**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION.**

**A Project Report**

*Submitted in partial fulfilment for the award of the degree*

*Of*

**Master of Technology**

***In***

**POWER ELECTRONICS AND EMBEDDED SYSTEMS**

*By*

**VINU XAVIER**

**(16MPD0024)**

*Under the guidance of*

**A.Rammohan**

**Assistant Professor (Sr.), TIFAC-CORE,**

**Vellore Institute of Technology**



**Institute for Industry and International Program**

November, 2018



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**DECLARATION BY THE CANDIDATE**

I hereby declare that the thesis entitled “**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION.”** submitted by me to Vellore Institute of Technology, Vellore in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **Power Electronics and Embedded Systems** is a record of bonafide project work carried out by me under the supervision of Mr. A.Rammohan. I further declare that the work reported in this project has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other Institute or University.

**Place**: Bangalore

**Date**: 07 October 2, 2018 **Signature of the Candidate**



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**BONAFIDE CERTIFICATE**

This is to certify that the project work entitled “**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION”** by **VINU XAVIER (16MPD0024)**, to Vellore Institute of Technology, Vellore, in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **POWER ELECTRONICS AND EMBEDDED SYSTEMS** is a project bonafide work carried out by him under my supervision. The project fulfills the requirement as per the regulations of this Institute and in my opinion meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this Institute or any other Institute or University.

**A.Rammohan**

**Internal Supervisor External Supervisor**

**Asst.Prof (Sr.)**

**TIFAC-CORE**

**VIT**

**Internal Examiner(s) External Examiner(s)**

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Place:

Date: **VINU XAVIER**

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# ABSTRACT

The most modern trends in the automotive industry is heading towards highly or fully automated driving. When we consider how far it can resolve the existing troubles which cause the road accidents, it's a very important fact that the human error is the most probable root cause for the majority of all accidents. The studies say that the driver negligence plays a vital role in the in the various reasons which cause an accident. Each and every abnormality in the driving behaviour is visible as a pattern and this thesis would like to consider various algorithms to detect the abnormalities in the driving behaviour and thereby either taking failed reactions in an appropriate manner so that prevention of accidents are possible. A drowsy or a drunken driver will always follow a driving behavioural pattern. It is also called the degree of abnormality when comparing with the regular way of driving to the same road in the same conditions. These abnormalities are visible mainly in the brake pedals the steering wheel and the suspension sensors. By carefully studying the factors which are observed in these sensors, it is possible up to an extent, to detect the abnormality which is not expected in that driving situation. The driving style can be continuously monitored into a database which may be efficient inside the cloud and make available continuously to run this comparison in the entire duration of driving. This thesis is mainly concentrated on the steering wheel and a sensor and various patterns which are carefully studied when taking the actual vehicle data. The software algorithm is developed as a prototype simulation in Matlab.

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**LIST OF Abbreviations**

|  |  |
| --- | --- |
| **ACRONYM** | **EXPANSION** |
| **MOSFET** | Metal Oxide Semiconductor Field Effect Transistor |
| **PWM** | Pulse Width Modulation |
| **DPDT** | Double Pole Double Throw |
| **LED** | Light Emitting Diode |
| **USB** | Universal Serial Bus |
| **ADC** | Analog To Digital Converter |
| **IDE** | Integrated Development Environment |
| **EMF** | Electromotive force |
|  |  |
|  |  |
|  |  |

# INTRODUCTION

## MOTIVATION

The road accident cause death of millions and facilities of more than that every year in the world. According to the reports of World Health Organisation, report shows up nearly 3500 human deaths are causing every day in the world by traffic accidents. The majority of these accidents are reported as human errors.

Even though the most modern technology heading towards autonomous driving, the limitation of the technology is always the human driver and the various decisions he makes while handling the vehicle. Irrespective of how much advanced is the technology, the errors caused by the situations of negligence, situations of lack of skills, situations of ignorance, situations of absence of mind, situations of carelessness etc. be in the leading position of the root causes of any accidents. Irrespective of how best is the system which is fitted into a car or any automotive, it can only react to the situation but cannot prevent it completely. More than that, it is impossible to predict the future and take early preventive mechanism. The root cause of the situation is, we do not having as many trained and skilled drivers, as many automotive vehicles available in the world. A highly or a fully automated driving can be the final solution for this, but the time it would take to come into an action can be decades or more than that. Under developing countries like India needs more time to have that infrastructure, which can help the introduction of fully automated driving. In the next 5 years, India will be the third largest automotive vehicle producing countries in the world. When considering the death rate of road accidents caused every year in India we stand in the top of the world.

In parallel, the computational Technologies and the cost of implementing that is going down drastically into a very cheap opportunity so that implementing a Complex algorithm and deploying that it to bigger Industries like automotive would not make a huge amount of time to come into the market as compared to the fully automated driving. More than that, people following the road rules and having the right skill set to be eligible to drive in a complex driving situation like in Indian roads, is very less. The authority is even providing out the driving licenses, without even checking whether the driver has the right skills physically and mentally to handle complex situations. People do not even think about following the line, wearing a seatbelt, following the speed rules and giving way to the most deserved.

Policing each and every situation like this is hard. The only way in which it can be solved is self-monitoring of the driving behaviour by an installed system which is fitted into the vehicle itself. The system will be effective when it try to re-use the existing sensorics in the same vehicle environment. This system should be able to take care by itself when an abnormality is continuously visible and the human driver who is driving that vehicle is not taking care of or not improving the driving situations. Accumulating all these decisions, the system should be able to judge that the person who is driving the car is not in the physical and mental situation to safely execute the driving manoeuvre.

By that way, the software mechanism would be helpful to detect such kind of situations. The installed software can react by taking preventive actions like, reducing after speed limit or glowing the hazard warning lamps or even take over the control of the vehicle and park to the nearest safest possible area and thereby allowing removing this vehicle from the traffic. The software could be complex to detect pattern based on machine learning and therefore, lead to complex hardware to be installed into each and every vehicle , can increase the cost of the vehicle from affordable range. This situation can be solved by the technology of cloud computing where the input data is transferred into the cloud and the complex data processing happens in a remote area in the cloud. And, the decisions are given back to each and individual vehicles so that there are actuators which are mechanical and software facilitated and thereby reacting to the situation by considering the intensity of abnormality in the driving behaviour.

# **Literature** Survey

Literature review was conducted to better understand the principles and applications of this research. Below are the findings of this review.

## ABNORMALITY IN DRIVING

In this chapter let's consider about, the basic abnormality in driving when considering to the acceleration behavior. A sudden acceleration is always treated as a chance of losing the vehicle stability. Especially, when the road condition is not demanding to have a sudden acceleration at that situation ,or acid and deceleration in other words the hard breakings and in case the driver is doing this so repeatedly then the degree of abnormality is counted up and should be treated as a suspicious abnormality in the driving. Acceleration is a rate of change of velocity. When doing so the Dynamics accepted into a vehicle act longitudinally, which can overtake the static friction range provided by the road friction. If the static friction range is overridden, then the vehicle can move sliding away into a condition which is not controllable by the driver. There is a big chance that the driver is not doing this intentionally, but due to the effect of alcohol consumption, or by the effective physically and mentally tiredness due to the absence of a proper relaxation which is mandatory to maintain a healthy situation while driving.

It is also very much important that the wrong detection of this normality in driving behavior can lead to frequent and unexpected degradation of the services which itself can cause the public projection of such kind of a system in a car. Due to that, in the case when the system detects the abnormality of a driving behavior then it has to be 100 percentage evaluated against the very recent and massive collected data in this am driving situations.

Let's think about how this abnormality behavior can be listed down. In general cases, the drivers are always affected by fatigue drugs alcohol or any kind of distraction such as cell phones texting. This drivers are not only dangerous to themselves but also dangerous to the other innocent and regular drivers around.

If two driver makes cornering without making the term indication lamps illuminated is a very generic case of absence of mind while driving. Such kind of situation has taken out huge amount of lives. In a very special case while driving in the night and not making the headlamp on is a very clear case of the abnormality in driving.

While considering the steering behavior, which is going to be more focused in this thesis, let’s consider various situations which can be deeply analyzed and identified symptoms of abnormality. And illegal of a sudden turning return which is responded late etc. can be treated as input situations for our studies. During a straight line driving, if the driver continuously is keeping the steering wheel angle not in the straight line but into a very minute way of moving the car in the left or right slide away, and late responding to that by making a fast turn back into the line was identified as a situation to analyze.

## SENSORICS AVAILABLE

In this chapter let us consider the various sensors available in automotive electronics system and which can be made useful for the input data collector for the abnormality driving behavior software algorithm. The main aim is to reuse the existing sensors thereby reducing the extra hardware cost come as a burden to install a new system into the automotive electronics clusters.

### BRAKE PRESSURE SENSOR

The brake pressure sensor is so high-pressure piezoelectric sensor, which can measure the hydraulic brake fluid pressure when pressurized by the brake pedal unit. The piezoelectric high-pressure sensor is able to measure the pressure input which is in the range of light pedal touch until the high slamming of the brakes. This sensor is available with an electronic brake system unit, which is going to be a mandatory safety measure in any future automotive vehicles. This statement is true for the cars getting produced and used in India.

The positioning of the brake pressure sensor is in the Hydraulic electronic control unit of the electronic brake system. These sensors are assumed as very highly accurate with respect to the accuracy and the reproducibility of the pressure profiles exerted by the human driver. The brake pressure sensors are even visible to the pressure ranges of lesser than one bar, which is generally any gentle touch of the brake pedal. In other words, these pressure sensors shall monitor any activity applied on the brake pedal. These pressure values are continuously sensed in the range of 2-3 milliseconds. Moreover, the brake pressure sensor is also made available in the vehicle CAN/FlexRay network communication bus. The availability of this pressure values shall be considered as the primary input into the SW algorithm to detect the driving abnormalities

### STEERING WHEEL ANGLE SENSOR

The steering wheel angle sensor is an absolute sensor which is a critical and mandatory component of Electronic Brake system. The sensor is positioned in the steering column. The steering wheel angle sensor is also widely referenced by the name SAS (Steering angle sensor). The absolution position of the steering and the rate of steering is measured by this sensor. For any vehicle which is equipped with Electronic Stability control, shall have the steering wheel angle sensors associated with it. Being remotely positioned from the ESC control unit, the SAS acts always as an independent sensor and always have an intelligent part to have the data processing associated and included in the sensor unit itself. The SAS is also able to make self-calibration of the steering sensory. Mostly, the ESC unit is helping the steering wheel angle sensor to have the steering center detection every time when the vehicle undergoes an straight line driving maneuver ,which is visible in the wheel speed sensor unit.

### SUSPENSION SENSORS /HEIGHT SENSORS

The sensors placed in a suspension unit is not widely used in a common automotive scenario. With the introduction of advancement into the electronic brake system unit and Vehicle Dynamics control the importance of being the sensors in suspension is increasing. In general these sensors can be used to see the dynamics which are occurring in the vertical direction for any vehicle. These sensors are also known as ride height position sensing, the distance between a specific points in the gases suspension of car body when compared to the road positions. These sensors can be used to measure the vertical oscillation or in general known as the pitching motion of any vehicle after the potential behavior of abnormality. The sensors are also indirect sensors which are sometimes pressure sensors which continuously monitor the compression of the suspension Springs and calculate the vehicle height from a mathematical model.

## ANALYSIS OF INPUT SENSORS DATA

While designing the software algorithm needs a careful analysis about which all abnormality is visible in the available sensors. Let's consider a detailed analysis associated with each sensor described above.

### Abnormality in the suspension behaviour

When considering the driving pattern shown up by a drunken driver it is very common that he cannot judge the humps present on the road. in most of the cases, the recognition of the hump happens too late followed by if delayed reaction which mostly results in jumping onto the home with the not so reduced speed which additionally makes pitch motion together with a not well-planned braking. Such kind of incidents is collectively visible in the suspension sensors and the brake pedal angle sensors. Especially the road hump is permanently positioned and may be well known to the driver if he is a regular user of that Road.

# DESIGN OF THE PROJECT

## BLOCK DIAGRAM



Figure 4.1: Block diagram SW Algorithm subcomponents

## HW design

### CIRCUIT DIAGRAM

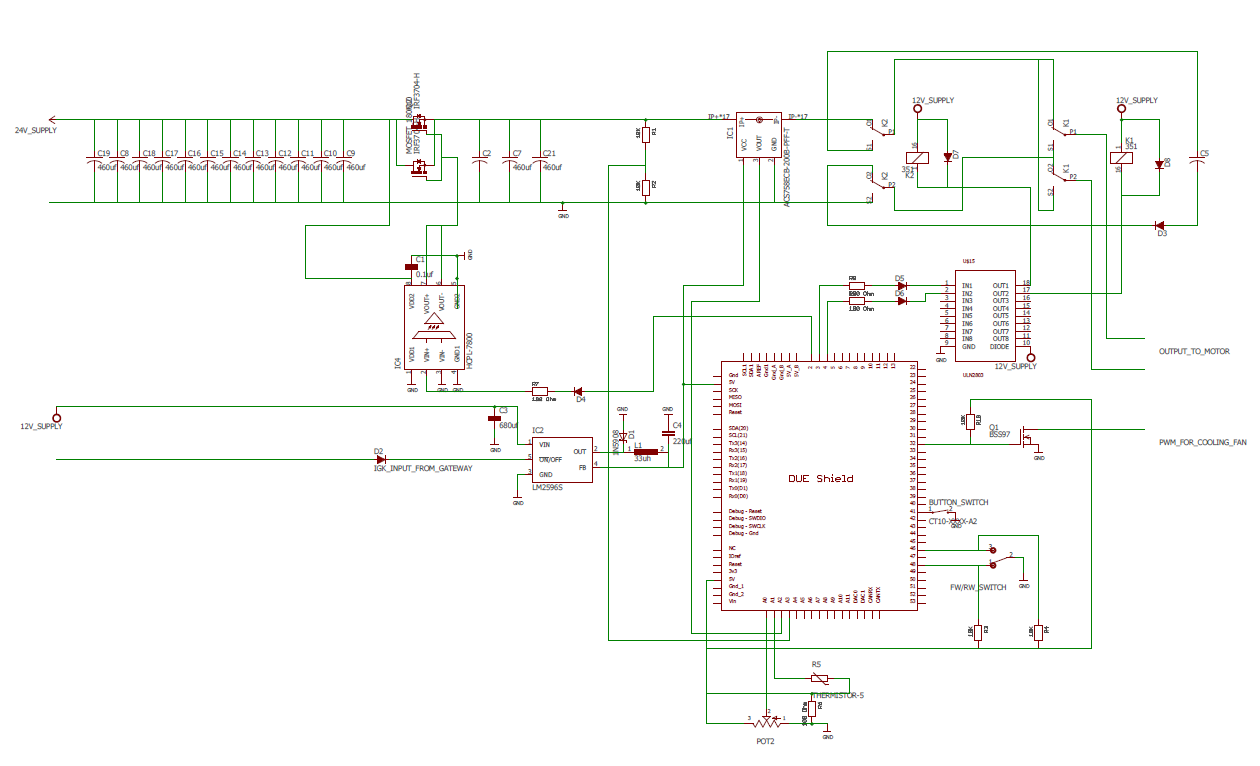


Figure 4.2:Circuit Diagram

### Hardware Components

#### MOSFET:

To control the motor speed using PWM. We are using N-Channel MOSFET at higher power side of the circuit. Mosfet is a 3 terminal device with “Gate” “Drain” and “Source” which is used for amplifying and switching the electrical signals in electronic devices. By generating the electrical field to control the flow of current through the channel between the source and drain. The electrical connection of MOSFET is as shown below.

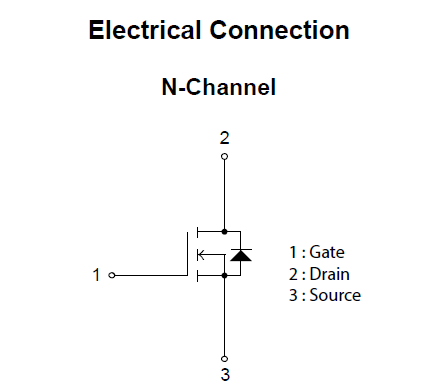


Figure 4.3: Electrical connection of MOSFET

The Gate terminal is electrically insulated from the main semiconductor by the thin layer of insulation materials (Glass, Fibre). This insulated metal gate terminal is like a plate of a capacitor which is having a very good high input resistance to almost infinity. Because of this isolation of the Gate terminal, there will be no current flows into the MOSFET from Gate terminal.

When some voltage is applied to the gate terminal, it changes the width of the Drain to Source channel along with which electron or hole flows. The wider is the channel, the better is the MOSFET conduction.

The electrical characteristics of MOSFET 180N10 at room temperature is as below.

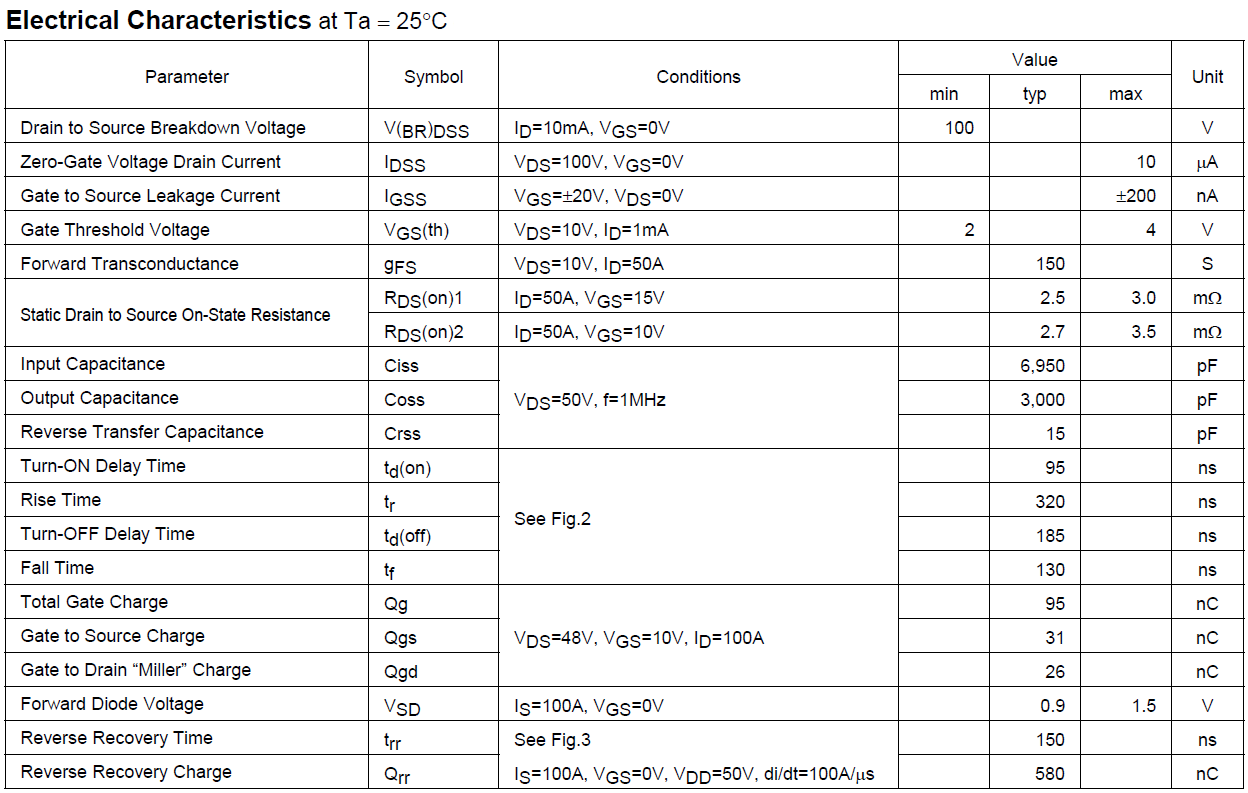


Table 4.1: Electrical Characteristics of MOSFET

#### DC MOTOR:

The Motor used for the demo purpose is MY1016 250W 24V DC Motor with 11 tooth chain sprocket. This dc motor is capable of rotation in both clockwise and anti clockwise direction by reversing the motor's power wires or terminals. Specifications of a demo motor is given below.

Model: MY1016

Power: 250 watt

Voltage: 24 volts DC

Speed: 3000 RPM

Weight: 2.90 Kg.

Torque: 11 N.m (110 kg.cm)

Stall Torque: 55 N.m (550 kg.cm)

Current: 13.5 amp



Figure 4.4: MY1016 250W 24V DC Motor

**RELAY:**



Figure 4.5: DPDT Relay

DPDT(Double Pole Double Throw) relay is the electromagnetic device. Which we are using to separate two circuits electrically and also to connect them magnetically. DPDT relays are often used to interface an electronic circuit also, which works at a very low voltage level in the electrical circuit which works at a very high voltage levels. DPDT relay we have used for demo is with the configuration of operating voltage of 24V and has a capacity to withstand upto 22A current flow.

In this DPDT relay we have two sections input and the output. The input section of the relay consists of the copper coil with two pins which are connected one to the ground and the other at the input supply. The output section of relay consists of a contactors which to connect or to disconnect the circuit mechanically. The output section relay consists of six connectors with two sets. Each sets has three changeover contnections, named as, NO (normally open), NC ( normally closed) and COM (common terminal). When there is no supply is given the COM terminal which will be connected to NC terminal. When some operating voltage from power supply is applied to the relay copper coil gets energized and the COM terminal changes its contact to NO (Normally Open).

This relay we can be used to power with one device to another. Where SPDT relay can be used only to switch the output circuits to on and off states.

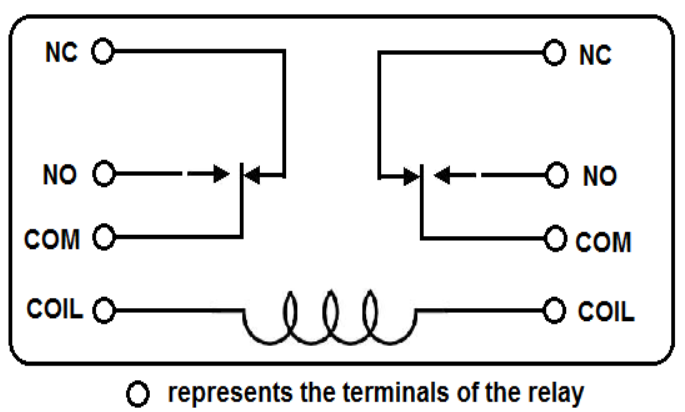


Figure 4.6: DPDT Relay Wiring Diagram

To drive the DC motor in both clockwise and anticlockwise directions. We have used this DPDT relay to change the polarity at the terminals of a device. When we provide the input signal, the contactors in the relay changes their positions, by resulting in the change in direction of the rotation of motor. So clockwise or anti clockwise rotation of motor is depending on the connection of relays terminals.

**Current Sensors**

Two current sensor IC’s are used in this project. One to measure the current in the circuit and the other to measure the voltage level in the circuit dynamically.

The current sensor ICs which we have used are integrate with a low-resistive copper primary conduction path for current. Where by enhancing the performance of the current sense in many ways, still in this current sensor there are some limitations imposed in current level which we will discuss later.

This current sensors uses a inovative methods by increasing the sensing range of current measurement. The simple methods that is involved in current sensing is by splitting the path where the current needs to be sensed. And the technology used in this sensor to sense the current is based on high precision linear Hall effect and magnetic field sensing method. Which allows the current to flow in both directions.

Current sensing technique at high level current sensor is as shown below.

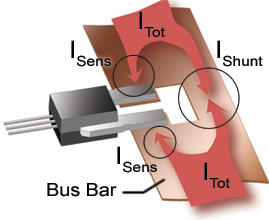


Figure 4.7 : Current sensing technique at high current.

Current sensing technique at low level current sensor is as shown below.

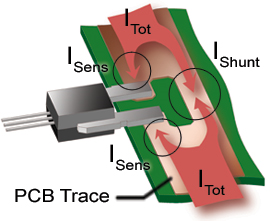
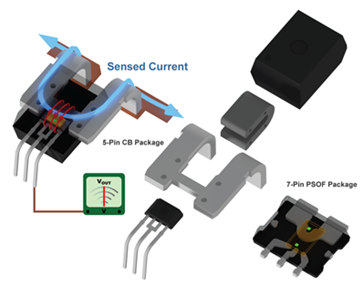


Figure 4.8 : Current sensing technique at low current

To increase the accuracy of the sensor which is optimized through a closed proximity of the current to a Hall effect transducer. In two sensors one current sensor is connected directly to the higher current side in the circuit which is of about 100A current to measure the current directly the other is connected parallely to the circuit with 1M resistor in series to measure the voltage. Where this circuit works as a voltage divider circuit.



The magnetic field generated by the current is sensed by the integrated Hall IC in the current sensor and converts it into a proportional voltage level. Even though there are lot of advantages in this sensors, but still there some disadvantages in them. Sensor reduces the resolution of the system current by the some small proportion as the sensed current is divided.

#### Opto coupler:

As we all know about the Transformers that they can be used to step up and step down the voltage levels, along with providing the electric isolation between the higher voltage level in primary side with lower voltage level on the secondary side of the transformer.

We can also define it as, transformers are used to isolate the primary input voltage from the secondary output voltage by using electromagnetic coupling. Which is achieved by using the magnetic flux circulating within the laminated iron core of the transformer.

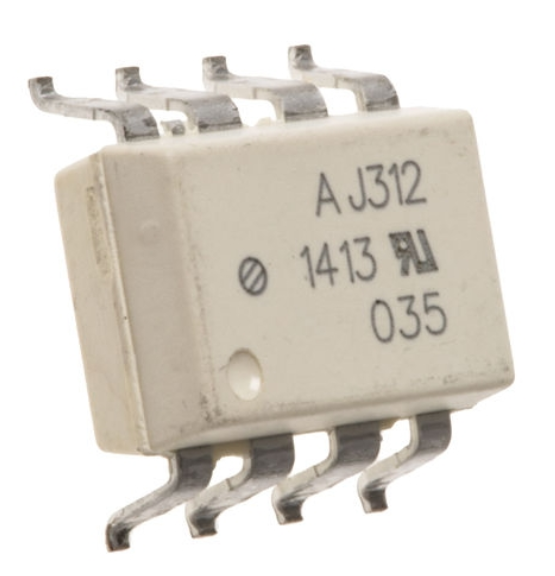


Figure 4.9: Opto coupler

The electrical isolation between the input side and the output side is provided by using just light or by using a electronic integrated component which is called as **Optocoupler**.

The design of the optocoupler is consists of an LED bulb that produces a light and a semiconductor on the other side is a photo-sensitive component which is used to detect the emitted light from LED bulb. Both the LED and photo-sensitive component are enclosed in a closed package with metal legs for the electrical connections as shown in above optocoupler image.

Optocoupler which is also called as opto-isolator is consists of a light emitter, the LED and the light sensitive receiver which is a single photo transister, photo resistor, photo diode, with this basic explaination of operation of an optocoupler is very easy to understand.

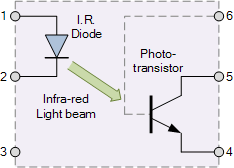


Figure 4.10: Working of opto coupler.

Assume a photo transistor device as shown in the above figure. Assume current from the supply passes through the input of LED bulb connected to terminal 1 and 2 as shown, which emits the light where intensity of the light is directly proportional to the input of an applied electrical signal.

The emitted light from the LED bulb falls on the photo sensitive plate of the photo transistor, making photo transister to switch it ON and conduct in a same way as a bipolar transistor.

The photo sensitive plate connection of the photo transistor device can be left unconnected for a more sensitivity to the LEDs light energy or can also be connected to ground using pulldown resistor to control the sensitivity of switching and making switching more stable and resistive for the false activaition from an a external electrical disturbances.

If the flow of current via LED bulb is disturbed/interrupted, which will cut’s off the emitted light. Leading the photo transister to stop conducting. To switch the ouput current in the circuit we are using a photo transister. The combination of bulb and the photo sensitive plate are isolated by a glass material or by a plastic material. As there are not direct electrical connection between the input and the output of the opto isolator, maximum up to 16kv isolation can be achieved by the optocoupler.

As explained previously we have four different types of **Optocouplers**. Every optocoupler will be having an LED at input side but will have different photo-sensitive materials in it.

The four optocouplers are:

1) *Photo-transistor*

2) *Photo-darlington*

3) *Photo-SCR*

4) *Photo-triac*.

In this project AJ312 optocoupler is used where functional diagram of this optocoupler and its truth table is as shown in below

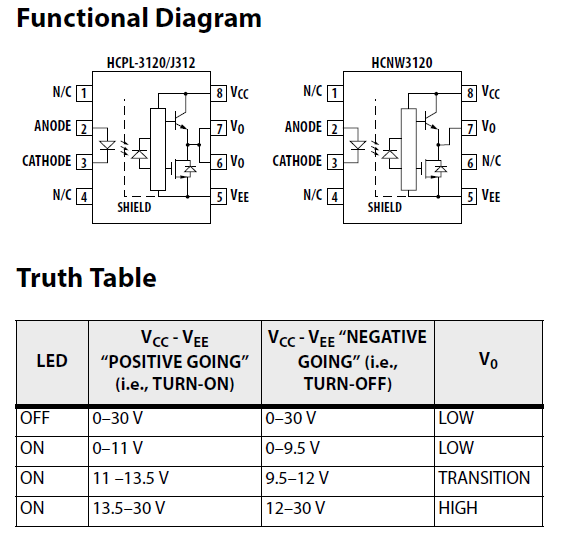


Table 4.2: Truth table of Optocoupler output voltage.

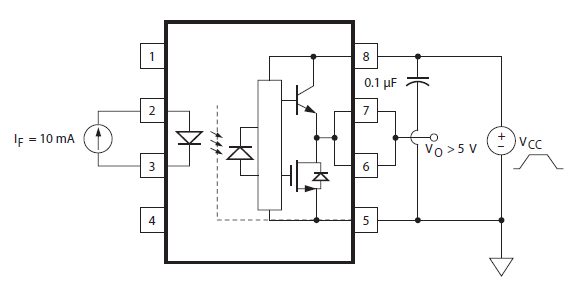
The testing circuit of the A J312 optocoupler specified by the component manufacturer or supplier.

Figure 4.11: Testing circuit for opto coupler.

### Arduino Board:

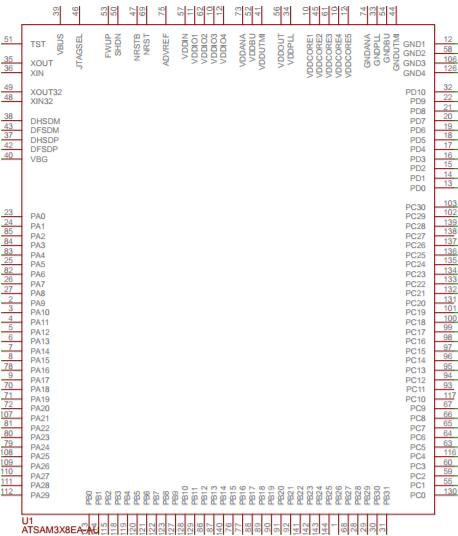


Figure 4.12: Arduino Due Pin Diagram

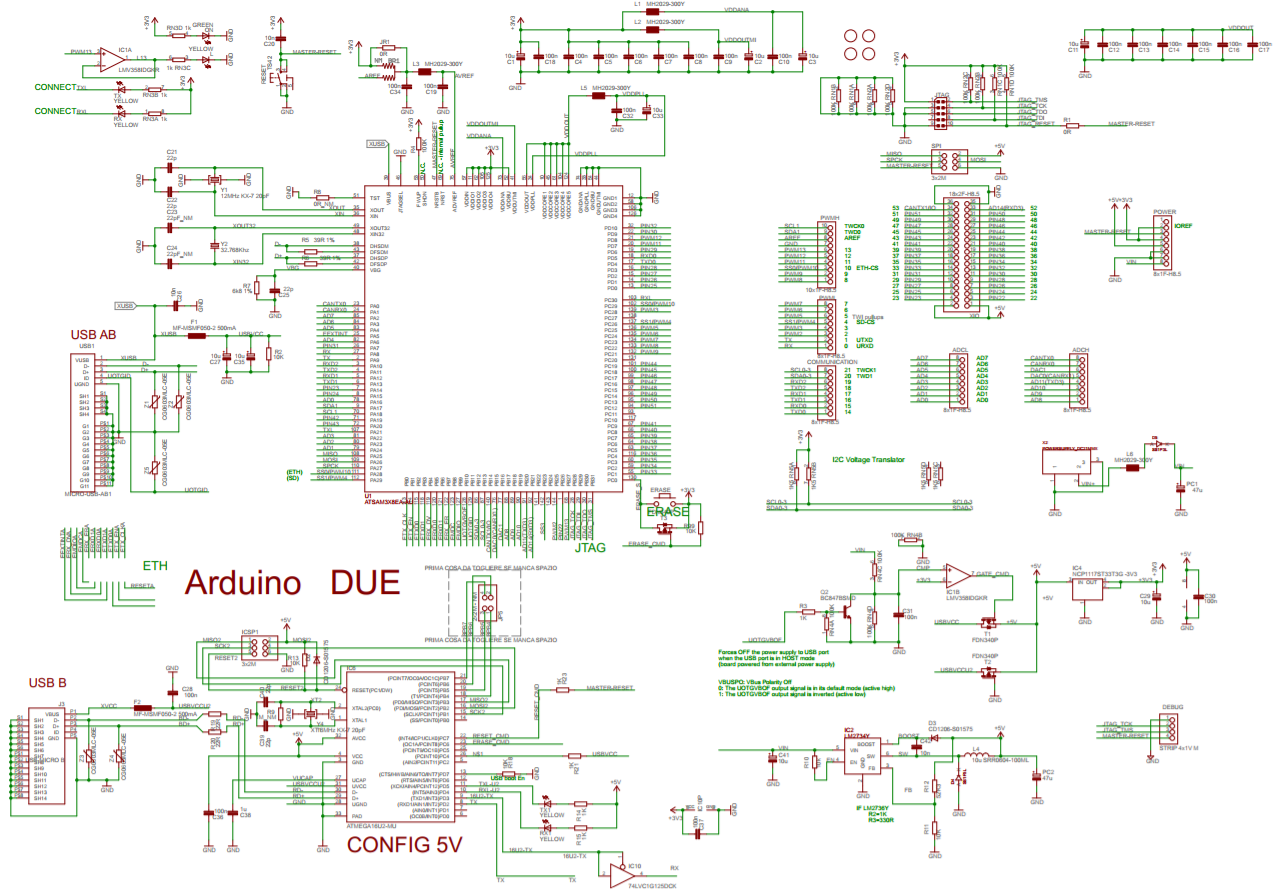


Figure 4.13: Arduino Due Schematic Diagram

Arduino due board is similar to other normal arduino boards we use for smaller operations. But we have a major difference in its operation and the expanded functionalities. The arduino Due is having the same footprint as the arduino Mega 2560.

In the arduino due the microcontroller mounted at the center of the board and it runs at 3.3Volts, which means in only 3.3 volts we have power the sensors and drivers to an a actuartors. As a other arduino boards if we try to connect more than 3.3volts may damage the controller or even burn the controller in arduino due.

The board is capable of taking the power from DC Adptors or also from USB connectors. If we are using the DC adaptors with the supply voltage upto 12V is OK. As Arduino Due is having built in voltage regulator to regulate the voltage level to 3.3volts from 12v which is required for microcontroller and also compatible with the micro USB. In the board power to the controller can also provided by USB cable. But when we use the board as a usb host, external power from the DC Adaptor is must required.

The Arduino Due board consists of two USB ports in it. USB is connected directly to the SAM3X micro controller unit. And the other USB is for programming. Which is connected to ATMEL 16U2 USB-to-Serial converter. The programming USB port is the default programming port for uploading and communicating to controller.

This USB to serial converter of the programming port is connected first to the UART. By using the Serial object in the arduino programming language, we can be able to communicate on this port.

The USB connector port is directly connected to the USB host pins of the controller. We can use arduino due as a client USB pheriperals to connect the keyboard, mouse and phones by using the native port or by using a USB host device. Serial USB object in arduino programming language can be used to use this USB port as a virtual serial port.

**Automatic Software Reset**

Because of the flash memory, flash memory needed to be erased everytime before the controller re-programing. so this Arduino due microcontroller is differing from other AVR microcontrollers. By holding the button provided to erase for a second, we can erase controller by manually, later need to press the reset button. Due to this manual erase of the flash is repetitive, arduino has managed automatically in two different ways:

**Native USB port** : Opening and closing of the Native port at the baud rate of 1200bps triggers the soft erase procedure, the flash memory is erased and the board is restarted with the bootloader. Due to some reason, if the microcontroller is crashed during this process, it is likely that the soft erase procedure not worked.

Opening and closing of the Native port at a baudrate other than 1200bps will not reset the controller. To see what your sketch does from the beginning and to use the serial monitor, we need to add some lines of code in the setup.

By pressing the Reset button on the Arduino Due will causes the controller to reset as well as resets the USB communication. This interruption means that if the serial monitor is open, it's necessary to close and reopen it to restart the communication.

**Programming port :** The Programming port in the arduino due uses a USB to serial chip connected to the first UART of the Microcontroller. The USB-to-serial chip has two pins connected to the Reset and Erase pins of the SAM3X. When we open this serial port, the USB to Serial will activates the Erase and Reset sequence before it begins to communicate with the UART of the SAM3X. This procedure is much more reliable and should work even if the main microcontroller unit has crashed.

**USB Host**

The Arduino Due has the ability to act as a USB host for peripherals connected to the SerialUSB port. When we are using the Arduino Due as a host, Due will be providing power to the attached device. It is strongly recommended to use the 12v DC power connector when acting as a host.

**ADC and PWM resolutions**

The Arduino Due has the ability to change its default analog read and analog write resolutions from 10-bits and 8-bits respectively. Due can support up to 12-bit ADC and PWM resolutions.

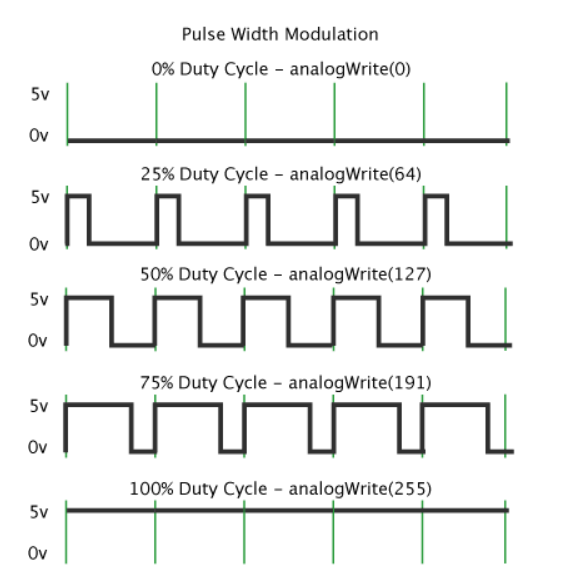


Figure 4.14: PWM resolutions.

**Expanded SPI functionality:**

The Arduino Due has a expanded functionality on its SPI bus, which is useful for communicating with multiple devices that can speak at different speeds.

### HW Functional Description

As shown in circuit diagram the circuit is powered with two different sources which is from BCM(Battery Control Module) module in vehicle, For demo purpose we have used two DC adapters to power the circuit. One is 12v 1A DC supply to control low power components. And the other with 24v 10A DC supply which is the main supply to the MOTOR. Potentiometer, Brake switch, Current sensor, Voltage sensor, Gear Switch and Temperature Sensor, are connected as input to the microcontroller. And at output side we have Cooling fans, Relays, Buzzer, PWM output to DC motor and PWM output to Cooling fans. The components with high power rating requirement are connected with drivers to controller to drive them.

DPDT relay connection in circuit is as shown below.

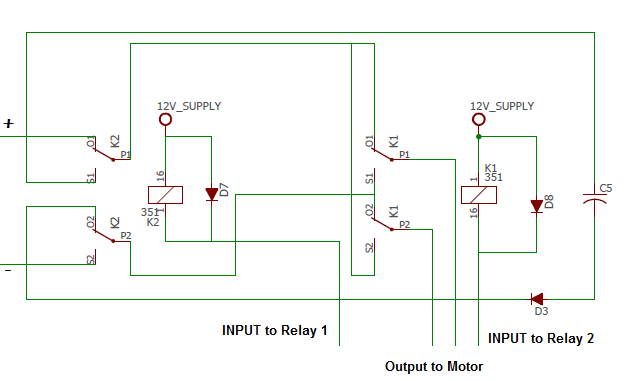


Figure 4.15: DPDT relay connection

For safety purpose, if the vehicle is moving with certain speed and by accidentally someone changes the gear switch position. As explained previously the change in direction of motor is also based on motor speed, the vehicle will continues to move in the same direction as its moving. In such accidental situation to inform the driver regarding the wrong attempt/wrong position of the switch a audible sound will be produced by the buzzer connected for ten seconds.

## SW DESIGN:

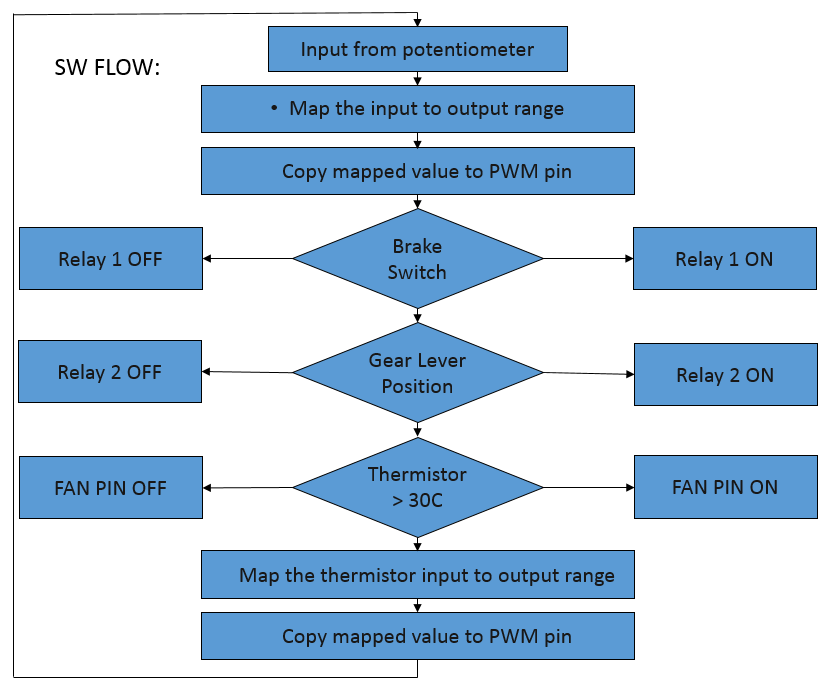


Figure 4.16: SW flowchart

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive the GNU tool chain also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

# RESULTS AND DISCUSSIONS

Pulse with fixed frequency is generated by the microcontroller, which is fed to the base of transistor. Transistor acts here as a switch. The output voltage of the motor is dependent on the amount of the on time of the transistor. The more time transistor remain on more the voltage will produce. A Freewheeling diode is used for back e.m.f. protection given to other portion. CONCLUSION AND FUTURE WORK

## CONCLUSION

PWM duty cycle control techniques enable greater efficiency of the DC motor. PWM switching control methods improve speed control and reduce the power losses in the system and the pulses reach the full supply voltage and will produce more torque in a motor by being able to overcome the internal motor resistances more easily. By using PWM technique power loss in the switching devices is very low.

## FUTURE WORK

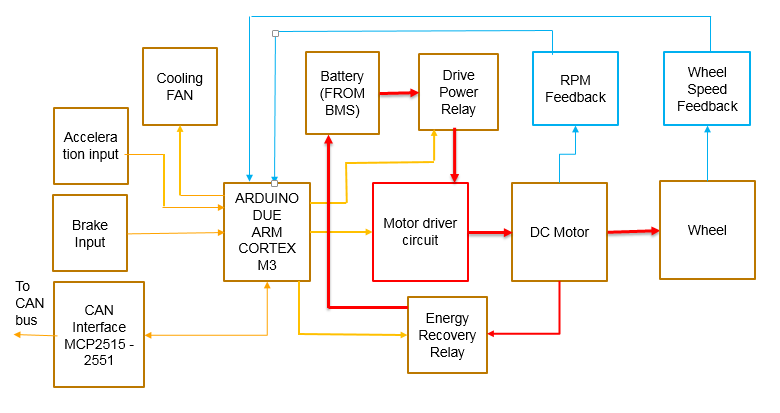


Figure 6.1: Expanded Block diagram DC Motor control

The speed of a D.C motor can be controlled using two types of loop configurations such as open loop speed control and closed loop speed control techniques. The open loop speed control characteristics has been verified using current implementation as discussed above.

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