Light Seeking Robot

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ABSTRACT

The present work decomposes all of the methodology utilized for the creation of the Light Seeking Robot of both individual and team parts of the project. Its implications on design and manufacture are discussed in a reflective manner.

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1. Introduction

A complex task was issued in September of 2015: To create a basic light-seeking robot with sound, light, face and a body design. The submitted prototype developed from more basic designs and prototypes. Its development process included tracking up the PCBs on Proteus 8-8.1, following their corresponding component layout design. Respectively, a single design was chosen to be sent for production (milling). Every PCB was both populated and soldered up, tested and debugged to ensure correct functionality. As the designing and prototyping phase was approached, team-brainstorming, discussions and considerations were expected to take place.

2. LDR Sensors

Since PCB 1 (C. Benjamin, 2015) was already designed and produced, its *actual* development began by designing its Low Pass Filter formed by R11 and C1. The cut-off frequency for the filter is known to have a period of five seconds, so its frequency was calculated to be 0.2 Hz. Using the re-arranged cut-off frequency formula shown below, a number of suitable values were calculated for R11 by determining a value for C1. The formula was rearranged for R rather than for C, because the available range of electrolytic capacitors was narrower than the possible resistor values. Thus a time-effective process was held.

$$fc = \frac{1}{2\pi RC} \qquad R= \frac{1}{2\pi C(fc)}$$

C1 (μF)	R11 (kΩ)	Values (+/- 10%)
8	99.5	100
45	17.7	18
90	8.8	8.2
135	5.9	5.6
180	4.4	4.7
280	2.8	2.7
335	2.3	2.2
450	1.8	1.8

Table 1. Calculated values for R11, and nearest preferred values for soldering onto PCB1.

The inversely proportional relationship between C1 and R11 is clearly shown in the above table. 10 μF was used for C1, causing R11 to equal approximately 80 kΩ, which in the E 12 system is 82 kΩ.[1] The time constant was calculated by multiplying the preferred values:

$$T = RC \qquad 82\Omega \; x \; 10\mu F = 8.2 \; x \; 10^{-4} \; s$$

When discussing about capacitors in DC circuits, the time constant itself is equivalent to the time it would take the capacitor to charge up to 63%.(C. Benjamin & J. Powell, 2015) By referring to table 2, the time constant would need to be multiplied by three when calculating the time it would take C1 to charge up to 95%, which would, in this case, be 3T= 0.00246 s.

T	2T	3T	4T	5T
63%	85%	95%	98%	99%

Table 2. Relationship between capacitor's charge percentage and time constant.

After all corresponding component sections were soldered up by each team member at a time, PCB 1 was tested for its functionality and demonstrated to be working effectively. The constructive feedback received focused on the presentation of PCB 1. It was said to have a few components facing different directions, causing difficulty when “reading” the circuit. The solder finish was uncosistent, probably influenced by the fact that all members of the team participating held different levels of soldering skill. PCB 1’s presentation was then considerably improved by re-soldering a few components.

Fig 1. PCB 1 (LDR Sensor circuit) before feedback.

Fig 2. Variety in solder thickness from side view.

3. Motor Drive

The Motor Drive PCB (PCB 2), had a given component layout- designed by C. Benjamin. Its design remained unchanged, and it was then tracked up as shown below in Figures 3 and 4.

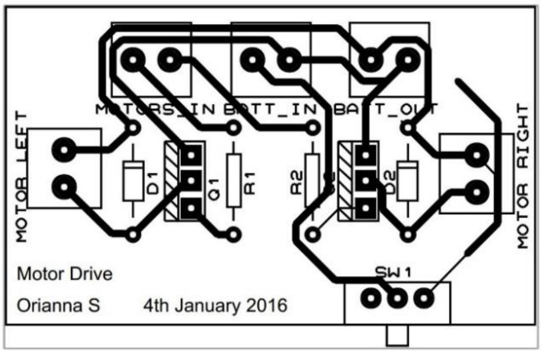

Fig 3. PCB 2 tracked up.

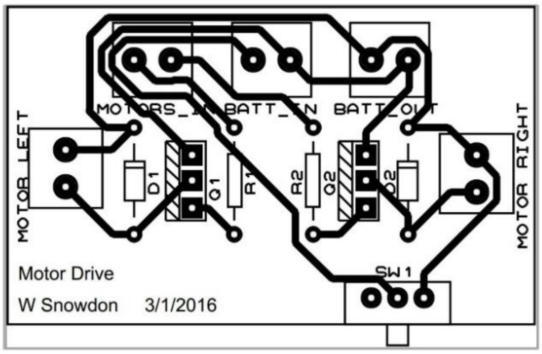

Fig 4. PCB 2 by Will Snowdon, submitted for production.

The process for testing PCB’s functionality was repeated once all components were soldered, this time, with the lessons learned from PCB 1 taken into account. Given that a higher resistance was required, 10k ohms resistors were soldered for R1 and R2. Once presented, a higher mark than PCB 1 was achieved. Later on, the most adequate robot base was selected, and a battery holder was provided as well as the motor wheels. Both PCBs were ready to be connected with the jumping wires. After demonstrating the robot’s efficiency, it was pointed out that the wrong face of the MDF base had been used- causing the battery holder not to be *correctly* placed in the center. The battery holder’s “legs” were fixed into their corresponding holes of the base later on.

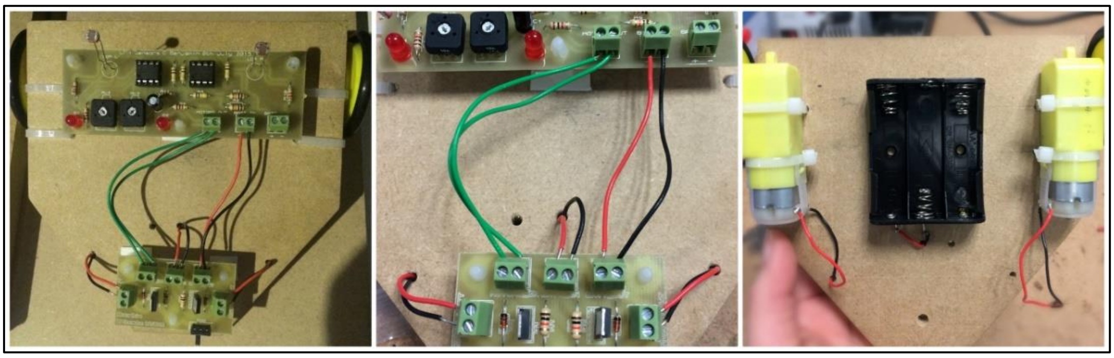

Fig 5. Robot’s base with PCB 1 and 2 connected to the motor wheels and battery holder for the first time.

4. Concept design

A futuristic design approach was used. The first concept design was based on Li-fi (Light fidelity): A wireless optical networking technology that uses LEDs for data transmission. [2] This idea of data transmission through sudden changes in the brightness of light was brought up by Prof. Harald Haas in 2011. During his first public demonstration of a functioning prototype, Harald used a laptop connected to a solar cell as the light/ data receiver, and successfully streamed a HD video. The solar panel concept design has been based on Harald's theory of "the internet of things."[3] If the robot's front face acted as the receiver (solar panel), then the body would've been allowed to act as the "thing" i.e. a vehicle, turbine, building, or laptop.

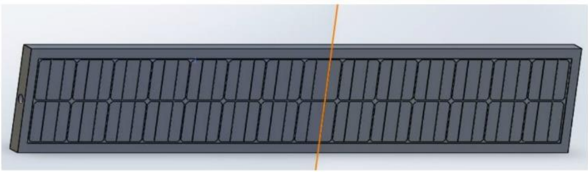

Fig 6. First concept design produced in Solidworks.

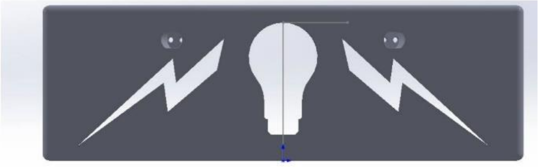

Fig 7. Front face used in final prototype, by Will Snowdon.

5. Front Face

A secondary concept was given some thought: Turbines, assuming the robot's cardboard body to be a futuristic vehicle. There were not enough team meetings dedicated to brainstorm design ideas. But after the front face was 3D-printed, one meeting took place, where it was decided to base the body of the robot on the MSE-6-series-repair droid from Star Wars.[4]

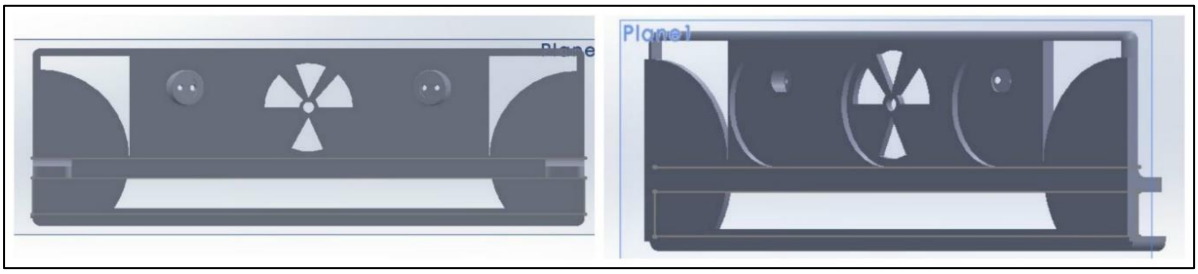

Fig 8. Second concept design. From left to right: View from the back and front.

It was agreed that the LEDs would need to be sticking upwards within two rows, mimicking the Mouse droid's top section. A series of LEDs' functions were agreed upon, shown in the flow diagram, which can be found in the Appendix as Fig 9. The sounds made by the original Mouse droid are random in sequence, but consistent in pitches.[4] Based on its description, a number of sequences were programmed, with the PICkit2 programmer in MPLAB, into a PIC microcontroller that belongs to the LEDs and Buzzer circuit (PCB 3). The firmware listing to realise flow diagram can too be located in the Apendix, as Fig 10. At the end, the final prototype was submitted with a different code- produced by Will Snowdon.

6. LEDs and Buzzer

After designing the component layout for PCB3, it proceeded to be tracked, *incorrectly*. As show below in the first design of Figure 12, the microcontroller was tracked upside-down. So the layout design needed to be *slightly* changed. The final design allowed for wider tracks (T 30) and a smoother process. The second tracked-up design was sent for production. It was pointed out that the chosen green LEDs wouldn't shine as bright as other colours, but since the preferred colour was green, a lower resistance was used in the circuit. 8k2 ohms resistors were soldered for R1-R10. PCB 3's component-layout design development can be found in the Appendix as Fig 11.

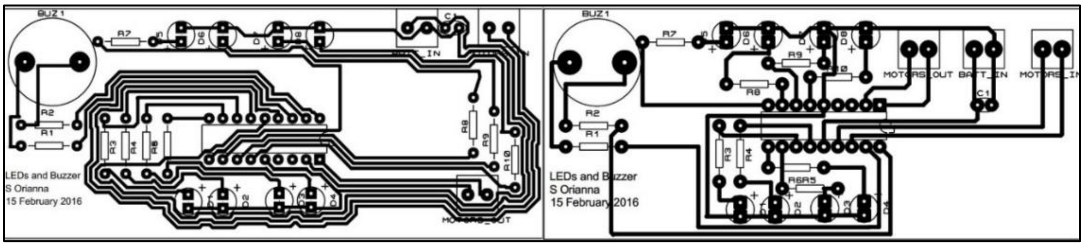

Fig 12. PCB 3 tracking-up development.

7. Prototypes

Fig 13. First basic robot-body prototype.

The first prototype was made with recycled cardboard, and was then painted black, again, to mimic the Star Wars' Mous- droid look. For the second and final prototype, a neater finish was preferred, so a black card was used instead of the paint, and small holes for the LEDs were provided, rather than just a plane couple of holes. Since the Mouse droid is all-black, the Robot's base and wheels were painted black, but the friction in the motor wheels caused the acrylic paint to constantly peel off. Silver drawing pins were used to place the body on the robot. A detailed Bill of Materials for the complete robot can be found in the Appendix as Table 3.

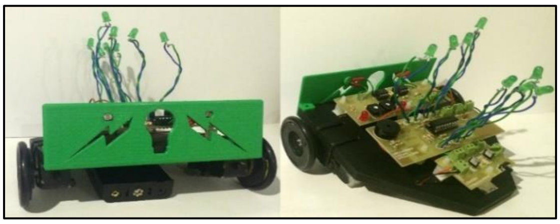

Fig 14. Painted Robot's base.

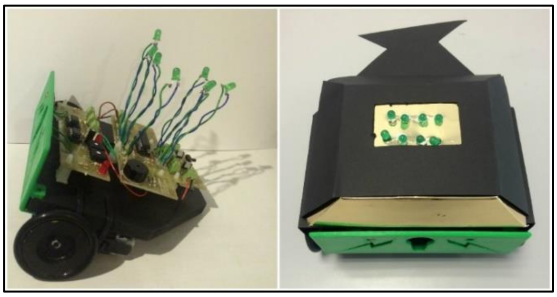

Fig 15. Final functioning prototype, ready for submission.

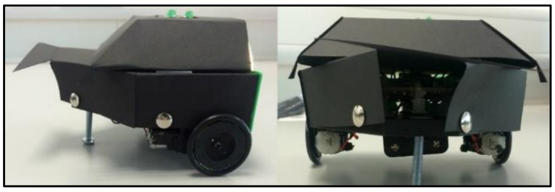

Fig 16. Final prototype. View from right and back side.

8. Reflection

The final prototype's finality is only defined by the deadline. If provided more time, a number of prototypes showing positive development would've been produced. Given that the project was made up of different stages, the approach was adapted to every task. There was a unique level of skill per every completed task. An objective approach was used for the RC filter's mathematical-modelling and its preferred values' selection. The delivered presentation was a challenge, because of its time-limit. The first concept design for the robot was not quite specific enough to be presented within the time-constrained presentation, unlike the BoM for PCB 1. The short presentation should've been practiced more beforehand, so these issues would've, most likely, been avoided. A higher quality team-work input was achieved in the first task, where the PCB 1 and PCB 2 were soldered up. Annotations were made for the constructive feedback received after each PCB demonstration, making a positive development possible.

Parts 1 and 2 of the second task depended mainly on the decisions made as a team. A set of sequences for the LEDs and Buzzer was to be produced, depending on the chosen concept design for the front face and body, simply because these are all part of one system; The robot . The problem encountered was that not all team members agreed with that. Since choosing a concept design for the body and front face wasn't considered to be equally important, or a relevant influence for PCB 3, the team's final prototype pocessed more of a general concept design. Several team meetings were planned, but did not turn out- to be efficient enough, similarly to the Facebook-group chat. There was an inconsistent work input from team members, causing others to make up for the lack of work.

When producing the final BoM (based on the PCB 1 BoM), an even greater understanting of the range of components was gained. Principally, the basic principles of their use was quickly understood during the practical processes, where one got to physically place, and solder each electrical and electronics components on the circuit boards- respectively. But the methodologies used for designing with analogue and digital technologies took more practice to learn. The time was managed in a way so mistakes could be afforded, as seen in the development of PCB 3's layout design. Enough practice labs were provided for the understanding of MPLAB's use in coding and programming. As mentioned before, all implemented components in the robot are interconnected, so there are present implications on one another, for which a hollistic approach was utilized.

Considering one was new to all of the concepts covered throught the project, it can be stated that an increasing level of skill, on the different aspects, has been potentially developed. As seen in Chart 1 in the Appendix, the more practice, the higher the level of skill achieved. One of the most developed skills has been soldering, like it is shown in Chart 2, where the exponential growth for the amount of practice is clear. One's methodological mindset has been put to practice all through the project. Despite the inconveniences, the goal was achieved.

The issues encountered were addressed to the team members, but little positive change was provided as a response. A wide range of communication methods were available between the members of the team: Face-to face, email, Facebook. Yet, there was unconsistent, if any, responses. All possible input work was put in, the rest was a matter of attitude and self-motivation as a team. Mantaining formal communication between team members has to be done by more than one individual for it to work. The professionalism of this project was affected by the different levels of auto-motivation in every individual. In a group of three, it takes a *minimum* of two active members to drive the whole team, *usually* the third less-active individual, would naturally attempt to catch up.

9. Conclusion

To achieve the task's completion, a hollistic design approach was used and adapted to every part of the diverse tasks. Both individual, and team work was attempted to be of improved quality each time. Some complications were met along the way, but these were addressed imediately, in hopes of improvement. One's ability to apply and understand the robot components' uses, as well as designing with analogue and digital technologies was tested within different stages, in contrasting aspects.

References

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3. C. Benjamin (2015) PCB2 'Motor Drive' Schematic & Layout In: Bournemouth University.
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Online:

1. Eric Coates (2015) In: *Module 2.2 Preferred Resistor Values.* At: http://www.learnabout-electronics.org/Resistors/resistors_05.php

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3. Harald Haas (2015) In: TEDGlobal>London: *Forget Wi-Fi. Meet the new Li-Fi Internet.* At: https://www.ted.com/talks/harald_haas_a_breakthrough_new_kind_of_wireless_internet

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Appendix

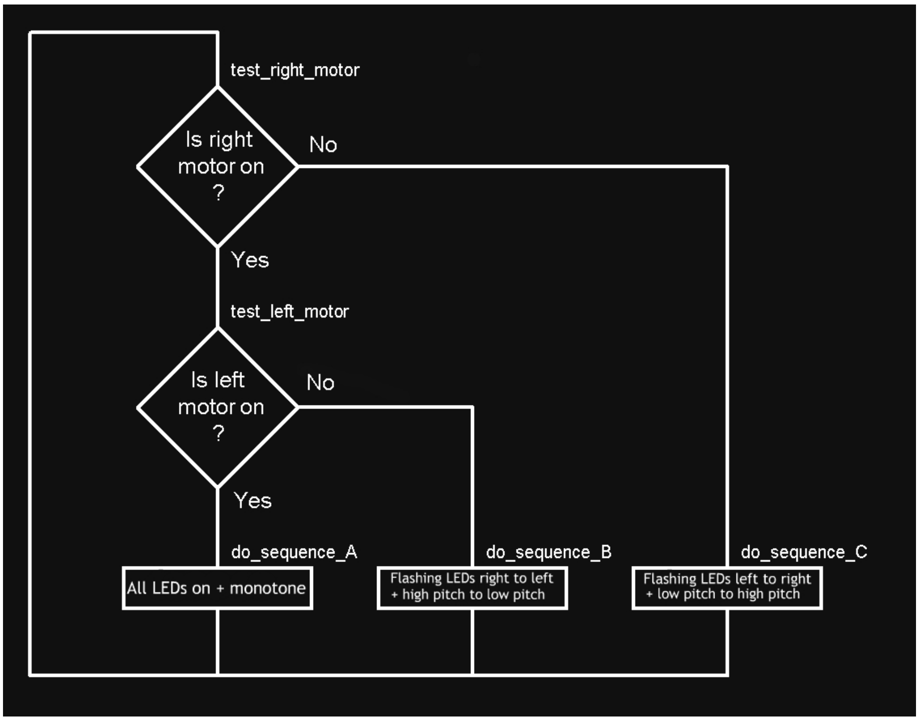
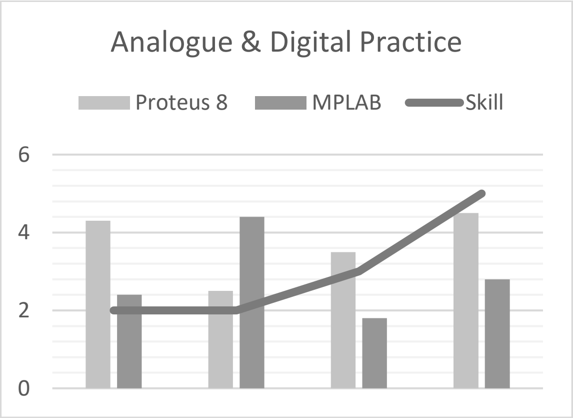


Fig 9. Flow Diagram.



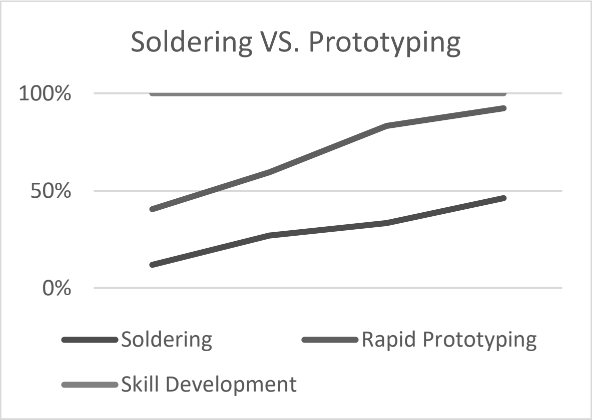
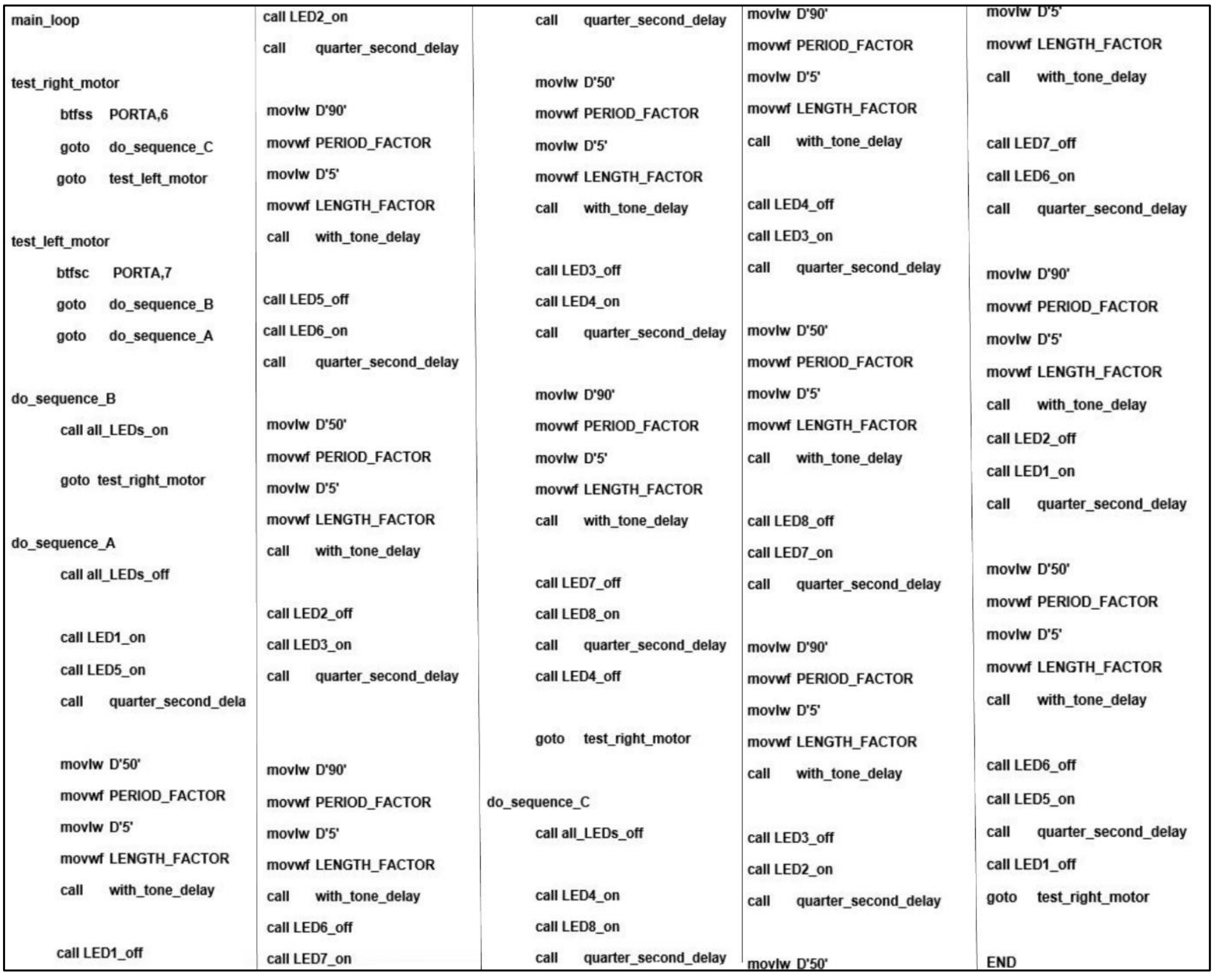


Chart 1. Skill level:Analogue and Digital technologies. **Chart 2.** Difference in level of skill developed.



```
main_loop

test_right_motor
        btfss   PORTA,6
        goto    do_sequence_C
        goto    test_left_motor

test_left_motor
        btfsc   PORTA,7
        goto    do_sequence_B
        goto    do_sequence_A

do_sequence_B
        call all_LEDs_on

        goto  test_right_motor

do_sequence_A
        call all_LEDs_off


        call LED1_on
        call LED5_on
        call    quarter_second_dela


        movlw  D'50'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay


        call LED1_off
        call LED2_on
        call    quarter_second_delay

        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED5_off
        call LED6_on
        call    quarter_second_delay

        movlw  D'50'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED2_off
        call LED3_on
        call    quarter_second_delay

        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay
        call LED6_off
        call LED7_on
        call    quarter_second_delay

        movlw  D'50'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED3_off
        call LED4_on
        call    quarter_second_delay

        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED7_off
        call LED8_on
        call    quarter_second_delay
        call LED4_off

        goto    test_right_motor

do_sequence_C
        call all_LEDs_off

        call LED4_on
        call LED8_on
        call    quarter_second_delay
        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED4_off
        call LED3_on
        call    quarter_second_delay

        movlw  D'50'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED8_off
        call LED7_on
        call    quarter_second_delay

        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED3_off
        call LED2_on
        call    quarter_second_delay

        movlw  D'50'
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED7_off
        call LED6_on
        call    quarter_second_delay

        movlw  D'90'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay
        call LED2_off
        call LED1_on
        call    quarter_second_delay

        movlw  D'50'
        movwf  PERIOD_FACTOR
        movlw  D'5'
        movwf  LENGTH_FACTOR
        call    with_tone_delay

        call LED6_off
        call LED5_on
        call    quarter_second_delay
        call LED1_off
        goto    test_right_motor

        END
```

Fig 10. Firmware listing to realise flow diagram.

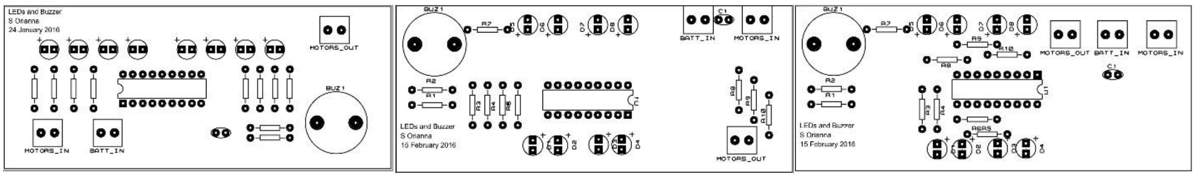


Fig 11. PCB 3 component's layout design development in order, from left to right.

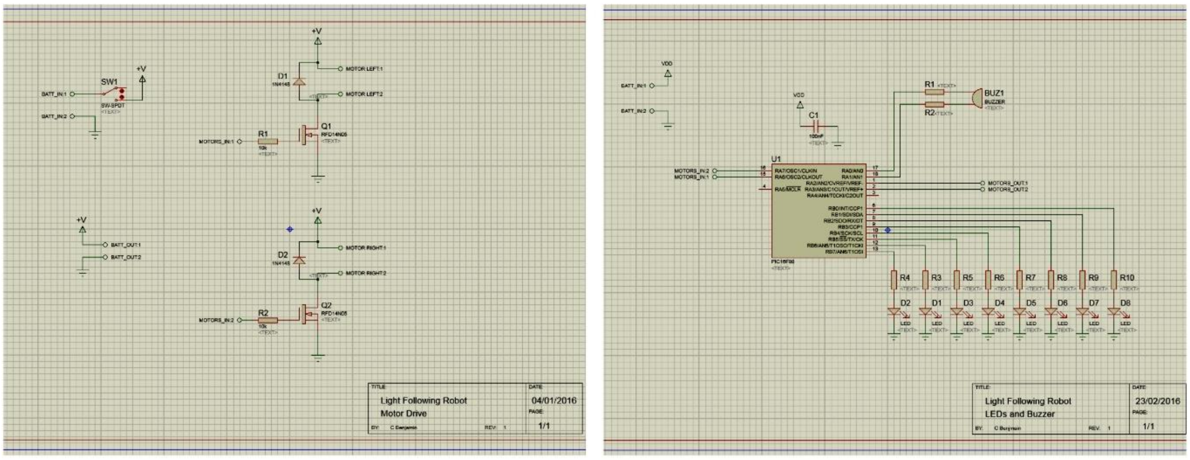


Fig 12. Schematics used for (from left to right) PCB 2, and PCB 3. Produced by C. Benjamin.

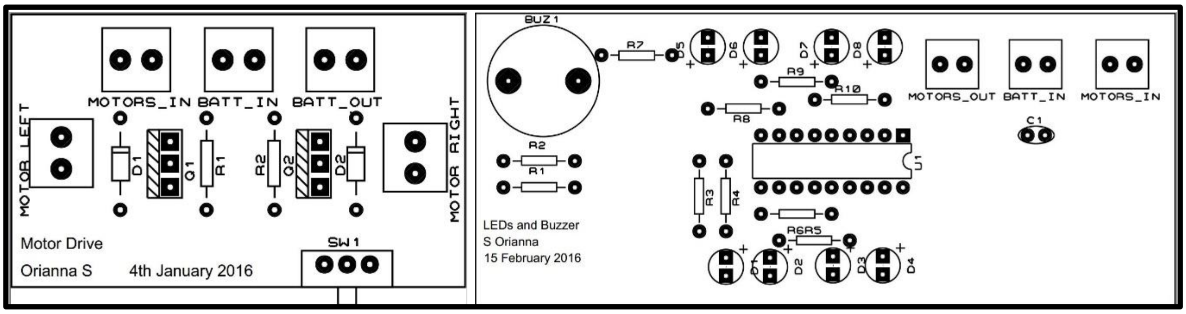


Fig 13. Final component-layouts used for PCB 2 (designed by C. Benjamin) and PCB 3.

Reference	Component	Qty	Value/ Description	MANF./ Vendor	MANF. Part No.	Website	Data Sheet	Comments	£	£ unit / mass production
R1,R9	1k Ohm Resistor	2	5% Tolerance 1 /4W Power Rating.	Yageo/ Digi-key	CFR-25JR-52-1K	1k	1k	For PCB 1	**0.07**	**0.01**
R2, R10	2k2 Ohm Resistor	2	2.2kΩ Carbon Film Resistors, 5% Tolerance.	Stackpole Electronics/ "	CF14JT2K20	2k2	2k2	For PCB 1	**0.07**	**0.01**
R7,R8, RV2, RV3 + R1, R2	10k Ohm Resistor	6	10KΩ Carbon Film Resistors, 5% Tolerance	"	CF14JT10K0	10k	10k	For PCB 1 + 2	**0.07**	**0.01**
R3-R6 + R1 - R10	8k2 Ohm Resistor	14	82kΩ Carbon Film Resistors, 5% Tolerance	Yageo/ "	CFR-25JB-52-82K	82k	82k	For PCB 1 +3	**0.07**	**0.01**
R11	100k Ohm Resistor	1	100kΩ Carbon Film Resistors, 5% Tolerance	Stackpole Electronics/ "	CF14JT100K	100k	100K	For PCB 1	**0.07**	**0.01**
U1, U2	8 Pin DIL IC Socket	2	Narrow, 8 pin DIP.	RK-Education/ RKonline	IC SOCKET 8 PIN PK 10	8-pin-dil-ic-socket	8-pin-dil-ic-socket	Pack of 10 +£0.99 delivery. For PCB 1	**0.049**	**0.03**
U1	Op Amp	1	Single, 10 MHz, 1, 7 V/µs, 2.5V to 5.5V, DIP, 8	MICROCHIP/ Farnell	MCP6021-E/P	MCP6021	MCP6021	For PCB 1	**0.736**	**0.505**
U2	Op Amp	1	Dual, 1 MHz, 2, 0.6 V/µs, 1.8V to 6V, SOIC, 8	"	MCP6002-I/SN	MCP6002	MCP6002	For PCB 1	**0.289**	**0.164**
C1	Capacitor	1	10uF Electroytic Capacitor 16VDC 105°	RK-Education/ RKonline	10 ELEC 16V PK 10	10uf-CAP	10uF-CAP	Pack of 10 +£0.99 delivery. For PCB 1	**0.025**	**0.05**
LDR R, LDR L	LDR	2	5mm, clear epoxy finish.	TruOpto/ Rapid electronics	GL5528	LDR	LDR	For PCB 1	**0.363**	**0.195**
RV2, RV3	Potentiometer	2	Horizontal preset, single turn.	Iskra/ "	PNZ10Z	Potentiometer	Potentiometer	For PCB 1	**0.14**	**0.075**
MOTORS_OUT, BATT_IN- OUT	Screw Terminal Block	11	5.08mm pitch, with 2 poles.	PTR/ "	50350020001FV	STB	STB	For all PCBs	**0.306**	**0.235**
D1, D2	Red LED	2	Low current 5mm LED housed in red package.	Kingbright/ "	L-7113LID	Red LED	Red LED	For PCB 1	**0.075**	**0.036**
Light Sensor PCB	PCB 1	1	Plain copper-clad fiberglass CB.	RVFM/ "	IPC-4101C/21	PCB 1	PCB 1	100 x 160mm. + £1.60 Production + £7 Soldering/ 1hr	**1.04**	**0.73**
SW 1	Switch	1	Miniature sllide-switch.	Rapid electronics	S1105A	Switch	Switch	4.4mm. For PCB 2	**0.27**	**0.189**
D1, D2	Diode	2	Signal diode. 75V. 150mA	"	1N4148	Diode	Diode	For PCB 2	**0.01**	**0.008**
Q1, Q2	Transistor	2	NPN Gp Transistor	"	TIP31A	Transistor	Transistor	Order Code: 81-0154. For PCB 2	**0.21**	**0.164**
Motor Drive PCB	PCB 2	1	Plain copper-clad fiberglass CB.	RVFM/ "	IPC-4101C/21	PCB 2	PCB 2	50 x 60mm + £1.60 Production + £7 Soldering/ 1 hr	**1.04**	**0.73**
D1 - D8	Green LED	8	5mm 2.1V Green LED	TruOpto/ Rapid electronics	OSNG5164A	Green LED	Green LED	Industry standard 1.2V x 100. For PCB 3	**0.062**	**0.045**
BUZ 1	Buzzer	1	6V Buzzer	SonyCrest/ "	HCM1206BX	Buzzer	Buzzer	Low profile Buzzer. For PCB 3	**0.707**	**0.403**
C 1	Capacitor	1	Ceramic capacitor. 2Pf. 100NF	Ebay	CC10	10uF CCAP	10uF CCAP	10 pack. For PCB 3	**0.99**	**0.502**
U 1	Microcontroller	1	8-bit Microcontroller 8K Flash	Rapid electronics	PIC16F887-I/P	Microcontroller	Microcontroller	Pin socket needed. For PCB 3	**1.77**	**1.39**
U 1	Socket	1	18 Pin 0.3in	TruConnect/ Rapid electron	110-87-318-41001	Pin Socket	Pin Socket	Turned Pin Socket. For PCB 3	**0.579**	**0.345**
LEDs and Buzzer	PCB 3	1	Plain copper-clad fiberglass CB.	RVFM/ "	IPC-4101C/31	PCB 3	PCB 3	120 x 170mm + £1.60 Production + £7 Soldering/ 1 hr	**1.04**	**0.73**
Jump Wire Kit	Jump wires	30	Red, black, green, blue and brown wires.	Maplin	FS65V	Wires	N/A	Approximate price [25 wires per each length] (14 diff. length	**0.38**	**N/A**
Sticky pads	Sticky pads	10	Double sided sticky pads.	Ebay	S95372	Sticky Pads	N/A	To mount all PCBs, and battery holder.	**0.1**	**N/A**
Plastic rivets	PCBs' rivets	9	100 pack	Ebay	a14052800ux0932	Rivets	N/A	3/ PCB	**0.45**	**N/A**
Screw	Machine screw	1	Pozi Countersunk M6 Screw	Nuts, Bolts & Things	CRC3	Screw	N/A	Place in hole, in the back of robot's body	**0.02**	**N/A**
Robot Body	MDF base + Plastic bits	1	Plastic wheel + miniature motor	N/A	N/A	N/A	N/A	Approx.: £2.50 / Wheel and motor + £2/ MDF base	**6.5**	**N/A**
								Total w/o delivery fee	**31.301**	**11.759**
								Total w/ delivery fee	**43.101**	**free delivery**

Table 3. BoM. Cost of 1 unit with and without delivery fee VS. mass production cost (front face was neglected).