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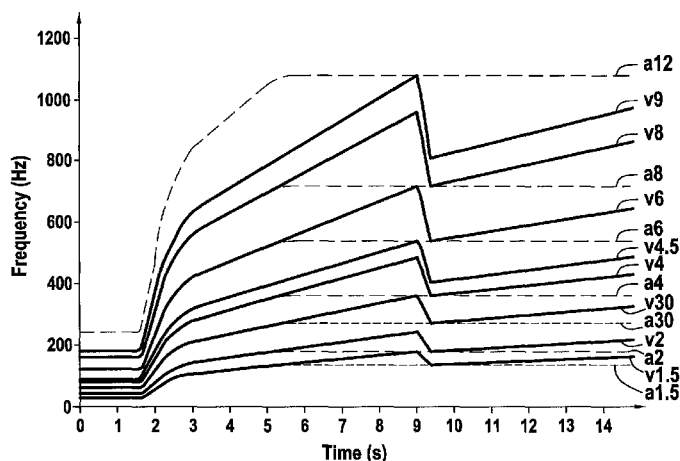


FIG.3

(57) Abstract: The invention refers to a control device (1) for a sound-system (9) of a vehicle (10) with an engine (3), the engine being operated with a constant saturated rotation per minute (rpm). The control device (1) controls the sound-system (9) to generate an artificial engine sound corresponding to a step shift pattern of a virtual engine with a fixed gear transmission. The artificial engine sound comprises one or more orders which are superimposed on the orders of the actual sound generated by the engine (9) of the vehicle (10). The frequency of a dominant order of the artificial engine sound is increased until a frequency maximum, before a virtual up-shift is performed. A dominant order of the artificial engine sound blends at the frequency maximum with the main firing order of the actual engine sound or with one of its harmonics. The invention also refers to a corresponding method of generating an artificial engine sound for a vehicle.

Control device and method for generating an artificial engine soundFIELD OF THE DISCLOSURE

5 [0001] The present disclosure is related to a control device for a sound-system of a vehicle for generating an artificial engine sound and also to a method of generating an artificial engine sound for a vehicle.

BACKGROUND OF THE DISCLOSURE

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[0002] The use of stepless transmissions in vehicles, as e.g. continuously variable transmissions (CVT) or respective planetary gearbox transmissions, has become popular due to their enhanced efficiency. In particular, such transmissions are used in hybrid vehicles. A stepless transmission can provide improved fuel economy when compared to fixed gear ratio transmissions. However, when accelerating a vehicle with a stepless transmission, the actual engine rotation per minute (rpm) will increase fast to high levels and will remaining constant at a maximum rpm, meanwhile the vehicle is further accelerating. In other words, the transmission is configured such that the engine rpm is regulated independent of the vehicle speed. Said maximum rpm is a constant saturated rpm. The resulting engine sound has a constant, relatively high frequency, which causes a rubber band feeling. This engine sound creates annoyance, especially for customers who are used to drive manual or automatic gearbox vehicles with a fixed gear transmission. Such gearbox vehicles provide an increasing engine sound frequency when accelerating. Once a certain maximum frequency is reached, the fixed gear transmission is shifted to the next upper gear and the engine sound frequency is returned to a lower frequency, in order to be re-increased. The resulting engine sound has thus a step shift pattern comprising a plurality of up-shifts of the fixed gear transmission.

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[0003] It is known to provide a vehicle comprising a stepless transmission with a so-called engine sound enhancement (ESE) system. Such a system generates an artificial engine sound, which shall ameliorate the impression of the customer.

[0004] For example, US 2013/0294619 A1 discloses an ESE system in a CVT vehicle for emitting an audio signal that is blended with an engine sound emitted from the engine to mimic a shifting sound that a theoretical fixed gear transmission creates while shifting gears. In particular, a plurality of ESE tones can be superimposed on the engine orders.

[0005] However, the customer may anyhow recognize the existence of the supplementary artificial audio signal, i.e. it can be possible for him to distinguish between the actual engine sound and the superimposed audio signal. Hence, the resulting sound does not appear natural to the customer.

SUMMARY OF THE DISCLOSURE

[0006] Currently, it remains desirable to provide a control device which provides a more realistic engine sound generation.

[0007] Therefore, according to embodiments of the present disclosure, a control device is provided for a sound-system of a vehicle with an engine. The engine is operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle. The control device is configured to control the sound-system to generate an artificial engine sound corresponding to a step shift pattern of a virtual engine with a fixed gear transmission. The artificial engine sound comprises one or more orders which are superimposed on the orders of the actual sound generated by the engine of the vehicle. The frequency of a dominant order of the artificial engine sound is increased until a frequency maximum, before a virtual up-shift is performed. The dominant order of the artificial engine sound blends at the frequency maximum with the main firing order of the actual engine sound or with one of the harmonics of the main firing order of the actual engine sound.

[0008] By providing such a configuration it is possible that the artificial engine sound and the actual engine sound blend with each other. In particular, it is possible that the dominant order of the artificial sound blends or merges with the main firing order of the actual engine sound of the vehicle, before a virtual shifting is performed. In other words, the sound of the virtual engine and the sound of the engine of the vehicle are not distinguishable, or are at least hardly distinguishable, before the time of the virtual shifting.

[0009] The main firing order m of an engine is equal to the number of cylinders n divided by two, i.e. $m=n/2$. For example, if an engine comprises 4 cylinders, its main firing order is 2. It shall be noted that the main firing order of the engine sound of the vehicle can also be referred to as the dominant order of said engine sound. Vice versa, the dominant order of the artificial engine sound can also be referred to as the main firing order of the virtual engine. The different terms as used above merely serve for an easier discrimination between the artificial sound of the virtual engine and the actual sound of the real engine.

10 [0010] Preferably, the dominant order of the artificial sound is set to be smaller than a main firing order of the actual engine sound of the vehicle.

[0011] By providing such a configuration, the dominant order of the artificial sound can converge to the main firing order of the actual engine sound by increasing its frequency and match at its frequency maximum with the frequency of the main firing order of the actual engine sound. Alternatively, it is also possible that the dominant order of the artificial sound is set to be equal to or greater than a main firing order of the actual engine sound of the vehicle. In these cases, in particular, if the dominant order of the artificial sound is set to be greater than the main firing order of the actual engine sound, the frequency maximum may be determined such that the dominant order of the artificial engine sound blends at the frequency maximum with the the nearest, above lying harmonic of the main firing order of the actual engine sound.

20 [0012] Advantageously, the dominant order of the artificial engine sound is the closest smaller order with respect to the main firing order of the actual engine sound of the vehicle. In particular it may be a half order or one order smaller than the main firing order of the actual engine sound.

[0013] In this way, the dominant order of the artificial engine sound can be relatively close to the main firing order of the actual engine sound of the vehicle, so that their frequency levels differ generally less. At the same time the dominant order of the artificial engine sound can mimic an acceleration sound thereby increasing its frequency and converting to the constant frequency of the main firing order of the actual engine sound, until it matches with the main firing order of the actual engine sound, before the virtual shifting is performed. Consequently, it is preferable that during acceleration of

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the vehicle the frequency of the dominant order of the artificial sound is increased until a predetermined frequency maximum, before the virtual shifting is performed.

[0014] The dominant order of the artificial engine sound may depend on the cylinder configuration, in particular on the number of cylinders of the vehicle.

[0015] In particular, the dominant order of the artificial engine sound may be determined by the equation $d=(n/2)-0.5$, wherein d is the dominant order of the artificial engine sound and n is the number of cylinders of the vehicle.

[0016] In such a configuration, the dominant order of the artificial engine sound is a half order smaller than the main firing order of the actual engine sound.

[0017] For example, in case the engine of the vehicle has 4 cylinders, the main firing order of the engine sound is 2. In this case the dominant order of the artificial engine sound is preferably 1.5. In other words the virtual engine comprises preferably 3 virtual cylinders.

[0018] As another example, in case the engine of the vehicle has 5 cylinders, the main firing order of the engine sound is 2.5. In this case the dominant order of the artificial engine sound is preferably 2. In other words the virtual engine comprises preferably 4 virtual cylinders.

[0019] As still another example, in case the engine of the vehicle has 6 cylinders, the main firing order of the engine sound is 3. In this case the dominant order of the artificial engine sound is preferably 2.5. In other words the virtual engine comprises preferably 5 virtual cylinders. Alternatively, the dominant order of the artificial engine sound may also be 2. In other words the virtual engine may also comprise 4 virtual cylinders. Hence, the dominant order of the artificial engine sound may alternatively be determined by the equation $d=(n/2)-1$.

[0020] The dominant order of the generated active sound may additionally depend on the engine type of the virtual vehicle, in particular its virtual cylinder configuration and/or its number of virtual cylinders.

[0021] Hence, it is possible to design a specific virtual engine and a corresponding artificial sound of the virtual engine, which mimics a certain engine type, e.g. a specific cylinder configuration.

[0022] The manual shift pattern of the virtual engine may comprise substantially a sawtooth profile. In particular, during acceleration of the vehicle the successive sawteeth of the manual shift pattern may be increasingly lengthened in time. Hence, the artificial engine sound can
5 optimally mimic the acceleration sound of a vehicle with a fixed gear transmission.

[0023] During the acceleration of the engine of vehicle, the artificial engine sound may blend with the actual engine sound, such that the frequency of the dominant order of the artificial engine sound matches the frequency
10 progression of the equal order of the actual engine sound. This blending is preferably performed until the saturation of the acceleration of the engine starts, e.g. at least until the engine reaches 70%, 80% or 90% of its constant saturated rpm. The equal order of the actual engine sound advantageously has the same order number as the dominant order of the artificial engine
15 sound, e.g. in case the dominant order of the artificial engine sound is 1.5 the equal order of the actual engine sound is also 1.5.

[0024] In other words, during acceleration of the engine of the vehicle and preferably before the start of saturation of the constant saturated rotation per minute (rpm), the frequency of at least the dominant order, preferably of all
20 orders, of the artificial engine sound may harmonically follow the frequency progression of the respectively equal orders of the actual sound generated by the engine of the vehicle.

[0025] Hence, it is impossible or at least almost impossible for the customer to distinguish between the artificial engine sound and the actual
25 engine sound during acceleration of the engine of the vehicle.

[0026] Furthermore, when the saturation of the engine acceleration starts, i.e. when the engine starts saturating toward the constant saturated rotation per minute (rpm), the frequency of the dominant order of the artificial engine sound may increase until reaching the frequency maximum, in particular in a
30 substantially linear slope. Preferably, the frequency of all orders of the artificial engine sound increase up to their respective frequency maxima, in particular in a substantially linear slope.

[0027] By this configuration it is possible to superimpose the annoying constant saturated engine sound of the actual engine by the artificial engine
35 sound, which mimics an acceleration of the virtual engine.

[0028] After reaching the frequency maximum, the frequency of the dominant order may be lowered to blend with the equal order of the actual engine sound. Preferably, the frequencies of all orders are lowered to blend with the respective equal orders of the actual engine sound.

5 [0029] By this configuration, it is possible to mimic a shifting of the virtual engine.

[0030] The invention further refers to a sound system for a vehicle with an engine. The engine is preferably operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle. The sound system
10 comprises at least one cabin speaker and/or at least one electromagnetic shaker to generate an artificial engine sound. The sound system further comprises a control device as described above.

[0031] The invention additionally refers to a vehicle, which comprises an engine, which is preferably operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle, and a sound system as
15 described above.

[0032] The vehicle preferably comprises a stepless transmission configured such that the engine is operated at the constant saturated rotation per minute (rpm). Such a stepless transmission may be a continuously variable
20 transmission (CVT) or a planetary gearbox transmission configured for a stepless transmission.

[0033] Moreover the invention refers to a method of generating an artificial engine sound for a vehicle with an engine. The engine is operated with a constant saturated rotation per minute (rpm) during acceleration of the
25 vehicle. In the method the artificial engine sound is generated, which corresponds to a step shift pattern of a virtual engine with a fixed gear transmission. The artificial engine sound comprises one or more orders which are superimposed on the orders of the actual engine sound generated by the engine of the vehicle. The frequency of a dominant order of the artificial
30 engine sound is increased until a frequency maximum, before a virtual up-shift is performed. The dominant order of the artificial engine sound blends at the frequency maximum with the main firing order of the actual engine sound or with one of its harmonics

[0034] Preferably the method also comprises any one of the steps, which
35 may be carried out by the control device, as described above.

[0035] It is intended that combinations of the above-described elements and those within the specification may be made, except where otherwise contradictory.

5 [0036] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.

[0037] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the disclosure and together with the description, serve to explain the principles thereof.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0038] Fig. 1 shows a schematic representation of a vehicle comprising a control device according to an embodiment of the present disclosure;

15 [0039] Fig. 2 shows a schematic diagram of a step shift pattern according to an embodiment of the present disclosure, wherein one order is shown;

[0040] Fig. 3 shows a schematic diagram of a step shift pattern according to an embodiment of the present disclosure, wherein a plurality of orders is shown;

20 [0041] Fig. 4 shows a table of the parameters represented by the diagram of fig. 3.

DESCRIPTION OF THE EMBODIMENTS

25 [0042] Reference will now be made in detail to exemplary embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0043] Fig. 1 shows a schematic representation of a vehicle 10 comprising
30 a control device 1 according to an embodiment of the present disclosure. The vehicle 10 may be a hybrid vehicle. The vehicle 10 comprises an engine 3, which includes preferably an internal combustion engine. Alternatively or additionally the engine 3 may be a hybrid engine. The vehicle 10 further comprises a continuously variable transmission (CVT) 4. Instead of the CVT,
35 the vehicle 10 may also comprise another type of a stepless transmission, as

e.g. a respective planetary gearbox transmission. The CVT 4 is connected to the engine 3. The CVT 4 and the engine 3 are comprised by a drivetrain 11 of the vehicle. Due to the CVT, the engine 3 can be operated with a constant saturated rotation per minute (rpm) during acceleration of the vehicle 10. The engine 3 and the CVT 4 are connected to a vehicle bus 2, which controls the engine 3 and the CVT 4 by transmitting control signals to the engine 3 and the CVT 4 and receiving measuring signals from the engine 3 and/or the CVT 4. For this purpose the vehicle bus may be connected to or comprise a central control unit, such as an electronic control unit (ECU) (not shown).

10 [0044] The control device 1 is connected to the CVT 4 and the engine 3, preferably via the vehicle bus 2. The control device 1 may also be connected to the central control unit (not shown) of the vehicle or may constitute said central control unit.

15 [0045] The control device preferably receives operating conditions of the vehicle, in particular of the engine 3 and/or the CVT 4, such as the current rotation per minute (rpm) of the engine, the vehicle speed, the engine speed, the engine torque, the accelerator pedal position, the vehicle acceleration, and/or the transmission state of the CVT 4.

20 [0046] Moreover the control device may be connected to or may comprise a memory (not shown). The memory may store operating parameters of a virtual engine, whose artificial engine sound is simulated by the control device 1. In particular, these operating parameters of the virtual engine may include the virtual engine type, the number of virtual cylinders and the virtual cylinder configuration of the virtual engine, the rpm range and/or the acceleration characteristics of the virtual engine. Additionally or alternatively said operating parameters may include the sound frequency progression profiles of the virtual engine, as they are described below in context of fig. 2 to 4, especially the orders of the artificial engine sound. Hence, said operating parameters may also include information regarding the dominant order, i.e. the main firing order of the virtual engine.

30 [0047] The memory may additionally store operating parameters of a virtual fixed gear transmission. In particular, the virtual fixed gear transmission may be any type of fixed gear transmission that upshifts from a lower gear to a higher gear based on operating conditions of the virtual engine, or downshifts from a higher gear to a lower gear. The virtual fixed

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gear transmission may be e.g. a five-speed or a six-speed automatic transmission. Accordingly, said operating parameters may include the number of virtual gears and information regarding the sound characteristics when the upshifts or downshifts are performed.

5 [0048] The control device 1 may comprise an application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), a combinational logic circuit, a memory that executes one or more software programs, and/or other suitable components that provide the described functionality.

10 [0049] The control device 1 is further connected to a sound-system 9. The control device 1 controls the sound-system 9 such that it outputs the artificial engine sound of the virtual engine. The sound-system 9 may comprise a cabin speaker system 5 and/or at least one electromagnetic shaker 7. The cabin speaker system 5 may comprise an amplifier 6 and one or more speakers 7.

15 The electromagnetic shakers 8 may be attached to the fire wall of the vehicle.

[0050] Fig. 2 shows a schematic diagram of a step shift pattern according to an embodiment of the present disclosure, wherein one order is shown. Accordingly, fig. 2 shows one order (e.g. the 1.5th order) of the actual engine sound (indicated as dashed line), when the vehicle is accelerated from zero

20 km/h. Fig. 2 also shows the corresponding (i.e. equal) order (i.e. of the same order number, thus e.g. the 1.5th order) of the artificial engine sound of the virtual engine (indicated as continuous line). However, even if only one order is shown, the principles described in context of fig. 2 are applicable to a plurality or all orders of the actual engine sound and the artificial engine

25 sound.

[0051] The diagram of fig. 2 indicates the rotations per minute (rpm) on its y-axis and the time on its x-axis. Since the frequency is dependent on the rpm, the diagram also indicates the frequency progression of one order of the actual engine sound and the frequency progression profile of the

30 corresponding order of the artificial sound.

[0052] At the time $t=0$, i.e. when the vehicle starts moving and accelerates, the artificial sound follows the actual engine sound, until a saturation of the engine acceleration begins (in fig. 2 at the time t_s). The saturation of the engine (i.e. the saturation frequency f_s) may be e.g. at 5415

35 rpm. In particular, before the start of saturation of the engine acceleration,

the frequency of the order of the artificial engine sound may harmonically follow the frequency progression of the equal order of the actual sound generated by the engine of the vehicle.

[0053] From the start of saturation, the artificial engine sound follows a step shift pattern, which may correspond substantially to a sawtooth profile. In particular, the order of the artificial engine sound increases, e.g. substantially linearly, until it reaches a frequency maximum $f_{\max}$ and thus a maximum rpm of the virtual engine, e.g. at 7220 rpm. In this way the artificial engine sound can mimic a further acceleration of the virtual engine. The frequency maximum $f_{\max}$ may correspond to the saturation frequency of the next higher order of the actual engine sound, as it is described in more detail in context of fig. 3 and 4.

[0054] The frequency maximum $f_{\max}$ may be a predetermined frequency maximum $f_{\max}$, i.e. it may be stored in memory of the control device 1. Alternatively it may be determined based on engine parameters, e.g. based on the current rpm of the engine.

[0055] After reaching $f_{\max}$ (at the time $t_{f_{\max}}$) the order of the artificial engine sound returns again to the saturation frequency f_s of the same order of the actual engine sound. This maneuver can mimic a fixed gearbox upshift. After the upshift maneuver, the active sound converges again to $f_{\max}$ (starting at the time t_{fs}). Depending on the duration of the total acceleration, additional upshifts will be played until the end of the acceleration. Preferably subsequent upshifts, i.e. the successive sawteeth of the step shift pattern, are increasingly lengthened in time. In case the acceleration is stopped (i.e. the accelerator pedal is released) during a virtual step shift acceleration, the virtual engine rpm will drop back to the actual engine rpm and follows its further time profile.

[0056] Fig. 3 shows a schematic diagram of a step shift pattern according to an embodiment of the present disclosure, wherein a plurality of orders are shown. The diagram is an acoustic waterfall representation indicating sound frequency vs time.

[0057] In the exemplary embodiment of Fig. 3 the vehicle comprises a motor with $n = 4$ cylinders. Accordingly, its main firing order is $m = n/2 = 2$. In other words the 2nd order is the main firing order, i.e. the dominant order of the actual engine sound of the vehicle.

[0058] The dominant order of the artificial engine sound of the virtual engine is smaller than the main firing order of the actual engine sound of the vehicle. Preferably, the dominant order of the artificial engine sound is $d = n/2 - 0.5 = 1.5$. In other words the 1.5th order is the dominant order of the artificial engine sound, i.e. the main firing order of the virtual engine.

[0059] Fig. 3 shows seven orders of the actual engine sound (indicated as dashed lines), i.e. its 1.5th order a1.5, its 2nd order a2 (which is in this exemplary embodiment the main firing order of the actual engine sound), its 3rd order a3, its 4th order a4 (which is the 2nd harmonic of the main firing order), its 6th order a6 (which is the 3rd harmonic of the main firing order), its 8th order a8 (which is the 4th harmonic of the main firing order), and its 12th order a12 (which is the 6th harmonic of the main firing order).

[0060] Furthermore, Fig. 3 shows eight orders of the artificial engine sound of the virtual engine (indicated as continuous lines), i.e. its 1.5th order v1.5 (which is in this exemplary embodiment the dominant order of the artificial engine sound), its 2nd order v2, its 3rd order v3 (which is the 2nd harmonic of the dominant order), its 4th order v4, its 4.5th order v4.5 (which is the 3rd harmonic of the dominant order), its 6th order v6 (which is the 4th harmonic of the dominant order), its 8th order v8, and its 9th order v9 (which is the 6th harmonic of the dominant order).

[0061] As illustrated in fig. 3, during acceleration of the engine of the vehicle and before the start of engine acceleration saturation there is a frequency matching between the orders of the artificial engine sound and the respective orders of the actual engine sound, e.g. of the 1.5th order v1.5 of the artificial engine sound and the respective 1.5th order a1.5 of the actual engine sound, etc.

[0062] Once the actual engine rpm starts to saturate, the artificial engine sound can start the step shift pattern, increasing the artificial engine sound rpm until a frequency maximum is reached (in fig. 3 app. at $t=9s$). At the frequency maximum the dominant order v1.5 of the artificial engine sound and its higher harmonic orders v3, v4.5, v6, v9 etc. match with the main firing order a2 of the actual engine sound and its higher harmonic orders a4, a6, a8, a12 etc., respectively. Hence, at this time, when the artificial engine sound appears to have its volume maximum (i.e. to be loudest), the dominant order of the artificial engine sound and the main firing order of the actual engine

sound blend have the same frequency, i.e. they blend with each other. Moreover, also the harmonics of the artificial engine sound and the harmonics of the actual engine sound have the same frequencies. Since furthermore the dominant order and its harmonics are the loudest frequencies, the artificial engine sound and the actual engine sound can optimally merge at that time, before the virtual up-shift is performed.

[0063] Fig. 4 shows a table of the parameters represented by the diagram of fig. 3. In this exemplary embodiment the vehicle is equipped with a 4 cylinder engine (with main firing order 2). Accordingly, the virtual engine comprises 3 virtual cylinders. The control device therefore generates an artificial engine sound with the dominant order 1.5.

[0064] Given that the actual 4 cylinder engine is saturating at 5415rpm during a certain acceleration maneuver, the artificial engine sound of the virtual 3 cylinder engine will need to converge to a calculated harmonic max rpm of 7220rpm to achieve the best blending between the actual engine sound and the artificial engine sound.

[0065] As it can be seen in fig. 4, there is a frequency matching between the frequency maximum of the dominant order (and its harmonics) of the artificial engine sound and the main firing order (and its harmonics) of the saturated engine sound of the actual engine. For example the frequency maximum of the dominant order of the virtual engine at 7220 rpm is $f_{\max} = 7220 \cdot 1.5 / 60 = 180.5$ Hz, what corresponds to the frequency of the main firing order of the actual saturated engine at 5415 rpm. Hence, the dominant order of the artificial sound can blend at its frequency maximum $f_{\max}$ with the main firing order of the actual engine sound of the vehicle.

[0066] It should be understood that the invention is not necessarily limited to the scenario that the generated artificial engine sound comprises only one dominant order. In case the artificial engine sound comprises more than one dominant order, at least one of its dominant orders shall be set to be smaller than the main firing order of the actual engine sound.

[0067] Throughout the disclosure, including the claims, the term "comprising a" should be understood as being synonymous with "comprising at least one" unless otherwise stated. In addition, any range set forth in the description, including the claims should be understood as including its end value(s) unless otherwise stated. Specific values for described elements

should be understood to be within accepted manufacturing or industry tolerances known to one of skill in the art, and any use of the terms "substantially" and/or "approximately" and/or "generally" should be understood to mean falling within such accepted tolerances.

- 5 [0068] Where any standards of national, international, or other standards body are referenced (e.g., ISO, etc.), such references are intended to refer to the standard as defined by the national or international standards body as of the priority date of the present specification. Any subsequent substantive changes to such standards are not intended to modify the scope and/or
- 10 definitions of the present disclosure and/or claims.

[0069] Although the present disclosure herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present disclosure.

- 15 [0070] It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims.

CLAIMS

1. A control device for a sound-system of a vehicle with an engine, the engine being operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle,
5 the control device being configured to control the sound-system to generate an artificial engine sound corresponding to a step shift pattern of a virtual engine with a fixed gear transmission,
the artificial engine sound comprising one or more orders which are
10 superimposed on the orders of the actual engine sound generated by the engine of the vehicle,
wherein the frequency of a dominant order of the artificial engine sound is increased until a frequency maximum, before a virtual up-shift is performed, and
15 wherein the dominant order of the artificial engine sound blends at the frequency maximum with the main firing order of the actual engine sound or with one of its harmonics.
2. The control device according to claim 1, wherein
20 the dominant order of the artificial engine sound is set to be smaller than the main firing order of the actual engine sound.
3. The control device according to claim 1 or 2, wherein
the dominant order of the artificial engine sound is the closest
25 smaller order with respect to the main firing order of the actual engine sound, in particular a half order or one order smaller than the main firing order of the actual engine sound.
4. The control device according to any one of the preceding claims,
30 wherein
the dominant order of the artificial engine sound depends on the cylinder configuration of the vehicle, in particular on the number of cylinders of the vehicle.

5. The control device according to any one of the preceding claims, wherein
the dominant order of the artificial engine sound is determined by the equation $d=(n/2)-0.5$, wherein d is the dominant order of the artificial engine sound and n is the number of cylinders of the engine of the vehicle.
6. The control device according to any one of the preceding claims, wherein
the dominant order of the artificial engine sound additionally depends on the engine type of the virtual engine, in particular its virtual cylinder configuration and/or its number of virtual cylinders.
7. The control device according to any one of the preceding claims, wherein
the step shift pattern of the virtual engine presents substantially a sawtooth profile, wherein during acceleration of the vehicle the successive sawteeth of the step shift pattern are increasingly lengthened in time.
8. The control device according to any one of the preceding claims, wherein
during acceleration of the engine of vehicle, the artificial engine sound blends with the actual engine sound, such that the frequency of the dominant order of the artificial engine sound matches the frequency progression of the equal order of the actual engine sound.
9. The control device according to any one of the preceding claims, wherein,
when the saturation of the engine acceleration starts, the frequency of the dominant order of the artificial engine sound increases until reaching the frequency maximum.
10. The control device according to any one of the preceding claims, wherein

after reaching the frequency maximum, the frequency of the dominant order is lowered to blend with the equal order of the actual engine sound.

5 11. A sound system for a vehicle with an engine, the engine being operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle, comprising:

a speaker system and/or at least one electromagnetic shaker to generate an artificial engine sound, and
10 the control device according to any one of the preceding claims.

12. A vehicle comprising:
an engine operable with a constant saturated rotation per minute (rpm) during acceleration of the vehicle, and
15 a sound system according to the claim 12.

13. The vehicle according to claim 12, further comprising:
a stepless transmission configured such that the engine is operable at the constant saturated rotation per minute (rpm).

20 14. A method of generating an artificial engine sound for a vehicle with an engine, the engine being operated with a constant saturated rotation per minute (rpm) during acceleration of the vehicle, the method comprising the following steps:

25 generating the artificial engine sound, which corresponds to a step shift pattern of a virtual engine with a fixed gear transmission and which comprises one or more orders which are superimposed on the orders of the actual engine sound generated by the engine of the vehicle,
increasing the frequency of a dominant order of the artificial engine
30 sound until a frequency maximum, before performing a virtual up-shift, and
blending the dominant order of the artificial engine sound at the frequency maximum with the main firing order of the actual engine sound or with one of its harmonics.

35 15. The method according to claim 14, wherein

the dominant order of the artificial engine sound is set to be smaller than the main firing order of the actual engine sound.

16. The method according to claim 14 or 15, wherein
5 the dominant order of the artificial engine sound is the closest smaller order with respect to the main firing order of the actual engine sound, in particular a half order or one order smaller than the main firing order of the actual engine sound.
- 10 17. The method according to any one of the claims 14-16, wherein the dominant order of the artificial engine sound depends on the cylinder configuration of the vehicle, in particular on the number of cylinders of the vehicle.
- 15 18. The method according to any one of the claims 14-17, wherein the dominant order of the artificial engine sound is determined by the equation $d=(n/2)-0.5$, wherein d is the dominant order of the artificial engine sound and n is the number of cylinders of the engine of the vehicle.
- 20 19. The method according to any one of the claims 14-18, wherein the dominant order of the artificial engine sound additionally depends on the engine type of the virtual engine, in particular its virtual cylinder configuration and/or its number of virtual cylinders.
- 25 20. The method according to any one of the claims 14-19, wherein the step shift pattern of the virtual engine presents substantially a sawtooth profile, wherein during acceleration of the vehicle the successive sawteeth of the step shift pattern are increasingly lengthened in time.
- 30 21. The method according to any one of the claims 14-20, wherein during acceleration of the engine of vehicle, the artificial engine sound blends with the actual engine sound, such that the frequency of the dominant order of the artificial engine sound matches the frequency progression of the equal order of the actual engine sound.

22. The method according to any one of the claims 14-21, wherein, when the saturation of the engine acceleration starts, the frequency of the dominant order of the artificial engine sound increases until reaching the frequency maximum.

5

23. The method according to any one of the claims 14-22, wherein after reaching the frequency maximum, the frequency of the dominant order is lowered to blend with the equal order of the actual engine sound.

10

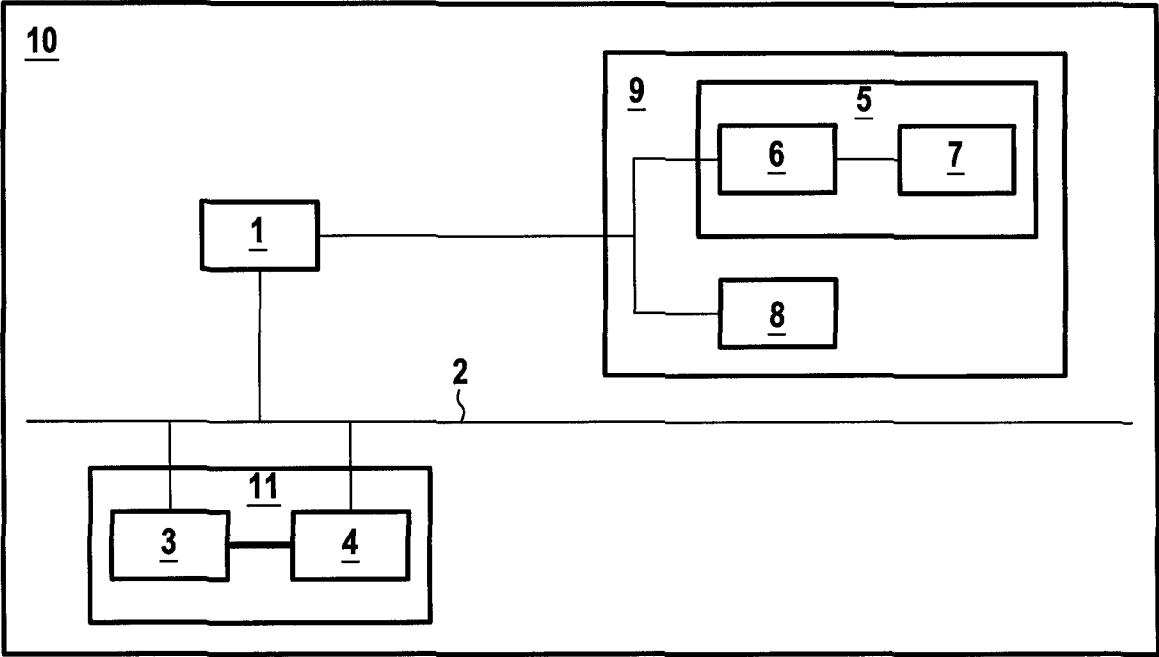


FIG.1

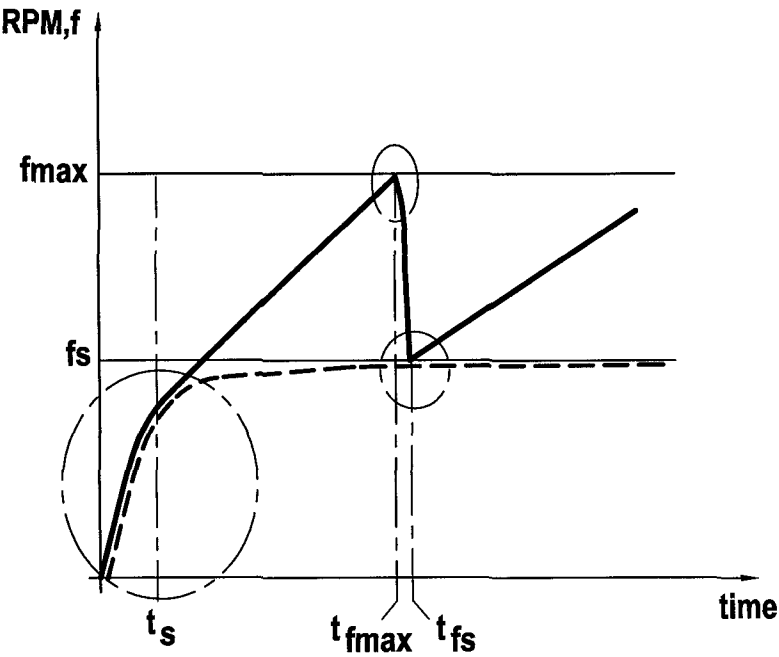


FIG.2

2/2

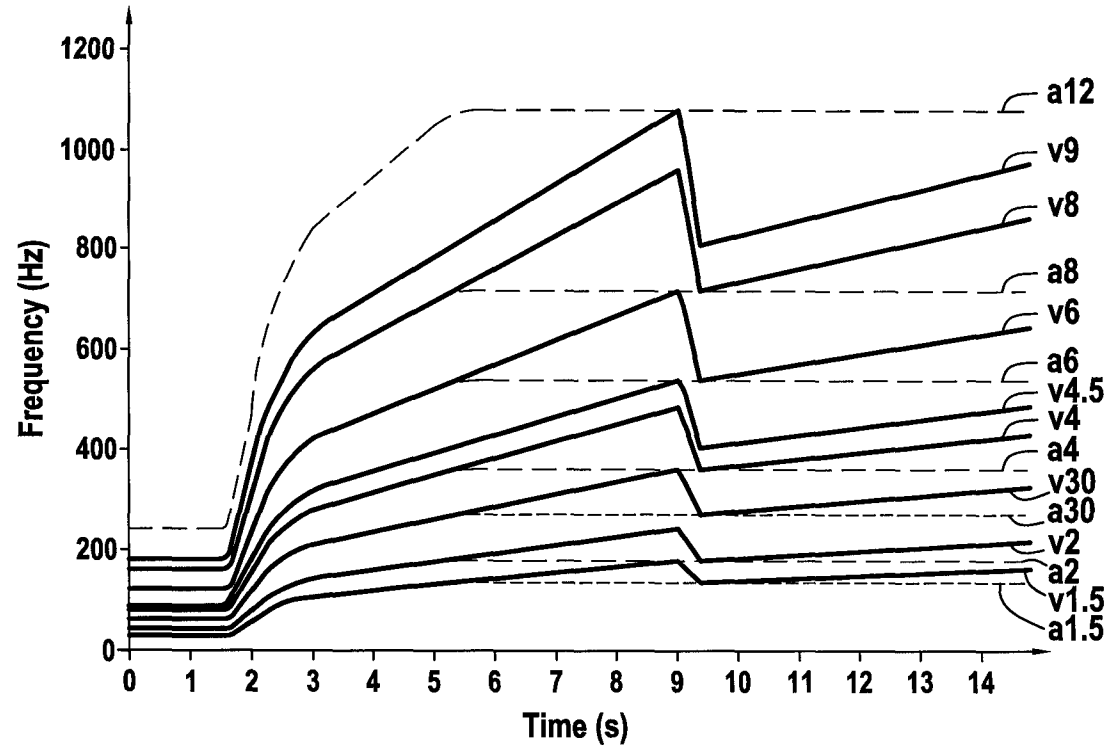


FIG.3

		Engine order sound frequency (Hz)					
		1.50	2.00	3.00	4.00	6.00	8.00
		Artificial stepshift	Actual saturated	Artificial stepshift	Actual saturated	Artificial stepshift	Actual saturated
RPM	1500	37.50	50.00	75.00	100.00	150.00	200.00
	3500	87.50	116.67	175.00	233.33	350.00	466.67
	5415	135.38	180.50	270.75	361.00	541.50	722.00
	7220	180.50		361.00		722.00	

FIG.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/074151

A. CLASSIFICATION OF SUBJECT MATTER
INV. G10K15/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G10K B60W B60Q H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/294619 A1 (VALERI FRANK C [US] ET AL) 7 November 2013 (2013-11-07) abstract figures 1-3 paragraphs [0001], [0016], [0020] - [0023] claims 1-20	1-23
A	US 2014/121896 A1 (VALERI FRANK C [US] ET AL) 1 May 2014 (2014-05-01) abstract figures 1-6 paragraphs [0001], [0022] - [0032]	1-23
A	US 2015/016627 A1 (BARLOW JR ROGER C [US] ET AL) 15 January 2015 (2015-01-15) figures 1,2 paragraphs [0023] - [0025]	1-23
	- / - -	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

23 June 2016

Date of mailing of the international search report

12/07/2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/074151

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No

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