

Oliver Kucyj Electronics 1 assignment

by Oliver Kucyj

Submission date: 27-Jan-2022 01:27PM (UTC+0000)

Submission ID: 170404919

File name: 33333_Oliver_Lee_Kucyj_Oliver_Kucyj_Electronics_1_assignment_394634_643033149.docx
(1.83M)

Word count: 5633

Character count: 29187

Oliver Kucyj – Electronics 1

Learner Name: Oliver Kucyj

Course: B.Eng Electrical and Electronic Engineering

Module Code: ACDA5002

Module Name: Electronics 1

Assignment Title: Design of a smart rear bicycle

Table of Contents

Introduction.....	3
Research into the existing market	4
Choosing the high-powered LEDs.....	6
PWM (Pulse width modulation).....	7
LED Driving circuit	8
Flashing the LEDs.....	9
Switching the bike light on/off based on movement detection	10
Changing the light intensity based on visual light.....	12
Rechargeable battery system	13
Voltage regulation	15
Battery monitoring and protection	16
Mode selection using the switch.....	17
Selecting the microcontroller.....	18
Circuit Schematic	19
System Block Diagram	20
Pseudocode	21
Parts list	24
Conclusion	25
Reference list.....	26

Introduction

The aim of this project is to design a smart rear bike light with multiple functions which will make it a useful product for the user. The rear bike light will:

- Use high power LEDs
- Have multiple light intensity modes controlled by PWM
- Have multiple flashing modes designed to optimise visibility
- Be powered by USB rechargeable Li-ion batteries
- Switch on/off automatically by detecting movement
- Automatically use lower light intensity at night to increase battery life
- Enter power saving mode when the battery is low
- Have LEDs to show charging and fully charged statuses.
- Automatically disconnect the battery when fully charged
- Increased brightness to replicate a break light when slowing down

The smart rear bike light circuit will be controlled by a microcontroller along with additional circuitry to complete the functions listed above.

Research into the existing market

There are many existing smart rear bike lights already on the market, to ensure this project is effective and professional it is important to analyse the features of the existing products. In this section, some available rear bike lights and their features are listed.

Nkomax smart bike light [1]

COB LEDs

Auto start and stop

Higher brightness when breaking

20 hours run time

400mAh Li-ion USB rechargeable battery

Dimensions – 127mm x 25mm x 76mm

Costs £21.99

Higomore ultra-smart bike taillight [2]

Higher brightness when breaking

600mAh USB rechargeable battery

8-12 hours run time

3 hours charging time

COB LEDs

100lm

6 light modes

Dimensions – 53mm x 53mm x 38mm

Costs £19.99

Moon nebular rear light [3]

COB LEDs

Uses aluminium heat sink casing for cooling

Rechargeable Lithium Polymer battery 800mAh

Mode memory function

8 light modes

Low battery, charging and fully charged indicator

Fully charged cut-off system to protect battery

2.5 hour charging time

200lm

Dimensions – 93mm x 22.5mm x 17.7mm

Costs £27.49

Garmin Varia RTL515 rear light [4]

51-150lm

16-hour battery life

Connects wirelessly to smartphone or compatible devices

Provides visual and audible alerts when vehicles approach from behind

Can indicate the position and speed of approaching cars

4 light modes

98.6mm x 19.7mm x 39.6mm

Costs £169.99

These lights were chosen at random from the shopping section of Google to give an idea of what specifications are available.

An article on the best available bike lights written by J. Stevenson [5] listed the Exposure TraceR MK2 as the best overall rear bike light. At the start of the article Stevenson mentions some of the desirable features when looking for a rear bike light. These are a longer battery life, rechargeable batteries, and flashing modes.

One light listed in this article is the Hope District Plus. The interesting feature with this light is that it uses an external battery to allow for up to 200 hours of use without the hindrance of fitting a battery into the rear light itself. This is something to consider later in the project when designing the battery pack.

Flashing the rear bike light

This rear bike light will have flashing modes. There are advantages to using different flashing modes whilst cycling however there are also disadvantages. Having a flashing rear light means the bike can be detected from further distances and can preserve battery life of the rear bike light. Using a pattern to flash the light, rather than having a steady light, can also increase the chances of being detected. However, flashing lights can make it difficult for the speed and distance of the bike light to be detected as there is no constant light to focus on. Fast flashing lights can potentially be dazzling to drivers too, which will reduce the safety of the cyclist, the motorist, and pedestrians. Flashing lights are illegal in some countries such as Germany and the Netherlands for this reason [6].

In the UK, the law is that the rear bike light flashing frequency must be from 1-4Hz.

Choosing the high-powered LEDs

Red high powered COB LEDs will be used for this project. After analysing the research conducted previously it is clear that high powered COB LEDs are the most used on the market. COB LEDs are a relatively new technology which were designed to limit the issues encountered with standard LEDs. They consist of multiple LEDs directly mounted to one module. This helps to greatly reduce the space they take up, provided more lumens per cm² than is achievable with standard LEDs [7]. The COB LEDs are also faster to incorporate into a design as there are only 2 connections to energize multiple LEDs which are mounted on one module. The different chip structure also means the COB LEDs generally produce less heat [8].

The LED which will be used for this project is the cree XPEBRD. It is a red COB type LED with a starboard configuration. The starboard configuration has a large surface area allowing for good heat dissipation which can help to improve the reliability and efficiency of the LED. This LED has a viewing angle of 130° which will allow the bike light to have a relatively wide coverage, however when installing the LEDs, it may be possible to arrange them in a way that increases this angle by angling them outwards slightly.

The datasheet [9] states that the forward current is 350mA, providing a luminous flux rating of 80.6lm. Two of these high-powered LEDs will provide 161.2lm, based on the research this is sufficient.

It is worth noting that these are red LEDs which will be used with a red lens. Should a white LED have been used, there would be wasted energy being filtered out by the lens.

PWM (Pulse width modulation)

PWM is a very widely used concept which has a multitude of purposes. It works by reducing the amount of current being used to power a device by changing the width of a pulse rather than changing the peak voltage. The width of the pulse is known as duty cycle, as shown in figure 1.

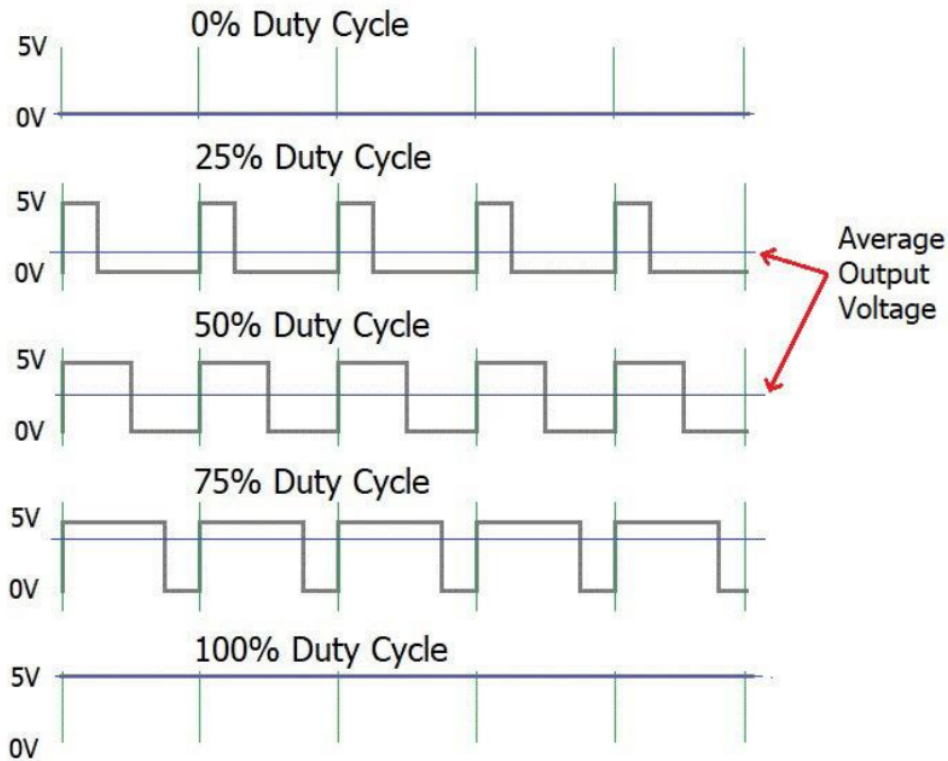


Figure 1 – PWM duty cycle [10]

A 50% duty cycle means the power is only on for 50% of the time, meaning the average voltage at the load is 50% of the peak voltage (2.5V in this case). Often, some form of smoothing circuit is used to smooth the square wave output. PWM is usually switched with a very high frequency, so the time the output spends at 0V does not create a flickering effect.

PWM is used for controlling motor speeds, ramping up the voltage to provide a soft start device and for the application of the rear bike light, to limit the current being drawn by the LED.

LED Driving circuit

The LEDs will require a driving circuit. As mentioned, PWM is being used to control the brightness. The PWM output from the microcontroller is not capable of driving a 700mA load so a switching circuit is required.

The circuit is shown in figure 2. An N-channel MOSFET is used to switch the LEDs on/off with the PWM signal from the microcontroller. When the PWM signal is high, the MOSFET connects ground, completing the circuit. When the PWM signal is low, the MOSFET disconnects the ground, disconnecting power from the LED circuit.

The Inductor, L2 is used to smooth the PWM signal during the off period to prevent the LED from flickering. The diode, D5, is used to provide a negative to the LED circuit when the MOSFET is open.

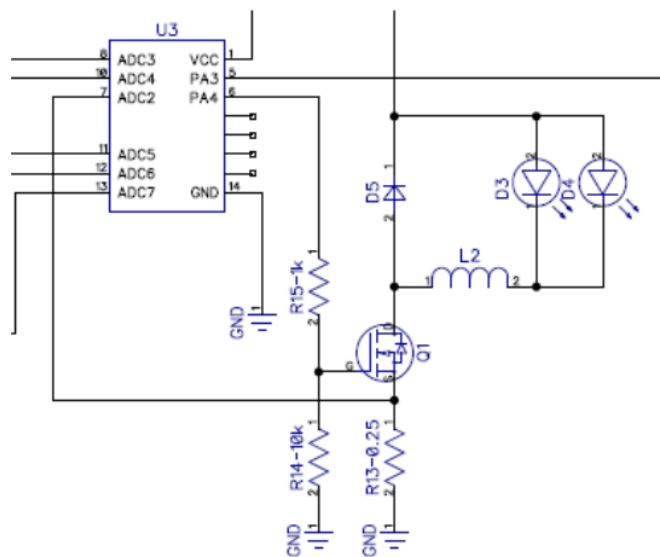


Figure 2 – LED driving circuit

Using this circuit along with the PWM theory from the previous section allows the LED brightness to be adjusted. It also enables the LEDs to be powered directly from the battery, improving efficiency as there is no high current loading on the voltage regulator.

The PWM is used to maintain a constant current value. The microcontroller monitors the current using the current sensing resistor R13. It measures the voltage drop and uses Ohms law to calculate the current. As current is directly proportional to the brightness, regardless of any temperature variations, any percentage of full power can be maintained by adjusting the PWM duty cycle based upon the value of the current sensing resistor. This is a particularly accurate method of maintaining a set brightness, especially on a bike light which will likely be exposed to lower temperatures.

The MOSFET which will be used is the IPW60R280E6FKSA1 [11]. This has a V_{GS} (Voltage between gate and source to switch on) of 2.5-3.5V and an R_{DS} value (Resistance when on) of 0.25-0.66 Ω . This means the device can be switched on with 3.3V and will not have much effect on the efficiency of the circuit due to the low R_{DS} .

Flashing the LEDs

This device will have two flashing modes. One will flash on for 0.5 seconds and off for 0.5 seconds in a consistent flash pattern. The other will flash on for 0.75 seconds and off for 0.25 seconds. This would provide an inconsistent flash to help grab the attention of motorists.

The flashing modes will be incorporated using the same constant voltage principle described previously. For the mode which uses 0.75 seconds on 0.25 second off flashing sequence, the pre-set constant voltage is maintained for the 0.75 seconds on and then dropped to 0V during the 0.25 seconds off period. For example, should the device be used with a 50% light output in this operating mode, the constant voltage would be 1.05V for 0.75 seconds, followed by 0V for 0.25 seconds. This cycle will repeat until the device mode is change

Switching the bike light on/off based on movement detection

One feature of this bike light is to switch the light off when the bike is stopped and switch the light on once the bike starts moving again. This will help to prolong battery life. This can be done using MEMS (Microelectromechanical systems) accelerometers. There are two main types of accelerometers, VC (variable capacitive) and PR (Piezoresistive). VC accelerometers are the best suited to this project as they offer higher sensitivity than the PR accelerometers [12].

Figure 3 shows the basic principle of a VC MEMS accelerometer. Multiple capacitors are created using an air gap as the dielectric. One side of each capacitor is a fixed electrode, and the other side is a moveable electrode. When there is acceleration, the moveable electrode will increase the size of some capacitors and decrease the size of others. The change in voltage can then be measured to monitor movement. This example is for a simple single axis accelerometer. Many MEMS accelerometers will cover 3 axis of movement, X, Y and Z to provide higher accuracy in movement detection.

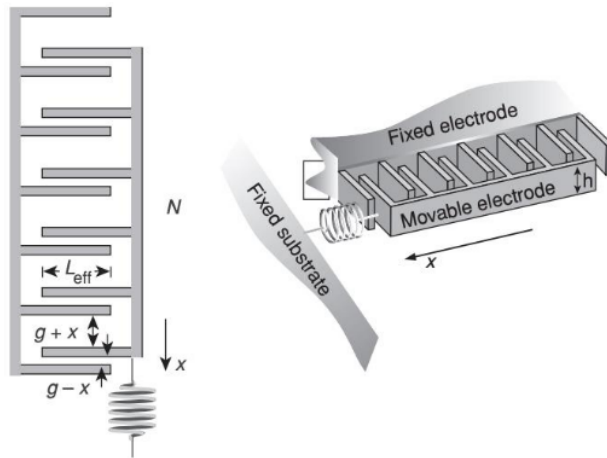


Figure 3 – VC MEMS accelerometer working principal [13, P. 9]

The MEMS accelerometer chip which will be used for this project is the ADXL335 [14]. This is a triple axis accelerometer which will provide very high accuracy in detecting movement. Adafruit have a module incorporating this chip which can be used [15]. It requires a 3.3V input and provides analogue outputs on axis X, Y and Z. The output of each Axis will be 1.65V with zero acceleration, 3.3V with 3g of acceleration and 0V with -3g of acceleration. The response between these values is linear.

When there is no acceleration in any direction for a 60 second period the bike light can switch off. When acceleration is then detected in any axis, the light will switch back on. If no movement is detected for one hour, the device will switch into power down mode and movement will not restart the device. The MEMS accelerometer can implement this because when on a bike, even when stopped in traffic, there is always likely to be movement in some direction through wobbling, so when there is no movement in any axis, it is highly likely the bike is parked.

The break light feature is also implemented using this. When deceleration in the forward X axis is detected, the higher intensity (100% power) bike light mode can be switched on until the deceleration stops.

To reduce cost, the MEMS accelerometer module can be implemented directly into the circuit. The built-in regulator will not be used either, further decreasing cost. This is shown in figure 4.

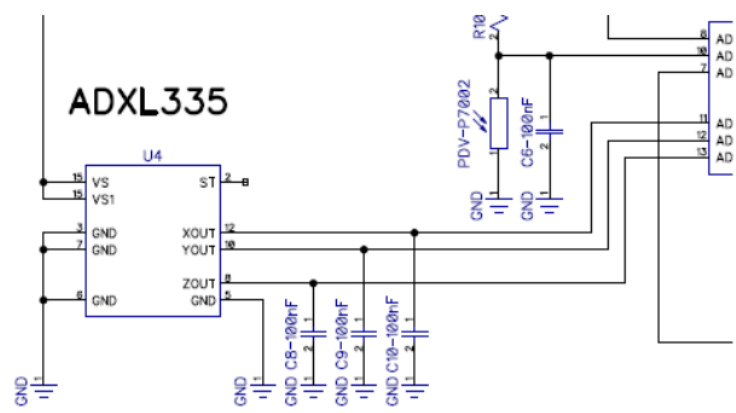


Figure 4 – MEMS accelerometer circuit using ADXL335.

Changing the light intensity based on visual light

The operating mode of the device will change depending on whether it is night or day. At night, the bike light will not need to be as bright during the day to draw attention, so battery life can be persevered. To implement this, some form of light sensing component is required. There are 3 components which can be used to achieve this, LDRs (Light-dependant resistors), photodiodes and phototransistors.

The resistance of LDRs decreases with an increase in visible light (400-700nm). They are cheap devices with low accuracy and a slow response time to the change in light.

Photodiodes are diodes which leak more reverse current as lux levels increase with very fast response times. Phototransistors work the same as photodiodes, however they amplify the output current so there is no need for additional amplification circuitry. The downfall of photodiodes and phototransistors is that they respond to light spectrums which are not visible to the human eye, so a light filter is required. This then leaves the risk of unwanted light leakage causing inaccuracies and overcomplicates the system. High accuracy and fast response times are not important for this project, so the LDR is the best option.

The LDR which will be used is the PDV-P7002 [16]. Many LDRs act the same way so the choice here isn't of massive importance. A voltage divider will be used to read the value of the LDR and it will be powered by the voltage regulator to ensure a stable, reliable input is provided. An inaccurate input would create an inaccurate output. A 100nF capacitor is used to smooth out any spikes created by sudden changes in light caused by shadows or lights. The circuit is shown in figure 5.

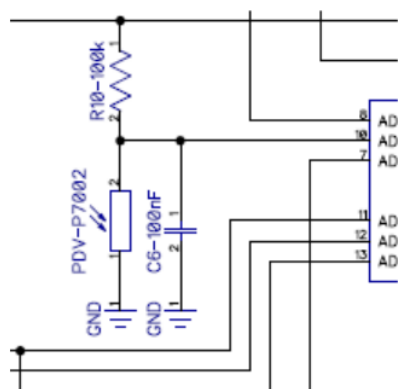


Figure 5 – Voltage divider circuit with LDR and delay capacitor

The device will always have two brightness options, presuming the battery is charged. During the daytime, the two brightness settings will be 80% and 50% brightness. At night-time, the brightness settings will be 70% and 40% brightness.

The input value to switch from day mode to night mode will be different to the value to switch from night mode to day mode. This is to prevent the light from repeatedly switching between the two modes due to the light level being on the limit. This is commonly known as hysteresis. The values to switch between night and day mode will need to be selected once the LDR has been tested and suitable light levels can be chosen.

There will also be a software delay included to prevent sudden changes in light levels due to infrastructure from triggering the change, as well as the capacitor mentioned previously.

Rechargeable battery system

The first step to designing a rechargeable battery system is to identify the size of battery required. The main power consuming side of this circuit will be the COB LED. As mentioned previously, there will be two 2.1V, 350mA high power LEDs being used.

This provides insight into how much power the LEDs will require. In terms of space available, the average dimensions of rear bike lights on the market is around 100mm x 20mm x 30mm, however the cyclists seem to prefer the smaller more compact designs. This must be considered when choosing the battery, as the PCB and battery must fit inside, with factors such as heat dissipation also needing consideration.

These LEDs can be configured either in series or parallel. In series, the battery will need to provide at least 4.2V to drive the LEDs and most small batteries will not provide this when low on battery, so they will need to be connected in parallel, meaning 700mA will be drawn on full power.

A commonly used battery is the Li-ion 18650. These have a nominal voltage of 3.7V and need to be disconnected before the voltage drops down to 2.5V. The dimensions of these batteries are 18mm x 65mm.

The Li-ion 18650 batteries come in a range of capacity ratings and can be purchased with protection circuits built into them. This is important as the protection circuitry will have over discharge protection, preventing the battery from being damaged.

Adafruit supply both Li-ion batteries and Li-ion USB charging modules to go with them. The ICR18650 [17] is a 2200mAh 3.7V Li-ion battery, which provides plenty of charge to power the LEDs. With the LEDs on full power, the consumption will be 700mA. This means the light will run on constant maximum power for around 3 hours. The microcontroller will also consume power, however this will be minimal when compared to the LEDs.

The Adafruit USB Li-on/Lipoly charger V1.2 [18] uses a MCP73833 chip. By changing the built in PROG resistor to 10k Ω , 1000mA fast charging is provided. The THERM resistor can also be replaced with a 10K thermistor to provide temperature monitoring, which will be necessary considering the fast charging is being used. The circuit will use a CC-CV (Constant current - Constant Voltage) system which is the most popular method of charging Li-ion batteries. This works by initially charging the battery using a constant current value until the maximum voltage is reached. Once the maximum voltage is reached (4.2V) a constant voltage matching this value is used and the current value will begin decreasing as the battery charges. Once the average charging current drops to the termination current (7.5% of 4.2V), charging is stopped, and the circuit will enter charging complete mode. The CC part of this is much faster than the CV charging. Increasing the charging current will only decrease the charge time of the CC part of the process [19].

The datasheet for the battery states that with a constant current charge rate of 0.5C (charging current 50% of battery capacity), the battery will charge in approximately 4 hours using CC-CV charging. The constant current charge rate of this system will be 0.45, so it can be estimated that the charging time will be approximately 4.5 hours.

This module can be implemented directly into the circuit as shown in figure 6. The ST1 pin is connected to an orange LED (D1) to confirm the device is charging, ST2 is connected to a green LED (D2) to confirm charging is complete. The battery is disconnected from the USB input when charging is complete for overcharge protection. The battery also has overcharge protection built in.

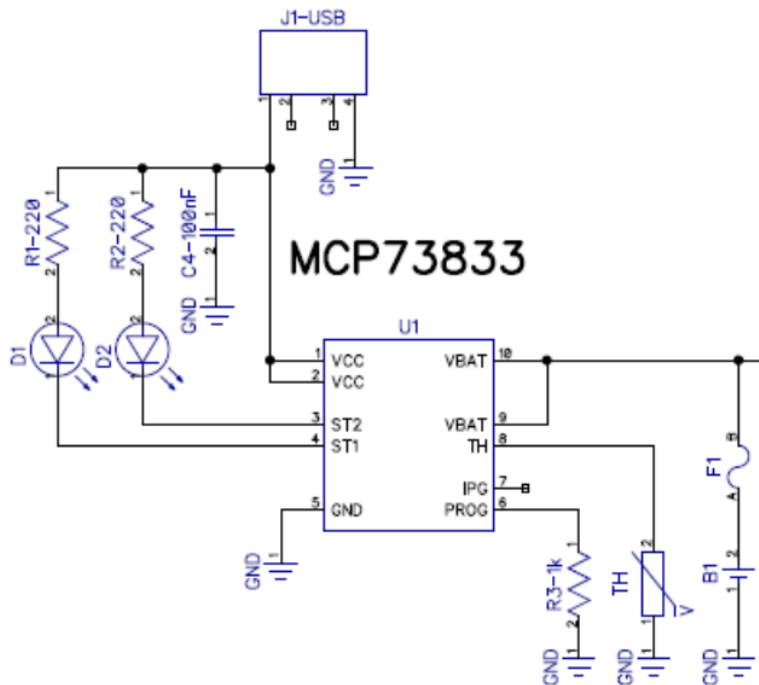


Figure 6 – Charging circuit using MCP73833

Voltage regulation

The issue with battery powered circuits is the voltage. With a Li-ion battery, the voltage will range from 4.2V when fully charged down to 2.5V at the absolute lowest charge. This range in voltage is not good for most components. Not only must the voltage be kept consistent across components such as the LDR for voltage measurement, but chips such as the microcontroller and the MEMS accelerometer require a voltage within a specific range, which is usually above 3V. The MEMS accelerometer requires a 3.3V input, so when the battery is low, the voltage needs to be boosted as well as regulated.

To do this, a LTC3440 buck-boost DC/DC converter chip can be used. This chip sold by analogue electronics is designed for use with 3.3V circuits powered by batteries. An article written by M. Jordan [20] published on their website includes a full working circuit for using this chip with single cell Li-ion batteries which is perfect for this project. The input voltage can range from 2.5V-4.2V and still provide a 3.3V output.

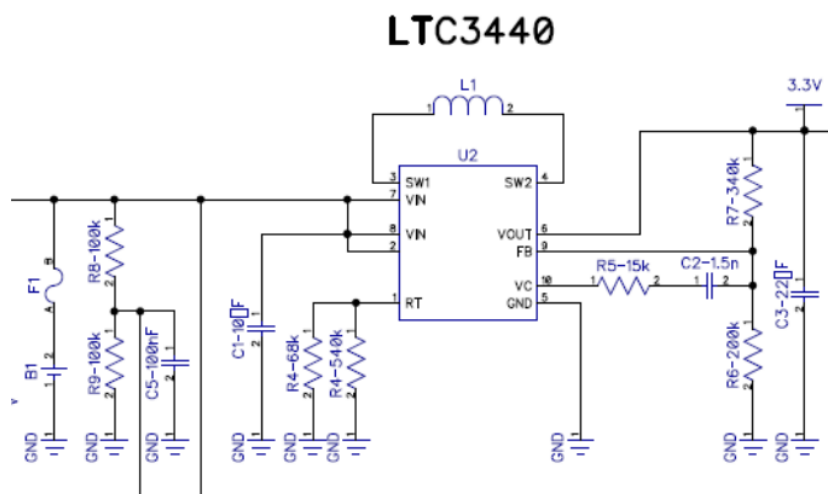


Figure 7 – Voltage regulation using LTC3440

Please note: The software would not allow the μF symbol to be used. This has been replaced with the empty box shown on C1 and C3. Also, R4 consists of a 68K Ω and 540K Ω resistor in parallel to generate 60.4k Ω , which is not a readily available resistor size.

Battery monitoring and protection

The battery level can be monitored by measuring the output voltage. Microcontrollers cannot use inputs higher than the supply voltage (3.3V) and the fully charged battery voltage is 4.2V, so a voltage divider is required to ensure the measured voltage does not exceed 3.3V allowing the value to be read by an analogue input on the microcontroller. This circuit is shown in figure 8.

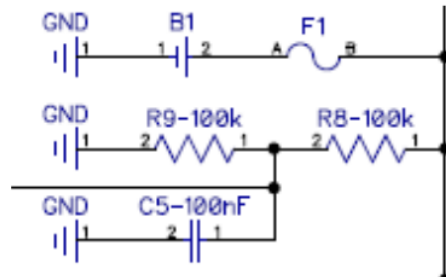


Figure 8 – battery monitoring circuit

The battery will need to be protected using a combination of this circuit, software, and the built-in protection it already has. The built-in circuitry will disable the battery at 2.5V, however the battery reaching this level is the worst-case scenario. The output voltages from the divider will be half of the input voltage.

If the actual voltage is 3-3.3V, low battery mode is activated. In low battery mode the light will be fixed at a 40% brightness, with a 0.5 seconds on 0.5 seconds off flashing sequence.

Below 3V battery level, the microchip remains powered in low power mode with all functions disabled, except for the battery monitoring feature. If the battery is not charged for a long period of time, the battery would eventually drain to 2.5V and be cut off by its built-in protection.

Mode selection using the switch

There will be six selectable operating modes, 2 flashing modes (each with high and low brightness options) and a solid light mode with high and low brightness options. The switch will be used to select these modes.

Each time the switch is pressed, a digital pulse is sent to the microcontrollers digital input. Each pulse will trigger a section of software which increases a variable by 1. The variable will only work in the range 1-6. When a pulse is received when the variable is already at 6, the number will be reset to 1. Each number in this variable will dictate which operating mode is being used. For example, if the variable reads '1' then high power constant light mode is active.

Holding down the switch for 5 seconds will power the light off, the chip will then enter power down mode.

The circuit for the switch is shown in figure 9. C7 is known as a debounce capacitor and is used to smooth out any voltage spikes which occur when the switch is activated.

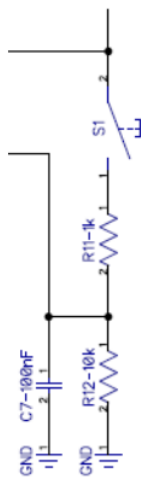


Figure 9 – Switch circuit

Selecting the microcontroller

The microcontroller can be selected based upon the circuit voltage, number of inputs and the number of outputs. The minimum requirements are listed below.

- 3.3V
- PWM module with 1 output channel
- 6 analogue inputs
- 1 digital input
- Have low power modes and low power consumption

Based on these requirements, the ATtiny104 [21] can be used as it can provide all the functions. It is an 8-bit microcontroller which is specifically designed for low power use. It has 1k of programmable flash memory and 32bytes of SRAM (Static Random Access Memory). It contains a built-in watchdog timer, which will reset the device in the event of a software glitch, 8 10-bit ADC channels and 2 PWM channels.

Some of the ADC inputs are 4-bit and some are 8-bit. High precision accuracy is not essential here, so this is not a problem. The pin configuration is shown below in figure 10.

The device operating mode is stored in RAM which is volatile memory, however the RAM is saved during power saving modes. This will mean the user will not need to select their operating mode every time they switch the device on, it will come on in the mode they left it in. The only time this will not work is if the battery is disconnected. The device will disable everything once the battery reached 3V however the RAM is still saved as the battery is still connected. If the device is not charged for long a period of time, the battery level will drop to 2.5V and the RAM will be lost.

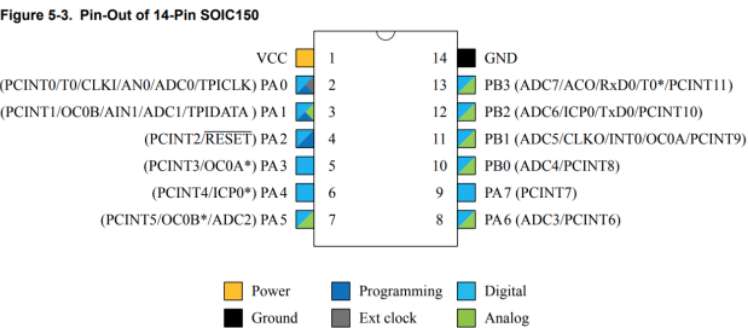


Figure 10 – ATtiny104 pin configurations

Circuit Schematic

The full circuit schematic is shown in figure 11. This consists of all previously discussed sections.

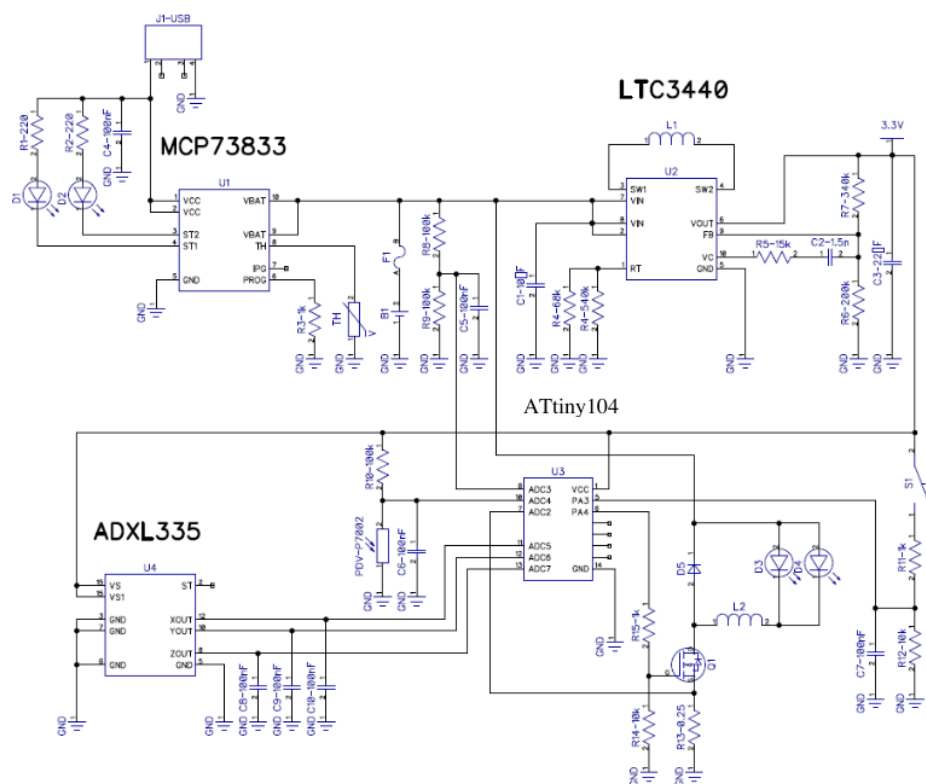
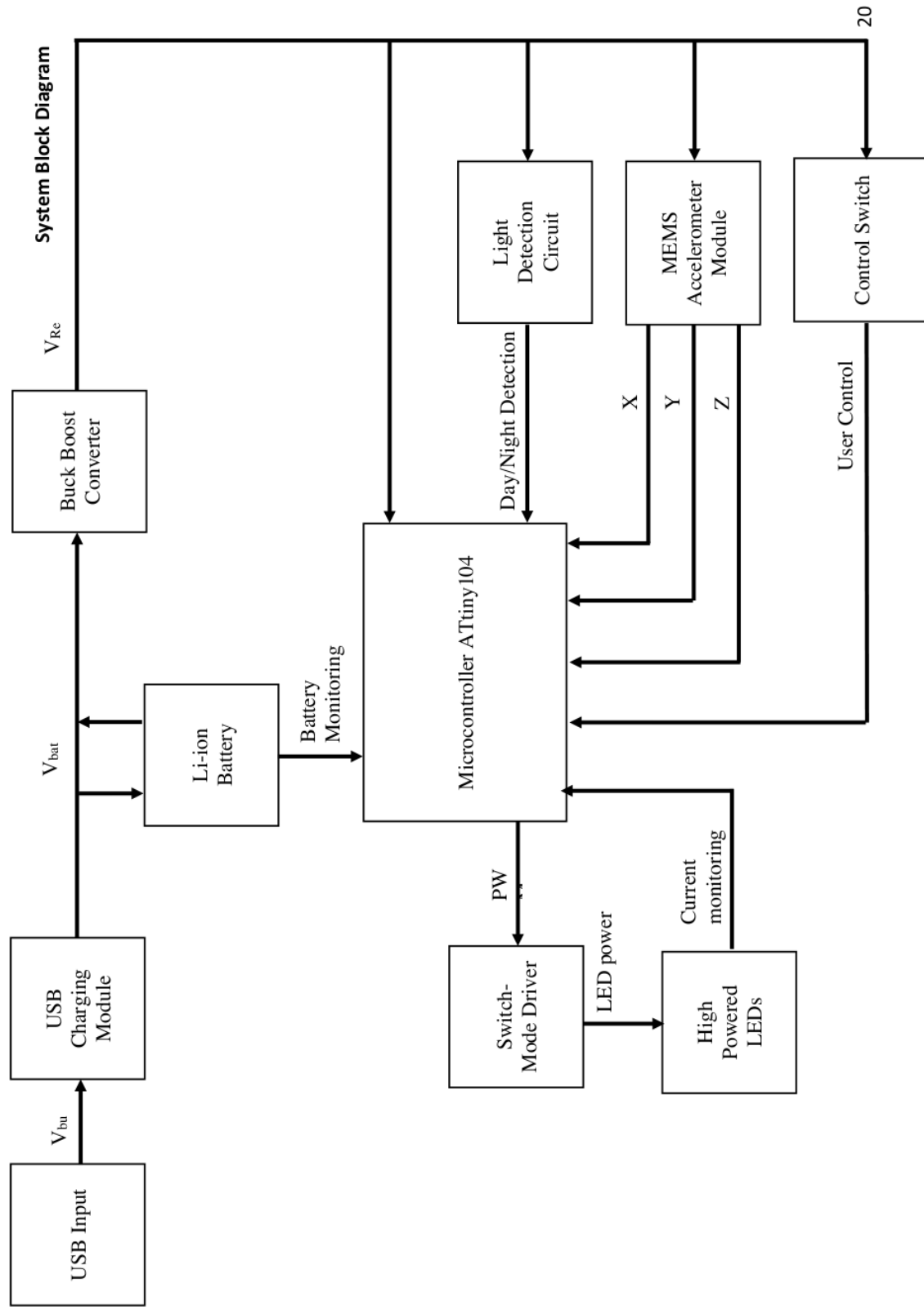


Figure 11 – Full circuit schematic



Pseudocode

Define integer variables

ModeSelect = 1 // Defines operating mode

SwitchInput = PA3 //digital Input from switch

HighBrightness // High brightness Constant current value

LowBrightness // Low brightness Constant current value

LDRInput = ADC4 // Input from LDR

MEMSX = ADC5// Input from X axis

MEMSY = ADC6 // Input from Y axis

MEMSZ = ADC7 // Input from Z axis

BatteryLevel = ADC3// Battery level input

DayNight = 1 // Defines day or night mode. Day = 1, Night = 2. Day by default

LEDCurrent = ADC2/0.25 // Input from current sensing resistor, converted to current value using Ohms Law

Set PA4 as PWM output channel //PWM output pin

Define Boolean variable

LightOff = True// Used to switch light off, enabling ModeSelect position to be remembered when the light is switched off

AutoMode = False // Triggered with no movement for 60 seconds. Waits for movement to reactivate

IF SwitchInput = on for less than 5 seconds then

 ModeSelect +1 //Short press switch to change modes

 IF ModeSelect = 7 then // Switches back to the first mode after cycling past the 6th mode

 ModeSelect = 1

 IF SwitchInput = on for more than 5 seconds then

 Set LightOff = True // Switches light off with long press of switch

ENDIF

IF LDRInput $\geq$ X for 10 seconds or more AND DayNight = 1 then //10 second delay to avoid constant switching

 DayNight = 2 //Switch from day to night

ELSEIF LDRInput $\leq$ Y for 10 seconds or more AND DayNight = 2 then

 DayNight = 1 // Switch from night to day. X and Y to be set once LDR is received

ENDIF

IF DayNight = 1 then // Set brightness modes in daytime

 HighBrightness = 560mA //maintain 560mA constant current

 LowBrightness = 350mA //maintain 350mA constant current

ELSEIF DayNight = 2 then //Set brightness modes in night time

 HighBrightness = 490mA //maintain 490mA constant current

 LowBrightness = 280mA // maintain 280mA constant current

ENDIF

IF LightOff = True then

 Put microcontroller in Power down mode

 Wait for signal at PB1 //Circuit in low power mode until interrupt is triggered by switch

ENDIF

```
IF MEMSX = 1.65 AND MEMSY = 1.65 AND MEMSZ = 1.65 for 60 seconds then
    AutoMode = True //If no movement for 60 seconds, switch to AutoMode. Light is switched
off in AutoMode until movement is detected
ENDIF

IF AutoMode = True for one hour then
    AutoMode = False
    LightOff = True //If unit has not moved for one hour, it enters off mode and no longer
monitors movement
ENDIF

IF AutoMode = True AND (MEMSX != 1.65 OR MEMSY != 1.65 OR MEMSZ != 1.65) then
    AutoMode = False //If movement is detected on any axis, unit is switched back on
ENDIF

WHILE BatteryLevel ≥ 1.65 AND LightOff = False AND AutoMode = False //Loop whilst battery is
charged above 3.3V, light is on and AutoMode is off

    WHILE MEMSX > 1.65 then //If deceleration is detected
        Adjust PWM to maintain 700mA LEDCurrent //Switch to full power for brake light
        Once While condition is no longer met, revert to previous constant current value

    IF ModeSelection = 1 then //High power constant light
        Adjust PWM to maintain LEDCurrent = HighBrightness
    ELSEIF ModeSelection = 2 then // Low power constant light
        Adjust PWM to maintain LEDCurrent = LowBrightness
    ELSEIF ModeSelection = 3 then //Constant flash high power
        Adjust PWM to maintain LEDCurrent = HighBrightness for 0.5 seconds
        Adjust PWM to maintain LEDCurrent = 0mA for 0.5 seconds
        Repeat
    ELSEIF ModeSelection = 4 then //Low power constant flash
        Adjust PWM to maintain LEDCurrent = LowBrightness for 0.5 seconds
        Adjust PWM to maintain LEDCurrent = 0mA for 0.5 seconds
        Repeat
    ELSEIF ModeSelection = 5 then // High power inconsistent flash
        Adjust PWM to maintain LEDCurrent = HighBrightness for 0.75 seconds
        Adjust PWM to maintain LEDCurrent = 0mA for 0.25 seconds
        Repeat
    ELSEIF ModeSelection = 6 then // Low power inconsistent flash
        Adjust PWM to maintain LEDCurrent = LowBrightness for 0.75 seconds
        Adjust PWM to maintain LEDCurrent = 0mA for 0.25 seconds
        Repeat
    ENDIF
ENDWHILE

WHILE 1.5 ≤ BatteryLevel < 1.65 AND LightOff = False // Loop in Low battery mode from 3-3.3V
    Disable all inputs except for PA3 and ADC3 //Disables features to preserve battery. Battery
monitoring and switch are kept active
```

Oliver Kucyj – Electronics 1

Adjust PWM to maintain LEDCurrent = 280mA for 0.5 seconds

Adjust PWM to maintain LEDCurrent = 0mA for 0.5 seconds *//40% power flash*

Repeat

ENDWHILE

WHILE BatteryLevel < 1.5 *//battery below 3V*

Power down mode with no functionality except adc3 *//Battery too low, switch everything off to protect the battery. Battery monitoring is kept.*

ENDWHILE

End of code.

Parts list

A full list of required parts is below along with their cost. The total is £29.79. Considering metalwork and labour costs are not included in this it is relatively expensive compared to other options on the market, however this is a sample using the prices of one-off purchases. When purchased in bulk, components tend to be available for cheaper.

Part Number	Cost Estimation
XPEBRD x2	£5.75 each
ADXL335 MEMS accelerometer	£6.98
ICR18650 Li-ion battery	\$9.95 (£7.32)
MCP73833 Charging Chip	£0.63
PDV-P7002	£1.15
LTC3440 Voltage regulator	£2.94
10k Ω NTC thermistor by Adafruit	\$4 (£2.96)
Microcontroller ATtiny104	£0.56
IPW60R280E6FKSA1 N-Channel MOSFET	£1.123
10 μ H Inductor x2	£0.569
1A Fuse	£0.168
220 Ω resistor x2	£0.10 each
1k Ω resistor x 2	£0.10 each
0.25 Ω resistor	£0.10
100k Ω resistor x3	£0.10 each
68k Ω resistor	£0.10
540k Ω resistor	£0.10
15k Ω resistor	£0.10
340k Ω resistor	£0.10
200k Ω resistor	£0.10
10k Ω resistor x2	£0.10 each
100nF capacitor x7	£0.20 each
10 μ F capacitor	£0.10
1.5nF capacitor	£0.15
Orange LED	£0.20
Green LED	£0.20
Micro USB connector	£0.86
Pulse switch	£0.41
TOTAL	£29.79

Conclusion

Overall, the final circuit for this project can be considered a success. It meets all features which were set out at the beginning of the paper, however the overall cost is a little bit higher than expected. The pseudocode could have been made simpler with the same outcome, however this could be achieved at the next stage of the design which is not part of this assignment.

There are 4 changes which could have been made to the final design.

A tachometer connected to the bike wheel could have been used to monitor movement as a more accurate version of the MEMS accelerometer. This would also provide the exact speed of the bike. The device could have used the more modern USB C charging rather than the standard micro-USB. This would have allowed for faster charging times, however incorporating this would have been complex.

A different LED arrangement could have been used which would allow the LEDs to be switched separately. This would have allowed one LED to be left on, whilst the 2nd LED carried out a flashing sequence, maximising visibility.

A low power LED would have been simple to incorporate and would provide feedback to users so they know why the functionality is limited. Some users may think the device is broken when the battery is low without this.

Reference list

- [1] Amazon. Nkomax Smart Bike Tail Light Ultra Bright, Bike Light Rechargeable Auto On/Off, IPX6 Waterproof LED Bicycle Lights, High Intensity Rear LED Accessories Fits On Any Road Bikes (Black) [Online]. Available: https://www.amazon.co.uk/Nkomax-Rechargeable-Waterproof-Intensity-Accessories/dp/B07DF8RTM4/ref=asc_df_B07DF8RTM4/?tag=googshopuk-21&linkCode=df0&hvadid=310552789112&hvpos=&hvnetw=g&hvrand=5588471956523272625&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmid=&hvlocint=&hvlocphy=9045263&hv targid=pla-556312825330&psc=1
- [2] HigoLot. *Higomore ultra-smart bike taillight* [Online]. Available: https://higoLot.com/products/ultra-smart-bike-tail-light?variant=158264363&gclid=EALalQobChMI09Ltrb-i9QIVibbtCh2x1AQTEAQYASABEgLBbPD_BwE
- [3] Tredz. *Moon nebular rear light* [Online]. Available: https://www.tredz.co.uk/.Moon-Nebula-Rear-Light_217883.htm?sku=691891&utm_source=google&utm_medium=cpc&utm_campaign=google_shopping&gclid=EALalQobChMIgJLC47-i9QIVQztCh3Nug7iEAQYAiABEgJf2fD_BwE#
- [4] Wheelbase. *Garmin Varia Radar RTL515* [Online]. Available: https://www.wheelbase.co.uk/product/christmas-gifts/ultimate-gifts/garmin-varia-radar-rtl515-2/?size=One%20Size&colour=Black&gclid=EALalQobChMIkpX7ssCi9QIV0mDmCh1ktwAtEAQYASABEgLDYfD_BwE
- [5] J. Stevenson (2021, Dec. 27). *10 best rear bike lights for 2021 – boost your day and night visibility* [Online]. Available: <https://road.cc/content/buyers-guide/10-best-rear-bike-lights-2021-283053>
- [6] A. Thomson (2021, Dec. 17). *Flashing vs steady bike lights: which is safest and what does the law say?* [Online]. Available: <https://www.bikeradar.com/advice/buyers-guides/flashing-bike-lights/>
- [7] D. Czyżewski, "Investigation of COB LED luminance distribution," 2016 IEEE Lighting Conference of the Visegrad Countries (Lumen V4), 2016, pp. 1-4.
- [8] R. Miron (2016, Aug. 03). *The Basics of Chip on Board (COB) LEDs* [Online]. Available: <https://www.digikey.com/en/articles/the-basics-of-chip-on-board-cob-leds>
- [9] New Energy, "Cree High Power Starboards," XPEBRD datasheet.

- [10] A. Raj (2018, Sep. 19). *What is PWM: Pulse Width Modulation* [Online]. Available: <https://circuitdigest.com/tutorial/what-is-pwm-pulse-width-modulation>
- [11] Infineon, "600V CoolMOS E6 Power Transistor," IPW60R280E6FKSA1 datasheet, 2014.
- [12] PCB Piezotronics. *Introduction to MEMS Accelerometers* [Online]. Available: <https://www.pcb.com/resources/technical-information/mems-accelerometers>
- [13] T. B. Jones and N. G. Nenadic, *Electromechanics and MEMS*. Cambridge: Cambridge University Press, 2013.
- [14] Analog Devices, "Small, Low Power, 3-Axis ± 3 g Accelerometer," ADXL335 datasheet.
- [15] Adafruit. *ADXL335 – 5V ready triple-axis accelerometer (+-3g analog out)* [Online]. Available: <https://www.adafruit.com/product/163>
- [16] Luna Optoelectrics, "CDS Photoconductive Photocells," PDV-P7002 datasheet, Apr. 2016.
- [17] PKCELL, "Polymer Li-ion Battery Technology Specification," ICR18650 datasheet, Aug. 2014.
- [18] Adafruit. *USB Lilon/LiPoly charger – v1.2* [Online]. Available: <https://www.adafruit.com/product/259#technical-details>
- [19] A. B. Khan and W. Choi, "Optimal Charge Pattern for the High-Performance Multistage Constant Current Charge Method for the Li-Ion Batteries," in *IEEE Transactions on Energy Conversion*, vol. 33, no. 3, pp. 1132-1140, Sept. 2018.
- [20] M. Jordan. *It Just Got Easier to Convert Lithium-Ion Battery Voltage to 3.3V with this Efficient Single Inductor Synchronous Buck-Boost Regulator* [Online]. Available: <https://www.analog.com/en/technical-articles/it-just-got-easier-to-convert-lithium-ion-battery-voltage-to-33v.html>
- [21] Atmel, "8-bit AVR Microcontroller," ATtiny104 datasheet, Oct 2016.

Oliver Kucyj Electronics 1 assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

82/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

GRADING FORM: GJ_2019

OLIVER KUCYJ

411

ENGAGEMENT WITH LITERATURE



Excellent level and range of research sources used. The reference list - its not a huge problem, but is this actually IEEE formatted? its close. Really need the 'accessed' fields etc when using web pages for all web sources.

80

KNOWLEDGE AND UNDERSTANDING



Excellent K&U demonstrated in all areas!

89

COGNITIVE AND INTELLECTUAL



Very sensible thought processed demonstrated.

85

PRACTICAL APPLICATION



Circuit looks eminently sensible and the pseudocode is detailed enough for this type of assignment.

85

TRANSFERABLE SKILLS



Generally well laid out and presented. The cover sheet is a little plain though :-)

72