(12) STANDARD PATENT (11) Application No. **AU 2017202253 C1**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Vehicle control systems and methods and related vehicles

(51) International Patent Classification(s)
B62D 7/18 (2006.01) ***B62D 6/00*** (2006.01)

(21) Application No: **2017202253** (22) Date of Filing: **2017.04.05**

(43) Publication Date: **2017.04.27**
(43) Publication Journal Date: **2017.04.27**
(44) Accepted Journal Date: **2019.09.26**
(44) Amended Journal Date: **2020.03.26**

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(56) Related Art
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US 20090250270 A1
US 20090241708 A1
JP 2004149052 A

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ABSTRACT

Systems for controlling the speed and direction of vehicles, including vehicles that have low to zero turning radius capability.

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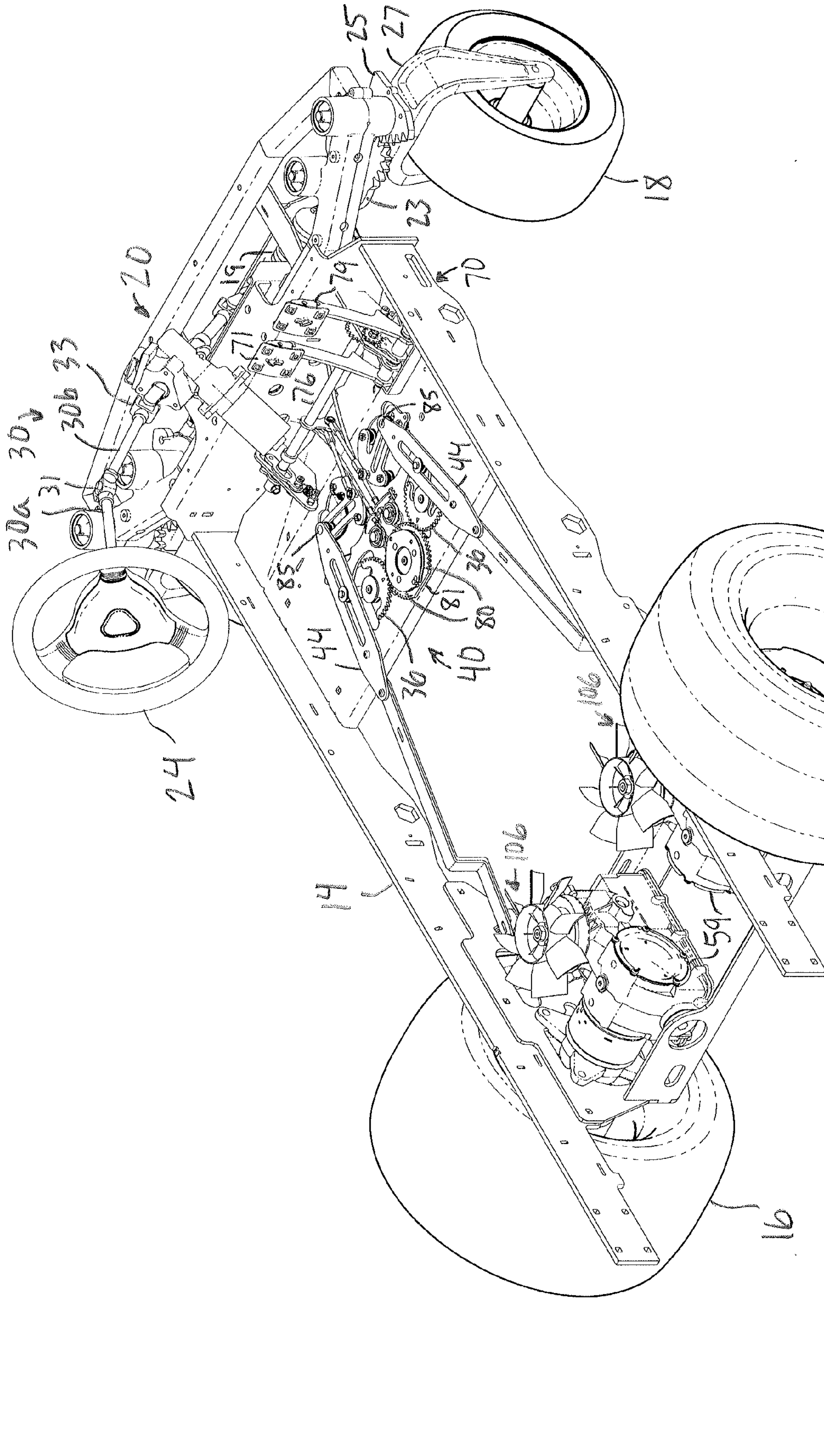

FIG. 2

VEHICLE CONTROL SYSTEMS AND METHODS AND RELATED VEHICLES

The disclosure of the complete specification of Australian Patent Application No. 2011377602 as originally filed is incorporated herein by reference.

BACKGROUND

Embodiments of the invention relate generally to vehicles that have low to zero turning radius capability. In the art, zero turning radius vehicles are often described as ZTR vehicles, although this name has also been used to described vehicles capable of a turning radius that is not precisely zero. More specifically, embodiments of the invention relate to steering systems for such vehicles, to steering and speed coordination systems for such vehicles, to vehicles that comprises one or both types of systems, and to methods of coordinating steering and speed inputs in operating a vehicle.

SUMMARY

An aspect of the present invention provides a vehicle control system comprising: a rotatable steering input device; a speed control device; a first speed input member coupled to the speed control device such that movement of the speed control device to cause forward vehicle movement causes rotational movement of the first speed input member, the first speed input member comprising a curved slot; a link coupled to the rotatable steering input device through a steering shaft, where rotational movement of the rotatable steering input device causes rotational movement of the steering shaft and substantially lateral shifting of the link; a first steering input gear coupled to the link such that substantially lateral shifting of the link causes rotational movement of the first steering input gear; a first steered gear engaged with the first steering input gear such that rotational movement of the first steering input gear causes rotational movement of the first steered gear; a first steerable wheel coupled to the first steered gear such that rotational movement of the first steered gear causes the first steerable wheel to turn; a first flexible cable coupled to the steering input gear; a control member coupled to the first flexible member; and a first integration link coupled to the control member and to a first drive unit; where movement of the control member causes movement of the first integration link relative to the curved slot of the first speed input member, and where rotational movement of the first speed input member responsive to movement of the speed control device to cause forward vehicle movement causes movement of the first integration link and movement of a control mechanism of the first drive unit.

There is described herein a vehicle control system, embodiments of which comprise a first flexible member configured to be coupled to a first steering input member; a control member operatively engaged with the first flexible member; and a first integration link coupled to the control member and configured to be coupled to a first drive unit. The control member may comprise gear teeth. The control member may be a rigid structure. The control member may be operatively engaged with the first flexible member such that movement of the first flexible member results in movement of the control member. The first integration link may be a rigid structure and may pivot laterally as a result of movement of the control member, which may be rotational movement. The vehicle control system may have a second flexible member configured to be coupled to a second steering input member, and a second integration link coupled to the control member and configured to be coupled to a second drive unit. The vehicle control system may have first and second integration members coupling the control member to the first and second integration links, respectively. The vehicle control system may have first and second speed input members responsive to movement of a speed input device, such as a pedal, and coupled to the first and second integration links, respectively, such that movement of the speed input device will cause forward or rearward movement of the links.

There is further described herein a vehicle control system, embodiments of which comprise a first steering system for a first steerable wheel, wherein the first steering system comprises a first steering input member configured to be coupled to a steering input device; a control member configured to receive a steering input from the first steering input member; and a first integration link coupled to the control member and configured to be coupled to a first drive unit. The first control member may be a rigid structure and may rotate as a result of receiving the steering input. The first steering member may be a geared member that moves as a result of movement of a rack-and-pinion assembly coupled to a steering input device, such as a steering wheel. The first integration link may be a rigid structure and may pivot laterally as a result of movement of the control member. The vehicle control system may have a second integration link coupled to the control member and configured to be coupled to a second drive unit. The vehicle control system may have first and second integration members coupling the control member to the first and second integration links, respectively. The vehicle control system may have first and second speed input members responsive to movement of a speed input device, such as a pedal, and coupled to the first and second integration links, respectively, such that movement of the speed input device will cause forward or rearward movement of the links.

There is described herein a vehicle control system, embodiments of which comprise a control member that will move as a result of movement of a steering input device; a first integration link coupled to the control member and configured to be coupled to a first drive unit; and a first integration member coupled to the first integration link such that rotational movement of the control member will cause movement of the first integration member, which will cause movement of the first integration link. In some embodiments, the first integration member is not attached to a rigid link that extends forward of the control member. In some embodiments, the vehicle control system is configured so as to not send a steering signal forward of the control member. The vehicle control system may have a second integration link coupled to the control member and configured to be coupled to a second drive unit. The first and second integration links may be rigid and may have each have a slot that is substantially straight along at least the majority or all of its length. The vehicle control system may also have second integration member operatively engaged with the control member and coupled to the second integration link such that rotational movement of the control member will cause movement of the second integration member, which will cause movement of the second integration link. The vehicle control system may have first and second speed input members responsive to movement of a speed input device, such as a pedal, and coupled to the first and second integration links, respectively, such that movement of the speed input device will cause forward or rearward movement of the links.

There is also described herein a vehicle control system, embodiments of which comprise a gear that will rotate in response to movement of a steering input device; a control member operatively engaged with the gear and configured to rotate as a result of rotation of the gear; a first integration link coupled to the control member and configured to be coupled to a first drive unit; and a first integration member operatively engaged with the control member and coupled to the first integration link such that rotational movement of the control member will cause movement of the first integration member, which will cause movement of the first integration link. The vehicle control system may have a second integration link coupled to the control member and configured to be coupled to a second drive unit. The first and second integration links may be rigid and may have each have a slot that is substantially straight along at least the majority or all of its length. The vehicle control system may also have second integration member operatively engaged with the control member and coupled to the second integration link such that rotational movement of the control member will cause movement of the second integration member, which will cause movement of the second integration link. The vehicle control system may have first and second speed input members responsive to movement of a speed input device, such as a pedal, and coupled to the first and second integration links, respectively, such that movement of the speed input device will cause forward or rearward movement of the links.

Embodiments of the present vehicle control systems, including those illustrated in the figures below, are configured to reduce the speed of the vehicle of which it is a part (specifically the outboard drive wheel) when it enters a sufficiently extreme turn (e.g., one in which a steerable wheel of the vehicle (such as one engaging the ground through a tire) can be turned no further) under a constant speed input. Embodiments of the present vehicle control systems, including those illustrated in the figures below, are configured to provide correct steering of the vehicle of which it is a part in forward and reverse for a given steering input (meaning the vehicle will follow the same arc for a given turn in forward as it will in reverse).

In another respect, the invention is a vehicle that includes any of the present vehicle control systems.

There is described herein a method of integrating a steering input with a speed input in operating a vehicle, where the method comprises: receiving a steering input from a steered wheel that is configured to engage the ground (such as through a tire); positioning a follower along a cam of a speed input member as a result of the receiving; moving the speed input member by manipulating a speed input device (such as a pedal); and moving an integration link coupled to the follower as a result of moving the speed input member. The cam may be a slot and the follower may be a coupling member, and the method may involve a second speed input member with a second cam and a second integration link coupled to a second follower that can be positioned along the second cam.

There is further described herein a method of integrating a steering input with a speed input in operating a vehicle, where the method comprises: receiving a steering input from a steering input device (such as a steering wheel); positioning a follower along a cam of a speed input member as a result of the receiving; moving the speed input member by manipulating a speed input device (such as a pedal); and moving an integration link coupled to the follower as a result of moving the speed input member. In some embodiments, a steering signal is not sent forward of a control member that is coupled to the integration link. The cam may be a slot and the follower may be a coupling member, and the method may involve a second speed input member with a second cam and a second integration link coupled to a second follower that can be positioned along the second cam.

Any embodiment of any of the present systems, devices, and methods may consist of or consist essentially of-rather than comprise/include/contain/have-the described features or steps. Thus, in any of the claims, the term "consisting of' or "consisting essentially of' may be substituted for any of the open-ended linking verbs recited above, in order to change the scope of a given claim from what it would otherwise be using the open-ended linking verb.

The feature or features of one embodiment may be applied to other embodiments, even though not described or illustrated, unless expressly prohibited by this disclosure or the nature of the embodiments.

Details associated with these embodiments and others are provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings illustrate by way of example and not limitation. Identical reference numerals do not necessarily indicate an identical structure. Rather, the same reference numeral may be used to indicate a similar feature or a feature with similar functionality. Every feature of each embodiment is not always labeled in every figure in

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which that embodiment appears, in order to keep the figures clear. The embodiments of the present devices and systems (and their components) shown in **FIGS. 1-15** are drawn to scale.

FIG. 1 is a perspective view of a lawn and garden type vehicle;

FIG. 2 is a perspective view of the chassis and vehicle control assemblies of the vehicle of **FIG. 1;**

FIG. 3 is a partial perspective view of the control assembly of the vehicle of **FIG. 1**;

FIG. 4 is a partial perspective view of the control assembly of the vehicle of **FIG. 1;**

FIG. 5 is a partial perspective view of the steering assembly of the vehicle of **FIG. 1;**

FIG. 6 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a neutral steering input and a neutral speed input;

FIG. 7 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a left turn steering input and a neutral speed input;

FIG. 8 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a right turn steering input and a neutral speed input;

FIG. 9 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a neutral steering input and a forward speed input;

FIG. 10 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a left turn steering input and a forward speed input;

FIG. 11 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a right turn steering input and a forward speed input;

FIG. 12 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a neutral steering input and a reverse speed input;

FIG. 13 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a left turn steering input and a reverse speed input;

FIG. 14 illustrates a top view of the control and steering assemblies of the vehicle of **FIG. 1** with a right turn steering input and a reverse speed input; and

FIG. 15 illustrates a partial top view of another embodiment of one of the present control assemblies.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The terms “comprise” (and any form of comprise, such as “comprises” and “comprising”), “have” (and any form of have, such as “has” and “having”), “contain” (and any form of contain, such as “contains” and “containing”), and “include” (and any form of include, such as “includes” and “including”) are open-ended linking verbs. Thus, a vehicle that
“comprises” a steering input member; a first control member operatively engaged with the steering input member; a first steering link coupled to the first control member and to a steering system for a first steered wheel; and a first integration link coupled to the first control member and to a control system for a first drive unit, is a vehicle that possesses the listed elements, but is not prohibited from possessing elements that are not listed (such as a steerable structure).

Likewise, an element of a device or apparatus that “comprises,” “has,” “contains” or “includes” one or more features possesses those one or more features, but is not limited to possessing only those one or more features. Furthermore, a structure that is configured in a certain way must be configured in at least that way, but also may be configured in a way or ways that are not specified.

The terms “a” and “an” are defined as one or more than one unless this disclosure explicitly requires otherwise. The term “coupled” is defined as connected, although not necessarily directly, and not necessarily mechanically. The term “substantially” and its variations (e.g. “approximately” and “about”) are defined as being largely but not necessarily wholly what is specified (and include wholly what is specified) as understood by one of ordinary skill in the art. In any disclosed embodiment, the terms “substantially,” “approximately,” and “about” may be substituted with “within [a percentage] of” what is specified, where the percentage includes .1, 1, 5, and 10 percent.

General Configuration

Referring now to the figures, **FIG. 1** illustrates a vehicle 10, such as a lawn and garden tractor. The vehicle 10 includes a prime mover 12, such as an engine, that is mounted to a structural frame or frame 14. The vehicle 10 includes drive wheels 16, such as left and right

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rear drive wheels that are coupled to the frame 14. The drive wheels 16 are coupled to the engine 12 through a transmission system to provide locomotion to the vehicle 10. The vehicle 10 also has steerable structures 18, such as right and left front wheels, which may be non-driving wheels. Other embodiments of the vehicles have only one steerable structure (e.g., three-wheeled all-terrain vehicles). Furthermore, in some embodiments, steerable structures such as skis may be used instead of wheels.

The frame 14 supports an operator station comprising a seat 22. Vehicle 10 also includes a mower deck 26 mounted to the vehicle 10 in any suitable manner. In some embodiments, the invention is applicable to other types of vehicles, including but not limited to utility vehicles, off road vehicles, tractors, golf carts, and even automobiles.

As shown in **FIG. 5**, the front steerable wheels 18 are coupled to the frame of the vehicle through a rack and pinion assembly 19 coupled to (and, more specifically, mounted on) the frame 14. The steerable wheels 18 are also coupled to a steering assembly 20, which is configured to control the direction they turn as discussed more fully below. In the embodiment of the present vehicles shown in the figures, the front wheels are the steerable wheels 18 and the rear wheels are the drive wheels 16. However, one skilled in the art will understand that the rear wheels may be the steerable wheels and the front wheels may be the drive wheels in other embodiments. Likewise, the front wheels may be both steerable and drivable.

A steering input device 24 (which is part of the embodiment of the steering assembly 20 shown in the figures) and a speed control device 71 (which is part of the embodiment of the speed control assembly 70 discussed below) are located near the seat 22 (**FIG. 1**) so that they are accessible to the operator of the vehicle. An operator may apply a steering input to the steering input device 24, which transfers the steering input to the steering assembly 20. Steering input device 24 may take the form of a conventional steering wheel. However, the steering input device 24 may be another suitable steering device, including, but not limited to, a steering rod or joystick (not shown).

Speed control devices 71 and 79 provide a forward and reverse speed input, respectively, to the balance of the speed control assembly 70, and (at least in part) regulate the forward and reverse speed of the vehicle 10. In certain embodiments, speed control devices 71 and 79 may take the form of a single pedal, such as a treadle pedal arrangement mounted on a single shaft. In such an embodiment, the speed control device can be rocked forward to select forward drive, or rocked backward to select reverse drive. Speed control devices 71 and 79 may be biased toward a central position that corresponds to a neutral or stationary condition.

Vehicle 10 also includes a control system 40 that is configured to integrate a steering input received by the steering assembly 20 via the steering input device 24 with a speed input received by the speed control assembly 70 (discussed below) via the speed control devices 71 and 79 to drive and help steer the vehicle 10. The configurations of the present steering assemblies, speed control assemblies and integration devices allow the vehicle to make small- to zero-radius turns.

The left and right drive wheels 16 are driven through a transmission system that, in the depicted embodiment, comprises left and right drive units 59. Vehicle 10 includes a speed control assembly 70 that controls the direction and magnitude of rotation of the rear drive wheels 16. The drive units 59 may comprise hydrostatic transmissions (as shown) or electric motors, both of which are well known in the art. Each drive wheel 16 is mounted on a hub coupled to an output shaft of each drive unit 59. The drive units 59 may also be transmissions of the continuously variable type, capable of providing a continuous range of ratios from forward to reverse. Examples of a suitable transmission utilizing a ratio varying-device, or variation, in conjunction with an epicyclic shunt gear to provide a geared neutral facility is described in International Application PCT/GB03/00332, published under WO 03/064892, and International Application PCT/GB03/02332, published under WO 03/100295, both of which are incorporated by reference for those descriptions. The drive units 59 may be used to independently drive the drive wheels 16 at rates and directions that propel as well as help steer the vehicle.

The driver dictates the speed and direction of the vehicle 10 by manipulating steering input device 24 and speed control device 71, which transmit the steering and speed inputs received from the driver to control system 40, the operation of which is described in more detail below. In the embodiment of vehicle 10 shown in the figures, the amount of torque that the rear drive wheels must produce to turn the vehicle 10 is reduced because front wheels are steerable wheels 18. In contrast, the drive wheels 16 of some conventional ZTR vehicles with non-steerable castor wheels must produce significant torque to cause the castor wheels to react and point in the desired direction.

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In the embodiment of vehicle 10 shown in the figures, the right and left drive wheels 16 are coupled to frame 14 such that their direction is fixed and their rotational axes are substantially in constant alignment. In contrast, the front steerable wheels 18 are coupled to the frame 14 in a way that gives them the ability to change direction. The use of a substantially-true Ackermann steering geometry (which can be achieved using some of the embodiments discussed below) can help to avoid scrubbing rubber from the tire tread on the outboard wheel or damaging vegetation under the front wheels.

Steering Assembly

Aspects of steering assembly 20 are depicted in, e.g., **FIGS. 2** and **5-14**. One function of the steering assembly 20 is to couple the steering input device 24 to the front steerable wheels 18 to aid in guiding vehicle 10. Another function of the steering assembly 20 is to provide a steering input from a steerable wheel 18 to the control system 40, which can coordinate that steering input with a speed input received through speed control device 71. Another function of the steering assembly 20 is its ability to turn the steerable wheels of the vehicle 10, even in a zero turning radius mode (or a small turning radius mode), while receiving an input from a conventional steering input device such as a steering wheel.

In one embodiment, the steering assembly 20 includes a steering shaft 30 coupled to steering input device 24 and rack and pinion assembly 19. Steering shaft 30 includes at least three segments in the depicted embodiment: 30a, which extends from steering input device 24 to a first u-joint 31; 30b, which extends from first u-joint 31 to second u-joint 33; and 30c, which is disposed between u-joint 33 and u-joint 35. U-joint 31 allows the angle of steering shaft segment 30a to be adjusted relative to steering shaft segment 30b, so as to best suit a given rider. Electric power assist assembly 34 is disposed between u-joints 33 and 35 and includes an electric motor (which receives power from a battery coupled to the vehicle (not shown)) that functions to help turn steering shaft segment 30c. The steering shaft 30 and rack and pinion assembly 19 take part in transmitting the steering input received through the steering input device 24 to front wheel assemblies 50, the operation of which is described in more detail below. In certain embodiments, front wheel assemblies 50 are configured to provide Ackermann steering so that the inner front wheel turns about a smaller radius than the outer front wheel.

Referring specifically to **FIG. 5**, in one embodiment, the coupling between the steering shaft 30 and the front wheel assemblies is accomplished using rack and pinion assembly 19, which includes links 21 coupled to steering input members 23, which in the depicted embodiment is a steering input gear. Steering input members 23 are engaged with steering gear members 25, which are coupled to wheel supports (yokes, in this embodiment) 27. As steering shaft 30 is rotated, links 21 are shifted laterally to rotate steering input members 23, which in turn cause wheel supports 27 and front steerable wheels 18 to turn. In this way, steering assembly 20 is configured to receive a rotational steering input and translate it into two separate linear outputs that are transmitted substantially laterally to two different steerable wheel assemblies (50, in this embodiment). The steering input member 23 and steering gear member 25 of a given front wheel assembly 50 are connected to the same structural member 15 of frame 14 such that their positions relative to each other are fixed.

In this embodiment, each steering input member 23 is coupled (and, in the depicted embodiment, directly connected) to a flexible member 80. In certain embodiments, each flexible member 80 is configured as a cable. In other embodiments, flexible members 80 may be configured as a belt, chain, or other suitable device. In certain embodiments, a single flexible member may be coupled to both steering input members 23. The rotation of steering input members 23 causes flexible members 80 to move, as will be discussed in more detail below.

Steering assembly 20 is configured such that rotation of the steering input device 24 and steering shaft 30 causes rotation (and more specifically, taking into account manufacturing tolerances and play in the u-joints, near-simultaneous rotation) of front steerable wheels 18. In certain exemplary embodiments, the steering input device 24 and steering shaft 30 may be rotated through about 120 degrees of movement. For example, the steering input device 24 may be selectively rotated 60 degrees in a first direction with respect to a neutral (straight-ahead) steering position and 60 degrees in a second direction. However, the steering input device 24 and steering shaft 30 may be configured for rotation through any range of angles suited to a given application.

Speed Control Assembly

Referring now to **FIGS. 1-4**, speed control assembly 70 comprises speed control devices 71 and 79. In this embodiment speed control device 71 is configured to control the forward speed of vehicle 10, while speed control device 79 is configured to control the rearward speed of vehicle 10. It is understood that in other embodiments, a single speed control device can be utilized to control both forward and rearward speed of vehicle 10. While the effects of manipulating speed control device 71 will primarily be discussed, it is understood that the manipulation of speed control device 79 will have similar but opposite effects on control system 40 and vehicle 10 (*e.g.*, a reverse speed input rather than a forward speed input).

Speed control device 71 is coupled to shaft 76 such that when speed control device 71 is pressed forward, shaft 76 rotates counter-clockwise (when viewed from the end of shaft 76 nearest speed control device 71). As shaft 76 rotates counter-clockwise, coupling members 75 are moved toward the front of vehicle 10 (*e.g.*, away from drive units 59). Coupling members 75 are, in the depicted embodiment, rigid links (*e.g.*, rods) that are coupled to a pair of speed input members 78, which each comprise a slot 77. As coupling members 75 are shifted forward, speed input members 78 are rotated such that the inner ends 49 of slots 77 are shifted toward the front of the vehicle 10 (*e.g.*, when viewed from above, the right speed input member 78 rotates clockwise and the left speed input member 78 rotates counter-clockwise).

As previously discussed, flexible members 80 move as a result of a steering input being provided through steering input device 24. Flexible members 80 are coupled (and, in the depicted embodiment, directly connected) to a control member 81 such that movement of flexible members 80 causes rotation of control member 81. For example, when steering input device 24 is rotated clockwise (when viewed from above) to effect a right turn, flexible members 80 will cause control member 81 to rotate counter-clockwise (when viewed from above). In the depicted embodiment, control member 81 comprises a geared structure having teeth that are substantially equidistant from the rotational axis of the control member, and that surround at least 50 percent (more specifically, at least 75 percent, and even more specifically at least 90 percent) of the control member. Control member 81 includes a flexible member connector plate 83a (which has an at least partially circular shape) that is attached to a geared plate 83b and to which flexible members 80 are directly connected. In this way, the positions of the flexible members do not impair the contact between control member 81 and integration members 36, discussed in more detail below.

Control member 81 is engaged with at least one integration member that is a rigid structure configured to affect the position of the integration links relative to the speed input

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members and that in this embodiment comprises two integration members 36 such that rotation of control member 81 also causes rotation of integration members 36. Therefore, as steering input device 24 is rotated to initiate a turn, integration members 36 also rotate. Integration members 36 are coupled to integration links 44 via coupling members 45 such that rotation of integration members 36 moves integration links 44 such that the integration links pivot laterally about the point of connection between drive links 104 (to which the integration links are coupled) and control mechanisms 106 for drive units 59. Although not highlighted in the figures, a sealed ball bearing may be used to connect each drive link to a respective control mechanism. In the depicted embodiment, integration members 36 comprise geared structures having teeth that are substantially equidistant from the rotational axis of the respective integration member, and that surround at least approximately 50 percent of the respective integration member. In the depicted embodiment, the turning radius of geared plate 83b (or, more generally, of control member 81) is greater than the turning radii of integration members 36.

In the depicted embodiment, control member 81 and integration members 36 are rotatable in one of more parallel planes. In addition, integration links 44 and speed input members 78 can laterally pivot in the (same) one or more parallel planes. In the embodiment shown, speed input members 78 comprise a plurality of rollers 98 configured to follow respective openings 99 in panel 97. Openings 99 may have a curved shape, and the shape may be comprised of differently-shaped curved segments. Each roller 98 may include a sealed ball bearing (not shown).

In certain embodiments, integration links 44 are coupled to integration members 36 via coupling members 45 (which may be characterized as followers) that engage the slots 43 (which may be characterized as cams or cam slots) in integration links 44. In certain embodiments, slots 43 are straight along substantially their entire length. In some embodiments, a given coupling member 45 is attached to (*e.g.*, bolted to, threaded into, welded to) or even integral with integration member 36 and couples (more specifically, directly connects) integration member 36 to integration link 44 by extending vertically through slot 43 of integration link 44. Coupling members 45 may include bolts or pins with threaded ends that may be coupled to integration links 44 via a threaded coupling.

In the depicted embodiment, coupling members 45 are coupled to integration members 36 so that as integration members 36 rotate, coupling members 45 move in an arc, which movement includes both a forward or a backward component (towards the front or back of vehicle 10) and a lateral component (towards one side of vehicle 10). As a result, coupling members 45 can slide forward or back within slots 43 and can also cause integration links 44 to pivot laterally (as discussed above) by exerting a force on the side of slots 43.

Integration links 44 are also coupled to speed input members 78 via speed input coupling members 85 (which may be characterized as followers). In one embodiment, speed input coupling members 85 are pins that extend vertically from integration links 44 and through speed input members 78.

Coupling members 45 act on right and left integration links 44, which are laterally pivoted and, through speed input coupling members 85, engage slots 77 (which may also be characterized as cams or cam slots) of speed input members 78 in different locations within slots 77. For example, when steering input device 24 is placed in a neutral position as shown in **FIG. 6**, integration links 44 are arranged so that they are proximate to the outer ends 51 of slots 77. However, as steering input device 24 is turned to the left as shown in **FIG. 7**, left integration link 44 (and speed input coupling member 85) is moved proximate to inner end 49 of slot 77, while right integration link 44 is moved generally sideways (or, more specifically, pivoted laterally counter-clockwise) toward inner end 49 to a lesser degree. Similarly, when steering input device 24 is turned to the right, as shown in **FIG. 8**, right integration link 44 is moved proximate to inner end 49 of slot 77, while left integration link 44 is moved generally sideways (or, more specifically, pivoted laterally clockwise) toward inner end 49 to a lesser degree.

As discussed more fully below, the manipulation of speed control device 71, along with steering input device 24, affects the rotational speed and direction of rotation of drive wheels 16.

Control System

Embodiments of the present vehicle control systems, including those illustrated in the figures, are configured to reduce the speed of the outboard drive wheel during a sufficiently extreme turn under a constant speed input. Embodiments of the present vehicle control systems, including those illustrated in the figures, are configured to provide correct steering of the vehicle of which it is a part in forward and reverse for a given steering input. These configurations may be achieved using, for example, the embodiments of control system 40

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shown and described in this disclosure, including, in at least some embodiments, through the operation of the control member, the integration members, the integration links, and the speed input members.

FIGS. 6-8 illustrate views of control system 40 in a neutral speed position for speed control devices 71 and 79 and with different steering inputs from steering input device 24. With speed control devices 71 and 79 in a neutral speed position, control system 40 is configured so that manipulation of steering input device 24 does not cause right or left integration link 44 to be shifted towards the front or rear of vehicle 10. For example, each slot 77 of the speed input members 78 is slightly curved at a radius equivalent to the combined effective length of integration link 44 and a drive link 104 (the distance between slot 47 and the connection point where drive link 104 connects to drive unit 59). Therefore, right and left drive units 59 will not be manipulated to cause rotation of either drive wheel 16 based on a steering input alone. The relationship between the position of integration links 44 and the output of drive units 59 is discussed more fully below.

As shown in **FIG. 3**, each integration link 44 is coupled to a drive link 104, which is in turn coupled to a control mechanism 106 for drive unit 59. Integration link 44 and drive link 104 may be integral components in certain embodiments. As explained more fully below, integration link 44 delivers an integrated steering and speed signal (when a speed signal has been inputted) to drive unit 59 that controls the rotational speed and direction of the attached drive wheel 16. The integrated steering and speed signal is affected by the steering input from steering input device 24, if any, and the speed input of speed control device 71 (or speed control device 79, as the case may be).

Integration link 44 can be moved from a neutral position toward drive unit 59 (toward the rear of vehicle 10). Such movement may be characterized as being along the longitudinal axis of the integration link. With such movement, control mechanism 106 is manipulated so that drive unit 59 rotates its corresponding drive wheel 16 in a forward direction. Conversely, if integration link 44 is moved away from drive unit 59 from a neutral position, control mechanism 106 is manipulated so that drive unit 59 rotates drive wheels 16 in a reverse direction. If integration link 44 is not moved from a neutral position longitudinally toward or away from drive unit 59, control mechanism 106 will not be manipulated. Consequently, drive unit 59 will not cause forward or reverse rotation of drive wheel 16. In other embodiments, drive link 104 may be coupled to control mechanism 106 such that rearward

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movement of integration link 44 causes reverse, rather than forward, rotation of drive wheel 16 (and forward movement of integration link 44 may cause forward rotation of drive wheel 16).

FIGS. 9-11 illustrate views of control system 40 with a full forward speed input from speed control device 71 and neutral, left turn, and right turn steering inputs, respectively, from steering input device 24. As shown in the comparison of **FIGS. 6** and **9**, when speed control device 71 is provided with a forward speed input, outer ends 51 of slots 77 are moved towards the rear of vehicle 10, and inner ends 49 of slots 77 are moved towards the front of vehicle 10.

As shown in **FIG. 9**, with neutral steering and full forward input from speed control device 71, both integration links 44 are pushed toward the rear of vehicle 10 an equal amount. With right and left integration links 44 moved from a speed-neutral position toward drive units 59, both drive units 59 will cause drive wheels 16 to rotate in a forward direction. As shown in **FIG. 9**, steering input device 24 is in a neutral position, therefore both front wheel assemblies 50 are positioned so that the front wheels 18 would direct vehicle 10 straight ahead. In **FIG. 9**, each integration link 44 is placed in an equivalent relative position within slot 77. Therefore, each integration link 44 is moved an equivalent amount toward the rear of vehicle 10 when speed control device 71 is manipulated. As a result, the drive units 59 are manipulated to rotate drive wheels 16 at equivalent forward rotational speeds. Drive wheels 16 will therefore work in conjunction with front wheels 18 to cause vehicle 10 to maintain a forward path straight ahead.

However, as steering input device 24 is manipulated to cause a right or left turn for vehicle 10, control system 40 causes right and left drive wheels 16 to rotate at different speeds. By rotating the right and left drive wheels 16 at different speeds, the drive wheels are able to assist vehicle 10 in turning. In particular, the outside drive wheel 16 (the drive wheel farthest from the center of the turning arc) can rotate at a faster rotational speed than the inside drive wheel. In sharp turns, the outside and inside drive wheels may also rotate in opposite directions. When the rotation of right and left drive wheels 16 is coordinated with the angle of front wheels 18, vehicle 10 can make small- or zero-radius turns and reduce the likelihood of a wheel skidding and damaging the turf or vegetation below vehicle 10.

Referring now to **FIG. 10**, speed control device 71 is placed in the full forward position, and steering input device 24 has been manipulated so that steering assembly 20 configures front wheel assemblies 50 for a left turn. Control system 40 receives steering input from wheel assemblies 50 via flexible members 80. Control system 40 is therefore configured for a full-forward speed left turn in **FIG. 10**. Comparing **FIG. 10** (full-forward speed left turn) to **FIG. 7** (neutral speed input, left turn), right integration link 44 has been shifted rearward from the neutral position in **FIG. 7**. In addition, left integration link 44 has been shifted forward. As a result, right drive wheel 16 will rotate in a forward direction, while left drive wheel 16 will rotate in a reverse direction. This combined rotation of the drive wheels 16 in opposite directions will assist vehicle 10 in making a small- or zero-radius turn.

As shown in **FIGS. 9** and **10**, outer ends 51 (rather than inner ends 49) of slots 77 are closer to the rear of vehicle 10. Therefore, as steering input device 24 is turned and integration links 44 are translated away from the center of vehicle 10, integration links 44 and drive links 104 will also be moved rearward towards the rear of vehicle 10. Each control mechanism 106 will therefore also be rotated toward its respective drive unit 59, so that the forward rotational speed of each drive wheel 16 is increased. Control system 40 is configured such that integration link 44 associated with inner drive wheel 16 will be shifted forward more than integration link 44 associated with outer drive wheel 16. Consequently, the forward rotational speed of inner drive wheel 16 will be reduced more than that of outer drive wheel 16. When steering input device 24 is provided with a sufficient amount of input, the inner drive wheel 16 will eventually cease forward rotation and begin reverse rotation. This combined rotation of the drive wheels 16 in opposite directions will assist vehicle 10 in making a small- or zero-radius left turn.

Referring now to **FIG. 11**, control system 40 is configured for a full-forward speed input and a full right turn. This configuration is equivalent to **FIG. 10**, with the exception that steering input device 24 (shown in FIG. 3) has been turned to the right instead of the left. In this configuration, right integration link 44 is positioned so that right drive unit 59 will provide a reverse rotation of inner (right) drive wheel 16. Vehicle 10 can therefore perform a small- or zero-radius turn to the right.

Referring now to **FIGS. 12-14**, speed control device 79 has been positioned to provide a reverse speed input to control system 40. In **FIG. 12**, control system 40 is configured for a neutral steering input. In **FIGS. 13** and **14**, control system 40 is configured for a left-turn and a right-turn, respectively. In **FIGS. 12-14**, speed input members 78 are positioned so that inner ends 49 (rather than outer ends 51) of slots 77 are closer to the rear of vehicle 10.

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Therefore, as integration links 44 move inward (toward the center of vehicle 10) in response to a steering input, they will also move toward the rear of vehicle 10. As a result, control mechanism 106 will reduce the reverse rotational speed of each drive wheel 16. If a sufficient steering input is provided, integration link 44 associated with inside drive wheel 16 will be pushed far enough rearward to cause inside drive wheel to cease reverse rotation and begin forward rotation. Inside drive wheel 16 can therefore rotate forward and outside drive wheel 16 can rotate in reverse during a full turn with a reverse speed input.

In **FIG. 13**, control system 40 is positioned for a left turn and speed control device 79 is positioned for a reverse speed input. The left integration link 44 is pushed sufficiently rearward so that left (inside) drive wheel 16 will rotate forward. Right integration link 44 is placed sufficiently forward so that outer (right) drive wheel 16 will rotate in reverse. With this configuration, vehicle 10 can make a small or zero-radius reverse left turn.

Referring now to **FIG. 14**, control system 40 is positioned for a right turn with speed control device 79 providing a reverse speed input. The right integration link 44 is pushed sufficiently rearward so that right (inside) drive wheel 16 will rotate forward. Left integration link 44 is placed sufficiently forward so that outer (left) drive wheel 16 rotates in reverse. With this configuration, vehicle 10 can make a small- or zero-radius reverse right turn.

Referring now to **FIG. 15**, an alternate embodiment of the present control systems is shown. Control system 140 is similar to previously-described control system 40. Control system 140, however, does not comprise a flexible member or flexible members coupled to steering assemblies for front steerable wheels. Instead, control system 140 comprises a steering input gear 180 operatively engaged with control member 181 (which, in the depicted embodiment, is a geared member, like control member 81). In exemplary embodiments, steering input gear 180 can be coupled to a steering input device (not shown) such as a steering wheel. Similar to the previously described embodiment, control member 181 is operatively engaged with integration members 136 (which, in the depicted embodiment, are geared members, like integration member 36), which are in turn coupled to integration links 144 via coupling members 145. Also similar to the previously described embodiment, integration links 144 are coupled to speed input members 178, which are coupled to a speed input device (not shown), including for example a throttle pedal. Each integration link 144 can be coupled to a drive unit (not shown), such as hydrostatic transmission or a drive unit that includes an electric motor, in a manner similar to the previously described embodiment.

During operation, steering input gear 180 can be rotated (*e.g.*, via rotation of a steering input device) such that control member 181 is also rotated. The rotation of control member 181 also provides for the rotation of integration members 136 such that rotation of control member 181 also rotates integration members 136. The rotation of integration members 136 provides for the lateral pivoting of integration links 144 in a manner similar to the previously described embodiment. When speed input members 178 receive a speed input, slots 177 of speed input members 178 will be positioned at an angle such that lateral pivoting of integration links 144 will also provide a forward or rearward translation of integration links 144. As described in the previous embodiment, the differentiation of the forward or rearward positioning of integration links 144 provides for different speed inputs to the right and left drive units and can assist in turning the vehicle. Control system 140 is suitable for use in any vehicle with drive units that may be independently controlled to effect (or help effect) a turn of the vehicle.

Descriptions of well known manufacturing and assembly techniques, components and equipment have been omitted so as not to unnecessarily obscure the present systems and devices in unnecessary detail. Further, the present systems and devices are not intended to be limited to the particular forms disclosed. Rather, they are to cover all modifications, equivalents, and alternatives falling within the scope of the claims.

For example, the control members may be configured differently than shown in the figures. In alternative embodiments, the integration member that is a rigid structure configured to affect the position of the integration links relative to the speed input members of a given vehicle control system can be a single structure, rather than two structures as shown in the depicted embodiment; for example, the integration member can be a rigid structure that is connected to the control member and rotates with it (like an angled bar pinned to the control member and having the same rotational axis as the control member) and that includes coupling members (or followers) that are positioned in the slots (or cams) of the integration links. Furthermore, the drive rods and the integration links may be a single component rather than separate components. In still other embodiments, the linkage coupling the speed control device to the speed input members may be a different configuration from that shown. For example, the linkage may be coupled to a single speed input member, which in turn provides an input to the other speed input member via a geared engagement at the ends of the speed input members. As another example, in other embodiments, the guide rollers (shown but not labeled in the figures) that are adjacent the flexible members and proximate to the control member may be eliminated.

The appended claims are not to be interpreted as including means-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase(s) “means for” and/or “step for,” respectively.

CLAIMS

1. A vehicle control system comprising:

a rotatable steering input device;

a speed control device;

a first speed input member coupled to the speed control device such that movement of the speed control device to cause forward vehicle movement causes rotational movement of the first speed input member, the first speed input member comprising a curved slot;

a link coupled to the rotatable steering input device through a steering shaft, where rotational movement of the rotatable steering input device causes rotational movement of the steering shaft and substantially lateral shifting of the link;

a first steering input gear coupled to the link such that substantially lateral shifting of the link causes rotational movement of the first steering input gear;

a first steered gear engaged with the first steering input gear such that rotational movement of the first steering input gear causes rotational movement of the first steered gear;

a first steerable wheel coupled to the first steered gear such that rotational movement of the first steered gear causes the first steerable wheel to turn;

a first flexible cable coupled to the steering input gear;

a control member coupled to the first flexible member; and

a first integration link coupled to the control member and to a first drive unit;

where movement of the control member causes movement of the first integration link relative to the curved slot of the first speed input member, and where rotational movement of the first speed input member responsive to movement of the speed control device to cause forward vehicle movement causes movement of the first integration link and movement of a control mechanism of the first drive unit.

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2. The vehicle control system of claim 1, further comprising:

a second integration link coupled to the control member and configured to be coupled to a second drive unit.

3. The vehicle control system of claim 1, wherein the control member is configured to rotate as a result of movement of the first flexible cable.

4. The vehicle control system of claim 1, further comprising:

a second steering input gear;

a second flexible cable coupled to the second steering input gear and to the control member; and

a second integration link coupled to the control member and to a second drive unit.

5. The vehicle control system of claim 6, wherein the first drive unit comprises a first hydrostatic transmission and the second drive unit comprises a second hydrostatic transmission.

6. The vehicle control system of claim 4, wherein the first and second integration links each includes a slot.

7. The vehicle control system of claim 6, wherein the slot in the first second integration link is straight along its length and the slot in the second integration link is straight along its length.

8. The vehicle control system of claim 7, further comprising first and second integration members operatively engaged with the control member.

9. The vehicle control system of claim 8, further comprising:

a first coupling member coupling the first integration member to the first integration link; and

a second coupling member coupling the second integration member to the second integration link;

wherein at least a portion of the first coupling member is positioned in the slot of the first integration link and at least a portion of the second coupling member is positioned in the slot of the second integration link.

10. The vehicle control system of claim 9, wherein the first integration link is directly coupled to the first integration member via the first coupling member and the second integration link is directly coupled to the second integration member via the second coupling member.

11. The vehicle control system of claim 8, wherein the first and second integration members are configured to rotate in the same plane in response to a rotation of the control member.

12. The vehicle control system of claim 1, further comprising:

a first integration member coupled to the first speed input member through the first integration link.

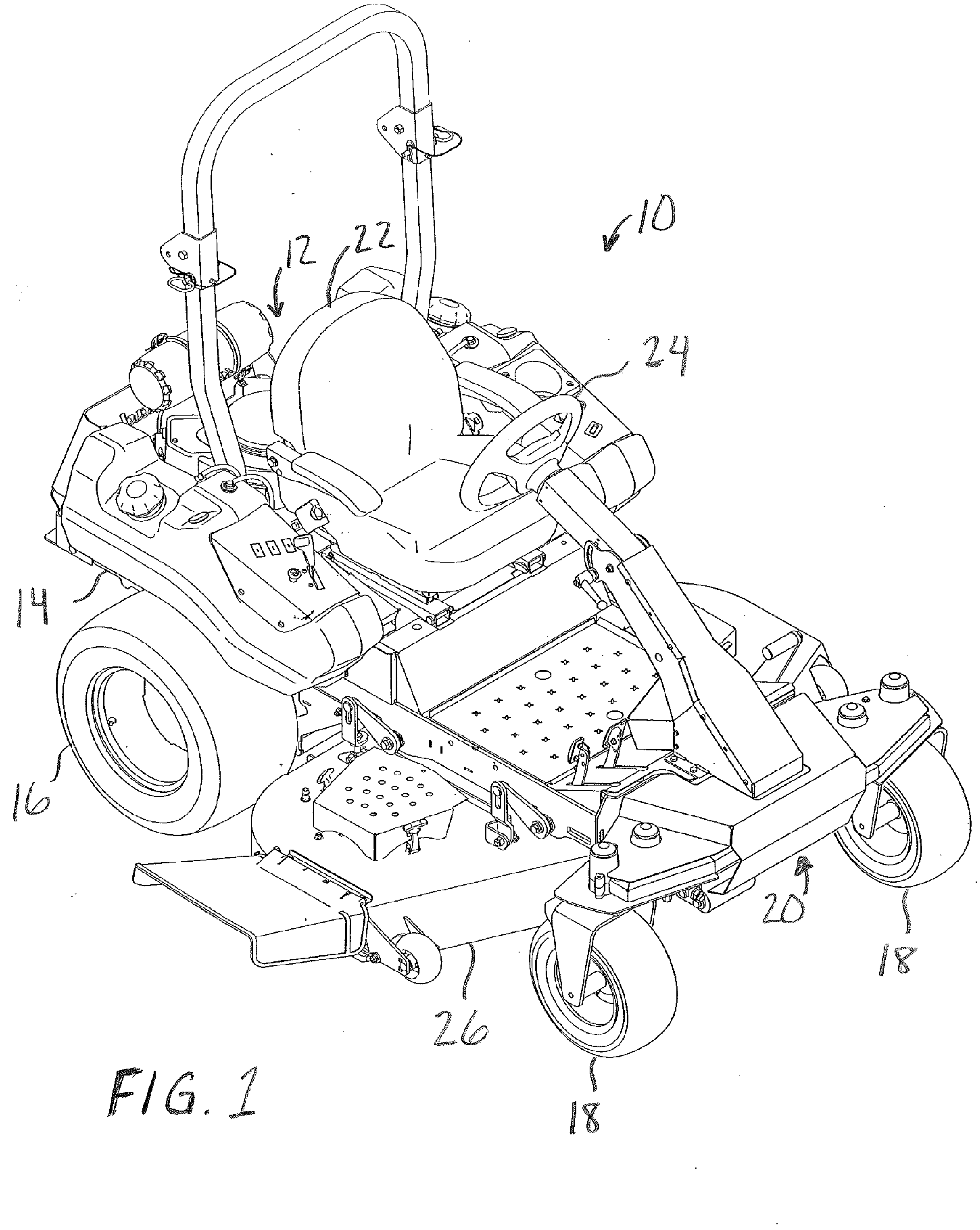

FIG. 1

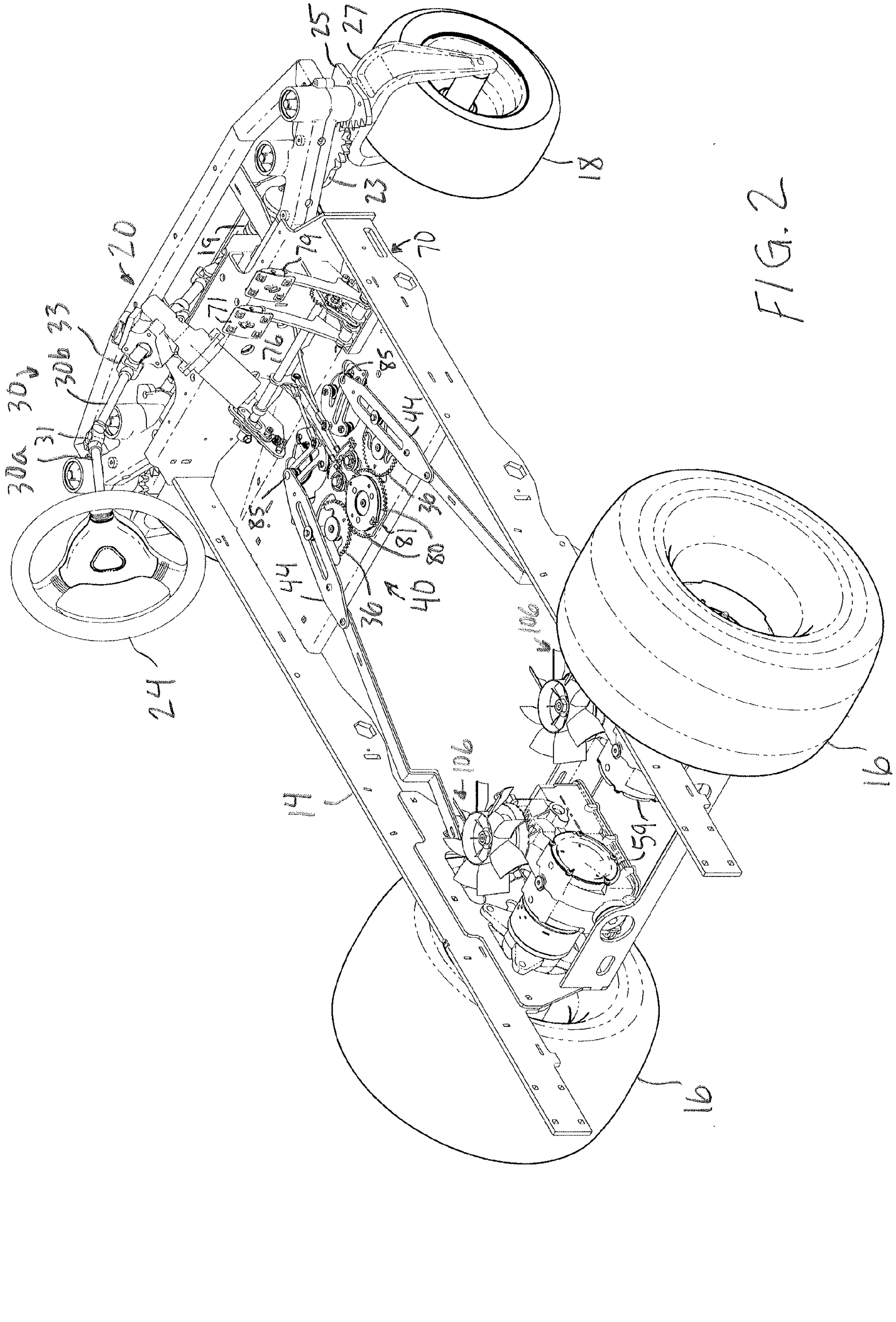

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FIG. 2

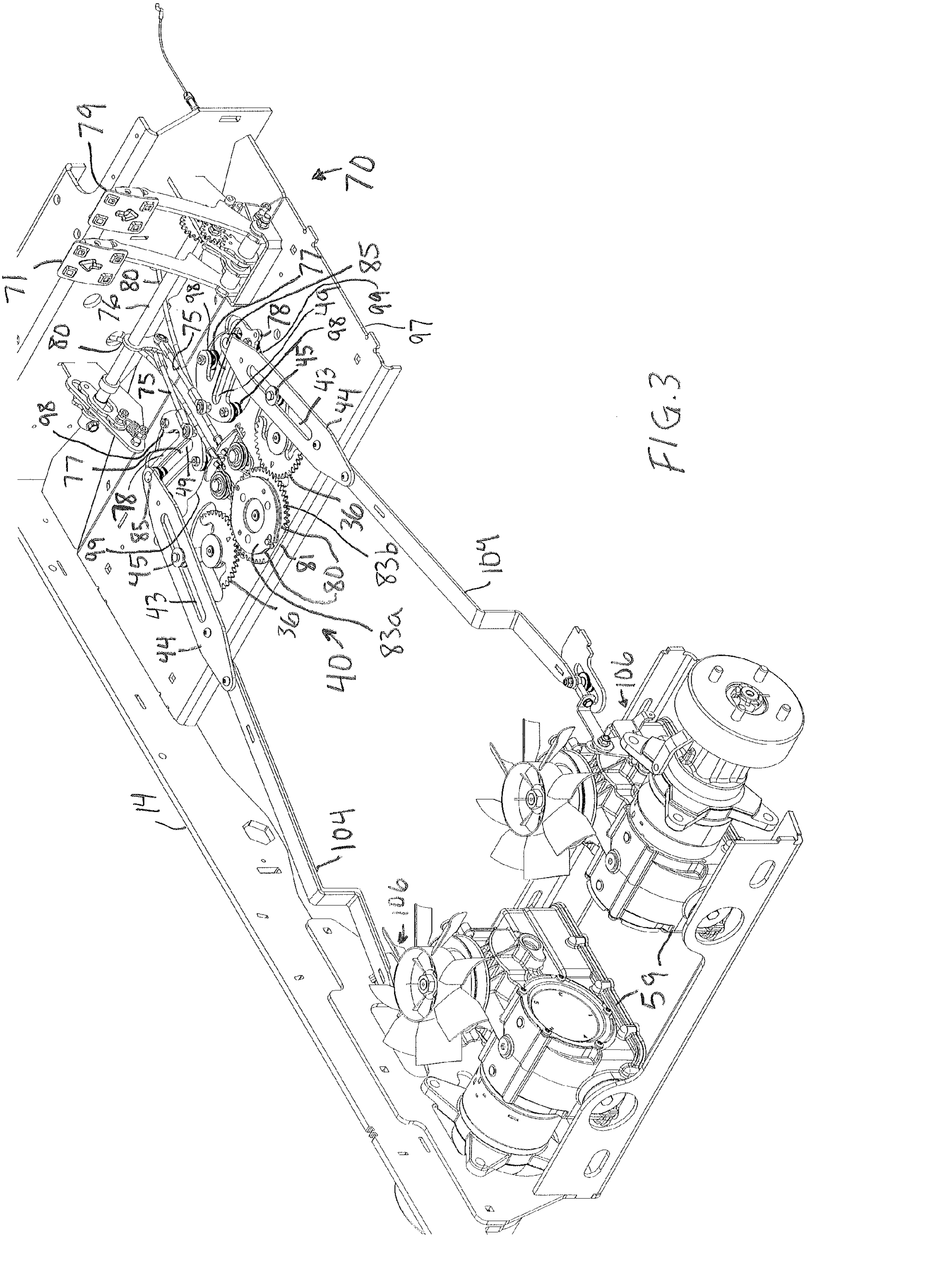
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FIG.3

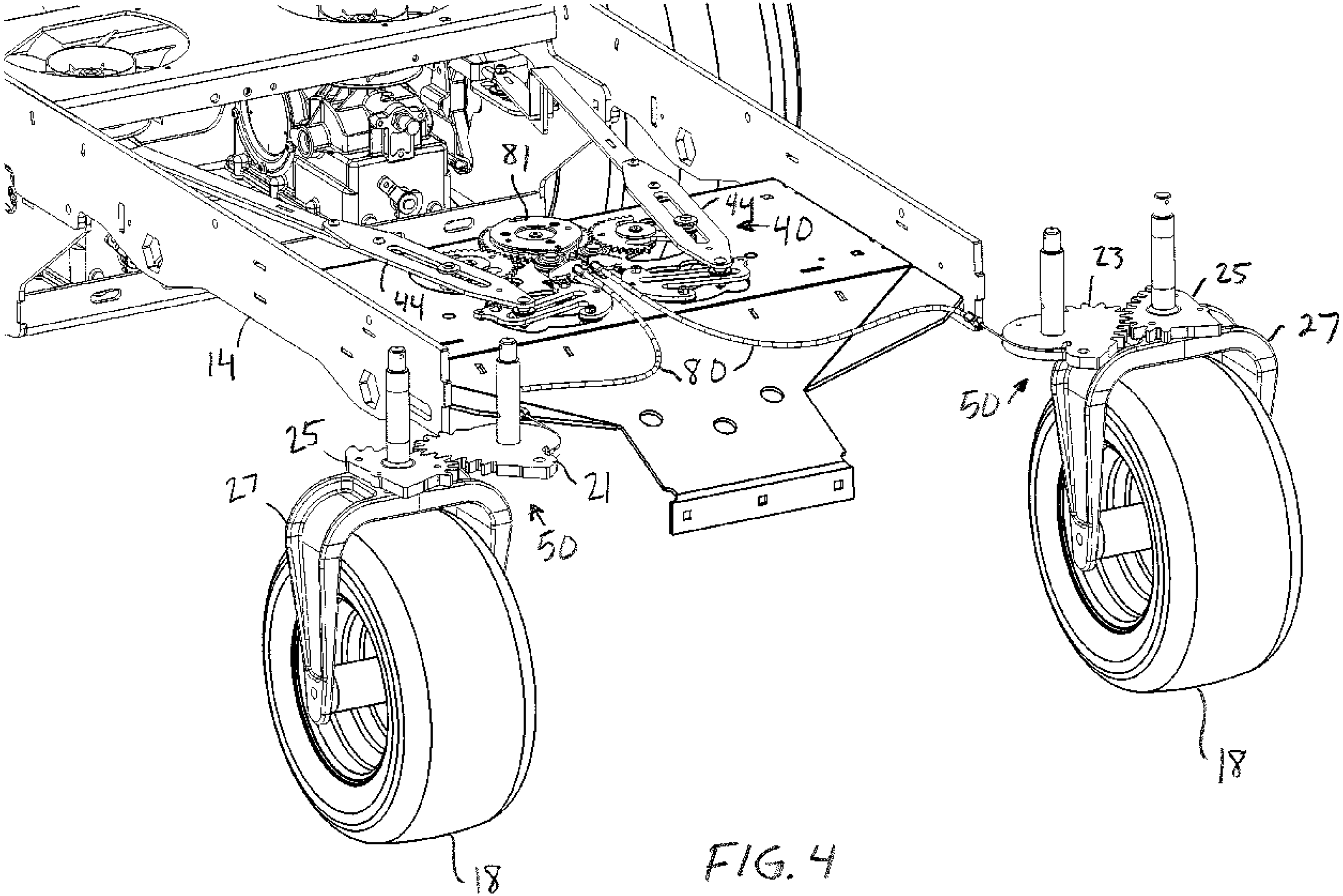

FIG. 4

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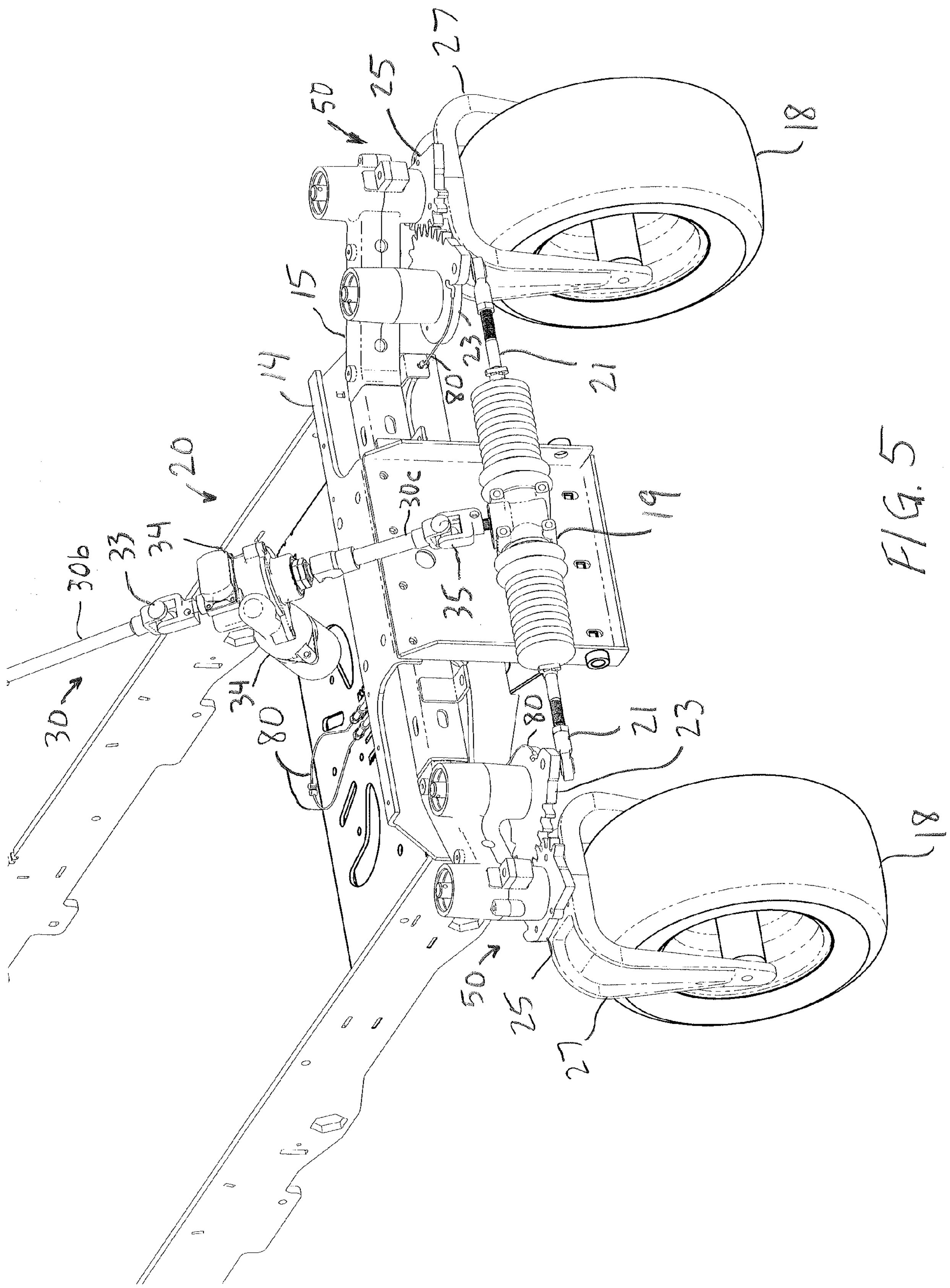

FIG. 5

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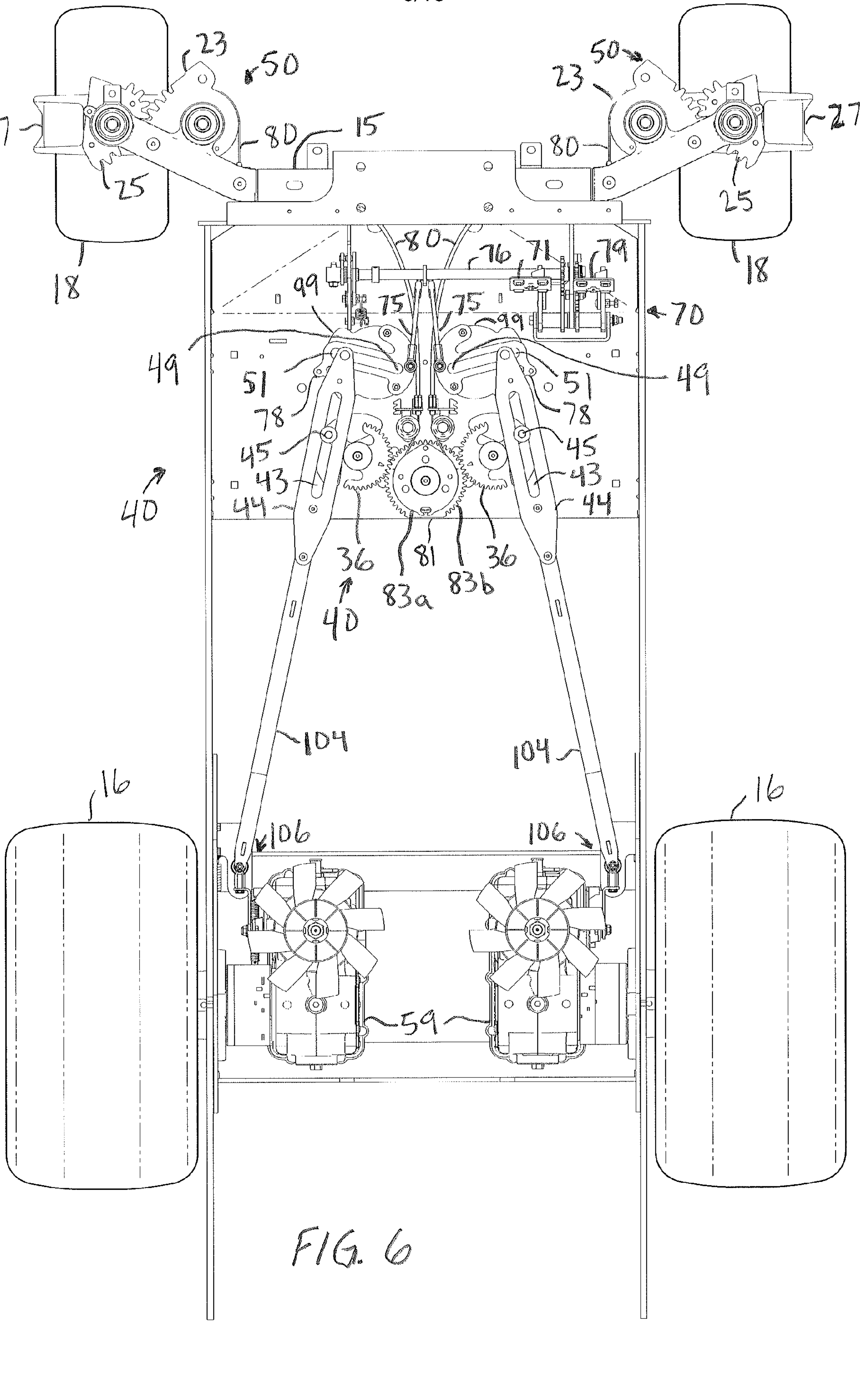

FIG. 6

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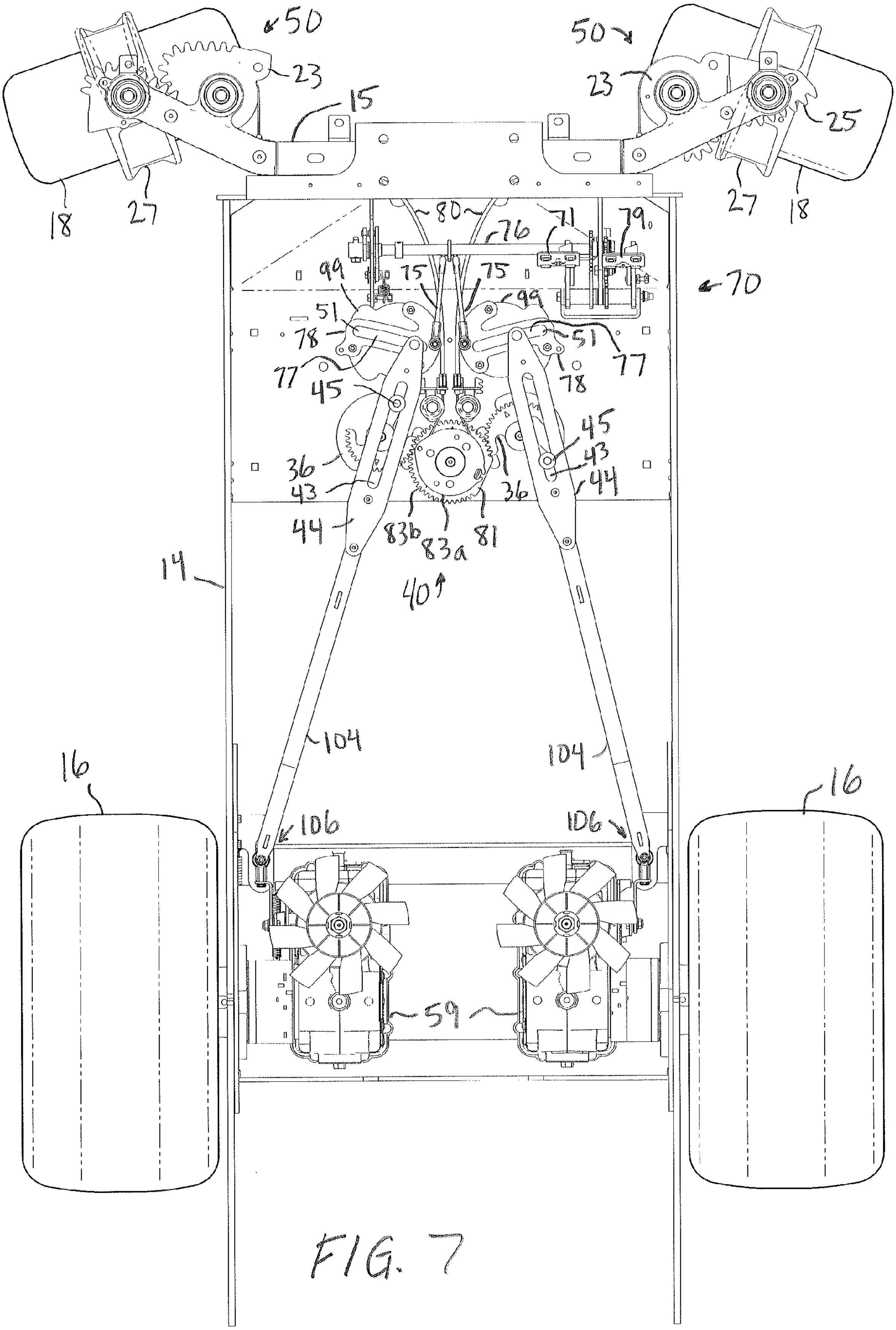

FIG. 7

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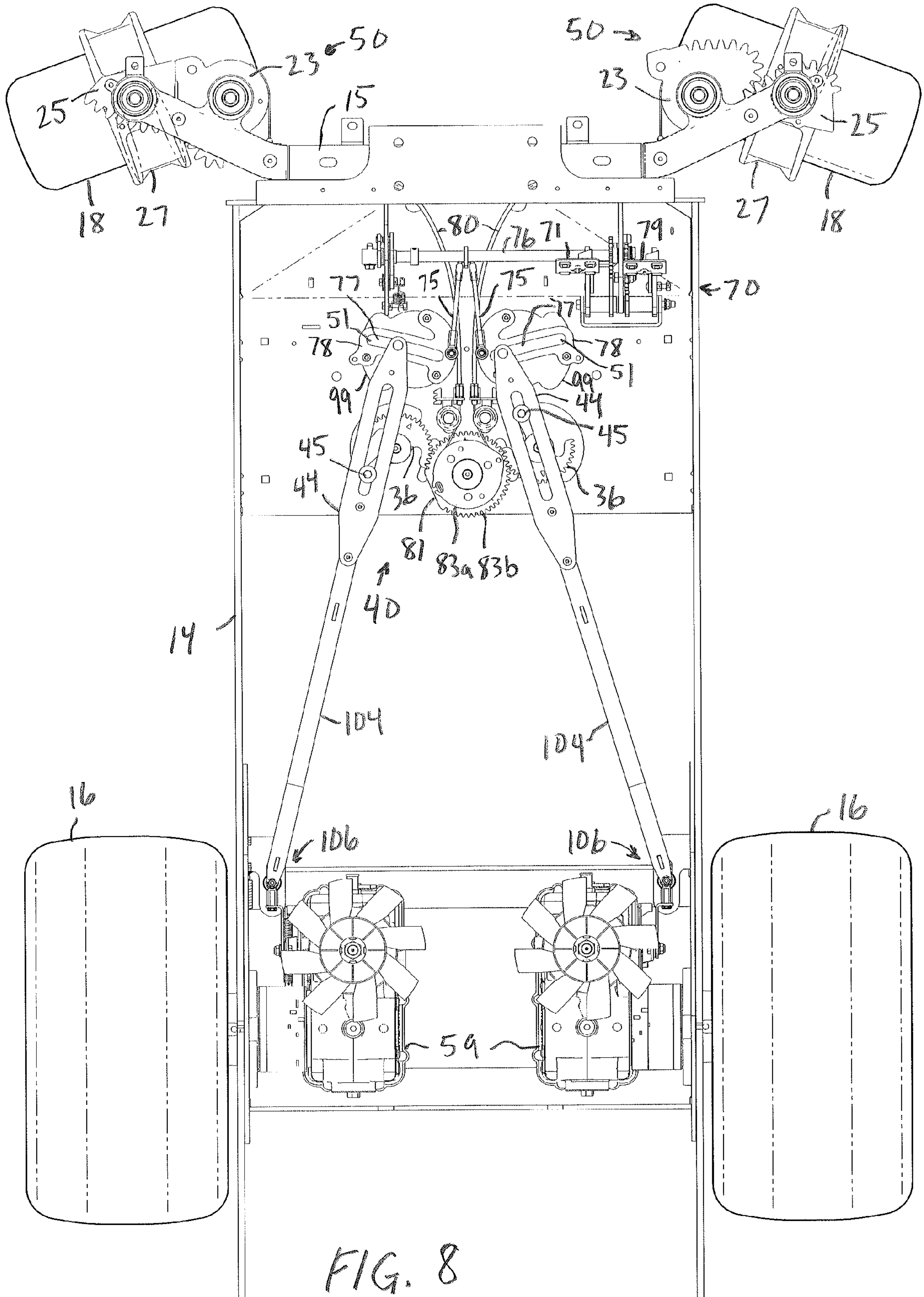

FIG. 8

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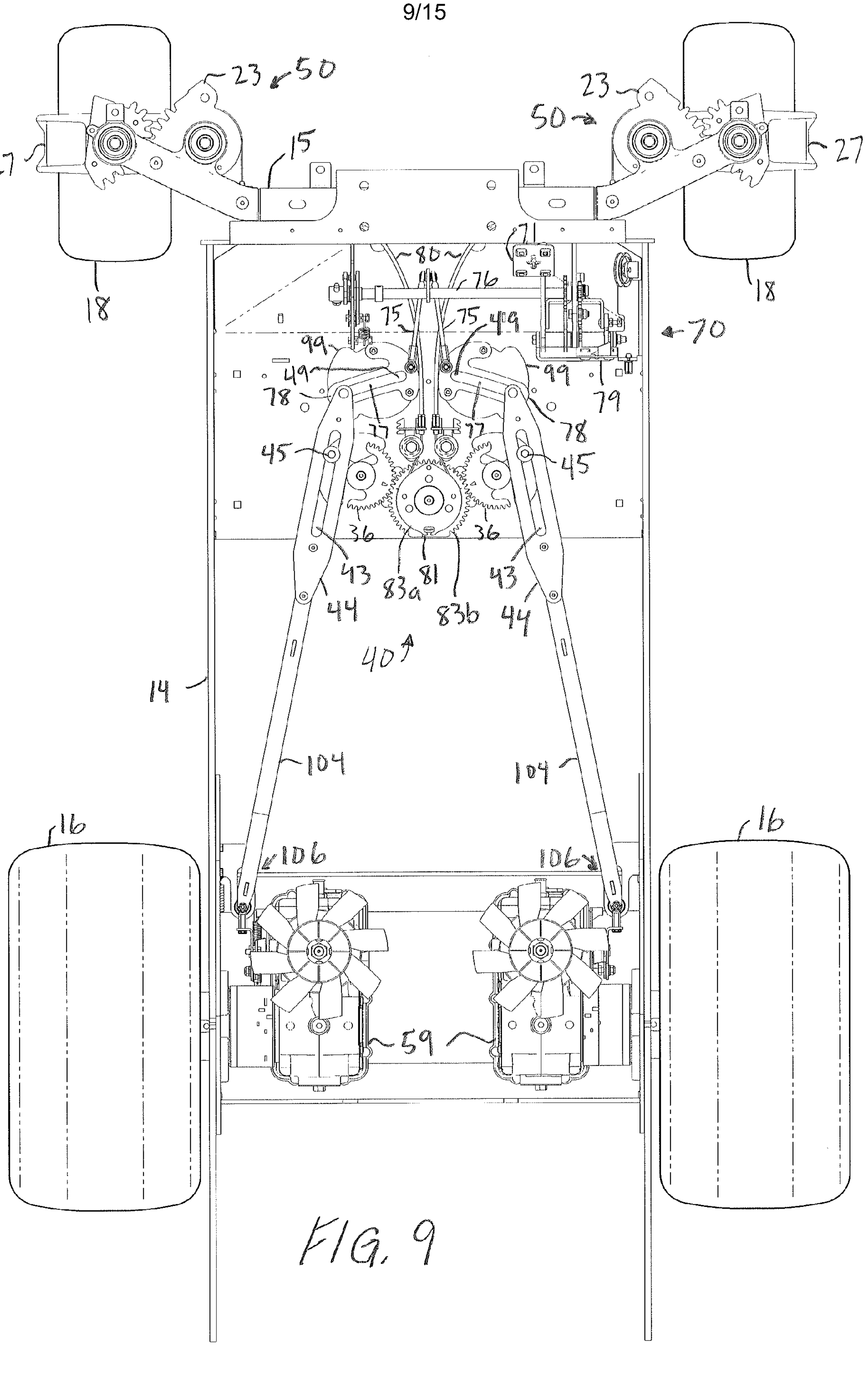

FIG. 9

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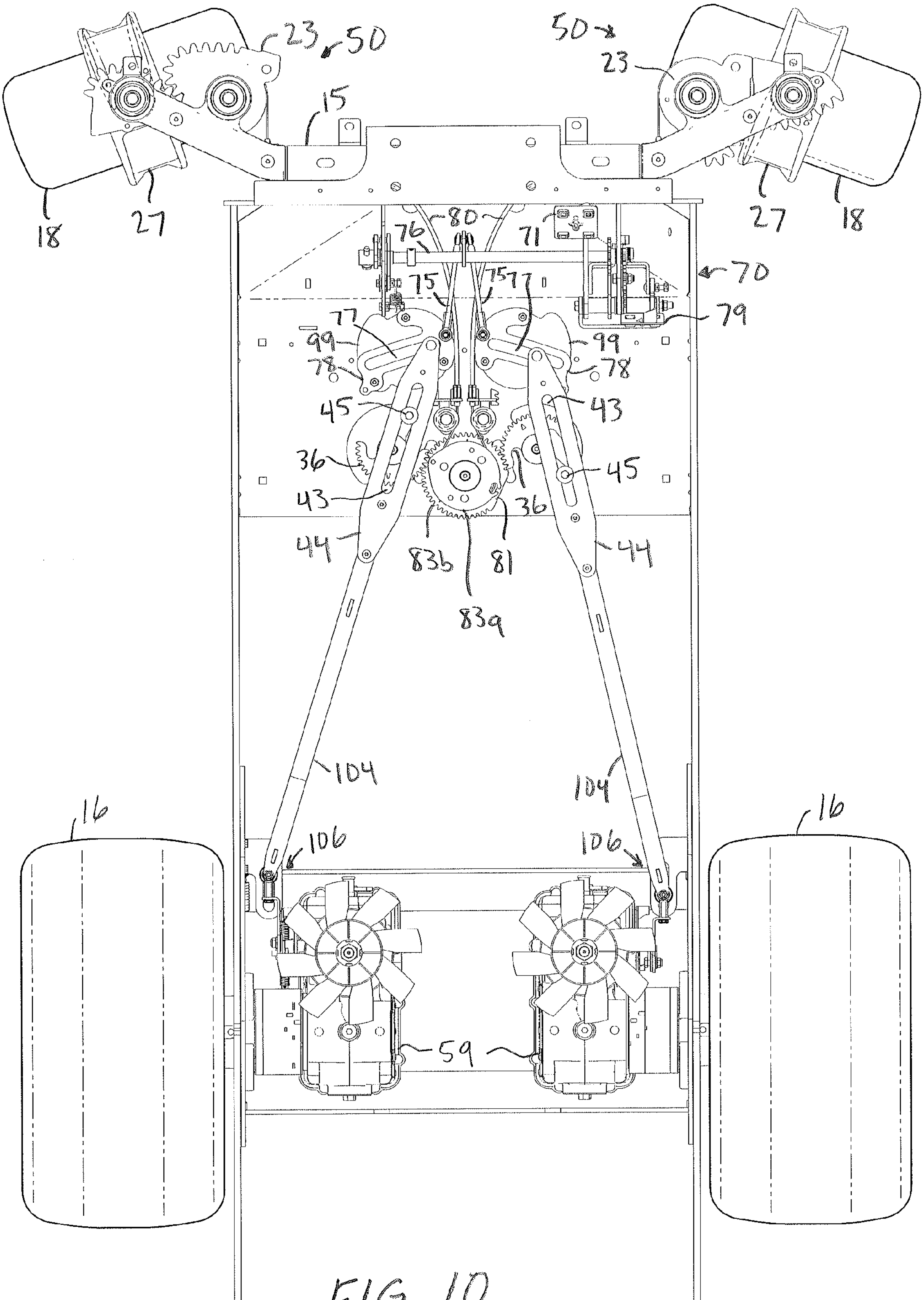

FIG. 10

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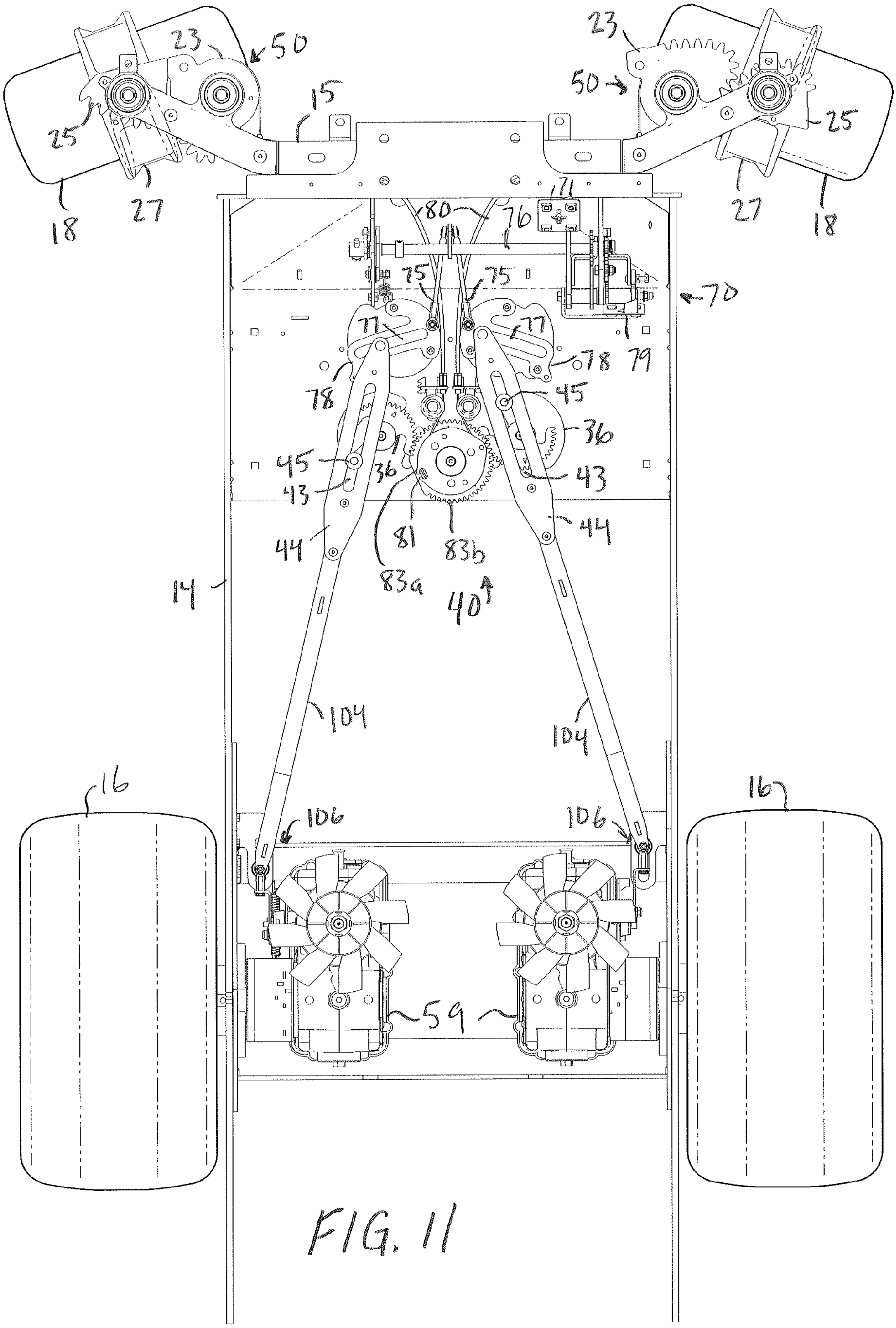

FIG. 11

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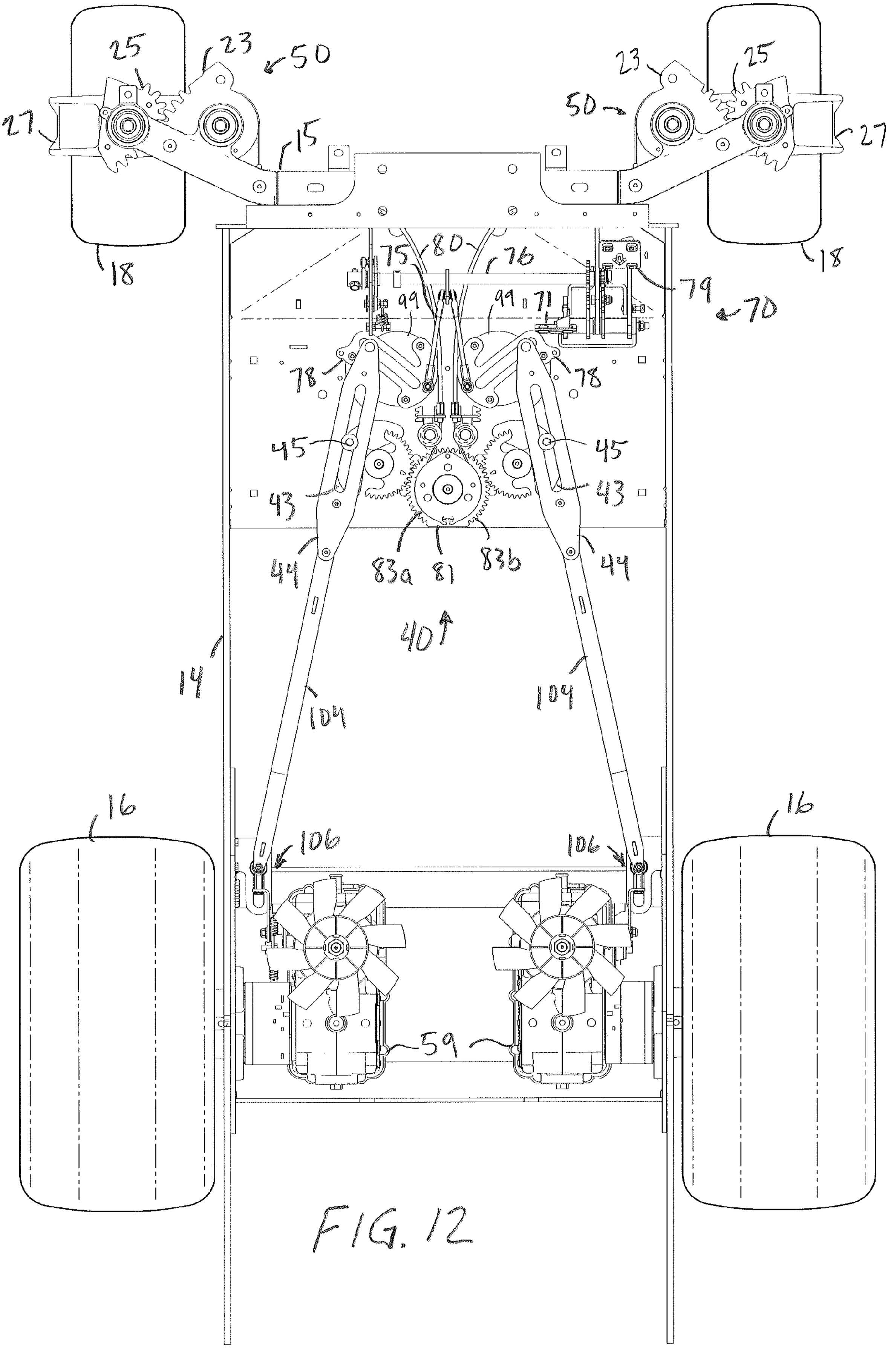

FIG. 12

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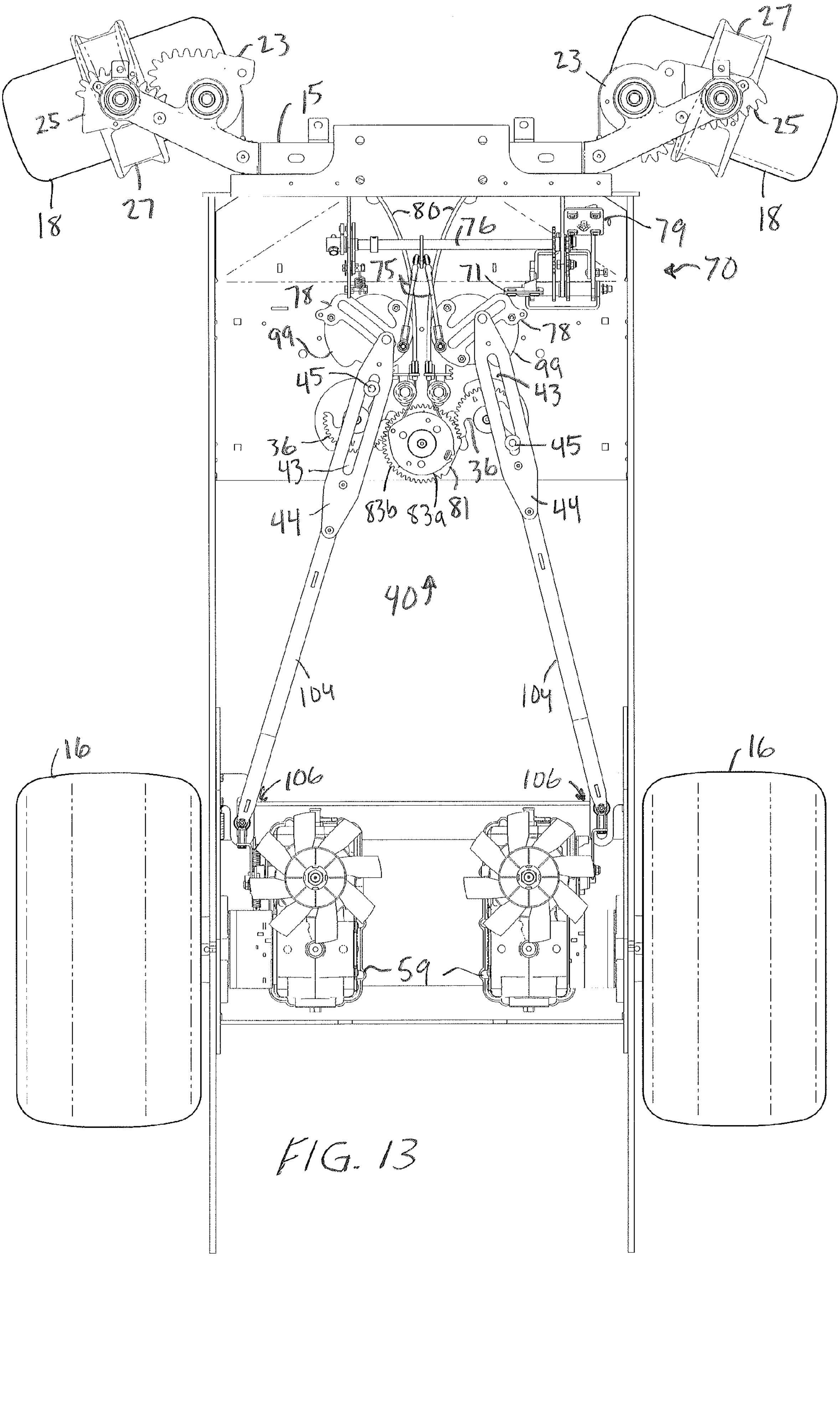

FIG. 13

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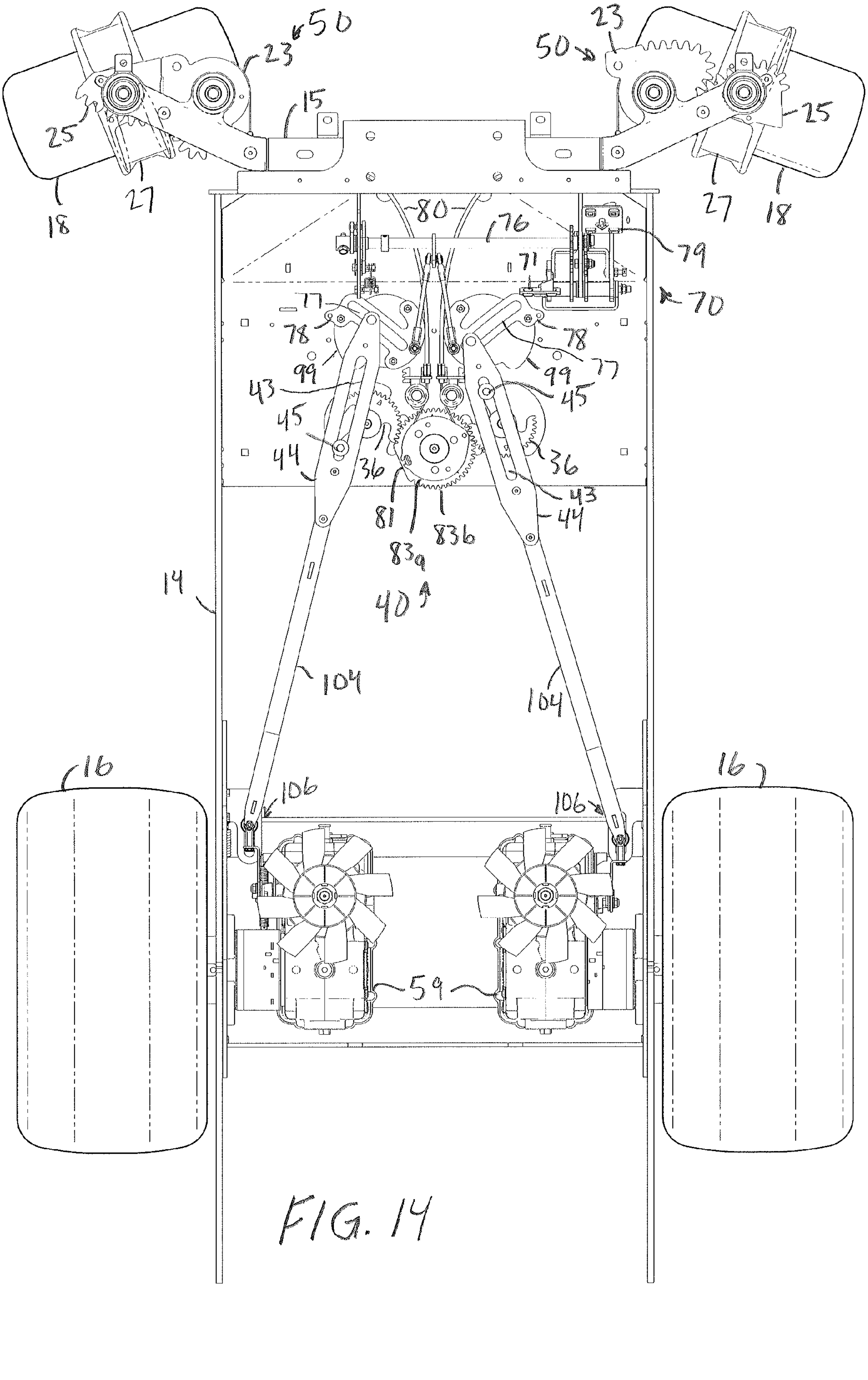

FIG. 14

FIG. 15