THE UNIVERSITY OF
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School of Electrical, Electronic and Computer Engineering

Final Year Project Thesis

ELECTRICAL CIRCUIT DESIGN WITH WHEEL SPEED CONTROL & DOCUMENTATION

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Abstract

Vehicle electronics play a vital role in all comfort and safety structures. The key interaction of intricate electrical system safeguards error free function and increases safety. Sensors enable critical data communication required in the vehicle's electronics. Computer microcontrollers controls electrical changes and then take the suitable actions. Therefore electronics play essential part in the vehicle driving. This change opened the door for computers to enhance human judgment.

This paper aims to provide electronic system that improves both the stability and performance of the SAE vehicle. With advanced research, the power control and steering capabilities are developed for sensing and high-performance processing for driver assistance and autonomous vehicle operation.

A comprehensive electrical system documentation for the vehicle is also developed. A highly integrated circuit was implemented on a printed circuit board to meet the required low level control of the vehicle. Along with these, calibration of battery monitor system is developed. To give computers control over driving, wheel speed sensor integration is developed. Brake servo / brake reservoirs for overcurrent protection are implemented that prevents servo failure. The wheel slip control systems is developed which enable controlling of braking force. In order to achieve the superior braking performance through the wheel slip control, real-time data such as the wheel braking power at each wheel is required for better stability and enhancement. Wheel slip control method is developed for make the most of the braking force and maintaining the vehicle stability.

Much research is being conducted to improve the accuracy and simplify the systems that are being implemented on various platforms. Advanced vehicular safety and navigation systems using LiDARs and GPUs deliver the most capable solution for real – t ime object detection, tracking, recognition and classification.

Acknowledgements

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1. Introduction

Project Background: Formula SAE (Society of Automotive Engineers) (1) is an international competition for university graduate and undergraduate students of any country which will enable them to conceive, design, fabricate, develop and compete with small formula style vehicles. Historically the vehicles were driven by small internal combustion engines and later new group of electric vehicle emerged. In UWA the first Formula SAE Prototype vehicle for the non-professional, weekend, competition market was built in 2009-10 under Renewable Energy Vehicle REV group by UWA Motorsport. For the 2012 Formula SAE competition, a new vehicle design began in 2010 and its construction started in 2011. The Formula SAE projects enable the team of students to build creative ideas.

In UWA, two electric vehicles were developed which is a Hyundai Getz and a Lotus Elise. In addition to this, UWA has also designed electric cars under the Renewable Energy Vehicle Project (REV) called electric Formula SAE cars. The REV Project has enabled the racing car to direct a race track autonomously by the use of laser tracking, GPS and Digital camera system applications (2). The Formula SAE was converted to the Electric car in 2010 and the complete drive – by - wire system was implemented. For real time interfacing, the autonomous low - level controller has been used along with a high - level control system that is mainly used for identifying the path of the vehicle. By the three main driving processes of steering, braking and the acceleration, the low level system is capable in converting the formula SAE car to complete Drive – by - wire system. The low - level system was designed to provide easy disengaging of the steering motor. Also for the control of the low-level system an Arduino Uno microcontroller was used in order to achieve the low level system control. Further improvements were required in development of the vehicle data loggings control along with its safety measures and performance. However the high level design approach that was designed involved the working of LIDAR which detects the path edges and a 6 - DOF IMU combination unit with a commercial GPS system (3). The control system designed enables the mapping of the waypoints during the vehicle movement and allows recording of the vehicle trajectory.

Further interesting research that were carried out in previous years outlines the drive by platoon system which enables the Autonomous vehicle to drive in front of any human, other car or any object by following/tracking it in case of traffic problems. This design plots the data points by using gnu plot program. The main factors were to implement system reliability and robust in terms of the object identification.

2. Thesis overview

Autonomous vehicle technology based on computer technology, information and software will lead the automotive industry in the near future. The renewable energy vehicle team (REV) is a student oriented operation and as such is a learning experience for all those involved in the project. This leads to some innovative designs and some exceptional work, though it does however lend itself to some experimental errors. With the current car, there were immediate errors found in the electrical design of many of the working components. These errors led to poor reliability and performance of the vehicle. Identification of these errors was carried out within the drive line system of the vehicle and the process of eliminating them was the priority task. The electrical wiring design included comprehensive evaluation of components, redesigning the components and safety assessment in case of any future failure.

The goal of the project is to provide control electronic system that improves both the stability and performance of the vehicle. During past years, drive – by – wire and Navigation control were implemented with the aim of having Autonomous control of the vehicle (2) & (4). Designs in Path Planning, Electronic & software control with the GPS & LIDAR integration were carried out. Basically a platform for research into autonomous driving of the UWA's SAE vehicle was developed in order to improve the safety and efficiency in transportation systems as well as to implement optimized performance driving. This was achieved by developing map - based navigation system and by the development and integration of safety systems.

In 2015 the main aim of SAE Project was to improve vehicle performance in terms of platforms in both hardware & software section. Research in advanced path planning with GPS control and improvements in vehicle control were carried out and this particular project aimed in achieving better vehicle electronics performance as well as documentation of electrical designs. To achieve stability control, modeling of vehicle's effective braking system using M-Simulink was designed and for better circuit implementation, highly integrated Printed Circuit Board (PCB) were implemented using Altium Designer.

3. Vehicle stability control

Proposed Model using M - Simulink:

The Proposed Model allows better stability by controlling wheel as well as vehicle speed. The system is a vehicle safety method that allows the wheels on the vehicle to sustain tractive connection with the path surface according to driver inputs while braking, avoiding the wheels from uncontrolled slewing. It generally offers improved vehicle control and reduces the stop distances on various different surface types.

It modulates the brake pedal pressure independent of the pedal force, to bring the wheel speed back to the slip value range that is required for ideal braking performance. In this method, the steering ability increases even during emergency braking and thus the collision or obstacle in front of the vehicle can be safely and securely avoided (4). The Model is designed for low - level control of the vehicle.

The main components required in the model are as given below:
Electronic Control Unit (ECU): The Electronic control unit receives the wheel speed sensor signals and controls the brake pressure. It also helps in regulating the wheel slip.
Modulator: The Modulator receives the signals from ECU and modulates the vehicle brake pedal.
Wheel speed sensor unit: The wheel speed sensor considered as Hall effect sensor are present in all four wheels and the complete unit monitors the rotational speed of wheels and transmits the data to the control module.

Working: The velocity sensor is very expensive for a conventional race car. Therefore, the velocity obtained from the GPS and acceleration sensor / accelerator is to be used to estimate the vehicle longitudinal velocity. At each wheel, we have the encoder to calculate the wheel speed. Thus, we can calculate the slip ratio at each wheel in real time. The calculated slip ratio is matched with the reference slip rate, and a simple controller is designed in order to generate the vehicle torque value of the in – wheel part of motor. The driver acceleration command is compensated.

A slip angle is the angle between the course the wheel is aiming and the direction the tire contact patch is traveling. This is a result of the flexible properties of wheel rubber, which deform under friction. The slip angles of the front and rear tires are directive whether or not the car is under - steering or over - steering, and they also influence lateral grip as slip angle is related to the constant quantity of friction (co-efficient) of the tire.

S – wheel slip, V – Longitudinal speed of wheel, w – angular speed, R – effective wheel radius.

$$S = -\frac{(V - Rw)}{V}$$

The vehicle force is proportional to slip using effective longitudinal stiffness C_X, the force can be given as;

$$F = C_X.S$$

Velocity measurement derived from GPS can be used to provide absolute velocity for wheel slip which in turn increases the vehicle stability. Drift problems can be avoided based on wheel speed measurements. This can be used in model based brake performance simulation or driver assistance system for lane keeping or collision avoidance.

GPS velocity measurements are differenced to obtain absolute vehicle acceleration which is then multiplied by vehicle mass to find longitudinal force on wheels. Accuracy of GPS provides linear relation between force-slip curves.

Motion of Vehicle equation can be given as: $Fxf + Fxr - Mgsin\theta = Max$

Where, Fxf & Fxr – longitudinal forces of front and the rear wheel

θ – Vehicle rating angle calculated from GPS receiver by calculating the ratio of vertical to horizontal velocity

Assuming the linear region of Force, the longitudinal equation can now be given as:

$$F = Fxf + Fxr = C_X.S = -C_X\frac{(V - Rw)}{V}$$

.

$$F = Ma_X = -C_X\frac{(V - Rw)}{V}$$

The vehicle acceleration is found by differencing GPS velocity values given by;

$$a(n) = (v(n + 1) - v(n - 1))/2T\ ,$$

Where, time T = 0.1s is between the consecutive GPS data points obtained.

$$a(n) = \frac{1}{M}.-C_X\frac{(V(n) - Rw(n))}{V(n)}$$

with the vehicle Speed ratio P as, $P = \frac{w(N)}{V(n)}$, we can obtain,

$$a(n) = -\frac{C_X}{M}.(1 - RP(n))$$

which can also be given as,

$$a(n) = -\frac{C_X}{M}.(C_X\frac{RP(n)}{M})$$

The derived equations shows the linear relation between the acceleration a(n) and speed ratio P(n) that are obtained from GPS and wheel speed sensor readings. Then using simple least square estimate, the slope 'm' and intercept 'c' can be found using;

$$a(n) = mP(n) + c$$

From slope 'm' and intercept 'c', the longitudinal wheel stiffness can be found from,

$$C_X = -Mc$$

Finally wheel slip can be found using the equation shown below;

$$S = -\frac{(V - Rw)}{V}$$

Simulation chart algorithm of the vehicle stability control model can be given as shown in fig 1 given below;

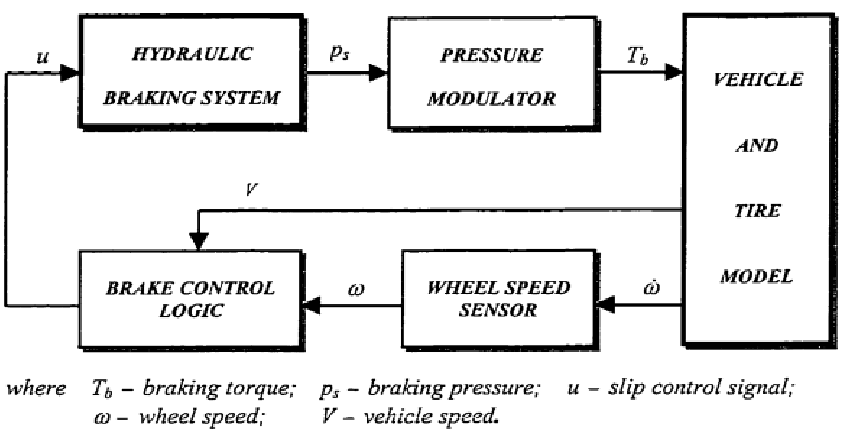
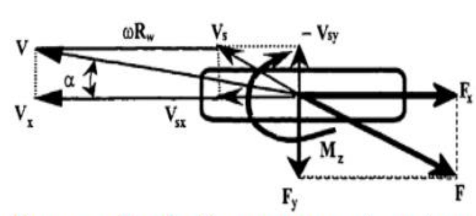


Fig 1: Vehicle stability Algorithm, source (5)

The stability control from proposed model is obtained by controlling both vehicle as well as wheel speed.

Vehicle control: From Newton's second law of motion we have;

$$m.V = -F_t - F_a$$



Force and velocity components on tyre
Fig 2. Source (6)

Now the vehicle weight equation can be given as,

$$m = -m_{wheel} - \frac{m_c}{4}$$

From Coulombs equation of path friction we have,

$$F_t = \mu N$$

And lastly the load on vehicle considered under nrmal condition can be given as;

$$N = mg - F_l$$

From all these dynamic equations, a model is built usning Matlab Simulink tool and is shown in fig below.

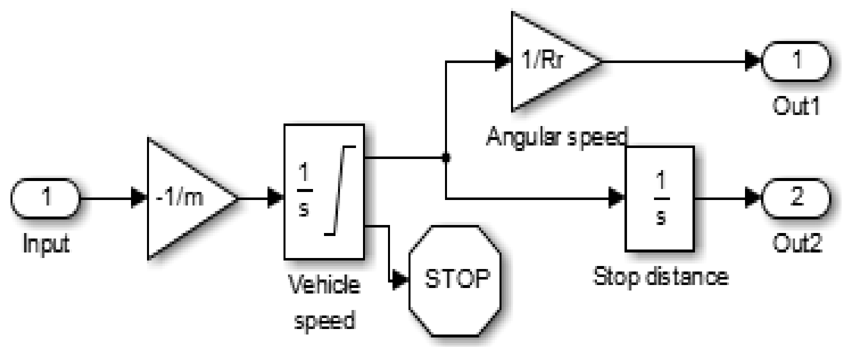


Fig 3. Vehicle control model in Simulink

Wheel control: for controlling of the wheel speed, primarily Newton's second law of motion is considered where at wheel level we have;

$$J\omega = -T_b + F_t R$$

This is modeled using Simulink tool as shown below in figure 4.

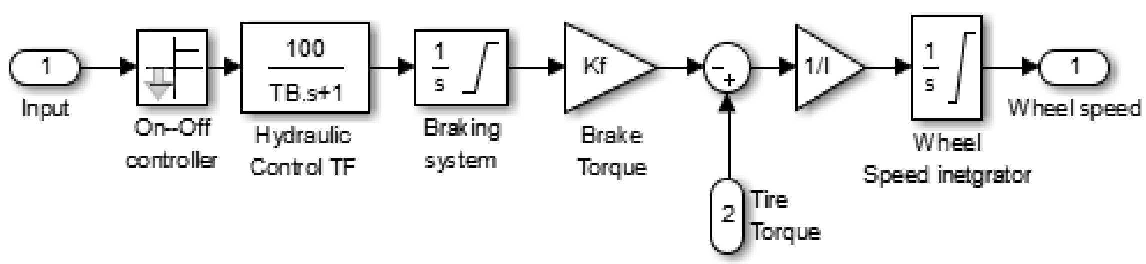


Fig 4. Wheel control model in Simulink

Working: The mathematical concept has been introduced and this concept is followed by the model working which is explained briefly in the section below.

The vehicle friction constant between the wheel and the path surface $'\mu'$, is an pragmatic function of slip. Slip curves are created by passing MATLAB variables into the block diagram using a Simulink feature called lookup table that allows plotting graphs given values of slip at different time. The model multiplies the friction coefficient, by the weight on the wheel, W, to obtain the frictional force F_f, acting on the perimeter / boundary of the wheel. F_f is then divided by the weight of the vehicle to obtain the vehicle deceleration, which the model then integrates to obtain vehicle velocity.

In this model, an ideal controller called the 'on – off' control is used centered upon the error between actual slip and required slip. The required slip value is set to a value of slip at which the slip curve reaches a peak value, this being the ideal value for minimum brake distance.

Vehicle slip is always zero when wheel speed and vehicle speed are equal, and the slip equals to one when the values are not equal. A desirable slip value is 0.2, which means that the number of wheel revolutions equals 0.8 times the number of revolutions under non - braking conditions with the same vehicle velocity (5). This increases the linkage between the tire and path and minimizes the stop distance with the existing friction.

The vehicle wheel rotates with an initial angular speed that corresponds to the vehicle speed as previous to the application of brakes. Distinct integrators are used to calculate the wheel angular speed and vehicle speed of the vehicle.

$$\omega = V/R$$

If V=R, there is no wheel slip taking place

In other words, wheel slip can be given as the ratio of the difference between the wheel speed and ground speed to the wheel speed. Wheel slip occurs when too much power is applied to the wheels of the vehicle. The absolute value of power at which traction will be lost is dependent on factors including the weight of the vehicle, the size of the tires as well as the path surface and environmental conditions (8).

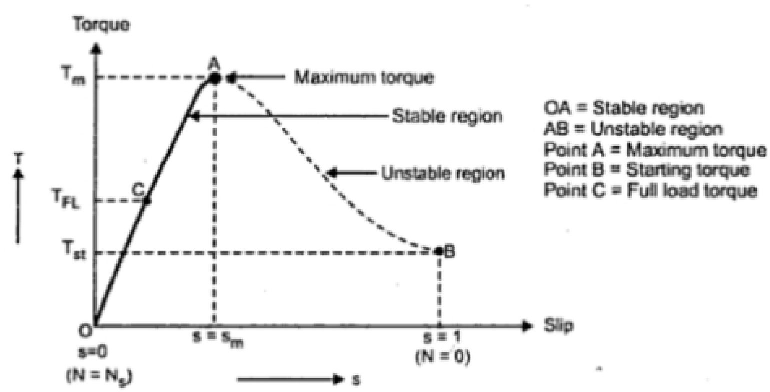


Fig 5: Wheel - slip curve (7)

Figure 5 above. shows a generic torque - slip characteristic curve of a vehicle. In the Stable region, the torque increases linearly with the slip. This means that as more power is applied, the output torque will respond proportionally. Once the maximum torque is reached, however, more power will not give a desirable torque output. This is due to extra slip that is occurring. In order to gain the most efficient performance during vehicle launching, the power being delivered to the vehicle wheels will ideally remain in the stable, linear region and around the torque peak where possible.

GPS receiver provides absolute velocity information at a particular frequency. The GPS reciever is connected to a magnet mounted antenna placed on centerline of the vehicle. the velocity data is averaged internally by the reciever giving each velocity point a theoretical expectancy.

The various constants considered in the model implementation are: Gravitational constant g = 9.81 $m/s2$ Radius of the wheel Rr = 0.2575 mt, Maximum Braking Torque Tb = 1500 $lbf*ft$ steering control TB = 0.01 s, Moment of Inertia Jw = 5 $ft4$

If a wheel speed sensor signals bad performance, the Electronic Control Unit sends a current to the steering / hydraulic unit. This energizes the control device. The action of the control device is to detach the brake circuit from the brake cylinder. This stops the braking pressure at that wheel from increasing, and retains it to be a constant value. It allows the wheel velocity to increase and the vehicle slip to decrease. When the velocity increases, Electronic Control Unit re - applies the brake pressure to limit the wheel slip to a particular value. The steering control unit controls the brake force in each wheel based on the inputs from the wheel speed sensor.

For complete working, both the vehicle speed control model as well as wheel speed control model are combined together to create a complete Simulink model as shown in fig 6 below. The top line is designed for wheel speed control and the bottom line is designed for vehicle speed control. The model is effective since there exists feedback loop control that enables comparison between the required slip as well as calculated vehicle slip values.

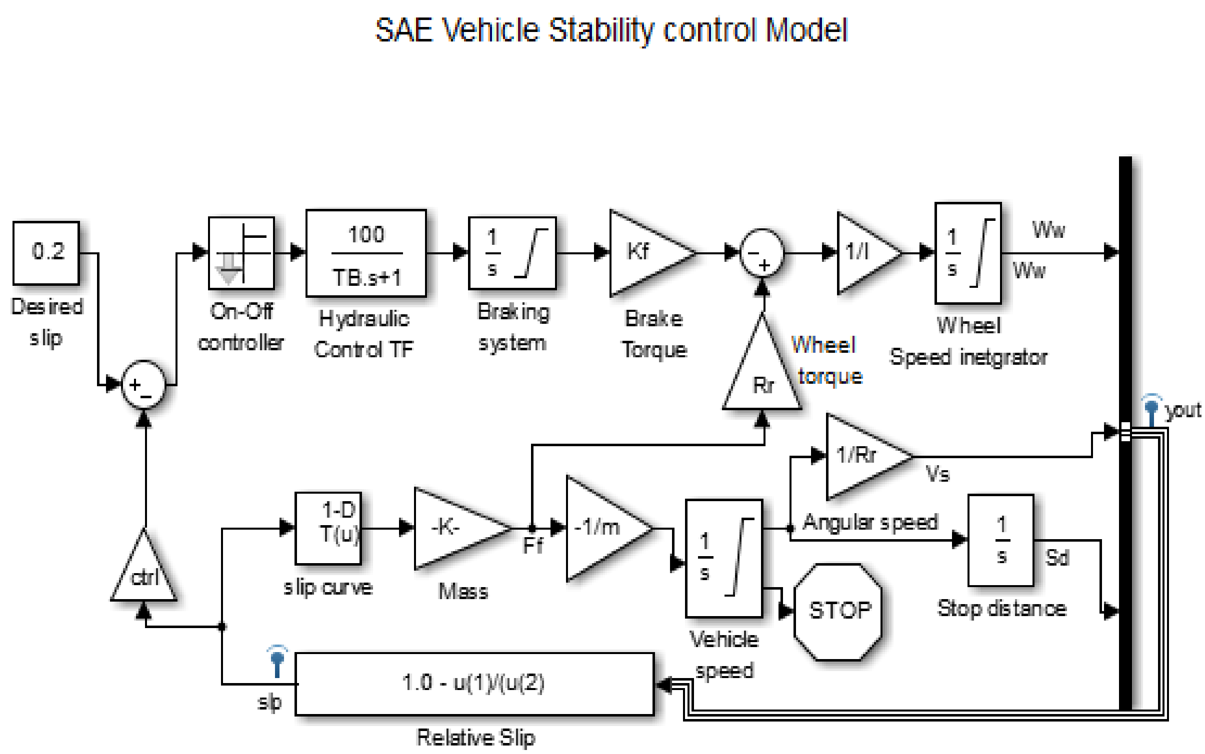


Fig 6: Complete Simulink Model for better brake performance of SAE

The designed model is then executed using Matlab – Simulink tool and the plots obtained are as shown below. When the feedback control loop is considered as’0’, the slip is not rgulated or not under control and increases rapidly with time but when the feedback is connected, the slip is regulated and hence can be controlled for better performance.

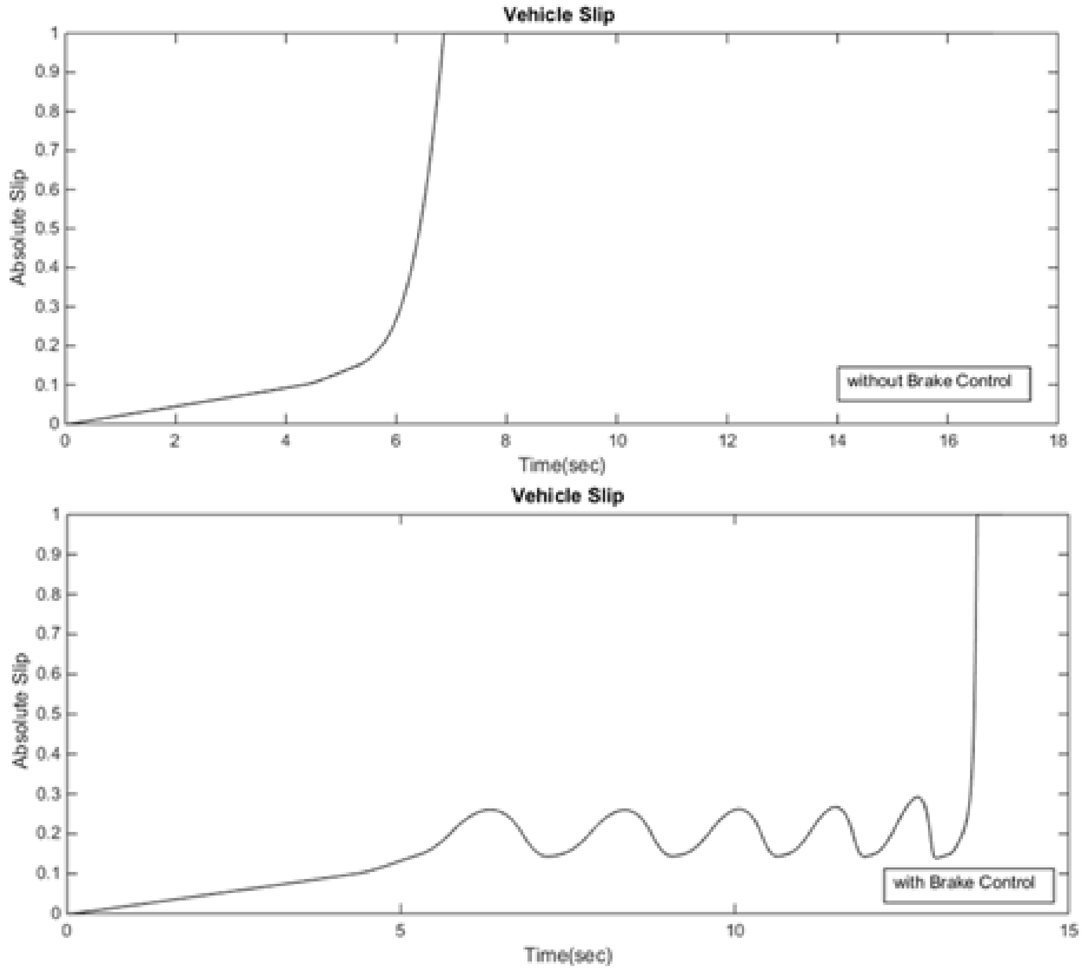


Fig 7: Vehicle slip with and without feedback control

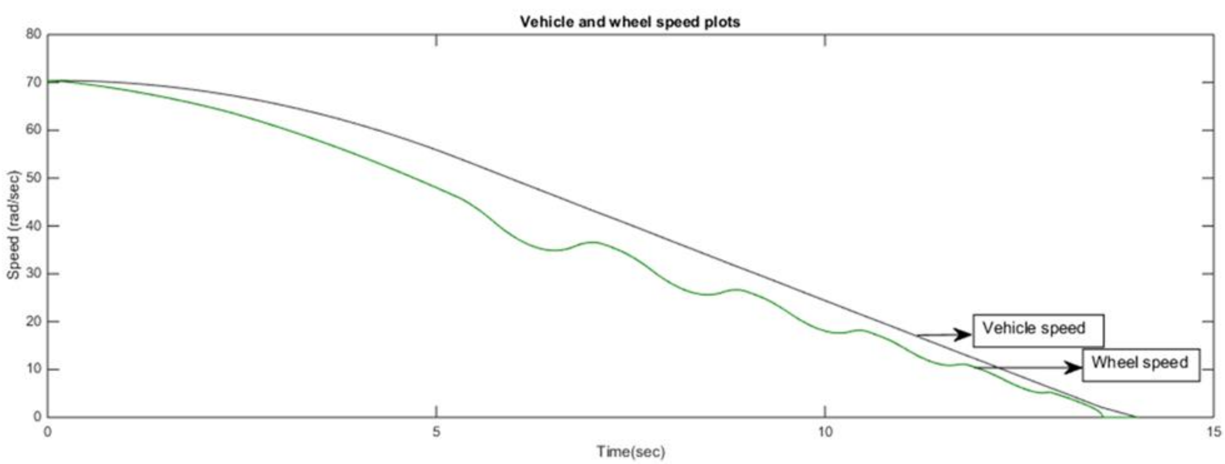


Fig 8: Vehicle and the wheel speed (Comparison) with feedback control

From the fig 8 the comparison is done between vehicle as well as wheel speed and the graph shows that the wheel speed is slightly less than the vehicle slip which ensures better stability and performance. This proposed Simulink model shows how Simulink tool can be used to model a braking method. The controller used in the model is ideal, but depending on design situations, ‘on – off’ control can be replaced by any other proposed control algorithm to estimate the system's performance. In terms of software coding, the Simulink® Coder™ with Simulink can be used as a valuable tool for quick sample of the proposed algorithm model. C code is produced and compiled for the controller hardware to assess the conception theory of a vehicle. This considerably moderates the time required to prove new ideas by allowing actual analysis early in the advanced cycle.

For a hardware – in – the – loop vehicle brake system model, the ideal 'on – off' controller can be detached and equations of motion calculated can be simulated on real – time hardware to imitate the wheel and vehicle control theory. This can be done by creating a real – time C code for this model using the Simulink Coder tool. Then the tests can be carried out on the controller by interacting it to the real – time hardware, which runs the generated C code. In this situation, the real – time model would direct the wheel speed to the controller, and in turn, the controller will send brake action to the model.

4. Wheel speed Integration:

A vehicle's Traction control, Electronic stability control, great safety developments all can be designed and implemented however, none of them could exist without wheel speed sensors. Even variable assistance power steering and variable drive systems depend on the part on data from the wheel speed sensors. Along with an accelerometer input, the wheel speed information is crucial to have better stability control.

SAE vehicle has wheel speed sensors mounted on all four wheels. They are placed on 2 front wheels and for the vehicle rear end, the wheel speed sensor are inbuilt on the individual motor controllers. In case of rotors, the fixed Hall sensors in the stator, positioned depending on the wheel configuration can be used to drive the vehicle motor. The sensors used are the Hall effect sensors. These sensors use the principle of the Hall effect and the known relative position of the wheel configuration to determine the position of the wheel. The simplest way to measure wheel speed is to count the RPMs (Revolutions Per Minute). Using a sensor that detects every time a point on the wheel passes a stationary location, and then using the Arduino controller, to count this is one way to measure the speed. The two main sensors that would be suitable for this application are a hall switch and an optical sensor.

The front wheel speed sensors are integrated onto the existing Arduino. The two IC chips are placed underneath the Arduino on the existing proto – board of the car. For fine tuning or adjusting the sensitivity of the hall sensors, there is a variable resistor / potentiometer connected in the design circuit. The hall sensors are attached to the front wheels and there are seven magnets attached next to each bolt that the hall sensor picks up.

The rear wheel speed sensors can be configured with a separate Arduino controller. The reason why the two systems are not on the same Arduino is because of the differing ground voltages of both the voltage level. The difference in ground causes noise if the sensors are connected directly to the front Arduino. A circuit is designed which uses a photocoupler / optocoupler to connect the two isolated low level and high level signals. The hall sensor outputs 22 pulses per revolution and this has been used in the code provided to calculate the rpm and the output is obtained using the serial monitor.

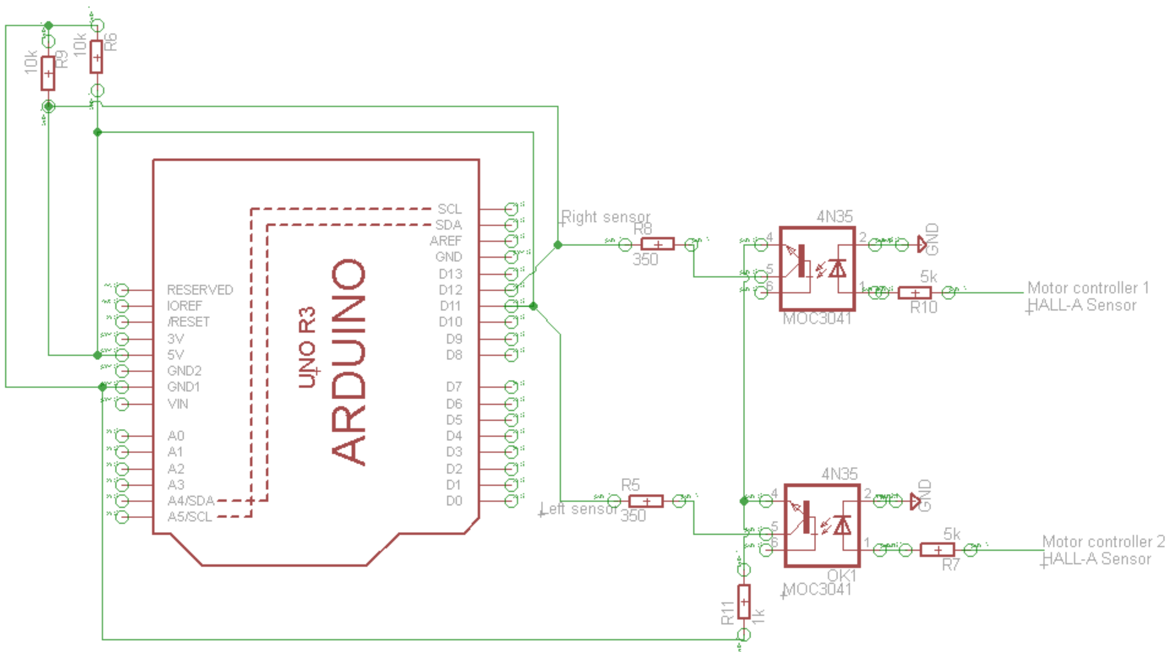


Fig 9: Wheel speed sensor isolation circuit using two Photocouplers

The designed circuit as shown in Fig 9 is the isolation circuit build in order to isolate the low level control in the front to high level control in the rear end of the vehicle. The design makes use of two MOC3041 Zero Crossing Triac Optocouplers for the low level as well as high level connected sensors. This circuit enables isolation of both ground levels ensuring safety and preventing noise problems.

The main task was to compare between the existing Arduino uno and Arduino nano controllers for the wheel speed integration. The table below shows the important features (10).

Name	Processor	Operating/Input Voltage	CPU Speed	Analog In/Out	Digital IO/PWM	EEPROM [KB]	SRAM [KB]	Flash [KB]	USB	UART
Nano	ATmega168 ATmega328P	5 V / 7-9 V	16 MHz	8/0	14/6	0.512 1	1 2	16 32	Mini	1
Uno	ATmega328P	5 V / 7-12 V	16 MHz	6/0	14/6	1	2	32	Regular	1

By comparing the differences between both Uno and Nano, it is evident to use a Nano controller for better performance even though both are similar in some aspects apart from the physical size and memory size, nano arduinio could be used in future for the sensor integration.

To calculate the speed of the wheel, the RPM value is multiplied by the circumference of the wheel. i.e, (4*π* radius of wheel [in meters]). The result will be in meters per minute which can be changed in Kilometre Per Hour (KPH).

Apart from hall sensors, there are differential Hall Effect sensors which are the type of sensors that are reasonably safe to interference and noise. Wheel speed sensors limit their operations to speeds which give a changing frequency better than a smallest operating frequency. Wheel speed sensors obtain data for vehicle stability systems and controls each wheel independently.

5. Battery Management System

The Power Monitoring and Acceleration Sensing for vehicle's driving force system had to be carried out by calibrating the already existing Battery management system. This process provides better indications to the vehicle driver by integrating the Battery Monitor system.

Performing the battery synchronisations frequently is essential to keep the battery of the vehicle well and to increase the battery lifetime. It allows the battery to be in in sync with the battery monitor system.
In addition to the automatic synchronisations based on the Auto – Sync Functions on the BMS, manual synchronizing can also be performed. This can be done by pressing both < and > keys at the same time for three seconds. After these three seconds, the BMS will ouput a message that will appear on the the display same as when it is automatically synchronized.

6. Printed Circuit board – EagleCAD and Altium Designer

Electronic assemblies in SAE vehicle have to be reliable, and they have to be proficiently put in place to have better consistency and control. The Low level control circuit of SAE vehicle was redesigned using Printed Circuit Board (PCB).

Printed Circuit Boards requires the additional design effort to lay out the circuit but with manufacturing and assembly automated. Manufacturing circuits with PCBs is inexpensive and quicker than with other wiring procedures as the electrical components of the circuit are placed and wired with one single part. Additionally, with PCB's the operator wiring errors can be eliminated.

With the wiring of Vehicle circuitry already built in previous years, advanced integration had to be carried out and hence PCB design was implemented using the EagleCAD PCB for schematic layout as design tool. However with the manufactures point of view, the layout were redrawn using another software called Altium Designer 15.1 for implementing the PCB board structure.

Low - level circuitry, Isolation circuit and Safety supervisor circuit of the vehicle were implemented using the design tools.

When designing a circuit and drawing up the schematic diagram using EagleCAD as well as Altium Designer, the primary objective is the precise application of electronics theory and coping up with application requirements so that the final product works as planned. Once the schematic is complete with all necessary components in the layout, the next important step called the PCB trace routing must be performed. This is the revolution step from a circuit design schematic to a trace layout which will be the source on which the PCB is manufactured. PCB trace routing is an artistic / imaginative process. The options of manual routing and Auto routing are present however, people who have used the auto router options in various pcb CAD packages often quote how low the outcomes are. This is because the auto router function is an essentially an algorithmic process, it cannot think creatively as humans do.

PCB design is no longer a matter of retaining tracks to construct the connections. High speed logic controls combined with reduced and more composite packaging / tools expertise produces new demands on the PCB Designer. There are various advanced options provided by the software tool, however, it is not possible to satisfy all the circuit design requirements by only bearing in mind the values of clearance between tracks, pads and vias. Designs today can also involve application of detailed requests to individual nets, components or areas of the board as well as making an allowance for such problems as crosstalk, reflections and net lengths. Altium Designer's PCB Editor allows to define design rules that monitor and test for these and other requirements. (11)

Various features to keep in mind while designing the PCB layout are; Component spacing, the track width, the shape and diameter of solder lands, Dimensions of SMD (Surface Mount Device),
Text size and thickness and so on. Various ULP (User Language Program) allows converting the EagleCAD data into other formats such as Altium Protel, Gerber, Orcad, etc.

Other than achieving a fine, accurate and consistent route layout, the other consideration is the width of the actual traces. The Low – Level circuit deals with low current which flows in the main safety circuit path but also with small currents and in addition to the manufactures point of view, the track width was considered as 20mil. The minimum track width was taken as 10mil. The clearance value was again taken as 20mil.

1) Low - level control circuit designed first using EagleCAD tool.

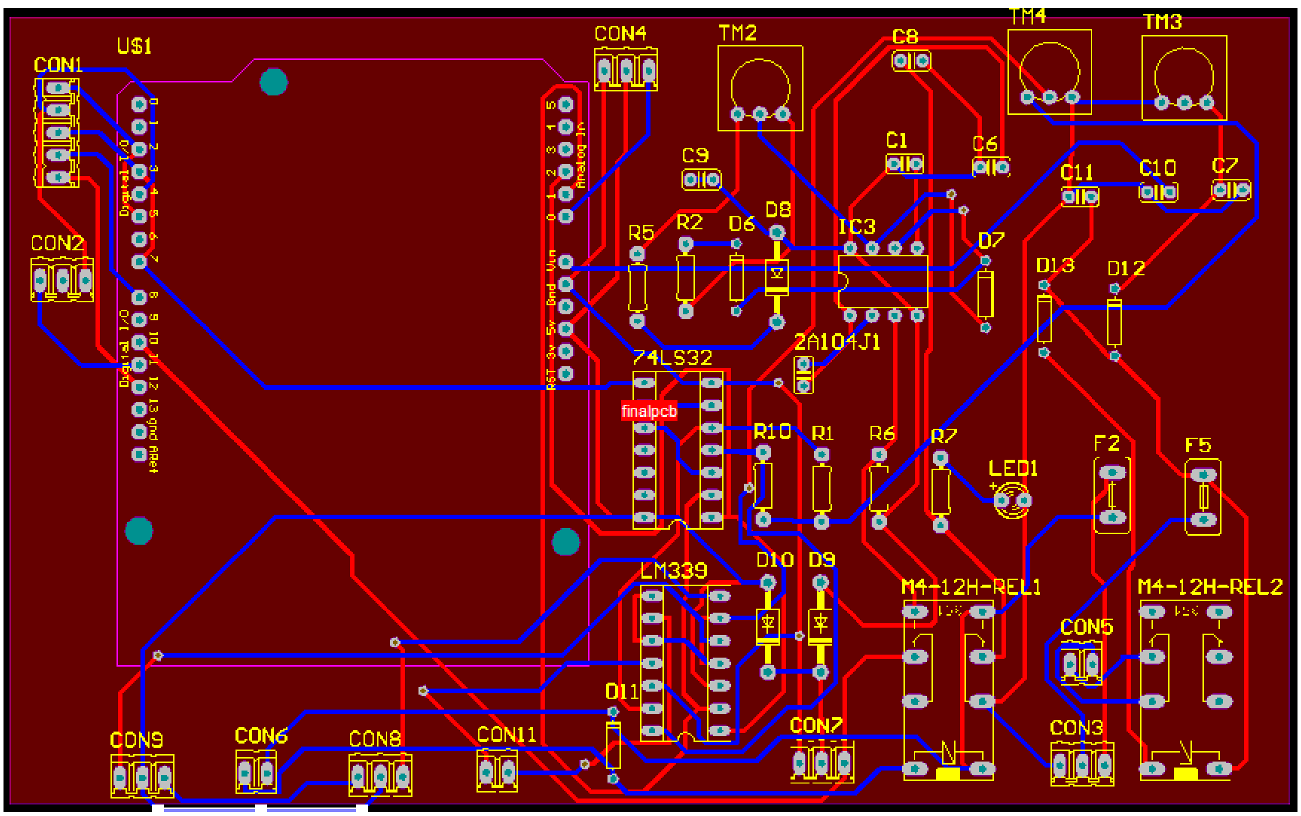


Fig 10. SAE Low – level control circuit, PCB layout using Altium Designer tool

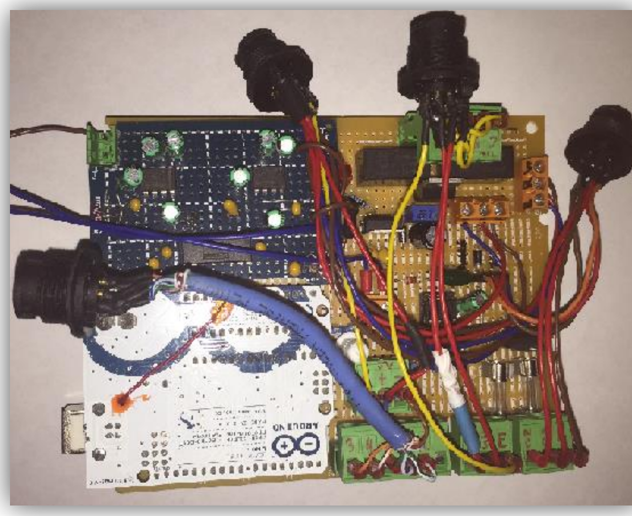


Fig 11. SAE Low – level control circuit, existing circuit wiring

The low level control circuit was designed by enabling the installation of actuators and a low-level microcontroller that is capable of controlling the autonomous system of the vehicle. To manage the drive – by – wire components, a microcontroller system based on the Arduino Uno was set up. So the task of this microcontroller is to connect with a high - level control system with the purpose of receiving steer and brake – by – wire commands. The high – level system provides decision making abilities. The circuit also provides power to the sensor interface and retrieves data from the sensor such as to detect if a collision is about to happen. The Low level information from the Arduino microcontroller is provided to the high - level system to evaluate the performance of obstacle avoidance algorithms in order to judge the effectiveness of various techniques.

The PCB layout was designed using the EagleCAD as well as Altium designer tool with the total of 44 number of components.

2) SAE Isolation circuit

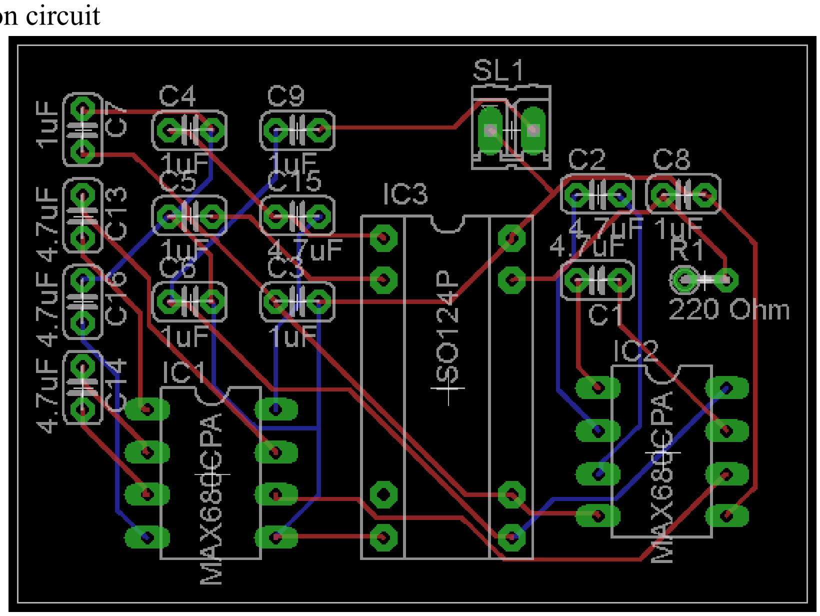


Fig 12. SAE Isolation circuit designed using EagleCAD PCB

Fig 13. SAE Isolation circuit existing circuit

Isolation circuit was designed to provide an analogue feedback signal to the drive motor controllers. To implement this, an ISO124 isolation amplifier was used (4). This circuit provides isolation in terms of throttle – by – wire isolation amplifier. The 5V from Motor controllers are isolated from 5V of arduino controller.

The PCB was designed using Eagle CAD tool. The total number of components required was 18 nos.

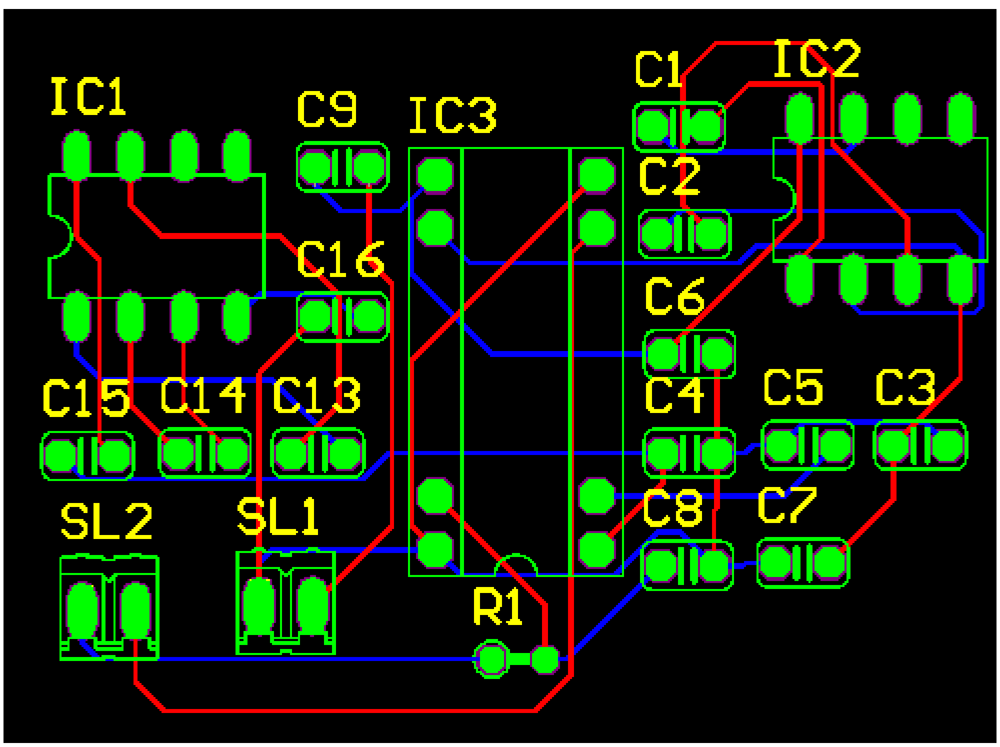


Fig 14. SAE Isolation circuit designed using Altium Designer

3) Safety supervisor circuit

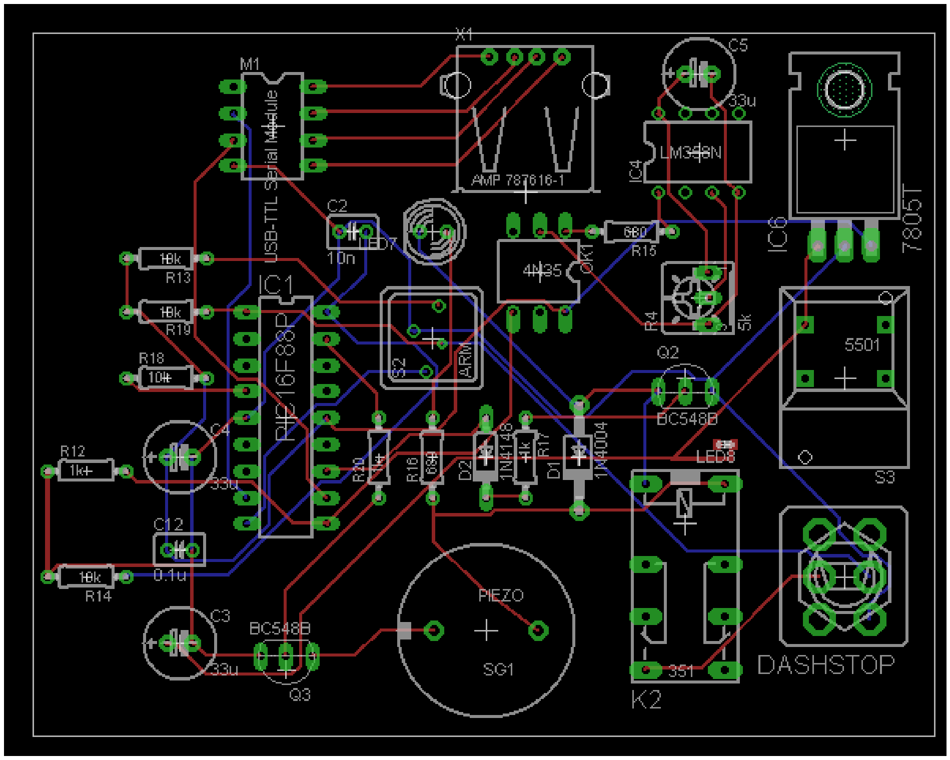


Fig 15. SAE Safety supervisor circuit designed using EagleCAD PCB

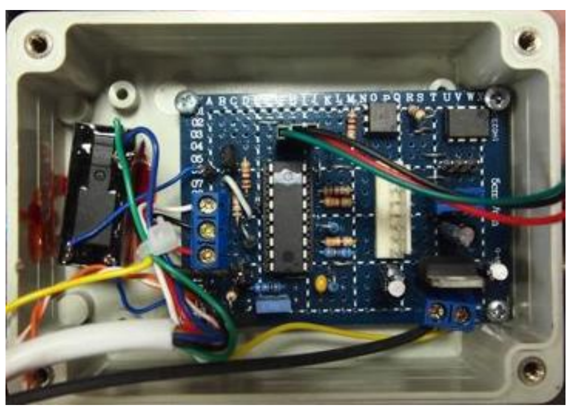


Fig 16. SAE Safety supervisor existing circuit

The safety supervisor circuit system design is based around the PIC16F88, an 8-bit micro-controller from Microchip (3). The microcontroller was selected for its integral hardware UART (Universal Asynchronous Receiver/Transmitter), a DIP-18 (Dual inline Package), its capability to provide current of 25mA from an Input/Output pin, with an oscillator. As a result of these features the circuit was able to be constructed using through-hole techniques on a 7x5cm circuit board and along with the PIC controller, another two ICs were required for circuit implementation.

The PCB layout designed was EagleCAD and the total number of 31 components was used.

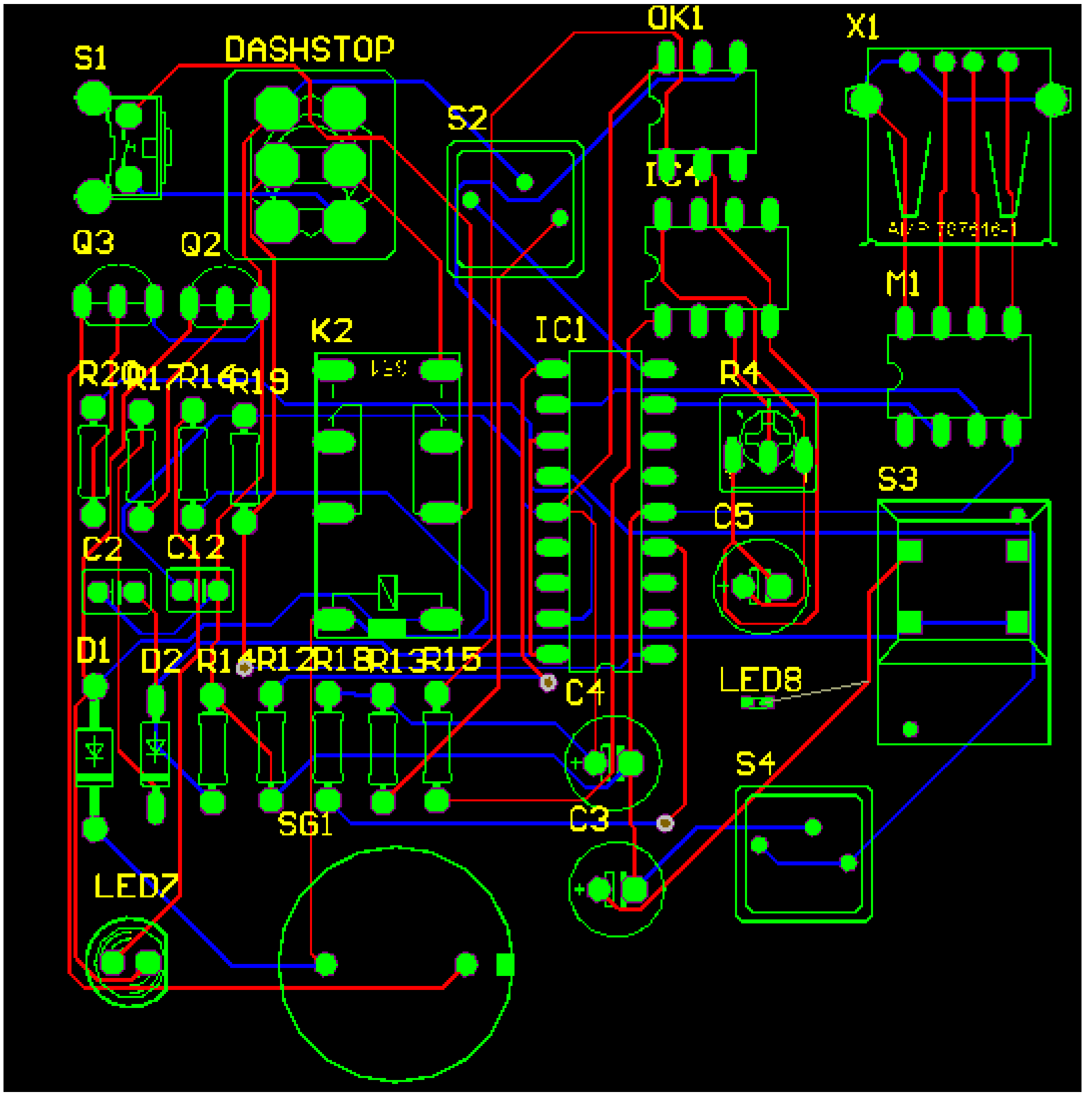


Fig 17. SAE Safety supervisor circuit designed using Altium Designer

The PCB Design implemented in the PCB layout must undergo various rules or checks that enable both the logical, consistency and physical reliability or integrity of the design. Checks are made against any or all enabled design rules and can be prepared as it's worked on, and / or as a set check, with results if required are listed in the comments section and a generated report can be obtained. This feature should be used on every routed board to confirm that lowest clearance rules have been retained and that there are no other design defilements or violations. Each violation if exists during the design work, that was located is listed with full details of any reference data, such as the design layer, the net name, component designator details, the PCB pad number, as well as the location of the object.

Another critical feature to be considered while designing PCB layout was the heat dissipation factor. The voltage regulators have high heat dissipation hence while designing the schematic, linear drop in replacements had to be carried out. This reduces the heating problems and ensures safety for the neighboring electrical elements.

7. Electrical circuit documentation

Documentation, leaving a paper traces, accomplishing requirements – all these features are crucial in automotive electronics design. The responsibility weighs on electronics and PCB designs to make sure the supervisory and regulatory compliance standards are achieved such that the drivers can maintain confidence in their vehicle while on the road. The SAE electrical circuits were not appropriately documented which were the issues faced as the electrical circuits were not clear. In order to have clear understanding of the electrical design and to have better understanding for future purposes, the complete SAE circuit wiring were traced and schematics were built using Eagle CAD wiring schematic tool. Document revisions in future will help maintain the project best practice, along with design release and lifecycle management. The circuits are all provided in the appendix section.

The circuits built were:

1) SAE porting details
2) SAE contactor schematic
3) Low level control circuit
4) Isolation circuit
5) Safety supervisor circuit

8. Conclusion

In order to achieve the superior braking performance through the wheel slip control, real-time information such as the tire braking force at each wheel is required for better stability and enhancement. To achieve this, GPS as well as Wheel speed sensor data were obtained.

Integrated PCB designs proved as an interconnect platform for the electrical components on the vehicle. The reliability of the vehicle system and the system's implications on safety to both the vehicle's occupants and its existing systems are the highest priority and are critically assessed.

The PCB designed proves to enhance the style and to have elegance electronic design. There were various challenges faced during PCB construction as two complete different software tools had to be studied and implemented for manufacturing purpose. The designed low level PCB has to be placed onto the front end of the vehicle and has to complement the vehicle by making it fix on to the existing space. Eagle CAD was initially used for PCB design however from manufactures point of view, Eagle CAD schematic had to be changed to Altium design schematic.

The existing circuit causes lots of issues relating to slack wiring and soldering problems hence PCB provides better stability of electrical wiring and hence increases safety as well as better performance.

9. Future work

To achieve further intelligent driving and mapping functionality, research can be made into the operation of Autonomous vehicles in traffic scenarios

Real-Time model implementation can be carried out. Various methods can be investigated to increase speed of the vehicle with further intelligent driving methods.

Setting up reversing capability of the vehicle that can be controlled by microcontroller can be implemented

Better web based interfacing can be investigated and methods to improve safety reliability can be carried out.

Another interesting approach is to implement Computer vision for better autonomous driving. The Raspberry pi can be replaced by a Graphical Processing Unit (GPU) also called Visual; Processing Unit (VPU) for enhancing the autonomous control.

10. References:

(1) SAE International. “About Formula SAE Series” [Online]. Retrieved from; http://students.sae.org/cds/formulaseries/about.htm. [Accessed: Oct. 15, 2015]

(2) Thomas Drage, Jordan Kalinowski and Thomas Bräunl, “Integration of Drive – by – Wire with Navigation Control for a Driverless Electric Race Car”, REV Project thesis, UWA, 2014

(3) T. Drage, “Development of a Navigation Control System for an Autonomous Formula SAE – Electric Race Car”, Final Year BE Project Thesis, UWA, 2013

(4) J. Kalinowski, “Conversion of a Formula SAE Vehicle to Full Drive-by-Wire Capability”, REV Project, UWA, 2013

(5) Fu Tianku, “Modeling and performance analysis of ABS systems with nonlinear control”, Thesis (M.A. Sc.) – Dept. of Mechanical Engineering, Concordia University, 2000

(6) Wirje, A. and Carlsson, K., "Modeling and Simulation of Peak Load Events Using Adams - Driving Over a Curb and Skid Against a Curb," SAE Technical Paper, Retrieved from SAE International Technical, available online: http://papers.sae.org/2011-01-0733/

(7) R. Dijual, 2011, “Torque - slip Characteristics”. Retrieved from myElectricHome, Available online: http://yourelectrichome.blogspot.com.au/2011/08/torque---slip---characteristics.html

(8) Hondata, Inc., 2009, ”Traction Control: Theory of Operation”, Retrieved from Hondata, Available online: http://www.hondata.com/help/tractioncontrol/index.html?theory_of_operation.htm.

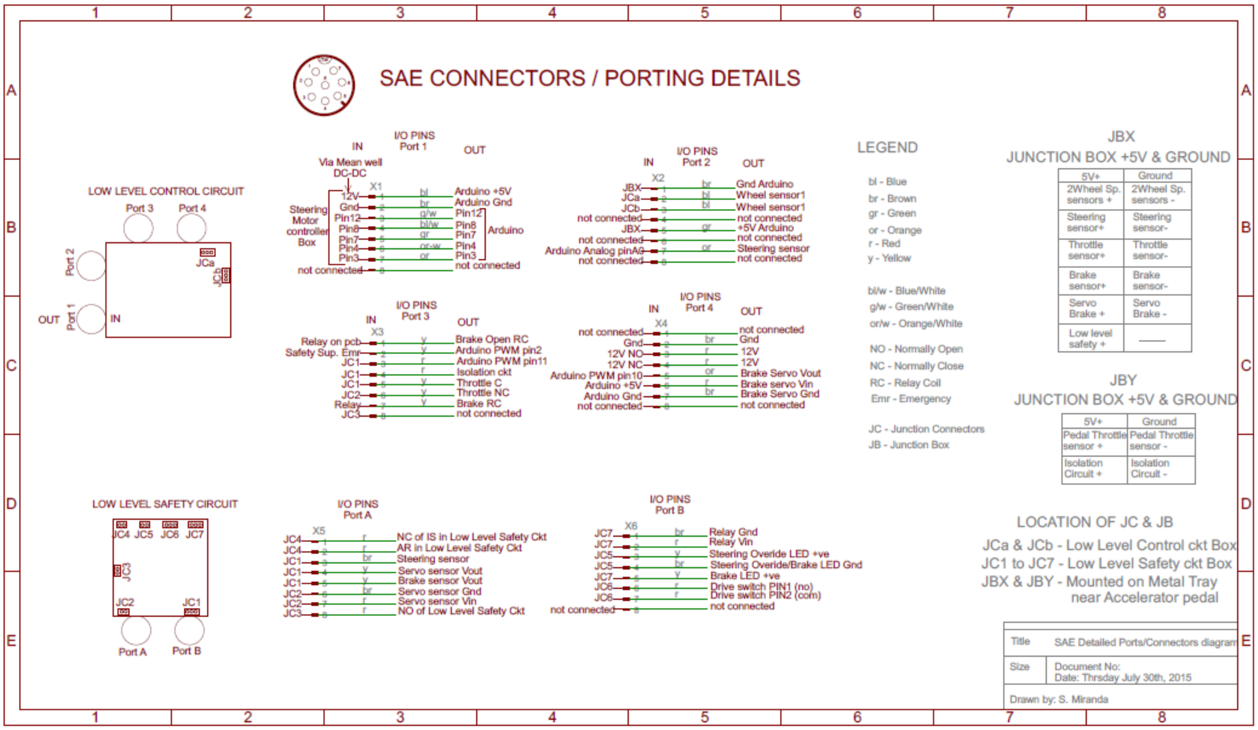
(9) Battery monitor system High Precision Battery Monitor e-xpert pro, Retrieved from TBS Electronics, available online; http://www.tbs-electronics.com/products_expertpro_features.htm

(10) Arduino microcontrol, Retrieved from Arduino Home page, available online; https://www.arduino.cc/en/Main/Products

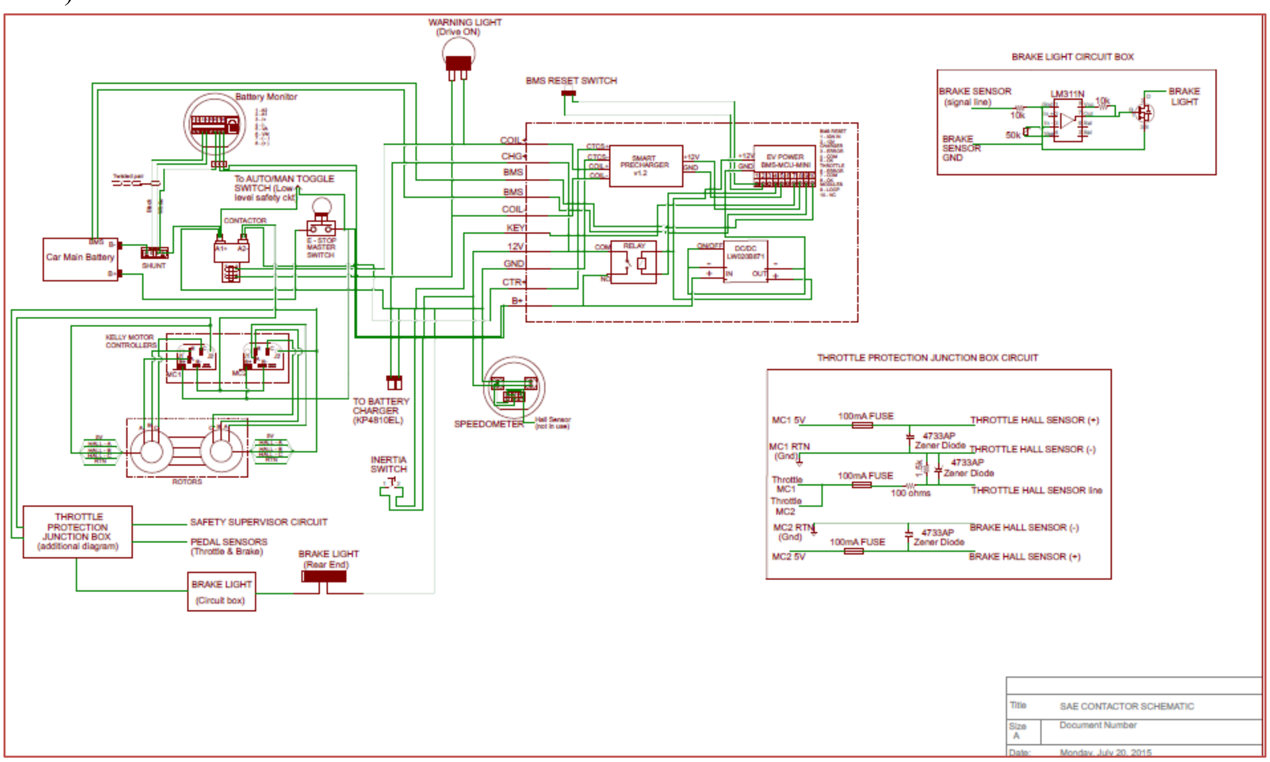
(11) Altium Designer 15 PCB implementation tool, Retrieved from Altium techdocs, available online: http://techdocs.altium.com/display/ADOH/Board+Implementation

11. Appendix:

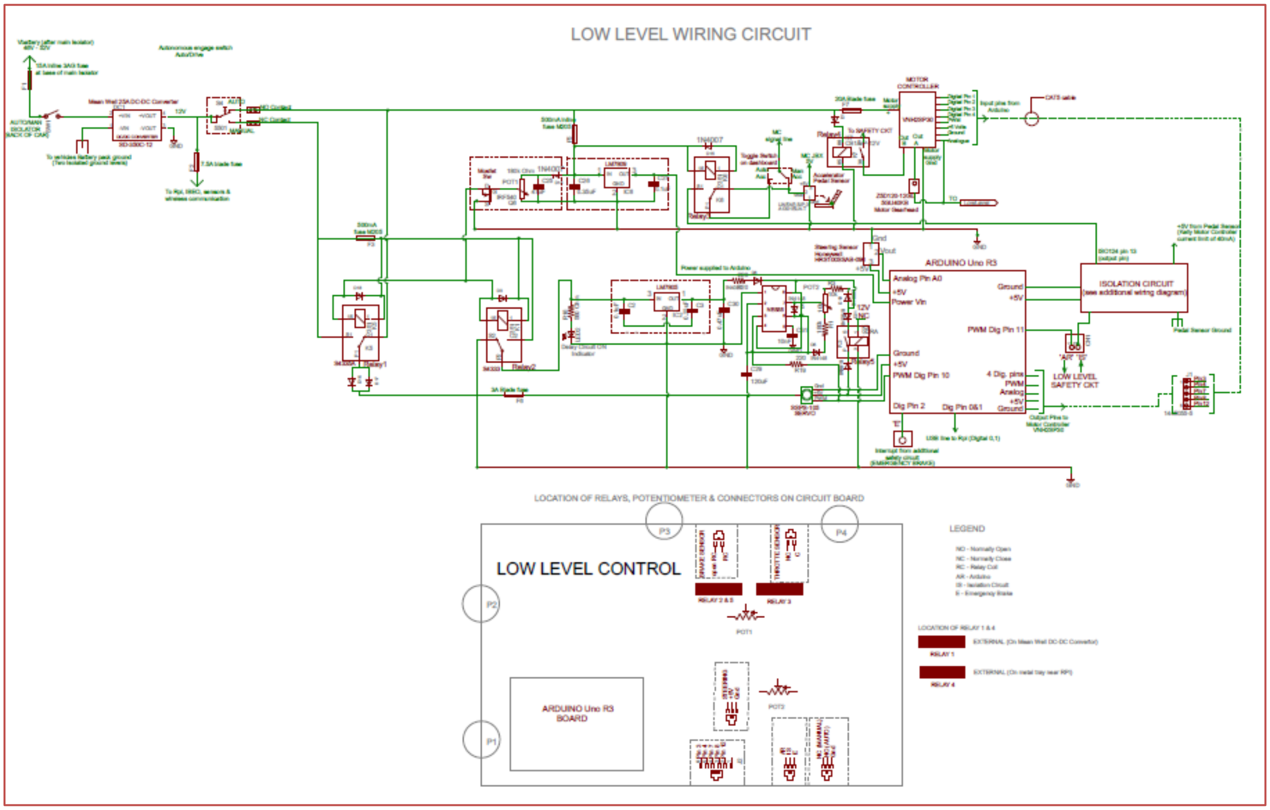
1) SAE circuit porting details



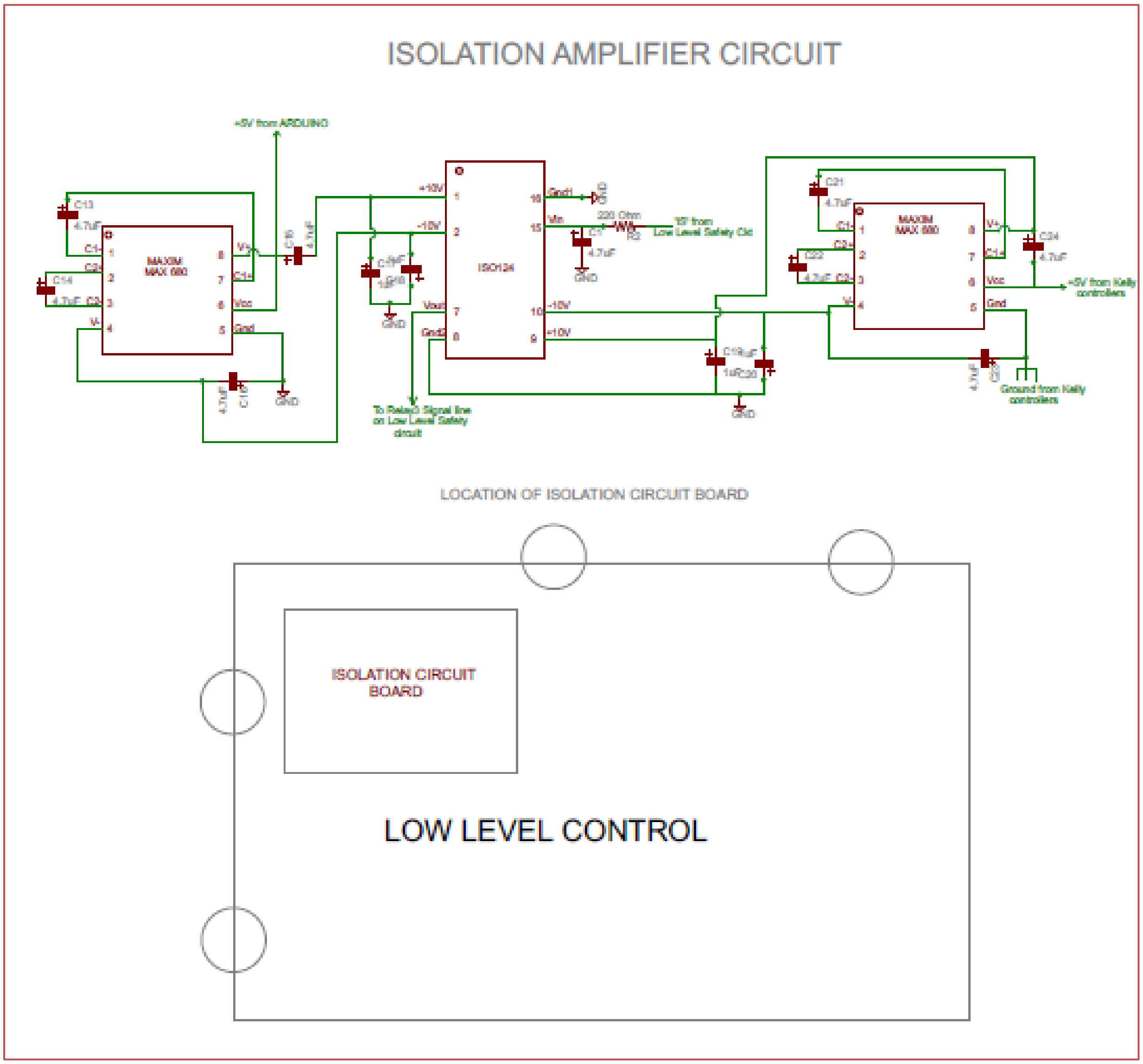
2) SAE Contactor schematic



3) SAE Low Level control circuit



4) SAE isolation circuit



5) SAE safety supervisor circuit