US 20230311756A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2023/0311756 A1**

LEE (43) **Pub. Date: Oct. 5, 2023**

(54) **VIRTUAL ENGINE SOUND GENERATION SYSTEM AND VIRTUAL ENGINE SOUND GENERATION METHOD**

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(21) Appl. No.: **18/146,415**

(22) Filed: **Dec. 26, 2022**

(30) **Foreign Application Priority Data**

Mar. 29, 2022 (KR) 10-2022-0038745

Publication Classification

(51) **Int. Cl.**

B60Q 5/00	(2006.01)
G10K 15/02	(2006.01)
H03G 5/16	(2006.01)

(52) **U.S. Cl.**

CPC ***B60Q 5/008*** (2013.01); ***G10K 15/02*** (2013.01); ***H03G 5/165*** (2013.01)

(57) **ABSTRACT**

Provided are a virtual engine sound generation system and a virtual engine sound generation method using the same, and more particularly, a virtual engine sound generation system and a virtual engine sound generation method using the same capable of providing a virtual engine sound to which a sensation of gear shifting is added by calculating a virtual gear stage and a virtual RPM signal through a current vehicle speed and current APS information and generating a virtual engine sound based on the virtual gear stage and the virtual RPM signal.

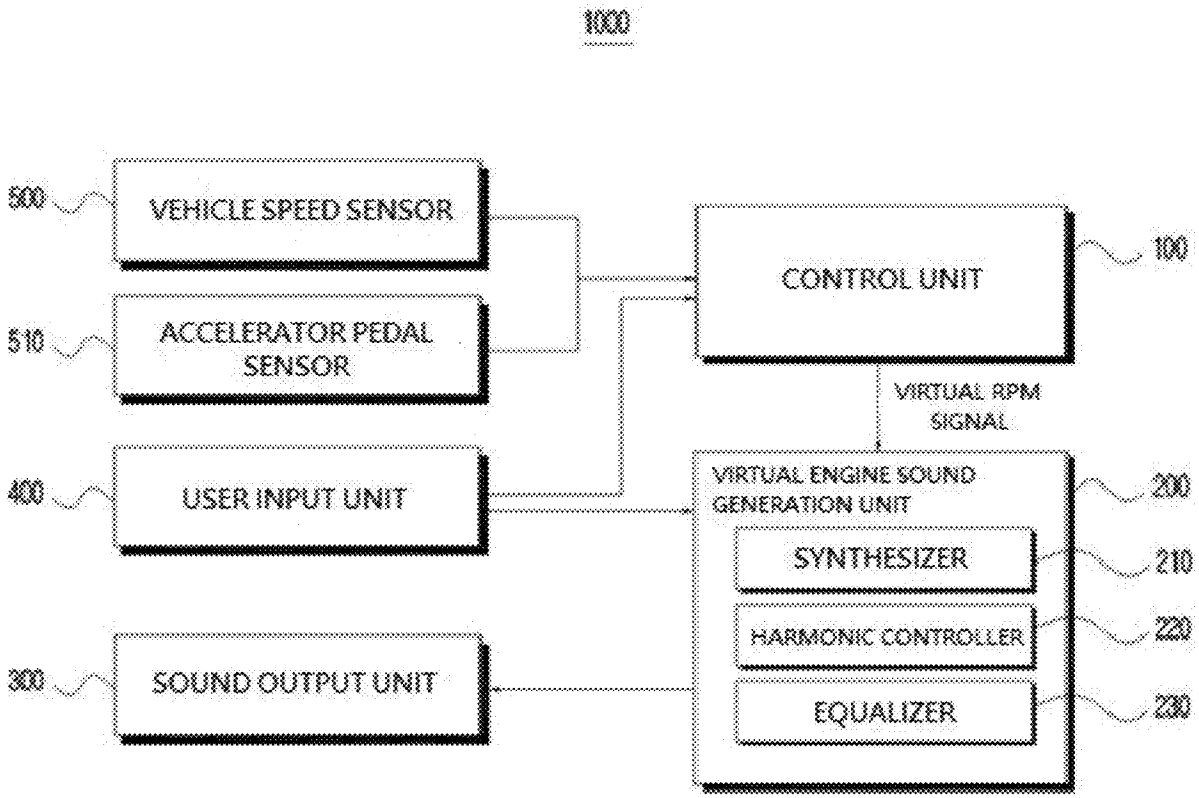


FIG. 1

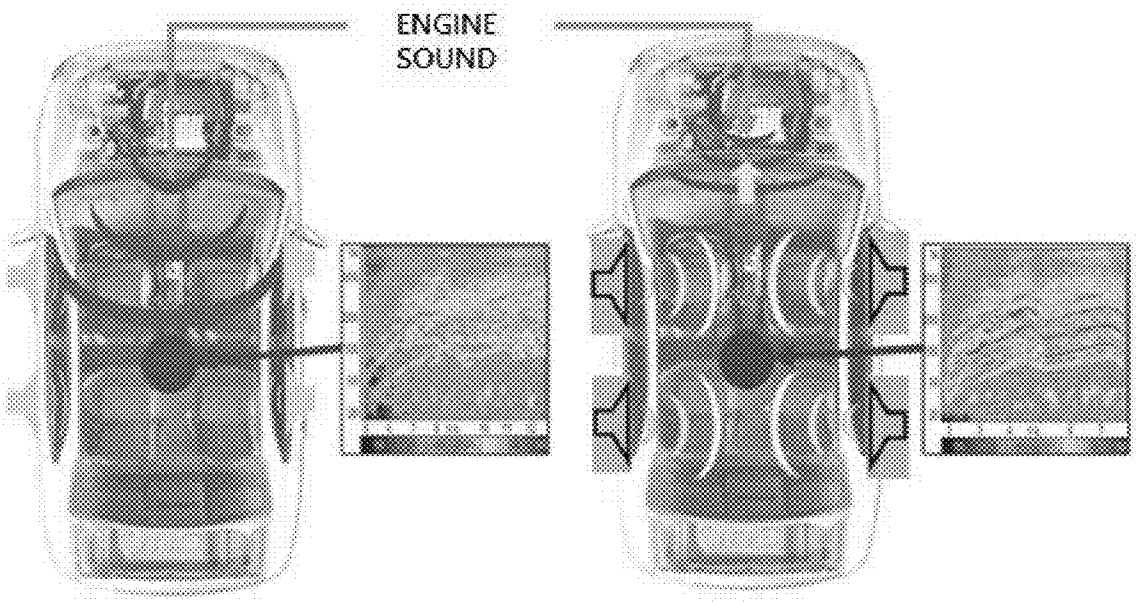


FIG. 2

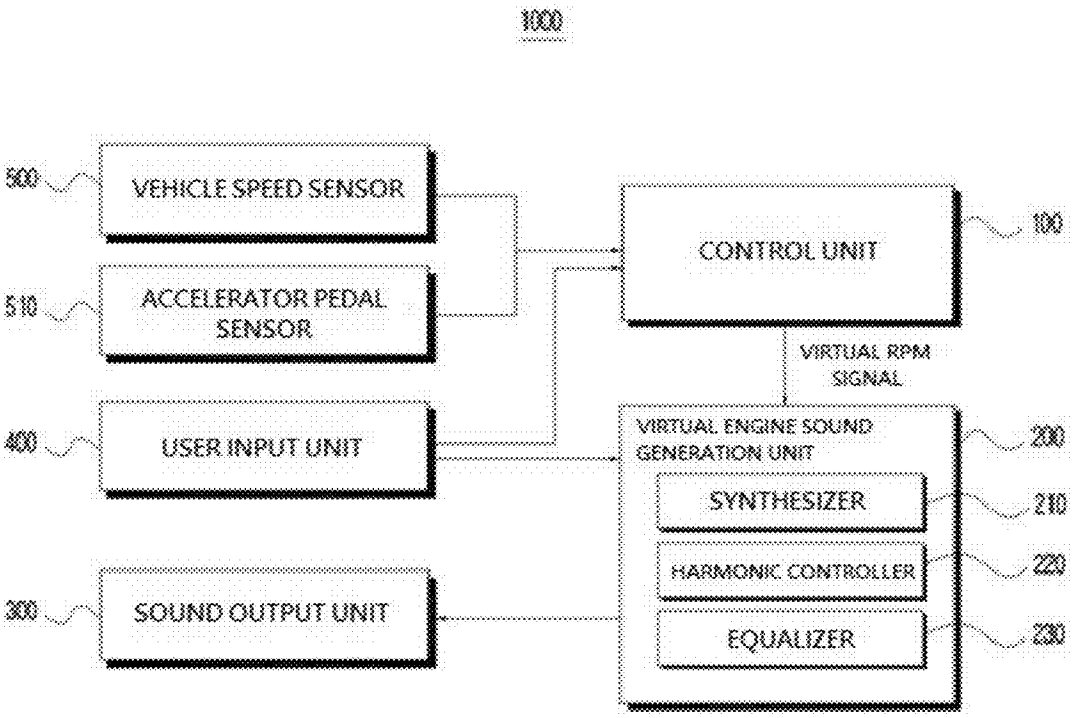

1000
500
VEHICLE SPEED SENSOR
510
ACCELERATOR PEDAL SENSOR
400
USER INPUT UNIT
300
SOUND OUTPUT UNIT
CONTROL UNIT
100
VIRTUAL RPM SIGNAL
VIRTUAL ENGINE SOUND GENERATION UNIT
200
SYNTHESIZER
210
HARMONIC CONTROLLER
220
EQUALIZER
230

FIG. 3

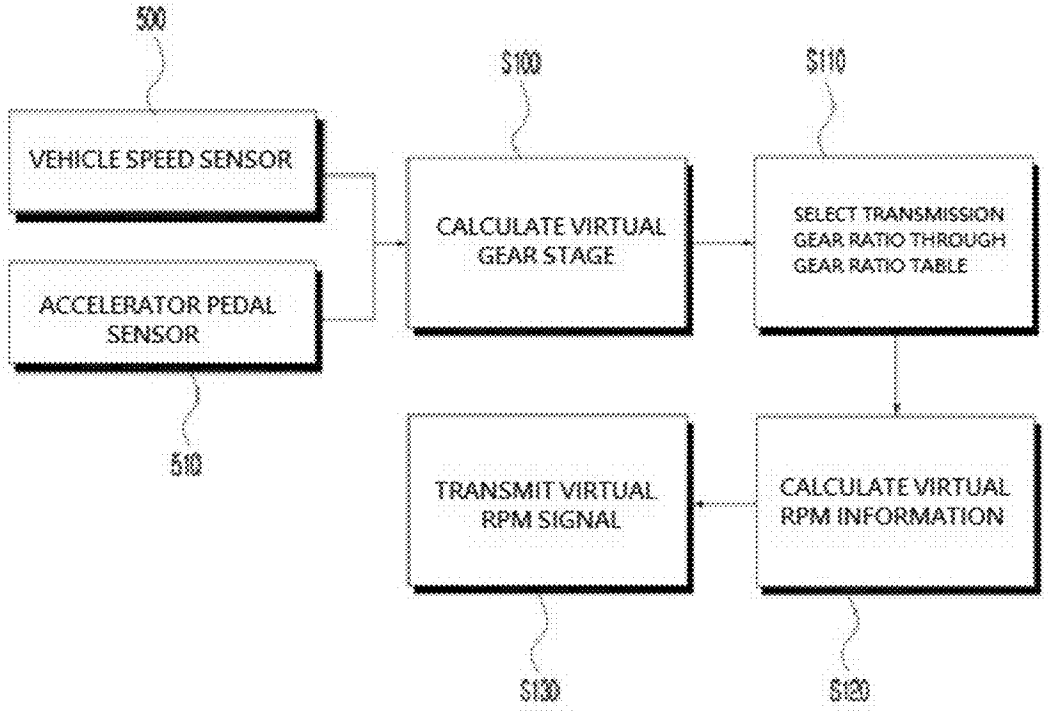

500
VEHICLE SPEED SENSOR
ACCELERATOR PEDAL SENSOR
510
S100
CALCULATE VIRTUAL GEAR STAGE
S110
SELECT TRANSMISSION GEAR RATIO THROUGH GEAR RATIO TABLE
CALCULATE VIRTUAL RPM INFORMATION
S120
TRANSMIT VIRTUAL RPM SIGNAL
S130

FIG. 4

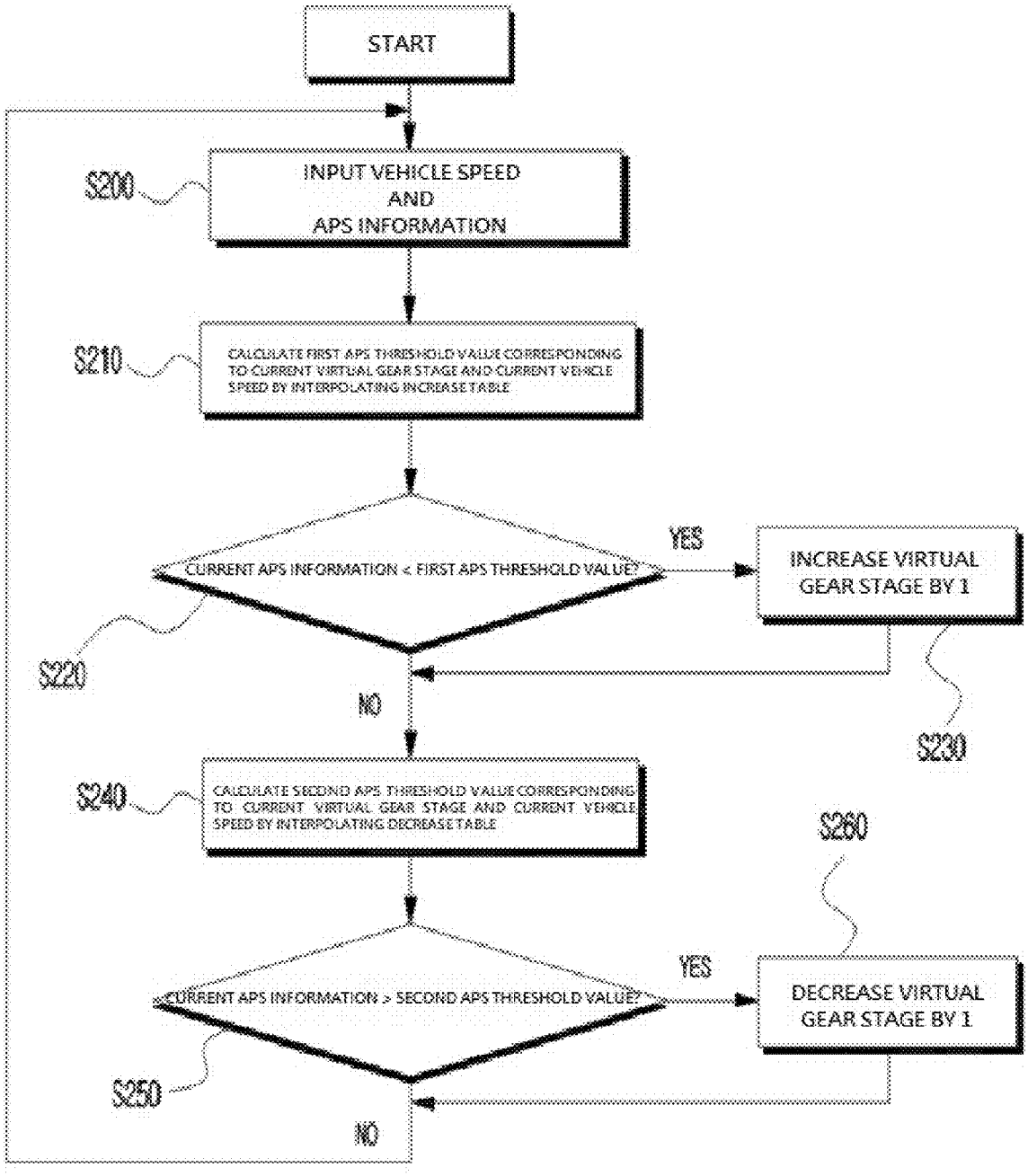

START
S200
INPUT VEHICLE SPEED AND APS INFORMATION
S210
CALCULATE FIRST APS THRESHOLD VALUE CORRESPONDING TO CURRENT VIRTUAL GEAR STAGE AND CURRENT VEHICLE SPEED BY INTERPOLATING INCREASE TABLE
CURRENT APS INFORMATION < FIRST APS THRESHOLD VALUE?
YES
INCREASE VIRTUAL GEAR STAGE BY 1
S220
NO
S230
S240
CALCULATE SECOND APS THRESHOLD VALUE CORRESPONDING TO CURRENT VIRTUAL GEAR STAGE AND CURRENT VEHICLE SPEED BY INTERPOLATING DECREASE TABLE
S260
CURRENT APS INFORMATION > SECOND APS THRESHOLD VALUE?
YES
DECREASE VIRTUAL GEAR STAGE BY 1
S250
NO

FIG. 5

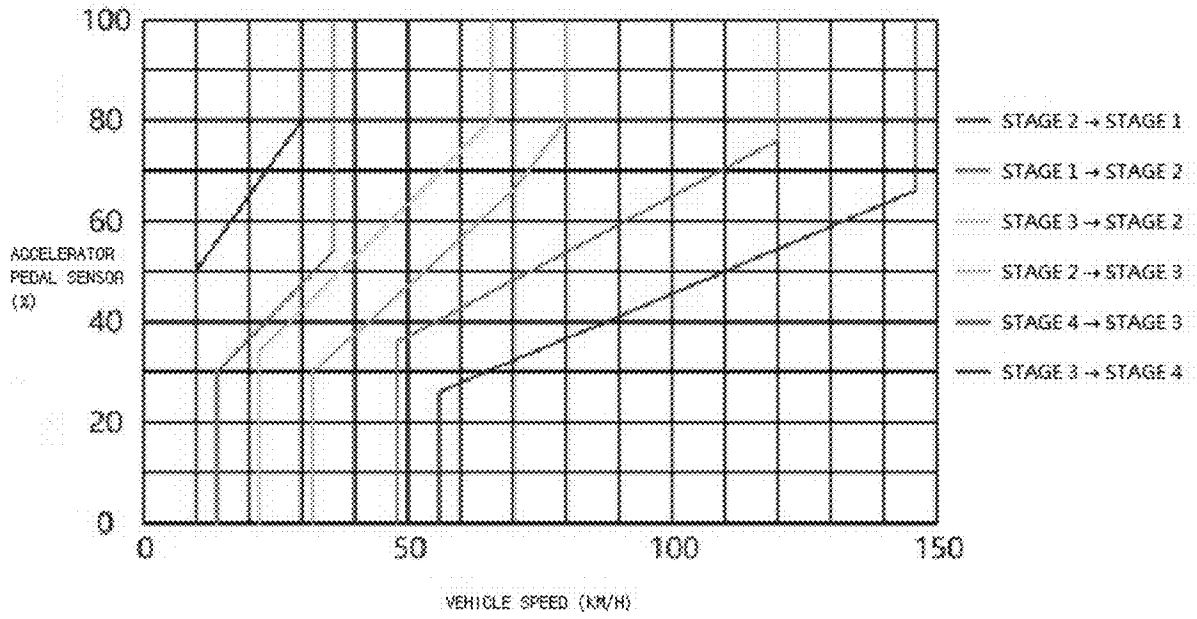

100
80
60
40
20
0
ACCELERATOR PEDAL SENSOR (%)
0
50
100
150
VEHICLE SPEED (KM/H)
STAGE 2 → STAGE 1
STAGE 1 → STAGE 2
STAGE 3 → STAGE 2
STAGE 2 → STAGE 3
STAGE 4 → STAGE 3
STAGE 3 → STAGE 4

FIG. 6

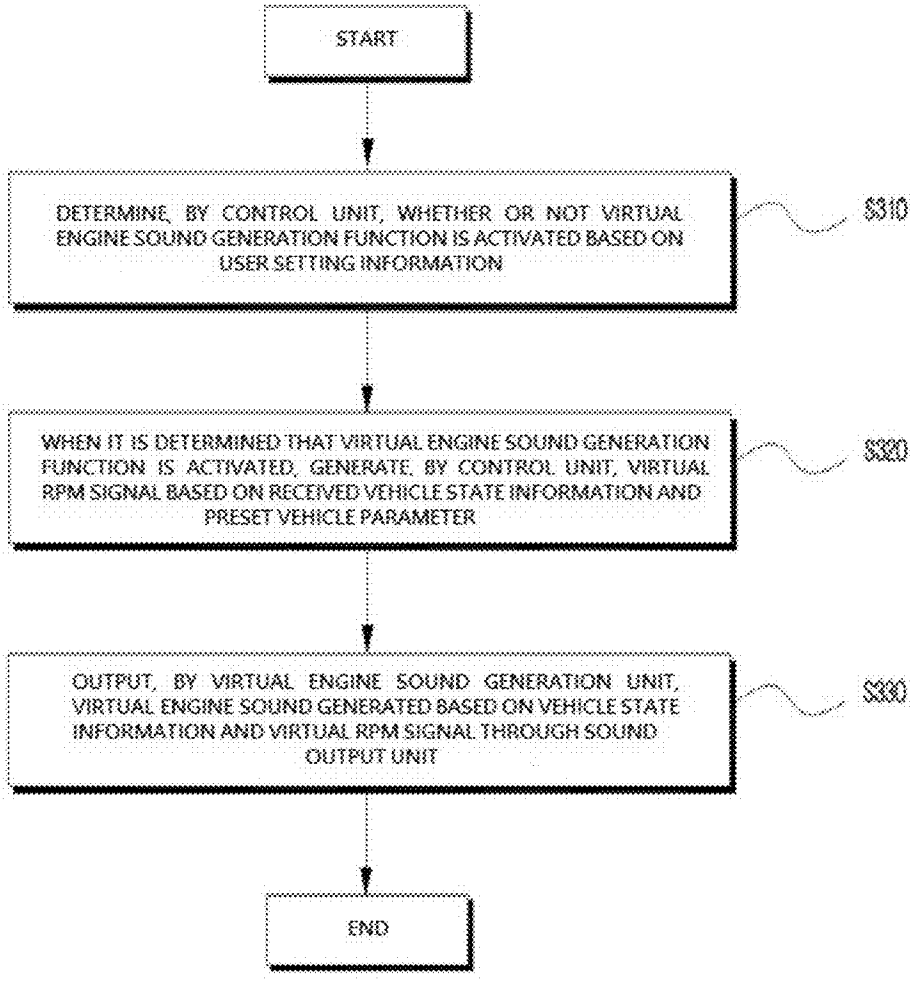

START
DETERMINE, BY CONTROL UNIT, WHETHER OR NOT VIRTUAL ENGINE SOUND GENERATION FUNCTION IS ACTIVATED BASED ON USER SETTING INFORMATION
S310
WHEN IT IS DETERMINED THAT VIRTUAL ENGINE SOUND GENERATION FUNCTION IS ACTIVATED, GENERATE, BY CONTROL UNIT, VIRTUAL RPM SIGNAL BASED ON RECEIVED VEHICLE STATE INFORMATION AND PRESET VEHICLE PARAMETER
S320
OUTPUT, BY VIRTUAL ENGINE SOUND GENERATION UNIT, VIRTUAL ENGINE SOUND GENERATED BASED ON VEHICLE STATE INFORMATION AND VIRTUAL RPM SIGNAL THROUGH SOUND OUTPUT UNIT
S330
END

FIG. 7

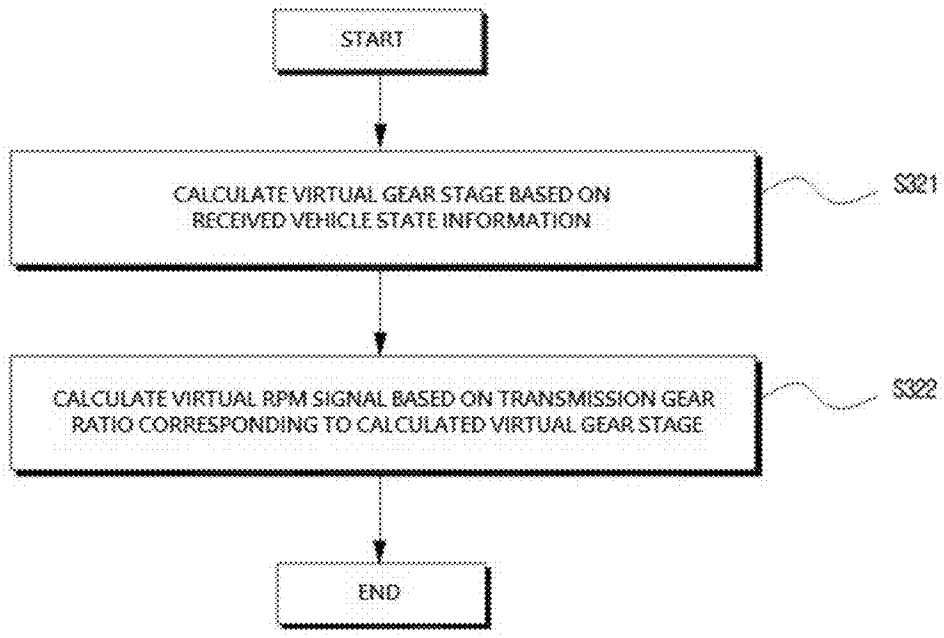
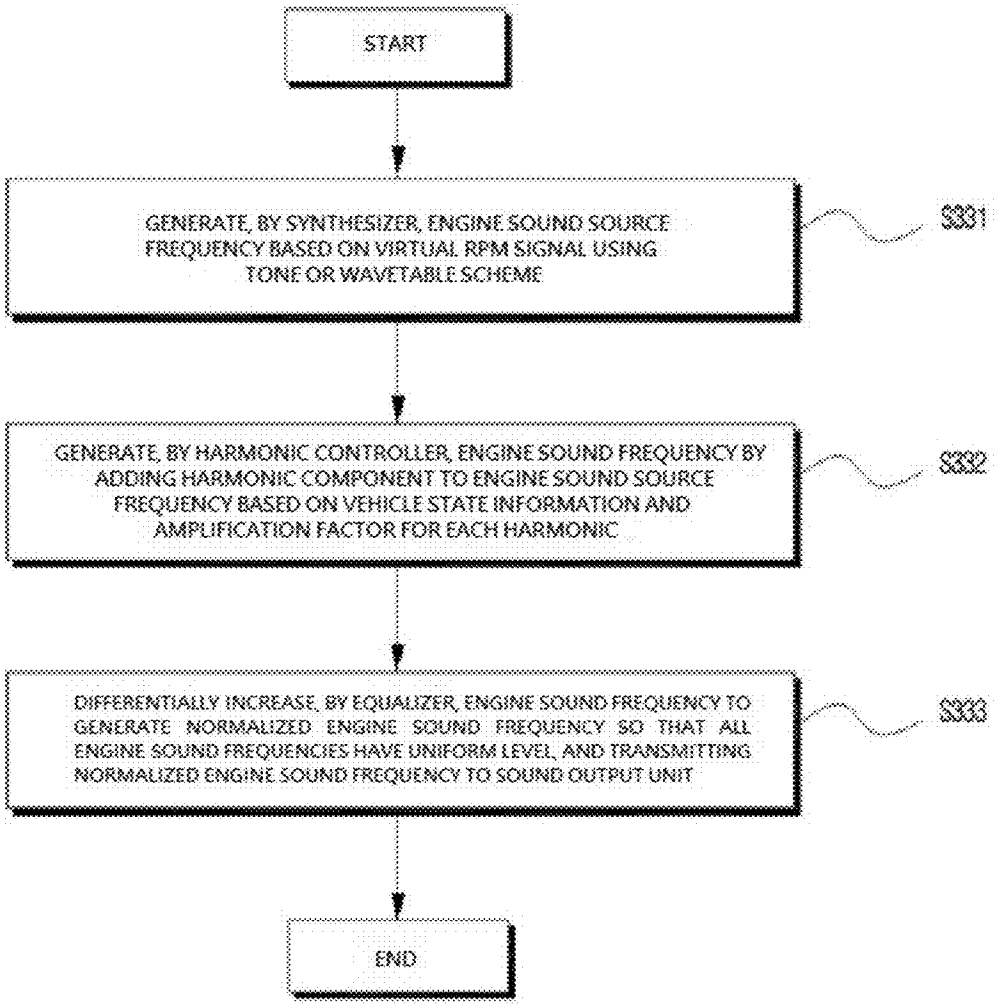

START
CALCULATE VIRTUAL GEAR STAGE BASED ON RECEIVED VEHICLE STATE INFORMATION
S321
CALCULATE VIRTUAL RPM SIGNAL BASED ON TRANSMISSION GEAR RATIO CORRESPONDING TO CALCULATED VIRTUAL GEAR STAGE
S322
END

FIG. 8


START
GENERATE, BY SYNTHESIZER, ENGINE SOUND SOURCE FREQUENCY BASED ON VIRTUAL RPM SIGNAL USING TONE OR WAVETABLE SCHEME
S331
GENERATE, BY HARMONIC CONTROLLER, ENGINE SOUND FREQUENCY BY ADDING HARMONIC COMPONENT TO ENGINE SOUND SOURCE FREQUENCY BASED ON VEHICLE STATE INFORMATION AND AMPLIFICATION FACTOR FOR EACH HARMONIC
S332
DIFFERENTIALLY INCREASE, BY EQUALIZER, ENGINE SOUND FREQUENCY TO GENERATE NORMALIZED ENGINE SOUND FREQUENCY SO THAT ALL ENGINE SOUND FREQUENCIES HAVE UNIFORM LEVEL, AND TRANSMITTING NORMALIZED ENGINE SOUND FREQUENCY TO SOUND OUTPUT UNIT
S333
END

VIRTUAL ENGINE SOUND GENERATION SYSTEM AND VIRTUAL ENGINE SOUND GENERATION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119 to Korean Patent Application No. 10-2022-0038745, filed on Mar. 29, 2022, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The following disclosure relates to a virtual engine sound generation system and a virtual engine sound generation method using the same, and more particularly, to a virtual engine sound generation system and a virtual engine sound generation method using the same capable of providing a virtual engine sound to which a sensation of gear shifting is added by calculating a virtual gear stage and a virtual RPM signal through a current vehicle speed and current APS information and generating a virtual engine sound based on the virtual gear stage and the virtual RPM signal.

BACKGROUND

[0003] Active sound design (ASD) is for synthesizing vehicle sounds using sound reinforcement techniques in order to change or improve the sounds inside and outside the vehicle.

[0004] Recently, as the demand for eco-friendly engines has increased, the efficiency of engine systems has increased, but auditory satisfaction given to consumers has decreased.

[0005] In addition, electric vehicles and fuel cell vehicles produce high-pitched sounds that general combustion engines do not have. For this reason, in order to satisfy consumers as to an emotional quality of engine sound, the ASD is used to generate or enhance an engine sound to be output through a sound output unit as illustrated in FIG. **1**.

[0006] The left side of FIG. **1** illustrates that, in a state where ASD is turned off, an engine sound of a 4-cylinder engine flows to the inside of a vehicle, and the right side of FIG. **1** illustrates that, in a state where ASD is turned on, an engine sound of a 6-cylinder engine is generated by the ASD and output through a sound output unit.

[0007] In a current electric vehicle, noise and vibration transmitted to the interior of the vehicle are significantly small by virtue of an electric motor rotating quietly and smoothly. So, a driving sound of the electric vehicle is very small, which may cause a driver to feel bored during movement in the vehicle.

[0008] Therefore, an ASD technique for an electric vehicle has been developed to maximize driving immersion by adding an auditory element to the electric vehicle. In this technique, an output torque of the electric vehicle is received, the output torque is converted into an engine sound at a specific RPM, and then the engine sound is output to the interior of the vehicle through a sound output unit.

[0009] However, an electric vehicle is operated by a motor and a decelerator, provides a higher RPM than a vehicle operated by an engine, and has only a small change in output torque during gear shifting. As a result, when an electric vehicle implements a driving sound by receiving a motor torque signal, it is difficult for the electric vehicle to generate a sound caused when the RPM periodically changes during gear shifting as in an internal combustion engine vehicle.

[0010] That is, in order to satisfy consumers who want the driving sound of an internal combustion engine vehicle, a method capable of making an electric vehicle replicate the driving sound of the internal combustion engine vehicle is required.

SUMMARY

[0011] An embodiment of the present invention is directed to providing a virtual engine sound generation system and a virtual engine sound generation method using the same capable of adding a sensation of gear shifting to increase a driver's immersion and satisfaction during driving by calculating a virtual gear stage and a virtual RPM signal based on a current vehicle speed, current APS information, and a vehicle parameter and generating a virtual engine sound through the virtual gear stage and the virtual RPM signal, and capable of reducing a system construction cost by utilizing conventional active sound design (ASD).

[0012] In one general aspect, a virtual engine sound generation system includes: a control unit generating a virtual RPM signal based on received vehicle state information and a preset vehicle parameter; and a virtual engine sound generation unit generating a virtual engine sound based on the vehicle state information and the virtual RPM signal, so that the virtual engine sound is output through a sound output unit.

[0013] The vehicle state information may be at least one of APS information, which is an accelerator pedal pressing rate, and a vehicle speed, and the vehicle parameter may be at least one of a transmission gear ratio, a final speed reduction ratio, a gear shift pattern, a tire width, a tire flatness ratio, a wheel diameter, the number of stroke cylinders, the number of cylinders, and an amplification factor for each harmonic.

[0014] The control unit may calculate a virtual gear stage based on the vehicle state information and the gear shift pattern, and generate the virtual RPM signal based on a preset transmission gear ratio corresponding to the calculated virtual gear stage.

[0015] The control unit may calculate the virtual RPM signal through the following Equation 1:

[Equation 1]

$$\text{virtual } RPM \text{ signal} = \frac{\text{vehicle speed (km/h)} \times \text{transmission gear ratio} \times \text{final speed reduction ratio} \times 10^6}{(3.78 \times \text{tire width (mm)} \times \text{flatness ratio}) + (4800 \times \text{wheel diameter(inch)})}.$$

[0016] The control unit may calculate a first APS threshold value and a second APS threshold value based on the vehicle speed and the APS information, increase the virtual gear stage by at least 1 when the APS information is smaller than the first APS threshold value, and decrease the virtual gear stage by at least 1 when the APS information is greater than or equal to the first APS threshold value or when the APS information is greater than the second APS threshold value.

[0017] Based on the vehicle speed and the APS information, the control unit may calculate the first APS threshold value corresponding to the virtual gear stage and the vehicle speed by interpolating an up shift table for the gear shift pattern, and calculate the second APS threshold value corresponding to the virtual gear stage and the vehicle speed by interpolating a down shift table for the gear shift pattern.

[0018] The virtual engine sound generation unit may include: a synthesizer generating an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal; a harmonic controller generating an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and an equalizer differentially increasing the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

[0019] The synthesizer may calculate the engine sound source frequency based on the virtual RPM signal and the vehicle parameter through the following Equation 2:

[Equation 2]

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E,$$

[0020] where S is the number of stroke cylinders, and E is the number of cylinders.

[0021] In another general aspect, a virtual engine sound generation method includes: a) determining, by the control unit, whether or not a virtual engine sound generation function is activated based on user setting information; b) when it is determined that the virtual engine sound generation function is activated, generating, by the control unit, a virtual RPM signal based on received vehicle state information and a preset vehicle parameter; and c) generating, by the virtual engine sound generation unit, a virtual engine sound based on the vehicle state information and the virtual RPM signal, so that the virtual engine sound is output through the sound output unit.

[0022] The vehicle state information may be at least one of APS information, which is an accelerator pedal pressing rate, and a vehicle speed, and the vehicle parameter may be at least one of a transmission gear ratio, a final speed reduction ratio, a gear shift pattern, a tire width, a tire flatness ratio, a wheel diameter, the number of stroke cylinders, the number of cylinders, and an amplification factor for each harmonic.

[0023] The step b) may include: b-1) calculating, by the control unit, a virtual gear stage based on the received vehicle state information; and b-2) calculating, by the control unit, the virtual RPM signal based on a preset transmission gear ratio corresponding to the calculated virtual gear stage.

[0024] The step b-1) may include: b-11) receiving, by the control unit, the vehicle speed and the APS information; b-12) calculating, by the control unit, a first APS threshold value corresponding to the virtual gear stage and the vehicle speed by interpolating an up shift table for the gear shift pattern based on the vehicle speed and the APS information; b-13) determining, by the control unit, whether or not the APS information is smaller than the first APS threshold value; b-14) increasing, by the control unit, the virtual gear stage by at least 1 when the APS information is smaller than the first APS threshold value; b-15) calculating, by the control unit, a second APS threshold value corresponding to the virtual gear stage and the vehicle speed, by interpolating a down shift table for the gear shift pattern, when the APS information is greater than or equal to the first APS threshold value or when the step b-14) is performed; and b-16) decreasing, by the control unit, the virtual gear stage by at least 1 when the APS information is greater than the second APS threshold value, and returning to the step b-11).

[0025] The virtual engine sound generation unit may include: a synthesizer generating an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal; a harmonic controller generating an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and an equalizer differentially increasing the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

[0026] The step c) may include: c-1) generating, by the synthesizer, an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal; c-2) generating, by the harmonic controller, an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and c-3) differentially increasing, by the equalizer, the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

[0027] In the step c-1), the synthesizer may calculate the engine sound source frequency based on the virtual RPM signal and the vehicle parameter through the following Equation 2:

[Equation 2]

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E,$$

[0028] where S is the number of stroke cylinders, and E is the number of cylinders.

[0029] According to the present invention, by adding to a virtual engine sound a virtual RPM signal in which a gear shifting process is replicated, the virtual engine sound output from the ASD does not monotonically increase, but shifts up and down.

[0030] Accordingly, it is possible to increase driving immersion and user satisfaction for an occupant of a driving vehicle, and it is also possible to reduce a system construction cost by utilizing conventional ASD.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. **1** is a diagram illustrating an operation principle of conventional active sound design (ADS).

[0032] FIG. **2** is a diagram illustrating an internal configuration of a virtual engine sound generation system according to an embodiment of the present invention.

[0033] FIG. **3** is a diagram illustrating a process in which a control unit calculates a virtual RPM signal according to an embodiment of the present invention.

[0034] FIG. **4** is a diagram illustrating a process in which the control unit calculates a virtual gear stage according to an embodiment of the present invention.

[0035] FIG. **5** is a diagram illustrating an example of the gear shift pattern.

[0036] FIG. **6** is a diagram illustrating a process of generating a virtual engine sound according to an embodiment of the present invention.

[0037] FIG. **7** is a diagram illustrating step S**320** of FIG. **6** in more detail.

[0038] FIG. **8** is a diagram illustrating step S**330** of FIG. **6** in more detail.

DETAILED DESCRIPTION OF EMBODIMENTS

[0039] Hereinafter, preferred embodiments of the present invention will be exemplified and referred to so as to describe the present invention, operational advantages of the present invention, and objects to be achieved by implementing the present invention.

[0040] FIG. **2** is a diagram illustrating an internal configuration of a virtual engine sound generation system according to an embodiment of the present invention.

[0041] Referring to FIG. **2**, a virtual engine sound generation system **1000** according to an embodiment of the present invention includes: a control unit **100** generating a virtual RPM signal based on received vehicle state information and preset vehicle parameters; and a virtual engine sound generation unit **200** generating a virtual engine sound based on the vehicle state information and the virtual RPM signal, so that the virtual engine sound is output through a sound output unit **300**.

[0042] In the virtual engine sound generation system **1000** according to the present invention, in order to solve a problem of a conventional virtual engine sound generation device that is not capable of giving a sensation of gear shifting because a virtual engine sound is generated through information on a vehicle speed and an engine torque, the control unit **100** calculates a virtual gear stage and calculates a virtual RPM signal based on the virtual gear stage.

[0043] The virtual engine sound generation unit **200** generates a virtual engine sound through the virtual RPM signal generated as described above. As a result, it is possible to generate a virtual engine sound to which a sensation of gear shifting is added based on a vehicle speed and accelerator pedal sensor (APS) information, which is an accelerator pedal pressing rate, of the vehicle at a current time.

[0044] A process of generating such a virtual engine sound to which a sensation of gear shifting is added will be described in detail below. First, as described above, the control unit **100** is configured to generate a virtual RPM signal based on the received vehicle state information and the preset vehicle parameters.

[0045] In a conventional internal combustion engine vehicle, RPM information may be obtained. However, in a vehicle driven by a motor, such as an electric vehicle, which is not capable of obtaining RPM information, in order to generate a virtual RPM signal, a virtual gear stage corresponding to a current state of the vehicle is calculated through a current vehicle speed as a speed of the vehicle, current APS information as an accelerator pedal pressing rate of the vehicle, and a preset gear shift pattern as illustrated in FIG. **3**, according to the present invention.

[0046] When the virtual gear stage is calculated, a transmission gear ratio corresponding to the calculated virtual gear stage is selected from a preset gear ratio table, and a virtual RPM signal is calculated through the selected transmission gear ratio.

[0047] The virtual RPM signal is calculated through the following Equation 1.

[Equation 1]

$$\text{virtual } RPM \text{ signal} = \frac{\text{vehicle speed (km/h)} \times \text{transmission gear ratio} \times \text{final speed reduction ratio} \times 10^6}{(3.78 \times \text{tire width (mm)} \times \text{flatness ratio}) + (4800 \times \text{wheel diameter(inch)})}$$

[0048] Here, the tire width (mm), the tire flatness ratio, the wheel diameter (inch), the transmission gear ratio, and the final speed reduction ratio are preset vehicle parameters input from a user through a user input unit **400**, which will be described below.

[0049] Additionally, the vehicle parameters include a gear shift pattern, the number of stroke cylinders, the number of cylinders, an amplification factor for each harmonic, etc. These parameters have initial default values, which may be changed through the user input unit **400**.

[0050] In addition, the vehicle speed and the APS information are vehicle state information, and the control unit **100** and the virtual engine sound generation unit **200** receive the vehicle state information from sensing means such as a vehicle speed sensor **500** and an accelerator pedal sensor **510** provided in the vehicle.

[0051] The vehicle speed and APS information may be obtained through other sensing means in addition to the vehicle speed sensor **500** and the accelerator pedal sensor **510**, and the present invention is not limited to these sensing means.

[0052] In addition, when a virtual RPM signal is calculated, the control unit **100** transfers the virtual RPM signal to the virtual engine sound generation unit **200**.

[0053] Meanwhile, the virtual engine sound generation unit **200** includes: a synthesizer **210** generating an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal; a harmonic controller **220** generating an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and an equalizer **230** differentially increasing the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit **300**.

[0054] The virtual engine sound generation unit **200** is a component identical or similar to a conventional active sound design (ASD) system. However, while the conventional ADS system generates a virtual engine sound through a vehicle speed and a motor torque received as vehicle state information, the virtual engine sound generation unit **200** according to the present invention generates a virtual engine sound by receiving a virtual RPM signal, rather than a motor torque, together with a vehicle speed and APS information to add a sensation of gear shifting.

[0055] The biggest difference between the two methods is whether or not a sensation of gear shifting is included. In a conventional internal combustion engine vehicle, a sensation of gear shifting has a pattern in which an engine RPM increases according to a vehicle speed, decreases after gear shifting, and then increases again.

[0056] The sensation of gear shifting may cause the driver to have fun during driving, increasing a driver's immersion and satisfaction during driving. Also, the sensation of gear shifting may cause the driver to perceive a current speed, which is effective in driving safety.

[0057] Meanwhile, the synthesizer **210** generates a signal using a tone or wavetable scheme, based on the virtual RPM signal, the vehicle speed, and the APS information received from the control unit **100** described above.

[0058] The frequency in the generated signal may be changed according to the virtual RPM signal. Therefore, the engine sound source frequency generated by the synthesizer **210** may be calculated through the following Equation 2.

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E \quad \text{[Equation 2]}$$

[0059] Here, S is the number of stroke cylinders and E is the number of cylinders, which are vehicle parameters as described above, and have preset values.

[0060] In addition, the harmonic controller **220** synthesizes a harmonic component with the engine sound source frequency transmitted from the synthesizer **210** based on the amplification factor for each harmonic, which is a preset vehicle parameter. The synthesized engine sound frequency is normalized by the equalizer **230**, and the normalized engine sound frequency is transmitted to the sound output unit **300**.

[0061] Meanwhile, in the present invention, the user input unit **400** may be included to receive vehicle parameters from the user and to receive user setting information regarding whether to operate the control unit.

[0062] Therefore, the control unit **100** first checks the user setting information regarding whether to operate the control unit **100** when generating a virtual RPM signal. When the control unit **100** is set to be operated, the control unit **100** generates a virtual RPM signal and transmits the virtual RPM signal to the virtual engine sound generation unit **200** as described above.

[0063] Hereinafter, a process in which the control unit **100** calculates a virtual RPM signal and a process in which the control unit **100** calculates a virtual gear stage will be described with reference to the drawings.

[0064] FIG. **3** is a diagram illustrating a process in which the control unit generates a virtual RPM signal according to an embodiment of the present invention.

[0065] Referring to FIG. **3**, as described above, the control unit **100** generates a virtual RPM signal based on the received vehicle state information and vehicle parameters. To this end, the control unit **100** first calculates a current virtual gear stage of the vehicle based on a vehicle speed and APS information of the vehicle currently received from the vehicle speed sensor **500** and the accelerator pedal sensor **510**, and a preset gear shift pattern (S**100**), and selects a transmission gear ratio corresponding to the virtual gear stage based on a preset gear ratio table (S**110**).

[0066] When the transmission gear ratio is specified, a virtual RPM signal is calculated according to the following Equation 1 (S**120**).

$$\text{virtual } RPM \text{ signal} = \frac{\text{vehicle speed}\,(\text{km/h}) \times \text{transmission gear ratio} \times \text{final speed reduction ratio} \times 10^6}{(3.78 \times \text{tire width}\,(\text{mm}) \times \text{flatness ratio}) + (4800 \times \text{wheel diameter(inch)})} \quad \text{[Equation 1]}$$

[0067] As described above, the tire width (mm), the tire flatness ratio, the wheel diameter (inch), and the final speed reduction ratio are preset vehicle parameters.

[0068] Accordingly, the control unit **100** transmits the generated virtual RPM signal to the virtual engine sound generation unit **200** (S**130**).

[0069] FIG. **4** is a diagram illustrating a process in which the control unit calculates a virtual gear stage according to an embodiment of the present invention, and FIG. **5** is a diagram illustrating an example of the gear shift pattern.

[0070] Referring to FIG. **4**, the process of calculating a virtual gear stage in the above-described step S**100** will be described in more detail. First, the control unit **100** continues to receive a current vehicle speed and current APS information of the vehicle from the vehicle speed sensor **500** and the accelerator pedal sensor **510** (S**200**), and calculates a first APS threshold value corresponding to the current virtual gear stage and the current vehicle speed by interpolating an up shift table for the gear shift pattern based on the vehicle speed and the APS information (S**210**).

[0071] Here, as illustrated in FIG. **5**, the up shift table shows lines indicating threshold values for increasing the virtual gear stage from stage **1** to stage **2**, from stage **2** to stage **3**, and from stage **3** to stage **4**. At a time point of an immediate previous virtual gear stage and vehicle speed of the vehicle, a threshold value for increasing the virtual gear stage, that is, a first threshold value, may be calculated from the up shift table.

[0072] Once the control unit **100** calculates the first threshold value, at a moment when continuously received current APS information becomes smaller than the first APS threshold value, the virtual gear stage is increased by 1 as compared with the immediately previous virtual gear stage.

[0073] In this manner, the control unit **100** calculates a first threshold value, compares the current APS information with the first APS threshold value, and determines whether the current APS information is smaller than the first APS threshold value (S**220**).

[0074] When it is determined the current APS information is smaller than the first APS threshold value, the virtual gear stage is increased by 1 (S**230**). When it is determined the current APS information is greater than or equal to the first APS threshold value, or when the step S**230** is performed, the control unit **100** calculates a second APS threshold value corresponding to the current virtual gear stage and the current vehicle speed by interpolating a down shift table for the gear shift pattern (S**240**).

[0075] When the current APS information is greater than the second APS threshold value, the current virtual gear stage is decreased by 1, and the process returns to the step S**200** (S**250**).

[0076] While the step S**200** to the step S**250** are continuously repeated, when a condition for stopping the operation of the control unit **100** occurs, such as when user setting information is input or the operation of the vehicle is stopped, the process of calculating a virtual gear stage may end.

[0077] FIG. **6** is a diagram illustrating a process of generating a virtual engine sound according to an embodiment of the present invention, FIG. **7** is a diagram illustrating step S**320** of FIG. **6** as a more specific process, and FIG. **8** is a diagram illustrating step S**330** of FIG. **6** as a more specific process.

[0078] Referring to FIGS. **6** to **8**, a virtual engine sound generation method according to an embodiment of the present invention largely includes: determining, by the control unit **100**, whether or not a virtual engine sound generation function is activated based on user setting information (S**310**); when it is determined that the virtual engine sound generation function is activated, generating, by the control unit **100**, a virtual RPM signal based on received vehicle state information and preset vehicle parameters (S**320**); and generating, by the virtual engine sound generation unit **200**, a virtual engine sound based on the vehicle state information and the virtual RPM signal, so that the generated virtual engine sound is output through the sound output unit **300** (S**330**).

[0079] Here, as described above for the virtual engine sound generation system **1000**, the vehicle state information is APS information, which is an accelerator pedal pressing rate, and a vehicle speed, and the vehicle parameters are a transmission gear ratio, a final speed reduction ratio, a gear shift pattern, a tire width, a tire flatness ratio, a wheel diameter, the number of stroke cylinders, the number of cylinders, and an amplification factor for each harmonic.

[0080] In addition, the step S**320**, which is a step in which the control unit **100** generates a virtual RPM signal, includes: calculating, by the control unit **100**, a virtual gear stage based on the received vehicle state information (S**321**); and calculating, by the control unit **100**, a virtual RPM signal based on a preset transmission gear ratio corresponding to the calculated virtual gear stage (S**322**).

[0081] In order to calculate a virtual gear stage in the step S**321**, the control unit **100** first receives a current vehicle speed and current APS information of the vehicle, and calculates a first APS threshold value corresponding to the current virtual gear stage and the current vehicle speed by interpolating an up shift table for the gear shift pattern based on the current vehicle speed and the current APS information.

[0082] In addition, the control unit **100** determines whether or not the current APS information is smaller than the first APS threshold value. When the current APS information is smaller than the first APS threshold value, the control unit **100** increases the current virtual gear stage by at least 1. When the current APS information is greater than or equal to the first APS threshold value, or when the current virtual gear stage is increased by at least 1, the control unit **100** calculates a second APS threshold value corresponding to the current virtual gear stage and the current vehicle speed by interpolating a down shift table for the gear shift pattern.

[0083] When the current APS information is greater than the second APS threshold value, the control unit **100** decreases the current virtual gear stage by at least 1, and returns to the beginning of the process to continue to calculate a virtual gear stage.

[0084] Meanwhile, the step S**330** includes: generating, by the synthesizer **210**, an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal (S**331**); generating, by the harmonic controller **220**, an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic (S**332**); and differentially increasing, by the equalizer **230**, the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit **300** (S**333**).

[0085] In this case, in the step S**331**, the synthesizer **210** calculates an engine sound source frequency based on the virtual RPM signal and the vehicle parameters through the following Equation 2.

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E \quad \text{[Equation 2]}$$

What is claimed is:

1. A virtual engine sound generation system comprising:

a control unit for generating a virtual RPM signal based on received vehicle state information and a preset vehicle parameter; and

a virtual engine sound generation unit for generating a virtual engine sound based on the vehicle state information and the virtual RPM signal, to be produced through a sound output unit.

2. The virtual engine sound generation system of claim **1**, wherein the vehicle state information is at least one of APS information, which is an accelerator pedal pressing rate, and a vehicle speed.

3. The virtual engine sound generation system of claim **2**, wherein the vehicle parameter is at least one of a transmission gear ratio, a final speed reduction ratio, a gear shift pattern, a tire width, a tire flatness ratio, a wheel diameter, number of stroke cylinders, number of cylinders, and an amplification factor for each harmonic.

4. The virtual engine sound generation system of claim **3**, wherein the control unit calculates a virtual gear stage based on the vehicle state information and the gear shift pattern and generates the virtual RPM signal based on a preset transmission gear ratio corresponding to the calculated virtual gear stage.

5. The virtual engine sound generation system of claim **4**, wherein the control unit calculates the virtual RPM signal through the following Equation 1:

[Equation 1]

$$\text{virtual } RPM \text{ signal} = \frac{\text{vehicle speed (km/h)} \times \text{transmission gear ratio} \times \text{final speed reduction ratio} \times 10^6}{(3.78 \times \text{tire width (mm)} \times \text{flatness ratio}) + (4800 \times \text{wheel diameter(inch)})}.$$

6. The virtual engine sound generation system of claim **5**, wherein the control unit

calculates a first APS threshold value and a second APS threshold value based on the vehicle speed and the APS information,

increases the virtual gear stage by at least 1 when the APS information is smaller than the first APS threshold value, and

decreases the virtual gear stage by at least 1 when the APS information is greater than or equal to the first APS threshold value or when the APS information is greater than the second APS threshold value.

7. The virtual engine sound generation system of claim **6**, wherein, based on the vehicle speed and the APS information, the control unit:

calculates the first APS threshold value corresponding to the virtual gear stage and the vehicle speed by interpolating an up-shift table for the gear shift pattern, and

calculates the second APS threshold value corresponding to the virtual gear stage and the vehicle speed by interpolating a down-shift table for the gear shift pattern.

8. The virtual engine sound generation system of claim **3**, wherein the virtual engine sound generation unit includes:

a synthesizer for generating an engine sound source frequency, using a tone or wavetable scheme, and based on the virtual RPM signal;

a harmonic controller for generating an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and

an equalizer for differentially increasing the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

9. The virtual engine sound generation system of claim **8**, wherein the synthesizer calculates the engine sound source frequency based on the virtual RPM signal and the vehicle parameter through the following Equation 2:

[Equation 2]

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E,$$

where S is the number of stroke cylinders, and E is the number of cylinders.

10. A virtual engine sound generation method of the virtual engine sound generation system of claim **1**, the virtual engine sound generation method further comprising:

a) determining, by the control unit, whether or not a virtual engine sound generation function is activated based on user setting information;

b) when it is determined that the virtual engine sound generation function is activated, generating, by the control unit, a virtual RPM signal based on received vehicle state information and a preset vehicle parameter; and

c) generating, by the virtual engine sound generation unit, a virtual engine sound based on the vehicle state information and the virtual RPM signal, so that the virtual engine sound is output through the sound output unit.

11. The virtual engine sound generation method of claim **10**, wherein the vehicle state information is at least one of APS information, which is an accelerator pedal pressing rate, and a vehicle speed, and

the vehicle parameter is at least one of a transmission gear ratio, a final speed reduction ratio, a gear shift pattern, a tire width, a tire flatness ratio, a wheel diameter, number of stroke cylinders, number of cylinders, and an amplification factor for each harmonic.

12. The virtual engine sound generation method of claim **11**, wherein step b) includes:

b-1) calculating, by the control unit, a virtual gear stage based on the received vehicle state information; and

b-2) calculating, by the control unit, the virtual RPM signal based on a preset transmission gear ratio corresponding to the calculated virtual gear stage.

13. The virtual engine sound generation method of claim **12**, wherein step b-1) includes:

b-11) receiving, by the control unit, the vehicle speed and the APS information;

b-12) calculating, by the control unit, a first APS threshold value corresponding to the virtual gear stage and the

vehicle speed by interpolating an up-shift table for the gear shift pattern based on the vehicle speed and the APS information;

b-13) determining, by the control unit, whether or not the APS information is smaller than the first APS threshold value;

b-14) increasing, by the control unit, the virtual gear stage by at least 1 when the APS information is smaller than the first APS threshold value;

b-15) calculating, by the control unit, a second APS threshold value corresponding to the virtual gear stage and the vehicle speed, by interpolating a down shift table for the gear shift pattern, when the APS information is greater than or equal to the first APS threshold value or when step b-14) is performed; and

b-16) decreasing, by the control unit, the virtual gear stage by at least 1 when the APS information is greater than the second APS threshold value, and returning to step b-11).

14. The virtual engine sound generation method of claim **11**, wherein the virtual engine sound generation unit includes:

a synthesizer for generating an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal;

a harmonic controller for generating an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and

an equalizer for differentially increasing the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

15. The virtual engine sound generation method of claim **14**, wherein step c) includes:

c-1) generating, by the synthesizer, an engine sound source frequency, using a tone or wavetable scheme, based on the virtual RPM signal;

c-2) generating, by the harmonic controller, an engine sound frequency by adding a harmonic component to the engine sound source frequency based on the vehicle state information and a preset amplification factor for each harmonic; and

c-3) differentially increasing, by the equalizer, the engine sound frequency to generate a normalized engine sound frequency so that all engine sound frequencies have a uniform level, and transmitting the normalized engine sound frequency to the sound output unit.

16. The virtual engine sound generation method of claim **15**, wherein, in step c-1), the synthesizer calculates the engine sound source frequency based on the virtual RPM signal and the vehicle parameter through the following Equation 2:

$$\text{engine sound source frequency} = \frac{\text{virtual } RPM \text{ signal} \times 2}{60 \times S} \times E, \quad \text{[Equation 2]}$$

where S is the number of stroke cylinders, and E is the number of cylinders.

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