature.

B. MATLAB® Program

The following MATLAB® program was developed to display the temperature of the thermistor (i.e.: ambient, body, or any that is in the vicinity of the thermistor) provided the absolute voltage of thermistor and voltage across 1kΩ resistor is fed into the program by the user.

```
% MATLAB® Program to calculate the temperature of the thermistor

Vin = 5; % supply voltage is 5 V
R1 = 1; % 1 k resistor is used for the current measurement

prompt = 'Enter the voltage after thermister (V1):\n';
V1 = input(prompt);
prompt = 'Enter the voltage across 1k (V2): \n';
V2 = input(prompt);

I = V2/R1; % current through the circuit
Rt = (Vin - V1)*R1 / V2; % resistance of thermistor

% Best curve fit is 5th degree polynomial. Therefore the following formula
% is used to calculate body temperature along with ratio of resistance
% values.

p1 = -8.8309;
p2 = 77.912;
p3 = -253.95;
p4 = 382.16;
p5 = -283.21;
p6 = 112.27;

ratio = Rt / 10;
temp = p1*ratio^5 + p2*ratio^4 + p3*ratio^3 + p4*ratio^2 + p5*ratio + p6;
```

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```
disp('Temperature is ');  
disp(temp);
```

Table 1: MATLAB® Code

Instructions to students for MATLAB® exercise

1. Open workstation and open a new project new M-file....
2. Use 'clear all' – command to clear your workspace and clear command window. Clr is a quick way to reset MATLAB®.
3. We have to assign 5 V as input voltage of the circuit. Therefore, here it is assigned to $V_{in} = 5$. Similarly, resistor R1 is assigned to 1 k Ω , $R1 = 1$;
4. Now we have to enter the voltage value of potentiometer as we found in the circuit board. The below commands allow us to get voltage input:

>> Enter the voltage after thermistor (V1):\;

V1 = input(prompt);

5. V1 stores now the input voltage of potentiometer.
6. Now, Resistor value of the potentiometer has to be entered as it is measured in the circuit board. The below commands allow us to get resistor value of the potentiometer:

>> Enter the voltage across 1k (V2):

V2 = input(prompt);

7. V2 stores now the voltage across the 1 k Ω resistor. Now current in the thermistor can be calculated using simple equation governed by ohm's law. $I = V2/R1$.
8. Now we can calculate the resistor of thermistor in MATLAB® with a simple voltage divider formula:

$$R_t = (V_{in} - V1) * R1 / V2;$$

9. R_t is now a variable which stores resistor value of thermistor.
10. Now, it is time to calculate the temperature by a formulation in MATLAB®. When we look at the datasheet of the thermistor, the temperature of the thermistor values are given against the ratio of resistor of thermistor (R_t) and the thermistor resistor at 25°C and 10 k Ω for the

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thermistor we chosen. Therefore, first we have to get ratio value in MATLAB® using the following command:

```
ratio = Rt / 10;
```

11. Based on this ratio, the temperature can be now found by looking at the datasheet of the thermistor. In a separate MATLAB® program, we developed a formula for temperature for a given ratio of resistor based on the datasheet. This formula was developed using the best-fit tool that is available in MATLAB®. B After a series of trails, the following formula (5th degree polynomial) was established to calculate body temperature.

```
p1 = -8.8309;
```

```
p2 = 77.912;
```

```
p3 = -253.95;
```

```
p4 = 382.16;
```

```
p5 = -283.21;
```

```
p6 = 112.27;
```

```
temp = p1*ratio^5 + p2*ratio^4 + p3*ratio^3 + p4*ratio^2 + p5*ratio + p6;
```



12. temp variable now stores the temperature of the body based on ratio values on the datasheet and displayed using the following two commands.

```
disp('Temperature is ');
```


```
disp(temp);
```

APPENDIX III

The brief given to the volunteer students before they evaluate the circuit is given below.



Learning electronics with the use of MATLAB



Principal Investigator
Dr N Manivannan
Department of Design

What is TeachBrunel?

- Brunel University Initiative to explore various ideas and methods to enhance teaching and learning experience in Brunel
- fit into one of these three themes:
 - *Innovation in Teaching*
 - *Innovation in Assessment*
 - *Innovation in Feedback*
- These themes tie into the themes for the Framework for teaching excellence, and the responses to NSS, PTES and PRES, as well as the Education Strategy.
- committed to investing in projects covering a range of opportunities that will ultimately benefit our students, however, any proposals designed to replicate current activity/already planned to happen, building costs or the establishment of academic posts will not be accepted.

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What is this project - 'Learning Electronics with the use of Matlab'?

- To explore learning electronics in conjunction with a simple MATLAB program
 - aimed for BA first years
 - with a couple of student partners (3rd year Design BA students)
 - with volunteer BA first year students
- Feedback from the student partners and volunteer students will be used to make recommendation if MATLAB is a useful tool for Learning electronics

Why Matlab?

- A high-level, well established, very popular software for many engineering applications
- Very user friendly to all levels
- Simple and reliable built-in functions and routines
- Can Perform easy tasks as well as very complicated tasks

Explore new ideas

MATLAB® is the high-level language and interactive environment used by millions of engineers and scientists worldwide. It lets you explore and visualize ideas and collaborate across disciplines including signal and image processing, communications, control systems, and computational finance.

Put your ideas into action

You can use MATLAB in projects such as modeling energy consumption to build smart power grids, developing control algorithms for hypersonic vehicles, analyzing weather data to visualize the track and intensity of hurricanes, and running millions of simulations to pinpoint optimal dosing for antibiotics.

As mentioned in
the MATLAB
website

What is your role?

- A volunteer student to evaluate the circuit
- Provide a constructive feedback

The temperature sensor circuit

- Electronic Circuit
- Matlab Code

Evaluating the circuit

- Measure two voltages
- Use a set of equations to get the temperature
- Feed the voltage values into a small Matlab code to get the exact temperature
- Repeat the above three steps a couple of times

Feedback

- Your feedback is important as your are BA first year UG
- Gives me make decisions
 - Include in the electronics curriculum – DM1313
 - Carryout further research
 - Drop the idea

So please be open as possible and fill all the feedback questions

Finally..

- Thank you for your time and effort
- Your participation is very much appreciated and recognised
 - Lunch vouchers (£20 pounds work)
 - Your certificate of participation

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Learning electronics with the use of MATLAB®

Feedback from Volunteer first year BA students

(1) Do you like electronics in general?

Yes / No/ Not sure

(2) Do you think that you will progress your career in electronics design?

Yes / No/ Not sure

(3) How did you find today's exercise?

Too easy/ moderate / too difficult

(4) Do you think that learning these kind of electronic circuits is useful for your career?

Yes / No/ Not sure

(5) Have you used MATLAB® before?

Yes / No/ Not sure

(6) Do you think that the use of MATLAB® has helped to learn the temperature sensing circuit better?

Very much / a little / not at all

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(7) Will you recommend to teach the basic MATLAB® programing in DM1313 (electronics) module?

Yes/ No/ Not sure

(8) Any other comments.

APPENDIX V: Certificate of participation

The following is a copy of the certificate distributed to the volunteer student participants. The artwork was designed by a student partner J Khan.



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