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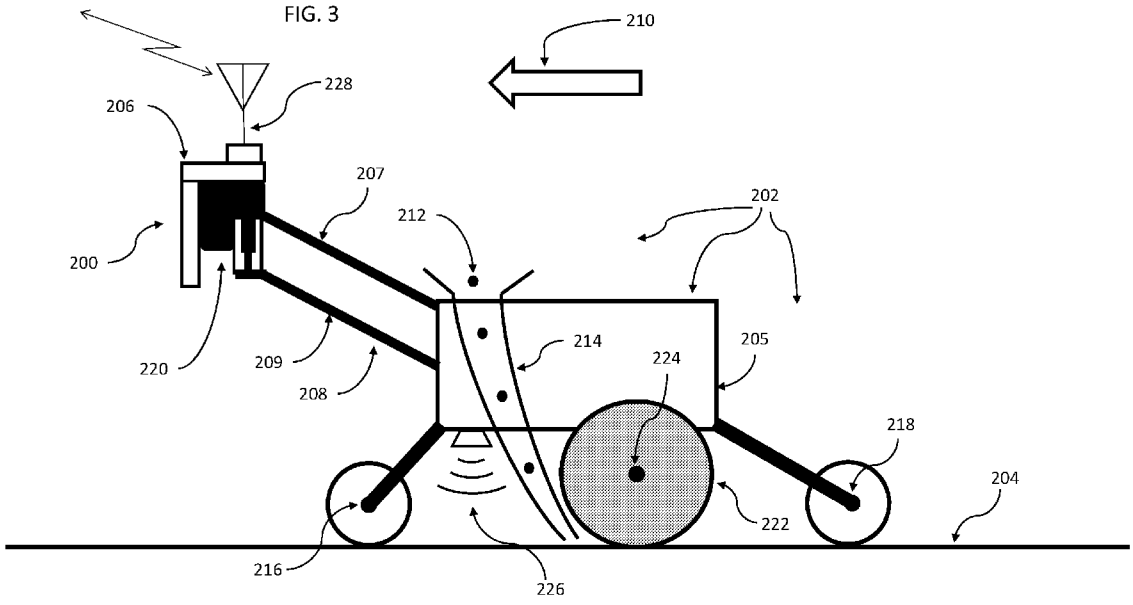
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(54) Title: A PRECISION PLANTING SYSTEM FOR CONTROLLING SEED DEPTH

FIG. 3



(57) Abstract: An apparatus and method for controlling the seed depth for a row planter (104) controls the force upon a gauge wheel (222) with a hybrid electric-hydraulic piston assembly (220). The piston assembly is operably connected to a controller programmed with a proportional integral control function that processes downward force data from sensors to control movement of the piston assembly (220) that changes the force created by the gauge wheel (222) upon the ground. The piston assembly (220) regulates the planted seed depth and force upon the gauge wheel (222) in response to force data from a force sensor connected to the gauge wheel (222), distance data from a distance sensor connected to the planter (104), and a movement data from a movement sensor connected to the gauge wheel (222).

WO 2019/157521 A1

[Continued on next page]

SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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A PRECISION PLANTING SYSTEM FOR CONTROLLING SEED DEPTH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority in U. S. Provisional Patent Application Serial No. 62/710,189, filed February 12, 2018, the contents of which are hereby incorporated by reference.

BACKGROUND

1. Field of the Disclosed Subject Matter

[0002] The present disclosed subject matter relates generally to agricultural systems. More particularly, control of a line or row planter to control the depth that seeds are immersed in soil.

2. Background

[0003] Modern agriculture uses mechanical planters to deposit or immerse seeds into the ground or soil. In general, the process consists of: (1) cutting a furrow; (2) dropping a seed into the furrow; and (3) covering the seed with soil. Accurate seed placement effects yield. For example, seeds might be too deep and so not emerge. Seeds might be too shallow and so not receive sufficient moisture. The weight on the load-bearing wheels of the mechanical planter might over-compact the soil covering the seed and stunt root growth.

[0004] The most common type of planter uses a gauge that sets the planting depth. The gauge is a measurement between the planter load-bearing wheels (also called gauge wheels) that ride on the surface of the ground and the sharp furrow-cutting wheel that penetrates the ground. Seed depth is set by the immersion of the cutting wheel into the soil, and the immersion will be consistent as long at the gauge wheels maintain contact with the soil, which is traditionally accommodated by placing a large weight on the gauge wheels. Yet, as discussed above, large weight can over-compact

the soil. In contrast, too little weight will cause the gauge wheels to bounce off the soil so that seeds are planted too shallow. With this basis, the most ideal weight is just enough to maintain gauge wheel ground contact without the wheels bouncing off irregularities in the soil.

[0005] Conventional solutions result in a consistent seed depth as long as the soil type is relatively consistent (for example does not change from loose sand to heavy clay). However, the conventional solutions require a large weight on the gauge wheels which can cause the soil to be over-compacted which in turn can cause the roots of the plant to be confined to a narrow strip.

[0006] One solution to the root-confinement problem is to adjust the weight on the wheels according to the soil conditions. This is referred to as down-force control. Down-force control is presently accomplished with hydraulic or pneumatic pistons that are set to apply force as set by the user, usually a farmer.

[0007] Fundamentally, down-force control is a means to remotely adjust the weight applied to a planter and so requires knowledge of the required weight needed to maintain the cutting wheel depth. However, the, required weight can change depending on soil type and conditions.

[0008] As such, conventional down-force control has several deficiencies: (1) the pneumatic or hydraulic actuators require a series of hoses with a large pump which are complex, expensive, and require frequent maintenance; (2) to work optimally, it requires knowledge of the soil consistency, which might change over the course of planting; and (3) it often applies more than the needed weight to maintain cutting wheel depth and so over-compacts the soil which in turn hurts the root systems.

[0009] Accordingly, there is a need for a precision seed depth control system that requires minimal maintenance, controls seed depth independent of soil type, and minimizes the force transmitted by the planter gauge wheel to the soil.

SUMMARY

[0010] Accordingly, it is an object of the present invention to improve reliability of seed planting systems by eliminating hoses and a large central pump by instead adjusting the gauge wheel force with a hybrid electrical-hydraulic actuator on each planter. It is a further objective to adjust the force on the gauge wheels to the optimum level based on the soil conditions which is just enough to keep the wheels in contact with the soil. It is a further objective to control the immersion depth by using the gauge wheel to measure immersion depth without the gauge wheel also providing support for the planter.

[0011] In an embodiment, the system includes a wireless control system for monitoring and controlling the force and planting depth.

[0012] Optionally, the force may be set manually by the farmer based on the knowledge of the required force on the gauge wheels.

[0013] Optionally, force is adjusted according to the measured cutting wheel immersion into the soil measured with a gauge such as an ultrasonic distance gauge.

[0014] Optionally, the force is adjusted based on measured gauge wheel force.

[0015] Optionally, the force is adjusted based on measured hydraulic pressure in the hybrid electric-hydraulic actuator.

[0016] Optionally, the force is adjusted based on measuring G-forces experienced on the gauge wheels.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present disclosed subject matter is described herein with reference to the following drawing figures, with greater emphasis being placed on clarity rather than scale:

[0018] FIG. 1 is a plan view of a prior art planting system.

[0019] FIG. 2. is a left elevation view of a prior art planter.

[0020] FIG. 3 is a left elevation view of an embodiment of the precision planting system.

[0021] FIG. 4 is a schematic diagram of the hydraulic control system.

[0022] FIG. 5 is a schematic diagram of an embodiment of the precision planting system.

[0023] FIG. 6 is a schematic diagram of an embodiment of the hydraulic control system.

[0024] FIG. 7 is a schematic diagram of an embodiment of the hydraulic control system.

DETAILED DESCRIPTION

[0025] Referring to FIG. 1, a prior art planting system is shown whereby a tractor 101 uses a hydraulic or pneumatic pump 102 to distribute fluid or air through a series of hoses 103 to a plurality of hydraulic or pneumatic pistons 124 (FIG. 2) for creating down force for planters 104 connected by a front frame 108 to a towing frame, with the towing frame connected to the tractor 101 by a tow bar.

[0026] FIG. 2 is a side view of the prior art planter 104 set on the ground or soil 106 with its frame 105 attached to a front frame 108 with a hinge or linkage assembly 110. Hinge 110 has an upper link 130 and a lower link 132. Arrow 112 shows the direction of travel. Seeds 114 are dropped through a feed chute 116 into a furrow in the soil 106 created by a cutting wheel 118. A closing wheel 120 pushes soil over the furrow after the seed 114 is dropped. High pressure fluid or air is supplied by a hose 122 connected to the pump 102 of the tractor 101. The fluid or air supplies a hydraulic or pneumatic piston 124 which is connected to the front frame 108 and hinge 110 mechanism of the planter 104, which in turn applies force to a gauge wheel 126 as set by a user, such as a farmer. The total force applied to the soil 106 by the wheel 126 is a combination of the force of gravity due to the weight of the associated planter 104 plus the force from the piston 124. The total force is measured by a load cell 128 and used to determine whether more or less hydraulic fluid or air should be pumped into the piston 124.

[0027] FIG. 3 is a side view of an embodiment of the disclosed subject matter showing a row unit or planter 202 with a frame 205 set on the ground 204 and pivotally attached to a front frame 206 with a hinge 208. Hinge includes an upper link 207 and lower link 209. Front frame 206 is connected to a towing frame, with the towing frame connected to a tractor by a tow bar moving the planter 202 in the direction of travel denoted by arrow 210. Seeds 212 are dropped through a feed chute 214 into the furrow created by a cutting wheel 216. A closing wheel 218 pushes soil over the furrow after the seed 212 is dropped. A hybrid electric-hydraulic piston assembly 220, such as a

Warner Linear® H-Track electric actuator, applies force as set by the user to the gauge wheels 222. The piston assembly 220 includes a rod that moves within a barrel. The force is applied by the rod of the piston assembly 220 to a cross bar, and the cross bar contacts the links, such as the lower links 209 forcing the frame 205 downward toward the ground 204 and the gauge wheel 222 into contact with the ground 204. The total force upon the gauge wheel 222 is the combination of the force of gravity due to the weight of the associated planter 202 plus the force from the piston assembly 220. The total force is measured by a sensor, such as a load cell 224, operably connected to the gauge wheel 222. Load cell 224 sends a load signal to a processor of a controller. A ground distance sensor 226 mounted to the planter 202 measures the distance to the ground sending a distance signal to the controller to determine the depth of seed 212 placement and immersion in the ground 204. In an embodiment, the sensor 226 emits and detects ultrasound. The ground distance sensor 226 measurement and/or load cell 224 measurement are used by the controller to determine whether more or less force should be applied to the gauge wheel 222 by the hybrid electric-hydraulic piston assembly 220.

[0028] Actuation settings are sent to the piston assembly 200 by a control system in response to data from the load cell 224 and distance sensor 226. The communication between the control system and the planter 202 may be sent wirelessly using a data link 228. Movement of the planter 202 over the ground 204 can cause the gauge wheel 222 to bounce when it encounters uneven terrain. The load cell 224 detects increases and decreases in pressure upon the gauge wheel 222. In an embodiment, in response to the signal from the load cell 224, the controller adjusts the piston assembly 220 to create the force necessary for the gauge wheel 222 to remain in contact with the ground 204 when the gauge wheel 222 encounters uneven ground 204.

[0029] FIG. 4 is a schematic diagram of the hybrid electric-hydraulic system 200 with a hydraulic piston assembly 220. The system 200 includes an enclosure 230 with hydraulic fluid 232, a small electric pump 234, force limiting valve 236, and

hydraulic piston 220. The electric pump 234 is commanded to move hydraulic fluid to and from the reservoir 238 into and out of the piston chamber 240 thereby moving the rod of the piston assembly 220 out or in, with the force applied to move the rod out providing downforce upon the planter 202 and in turn, the gauge wheel 222.

[0030] FIG. 5 is a schematic diagram of a control system used to control the system 200. Here sensor signals 242 from a load cell 224 and ground distance sensor 226 are supplied to the processor programmed with a proportional/integral (PI) control function 244 to control operation of the pump motor 234 to thereby regulate the distance 246 of the planter 202 above the ground 204. An error signal is processed by the PI control function by adding a proportional and integrated error signal with separate gain constants. The error is the difference between measured height and set point height. The controller uses force limits, such as the maximum force created by the piston assembly 220, to prevent damage to the system.

[0031] FIG. 6 is a schematic diagram of an embodiment of the control system used to control the system 200. Here sensor signal 248 from a pressure sensor 250 is applied to a controller that uses PI control function 244 to regulate the pressure applied by hydraulic piston assembly 220. The pressure of the hydraulic piston assembly 220 is measured by pressure sensor 250, and changes in the measured pressure, such as a reduction of the pressure due to the gauge wheel 222 bouncing off of the ground 204, is read by the controller 244, and the controller operates pump 234 to increase the pressure of piston assembly 220 to engage wheel 222 with the ground 204. An error signal is processed by the PI control function by adding a proportional and integrated error signal with separate gains constants. The error is the difference between the target pressure and the measured pressure.

[0032] FIG. 7 is a schematic diagram of an embodiment of the control system used to control the hybrid pump motor 234. Here sensor signal 252 from a G-sensor 254 is applied to a controller to regulate the pressure applied by hydraulic piston

assembly 220 to the planter 202. Movement or vibration of the gauge wheel 222 is measured by the G-sensor 254, and change in the measured pressure, such as a reduction in the measured force due to the gauge wheel 222 bouncing off of the ground 204, is read by the controller 244, and the controller operates pump 234 to increase the pressure of piston assembly 220 to increase engagement of the wheel 222 with the ground 204. The controller responds to vibrations (bounces) by increasing pressure until the vibrations reach a prescribed, acceptable level such as little or no bouncing due to the constant contact of the gauge wheel 222 with the ground 204.

[0033] In all cases, adjustments of control settings and monitoring of performance may be accomplished through a wireless data link. Control and monitoring is typically performed inside a tractor but may also be performed prior to tractor hook-up.

[0034] Prior art was costly and complex because each planter 104 required a hose 103 connection and a control signal connection. As such, the disclosed subject matter is much simpler because the hybrid electric/hydraulic system 200 alleviates the need for the hoses 103 shown in FIG. 1. Further, the various means to set the pressure on the gauge wheels 222 just above the minimum required to prevent the gauge wheels 222 from bouncing on the ground 204 will reduce soil compaction and so prevent root damage of the plants growing from the planted seeds 212.

[0035] As required, detailed aspects of the present disclosed subject matter are disclosed herein; however, it is to be understood that the disclosed aspects are merely exemplary of the disclosed subject matter, which may be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosed subject matter in virtually any appropriately detailed structure.

[0036] Although the subject matter has been disclosed with reference to various

particular embodiments, it is understood that equivalents may be employed and substitutions made herein without departing from the scope of the disclosed subject matter.

CLAIMS

Having described the disclosed subject matter, what is claimed as new and desired to be secured by Letters Patent is:

1. A seed planting system, comprising:

a row unit, comprising:

a front plate;

a planter frame;

a gauge wheel connected to the planter frame for engaging the ground;

a link pivotally connecting the planter frame to the front plate;

a hydraulic piston assembly connected to the front plate, comprising:

an electric hydraulic pump; and

a hydraulic piston operably connected to the electric pump, and connected to the link by a crossbar for providing downward force upon the lower link;

a first sensor operably connected to the gauge wheel for measuring the downward force of the agricultural row unit upon the gauge wheel;

a controller with a processor, the controller being operably connected to the hydraulic piston assembly and the sensor; and

wherein the controller actuates the electric hydraulic pump to move the hydraulic piston to increase and decrease the downward force of the gauge wheel upon the ground in response to data from the first sensor.

2. The seed planting system of claim 1, further comprising:

wherein the processor is programmed with a proportional integral control function that processes the first sensor downward force data to control movement of the hydraulic piston.

3. The seed planting system of claim 1, further comprising:

a second sensor operably connected to the row unit;

wherein the second sensor measures the distance between the row unit and the ground.

4. The seed planting system of claim 3, further comprising:

wherein the processor is programmed with a proportional integral control function that processes the difference between the measured height of the planter above the ground and a set point height of the planter above the ground to control movement of the hydraulic piston.

5. The seed planting system of claim 1, further comprising:

wherein the controller includes a piston assembly maximum force limit; and

wherein a maximum force applied to the gauge wheel by the hydraulic piston is limited by the piston assembly maximum force limit.

6. The seed planting system of claim 1, further comprising:

a third sensor operably connected to the piston assembly;

wherein the third sensor measures vibration of the gauge wheel;

wherein the processor is programmed with a control function that processes the third sensor data to control movement of the hydraulic piston to increase or decrease the downward force of the gauge wheel upon the ground in response to the vibration measured by the third sensor.

7. A method of controlling the downforce upon a gauge wheel of a seed planter, comprising:

providing a row unit, comprising:

a front plate;

a planter frame;

a gauge wheel connected to the planter frame for engaging the ground;

a link pivotally connecting the planter frame to the front plate;

a hydraulic piston assembly connected to the front plate, comprising:

an electric hydraulic pump; and

a hydraulic piston operably connected to the electric pump, and connected to the link by a crossbar for providing downward force upon the link;

a first sensor operably connected to the gauge wheel for measuring the downward force of the agricultural row unit upon the gauge wheel and generating downward force data;

a controller with a processor, the controller being operably connected to the hydraulic piston assembly and the sensor;

calculating by the processor the downward force of the agricultural row unit upon the gauge wheel; and

actuating by the controller the electric hydraulic pump to move the hydraulic piston to increase and decrease the downward force of the gauge wheel upon the ground in response to downward force data from the first sensor.

8. The method of claim 7, further comprising:

providing a second sensor operably connected to the row unit and the controller;

wherein the second sensor measures the distance between the row unit and the ground; and

actuating by the controller the electric hydraulic pump to increase and decrease the downward force of the gauge wheel upon the ground in response to the difference between the measured height of the planter above the ground and a set point height of the planter above the ground.

9. The method of claim 1, further comprising:

wherein the controller includes a piston assembly maximum force limit;

determining by the processor a maximum force limit of the hydraulic piston;

calculating by the processor the force applied to the gauge wheel by the hydraulic piston; and

actuating by the controller the electric hydraulic pump to limit the downward force of the gauge wheel upon the ground in response to the maximum force limit of the hydraulic piston.

10. The method of claim 1, further comprising:

providing a third sensor operably connected to the piston assembly;

wherein the third sensor measures vibration of the gauge wheel;

actuating by the controller the electric hydraulic pump to increase and decrease the downward force of the gauge wheel upon the ground in response to the vibration measured by the sensor.

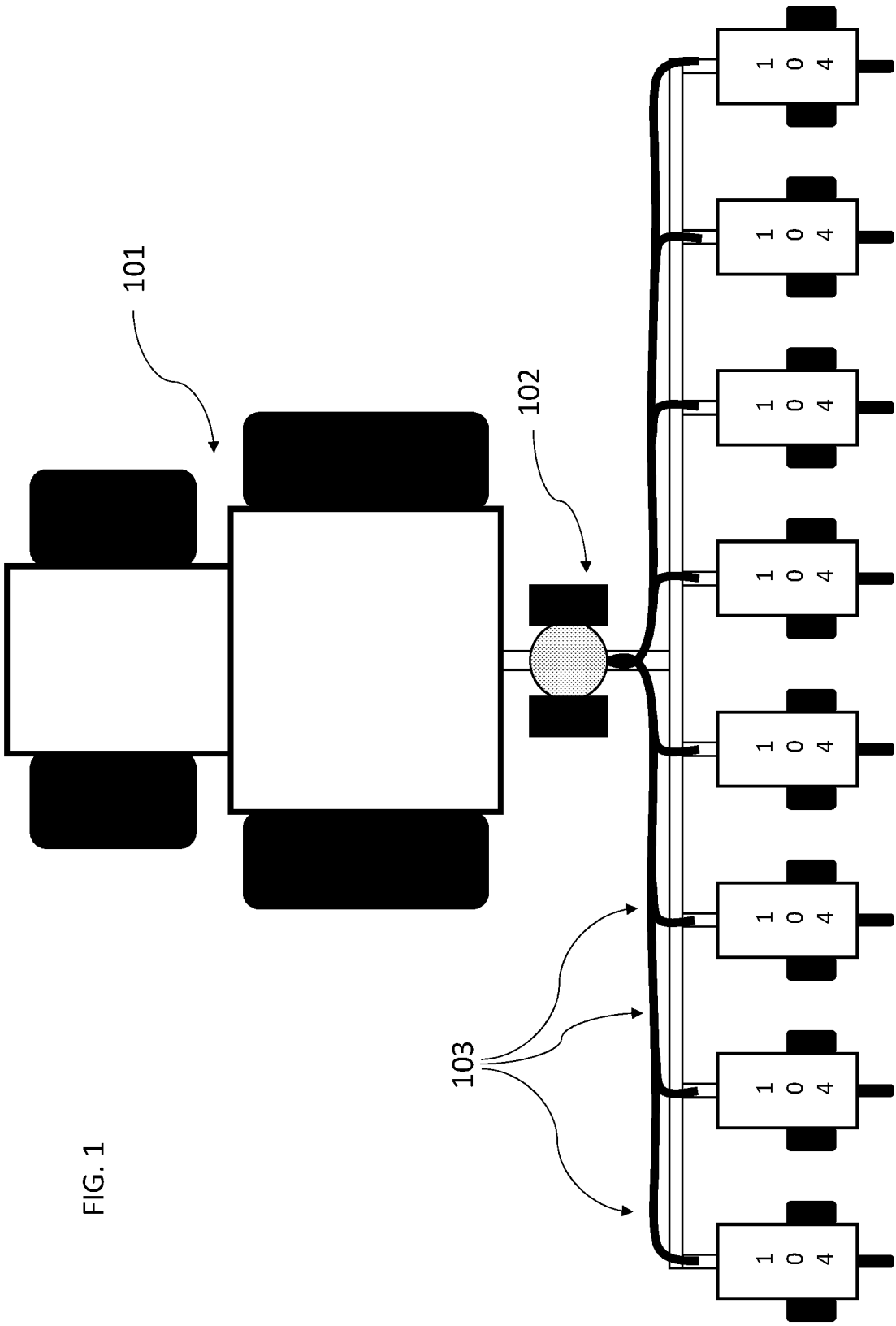


FIG. 1

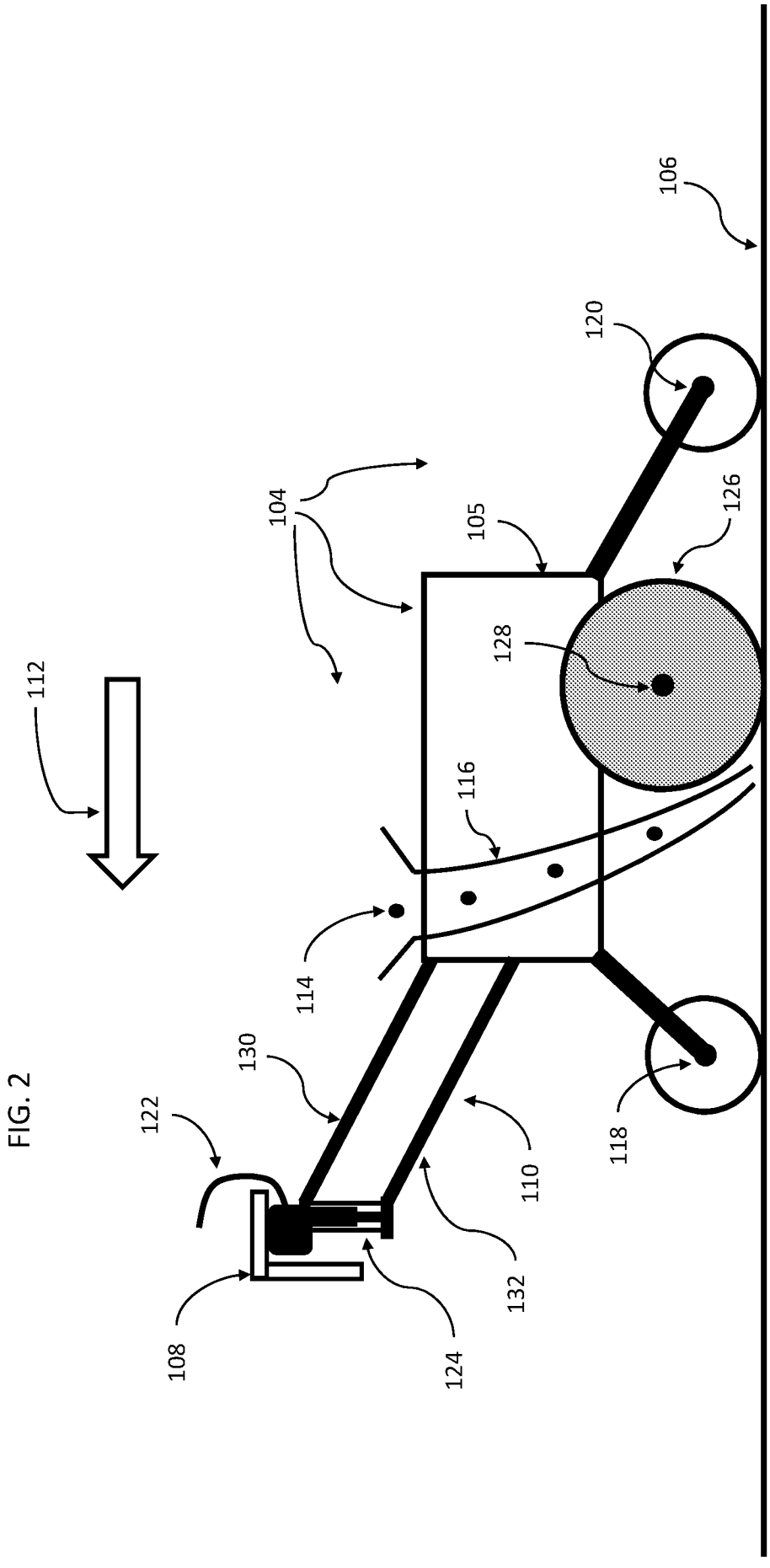


FIG. 2

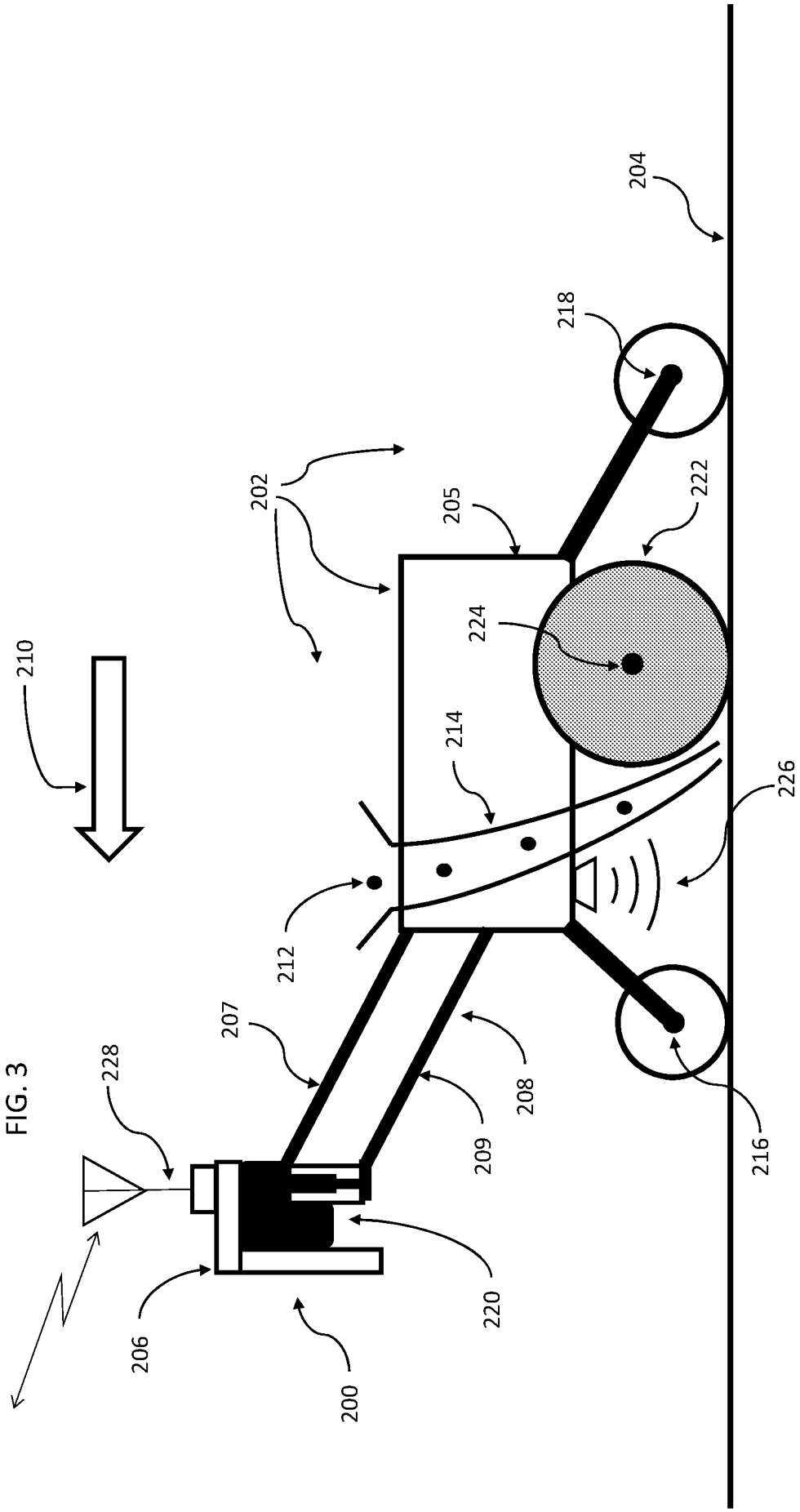

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FIG. 3

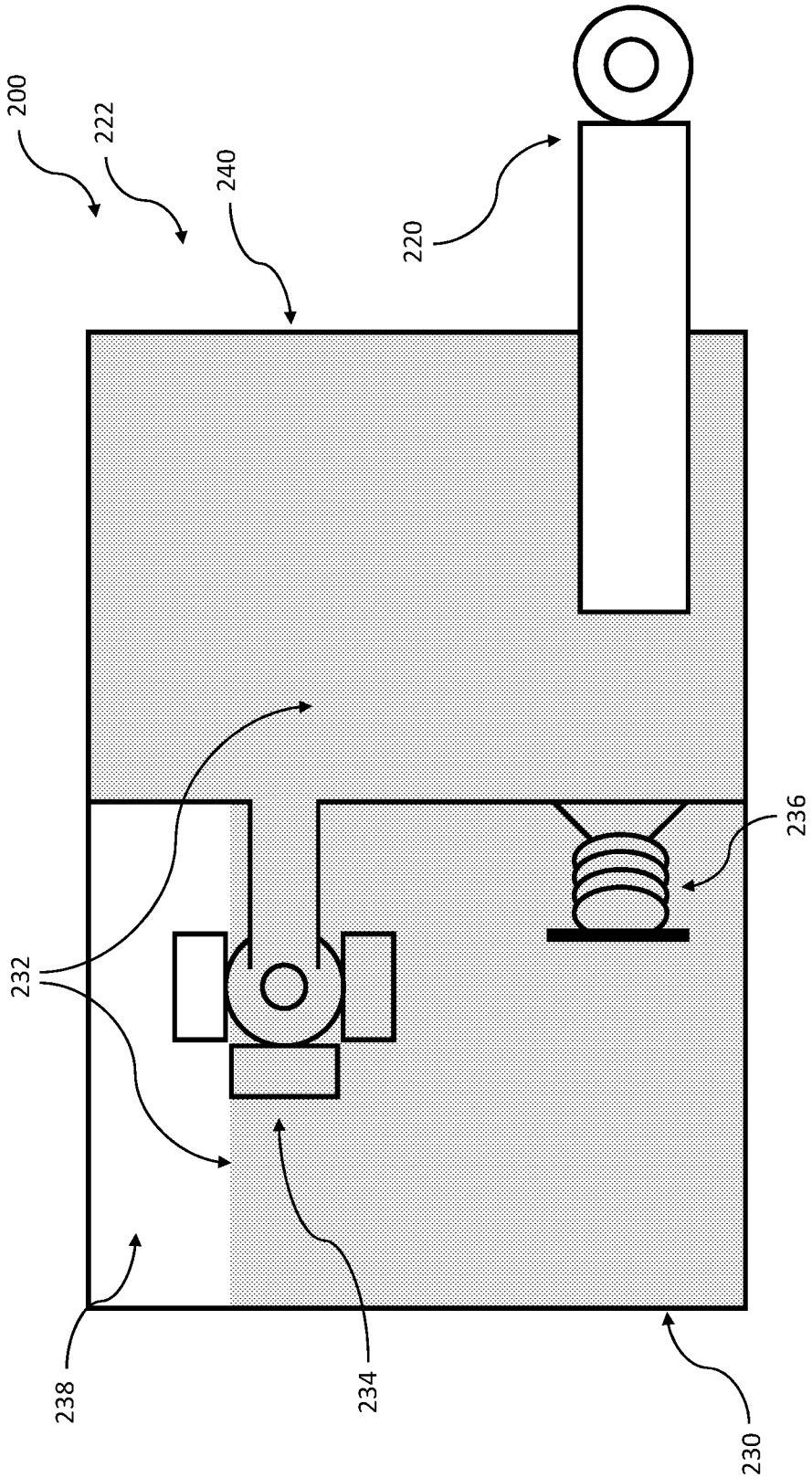


FIG. 4

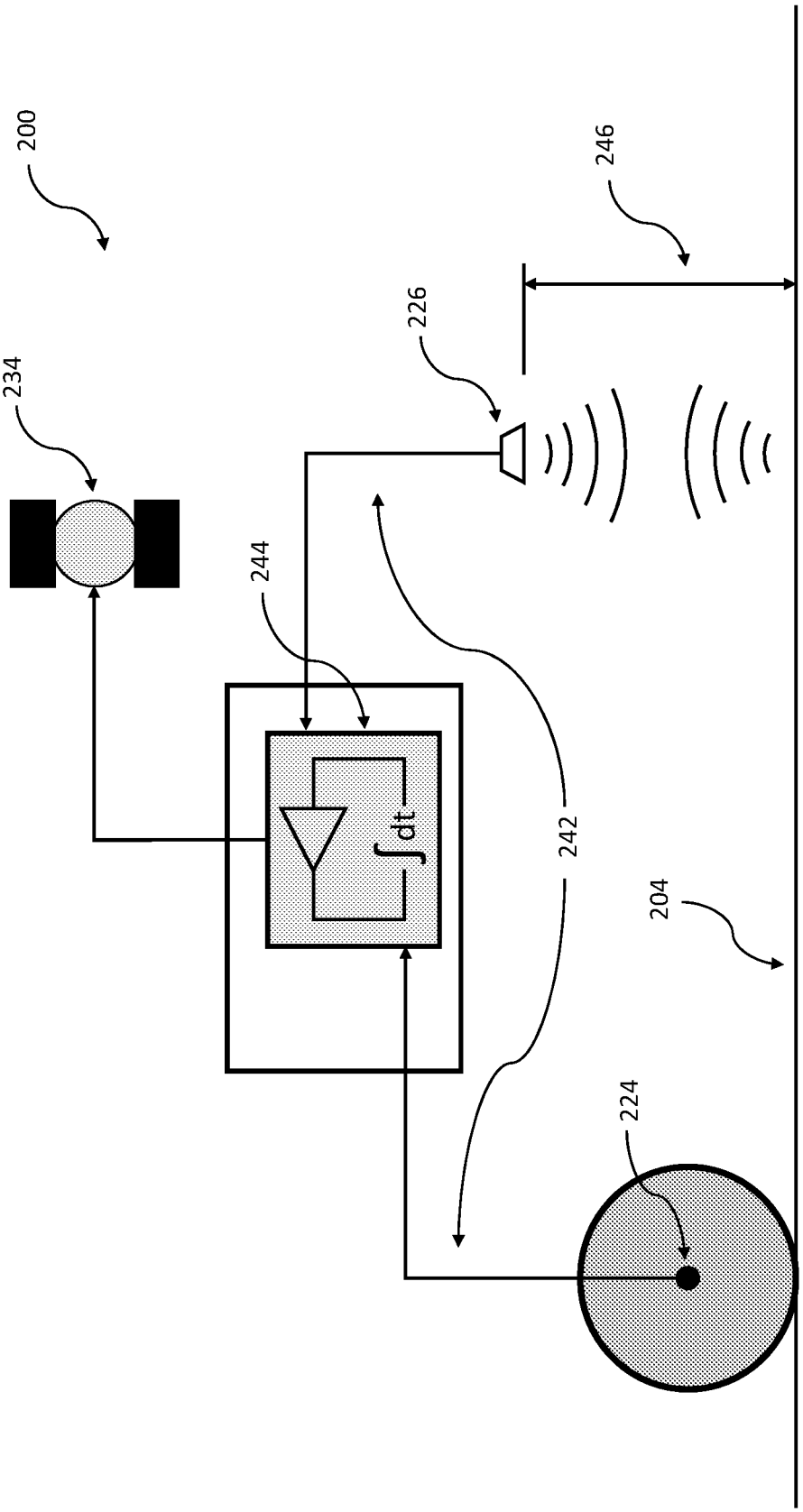


FIG. 5

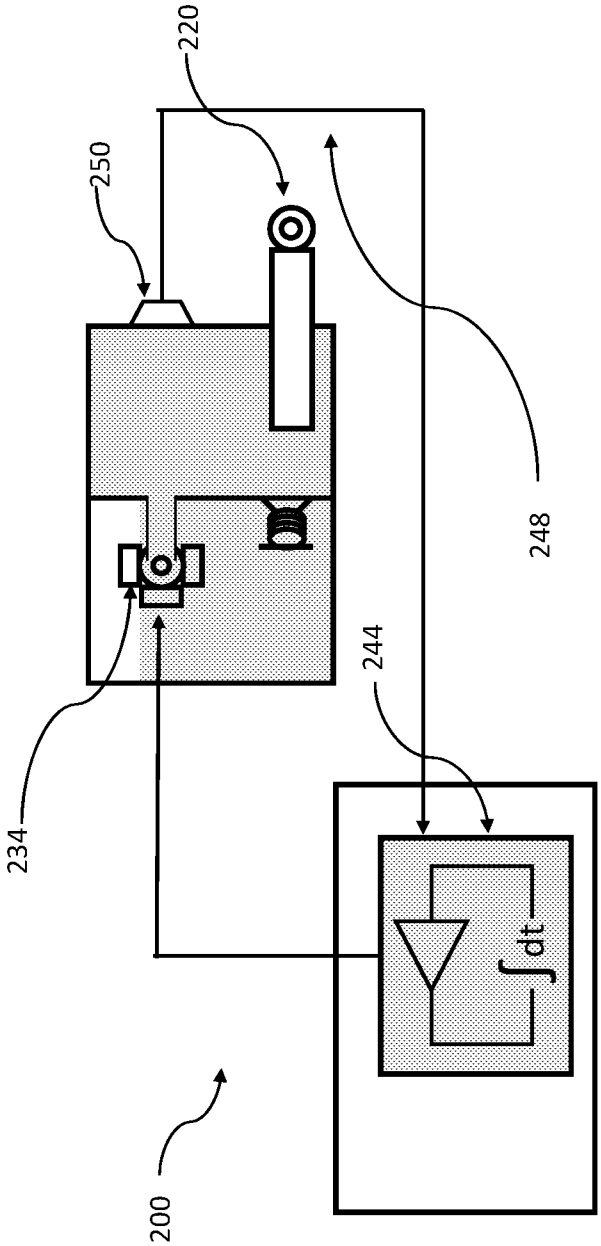


FIG. 6

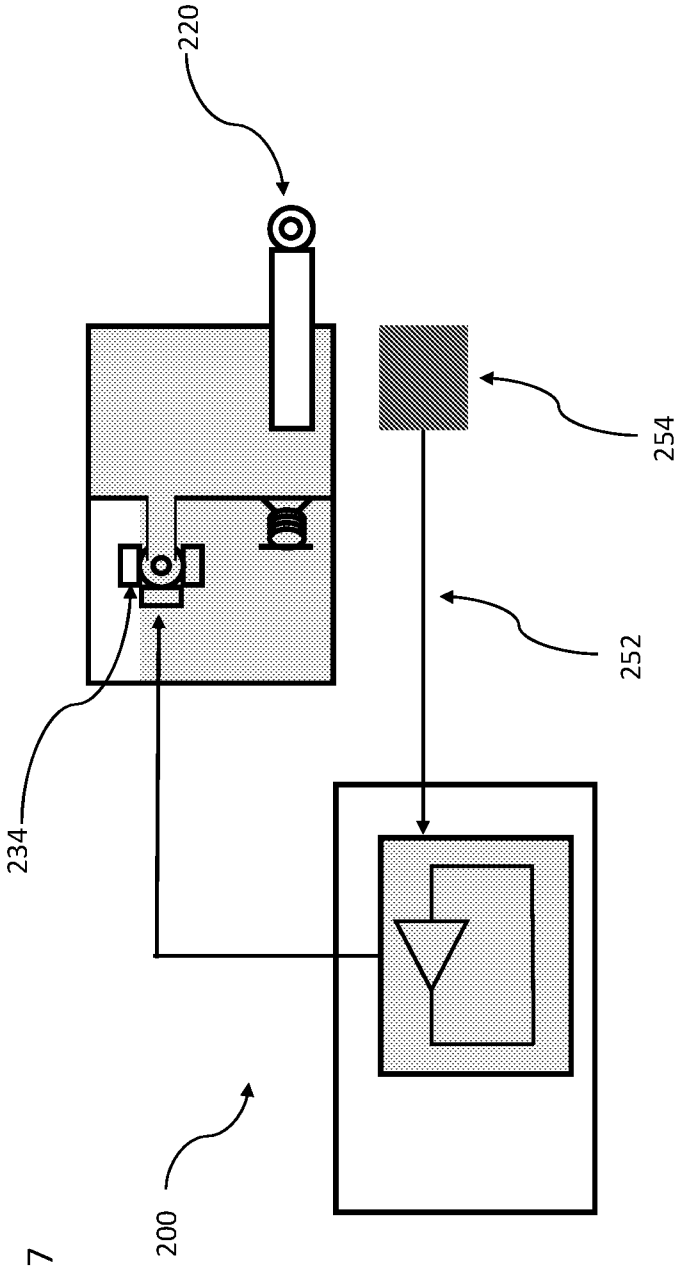


Figure 7

INTERNATIONAL SEARCH REPORT

019/017696 23.04.2019
International application No.
PCT/US19/17696

A. CLASSIFICATION OF SUBJECT MATTER

IPC - A01B 63/10, 63/16, 63/22, 63/118, 63/12, 63/114; A01C 7/20; G05B 11/42 (2019.01)

CPC - A01B 63/10, 63/16, 63/22, 63/118, 63/12, 63/1112, 63/114; A01C 7/208, 7/205, 7/203; G05B 11/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2016/0165789 A1 (CNH INDUSTRIAL CANADA LTD) 16 June 2016; figures 1-3; paragraphs [0021, 0023, 0029-0032, 0037-0040]	1, 5-7, 10 --- 2-4, 8
X	US 2016/0157412 A1 (PRECISION PLANTING LLC) 09 June 2016; abstract; figures 1b, 2-3b, 4a, 4d; paragraphs [0024-0032, 0036-0040]	7, 9
Y	US 6,701,857 B1 (JENSEN, L et al.) 09 March 2004; figure 11; column 10, line 20 to column 11, line 19	2
Y	US 2014/0041351 A1 (BOLLIN, D et al.) 13 February 2014; figures 2-3; paragraphs [0017-0021, 0041]	3-4, 8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
04 April 2019 (04.04.2019)	23 APR 2019
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774