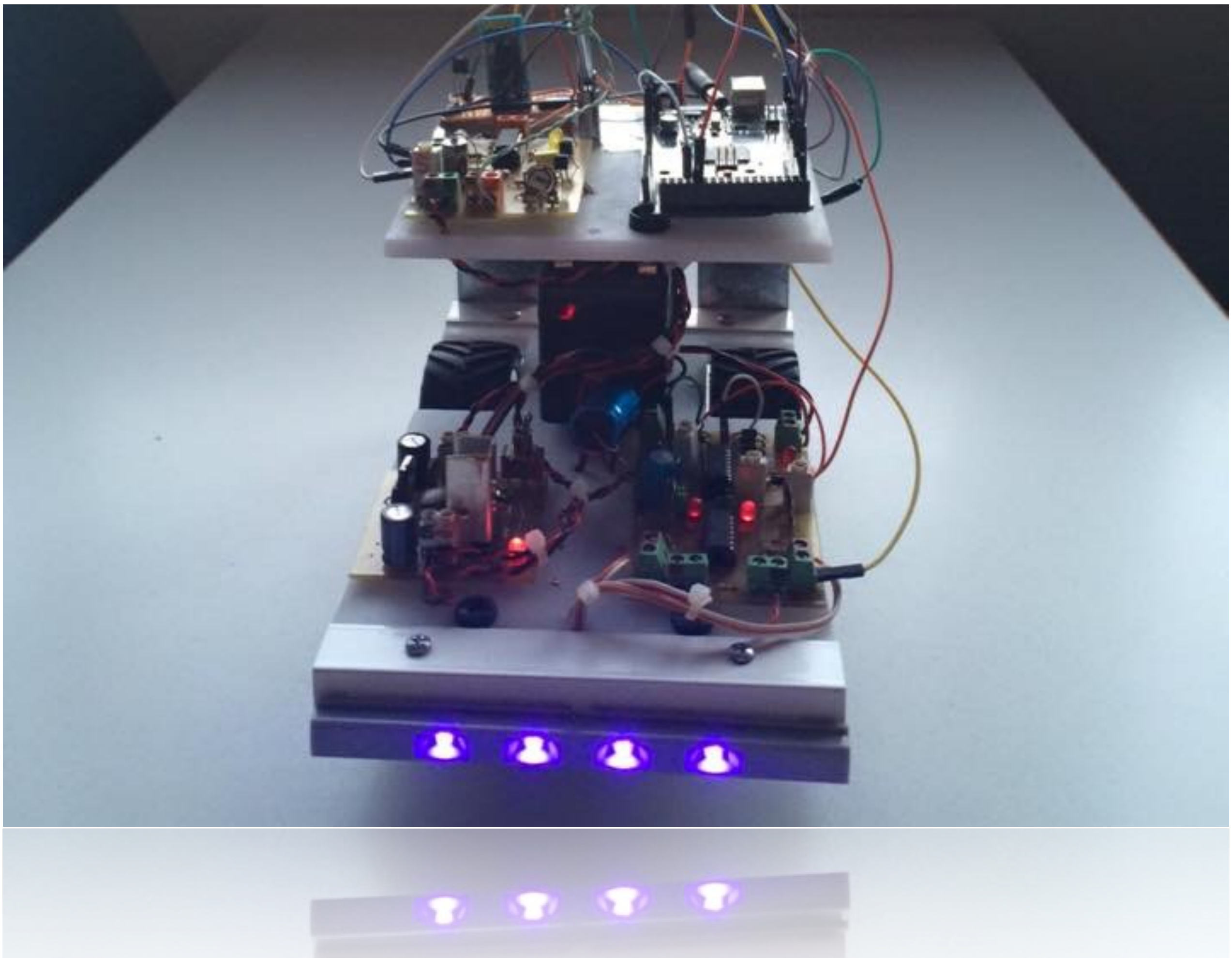
Smart Car Final Report

Team 14



ENGG1000 Electrical Stream

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Smart Car Final Report

Executive Summary

The project was a huge success. Throughout the semester each team member displayed outstanding teamwork and communication skills eventuating in a smooth design process and excellent execution and implementation of the design.

The Smart Car Team 14 created has many advantages lying in its ultimate ability to achieve what it is intended to (it is autonomous) and its engineering design; simplicity, innovation and robustness. The simplistic design with PCBs means that it is easily replicated whilst also looking clean and aesthetically appealing. The design uses a heavy duty battery that is both more durable and provides longer usage time. A disadvantage of this however is the extra weight that it adds. Another current disadvantage with the Smart Car is that it is difficult to adjust the speed due to the inability to lower the duty cycles. Without time constraints this would not be too difficult to perfect and could be easily implemented.

The design performed very well in the competition coming second overall and scoring an extremely high score (103/120). The lane following and the traffic light detection components performed without fault leading to high marks in this section. The speed detection was not quite perfected however the designed circuit and code could detect the speed but struggled to control the motor effectively. Overall, I believe this was a very impressive effort.

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1. Introduction

The Final Design Report intends to present the final results of the team's Smart Car prototype developed throughout this semester. Indeed, the following problem definition has reflected the team's development of the project:

There is a need to design and build a small scale autonomous car that can navigate appropriately in various traffic conditions such as red or green lights, variable speed limits and lane constraints including curvature in roads. The car must be independent of human interaction upon activation, have a maximum height of 40cm and width of 50cm, and drive on a standard grade MDF board. It must cost less than $120.

The engineering of the Smart Car had to address these design requirements, raising key issues to be dealt with by the team during the design brief. Initially, the team had to develop a design to address these aims to allow the start of the construction on the project. Moreover, the team had to revolve the design around the constraints given in the problem definition. And hence, had to find the means to implement these design solutions into the final product to address the problem given.

The development phase of the Smart Car project raised further key problems that needed to be raised to individually address each part of the design requirements. Many of the solutions suggested during the design formation process were developed into sub-components. Thus, they were experimented with to determine the optimum design component to be developed into the final design.The team also had to deal with many technical errors, in both the circuitry and coding, which prevented the successful operation of the design system to meet the requirements.

The final issue that faced the complete development of the Smart Car was the full integration of each individual sub-component into one system; attempting to combine differing computing programs, and the unification of the electronic components of the Smart Car. Indeed, the team had to adjust their individual sub-components into a standardised system for effective system operation. This was achieved by repeatedly adjusting the different codes of the program, and the simultaneous rewiring of the circuit to fit both systems.

The testing of the final design saw complication with the Smart Car's capacity to pass the technical conditions provided by the test itself. The initial issue was adjusting the system to pass the testing requirements, using parts of the testing equipment itself in order to achieve this. On the final testing day, the initial phase of final testing saw the unintended interference of the Smart Car operation from an external source, which caused the failure of the design to pass some of the basic testing requirements. With later minimal adjustment of the integrated system, the Smart Car on the final phase of testing ultimately passed the main design requirements for operational capability.

The following parts of the report will provide an explanation of the technical parts of the final solution that addressed the design requirements. Hence the remainder of the report intends to answer the following questions:

1. What is the team's final solution to the problem addressed?
2. What is the technical aspect for the final design?
3. How did the team implement the final design?
4. How did the team interpret the final testing results?
5. What recommendations are there to be made to improve the system?

2. Final Design and Implementation

2.1 Circuits and Code

LINE FOLLOWING SYSTEM

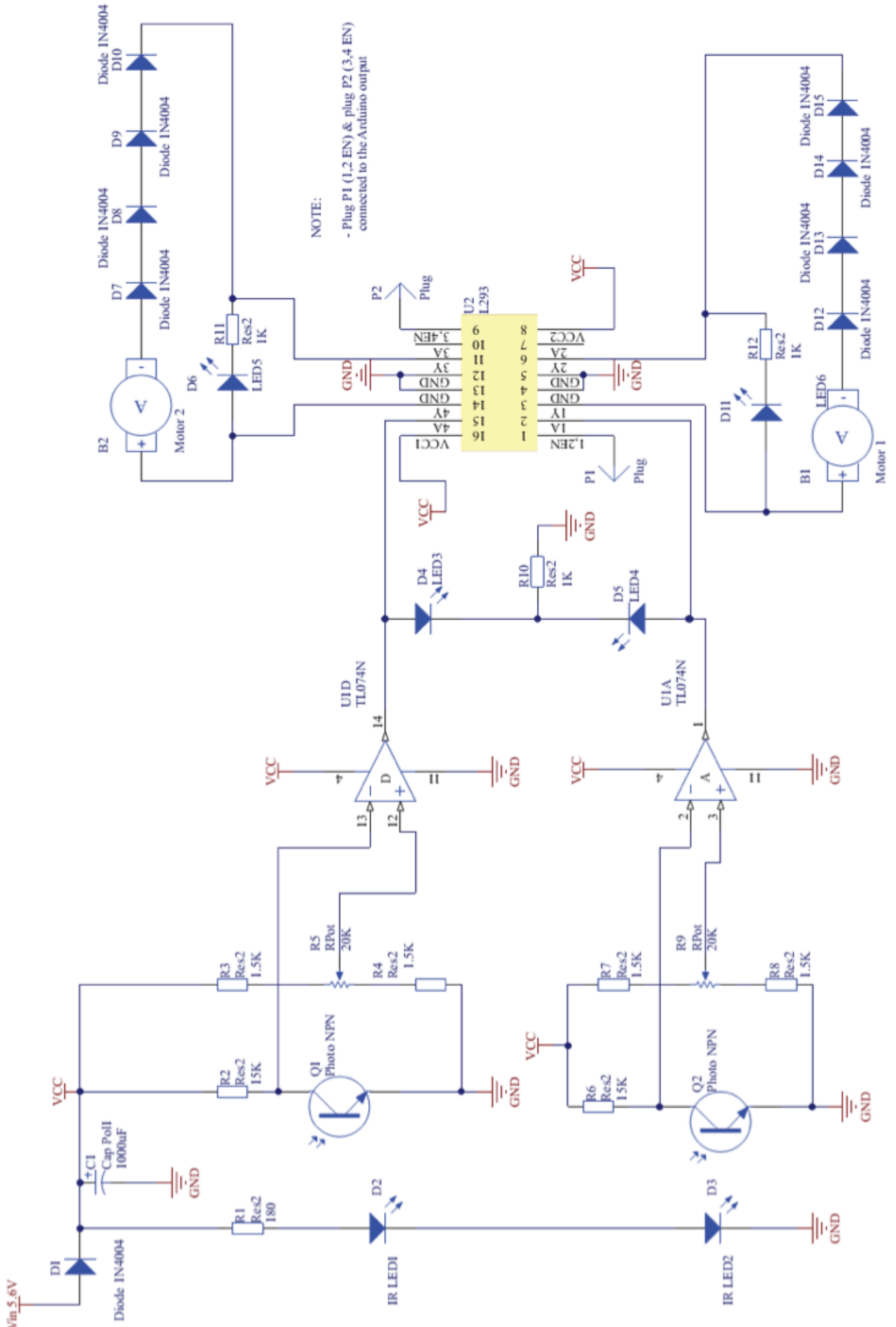

Figure 2.1.1 Line following circuit diagram

The line following system allows the design to follow a black line on a white surface, ultimately allowing the car to remain within the lane on the road as well as successfully steer through any curves in the road.

The line following system schematic (Figure 2.1.1) was formulated based on the concept that white surfaces reflect light and black surfaces absorb light [1]. As shown above in figure 2.1.1, the line following circuit is supplied with a constant 5.6 volts DC. A 1A diode (1N4004) is placed in series to the supply to prevent current in the reverse direction from flowing through the circuit and an electrolytic capacitor is added to further smooth the supply voltage. Two 5mm IR LEDs are placed in series together with a 180Ω resistor to limit the current. Two 5mm IR phototransistors, shielded with electrical tape to reduce interference from ambient light, are connected parallel to the power supply, each phototransistor is physically positioned next to one IR LED to create a sensing pair.

Each sensor pair is soldered onto a small piece of prototype board with 10cm wires. The wires are fed through a hole in the base of the chassis and are connected to the line follower PCB with screw connectors. The two boards are screwed onto two small metal L brackets which are mounted underneath the base to the front and centre of the chassis. Each bracket contains two slots on either face with the screws placed within the slots holding the prototype board to the bracket and bracket to the chassis base. An image of the brackets used on the chassis is shown in figure 2.1.2 below. The slots and screws allow the positioning of the sensors to be adjusted both vertically and horizontally.

A 15kΩ resistor is placed in series with each phototransistor to limit the current as well as act as a voltage divider. The signal from each of the phototransistors is fed to its own inverting input on the TL074N chip, an operational amplifier which is connected to work as a comparator. Two 20 kΩ potentiometer with two 1.5 kΩ resistors each are connected in parallel to the battery, the voltage signal from each of the pots is fed into the non-inverting inputs of their corresponding comparator to set the reference voltages for each comparator. A 1 kΩ resistor and 5mm red LED are connected between each comparator output and ground to visually display the state (high/low) of the output signal from their corresponding comparators. When an LED turns on, it indicates its comparator has an output close to the positive supply rail, that is, it is high. The sensitivity of the IR sensing pair on black and white surfaces is adjusted with the pots and the effect is seen by watching if the LEDs turn on or off when desired. The outputs of the comparators are each feed into an input of the motor driver IC (L293D). Both enable pins of the motor driver IC are sourced by an Arduino via plugs P1 and P2 (see Figure 2.1.1) which provides them with a Hz digital signal with a varying duty cycle so as to vary the speed of the motors. The IC provides outputs to each motor based on a truth table (see Table 2.1.1). The combination of the two states (on or off) of the left and right motor determines the resultant motion of the car, this is also shown in Table 2.1.1 below.

Figure 2.1.2 bracket used in the final design

INPUT 1 (right sensor)	EN 1	MOTOR 1 (right motor)	MOTION (right motor)	INPUT 2 (left sensor)	EN 2	MOTOR 2 (right motor)	MOTION (left motor)	FINAL MOTION OF CAR
1	1	1	forward	0	1	0	stop	left
0	1	0	stop	1	1	1	forward	right
1	1	1	forward	1	1	1	forward	forward
0	1	0	stop	0	1	0	stop	stop

(For inputs 1 & 2 1 = on white surface 0 = on black surface)

Table 2.1.1. Motor Driver IC (L293D) truth table and final motion of the car

Each output of the motor driver is sent to each motor with four N14004 diodes connected in series with it to drop the voltage going across the motor, lowering the maximum speed of the motors to approximately 10 cm/s. One 5mm red LED is connected parallel to each motor as a visual representation of the output from the motor driver IC and if the motor is working, so that, if the LED is on, the output to that motor is high and the motor is also on. Both motors are attached to a gear box as well as wheels which are mounted on the chassis, allowing the car to move.

Please refer to table 7.2 in the Appendix for the names, functions and exact values of the components used in the line following circuit.

Decisions Made for the Final Design and Reasoning

An IR LED and IR phototransistor pair was used instead of the original LED and LDR pair to detect the black line on the white track as the IR sensors where more reliable and less affected by ambient light.

The motor driver IC L293D was chosen for the final design to control the motors as it is fast, simple to implement and allowed for the Arduino to be easily interfaced with the motors through the chip's enable pins. The IC was also chosen as it already contains built-in flyback diodes for the motors and can supply each motor with a maximum current of 300mA.

The sensors were lightly screwed onto L brackets as it allowed for the sensor pairs to be easily adjusted width and height wise for the surface that is being sensed resulting in the line following circuit, that is, the car, to be able to work flawlessly on any surface.

Evolution of the Design

The original line following circuit consisted of two pairs of LEDs and LDRs to sense the black line on the track. Also, two transistors were used to control the motors. The original circuit diagram of the line follower can be seen in figure in the Appendix Figure 7.1. Upon creating the final design, the transistors were replaced with an H-bridge motor driver IC as it was more practical and allowed for better control of the motors with an Arduino. Also the LED/LDR sensor pairs were replaced with IR LED/IR phototransistor sensors as after some testing they proved to be more effective. Potentiometers were also added to the circuit to adjust the sensitivity of the phototransistors and test LEDs were incorporated for a visual indication of the the outputs of the comparators when placed on different coloured surfaces. The finalised line following circuit diagram is shown above, in figure 2.1.1.

TRAFFIC LIGHT SENSOR SYSTEM

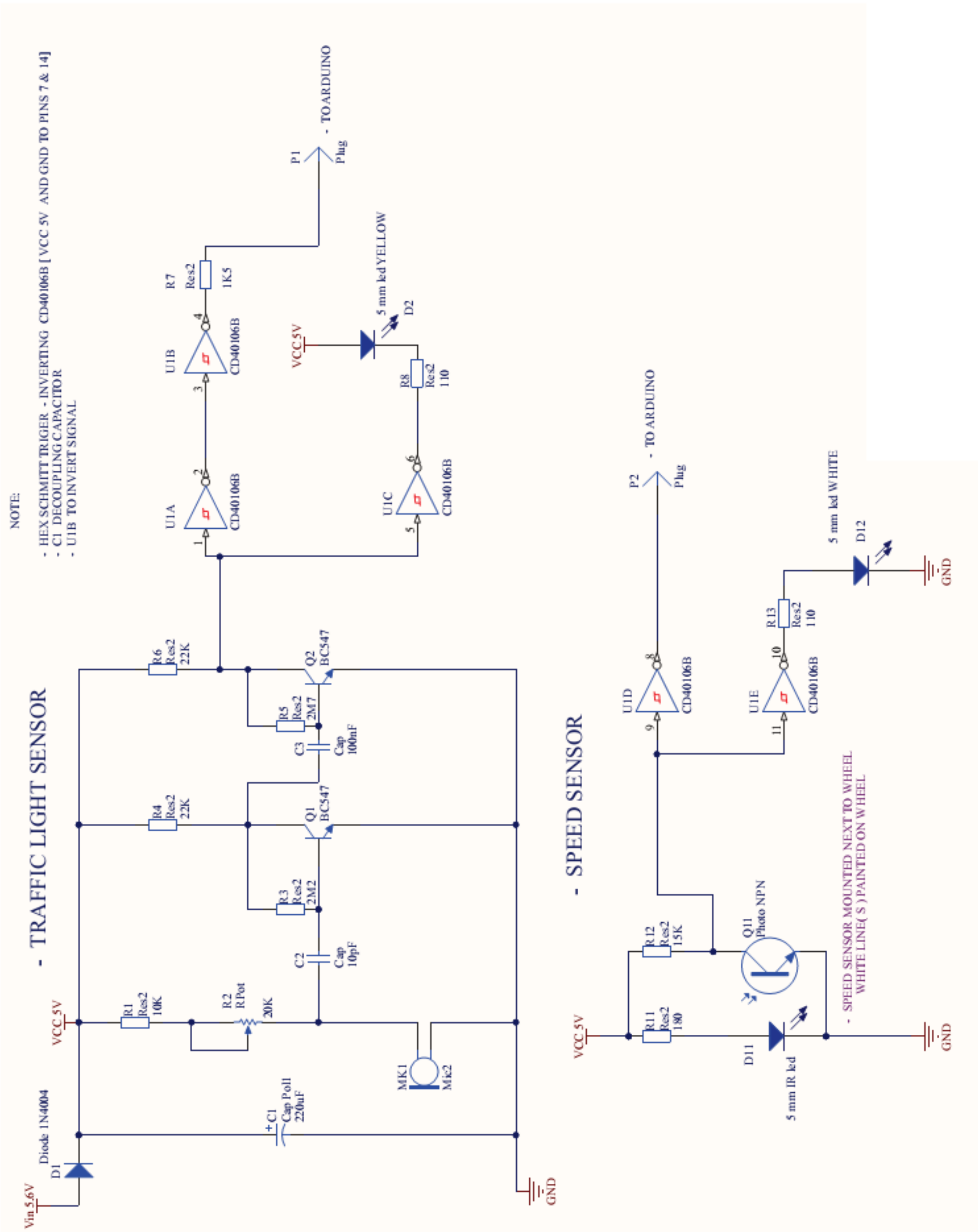

Figure 2.1.3 Traffic light sensor circuit diagram

The traffic light sensor system is a circuit which detects the tone generated by the traffic light and then converts it into a digital signal which is sent to an Arduino to detect a 3kHz tone and 7kHz. The Arduino stops the car when it reads in a 7kHz tone, that is, the traffic light is red. Refer to figure 2.1.3 above for a more detailed understanding of the working of the system. The traffic light sensor circuit is powered by a constant 5.6V DC. An electret microphone is connected with a 10kΩ to the supply, a 20kΩ potentiometer is also placed in series with the microphone to adjust its sensitivity. A small plastic funnel is secured to the microphone to increase the range the microphone can detect sound. The microphone is also mounted onto the tip of a radio antenna which can be both lengthened and moved around. From there, a 10pF capacitor is used for AC coupling, removing the DC signal from the detected sound signal. The sound signal is fed to a two stage amplifier circuit [2]. The amplified signal is then inputted into an inverting Schmitt trigger (CD40106B), the digitised output is then fed again into another input of the Schmitt trigger to revert the digital sound signal back to is non-inverted state. Finally, a 1.5kΩ resistor is used to limit the current and the digital sound signal is fed into an input of an Arduino through plug P1 (see figure 2.1.3). A test LED is also used in the circuit to visually display the frequency being detected by the circuit. The LED flashes with different frequencies according to the frequencies the being sensed, see figure 2.1.3 for more detail.
Using the FreqCount[3] library, the Arduino(Arduino Mega 2560, ATMega 1280) is able to utilise internal interrupts to determine the frequency at which an input pin receives a high(5v). The two specific frequency ranges are; ~3000kHz - ~4000kHz (Green Range) and ~6000kHz - ~9000kHz (Red Range). It is important to use internal interrupts (Consistent pin polling) as there is a need to be able determine, as soon as possible, whether there lies a frequency in either of the ranges. If the Red Range is detected a 0% duty cycle is sent to the enable pins of the H-bridge, this is treated as a low (0v) and will stop any motor movement. After stopping, if a frequency in the Green Range is detected, the enable pins of the H-bridge will be supplied a 100% duty cycle for a short period before quickly stepping it down to adhere to the speed limit. This is necessary to avoid stalling at low duty cycles.

Decisions Made for the Final Design and Reasoning

A plastic funnel was used to increase the range of the microphone's detection ability as well as for further amplification as the signal from the traffic light was relatively low in amplitude.
An extendable radio antenna was used to easily position the microphone closer to the traffic light as well as have the microphone directly facing the traffic light so that it could easily pick up the sound signal.
No filters were used to filter out any unwanted frequencies as the Arduino was simply programmed to disregard any frequencies below or above 6kHz – 9kHz that were sensed by the circuit.

Evolution of the Design
An infra-red sensing circuit using an IR phototransistor was originally used to detect the infra-red pulses generated from the traffic lights. The detected signal was then sent to a Schmitt trigger to output a perfect digital signal which would then be processed by the Arduino to determine the frequency of the detected signal and cause the car to act accordingly. Although the circuit was functional, it proved unsuccessful when tested on the track as the phototransistor had to be directly positioned facing the infra-red LED of the traffic lights. This method was unreliable. Because of this, the decision of using a microphone to detect the tone generated by the traffic lights was made. After some research, an appropriate circuit was found [2] and tested. Modifications were made and the circuit was tested successfully on the track. This circuit became the final design for the traffic light sensor system as shown in figure 2.1.3.
Please refer to table 7.4 in the Appendix for the names, functions and exact values of the components used in the traffic light sensor circuit.

CAR SPEED SENSOR SYSTEM

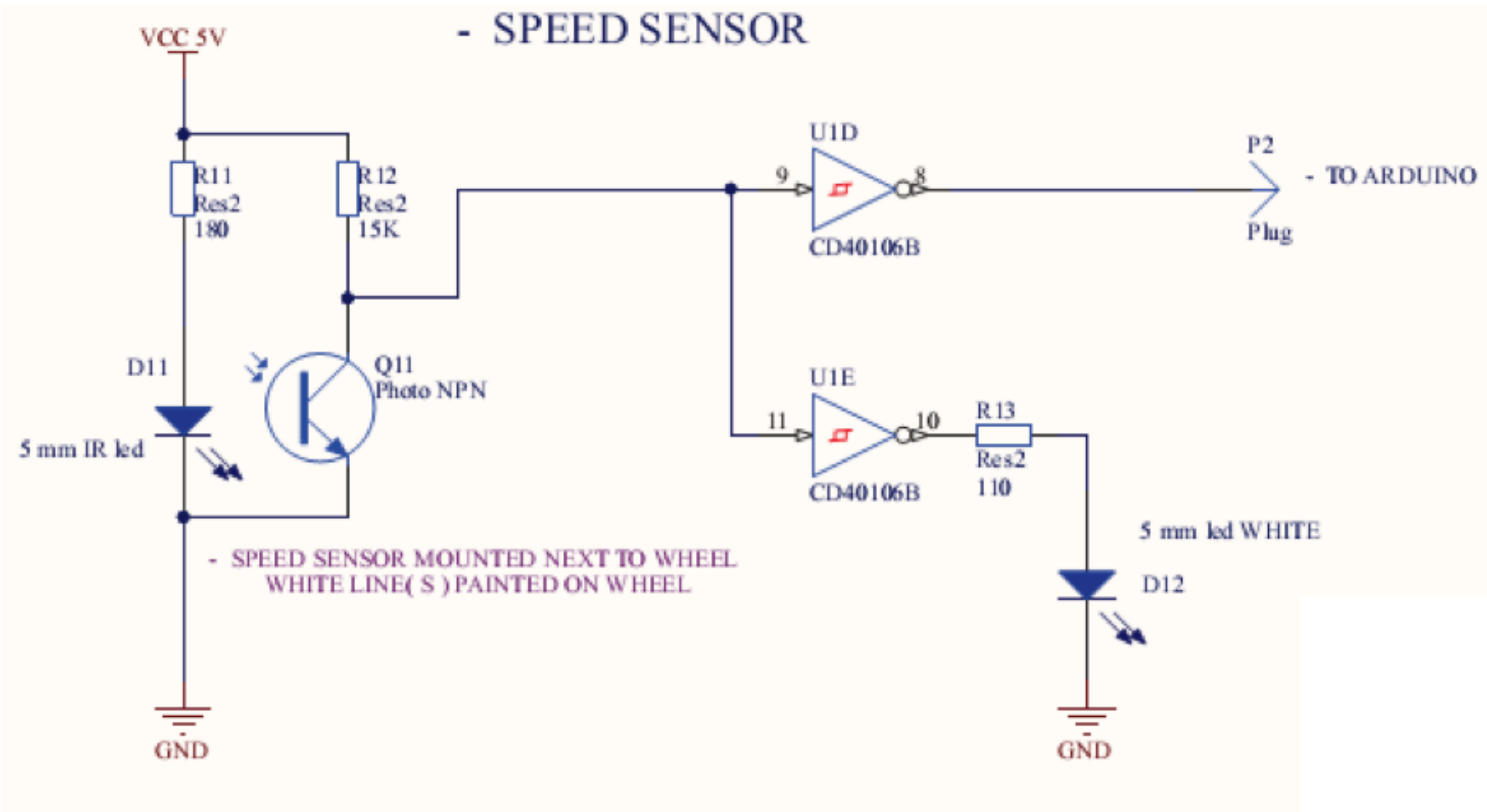

Figure 2.1.4 Car speed sensor circuit diagram

The car speed sensor system is a circuit which finds and displays the speed of the car at all times. This information is processed by an Arduino and displayed on an LCD screen. It allows for easy monitoring of the car's speed at different duty cycles and in accordance to the speed zones.

The whole circuit is supplied with 5.6V DC. A 5mm infra-red LED and a 180 Ω resistor, to limit the current so as not to exceed 50mA, are connected to the supply. A 5mm IR phototransistor is connected in series with a 15k Ω resistor forming a voltage divider with the phototransistor connected to ground. The IR LED and phototransistor are physically placed next to each other and soldered onto a small piece of prototype board with wires long enough to be fed through a hole drilled into the base of the chassis and connected to the PCB. The prototype board is mounted with a screw on the underside of the base closes to one of the motors, with the sensing pair facing the black wheel. A single white line approximately 5mm thick is painted across the black wheel. The signal from the phototransistor is fed to the Schmitt trigger (CD40106B) and its output is then sent to an Arduino. The IR LED will emit onto the wheel and the phototransistor will detect any reflected light. So, when the motors are on, that is, the car is in motion, the white line on the black wheel will rotate, the light from the IR LED will be reflected off the white surface, whereas on black it is absorbed, and the phototransistor will sense the reflected light. The phototransistor is then pulled to the ground and a low signal is sent to the Schmitt trigger which is then converted into a high signal. A test LED is also used in the circuit to display when the white line comes in contact with the sensing pair, see figure 2.1.4 for more detail.

The use of FreqMeasure[4] enables measurements of input pin frequencies below 1Hz. The pin will receive one high each rotation of the wheel from the circuit. Hence the speed can be calculated by multiplying the frequency by the circumference of the wheel (15.08mm). To increase precision you can increase the number of white 'checkpoints' and adjust the circumference accordingly.

Please refer to table 7.3 in the Appendix for the names, functions and exact values of the components used in the traffic light sensor circuit.

Decisions Made for the Final Design and Reasoning

An infra-red sensing pair was used to detect the white line of the car's black wheel as it was based off the same concept as the line following system which also utilised infra-red LEDs and phototransistors.

A Schmitt trigger IC CD40106B was used in the final design as it was the most convenient method to turn the pulses detected by the sensing pair into a digital signal which could then be fed to the Arduino. It was also chosen due to its ease of implementation and to utilise the left over inputs of the hex Schmitt trigger IC used in the traffic light sensor circuit.

SPEED ZONE DETECTION

In order to detect the speed transmitted by the speed signs a 38 kHz infrared receiver module (TSOP 4438) is used. The receiver is able to demodulate the 38 kHz carrier wave and output a stream of logical highs and lows, shown in figure A. Due to its convenient output the receiver is connected directly to one of the Arduino's external interrupt pins.

The interrupt listens for risings edges and stores the time between each rising edge in an array. Using an external interrupt removes the need to constantly poll one of the Arduino pins, holding up other vital processes, and instead the array of 'time between each rising edge' can be read when it is needed. The array of rising edges can be used to identify the speed limit.

When a new speed limit is detected, the duty cycle voltage supplied to the enable pins of the H-bridge is altered in order to comply with the limit.

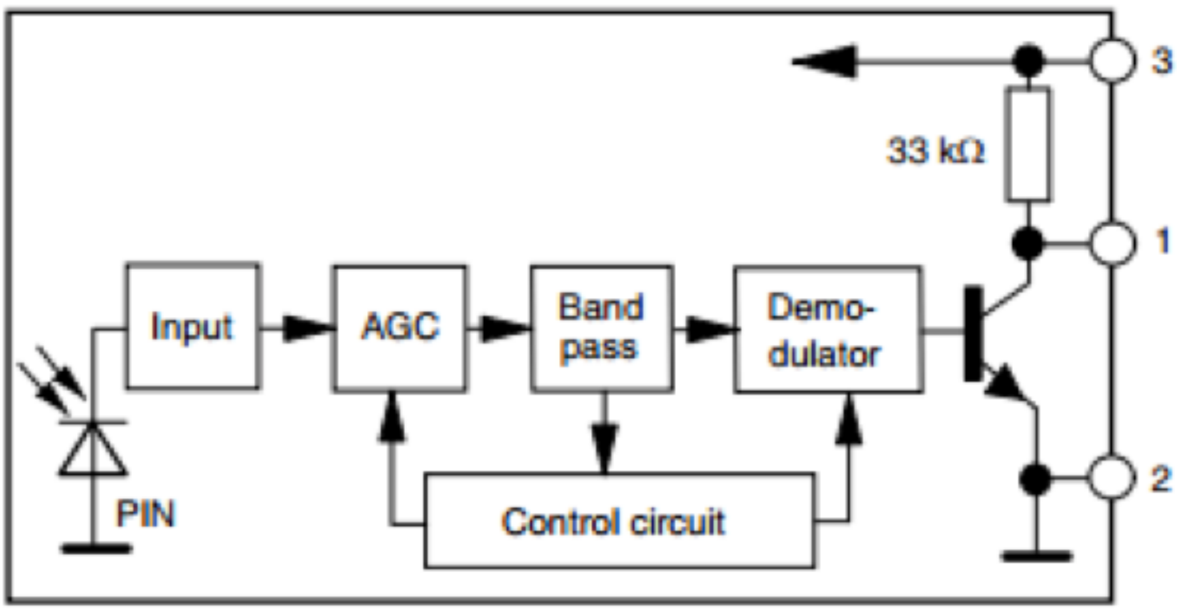

Figure 2.1.5 Block Diagram of the TSOP 4438

MONITOR

The monitor system of the project has two major components: the on-car hardware bluetooth module(HC-05) with its controlling software to send the data and the software on the computer to receive and display data in a human-friendly way.

An Arduino Mega 2560 is needed in order to achieve the proposed function.

On-car Component

The bluetooth module (HC-05) communicates with micro controller (Arduino Mega 2560) via serial port2 i.e. pin TX2 and RX2. The micro controller gathers and encodes data in a pre-defined convention (Appendix 1) and sends them to the bluetooth using serial port in a 115200 baud rate which then broadcasts the data using bluetooth protocol to the computer. Please see Appendix 2 for code and hardware connections.

Computer (receiver) Component

When the data are received, the computer performs a reverse operation to decode the data to a software "object" and then performs a series of manipulations to the object which in the sequential of order are:

1. Calculating position using speed data

2. Formatting the data (Appendix 3) to prepare for UI display

3. Invoking certain event to notify the UI of the data update

The UI, having received one or more the update event(s), updates the UI element(s) according to the type of data.

Code

All the codes of the computer software are stored in a git repository which is shared on Github[5] for future reference.

Cost

The only part that incurs monetary cost of the monitor system is the bluetooth module which has a price of $8(AUD).

2.2 Mechanical Components

Overview:
The chassis of our vehicle was simplistic, being more of a support structure for the car, rather than a casing. We wanted this simplistic look to show the circuits used. With the steering mechanism we also chose more a simplistic design, using differential steering rather than ackerman steering which proved to be successful in the final test.

Chassis:
Our chassis was an open design, featuring the circuits used by the team. The design was constructed using kitchen chopping boards, which gave a low cost to the design, aiding the team in maintaining the budget and allowing for more expenses to be used for other components. the final chassis was 140x220x120mm (WxLxH) (detailed dimensions in fig1.1.1). It featured two levels; a base level which was connected to the wheels and carried the battery and majority of the circuits, the uppermost level sat just above the battery, holding the microphone sensor and its circuit as well as an arduino.

Steering:

The team chose to utilise differential steering over ackerman steering, being the more simplistic and convenient to implement. This is a three wheel design with two back wheels powered by two separate motors and a castor wheel at the front, forming as triangle shape with the other two. The back wheels were on opposite sides of the car, with the castor wheel at the front end, centre width. The mechanism used the power supply to each wheel in order to turn the car, with the free moving castor wheel being allowing for pivoting of the car and turning. This method was highly effective, the car turned the corner of the test track perfectly, achieving full marks.

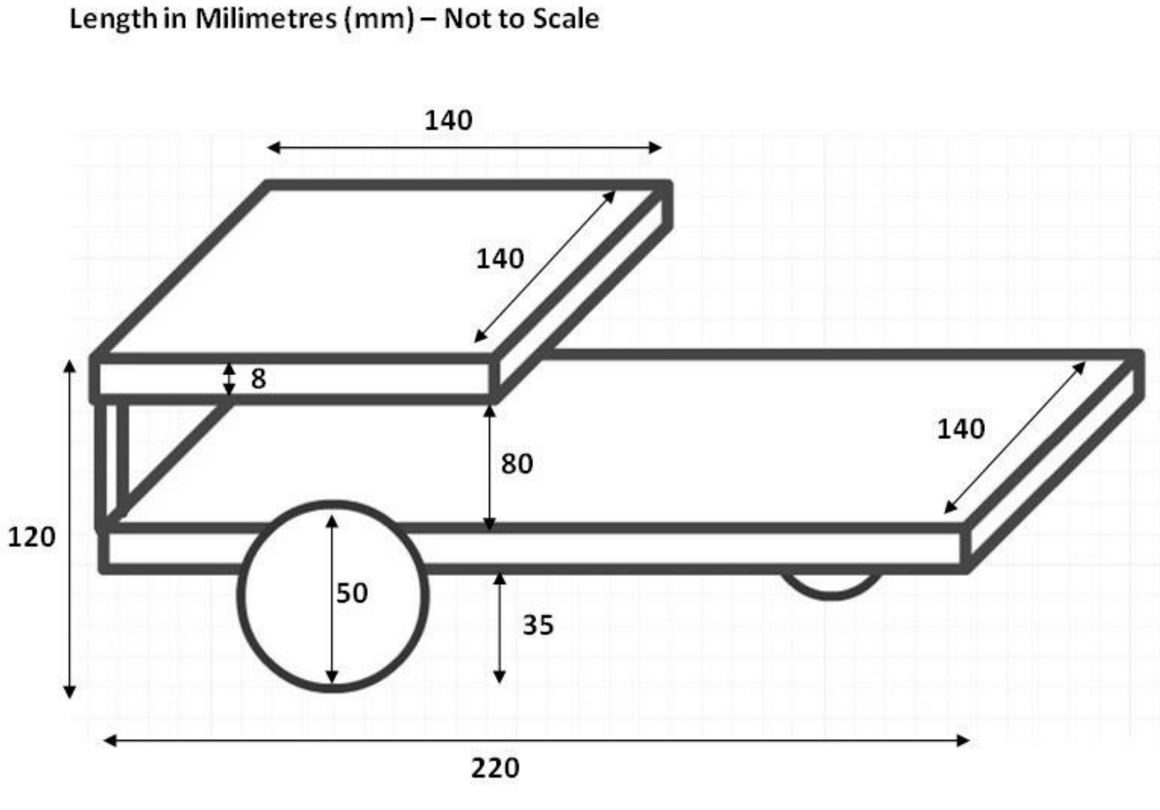

Figure 2.2.1 Schematic representation of the design of the Smart Car

3. Analysis of Final Testing Results

On testing day there were two attempts in which the car attempted to pass the track.

Test 1: During pretesting there were issues with speed detection however the team were confident with everything else. During the run however the traffic light detection malfunctioned and was stopping on both a green and red light. Speed detection was not working properly however lane curving went perfectly. Due to constant stops, marks were lost in the autonomous section and the bluetooth detection also did not work resulting in an overall poor mark (58.00/100) for Test 1.

Test 2: After having an hour to fix any issues, the team believed a higher mark was easily achievable from this run. Traffic light detection went very well without any issues, though speed detection and control still didn't completely work effectively. Lane curving again went exceptionally well and without the constant stops, the car behaved like an autonomous vehicle. The bluetooth system also worked with it only displaying some incorrect information regarding speed changes. This run went much better than the first run giving the team a higher mark (84.34/100).

Both tests marks were added to the mark of 19/20 for engineering quality of the car. This gave a total mark of 103.34/120.

Pictures of test day and the car:

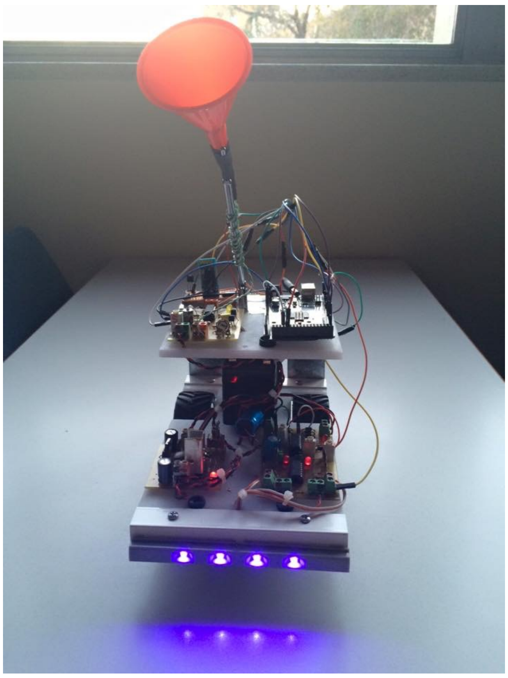

Figure 3.1 Front view of car

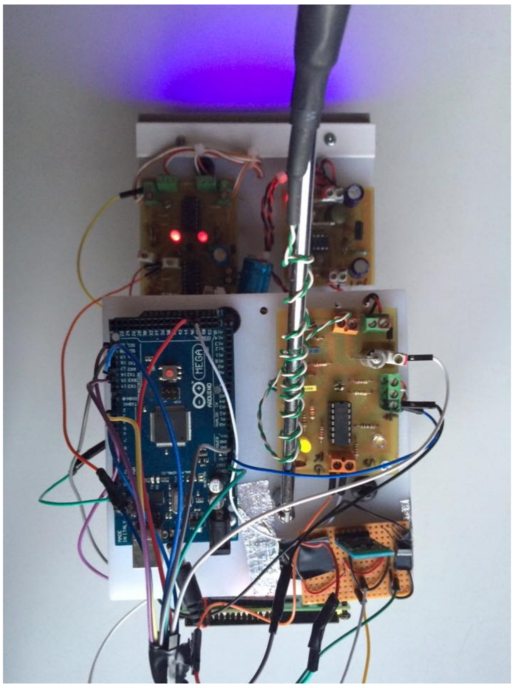

Figure 3.2 Top view of car

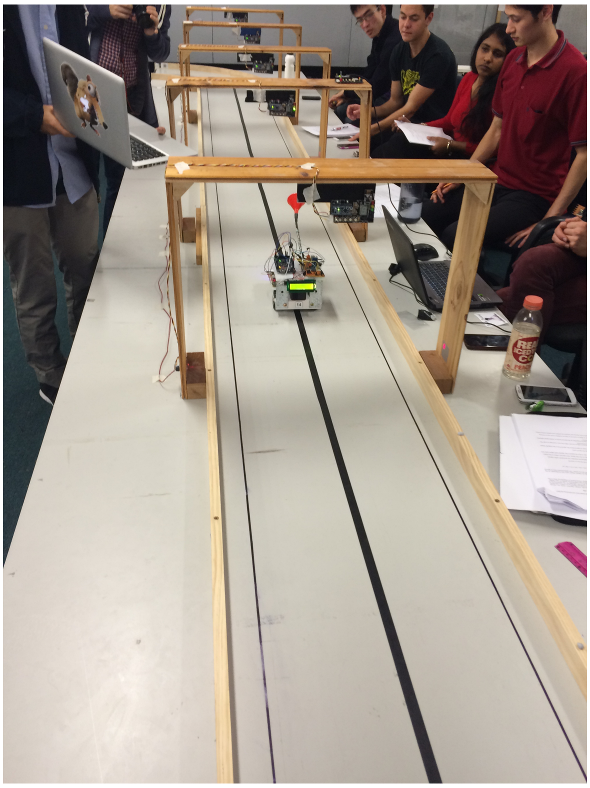

Figure 3.3 The car just before it stops at the light

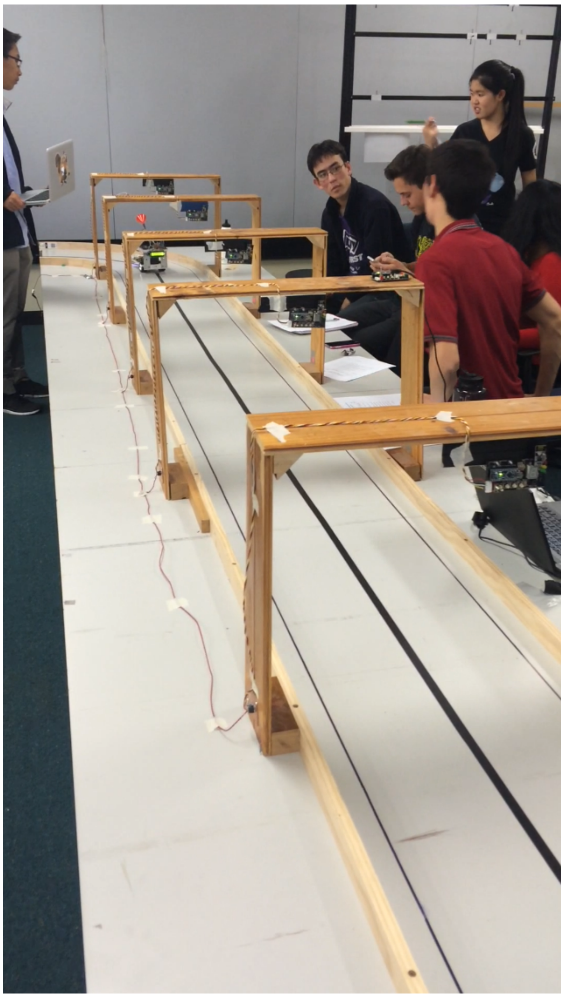

Figure 3.4 The car before it enters the curve

This mark obtained was due to the way the car was designed. The high mark in engineering quality was due to the car satisfying the requirements of robustness, simplicity, aesthetics and innovation. The use of veroboard and PCB, screwed on modules and the body made out of a chopping board contributed to a very robust design. The car itself was also quite simple due to nothing complex being used in the design. This simplicity allows for easy conversion to manufacturers in that the design could be easily replicated. The car also looked aesthetically pleasing with its purple headlights, multiple platforms and PCBs. The car was also remarkably innovative with its adjustable sensor height, LCD display that displayed speed, traffic light conditions and position. The use of the bluetooth system to allow people to remotely view the status of the car also added to the astounding innovation of the car.

The four main components for the requirements of the car are speed detection, traffic light detection, lane curving and the bluetooth, which all contributed to a mark out of 100. The speed detection which was done through infra-red, though working before, failed to properly change the motor speed of the car. This resulted in a reduced mark for its corresponding section and thus affected final testing in a negative manner. Lane-curving, which was executed using sensors that detected if it was crossing over the line or not, worked perfectly in both tests and resulted in a big contribution to the final result. Bluetooth did not work during the first run however the second time it did and thus resulted in a stronger demonstration in the second test and therefore overall final result. Finally traffic detection though it did not work properly during the first test run, due to some small alterations, it performed exceedingly well in the second run and contributed hugely to the overall mark. As detection of the traffic lights was worth more than speed detection, the focus was shifted to the traffic lights thus allowing for a better overall final testing result.

The final result that the group obtained was the second highest achieved out of all of the groups competing. This showed that the result was extremely good and this was due to a number of factors. These factors involved good planning, managing time well and good teamwork. From the beginning of this project everyone in the group was eager to contribute and thus the team started working on the final design a lot earlier than it may have been expected. This allowed the team to attempt final testing with a project that could focus on all aspects of the criteria instead of perhaps only some focused areas. This broadened the overall amount of criteria in which the car could satisfy and perform well in. Being ahead of schedule can also be attributed to following a plan that was set from an early stage of the project. By following this plan everyone knew what needed to be done and by when. With everyone being on the same page and all of the team working extremely well with each other it was evident that it would be extremely disappointing if a negative result came out of this project. At final testing fortunately both the bluetooth and traffic light detection worked without any issues for the second test. For the issues with speed detection and speed control however the team could have avoided them by making some slight changes which most likely affected the way in which the motors would react to any speed change thus potentially improving the overall result.

Upon reflecting on the team's analysis of the problem and priorities to focus on, it is clear from the final result that the solutions decided upon and the method it was approached with were sound. This is because the team understood very well that the design's success (how well it solved the problem) was based on how high the design scored. Thus, the design's priorities were based on what provided the most points as well as how achievable (difficulty) the function is (being realistic). To illustrate, a prevalent issue before final testing was successfully performing both traffic light and speed control. If the design were to integrate both systems together, it would lead to total failure. But it was clear that in isolation, each system performed soundly. Provided with only a short and limited amount of time to solve the issue, it was decided that one system must be forfeited for another. Evaluating the success of the design overall based on how high it could possibly score, it was decided that traffic control was to be taken up. This is because the performance score for traffic control provided 20 points which was more easily achievable than the 15 points that hoped to be gained from speed control. Furthermore, there were issues with reducing the speed to less than 4cm/s as a result of the choice in motor. But again, this was critically analysed and evaluated by the team to produce the best design possible. Because, if the motor was to be compromised for speed control, not only would the team lose 20 points instead of 15 points, but also it was uncertain how successful the speed control will be.

Testing was a very important aspect that contributed significantly to the success of the final design. Testing allowed for real time, solid confirmation on the faults and successes associated with each function and thus, brought continual tweaks and modifications to the design which may never have been found otherwise. For example, the programming of Arduino micro-controllers ran smoothly separately, but when integrating it as one system, it produced many unforeseen bugs. It was only through testing that whether the design actually worked could be clarified. Testing also provides the team with a meaningful understanding of how successful the final chosen design was in solving the problem. In the Acceptance Testing, it was revealed that the design's infrared sensors were unable to receive the signals of the speed's infrared diodes yet was able to receive an external device's infrared signals. This issue revealed the significance of testing because by testing with what the design will specifically be using, it truly, accurately measures the success of the design's performance.

However, as the problem was based around a small-scale autonomous car, the vision of the design did not decide on whether supporting passenger's was a necessity. It was unclear whether the solution to this problem will extend to a larger scale vehicle that carries people. It may be that the solution is intended to be part of a very convenient delivery system of small-scale autonomous vehicles and thus, capacity was not a major factor. So one limitation of the final design is its ability to carry passengers and/or objects as it was not taken into consideration. Also, apart from the speed control limitation (not being able to change the speed to that required by the speed zone), it should be made clear that the final design was quite heavy as a result of a large battery. But although this is a clear limitation, it allowed for the success of the motor control because of the traction it provided for the wheels.

In conclusion, the analysis, priorities and decisions made on the final design solution were sound because it was tailored to suit the team's current situation, skills, and achievability. By making very good use of testing opportunities and limitations, a successful solution was able to be produced.

4. Recommendations

The final design was quite successful overall in testing. The systems regarding turning and staying within the bounds of the lanes did exceptionally well achieving full marks. The traffic light system was quite effective also, stopping at red traffic lights and continuing along the course when the traffic light changed to green. Our system regarding the speed zones and motor control was probably the least effective system.

The recommendations of the team with regard to the lane following system would be that it may be necessary to adjust the IR phototransistor width to suit the thickness of the black line on the road. Adjusting said sensors would cause a smoother turning system compared to sensors which are too wide and be more effective in following the road than a pair of sensors that are too close together. The sensors must be adjusted to be within 2mm of the width of the line in order to function at an optimal level.

The traffic light system, whilst being effective could have a few improvements made to it. The model was stopping at each red light, which is very important for the design, however the distance at which the car stopped from the traffic was variable, and quite large. The team would recommend the adjusting of the sensors in order to only detect red light at a suitable distance for the car to stop to become closer to the traffic light and also stop at a more consistent distance. Another improvement to the traffic light mechanism could be brakes. This would allow for the car to stop faster if the car would be traveling at faster speeds. A full scale car would require some method of braking in order to stop due to the higher momentum of the car. A suitable braking method could be to use disk brakes, or even using electro-magnetic braking.

The speed control systems were not very effective. The system was able to detect speed zones reasonably well, however there were issues regarding the use of internal interrupts. The team recommends the use of external interrupts instead of internal interrupts. The team were unable to implement this feature due to time constraints on the project, however this is an important improvement that will greatly enhance the performance of the speed zone detection. The team also encountered trouble with speed control, this was due to the limitations of lowering the duty cycle of the motor. The team recommends that this part of the system is improved in order to address the issue of speed management.

5. Conclusion

In summary, the design consisted of three main systems: the computing, electronic and sensor system. The computing part fundamentally provides the core programming to run the Smart Car using the Arduino system, with the simultaneous bluetooth and LCD system. The electronic parts link to the computing and sensor systems together in order to provide the physical operation of the system. And the sensors ultimately provide the analog reading to help interpret and execute the signals to meet the design requirements.

The final design predominantly addressed the design problem successfully with some minor limitations that could be addressed with further development. Indeed, the traffic light detection and interpretation by the system was completely successful after long developments, which led to the final adoption of the microphone sensors circuit to interpret the traffic light sound source through the Arduino. Moreover, the lane detection aspect of the system was a complete success through the effective operation of infra-red sensors carefully aligned together, to provide the most efficient lane following system. Simultaneously, despite minor signal issues, the bonus transmission is predominantly successful through the use of Bluetooth, transmitting data to both the Java computer interface and the LCD screen.

However, issues with the integration of the computing, electronics and sensors systems in regard to speed consequently affected aspects of the speed system, limiting the capabilities for the system to detect the speed zone and control the speed of the Smart Car. Nevertheless the integration and the autonomous nature of the car mainly satisfy the problem, with an overall very high Engineering Quality in terms of: Robustness, Simplicity, Aesthetics and Innovation.

Thus, the outcome of the design project to develop an autonomous Smart Car that adheres to basic traffic was successfully achieved, through the implementation of the Engineering Design Process. Hence future recommendations for the development of similar projects will emphasise the more time dedicated for the integration of different sub-components, and setting equal priorities on developing all aspects of the design requirements to ultimately produce a more effective and efficient end-product.

6. References

[Figure 2.1.2] http://beveragetruckparts.com/stainless-steel-l-bracket-allows-mounting-of-convex-mirror-773.html

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7. Appendices

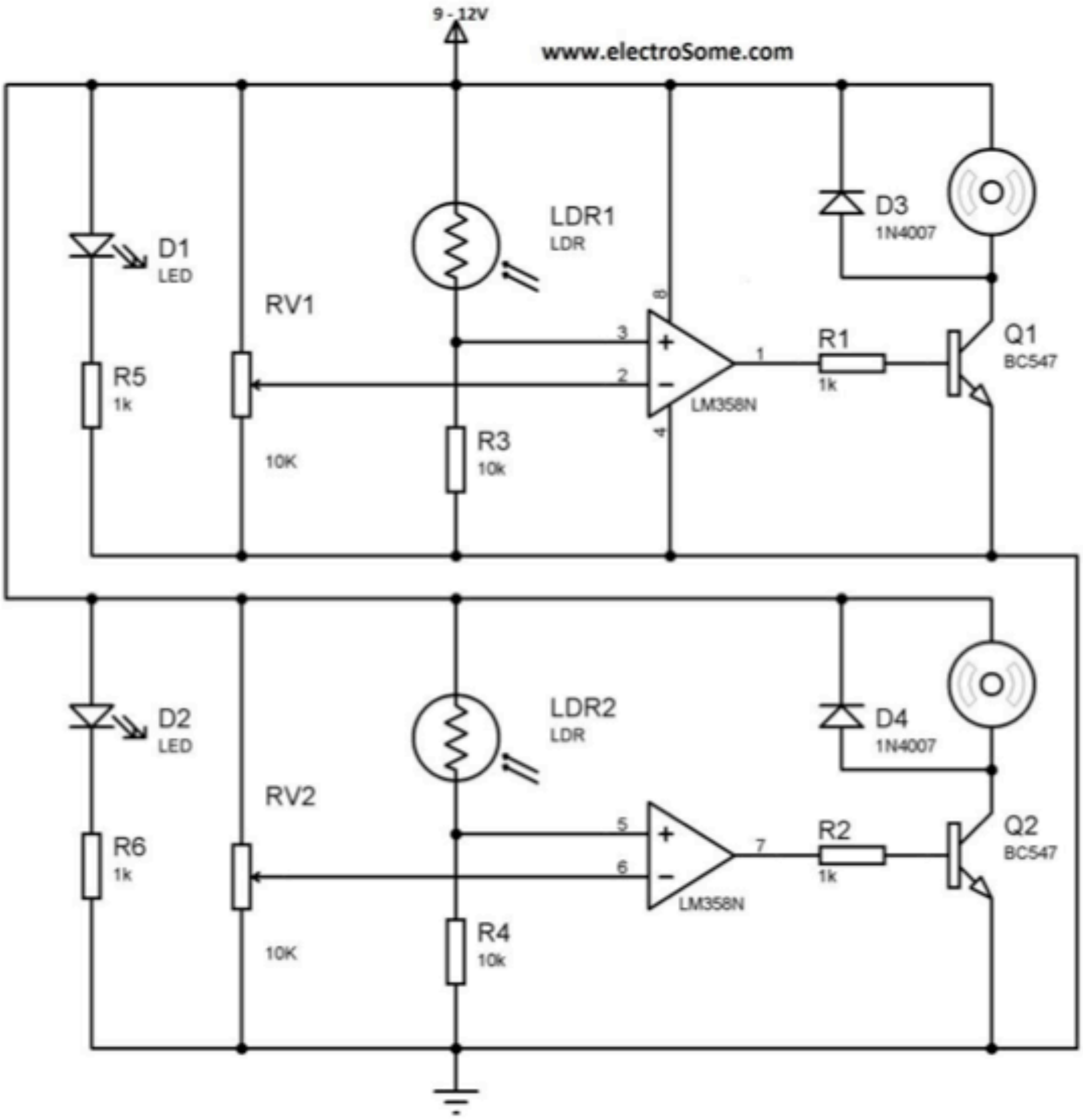

Figure 7.1 The original line following circuit [8]

Component Name	Function	Value
C1	Smoothing capacitor (electrolytic)	100uF
R1	Current limiting resistor	180 Ω
D2 & D3	5mm Infra-red transmitting LED	
R2 & R6	Voltage divider resistor	15 kΩ each
Q1 & Q2	5mm Infra-red NPN phototransistor	
R3, R4, R7 & R8	Voltage divider resistor	1.5 kΩ each
R5 & R9	Potentiometer to adjust the sensitivity of the IR phototransistor	20 kΩ each
U1A & U1B	Operational amplifier (TL074N) used as a comparator	-
R10, R11 & R12	Current limiting resistor	1 kΩ each
D4, D5, D6 & D11	5mm red LED for visual representation and circuit testing (testing LEDs)	-
U2	Motor drive IC/Quadruple half-H Bridge Driver (L293D)	-
D1, D7, D8, D9, D10, D12, D13, D14 & D15	Voltage dropping diode (1N4004)	1 A
B1 & B2	DC motors to drive wheels	3 V

Table 7.2 Component functions and values used in the line following circuit

Component Name	Function	Value
D1	Protection diode (1N4004)	1 A
C1	Smoothing capacitor (electrolytic)	220 uF
R1	Current limiting resistor	10 kΩ
D2	5mm yellow LED	-
R2	Transistor biasing	2.2 MΩ
Q1 & Q2	NPN transistor (BC547). Amplify sound signal.	-
R4 & R6	Voltage divider resistor	22 kΩ each
R5	Transistor biasing	2.7 MΩ
C2	AC coupling capacitor	10pF
C3		100nF
MK 1	Electret microphone	-
U1A, U1B & U1C	Inverting Hex Schmitt Trigger (CD40106B). Converts analogue sound signal into digital signal	-
R7	Voltage dropping diode (1N4004)	1.5 kΩ
R8	Current limiting resistor	110 kΩ

Table 7.3 Component functions and values used in the car speed sensor circuit

Component Name	Function	Value
D11	5mm Infra-red transmitting LED	-
R11	Current limiting resistor	180 Ω
R12	Voltage divider & current limiter	15 kΩ
Q11	5mm Infra-red NPN phototransistor	-
U1D & U1E	Inverting Hex Schmitt Trigger (CD40106B)	-
R13	Current limiting resistor	110 Ω
D12	5mm white LED	-

Table 7.4 Component functions and values used in the traffic light sensor circuit