

Development of Personalized Engine Sound System using Active Sound Design Technology

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ABSTRACT

An important trend among vehicle NVH engineers is the production of attractive engine acceleration sound quality for the enhancement of a vehicle's image and performance. In addition, customers have increasing interest and enjoyment in customizing their cars to reflect their personal taste and preferences.

The PESS (Personalized Engine Sound System) has been developed for making a unique and individually customizable vehicle concept. The system allows the customers an opportunity to create a variety of engine sounds in a single vehicle using active sound design technology.

In this system, three different engine sound concepts are pre-defined, Dynamic, Sporty, and Extreme. Each of the engine sounds can then be adjusted with parameters that determine the timbre, such as main order, rumble, and high order. In addition, the pedal position during acceleration has also been used as a parameter to further personalize the experience. An application in the Audio-Video Navigation system (AVN) has been implemented that allows users to easily customize these functions.

It is expected that the system will provide a new auditory experience as well as an enhancement to the marketability of a vehicle.

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INTRODUCTION

Recently, various technologies are employed for vehicle engine sound implementation including active control systems, which go beyond conventional methods that involve intake and exhaust systems and hardware. Generally, engine sound experienced within the cabin, can be implemented with a vehicle audio system or an electric actuator (ESG: Electric Sound Generator). In particular, ASD (Active Sound Design) that uses the vehicle audio system enables users to create and experience various sounds, not limited by physical properties of the engine and vehicle body, delivering a variety of engine sound options to the driver. Especially for vehicles sold to diverse regions in the world, differentiated engine sound can be applied to suit the preferences of each region.

This research has led to the development of a new engine sound design system that can reflect customer characteristics of each region, so as to provide an exciting driving experience for each specific customer. For customers in North America, ASD has been applied to provide a consistent, sporty engine sound enhancement suitable for

the vehicle concept. For Korean domestic market customers, a system with enhanced personalization has been developed to allow those who have strong preferences to select and adjust the engine sound to their own taste. The aforementioned PESS (Personalized Engine Sound System) offers a customizable driving experience, increasing the 'fun to drive' factor, and providing customers with the chance to express their individuality through the engine sound of their choice.

ENGINE SOUND DESIGN USING ASD

As shown in [Figure 1](#), ASD (Active Sound Design) technology aims to reach a target sound through the use of interior audio speakers or an excitation system, based on the vehicle driving information sent to the controller. In a broad sense, the technology provides both the ability to remove sound through anti-phase (cancellation), as well as the ability to add sound elements based on the vehicle's dynamic input parameters. This paper, however, deals only with the sound enhancement aspect, and in this regard, will describe how it is applied to the ASD and PESS technologies.

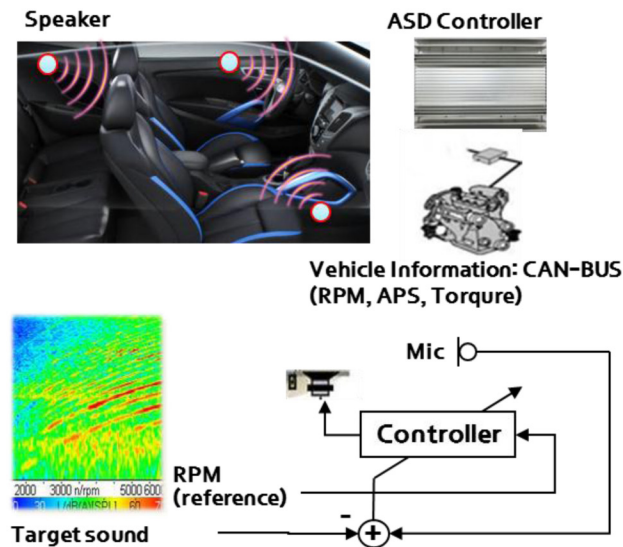


Figure 1. ASD Concept Diagram

ASD System Configuration

As previously stated, ASD is a system that outputs a preset target sound through the speakers according to the vehicle driving information sent to the controller. As illustrated in Figure 2, ASD consists of the Input system that has engine information such as engine rpm, torque, accelerator pedal position and vehicle velocity; the Control system that composes a configured engine sound based on the inputs and the vehicle transfer function; and the Output system that plays the composite engine sound through the speakers. The set target sound is played according to the engine and vehicle information, within the original engine sound environment.

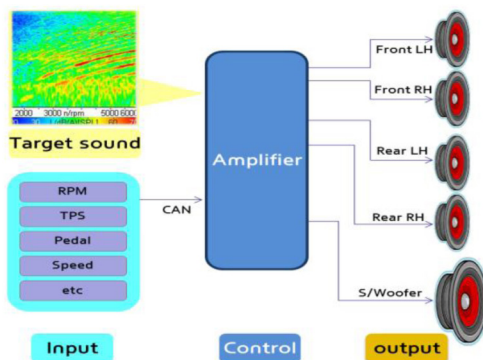


Figure 2. ASD System Diagram

Engine Sound Generation

The Control system produces an engine sound by order using rpm among the information received from the Input. Also, further variances in engine sound are provided by the driver's acceleration behaviors, which are defined by the accelerator pedal position and engine torque demand.

Engine Sound Generation by Order

Orders are created by tracking the engine rotation. The relationship with the number of engine rotations is shown in Formula (1).

$$C(n) = A(n) * \sin(\omega * t) \quad (1)$$

($\omega = 2 * \pi * \text{RPM} / 60$, n: rational number)

In the equation, C is order; A is the size of each order; ω is engine rotation frequency; t is time (sec.); and RPM is the number of engine revolutions per minute. Figure 3(a) shows orders with different levels by time at 3000rpm. The graph in Figure 3(b) is the composition of the different-level orders by time.

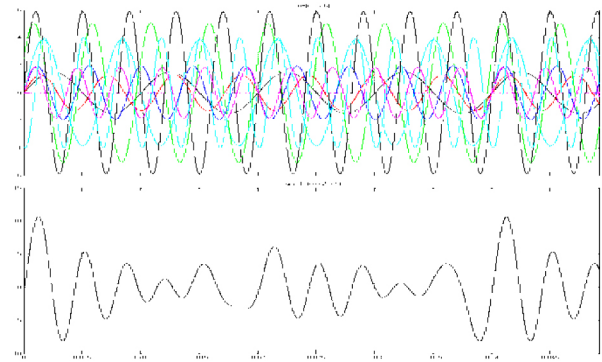


Figure 3. (a) Signals by Order (b) Composite Signal (Different Levels)

Engine Sound Generation by Acceleration Behavior

In addition, sound volume can be adjusted to suit the varying acceleration behavior of the driver through multiple sensitivity curves as shown in Figure 4. These curves are in relation to the accelerator pedal position, engine torque and vehicle velocity.

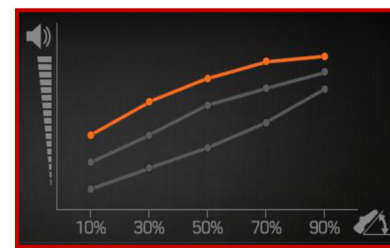


Figure 4. Sensitivity Curve by APS (Acceleration Position Sensor)

Engine Sound Composition

Formula (2) can be obtained as follows by applying both the engine order sound and the response sensitivity by driver's acceleration behavior.

$$C = \sum_{i=1}^n \alpha * A(i) * \sin(\omega * t) \quad (2)$$