

ELECTRONICS 1 - ASSIGNMENT 1 - MICHAEL HOWELLS

by Michael Howells

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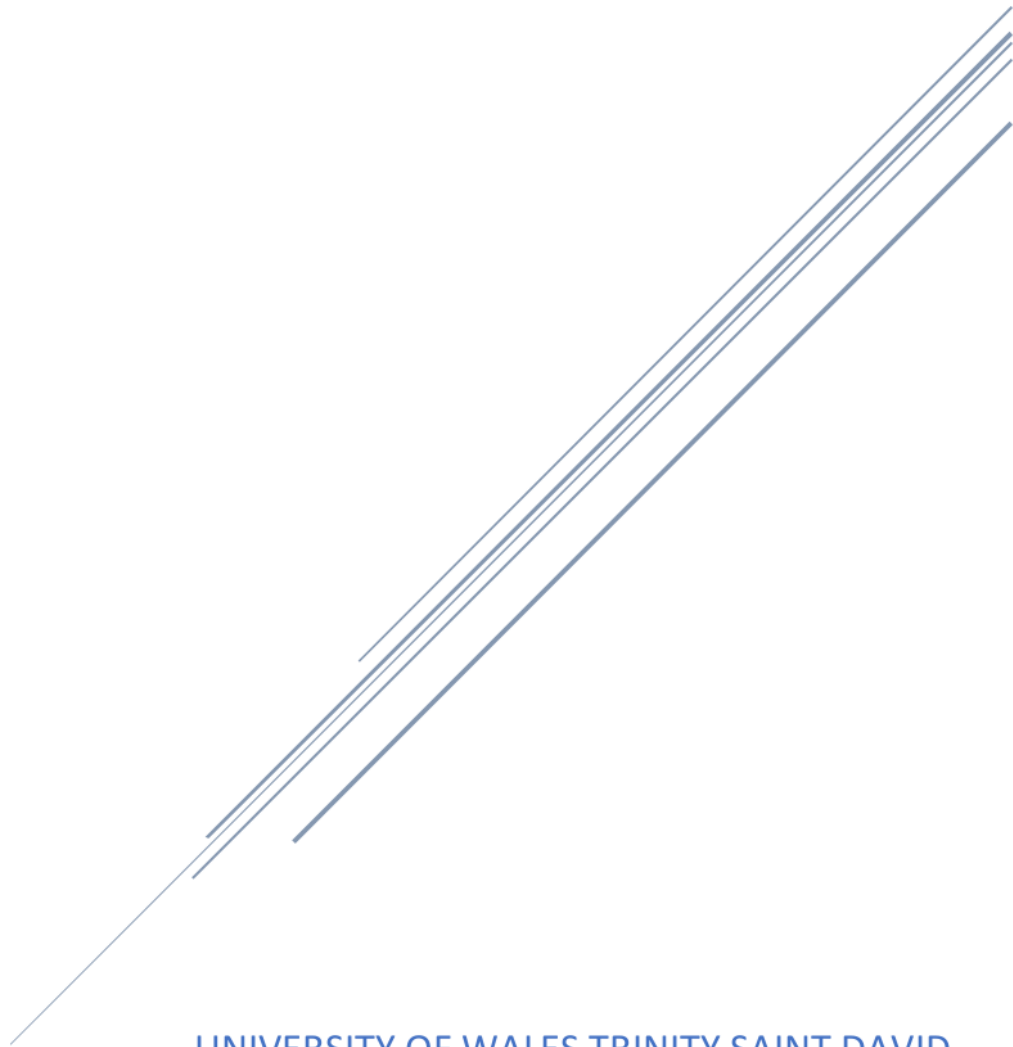
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DESIGN OF A SMART REAR BICYCLE LIGHT

ASSIGNMENT 1

BY MICHAEL HOWELLS



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ELECTRONICS 1 – ACDA5002

DESIGN BRIEF

“Design a ‘smart rear bicycle light’ that is controlled by a PIC microcontroller.”

REQUIREMENTS

Cycling is a mode of transport with has inherent dangers as the cyclist will often take public roads where incidents can commonly occur for a multitude of reasons such as collisions with other traffic. Figure 1 shows the total pedal cyclist casualties from 2010 – 2020. The average casualties per year in this time is 18,417 [1]. This shows that each year there is a large amount of people are affected and there are ways in which individuals can help to mitigate this issue.

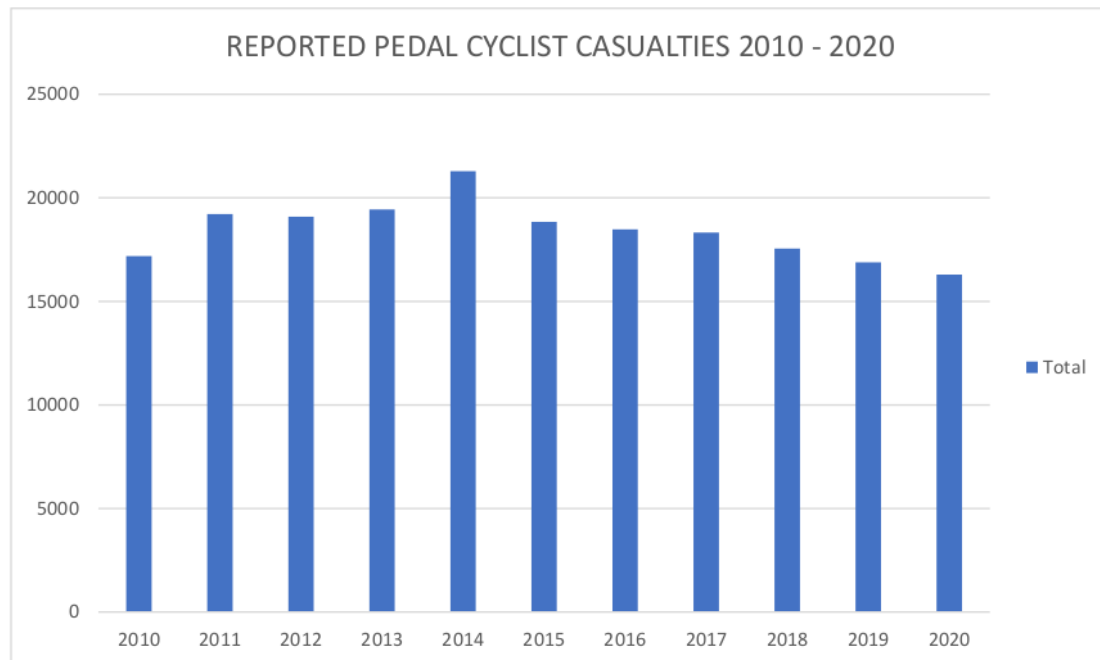


Figure 1

Most cycling accidents occur in urban areas, however the likelihood of a fatal injury is higher in rural areas. This is due to the higher average speeds on urban roads and the increased amount of narrow roads, dips and blind bends [2]. It is therefore key for cyclist to make themselves as conspicuous as possible when out on the road.

It is a legal requirement in the UK to use a white front lamp, red rear lamp, red rear reflector and amber pedal reflectors on the front and rear on a bike if it is to be ridden in hours of darkness. [3] Flashing lights are permitted but it is recommended that cyclists use a static front light in areas without street lighting [4]. Hours of darkness is defined as from half an hour after sunset to half an hour before the sun rise.

In summary, the rear bike light design that is specified in this document must be red to meet the requirements set in The Road Vehicle Lighting Regulations Act 1989 [3]. The design should also meet the BS6102/3 if it was to be sold in the UK [5]. This standard specifies the photometric and physical requirements of lighting equipment for bicycles. However, as this document is not freely available the product designed may not meet these requirements. The design could be reviewed retrospectively if it were to be taken to market.

MARKET RESEARCH

To understand the existing specifications of rear bike lights in the market, data has been gathered from bike supplier websites. A compiled dataset showing 25 different rear bike lights and noting their characteristics such as price / maximum brightness / maximum battery life and how much they weigh. Not all products had each characteristic shown on their supplier webpage and so some are not represented in all the graphs below. The dataset can be seen under the 'RESEARCH DATA' heading at the end of this assignment.

The purpose of this research is to understand the ranges of certain characteristics of existing products. This information can be used to help influence design choices to ensure it has characteristics that are comparable to existing products. For example, how bright will it need to be? How long does the battery need to last? It is even possible to identify gaps in the market and target a new design to exploit it.

The research is presented on subsequent pages.

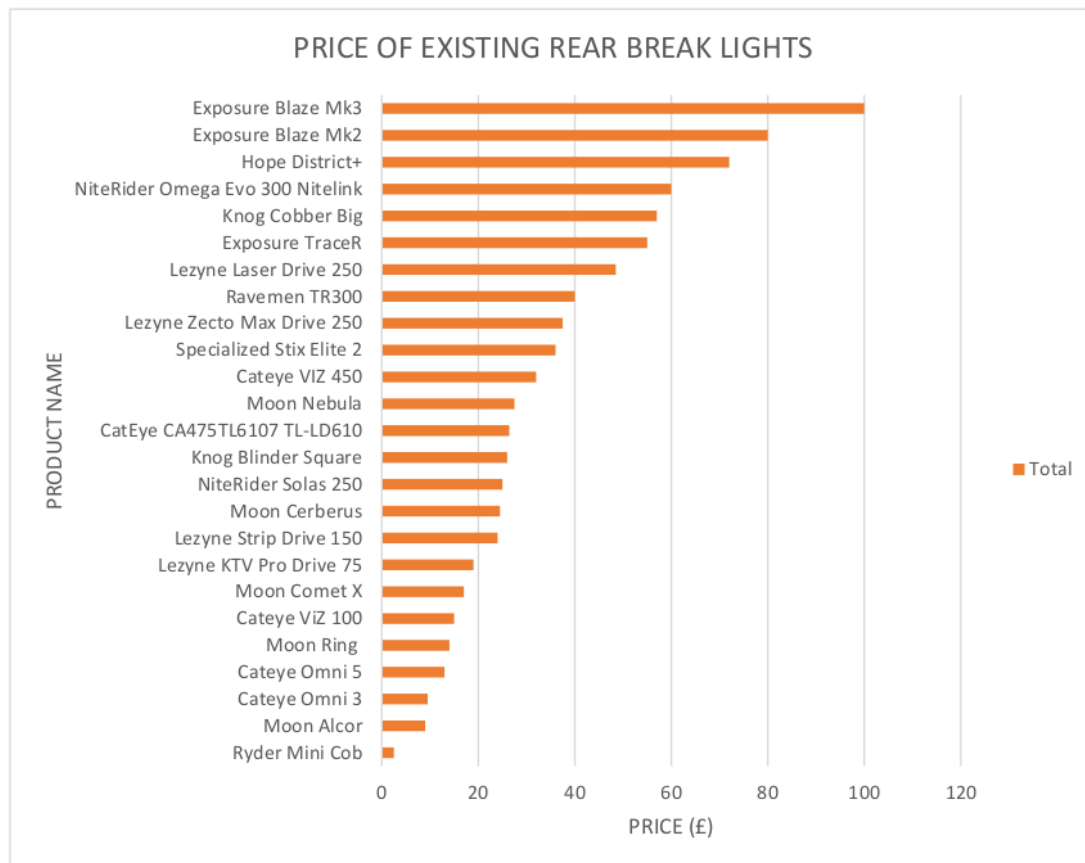


Figure 2

Figure 2 shows a graph of the prices for the existing products. There is a broad range of prices from £2.49 up to £100.

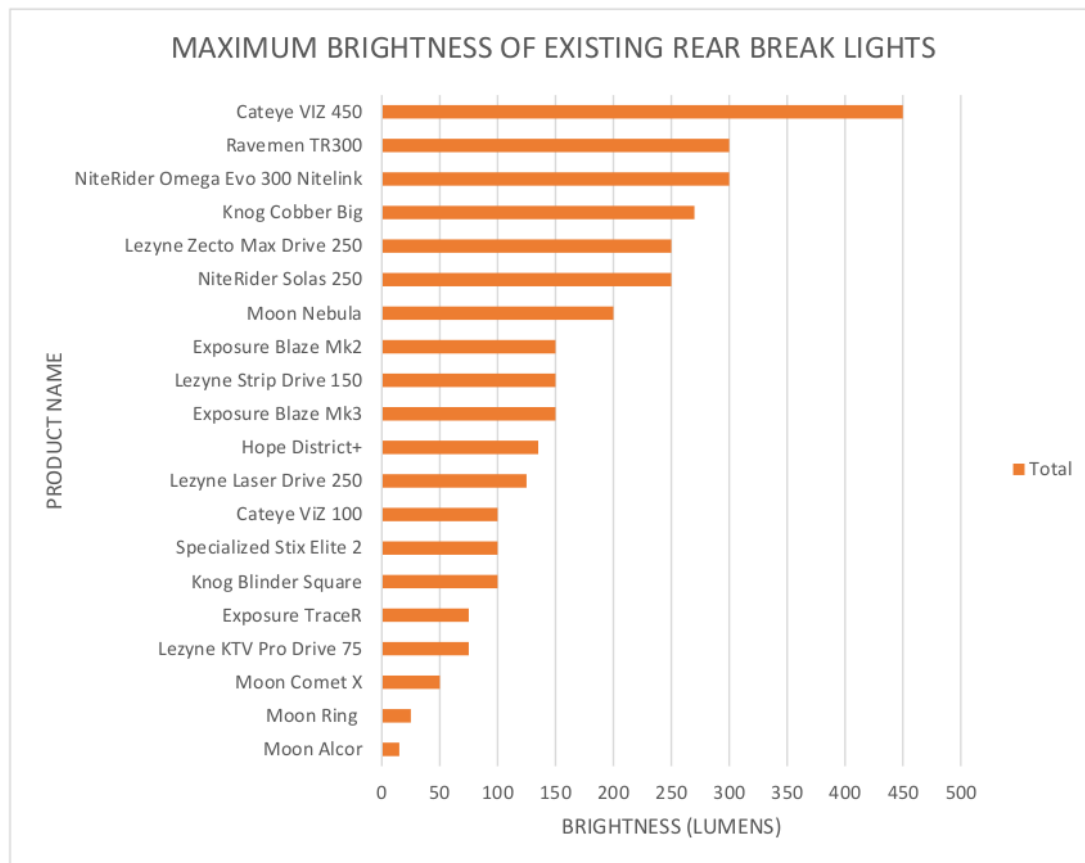


Figure 3

Figure 3 shows a graph of the maximum brightness for the existing products. The maximum brightness ranges from 15 – 450 lumens.

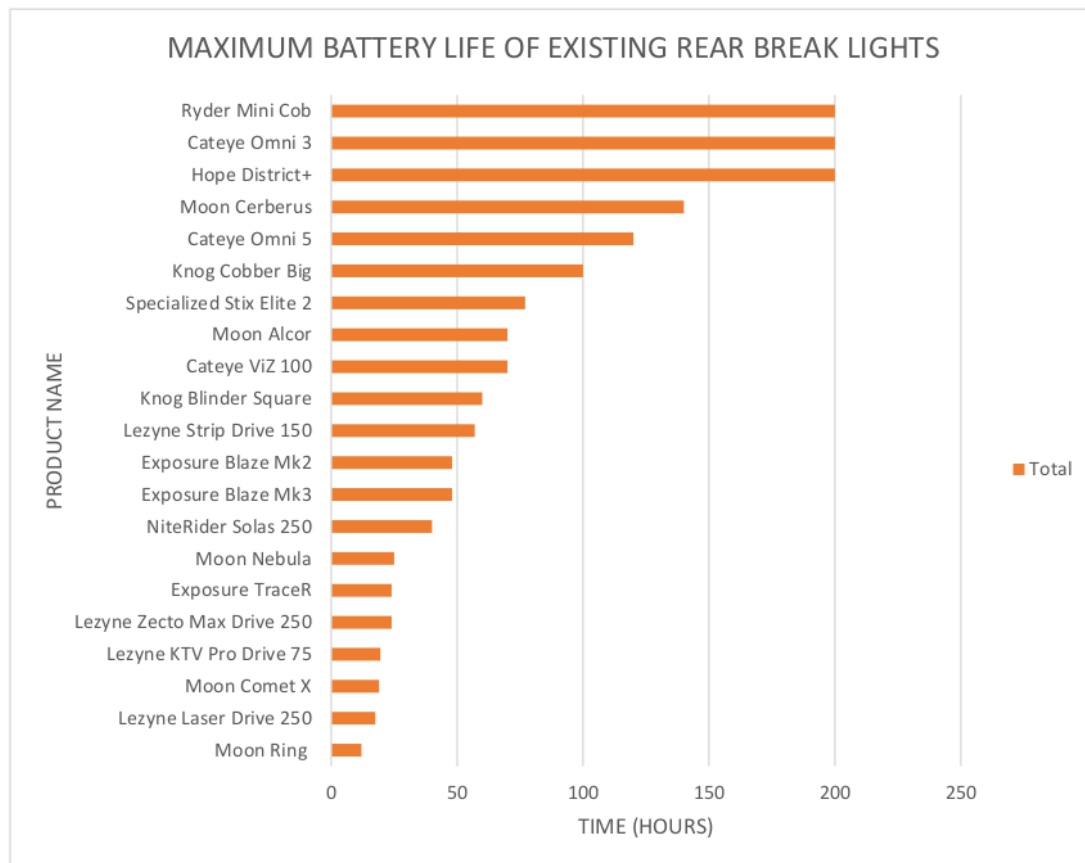


Figure 4

Figure 4 shows a graph of the maximum battery life for the existing products. The maximum battery life ranges from 12 – 200 hours.

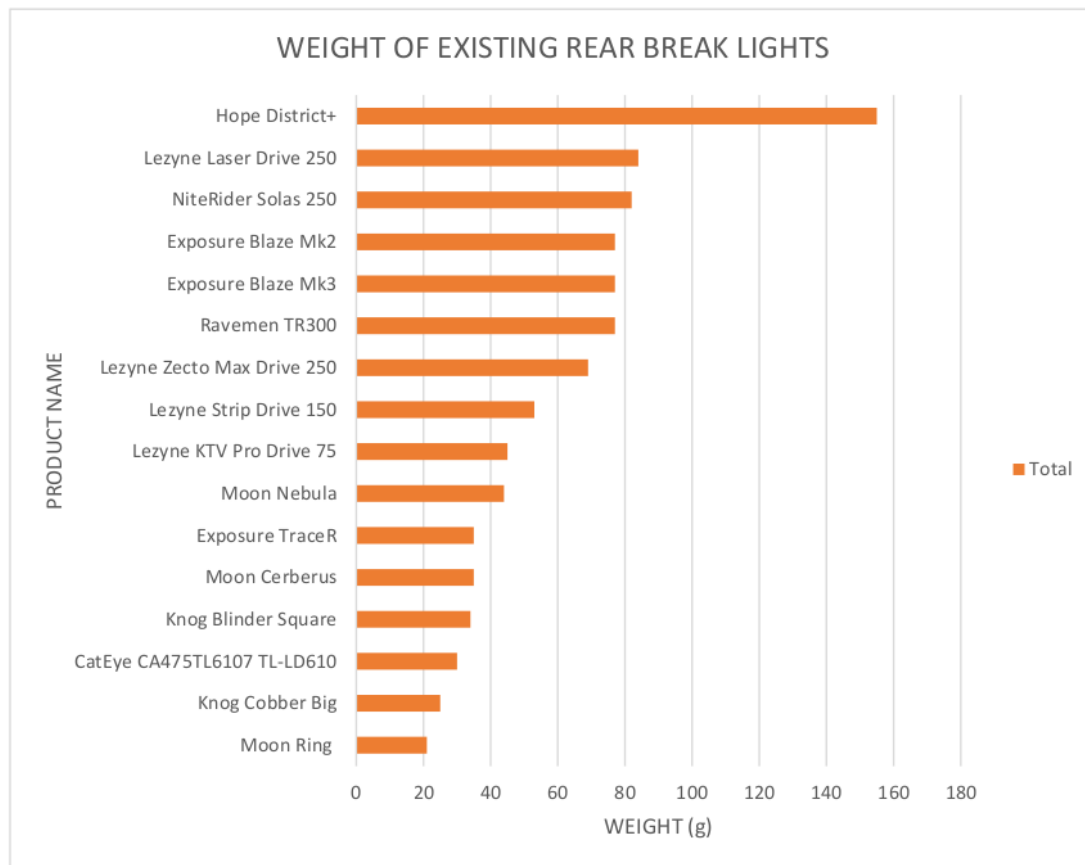


Figure 5

Figure 5 shows a graph of the weights of existing products. The weights ranges from 21 – 155 grams.

MARKET RESEARCH SUMMARY

The market research shows that there is a large variation in the characteristics of rear bike lights. There were not any clear trends within the data. It does seem that the higher priced bike lights have more custom features designed into them. For example, the Exposure Blaze Mk3 Rear Light has a feature called peloton mode which causes it to detect if the cyclist is in a group; it will then increase the brightness of the light on the bike at the back of the group and all others will remain dimmer as it could be a distraction for the cyclists. [6]

With this data it will be easy to compare any new designs with existing products and see where it fits within the current market. The new design could also take inspiration from the higher end products and include some more advanced features.

DESIGN ELEMENTS

This section will explain some of the concepts that will need to be understood in order to design a rear bike light. The circuit should include the following elements:

- PIC microcontroller
- Red LED
- Power switch
- Button to control different brightness modes.
- Power indicator light
- Rechargeable lithium ion batteries
- Rechargeable battery circuit
- Bluetooth connectivity and functionality

PWM

Pulse width modulation is a method of controlling the power to a device by modulating the high and low components of a square wave (mark space ratio [7]). This is described as the duty cycle and it allows power to be easily controlled as it is proportional to the average voltage. The higher the duty cycle, the higher the power being supplied to a device. [8]

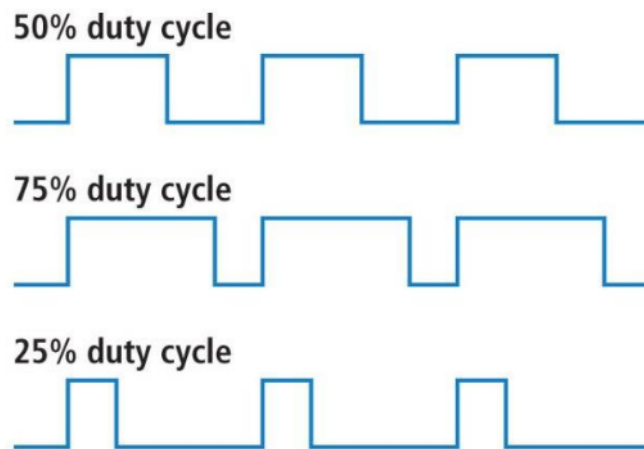


Figure 6 – Duty Cycle [9]

PWM can be used to control the brightness of LEDs and will be a key component in the rear bike light as it can be used to control the brightness. The brightness will be proportional to the power being supplied through PWM. High duty cycle will produce a bright light and a low duty cycle will produce a dim light.

BATTERIES AND CHARGING

To find a suitable battery for this circuit, battery reference tables were analyzed from the Art of electronics. [10] The 18650 type was identified as a suitable choice for multiple reasons: firstly, it is

rechargeable, it is very light at 45g, has a nominal voltage of 3.6V which is suitable for applications within the circuit. The discharge capacity of an 18650 battery is 2900mAh which is more than any of the other rechargeable batteries shown in the table.

The TP4056 is the battery charge controller IC that has been selected for the circuit. This device is capable of providing a constant current to the battery if its voltage is below 4.2V which is the fixed charge voltage. After the battery has reached this voltage the current will begin to decrease. [11]

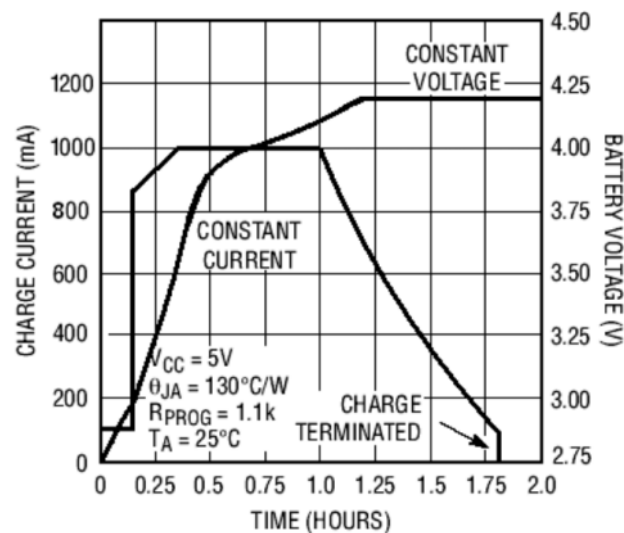


Figure 7 - TP4056 CHARGE CYCLE [11]

LEDs

In order to select a suitable LED for the rear bike light the characteristics of high power LEDs have been compared; see figure 6. It shows how the typical power consumption of each LED (blue) related to its luminous flux output (orange)(metric of perceived light by the human eye [12]). The dataset can be seen under the 'RESEARCH DATA' heading at the end of this assignment.

From the data it is clear that 7 of the LEDs have a much higher luminous flux value than others; all 7 however emit a higher wavelength of red light. This means that it is nearer the upper end of the visual light spectrum. As the LEDs will be used on a device intended to keep a bicycle rider safe, the red should be as visible as possible and so I don't think the higher wavelength LEDs are suitable.

As the device will be battery powered, the power consumption of the circuit is a key factor that must be considered when choosing components. For this reason, the XQARED-00-0000-000000Y01 has been selected for the circuit. The typical power consumption of this part is 0.385W which is joint lowest, and it has the highest luminous flux value of all LEDs with the same power consumption.

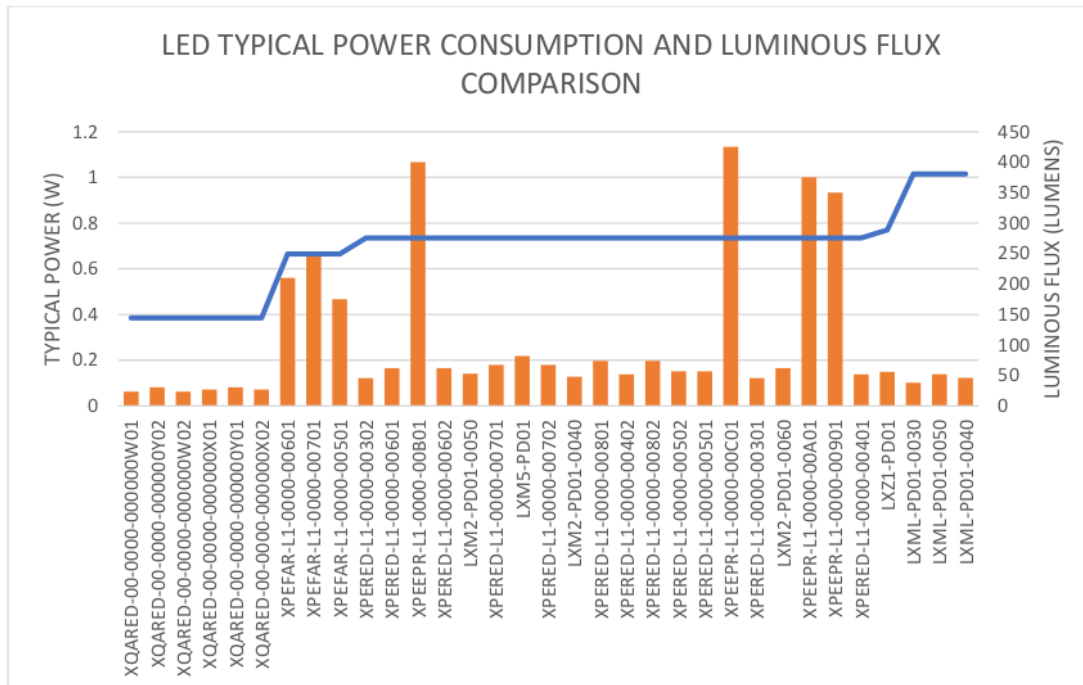


Figure 6 – LED Comparison

PIC MICROCONTROLLER

The design brief specifies a PIC microcontroller is to be used as the ‘brains’ of the light. A microcontroller is a silicon device that can be programmed to do complex operations and control circuitry by utilizing its input and output pins. A program must be designed and written for it, explicitly describing its function which will then be programmed to its memory to allow it to operate as desired.

A PIC (Programmable logic controller) is a type of microcontroller developed by Microchip. These devices are available with a vast variety of features and are selected based on the requirements of the design.

Product Family	Pin Count	Program Flash Memory (KB)	RAM (KB)	Data EE (B)	8-bit PIC® Microcontrollers																																										
					Intelligent Analog						Waveform Control										Logic and Math	Safety and Monitoring	Communications			User Interface	Low Power and System Flexibility																				
					ADC (# of bits)	Comp	HSComp	DAC (# of bits)	OPA	SlopeComp / PRG	ZCD	CCP/ECPP	10-bit PWM	16-bit PWM	COG	CMG	NCO	DSM	HLT (B-bit)	Universal Timer	NCO (B-bit)	SMT (B-bit)	RTCC	TEMP/TS	CLC	MULT	MathACC	CRC/SCAN	HLT	WWDT	USART	UART with Protocols	I2C/SPI	USB with ACT	LIN Capable	mTouch® Sensing	HCVD	LCD w/ charge pump	PFS	IDLE/DOZE/PMD	DMA/VI	DMA/MP					
PIC10(LF)30X	6	384-896 B	0.064	HEF	8																																										
PIC16F1520X	8-40	3.5-28	0.5-2	-	10																																										
PIC12/16 LF155X/6X	14-20	7-14	1.024	HEF	10 ^m																																										
PIC16(LF)145X	14-20	14	1.024	HEF	10																																										
PIC1X(LF)157X	8-20	1.75-14	1.024	HEF	10			5																																							
PIC16(LF)1530X	8-48	3.5-28	2.048	HEF	10			5																								2															
PIC1X(HV)F752/53	8-14	1.75-3.5	0.128	-	10			5/9	✓	SC																																					
PIC1X(LF)161X	8-14	3.5	0.256	HEF	10			8																																							
PIC16(LF)161X ^m	14-20	7-14	1.024	HEF	10			8																																							
PIC18-Q40/1	14-20	16-32	1-4	512	12 ^m			8	✓ ¹⁸																							2	1														
PIC16(LF)170X/71X	14-40	3.5-28	2.048	HEF	10			5/8																																							
PIC16(LF)176X/77X	14-40	7-28	2.048	HEF	10			5/10																																							
PIC16(LF)1830X	8-20	3.5-14	2.048	256	10			5																																							
PIC16(LF)1840X	14-28	7-28	2.048	256	12 ^m			5																																							
PIC16(LF)1880X	28-40	7-56	4.096	256	10 ^m			5																																							
PIC18-Q10	28-40	16-128	1-3.6	256-1K	10 ^m			5																								2															
PIC18-Q43	28-48	32-128	2-8	1024	12 ^m			8																																							
PIC18-Q84 ^m	28-48	64-128	8-13	1024	12 ^m			8																																							
PIC16(LF)1910X	28-64	14-56	4.096	256	12 ^m			5																																							
PIC18-K40	28-64	16-128	3.728	256-1K	10 ^m			5																																							
PIC18-K42	28-48	16-128	8.192	256-1K	12 ^m			5																																							
PIC18-J94	64-100	32-128	4.096	-	12																																										

Figure 7 – 8bit PIC Microcontrollers [13]

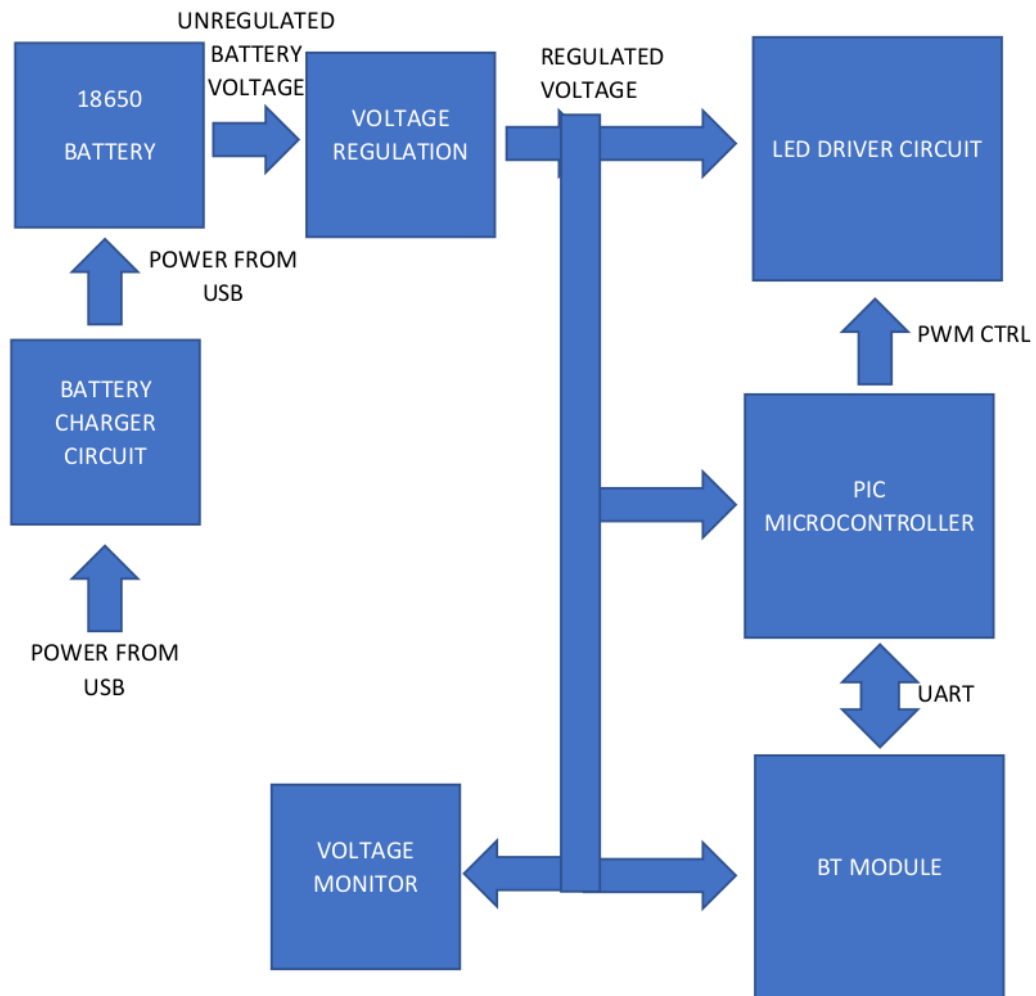
Figure 7 shows an example of the range of devices that are available in the 8-bit pic microcontroller family and the numerous features and specifications they can have. The higher bit microcontrollers can have more complex features such as ethernet [14].

The PIC18-Q40 is the microcontroller that has been selected to control the rear bike light circuit in this assignment. It has all the features that would be required in order to control the design elements specified previously. It has a PWM output to control the LED brightness, UART communication capabilities for the BT module and IOs that can be configured for other functions.

REAR BIKE LIGHT DESIGN

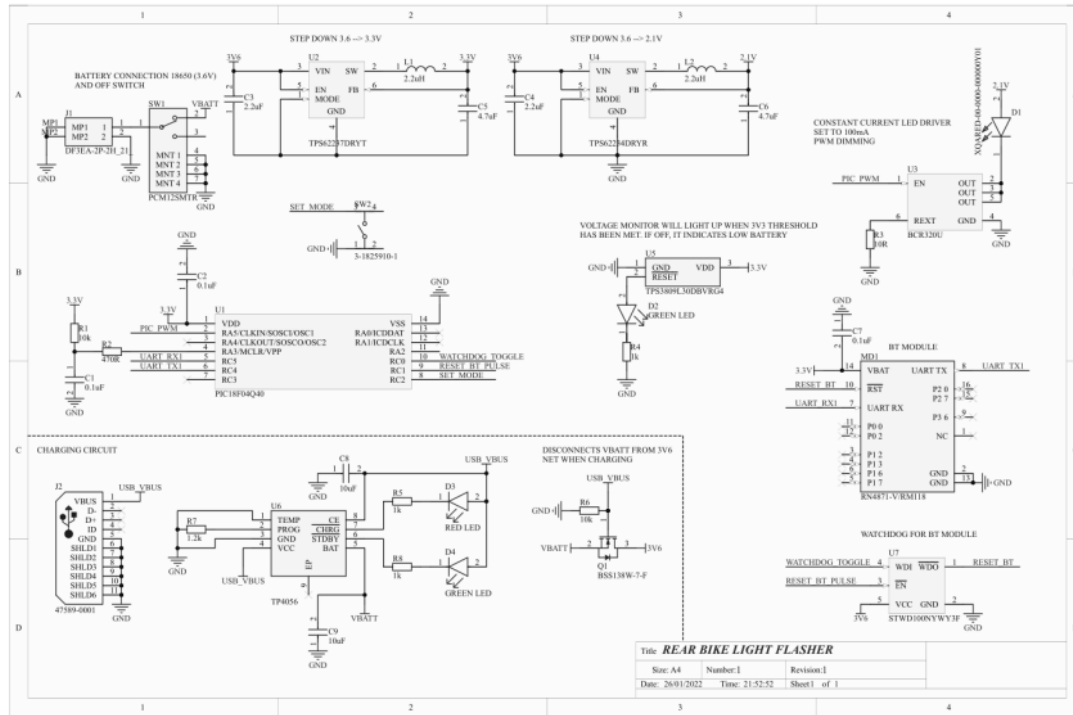
The documents on the following pages show the design for the rear bike light that was created for this assignment.

BLOCK DIAGRAM



SCHEMATIC

(Larger schematic on later pages)



The rear bike light design has the following features: Battery connector, battery switch, 2 step down converters (3.3V and 2.1V), PIC18F04Q40 microcontroller, voltage monitor, constant current LED driver IC, bluetooth module, watchdog for BT module and a battery charge circuit.

J1 is a connector that is designed to connector to the 3.6V input of a 18650 battery. The battery symbol is not shown on the schematic however the positive of the battery is shown as the Vbatt net and negative of the battery is connected to the circuit ground.

The Vbatt net is connected to the rest of the circuit through Q1, a P-channel MOSFET. This FET is pulled low using R6 so that Q1 will conduct if there is no positive voltage on USB_VBUS net. If USB_VBUS is high (+5V), which is the case if the USB connector is connected to a power supply then Q1 will not conduct from the drain to source. The purpose of Q1 is to disconnect the battery from the main part of the circuit during charging.

When USB_VBUS is at 5V, the charging circuit will be enabled. U6 will power up and start charging using power supplied through J2 and the supply it is connected to. U6 is a TP4056 [11] which is a 1A standalone linear li-ion battery charger with thermal regulation. In my circuit it has been configured to allow a 1A charge current up to 4.2V. R7 is used to configure the charge current of the circuit; I have used a 1.2k resistor to set a 1A charge current. This is specified in the datasheet. There are also 2 indicator LEDs, D3 (red) and D4 (green). They behave in the following manner; during charging, D3 will light up and D4 will go off. When charging has completed, D3 will go off and D4 will light up. If Vcc is too

low then neither will be on; such as if the charging circuit is not in use. If the charging circuit is on but the battery is not connected then D4 will be on and D3 will be flashing. These functions are designed into this IC. D3 is connected to pin 7 which is pulled low when the battery is being charged. Pin 6 is pulled low when the battery charging has completed. This IC does have a temperature sense input however it is not used in this design. C8 and C9 are filter capacitors that are used to filter out unwanted noise from the power VBAT and USB_VBUS nets.

The circuit contains two step down converts. U2 is the first and is a TPS62237DRYT. This is a step down converter that will lower a voltage to 3.3V. This is sufficient to supply the majority of components in my circuit. The reason it was added to the circuit was to reduce effect of a batteries varying voltage on the circuit. The nominal voltage of my selected 18650 batter is 3.7V, however after an extended period of time this voltage will decrease. After a charge the batteries voltage may also be higher than the nominal value. U2 will protect the circuit from any potential damage from such cases.

U2 is another step down converter IC, however it lowers the voltage to 2.1V. The LED that was selected can operate with a forward voltage of 2.1V. The current will however be considerably lower than the maximum. This lower current consumption will allow the battery life of the device to last longer.

ELECTRICAL CHARACTERISTICS ($T_j = 25^\circ\text{C}$)

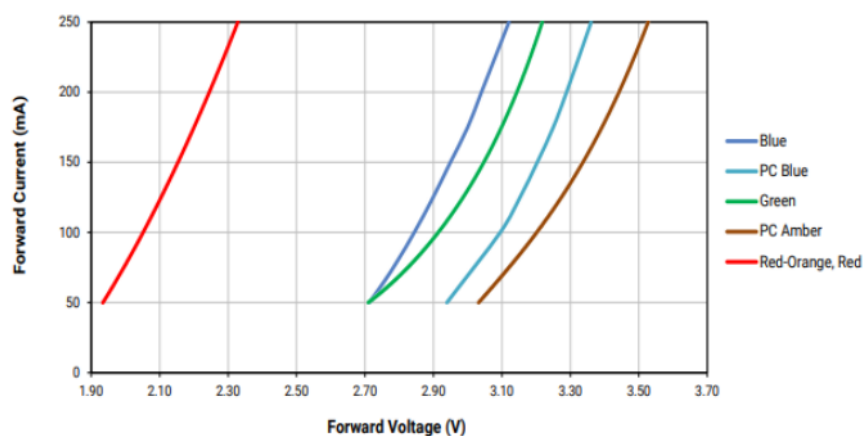


Figure 8 - ELECTRICAL CHARACTERISTIC OF XQARED-00-0000-000000Y01 [15]

U3 is a constant current LED driver IC which has been configured to maintain a current of 100mA. This device was selected to help prevents thermal runaway. Thermal runaway is when the characteristics of an LED change as its temperature increases. When the temperature increases in the LED, the resistance is lowered and so more current can flow. If the current is not regulated, then this process of decreasing resistance and increasing current can destroy the LED. [16]

100mA of current will turn the LED on at about 62.5% of the specified value. This means that my light will be 19.125 lumens of brightness at maximum. This is comparable to some of the lower brightness rear light models shown previously. U3 also has a enable line which can be connected to a PWM signal to decrease the brightness of the LED. My circuit has this connected to a PWM line on my PIC.

RELATIVE FLUX VS. CURRENT ($T_j = 25^\circ\text{C}$)

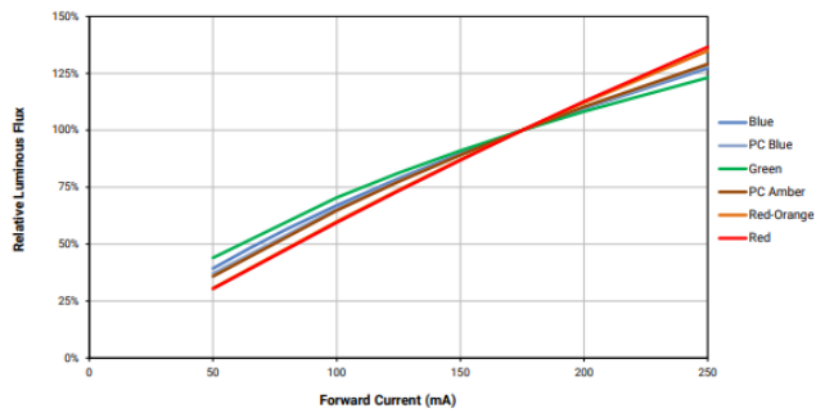


Figure 9 - RELATIVE FLUX VS. CURRENT XQARED-00-0000-000000Y01 [15]

A voltage monitor is also included in my design (U5). The purpose of this device is to ensure that 3V3 is available. If 3V3 has been detected by U5 [17], then it will light up D2, which is a green LED. This indicates that there is a sufficient voltage being supplied to the circuit. If D2 is not on then the battery may be low and need to be charged.

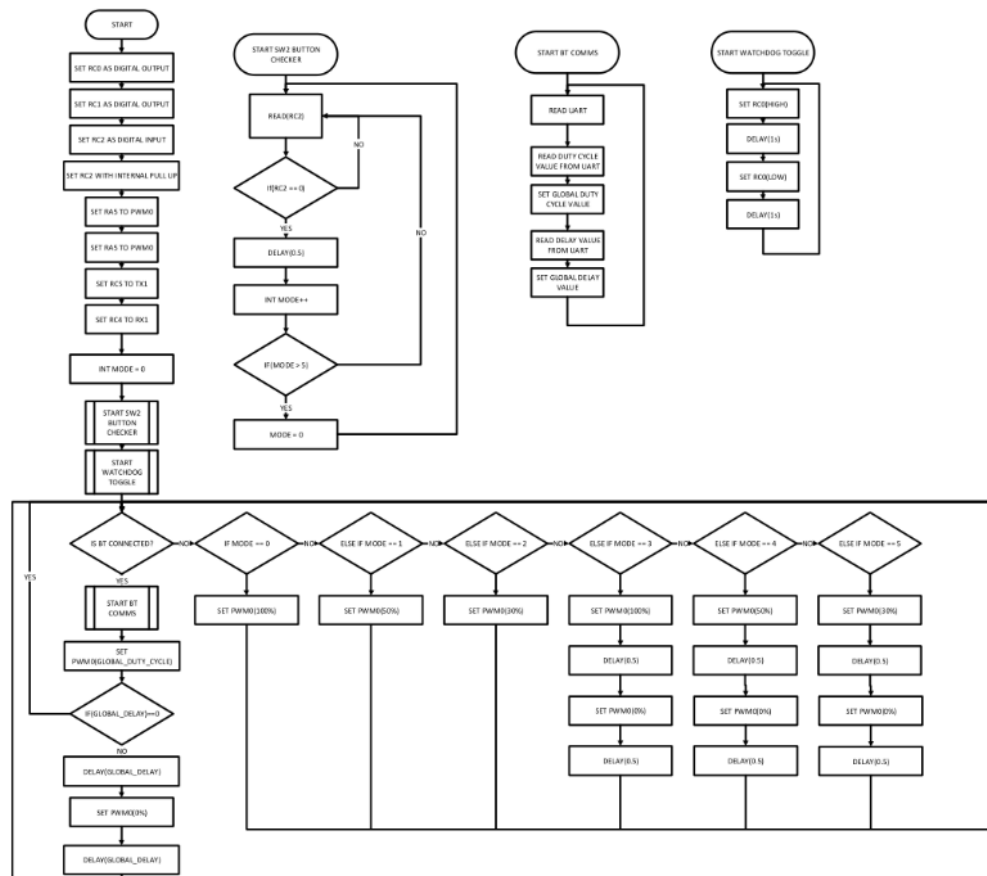
The micro controller selected for the device is a PIC18F04Q40. It was selected because it has all the features required for the design: UART, PWM and IO. The UART is to be used to communicate to the Bluetooth module (MD1) [18]. The PWM is designed to control the brightness of D1 through the enable line of U3. The IO pins that are used, toggle the watchdog timer at regular intervals. If the toggles do not happen then it indicated a problem with the microcontroller and the watchdog will reset the Bluetooth module.

A Bluetooth module is included to allow for remote control of the device through an app. This will control features such as, brightness and flashing frequency. Communication to the BT module can be done over UART which is how I intend to program it.

The battery switch, SW1 is used to power off the device when it is not being used. This will help save the battery life of the device. SW2 is used to select the flash mode manually.

OPERATIONAL FLOW CHART

The flow chart below shows the rear bike light features 5 modes that can be selected manually and 1 mode that allows the brightness and delay to be configured by values defined through Bluetooth on the UART communication port. There are 3 sub processes that are run along side the main process. These are to check the state of the button IO, to read the UART port and to continually toggle the watchdog. The delay and brightness values on the UART port would be set from an app on the users mobile phone.



BOM

DESIGNATOR	PART NUMBER	DESCRIPTION	SUPPLIER	COST (£)	REFERENCE
BATTERY 18650	MOLICEL INR18650 P26A	MOLICEL INR18650 P26A - 18650 BATTERY		5.99	[19]
J1	DF3EA-2P-2H_21_		MOUSER	0.41	[20]
SW1	PCM12SMTR		DIGIKEY	0.68	[21]
C3	CC0603KRX6S6BB225	2.2UF	DIGIKEY	0.15	[22]
C4	CC0603KRX6S6BB225	2.2UF	DIGIKEY	0.15	[22]
U2	TPS62237DRYT		MOUSER	1.23	[23]
U4	TPS62234DRYR		MOUSER	1.14	[24]
L1	LQW15CE2R2M10D	2.2UH	MOUSER	0.2	[25]
L2	LQW15CE2R2M10D	2.2UH	MOUSER	0.2	[25]
SW2	3-1825910-1		FARNELL	0.2136	[26]
U1	PIC18F04Q40		MOUSER	0.784	[27]
R1	RE0603BRE0710KL	10K	DIGIKEY	0.27	[28]
R2	CHP0603AFX-4700ELF	470R	DIGIKEY	0.43	[29]
C1	UMF107B7104KAHT	0.1UF	DIGIKEY	0.16	[30]
C2	UMF107B7104KAHT	0.1UF	DIGIKEY	0.16	[30]
U5	TPS3809L30DBVRG4		MOUSER	0.315	[31]
D2	SML-D12P8W	GREEN LED	MOUSER	0.292	[32]
R4	MCT0603MC1001FP500	1K	DIGIKEY	0.25	[33]
U3	BCR320U		MOUSER	0.569	[34]
D1	XQARED-00-0000-000000Y01	RED LED	DIGIKEY	0.3267	[35]
R3	FRC16C1J100JTP	10R	DIGIKEY	0.07	[36]
MD1	RN4871-V/RM118		DIGIKEY	5.72	[37]
C7	UMF107B7104KAHT	0.1UF	DIGIKEY	0.16	[30]
U7	STWD100NYWY3F		MOUSER	0.922	[38]
R6	RE0603BRE0710KL	10K	DIGIKEY	0.27	[28]
Q1	BSS138W-7-F	P CHANNEL MOSFET	MOUSER	0.246	[39]
D3	SML-D12U8W	RED LED	MOUSER	0.361	[40]
D4	SML-D12P8W	GREEN LED	MOUSER	0.292	[32]
R5	MCT0603MC1001FP500	1K	DIGIKEY	0.25	[33]
R8	MCT0603MC1001FP500	1K	DIGIKEY	0.25	[33]
C9	AMK107ABJ106KAHT	10UF	DIGIKEY	0.14	[41]
U6	TP4056		ALI EXPRESS	0.46	[42]
R7	RMCF0603FT1K20	1.2K	DIGIKEY	0.07	[43]
C8	AMK107ABJ106KAHT	10UF	DIGIKEY	0.14	[41]
J2	47589-0001		MOUSER	0.922	[44]

CONCLUSION

The rear bike light that was design and presented in this assignment is a success as it has features that are comparable to those in existing products. Firstly, the maximum brightness of the LED in the current design would be around 19.125Lumens. This is the second lowest maximum brightness however.

The total cost of all parts on the current BOM is £22.58 which is far from the most expensive costing product from the existing product sample. The cost of parts in shown in the BOM was mostly from buying single parts and so if this product was mass produced and parts were bought in bulk, the price would decrease considerably. A cost that is not included in the BOM is that of the PCB which would need to be manufactured in order to build the product. The cost of populating the parts, programming and testing is also not included and this would also need to be added to the total costs of manufacturing. If a PCB were made of this design, the programming could be done via test point connected to the two ICSP pins on the PIC. A bed of nails jig that has a programming tool connected could do the programming. This is not reflected in the design at the moment however.

If a second revision of this bike light was designed, there are some additional features that could be included to improve upon the existing design. The Bluetooth connectivity function in the software could be expanded further to allow for different flashing options. Currently the software only allows for intervals with the same on and off time however this could be changed in future iterations.

The driver circuit for the main LED could also improved to include additional LEDs. This would add some redundancy to the design as currently there is only 1 LED and if it breaks the device is effectively useless. If the system had 3 LEDs and 1 broke then it would still operate correctly and as the rear light is a safety feature, the redundancy could save someone's life.

Even if there are ways in which the current bike light can be improved, the current design will meet the requirements of a rear bike light and allow a user to cycle at night.

RESEARCH DATA

Year	Killed	Seriously injured (unadjusted)	Seriously injured (adjusted)	KSI (unadjusted) ¹	KSI (adjusted) ¹	Slightly injured (unadjusted)	Slightly injured (adjusted)	All casualties
2010	111	2,660	3,854	2,771	3,965	14,414	13,220	17,185
2011	107	3,085	4,410	3,192	4,517	16,023	14,698	19,215
2012	118	3,220	4,560	3,338	4,678	15,753	14,413	19,091
2013	109	3,136	4,530	3,245	4,639	16,193	14,799	19,438
2014	113	3,399	4,947	3,512	5,060	17,775	16,227	21,287
2015	100	3,237	4,551	3,337	4,651	15,507	14,193	18,844
2016	102	3,371	4,326	3,473	4,428	15,004	14,049	18,477
2017	101	3,673	4,311	3,774	4,412	14,547	13,909	18,321
2018	99	3,693	4,301	3,792	4,400	13,758	13,150	17,550
2019	100	3,657	4,121	3,757	4,221	13,127	12,663	16,884
2020	141	3,828	4,215	3,969	4,356	12,325	11,938	16,294

[1]

PRODUCT NAME	PRICE (£)	WEIGHT (g)	MAXIMUM BRIGHTNESS (lumens)	MINIMUM BRIGHTNESS (lumens)	MAXIMUM BATTERY LIFE (HOURS)	MINIMUM BATTERY LIFE (HOURS)	SOURCE	NOTES
Ryder Mini Cob Rear Light	2.49				200		[45]	
Moon Alcor Rechargeable Rear Bike Light	8.99		15	3	70	8	[46]	
Cateye Omni 3 LED Rear Bike Light	9.49				200		[47]	
Cateye Omni 5 LED Rear Bike Light	12.99				120		[48]	
Moon Ring USB Rechargeable 25 Lumens Rear Bike Light	13.99	21	25	6	12	1.5	[49]	
Cateye VIZ 100 Rear Bike Light	14.99		100	10	70	5	[50]	
Moon Comet X Rear Light	16.99		50		19		[51]	
Lezyne KTV Pro Drive 75 USB Rechargeable Rear Light	19	45	75		19.5		[52]	
Lezyne Strip Drive 150 USB Rechargeable Rear Light	24	53	150		57		[53]	
Moon Cerberus Rear Light	24.49	35			140		[54]	
NiteRider Solas 250 Rear Light	25	82	250		40	4.3	[55]	
Knog Blinder Square USB Rechargeable Rear Light	25.99	34	100		60	2.5	[56]	
CatEye CM75TL6107 TL-LD610 LED Rear Light, Black	26.41	30					[57]	
Moon Nebula Rear Light	27.49	44	200	20	25	1.1	[58]	
Cateye VIZ 450 Rear Light	31.99		450				[59]	
Specialized Stix Elite 2 Taillight	36		100	12	77	2.5	[60]	
Lezyne Zecto Max Drive 250 USB Rechargeable Rear Light	37.49	69	250	5	24	6	[61]	
Ravemen TR300 USB Rechargeable Rear Light - 300 Lumens	39.99	77	300				[62]	
Lezyne Laser Drive 250 USB Rechargeable Rear Light	48.5	84	125	6	17.5	4	[63]	
Exposure TraceR Rear Light	55	35	75		24	3	[64]	
Knog Cobber Big USB Rechargeable Rear Light	56.99	25	270	15	100	2	[65]	
NiteRider Omega Evo 300 Nitelink Rear Light	60		300				[66]	
Hope District+ Rear Light	72	155	135		200	15	[67]	
Exposure Blaze Mk2 DayBright Rear Light	79.99	77	150		48	6	[68]	
Exposure Blaze Mk3 Rear Light	100	77	150		48	6	[6]	Peloton made

Part Number	Typical Luminous Flux	Typical Forward Voltage (V)	Typical Forward Current (A)	Typical Power Consumption (W)	Max Forward Current (mA)	Note	Source
LXM2-PD01-0040	48	2.1	0.35	0.735	700	red	[69]
LXM2-PD01-0050	53	2.1	0.35	0.735	700	red	[69]
LXM2-PD01-0060	62	2.1	0.35	0.735	700	red	[69]
LXM5-PD01	82	2.1	0.35	0.735	700	red	[69]
LXML-PD01-0030	38	2.9	0.35	1.015	700	red	[69]
LXML-PD01-0040	46	2.9	0.35	1.015	700	red	[69]
LXML-PD01-0050	52	2.9	0.35	1.015	700	red	[69]
LXZ1-PD01	56	2.2	0.35	0.77	700	red	[70]
XPEEPR-L1-0000-00901	350	2.1	0.35	0.735	1000	HE Photo Red, higher wavelength	[71]
XPEEPR-L1-0000-00A01	375	2.1	0.35	0.735	1000	HE Photo Red, higher wavelength	[71]
XPEEPR-L1-0000-00B01	400	2.1	0.35	0.735	1000	HE Photo Red, higher wavelength	[71]
XPEEPR-L1-0000-00C01	425	2.1	0.35	0.735	1000	HE Photo Red, higher wavelength	[71]
XPEFAR-L1-0000-00501	175	1.9	0.35	0.665	1000	far red higher wavelength	[71]
XPEFAR-L1-0000-00601	210	1.9	0.35	0.665	1000	far red higher wavelength	[71]
XPEFAR-L1-0000-00701	250	1.9	0.35	0.665	1000	far red higher wavelength	[71]
XPERED-L1-0000-00301	45.7	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00302	45.7	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00401	51.7	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00402	51.7	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00501	56.8	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00502	56.8	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00601	62	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00602	62	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00701	67.2	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00702	67.2	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00801	73.9	2.1	0.35	0.735	1000	red	[71]
XPERED-L1-0000-00802	73.9	2.1	0.35	0.735	1000	red	[71]
XQARED-00-0000-00000W01	23.5	2.2	0.175	0.385	250	red	[15]
XQARED-00-0000-00000W02	23.5	2.2	0.175	0.385	250	red	[15]
XQARED-00-0000-00000X01	26.8	2.2	0.175	0.385	250	red	[15]
XQARED-00-0000-00000X02	26.8	2.2	0.175	0.385	250	red	[15]
XQARED-00-0000-00000Y01	30.6	2.2	0.175	0.385	250	red	[15]
XQARED-00-0000-00000Y02	30.6	2.2	0.175	0.385	250	red	[15]

REFERENCES

- [1] Department for Transport, "Reported road accidents, vehicles and casualties tables for Great Britain - RAS30001," 24 6 2021. [Online]. Available: <https://www.gov.uk/government/statistical-data-sets/reported-road-accidents-vehicles-and-casualties-tables-for-great-britain>. [Accessed 5 1 2022].
- [2] Department for Transport, "Facts on pedal cycle casualties," 6 2015. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/447674/pedal-cyclists-2013-data.pdf. [Accessed 5 1 2021].
- [3] UK Government, "The Road Vehicles Lighting Regulations 1989," 1 11 1989. [Online]. Available: <https://www.legislation.gov.uk/uksi/1989/1796/made>. [Accessed 5 1 2022].
- [4] Department for Transport, "Rules for cyclists (59 to 82)," 1 10 2015. [Online]. Available: <https://www.gov.uk/guidance/the-highway-code/rules-for-cyclists-59-to-82>. [Accessed 5 1 2021].
- [5] The British Standards Institution, "BS 6102-3," The British Standards Institution, 28 2 1986. [Online]. Available: <https://landingpage.bsigroup.com/LandingPage/Undated?UPI=00000000030100872>. [Accessed 5 1 2022].
- [6] Tredz, "Exposure Blaze Mk3 Rear Light," [Online]. Available: https://www.tredz.co.uk/.Exposure-Blaze-Mk3-Rear-Light_128114.htm. [Accessed 4 1 2022].
- [7] J. Morton, "Advanced operations and the future," in *The PIC Microcontroller: Your Personal Introductory Course - Third Edition*, Elsevier, 2005, p. 140.
- [8] T. R. Kuphaldt, "Lessons In Electric Circuits, Volume III –," All About Circuits, 3 2009. [Online]. Available: <https://www.allaboutcircuits.com/textbook/semiconductors/chpt-11/pulse-width-modulation/>. [Accessed 6 1 2022].
- [9] "512e869bce395fbc64000002.JPG (650×446)," [Online]. Available: <https://cdn.sparkfun.com/assets/f/9/c/8/a/512e869bce395fbc64000002.JPG>. [Accessed 6 1 2022].
- [10] W. H. Paul Horowitz, *The Art of Electronics - Third Edition*, Cambridge University Press, 2015.
- [11] "TP4056 1A Standalone Linear Li-Ion Battery Charger with Thermal," [Online]. Available: <https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf>. [Accessed 26 01 2022].
- [12] R. Nave, "Luminous Flux," [Online]. Available: <http://hyperphysics.phy-astr.gsu.edu/hbase/vision/lumpow.html>. [Accessed 8 1 2021].

- [13] Microchip, "30010068G.pdf," [Online]. Available: <https://ww1.microchip.com/downloads/en/DeviceDoc/30010068G.pdf>. [Accessed 7 1 2022].
- [14] Microchip, "60001455F.pdf," [Online]. Available: <https://ww1.microchip.com/downloads/en/DeviceDoc/60001455F.pdf>. [Accessed 7 1 2022].
- [15] CREE LED, "XLamp XQ-A LEDs Data Sheet," [Online]. Available: <https://cree-led.com/media/documents/ds-XQA.pdf>. [Accessed 8 1 2021].
- [16] B. Sault, "Thermal Runaway Explained," LED SUPPLY, 05 02 2019. [Online]. Available: <https://www.ledsupply.com/blog/thermal-runaway-explained/>. [Accessed 26 01 2022].
- [17] Texas Instruments, "TPS3809x 3-Pin Supply Voltage Supervisors," [Online]. Available: https://www.ti.com/lit/ds/symlink/tps3809.pdf?HQS=dis-mous-null-mouser-mode-dsf-pf-null-ww&ts=1643150101577&ref_url=https%253A%252F%252Fwww.mouser.co.uk%252F. [Accessed 26 01 2022].
- [18] Microchip, "RN4870/71 Datasheet," [Online]. Available: <https://ww1.microchip.com/downloads/en/DeviceDoc/RN4870-71-Data-Sheet-DS50002489E.pdf>. [Accessed 26 01 2022].
- [19] 18650, "MOLICEL INR18650 P26A - 18650 BATTERY," [Online]. Available: <https://www.18650.uk/molicel-inr18650-p26a-18650-battery>. [Accessed 27 01 2022].
- [20] MOUSER, "DF3EA-2P-2H_21_," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Hirose-Connector/DF3EA-2P-2H21?qs=2YoLD1ZR6YmLH1EuLTO%2FuQ%3D%3D>. [Accessed 27 01 2022].
- [21] DIGIKEY, "PCM12SMTR," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/c-k/PCM12SMTR/1640112>. [Accessed 27 01 2022].
- [22] DIGIKEY, "CC0603KRX6S6BB225," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/yageo/CC0603KRX6S6BB225/15766663>. [Accessed 27 01 2022].
- [23] MOUSER, "TPS62237DRYT," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Texas-Instruments/TPS62237DRYT?qs=%2Fqzd9s%252BcLd7vFZjJWIGI9A%3D%3D>. [Accessed 27 01 2022].
- [24] MOUSER, "TPS62234DRYR," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Texas-Instruments/TPS62234DRYR?qs=c7TMWsStreSCXWa6zj1wIQ%3D%3D>. [Accessed 27 01 2022].
- [25] MOUSER, "LQW15CE2R2M10D," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Murata-Electronics/LQW15CE2R2M10D?qs=XAiT9M5g4x9OmD64WY3OoQ%3D%3D>. [Accessed 27 01 2022].

- [26] FARNELL, "3-1825910-1," [Online]. Available: https://uk.farnell.com/alcoswitch-te-connectivity/3-1825910-1/tactile-switch-spst-50ma-24v-though/dp/2531294?gclid=Cj0KCQiA_8OPBhDtARIsAKQu0gbJEDBReLtaJaCxtmrXR4wxjzawDYxLV6dfd7fuqkxLy8HGiM6ZZQaArfxEALw_wcB&mckv=syfoEiFnx_dc|pcrid|378026980069|kword|3-18. [Accessed 27 01 2022].
- [27] MOUSER, "PIC18F04Q40," [Online]. Available: https://www.mouser.co.uk/ProductDetail/Microchip-Technology/PIC18F04Q40-I-SL?qs=W%2FMpXkg%252BdQ7rrkIL9P6HoA%3D%3D&gclid=Cj0KCQiA_8OPBhDtARIsAKQu0gbSUHeOfRyVYK-UHe7qEx3GgqJOfoTT6AACnzawfKBKoxXqY8d1wicaApGNEALw_wcB. [Accessed 27 01 2022].
- [28] DIGIKEY, "RE0603BRE0710KL," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/yageo/RE0603BRE0710KL/5923093>. [Accessed 27 01 2022].
- [29] DIGIKEY, "CHP0603AFX-4700ELF," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/bourns-inc/CHP0603AFX-4700ELF/12144442>. [Accessed 27 01 2022].
- [30] DIGIKEY, "UMF107B7104KAHT," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/taiyo-yuden/UMF107B7104KAHT/10379126>. [Accessed 27 01 2022].
- [31] MOUSER, "TPS3809L30DBVRG4," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Texas-Instruments/TPS3809L30DBVRG4?qs=sGAEPiMZZMunEhqKs81nFKfiE9Blw%252BwNwSdbdUGq8k%3D>. [Accessed 27 01 2022].
- [32] MOUSER, "SML-D12P8W," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/ROHM-Semiconductor/SML-D12P8WT86C?qs=HXFqYaX1Q2wFepzn1zWRrg%3D%3D>. [Accessed 27 01 2022].
- [33] DIGIKEY, "MCT0603MC1001FP500," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/vishay-beyschlag-draloric-bc-components/MCT0603MC1001FP500/3882983>. [Accessed 27 01 2022].
- [34] MOUSER, "BCR320U," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Infineon-Technologies/BCR-320U-E6327?qs=OWKQh20chupWV8Dc03fqPg%3D%3D>. [Accessed 27 01 2022].
- [35] DIGIKEY, "XQARED-00-0000-000000Y01," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/cree-inc/XQARED-00-0000-000000Y01/5808011>. [Accessed 27 01 2022].

- [36] DIGIKEY, "FRC16C1J100JTP," [Online]. Available:
<https://www.digikey.co.uk/en/products/detail/kamaya-inc/FRC16C1J100JTP/15181275>.
[Accessed 27 01 2022].
- [37] DIGIKEY, "RN4871-V/RM118," [Online]. Available:
<https://www.digikey.co.uk/en/products/detail/microchip-technology/RN4871-V-RM118/6130476>. [Accessed 27 01 2022].
- [38] MOUSER, "STWD100NYWY3F," [Online]. Available:
<https://www.mouser.co.uk/ProductDetail/STMicroelectronics/STWD100NYWY3F?qs=jWm4idrLpzx15dHtESXwMQ%3D%3D>. [Accessed 27 01 2022].
- [39] MOUSER, "BSS138W-7-F," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/Diodes-Incorporated/BSS138W-7-F?qs=5zGBC69kmp6%2FnOvJMzpLyg%3D%3D>. [Accessed 27 01 2022].
- [40] MOUSER, "SML-D12U8W," [Online]. Available: <https://www.mouser.co.uk/ProductDetail/ROHM-Semiconductor/SML-D12U8WT86C?qs=HXFqYaX1Q2wNcb%2FPJz96zg%3D%3D>. [Accessed 27 01 2022].
- [41] DIGIKEY, "AMK107ABJ106KAHT," [Online]. Available:
<https://www.digikey.co.uk/en/products/detail/taiyo-yuden/AMK107ABJ106KAHT/10473822>.
[Accessed 27 01 2022].
- [42] ALI EXPRESS, "TP4056," [Online]. Available:
https://www.aliexpress.com/item/32945436712.html?_randl_currency=GBP&_randl_shipto=GB&src=google&aff_fcid=f408a959e3e04b6e836413c298e4ed90-1643240443456-09289-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=f408a959e3e04b6e836413c298e. [Accessed 27 01 2022].
- [43] DIGIKEY, "RMCF0603FT1K20," [Online]. Available:
<https://www.digikey.co.uk/en/products/detail/stackpole-electronics-inc/RMCF0603FT1K20/1761134>. [Accessed 27 01 2022].
- [44] MOUSER, "47589-0001," [Online]. Available:
<https://www.mouser.co.uk/ProductDetail/Molex/47589-0001?qs=KKUMDL8WE1J88PqW%2FNep5w%3D%3D>. [Accessed 27 01 2022].
- [45] Tredz, "Ryder Mini Cob Rear Light," [Online]. Available: https://www.tredz.co.uk/.Ryder-Mini-Cob-Rear-Light_229914.htm. [Accessed 1 4 2022].
- [46] Tredz, "Moon Alcor Rechargeable Rear Bike Light," [Online]. Available:
<https://www.merlincycles.com/moon-alcor-rechargeable-rear-bike-light-104686.html>. [Accessed 1 4 2022].
- [47] Tredz, "Catye Omni 3 LED Rear Bike Light," [Online]. Available:
https://www.tredz.co.uk/.Catye-Omni-3-LED-Rear-Bike-Light_67369.htm. [Accessed 4 1 2022].

- [48] Tredz, "Cateye Omni 5 LED Rear Bike Light," [Online]. Available: https://www.tredz.co.uk/.Cateye-Omni-5-LED-Rear-Bike-Light_68134.htm. [Accessed 4 1 2022].
- [49] Tredz, "Moon Ring USB Rechargeable 25 Lumens Rear Bike Light," [Online]. Available: https://www.tredz.co.uk/.Moon-Ring-USB-Rechargeable-25-Lumens-Rear-Bike-Light_84416.htm. [Accessed 4 1 2022].
- [50] Tredz, "Cateye ViZ 100 Rear Bike Light," [Online]. Available: https://www.tredz.co.uk/.Cateye-ViZ-100-Rear-Bike-Light_229424.htm. [Accessed 4 1 2022].
- [51] Tredz, "Moon Comet X Rear Light," [Online]. Available: https://www.tredz.co.uk/.Moon-Comet-X-Rear-Light_97634.htm. [Accessed 4 1 2022].
- [52] Tredz, "Lezyne KTV Pro Drive 75 USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Lezyne-KTV-Pro-Drive-75-USB-Rechargeable-Rear-Light_216197.htm. [Accessed 4 1 2022].
- [53] Tredz, "Lezyne Strip Drive 150 USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Lezyne-Strip-Drive-150-USB-Rechargeable-Rear-Light_216206.htm. [Accessed 4 1 2022].
- [54] Chain Reaction, "Moon Cerberus Rear Light," [Online]. Available: https://www.chainreactioncycles.com/moon-cerberus-rear-light/rp-prod173672?utm_source=affiliate-window&utm_medium=affiliates&utm_campaign=Skimlinks&utm_term=Skimlinks&utm_content=Sub+Networks&sv_campaign_id=78888&sv_tax1=affiliate&sv_tax2=375403%7C375413%. [Accessed 4 1 2022].
- [55] Tredz, "NiteRider Solas 250 Rear Light," [Online]. Available: https://www.tredz.co.uk/.NiteRider-Solas-250-Rear-Light_200773.htm. [Accessed 4 1 2022].
- [56] Tredz, "Knog Blinder Square USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Knog-Blinder-Square-USB-Rechargeable-Rear-Light_227579.htm. [Accessed 4 1 2022].
- [57] Amazon, "CatEye CA475TL6107 TL-LD610 LED Rear Light, Black," [Online]. Available: https://www.amazon.co.uk/CatEye-CA475TL6107-TL-LD610-Light-Black/dp/B003RGEM8U/ref=as_li_ss_tl?ie=UTF8&linkCode=sl1&tag=roadcc-21&linkId=23452e0875f43949095fb08ab6afde2e&language=en_GB&th=1. [Accessed 4 1 2022].
- [58] Tredz, "Moon Nebula Rear Light," [Online]. Available: https://www.tredz.co.uk/.Moon-Nebula-Rear-Light_217883.htm. [Accessed 4 1 2022].
- [59] Tredz, "Cateye ViZ 450 Rear Light," [Online]. Available: https://www.chainreactioncycles.com/cateye-viz-450-rear-light/rp-prod208103?utm_source=affiliate-window&utm_medium=affiliates&utm_campaign=Skimlinks&utm_term=Skimlinks&utm_content

=Sub+Networks&sv_campaign_id=78888&sv_tax1=affiliate&sv_tax2=375403%7C375413.
[Accessed 4 1 2022].

- [60] Tredz, "Specialized Stix Elite 2 Taillight," [Online]. Available: https://www.tredz.co.uk/.Specialized-Stix-Elite-2-Taillight_237577.htm. [Accessed 4 1 2022].
- [61] Tredz, "Lezyne Zecto Max Drive 250 USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Lezyne-Zecto-Max-Drive-250-USB-Rechargeable-Rear-Light_111999.htm. [Accessed 4 1 2022].
- [62] Tredz, "Ravemen TR300 USB Rechargeable Rear Light - 300 Lumens," [Online]. Available: https://www.tredz.co.uk/.Ravemen-TR300-USB-Rechargeable-Rear-Light-300-Lumens_228867.htm. [Accessed 4 1 2022].
- [63] Tredz, "Lezyne Laser Drive 250 USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Lezyne-Laser-Drive-250-USB-Rechargeable-Rear-Light_100120.htm. [Accessed 4 1 2022].
- [64] Tredz, "Exposure TraceR Rear Light USB Rechargeable With Daybright & ReAKT Technology & Peleton Mode," [Online]. Available: https://www.tredz.co.uk/.Exposure-TraceR-Rear-Light-USB-Rechargeable-with-Daybright-ReAKT-Technology-Peleton-Mode_128116.htm. [Accessed 4 1 2022].
- [65] Tredz, "Knog Cobber Big USB Rechargeable Rear Light," [Online]. Available: https://www.tredz.co.uk/.Knog-Cobber-Big-USB-Rechargeable-Rear-Light_213712.htm. [Accessed 4 1 2022].
- [66] Tredz, "NiteRider Omega Evo 300 Nitelink Rear Light," [Online]. Available: https://www.tredz.co.uk/.NiteRider-Omega-Evo-300-Nitelink-Rear-Light_231785.htm. [Accessed 4 1 2022].
- [67] Merlin Cycles, "Hope District+ Rear Light," [Online]. Available: <https://www.merlincycles.com/hope-district-rear-light-1-58968.html>. [Accessed 4 1 2022].
- [68] Tredz, "Exposure Blaze Mk2 Daybright Rear Light," [Online]. Available: https://www.tredz.co.uk/.Exposure-Blaze-Mk2-Daybright-Rear-Light_128115.htm. [Accessed 4 1 2022].
- [69] LUMILEDS, "1971453.pdf," [Online]. Available: <https://www.farnell.com/datasheets/1971453.pdf>. [Accessed 8 1 2021].
- [70] LUMILEDS, "1812498.pdf," [Online]. Available: <https://www.farnell.com/datasheets/1812498.pdf>. [Accessed 8 1 2021].
- [71] CREE LED, "Cree XLamp XP-E LEDs Data Sheet," [Online]. Available: <https://cree-led.com/media/documents/XLampXPE-25A.pdf>. [Accessed 8 1 2021].

- [72] S. Fotios and H. Castleton, "Lighting for cycling in the UK - A review," *Lighting Research & Technology*, vol. 49, pp. 381-395, 2017.
- [73] CREE LED, "XLamp XQ-A LED Data sheet," [Online]. Available: <https://cree-led.com/media/documents/ds-XQA.pdf>. [Accessed 26 01 2022].

ELECTRONICS 1 - ASSIGNMENT 1 - MICHAEL HOWELLS

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: GJ_2019

MICHAEL HOWELLS

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ENGAGEMENT WITH LITERATURE



Superb level of focused research material.

90

KNOWLEDGE AND UNDERSTANDING



Excellent demonstration of knowledge and understanding at a system and component level

85

COGNITIVE AND INTELLECTUAL



Mostly very well reasoned. Perhaps more creativity could have been demonstrated in suggesting various 'add-ons' or enhancements.

78

PRACTICAL APPLICATION



Flowchart shows good thought. Circuit has generally sensible modules, although perhaps the voltage regulation side would not actually be needed for the LED drive?

78

TRANSFERABLE SKILLS



Very well laid out and presented. Excellent use of diagrams and graphs etc. Perhaps consider trying to avoid writing in the 1st person - you will need to do this for your major project.

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