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(54) **FLY-BY-WIRE LIMP HOME AND MULTI-PLEX SYSTEM**

(75) Inventors: **Charles F. Long**, Pittsboro, IN (US); **Phillip F. McCauley**, Zionsville, IN (US); **Darren J. Weber**, Indianapolis, IN (US); **Scott E. Mundy**, Carmel, IN (US); **Jeffrey E. Shultz**, Zionsville, IN (US)

(73) Assignee: **GM Global Technology Operations LLC**, Detroit, MI (US)

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Filed: **Oct. 28, 2004**

(51) **Int. Cl.**
F16H 31/00 (2006.01)

(52) **U.S. Cl.** **475/119**; 475/128

(58) **Field of Classification Search** 475/119, 475/121–123, 128; 477/906
See application file for complete search history.

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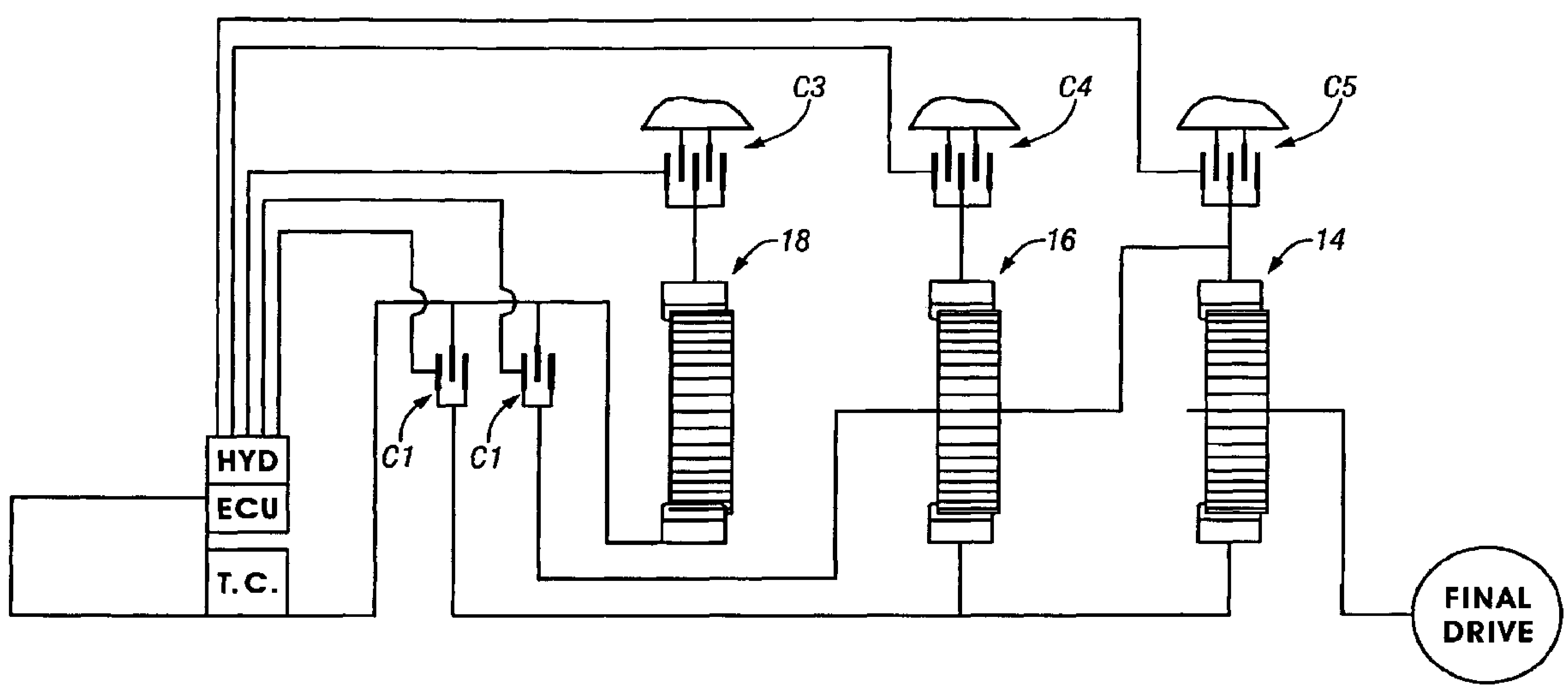
Primary Examiner—Ha D. Ho
(74) *Attorney, Agent, or Firm*—Quinn Law Group, PLLC

(57) **ABSTRACT**

An electro-hydraulic control mechanism for use with a multi-speed transmission includes a pair of logic valves, which are manipulated during the ratio interchanges and the ratio establishment by aiding in the distribution of fluid pressure from a plurality of trim valves. The logic valves are retained in specific drive ranges in the event of electrical discontinuance.

9 Claims, 10 Drawing Sheets



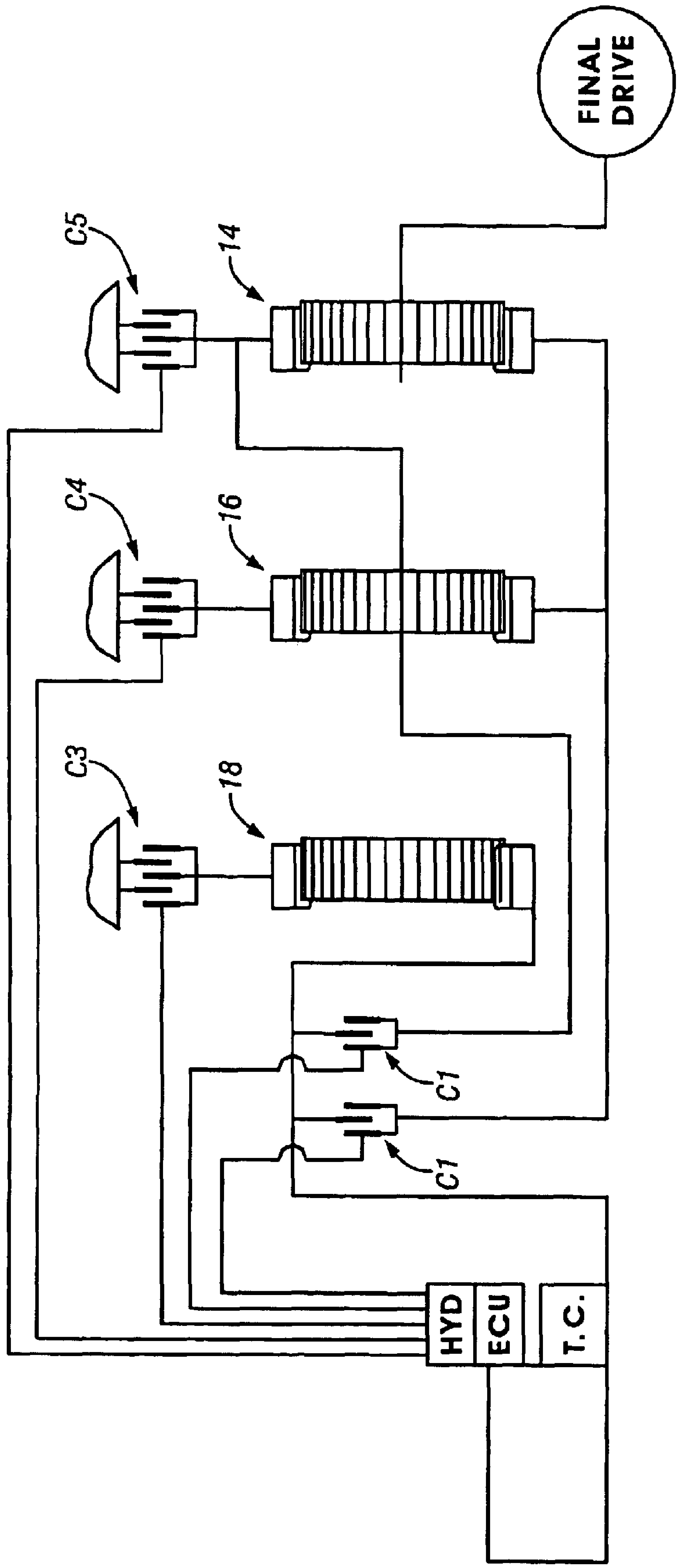
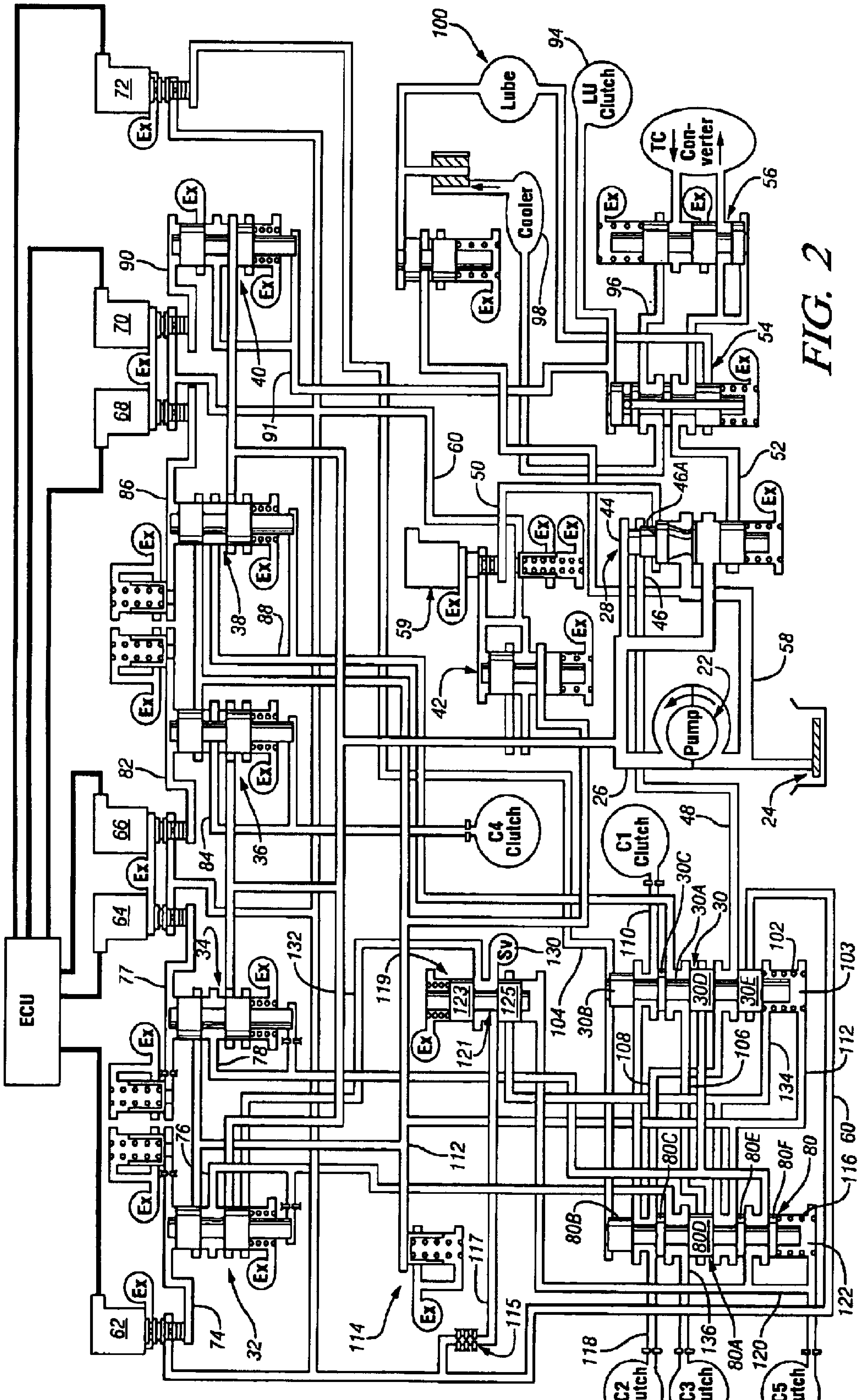


FIG. 1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Lube
LU Clutch
TC Con-verter
Cooler
Pump
C1 Clutch
C2 Clutch
C3 Clutch
C4 Clutch
C5 Clutch
Sv
Ex

FIG. 2

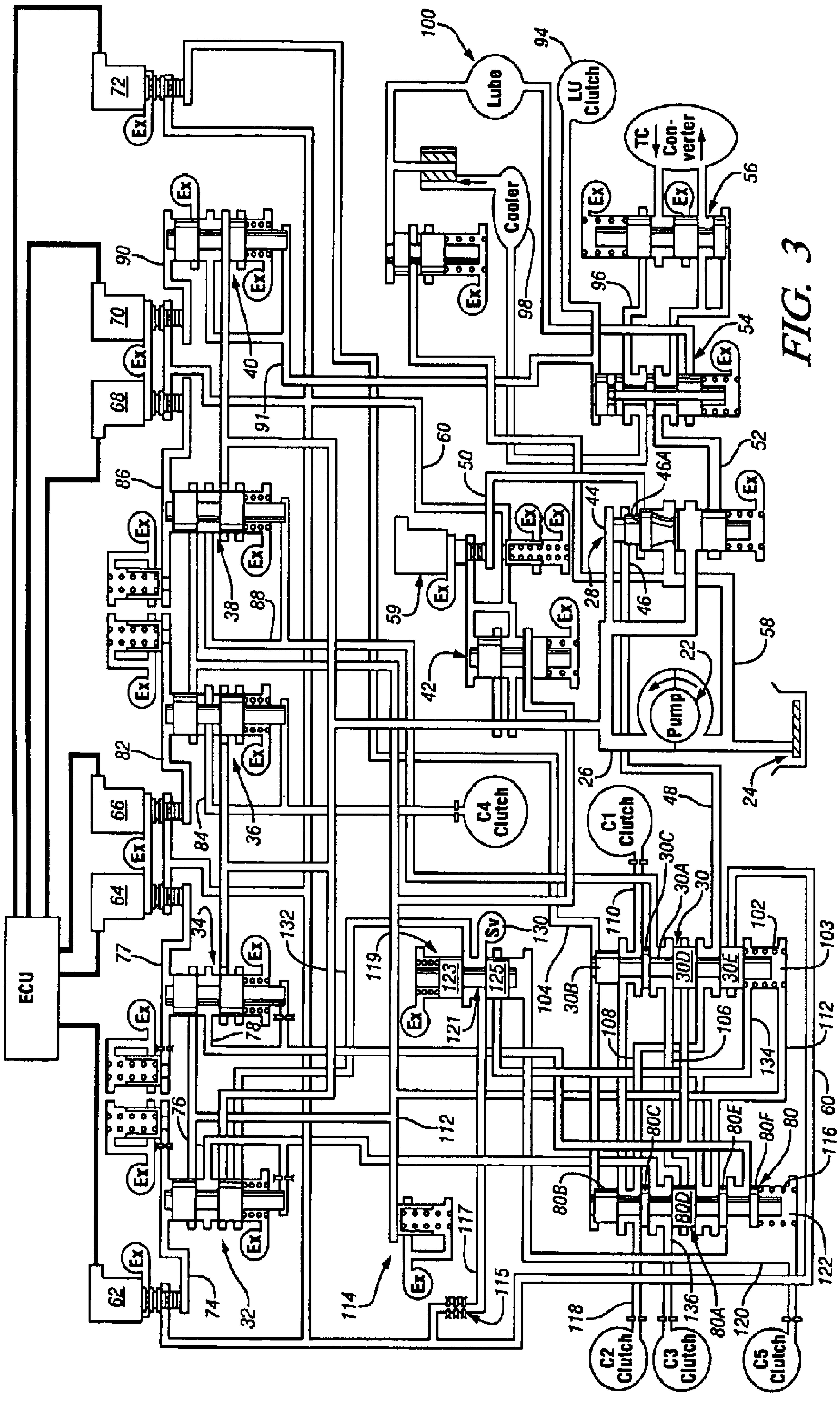
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FIG. 3

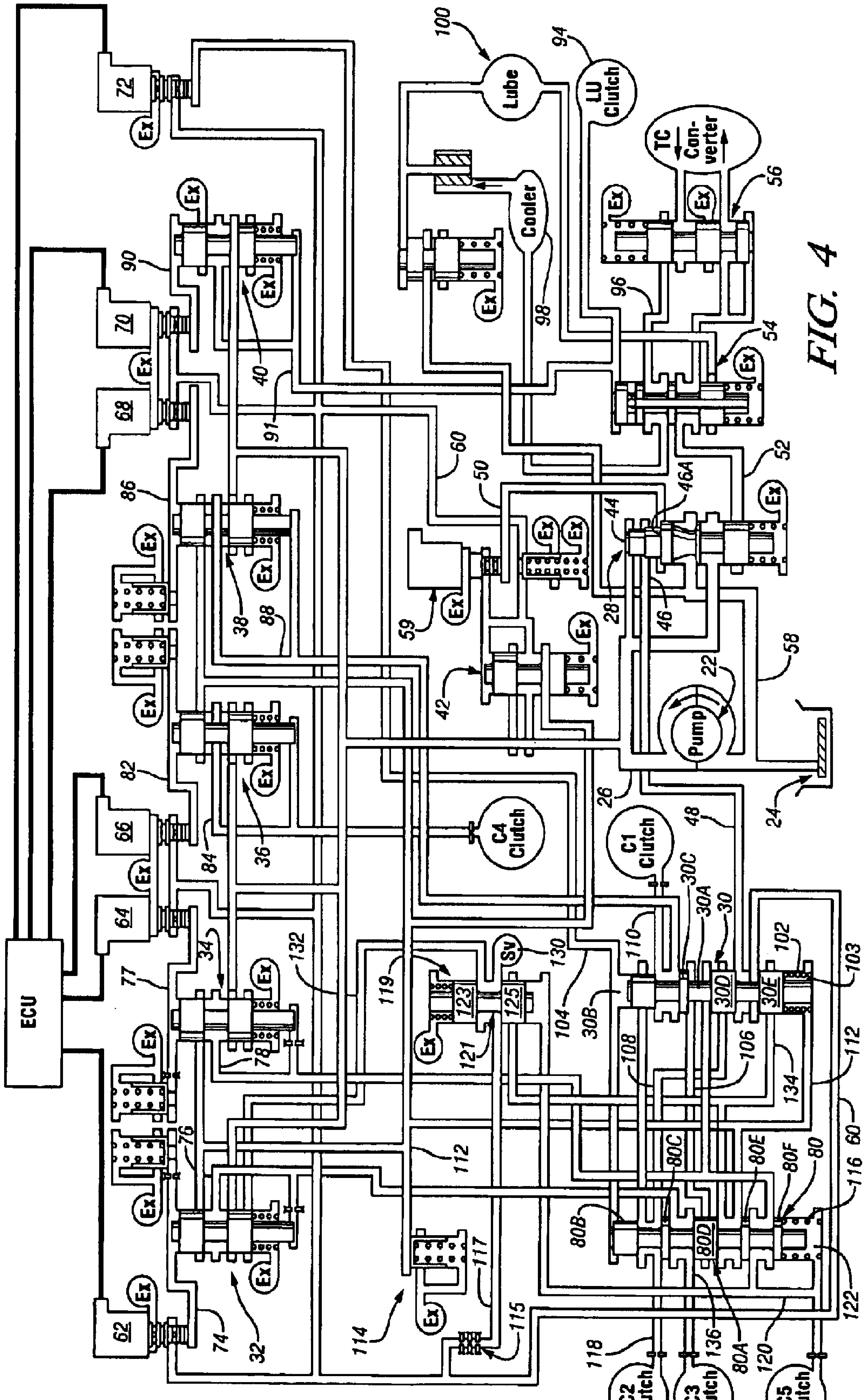
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FIG. 4

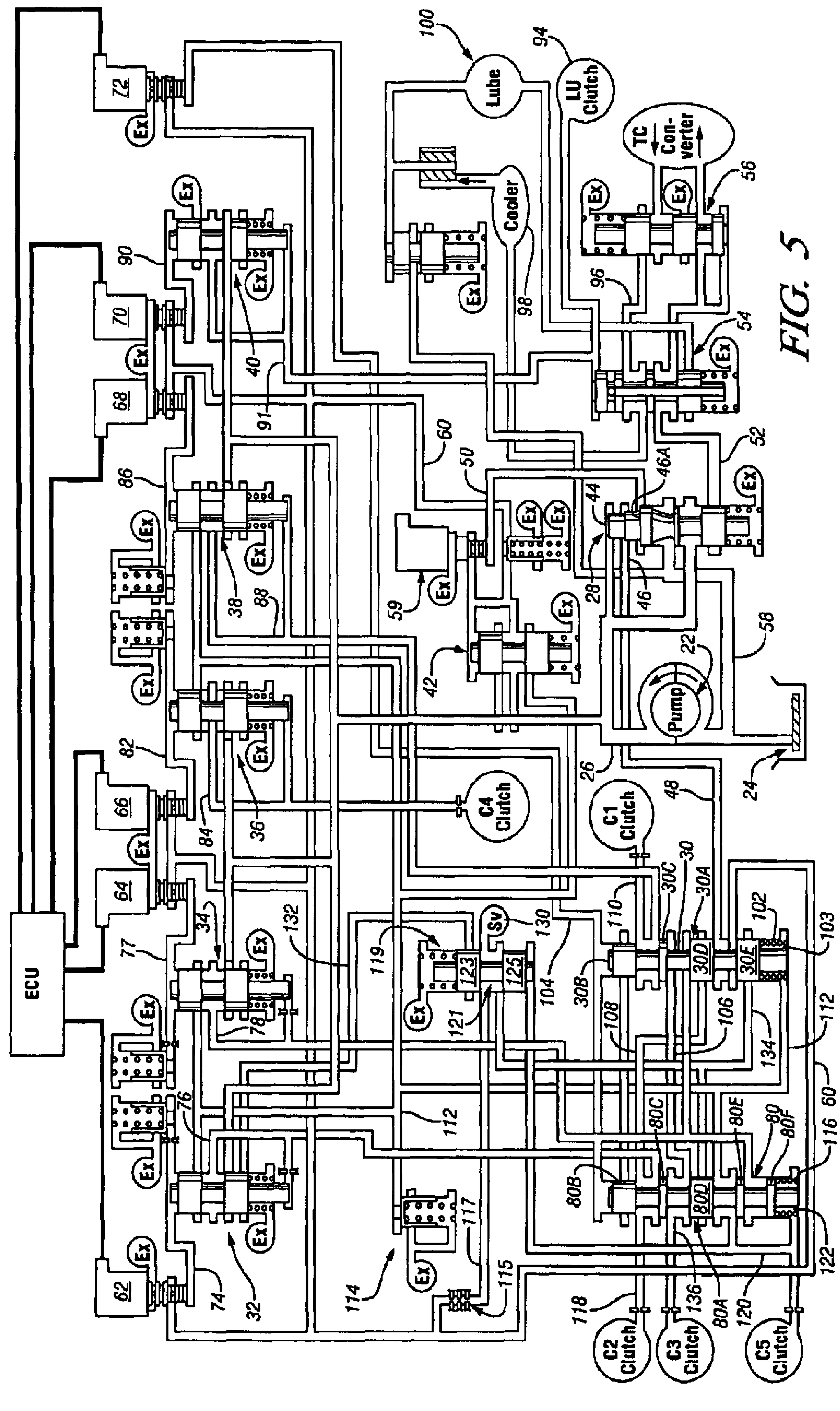
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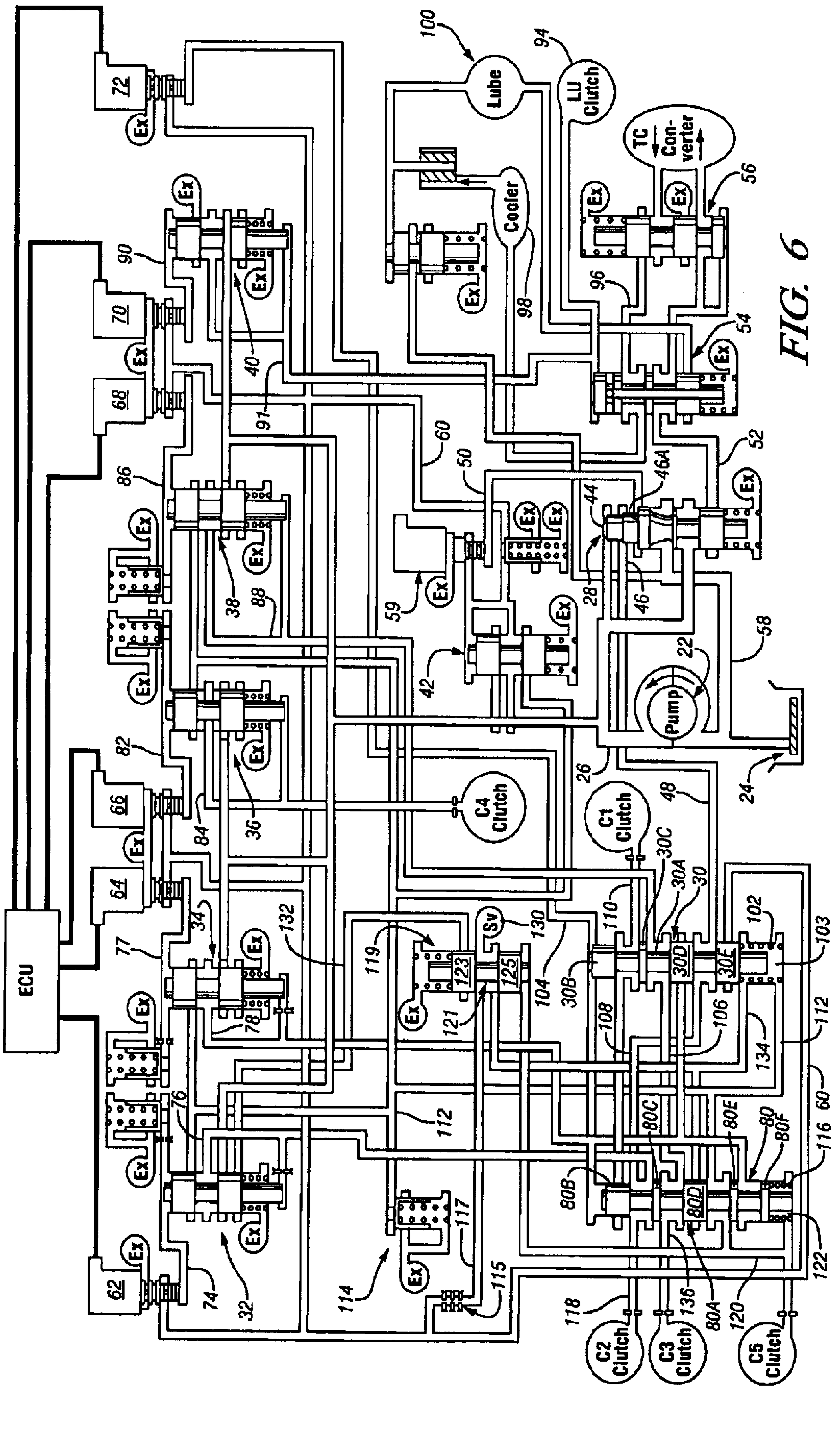
FIG. 5



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C5 Clutch
Ex
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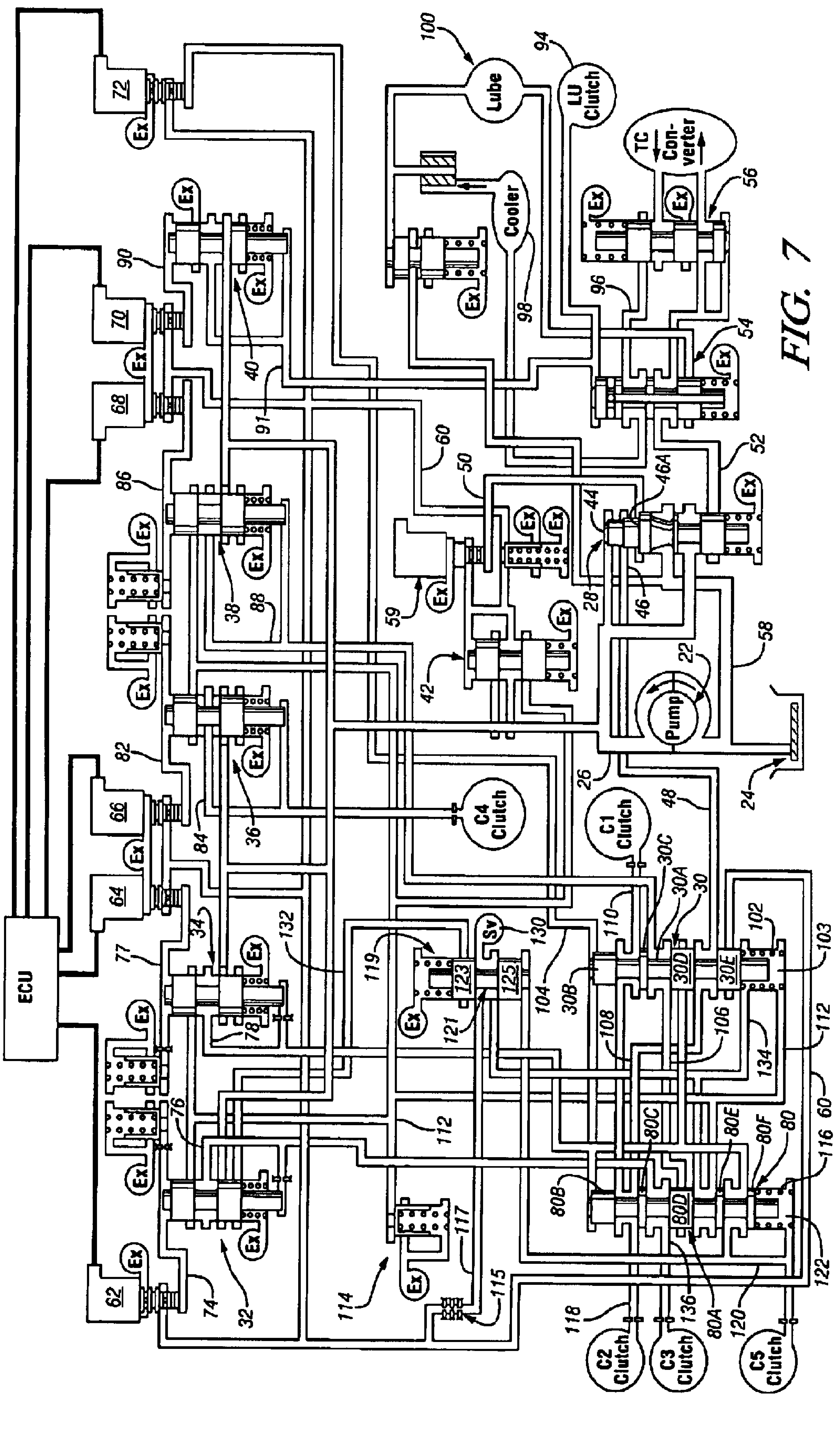
FIG. 6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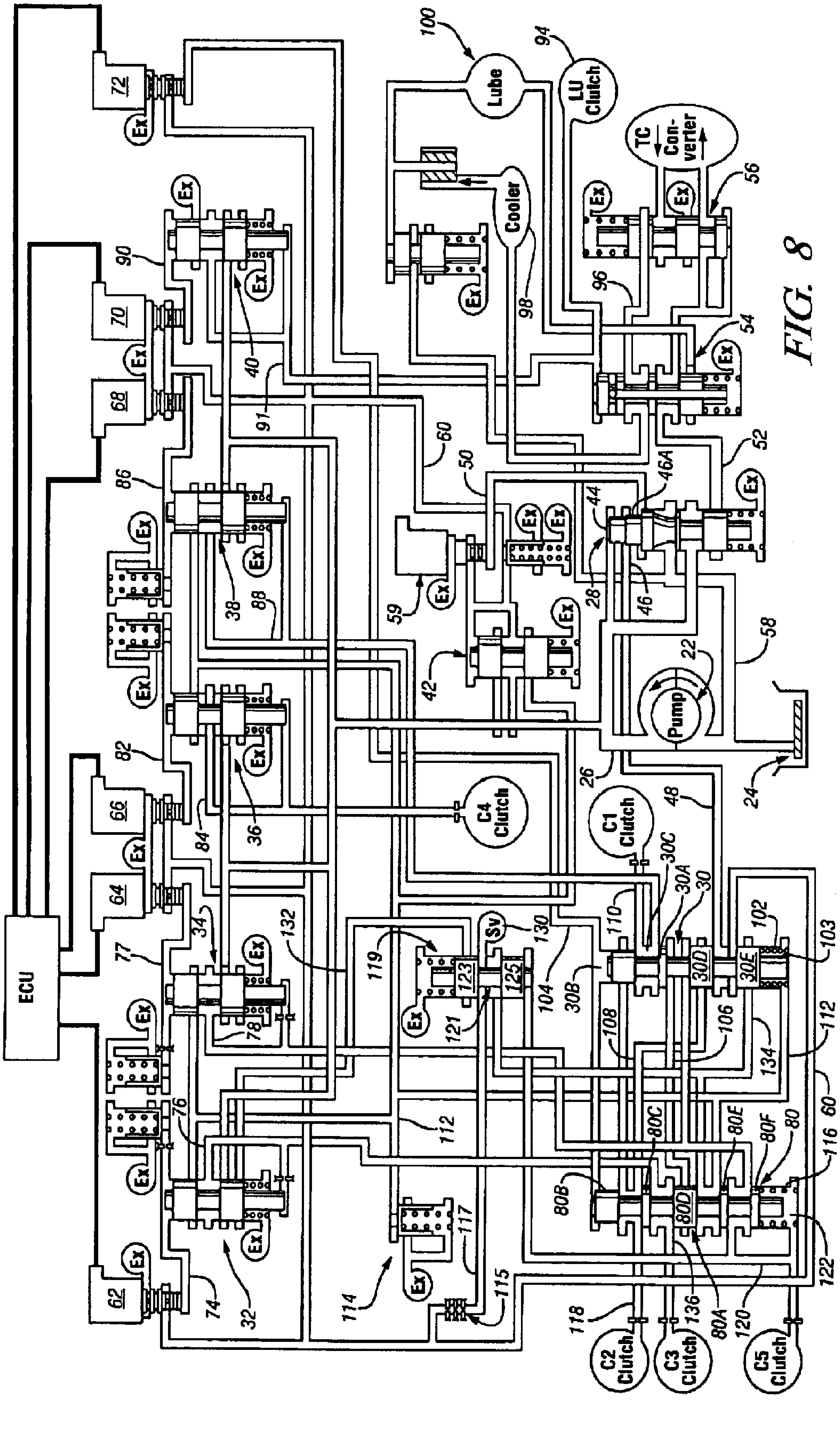
C4 Clutch
C5 Clutch
Ex
Sv

FIG. 7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C5 Clutch
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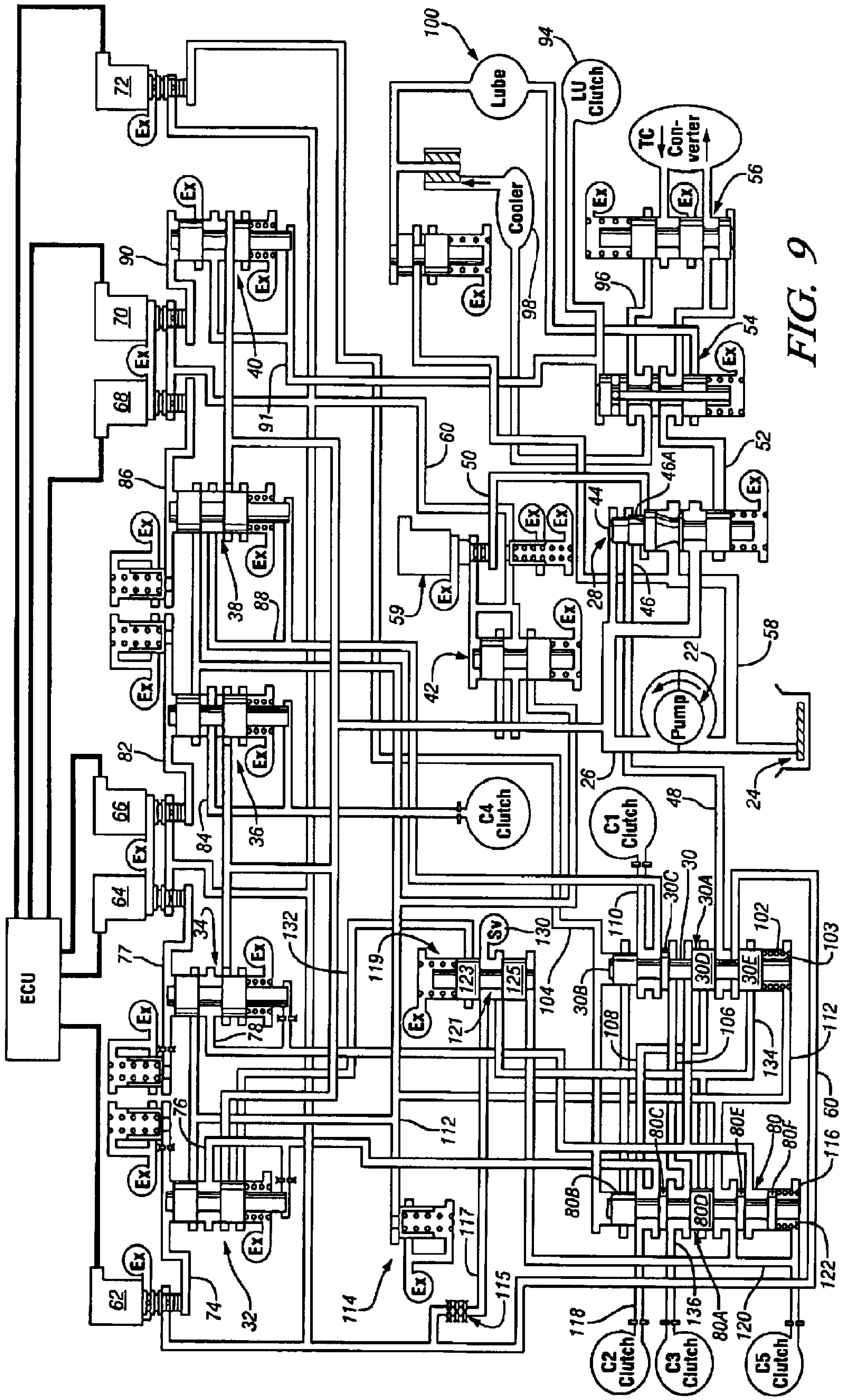
FIG. 8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C2 Clutch
C3 Clutch
C4 Clutch
C5 Clutch
Ex
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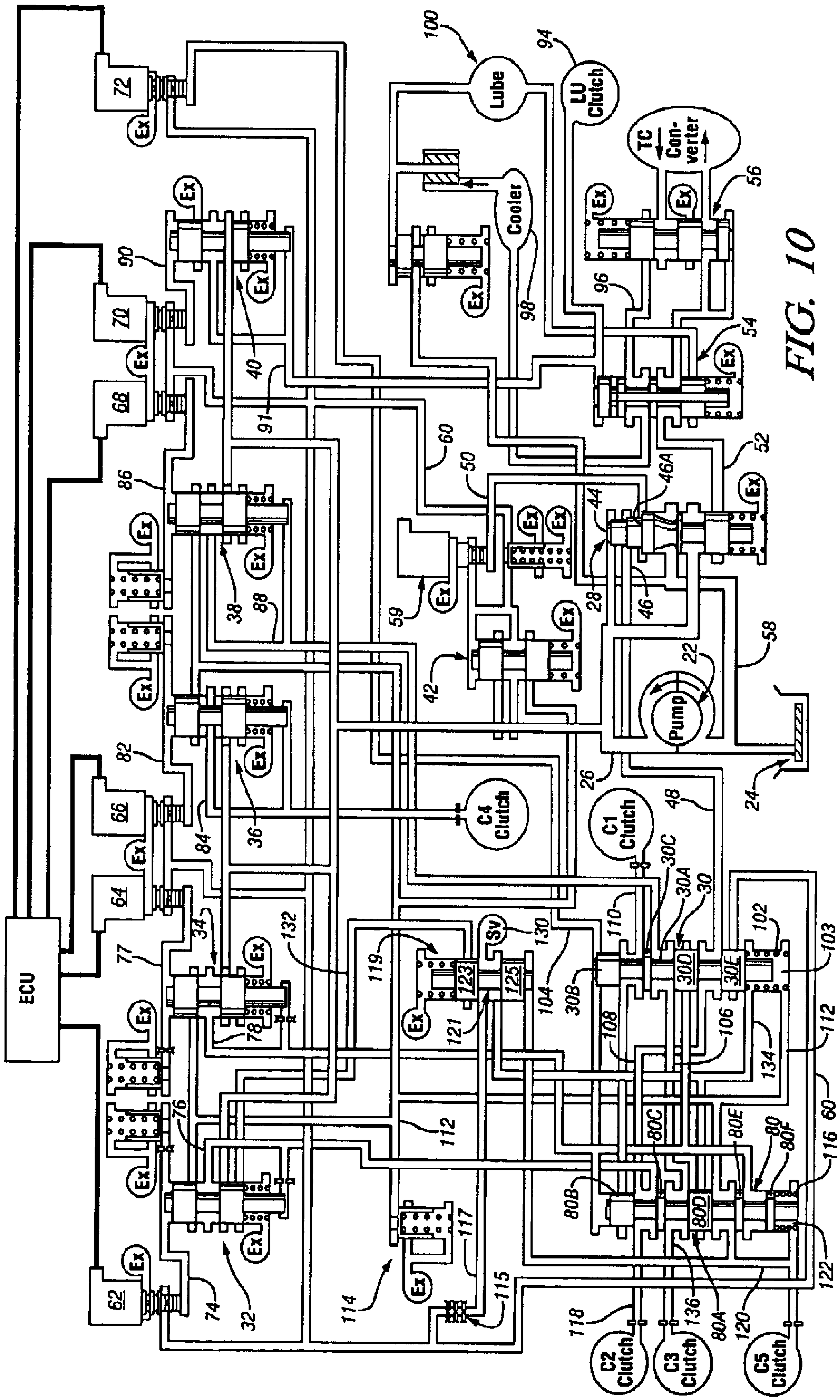
FIG. 9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TC Con-verter
Cooler
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C1 Clutch
C2 Clutch
C3 Clutch
C4 Clutch
C5 Clutch
Sv
Ex

FIG. 10

FLY-BY-WIRE LIMP HOME AND MULTIPLEX SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

TECHNICAL FIELD

This invention relates to electro-hydraulic controls for transmissions, and more particularly, to controls having electronic mechanisms.

BACKGROUND OF THE INVENTION

Many of the currently-available high performance planetary transmissions employ what is termed clutch-to-clutch shifting. This term indicates that the ratio change is performed by disengaging one disc-type friction device while engaging another disc-type friction device. This is accomplished without the use of one-way devices. Therefore, the overlap control needs to be quite accurate in these situations and the position of the control must also be accurate.

At least one planetary transmission that is utilized with clutch-to-clutch shifting controls is shown in U.S. Pat. No. 4,070,927 issued to Polak on Jan. 31, 1978. This transmission has a control that is equipped with solenoid controlled trim valves that are actuated by electronic control units to provide engagement and disengagement pressures for the torque-transmitting friction devices within the transmission. One such solenoid control is shown in U.S. Pat. No. 5,601,506 issued to Long et al. on Feb. 11, 1997. Also, the transmissions in this category use what is known as skip shifting, that is, a first-to-third ratio interchange or a second-to-fourth ratio interchange. The above-identified Long et al. patent does not provide for skip shifting.

It is also desirable to ensure that the vehicle incorporating these transmissions can be returned to a repair facility in the event of a discontinuance of electrical power, which is known as limp home capability. Such control systems can be found in U.S. Pat. No. 4,827,806 issued to Long et al. on May 9, 1989, and U.S. Pat. No. 5,616,093 also issued to Long et al. on Apr. 1, 1997.

The transmission controls utilize trim valves, which are operating in combination with shift valves to control the on-coming and off-going friction devices. The trim valves are equipped with variable pressure solenoids while the shift valves are controlled by on/off-type solenoid valves.

U.S. Pat. No. 6,520,881 issued to Long et al. on Feb. 18, 2003, describes a control system wherein four solenoid valves control four trim valves, which in turn control the on-coming and off-going pressures in five torque-transmitting mechanisms. This control mechanism incorporates two latching valves, which are multi-plexed to control fluid pressure distribution to three torque-transmitting mechanisms. Limp home capability is provided by the control system disclosed in this Patent. The control of U.S. Pat. No. 6,520,881 will permit limp home capability in either the third or fifth forward ranges

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved electro-hydraulic control mechanism for a multi-speed power transmission having limp home capability.

In one aspect of the present invention, a pair of logic valves that are positionable to direct fluid to the desired torque-transmitting mechanisms, during normal operation, will assume a neutral condition in the event of electrical discontinuance from either neutral or reverse range.

In another aspect of the present invention, the logic valves will assume a third range condition in the event of electrical discontinuance of electrical signals during normal operation in either first, second, or third range.

In yet another aspect of the present invention, the logic valves will assume a fourth range condition in the event of electrical discontinuance during normal fourth range operation.

In still another aspect of the present invention, the logic valves will assume a fifth range condition in the event of electrical discontinuance during normal operation in either fifth or sixth range.

An improved electro-hydraulic control mechanism for a multi-speed power transmission is provided having a multi-clutched diagnostic system.

In one exemplary embodiment, a diagnostic valve is displaced within the hydraulic portion of the transmission and is positionable by fluid pressure within the transmission control system.

In one exemplary embodiment, the diagnostic valve also incorporates or has associated therewith an electronic or electric switch mechanism, which signifies the pressure available at the diagnostic valve.

In one exemplary embodiment, fluid pressure from a control circuit is continuously fed by a control pressure, which is directed through a restricted passage prior to reaching the diagnostic valve and the switch.

In one exemplary embodiment, the diagnostic valve is operably hydraulically connected with two logic control valves in the transmission control system.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation showing a multi-speed power transmission incorporating the present invention.

FIG. **2** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for neutral.

FIG. **3** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for reverse.

FIG. **4** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for first.

FIG. **5** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for fourth.

FIG. **6** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for sixth.

FIG. **7** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for reverse/neutral power off.

FIG. **8** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for first through third power off.

FIG. **9** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for fourth power off.

FIG. **10** is a diagrammatic representation of an electronic control system incorporating the present invention and utilized with the power transmission shown in FIG. **1** and conditioned for fifth and sixth power off.

DESCRIPTION OF AN EXEMPLARY EMBODIMENT

A power transmission shown in FIG. **1** includes an engine and torque converter (TC), an input shaft **10**, an output shaft **12**, and three planetary gearsets **14**, **16**, and **18**. The planetary gearsets **14**, **16**, and **18** are controlled to provide six forward speed ratios, a reverse speed ratio, and a neutral condition between the input shaft **10** and the output shaft **12**. These conditions are provided by five torque-transmitting mechanisms C**1**, C**2**, C**3**, C**4**, and C**5**. The torque-transmitting mechanisms C**1** and C**2** are rotating-type torque-transmitting mechanisms commonly termed clutches, and the torque-transmitting mechanisms C**3**, C**4**, and C**5** are stationary-type torque-transmitting mechanisms commonly termed reaction clutches or brakes.

To establish a reverse ratio, the torque-transmitting mechanisms C**3** and C**5** are engaged. In the neutral condition, the torque-transmitting mechanism C**5** is engaged. During the neutral to first ratio interchange, the solenoid is activated to place the logic valve **30** in the stroked position. For the first forward ratio, the torque-transmitting mechanisms C**1** and C**5** are engaged. During the first to second interchange, the solenoid **72** is deactivated but the logic valve **30** is latched by the pressure acting on the differential area between lands **30**B and **30**C. To establish the second forward ratio, the torque-transmitting mechanisms C**1** and C**4** are engaged, and the solenoid valve is activated to place the logic valve **80** in the stroked position. To establish the third forward range, the torque-transmitting mechanisms C**1** and C**3** are engaged. The torque-transmitting mechanism C**3** is controlled by the trim valve **34**. To establish the fourth forward range, the torque-transmitting mechanisms C**1** and C**2** are engaged. Engagement of the torque-transmitting mechanism C**2** latches the logic valve **80** in the stroked position. During the fifth forward range, the torque-transmitting mechanisms C**2** and C**3** are engaged. The trim valve **38**, which was on in the fourth range, is turned off and the latch pressure on the logic valve **30** is released. During the sixth range, the torque-transmitting mechanisms C**2** and C**4** are engaged. The logic valve **30** is conditioned by the solenoid **72** to a low pressure state. A more complete description of the power transmission can be found in U.S. Pat. No. 4,070,925.

The torque-transmitting mechanisms C**1**, C**2**, C**3**, C**4**, and C**5** are all selectively engageable hydraulically controlled torque-transmitting mechanisms, which are well known in the art of power transmissions. The hydraulic fluid to engage these torque-transmitting mechanisms is provided by an electro-hydraulic control mechanism **20** that includes an electronic control unit (ECU) which incorporates a programmable digital computer to provide electronic signals to a hydraulic control (HYD) which in turn distributes the hydraulic fluid to various torque-transmitting mechanisms as required by the driving conditions.

The ECU receives a number of input signals from the engine, torque converter, and also the transmission elements in the vehicle, which partially determine the electronic signals that are generated and distributed to the hydraulic system to provide for upshifting and downshifting of the transmission by controlling the engagement and disengagement of the torque-transmitting mechanisms.

As seen in FIG. **2**, the hydraulic portion of the electro-hydraulic control **20** includes a pump **22**, which withdraws hydraulic fluid from a reservoir **24** for distribution through a main passage **26**. The main passage **26** is in continuous fluid communication with a main regulator valve **28** and five trim valves **32**, **34**, **36**, **38**, and **40**, and a control regulator valve **42**. The main regulator valve **28** is effective to set the maximum system pressure within the passage **26**. The main regulator valve **28** has a bias area **44** on the upper end of the valve **28**, a differential bias area **46** that is in fluid communication with a latch or logic valve **30** through a passage **48**. The valve **28** has a second differential bias area **46**A that is in fluid communication with a passage **50**.

The pressure regulator valve **28** supplies fluid pressure to the main passage **26** and when the pressure in that passage has been satisfied, the regulator valve **28** distributes fluid pressure to a passage **52** that is in communication with a torque converter flow valve **54** which in turn communicates with a converter regulator valve **56** which in turn distributes fluid to a torque converter (TC). If there is excess fluid after the torque converter (TC) is satisfied, the remaining fluid is distributed through the sump **24** to a return passage **58**.

The passage **50** is also in communication with a line modulator valve **59**. The line modulator valve **59** is a conventional solenoid controlled valve, which is a normally closed valve; that is, the fluid pressure in passage **50** is essentially zero when the line modulator valve **59** is inoperable

The solenoid valve **62** is controlled by the ECU to establish a control pressure in a passage **74**, which determines the fluid pressure distributed from the trim valve **32** to a passage **76**, which is in communication with a latch or logic valve **80**. The solenoid valve **62** is a normally on solenoid that has maximum output pressure when there is no electrical power delivered thereto. The solenoid valve **64** distributes fluid pressure in a passage **77** that is distributed to trim valve **34** to control the pressure in a passage **78**, which is in fluid communication with the logic valves **30** and **80**. The solenoid valve **66** controls fluid pressure in a passage **82**, which is effective to establish the output pressure of the trim valve **36** and a passage **84** that is in fluid communication with the torque-transmitting mechanism C**4**. The solenoid valves **64**, and **66** are normally off mechanisms. The solenoid valve **68** distributes fluid pressure to a passage **86**, which is effective to establish the output pressure of the trim valve **38**, which is distributed through a passage **88** to the logic valve **30**. The solenoid valve **68** is a normally on mechanism, thus producing a maximum output signal when the electrical signal is off. The solenoid valve **70**, a normally off solenoid, is effective to control pressure in a passage **90**, which establishes an outlet pressure of the trim valve **40** in a passage **91** for distribution through the converter flow valve **54** and a torque converter clutch (LU) **94**. When the converter flow valve **54** is in the spring set position shown, the pressure in passage **52** is distributed through the valve **54** and the valve **56** to the torque converter (TC).

Flow out of the torque converter (TC) is distributed through a return passage **96** and through the converter flow valve **54** to a cooler **98**. The fluid returning from the cooler **98** passes through a lube circuit **100**, which distributes fluid to lubricate the various components of the transmission such as gears and bearings.

The logic valve **30** includes a valve spool **30**A, which is slidably disposed in a valve bore and urged to a spring set position shown by a spring **102** and to a pressure set position by fluid pressure acting in a passage **104** on the upper end of the valve spool **30**. The passage **104** communicates with the solenoid valve **72**, which is a conventional on/off-type solenoid valve such that the fluid pressure in passage **104** is either essentially zero or an established control pressure, which is set in passage **60** by the control regulator valve **42**. The solenoid **72** is a normally off device. The spring **102** is disposed within a spring chamber **103**.

As mentioned above, the solenoid valve **72** is an on/off-type solenoid and while the solenoid valves **62**, **64**, **66**, **68**, and **70** are variable type solenoid valves, which distribute a variable control signal depending upon the electrical signal received from the electronic control unit. The solenoid valves **62** and **68** are normally open-type valves, which means that the control signal generated from these valves is maximum when the electronic signal conducted thereto is minimum. The solenoid valves **64**, **66**, and **70** are normally off-type solenoid valves, which means that the pressure distributed thereby is minimum when the electronic control signal directed thereto is minimum.

In the spring set position shown, the fluid in passage **88** is distributed through the valve **30** to a passage **106**, which communicates with the logic valve **80**. The logic valve **30** has four lands formed thereon, **30**B, **30**C, **30**D, and **30**E. The logic valve **80** has a valve spool **80**A, which includes five valve lands **80**B, **80**C, **80**D, **80**E, and **80**F. The valve spool **80**A is operated on by a spring **116** which is disposed in a spring pocket or chamber **122**. The passage **48** communicates between the passages **30**D and **30**E of the valve spool **30**A in the spring set position with a passage **108**, which in turn communicates between passages **80**B and **80**C in the spring set position of valve **80**, and with an exhaust passage **112**, which also communicates between the lands **30**B and **30**C through a passage **110** with the torque-transmitting mechanism C**1**. Thus, in the spring set position of the valves **30** and **80**, the torque-transmitting mechanism C**1** and C**2** inoperable.

The passage **112** communicates with an exhaust valve **114**, the trim valves **32**, **34**, **36**, and **38**, and the control regulator valve **42**. The exhaust valve **114** establishes a minimum pressure within the control system such that the torque-transmitting mechanisms have disposed therein or fed thereto a minimum pressure, which simplifies the engagement and disengagement control of the torque-transmitting mechanism. The use of a back fill exhaust valve to maintain a minimum pressure within torque-transmitting mechanisms is well known in the art.

The control regulator valve **42**, as previously mentioned, distributes a reduced pressure from the main pressure in passage **26** to the passage **60**. Passage **60** communicates with the solenoid valves **62**, **64**, **66**, **68**, **70**, and **72**. The solenoid valves operate in a well-known manner to control the output pressure from the respective valves to their control passages by reducing the pressure in passage **60** to the respective output pressures of the solenoid valves. The passage **60** also communicates with the logic valve **30**. The logic valve **30** blocks the passage **60** in the spring set position by the valve land **30**E. The passage **60** also communicates through a multiple restriction **115** with a passage **117**, which communicates in turn with a diagnostic valve **119**.

The diagnostic valve **119** has a valve spool **121**, which includes spaced valve lands **123** and **125**. The passage **117** communicates between the valve lands **123** and **125** and in the pressure set position shown in FIG. **2**, communicates between the valve lands **123** and **125** with a pressure switch **130**. The pressure switch **130** is connected with the ECU and provides a signal thereto which indicates the pressure in the passage **117**.

The diagnostic valve **119** also communicates with a passage **132**, which is connected with the trim valve **32** and with a passage **134**, which communicates with the spring chamber **103** of valve **30**. The spring chamber **103** also communicates with the passage **112**, which in turn communicates with the logic valve **80**. In the pressure set position of the valve **119**, the valve land **125** blocks the passage **134** from reaching the passage **117** while the passage **132** is open between the valve lands **123** and **125** with the passage **117**. Thus, when valve **32** is in the spring set position, the pressure at the switch **130** is at an exhaust value, which is determined by the pressure in the passage **132**. In the spring set position of the diagnostic valve **119**, the pressure in the passage **117** and therefore the switch **130** is determined by the pressure in passage **134**.

The passage **112** communicates with the logic valves **30** and **80** in a plurality of locations. In the spring set position shown for the valves **30** and **80**, the exhaust passage **112** communicates between the lands **30**B and **30**C and between the lands **80**B and **80**C. The exhaust passage **112** also communicates between the lands **80**D and **80**E when the valve **80** is in the spring set position. Thus, in the spring set position for both valves **30** and **80**, the passage **112** communicates with the passage **134**, which will connect with the diagnostic switch **130** when the valve **119** is in the spring set position.

The logic valve **80** communicates with the torque-transmitting mechanism C2 through a passage **118**, with the torque-transmitting mechanism C3 through a passage **136**, and with the torque-transmitting mechanism C**5** through a passage **120**. The passage **120** communicates with the spring chamber **122** and in a spring set position of valve **80** communicates with a passage **78**, which in turn delivers fluid pressure from the trim valve **34**. The passage **76**, which distributes fluid pressure from the trim valve **32** communicates with the logic valve **80** in the spring set position between the lands **80**C and **80**D, which in turn communicates with the passage **136** and therefore torque-transmitting mechanism C**3**.

In the pressure set position of the logic valve **80**, the passage **76** communicates between the lands **80**B and **80**C with the torque-transmitting mechanism C**2**. It will be noted that the land **80**B is smaller in diameter than the land **80**C, thus once the valve **80** is in the pressure set position and the torque-transmitting mechanism C**2** is engaged, the pressure in passages **76** and **118** will latch the valve **80** in the pressure set position.

The logic valve **30** is in fluid communication with the passage **88** between the lands **30**C and **30**D in the spring set position of valve spool **30**A. The passage **88**, as previously commented, delivers control fluid pressure from the trim valve **38**. The pressure in passage **88** is distributed between the valves **30**C and **30**D to the passage **106** when the valve **30** is in the spring set position. Passage **106** is blocked by the land **80**D when the valve **80** is in the spring set position. However, when the valve **80** is in the pressure set position, the passage **106** communicates with the torque-transmitting mechanism C**3**. In the spring set position of the valve **80**, the passage **76** is fluid communication with the torque-transmitting mechanism C**3**.

As noted, the hydraulic control shown in FIG. **2** is in the neutral condition. In this condition, the torque-transmitting mechanism C**5** is held in controlled engagement by the trim valve **34** through the passage **78** between the lands **80**E and **80**F in the passage **120**. The passage **120** also communicates with the diagnostic valve **119**, which places the valve **119** in the pressure set position. In the neutral condition, the trim valve **32** is inoperable and therefore the passage **76** is connected with exhaust through the trim valve **32**.

To condition the transmission for reverse operation, the trim valve **32** is made active by the solenoid **62**, which does two things. First, it distributes control fluid pressure through the passage **76** to the torque-transmitting mechanism C**3** through the logic valve **80** to enforce engagement thereof. When the torque-transmitting mechanisms C**3** and C**5** are engaged, the transmission shown in FIG. **1** is conditioned for reverse second, the trim valve **32** blocks the exhaust of passage **132** and therefore prevents flow of fluid through the restriction **115**, which of course raises the pressure within the passages **117** and **132** and the diagnostic switch **130**. Thus, in reverse, the diagnostic switch **130** is energized indicating to the control system that the system is operating properly in reverse.

To establish the first and lowest forward range, the control mechanism is operated to engage the torque-transmitting mechanism C**1** through the operation of the trim valve **38** which is responsive to the control pressure from the solenoid valve **68**. When the transmission is shifted from the neutral to the forward range, the solenoid valve **72** is energized, which emits a control pressure to the passage **104** and to the valve lands **80**B and **30**B. In the first range of operation, the logic valve **30** is shifted to the pressure set position. However, the logic valve **80** cannot shift to the pressure set position because of the fluid pressure in the spring chamber **122**, which is equal to the pressure in the torque-transmitting mechanism C**5** and establishes a greater force on the valve spool **80**A than the pressure acting on the valve land **80**B. The trim valve **68** is operated to control the engagement of the torque-transmitting mechanism C**1** such that the transmission operates in the first forward range. When the trim valve **38** energizes the torque-transmitting mechanism C**1**, the trim valve **32** de-energizes the torque-transmitting mechanism C**3**, thus returning the passage **132** to the exhaust condition, which exhausts the diagnostic switch **130** and the passage **117**, and informs the ECU that the reverse range of operation has been de-activated. When the transmission is operating in first range, fluid pressure in the passage **60** is directed through the valve **30** between the lands **30**D and **30**E to the passage **48** and the bias area **46** thereby affecting the regulation pressure of the system at the regulator valve **28**. In first range, the maximum system pressure is reduced by the bias pressure.

During a ratio interchange from first-to-second, the torque-transmitting mechanism C**4** is brought into controlled engagement by the trim valve **36** while the torque-transmitting mechanism C**5** is disengaged in a controlled manner by the trim valve **34**. Upon completion of the first-to-second interchange, the torque-transmitting mechanism C**5** is fully disengaged such that the logic valve **80** is moved to the pressure set position. When the torque-transmitting mechanism C**5** is disengaged, the diagnostic valve **119** is moved to the spring set position thereby permitting fluid pressure to be developed within the passage **117** and also within the passage **134**. The switch is now activated indicating the stroke of the valve **80** has been completed

In the third range of operation, the logic valves **30** and **80** are both in the pressure set position thereby permitting the trim valve **34** to control the engagement of the torque-transmitting mechanism C**3**. This control pressure is effective in the passage **78** between the lands **30**C and **30**D and into passage **106** and then between lands **30**C and **30**D into the passage **136** and torque-transmitting mechanism C**3**. During the third range of operation, the diagnostic valve **119** remains in the spring set position and the switch **130** remains activated.

As the ratio interchange from third range to fourth range is accomplished by controlled disengagement of the torque-transmitting mechanism C**3** by the trim valve **34** and the controlled engagement of the torque-transmitting mechanism C**2** by the trim valve **32**, the trim valve **32** distributes pressure through the passage **76** between the lands **80**B and **80**C through the passage **118** and thus the torque-transmitting mechanism C**2**. During the fourth range of operation, the diagnostic valve **119** remains in the spring set position and the switch **130** remains activated and the fluid pressure on the bias **46** remains controlled.

The fifth range of forward operation is established by the controlled disengagement of the torque-transmitting mechanism C **1** by operation of the trim valve **38**, and the controlled engagement of the torque-transmitting mechanism C**3** by the controlled operation of the trim valve **34**. As with the third range of operation, the torque-transmitting mechanism C**3** is engaged by the fluid pressure in passage **78** passing through the logic valve **30** to the passage **106** and then through the logic valve **80** to the passage **136**. During the fifth range of operation, the diagnostic valve **119** remains in the spring set position and the switch **130** remains pressurized or activated.

The sixth range of operation is established by the controlled disengagement of the torque-transmitting mechanism C**3** by the trim valve **34** and the controlled engagement of the torque-transmitting mechanism C**4** by the trim valve **36**. During the fifth ratio to sixth ratio interchange, the diagnostic valve **119** remains in the spring set position and the switch **130** remains activated. However, upon reaching the sixth range of operation, the solenoid valve **72** is conditioned to the "off" mode thereby eliminating the pressure bias on the valve lands **30**B and **80**B. The valve **80** remains in the latched condition due to the pressure in the torque-transmitting mechanism C**2**, which operates on the bias area between valve lands **80**B and **80**C. The logic valve **30**, however, has no such bias at this point and returns to the spring set position. In the spring set position, the spring chamber **103** communicates with the passage **134** and thereby exhausts the pressure within that passage such that insufficient flow through the restriction **115** is permitted and the diagnostic switch **130** is moved to the "off" position or deactivated condition indicating that the valve **30** has moved to the spring set position.

Thus, as described above, the diagnostic pressure switch **130** is activated during reverse, is deactivated during neutral, is deactivated during the first-to-second ratio interchange, is activated during the second range, is activated during the fifth-to-sixth ratio interchange, and is deactivated upon achieving sixth range.

When operating in reverse, if the electronic power should be discontinued for some reason, the solenoid valves **62** and **68** will produce maximum outlet pressure at their respective trim valves **32** and **38**. Thus, should the power be eliminated in reverse or neutral, the torque-transmitting mechanism C**3** is engaged by the trim valve **32** while all other torque-transmitting mechanisms are discontinued. Also, under this condition, should the power be eliminated, the passage **134** is connected through the spring chamber **103** with the exhaust passage **112** and therefore the diagnostic switch **130** is deactivated indicating that the reverse ratio has not been achieved since during normal operation the switch is activated in reverse.

Should a power discontinuance occur during first through third forward ratios, the trim valve **38** will maintain the torque-transmitting mechanism C**1** engaged, however, the logic valve **80** will return to the spring set position due to loss of control pressure on land **80**B and the trim valve **32** will engage the torque-transmitting mechanism C**3** thereby conditioning the transmission to third ratio, however, the passage **134** is exhausted through the logic valve **80** between lands **80**D and **80**E, which communicates with the exhaust passage **112**. Thus, on a power discontinuance at the control system, the switch **130** will be deactivated, however, the transmission control will indicate third ratio and since the switch **130** should be activated, the operator will be informed that some malfunction has occurred within the transmission control.

If an electronic malfunction should occur during fourth ratio, the valves **30** and **80** will both have been latched in the pressure set condition and will remain that way since the trim valves **32** and **38** will charge the differential areas of the respective logic valves during minimum electronic input to the solenoid valves **62** and **68**. If a malfunction should occur during fifth ratio or sixth ratio, the torque-transmitting mechanism C**2**, which was in a latched condition during fifth or sixth ratio, will remain so since the fluid pressure distributed by the trim valve **32** will remain at maximum, and the trim valve **38** will distribute maximum pressure through the passage **88** which connects between the lands **30**C and **30**D of the logic valve **30** with the passage **106** and then between the lands **80**C and **80**D through the torque-transmitting mechanism C**3**. Note that on a malfunction, the hydraulic bias through the logic valves **30** and **80** is discontinued and this pressure is discontinued during sixth range of operation in any situation.

The passage **134** will be exhausted through the spring chamber **103**, thus deactivating the switch **130**. However, the transmission will indicate that fifth range of operation is attained but the switch **130** is de-energized and therefore a malfunction has occurred and the system will inform the operator of this condition.

Upon the recognition of a malfunction, the diagnostic switch **130** can be interrogated under various conditions to determine where the malfunction might be. During the diagnostics, the torque-transmitting mechanism C**5** is engaged thereby placing the diagnostic valve **119** in the pressure set position. If the solenoid valve **62** has malfunctioned to the closed position, the trim valve **32** will not issue a control pressure and the switch **130** will be exhausted through the passage **132**. If the solenoid **62** cannot be taken from the high state, the maximum output pressure will be produced at the trim valve **32** thereby blocking the passage **132** from the valve **119** indicating that the trim valve is pressurized when in fact the command is calling for it to be depressurized.

Also, during diagnostic testing, the torque-transmitting mechanism C**5** can be placed in the unapplied position and if both valves **30** and **80** are destroked to the spring set position, the switch **130** is exhausted and remains in the de-energized state. If the logic valve **30** is stroked to the pressure set position and the logic valve **80** is spring set, the switch **130** is exhausted through the logic valve **80** and will remain in the de-energized state. If the logic valve **80** is stroked to the pressure set position and the logic valve **30** is destroked, this will allow the diagnostic switch **130** to be exhausted to the logic valve **30** and the valve will remain in the de-energized state. If both the logic valves **30** and **80** are in the latched or stroked position, this blocks the exhaust path for the pressure switch and results in pressure switch actuation.

These diagnostic techniques thereby indicate the positioning of the valves and permit the diagnostician to determine where a malfunction may have occurred. There are three times when it is important that malfunctions are detected. In neutral, a single point malfunction in the control circuit or trim valve **32** could permit a shift to reverse, however, the pressure at the switch **130** will detect this before the fill begins to prevent such action knowing that a neutral condition has been commanded. The logic valve **80** goes through transition after the first-to-second shift and before the second-to-first shift. The pressure switch changes state during this transition and thereby provides a positive feedback to the electronic control mechanism to inform the system that the shift is occurring. The logic valve **30** undergoes a transition after the fifth-to-sixth interchange and before the sixth-to-fifth interchange. The diagnostic switch **130** changes states during the transition and thereby provides a feedback signal to the electronic control mechanism to indicate that the shift is occurring.

In FIG. **3**, the electro-hydraulic control is shown in the Reverse ratio operation. Both of the logic valves **30** and **80** are in the unstroked position, the trim valve **34** supplies fluid to the torque-transmitting mechanism C**5**, and the trim valve **32** supplies fluid to the torque-transmitting mechanism C**3**. In FIG. **4**, the electro-hydraulic control is shown in the first forward range. The logic valve **80** is blocked in the unstroked position by pressure at torque-transmitting mechanism C**5** and the torque-transmitting mechanism C**1** is supplied by the trim valve **38**, and the solenoid valve **72** is actuated during the neutral to first range interchange. The pressure from the trim valve **38** latches the logic valve **30** in the stroked position.

FIG. **5** displays the electro-hydraulic control in the fourth forward range. The logic valve **80** is in the stroked position since the latching pressure at torque-transmitting mechanism C**5** was released during a first to second interchange. The torque-transmitting mechanism C**2** is engaged by the trim valve **32** and the logic valve **80** is latched in the stroked position. The torque-transmitting mechanism C**1** is controlled by the trim valve **38** and the logic valve **30** is latched in the stroked position. The electro-hydraulic control is depicted in sixth forward range in FIG. **6**. The torque-transmitting mechanisms C**2** and C**4** are controlled by the trim valves **32** and **36** respectively, and the solenoid valve **72** is deactivated.

In the event of a unintended discontinuance electrical power to the solenoids **62**, **64**, **66**, **68**, **70**, and **72**, the trim valves **32** and **38** will produce maximum output pressure. The remaining trim valves **34**, **36**, and **40** will have a minimum or zero output pressure. If this discontinuance occurs during reverse or neutral operation, only the torque-transmitting mechanism C**3** will be engaged as shown in FIG. **7**. If this discontinuance occurs during operation in the first, second, or third forward ranges, the torque-transmitting mechanisms C**3** and C**1** will be engaged as shown in FIG. **8**. In each of these ranges, the torque-transmitting mechanism C**1** will have been engaged prior to the discontinuance. The logic valve **80** will return to the unstroked condition and the trim valve **32** will engage the torque-transmitting mechanism C**3**.

In the event the discontinuance occurs during fourth range operation, the electro-hydraulic control will be in the position shown in FIG. **9**. This position is the normal fourth range position as described above in FIG. **5**. The logic valves **30** and **80** are both latched in the stroked position by the trim valves **38** and **32** respectively both before and after the discontinuance. If this discontinuance occurs during the fifth or sixth forward ranges, the electro-hydraulic control will be positioned as shown in FIG. **10** and the control will establish the fifth range. The torque-transmitting mechanisms C**2** and

C3 will be engaged by the trim valves **32** and **38** respectively. Prior to the discontinuance, the logic valve **30** was de-latched during both fifth and sixth range and will remain de-latched. The logic valve **80** was latched by the trim valve **32** during normal operation in fourth, fifth, or sixth ranges and will remain latched.

Following an unexpected discontinuance of electrical power, the electro-hydraulic control will remain in one of the above described conditions (third, fourth, or fifth range) until the engine operation is ceased. This will permit moving of the vehicle in the forward direction to a repair facility where the engine operation can be discontinued, the problem analyzed and the control repaired.

The invention claimed is:

1. An electro-hydraulic apparatus for a power transmission having a plurality of torque-transmitting mechanisms selectively engageable by said apparatus to provide six forward ratio ranges, said electro-hydraulic apparatus comprising:

a supply of electrical power to activate said electro-hydraulic apparatus;

first and second logic valves each positionable to a latched position and an unlatched position;

first and second trim valve*s* **[**means**]** for providing maximum output pressure when said electrical power is discontinued;

third and fourth trim valves controlled by normally closed solenoid valves that have a minimum output pressure when said electrical power is discontinued;

said trim valves and said logic valves cooperating to provide control of the torque-transmitting mechanisms to establish said six forward ratios wherein said first trim valve is effective to maintain said first logic valve in said latched position during the first, second, third, and fourth of said forward ratio ranges, said second trim valve is effective to maintain said second logic valve in said latched position during the fourth, fifth, and sixth forward ratio ranges;

said first trim valve and said first logic valve being effective to maintain a first of said torque-transmitting mechanisms engaged during an electrical power discontinuance occurring in either said third or fourth ratio range, said second trim valve and said second logic valve being effective to maintain a second of said torque-transmitting mechanisms engaged during an electrical discontinuance occurring in said third ratio range, said second trim valve and said second logic valve being effective to maintain said second logic valve stroked and a third of said torque-transmitting mechanisms engaged during an electrical discontinuance occurring in said fourth ratio range, and said first trim valve, said first logic valve in said unlatched position, and said second logic valve in said latched condition cooperating to maintain said second torque-transmitting mechanism engaged during an electrical power discontinuance in said fifth ratio range; and

said electro-hydraulic apparatus being effective to maintain the transmission in third ratio range in the event of an electrical discontinuance during operation in either said first, second, or third forward ratio range, in said fourth forward ratio range during an electrical discontinuance during operation in said fourth range, and in said fifth forward ratio range in the event of an electrical discontinuance during operation in either said fifth or sixth ratio range.

2. The electro-hydraulic apparatus for the power transmission having the plurality of torque-transmitting mechanisms selectively engageable by said apparatus to provide the six forward ratio ranges, said electro-hydraulic apparatus defined in claim **1** further comprising:

means for urging said first and second logic valves to said latched position during an interchange from a neutral condition to said first forward range.

3. The electro-hydraulic apparatus for the power transmission having the plurality of torque-transmitting mechanisms selectively engageable by said apparatus to provide the six forward ratio ranges, said electro-hydraulic apparatus defined in claim **1** further comprising:

means for urging said first and second logic valves to said latched position during an interchange from a neutral condition to said first forward range and said means being discontinued during a ratio interchange from said fifth forward ratio range to said sixth forward ratio range whereby said first logic valve is moved to said unlatched position.

4. The electro-hydraulic apparatus for the power transmission having the plurality of torque-transmitting mechanisms selectively engageable by said apparatus to provide the six forward ratio ranges, said electro-hydraulic apparatus defined in claim **1** further comprising:

means for urging said first and second logic valves to said latched position during an interchange from a neutral condition to said first forward range, and said means being inoperative during an electrical discontinuance.

5. The electro-hydraulic apparatus for the power transmission having the plurality of torque-transmitting mechanisms selectively engageable by said apparatus to provide the six forward ratio ranges, said electro-hydraulic apparatus defined in claim **1** further comprising:

means for urging said first and second logic valves to said latched position during an interchange from a neutral condition to said first forward range, said means being discontinued during a ratio interchange from said fifth forward ratio range to said sixth forward ratio range whereby said first logic valve is moved to said unlatched position and said means being inoperative during an electrical discontinuance.

6. An automatic transmission control apparatus comprising:

a source of fluid pressure;

an exhaust apparatus;

a first logic valve having a spring set position and a pressure set position;

a second logic valve having a spring set position and a pressure set position;

a plurality of trim valves for supplying fluid pressure to said logic valves, one of said trim valves being operable to supply fluid pressure to said logic valves to urge said logic valves to said pressure set position, said logic valves being effective to distribute fluid pressure to a plurality of torque transmitting mechanisms, said second logic valve being urged to said spring set position when a second of said trim valves is operated to engage a first of said torque transmitting mechanisms;

a diagnostic apparatus having a spring set condition and a pressure set condition for issuing a signal dependant on the operating condition of said torque transmitting mechanisms; and

said diagnostic apparatus being urged to said pressure set condition when said second logic valve is held in said spring set position and a first of said torque transmitting mechanisms is engaged and being in said spring set position when said first torque-transmitting mechanism is not engaged.

7. An automatic transmission control apparatus comprising:

a source of fluid pressure;

an exhaust apparatus;

a first logic valve having a spring set position and a pressure set position;

a second logic valve having a spring set position and a pressure set position;

a plurality of trim valves for supplying fluid pressure to said logic valves, one of said trim valves being operable to supply fluid pressure to said logic valves to urge said logic valves to said pressure set position, said logic valves being effective to distribute fluid pressure to a plurality of torque transmitting mechanisms, said second logic valve being urged to said spring set position when a second of said trim valves is operated to engage a first of said torque transmitting mechanisms;

a diagnostic apparatus having a spring set condition and a pressure set condition for issuing a signal dependant on the operating condition of said torque transmitting mechanisms; and

said diagnostic apparatus being connected with said exhaust apparatus when said first logic valve is in said spring set position and said diagnostic apparatus is in said spring set position.

8. An automatic transmission control apparatus comprising:

a source of fluid pressure;

an exhaust apparatus;

a first logic valve having a spring set position and a pressure set position;

a second logic valve having a spring set position and a pressure set position;

a plurality of trim valves for supplying fluid pressure to said logic valves, one of said trim valves being operable to supply fluid pressure to said logic valves to urge said logic valves to said pressure set position, said logic valves being effective to distribute fluid pressure to a plurality of torque transmitting mechanisms, said second logic valve being urged to said spring set position when a second of said trim valves is operated to engage a first of said torque transmitting mechanisms;

a diagnostic apparatus having a spring set condition and a pressure set condition for issuing a signal dependant on the operating condition of said torque transmitting mechanisms; and

said diagnostic apparatus being urged to said pressure set condition when said second logic valve is held in said spring set position and a first of said torque transmitting mechanisms is engaged, said diagnostic apparatus being connected with said exhaust apparatus when said first logic valve is in said spring set position and said diagnostic apparatus is in said spring set position, and said diagnostic apparatus being connected with said pressure source when both of said logic valves are in said pressure set position.

9. The automatic transmission control apparatus defined in claim 8 further comprising:

said diagnostic apparatus being connected with said exhaust apparatus when said first logic valve is in said pressure set opposition and said second logic valve is in said spring set position.

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