AS COURSEWORK.
ELEC3

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2016

warning system to prevent unnecessary use of battery power in older cars.

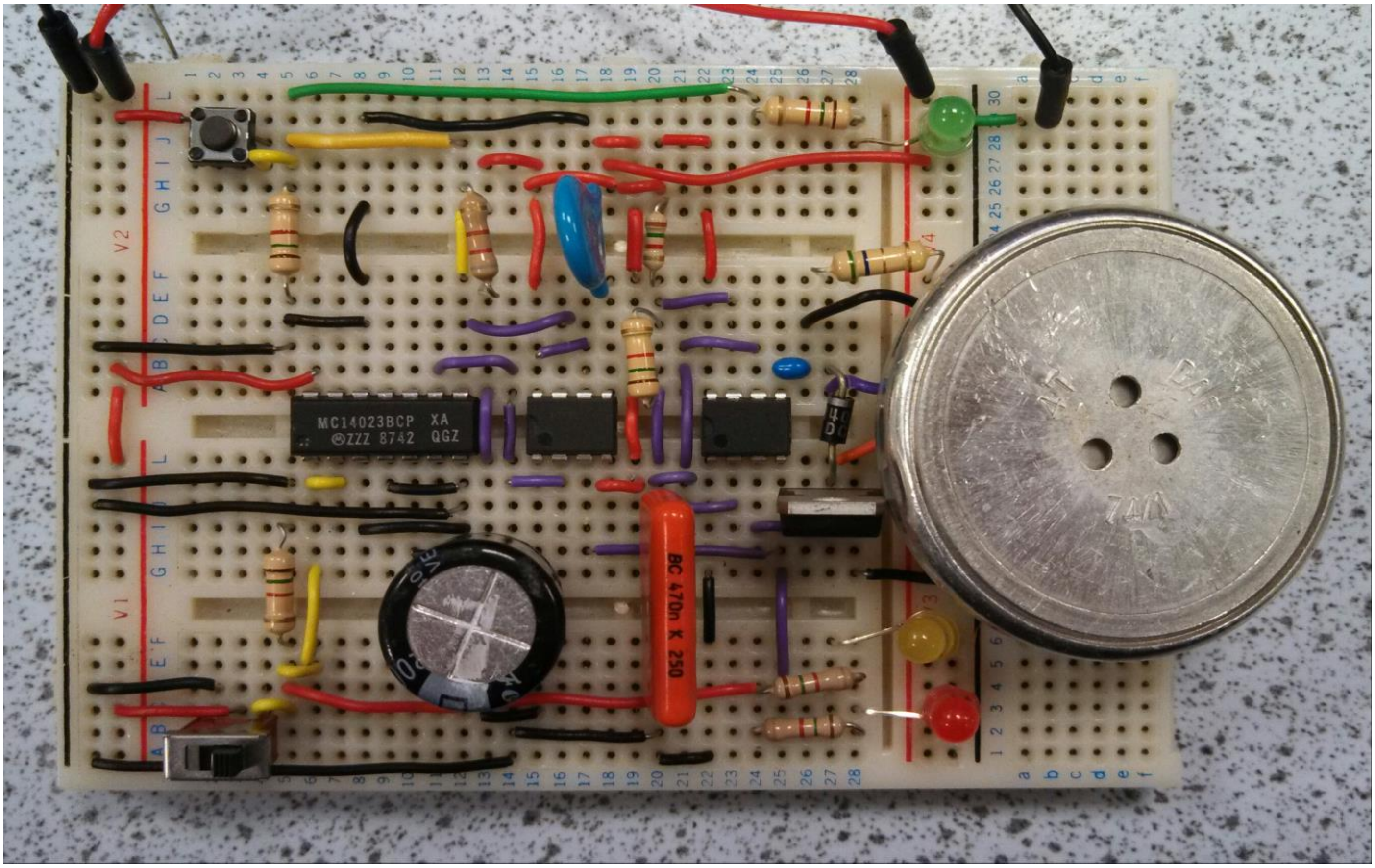


Fig 1. Completed system as of 05/04/16

contents.

SECTION A
problem analysis and solution design.
a-g

Aa - Problem & Solution

On older cars there is no system to remind the driver that the headlights have been left on when they have the door open, to prevent unnecessary drainage of the battery.

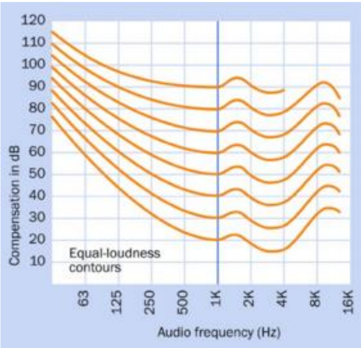
A system that notifies the driver with an Audible Warning Device when the door is open to prevent unnecessary use of headlights when it's dark thus reducing amount of power wasted and therefore extending the battery's lifetime.

Ab - Relevant Research

Due to the large amount of aftermarket 'headlight reminder alarms', it can be said that many people have dealt with the issue of accidentally leaving their headlights on when the car door is open. [1]. Many of these products range of £6 - £20, it would therefore be a positive aspect of the system if the total cost of the parts to be less than or equal to £6.

The human hearing range is between 20Hz and 20 kHz, so obviously the alarm's frequency must fall in between that range. Elderly people however cannot hear the upper and lower end of this frequency spectrum, so that must also be accounted for. Elderly hearing spectrum ranges from +1 kHz of the lower spectrum and -2 kHz of the upper frequency spectrum. [2] Our frequency range is now narrowed down to between 1.02 kHz and 18 kHz. Most alarms and sirens fall into the frequency range 1-3 kHz where the human hearing is the most sensitive [3], a suitable frequency to begin experiments for the AWD would therefore be ~1.5kHz, the midpoint between those ranges.

The reference vehicle will be a BMW 525i E34, I have direct, physical access to this vehicle's official documentation, produced from 1988-1995[4] - this vehicle does not come with a headlight reminder and therefore is useful for reference purposes. From viewing the BMW 525i wiring diagram, I have found that X1035, is not used, but it also connected to the headlights, this will be useful for later circuit integration because it will be possible to directly connect the system into the headlight circuit. This specific node can give up to 0.5A, 9V DC, which is more than necessary for a simple circuit. This gives a figure which can be used to choose a battery, for testing purposes. The negative terminal of the battery and all circuits are connected to the vehicle's chassis acting as a ground. [5].



Because of the subjective assessment of sound is complicated by the nonlinear frequency response of the human ear, chosen frequency values for an AWD will appear louder than actuality because our ears are arguably more sensitive to certain frequencies [11], If a value chosen is in a certain range called the '*equal-loudness contour*' less power will be required to achieve the same perceived level of volume thus increasing the AWD's efficiency. Perceived level of hearing causes some levels of frequencies to sound louder than others, even though the sound pressure is identical, these perceived alterations in sound loudness are known as *equal-loudness contour*, *shown* in the graph left [6].

Fig 2. Equal loudness contour graph [10]

[1] Car headlight buzzer. (n.d.). Retrieved January 24, 2016, from http://www.ebay.co.uk/sch/i.html?_odkw=car+headlight+buzzer&_osacat=0&_from=R40&_trksid=m570.l1313&_nkw=car+headlight+buzzer&_sacat=0

[2] Chou, R. (n.d.). Retrieved January 25, 2016, from http://www.ncbi.nlm.nih.gov/books/NBK53869/

[3] Alarms and sirens. (n.d.). Retrieved January 25, 2016, from http://www.physics.org/featuredetail.asp?id=75

[4] BMW e34 Index. (n.d.) Retrieved January 24, 2016, from http://www.armchair.mb.ca/~dave/BMW/e34/e34_88.pdf

[5] Bosch AutoMechanica, BMWe34 (n.d.) Retrieved January 24, 2016, from https://www.bosch-automechanika.com/en/wp-content/uploads/sites/3/2014/09/P_Pkw-Batterien_en.pdf

[6] Platt, C. (2012). *Encyclopedia of electronic components*. Farnham: O'Reilly.

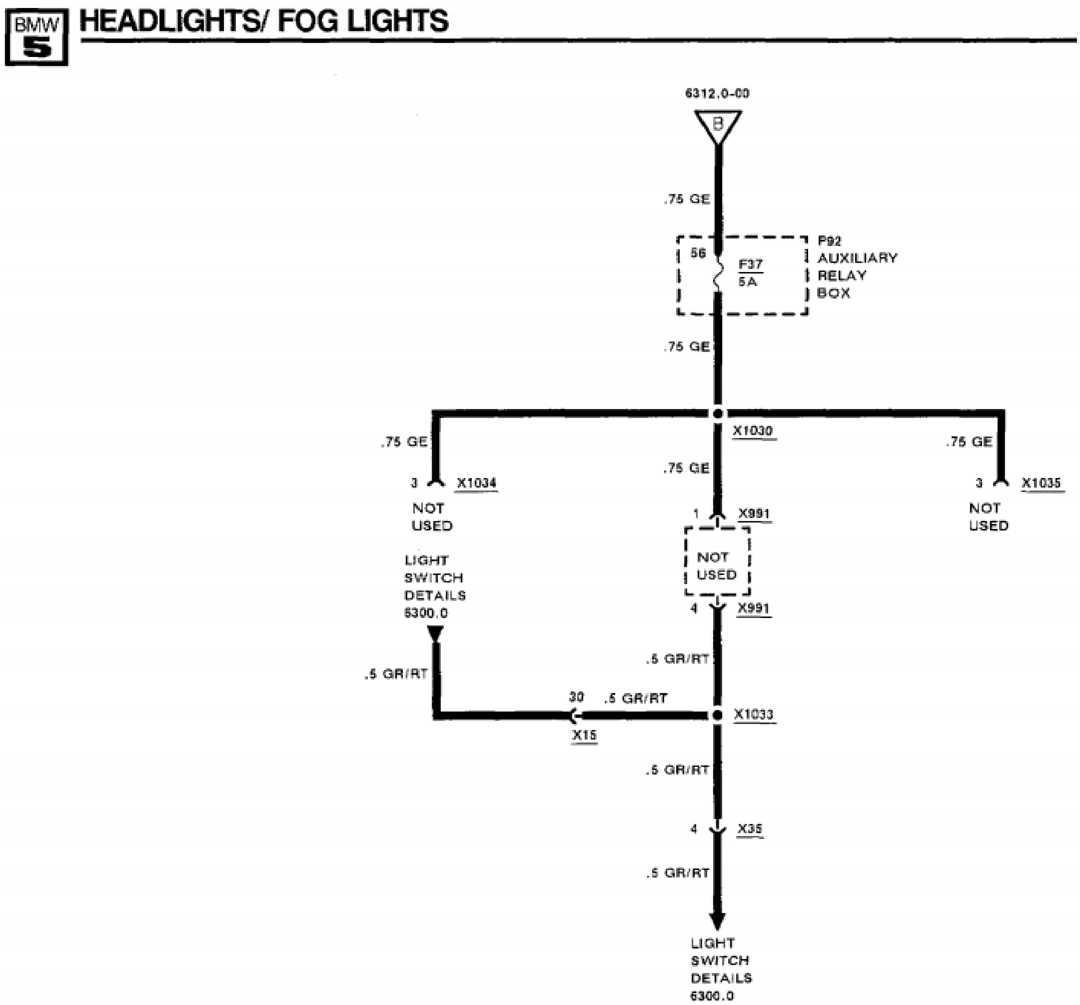


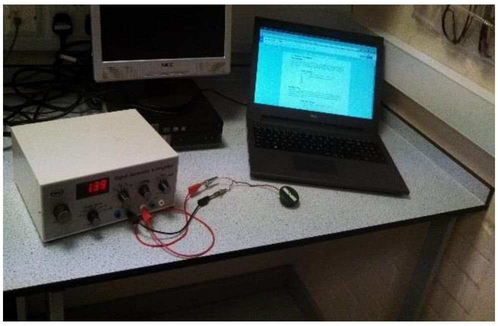
Fig 3. Fuse layout of a BMW 525i battery [5]

A BMW 525i E34 series uses a Bosch S5 A08 12V Type 760A lead acid battery rated at 70Ah.[6] Each low-beam headlight uses 12V, 4.5A each, so 9A overall. If the headlights were left on without the car's engine on, the battery would only last approximately 7 hours. A lead acid battery does not last forever, and a full discharge of the battery from user negligence only results in a shorter battery lifespan. A typical lead-acid battery 'stratifies' (*Excessive acid concentration induces 'sulfation' on the lower half of the plate*s.) once the it has been discharged below 2V, 30 times[7] rendering it unusable, considering a new battery and installation costs around ~£150[8], a user would want their battery to last as long as possible.

Busy outside urban roadside loudness level are, on average 80dB [9], however, sound levels of over 100dB can cause permanent damage to a user's hearing [10]. Inside the car however, the predicted sound level would be significantly lower than outside road loudness levels, around 65dB, and should therefore be higher than this, 70dB, high enough to hear the device over the sound of traffic in an urban environment inside a vehicle, yet low enough to not damage the user's hearing.

[7] Can the Lead-acid Battery Compete in Modern Times? (n.d.). Retrieved January 24, 2016, from
http://batteryuniversity.com/learn/article/can_the_lead_acid_battery_compete_in_modern_times
[8] BMW 5 Series Battery Replacement Cost. (n.d.). Retrieved January 23, 2016, from
https://www.clickmechanic.com/price-estimates/bmw/5-series/battery-replacement
[9] Maryland Gov. (n.d.). Retrieved May 02, 2016, from
http://www.roads.maryland.gov/Index.aspx?PageId=827
[10] Dangerous Decibels - Prevention of noise-induced hearing loss. (n.d.). Retrieved February 01, 2016, from
http://dangerousdecibels.org/education/information-center/noise-induced-hearing-loss/

Ac - Practical Investigation
i) frequency test.
In order to find a suitable frequency for the alarm, I must experiment by changing the independent variable, which is the frequency emitted by frequency generator, the amplitude of the wave will be the same throughout. A series of +400Hz increments will be made, going from the research of 1 kHz up to 3 kHz.

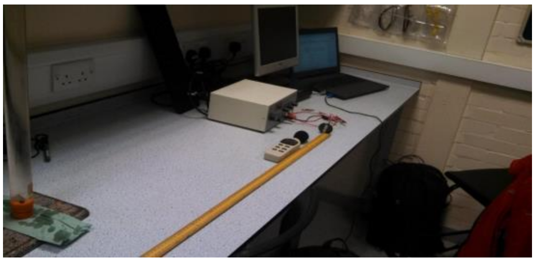


f (kHz)	Comment
1	The low pitch is not alarming and quite easy to ignore.
1.4	Similar to the 1kHz, somewhat more piercing of a noise- yet still fades quite easily into the background.
1.8	Has a greater sense of urgency and is significantly more noticeable than the other frequencies.
2.2	Similar to 1.8 kHz
2.6	Perfect frequency, high pitch makes the audio sound louder than it actually is, not irritating but alarming enough to alert the user, because of the *equal-loudness contour*.
3	Too high, frequency is becoming quieter than it seems.

Fig 4. Setup to test voltage & load effect on current

This chosen result is different from the one expressed in the research of 1.5 kHz, therefore it was a beneficial use of time to experiment with different frequencies to be used for the AWD.

ii) loudness test.
I will also need to find a suitable loudness for the alarm, such that it is not deafening but adequate to create alarm and notify the driver in ambient roadside conditions. To do this it is necessary to find the roadside ambient sound level and then set the loudness of the loudspeaker proportionally at the frequency chosen in the above test. The frequency will be at 2.6 kHz, with a starting position of 50cm moving up at 30 cm increments. The sound level directly in front of the loudspeaker was 116dB. Ambient sound was 62.6dB

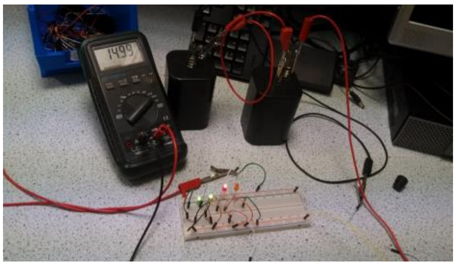


D (cm)	R (dB)	Comment
50	92.5	Far too loud, deafening almost.
80	96.2	Still too loud, but becoming bare.
110	84.1	Uncomfortable to listen to for extended period of time.
140	79.9	Not uncomfortable, but enough to drive me to turn it off.
170	75.2	Adequate
200	74.1	Beginning to become ignorable.

Fig 5. Loudness test w/ distance

Although this experiment does not relate to the possible interference of *equal-loudness contours*, it shows clearly how quickly sound dissipates the further away from the emitter you are, as shown graphically in vi) Graphs.

iii) current variation with load & current variation with voltage change.
From the research, I know the maximum current that can be supplied is 500mA and the maximum voltage is 12V, although this is more than is required to operate a circuit of this scale, it is a good exercise to test how much current is drawn with the number of active components that are going to be used, 5 for example. The input voltage will always be 12V.



No. components	Component Current (mA)				
	a	b	c	d	e
1	15.19	21.75	15.53	15.40	15.39
2	14.93	21.54	15.26	15.26	15.16
4	14.87	20.85	15.08	15.10	15.01
4	14.81	20.69	14.95	14.79	14.89
5	14.71	20.54	14.53	14.33	14.76

Voltage (V)	Current (mA)
2	1.88
4	4.33
6	6.8
8	8.17
10	10.65
12	14.5

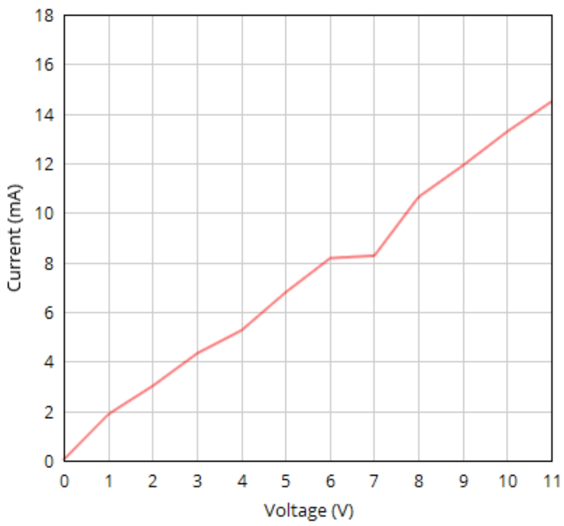
Fig 6. Setup to test voltage & load effect on current

From the results, it shows that an increase in components affects the current draw to other components, but only by a marginal amount. However this should still be taken into account when calculating resistor values, for example, the maximum power dissipation if only one component is attached (thus current across it increases). Although the difference in current is only ±1mA, it should not be ignored.

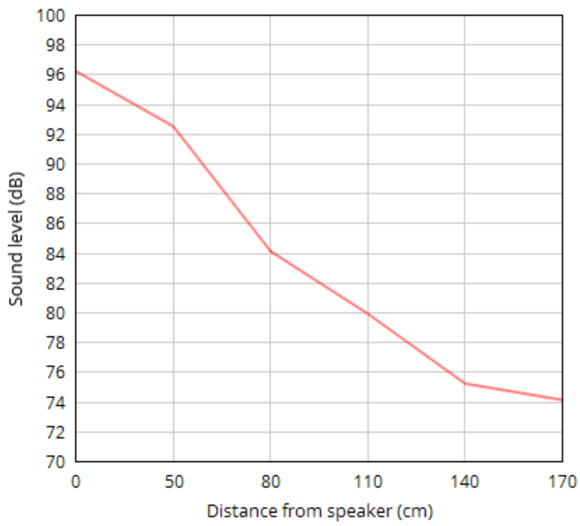
We can also see the positive correlation between voltage and current- due to the nature of the voltage input, a battery which can discharge, it will be useful to see at battery level the imagined circuit can operate at depending on the current draw that is necessary.
Current variation with load and voltage change is expressed graphically below in iv).

iv) – Graphs

loudness test.

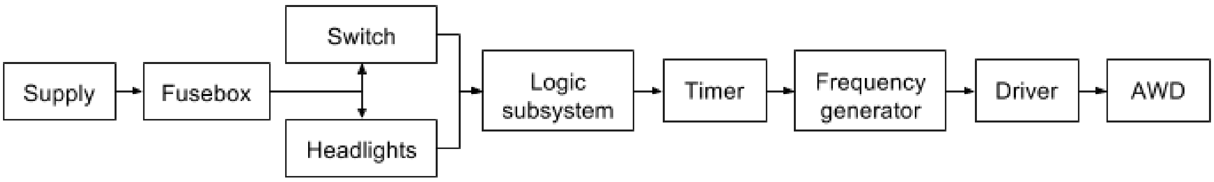


current variation with load.



Ad - Qualitative Description

The system must alert the user using a loudspeaker powered by a frequency generator when; the headlights are on and the door is open to prevent unnecessary use of battery power. The door signal will be generated using a push to make switch. The device must also integrate with the car's power supply system to eliminate any need for external batteries that would need to be replaced over time.



Ae - Quantitative Description

Battery (Bosch S5 A08, X1035)
Voltage 12V ± xV DC
xV depends on battery voltage level)
Current draw 0.45A ±0.05A

AWD Loudness 70dB ± 5dB @1m
Frequency 2.6 kHz ± 100 Hz (continuous tone)
On for 10 seconds ± 2 second

Cost <£6

Af - Subsystem specification

Subsystem	Alternate options	Comment	Cost	Availability
Timer	555 Monostable	Single IC, simpler	In-expensive	High
	Capacitor / Resistor	Expensive Cap. Required	Expensive	High
Frequency generator	555 Astable			
Switch	Reed switch (SPST)	Fragile, requires magnet	Expensive	Low
	PTM switch (SPST)	Simple, rugged		
			In-expensive	High
AWD	Loudspeaker	Loud, cheap	Expensive	Low
	Piezo buzzer	Cheaper, only on frequency	In-expensive	High
Driver	Transistor	Cannot switch at very high frequencies	In-expensive	High
	MOSFET	Can switch at high frequencies	Expensive	High
Logic system	AND gate		In-expensive	Low
	OR gate		In-expensive	Low
	NAND/NOR gate sub.	Allows multiple gates to be built with on IC	In-expensive	High

Category	Object	Cost (£)	Advantages	Disadvantages
Timer	555 Monostable	0.21-0.87	High accuracy component, cheaper.	Low output current.
	Electrolytic Capacitor	1.01-2.17	Output = $+V_s$	High tolerance = inaccurate timing.
Frequency generator	555 Astable	0.21-0.87	Frequency output can be controlled.	Low output current, requires driver.
Switch	Reed switch	3.74-10.81	Sensitive to magnetic fields, useful for detecting physical environmental change.	Expensive, large and fragile due to construction, can only supply low currents (<0.2A)
	PTM switch	0.36-5.83	Cheaper, can supply larger currents	
AWD	Piezo Buzzer	0.39-4.05	Electrically efficient (3-12V @ ~0.005A), smaller, does not require driver.	High impedance, not very loud at smaller sizes.
	Loudspeaker	2.04-7.36	Loud	Large, large power draw (12V @ ~0.03A)
Driver	Transistor	0.35-0.90	Cheaper, high current & voltage gain, high output impedance.	Poor high frequency response, high thermal tendencies.
	MOSFET	1.00-1.49	High input resistance (>50MΩ), large current gain.	Expensive.
Logic subsystem	OR gate	0.27-0.41		
	AND gate	0.26-0.45		
	NOR/NAND substitution	0.29-0.30, 0.26-1.44, respectively		

Driver justification:

MOSFET vs Transistor

The MOSFET has been chosen since it is the only driver available that can switch at the specified speed, 2.6 kHz, this is a vital part of the overall systems function, and to choose a large element of functionality over a very small price difference would be illogical. The MOSFET also has a very high input resistance, which reduces the risk of failure, because a Transistor can be damaged if the base voltage is too high, the MOSFET also has a positive thermal coefficient, which; the transistor does not, and it therefore more likely to be damaged in a constant-use environment. Due to these factors, the MOSFET is the only available option that meets the specified requirements.

Output justification:

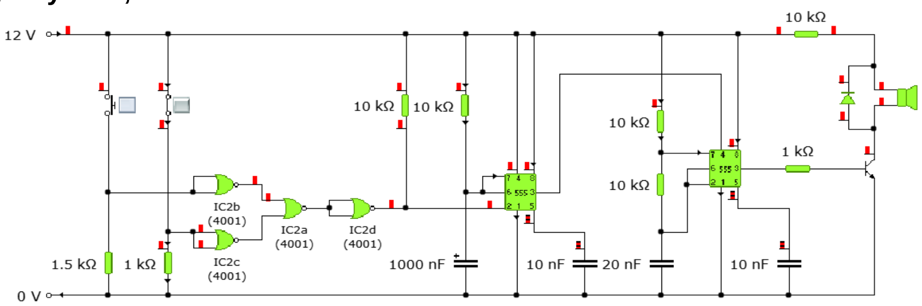
Loudspeaker vs Buzzer

In the spec, it was noted that the output frequency should be 2.6 kHz, due the nature of a buzzer, alternate frequencies cannot be set, however, the use of a loudspeaker makes the overall system more complex, since it requires and Astable frequency generator. The buzzer is also quieter in comparison to the loudspeaker, since it only operates at around 6V. The spec specified that the frequency should be 2.6 kHz and 70dB @ 1m, the loudspeaker therefore is the only available option to meet these requirements.

Ag - Alternate subsystem justification

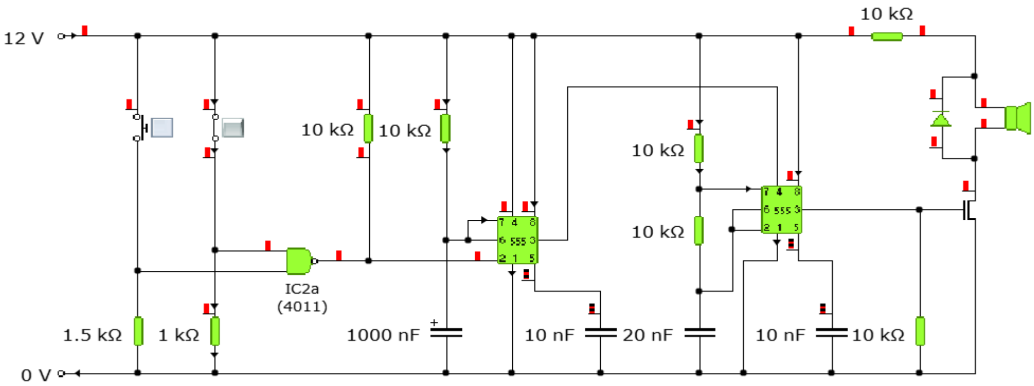
Using the lowest cost, a total estimated price will be gathered for each design, all prices have been taken from uk.rs-online.com [11].

1 Logic system, NOR substitution



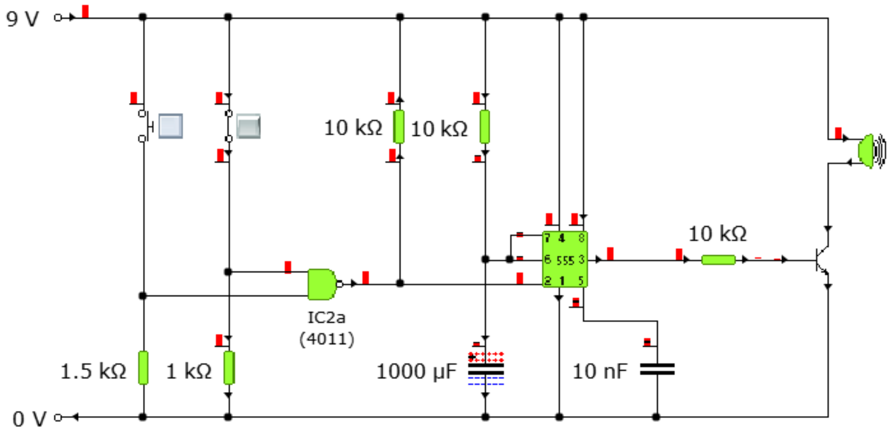
Components	Cost	Complexity	No. of components	Availability
1*PTM switch	£0.360	Requires 3 more logic gates to be used, much more complex than a single NAND.	19	High
1*SPST switch	£0.206			High
1* two-input quad NOR IC	£0.260			Low
3*1kΩ resistor	£0.045			Low
5*10kΩ resistor	£0.140			Low
2*10nF capacitor	£0.290			High
1*20nF capacitor	£0.148			High
2*555 IC	£0.420			High
1*0.12F capacitor	£0.502			High
1*Transistor	£0.350			High
1*8Ω loudspeaker	£2.04			High
1* diode	£0.027			High
TOTAL	**£5.04**			

2 Driver w/ MOSFET (Metal-Oxide Semiconductor Field Effect Transistor)



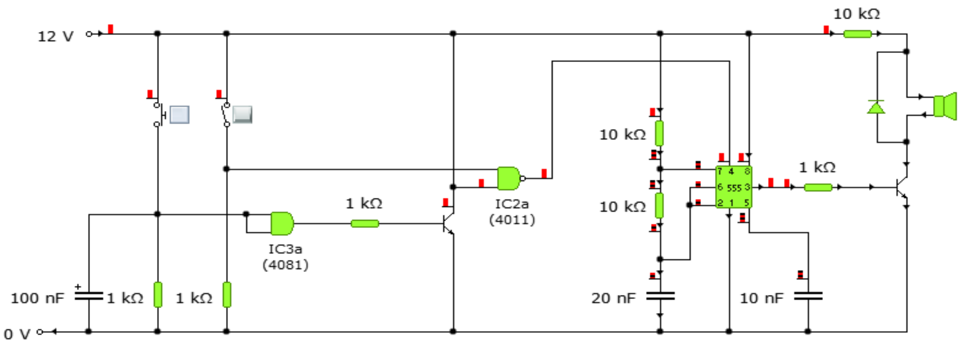
Components	Cost	Complexity	No. of components	Availability
1*PTM switch	£0.360	Same as using a NPN transistor, except resistor is not in series with driver, but acting as a protection from static charge because of MOSFET's high impedance.	20	High
1*SPST switch	£0.206			High
1* two-input quad NAND gate	£0.290			Low
2*1kΩ resistor	£0.030			High
6*10kΩ resistor	£0.168			High
2*10nF capacitor	£0.290			High
1*20nF capacitor	£0.148			High
2*555 IC	£0.420			High
1*0.12F capacitor	£0.502			High
1*MOSFET	£1.000			High
1*8Ω loudspeaker	£2.040			High
1* diode	£0.027			High
TOTAL	**£5.48**			

3 Buzzer output substitution



Components	Cost	Complexity	No. of components	Availability
1*PTM switch 1*SPST switch 1* two-input quad NAND IC 3*1kΩ resistor 2*10kΩ resistor 1*10nF capacitor 1*555 IC 1*0.12F capacitor 1*Transistor 1*buzzer 1*diode	£0.360 £0.206 £0.290 £0.045 £0.056 £0.145 £0.012 £0.210 £0.502 £0.350 £0.045 £1.260 £0.027	Requires no astable, therefore easier to construct, however, the frequency output cannot be altered, limited sound output (dB).	13	High
TOTAL	**£3.451**			

4 Timing using capacitors



Components	Cost	Complexity	No. of components	Availability
1* PTM switch 1* SPST switch 4* 1kΩ resistors 3* 10kΩ resistors 1* dual-input quad NAND IC 2* transistors 1* 100nF capacitor 1* 10nf capacitor 1* 20nf capacitor 1* loudspeaker 1* diode 1* 555 IC	£0.360 £0.206 £0.060 £0.084 £0.290 £0.350 £0.283 £0.148 £0.410 £2.040 £0.027 £0.210	Requires additional logic and drivers,	19	High
TOTAL	**£4.144**			

[11] RS Components | Electronic and Electrical Components. (n.d.). Retrieved February 01, 2016, from http://uk.rs-online.com/

Chosen system: Driver w/ MOSFET (Metal-Oxide Semiconductor Field Effect Transistor)

This system is the least complex; in terms of logic, whilst also providing the complete specified functionality. The astable allows for accurate output frequency, which the MOSFET can supply, and the monostable can output accurate timing, which is necessary for an alarm and the loudspeaker is loud enough for the device to be effective in alerting the user. It is also under the £6 cost.

Alternatives:

Logic system, NOR substitution

Requires three more logic gates to be used, adding unnecessary complexity to the device which can be avoided using NAND gates. Under the £6 cost.

Timing using capacitors

Inaccurate timing caused by capacitors high tolerance, of 50% which does not meet the specification of 10 seconds ± 1 second. Under the £6 cost.

Buzzer output substitution

Unable to set the frequency to 2.6 kHz, it also does not meet the 70dB requirement unlike the loudspeaker. Under the £6 cost.

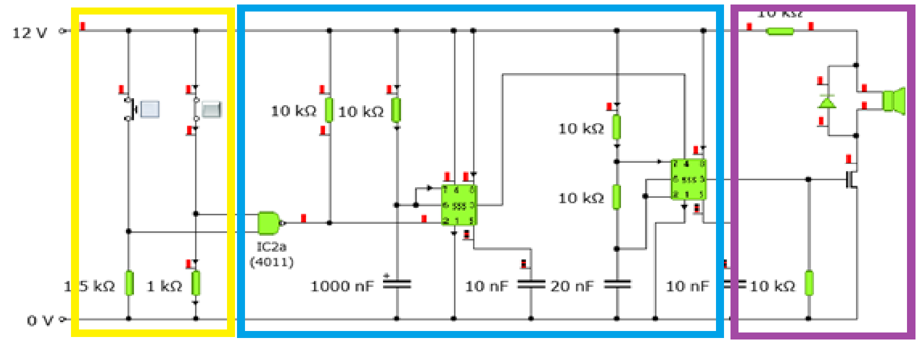
SECTION B
system development.
a-h

Ba - Circuit subsystem development

The following components are used in the final construction.

Component	Quantity	Subsystem
PTM switch	**1**	**Input**
SPST switch	**1**	**Input**
Dual triple-input NAND IC - 7410	**1**	**Processing**
1kΩ resistor (250mW)	**2**	**Input**
10kΩ resistor (250mW)	**6**	**Processing**
10nF capacitor	**2**	**Processing**
20nF capacitor	**1**	**Processing**
555 IC	**2**	**Processing**
0.12F capacitor	**1**	**Processing**
N-channel MOSFET IRF630	**1**	**Output**
8Ω loudspeaker	**1**	**Output**
1N4148 diode	**1**	**Output**

Yellow = Input **Blue = Processing** **Purple = Output**



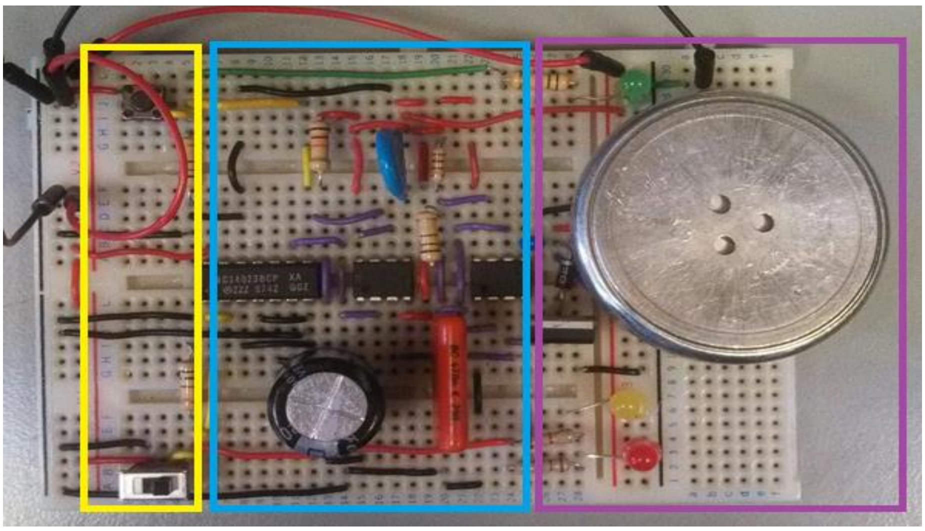
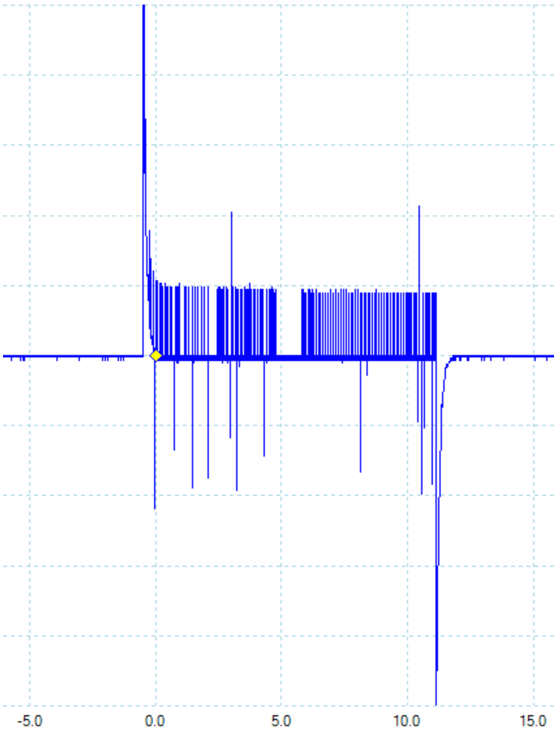


Fig 7. Circuit systems diagram. Fig 8. Physical systems diagram

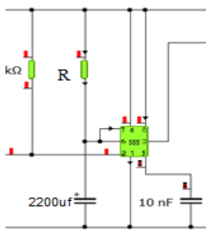
Bb/c - Component calculation & Subsystem measurements

Monostable time period, capacitance value



To calculate the resistor value for the monostable timing circuit, the following calculation was made. The time on is 10 seconds and the capacitance of C is 0.0022F; so *'T' & 'C'* can be substituted into the equation to find R as shown below.

$$T = 1.1 * R * C$$
$$\Rightarrow 10 = 1.1 * R * 0.0022$$
$$\Rightarrow R = \frac{10}{(1.1 * 0.0022)}$$
$$\therefore R = 4132.23\Omega$$



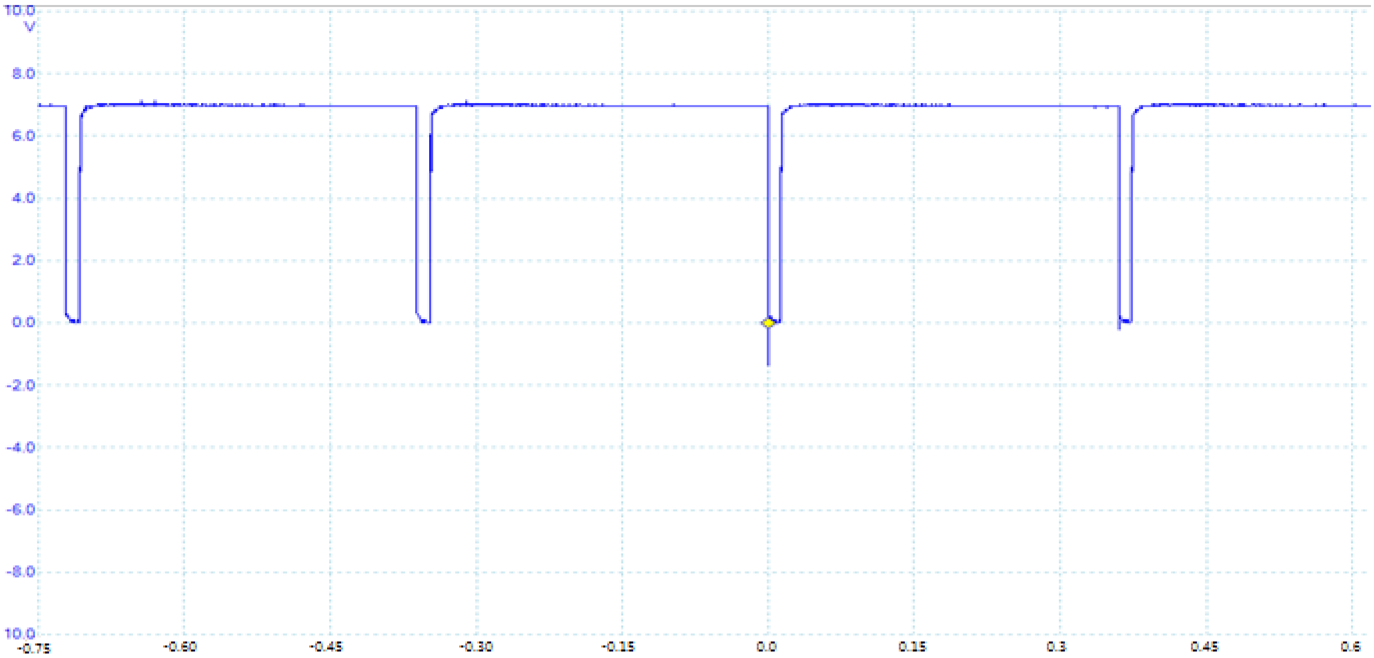
The resistor value is 4.132kΩ, but there is no single resistor with that specific value on the E24 series of resistors, the next closest will be chosen, 5.1kΩ

The time high period on the graph starts at -0.36 and ends at 11.74 seconds. Therefore the total time high is:

$$t_H = -0.36 + 11.74$$
$$\therefore t_H = 11.30 \; seconds$$

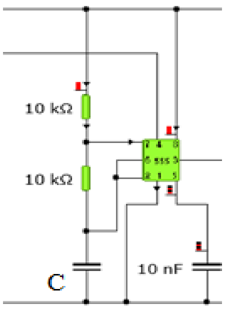
11.3 seconds is within the ±2 second tolerance, mentioned in the spec, Output voltage of the monostable was recorded as 7.38V.

Astable frequency, capacitance value



$$f = \frac{1.44}{(3(R)) * C}$$
$$\Rightarrow C = \frac{1.44}{(3(R)) * f}$$
$$\Rightarrow C = \frac{1.44}{(3(10 * 10^{\wedge}3)) * 2.6 * 10^{\wedge}3}$$
$$\therefore C = 0.1248F$$

Since there is no 0.1248F capacitor, a 0.12F capacitor will be chosen.



To calculate the capacitor value for the astable frequency generator circuit, the following calculation was made. The desired frequency is 2.6 kHz; and the R value is 10,000, since R_1 is the same as R_2, so *'f'* can be substituted into the equation to find C as shown below.

In order to calculate the actual output frequency, we must use the results gathered from the graph above (made in PicoScope 6). Starting from the origin, 0, the initial pulse begins at, 0.2µs, and the wave ends at 0.374µs. To find the frequency we use:

$$f = \frac{1}{t}$$

Where t = 0.002µs + 0.374µs = 0.376µs (peak to peak)

$$\therefore f = \frac{1}{0.376}$$
$$f = 2.659kHz$$

Output voltage was recorded as 7.27V.

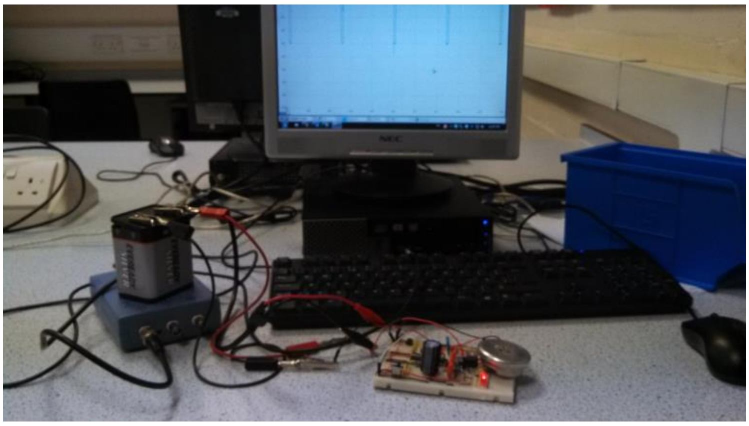
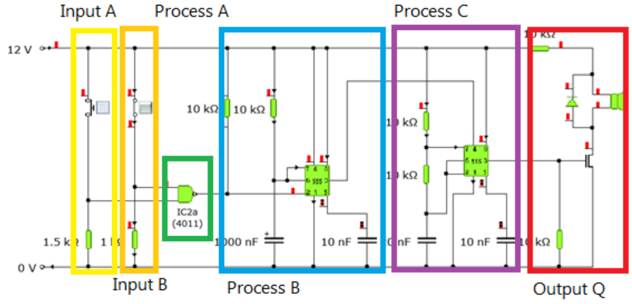
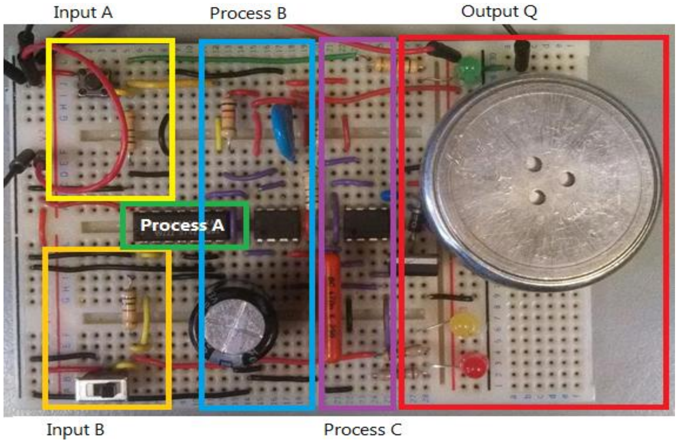


Fig 9. Using PicoScope to find output frequency and timing.

Bd - Overall system function explanation





The system function can be made by utilising several subsystems; in logical order these are: input subsystems, a logic system, a timer system, a frequency generator, a driver, and finally the output subsystem.

The first of these subsystems are the inputs, there are two inputs, the headlights, Input A and door opening, Input B. The headlight signal is generated by another, irrelevant subsystem, when the headlights are on, a 'high' signal is generated. The second input is a Push-to-make switch, when pressed the output, is 'high' for a very short period, however it can be held down to create a high signal for a longer period of time, however the process of pressing the PTM switch momentarily when the door is opens is an engineering, not electronic task to solve.

In order to trigger an AWD for a set amount of time, a 555 monostable must be created. This generates a 'high' signal for a custom amount of time, however, this IC is triggered only by a falling-edge pulse, from 1 to 0, high to low. In order to create this low-going pulse, a logic subsystem, Process A, must output 0, to trigger the monostable only when; the headlights are on (logic 1) and the door is open (logic 1), it must not however, output 0 when the lights are open and the door is closed, and when the lights are off and the door is open. This can be explained the Boolean table as shown:

A	B	Q
0	0	1
1	0	1
0	1	1
1	1	0

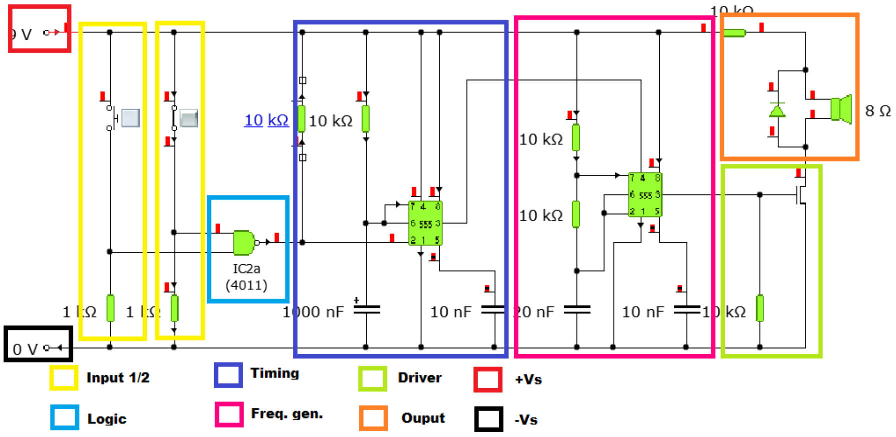
Where A is the headlights, and B is the door.

As you can see from the above, Q is low, when headlights (A) AND the door (B) are high, this can be achieved easily using a NAND gate. The NAND gate takes the two inputs and AND's and then NOT's them, generating a 0 signal. If the headlight is off, and the door is open, the signal is high and will not make a falling-edge pulse and will be high. If the door is closed, and the headlight is on, the output signal is also high. Since the PTM switch is only triggered 1 for a millisecond or so, the output of the NAND gate will also be 0 for a millisecond or so, this logic system generates the falling-edge signal required to trigger a monostable.

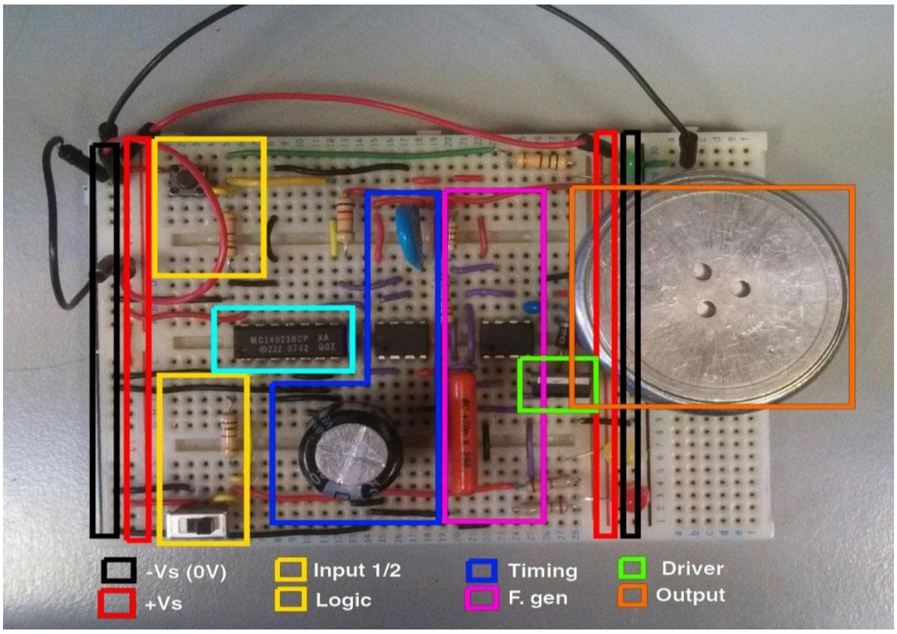
When the input voltage signal to the monostable, Process B, generated by the output of the NAND gate, Process A , Vin, goes below 1/3 of the supply voltage, +Vs, the monostable output, Vout, becomes +Vs and the discharge terminal becomes an open circuit. This allows the capacitor, C, to charge via its series resistor. The output voltage will remain at +Vs until the voltage across the capacitor becomes greater than the threshold switching voltage, which is 2/3 of +Vs. When this happens, Vout will return to 0V and the discharge terminal will connect back to 0V, this causes the capacitor to discharge, creating Vout's 1 signal. This state is stable and will remain so until Vin becomes less than 1/3 +Vs, or until the output of the NAND gate goes low.

The stable high output signal of the monostable can then be used to trigger a frequency generator, Process C, in this case a 555 Astable, via it's reset terminal. When the astable is first switched high by the monostable, via the reset, the capacitor, C is discharged and so the voltage across this capacitor is less than the trigger voltage, so the astable's Vout, becomes +Vs. The capacitor then charges through the two series resistors, until the voltage across it is greater than the threshold switching level, at this point Vout becomes 0V and the discharge terminal is connected to 0V.

The capacitor now discharges through the 2nd series resistor, until the voltage across it becomes less than the switching voltage. When this happens, Vout now becomes +Vs, and the process repeats until the monostable time period is over, i.e. no signal at reset is received.



Since in reality the fluctuating output voltage does not actually become +Vs, due to the internal construction of the 555 IC, the actual voltage will depend upon the current flowing through the output, which is typically only few mA, the actual output voltage is approximately +Vs -1 V. A few mA at +Vs -1 is unsuitable to drive a high power component such as a loudspeaker, which is what is going to be used for the Audible Warning Device. Therefore a driver is required to operate it. In such a case where switching high and low at 2.8 kHz is required, an Enhancement Mode metal-oxide-semiconductor field-effect transistor (MOSFET) is the only available solution. When the output of the Astable is sent to the gate of the MOSFET, it begins to saturate high at 0.1V when the Vout of the astable is about 2V. Any further increase in Vin has no effect on Vout, the MOSFET is therefore operating as a switch in the same way as transistor, and can be used to drive the loudspeaker or Output Q.



Input 1 / 2 is synonymous with Input A / B, respectively.

SECTION C
making measurements.
a-g

Ca - Test procedure planning

In order to make the system as effective and useful as possible, a series of tests must be carried out on the current completed systems performance, in order to propose improvements, these include;

i) Total current draw of completed system when idle and activated at a range of supply voltages.
   To see how the system performs, and can run of the specified fuse output.
ii) Output sound level of AWD over a series of voltages.
   To see if the voltage can affect the sound level until it is inaudible.
iii) Loudspeaker output frequency over a series of voltages.
   To see if lower/ higher voltages affect frequency so that a subsystem would need to be implemented to solve the issue.
iv) Monostable time period over a series of voltages.
   Most importantly, how long the system stays on for in the event of the headlights being on and the door open, this may require another subsystem to keep a constant 15 second time period over a range of voltages.
v) NAND gate logic output.
   To test if the inputs are correct to the Boolean table, described in Bd.

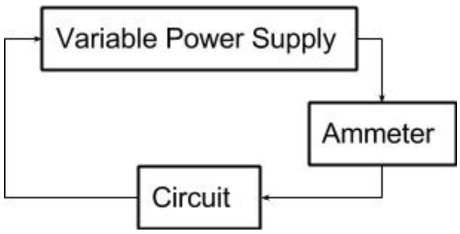
Once these have been carried out, and the results assessed, improvements will be made corresponding to the effect of voltage on each of these aforementioned tested areas of the system.

i) Total current draw of completed system when idle and activated at a range of supply voltages.

Equipment:

Completed system
Variable power supply
Multimeter, measuring current

Method:
Arrange the completed system in the below diagram (Fig 10.), with the Multimeter in series with the Completed system at the positive supply. Note down the current drawn when; the system is idle, i.e. loudspeaker is not on and when the switch has been triggered, and therefore the loudspeaker is on. This process must be repeated across a range of voltages from 3V to 12V. Record the results in the table below and comment on the effect of the voltage level.



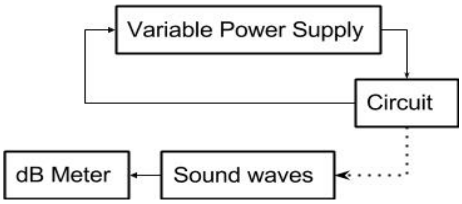
Voltage (Volts)	Current draw (Milliamps) Idle	AWD on	Comment
3			
6			
9			
12			

ii) Loudspeaker loudness across a range of supply voltages.

Equipment:

Completed system
Variable power supply
Decibel meter

Method:
Arrange the completed system as shown in the below diagram (Fig 11.), with the decibel meter approximately 20cm away from the loudspeaker, with the output facing directly towards the decibel meter microphone. Repeat the process 3 times over a range of voltages, so to increase reliability and average loudness accuracy. Record the results in the table below, once collected calculate and average loudness of each voltage. The sound level at 3V has been omitted since no sound is produced at this voltage.



Voltage (Volts)	Loudness of speaker (dB) Repeat 1	Repeat 2	Repeat 3	Average loudness level (dB)
6				
9				
12				

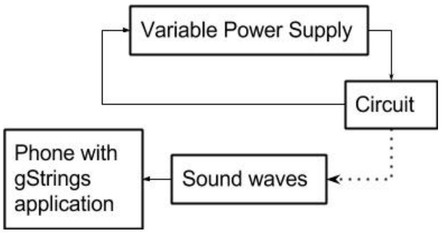
iii) Loudspeaker output frequency measured by guitar application across a range of supply voltages.

Equipment:

Completed system
Variable power supply
Phone with frequency measuring application

Method:

Arrange the completed system in the below diagram (Fig 12.), with the mobile device approximately 20cm from the loudspeaker, with the microphone facing directly towards of the output. Record the output frequency across a range of voltages from 6V to 12V, repeat the process 3 times for each voltage to increase reliability and average accuracy. Record the results in the table below, once collected calculate an average output frequency for each voltage.



Voltage (Volts)	Frequency of loudspeaker (Hertz) Repeat 1	Repeat 2	Repeat 3	Average frequency of loudspeaker. (Hertz)
6				
9				
12				

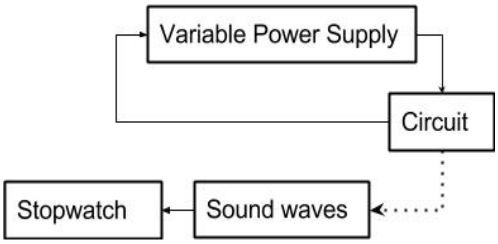
iv) Monostable time period when activated across a range of supply voltages.

Equipment:

Completed system
Variable power supply
Stopwatch

Method:

Arrange the completed system in the below diagram (Fig 13.). Using the stopwatch, time the time period of the monostable using an LED to alert you that the monostable output it high. Repeat the process 5 times, over a range of voltages from 6V to 12V, so to increase reliability and average accuracy, and to compensate for human error because of reaction time. Record the results in the table below, once collected calculate an average time period for each voltage. R = repeat.



Voltage (V)	Time period (seconds) R1	R2	R3	R4	R5	Average time period (seconds)	Comment
3							
6							
9							
12							

v) Logic system outputs

Equipment:

Completed system
Power supply
Voltmeter

Method:

Arrange the completed system in the below diagram (Fig 14.). Using the voltmeter record the outputs of both switches, Input A and B, record both the voltage and Logic output (Logic 1 is assumed to be >½ +Vs)

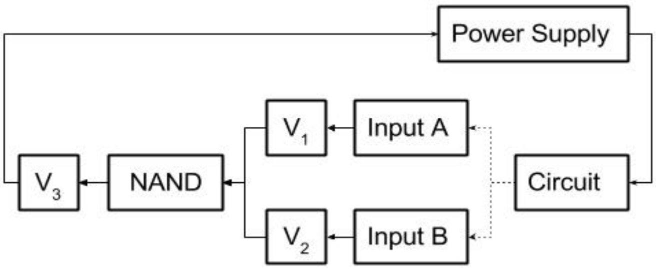
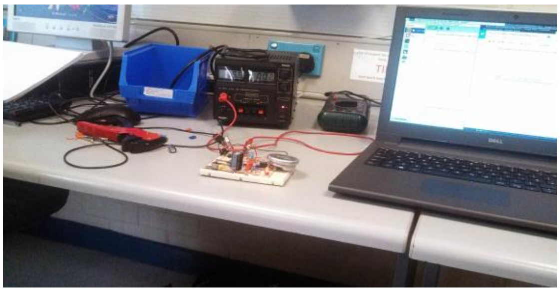


Fig 14. Diagram

V1 (A)	V2 (B)	V3 (NAND)
0	0	1
0	1	1
1	0	1
1	1	0

Cb - Test results

i) Total current draw of completed system when idle and activated at a range of supply voltages.



Voltage (Volts)	Current draw (Milliamps) Idle	AWD on	Comment
3	<10~	<10~	AWD does not function at this voltage.
6	20~	240~	
9	30~	390~	
12	40~	510~	AWD starts becoming quieter.

Fig 15. Setup to find current draw of the completed system.

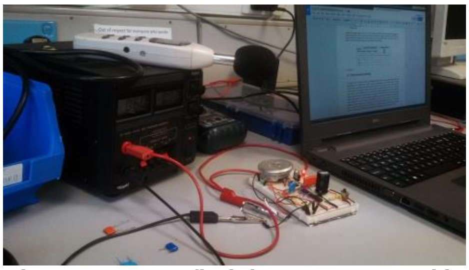
Conclusion:
As shown by the results, the total current draw is 10mA above the total output current of the voltage provided by the fuse mentioned in the spec. (12V), therefore in order for the system to function, the current draw must be lowered, this can be achieved by lowering the input voltage down to 9V. It must also be noted that once the output voltage drops below 6, it cannot be guaranteed that the system will function. At 12V the AWD begins to reach its peak input voltage and the sound level becomes quieter which is also expressed in test on output volume. The ideal voltage for current draw is therefore 9V, the input voltage of the entire system must be lowered to 9V, yet still run off the 12V supply. However another option would be to change the fuse used to power the system, this would negate the need of another subsystem to lower the input voltage.

ii) Loudspeaker loudness across a range of supply voltages.

Equipment:

Completed system
Variable power supply
Decibel meter

Method:
Arrange the completed system as shown in the below diagram (Fig 16.), with the decibel meter approximately 20cm away from the loudspeaker, with the output facing directly towards the decibel meter microphone. Repeat the process 3 times over a range of voltages, so to increase reliability and average loudness accuracy. Record the results in the table below, once collected calculate and average loudness of each voltage. The sound level at 3V has been omitted since no sound is produced at this voltage.



Voltage (Volts)	Loudness of speaker (dB) Repeat 1	Repeat 2	Repeat 3	Average loudness level (dB)
6	70.8	69.8	68.2	69.6
9	62.5	64.7	64.3	63.8
12	59.1	59.9	60.4	59.8

Fig 16. Setup to find the output sound level.

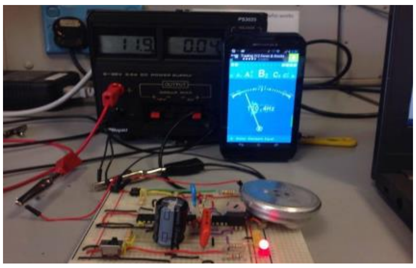
Conclusion:
It is peculiar to see that as voltage increases, sound level decreases - perhaps this is due to the optimal operating voltage being 6V, therefore in order reach maximum output sound level, the input voltage of the loudspeaker must be lowered to 6V to achieve the 70~dB level of sound mentioned in the spec.

ii) Loudspeaker output frequency measured by guitar application across a range of supply voltages.

Equipment:

Completed system
Variable power supply
Phone with frequency measuring application

Method:
Arrange the completed system in the below diagram (Fig 17.), with the mobile device approximately 20cm from the loudspeaker, with the microphone facing directly towards of the output. Record the output frequency across a range of voltages from 6V to 12V, repeat the process 3 times for each voltage to increase reliability and average accuracy. Record the results in the table below, once collected calculate an average output frequency for each voltage.



Voltage (Volts)	Frequency of loudspeaker (Hertz) Repeat 1	Repeat 2	Repeat 3	Average frequency of loudspeaker. (Hertz)
6	2594	2599	2597	2596.667
9	2607	2602	2604	2604.333
12	2618	2620	2617	2618.333

Fig 17. Using gStrings Android app to record output frequency.

Conclusion:
Increased voltage has little overall effect on the frequency output of the AWD, however the chosen value of, 2.6KHz is not the current frequency output. The frequency generator subsystem must therefore be altered to reach this frequency.

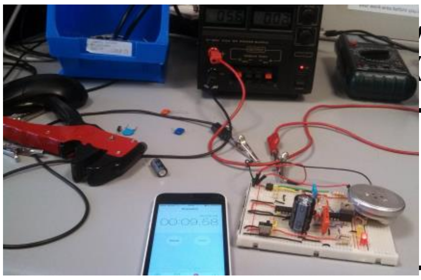
ii) Monostable time period when activated across a range of supply voltages.

Equipment:

- Completed system
- Variable power supply
- Stopwatch

Method:

Arrange the completed system in the below diagram (Fig 18.). Using the stopwatch, time the time period of the monostable using an LED to alert you that the monostable output it high. Repeat the process 5 times, over a range of voltages from 6V to 12V, so to increase reliability and average accuracy, and to compensate for human error because of reaction time. Record the results in the table below, once collected calculate an average time period for each voltage.



Voltage (Volts)	Time period (seconds) R1	R2	R3	R4	R5	Average time period (seconds)	Comment
3	21.58	22.78	22.75	22.73	22.53	22.474	AWD does not function
6	12.55	12.40	12.42	12.40	12.38	12.430	
9	10.96	10.93	10.86	10.68	10.90	10.866	
12	9.85	9.65	9.61	9.58	9.61	9.660	

Fig 18. Setup of iPhone timer and completed system

Conclusion:

The increased rate of discharge at higher voltages can easily be explained by explaining how a 555 Monostable functions and the relationship between capacitance and power draw. Using $W=1/2CV^2$ & $P=dW/dt$, we can see how much power is stored by the capacitor, with the capacitor, C, being 0.128F, which was a controlled variable, and the voltage being the independent variable.

$$W = \frac{1}{2}CV^2$$

Where:
W = energy stored - or work done in establishing the electric field (*joules, J*)
C = capacitance (*farad, F*)
V = potential difference (*voltage, V*
So when *V*=9

$$\Rightarrow W = \frac{1}{2}(0.128 * 10^{-6}) * 9^2$$
$$\therefore\ W = 0.1584J$$

But when *V* = 3,

$$\Rightarrow W = \frac{1}{2}(0.128 * 10^{-6}) * 3^2$$
$$\therefore\ W = 0.0033J$$

Using:

$$P = \frac{dW}{dt}$$

Where:
P = potential power (*watts, W*)
dt = dissipation time (*seconds, S*)
When *V*=12, P then =

$$\Rightarrow P = \frac{0.1584}{9.660}$$
$$\therefore\ P = 0.0001451W$$

And when *V*=3, P =

$$\Rightarrow P = \frac{0.0033}{22.74}$$
$$\therefore\ P = 0.1639W$$

This larger power storage explains why the capacitor of the monostable is able to discharge through the series resistor for longer.

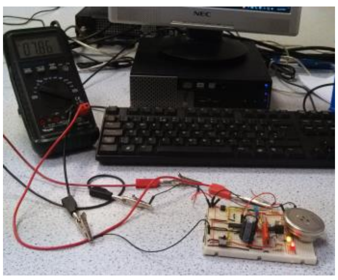
v) Logic system outputs

Equipment:

- Completed system
- Power supply
- Voltmeter

Method:

Arrange the completed system in the below diagram (Fig 19.). Using the voltmeter record the outputs of both switches, Input A and B, record both the voltage and Logic output (Logic 1 is assumed to be >½ +Vs)



V1, Input A		V2, Input B		V3, NAND; Q	
0	0.003	**0**	0.000	**1**	8.740
0	0.003	**1**	8.740	**1**	8.710
1	8.800	**0**	0.000	**1**	8.720
1	7.880	**1**	7.860	**0**	0.000

Conclusion:

The system responds to the inputs as specified, and thus the whole system works accordingly, all inputs when sent high returned a value of >1/2+Vs, and all inputs when sent low returned a value of <1/2+Vs.

Cc - System functionality comment:

Cd – System review

Initially in section Aa, the problem stated was:

> "On older cars there is no system to remind the driver that the headlights have been left on when they have the door open, to prevent unnecessary drainage of the battery."

In response to this I wanted:

> "A system that notifies the driver with an Audible Warning Device when the door is open to prevent unnecessary use of headlights when it's dark thus reducing amount of power wasted and therefore extending the battery's lifetime."

The system does alert the user, but if the alarm was set off in a busy environment, the current sound output level would not be suffice, and the user may be able to ignore the quiet sound, relative to ambient sound levels (as shown in the below table).

Specification	Measured output	Comment
Battery: 9V	-	-
Loudness 70dB ± 5dB @1m	63.8dB	Outside the tolerance value of the specification.
Frequency 2.6 kHz ± 100 Hz (continuous tone)	2604.333Hz	Inside Specification tolerance.
On for 10 seconds ± 2 second	10.866 seconds	Inside specification tolerance
Current 0.5A ±0.05A (when AWD on)	~390mA	Inside specification tolerance.

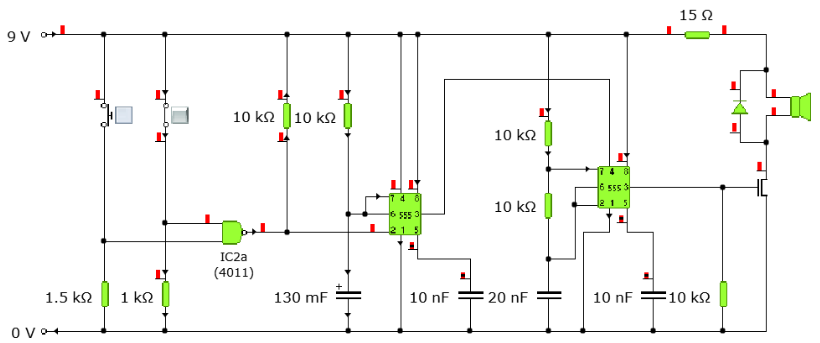
Ce – Circuit limitations and possible modifications

Limitations	Possible Modifications
Loudspeaker output sound is too low for the user to hear over loud ambient settings, such as a roadside.	Decrease loudspeaker input voltage to achieve maximum output sound, as shown in Cbii) where the highest level of sound is 68dB, which would be inside the tolerance of 5dB stated in the specification. This would be possible by creating a voltage drop across the output of the MOSFET using a resistor.
Loudspeaker does not turn off when the headlights are off.	Circuit could involve an AND gate, so that the loudspeaker would only turn on when the headlight switch was high and the monostable output was high.
Circuit does not turn headlights off automatically after a set amount of time.	Monostable could feed into the input of a logic system that would turn the headlight off once the entire pulse has finished.

Cf – System alterations

From the above limitations, the most important aspect of the system is to alert the user; therefore the best course of action is to reduce the input voltage to the loudspeaker so that the voltage to the loudspeaker would be 6V, instead of 9V, doing this would result in a higher output sound level, because the rated input voltage of the Loudspeaker is 6V, but it currently running from a 9V supply.

By adding a larger resistor to the input of the MOSFET, I created a larger voltage drop across it, thus reducing the input voltage to the loudspeaker from to 6V, the optimal voltage for maximum sound output; this is shown below.



Voltage	Loudness level (dB)
3	63.1
6	68.3
9	73.3
12	73.9

By repeating the same experiment in Ca; with the new resistor values, as shown in the results, with the smaller resistor in place, the voltage across the loudspeaker is now lower, and thus the output sound level is higher than before, 73.3dB is within the 5dB tolerance of 70dB and so the system is in full accordance with the initial specification. This modification has no disadvantages.

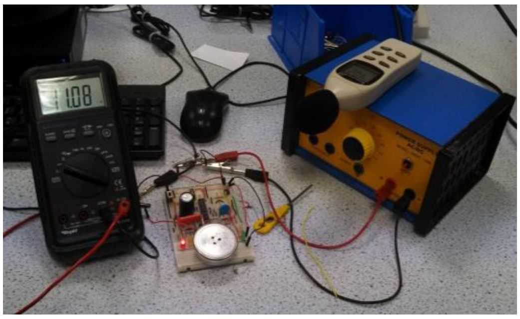


Fig 20. Ca repeat sound level

SECTION D bibliography. c

Dc - Bibliography

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I would like to acknowledge Owen Millett for his guidance in the production of this report.
- John Leggott College Electronics teacher
I would also like to acknowledge Steven Pearson for his help in the use of PicoScope 6.
- John Leggott College technician

List of figures.