February 15, 2016

Dr. Andrew Rawicz
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RE: ENSC 440W Functional Specification for J2VK Valvetronic Exhaust Control System

Dear Dr. Rawicz,

The following document is the proposed functional specifications for J2VK's exhaust system. J2VK is aiming to bring to market an affordable and versatile exhaust system that will allow for thoughtful driving pleasure. J2VK's exhaust system hopes to solve the inversely proportional relationship of driving pleasure and pedestrian satisfaction.

In this report we will outline the functional requirements of the exhaust system. The requirements will act as a guideline for our team to follow in order to bring a safe, reliable and effective exhaust system into fruition.

J2VK is comprised of a team of senior electronics and systems engineering students with a versatile background in their respective majors. The four members of the team are Justin Deng, Vincent Huang, Kenny Sun, and Cheng Ou. If you have any questions or comments related to the following functional specification please feel free to contact me at jou@sfu.ca.

Best Always,

Jadan Ou

Cheng Ou
Chief Executive Officer
J2VK

Enclosure: Functional Specification for J2VK Valvetronic Exhaust Control System

Functional Specifications for

J2VK Valvetronic Exhaust Control System

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Executive Summary

Driving is a part of everyday life. Some enjoy it, others don't. Some like to drive in style, often acquiring the newest model of cars, while others are happily content with their "oldmobile". Often times though, there are those who aren't satisfied with their vehicles no matter if the vehicle is new or old. When this dissatisfaction is allowed to continue to brew, these owners often seek aftermarket solutions that can quench their desires.

A quick search on any internet search engine provides many choices for modifying a car. In fact, the practice is so common and results are so competitive that companies often only specialize in perfecting one component of a car to sell. There are aftermarket wheels, exhausts, body panels, interiors, etc. Basically, any part of a car can be modified to the point where there are limitless combinations of changes that can be performed on it.

J2VK strives to bring to this crowded and competitive market a dynamic exhaust system that is both fulfilling to use as well as satisfying to hear (or not hear, depending on perspectives). The exhaust system will allow the driver of the vehicle to control the noise output of the exhaust by opening or closing metal flaps within the tunnel of the exhaust. To achieve such a system our development stages will be separated as follows:

<u>Development stage 1:</u>

- Research and construction of aluminum pipe(s)
- Installation of hydraulic flap(s) to control airflow within pipe(s)
- Manual testing of hydraulic flap(s)

<u>Development stage 2:</u>

- Form microcontroller connection to hydraulic flap(s)
- Software implementation to control hydraulic flap(s)

<u>Development stage 3:</u>

- Installation onto a mobile vehicle
- Stress, reliability and safety tests

For the following functional specification document the team at J2VK will highlight guidelines that must be adhered to for the development of the exhaust system. The expected completion date for the valvetronic exhaust system prototype is April 1, 2016.

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Glossary

V	Volts
kg	Kilograms
cm	Centimetres
rpm	Rotations per minute
ms	Milliseconds

1 Introduction

J2VK's valvetronic exhaust control system is a dynamic exhaust system that allows for modification of exhaust noise. With buttons to control the opening and closing of metal flaps within the exhaust pipes, the system allows for quiet cruising or loud acceleration. The exhaust system also has an automatic mode that detects airflow within the exhaust and opens/closes the metal flaps accordingly. With strong throttle input the metal flaps will open to allow for louder noise; while cruising throttle input will be low and thus the metal flaps will closed for quiet comfort. Our product will be designed for a majority of the cars on the market so then people from all walks of life may have the option to improve their driving experience.

1.1 Scope

The following document will describe the functional requirements for the J2VK exhaust system. The project will be designed and built based on such requirements.

1.2 Intended Audience

This document is intended for use by all members of the J2VK team. The functional requirements listed are meant to be used for the entirety of the project, from design to completion. This will ensure that the final product will meet all necessary requirements.

1.3 Classification

The following convention will be used for categorizing and ranking the functional requirements:

[Rn-p]

where R is an abbreviation for requirement, n is the functional requirement number and p is the priority of that functional requirement.

The priorities are ranked as follows:

i. Proof-of-Concept: requirements for proof-of-concept system
ii. Prototype: requirements for prototype build
iii. Production: requirements for final production version

2 System Overview

J2VK's Valvetronic Exhaust Control System is designed to satisfy both the car guys and their neighbours. Through the use of the Throttle-Position-Sensor, a sporty exhaust sound can be turned on/off either automatically or manually. The system is constituted by three components: the mechanical structure, the control system and the software. Figure 1 shows the high-level overall layout of the valvetronic system. The mechanical structure is mounted before the stock muffler where the exhaust pipe can obtain the undismissed sound from the engine. The smart valve is located in the branch of the mechanical structure, and the electronic control system is

nested within the vehicle to control the open degrees of the valve. As stated previously, the Throttle-Position-Sensor is what we will use to detect whether the user wants to open or close the valve. If the driver rapidly and deeply pushes the throttle pedal, the TPS sensor will transmit information of the amount of gasoline injected into the engine to the control box. The software reads the information to determine how much the valve will open and sends this information to the mechanical structure to be turned into physical actions.

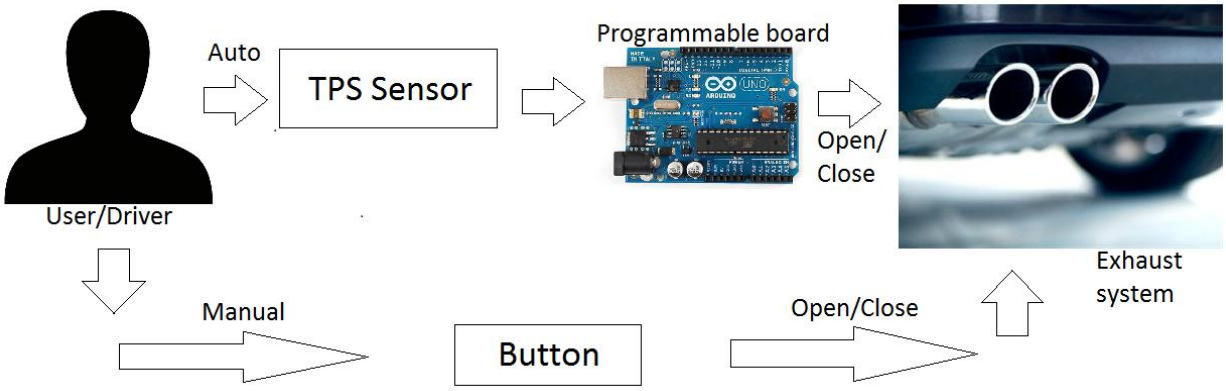

Figure 1. High Level Layout of the System

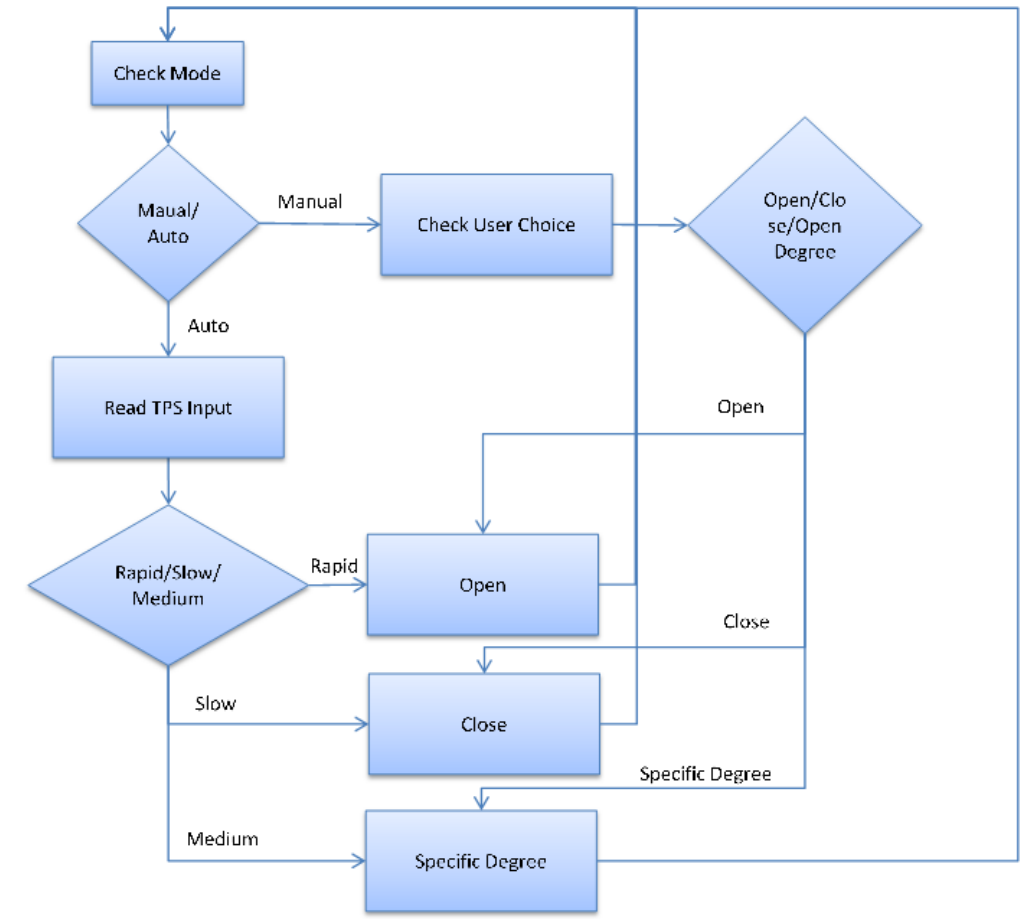

Figure 2. System Work State Flow Chart

2.1 General Requirements

[R1-ii] J2VK's Valvetronic Exhaust Control System should be powered using a car adapter.

[R2-iii] J2VK's Valvetronic Exhaust Control System is designed to operate on all kinds of cars as long as the exhaust system is OEM.

[R3-iii] J2VK's Valvetronic Exhaust Control System is designed to operate on all terrains and under all weather conditions.

[R4-iii] The final product of J2VK's Valvetronic Exhaust Control System should be under CAD $1000, including installation.

[R5-ii] J2VK's Valvetronic Exhaust Control System can be used both in automatic and manual modes.

[R6-i] Customized sound preference can be purchased separately.

2.2 User Interface Requirements

[R7-ii] A remote controller will be available to control the valve.

[R8-ii] A mode selection will be available to determine the operation mode of J2VK's Valvetronic Exhaust Control System.

[R9-i] The Throttle-Position-Sensor will be used as a valve control system for the automatic mode.

2.3 Electrical Requirements

[R10-ii] J2VK's Valvetronic Exhaust Control System can be operated either by using the car adapter or a 12V power supply.

[R11-iii] The battery of the remote controller can be replaceable.

2.4 Reliability & Durability Requirements

[R12-iii] The pipes of J2VK's Valvetronic Exhaust Control System will be able to endure high temperatures (can reach up to 900 degrees Fahrenheit) [7].

[R13-iii] The RF radio frequency receiver box of J2VK's Valvetronic Exhaust Control System will be chemical, corrosion and rust proof.

[R14-iii] The system has a lifetime warranty on the aluminium pipes and 10 years warranty on the electronic components.

2.5 Standards

[R15-iii] J2VK's Valvetronic Exhaust Control System should conform to ISO/TC 44 for welding and aligning processes [1].

[R16-iii] The pipes on J2VK's Valvetronic Exhaust Control System should conform to ISO/TC 156 for corrosion of metals and alloys [2].

[R17-iii] The valve on J2VK's Valvetronic Exhaust Control System should conform to ISO/TC 153 for valves [3].

[R18-iii] The electronic components should conform to CAN/CSA-C22.2 NO.60335-1.11 for safety of electrical appliances for household and similar purposes [4].

[R19-iii] The electronic components should conform to ISO/TC 22/SC 3 for Electrical and electronic equipments [5].

[R20-iii] The system should conform to CSA Z463 standards for maintenance of electrical systems [6].

3 Mechanical System

The mechanical system of J2VK's Valvetronic Exhaust Control System consists of an idle air control valve, a key fob with four RF remote control buttons, two pipes, and one 12V portable vehicle adaptor. The user can set the mode in either manual or automatic through the RF remote controller. After which the controller will supply an output to control the valve. The following figure is a conceptual design of the prototype for our exhaust system.

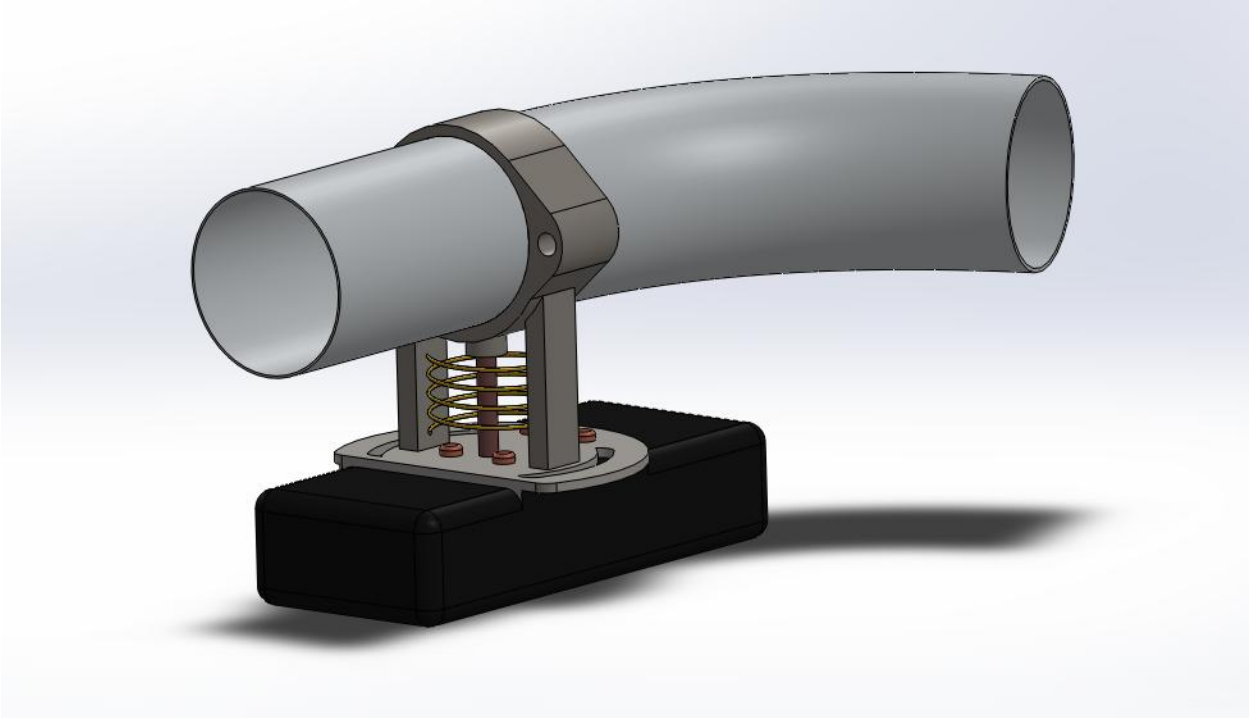

Figure 3. SolidWorks Model of Our Product

3.1 General Requirements

[R21-ii] A drivable car with OEM exhaust system.

3.2 Physical Requirements

[R22-ii] The whole mechanical exhaust system should not exceed 5kg in weight.
[R23-ii] The RF remote controller should not exceed 5x5x5 (cm) in dimensions.
[R24-ii] The idle air control valve should not exceed 10x10x20 (cm) in dimensions.
[R25-ii] The height of the idle air control valve should not touch the ground.
[R26-ii] The exhaust pipe should not exceed 5 cm in diameter.

3.3 Electrical Requirements

[R27-ii] The electric motor should operate at 12 V.

3.4 Performance Requirements

[R28-iii] In closed mode, the system helps the induction of car exhaust backpressure and increases torque at low rpm.
[R29-iii] In opened mode, the free flowing exhaust can deliver a more aggressive sound as well as increases of horsepower at high rpm.
[R30-iii] In auto mode, the system will enable automatic opening and closing of the valve based on the driver's driving habits.

3.5 Environmental Requirements

[R31-iii] The system should operate normally under regular vibration caused by the car or various terrains.

[R32-iii] The system should operate under shock and vibrations from travelling on different terrains.

[R33-iii] The system should operate normally in an environmental temperature range of -45 degrees Celsius to +45 degrees Celsius.

[R34-iii] The system should be able to operate under rain and snow conditions.

Figure 4. Vehicle to Install Our System

4 Control System

The control system of J2VK's Valvetronic Exhaust Control System consists of a throttle position sensor, a programmable board and a control valve connected with a motor that can be controlled by 4 remote buttons or the programmable board. For automatic control, the throttle position sensor measures how far the gas pedal is pushed down to determine how much the control valve opens. The programmable board receives a voltage signal from the throttle position sensor and then sends a more appropriate voltage signal to the motor, the motor then

opens/closes the control valve accordingly. For manual control, the motor rotates the control valve after receiving a signal from pressing a button. Two of those buttons are applied in this control system for rotating the valve in clockwise and anticlockwise directions to the maximum degrees that can be reached. Another two are used to rotate the valve in clockwise and anticlockwise directions only to certain degrees depending on how long the buttons are pressed. The purpose of this is to control the sound by controlling how much the valve is open.

4.1 General Requirements

[R35-i] The throttle position sensor should detect the position of the gas pedal.
[R36-i] The control system should be programmable by a programmable board.
[R37-ii] The maximum angle that the valve can rotate should be 90 degrees.
[R38-i] The valve connected to the motor should be controlled by the programmable board and all buttons.

4.2 Physical Requirements

[R39-ii] The valve should be placed in the exhaust pipe before the muffler.
[R40-ii] The throttle sensor should be connected to the programmable board.
[R40-ii] The programmable board should be placed inside the car.
[R40-ii] The remote button should be easily reachable by the user.

4.3 Electrical Requirements

[R40-ii] The control system should use the car adapter plug inside the car as its power source.
[R41-ii] The remote controller should use batteries as its power source.

4.4 Performance Requirements

[R42-i] The control system should perform different functions by pressing different buttons respectively.
[R43-i] The remote button should be able to send a signal to rotate the valve at a maximum distance of 3 metres.
[R44-i] The programmable board should be programmed to detect the signal from the throttle position sensor and send a corresponding output signal to the motor.
[R45-i] The control system should have a response time of less than 100ms.

5 Sustainability & Safety

5.1 Sustainability

J2VK's Valvetronic Exhaust Control System is designed with sustainability in mind from the outset. Protecting the environment is everybody's responsibility, and so each component used in the making of the exhaust system was considered for its reusability and environmental impact.

The exhaust system consists mainly of two components: the exhaust and the programmable board. Below we will list the components used in the making of the exhaust system and then briefly discuss their environmental impact and methods for reusability.

Exhaust System

The exhaust is made from aluminium pipes; aluminium is extremely easy to recycle, requiring only re-melting the metal. Aluminium will not lose quality no matter how many times it's recycled, resulting in it being the best choice of metal for the exhaust system [8].

Control Valve

The metal flap that allow/block airflow through the aluminium pipes will be made of steel. Steel is the most recycled material on Earth and thus its reusability is irrefutable [9]. The metal flap will be controlled by a DC motor that will be able to rotate it into it's open/closed position. The DC motor can be reused for other purposes and thus can remain outside of landfills or recycling facilities.

Wires

The wires are made from plastic and copper and so can be reused by smelting [10].

Power Supply

Since the power supply is a small electronic component it can be recycled at a nearby electronics retailer where it will be sent to an appropriate e-waste disposal facility [11].

Programmable Circuit Board

Electronic components such as circuit boards will be sent to an appropriate e-waste recycling facility where the metals inside will be extracted and reused [12].

5.2 Safety

J2VK's exhaust system does not require extensive modification of a vehicle's internals, thus it is safe to install and use. Modification of an existing OEM exhaust pipe will only change the exhaust airflow and will not harm the vehicle or its occupants in any way.

The components used to make the exhaust system are all reusable/recyclable as described above and thus the environmental footprint of J2VK's exhaust system is also small.

6 Conclusion

J2VK's Valvetronic Exhaust Control System is currently under the early stage of development. We are trying to create a sporty exhaust system that is affordable for everyone and the sound can be adjusted to satisfy both car guys and their neighbors. In this functional specification document, we included all the functional requirements of our prototype and the functions we will be designing for the future marketable product. The functional specifications are divided into three major categories:

- General Requirements: designed to be a smart exhaust system which can adjust its sound automatically or manually, as well as being affordable.
- Mechanical System: designed to have a universal structure which can fit on most of the production cars in the market and be easy to install.
- Control System: designed to read and understand the driver's throttle action to adjust the valve automatically.

All the basic features will be developed by the end of March and calibration will be done in Early April.

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