March 15, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia, V5A 1S6

Re: ENSC 440 Design Specification for ATVs (All-terrain vehicles) Anti-rolling System

Dear Dr. Rawicz:

The attached document outlines design specification of our project for ENSC 350W/440W. The team of ARS (Anti-rolling System) Innovations is designing and implementing an automatic protection system for ATVs to prevent the roll-over of the vehicle.

In this document we will be outlining the information and specifications necessary for design process of the proof-of concept model. Our project manager and design engineers will use this document as a guide for research and development activities.

ARS Innovations is found by five talented and innovative senior students from engineering science in SFU: Yuchen Tong, Eric Wang, Yigang Tao, Colman Wen, Xupeng He. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (604) 369-3316 or by e-mail at shitongw@sfu.ca.

Sincerely,

Yuchen Tong
President and CEO
ARS Innovations

Enclosure: *Design Specification for ATVs (All-terrain vehicles) Anti-rolling System*

Version 1.0
Sunday, March 15, 2015

Design Specification for

ATVs (All-terrain vehicles) Anti-rolling System

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Submitted to: Dr. Andrew Rawicz
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Executive Summary

All-terrain vehicle (ATV) has been more and more popular nowadays. However, safety has been a major issue with ATVs due to the high number of deaths and injuries with them. For any off-road vehicle, rollover is the most seen accident and may cause serious accidents and injuries. The driver may feel the vehicle is tilted, but as the eye level is parallel to the ground, he or she cannot tell how steep the ground is and rollover may easily happen. At ARS, we feel that more proactive actions need to be taken to prevent danger from rollover for any off-road vehicle while keeping the fun and concentration of driving [1].

The objective of ARS is to design a system that can provide prevention and protection to the driver from rollover. The system will measure the angle of the vehicle. When a certain angle is reached, a buzzer and flash light will be triggered to alert the driver. This can allow the driver to react and drive more carefully to prevent the vehicle from rolling over. If the driver's reaction is not enough, when a steeper angle is reached, a protection bar will be ejected at the back of the seat. This can create a safe triangle around the driver to provide protection.

The development of this project will be done in three stages: two development stages to create the device, and a final production stage to make final adjustments. The stages are broken down as follows:

This following document will provide detailed design specifications outlined for our system. It is intended for use by designers, developers, testers for this product as guideline and updated when necessary. Due to page number requirement by ENSC440w/305w, we are focus on the most important design specifications.

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Glossary

ANSI	**American National Standards Institute**
ARS	**Anti-rolling System**
ATV	**All-terrain vehicles**
CCC	**Compulsory Product Certification**
CMOS	**Complementary Metal–oxide–semiconductor**
DC	**Direct Current**
GPIO	**General-purpose Input/output**
LCD	**Liquid-crystal Display**
LED	**Light-Emitting Diode**
I/O	**Input/Output**
MOSFET	**Metal–oxide–semiconductor Field-effect Transistor**
PC	**Personal Computer**
RAM	**Random-access Memory**
TTL	**Transistor–transistor Logic**
TUV	**Technischer Überwachungs-Verein**
UL/CUL	**Underwriters Laboratories/Underwriters' Laboratories of Canada**
USB	**Universal Serial Bus**

1 Introduction

The ATVs Anti-rolling System (ARS) is a system that can provide prevention and protection to the driver from rollover. Automatic Protection System for ATV consists of two level sensors. One connects to a buzzer and LED light to notify the driver to mind the angle. Another one acts as a trigger to a protection bar that can be ejected when the vehicle is about to roll over. Using this system, the driver no longer needs to worry about the slope of the ground and injury caused by rolling over of ATV can be greatly minimized. This document layouts design specification of the ARS.

1.1 Scope

This document specifies the design of the Anti-rolling System (ARS) and explains how the design meets the functional requirements as described in *Functional Specification for ATVs Anti-rolling System (ARS)* [2]. The design specification includes major requirements for a proof-of-concept system and a partial set of requirements for a production model.

1.2 Intended Audience

This functional specifications will be used and implemented by all members of ARS Innovations. The team leaders can use this document as a guide to measure the process throughout all development phase. Design engineers can refer this document to reflect on the requirements needed for ATVs Anti-rolling System and make sure all requirements are met in the final product. Test engineers should use this guide to verify the functionalities of the system.

2 System Overview

ATVs Automatic Protection System is a portable protective device, which can be installed easily as an add-on by the user on various types of ATVs on the market. The system helps drivers have a safer experience by monitoring the vehicle's level constantly which assists drivers adjust their speed and direction with notification. In addition, if the vehicle is about to roll over, the protection system will be triggered automatically.

The system consists of level sensors, microcontroller, protection bar, LED lights and buzzers. The level sensors are connected to the microcontroller, and provide a continuous level measurement. Based on the measurement, the microcontroller will determine which situation the user currently in and activate LED lights, buzzers, or protection bar accordingly.

Figure 1 shows an overview of the system:

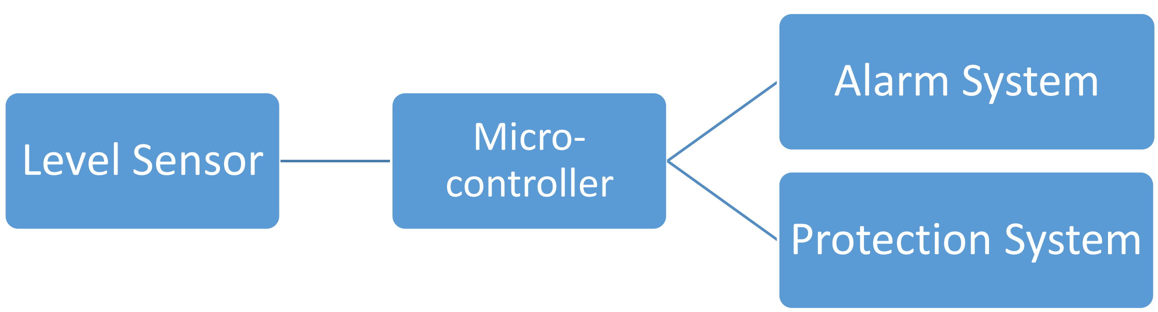


Figure 1: System Overview

3 Mechanic Design

3.1 Structural Overview

The anti-rolling bar is installed at the back of the vehicle which will eject and create a safe triangle space around the driver. The purpose of this compressible design is to prevent blocking by high level stumbling blocks and to meet North American road condition. Moreover, this design also helps the center gravity of the ATV remain low level. The system is triggered by the signal from the level sensor and release the electromagnet so that the spring will launch the bar to desired height. The system is powered by the 12V DC battery inside the vehicle. For safety reason, the power will be shut off 2 seconds later after the bar is launched and a manual reset is required. The schematic of the system is shown below in Figure 2.

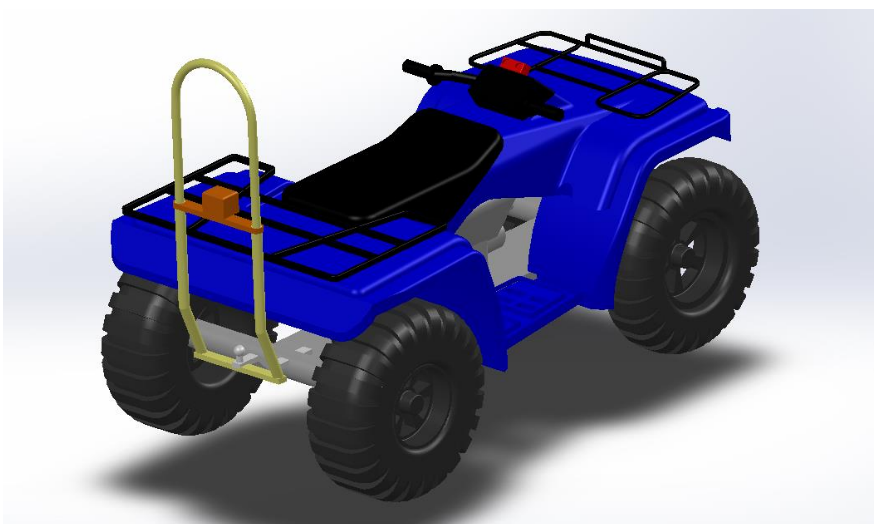


Figure 2: Simulation and matching check in Solidworks

3.2 Electromagnet Stopper

As shown in Figure 3, the power of the electromagnet that we select is 12V DC, 10 A under operating condition. The drag force can exceed 150N at full shock travel. To prevent circuit overload, the magnet is connected to a 15A fuse as well. We designed a U-shape hook with stopper to achieve hammer mode powered by full shock travel electromagnet. When the electromagnet is triggered by level sensor, the stopper will be released and launch the roll bar. After 2 seconds of launching, the power of the electromagnet will be shut off by micro-controller to prevent battery exhausted.

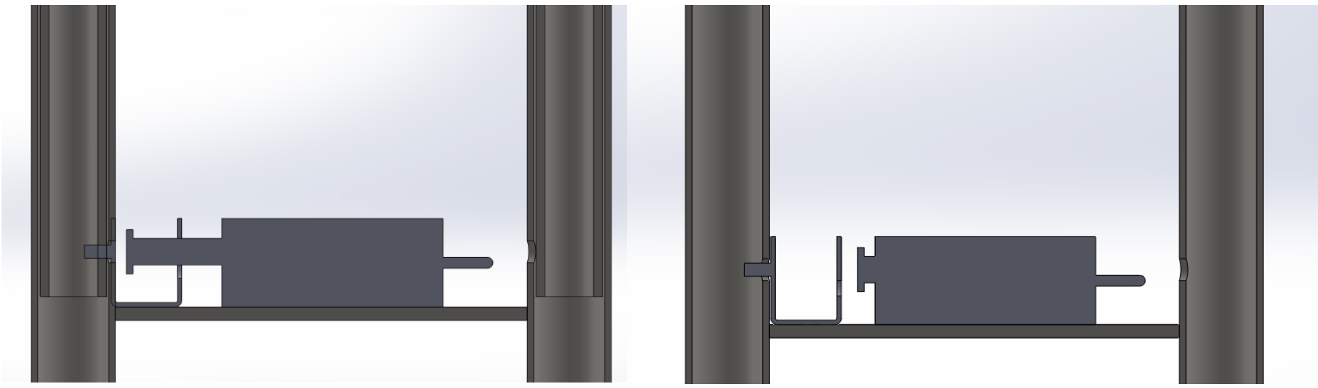


Figure 3: Diagrammatic Sketch of Stopper Release

3.3 Roll-bar

a) Material

The roll-bar is made of 304 stainless steel with 3mm wall thickness to handle huge shock load under extreme environment [3]. The reason we choose stainless steel rather than aluminum or steel is because stainless steel is the strongest among all of them. Although the price of stainless steel is higher, the strength is our first consideration for safety reason. Secondly, Stainless steel could provide the best anti-rust performance among these three since the application of ATV is truly outdoor. In future, the product can also be mass-produced in engineering plastics for lighter weight and better price performance. At the connection of each part, we selected M12, M16 grade 8.8 metric zinc plated bolt to provide durable and reliable structure. The single shear capacity of M12 bolt is 31.6kN while the 58.9kN for M16 [4].

From our simulation results by Solidworks the material and bolts that we selected are over qualify for this task.

b) Shape

As shown in Figure 4, our ARS roll bar is consist of three parts, the launch bar, body bar and mounting base. The launch bar is designed in cylindrical shape with no edge to prevent injury during accident. It is a U-shape metal rather than rectangle shape to provide better strength in one piece (Figure 5). The electromagnet stopper is placed on the bottom of body bar. At the end of the body bar, we use a straight stainless steel sheet to connect the outer bar to the supporting connection part on ATV. For the supporting connection part on ATV, we use triangular structure to enhance the strength of system. The mechanical device consists of 3 piece for easy packing and shipping.

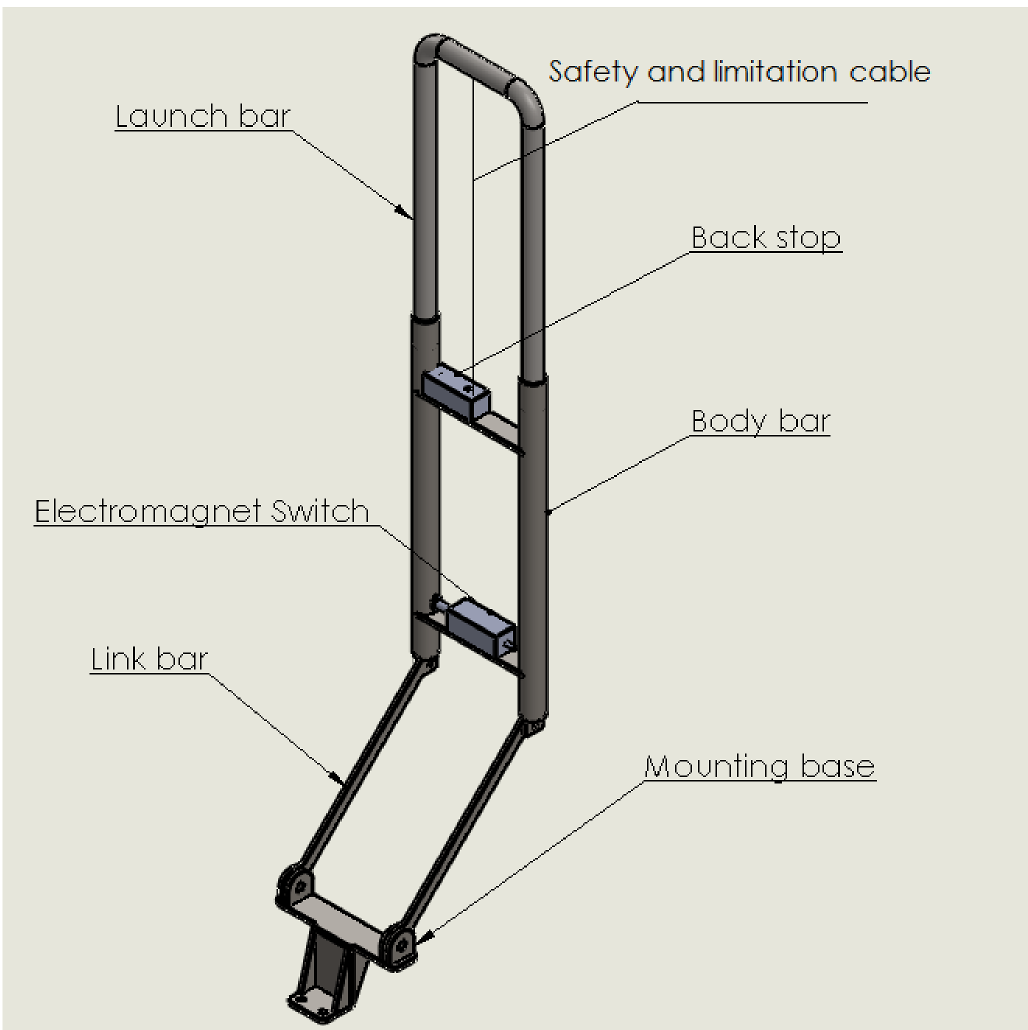


Figure 4: Assembly Overview

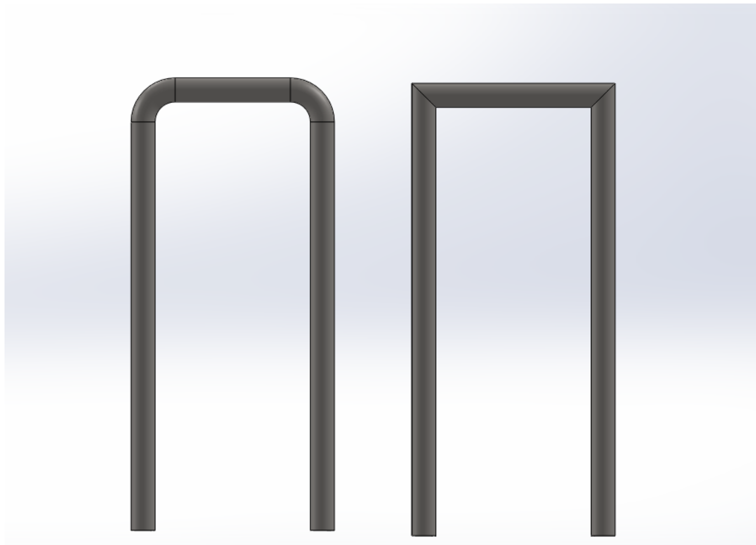


Figure 5: Comparison between two different styles

c) Safety Components

Safety first! As we are safety device designers, safety is always our first priority. Due to the high compression under normal operation in our system, to limit the unexpected motion is particularly important. We have three safety components assembled in our system. First, a back stop is mounted on the upper support plate of body bar to lock the launching bar at desired height. Moreover, there are two 1/8 inch diameter iron cable between launch bar and upper support plate. The longer one is called limitation cable. It could limits the launch bar travel within a safe distance. The shorter cable is called safety cable which lock the launch bar at compressed position no matter the stopper function or not. This is a very important feature because we do not want the bar launched out at transportation or loading/unloading.

4 Electrical Hardware Design

This section will present the detailed design of the micro-controller implementation and relay control circuitry. The purpose of micro-controller circuitry is to receive the analog signal from level sensor and then pass command signal to alarm or protection system. For safety consideration, relay control circuit is operated as a backup control system. Either relay control or micro-controller can trigger the protection system. The Figure 6 shows the internal connection for the system.

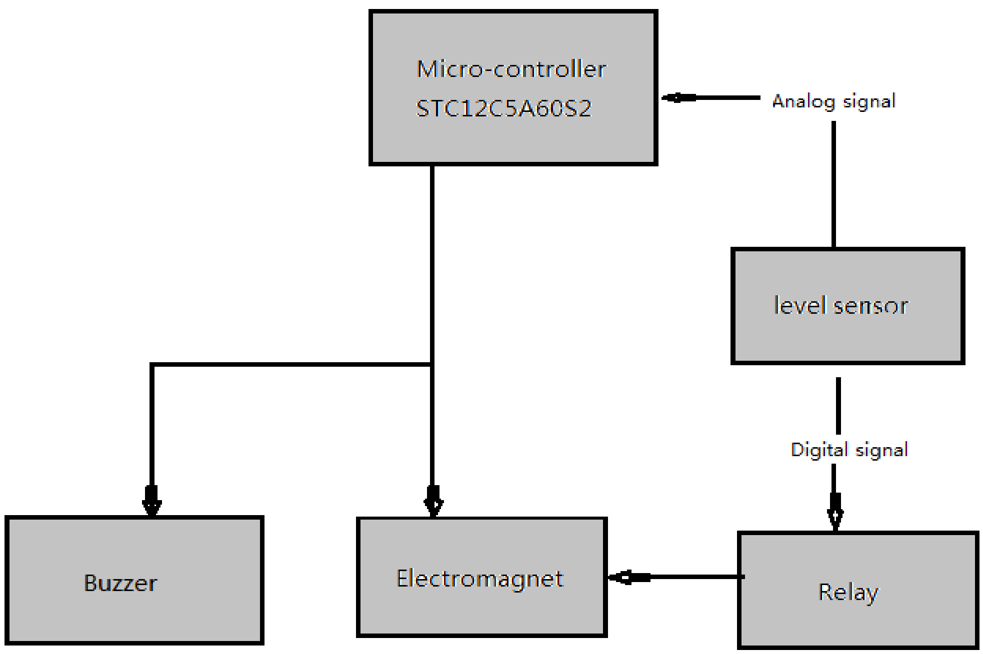


Figure 6: System Internal Connection

4.1 Micro-controller

The ARS choose a low-powered STC12C5A60S2 micro-controller in its design. This micro-controller provided an open-source software for programming which can easily connect with PC by USB. The controller also has I/O module for both digital and analog signal, which has the excellent association with the level sensor. In order to reduce the size and power consumption for our system, this controller has tiny size ($8cm^2$) and low operation voltage (5V).

The main features of STC12C5A60S2 are listed below

- operation: 3.5V-5.5V 20MHz-35MHz
- 256-Byte RAM
- 4K Flash memory
- 23 I/O ports

The picture and schematic of STC12C5A60S2 are listed below in Figure 7 and Figure 8.

Figure 7: STC12C5A60S2 micro-controller

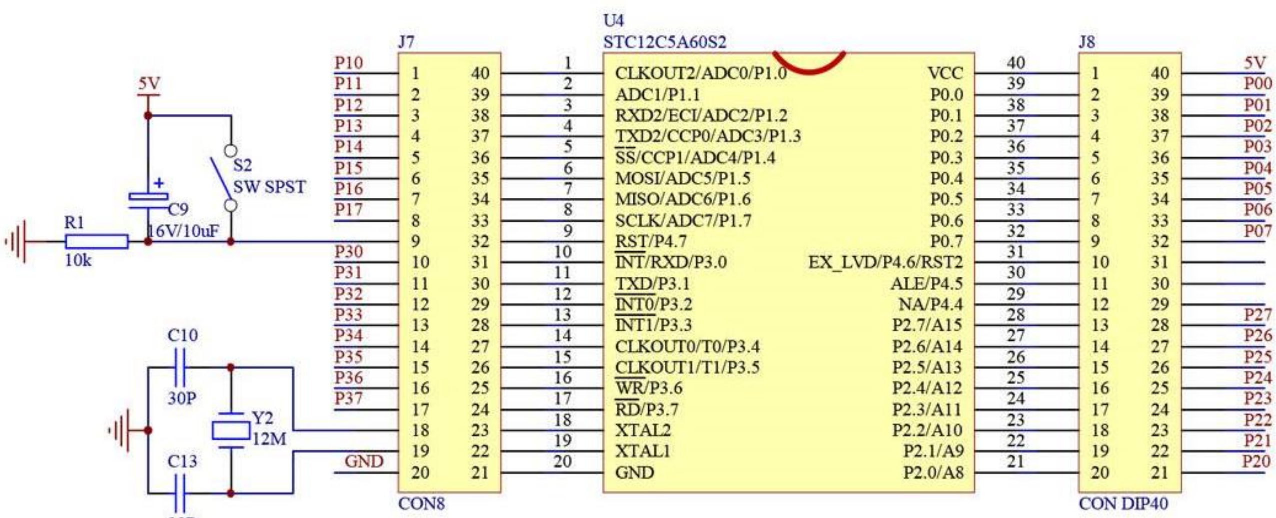


Figure 8: Schematic Diagram of STC12C5A60S2

4.2 Level Sensor

The level sensor we used in our design is DSCA60 level. The advantages of this sensor is that the sensor can generate both analog and digital signal. The analog will transfer the signal to micro-controller and the digital signal can operate the relay control circuit. Also, the sensor can operate by same as micro-controller. The appearance of level sensor is showing in Figure 9.

Figure 9: Level Sensor

The level sensor can detect level changing on both four directions of XY-plane. The following circuit is one of four detecting circuit integrated inside sensor.

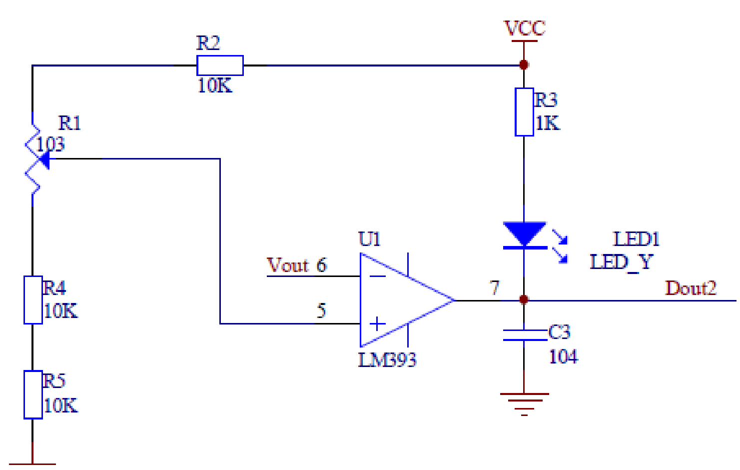


Figure 10: Comparison Circuit in Level Sensor

As the circuit shown above, the core component LM393 is called dual differential comparator. This device consists of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. The device is set to be differential mode in this circuit. The voltage output of port 6 in LM393 vary by the changing of port 5. The output voltage of Dout will depend on the comparison result of the port 5 and 6.

The main features of LM393 are listed below [5]

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage(3.3V-5.5V)
- Low Supply-Current Drain Independent of Supply Voltage: 0.4 mA (Typ) Per Comparator
- Low Input Bias Current: 25 nA
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: ±36 V
- Low Output Saturation Voltage
- Output Compatible With TTL, MOSFET, and CMOS

4.3 Relay control

As we know that the software may fall to operating due to flaw of programming. The protection system should have the backup plan for this kind of situation. The electrical control circuit is more reliable than software in complex environment. The component we used is 3-pin-5V electrical relay. The appearance of relay is showing in Figure 11.

Figure 11: 3-pin 5V Relay

The relay has following features: [6]

- Songle SRD-05VDC-SL-C Relay
- Relay UL/CUL Rating: 10A @ 125V AC, 28V DC
- Relay CCC/TUV Raiting: 10A @ 250V AC, 30V DC
- Control high-power devices up to 10A with a simple high/low signal
- Provides isolation between the microcontroller and the device being controlled
- Screw terminals for relay connections
- 3-pin servo-style header for power/signal interface
- Voltage requirements: 5V DC (Relay Power), 3.3V to 5V DC (Input Signal)
- Current requirements: ~85 mA (Relay Power)
- Operating temperature: -13 to +158 °F (-25 to +70 °C)

The goal of relay control circuit is to use low power control loop to control the high power load loop. This kind of circuit is called relay amplifier circuit which shown in Figure 12.

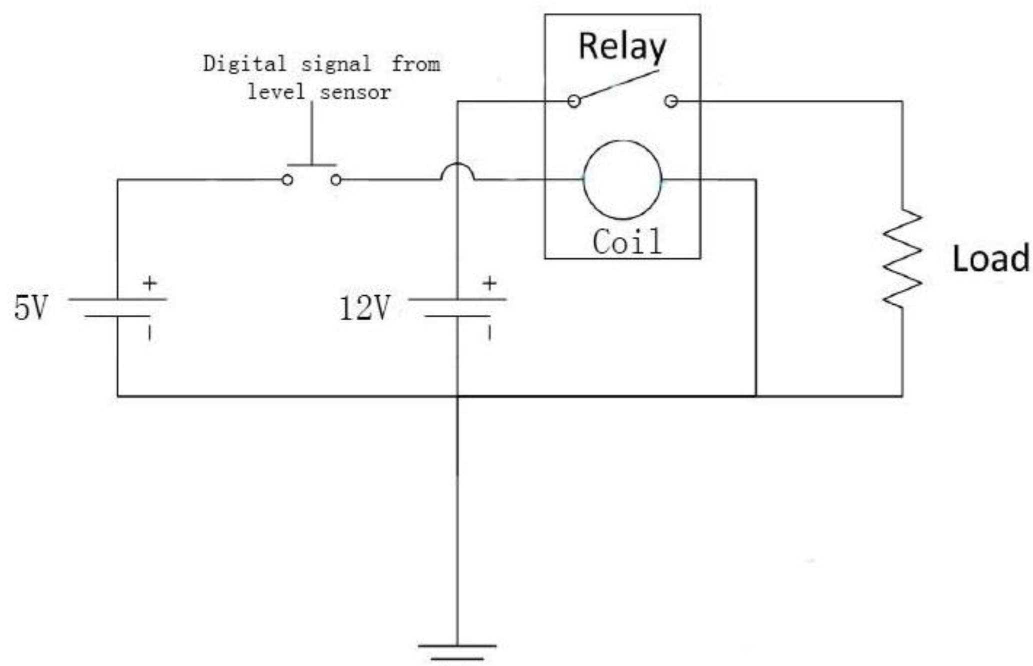
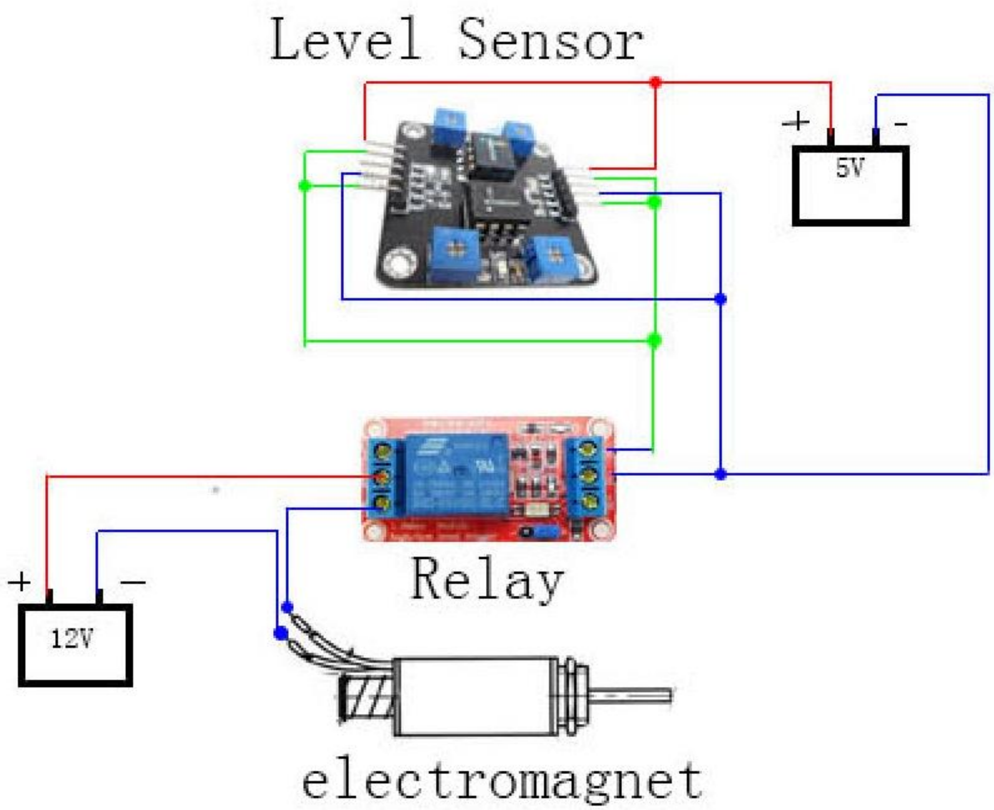


Figure 12: Relay Amplifier Circuit Diagram

After we finished both micro-controller and relay control circuit, we can now assemble our system as following:



Red wire :	Positive voltage
Blue wire:	Negative voltage
Green wire :	signal

Figure 13: Connection Diagram of Control System

5 Test plan

Each of the individual electrical components will initially be tested separately before integrated into control and feedback module. After that, the software control will be verified by measuring the voltage of GPIO pins. On the other hand, the hardware mechanical protection design will be tested in terms of safety and reliability. Finally, by interconnecting the electrical module and hardware module, the operation of the complete system will be tested and verified. The tests listed must be passed multiple times during different phases of the development cycle.

5.1 Electric level sensors

The electric level sensor will be tested to ensure that is functional to obtain level information, and the output voltages will change at certain level we desired for controlling the protection systems. Testing of the sensor includes, but is not limited to:

- Measuring the relationship between angle and voltage via analog output pins
- Measuring the voltage of digital signal output pins when it reach certain level
- Ensuring the sensors will be functional in different environments.
- Testing for the interference between sensors
- Measuring the output response delay of sensors

5.2 LEDs

The LED lights will be tested to ensure that the warning notifications signal from the programmed microcontroller could be displayed in time without any problems.

5.3 Buzzer

The buzzer will be tested to ensure that the helping signal from the programmed microcontroller could be read and trigger the alarm without any problems. Testing of the buzzer includes, but is not limited to:

- Measuring the volume of the buzzer sound
- Measuring the input voltage and current of the buzzer
- Ensuring the sound can reach long distance

5.4 Arduino UNO

The Arduino UNO microcontroller will be tested to ensure that it can receive and send signal base on our software program via GPIO pins. And be able in interconnect with different electric components without any problems. Testing of the microcontroller includes, but is not limited to:

- Measuring the accuracy of the signal transferred.
- Testing the accuracy of the angle calculation from the software.
- Measuring the time delay between signals send and receive.
- Testing the interference between different sensors, microcontroller as well as other electric components.
- Measuring the output voltage and current changes in different pins.
- Measuring the input voltage and current of the controller board.

5.5 Hardware Mechanical Protection Bar

The whole protection bar system will be tested to ensure that the electromagnet can be triggered by the controller signal and release the protection bar simultaneously. Also, the bar itself will be checked in terms of weight and hardness so that it can use for preventing the ATVs from rolling over without affecting driving experience. Testing of the whole protection bar system includes, but is not limited to:

- Calculating the energy stored in the springs before launching the bar
- Measuring the speed of the launching bar
- Measuring the maximum length of the bar
- Measuring the input voltage and current of the electromagnet
- Measuring the time delay between signals receive and launching the bar

- Testing the length lock of the bar when it stop at different length
- Ensuring all the possible human touching parts are insulated

5.6 Battery and Power Consumption Testing

Test and evaluate the power consumption of the whole anti rolling systems to ensure the system will not use out the car battery in short time. Testing of the Battery and power consumption includes, but is not limited to:

- Testing if the battery is supplying power to the system
- Ensuring all battery terminals are well insulated
- Measuring the power of the complete system

5.7 Unit Testing

By combining all individual parts, the final product will be tested in the real ATVs working environment for overall performance. Testing of the anti-rolling system includes, but is not limited to:

- Ease of installation
- Influences of driving experience
- Waterproof level of the electric components case
- The vibration-proof level of the electric components case
- The hardness of the electric components case
- The overall response time of the system when conducting dangerous condition
- The reliability of the hardware and software
- The compatibility of the design
- Ease of re-setting after launching

6 Conclusion

The proposed design solutions to meet the functional specification of the Anti-rolling System (ARS) have been discussed in this document. During the actual development, these design specifications will be adhered to as much as possible to meet the functional specification. Through the test plans included in the design specifications, we can ensure that all the required functionality of system is present. The design specification provides clear goals for the development of system prototype.

7 References

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