

TITLE OF THE INVENTION

AN ELECTRO-MECHANICAL CROSS STEER DRIVE DEVICE FOR A VEHICLE

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FIELD OF THE INVENTION

15 The invention relates to the field of drive devices useful as a
vehicle propulsion system and in particular, a electro-mechanical drive device
suitable for use in a wheeled or track laying vehicle supplying main propulsion and
steering functions.

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BACKGROUND OF THE INVENTION

A drive device suitable for use in a wheeled or track laying vehicle supplying main
propulsion and steering functions is provided. Typically, a track laying vehicle will
have a left-hand and right-hand track which can be driven at the same speed for
25 straight-line movement or one track driven slower relative to the other for steering
or pivot turning of the vehicle.

Referring to Fig. 1, the prior art shows separate electric motors/mechanical
transmission drive systems being used in a track laying vehicle, with one electric
30 motor/mechanical transmission per track. By varying the speed/torque of each
motor, the vehicle can be propelled in a straight line or steered. If a component

in one drive breaks, only one track on the intact side can be driven to continue vehicle movement. In addition, steering becomes inefficient as the inside track must often be slowed down (power absorbed) to enable steering; either the inside track must have a brake to slow it sufficiently (very inefficient) or the inside track's
5 motor becomes a generator (more efficient than a brake but losses occur turning mechanical power into electrical power, through the power control unit, then back into mechanical power at the outside track's motor).

An alternative drive device as provided by US 2005/0187067 and as shown in Fig.
10 2, is to use a gear assembly with one motor providing linear traction and a second motor providing steering overlaying power on the left- and right-hand outputs through a pair of summing planetary differentials. The advantage of this device is steering can be very efficient since power can be absorbed from the inside track and transferred to the outside track. However, the disadvantage is that a separate
15 motor and gearing system is required for steering and the steering motor cannot be used for linear traction and the linear traction motor cannot be used for steering.

The invention presented here solves the problem of choosing between a system which has the added weight of a separate steering system versus a less efficient
20 system which uses a dual independent motor drive.

Other objects of the invention will be apparent from the description that follows.

SUMMARY OF THE INVENTION

25 According to the present invention there is provided an electro-mechanical cross-steer device for a vehicle. The device may include a first and a second motor and first and second output planetary gear set, each having a transfer gear assembly mechanically connected to the first and second motors, respectively. Additionally,
30 a differential may be included which is mechanically connected to the first and second output planetary gear sets via a mainshaft connected to the first and

second output planetary gear sets. First and second input shafts may be mechanically connected to the first and second transfer gear assemblies and to the differential. First and second output shafts may be respectively connected to the first and second output planetary gear sets with each of the output shafts
5 operable to drive a particular side of a vehicle. When conditioning speeds of the first and second motors to equal values, speed ratios between the first and second output shafts may be 1:1 and the vehicle may move in a straight line. When conditioning the speeds of the first and second motors to unequal values, the speed ratios between the first and second output shafts may not be 1:1 and braking
10 energy from an output shaft may be transferred to the other output shaft thereby allowing steering of the vehicle without braking energy being dissipated as heat.

According to the present invention, there is also provided a method for electro-mechanically cross-steering a vehicle. The method may provide a first and a
15 second motor and first and second output planetary gear set, each having a transfer gear assembly mechanically connected to the first and second motors, respectively. Additionally, a differential may be provided which is mechanically connected to the first and second output planetary gear sets via a mainshaft connected to the first and second output planetary gear sets. First and second
20 input shafts may be provided that are mechanically connected to the first and second transfer gear assemblies and to the differential. First and second output shafts may be respectively provided and connected to the first and second output planetary gear sets with each of the output shafts operable to drive a particular side of a vehicle. When conditioning speeds of the first and second motors to
25 equal values, speed ratios between the first and second output shafts may be 1:1 and the vehicle may move in a straight line. When conditioning the speeds of the first and second motors to unequal values, the speed ratios between the first and second output shafts may not be 1:1 and braking energy from an output shaft may be transferred to the other output shaft thereby allowing steering of the vehicle
30 without braking energy being dissipated as heat.

Other aspects of the invention will be appreciated by reference to the detailed description of the preferred embodiment and to the claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

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The preferred embodiment of the invention will be described by reference to the drawings thereof in which:

Fig. 1 is PRIOR ART schematic of 2 separate electric motors/mechanical
10 transmission drive systems;

Fig. 2 is PRIOR ART schematic of an alternative gear assembly with one motor providing linear traction and a second motor providing steering;

15 Fig. 3 is a schematic of a single mode electro-mechanical cross-steer drive device of the present invention;

Fig. 4. is a schematic of a components of a center differential of Fig. 3;

20 Fig. 5 is partial cross section of the center differential of Fig. 3;

Fig. 6 is a schematic of a left hand (LH) output planetary of Fig. 3;

Fig. 7 is a schematic of a right hand (RH) output planetary of Fig. 3;

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Fig. 8 is a schematic of a single mode / single range electro-mechanical cross-steer drive device with motors coaxial with output shafts of the present invention;

Fig. 9 is a schematic of a dual mode / two range electro-mechanical cross-steer
30 drive device of the present invention;

Fig. 10 is a schematic of a dual mode / three range electro-mechanical cross-steer drive device of the present invention;

Fig. 11 is a schematic with a LH/RH motor coupling clutch and a differential brake added to the present invention;

Fig. 12 is a schematic with LH/RH motor coupling clutch active of the present invention;

Fig. 13 is a schematic of the preferred embodiment of the present invention;

Fig. 14 is a schematic of 1st range components driving/steering in the [referred embodiment of the present invention;

Fig. 15 is a schematic of 2nd range components driving/steering in the preferred embodiment of the present invention; and

Fig. 16 is a schematic of 3rd range components driving/steering in the preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Table of Components

#	Name
1	DRIVE DEVICE
2	LH MOTOR
3	RH MOTOR
4	LH OUTPUT SHAFT
5	RH OUTPUT SHAFT
6	ELECTRICAL POWER CONNECTOR

7	ELECTRICAL POWER CONNECTOR
9	FIRST BRAKE
10	SECOND BRAKE
11	CLUTCH
12	MAINSHAFT
19	DRIVE HOUSING (full housing not shown)
20	LH TRANSFER GEAR ASSEMBLY
30	RH TRANSFER GEAR ASSEMBLY
40	LH OUTPUT PLANETARY
50	RH OUTPUT PLANETARY
60	2 nd RANGE GEARSET
80	LH/RH MOTOR COUPLING CLUTCH
100	CENTER DIFFERENTIAL
101	LH INPUT SHAFT
102	RH INPUT SHAFT
103	CENTER DIFFERENTIAL OUTPUT SHAFT
105	LH SUN GEAR
106	RH SUN GEAR
107	CARRIER
109a, b...	LH COMPOUND PLANET GEAR
110a, b...	RH COMPOUND PLANET GEAR
170	DIFFERENTIAL BRAKE

Referring to Figs. 3 to 5, the drive device **1** includes left hand (LH) **2** and right hand (RH) **3** motors, respectively. A center differential **100** is provided with a LH input shaft **101**, a RH input shaft **102** and center differential output shaft **103**. Additionally, LH transfer gear assembly **20** and RH transfer gear assembly **30** are also provided. Furthermore, LH output planetary gear set **40** and RH output planetary gear set **50** are provided with each gear set having at least 3

components. The device **1** also includes a mainshaft **12**, LH output shaft **4** and RH output shaft **5**. A housing **19** supports the above components.

Additional details of LH and RH output planetary gear sets **40** and **50** are shown
5 in Figs. 6 and 7.

LH motor **2** is mechanically connected to a first component of the LH output planetary gear set **40** with LH transfer gear assembly **20**. In the preferred embodiment, the first component of the LH output planetary gear set **40** is a sun
10 gear **41**. In a similar manner, RH motor **3** is mechanically connected to a first component of the RH output planetary gear set **50** with RH transfer gear assembly **30**. In the preferred embodiment, the first component of the RH output planetary gear set **50** is a sun gear **51**.

15 LH and RH motors **2** and **3** are also connected to the LH and RH input shafts **101** and **102** respectively of center differential **100** with LH and RH transfer gear assemblies **20** and **30**.

The center differential **100** is connected to a second component of the LH output planetary gear set **40** with mainshaft **12** and to a second component of the RH
20 output planetary gear set **50** also with mainshaft **12**. In the preferred embodiment, the second components of the LH and RH output planetary gear sets **40** and **50** are ring gears **42** and **52** respectively.

25 A third component of the LH output planetary gear set **40** is connected to the LH output shaft **4**. A third component of the RH output planetary gear set **50** is connected to the RH Output Shaft **5**. In the preferred embodiment, the third components of the LH and RH output planetary gear sets **40** and **50** are carrier assemblies **43** and **53** respectively.

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In an alternate embodiment shown in Fig. 8, the LH and RH **2a** and **2b** motors are located coaxially with the LH and RH output shafts **4** and **5** and are directly connected to the output planetary gear sets **40** and **50**. The motors **2a** and **2b** of the alternate embodiment are constructed in a manner to allow the LH and RH output shafts **4** and **5** to pass freely through the rotational axes of the motors.

In yet another alternate embodiment (not shown) the first second and third components of the LH and RH output planetary gear sets **40** and **50** could be any of the suns, rings or carriers of the LH and RH Output Planetary Gear Sets **40** and **50**.

By conditioning the speeds of the motors to equal values, the speed ratios between left hand and right-hand outputs of the drive unit are both 1:1 and the vehicle moves in a straight line; torques are adjusted as required to maintain straight line operation.

By conditioning the speeds of the motors to unequal values, steering capability is enabled; torques are adjusted and may be negative (braking) at one output while positive (driving) at the other output. The steering is said to be regenerative since braking energy is transferred from the braking side to the driving side rather than being dissipated as heat through a conventional brake-steer system.

The mode described here is known as Cross Steer Mode meaning that mechanical power from the LH and RH Motors **2** and **3** interact before arriving at the LH and RH output shafts **4** and **5**.

In a further alternative embodiment, the LH and RH motors are variable displacement hydraulic motors accepting fluid pressure and flow from one or more hydraulic pumps and/or accumulators.

Referring back to Figs. 6 and 7, the LH output planetary gear set **40** includes three components, a sun gear **41**, a ring gear **42**, and a carrier assembly **43**. Carrier assembly **43** includes a carrier **44**, a plurality of planet gears **44a**, **44b**, etc. mounted in the carrier assembly with each planet gear meshing with sun gear **41** and ring gear **42**.

The LH output planetary gear set **40** has one component connected to the LH motor **2**, a second component connected to the LH output shaft **4** and a third component connected to the mainshaft **12**. The LH output planetary gear set **40** combines torque, speed and power from the LH motor **2** and the mainshaft **12** and transfers the combined torque, speed and power to the LH output shaft **4**.

Likewise, the RH output planetary gear set **50** includes three components in an analogous arrangement to the LH output planetary gear set **40**, a sun gear **51**, a ring gear **52**, and a carrier assembly **53**. Carrier assembly **53** also includes a carrier **54**, plurality of planet gears **54a**, **54b**, etc. mounted in the carrier assembly with each planet gear meshing with sun gear **51** and ring gear **52**. The RH output planetary gear Set **50** has one component connected to the RH motor **3**, a second component connected to the RH output shaft **5** and a third component connected to the mainshaft **12**. Analogous to the LH output planetary gear set **40**, the RH output planetary gear set **50** combines torque, speed and power from the RH motor **3** and the mainshaft **12** and transfers the combined torque, speed and power to the RH output shaft **5**.

As those skilled in the art will appreciate, the LH and RH output planetary gear sets **40** and **50** may also include are compound planetaries each with more than three components.

Referring back to Figs. 4 and 5, the center differential **100** includes a planetary which includes at least three components, a LH sun gear **105**, a RH sun gear **106**, and a carrier assembly **120**. Carrier assembly **120** includes a carrier **107**, a

plurality of LH compound planet gears **109a**, **109b**, etc. mounted in the carrier assembly with each planet gear meshing with LH sun gear **105**. A plurality of RH compound planet gears **110a**, **110b**, etc. mounted in the carrier assembly **120** with each planet gear meshing (as shown in dotted line **200**) with RH sun gear **106**.

- 5 The LH compound planet gears **109a**, **109b**, etc. mesh with the corresponding RH compound planet gears **110a**, **110b**, etc.

The center differential **100** has one component connected to the LH motor **2**, a second component connected to the RH motor **3** and a third component connected
10 to at least one output shaft. In the preferred embodiment, the center differential **100** has the LH sun gear **105** connected to the LH motor **2**, the RH sun gear **106** connected to the RH motor **3** and the carrier assembly **120** connected to center differential output shaft **103**.

- 15 The speed of center differential output shaft **103** is the average of the LH and RH input shafts **101** and **102**. When both inputs to the center differential **100** are turning at the same speed the output(s) from the center differential turns at that speed. When one input to the center differential **100** turns slower than the other input, the output(s) from the center differential turns at the average of the two input
20 speeds. When one input to the center differential **100** turns at the same but opposite speed as the other input, the output(s) from the center differential do not turn.

The function of the center differential **100** is similar to a differential in a passenger
25 car i.e. to balance the torque between LH and RH output shafts and while allowing a speed differential between LH and RH output shafts when required such as making a turn. As utilized in this invention and installed in a tracked vehicle (such as used in construction equipment or in a military tank), the center differential **100** works in concert with LH and RH output planetary gear sets and separate LH and
30 RH motors and, to introduce steering into the vehicle motion. With respect to the three speed input cases above for the center differential **100**:

1. The LH and RH output planetary gear sets and both see the same input speeds from the motors and and the center differential:
→ LH and RH outputs **104** and **105** turn at the same speed and the vehicle
5 moves in a straight line.
 2. The LH and RH Output Planetary Gear Sets see different input speeds from the motors and the center differential:
→ LH and RH outputs **104** and **105** turn at different speeds and the vehicle moves in an circular path (i.e. turns).
 - 10 3. The LH and RH Output Planetary Gear Sets both see the same but opposite input speeds from the motors and zero speed from the center differential:
→ LH and RH outputs **104** and **105** turn at the same but opposite speeds and the vehicle pivots about its center.
- 15 Referring to Fig. 9, clutch **11** is introduced between the center differential **100** and the mainshaft **12** and first brake **9** is introduced between the mainshaft **12** and the housing **19**. With clutch **11** engaged and first brake **9** disengaged, the drive device **1** operates as described above.
- 20 By disengaging clutch **11** and engaging first brake **9** a second mode of operation is enabled and hence a second speed/torque range is also enabled. The mode described here is known as Direct Steer Mode. In this mode, center differential **100** is not active and mainshaft **12** with LH and RH ring gears **42** and **52** are prevented from turning. Power from the LH motor **2** only flows through the LH
25 output planetary to the LH output shaft and likewise power from the RH Motor **3** only flows through the RH output planetary to the RH output shaft. Steering is enabled by adjusting the speed ratio between LH and RH motors **2** and **3** but mechanical regenerative steering is not enabled.
- 30 Referring to Fig. 10, intermediate gearset **60** is introduced between the center differential output shaft **103** and mainshaft **12**. In the preferred embodiment,

- intermediate gearset **60** is a planetary gearset with a first component connected to the center differential output shaft **103** and a second component connected to the mainshaft **12** and a third component. Second brake **10** is introduced between the third component of intermediate gearset **60** and the housing **19**. With second
- 5 brake **10** activated while first brake **9** and clutch **11** are deactivated, second brake **10** prevents the third component of intermediate gearset **60** from turning and enables a change in speed and torque between center differential output shaft **103** and mainshaft **12**.
- 10 In the preferred embodiment, the first component of intermediate gearset **60** is a sun gear, the second component is a carrier assembly and the third component is a ring gear. As those skilled in the art will appreciate, any of the sun, ring or carrier assembly is any of the first, second or third components. As those skilled in the art will also appreciate, the intermediate gearset **60** may be a compound planetary
- 15 with additional clutches and/or brakes capable of one or more speed ranges, or a spur gear set with a clutch to engage the gear set. One or more gearsets similar to intermediate gearset **60** may also be introduced between center differential output shaft **103** and mainshaft **12** along with means to individually engage each gearset to allow more than one speed/torque ratio change between center
- 20 differential output shaft **103**.

The following table illustrates which clutches/brakes must be applied to achieve any of the 3 drive device ranges of the embodiment shown in Fig. 10:

<i>RANGE</i>	<i>MODE</i>	<i>FIRST BRAKE 9</i>	<i>SECOND BRAKE 10</i>	<i>CLUTCH 11</i>
1 ST	DIRECT STEER	ENGAGED	-	-
2 ND	CROSS STEER	-	ENGAGED	-
3 RD	CROSS STEER	-	-	ENGAGED

As noted previously, more ranges are possible by adding additional gearsets between the center differential **100** and the mainshaft **12**.

5 As shown in Fig. 11 the LH and RH motors **2** and **3** may be mechanically coupled together with LH/RH motor coupling clutch **80**. In the event of the failure of a component directing power and torque to one side or the situation where the track or wheel has no traction (eg on ice), power and torque from both LH and RH motors may be directed to the side which is still operational and has traction. Further, in
10 the event of one track being frozen, all power and torque may be directed to breaking that track loose. Fig. 12 illustrates the example of loss of traction on the LH side in 1st range with the power flow from the LH Motor **2** to the coupling clutch **80** shown by slashed line 202 and the power flow from the RH Motor **3** to the coupling clutch **80** shown by slashed line 204. A similar example (not shown)
15 applies to the RH side.

Referring back to Fig. 11, the center differential **100** may be mechanically prevented from rotating by connecting it to the drive housing **19** by engaging the differential brake **170** allowing for steering control while coasting using a single
20 motor.

In a preferred embodiment of the invention as shown in Fig. 13, a Dual Mode / three Range Drive Device is depicted. Here, the drive device **1** can switch between two configurations or modes in conjunction with two geared ranges to attain three
25 output speed ranges along with regenerative steering in two of the three ranges.

The gear ratios of the gear sets are such that the following table qualitatively describes the torque and speed ratios in each range:

<i>RANGE</i>	<i>MODE</i>	<i>FIRST</i>	<i>SECOND</i>	<i>CLUTCH</i>	<i>Torque</i>	<i>Speed</i>	<i>Loaded</i>
		<i>BRAKE 9</i>	<i>BRAKE 10</i>	<i>11</i>	<i>Ratio</i>	<i>Ratio</i>	<i>Elements</i>

1 ST	DIRECT STEER	ENGAGED	-	-	Greatest	Least	Fig. 14
2 ND	CROSS STEER	-	ENGAGED	-	Medium	Medium	Fig. 15
3 RD	CROSS STEER	-	-	ENGAGED	Least	Greatest	Fig. 16

Torque Ratio is defined here as the combined torque at the LH and RH Output Shafts **4** and **5** divided by the combined torque provided by the LH and RH Motors **2** and **3**.

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Speed Ratio is defined here as the average speed at the LH and RH Output Shafts **4** and **5** divided by the average speed of the LH and RH Motors **2** and **3**.

While embodiments of the invention have been described and illustrated, such
 10 embodiments should be considered illustrative of the invention only. The invention may include variants not described or illustrated herein in detail. Thus, the embodiments described and illustrated herein should not be considered to limit the invention as construed in accordance with the accompanying claims.

15 The invention is susceptible to many variations, including scaling for capacity, in so long as design and process parameters are maintained. Accordingly, the drawings and description of the preferred embodiments are to be regarded as illustrative in nature, and not as restrictive.

20 The terms "an aspect", "an embodiment", "embodiment", "embodiments", "the embodiment", "the embodiments", "one or more embodiments", "some embodiments", "certain embodiments", "one embodiment", "another embodiment" and the like mean "one or more (but not all) embodiments of the disclosed invention(s)", unless expressly specified otherwise.

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A reference to "another embodiment" or "another aspect" in describing an embodiment does not imply that the referenced embodiment is mutually exclusive with another embodiment (e.g., an embodiment described before the referenced embodiment), unless expressly specified otherwise.

5

The terms "including", "comprising" and variations thereof mean "including but not limited to", unless expressly specified otherwise.

The terms "a", "an" and "the" mean "one or more", unless expressly specified otherwise. The term "plurality" means "two or more", unless expressly specified otherwise.

The phrase "at least one of", when such phrase modifies a plurality of things (such as an enumerated list of things) means any combination of one or more of those things, unless expressly specified otherwise. For example, the phrase "at least one of a widget, a car and a wheel" means either (i) a widget, (ii) a car, (iii) a wheel, (iv) a widget and a car, (v) a widget and a wheel, (vi) a car and a wheel, or (vii) a widget, a car and a wheel. The phrase "at least one of", when such phrase modifies a plurality of things does not mean "one of each of" the plurality of things.

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20

Numerical terms such as "one", "two", etc. when used as cardinal numbers to indicate quantity of something (e.g., one widget, two widgets), mean the quantity indicated by that numerical term, but do not mean at least the quantity indicated by that numerical term. For example, the phrase "one widget" does not mean "at least one widget", and therefore the phrase "one widget" does not cover, e.g., two widgets.

This description of preferred embodiments is to be read in connection with the accompanying drawings, which are part of the entire written description of this invention. In the description, corresponding reference numbers are used throughout to identify the same or functionally similar elements. Relative terms

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such as "left", "right", "horizontal", "vertical", "up", "down", "top" and "bottom" as well as derivatives thereof (e.g., "horizontally", "downwardly", "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and
5 are not intended to require a particular orientation unless specifically stated as such. Terms including "inwardly" versus "outwardly," "longitudinal" versus "lateral" and the like are to be interpreted relative to one another or relative to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer
10 to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. The term "operatively connected" is such an attachment, coupling or connection that allows the pertinent structures to operate as intended by virtue of that relationship.

15 Neither the Title (set forth at the beginning of the first page of the present application) nor the Abstract (set forth at the end of the present application) is to be taken as limiting in any way as the scope of the disclosed invention(s). The title of the present application and headings of sections provided in the present
20 application are for convenience only and are not to be taken as limiting the disclosure in any way.

25

CLAIMS

What is claimed is:

- 5 1. An electro-mechanical cross-steer device for a vehicle comprising:
- a first and a second motor;
- 10 a first and second output planetary gear set, each having a transfer gear assembly mechanically connected to said first and second motors, respectively;
- a differential mechanically connected to said first and second output planetary gear sets via a mainshaft connected to said first and second output planetary gear sets;
- 15 first and second input shafts mechanically connected to said first and second transfer gear assemblies and to said differential;
- 20 first and second output shafts respectively connected to said first and second output planetary gear sets, each of said output shafts operable to drive a particular side of a vehicle;
- 25 wherein conditioning speeds of said first and second motors to equal values, speed ratios between first and second output shafts are 1:1 and the vehicle moves in a straight line; and
- 30 wherein conditioning said speeds of said first and second motors to unequal values, said speed ratios between first and second output shafts is not 1:1 and braking energy from an output shaft is

transferred to the other output shaft thereby allowing steering of the vehicle without braking energy being dissipated as heat.

2. A method for electro-mechanically cross-steering a vehicle comprising:

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providing a first and a second motor;

10

providing a first and second output planetary gear set, each having a transfer gear assembly mechanically connected to said first and second motors, respectively;

15

providing a differential mechanically connected to said first and second output planetary gear sets via a mainshaft connected to said first and second output planetary gear sets;

20

providing first and second input shafts mechanically connected to said first and second transfer gear assemblies and to said differential;

25

providing first and second output shafts respectively connected to said first and second output planetary gear sets, each of said output shafts operable to drive a particular side of a vehicle;

wherein conditioning speeds of said first and second motors to equal values, speed ratios between first and second output shafts are 1:1 and the vehicle moves in a straight line; and

30

wherein conditioning said speeds of said first and second motors to unequal values, said speed ratios between first and second output shafts is not 1:1 and braking energy from an output shaft is

transferred to the other output shaft thereby allowing steering of the vehicle without braking energy being dissipated as heat.