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(54) Title: INFINITE VARIABLE TRANSMISSION WITH PLANETARY GEAR SET

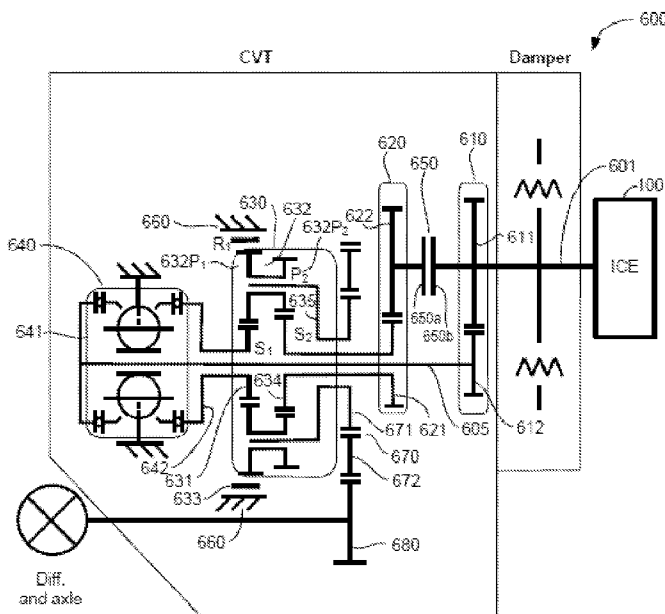


FIG. 6

610 Up-speed Ratio
620 Second Sun Ratio
630 Compound planetary
640 CVT
650 Input Coupling clutch
660 Ring brake clutch

(57) Abstract: A variable transmission includes various powerpath layouts comprising a dual mode with each mode being selected by closing a clutch/brake and releasing the other simultaneously. A first mode contains a powered neutral through a powersplit configuration. A second mode is a direct mode through the CVP. The configuration typically provides a maximum forward speed slightly higher than the negative speeds, a feature that is present in many applications such as premium forklifts. Modifications of ratios in the gears and planetary sets provide different forward and reverse speed, allowing the use of these configurations in different applications. It is also possible to change this feature by limiting the ratios achievable in the CVP.



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INFINITE VARIABLE TRANSMISSION USING VARIABLE TRANSMISSION WITH PLANETARY GEAR SET

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] The present application claims the benefit of US Provisional Patent Application Serial No. 61/905,732, filed November 18, 2013, US Provisional Patent Application Serial No. 62/004,756, filed May 29, 2014, and US Provisional Patent Application Serial No. 62/004,767, filed May 29, 2014 which applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Automatic and manual transmissions are commonly used on automobile vehicles. Those transmissions are becoming more and more complicated since the engine speed has to be more precisely controlled to limit the fuel consumption and the emissions of cars. This finer control of the engine speed in usual transmissions can only be done by adding more discrete step ratio gears and increasing the overall complexity and cost. Consequently, 6- speed manual transmissions then become more frequently used as are 8 or 9 speed automatic transmissions.

SUMMARY OF THE INVENTION

[0003] The present invention relates to various powerpath layouts consisting in dual modes. The maximum reverse speed is typically close to the forward speed, but the dual mode is intended to provide a slightly higher forward speed, while gaining in efficiency. These configurations might be used for forklift trucks that typically drive in forward and in reverse, but might also be used for other applications. Additionally, the speed characteristic of these configurations is only due to the particular gear ratios chosen. A different set of gear ratios might provide different forward and reverse speed while keeping the same configuration, allowing it to be used in other applications.

Configuration 1, Layout 1

[0004] Provided herein is a variable transmission comprising an input shaft comprising a first gear coupled to a second gear of a first gear set; the first gear set comprising the first gear and a second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a first sun of a compound planetary gear set; a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear; the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second sun drivingly engaged to

a third gear of a second gear set; the second gear set comprising the third gear and a fourth gear; the third gear drivingly engaged to the fourth gear and the fourth gear coupled to a first portion of a second clutch on the input shaft; the clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to the first gear on the input shaft and the ICE; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to an output gear; wherein the output gear is drivingly engaged to the output of the transmission.

[0005] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a down-speed ratio.

[0006] In some embodiments, the second clutch is an input coupling clutch.

[0007] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged mode when the input coupling is engaged.

[0008] In some embodiments, the braking clutch engages the direct forward mode when the ring goes to zero speed. In some embodiments, the output gear reverses the carrier output.

Configuration 1, Layout 2

[0009] Provided herein is a variable transmission comprising an input shaft comprising a first gear of a first gear set; the first gear set comprising the first gear and a second gear, the first gear drivingly engaged to the second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a third gear of a second gear set; the second gear set comprising the third gear and a fourth gear; the fourth gear drivingly engaged to a first sun of a planetary gear set; a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear; the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second sun drivingly engaged to a first portion of a second clutch; the second clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to a fifth gear of a third gear set; the third gear set comprising the fifth gear and a sixth gear; the fifth gear drivingly engaged to the sixth gear which is coupled to the offset shaft; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to an output gear; wherein the output gear is drivingly engaged to the output of the transmission.

[0010] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a carrier ratio.

[0011] In some embodiments, the second clutch is an input coupling clutch. In some embodiments, the transmission is in reverse mode when the input coupling is engaged.

Configuration 1, Layout 3

[0012] Provided herein is a variable transmission comprising an input shaft comprising a first gear coupled to a second gear of a first gear set; the first gear set comprising the first gear and a second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a common sun of a compound planetary gear set; a first set of planet gears is coupled to the common sun and is drivingly engaged to a first ring and a first carrier; the first carrier is drivingly engaged to a third gear; a second gear set comprising the third gear and a fourth gear; the third gear drivingly engaged to the fourth gear and the fourth gear coupled to a first portion of a second clutch on the input shaft; the clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to the first gear on the input shaft and the ICE; a second set of planet gears is coupled to the common sun and is drivingly engaged to a second ring and a second carrier; a braking clutch coupled to the second ring gear; the second carrier and the first ring are connected to an output gear; wherein the output gear is drivingly engaged to the output of the transmission.

[0013] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a down-speed ratio.

[0014] In some embodiments, the second clutch is an input coupling clutch. In some embodiments, the first carrier is connected to the ICE when the input coupling clutch is engaged.

[0015] In some embodiments, the reverse mode is engaged mode when the input coupling is engaged.

[0016] In some embodiments, the braking clutch engages the direct forward mode when the second ring goes to zero speed. In some embodiments, the output gear reverses the second carrier output.

Configuration 2, Layout 1

[0017] Provided herein is a variable transmission comprising an input shaft comprising a first gear coupled to a second gear of a first gear set; the first gear set comprising the first gear and a second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a third gear of a second gear set; the second gear set comprising the third gear and a fourth gear; the fourth gear drivingly engaged to a first sun of a planetary gear set; a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear; the dual planet

gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second sun drivingly engaged to a first portion of a second clutch; the second clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to a fifth gear of a third gear set; the third gear set comprising the fifth gear and a sixth gear; the fifth gear drivingly engaged to the sixth gear which is coupled to the offset shaft; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to an output gear; wherein the output gear is drivingly engaged to the output of the transmission.

[0018] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a down-speed ratio.

[0019] In some embodiments, the second clutch is a second sun coupling clutch. In some embodiments, the second sun is connected to the ICE when the second sun coupling clutch is engaged. In some embodiments, the forward mode is engaged when the second sun coupling clutch is engaged.

[0020] In some embodiments, the braking clutch engages the direct reverse mode when the ring goes to zero speed.

Configuration 3, Layout 1:

[0021] Provided herein is a variable transmission comprising an input shaft comprising: a first gear coupled to a second gear of a first gear set; the first gear set comprising the first gear and a second gear, wherein the second gear is on an offset axle; the second gear on the offset axle is coupled to a third gear of a second gear set; the second gear set comprising the third gear and a fourth gear; the third gear is drivingly engaged to the fourth gear; a variator comprising a first ring assembly is coupled to the fourth gear, and a second ring assembly coupled to a first sun of a compound planetary gear set; a first set planet gears of a dual planet gear set is coupled to the first sun and drivingly engaged to a ring gear; the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second sun drivingly engaged to a first portion of a second clutch; the second clutch comprising the first portion and a second portion; the second portion of the second clutch is coupled to the first gear on the input shaft; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to the output of the transmission.

[0022] In some embodiments, the first gear set and second gear set are an up-speed ratio. In some embodiments, the second clutch is an input coupling clutch.

[0023] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged.

[0024] In some embodiments, the braking clutch engages the direct forward mode when the ring goes to zero speed.

Configuration 3, Layout 2:

[0025] Provided herein is a variable transmission comprising an input shaft comprising a first gear coupled to a second gear of a first gear set; the first gear set comprising the first gear and the second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a third gear of a second gear set; the second gear set comprising the third gear and a fourth gear; the fourth gear drivingly engaged to a first sun of a planetary gear set; a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear; the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second sun drivingly engaged to a first portion of a second clutch; the second clutch comprising the first portion and a second portion; the second portion of the second clutch is coupled to the first gear on the input shaft; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to the output of the transmission.

[0026] In some embodiments, the first gear set and second gear set are an up-speed ratio. In some embodiments, the second clutch is an input coupling clutch.

[0027] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged.

[0028] In some embodiments, the braking clutch engages the direct forward mode when the ring goes to zero speed.

INCORPORATION BY REFERENCE

[0029] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0031] **FIG. 1** is an illustrative side sectional view of a continuously variable planetary (CVP) transmission;

[0032] **FIG. 2** is an illustrative magnified, side sectional view of a ball and ring of the CVP transmission of **FIG. 1**;

[0033] **FIG. 3** is a block diagram of a continuously variable transmission (CVT) used in a vehicle and an off-highway (OH) drivetrain;

[0034] **FIG. 4** is a generic layout of Configuration 1, an exemplary stick diagram powerpath based on a dual mode solution, each mode being selected by closing a clutch/brake and releasing the other. The CVP is connected to the sun of the planetary on one side and to the ICE through an up-speed ratio on the other side;

[0035] **FIG. 5** is a graph of a speed diagram of Configuration 1 for Layouts 1 and 2 of the planetary gear set of the CVT of **FIG. 4**;

[0036] **FIG. 6** is a block diagram of Configuration 1 for Layout 1 of a continuously variable transmission (CVT) according to one embodiment of **FIG. 4** used in a vehicle having a dual mode solution comprising a forward mode with a direct CVP mode and a reverse mode composed of a compound coupling planetary that combines input from the ICE and from the CVP into an IVT output;

[0037] **FIG. 7** is a block diagram of Configuration 1 for Layout 2 of a continuously variable transmission (CVT) according to another embodiment of **FIG. 4** used in a vehicle having a dual mode solution comprising a forward mode with a direct CVP mode and a reverse mode composed of a compound coupling planetary that combines input from the ICE and from the CVP into an IVT output; the main difference being that the CVT and the planetary are no longer on the same shaft;

[0038] **FIG. 8** is a graph of a speed diagram of Configuration 1 for Layout 3 of the planetary gear set of the CVT of **FIG. 9**;

[0039] **FIG. 9** is a block diagram of Configuration 1 for Layout 3 of a continuously variable transmission (CVT) according to another embodiment of **FIG. 4** used in a vehicle having a dual mode solution comprising a forward mode with a direct CVP mode and a reverse mode composed of a compound coupling planetary that combines input from the ICE and from the CVP into an IVT output; the main difference being the compound planetary utilizes a common sun gear.

[0040] **FIG. 10** is another generic layout of Configuration 2, an exemplary stick diagram powerpath based on a dual mode solution, each mode being selected by closing a clutch/brake

and releasing the other. The CVP is connected to the sun of the planetary on one side and to the ICE through an up-speed ratio on the other side;

[0041] **FIG. 11** is a block diagram of Configuration 2 for Layout 1 of another continuously variable transmission (CVT) according to one embodiment of **FIG. 4** used in a vehicle having a dual mode solution. The primary difference with this configuration is that the forward and reverse modes have been interchanged.

[0042] **FIG. 12** is another generic layout of Configuration 3, an exemplary stick diagram powerpath based on a dual mode solution, each mode being selected by closing a clutch/brake and releasing the other. The CVP is connected to the sun of the planetary on one side and to the ICE through an up-speed ratio on the other side. This configuration is based on a dual mode solution similar to the one of **FIG. 4**. The main difference is that the ICE is directly engaged to the middle element of the planetary;

[0043] **FIG. 13** is a graph of a speed diagram of Configuration 3 of the planetary gear set of the CVT of **FIG. 14**;

[0044] **FIG. 14** is a block diagram of Configuration 3 for Layout 1 of a continuously variable transmission (CVT) according to one embodiment of **FIG. 12** used in a vehicle

[0045] **FIG. 15** is another variant block diagram of Configuration 3 for Layout 2 of a continuously variable transmission (CVT) according to one embodiment of **FIG. 12** used in a vehicle. In this configuration, the CVP is on a different shaft than the planetary and an optional ratio is present between the CVP and the first sun of the planetary.

DETAILED DESCRIPTION OF THE INVENTION

[0046] Continuously Variable Transmissions or CVTs are of many types: belts with variable pulleys, toroidal, and conical, for non-limiting example. The principle of a CVT is that it enables the engine to run at its most efficient rotation speed by changing steplessly the transmission ratio in function of the speed of the car and the torque demand (throttle position) of the driver. If needed for example when accelerating, the CVT can also shift to the most optimum ratio providing more power. A CVT can change the ratio from the minimum to the maximum ratio without any interruption of the power transmission, as opposed to the opposite of usual transmissions which require an interruption of the power transmission by disengaging to shift from one discrete ratio to engage the next ratio.

[0047] A specific use of CVTs is the Infinite Variable Transmission or IVT. Where the CVT is limited at positive speed ratios, the IVT configuration can perform a neutral gear and even reverse steplessly. A CVT can be used as an IVT in some driveline configurations.

[0048] Provided herein are configurations based on a ball type CVT, also known as CVP (for constant variable planetary) or a variator, herein. Aspects of an example CVT are described in US20040616399 or AU2011224083A1, incorporated herein by reference in their entirety. The type of CVT used herein is comprised a variator comprising a plurality of variator balls **997** as shown in **FIG. 1**, depending on the application, two discs (input disc **995** and output disc **996**) or annular rings (i.e. a first ring assembly and a second ring assembly) each having an engagement portion that engages the variator balls **997**. The engagement portions may be in a conical or toroidal convex or concave surface contact with the variator balls **997**, as input and output. The variator may include an idler **999** contacting the balls **997** as well as shown on **FIG. 1**. The variator balls **997** are mounted on axes **998**, themselves held in a cage or carrier allowing changing the ratio by tilting the variator balls' axes **998**. Other types of ball CVTs also exist like the one produced by Milner but are slightly different. These alternative ball CVTs are additionally contemplated herein. The working principle generally speaking, of a ball-type variator of a CVT is shown in **FIG. 2**.

[0049] The variator itself works with a traction fluid. The lubricant between the ball and the conical rings acts as a solid at high pressure, transferring the power from the first ring assembly, through the variator balls, to the second ring assembly. By tilting the variator balls' axes, the ratio can be changed between input and output. When the axis of each of the variator balls is horizontal the ratio is one, when the axis is tilted the distances between the axis and the contact points change, modifying the overall ratio. All the variator balls' axes are tilted at the same time with a mechanism included in the cage.

[0050] As in a car **300**, the CVT **301** is used to replace the traditional transmission and is located between the engine **100** (ICE or internal combustion engine) and the differential **304** as shown in **FIG. 3**. In a typical drivetrain for an Off-Highway (OH) vehicle, a torsional damper **302** (alternatively called a damper) may be introduced between the engine **100** and the CVT **301** to avoid transferring torque peaks and vibrations that could seriously damage the variator **301**. In some configurations this damper **302** can be coupled with a clutch **303** for the starting function or to allow the engine to be decoupled from the transmission. Other types of CVT's (apart from ball-type traction drives) can also be used as the variator.

[0051] In addition to the configurations described, where the variator is used directly as the primary transmission, other architectures are possible. Various powerpath layouts can be introduced by adding a number of gears, clutches and simple or compound planetary gear sets. In such configurations, the overall transmission can provide several operating modes; a CVT, an IVT, a combined mode and so on.

[0052] Introduced within this specification are different layouts based on a similar working principle of using a planetary connected to the ICE and the CVP to allow powersplitting. They all have a direct drive mode as well as a power recirculation mode allowing zero and low speed. Several examples of architectures are proposed, but the invention is not restricted to these examples and it is assumed that all the layouts that perform similarly to the speed diagrams and generic layouts are part of the invention as well.

[0053] This coupling allows having a better efficiency in one part of the output range, typically the forward part, due to the powersplitting. Additionally, these configurations and their different layouts provide a powered neutral ratio. The spread given through them is sufficient to allow the engine to operate at more optimal points, providing fuel economy, while keeping the same vehicle operating speeds.

[0054] These configurations typically provide a symmetrical range of positive and negative speeds, a feature that is present in many applications such as forklifts. However, modifications of ratios in the gears and planetary gear sets might provide different forward and reverse speed, allowing the use of these configurations in different applications.

[0055] The present invention relates to various powerpath layouts consisting in dual modes. The maximum reverse speed is typically close to the maximum forward speed, but the dual mode is intended to provide a slightly higher forward speed, while gaining in efficiency. These configurations might be used for forklifts trucks that typically drive in forward and in reverse, but might also be used for other applications. Additionally, the speed characteristic of these configurations is only due to the particular gear ratios chosen. A different set of gear ratios might provide different forward and reverse speed while keeping the same configuration, allowing it to be used in other applications.

Configuration 1, Layout 1

[0056] This configuration is based on a dual mode solution, each mode being selected by closing a clutch/brake and releasing the other. The forward mode is a direct CVP mode, engaged by braking an element of the planetary. The planetary gear set wherein an element is braked at zero speed will act as a simple gear ratio. The reverse mode (also providing low forward speeds) is composed of a compound coupling planetary that combines input from the ICE and from the CVP into an IVT output. The CVP is connected to the bottom element of the planetary (when drawing the compound planetary speed diagram) on one side and to the ICE on the other side through an up-speed ratio.

This up-speed ratio tends to increase the speeds and decrease the torque acting on the CVP, allowing for a decrease in the variator size. The ICE is also connected to a middle element of the

planetary through a ratio in the reverse mode. It should be noted that the naming of the modes as Forward and Reverse is arbitrarily made and in this case, the reverse mode also provides low forward speeds as well as a powered neutral. However, as this mode covers the whole reverse speed range it has been named Reverse. An optional speed ratio between the CVP and the planetary could also be present.

[0057] As illustrated in the non-limiting **FIG. 4**, the central part of this configuration is the variator described previously. A ball ramp on each side of the variator provides the clamping force necessary to transfer the torque. Thanks to the planetary, the configuration uses only a CVP and is able to provide standstill and reverse function as an IVP. No starting device like a slipping clutch or torque converter is required, since the IVP capability addresses the starting function. However, these devices can be added to allow a safety disconnect or to start the engine. The ratio after the planetary is there to ensure that the maximum speeds and torques of the vehicle are still achieved. The output of the transmission is made on the upper element from the planetary.

[0058] Referring now to **FIG.5**, is the speed diagram of the planetary gearset of this first configuration. The four horizontal axes represent respectively, from the bottom to the top, the sun 1 rotation speed **501**, the sun 2 rotation speed **502**, the carrier rotation speed **503** and the ring rotation speed **504**.

[0059] In a first embodiment, the connections are made as follows: In the reverse mode, the second sun of the compound planetary gear set is linked to the ICE through a down speed ratio and then turns at the ICE speed times this down speed ratio, shown as a solid (blue) bar **505** on the second sun axis **502**. The ring is free to turn while the first sun is connected to the CVP and thus turns at the ICE speed times the CVP ratio times the up-speed and the optional ratio. In this reverse mode, the solid line **506** in the middle of the carrier axis (green interval) shows the speed achievable by the carrier, the output of the planetary, depending on the variator ratio. A minimum ratio in the CVP brings low forward speed of the vehicle while a maximum speed ratio in the CVP corresponds to the maximum reverse speed. The short dashed (green) lines **507a**, **507b** show the limits achievable. It should be noted that a positive speed of the carrier/output means a negative speed of the vehicle.

[0060] This mode is a power split mode, meaning that there are multiple power paths that will be used at the same time. A part of the power will flow through the CVP, the planetary first sun, the planets, and going out through the carrier, while a certain amount of the power will directly flow through the second sun, the planets and carrier of the planetary.

[0061] In the forward mode, the second sun is decoupled from the ICE, by opening a clutch, and the ring of the planetary is braked so that the planetary acts as a simple gear reduction. The

output of the CVP is still connected to the first sun of the planetary as in the reverse mode. The first ring speed is equal to zero and the output range is shown as a solid line **508** (in red) on the left side of the carrier/output axis. The design is made so that the maximum forward speed of the reverse mode corresponds to the minimum speed of the forward mode, allowing synchronous shifts. However, a slight change in the gear ratios might provide overlap between the two modes or even gap if this is needed for a specific reason.

[0062] Referring now to **FIG. 6**, is a non-limiting example of this configuration.

[0063] Provided herein is a variable transmission **600** comprising an input shaft **601** comprising a first gear **611** of a first gear set **610**; the first gear set comprising the first gear and a second gear; the first gear **611** drivingly engaged to the second gear **612**, wherein the second gear **612** is on countershaft **605**; a variator **640** comprising a first ring assembly **641** drivingly engaged to the second gear **612**, and a second ring assembly **642** coupled to a first sun **631** of a planetary gear set **630**; a first set of planet gears **632p1** of a dual planet gear set **632** coupled to the first sun **631** and drivingly engaged to a ring gear **633**; the dual planet gear set **632** comprising the first set of planet gears **632p1** and a second set of planet gears **632p2**; a braking clutch **660** coupled to the ring gear **633**; the second set of planet gears **632p2** drivingly engaged to a second sun **634**; the second sun **634** drivingly engaged to a third gear **621** of a second gear set **620**; the second gear set comprising the third gear **621** and a fourth gear **622**; the third gear **621** drivingly engaged to the fourth gear **622** and the fourth gear **622** coupled to a first portion **650a** of a second clutch **650** on the input shaft **601**; the 2nd clutch **650** comprising the first portion **650a** and a second portion **650b**; the second portion **650b** of the second clutch **650** coupled to the first gear **611** on the input shaft **601** and the ICE **100**; the dual planet gear set **632** is coupled to a carrier **635**; wherein the carrier **635** is drivingly engaged to a fifth gear **671** of an output ratio **670** comprising the fifth gear **671** and a sixth gear **672**; wherein the fifth gear **671** is drivingly engaged to the sixth gear **672**, and the sixth gear **672** is drivingly engaged to the output of the transmission **680**.

[0064] In some embodiments, the first gear set **610** is an up-speed ratio. In some embodiments, the second gear set **620** is a down-speed ratio.

[0065] In some embodiments, the second clutch **650** is an input coupling clutch.

[0066] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged when the input coupling is engaged.

[0067] In some embodiments, the braking clutch **660** engages the direct forward mode when the ring **633** goes to zero speed. In some embodiments, the output gear reverses the carrier **635** output.

Configuration 1, Layout 2

[0068] Provided herein is a variable transmission **700** comprising an input shaft **701** comprising a first gear **711** coupled to a second gear **712** of a first gear set **710**; the first gear set **710** comprising the first gear **711** and a second gear **712**, wherein the second gear **712** is on countershaft **705**; a variator **740** comprising a first ring **741** assembly drivingly engaged to the second gear **712**, and a second ring assembly **742** coupled to a third gear **771** of a second gear set **770**; the second gear set comprising the third gear **771** and a fourth gear **772**, wherein the third gear **771** is drivingly engaged to the fourth gear **772** which is coupled to a first sun **733** of a planetary gear set **730**; a first set of planet gears **732p1** of a dual planet gear set **732** coupled to the first sun **733** and drivingly engaged to a ring gear **731**; the dual planet gear set **732** comprising the first set of planet gears **732p1** and a second set of planet gears **732p2**; a braking clutch **760** coupled to the ring gear **731**; the second set of planet gears **732p2** drivingly engaged to a second sun **734**; the second sun **734** coupled to a first portion **750a** of a second clutch **750**; the second clutch **750** comprising the first portion **750a** and a second portion **750b**; the second portion **750b** of the second clutch **750** coupled to a fifth gear **721** of a third gear set **720**; the third gear set **720** comprising the fifth gear **721** and a sixth gear **722**, the fifth gear **721** drivingly engaged to the sixth gear **722**, wherein the sixth gear is coupled to the countershaft **705** and the ICE **100** through the first gear set; the dual planet gear set **732** is coupled to a carrier **735**; wherein the carrier **735** is drivingly engaged to a seventh (output) gear **736**; wherein seventh (output) gear **736** is drivingly engaged to the output of the transmission **780**.

[0069] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a carrier ratio.

[0070] In some embodiments, the second clutch is an input coupling clutch. In some embodiments, the transmission is in reverse mode when the input coupling is engaged.

Configuration 1, Layout 3

[0071] Another variant, Layout 3, uses a different compound planetary in order to perform substantially the same way. The speed diagram is very similar to that previous described, however the arrangement of the elements is slightly different. The first planetary type contains a single carrier with common planets but multiple suns. This variant incorporates a compound planetary gear set having a common sun together with multiple planets and two carriers.

[0072] Referring now to the Layout 3 Speed Diagram shown in **FIG. 8**, the four horizontal axes represent respectively, from the bottom to the top, the Sun rotation speed **801**, the Carrier 1 rotation speed **802**, the Carrier 2/Ring 1 rotation speed **803** and the Ring 2 rotation speed **804**.

[0073] The connections for Layout 3 are made as follows: In the reverse mode, the first carrier of the compound planetary gear set is linked to the ICE through a down speed ratio and then turns at the ICE speed times this down speed ratio, shown as a solid (blue) bar **805** on the carrier 1 axis **802**. The second ring is free to turn while the common sun is connected to the CVP and thus turns at the ICE speed times the CVP ratio times the up-speed and the optional ratio. In this reverse mode, the solid (green) interval line **806** crossing the midline of the carrier 2/ring 1 axis **803** shows the output speed achievable by the second carrier/first ring, the output of the planetary, depending on the variator ratio. A minimum ratio in the CVP brings low forward speed of the vehicle while a maximum speed ratio in the CVP corresponds to the maximum reverse speed. The (green) dotted lines **807a**, **807b** show the limits achievable. It has to be noted that a positive speed of the second carrier/output means negative speed of the vehicle.

[0074] This mode is a power split mode, meaning that there are multiple power paths that will be used at the same time. A part of the power will flow through the CVP, the planetary sun, planet and going out through the second carrier while a certain amount of the power will directly flow through the first carrier, planets and first ring/second carrier of the planetary (the output).

[0075] In the forward mode, the first carrier is decoupled from the ICE, by opening a clutch, and the second ring of the planetary is braked so that the planetary acts as a simple gear reduction. The output of the CVP is still connected to the sun of the planetary as in the reverse mode. The second ring speed is equal to zero and the output range is shown in as a solid (red) line **808** on the left side of the carrier 2/Ring 1 output axis **803**. The design is made so that the maximum forward speed of the reverse mode corresponds to the minimum speed of the forward mode, allowing synchronous shifts. However, a slight change in the gear ratios might provide overlap between the two modes or even gap if this is needed for a specific reason.

[0076] Referring now to **FIG. 9**, provided herein is a variable transmission **900** comprising an input shaft **901** comprising a first gear **911** of a first gear set **910**; the first gear set comprising the first gear **911** and a second gear **912**, wherein the first gear **911** is drivingly engaged to the second gear **912**, wherein the second gear **912** is on countershaft **905**; a variator **940** comprising a first ring assembly **941** drivingly engaged to the second gear **912**, and a second ring assembly **942** coupled to a common sun **932** of a compound planetary gear set **930**; a first set of planet gears **934p1** is coupled to the common sun **932** and is drivingly engaged to a first ring **931r1** and a first carrier **933c1**; the first carrier **933c1** is drivingly engaged to a third gear **921**; a second gear set **920** comprising the third gear **921** and a fourth gear **922**; the third gear **921** drivingly engaged to the fourth gear **922** and the fourth gear **922** coupled to a first portion **950a** of an input clutch **950** on the input shaft **901**; the input clutch **950** comprising the first portion **950a** and a second

portion **950b**; the second portion **950b** of the input clutch **950** coupled to the first gear **911** on the input shaft **901** and the ICE **100**; a second set of planet gears **934p2** is coupled to the common sun **932** and is drivingly engaged to a second ring **931r2** and a second carrier **933c2**; a braking clutch **960** is coupled to the second ring gear **931r2**; the second carrier **933c2** and the first ring **931r1** are coupled to a output gear **935**; wherein the planetary output gear **935** is drivingly engaged to an output ratio gear **970** and the output ratio gear **970** is drivingly engaged to the output **980** of the transmission.

[0077] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a down-speed ratio.

[0078] In some embodiments, the second clutch is an input coupling clutch. In some embodiments, the first carrier is connected to the ICE when the input coupling clutch is engaged.

[0079] In some embodiments, the reverse mode is engaged mode when the input coupling is engaged.

[0080] In some embodiments, the braking clutch engages the direct forward mode when the second ring goes to zero speed. In some embodiments, the output ratio gear reverses the second carrier output.

Configuration 2, Layout 1

[0081] The second configuration is similar to versions of the first configuration except that the forward and reverse modes have been interchanged, as illustrated in **FIG. 10**. The forward mode is thus a powersplit mode allowing speeds from max forward speed to low reverse speed while the reverse mode is now a direct CVP mode.

[0082] Due to the planetary, this configuration uses only a CVP and is able to provide standstill and reverse function as an IVP. No starting device like a slipping clutch or torque converter is required, since the IVP capability takes care of the starting function. However, these devices can be added to allow a safety disconnect or to start the engine. The ratio gear set after the planetary is there to ensure that the maximum speeds and torques of the vehicle are still achieved.

[0083] An inverted configuration such as this can be performed by adding or removing a gear train to the output. **FIG. 11** shows an example of Configuration 1 – Layout 2 in which a gear train has been added in dotted lines in order to reverse the forward and reverse mode. Such a modification can apply equally as well to Layout 1 and 3 from Configuration 1, but also to any other configuration that can be derived from the general principle of the first configuration presented in this disclosure.

[0084] Provided herein is a variable transmission **1100** comprising an input shaft **1101** comprising a first gear **1111** of a first gear set **1110**; the first gear set comprising the first gear

1111 and a second gear 1112, wherein the first gear 1111 is drivingly engaged to the second gear 1112 and the second gear 1112 is on a countershaft 1105; a variator 1140 comprising a first ring assembly 1141 drivingly engaged to the second gear 1112, and a second ring assembly 1142 coupled to a third gear 1171 of a second gear set 1170; the second gear set comprising the third gear 1171 and a fourth gear 1172; the third gear 1171 drivingly engaged to the fourth gear 1172; the fourth gear 1172 coupled to a first sun 1133 of a planetary gear set 1130; a first set of planet gears 1132p1 of a dual planet gear set 1132 coupled to the first sun 1133 and drivingly engaged to a ring gear 1131; the dual planet gear set 1132 comprising the first set of planet gears 1132p1 and a second set of planet gears 1132p2; a braking clutch 1160 coupled to the ring gear 1131; the second set of planet gears 1132p2 drivingly engaged to a second sun 1134; the second sun 1134 drivingly engaged to a first portion 1150a of a second clutch 1150; the second clutch 1150 comprising the first portion 1150a and a second portion 1150b; the second portion 1150b of the second clutch 1150 coupled to a fifth gear 1121 of a third gear set 1120; the third gear set 1120 comprising the fifth gear 1121 and a sixth gear 1122; the fifth gear 1121 drivingly engaged to the sixth gear 1122 which is coupled to the countershaft 1105 and the ICE 100 through the first gear set; the dual planet gear set 1132 is coupled to a carrier 1135; wherein the carrier 1135 is coupled to an output gear 1136; wherein the output gear is drivingly engaged to an output ratio gear 1180; and the output ratio gear 1180 is drivingly engaged to the output of the transmission 1190.

[0085] In some embodiments, the first gear set is an up-speed ratio. In some embodiments, the second gear set is a down-speed ratio.

[0086] In some embodiments, the second clutch is a second sun coupling clutch. In some embodiments, the second sun is connected to the ICE when the second sun coupling clutch is engaged. In some embodiments, the forward mode is engaged when the second sun coupling clutch is engaged.

[0087] In some embodiments, the braking clutch engages the direct reverse mode when the ring goes to zero speed.

Configuration 3, Layout 1:

[0088] This configuration is based on a dual mode solution similar to the one of configuration 1. The main difference is that the ICE is directly engaged to the middle element of the planetary.

[0089] Each mode is selected by closing a clutch/brake and releasing the other. The configuration also includes a compound planetary gear set. As illustrated in **FIG. 12**, the forward mode is a direct CVP mode, engaged by braking an element of the compound planetary; the planetary thus acting as a simple gear ratio. The reverse mode (also providing low forward speeds) is composed of a compound coupling planetary that combines input from the ICE and

from the CVP into an IVT output. The CVP is connected to the bottom element of the planetary (when drawing the compound planetary speed diagram) on one side and to the ICE on the other side through an up-speed ratio. This up-speed ratio tends to increase the speeds and decrease the torque acting on the CVP, allowing for a decrease in the variator size. The ICE is also connected to a middle element of the planetary in the reverse mode. It should be noted that the naming of the modes as Forward and Reverse is arbitrarily made, as in this case, the reverse mode also provides low forward speeds as well as a powered neutral. However, as this mode covers the whole reverse speed range it has been named Reverse. An optional speed ratio between the CVP and the planetary can also be present.

[0090] As with other configurations utilizing a planetary, the configuration uses only a CVP and is able to provide standstill and reverse function as an IVP. No starting device like a slipping clutch or torque converter is required, since the IVP capability takes care of the starting function. However, these devices might be added to allow a safety disconnect or to start the engine. A ratio after the planetary is there to ensure that the maximum speeds and torques of the vehicle are still achieved. The output of the transmission is made on the upper element from the planetary.

[0091] **FIG. 13** shows the speed diagram of the planetary gearset of this third configuration. The four horizontal axes represent respectively, from the bottom to the top, the sun 1 rotation speed **1301**, the sun 2 rotation speed **1302**, the carrier rotation speed **1303** and the ring rotation speed **1304**.

[0092] In one embodiment, the connections are made as follows. In the reverse mode, the second sun of the compound planetary gear set is directly linked to the ICE and then turns at the ICE speed, shown as a solid vertical (blue) bar **1305** on the second sun axis **1302**. The ring is free to turn while the first sun is connected to the CVP and thus turns at the ICE speed times the CVP ratio times the up-speed and the optional ratio. In this reverse mode, the solid (green) output interval **1306** illustrated about the center of the carrier axis **1303**, shows the speed achievable by the carrier, the output of the planetary, depending on the variator ratio. A minimum ratio in the CVP produces low forward speed of the vehicle while a maximum speed ratio in the CVP corresponds to the maximum reverse speed. The (green) dotted lines **1307a**, **1307b** show the limits achievable. It should be noted that a positive speed of the carrier/output means negative speed of the vehicle.

[0093] This mode is a power split mode, meaning that there are multiple power paths that will be used at the same time. A part of the power will flow through the CVP, the planetary first sun, planet and going out through the carrier while a certain amount of the power will directly flow through the second sun, planets and carrier of the planetary.

[0094] In the forward mode, the second sun is decoupled from the ICE, by opening a clutch, and the ring of the planetary is braked so that the planetary acts as a simple gear reduction. The output of the CVP is still connected to the first sun of the planetary as in the reverse mode. The first ring speed is equal to zero and the output range, is shown as a solid (red) line **1308** on the left side of the carrier/output axis. The design is made so that the maximum forward speed of the reverse mode corresponds to the minimum speed of the forward mode, allowing synchronous shifts. However, a slight change in the gear ratios might provide overlap between the two modes or even gap if this is needed for a specific reason.

[0095] Referring now to **FIG. 14** is a representative example of a physical layout for this configuration. The input is always linked to the up-speed ratio (comprising two gears sets) going to the CVP and to the first member of the input coupling clutch (to engage the “reverse mode”). The CVP output is linked to the first sun of the planetary. A brake allows braking the first ring to zero speed to engage the direct forward mode. The second sun of the planetary is linked to the input coupling clutch and can thus be connected to the ICE when the clutch is engaged. The carrier of the planetary is connected to the output of the transmission.

[0096] Provided herein is a variable transmission **1400** comprising an input shaft **1401** comprising: a first gear **1421** of a first gear set **1420**; the first gear set comprising the first gear **1421** and a second gear **1422**, wherein the first gear **1421** is drivingly engaged to the second gear **1422**, wherein the second gear **1422** is on a countershaft **1405**; the second gear **1422** on the countershaft **1405** is coupled to a third gear **1471** of a second gear set **1470**; the second gear set **1470** comprising the third gear **1471** and a fourth gear **1472**; the third gear **1471** is drivingly engaged to the fourth gear **1472**; a variator **1440** comprising a first ring assembly **1441** is coupled to the fourth gear **1472**, and a second ring assembly **1442** coupled to a first sun **1433** of a planetary gear set **1430**; a first set of planet gears **1432p1** of a dual planet gear set **1432** is coupled to the first sun **1433** and drivingly engaged to a ring gear **1431**; the dual planet gear set **1432** comprising the first set of planet gears **1432p1** and a second set of planet gears **1432p2**; a braking clutch **1460** is coupled to the ring gear **1431**; the second set of planet gears **1432p2** drivingly engaged to a second sun **1434**; the second sun **1434** is drivingly engaged to a first portion **1450a** of a second clutch **1450**; the second clutch **1450** comprising the first portion **1450a** and a second portion **1450b**; the second portion **1450b** of the second clutch **1450** is coupled to the first gear **1421** on the input shaft **1401** and the ICE **100**; the dual planet gear set **1430** is coupled to a carrier **1435**; wherein the carrier **1435** is coupled to an output gear **1436**, and the output gear **1436** is drivingly engaged to the output of the transmission **1480**.

[0097] In some embodiments, the first gear set and second gear set are an up-speed ratio. In some embodiments, the second clutch is an input coupling clutch.

[0098] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged.

[0099] In some embodiments, the braking clutch engages the direct forward mode when the ring goes to zero speed.

Configuration 3, Layout 2:

[00100] Referring now to **FIG. 15** is an alternate representation of a physical layout for this configuration. In this configuration, the CVP is on a different shaft than the planetary and an optional ratio is present between the CVP and the first sun of the planetary.

[00101] Provided herein is a variable transmission **1500** comprising an input shaft **1501** comprising a first gear **1521** of a first gear set **1520**; the first gear set **1520** comprising the first gear **1521** and a second gear **1522**; the first gear **1521** is drivingly engaged to the second gear **1522**, and the second gear **1522** is on a countershaft **1505**; a variator **1540** comprising a first ring assembly **1541** is drivingly engaged to the second gear **1522**, a second ring assembly **1542** is coupled to a third gear **1571** of a second gear set **1570**; the second gear set **1570** comprising the third gear **1571** and a fourth gear **1572**; the fourth gear **1572** is drivingly engaged to a first sun **1533** of a planetary gear set **1530**; a first set of planet gears **1532p1** of a dual planet gear set **1532** is coupled to the first sun **1533** and drivingly engaged to a ring gear **1531**; the dual planet gear set **1532** comprising the first set of planet gears **1532p1** and a second set of planet gears **1532p2**; a braking clutch **1560** is coupled to the ring gear **1531**; the second set of planet gears **1532p2** is drivingly engaged to a second sun **1534**; the second sun **1534** is coupled to a first portion **1550a** of a second clutch **1550**; the second clutch **1550** comprising the first portion **1550a** and a second portion **1550b**; the second portion **1550b** of the second clutch **1550** is coupled to the first gear **1521** on the input shaft **1501** and the ICE **100** through the first gear set; the dual planet gear set **1532** is coupled to a carrier **1535**; the carrier **1535** is coupled to an output gear **1536**, and the output gear **1536** is drivingly engaged to the output **1580** of the transmission.

[00102] In some embodiments, the first gear set and second gear set are an up-speed ratio. In some embodiments, the second clutch is an input coupling clutch.

[00103] In some embodiments, the second sun is connected to the ICE when the input coupling clutch is engaged. In some embodiments, the reverse mode is engaged when the input coupling clutch is engaged.

[00104] In some embodiments, the braking clutch engages the direct forward mode when the ring goes to zero speed.

[00105] Provided herein are different transmission layouts based on the same principle of having two modes, of which one contains a powered neutral due to a powersplit configuration, and the other one is a direct mode through the CVP. The shifting between the modes in all these configurations is done by engaging and releasing a clutch/brake simultaneously.

[00106] These couplings allow having a better efficiency in one part of the output range due to the powersplitting. Additionally, these configurations and their different layouts provide a powered neutral ratio. The spread given through them is sufficient to allow the engine to operate at more optimal points, providing fuel economy, while keeping the same vehicle operating speeds.

[00107] These configurations typically provide a maximum forward speed that is slightly higher than the negative speeds, a feature that is present in many applications such as premium forklifts. However, modifications of ratios in the gears and planetaries can provide different forward and reverse speed, allowing the use of these configurations in different applications. It is also possible to change this feature by limiting the ratios achievable in the CVP.

[00108] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. Provided herein is a variable transmission comprising:
 - an input shaft comprising a first gear of a first gear set;
 - the first gear set comprising the first gear and a second gear;
 - the first gear drivingly engaged to the second gear, wherein the second gear is on an offset axle;
 - a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a first sun of a compound planetary gear set;
 - a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear;
 - the dual planet gear set comprising the first set of planet gears and a second set of planet gears;
 - a braking clutch coupled to the ring gear;
 - the second set of planet gears drivingly engaged to a second sun;
 - the second sun drivingly engaged to a third gear of a second gear set;
 - the second gear set comprising the third gear and a fourth gear;
 - the third gear drivingly engaged to the fourth gear and the fourth gear coupled to a first portion of a second clutch on the input shaft;
 - the clutch comprising the first portion and a second portion;
 - the second portion of the second clutch coupled to the first gear on the input shaft and the ICE;
 - the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to an output gear;
 - wherein the output gear is drivingly engaged to the output of the transmission.
2. The variable transmission of claim 1, wherein the first gear set is an up-speed ratio.
3. The variable transmission of claim 1, wherein the second gear set is a down-speed ratio.
4. The variable transmission of claim 1, wherein the second clutch is an input coupling clutch.
5. The variable transmission of claim 1, wherein the second sun is connected to the ICE when the input coupling clutch is engaged.

6. The variable transmission of claim 5, wherein the reverse mode is engaged when the input coupling clutch is engaged.
7. The variable transmission of claim 1, wherein the braking clutch engages the direct forward mode when the ring goes to zero speed.
8. The variable transmission of claim 1, wherein the output gear reverses the carrier output.
9. Provided herein is a variable transmission comprising:
 - an input shaft comprising a first gear of a first gear set;
 - the first gear set comprising the first gear and a second gear,
 - the first gear drivingly engaged to the second gear, wherein the second gear is on an offset axle;
 - a variator comprising a first ring assembly drivingly engaged to the second gear,
 - and a second ring assembly coupled to a third gear of a second gear set;
 - the second gear set comprising the third gear and a fourth gear,
 - wherein the third gear is drivingly engaged to the fourth gear which is coupled to a first sun of a planetary gear set;
 - a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear;
 - the dual planet gear set comprising the first set of planet gears and a second set of planet gears;
 - a braking clutch coupled to the ring gear;
 - the second set of planet gears drivingly engaged to a second sun;
 - the second sun coupled to a first portion of a second clutch;
 - the second clutch comprising the first portion and a second portion;
 - the second portion of the second clutch coupled to a fifth gear of a third gear set;
 - the third gear set comprising the fifth gear and a sixth gear,
 - wherein the fifth gear is drivingly engaged to the sixth gear, and wherein the sixth gear is coupled to the offset axle;
 - the dual planet gear set is coupled to a carrier;
 - wherein the carrier is drivingly engaged to a seventh gear;
 - wherein seventh gear is drivingly engaged to the output of the transmission.
10. The variable transmission of claim 9, wherein the first gear set is an up-speed ratio.
11. The variable transmission of claim 9, wherein the second gear set is a carrier ratio.

12. The variable transmission of claim 9, wherein the second clutch is an input coupling clutch.
13. The variable transmission of claim 9, wherein the transmission is in reverse mode when the input coupling is engaged.
14. Provided herein is a variable transmission comprising:
 - an input shaft comprising a first gear of a first gear set;
 - the first gear set comprising the first gear and a second gear,
 - wherein the first gear is drivingly engaged to the second gear, wherein the second gear is on an offset axle;
 - a variator comprising a first ring assembly drivingly engaged to the second gear,
 - and a second ring assembly coupled to a common sun of a compound planetary gear set;
 - a first set of planet gears is coupled to the common sun and is drivingly engaged to a first ring and a first carrier;
 - the first carrier is drivingly engaged to a third gear;
 - a second gear set comprising the third gear and a fourth gear;
 - the third gear is drivingly engaged to the fourth gear and the fourth gear is coupled to a first portion of an input clutch on the input shaft;
 - the input clutch comprising the first portion and a second portion;
 - the second portion of the input clutch coupled to the first gear on the input shaft;
 - a second set of planet gears is coupled to the common sun and is drivingly engaged to a second ring and a second carrier;
 - a braking clutch is coupled to the second ring gear;
 - the second carrier and the first ring are coupled to a planetary output gear;
 - wherein the planetary output gear is drivingly engaged to an output ratio gear,
 - and the output ratio gear is drivingly engaged to the output of the transmission.
15. The variable transmission of claim 14, wherein the first gear set is an up-speed ratio.
16. The variable transmission of claim 14, wherein the second gear set is a down-speed ratio.
17. The variable transmission of claim 14, wherein the second clutch is an input coupling clutch.
18. The variable transmission of claim 14, wherein the first carrier is connected to the ICE when the input coupling clutch is engaged.

19. The variable transmission of claim 18, wherein the reverse mode is engaged when the input coupling clutch is engaged.
20. The variable transmission of claim 14, wherein the braking clutch engages the direct forward mode when the second ring goes to zero speed.
21. The variable transmission of claim 14, wherein the output ratio gear reverses the second carrier output.
22. Provided herein is a variable transmission comprising:
 - an input shaft comprising a first gear of a first gear set;
 - the first gear set comprising the first gear and a second gear, wherein the first gear is drivingly engaged to the second gear, and the second gear is on a countershaft;
 - a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a third gear of a second gear set;
 - the second gear set comprising the third gear and a fourth gear;
 - the third gear drivingly engaged to the fourth gear;
 - the fourth gear coupled to a first sun of a planetary gear set;
 - a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear;
 - the dual planet gear set comprising the first set of planet gears and a second set of planet gears;
 - a braking clutch coupled to the ring gear;
 - the second set of planet gears drivingly engaged to a second sun;
 - the second sun drivingly engaged to a first portion of a second clutch;
 - the second clutch comprising the first portion and a second portion;
 - the second portion of the second clutch coupled to a fifth gear of a third gear set;
 - the third gear set comprising the fifth gear and a sixth gear;
 - the fifth gear drivingly engaged to the sixth gear which is coupled to the countershaft; the dual planet gear set is coupled to a carrier; wherein
 - the carrier is drivingly engaged to an output ratio gear; and
 - the output ratio gear is drivingly engaged to the output of the transmission.
23. The variable transmission of claim 22, wherein the first gear set is an up-speed ratio.
24. The variable transmission of claim 22, wherein the second gear set is a down-speed ratio.

25. The variable transmission of claim 22, wherein the second clutch is a second sun coupling clutch.
26. The variable transmission of claim 22, wherein the second sun is connected to the ICE when the second sun coupling clutch is engaged.
27. The variable transmission of claim 26, wherein the forward mode is engaged when the second sun coupling clutch is engaged.
28. The variable transmission of claim 22, wherein the braking clutch engages the direct reverse mode when the ring goes to zero speed.
29. Provided herein is a variable transmission comprising:
an input shaft comprising a first gear of a first gear set;
the first gear set comprising the first gear and a second gear, wherein the first gear is drivingly engaged to the second gear, and the second gear is on an offset axle;
the second gear is coupled to a third gear of a second gear set;
the second gear set comprising the third gear and a fourth gear;
the third gear is drivingly engaged to the fourth gear;
a variator comprising a first ring assembly coupled to the fourth gear, and a second ring assembly coupled to a first sun of a compound planetary gear set;
a first set of planet gears of a dual planet gear set is coupled to the first sun and drivingly engaged to a ring gear;
the dual planet gear set comprising the first set of planet gears and a second set of planet gears;
a braking clutch is coupled to the ring gear;
the second set of planet gears drivingly engaged to a second sun;
the second sun is drivingly engaged to a first portion of a second clutch;
the second clutch comprising the first portion and a second portion;
the second portion of the second clutch is coupled to the first gear on the input shaft ;
the dual planet gear set is coupled to a carrier; and
the carrier is drivingly engaged to the output of the transmission.
30. The variable transmission of claim 29, wherein the first gear set and second gear set are an up-speed ratio.
31. The variable transmission of claim 29, wherein the second clutch is an input coupling clutch.

32. The variable transmission of claim 29, wherein the second sun is connected to the ICE when the input coupling clutch is engaged.
33. The variable transmission of claim 32, wherein the reverse mode is engaged when the input coupling clutch is engaged.
34. The variable transmission of claim 29, wherein the braking clutch engages the direct forward mode when the ring goes to zero speed.
35. Provided herein is a variable transmission comprising:
an input shaft comprising a first gear of a first gear set;
the first gear set comprising the first gear and a second gear;
the first gear is drivingly engaged to the second gear, wherein the second gear is on a countershaft;
a variator comprising a first ring assembly is drivingly engaged to the second gear, and a second ring assembly is coupled to a third gear of a second gear set;
the second gear set comprising the third gear and a fourth gear;
the third gear is drivingly engaged to the fourth gear;
the fourth gear is drivingly engaged to a first sun of a planetary gear set;
a first set of planet gears of a dual planet gear set is coupled to the first sun and drivingly engaged to a ring gear;
the dual planet gear set comprising the first set of planet gears and a second set of planet gears;
a braking clutch is coupled to the ring gear;
the second set of planet gears is drivingly engaged to a second sun;
the second sun is drivingly engaged to a first portion of a second clutch;
the second clutch comprising the first portion and a second portion;
the second portion of the second clutch is coupled to the first gear on the input shaft;
the dual planet gear set is coupled to a carrier, and
the carrier is drivingly engaged to the output of the transmission.
36. The variable transmission of claim 35, wherein the first gear set and second gear set are an up-speed ratio.
37. The variable transmission of claim 35, wherein the second clutch is an input coupling clutch.
38. The variable transmission of claim 35, wherein the second sun is connected to the ICE when the input coupling clutch is engaged.

- 39. The variable transmission of claim 38, wherein the reverse mode is engaged when the input coupling clutch is engaged.
- 40. The variable transmission of claim 35, wherein the braking clutch engages the direct forward mode when the ring goes to zero speed.
- 41. A vehicle driveline comprising an engine, a variable transmission of claim 1 and a vehicle output.
- 42. The variable transmission of claim 1 further comprising a traction fluid lubricant.
- 43. A vehicle comprising the variable transmission of claim 1.

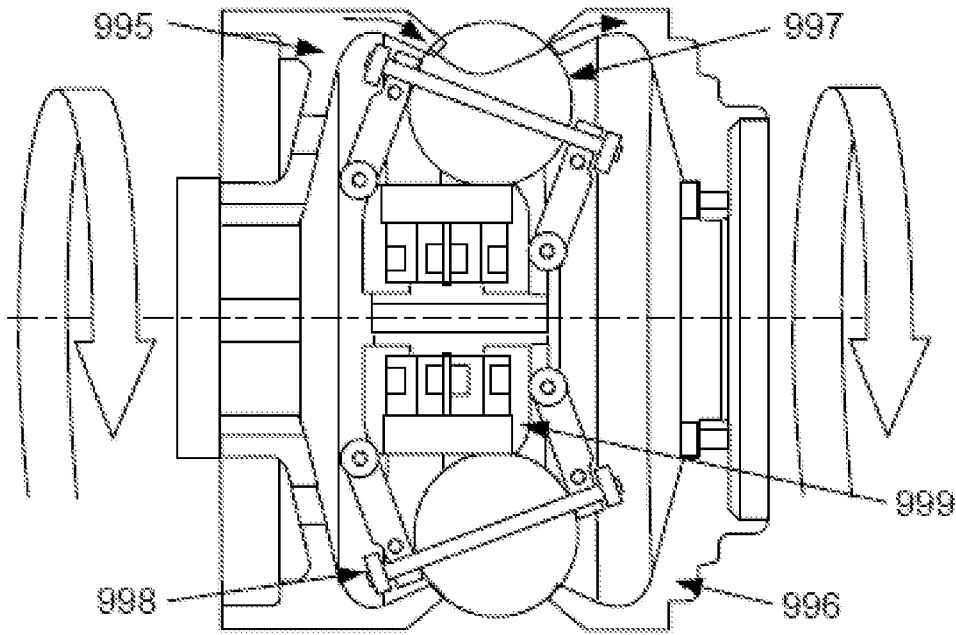


FIG. 1

2/15

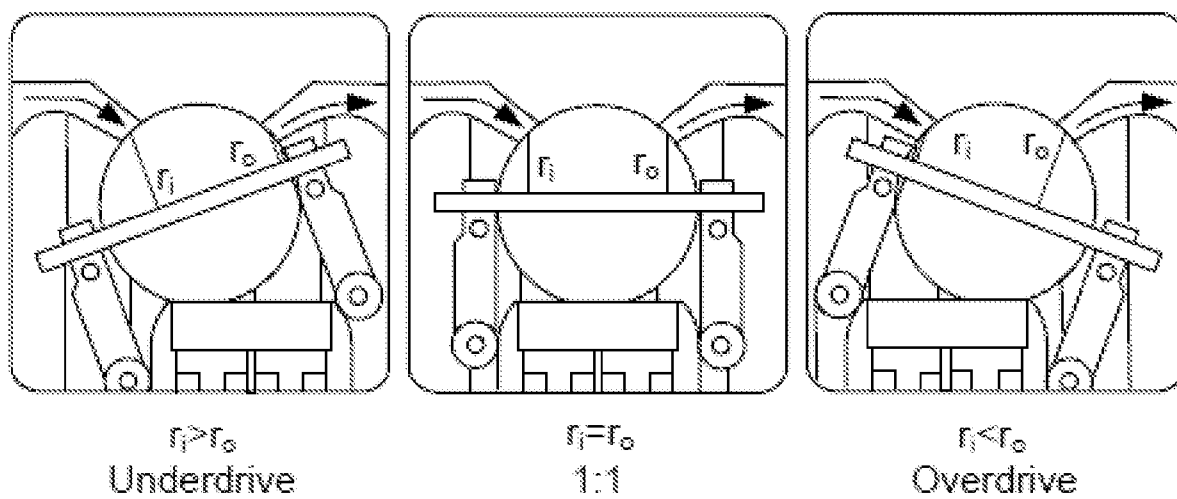


FIG. 2

3/15

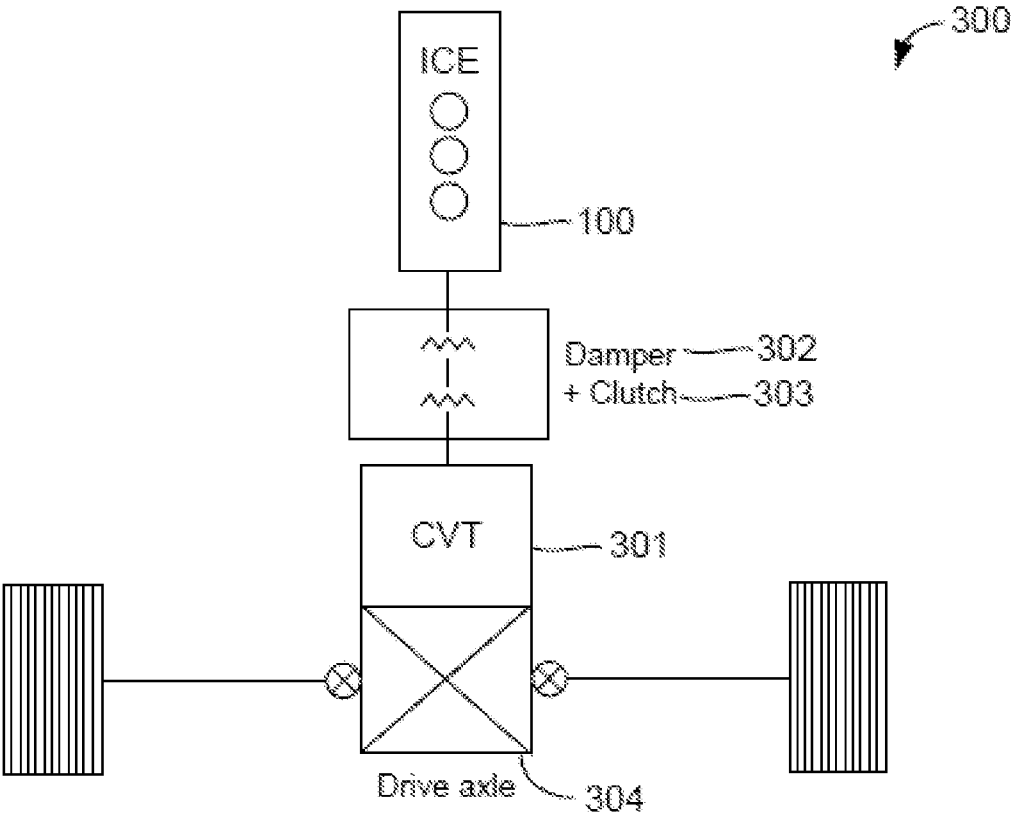


FIG. 3

4/15

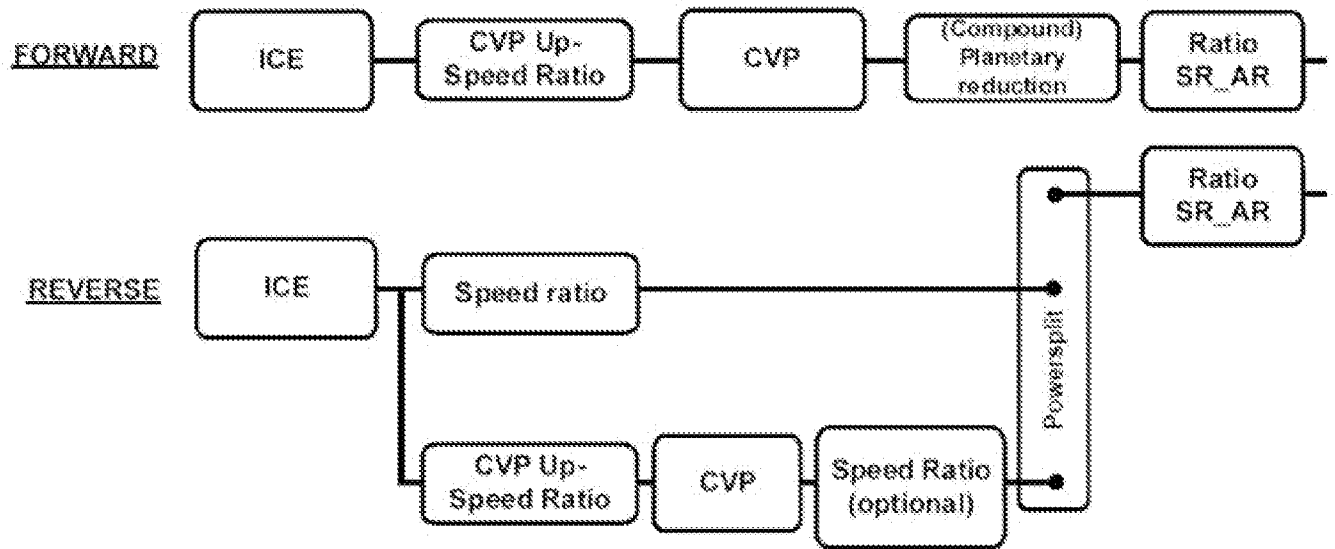


FIG. 4

5/15

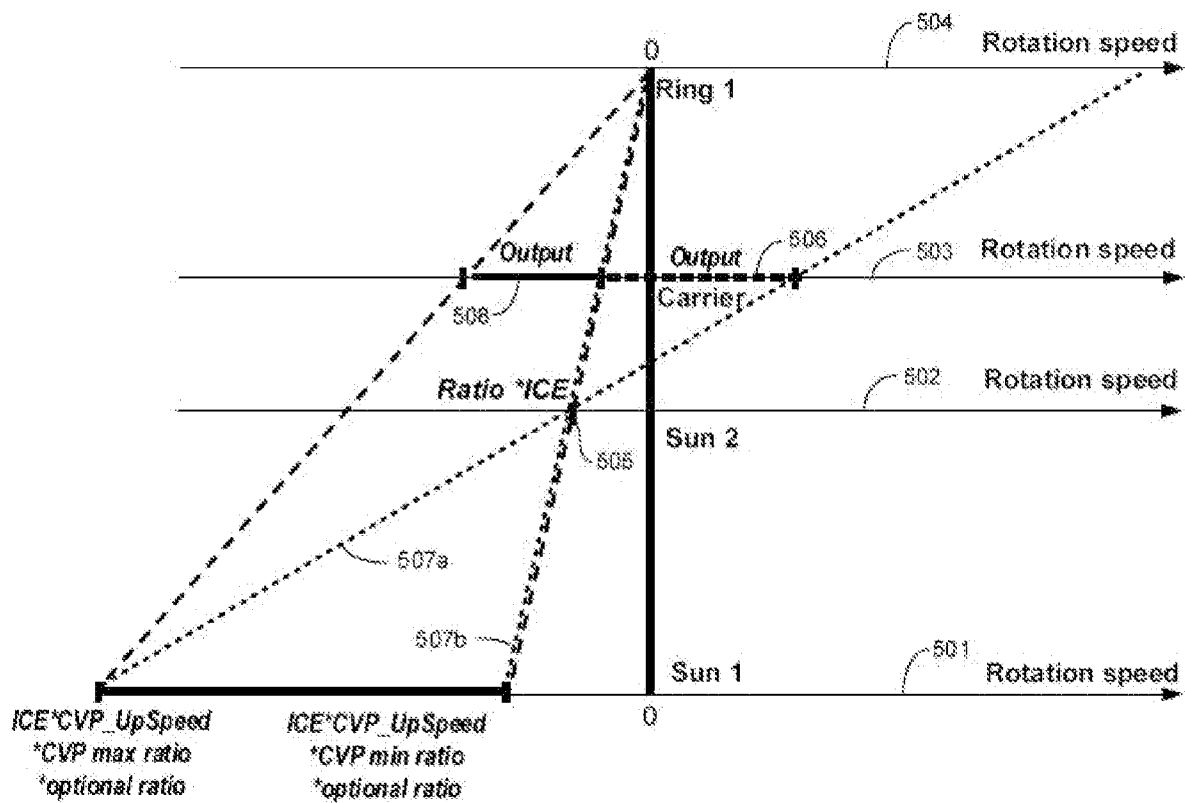


FIG. 5

6/15

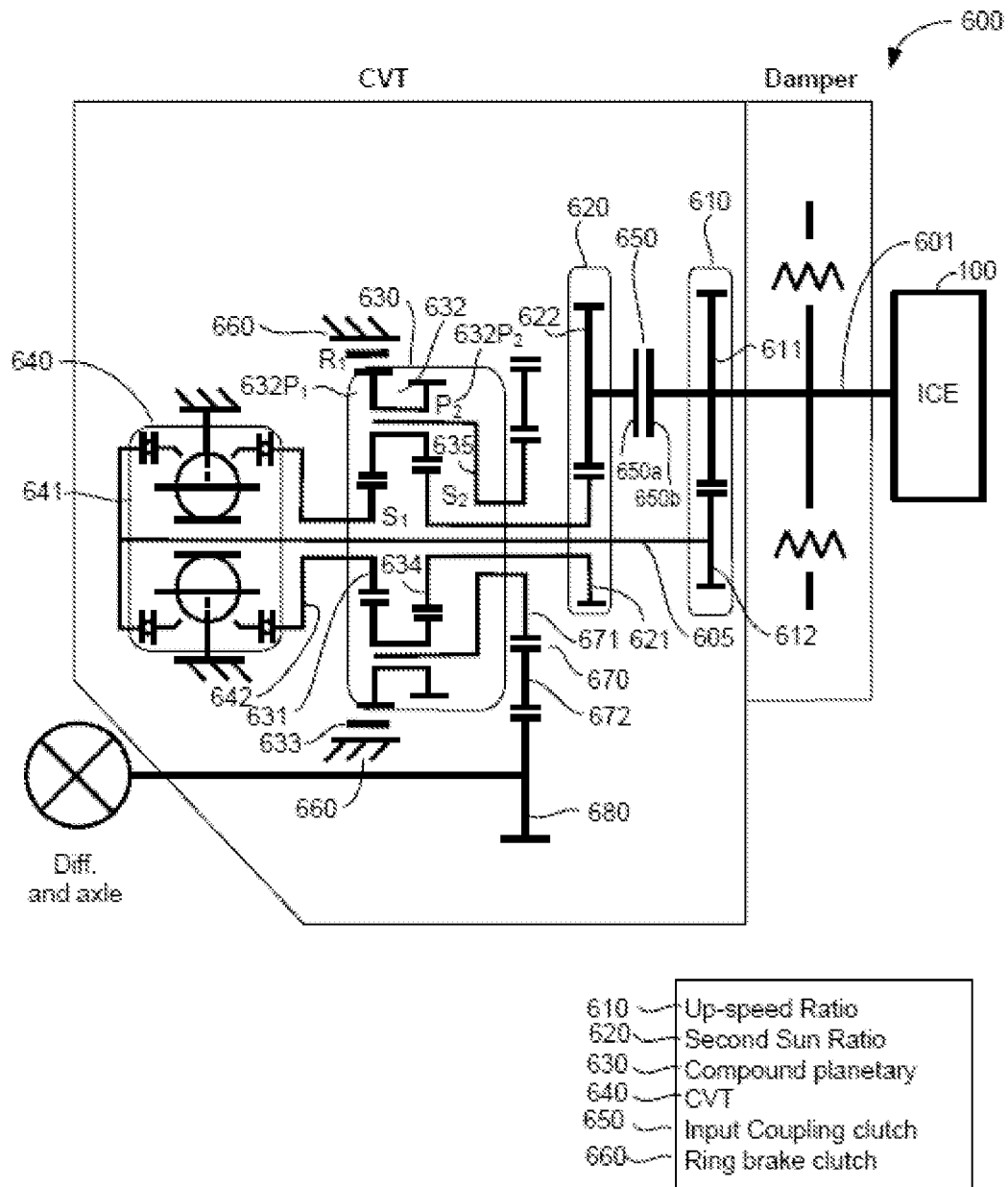


FIG. 6

7/15

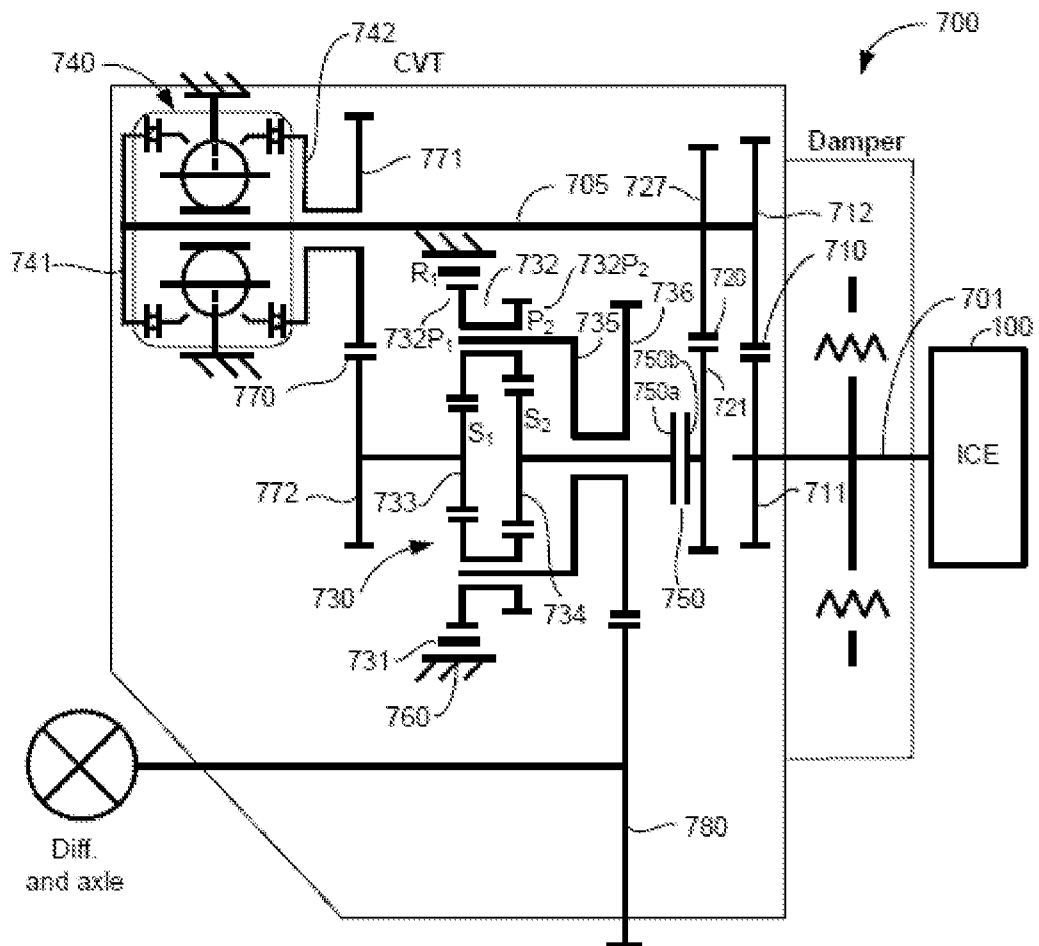


FIG. 7

8/15

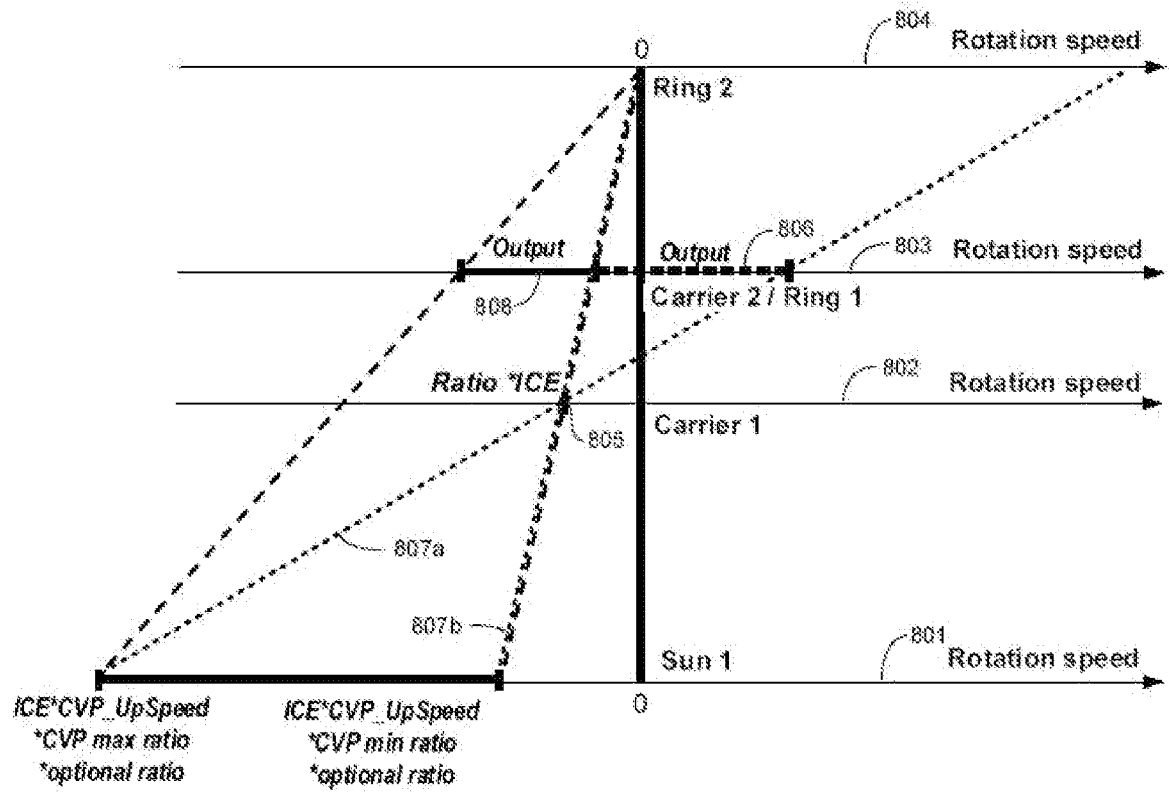


FIG. 8

9/15

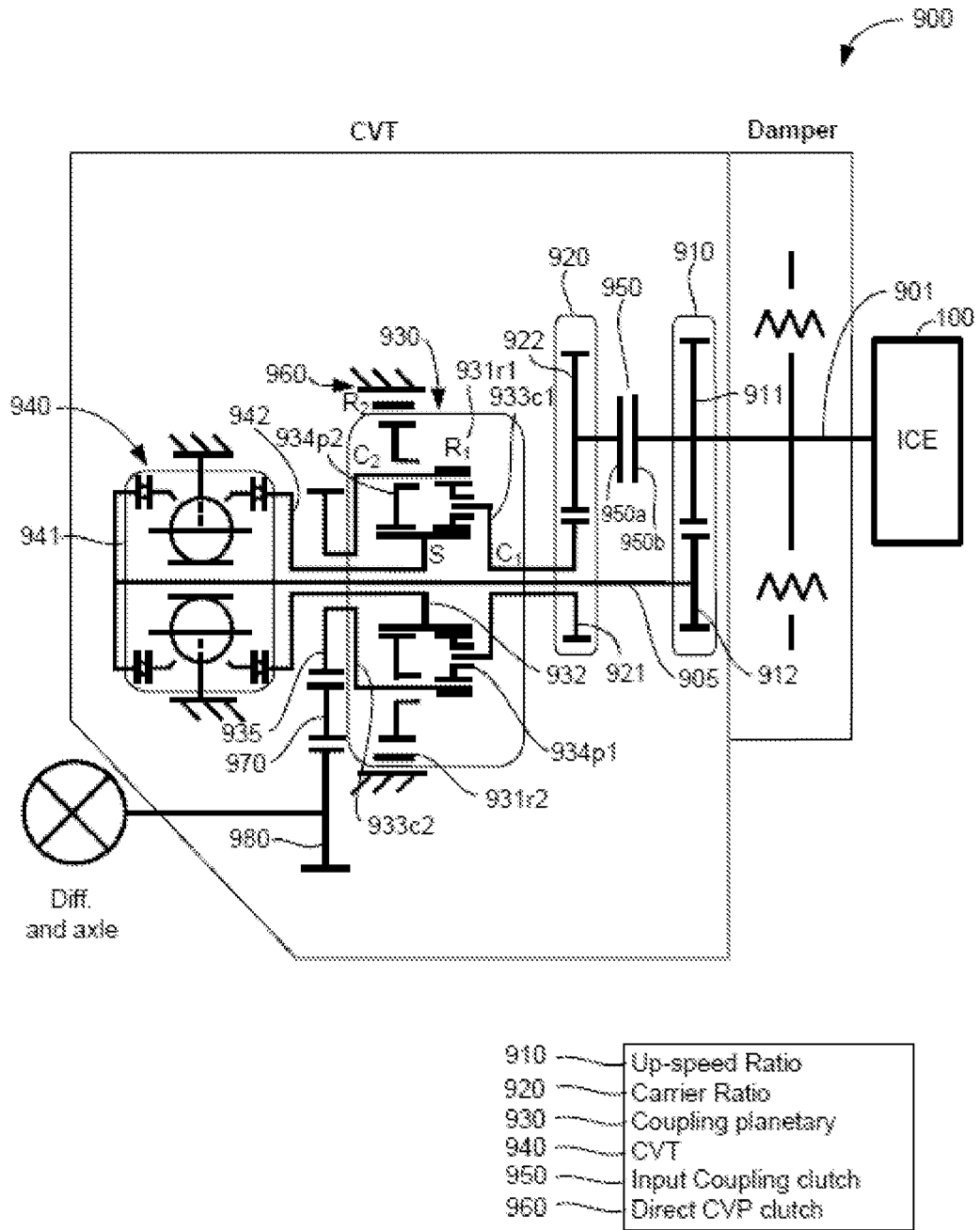


FIG. 9

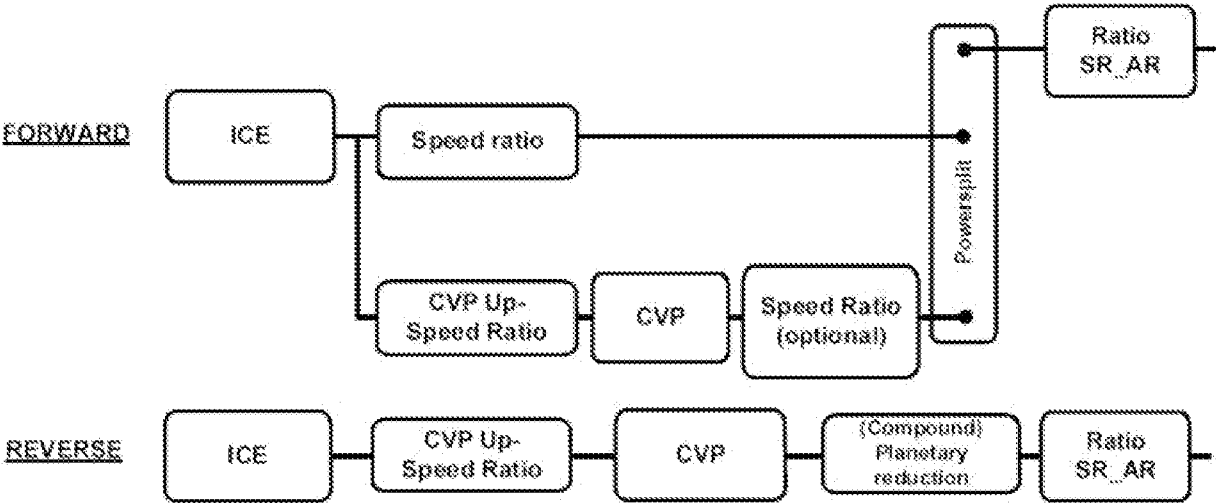


FIG. 10

11/15

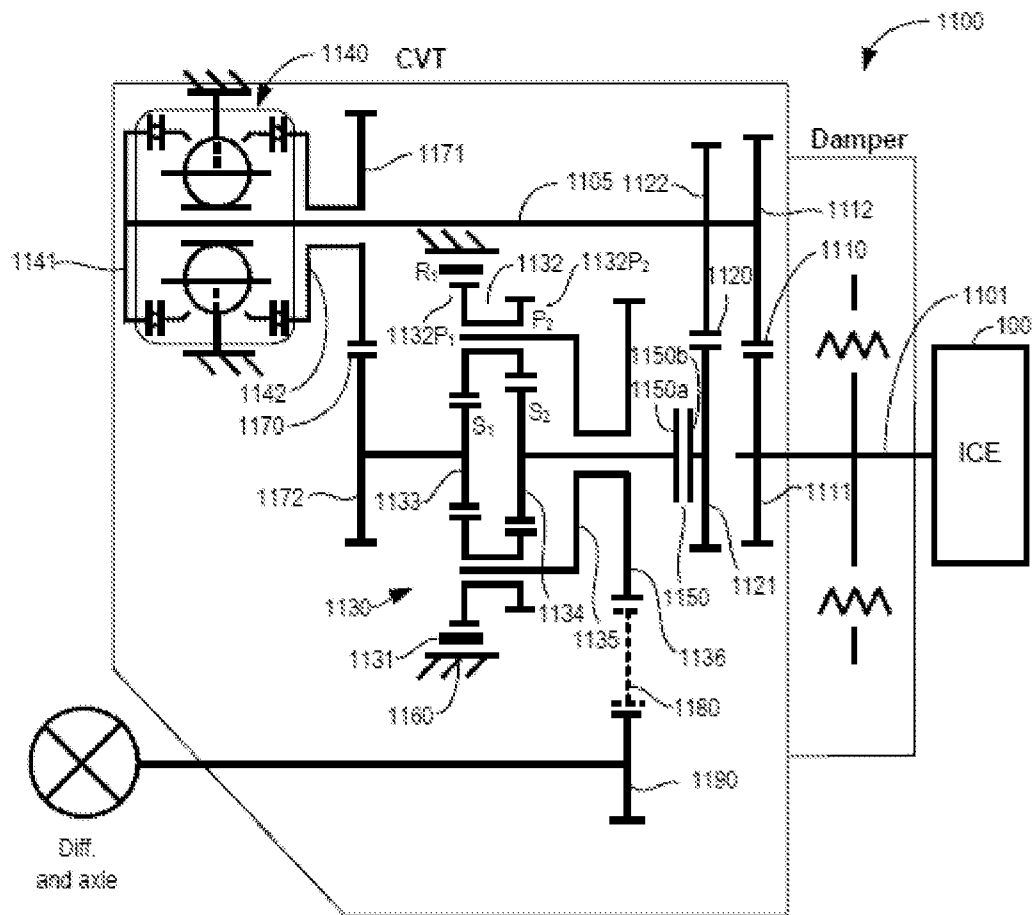


FIG. 11

12/15

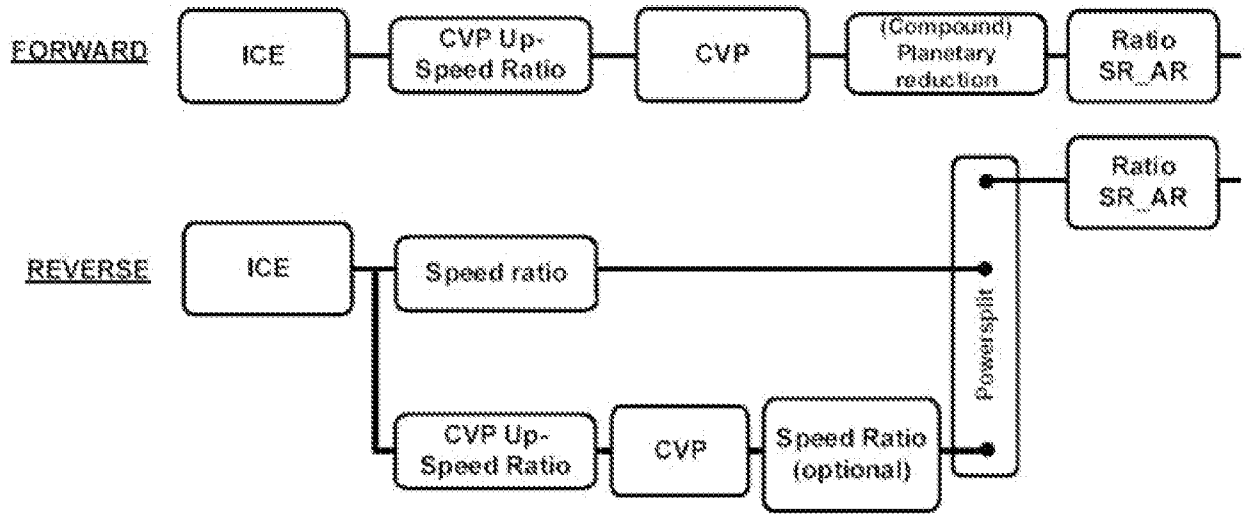


FIG. 12

13/15

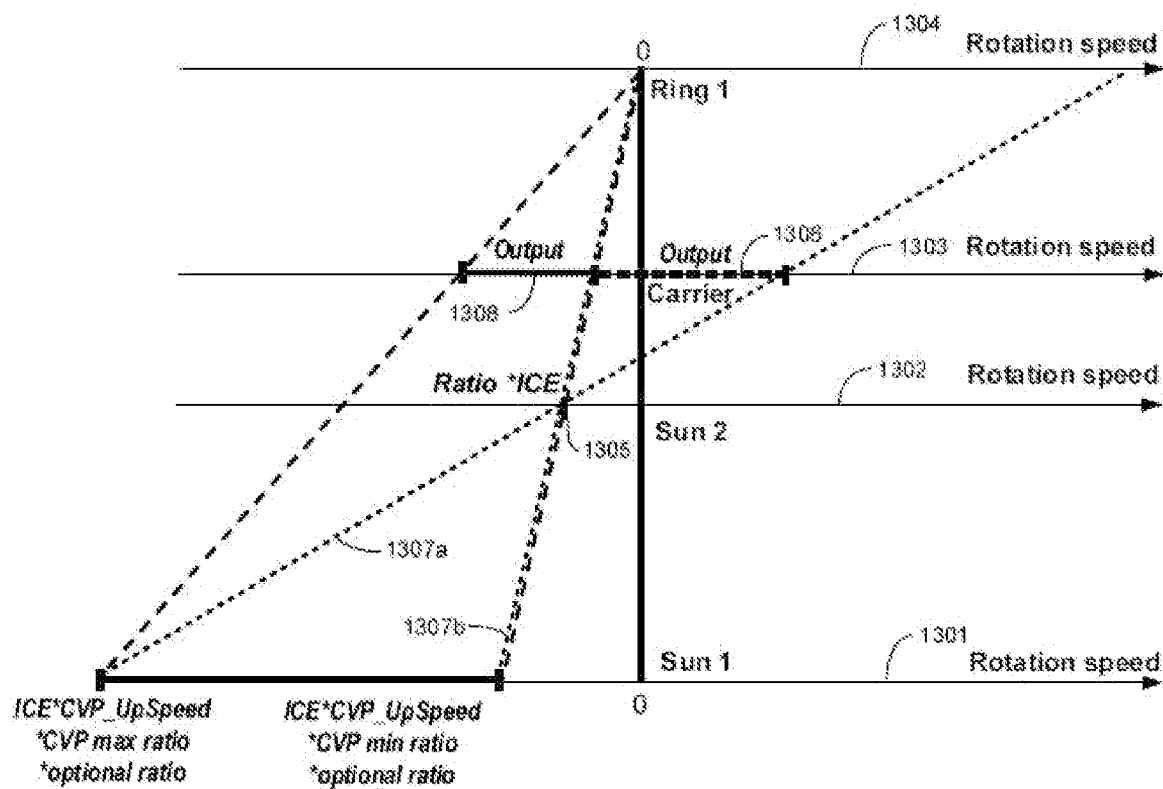


FIG. 13

14/15

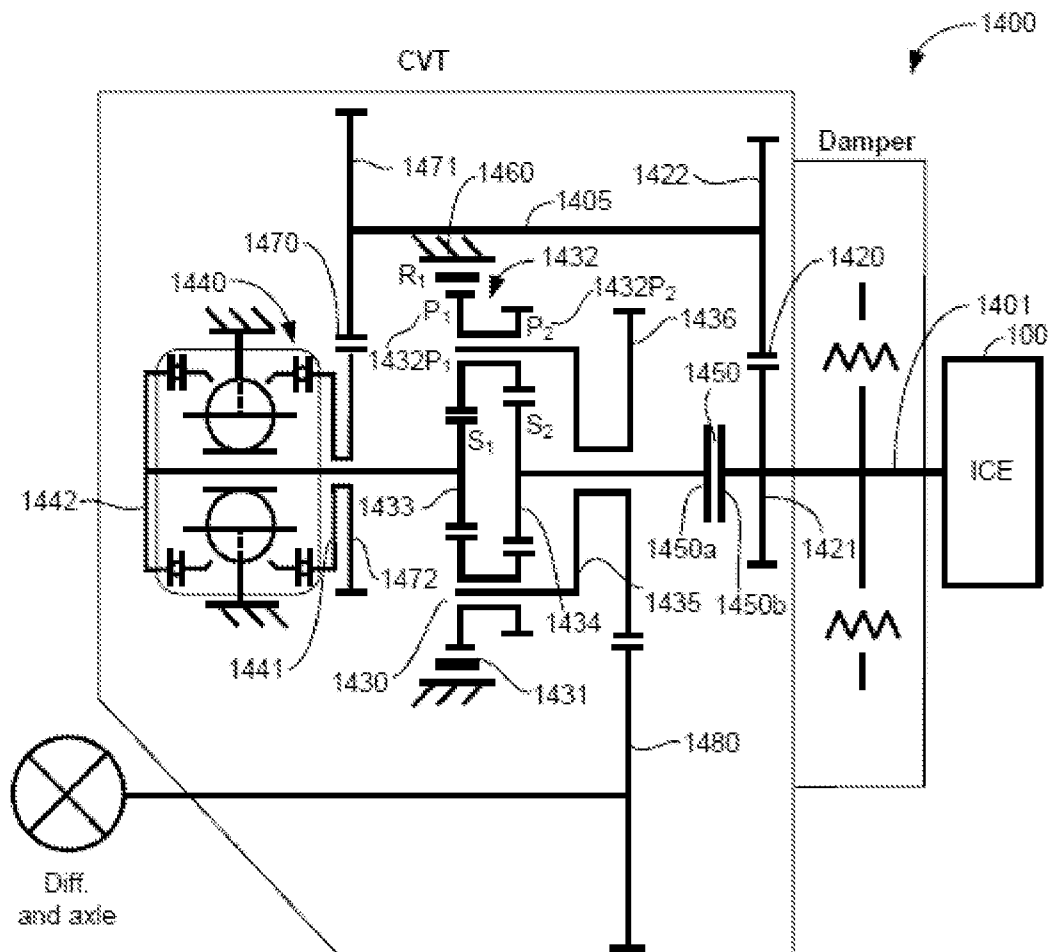


FIG. 14

15/15

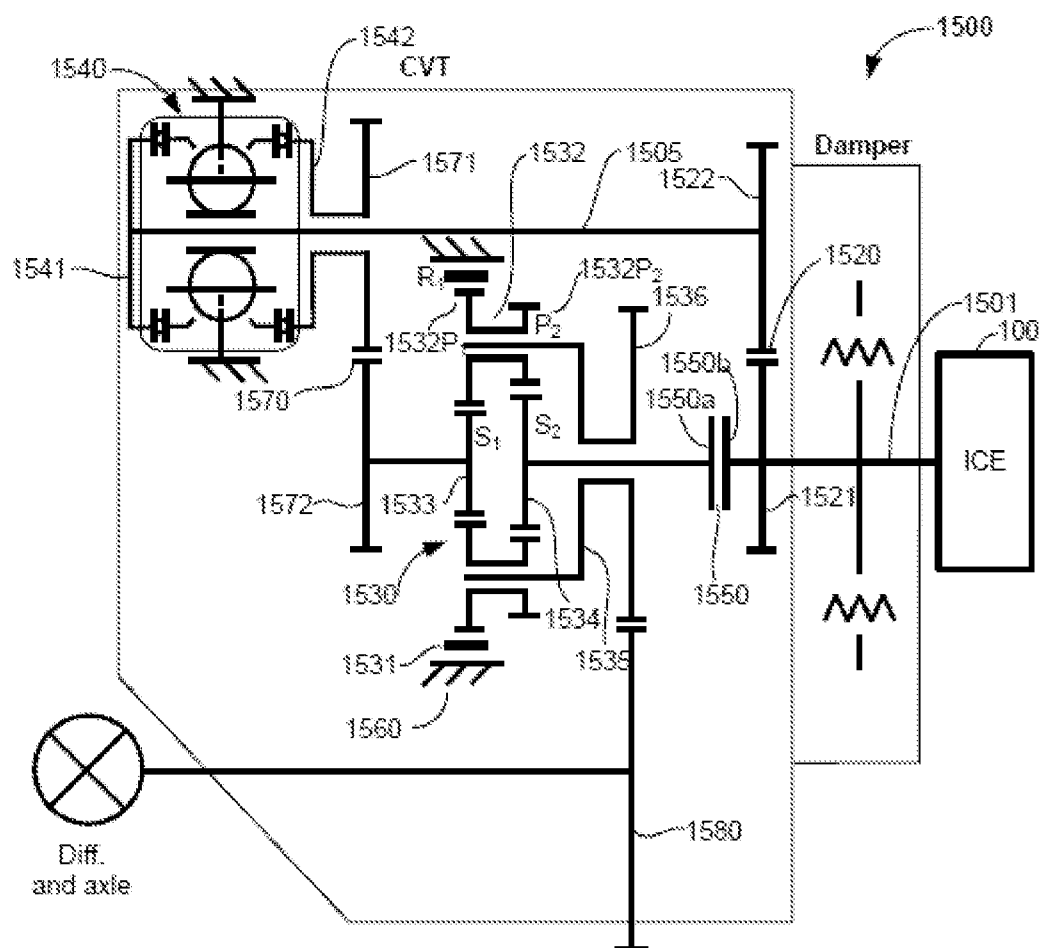


FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/65796

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16H 61/00, 61/02, 61/662 (2015.01)

CPC - F16H 15/38, 61/66259

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)

IPC(8) Classification(s): F16H 61/00, 61/02, 61/662 (2015.01)

CPC Classification(s): F16H 15/38, 61/66259; USPC Classification(s): 474/28; 476/10, 40

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)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data): infinite, continuous, variable, engine, transmission, planet, gear, ring, sun, carrier, variator, differential, forward, backward, reverse, input, shaft, output

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0166984 A1 (INOUE E.) August 26, 2004; figure 1; paragraphs [0080]-[0085]	1-6, 8
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Y		7
Y	US 2011/0015021 A1 (MAGUIRE J. M. et al.) January 20, 2011; paragraph [0023]	7
A	US 2008/0103002 A1 (HOLMES A. G.) May 01, 2008; entire document	1-8
A	US 2007/0032327 A1 (RAGHAVAN M. et al.) February 08, 2007; entire document	1-8

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 March 2015 (30.03.2015)

Date of mailing of the international search report

09 APR 2015

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/65796

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-Please See Supplemental Page-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-8

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US14/65796

---Continued from Box No. III: Observations where unity of invention is lacking---

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: claims 1-8 are directed toward a second sun drivingly engaged to a third gear of a second gear set.

Group II: claims 9-13, 22-43 are directed toward a second ring assembly coupled to a third gear of a second gear set.

Group III: claims 14-21 are directed toward a first carrier is drivingly engaged to a third gear

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons.

The special technical features of Group I include the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear (which is not present in Group III); the second sun drivingly engaged to a third gear of a second gear set (which is not present in Groups II, III); the fourth gear coupled to a first portion of a second clutch on the input shaft (which is not present in Group II).

The special technical features of Group II include a second ring assembly coupled to a third gear of a second gear set, wherein the third gear is drivingly engaged to the fourth gear which is coupled to a first sun of a planetary gear set (which is not present in Groups I, III); the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear (which is not present in Group III); the second sun coupled to a first portion of a second clutch; the second portion of the second clutch coupled to a fifth gear of a third gear set; the third gear set comprising the fifth gear and a sixth gear, wherein the fifth gear is drivingly engaged to the sixth gear, and wherein the sixth gear is coupled to the offset axle (which is not present in Groups I, III).

The special technical features of Group III include a first carrier; the first carrier is drivingly engaged to a third gear (which is not present in Groups I, II); the fourth gear is coupled to a first portion of an input clutch on the input shaft (which is not present in Group II); a second set of planet gears is coupled to the common sun and is drivingly engaged to a second ring and a second carrier; a braking clutch is coupled to the second ring gear; the second carrier and the first ring are coupled to a planetary output gear (which is not present in Groups I, II).

The common technical features of Groups I-III include an input shaft comprising a first gear of a first gear set; the first gear set comprising the first gear and a second gear; the first gear drivingly engaged to the second gear, wherein the second gear is on an offset axle; a variator comprising a first ring assembly drivingly engaged to the second gear, and a second ring assembly coupled to a first sun of a compound planetary gear set; a first set of planet gears of a dual planet gear set coupled to the first sun and drivingly engaged to a ring gear; the dual planet gear set comprising the first set of planet gears and a second set of planet gears; a braking clutch coupled to the ring gear; the second set of planet gears drivingly engaged to a second sun; the second gear set comprising the third gear and a fourth gear; the third gear drivingly engaged to the fourth gear and the fourth gear coupled to a first portion of a second clutch on the input shaft; the clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to the first gear on the input shaft and the ICE; the dual planet gear set is coupled to a carrier; wherein the carrier is drivingly engaged to an output gear; wherein the output gear is drivingly engaged to the output of the transmission.

These common technical features are disclosed by US 2004/0166984 A1 (INOUE); an input shaft (29; figure 1) comprising a first gear (4) of a first gear set (4, 39); the first gear set comprising the first gear and a second gear (39); the first gear (4) drivingly engaged to the second gear (meshingly engaged to gear 39 (second gear); figure 1; paragraph [0039]), wherein the second gear is on an offset axle (disposed adjacent (e.g., on axle) parallel (offset) shaft 30; paragraph [0039]); a variator comprising a first ring assembly (36) drivingly engaged to the second gear (39; figure 1; paragraph [0039]), and a second ring assembly (37) coupled to a first sun (44) of a compound planetary gear set (32; figure 1; paragraph [0042]); a first set of planet gears (47) of a dual planet gear set (32, 33) coupled to the first sun (44; figure 1; paragraph [0042]) and drivingly engaged to a ring gear (meshingly engaged to ring gear 45; paragraph [0042]); the dual planet gear set (32, 33) comprising the first set of planet gears (47) and a second set of planet gears (55); a braking clutch coupled to the ring gear (low speed clutch 27a (braking clutch) transmits to ring gear 45; paragraphs [0073]-[0074]); the second set of planet gears (55) drivingly engaged to a second sun (meshingly engaged to sun gear 52 (second sun); paragraph [0044]); the second gear set comprising the third gear (49) and a fourth gear (50); the third gear (49) drivingly engaged to the fourth gear (meshingly engaged with gear 50 (fourth gear); paragraph [0041]) and the fourth gear (50) coupled to a first portion of a second clutch on the input shaft (coupled to (e.g., at first portion) clutch 28a (second clutch) on input shaft 29; paragraph [0058]); the clutch comprising the first portion and a second portion; the second portion of the second clutch coupled to the first gear on the input shaft (when high speed clutch 28a (second clutch) is connected it takes a path to (e.g., at first portion) gear 50 (fourth gear) and to (e.g., at second portion) gear 4 (first gear); paragraphs [0081]-[0083]) and the ICE (input shaft 29 connected to an engine (e.g., internal combustion engine); paragraph [0037]); the dual planet gear set (32, 33) is coupled to a carrier (coupled to carrier 46; figure 1; paragraph [0084]); wherein the carrier is drivingly engaged to an output gear (power is transmitted from carrier 46 to gears 56, 57 (output gears); paragraph [0084]); wherein the output gear is drivingly engaged to the output of the transmission (power is transmitted from gears 56, 57 (output gear) to output shaft 34 (output of transmission); paragraph [0084]).

Because the common technical features are disclosed by INOUE, the inventions are not so linked as to form a single general inventive concept. Therefore, Groups I-III lack unity.