US009475385B1

(12) United States Patent
Pritchard et al.

(10) Patent No.: US 9,475,385 B1
(45) Date of Patent: Oct. 25, 2016

(54) **ELECTRONIC SHIFT ON THE FLY PART-TIME ELECTRO MECHANICAL TRANSFER CASE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/828,838**

(22) Filed: **Aug. 18, 2015**

(51) **Int. Cl.**

B60K 17/344	(2006.01)
F16D 28/00	(2006.01)
F16H 1/22	(2006.01)
F16H 57/02	(2012.01)

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

CPC ***B60K 17/344*** (2013.01); ***F16D 28/00*** (2013.01); ***F16H 1/22*** (2013.01); *F16D 2250/0084* (2013.01); *F16H 2057/02052* (2013.01); *F16H 2306/40* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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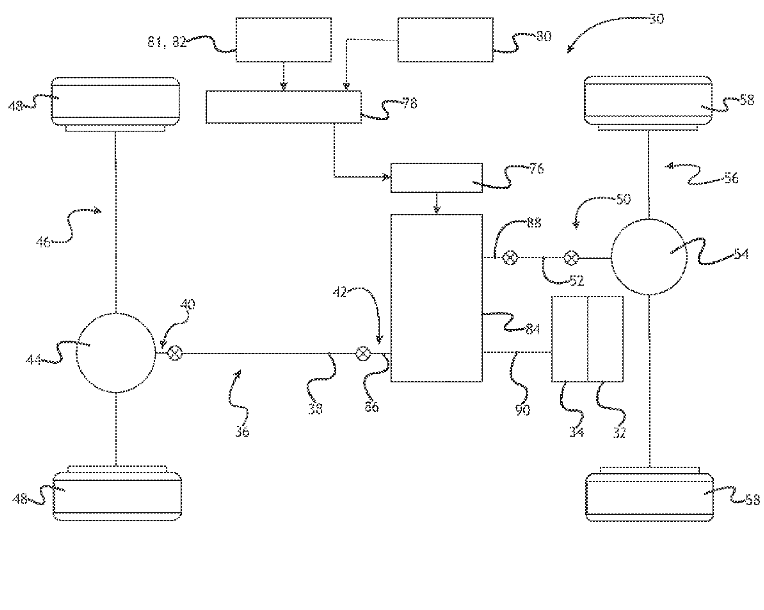
(57) **ABSTRACT**

A transfer case comprising an input shaft and a first output shaft sharing a primary axis of rotation; a second output shaft offset from the first output shaft; a range shifter comprising a first cam constructed and arranged to selectively shift a vehicle to a high-range drive mode, a low range drive mode, or a neutral drive mode; a mode shifter comprising a second cam constructed and arranged to actuate a synchronizer which selectively shifts the vehicle between a two-wheel drive and a four-wheel drive mode; and a dual drive gear interposed between the range shifter and the mode shifter which is rotatable to actuate the first cam and the second cam.

20 Claims, 4 Drawing Sheets



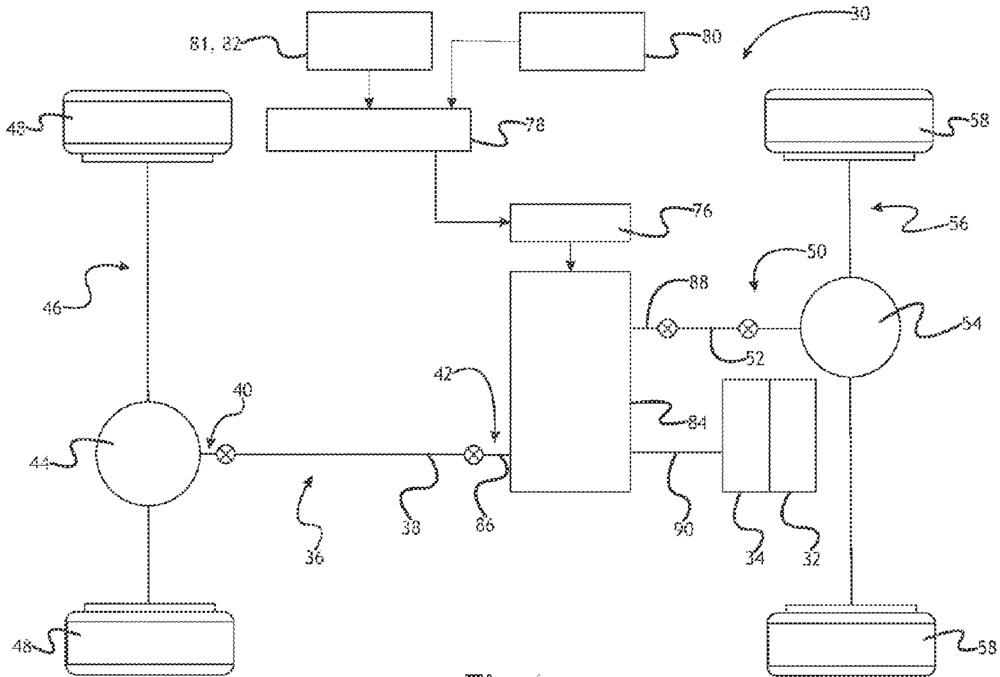

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Fig.1

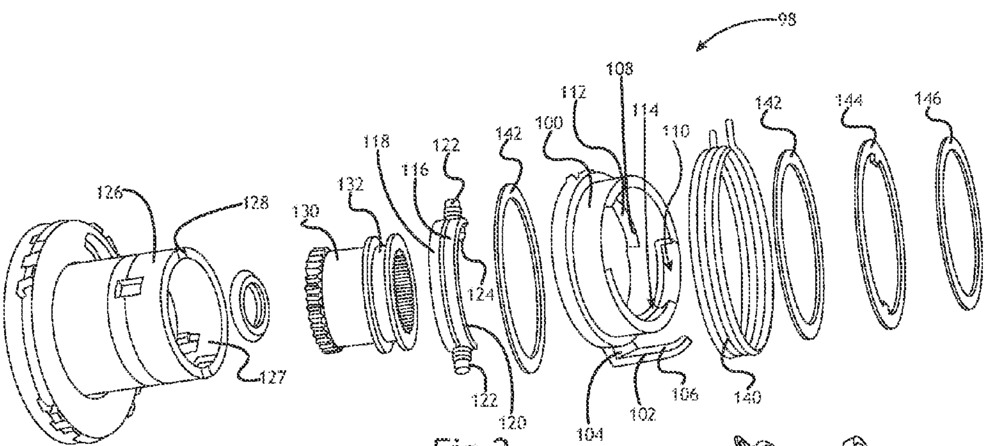
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Fig.2

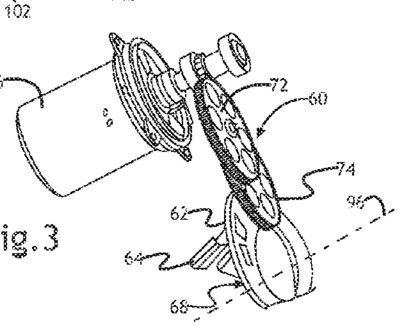
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Fig.3

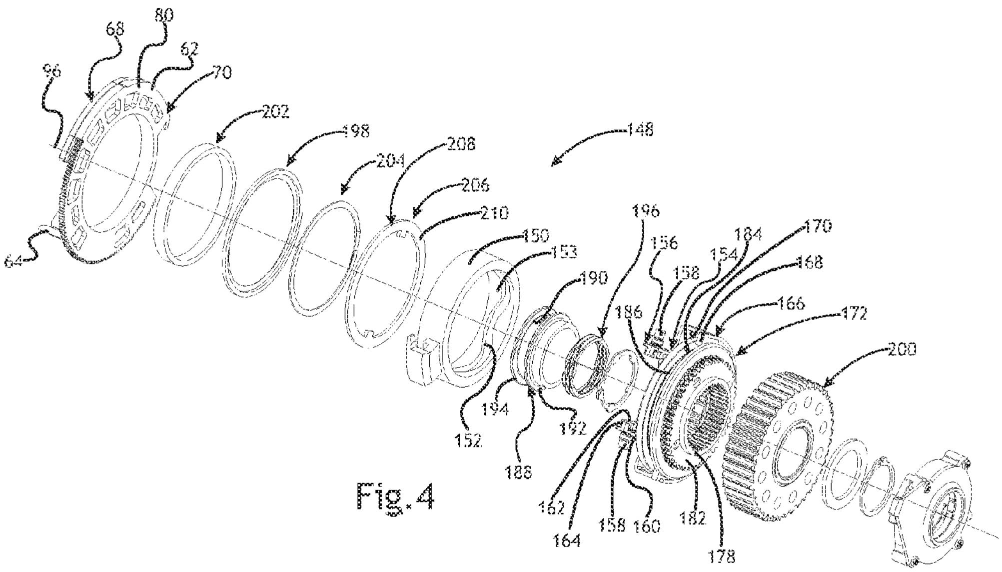

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Fig.4

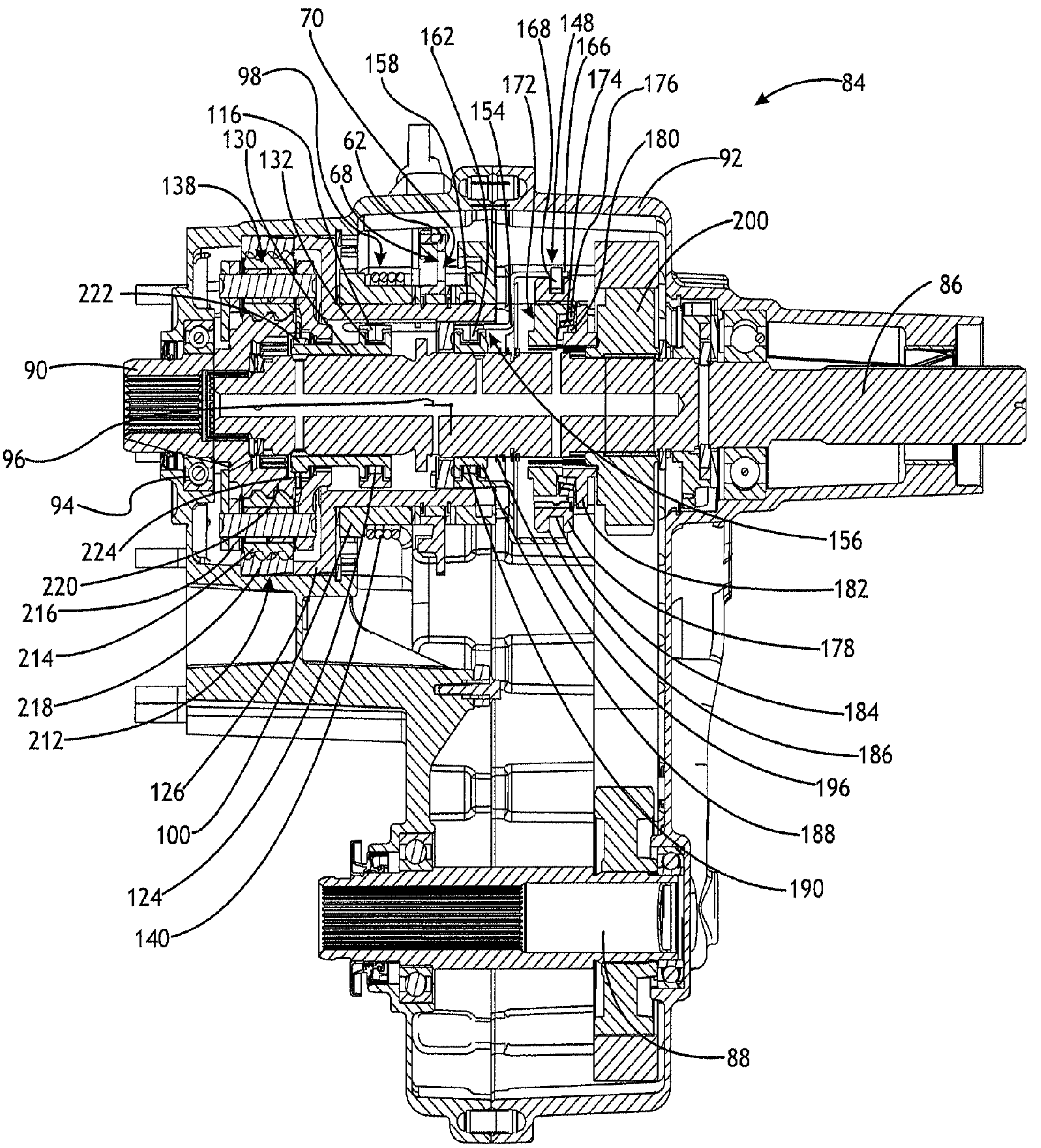
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Fig.5

ELECTRONIC SHIFT ON THE FLY PART-TIME ELECTRO MECHANICAL TRANSFER CASE

TECHNICAL FIELD

The field to which the disclosure generally relates to includes transfer cases.

BACKGROUND

A vehicle may include an electronic shift on the fly transfer case which may allow for the selective engagement of a four-wheel-drive mode or a two-wheel-drive mode.

SUMMARY OF ILLUSTRATIVE VARIATIONS

A number of variations may include a transfer case comprising: an input shaft having a primary axis of rotation; a first output shaft which is concentric with the input shaft; a second output shaft offset from the first output shaft; a range shifter comprising a first cam rotatable about the primary axis constructed and arranged to selectively shift a vehicle to a high-range drive mode, a low range drive mode, or a neutral drive mode; a mode shifter comprising a second cam rotatable about the primary axis constructed and arranged to actuate a synchronizer which selectively shifts the vehicle between a two-wheel drive and a four-wheel drive mode; and a dual drive gear interposed between the range shifter and the mode shifter, wherein a first side of the dual drive gear includes an actuating tab constructed and arranged to actuate the first cam and wherein the second cam is attached to a second side of the dual drive gear so that the mode shifter is activated by rotation of the dual drive gear.

A number of variations may include a transfer case comprising: an input shaft having a primary axis of rotation; a first output shaft which is concentric with the input shaft; a second output shaft offset from the first output shaft; a range shifter comprising a first cam, a first shift fork, wherein the first shift fork is driven axially by the first cam, and a first sleeve which is axially driven by the first shift fork; a mode shifter comprising a second cam, a second shift fork, wherein the second shift fork is driven axially by the second cam, and a synchronizer, wherein the synchronizer is actuated by the second shift fork through rotation of the second cam; and a dual drive gear, wherein the dual drive gear is rotated in a forward and a reverse direction to actuate the range shifter and the mode shifter.

A number of variations may include a method for assembling a transfer case comprising: providing an input shaft and a first output shaft coaxially on a primary axis of rotation; providing a second output shaft offset from the first output shaft; providing a power transmission device interposed between the first output shaft and the second output shaft; providing a range shifter operatively attached to the first output shaft comprising a first cam constructed and arranged for shifting between a low-range drive mode, a high-range drive mode, and a neutral drive mode; providing a mode shifter for shift-on-the-fly comprising a second cam operatively attached to a synchronizer constructed and arranged for shifting between a two-wheel drive mode and a four-wheel drive mode; providing a dual drive gear between the range shifter and the mode shifter constructed and arranged so that rotation of the dual drive gear actuates the range shifter and the mode shifter; and providing a gear train off axis from the primary axis constructed and arranged to drive the dual drive gear in a clockwise and counter clockwise direction.

Other illustrative variations within the scope of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing variations of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Select examples of variations within the scope of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** illustrates a schematic of a vehicle including a transfer case according to a number of variations.

FIG. **2** illustrates an exploded view of a range shifter according to a number of variations.

FIG. **3** illustrates a perspective view of an electric motor and a gear train according to a number of variations.

FIG. **4** illustrates an exploded view of a mode shifter according to a number of variations.

FIG. **5** illustrates a section view of a transfer case according to a number of variations.

DETAILED DESCRIPTION OF ILLUSTRATIVE VARIATIONS

The following description of the variations is merely illustrative in nature and is in no way intended to limit the scope of the invention, its application, or uses.

Referring to FIG. **1**, in a number of variations, a vehicle **30** may include an engine **32**, including, but not limited to, an internal combustion engine which may be operatively connected to a power transmission device **34** which may be operatively connected to a rear driveline **36** and a front driveline **50**. The power transmission device **34** may generate and deliver torque from the engine **32** to the rear driveline **36** and the front driveline **50**. In a number of variations, the rear driveline **36** may include a rear drive shaft **38**. A first end **40** of the rear drive shaft **38** may be operatively connected to a rear differential **44** which may be operatively connected to a rear axle **46**. A pair of rear wheels **48** may be attached to opposing ends of the rear axle **46**. A second end **42** of the rear drive shaft **38** may be operatively connected to and may be driven by a first output shaft **86** of an electro mechanical transfer case (EMTC) **84**. The EMTC **84** may be operatively connected to an input shaft **90** which may be operatively connected to the power transmission device **34**. The EMTC **84** may be used to selectively engage a four-wheel drive mode or and two-wheel drive mode of the vehicle **30** as well as to selectively put the vehicle **30** into a high or low range mode. The EMTC **84** may be operatively attached to a reversible electric motor **76**. The EMTC **84** may also include a second output shaft **88** which may be operatively connected to the front driveline **50**. In a number of variations, the front driveline **50** may include a front drive shaft **52** which may be operatively connected to the second output shaft **88** of the EMTC **84** and may be driven by the second output shaft **88**. The front driveline **50** may also include a front differential **54** which may be operatively connected to the front drive shaft **52** and a front axle **56**. A pair of front wheels **58** may be attached to opposing ends of the front axle **56**.

FIGS. **1-5** illustrate a number of variations. In a number of variations, the EMTC **84** may include a range shifter **98** which may be used to shift the vehicle **30** to a low-range drive mode, a high-range drive mode, or a neutral drive mode, variations of which are illustrated in FIGS. **2** and **5**. The EMTC **84** may also include a mode shifter **148** which may be used to engage a two-wheel drive mode and a four-wheel drive mode, variations of which are illustrated in FIGS. **4** and **5**. In a number of variations, the range shifter **98** and the mode shifter **148** may be mounted coaxially along a primary axis **96**, a variation of which is illustrated in FIG. **5**. In a number of variations, a gear train **60**, which may be off axis or offset from the primary axis **96**, may be used to rotate a dual drive gear **62** which may be mounted concentric to the range shifter **98** and the mode shifter **148** around the primary axis **96**, and may be used to actuate the range shifter **98** and/or the mode shifter **148**, a variation of which is illustrated in FIG. **3**. The gear train **60** may include a plurality of gears **72**, **74** which may also be constructed and arranged to be rotated in a clockwise or counterclockwise direction. In one variation, the gear train **60** may include an input gear **72** and an intermediate output gear **74**. The intermediate output gear **74** may be driven by the input gear **72**. The intermediate output gear **74** may drive and rotate the dual drive gear **62**. In a number of variations, a reversible electric motor **76**, which may also be off axis from the primary axis **96**, may be operatively connected to the gear train **60** and may be used to control the rotation of the dual drive gear **62** in a clockwise or counterclockwise direction. In a number of variations, an electronic control unit (ECU) **78** may be operatively connected to the reversible electric motor **76** and may be used to control the rotation of the dual drive gear **62**, a variation of which is illustrated in FIG. **1**. The ECU **78** may be operatively connected to at least one sensing element **80** which may detect a position of the dual drive gear **62**. In one variation, the at least one sensing element **80** may be located on a peripheral surface of the dual drive gear **62**, a variation of which is illustrated in FIG. **4**, and may be mechanical or electrical. The ECU **78** may then automatically signal the reversible electric motor **76** to drive the dual drive gear **62** in response to the detected position of the dual drive gear **62** by the at least one sensing element **80** for actuating movement of at least one of the range shifter **98** or the mode shifter **148**.

Referring to FIG. **1**, in one variation, the ECU **78** may be constructed and arranged to operate in an automatic drive mode which may automatically control the reversible electric motor **76** to control whether the vehicle **30** is in a four-wheel drive mode or a two-wheel drive mode. A driver may then manually select whether the vehicle **30** is in high-range or low-range through a range selection device **81** which may be accessible to the driver. In another variation, the ECU **78** may be constructed and arranged so that a driver may manually select one of the available drive modes and ranges through a mode/range selection device **82** which may be accessible to the driver. In another variation, the ECU **78** may be constructed and arranged so that a driver may choose whether the ECU **78** automatically chooses the drive mode setting or whether the driver may manually choose the drive mode or the range mode through the range/mode selection device **82**. The ECU **78** may process and relay control signals to the EMTC **84** to cause the EMTC **84** to actuate the range shifter **98** and/or the mode shifter **148** in response to the at least one sensing element **80** and/or the detected position of the dual drive gear **62**. In a number of variations, the ECU **78** may be part of or may be a general purpose or specific purpose computer.

Referring to FIG. **5**, in a number of variations, the EMTC **84** may include an input shaft **90**, as discussed above, which may be constructed and arranged to be driven by the power transmission device **34**. The engine **32** may rotate a drive shaft which may be coupled to the power transmission device **34** which may convert the output power from the engine **32** to a geared output drive power. The output drive power from the power transmission device **34** may be transmitted to the input shaft **90** of the EMTC **84**. The EMTC **84** may then selectively transmit output drive power to the front wheels **58** and/or the rear wheels **48**. In a number of variations, the EMTC **84** may include a housing **92** which may surround at least a portion of the range shifter **98**, the mode shifter **148**, and the dual drive gear **62**. The housing **92** may also include various seals, recesses, shoulders, flanges, bores, etc. which may be constructed and arranged to position and accept various components of the EMTC **84**. In a number of variations, the first output shaft **86** and the second output shaft **88** may extend within a portion of the housing **92** and may be rotatable within the housing **92**. In a number of variations, a portion of the input shaft **90** may also extend within the housing **92** and may be rotatable within the housing **92** and may be supported by one or more bearing assemblies **94**. In a number of variations, the input shaft **90** may be coaxial with the first output shaft **86**. Any number of suitable devices may be used to transfer torque between the first output shaft **86** and the second output shaft **88** including, but not limited to, a belt, a chain, or a gear train.

Referring again to FIG. **5**, in a number of variations, the input shaft **90** may be rotatable around a primary axis **96** of rotation. The range shifter **98** and the mode shifter **148** may be positioned coaxially with the input shaft **90** and may be spaced longitudinally adjacent from each other, which may allow for the use of fewer off-axis components to perform the shifting functions of the range shifter **98** and the mode shifter **148**. The dual drive gear **62** may also be coaxial with the input shaft **90** and may be interposed between the range shifter **98** and the mode shifter **148**. The dual drive gear **62** may be constructed and arranged so that it may be configured for reversible clockwise and counterclockwise rotation about the primary axis **96** through an angular arc of less than 360 degrees. The dual drive gear **62** may be constructed and arranged so that during a first end portion of angular rotation about the primary axis **96**, the dual drive gear **62** engages and operates the range shifter **98** and during a second opposite end portion of angular rotation about the primary axis **96**, the dual drive gear **62** actuates the mode shifter **148**.

Referring to FIGS. **2** and **5**, in a number of variations, a first side **68** of the dual drive gear **62** may be operatively connected to the range shifter **98** and may be used to shift the range shifter **98** to a low-range drive mode, neutral drive mode, or a high-range drive mode through rotation of a barrel cam **100**. In a number of variations, the barrel cam **100** may include a barrel tab **102**. The barrel tab **102** may include a first portion **104** which may extend radially outward from the outer perimeter of the barrel cam **100** and a second portion **106** which may extend axially from the first portion toward the dual drive gear **62**, a variation of which is illustrated in FIG. **2**. The barrel tab **102** may be constructed and arranged to be actuated by an actuating tab **64** on the dual drive gear **62**, as will be discussed hereafter. In a number of variations, the barrel cam **100** may include a cam surface groove **108** which may extend circumferentially and axially along an interior surface of the barrel cam **100** to define an axial range shift movement in response to rotation of the barrel cam **100**. In a number of variations, the cam surface groove **108** may include a first end portion **110**, a second end portion **112**, and an intermediate portion **114** extending therebetween. The first end portion **110** may include a predetermined circumferential arcuate length and may lie in a first plane perpendicular to the primary axis **96**. The second end portion **110** may include a predetermined circumferential arcuate length and may lie in a second plane perpendicular to the primary axis **96** spaced from the first plane. The intermediate portion **114** of the cam surface groove **108** may extend arcuately and axially between the first end portion **110** and the second end portion **112** to define axial shifting movement of a shift fork **116** between the low-range and high-range drive mode, as will be discussed hereafter. The barrel cam **100** may be rotatable about the primary axis **96** through an arc of less than 360 degrees in response to rotation of the dual drive gear **62** in either rotational direction.

In a number of variations, the range shifter **98** may also include a shift collar **126** which may include an axial groove **128** which may allow passage of a first and second pin **122** of the shift fork **116** to move radially into engagement within the cam surface groove **108** of the barrel cam **100** for driving axial travel of the shift fork **116** in response to rotation of the barrel cam **100**. The shift fork **116** may act as a cam follower traveling within the cam surface groove **108** of the barrel cam **100** as the barrel cam **100** is rotated in either rotational direction. The shift fork **116**, barrel cam **100**, and shift collar **126** may surround an axially moveable and rotatable internal range sleeve **130**. The internal range sleeve **130** may include a groove **132** which may be engageable with a protrusion **124** on the inner surface **120** of the shift fork **116** which may allow for rotation of the internal range sleeve **130** relative to the shift fork **116**. In one variation, the shift collar **126** may comprise a cylindrical element which may support the shift fork **116** through the axial groove **128** which may allow for guided axial movement of the shift fork **116** and may prevent rotational movement of the shift fork **116**. The shift collar **126** may allow the shift fork **116** to slide in an axial direction to drive the internal range sleeve **130** in response to shifting rotational movement of the barrel cam **100** between a low-range angular position, neutral angular position, and a high-range angular position.

Referring to FIG. **5**, in a number of variations, the internal range sleeve **130** may be engageable between the range shifter **98** and a gear reduction assembly **138** to the first output shaft **86** through a splined connection which my allow for axial movement of the internal range sleeve **130** with respect to the first output shaft **86**. The gear reduction assembly **138** may vary the drive power between the input shaft **90** and the first and the second output shaft **86**, **88**. In a number of variations, the gear reduction assembly **138** may include a planetary gear assembly **212** which may include a plurality of planetary gears **214** which may be operatively attached to a gear carrier **216**. The plurality of planetary gears **214** may rotate within a ring gear **218** and may be driven by a sun gear **220**. In a number of variations, when the shift fork **116** is driven into a low-range drive mode portion of the cam surface groove **108**, the internal range sleeve **130** may axially move to couple the first output shaft **86** with the planetary gear carrier **216**. When the shift fork **116** is driven into a high-range drive mode portion of the cam surface groove **108**, the internal range sleeve **130** may axially move to couple the first output shaft **86** with the sun gear **220**. The gear teeth **222** of the internal range sleeve **130** may engage with the internal teeth **224** of the sun gear **220**. The sun gear **220** may be driven by the input shaft **90**. The plurality of planetary gears **214** may be rotatable around the sun gear **220** and may be driven by the sun gear **220**. Drive torque may be transferred to the first output shaft **86** directly from the sun gear **220** or indirectly through the planetary gear carrier **216** depending on the drive ratio desired. The gearing ratio between the sun gear **220** and the plurality of planetary gears **214** may be a reduction ratio, rotating the first output shaft **86** at a different speed than the input shaft **90**. In a number of variations, the reduction ratio may be in a range between approximately 1:1 to approximately 10:1, inclusive, with a preferred ratio of approximately 2.6:1. It is noted that a person having ordinary skill in the art would recognize that any number of gear reduction assembly designs other than the one illustrated above may be used in the EMTC **84** without departing from the spirit and scope of the invention.

In a number of variations, a torsional wrap spring **140** may surround a portion of the outer circumference of the barrel cam **100** for biasing the barrel cam **100** to follow rotational movement of the dual drive gear **62**, which may allow for completion of range shift movement if temporarily blocked due to unmeshed gear teeth engagement during axial movement. The torsional wrap spring **140** may hold the barrel tab **102** and the dual drive gear actuating tab **64** in radial alignment with each other after completion of rotational driving movement. The torsional wrap spring **140** may be constrained to follow movement of the dual drive gear **62** and may be loaded with force in either rotational direction of the dual drive gear **62**. The loaded force of the torsional wrap spring **140** may urge rotational movement of the barrel cam **100** to follow rotational movement of the dual drive gear **62**. When the torsional wrap spring **140** is loaded with force, the torsional wrap spring **140** continually biases the barrel cam **100** in the desired direction of movement until the range shift movement is completed. In a number of variations, the barrel cam **100** may be rotatably biased toward the desired rotational movement by the torsional wrap spring **140**, even if axial movement of the shift fork **116** is temporarily blocked while the dual drive gear **62** continues to rotate. If the barrel cam **100** is axially blocked during rotation, the torsional wrap spring **140** may be loaded with rotational energy to bias the barrel cam **100** to move into a desired orientation when the blocked condition ceases. The torsional wrap spring **140** may store energy between the reverse electric motor **76** and the shift fork **116** until the desired range mode shift is completed.

In a number of variations, the barrel cam **100** may be interposed between a first thrust bushing **142** and a second thrust bushing **144**. The dual drive gear **62** may be positioned axially adjacent to the barrel cam **100**, the first thrust bushing **142** and one or more ring members **146** which may be interposed between the barrel cam **100** and the dual drive gear **62**. The dual drive gear **62** may also include a dual drive gear actuating tab **64**, as discussed above, which may extend axially toward the range shifter **98** and may be radially spaced from the barrel cam **100**. The dual drive gear actuating tab **64** may move angularly in either rotational direction (clockwise or counterclockwise) with respect to the barrel tab **102** and may be independently rotatable from the barrel tab **102**.

In a number of variations, the dual drive gear **62** may actuate the range shifter **98** through rotational movement of the dual drive gear actuating tab **64**. In a number of variations, when the vehicle **30** is in a low-range drive mode, or a high-range drive mode, the shift fork **116** may be in the first end portion **110** or the second end portion **112** of the cam groove surface **108**. When the shift fork **116** is in the first or second end portion **110**, **112** of the cam groove surface **108**, the mode shifter **148** may be actuated.

Referring to FIGS. **4** and **5**, in a number of variations, the mode shifter **148** may include a mode cam **150** which may actuate a synchronizer **172**. In a number of variations, the mode cam **150** may be rigidly attached to the dual drive gear **62** so that the mode cam **150** may rotate with the dual drive gear **62**. The mode cam **150** may also include a cam surface groove **152** which may extend circumferentially and axially along an inner surface **153** of the inner perimeter of the mode cam **150** and may form a wave-like pattern to define an axial travel path for a mode shift fork **154** in response to rotation of the mode cam **150** as discussed below. The mode cam **150** may be rotatable about the primary axis **96** through an arc of less than 360 degrees in response to rotation of the dual drive gear **62** in either rotational direction.

The mode cam **150** may actuate any number of variations of synchronizers **172** including, but not limited to, a single-cone, dual-cone, or triple-cone synchronizer. In one variation, the synchronizer **172** may include one or more internal rings **174**, a blocker ring **176**, a synchronizer sleeve **178**, a hub **180**, and an engagement ring **182**. In a number of variations, the synchronizer sleeve **178** may include a groove **184** along an outer surface **186** of the mode sleeve **188** which may be constructed and arranged to accommodate a second portion **166** of a mode shift fork **154**, as will be discussed hereafter.

In a number of variations, a mode shift fork **154** may be operatively attached to the mode cam **150** and the synchronizer **172** and may be used to shift the vehicle **30** between two-wheel drive and four-wheel drive. The mode shift fork **154** may include a first portion **156** and a second portion **166**. The first portion **156** may be constructed and arranged to operatively connect to the mode cam **150** and a mode sleeve **188**. The first portion **156** may include a first and second pin **158** which may extend radially from opposing ends of an outer surface **160** of the first portion **156**. The pins **158** may be constructed and arranged to travel within the mode cam surface groove **152** to allow for axial travel of the mode shift fork **154** in response to rotation of the mode cam **150**. The first portion **156** of the mode shift fork **154** may also include a protrusion **162** which may extend along a center portion of an inner surface **164** of the first portion **156** and may be constructed and arranged to rotate within a mode sleeve groove **190** in the mode sleeve **188**, as will be discussed hereafter. In a number of variations, the second portion **166** may be constructed and arranged to operatively attach to the synchronizer sleeve **178** and may move the synchronizer sleeve **178** axially in response to rotation of the mode cam **150**. The second portion **166** may include a protrusion **168** on an inner surface **170** of the second portion **166** which may be constructed and arranged to sit within a groove **184** in the synchronizer sleeve **178** so that the synchronizer sleeve **178** is moved axially in relation to the axial movement of the mode shift fork **154**.

In a number of variations, the mode sleeve **188** may extend around the first output shaft **86** and may move axially along the first output shaft **86**. The mode sleeve **188** may be cylindrical and may include a first lip **192** and a second lip **194** constructed and arranged to form the mode sleeve groove **190** which may accommodate the protrusion **162** on the first portion **156** of the mode shift fork **154** which may hold the mode shift fork **154** in place. A wave spring **196** and a snap ring **198** (which may act as a shoulder for the wave spring **196**) may be interposed between the mode sleeve **188** and the mode shift fork **154**. The wave spring **196** may provide a tension on the mode sleeve **188** and mode shift fork **154** which may assist in moving the mode sleeve **188** and mode shift fork **154** back axially toward the dual drive gear **62** when the vehicle **30** is shifted from four-wheel drive back to two-wheel drive.

In a number of variations, a first sleeve **202** may be axially adjacent to the second side **70** of the dual drive gear **62** and may extend within the inner perimeter of the dual drive gear **62** and may be used to rigidly fix the mode cam **150** to the dual drive gear **62**. A portion of the snap ring **198** may fit within the inner perimeter of the first sleeve **202**. A thrust washer **204** may sit within a portion of the snap ring **198**. A first side **208** of a separator thrust washer **206** may lay axially adjacent to the snap ring **198** and thrust washer **204** and a second side **210** of the separator thrust washer **206** may lay axially adjacent to the mode cam **150**. The sprocket **200** may be located axially adjacent to the engagement ring **182** of the synchronizer **172**.

In a number of variations, when the range shifter **98** is in a low-range drive mode or a high-range drive mode, the mode shifter **98** may be actuated to shift the vehicle **30** between the two-wheel drive mode and the four-wheel drive mode. During a two-wheel drive mode, the first output shaft **86** may rotate within the sprocket **200** without causing the sprocket **200** to rotate. The dual drive gear **62** may be rotated which may cause the mode cam **150** to rotate. This may cause the mode shift fork **154** to move axially toward the direction of the sprocket **200** which may cause the engagement ring **182** of the synchronizer **172** to push against and engage the sprocket **200** to cause the sprocket **200** to rotate. The blocker ring **176** may prevent the synchronizer sleeve **178** from engaging the engagement ring **182** while the sprocket **200** and the engagement ring **182** rotate at different speeds. Once the rotation of the sprocket **200** and the engagement ring **182** are synchronized, the synchronizer sleeve **178** may continue to axially move into a spline engagement with the engagement ring **182** so that the sprocket **200** and the first output shaft **86** are operatively attached. The synchronizer **172** may allow for engagement of four-wheel drive quickly by bringing the rotation of the sprocket **200** up to speed with the rotation of the first output shaft **86** so that alignment of the teeth on the engagement ring **182** and the synchronizer sleeve **178** occurs quickly.

The following description of variants is only illustrative of components, elements, acts, products and methods considered to be within the scope of the invention and are not in any way intended to limit such scope by what is specifically disclosed or not expressly set forth. The components, elements, acts, products and methods as described herein may be combined and rearranged other than as expressly described herein and still are considered to be within the scope of the invention.

Variation 1 may include a transfer case comprising: an input shaft having a primary axis of rotation; a first output shaft which is concentric with the input shaft; a second output shaft offset from the first output shaft; a range shifter comprising a first cam rotatable about the primary axis constructed and arranged to selectively shift a vehicle to a high-range drive mode, a low range drive mode, or a neutral drive mode; a mode shifter comprising a second cam rotatable about the primary axis constructed and arranged to actuate a synchronizer which selectively shifts the vehicle between a two-wheel drive and a four-wheel drive mode; and a dual drive gear interposed between the range shifter and the mode shifter, wherein a first side of the dual drive gear includes an actuating tab constructed and arranged to actuate the first cam and wherein the second cam is attached to a second side of the dual drive gear so that the mode shifter is activated by rotation of the dual drive gear.

Variation 2 may include a transfer case as set forth in Variation 1 further comprising a gear train operatively connected to the dual drive gear to drive the dual gear drive, wherein the gear train has a first axis offset from the primary axis; a reversible electric motor which drives the gear train in a clockwise and a counterclockwise direction and which has a second axis offset from the primary axis; and an electronic control unit constructed and arranged to control the reversible electric motor.

Variation 3 may include a transfer case as set forth in any of Variations 1-2 further comprising a housing surrounding at least a portion of the input shaft, the first output shaft, the second output shaft, the range shifter, the mode shifter, and the dual drive gear.

Variation 4 may include a transfer case as set forth in any of Variations 1-3 wherein the range shifter further comprising a spring interposed between the first cam and the dual drive gear which is constructed and arranged to bias the first cam to follow reversible rotational movement of the dual drive gear; a shift fork constructed and arranged to travel along a groove in the first cam in response to rotation of the first cam; a shift collar constructed and arranged to include an axial groove for supporting the shift fork and to allow axial movement of the shift fork while restricting rotation of the shift fork; and an internal range sleeve operatively connected to the shift fork to move axially in response to rotation of the first cam.

Variation 5 may include a transfer case as set forth in any of Variations 1-4 wherein the mode shifter further comprises a shift fork constructed and arranged to travel along a groove in the mode cam, a mode sleeve operatively attached to the shift fork and axially slideable on the first output shaft, a spring interposed between the shift fork and the mode sleeve constructed and arranged to bias the mode sleeve so that when the vehicle returns to the two-wheel drive mode, the spring applies a force to the mode sleeve to push the mode sleeve back axially toward the dual drive gear.

Variation 6 may include a transfer case as set forth in Variation 5 wherein the synchronizer includes an engagement ring axially adjacent to a sprocket, wherein the engagement ring is constructed and arranged to move axially toward the sprocket when the shift fork is moved axially toward the sprocket from rotation of the second cam so that the synchronizer rotates the sprocket to a speed of the first output shaft.

Variation 7 may include a transfer case as set forth in any of Variations 1-6 further comprising at least one sensing element located on a peripheral surface of the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

Variation 8 may include a transfer case comprising: an input shaft having a primary axis of rotation; a first output shaft which is concentric with the input shaft; a second output shaft offset from the first output shaft; a range shifter comprising a first cam, a first shift fork, wherein the first shift fork is driven axially by the first cam, and a first sleeve which is axially driven by the first shift fork; a mode shifter comprising a second cam, a second shift fork, wherein the second shift fork is driven axially by the second cam, and a synchronizer, wherein the synchronizer is actuated by the second shift fork through rotation of the second cam; and a dual drive gear, wherein the dual drive gear is rotated in a forward and a reverse direction to actuate the range shifter and the mode shifter.

Variation 9 may include a transfer case as set forth in Variation 8 wherein the range shifter is constructed and arranged to shift a vehicle from a low-range drive mode to a high-range drive mode and the mode shifter is constructed and arranged to shift the vehicle from a two-wheel drive mode to a four-wheel drive mode.

Variation 10 may include a transfer case as set forth in any of Variations 8-9 further comprising a gear train operatively connected to the dual drive gear to drive the dual drive gear, wherein the gear train has a first axis offset from the primary axis; a reversible electric motor which drives the gear train in a clockwise and a counterclockwise direction and which has a second axis offset from the primary axis; and an electronic control unit constructed and arranged to control the reversible electric motor.

Variation 11 may include a transfer case as set forth in any of Variations 8-10 wherein the dual drive gear further comprises a first actuating tab constructed and arranged to actuate a first tab on the first cam.

Variation 12 may include a transfer case as set forth in any of Variations 8-11 further comprising a gear reduction assembly, wherein the first sleeve is engageable between the range shifter and the gear reduction assembly to the first output shaft through a splined connection with respect to the first output shaft.

Variation 13 may include a transfer case as set forth in Variation 12 wherein the gear reduction assembly further includes a planetary gear set comprising a plurality of planetary gears operatively connected to a gear carrier, wherein the plurality of planetary gears rotate within a ring gear and are driven by a sun gear.

Variation 14 may include a transfer case as set forth in Variation 13 wherein the first cam includes a groove having a low-range portion and a high-range portion, and wherein when the first shift fork is driven to the low-range drive mode portion of the groove, the first sleeve moves axially to couple the first output shaft with the planetary gear carrier and when the first shift fork is driven to the high-range drive mode portion of the groove, the first sleeve moves axially to couple the first output shaft with the sun gear.

Variation 15 may include a transfer case as set forth in any of Variations 8-14 further comprising at least one sensing element located on a peripheral surface of the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

Variation 16 may include a transfer case as set forth in any of Variations 8-15 wherein the synchronizer further includes an engagement ring axially adjacent to a sprocket, wherein the engagement ring is constructed and arranged to move axially toward the sprocket when the shift fork is moved axially toward the sprocket from rotation of the second cam so that the synchronizer rotates the sprocket to a speed of the first output shaft.

Variation 17 may include a method for assembling a transfer case comprising: providing an input shaft and a first output shaft coaxially on a primary axis of rotation; providing a second output shaft offset from the first output shaft; providing a power transmission device interposed between the first output shaft and the second output shaft; providing a range shifter operatively attached to the first output shaft comprising a first cam constructed and arranged for shifting between a low-range drive mode, a high-range drive mode, and a neutral drive mode; providing a mode shifter for shift-on-the-fly comprising a second cam operatively attached to a synchronizer constructed and arranged for shifting between a two-wheel drive mode and a four-wheel drive mode; providing a dual drive gear between the range shifter and the mode shifter constructed and arranged so that rotation of the dual drive gear actuates the range shifter and the mode shifter; and providing a gear train off axis from the primary axis constructed and arranged to drive the dual drive gear in a clockwise and counter clockwise direction.

Variation 18 may include a method as set forth in Variation 17 further comprising an electric motor operatively attached to the gear train constructed and arranged for driving the gear train in a clockwise and a counterclockwise direction.

Variation 19 may include a method as set forth in any of Variations 17-18 further comprising an electronic control unit operatively connected to the electric motor constructed and arranged for controlling operation of the electric motor.

Variation 20 may include a method as set forth in any of Variations 17-19 further comprising at least one sensing element located on the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating at least one of the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

The above description of select variations within the scope of the invention is merely illustrative in nature and, thus, variations or variants thereof are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A transfer case comprising:

an input shaft having a primary axis of rotation;

a first output shaft which is concentric with the input shaft;

a second output shaft offset from the first output shaft;

a range shifter comprising a first cam rotatable about the primary axis and constructed and arranged to selectively shift a vehicle to a high-range drive mode, a low range drive mode, or a neutral drive mode;

a mode shifter comprising a second cam rotatable about the primary axis and constructed and arranged to actuate a synchronizer which selectively shifts the vehicle between a two-wheel drive mode and a four-wheel drive mode; and

a dual drive gear interposed between the range shifter and the mode shifter, wherein a first side of the dual drive gear includes an actuating tab constructed and arranged to actuate the first cam and wherein the second cam is attached to a second side of the dual drive gear so that the mode shifter is activated by rotation of the dual drive gear.

2. The transfer case of claim **1** further comprising a gear train operatively connected to the dual drive gear to drive the dual gear drive, wherein the gear train has a first axis offset from the primary axis;

a reversible electric motor which drives the gear train in a clockwise and a counterclockwise direction and which has a second axis offset from the primary axis; and

an electronic control unit constructed and arranged to control the reversible electric motor.

3. The transfer case of claim **1** further comprising a housing surrounding at least a portion of the input shaft, the first output shaft, the second output shaft, the range shifter, the mode shifter, and the dual drive gear.

4. The transfer case of claim **1** wherein the range shifter further comprising a spring interposed between the first cam and the dual drive gear which is constructed and arranged to bias the first cam to follow reversible rotational movement of the dual drive gear;

a shift fork constructed and arranged to travel along a groove in the first cam in response to rotation of the first cam;

a shift collar constructed and arranged to include an axial groove for supporting the shift fork and to allow axial movement of the shift fork while restricting rotation of the shift fork; and

an internal range sleeve operatively connected to the shift fork to move axially in response to rotation of the first cam.

5. The transfer case of claim **1** wherein the mode shifter further comprises a shift fork constructed and arranged to travel along a groove in the mode cam, a mode sleeve operatively attached to the shift fork and axially slideable on the first output shaft, a spring interposed between the shift fork and the mode sleeve constructed and arranged to bias the mode sleeve so that when the vehicle returns to the two-wheel drive mode, the spring applies a force to the mode sleeve to push the mode sleeve back axially toward the dual drive gear.

6. The product of claim **5** wherein the synchronizer includes an engagement ring axially adjacent to a sprocket, wherein the engagement ring is constructed and arranged to move axially toward the sprocket when the shift fork is moved axially toward the sprocket from rotation of the second cam so that the synchronizer rotates the sprocket to a speed of the first output shaft.

7. The transfer case of claim **1** further comprising at least one sensing element located on a peripheral surface of the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

8. A transfer case comprising:

an input shaft having a primary axis of rotation;

a first output shaft which is concentric with the input shaft;

a second output shaft offset from the first output shaft;

a range shifter comprising a first cam, a first shift fork, wherein the first shift fork is driven axially by the first cam, and a first sleeve which is axially driven by the first shift fork;

a mode shifter comprising a second cam, a second shift fork, wherein the second shift fork is driven axially by the second cam, and a synchronizer, wherein the synchronizer is actuated by the second shift fork through rotation of the second cam; and

a dual drive gear, wherein the dual drive gear is rotated in a forward and a reverse direction to actuate the range shifter and the mode shifter.

9. The transfer case of claim **8** wherein the range shifter is constructed and arranged to shift a vehicle from a low-range drive mode to a high-range drive mode and the mode shifter is constructed and arranged to shift the vehicle from a two-wheel drive mode to a four-wheel drive mode.

10. The transfer case of claim **8** further comprising a gear train operatively connected to the dual drive gear to drive the dual drive gear, wherein the gear train has a first axis offset from the primary axis;

a reversible electric motor which drives the gear train in a clockwise and a counterclockwise direction and which has a second axis offset from the primary axis; and

an electronic control unit constructed and arranged to control the reversible electric motor.

11. The transfer case of claim **8** wherein the dual drive gear further comprises a first actuating tab constructed and arranged to actuate a first tab on the first cam.

12. The transfer case of claim **8** further comprising a gear reduction assembly, wherein the first sleeve is engageable between the range shifter and the gear reduction assembly to the first output shaft through a splined connection with respect to the first output shaft.

13. The transfer case of claim **12** wherein the gear reduction assembly further includes a planetary gear set comprising a plurality of planetary gears operatively connected to a gear carrier, wherein the plurality of planetary gears rotate within a ring gear and are driven by a sun gear.

14. The transfer case of claim **13** wherein the first cam includes a groove having a low-range portion and a high-range portion, and wherein when the first shift fork is driven to the low-range drive mode portion of the groove, the first sleeve moves axially to couple the first output shaft with the planetary gear carrier and when the first shift fork is driven to the high-range drive mode portion of the groove, the first sleeve moves axially to couple the first output shaft with the sun gear.

15. The transfer case of claim **8** further comprising at least one sensing element located on a peripheral surface of the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

16. The transfer case of claim **8** wherein the synchronizer further includes an engagement ring axially adjacent to a sprocket, wherein the engagement ring is constructed and arranged to move axially toward the sprocket when the shift fork is moved axially toward the sprocket from rotation of the second cam so that the synchronizer rotates the sprocket to a speed of the first output shaft.

17. A method for assembling a transfer case comprising:

providing an input shaft having a primary axis of rotation and providing a first output shaft concentric with the input shaft;

providing a second output shaft offset from the first output shaft;

providing a range shifter comprising a first cam rotatable about the primary axis constructed and arranged to selectively shift a vehicle to a low-range drive mode, a high-range drive mode, or a neutral drive mode;

providing a mode shifter comprising a second cam rotatable about the primary axis and constructed and arranged to actuate a synchronizer which selectively shifts the vehicle between a two-wheel drive mode and a four-wheel drive mode; and

providing a dual drive gear interposed between the range shifter and the mode shifter wherein a first side of the dual drive gear includes an actuating tab constructed and arranged to actuate the first cam and wherein the second cam is attached to a second side of the dual drive gear so that the mode shifter is activated by rotation of the dual drive gear.

18. The method of claim **17** further comprising an electric motor operatively connected to the dual drive gear constructed and arranged for driving the dual drive gear in a clockwise and a counterclockwise direction.

19. The method of claim **18** further comprising an electronic control unit operatively connected to the electric motor constructed and arranged for controlling operation of the electric motor.

20. The method of claim **17** further comprising at least one sensing element located on the dual drive gear for detecting a position of the dual drive gear; and an electronic control unit for actuating at least one of the range shifter and the mode shifter in response to the detected position of the dual drive gear by the at least one sensing element.

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