Post-Mortem for
J2VK Valvetronic Exhaust Control System

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1. Introduction

J2VK's Valvetronic Exhaust Control System is an exhaust system that allows for both manual and automatic control of noise levels coming out from the car. The exhaust system has the capability to monitor throttle input from the driver and then adjust a metal flap in the exhaust system to allow for more or less noise to escape from the car. The exhaust system will address the issue where after-market exhaust systems are permanently loud and obnoxious to everyone but the driver. The exhaust system takes into perspective both the driver and pedestrian views; drivers may turn the exhaust valves open during energetic driving in open roads and close the valves in urban areas. If opening or closing the valves seems cumbersome or the driver is easily forgetful, an automatic mode will also be offered that will automate closing and opening the valves depending on throttle input. J2VK's exhaust consists mainly of two systems. The first is the mechanical system which includes the exhaust pipe and metal control valve. The second system is the control system which consists of an Arduino Uno, Throttle-Position-Sensor and a DC motor drive. The following design specification document will thoroughly explore each component used in the systems.

2. System Overview

J2VK's Valvetronic Exhaust Control System has three operating modes. "Manually Opened", "Manually Closed" and "Automatic" modes. The first two modes are self-explanatory; the exhaust can be manually controlled by buttons that fully opens or closes the metal valve that is in the exhaust pipes. This will be achieved by having an Arduino microcontroller monitor button presses and then send out appropriate signals to a relay. The relay will then allow specific voltage flow to pass through it from the 12V car outlet to the DC motor. To open the control valve the DC motor requires positive voltage flow, and thus the relay will be signaled to allow positive voltage flow. In order to close the control valve, voltage needs to be reversed through the DC motor and so the Arduino board will signal the relay to output the reversed voltage. For the automatic mode, once it is turned on, the Arduino microcontroller board will begin to monitor the voltage signal coming out from the Throttle-Position-Sensor. Depending on the voltage signal that is received from the Throttle-Position-Sensor, as well as the consistency of the signal to reach a specific value in a specific time interval, the valve will open in varying degrees to exhale different decibels of

exhaust volume. This will be performed by having the Arduino control the length of time the relay supplies voltage to the DC motor. In order to do this, the Arduino will output a pulse of signal with an extremely small time interval so that the relay will also only operate for that small time interval, resulting in the DC motor being powered just enough to slightly open/close the valve but not enough to do so completely.

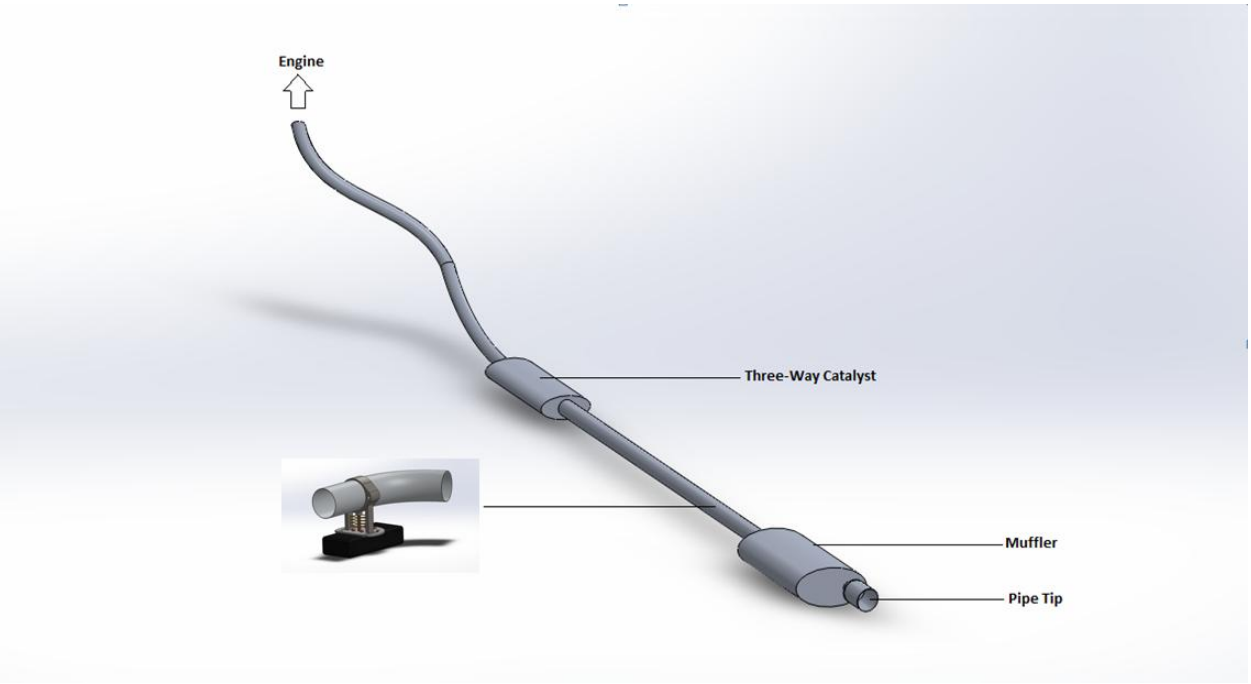

Figure 1: High-Level System Overview

3. Components & Costs

Since we have quite a lot design changes and unforeseen expenses, our project exceeded our expected cost of $915.00 as listed in the proposal document. The source of funding for the Cart-Follow-X1 project is through ESSEF and its sponsors, which they have provided $750.00 for this project. This funding will help cover the majority of the costs, while the remaining $230.07 will be split evenly among each team member.

Item	Estimated Cost	Actual Cost

Potentiometer plugs	6	5.65
Used Car	500	500
Car Stuff	60	35
Arduino+USB Cable+Jumper	50	45.37
Pedal	N/A	50
12V 5A Battery	N/A	33.41
Button+Relay+Diode	N/A	17.35
Wireless Transmitter & Receiver	N/A	28
Extra Breadboard + LEDs	N/A	5.05
Car Insurance	30	30
Gas	N/A	20
Remote Battery	N/A	6.71
Lock Smith (Unlock, and Keys)	N/A	45
Installation	100	200
Total	746	1073.54

Table 1: Estimated vs. Actual Costs

4. Proposed Schedule vs Actual Schedule

The comparison between our initial proposed schedule and our actual schedule is shown in Figure 1. The individual systems required more research than initially expected. The team performed extensive research to fully understand the principle behind Arduino and design our control system. This was the primary reason for falling behind the schedule. Delay in control system design further delayed the installation of the mechanical system since the installation of mechanical system design depends on the progress of control system. The team decided to build many components instead of purchasing components, due to high market price and power requirements. This added to the time and complexity of the project. These factors have contributed in delaying the project by approximately two weeks.

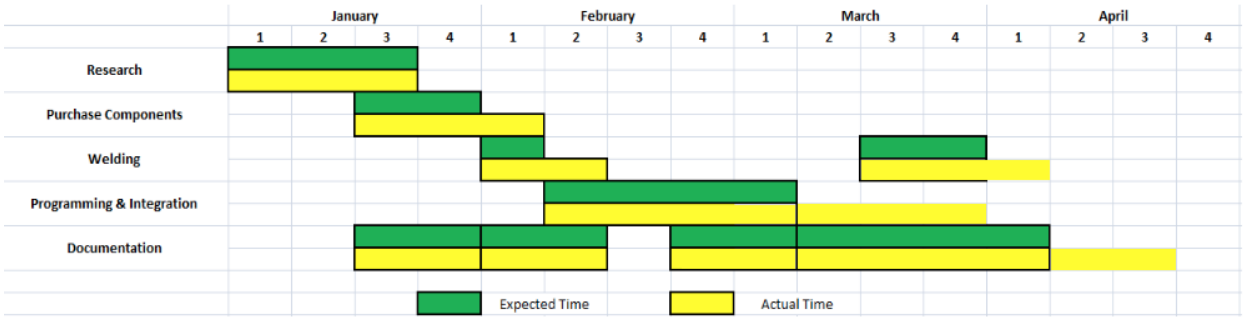

Table 2: Project Schedule

5. Challenges

The main challenges we faced with this project involved the control system of the smart valve.

Synchronization between Control system and Mechanical System

Synchronization between Arduino and the mechanical system (control valve) requires very precise detection of the driver's action. At the early stage we were unable to obtain correct distance readings from our sensors. After intensive research and investigation, we concluded that the problem came from the lack of synchronization on the trigger signals sent to the sensor. In order to obtain the correct strength of the signal, the signal must be more precise so the valve can adjust its position. To resolve this issue, we used the special transmitter and connected it to the paddle so it can detect the driver's action without and delay or distortion.

Design of the Smart Valve Exhaust

At the early stage we did not have any idea about how to design a exhaust pipe which can increase the sound without cause and safety issue or losing of horsepower. We went to the aftermarket auto parts store and did research on the existing product to give our prototype a design orientation. We studied on how the gas flows out from the engine and used Sold Works to draft our prototype. It was quite challenging to decide the position and degree of the pipe. And the installation of the pipe was more difficult than we imagine. The diameter stock exhaust pipe on the used car we bought was much smaller than the aluminum pipe we

bought. We designed an adaptor between our prototype and the stock exhaust pipe so that it can be installed.

6. Group Dynamics

J2VK consists of four senior engineering students who have worked very well together throughout the semester. We had two to three meetings every week throughout the semester, and our main method of communication was through Skype and mobile application.

In the design phase of the project, the team was separated into two groups. One group was responsible for designing the control system while the other group was responsible for the mechanical system. The groups were organized according to the strengths of each member, and since the control system required the longest time to complete, we had three members work on the control system, and two members on the mechanical.

Every member in the team has contributed towards the development of the project. The team worked very well together and meetings were held on a regular basis. There were no conflicts within the team because all possible issues were resolved during the frequent meetings.

7. Workload Distribution & Individual Learning

Table 2 shows the workload distribution of the Valvetronic Exhaust Control System project from each individual member.

Task	Justin	Kenny	Cheng	Vincent
Software - Arduino Programming			xxx	xxx
Software - TPS Sensor Control	x	x	xxx	xxx
Software - High Level Design	xx	x	xxx	xx
Software - Mode Switching & Valve Control	x	x	xxx	xxx
Control System - Parts Order			xxx	xxx
Control System - Wiring	x	x	xxx	xx
Mechanical – Prototype Design	xxx			
Mechanical – Parts Order	xxx	xxx		

Mechanical - Mounting	xxx	xxx	x	x
Mechanical - Wire Management	xx	xx	xx	xx
Integration & Soldering			xxx	xxx
System Testing	xxx	xxx	xxx	xxx
Documentation	xxx	xxx	xxx	xxx
Minutes/Administrative	xx	xx	xxx	xx

Table 3: Workload Distribution

Following this page are the individual learning experiences and personal reflections.

Cheng Jie (Jadan), Ou – CEO

As J2VK's CEO, I managed the project throughout the development cycle. I was responsible for assigning tasks to each individual team member and monitoring our entire development progress. I also played a leading role in designing and producing our control system and software. Throughout the development of J2VK's Valvetronic Exhaust Control System, numerous challenges were experienced and resolved. By working as a team, we were able to resolve those problems quickly, efficiently and sometimes reluctantly in order to complete our prototype on time. While designing the control system, I have learned a lot about the Arduino Uno development board and the Java programming language; Arduino software is based on Java. This learning experience will undoubtedly be of great help for future possible projects/hobbies using similar hardware and/or software.

Furthermore, I have also learned the proper way to produce engineering documentation while writing all the required specifications for this course. The rubrics were a great place to start and they often provided helpful information that showed me what is expected in professional engineering documents. Although all the previously stated technical skills were invaluable, I feel that the teamwork, management, and general soft skills were the highlight of my learning experience. Throughout these three months of development, my time management, teamwork and problem solving skills have greatly improved. I have also learned that in order to keep the project on schedule, aiming to finish each task earlier than expected is a huge asset. The extra days will act as cushioning time for solving unexpected problems and delays. J2VK often experienced problems during development, and those extra days earned by finishing tasks quickly allowed us to resolve remaining issues and keep the project on schedule. Finally, I have also learned that communication between team members is a vital aspect in project development. Our team was split into two groups in the very beginning, so it was important to keep all members up-to-date about the development progress and any significant changes. In doing so, this will ensure that our control system and mechanical system would work well together when it comes time for integration. Overall, developing J2VK's exhaust system has been an amazing experience. The skills I learned from this project will be invaluable experience for development of my career. All of us have worked very hard to complete this project, despite any friction or disagreements along the way. I am grateful to have worked with each and every member in our team and it would be an honour to work with this team again.

Justin Deng – CFO

By doing a capstone project, I have a deeper understanding of how engineer build things: trim down the impractical branches by trial and error, then leave in the main and the correct way to work. We have tried a few design ideas at the early stage, but later on they were not doable so we had to give up on them even though the idea may sound nice. One example is the wireless charging table, which can charge the entire device on the table and can be used as a regular dining table. However, due to the the expensive cost of the materials and lack of professional technical support in that area, we gave up on this cool idea and chose exhaust system in the end.

The most exciting learning experience is to design the exhaust system using Solid Works and implement it into a physical prototype. In order to reach precise position control we have chosen a DC motor as our motor choice. Then we started to learn the way of controlling the motor for the valve. This project also exposed my teamwork capabilities, whether good or bad. I'm glad I had Jadan, Vincent, and Kenny as my teammates. I think we worked well, and did our best to make sure we were always on the same page. However, it was hard for me to always stay focused on the task at hand because they are my friends. That's probably a reason why the Capstone instructors tell people not to form a group with friends.

The lesson I took out of this was to learn where to draw the line between co worker and friend. All our team members contribute the greatest effort on making the motor to function properly and precisely. In addition, I was new to the develop environment of Arduino before. This project gave me a chance to have a look at this open source platform. I got a lot of help on this friendly and generous community during the development of the first user interface of my life. I really enjoy working with our teammates, especially our CEO Jadan, who pushed us and encouraged us to move forward and worked the hardest. Also deepest thanks to our TAs and professors since they provide useful advice, guided us onto the right way, and showed us what a professional engineer should do.

Yujun (Kenny), Sun – COO

As a fourth year student majoring in electronics engineering and taking three courses beside ENSC 440/305, I believe this course was the most challenging one comparing with other courses. Through this project I have gained some incredible experiences not only technically, but also personally and emotionally. Our group was formed before the start of this semester. However, we had no idea what we were going to do in the beginning. After we had a better idea of the specialties and skills of each team member via the first Skype meeting, we proceeded to look for project ideas and conducted research regarding the ideas we came up with. I was surprised by the passion shown from the other teammates, thus I knew I would be able to learn a lot from them throughout the term.

In this project, I was responsible for designing and mounting the mechanical system. In the beginning, I had no idea how the control valve would be motorized, what materials we needed to buy, and where can we find those materials. Although we came up with the idea of the control valve by implementing some gears between pipes, the size of pipes and the control valve is different. We went to Canadian Tire and The Home Depot to browse every aisle to get inspired and to come up with some ideas to find a solution. Fortunately, we found a perfect solution for our project. The pipes and control valve are worked perfectly for our product. I also enhanced my knowledge in our mechanical design theoretically. Since I was responsible for the mechanical design of our project, I was required to do the SolidWorks and AutoCAD diagrams for our documents. From this work, I have improved my 2D and 3D drawing using both SolidWorks and AutoCAD extensively. I have had previous knowledge of SolidWorks from ENSC 489 but I have not used it after that. I felt all the SolidWorks knowledge come back to me after a few times of using it, and in the meanwhile, I learnt some new functions that I have never used before. Other than SolidWorks, I also had my first attempt on AutoCAD for the 2D technical drawings. This project has helped me gain a lot of technical drawing and prototyping skills. I also learned that teamwork is an important thing when working on a project. It was a pleasure working with my amazing teammates because I really learned a lot from them. I was not only impressed with their passion for the project, but also their positive attitudes and their senses of humour. Overall it is a great experience of handling of workload I had to deal with over the past four months.

Vincent Huang – CIO

By doing a capstone project in the past 4 months, I have a deeper understanding of how a product is built from an idea in a right way. In order to make it right, engineers have to trim down the impractical branches by trial and error. By experiencing all of this, we have leant to make progress by correcting mistakes. Initially, when we were discussing project ideas, we only considered about functionalities. By digging more and more to detail, I realized one functionality can be achieved by many ways and it was really hard to pick the best way at that moment. Even though if we pick the best way or better way at that moment, there is still another chance that the functionality can be messed up by adding another functionality. Therefore, forecasting problems is a very important factor to build a product in a right way, while trial and error is another factor.

I have learnt not only on technical skills, but also on interpersonal relationship management. As a CIO of J2VK, I have dealt with a lot of relationship issues in these four months. Every meeting can be challenging and time costing because people have different ideas and different way of thinking. It is really difficult to simply integrate everything together by just combine different ideas. It is really important to find a balance to make a decision between other people's ideas and my own ideas. Although we only have 4 people as a group, it is actually way harder than I thought to make a decision together. Every time when we needed to make a step further, we actually spent more time to make a decision than actually working on it. Through this whole process, I have deeply learnt that discussion patiently is the best way to solve this problem. The more you discuss your problems, the better result you can achieve. The sooner you discuss your issues, the sooner you will get it solved.

In addition, by working on this project, I have learnt to pay more attention on what costumers actually need and want from your product. Doing research ahead is really important to our success of our product in the market. You have to stand by your audience in the first place before rushing to decide what your product is, because no matter how good your product is, if you have mistakenly estimate the market need, you will lose your costumers.

Lastly, from this project, I have learnt to be more careful about how our product will affect the environment, as well as the legality. By experiencing all of this problems and mistakes, I have gained a deeper understanding of how to build a right product in a right way, as well as with a right group of teammates.

8. Conclusion & Future Work

The four members of J2VK was successful in carrying out our mission to design the Valvetronic Exhaust Control System to provide a balanced solution between the car guys and their neighbours. This course provided all of us a valuable learning experience, both technically and interpersonally. For our design, we were able to overcome the limitations of the TPS sensor reading driver's actions and synchronization issues to create a working prototype.

For future improvements on the control system, we hope to replace the synchronization wire with a wireless solution for better appearances. We also like to use better sensors to improve detecting performance.

For the mechanical system, we would like to enclose our valve system as well as improve its mounting and wiring to make the installation easier and safer. We also have a plan to improve our design so that the user can customize the sound of the exhaust system to fulfill their requirements.

Appendix

J2VK

Jan 7, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting: To greet team members, discuss project ideas

Minutes: 90 minutes

Items of Discussion:

A. Brainstorming for project ideas

Vincent: A remote control device for monitoring and feeding pets. This device can be connected with an application running on either iOS or Android. Features include monitoring with a camera, a control opener for dropping pet food. Users can use the application to monitor their pets, and manually control the device to drop foods to feed their pets as well as set regular time to drop foods automatically.

Jadan: Full table wireless charger. This device integrates wireless charging system in a table. User can put their phones anywhere in the table, and the system will detect the location of the phone and charge it.

Justin: Exhaust control valve. This is a control system that installs in vehicle exhaust in order to perform different sounds level either manually or automatically.

Kenny: Body motion charging watch. This is a watch that can be charged through motion when human body moves. This device allows kinematic energy transform to electric energy.

J2VK

Jan 13, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting: To finalize project topic, discuss funding presentation

Minutes: 120 minutes

Items of Discussion:

A. Finalize project topic: We got approved our project idea from professor and finalized our project topic to be exhaust control system.

B. Discuss functionalities of product: We discussed about different functionalities that should be included on our product, which includes manual control different levels of sounds as well as automatic control.

C. How to do related research: We discussed about in which way to do research on functionalities achievement and how to separate workload for everyone.

D. Discuss funding presentation

J2VK

Jan 20, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting: To discuss research results,

Minutes: 120 minutes

Items of Discussion:

A. We discussed about our research results from everyone and discussed which one is valuable and workable for our project.

B. We discussed about where to order parts and the cost of shipping

C. Determine the company name and Logo

D. First draft of project proposal need to be completed on January 25

J2VK

Jan 25, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Project tasks break down

Determine the role for each member in J2VK.

Project Proposal

Minutes: 120 minutes

Items of Discussion:

Role for each member

CEO: Cheng Ou
CIO: Vincent Huang
CFO: Kenny Sun
COO: Justin Deng

Project Research Tasks

Hardware: Justin Deng, Kenny Sun
Software: Vincent Huang, Cheng Ou

J2VK

Feb 04, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Functionality of the our product

Prototype design

Minutes: 120 minutes

Items of Discussion:

Determine the overall structure of our prototype

Define the material of the mechanical part

Starting sketching the prototype in Solid Works

Discuss the control system for the project

Figure out the rough cost of the prototype

J2VK

Feb 10, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Research materials discuss

Materials to purchase

Minutes: 100 minutes

Items of Discussion:

Problems from Hardware team

How to power the electric motor in the valve?

What materials are required for the system and where should we purchase them?

Circuit development of the system

Problems from Software team

Control interface function design

Functionality Report Due by Feb 15

J2VK

Feb 10, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Technical challenges

Minutes: 100 minutes

Items of Discussion:

How to make the exhaust system safe but give the car an aggressive sound?

To implement the design in Sold Works into a actual prototype.

How to detect the driver's action and what kind of sensor should we use?

How to connect the hardware and software part?

Which position should we install our product?

J2VK

Feb 17, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Plan for oral presentation

Review some modifications of production function and Finance

Initial framework for design specification

Minutes: 100 minutes

Items of Discussion:

Prepare the oral presentation materials

Discuss hardware progress

Sensors are purchased and starting to make the circuit

Finance

The total budget is discussed but not defined yet

J2VK

Feb 24, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

To update and discuss the design progress: software programming

To determine the new hardware components: TPS Sensor

Minutes: 100 minutes

Items of Discussion:

Determine the control board for the control system, Raspberry Pie or Adriuno?

Mechanical parts mostly delivered and started testing the parts

Software group share the progress with the mechanical group and exchange ideas

Connect the motor with 12V power source to test it

J2VK

March 01, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Plan the work for design specification

Feedback from hardware team about progress

Minutes: 100 minutes

Items of Discussion:

How to organize and write design specification?

Summarize the project progress and outline for the design specification

Still face many undermined design details, need to extend the submission day?

Any issues for hardware and wireless connection?

Need to start to build the communication by connecting TPS sensor and Arduino

J2VK

March 08, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Discuss the assemble of mechanical parts

Discuss the project car

Minutes: 100 minutes

Items of Discussion:

Finding a mechanical shop for installing our prototype

Contact sellers who sell very cheap used cars

Test the assembled mechanical system

Finding the problems of the mechanical system

Finding the problems of the software system

J2VK

March 16, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Buy the used car

Minutes: 100 minutes

Items of Discussion:

Bought a used car with $500

Test drive the car to see if it is capable for our project

Transfer the title of the car under a group member`s name

Store the car at Vincent`s home

Inspect the car for future product installation

J2VK

March 23, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Software system first implementation

Synchronization between mechanical system and software system

Minutes: 100 minutes

Items of Discussion:

How to synchronization the software part and mechanical part?

Test the motor with connecting to the control system

Adjust the mechanical system to synchronization with the software system

J2VK

April 01, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Installing the mechanical system onto our project car

Minutes: 100 minutes

Items of Discussion:

Move the car to a mechanical shop

Discuss with the mechanic to determine the position of our prototype

Installing the prototype and test it

Adjust the mechanical system so it can produce aggressive sound

Move the car back to the garage waiting for installing software system

J2VK

April 07, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Installing the software system onto our project car

Minutes: 150 minutes

Items of Discussion:

Connect the control system with programmed control box with the exhaust system

Try the automatic mode of our prototype

Switch between automatic and manual mode

Install the control system at a proper position in the vehicle

J2VK

April 14, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Road Test in the back lane

Minutes: 150 minutes

Items of Discussion:

Do a road test of our vehicle with both mechanical and control system installed

Listen to the sound of the car and do tweaks on the valve

Switching between auto and manual modes

Test the acceleration of the car at low RPM

Test the acceleration of the car at high RPM

Take a video of the demo of our car

J2VK

April 19, 2016
(12:00 PM –1:30 PM)
SFU Lab 4

Present: Vincent Huang, Kenny Sun, Jadan Ou, Justin Deng

Absent: None.

Purpose of Meeting:

Final Report and Post Mortem

Minutes: 400 minutes

Items of Discussion:

Work on the final report

Work on the post mortem

Make a box for our circuit