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(54) Title: MULTI-MODE CLUTCH SYSTEM FOR A DUAL-PASS CONTINUOUSLY VARIABLE AUTOMATIC TRANSMISSION

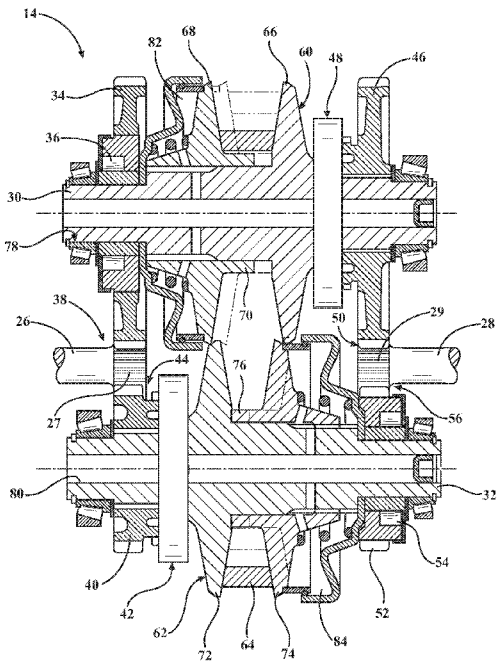


FIG. 2

(57) Abstract: A multi-mode clutch system for use with a dual-pass continuously variable automatic transmission (14) of a vehicle powertrain system (10) includes a first drive assembly (38) including a first one-way clutch (36) engaging an input shaft (26) with a first intermediate shaft (30) and allowing the first intermediate shaft (30) to overrun, a second drive assembly (44) including a first multi-mode clutch module (MMCM) (42) for engaging the input shaft (26) with a second intermediate shaft (32) and allowing the input shaft (26) to overrun, a third drive assembly (50) including a second MMCM (48) for engaging the first intermediate shaft (30) with an output shaft (28) and allowing the first intermediate shaft (30) to overrun, and a fourth drive assembly (56) including a second one-way clutch (54) engaging the second intermediate shaft (32) with the output shaft (28) and allowing the output shaft (28) to overrun.

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# MULTI-MODE CLUTCH SYSTEM FOR A DUAL-PASS CONTINUOUSLY VARIABLE AUTOMATIC TRANSMISSION

## CROSS-REFERENCE TO RELATED APPLICATION(S)

**[0001]** The present application claims priority to and all the benefits of U.S. Provisional Patent Application No. 62/148,847, filed on April 17, 2015, which is hereby expressly incorporated herein by reference in its entirety.

## BACKGROUND OF INVENTION

### 1. *Field of Invention*

**[0002]** The present invention relates generally to powertrain systems and, more specifically, to a multi-mode clutch system for a continuously variable automatic transmission.

### 2. *Description of the Related Art*

**[0003]** Conventional vehicle powertrain systems known in the art typically include an engine in rotational communication with a transmission. The engine generates rotational torque which is selectively translated to the transmission which, in turn, translates rotational torque to one or more wheels. The typical automotive transmission is shifted in discrete steps between a high-torque, low-speed mode for starting a vehicle and a high-speed, low-torque mode for vehicle operation at highway speeds. In a manual transmission shifting is accomplished by the engagement of gear sets. In an automatic transmission shifting is accomplished by the controlled engagement of friction elements. Because such shifting is in step functions, the most efficient vehicle operation can only be approximated. Automotive engineers have long recognized that

efficiency would be improved if the transmission could be adjusted continuously to compensate for changing loads, speeds, etc. This would allow the engine to be operated at maximum efficiency under changing conditions.

**[0004]** Continuously variable automatic transmissions or CVTs have been known for some time. The typical CVT employs a variator including a variable pulley with a pair of flanges mounted on a primary shaft such that one of the flanges is movable axially with respect to the other. Another similar variable pulley is mounted on a secondary shaft. A flexible belt couples the pulleys for transferring torque therebetween when the primary shaft is driven. When the pitch radius of one pulley is changed, the pitch radius of the other pulley is changed simultaneously in the opposite direction. As a result, the drive ratio between the shafts is variable in a continuous, smooth manner within the ratio range of the variator. Typically, the limits of this range are an underdrive or reduction ratio and an overdrive ratio.

**[0005]** A dual-pass CVT includes input and output shafts, first and second intermediate shafts, and a variator engaging the intermediate shafts. A first drive mechanism includes a first one-way clutch engaging the input shaft with the first intermediate shaft and allowing the first intermediate shaft to overrun. A second drive mechanism includes a clutching mechanism for engaging the input shaft with the second intermediate shaft, and also includes a second one-way clutch engaging the second intermediate shaft with the input shaft and allowing the input shaft to overrun. A third drive mechanism includes another clutching mechanism for engaging the first intermediate shaft with the output shaft, and also includes a third one-way clutch engaging the output shaft with the first intermediate shaft and allowing the first intermediate shaft to overrun. A fourth drive mechanism includes a fourth one-way clutch engaging the second intermediate shaft with the output shaft and allowing the output shaft to overrun.

**[0006]** As described above, the dual-pass CVT uses four one-way clutches and two dog (or jaw) clutches to selectively engage and disengage the second pass through the variator. Such a dual-pass CVT is disclosed in U.S. Patent No. 4,630,504 to Smirl, the disclosure of which is hereby incorporated by reference in its entirety. However, it is desirable to improve a shifting performance of the dual-pass CVT. Thus, there is a need in the art to provide a new multi-mode clutch actuation system for use with a dual-pass continuously variable automatic transmission that eliminates the dog clutches and some of the one-way clutches.

## SUMMARY OF THE INVENTION

**[0007]** The present invention provides a multi-mode clutch system for a dual-pass continuously variable automatic transmission of a vehicle powertrain system including a first drive assembly including a first one-way clutch engaging an input shaft with a first intermediate shaft and allowing the first intermediate shaft to overrun, a second drive assembly including a first multi-mode clutch module (MMCM) for engaging the input shaft with a second intermediate shaft and allowing the input shaft to overrun, a third drive assembly including a second MMCM for engaging the first intermediate shaft with an output shaft and allowing the first intermediate shaft to overrun, and a fourth drive assembly including a second one-way clutch engaging the second intermediate shaft with the output shaft and allowing the output shaft to overrun.

**[0008]** Further, the present invention provides a dual-pass continuously variable transmission including rotatable input and output shafts, first and second rotatable intermediate shafts, a first drive assembly including a first one-way clutch engaging the input shaft with the first intermediate shaft and allowing the first intermediate shaft to overrun, a second drive

assembly including a first multi-mode clutch module (MMCM) for engaging the input shaft with the second intermediate shaft and engaging the second intermediate shaft with the input shaft and allowing the input shaft to overrun, a third drive assembly including a second MMCM for engaging the first intermediate shaft with the output shaft and allowing the first intermediate shaft to overrun, a fourth drive assembly including a fourth one-way clutch engaging the second intermediate shaft with the output shaft and allowing the output shaft to overrun, and a variator engaging the intermediate shafts. The first and fourth drive assembly establish a first drive path from the input shaft through the first drive assembly, first intermediate shaft, variator, second intermediate shaft and fourth drive assembly to the output shaft, the second and third drive assembly, when the first MMCM and the second MMCM are engaged, establish a second drive path from the input shaft through the second drive assembly, second intermediate shaft, variator, first intermediate shaft and third drive assembly to the output shaft, and the second and third drive assembly, when the first MMCM and the second MMCM are not engaged, establish the third drive path from the output shaft through the third drive assembly, first intermediate shaft, variator, second intermediate shaft and second drive assembly to the input shaft.

**[0009]** In addition, the present invention provides a method for controlling a multi-mode clutch system for use with a dual-pass continuously variable automatic transmission of a vehicle powertrain system including the steps of engaging a first one-way clutch of a first drive assembly with an input shaft and a first intermediate shaft and allowing the first intermediate shaft to overrun, engaging a first multi-mode clutch module (MMCM) of a second drive assembly with the input shaft and a second intermediate shaft and allowing the input shaft to overrun, engaging a second MMCM of a third drive assembly with the first intermediate shaft and an output shaft and allowing the first intermediate shaft to overrun, and engaging a second one-way clutch of a

fourth drive assembly with the second intermediate shaft and the output shaft and allowing the output shaft to overrun.

**[0010]** One advantage of the present invention is that a new multi-mode clutch system is provided for a continuously variable (automatic) transmission (CVT). Another advantage of the present invention is that the multi-mode clutch system replaces the one-way clutches and dog clutches in a dual-pass CVT. Yet another advantage of the present invention is that the multi-mode clutch system improves the shifting performance of the dual-pass CVT. Still another advantage of the present invention is that the multi-mode clutch system enables additional flexibility of controls for the dual-pass CVT. A further advantage of the multi-mode clutch system is that it provides fewer components to the dual-pass CVT.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** Other objects, features, and advantages of the present invention will be readily appreciated as the same becomes better understood after reading the subsequent description taken in connection with the accompanying drawings wherein:

**[0012]** Figure 1 is a schematic view of a vehicle powertrain system including a continuously variable automatic transmission and a multi-mode clutch system, according to the present invention; and

**[0013]** Figure 2 is a schematic view of a first embodiment of the multi-mode clutch system, according to the present invention, for use with the continuously variable automatic transmission of Figure 1.

**[0014]** Figure 3 is a schematic view of a second embodiment of the multi-mode clutch system, according to the present invention, for use with the continuously variable automatic transmission of Figure 1.

## DETAILED DESCRIPTION OF THE INVENTION

**[0015]** Referring now to the figures, where like numerals are used to designate like structure unless otherwise indicated, a vehicle powertrain system is schematically illustrated at 10 in Figure 1. The powertrain system 10 includes an engine 12 in rotational communication with a dual-pass continuously variable (automatic) transmission (CVT) 14. The engine 12 generates rotational torque which is selectively translated to the CVT 14 which, in turn, translates rotational torque to one or more wheels, generally indicated at 16. To that end, a pair of continuously-variable joints 18 translates rotational torque from the CVT 14 to the wheels 16. The CVT 14 is typically controlled using hydraulic fluid. Specifically, the CVT 14 is cooled, lubricated, actuated, and modulates torque using hydraulic fluid. To these ends, the powertrain system 10 typically includes a hydraulic control system 20 that directs or otherwise controls fluid to the CVT 14 and a power controller 22 in electrical communication with one or more solenoids 24 used to direct, control, or otherwise regulate flow of fluid throughout the CVT 14. It should also be appreciated that the engine 12 and the CVT 14 of Figure 1 are of the type employed in a conventional "transverse front wheel drive" powertrain system 10. It should further be appreciated that the engine 12 and/or CVT 14 could be configured in any suitable way sufficient to generate and translate rotational torque so as to drive the vehicle, without departing from the scope of the present invention.

**[0016]** Referring to Figure 2, a first embodiment, according to the present invention, of the CVT 14 includes an input shaft 26 adapted to receive torque from a power source, for example the engine 12, and an input drive gear 27 secured to the shaft 26. The CVT 14 also includes an output shaft 28 adapted to direct torque to the joints 18 and an output driven gear 29 secured to the shaft 28. It should be appreciated that the drive gear 27 should be designed to mate the CVT 14 to the engine 12 with which it is to be used, and the driven gear 29 should be designed to mate the CVT 14 to the vehicle driveline.

**[0017]** The CVT 14 also includes first and second intermediate shafts 30 and 32 respectively, and a first driven gear 34 secured to an outer race of a one-way clutch 36, an inner race of which is secured to the shaft 30. The one-way clutch 36 is oriented such that shaft 30 may overrun the driven gear 34. It should be appreciated that the drive gear 27, driven gear 34, and one-way clutch 36 together constitute a first drive assembly, generally indicated at 38, for transferring torque from the input shaft 26 to the intermediate shaft 30, but not from the intermediate shaft 30 to the input shaft 26.

**[0018]** The CVT 14 includes a second driven gear 40 and a multi-mode clutch module (MMCM), generally indicated at 42, that may allow the intermediate shaft 32 to overrun the gear 40 or be engaged to lock the gear 40 to the shaft 32. It should be appreciated that the drive gear 27, driven gear 40, and MMCM 42 together constitute a second drive assembly, generally indicated at 44, for transferring torque in either direction between the input shaft 26 and intermediate shaft 32 when the MMCM 42 is engaged, and from the intermediate shaft 32 to the input shaft 26 when the MMCM 42 is not engaged.

**[0019]** The CVT 14 further includes a third drive gear 46 and a multi-mode clutch module (MMCM), generally indicated at 48, that may allow the intermediate shaft 30 to overrun

the gear 46 or be engaged to lock the shaft 30 to the gear 46. An example of the MMCM is disclosed in PCT Patent Application Publication No. WO 2014/120595, the disclosure of which is hereby incorporated by reference in its entirety. It should be appreciated that the drive gear 46, driven gear 29, and MMCM 48 together constitute a third drive assembly, generally indicated at 50, for transferring torque in either direction between the intermediate shaft 30 and output shaft 28 when the MMCM 48 is engaged, and from the output shaft 28 to the intermediate shaft 30 when the MMCM 48 is not engaged.

**[0020]** The CVT 14 includes a fourth drive gear 52 is secured to an outer race of a one-way clutch 54, an inner race of which is secured to the intermediate shaft 32. The one-way clutch 54 is oriented such that the drive gear 52 may overrun the intermediate shaft 32. It should be appreciated that the one-way clutch 54, drive gear 52, and driven gear 29 together constitute a fourth drive assembly, generally indicated at 56, for transferring torque from the intermediate shaft 32 to the output shaft 28, but not from the output shaft 28 to the intermediate shaft 32.

**[0021]** The particular application of CVT 14 will determine whether these four drive assemblies 38, 44, 50, and 56 provide underdrive or overdrive. For example, if CVT 14 is to be used in a passenger automotive vehicle with an internal combustion engine, it may be assumed that the drive assemblies 38 and 56 provide underdrive, and that the drive assemblies 44 and 50 provide overdrive. With this assumption, a gear set 44-27 has an underdrive ratio, and a gear set 40-27 has an overdrive ratio. Thus the ratio through a gear train having gears 34, 27 and 40 (from the shaft 30 to the shaft 32) is overdrive. In the opposite direction, the ratio is underdrive. Similarly, a gear set 29-46 has an overdrive ratio, and a gear set 29-52 has an underdrive ratio. Thus the ratio through a gear train of gears 46, 29 and 52 (from the shaft 30 to the shaft 32) is overdrive. In the opposite direction, the ratio is underdrive. It should be appreciated that this

relationship may be modified so long as the ratios through the gear trains (from one intermediate shaft to the other) are equal.

**[0022]** The CVT 14 further includes a variator 58 that engages the shafts 30 and 32. The variator 58 includes a variable pulley 60 on the intermediate shaft 30 and another variable pulley 62 on the intermediate shaft 32. The pulleys 60 and 62 are continuously variable respectively between minimum and maximum pitch radii. The CVT 14 also includes a suitable belt 64 or the like to couple the pulleys 60 and 62.

**[0023]** As is well known in the art, the pitch radii of the pulleys 60 and 62 may be varied such that the ratio of the variator 58 is continuously variable within a range having predetermined limits. These limits should provide a fifth, underdrive ratio and a sixth, overdrive ratio substantially equal to the overdrive ratio through the gear trains 34,27,40 and 46,29,52.

**[0024]** The pulley 60 includes a fixed flange 66 rotatable with the intermediate shaft 30 and a slidable flange 68 having a hub 70 rotatable with and slidable relative to the shaft 30. As shown in solid lines, the flange 68 is in its distal position relative to the flange 66. In this position, the pulley 60 develops its minimum pitch radius. As shown in dashed lines, the flange 68 is in its proximal position, with the hub 70 abutting the flange 66. It should be appreciated that, in this position, the pulley 60 develops its maximum pitch radius.

**[0025]** The pulley 62 is similar to the pulley 60 and includes a fixed flange 72 rotatable with the intermediate shaft 32 and a slidable flange 74 having a hub 76 rotatable with and slidable relative to the shaft 32. As shown in solid lines, the flange 74 is in its proximal position relative to the flange 72, with the hub 76 abutting the flange 72. This determines the maximum pitch radius of the pulley 62. As shown in dashed lines, the flange 74 is in its distal position, which determines the minimum pitch radius of the pulley 62.

**[0026]** The hydraulic control system 20 is provided for directing fluid through passages 78 and 80 to and from chambers 82 and 84, respectively, in order to slide the flanges 68 and 74, and thus to vary the pitch radii of the pulleys 60 and 62 between their predetermined minimum and maximum limits. It should be appreciated that the particular details of the hydraulic control system 20 form no part of the present invention. It should also be appreciated that typical control systems for conventional CVTs are disclosed in U.S. Pat. No. 4,458,318 issued July 3, 1984 and U.S. Pat. No. 4,522,086 issued June 11, 1985, the disclosures of which are both incorporated herein by reference in their entirety.

**[0027]** The sequence of events for a vehicle acceleration begins. A first drive path is established from the shaft 26 through the drive assembly 38, shaft 30, variator 58, shaft 32 and drive assembly 56 to the shaft 28. The gear 40 is rotating faster than the intermediate shaft 32, with the MMCM 42 disengaged. Similarly, the gear 46 is rotating slower than the intermediate shaft 30, with the MMCM 48 disengaged. At this point, the CVT 14 is in the low-range mode and provides underdrive from the input shaft 26 to the output shaft 28.

**[0028]** The variator 58 now is shifted continuously through its ratio range from underdrive to overdrive. This results in a continuous, smooth increase in the output speed at the output shaft 28.

**[0029]** At the end of the first pass through the variator 58, the CVT 14 provides direct drive from the shaft 26 to the shaft 28. The shaft 32 is in substantial synchronism with the gear 40, and the shaft 30 is in substantial synchronism with the gear 46. If desired, suitable sensors may be provided for transmitting appropriate torque and/or speed signals. In response to these signals, if provided, the hydraulic control system 20 engages the MMCM 42 and 48.

**[0030]** When the MMCM 42 and 48 are engaged, a second drive path is established from the input shaft 26 through the drive assembly 44, shaft 32, variator 48, shaft 30 and drive assembly 50 to the output shaft 28. The CVT 14 is in the high-range mode, but still provides direct drive from the input shaft 26 to the output shaft 28.

**[0031]** The CVT 14 is conditioned such that when the variator 58 is shifted in the opposite direction, one-way clutches 36 and 54 disengage automatically, allowing the intermediate shaft 30 to overrun the gear 34, and allowing the gear 52 to overrun the intermediate shaft 32. Thus a smooth changeover from the first drive path to the second drive path is achieved simply and easily.

**[0032]** The variator 58 now is shifted in the opposite direction continuously through its ratio range from underdrive to overdrive. This results in an additional continuous, smooth increase in the output speed at the output shaft 28.

**[0033]** At the end of the second pass through the variator 58, the CVT 14 provides overdrive from the shaft 26 to the output shaft 28. One operating cycle (two passes through the variator 58) has been completed. The belt 54 is in its initial, starting position, with the pulleys 60 and 62 rotating at correspondingly higher speeds.

**[0034]** It should be appreciated that the MMCM 42 and 48 are engaged when the CVT 14 is in the high-range mode; that is, when it is configured for the second drive path. The MMCM 42 and 48 establish a positive connection for the transfer of torque between the input shaft 26 and the output shaft 28. Thus, the CVT 14 provides engine braking in this mode.

**[0035]** If the vehicle operator closes a throttle (not shown) when the CVT 14 is in the low-range mode; that is, when it is configured for the first drive path, the one-way clutches 36 and 52 disengage immediately upon the transfer of torque from the shaft 28 to the shaft 26. Thus

no engine braking would normally be provided when the CVT 14 is in this mode. However, as one-way clutches 36 and 54 disengage, the MMCM 42 and 48 engage to establish the second drive path for the transfer of torque from the shaft 28 to the shaft 26. The CVT 14 provides engine braking through the second drive path at whatever ratio may be determined by the variator 58.

**[0036]** When the CVT 14 is in either the low-range mode or the high-range mode, engine braking is provided through the MMCM 42 and 48 until the vehicle speed decreases to a predetermined level.

**[0037]** The four operating mode of the CVT 14 are summarized as follows:

| Mode | OWC 36 | OWC 54 | MMCM 42 | MMCM 48 |
|---|---|---|---|---|
| Low Range-Driving | Driving | Driving | OWC-Overrun | OWC-Overrun |
| High Range-Driving | Overrun | Overrun | Locked | Locked |
| Low Range-Braking | Overrun | Overrun | OWC-Driving | OWC-Driving |
| High Range-Braking | Overrun | Overrun | Locked | Locked |

**[0038]** Referring to Figure 3, a second embodiment, according to the present invention of the CVT 14 is shown. Like parts of the CVT 14 of Figure 2 have like reference numerals. In this embodiment, the one-way clutches are replaced with MMCMs. As illustrated, the MMCM 36 and 54 allow engine braking in the low range through the first drive path instead of having to switch to the third drive path. It should be appreciated that, in this embodiment, the CVT 14 includes four (4) MMCMs. It should also be appreciated that, except as described above, operation of the CVT 14 of Figure 3 is similar to the operation of the CVT 14 of Figure 2.

**[0039]** The present invention has been described in an illustrative manner. It is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

**[0040]** Many modifications and variations of the present invention are possible in light of the above teachings. Therefore, within the scope of the appended claims, the invention may be practiced other than as specifically described.

**What is claimed is:**

1. A multi-mode clutch system for use with a dual-pass continuously variable automatic transmission (14) of a vehicle powertrain system (10), said clutch system comprising:

a first drive assembly (38) including a first one-way clutch (36) engaging an input shaft (26) with a first intermediate shaft (30) and allowing the first intermediate shaft (30) to overrun;

a second drive assembly (44) including a first multi-mode clutch module (MMCM) (42) for engaging the input shaft (26) with a second intermediate shaft (32) and allowing the input shaft (26) to overrun;

a third drive assembly (50) including a second MMCM (48) for engaging the first intermediate shaft (30) with an output shaft (28) and allowing the first intermediate shaft (30) to overrun; and

a fourth drive assembly (56) including a second one-way clutch (54) engaging the second intermediate shaft (32) with the output shaft (28) and allowing the output shaft (28) to overrun.

2. A multi-mode clutch system as set forth in claim 1 including a variator (58) engaging the intermediate shafts (30, 32), said first (38) and fourth (56) drive assembly establishing a first drive path from the input shaft (26) through said first drive assembly (38), first intermediate shaft (30), variator (58), second intermediate shaft (32) and fourth drive assembly (56) to the output shaft (28), said second (44) and third (50) drive assembly, when said first MMCM (42) and said second (48) MMCM are engaged, establishing a second drive path from the input shaft (26) through said second drive assembly (44), second intermediate shaft (32), variator (58), first intermediate shaft (30) and third drive assembly (50) to the output shaft(28), and said second (44) and third drive assembly (50), when said first MMCM (42) and

said second MMCM (48) are not engaged, establishing said second drive path from the output shaft (28) through said third drive assembly (50), first intermediate shaft (30), variator (58), second intermediate shaft (32) and second drive assembly (44) to the input shaft (26).

3. A multi-mode clutch system as set forth in claims 1 or 2 wherein said first (38) and second (44) drive assembly respectively includes first (27, 34) and second (27, 40) gear sets driven by the input shaft (26).

4. A multi-mode clutch system as set forth in claims 3 wherein said third (50) and fourth (56) drive assembly respectively includes third (46, 29) and fourth (52, 29) gear sets driving the output shaft (28).

5. A multi-mode clutch system as set forth in claim 4, said first one-way clutch (36) engaging a driven gear (34) of said first gear set (27, 34) with the first intermediate shaft (30), said first MMCM (42) for engaging a driven gear (40) of said second gear set (27, 40) with the second intermediate shaft (32) and engaging the second intermediate shaft (32) with the driven gear (40) of said second gear set (27, 40), said second MMCM (48) for engaging the first intermediate shaft (30) with a drive gear of (46) said third gear set (46, 29) and engaging the drive gear (46) of said third gear set (46, 29) with the first intermediate shaft (30), and said second one-way clutch (54) engaging said second intermediate shaft (32) with a drive gear (52) of said fourth gear set (52, 29).

6. A multi-mode clutch system as set forth in claim 5, wherein said variator (58) includes a variable pulley (60) rotatable with the first intermediate shaft (30), another variable pulley (62) rotatable with the second intermediate shaft (32), and a belt (64) coupling said pulleys (60, 62), each of said pulleys (60, 62) including a fixed flange (66, 72)) rotatable with its associated intermediate shaft (30, 32), and another flange (68, 74) rotatable with and slidable relative to its associated intermediate shaft (30, 32) between proximal and distal positions relative to its associated fixed flange (66, 72), the distal position of the slidable flange (68, 74) of said pulley (60) and the proximal position of the slidable flange (68, 74) of said other pulley (62) determining one of said limits, and the proximal position of the slidable flange (68) of said pulley (60) and the distal position of the slidable flange (74) of said other pulley (62) determining the other of said limits.

7. A dual-pass continuously variable transmission (14) comprising:

rotatable input (26) and output (28) shafts;

first (30) and second (32) rotatable intermediate shafts;

a first drive assembly (38) including a first one-way clutch (36) engaging said input shaft (26) with said first intermediate shaft (30) and allowing said first intermediate shaft (30) to overrun;

a second drive assembly (44) including a first multi-mode clutch module (MMCM) (42) for engaging said input shaft (26) with said second intermediate shaft (32) and engaging said second intermediate shaft (32) with said input shaft (26) and allowing said input shaft (26) to overrun;

a third drive assembly (50) including a second MMCM (48) for engaging said first intermediate shaft (30) with said output shaft (28) and allowing said first intermediate shaft (30) to overrun;

a fourth drive assembly (56) including a fourth one-way clutch (54) engaging said second intermediate shaft (32) with said output shaft (28) and allowing said output shaft (28) to overrun; and

a variator (58) engaging said intermediate shafts (30, 32), said first (38) and fourth drive assembly (56) establishing a first drive path from said input shaft (26) through said first drive assembly (38), first intermediate shaft (30), variator (58), second intermediate shaft (32) and fourth drive assembly (56) to said output shaft (28), said second (44) and third (50) drive assembly, when said first MMCM (42) and said second MMCM (48) are engaged, establishing a second drive path from said input shaft (26) through said second drive assembly (44), second intermediate shaft (32), variator (58), first intermediate shaft (30) and third drive assembly (50) to said output shaft (28), and said second (44) and third (50) drive assembly, when said first MMCM (42) and said second MMCM (48) are not engaged, establishing said second drive path from said output shaft (28) through said third drive assembly (50), first intermediate shaft (30), variator (58), second intermediate shaft (32) and second drive assembly (44) to said input shaft (26).

8. A dual-pass continuously variable transmission (14) as set forth in claim 7 wherein said first (38) and second (44) drive assembly respectively includes first (27, 34) and second (27, 40) gear sets driven by said input shaft (26).

9. A dual-pass continuously variable transmission (14) as set forth in claims 7 or 8 wherein said third (50) and fourth (56) drive assembly respectively including third (46, 29) and fourth (52, 29) gear sets driving said output shaft (38).

10. A dual-pass continuously variable transmission (14) as set forth in claim 9 wherein said first one-way clutch (36) engaging a driven gear (34) of said first gear set (27, 34) with said first intermediate shaft (30), said first MMCM (42) for engaging a driven gear (40) of said second gear set (27, 40) with said second intermediate shaft (32) and engaging said second intermediate shaft (32) with the driven gear (40) of said second gear set (27, 40), said second MMCM (48) for engaging said first intermediate shaft (30) with a drive gear (46) of said third gear set (46, 29) and engaging the drive gear (46) of said third gear set (46, 29) with said first intermediate shaft (30), and said second one-way clutch (54) engaging said second intermediate shaft (32) with a drive gear (52) of said fourth gear set (52, 29).

11. The dual-pass continuously variable transmission (14) as set forth in any one of claims 7-10, wherein said variator (58) includes a variable pulley (60) rotatable with said first intermediate shaft (30), another variable pulley (62) rotatable with said second intermediate shaft (32), and a belt (64) coupling said pulleys (60, 62), each of said pulleys (60, 62) including a fixed flange (66, 72) rotatable with its associated intermediate shaft (30, 32), and another flange (68, 74) rotatable with and slidable relative to its associated intermediate shaft (30, 32) between proximal and distal positions relative to its associated fixed flange (66, 72), the distal position of the slidable flange (68) of said pulley (60) and the proximal position of the slidable flange (74) of said other pulley (62) determining one of said limits, and the proximal position of the slidable

flange (68) of said pulley (60) and the distal position of the slidable flange (74) of said other pulley (62) determining the other of said limits.

12. A multi-mode clutch system for use with a dual-pass continuously variable automatic transmission (14) of a vehicle powertrain system (10), said clutch system comprising:

a first drive assembly (38) including a first multi-mode clutch module (MMCM) (30) engaging said input shaft (26) with said first intermediate shaft (30) and allowing said first intermediate shaft (30) to overrun;

a second drive assembly (44) including a second multi-mode clutch module (MMCM) (42) for engaging said input shaft (26) with said second intermediate shaft (32) and allowing said input shaft (26) to overrun;

a third drive assembly (50) including a third MMCM (48) for engaging said first intermediate shaft with said output shaft and allowing said first intermediate shaft to overrun; and

a fourth drive assembly (56) including a fourth MMCM (54) engaging said second intermediate shaft with said output shaft and allowing said output shaft to overrun.

13. A method for controlling a multi-mode clutch system for use with a dual-pass continuously variable automatic transmission (14) of a vehicle powertrain system (10), said method comprising the steps of:

engaging a first one-way clutch (36) of a first drive assembly (38) with an input shaft (26) and a first intermediate shaft (30) and allowing the first intermediate shaft (30) to overrun;

engaging a first multi-mode clutch module (MMCM) (42) of a second drive assembly (44) with the input shaft (26) and a second intermediate shaft (32) and allowing the input shaft (26) to overrun;

engaging a second MMCM (48) of a third drive assembly (50) with the first intermediate shaft (30) and an output shaft (28) and allowing the first intermediate shaft (30) to overrun; and

engaging a second one-way clutch (54) of a fourth drive assembly (56) with the second intermediate shaft (32) and the output shaft (28) and allowing the output shaft (28) to overrun.

14. A method as set forth in claim 13 including the steps of engaging a variator (58) with the intermediate shafts (30, 32), establishing a first drive path from the input shaft (26) through the first drive assembly (38), first intermediate shaft (30), variator (58), second intermediate shaft (32) and fourth drive assembly (56) to the output shaft (28), the second (44) and third (50) drive assembly, when the first MMCM (42) and the second MMCM (48) are engaged, establishing a second drive path from the input shaft (26) through the second drive assembly (44), second intermediate shaft (32), variator (58), first intermediate shaft (30) and third drive assembly (50) to the output shaft (28), and the second (44) and third (50) drive assembly, when the first MMCM (42) and the second MMCM (48) are not engaged, establishing the second drive path from the output shaft (28) through the third drive assembly (50), first intermediate shaft (30), variator (58), second intermediate shaft (32) and second drive assembly (44) to the input shaft (26).

15. A method as set forth in claims 13 or 14 including the step of providing the first (38) and second (44) drive assembly with first (27, 34) and second (27, 40) gear sets driven by the input shaft (26).

16. A method as set forth in claims 14 or 15 including the step of providing the third (50) and fourth (56) drive assembly with third (46, 29) and fourth (52, 29) gear sets driving the output shaft (28).

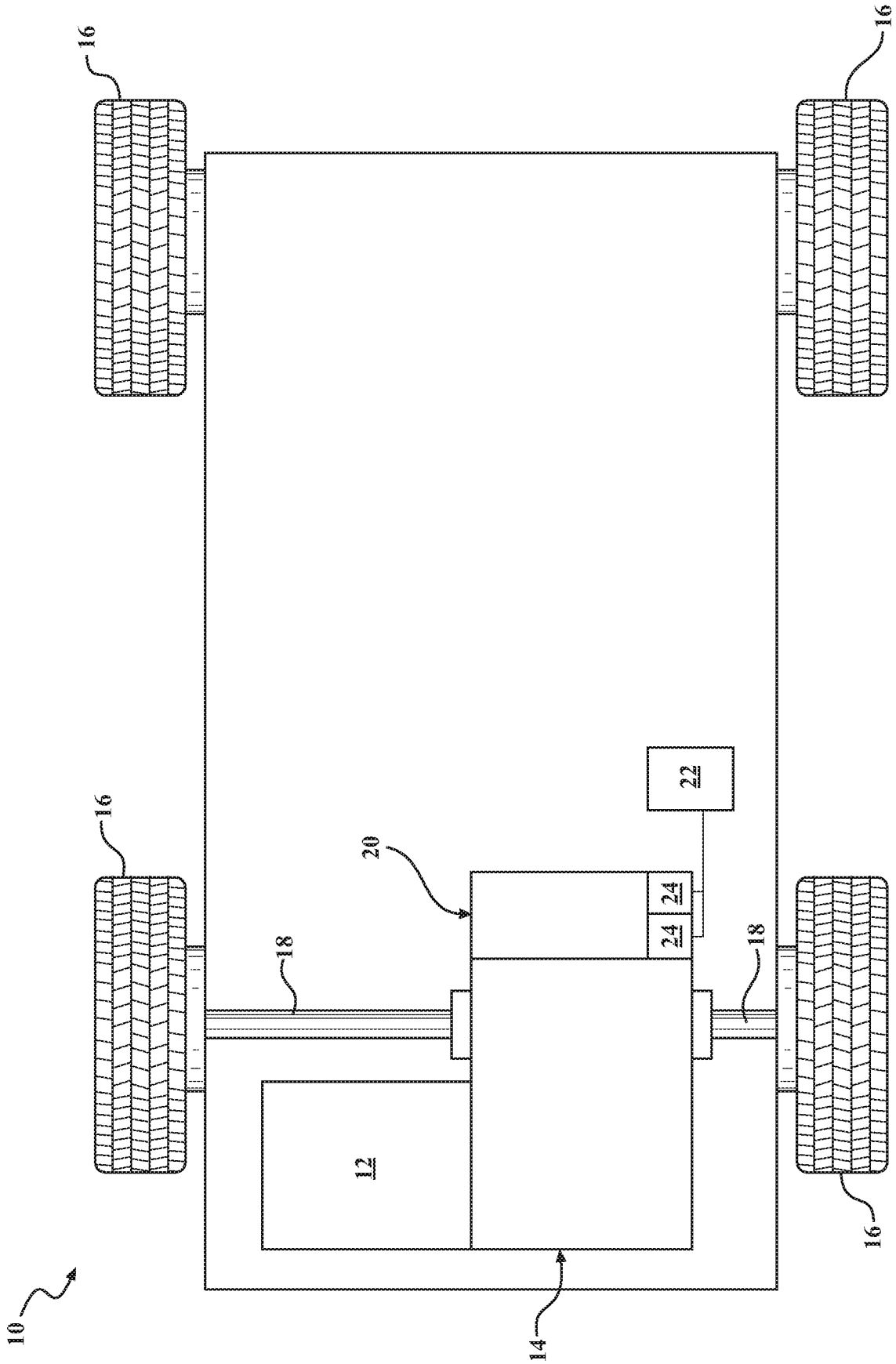


FIG. 1

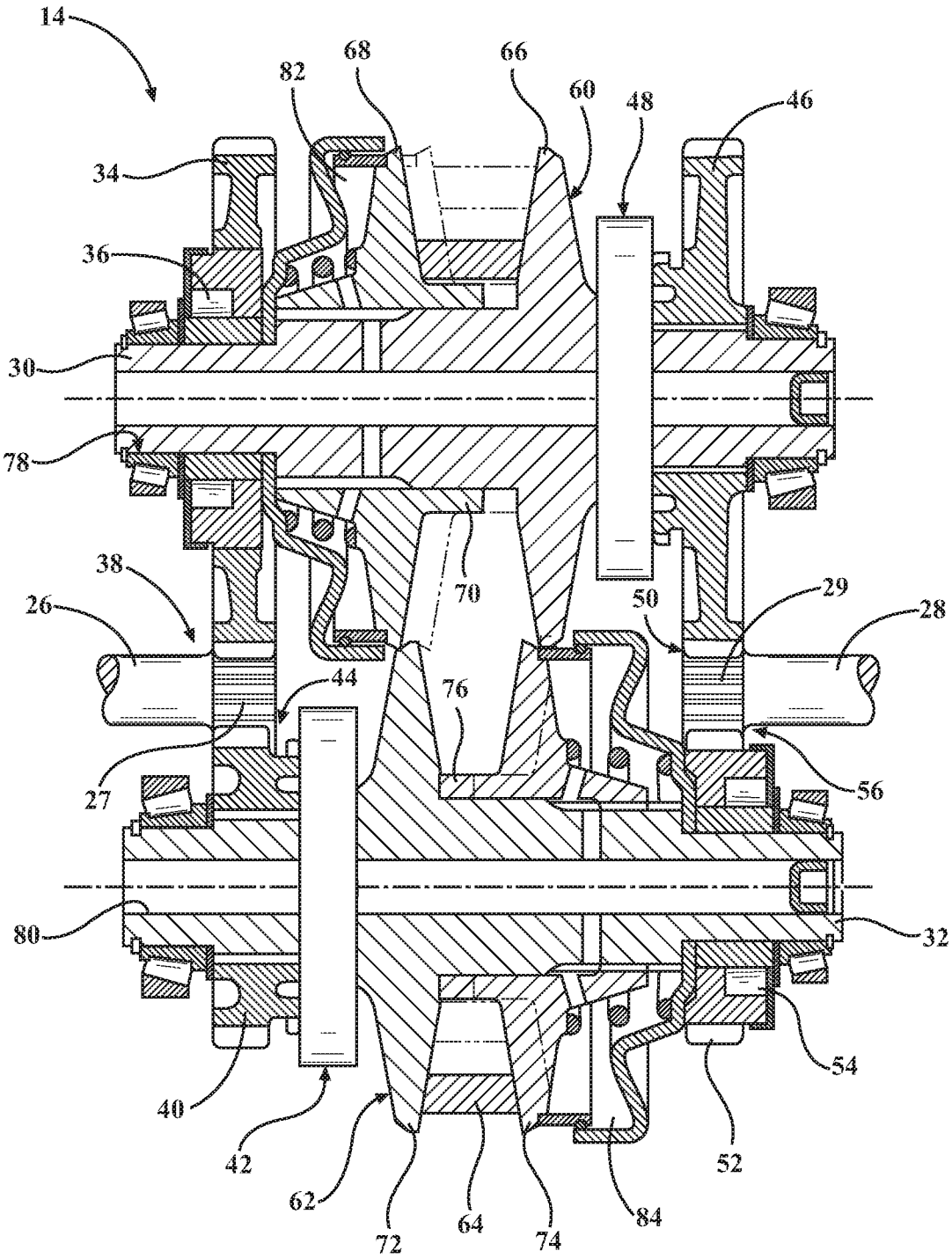
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FIG. 2

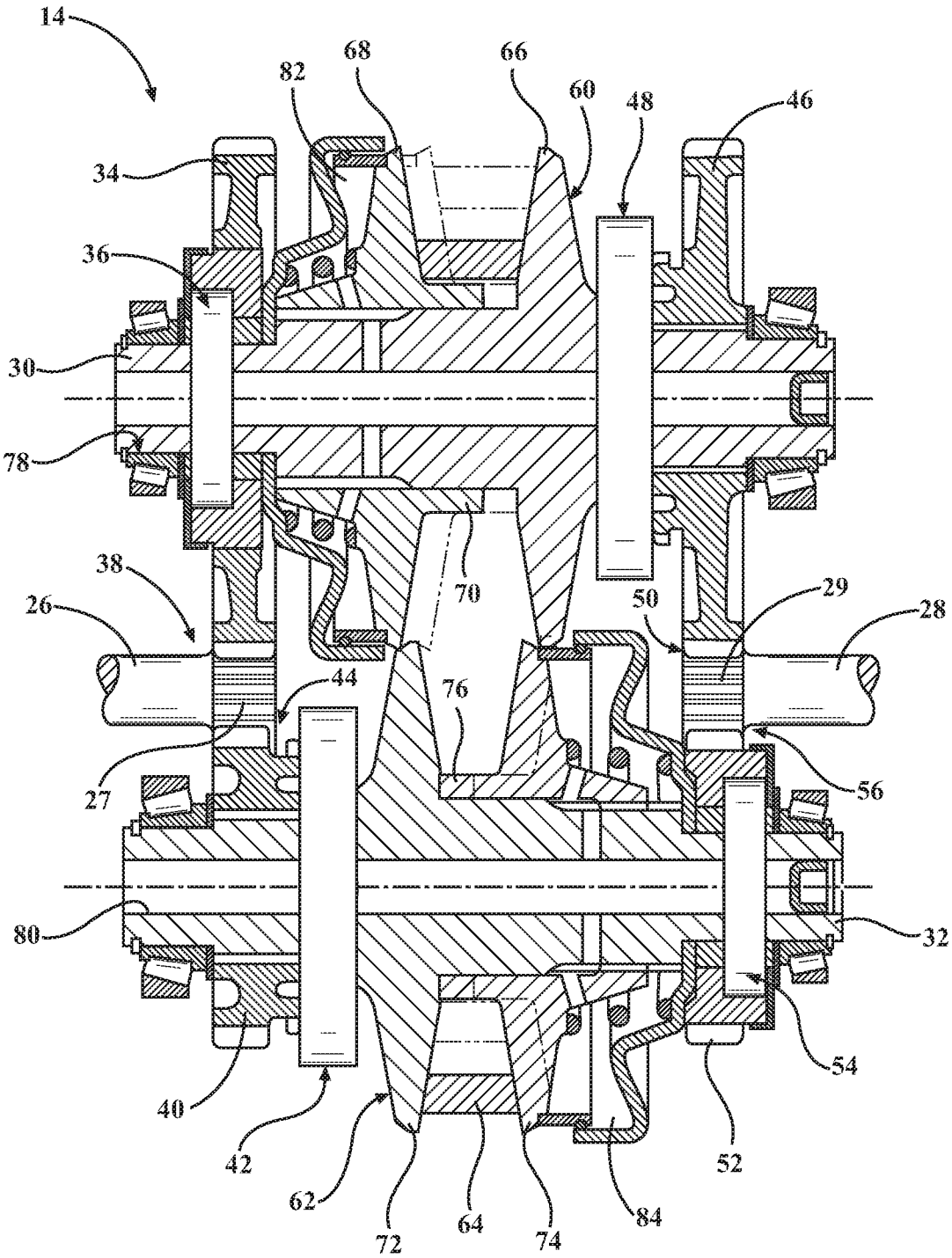
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FIG. 3

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/US2016/026903**

**A. CLASSIFICATION OF SUBJECT MATTER**

**F16H 61/662(2006.01)i, F16H 61/664(2006.01)i, F16D 41/08(2006.01)i**

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)
F16H 61/662; F16H 37/08; F16H 3/44; F16H 31/00; F16D 41/04; F16H 11/02; F16H 57/08; F16H 37/02; F16H 27/02; F16H 9/12; F16H 61/664; F16D 41/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: multi-mode, clutch, dual-pass, CVT, vehicle, shaft, input, output and variator

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 4630504 A (SMIRL, RICHARD L.) 23 December 1986<br>See claims 1-7 and figure 2. | 1-16 |
| Y | WO 2014-137798 A1 (BORGWARNER INC.) 12 September 2014<br>See claim 12 and figure 10. | 1-16 |
| A | US 2015-0065288 A1 (GM GLOBAL TECHNOLOGY OPERATIONS LLC.) 05 March 2015<br>See paragraphs [0006]-[0021] and claim 1. | 1-16 |
| A | US 2008-0194372 A1 (GLOCKLER, DIETER) 14 August 2008<br>See claim 1 and figure 1. | 1-16 |
| A | US 2002-0100340 A1 (BUONAURO, RICHARD T.) 01 August 2002<br>See paragraphs [0010]-[0016] and claim 1. | 1-16 |

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

☒ See patent family annex.

* 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
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"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 | Date of mailing of the international search report |
|---|---|
| 20 July 2016 (20.07.2016) | **20 July 2016 (20.07.2016)** |

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2016/026903**

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| | | US 8047944 B2 | 01/11/2011 |
| | | WO 2007-014706 A1 | 08/02/2007 |
| US 2002-0100340 A1 | 01/08/2002 | US 6758111 B2 | 06/07/2004 |