US011912545B2

(12) United States Patent
Post et al.

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(45) Date of Patent: Feb. 27, 2024

(54) WIRELESS HOIST SYSTEM

(71) Applicant: MILWAUKEE ELECTRIC TOOL CORPORATION, Brookfield, WI (US)

(72) Inventors: Matthew Post, Milwaukee, WI (US); Gareth Mueckl, Milwaukee, WI (US); Matthew N. Thurin, Wauwatosa, WI (US); Joshua D. Widder, Racine, WI (US); Timothy J. Bartlett, Waukesha, WI (US); Patrick D. Gallagher, Oak Creek, WI (US); Jarrod P. Kotes, Grafton, WI (US); Karly M. Schober, Milwaukee, WI (US); Kenneth W. Wolf, Muskego, WI (US); Terry L. Timmons, Oconomowoc, WI (US); Mallory L. Marksteiner, Naperville, IL (US); Jonathan L. Lambert, Milwaukee, WI (US); Ryan A. Spiering, Milwaukee, WI (US); Jeremy R. Ebner, East Troy, WI (US); Benjamin A. Smith, Milwaukee, WI (US); James Wekwert, Wauwatosa, WI (US); Brandon L. Yahr, Slinger, WI (US); Troy C. Thorson, Cedarburg, WI (US); Connor P. Sprague, Milwaukee, WI (US); John E. Koller, Brookfield, WI (US); Evan M. Glanzer, Milwaukee, WI (US); John S. Scott, Brookfield, WI (US); William F. Chapman, III, Delavan, WI (US); Timothy R. Obermann, Waukesha, WI (US)

(73) Assignee: Milwaukee Electric Tool Corporation, Brookfield, WI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 356 days.

(21) Appl. No.: 17/051,643

(22) PCT Filed: Jun. 26, 2020

(86) PCT No.: PCT/US2020/039908

§ 371 (c)(1),
(2) Date: Oct. 29, 2020

(87) PCT Pub. No.: WO2020/264359

PCT Pub. Date: Dec. 30, 2020

(65) **Prior Publication Data**

US 2022/0185639 A1 Jun. 16, 2022

Related U.S. Application Data

(60) Provisional application No. 62/965,676, filed on Jan. 24, 2020, provisional application No. 62/951,394,

(Continued)

(51) **Int. Cl.**

B66D 3/00 (2006.01)
B66D 3/26 (2006.01)
B66C 13/40 (2006.01)

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

CPC *B66D 3/26* (2013.01); *B66C 13/40* (2013.01); *B66D 2700/02* (2013.01)

(58) **Field of Classification Search**

CPC ... B66D 3/26; B66D 3/18; B66D 3/24; B66D 1/14; B66D 1/20; B66D 1/26; B66D 1/48;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,195,368 B1 * 6/2012 Leban B63B 27/10
212/277
9,630,810 B1 4/2017 Kinser, Jr.

(Continued)

FOREIGN PATENT DOCUMENTS

DE 3147158 A1 6/1983
JP H08324958 A 12/1996

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion for Application No. PCT/US2020/039908 dated Oct. 22, 2020 (16 pages).

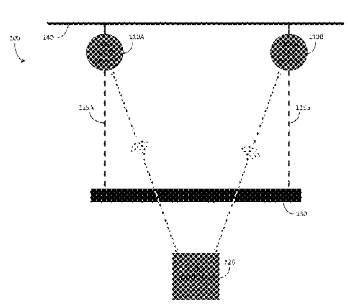
(Continued)

Primary Examiner — Emmanuel M Marcelo
(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich LLP

(57) **ABSTRACT**

A wireless hoist system including a first hoist device having a first motor and a first wireless transceiver and a second hoist device having a second motor and a second wireless transceiver. The wireless hoist system includes a controller

(Continued)



in wireless communication with the first wireless transceiver and the second wireless. The controller is configured to receive a user input and determine a first operation parameter and a second operation parameter based on the user input. The controller is also configured to provide, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device and provide, wirelessly, a second control signal indicative of the second operation parameter to the second hoist device. The first hoist device operates based on the first control signal and the second hoist device operates based on the second control signal.

19 Claims, 55 Drawing Sheets

Related U.S. Application Data

filed on Dec. 20, 2019, provisional application No. 62/868,297, filed on Jun. 28, 2019.

(58) **Field of Classification Search**
CPC . B66D 1/485; B66D 1/56; B66D 5/02; B66D 5/30; B66D 2700/02
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0179020	A1	8/2005	Taylor et al.
2006/0102578	A1	5/2006	Zakula, Sr. et al.
2014/0251935	A1	9/2014	Behnke
2018/0346294	A1	12/2018	Shely et al.
2019/0041821	A1	2/2019	Stagg et al.

FOREIGN PATENT DOCUMENTS

WO	WO-0214202	A1 *	2/2002	.... B65G 63/002
WO	WO-2015173773	A2 *	11/2015	.... G05B 19/0426
WO	2016153814	A1	9/2016	
WO	WO-2017072051	A1 *	5/2017	.... B66C 13/08

OTHER PUBLICATIONS

Partial Supplementary European Search Report for Application No. 20830553.2 dated Aug. 8, 2023 (19 pages).
Konecranes, "Crane Radio Control," brochure @ 2013 (12 pages).
Extended European Search Report for Application No. 20830553.2 dated Nov. 20, 2023 (16 pages).

* cited by examiner

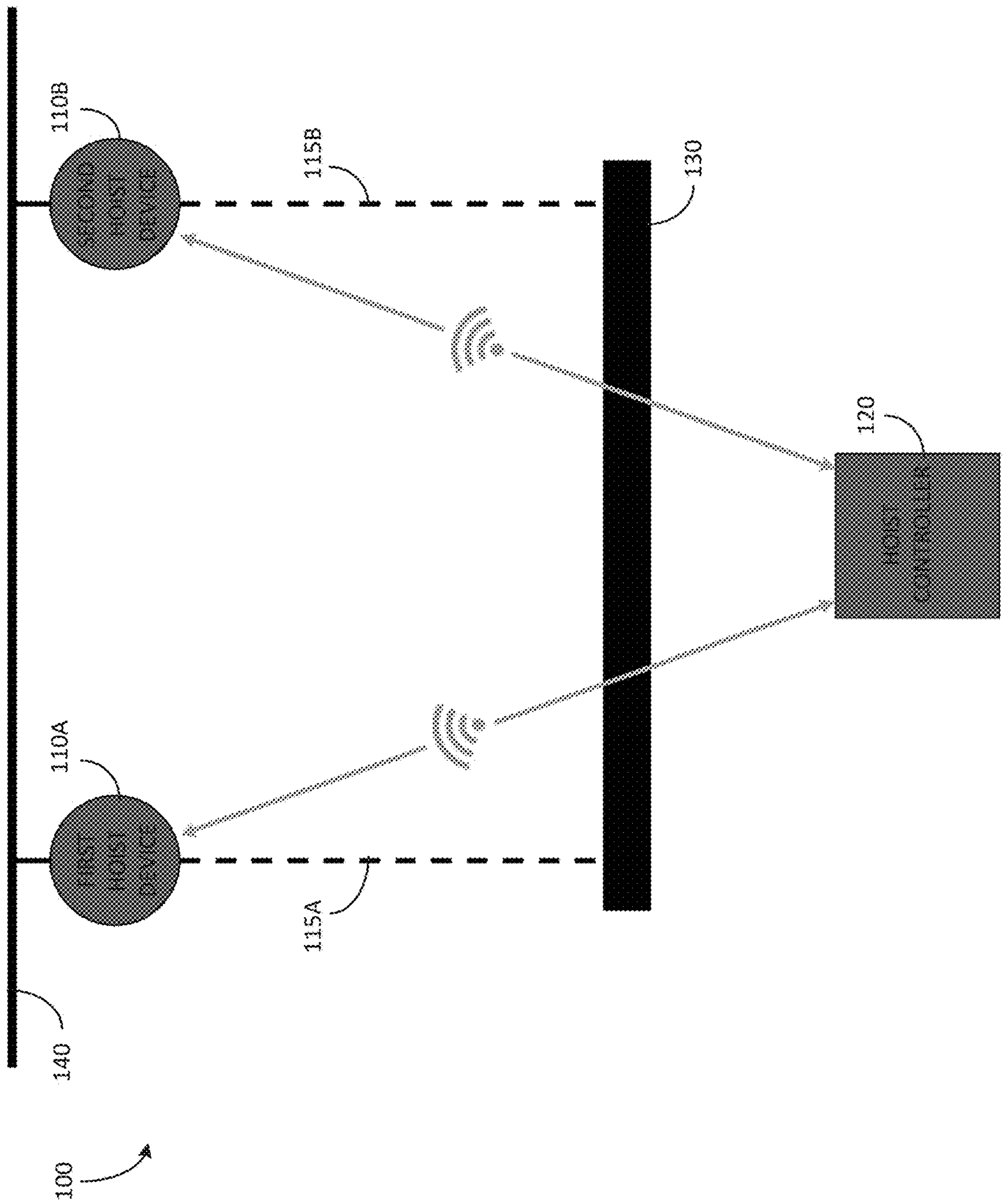

100
140
110A
FIRST HOST DEVICE
115A
110B
SECOND HOST DEVICE
115B
130
120
HOST CONTROLLER

FIG. 1

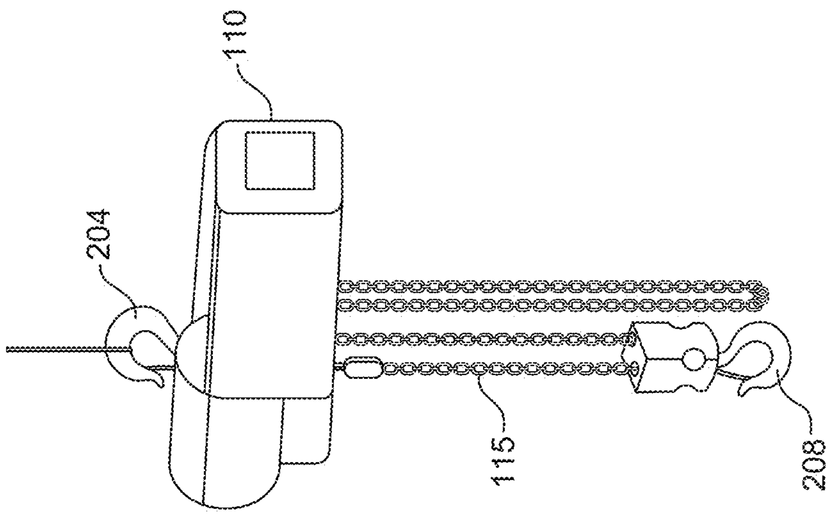


FIG. 2A

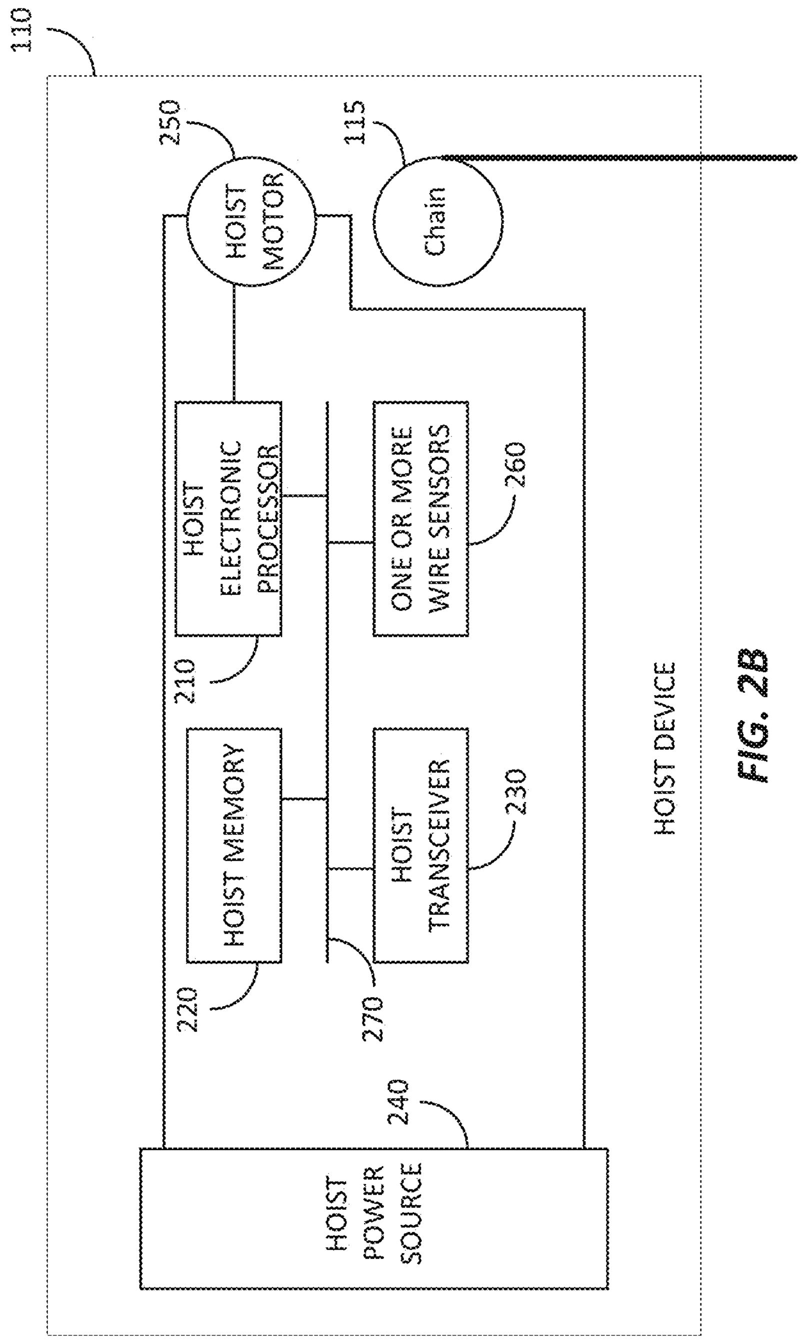

110
250
HOIST MOTOR
115
Chain
HOIST ELECTRONIC PROCESSOR
210
ONE OR MORE WIRE SENSORS
260
HOIST MEMORY
220
HOIST TRANSCEIVER
230
270
240
HOIST POWER SOURCE
HOIST DEVICE

FIG. 2B

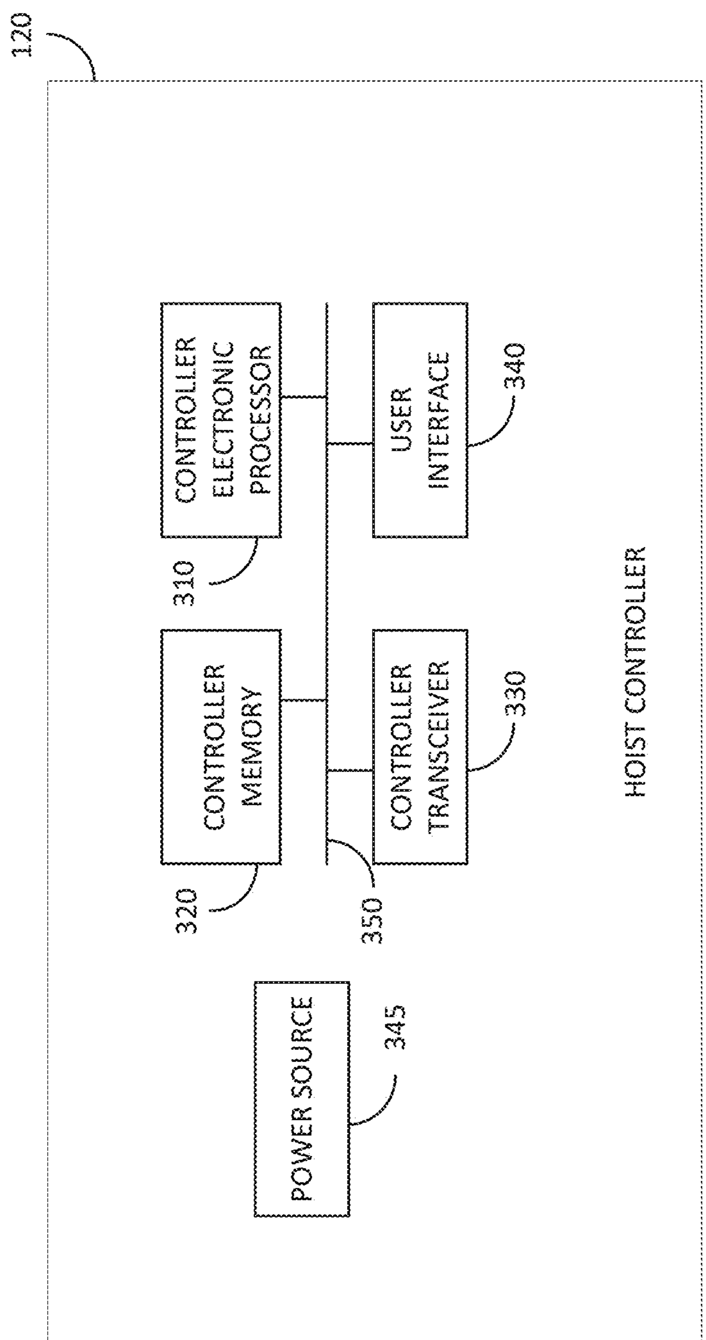

120
CONTROLLER ELECTRONIC PROCESSOR
310
CONTROLLER MEMORY
320
USER INTERFACE
340
CONTROLLER TRANSCEIVER
330
350
POWER SOURCE
345
HOIST CONTROLLER

FIG. 3

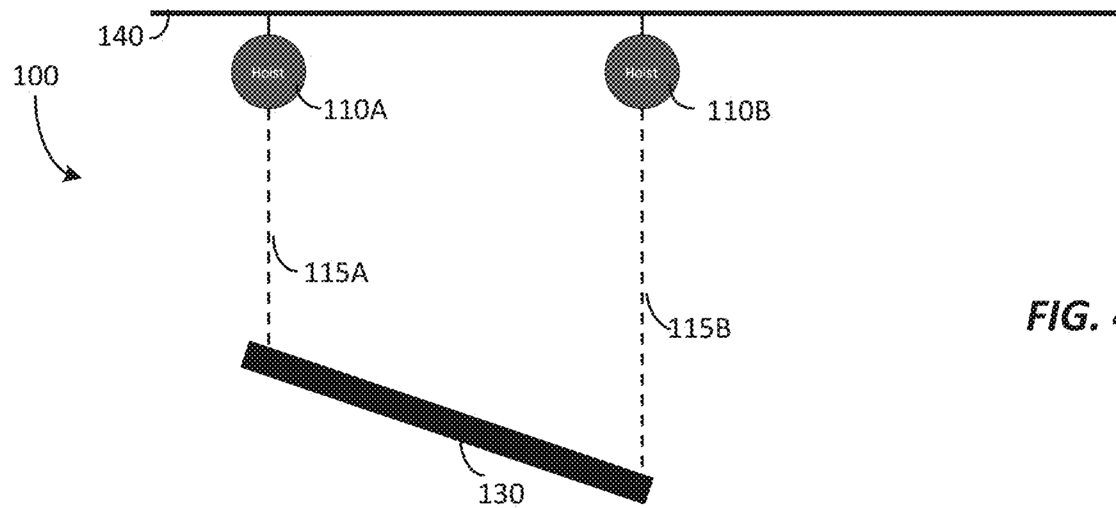


FIG. 4A

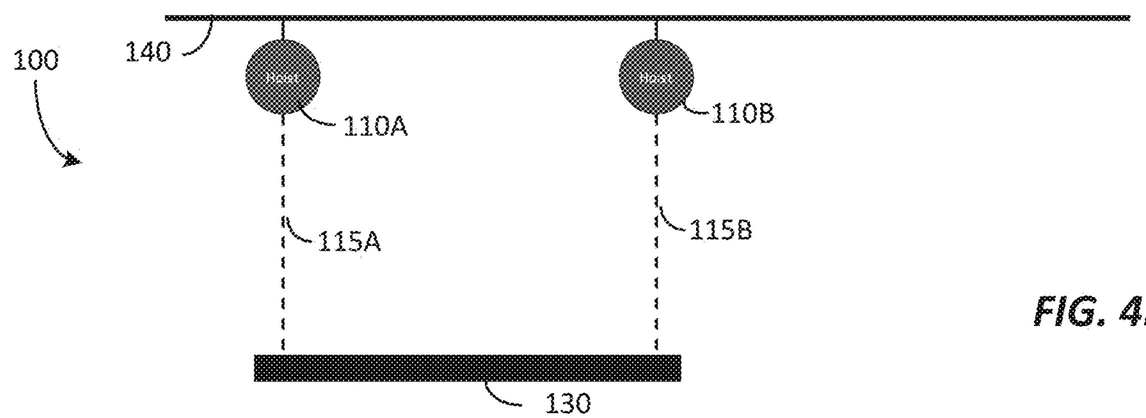


FIG. 4B

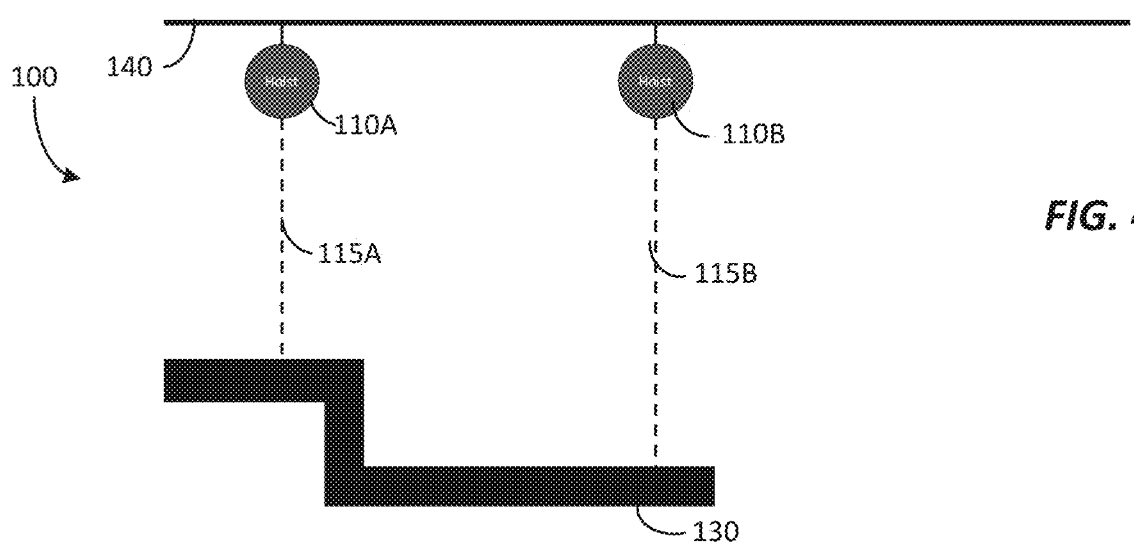


FIG. 4C

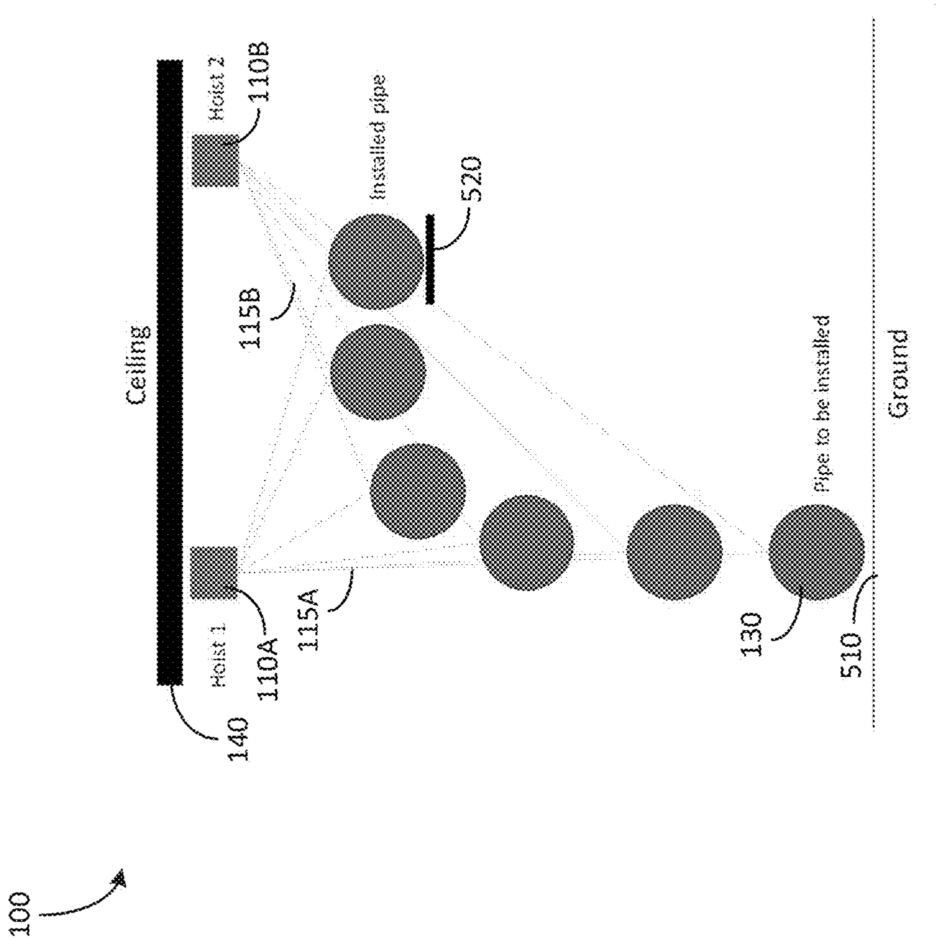

100
Ceiling
140
Hoist 1
110A
Hoist 2
110B
115A
115B
Installed pipe
520
Pipe to be installed
130
510
Ground

FIG. 5

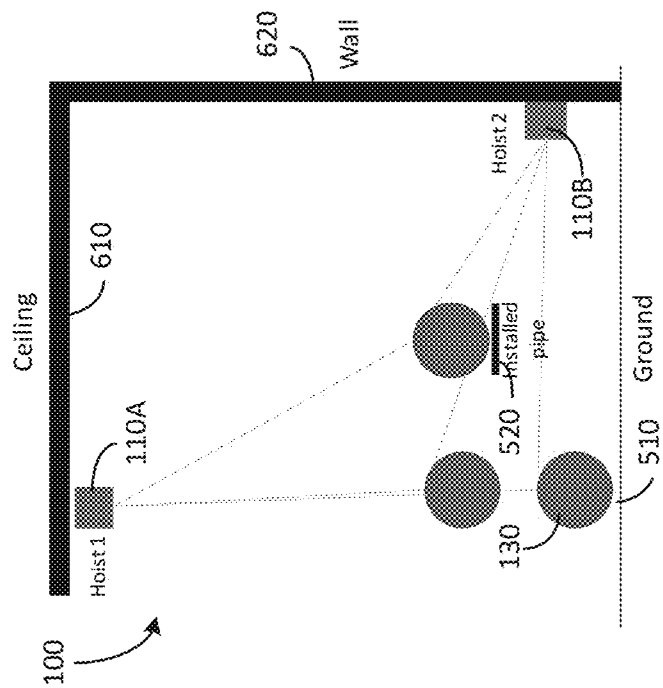

100
Ceiling
610
Wall
620
Hoist 1
110A
Hoist 2
110B
Installed pipe
520
510
130
Ground

FIG. 6A

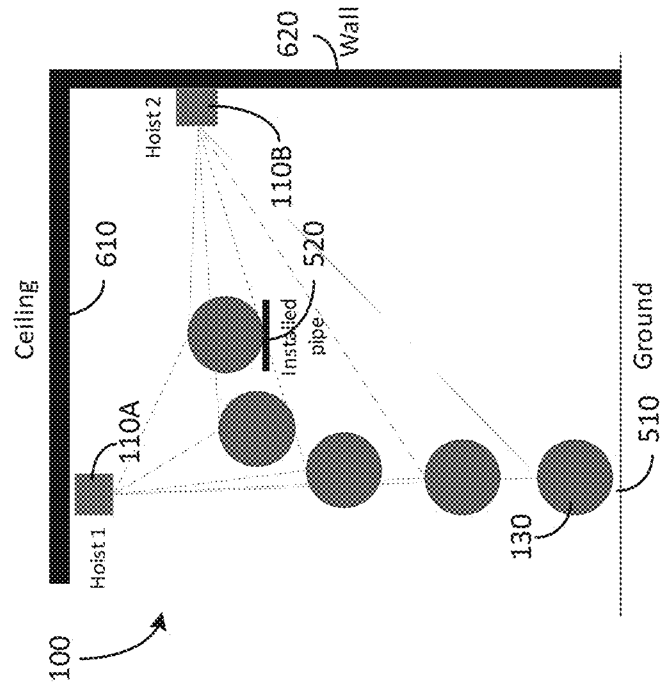

100
Ceiling
610
Wall
620
Hoist 1
110A
Hoist 2
110B
Installed pipe
520
510
130
Ground

FIG. 6B

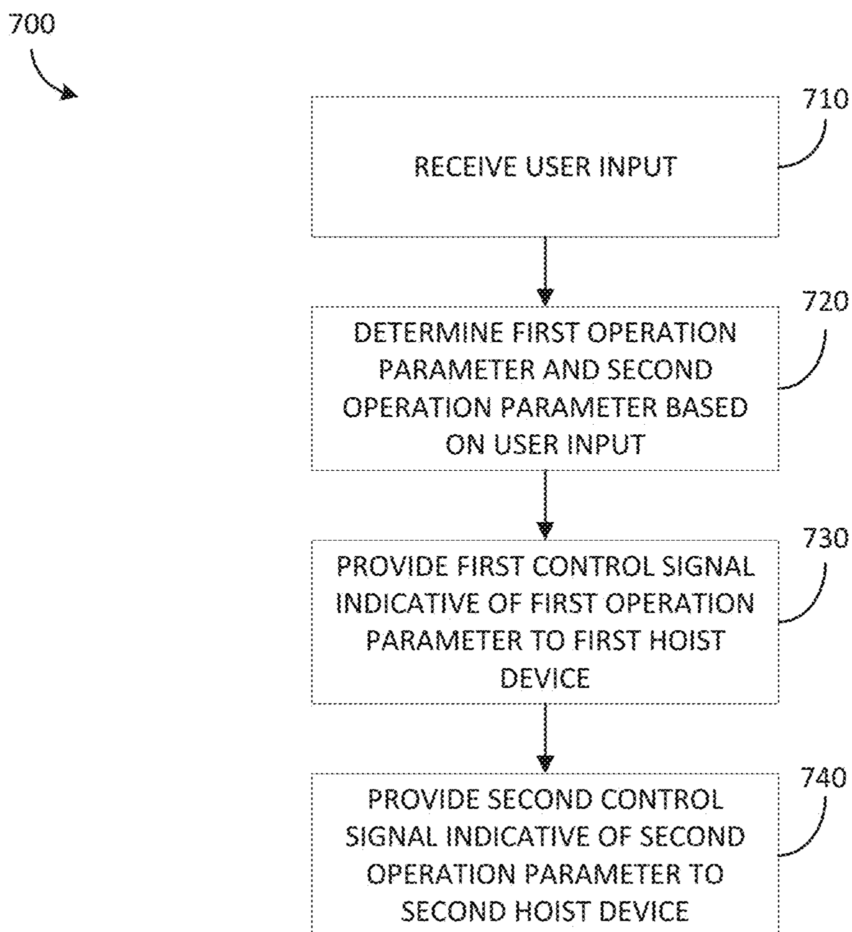

700
RECEIVE USER INPUT
710
DETERMINE FIRST OPERATION PARAMETER AND SECOND OPERATION PARAMETER BASED ON USER INPUT
720
PROVIDE FIRST CONTROL SIGNAL INDICATIVE OF FIRST OPERATION PARAMETER TO FIRST HOIST DEVICE
730
PROVIDE SECOND CONTROL SIGNAL INDICATIVE OF SECOND OPERATION PARAMETER TO SECOND HOIST DEVICE
740

FIG. 7

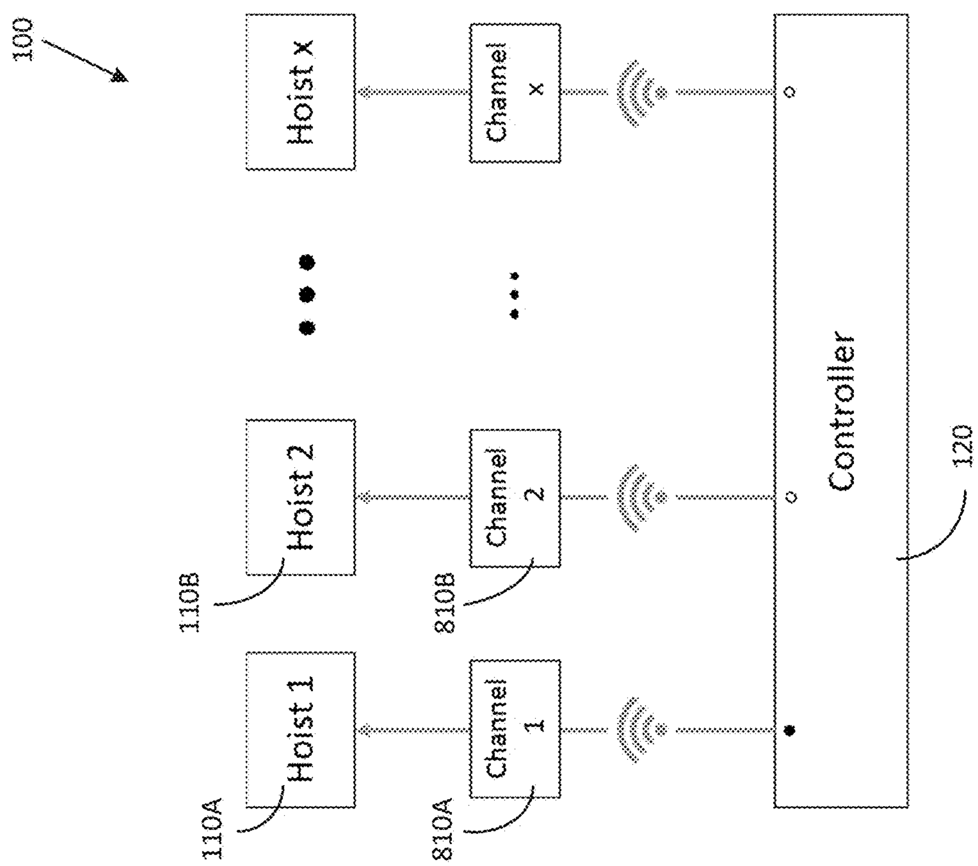

100
Hoist x
Channel x
Hoist 2
Channel 2
Hoist 1
Channel 1
110B
810B
110A
810A
Controller
120

FIG. 8

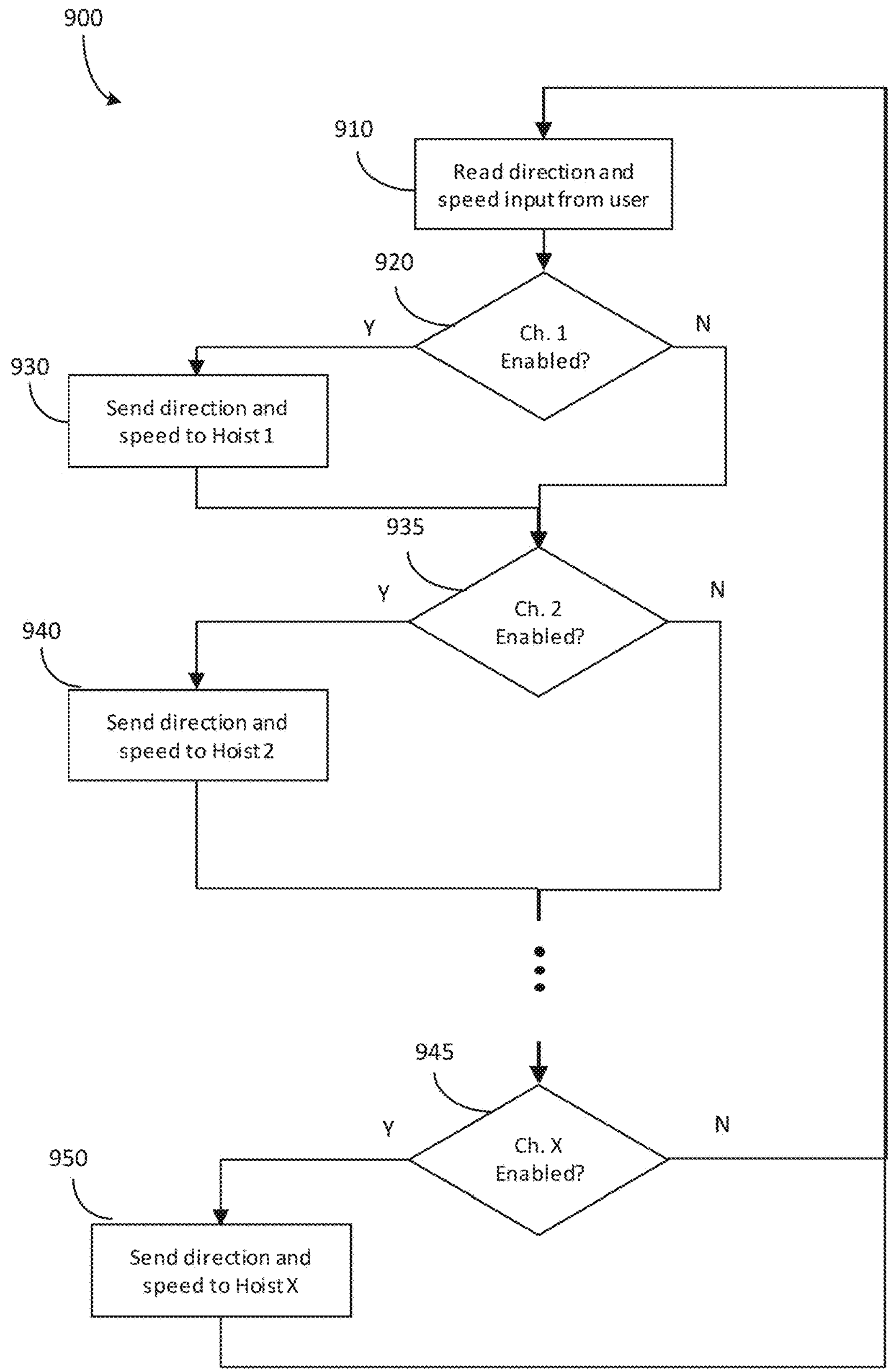

900
910
Read direction and speed input from user
920
Ch. 1 Enabled?
Y
N
930
Send direction and speed to Hoist 1
935
Ch. 2 Enabled?
Y
N
940
Send direction and speed to Hoist 2
945
Ch. X Enabled?
Y
N
950
Send direction and speed to Hoist X

FIG. 9

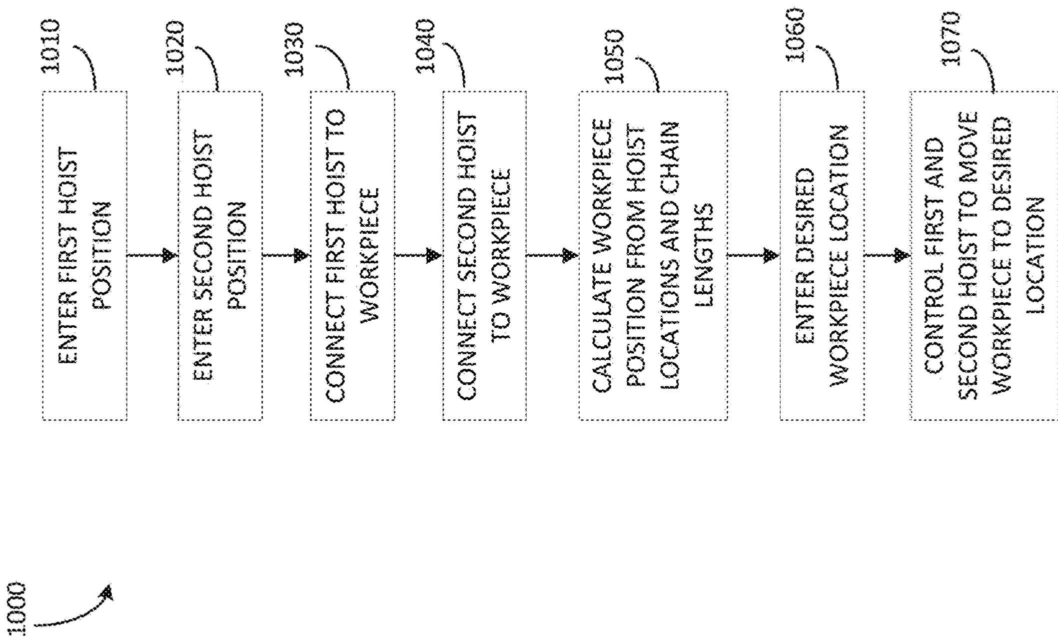

1000
1010
ENTER FIRST HOIST POSITION
1020
ENTER SECOND HOIST POSITION
1030
CONNECT FIRST HOIST TO WORKPIECE
1040
CONNECT SECOND HOIST TO WORKPIECE
1050
CALCULATE WORKPIECE POSITION FROM HOIST LOCATIONS AND CHAIN LENGTHS
1060
ENTER DESIRED WORKPIECE LOCATION
1070
CONTROL FIRST AND SECOND HOIST TO MOVE WORKPIECE TO DESIRED LOCATION

FIG. 10

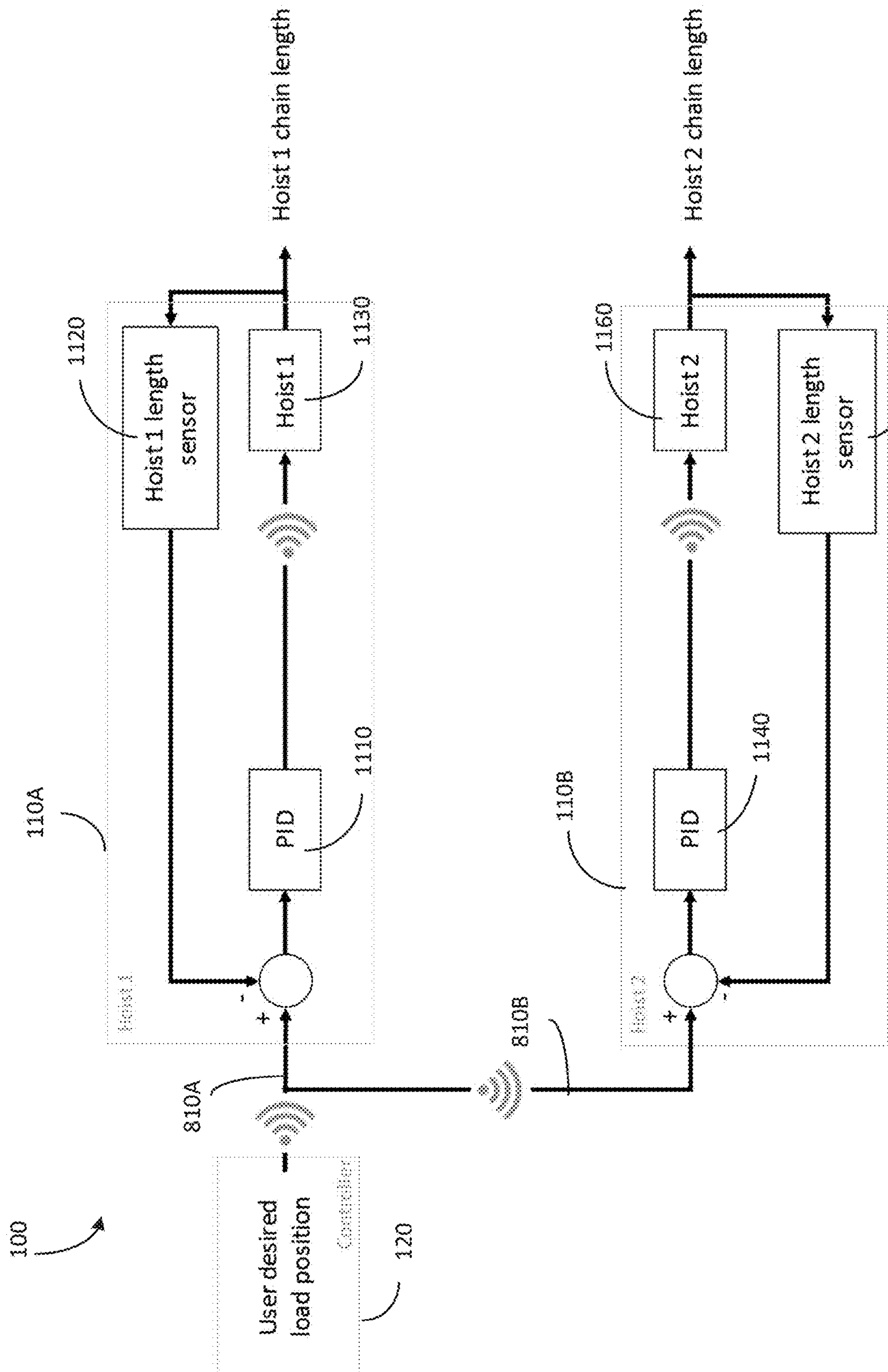

100
User desired load position
120
810A
810B
110A
110B
PID
1110
PID
1140
Hoist 1 length sensor
1120
Hoist 1
1130
Hoist 2
1160
Hoist 2 length sensor
1150
Hoist 1 chain length
Hoist 2 chain length
+
-
+
-

FIG. 11

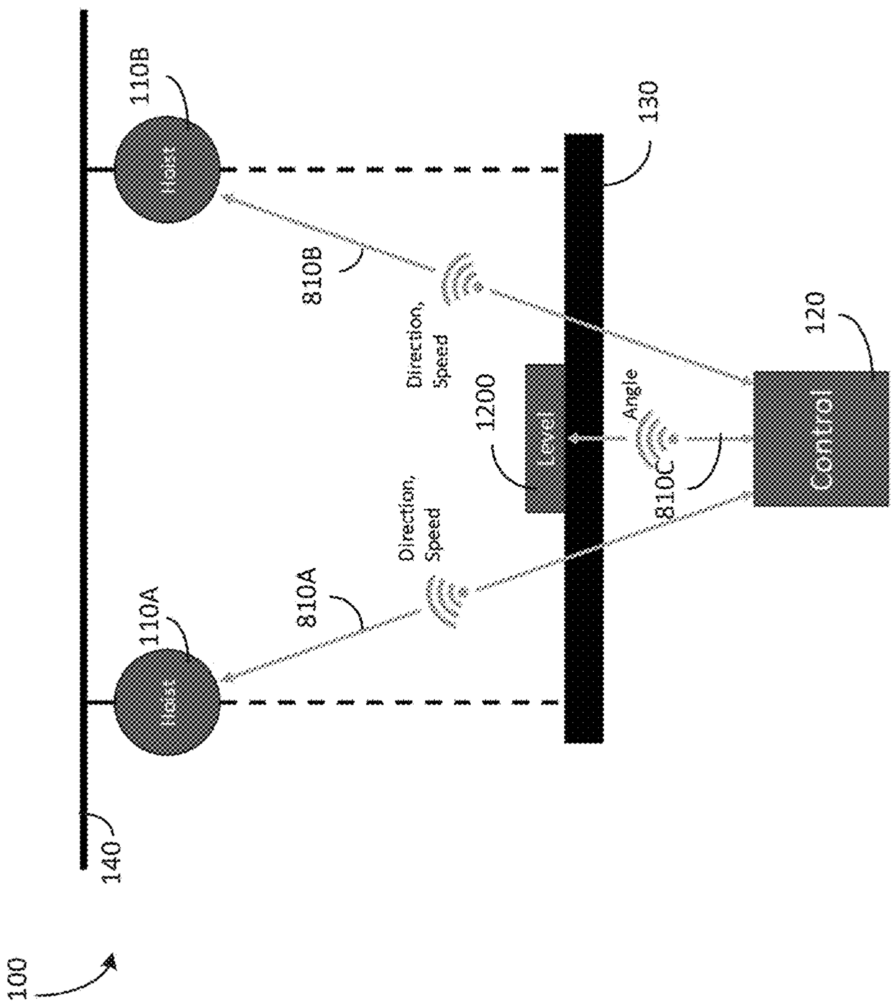

100
140
110A
110B
130
810A
810B
Direction, Speed
Direction, Speed
1200
Level
Angle
810C
120
Control

FIG. 12

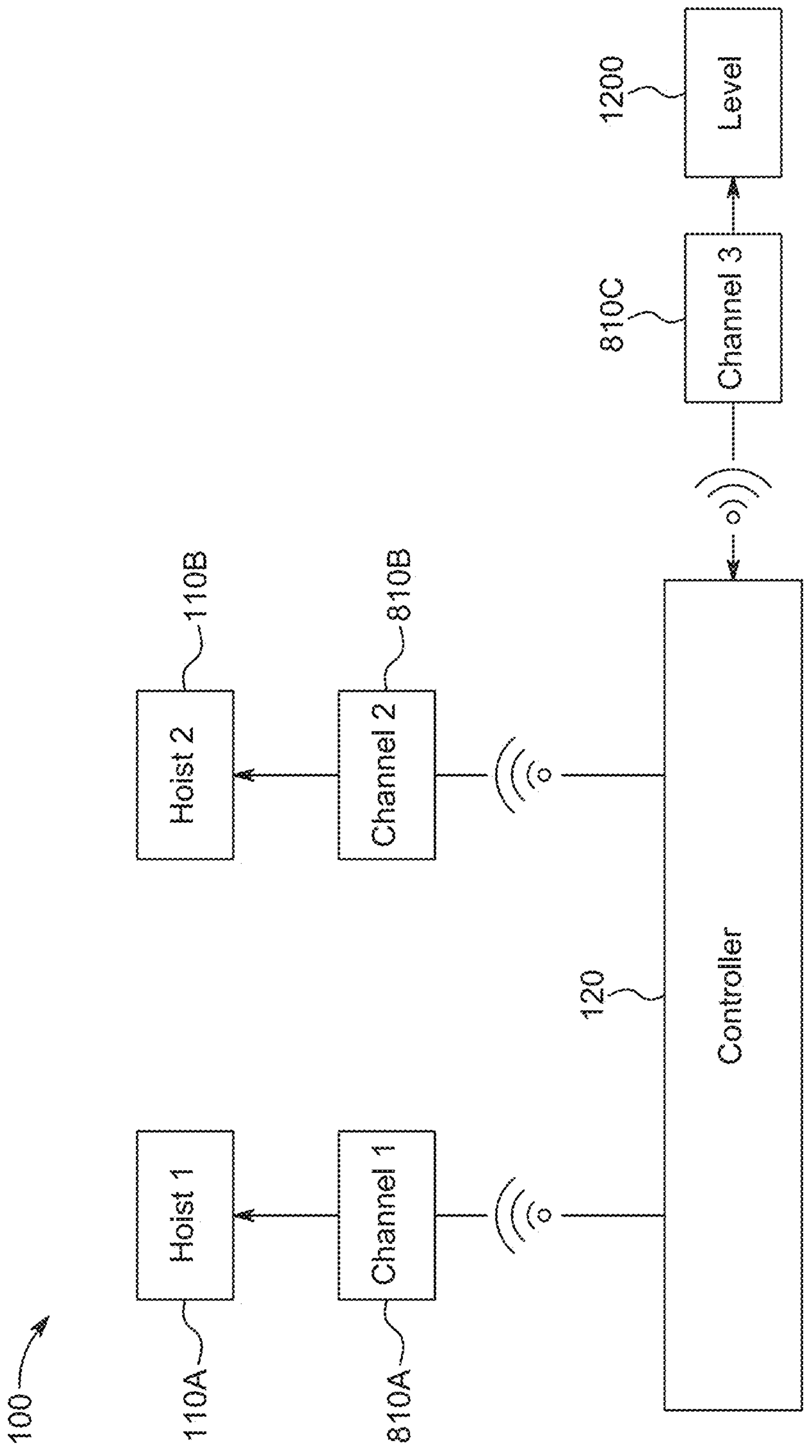

100
Hoist 1
110A
Channel 1
810A
Hoist 2
110B
Channel 2
810B
Controller
120
Channel 3
810C
Level
1200

FIG. 13

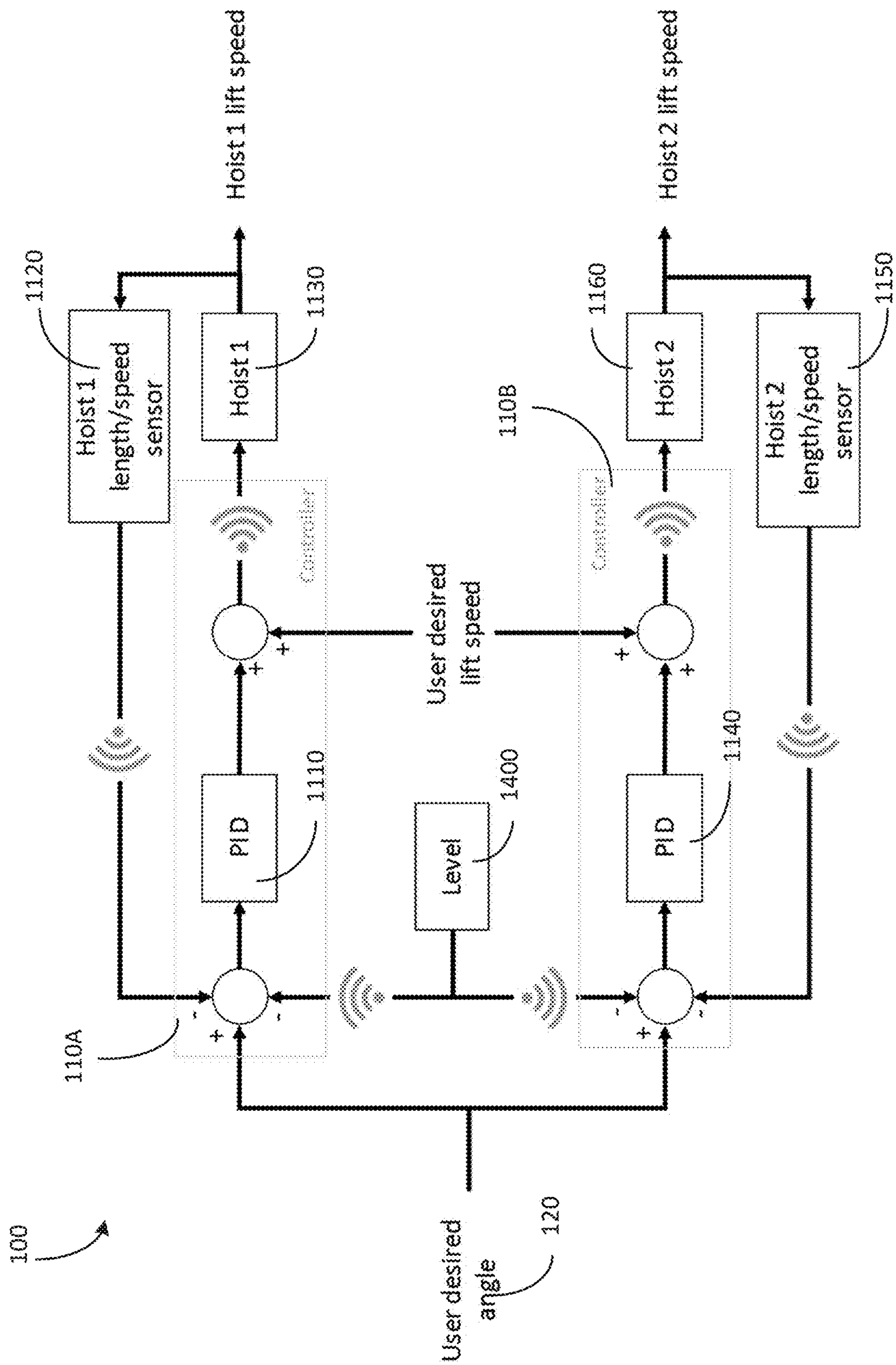

Hoist 1 lift speed
Hoist 2 lift speed
1120
Hoist 1 length/speed sensor
1130
Hoist 1
1160
Hoist 2
1150
Hoist 2 length/speed sensor
110B
Controller
User desired lift speed
PID
1110
Level
1400
PID
1140
110A
100
User desired angle
120

FIG. 14

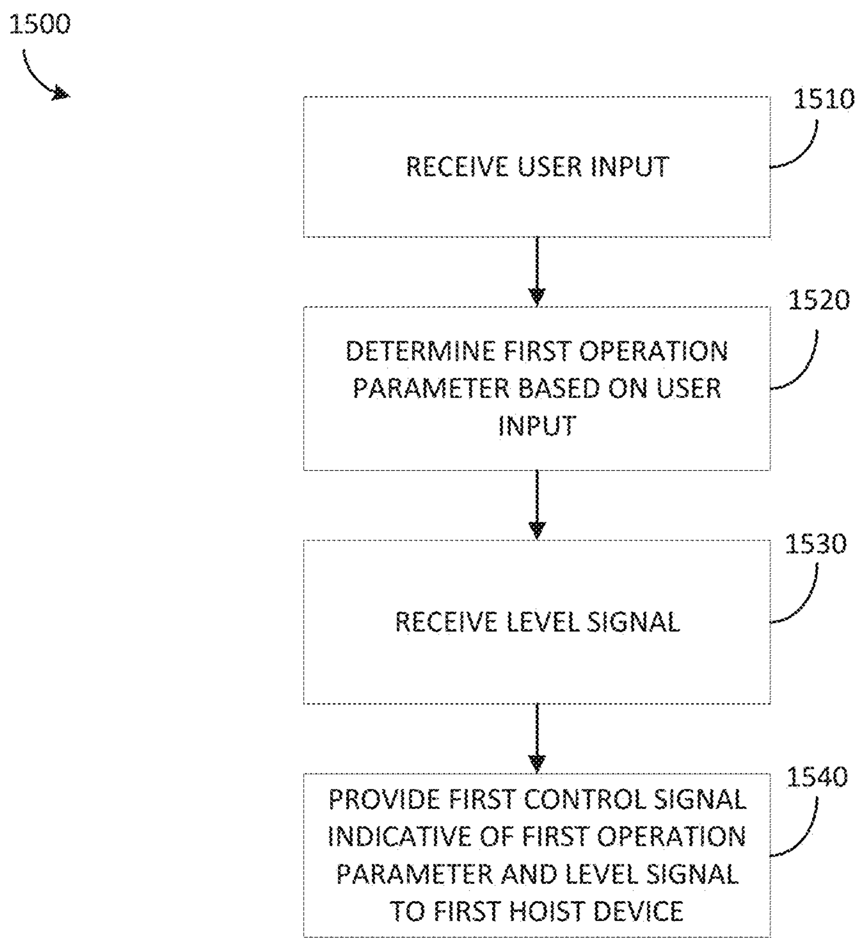

1500
1510
RECEIVE USER INPUT
1520
DETERMINE FIRST OPERATION PARAMETER BASED ON USER INPUT
1530
RECEIVE LEVEL SIGNAL
1540
PROVIDE FIRST CONTROL SIGNAL INDICATIVE OF FIRST OPERATION PARAMETER AND LEVEL SIGNAL TO FIRST HOIST DEVICE

FIG. 15

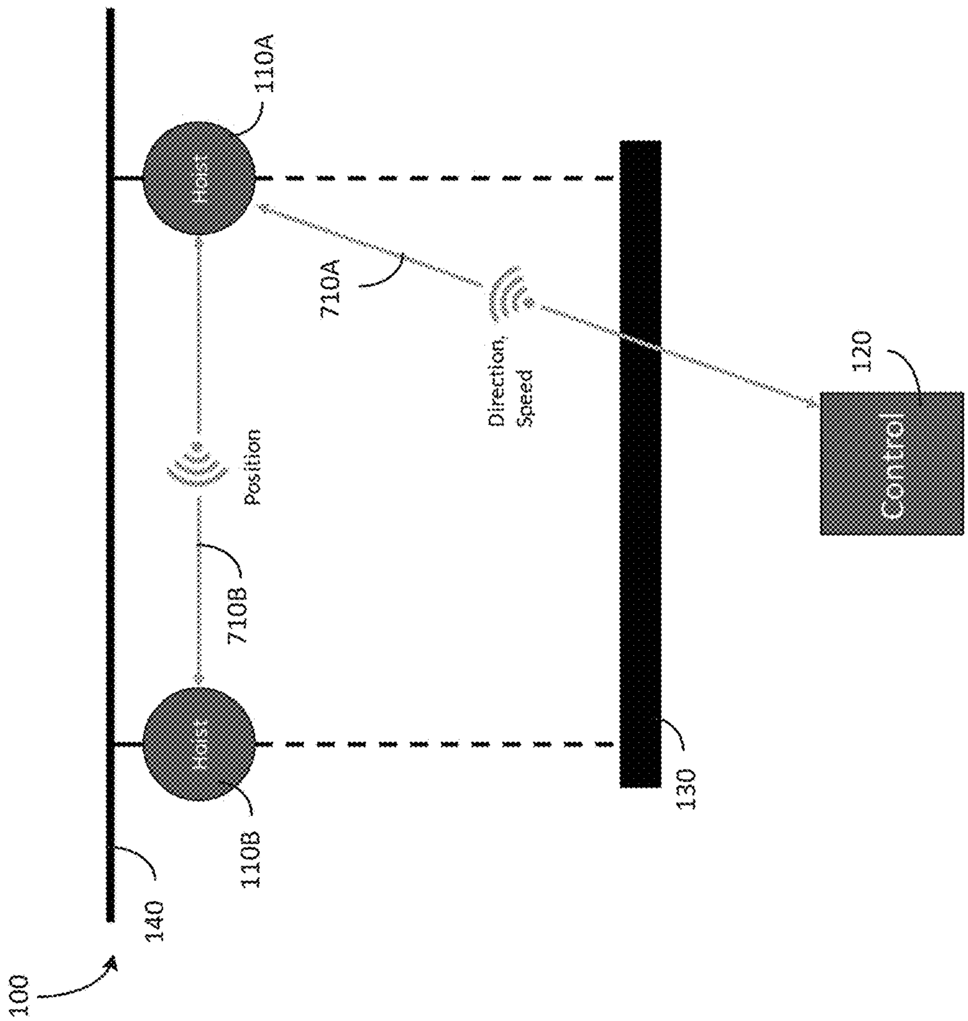

100
140
110A
110B
Hoist
Hoist
710A
710B
Position
Direction,
Speed
120
Control
130

FIG. 16

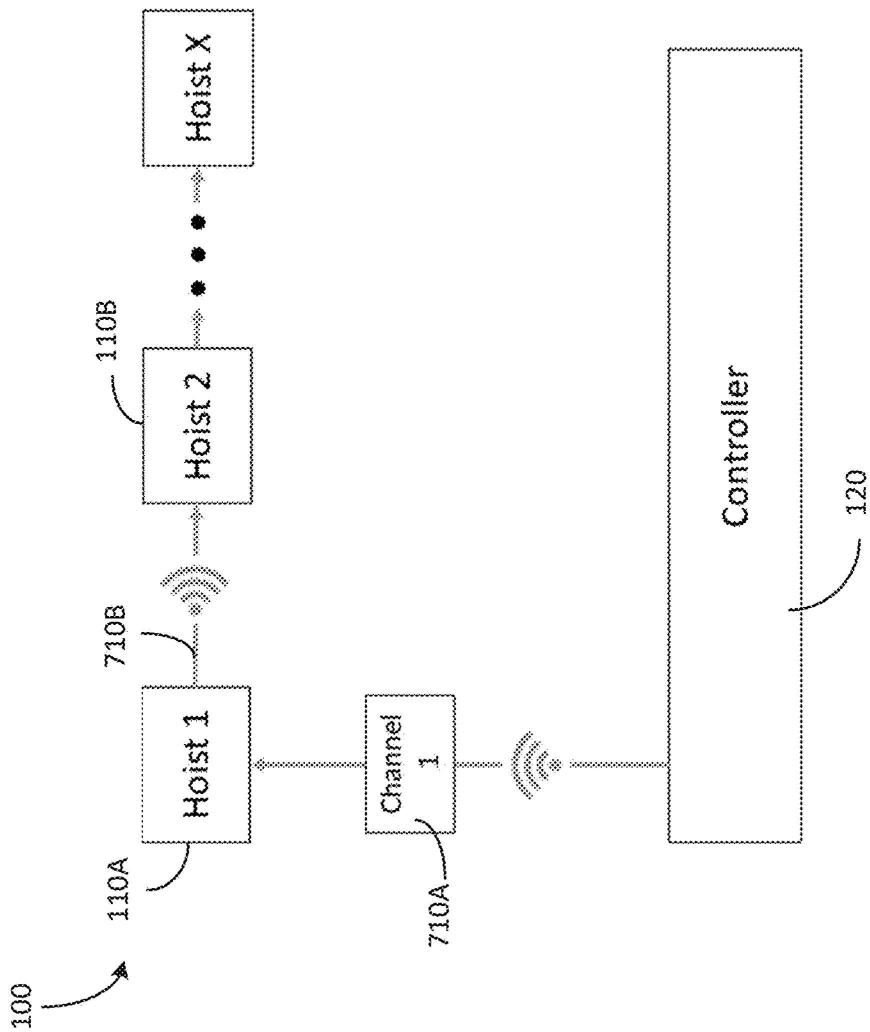

100
110A
Hoist 1
710B
110B
Hoist 2
Hoist X
Channel 1
710A
Controller
120

FIG. 17

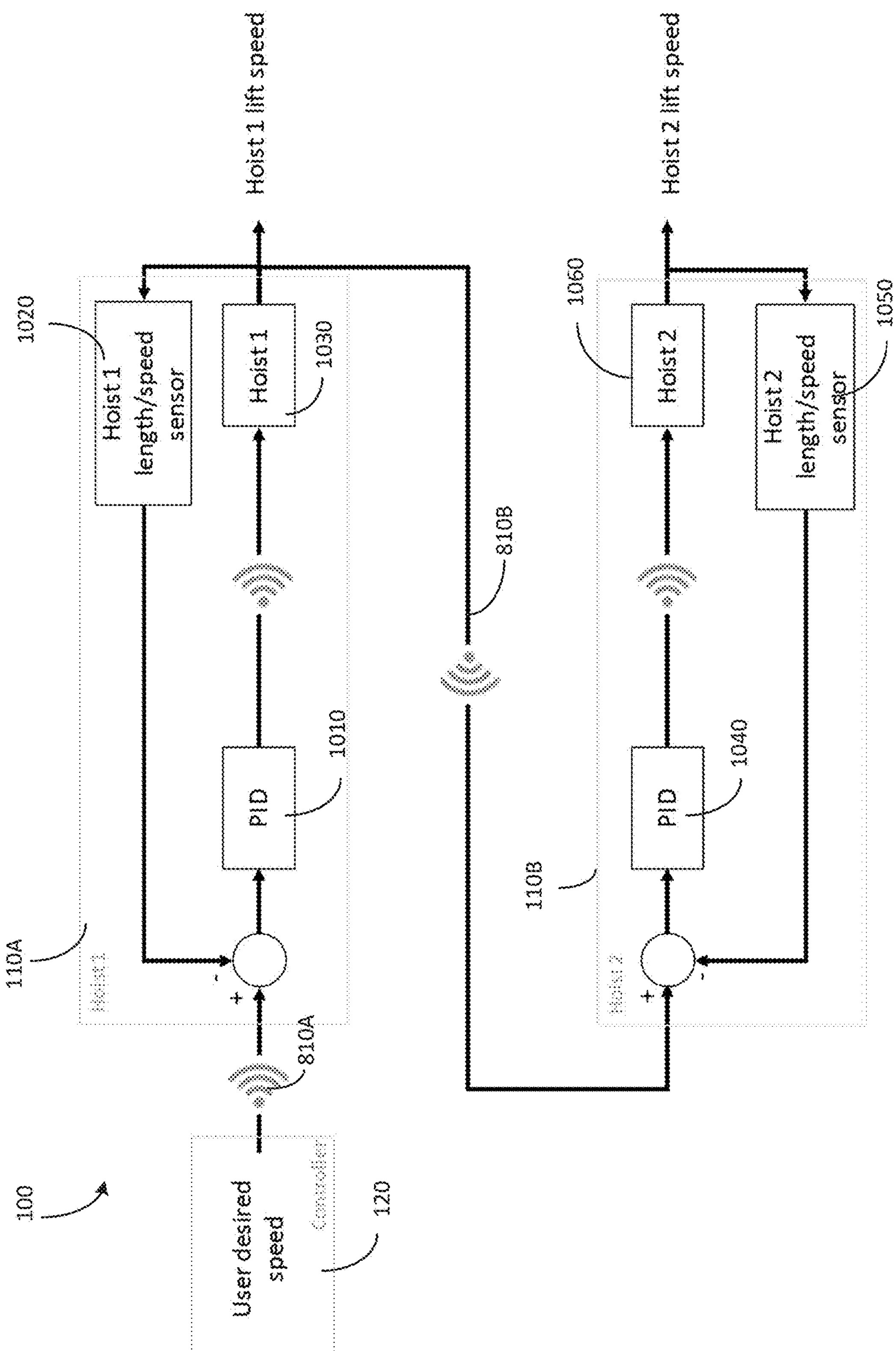

Hoist 1 lift speed
Hoist 2 lift speed
1020
Hoist 1 length/speed sensor
Hoist 1
1030
1060
Hoist 2
1050
Hoist 2 length/speed sensor
810B
PID
1010
PID
1040
110A
110B
+
-
+
-
810A
User desired speed
120
100

FIG. 18

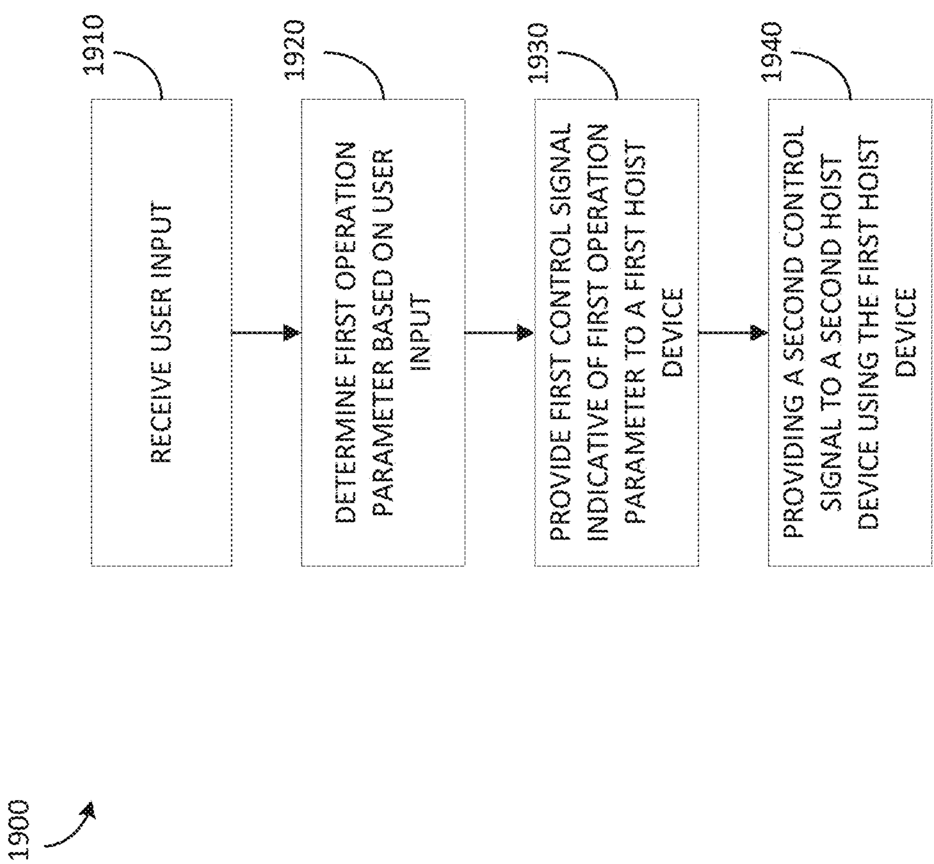

1900
1910
RECEIVE USER INPUT
1920
DETERMINE FIRST OPERATION PARAMETER BASED ON USER INPUT
1930
PROVIDE FIRST CONTROL SIGNAL INDICATIVE OF FIRST OPERATION PARAMETER TO A FIRST HOIST DEVICE
1940
PROVIDING A SECOND CONTROL SIGNAL TO A SECOND HOIST DEVICE USING THE FIRST HOIST DEVICE

FIG. 19

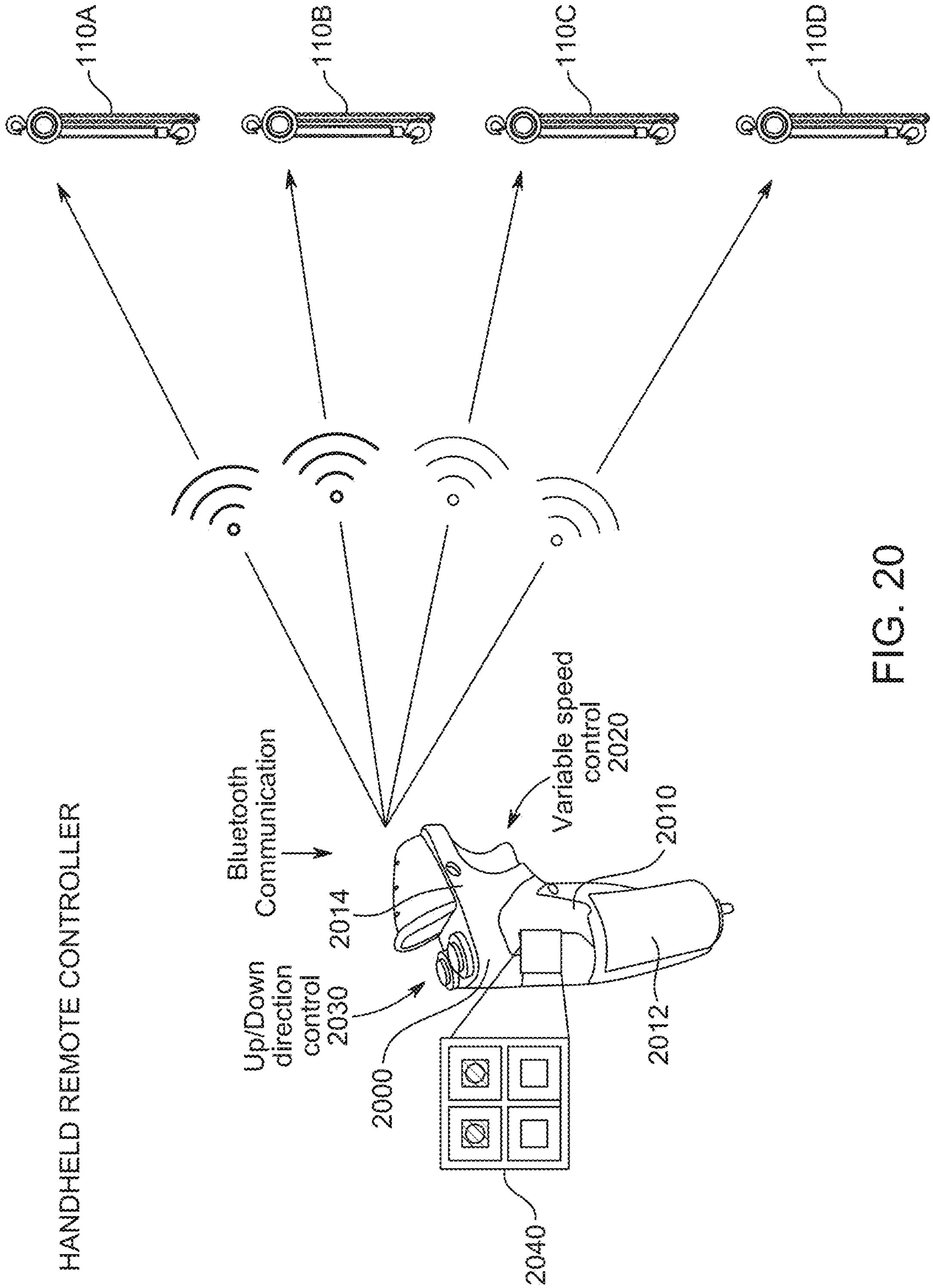

HANDHELD REMOTE CONTROLLER
110A
110B
110C
110D
Bluetooth Communication
Variable speed control 2020
2010
2014
2012
Up/Down direction control 2030
2000
2040

FIG. 20

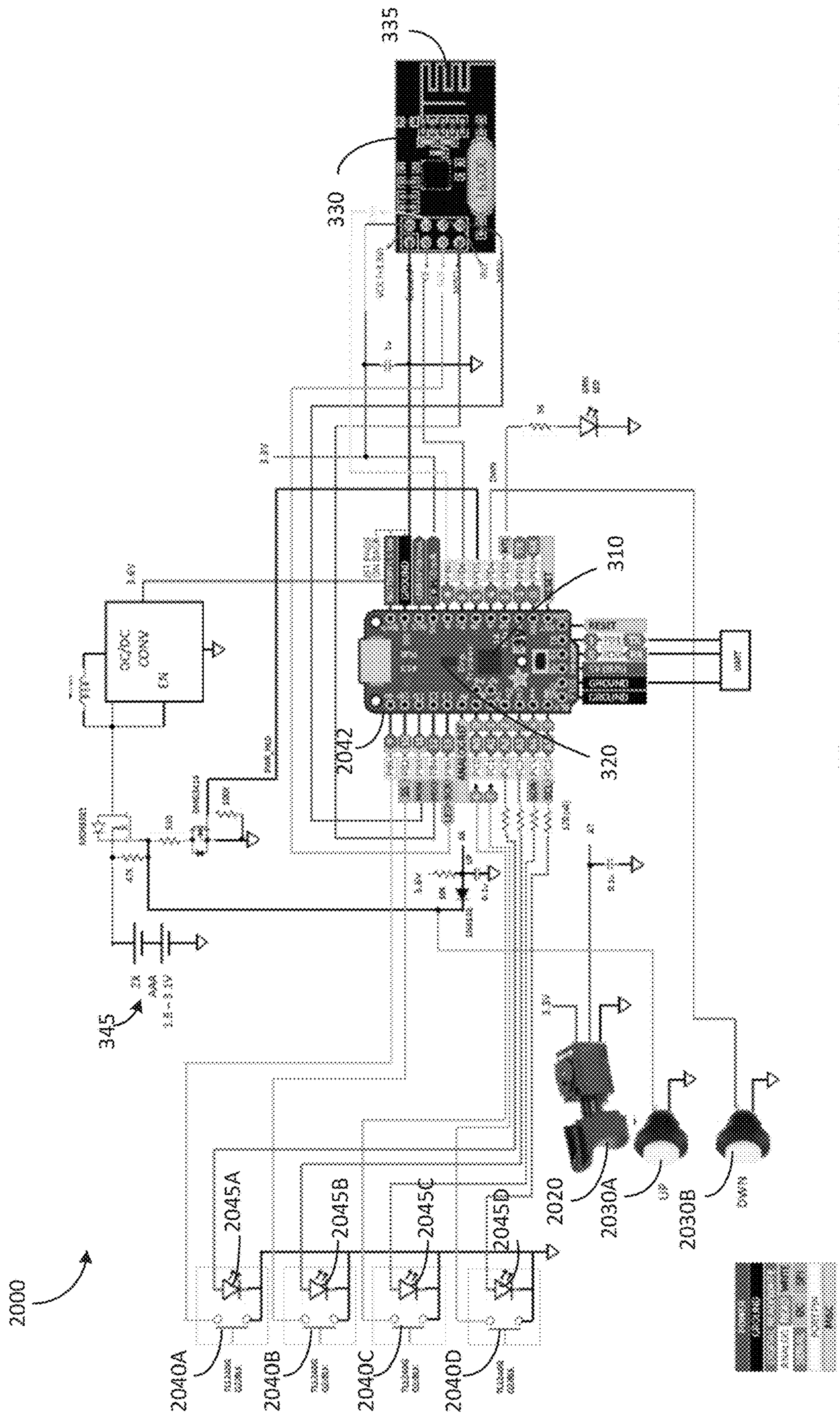

335
330
310
320
2042
345
2000
2020
2030A
2030B
2045A
2045B
2045C
2045D
2040A
2040B
2040C
2040D

FIG. 21

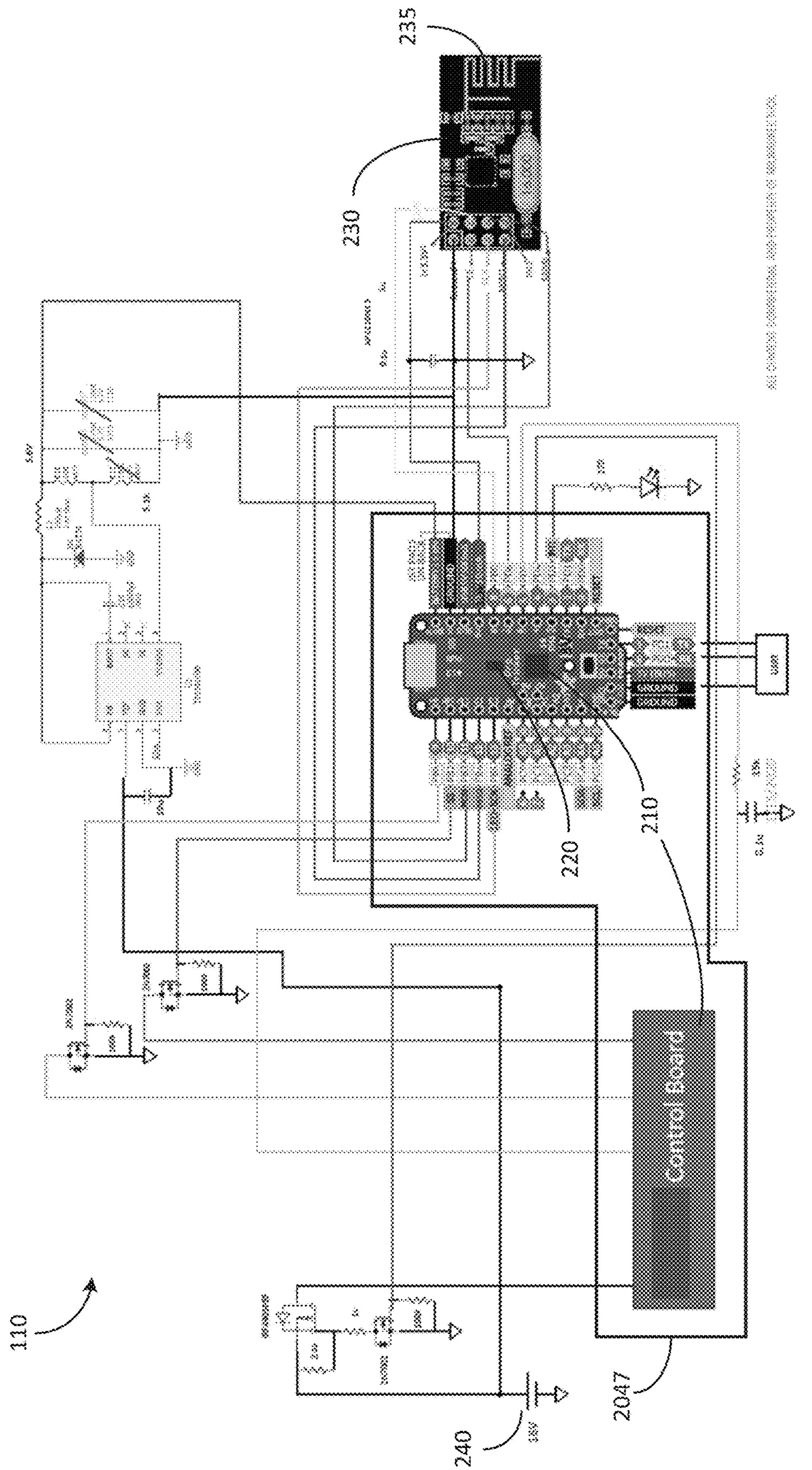
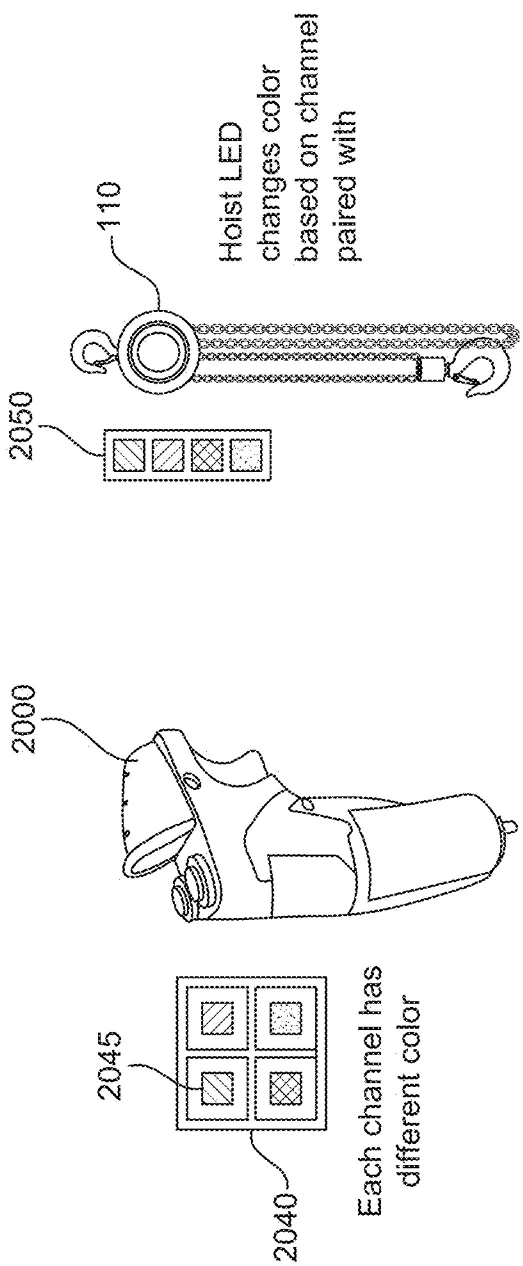


FIG. 22



110
Hoist LED changes color based on channel paired with
2050
2000
2045
2040
Each channel has different color

FIG. 23

2400

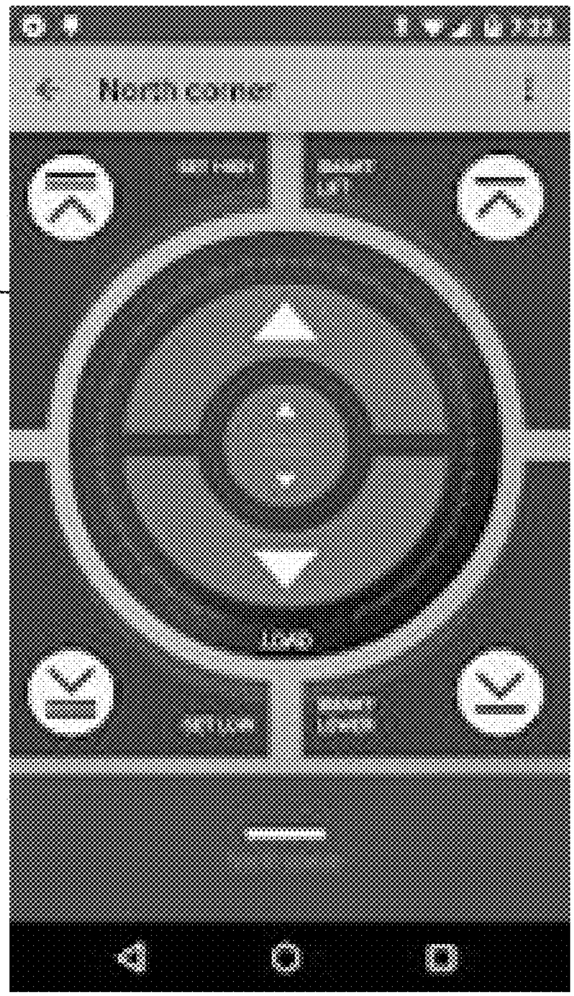


FIG. 24

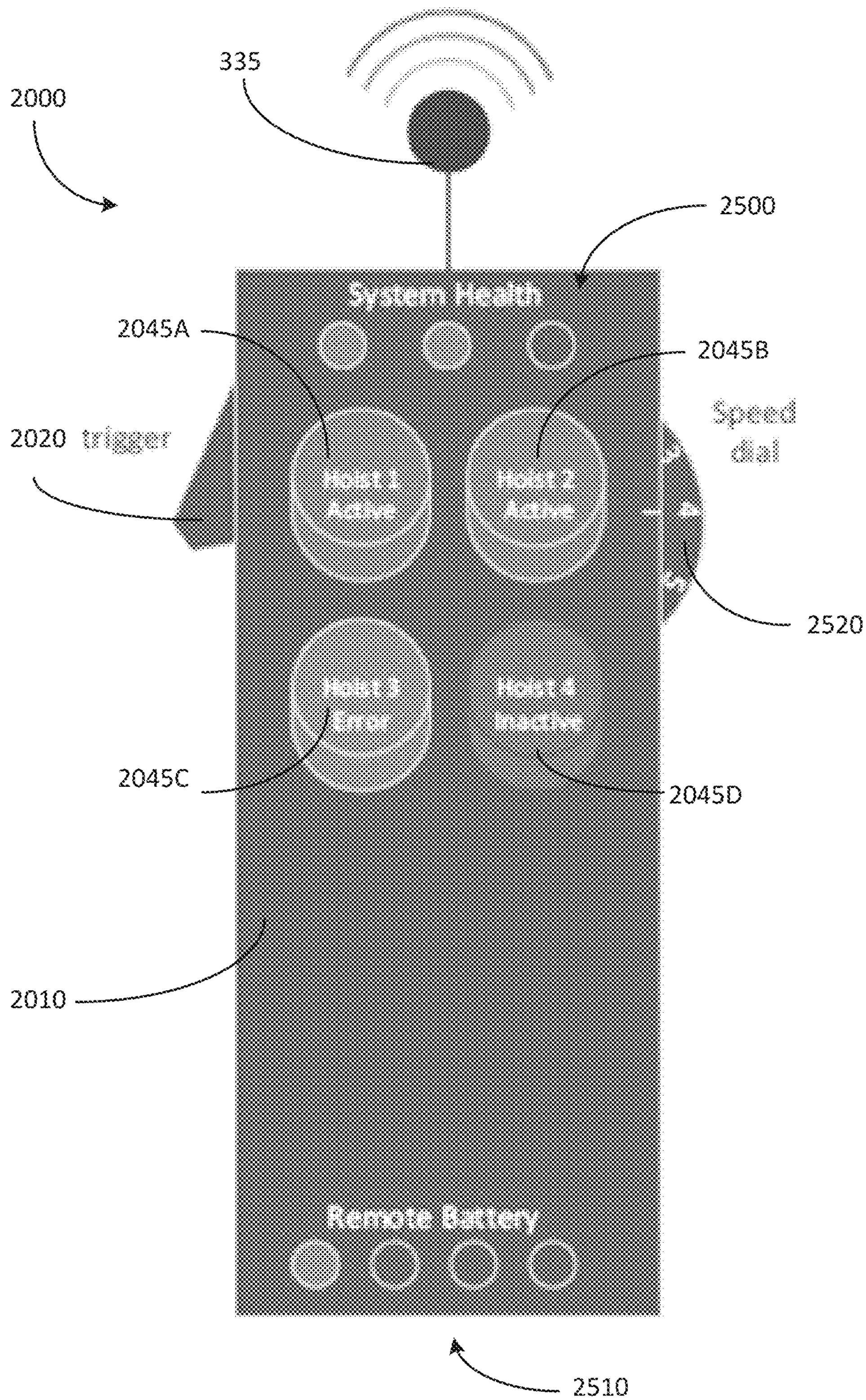

335
2000
2500
System Health
2045A
2045B
Speed
dial
2020 trigger
Hoist 1
Active
Hoist 2
Active
2520
Hoist 3
Error
Hoist 4
Inactive
2045C
2045D
2010
Remote Battery
2510

FIG. 25A

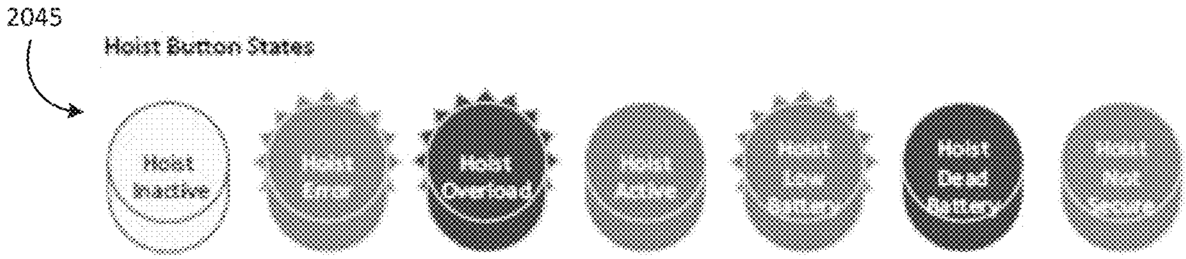


FIG. 25B

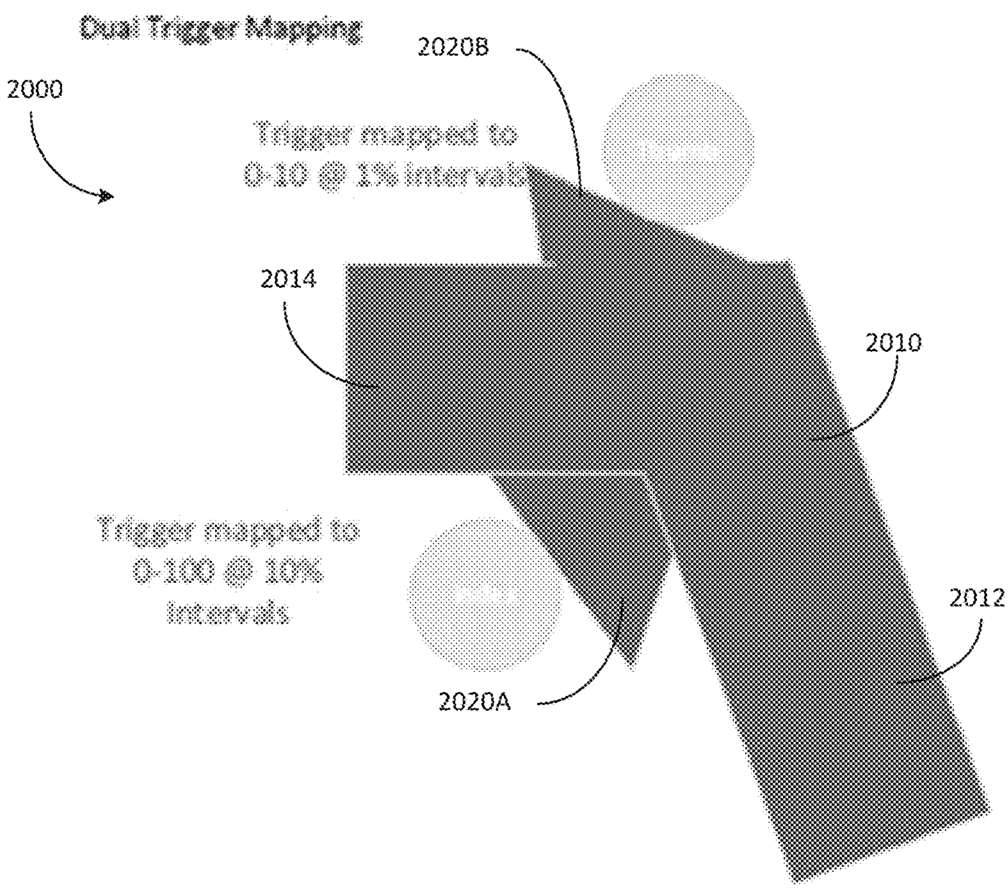


FIG. 25C

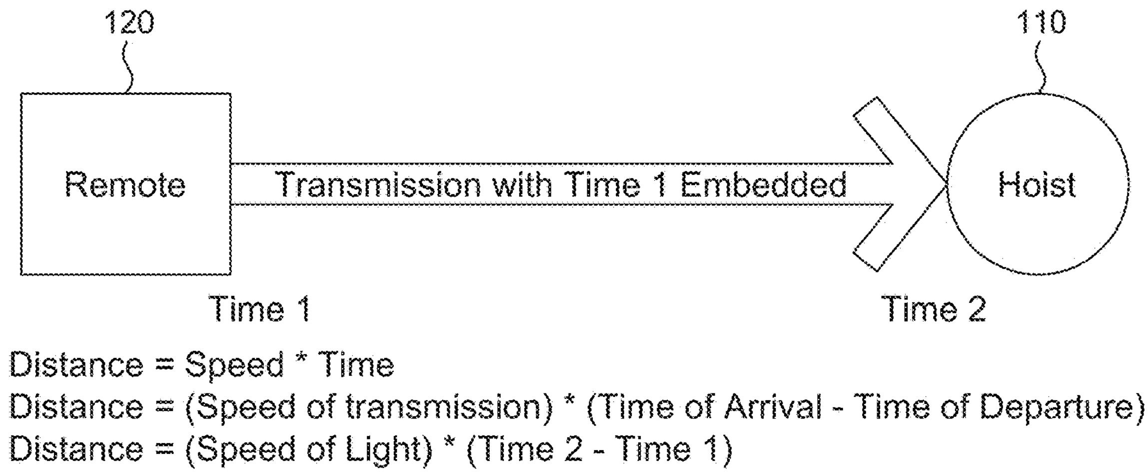


FIG. 26A

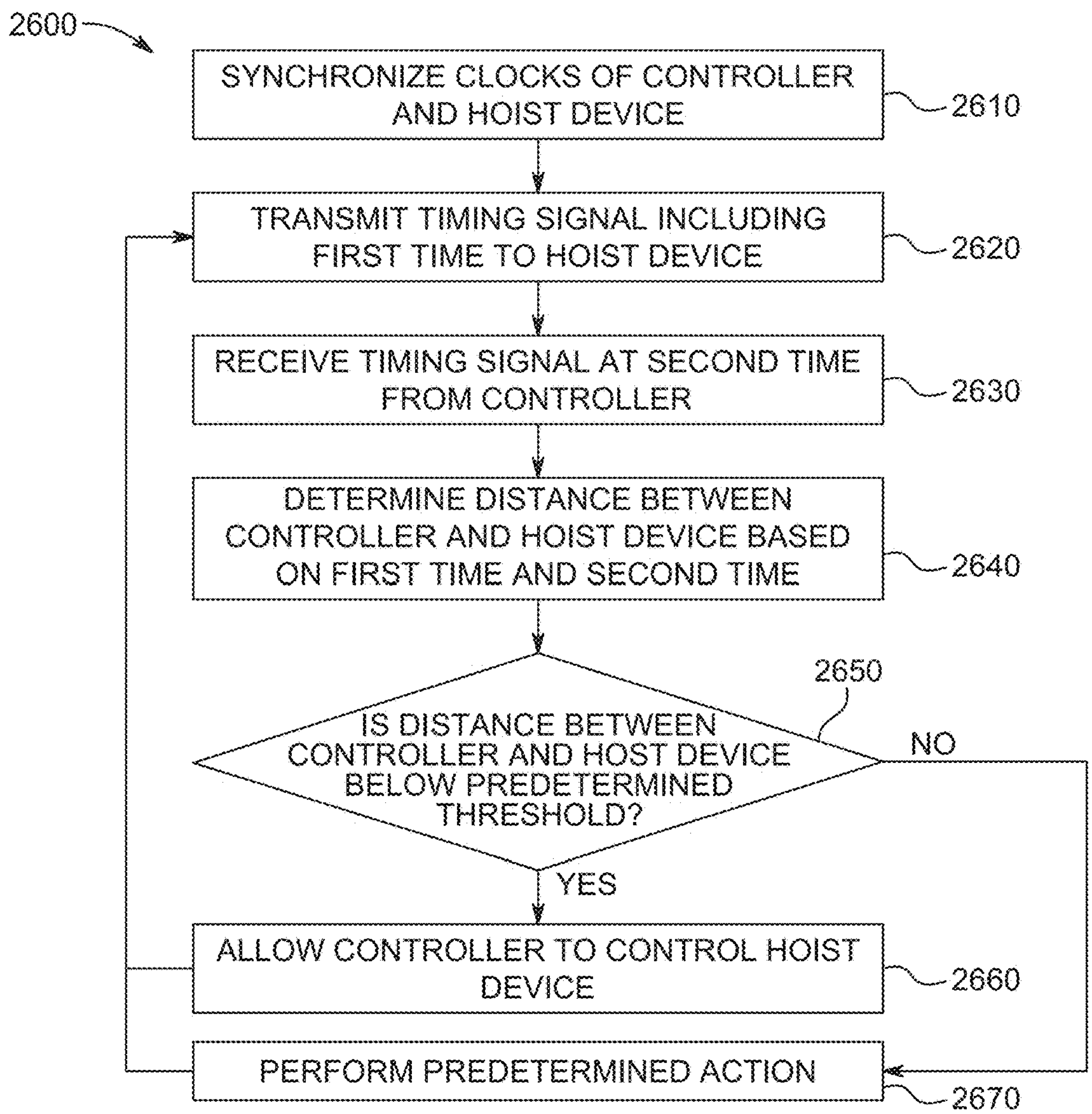


FIG. 26B

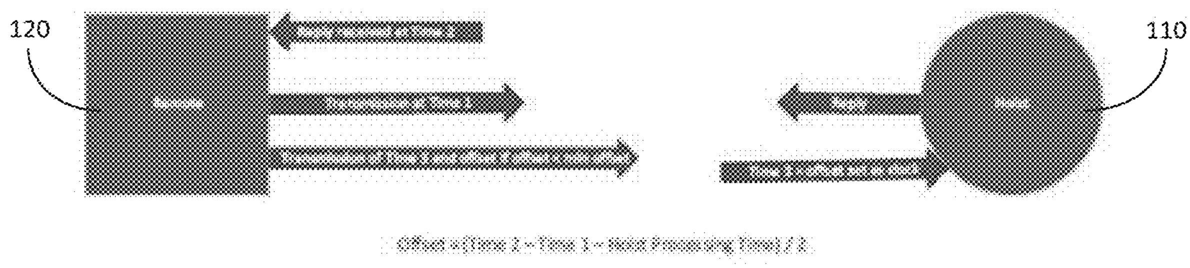


FIG. 27A

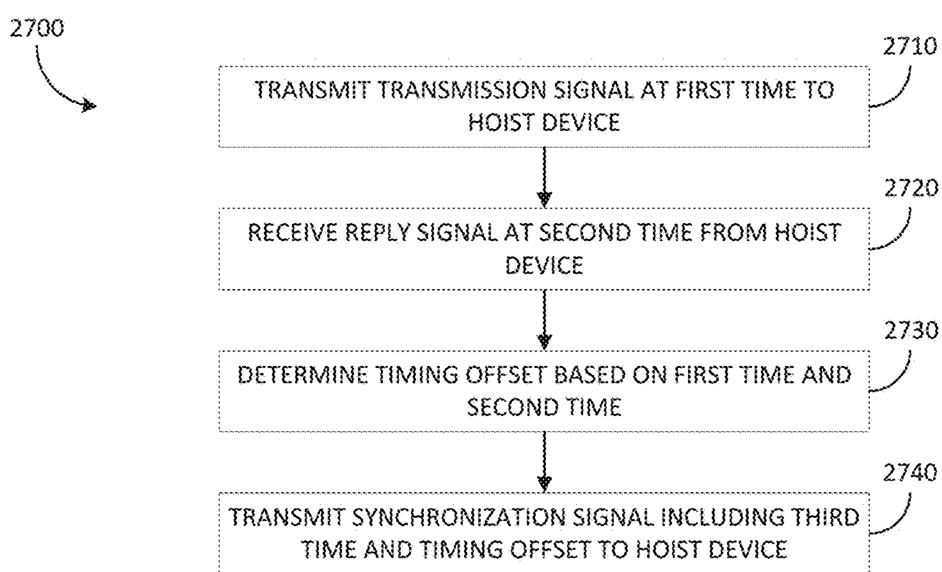


FIG. 27B

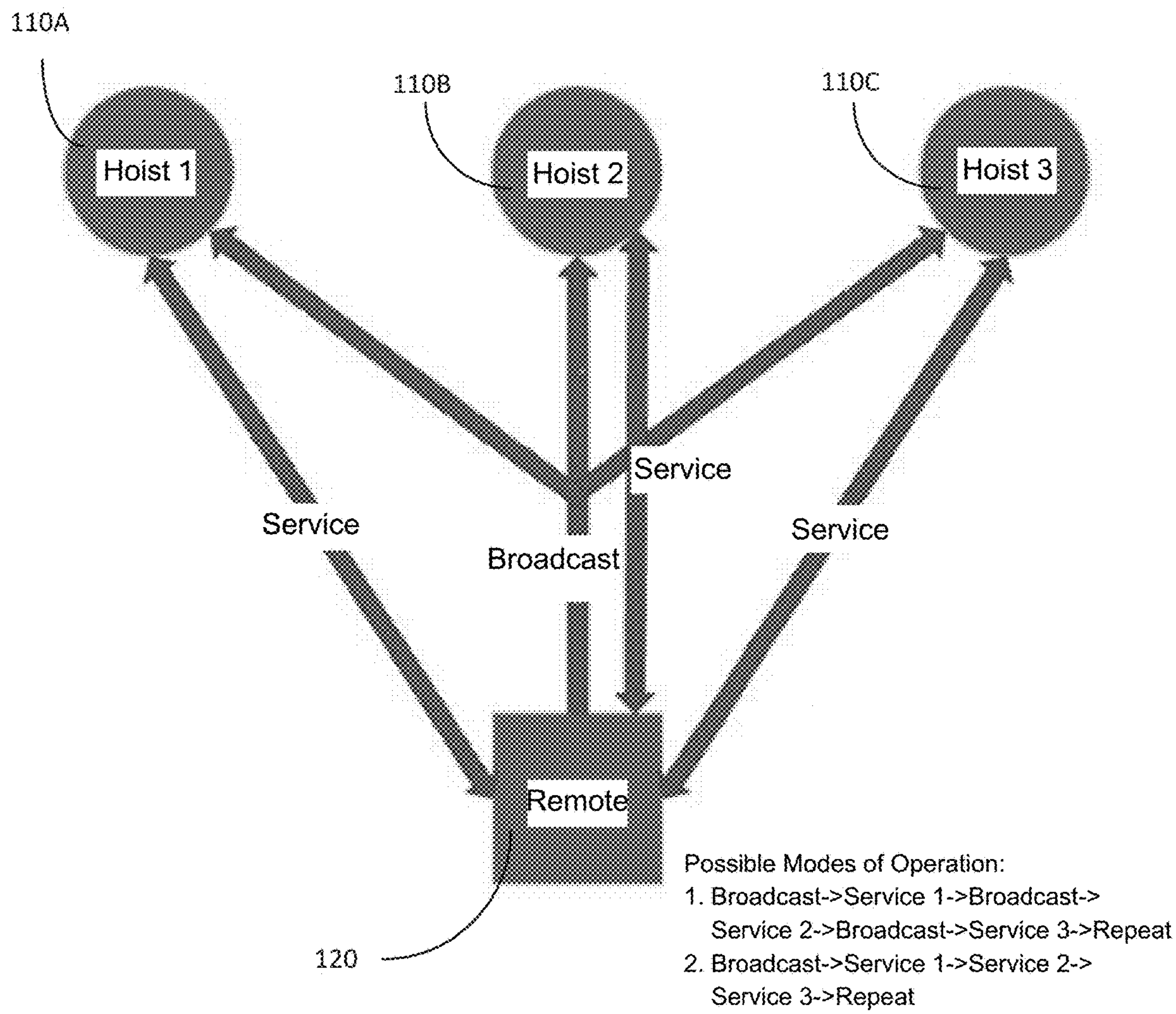

110A
110B
110C
Hoist 1
Hoist 2
Hoist 3
Service
Broadcast
Service
Service
Remote
120
Possible Modes of Operation:
1. Broadcast->Service 1->Broadcast->
Service 2->Broadcast->Service 3->Repeat
2. Broadcast->Service 1->Service 2->
Service 3->Repeat

FIG. 28A

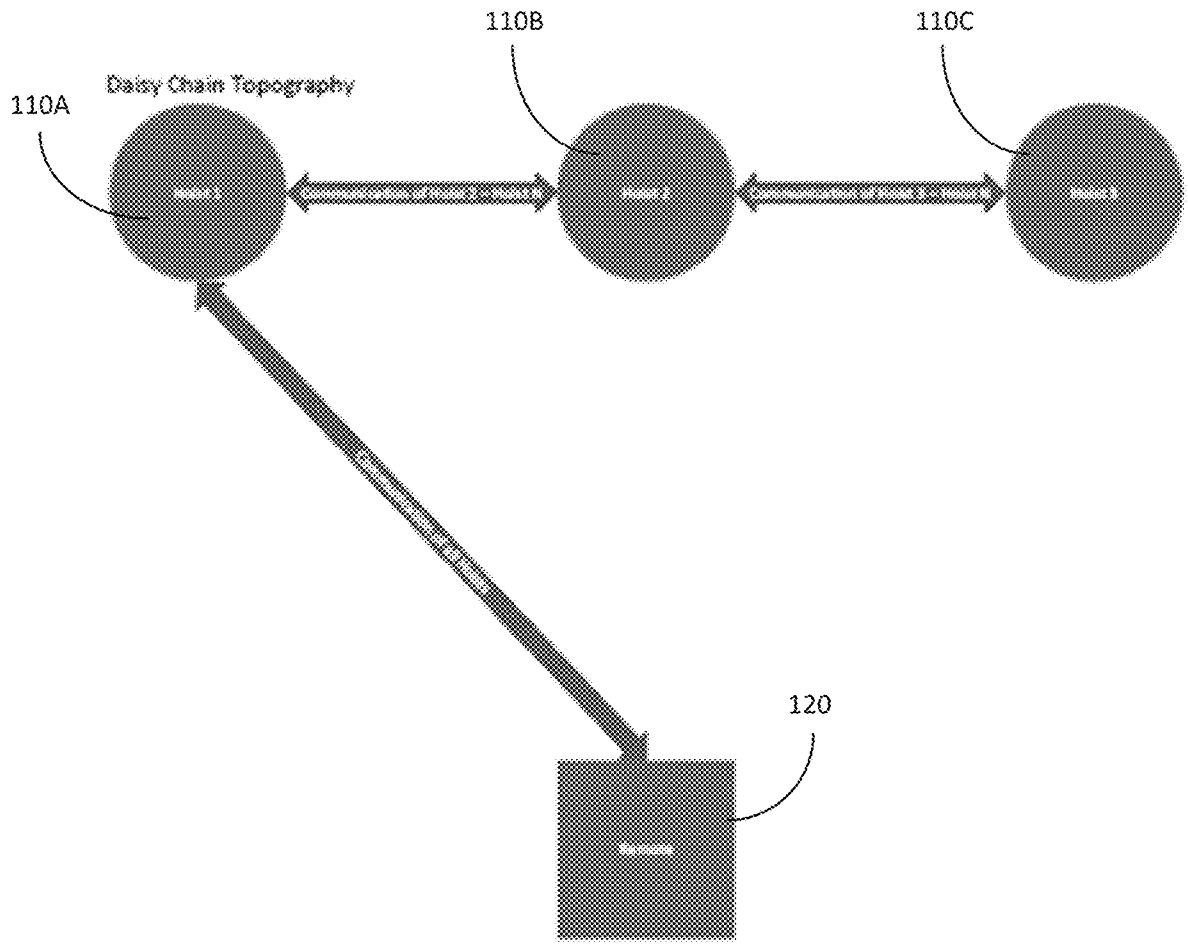


FIG. 28B

Broadcast Packet Example:

Identifier	Command	Timestamp	Padding	Checksum

Service Packet Example from Hoist

Identifier	Distance of Hoist	Operation in Progress	Statuses	Checksum

FIG. 28C

Pairing Process

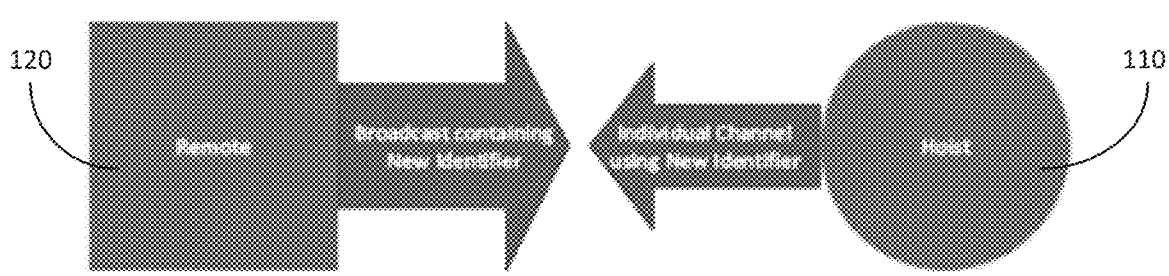


FIG. 28D

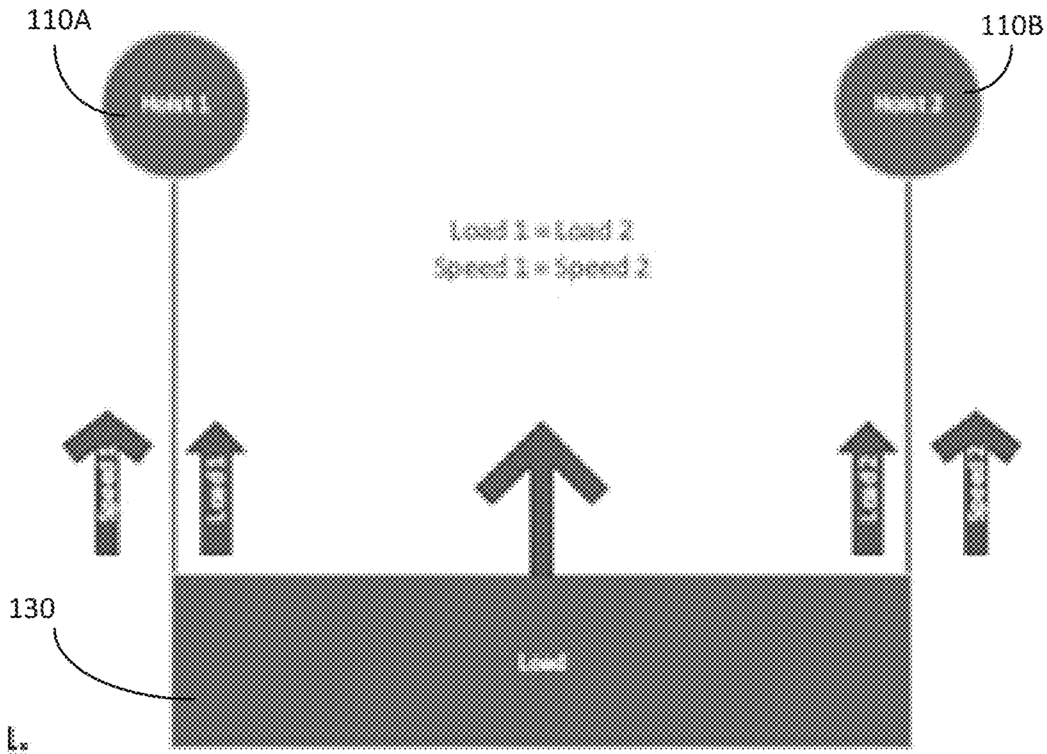


FIG. 29A

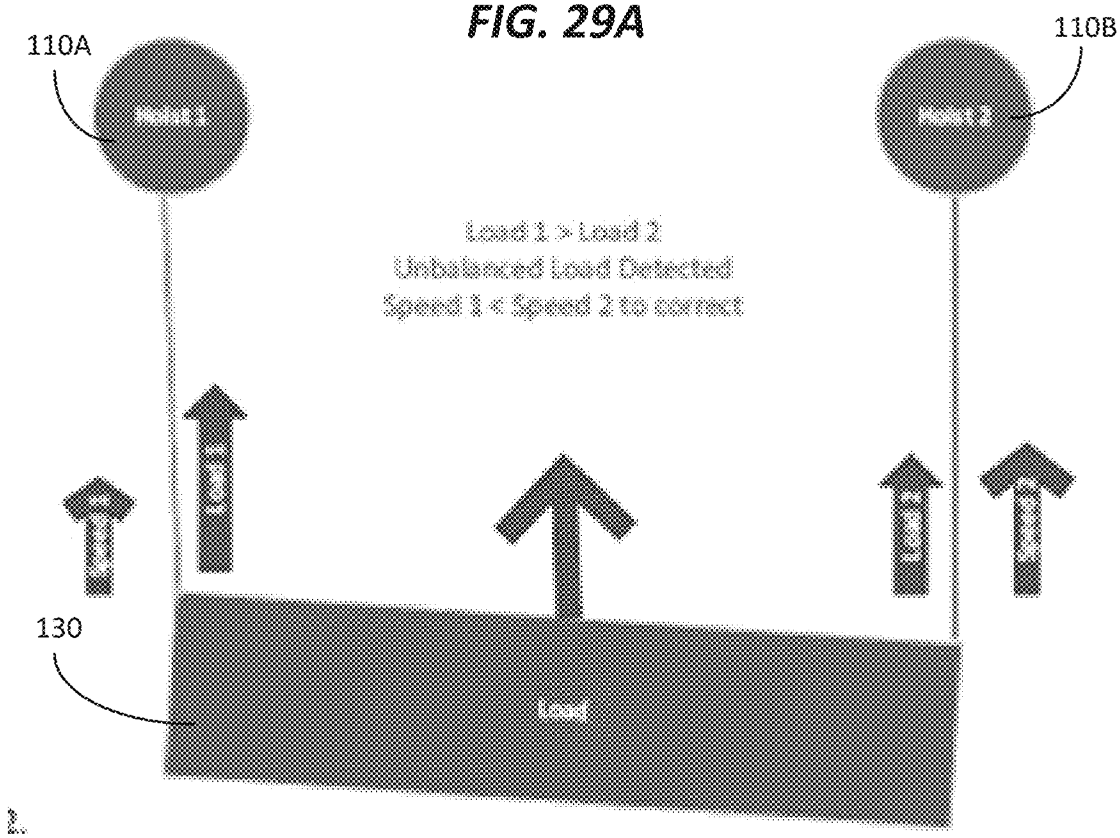


FIG. 29B

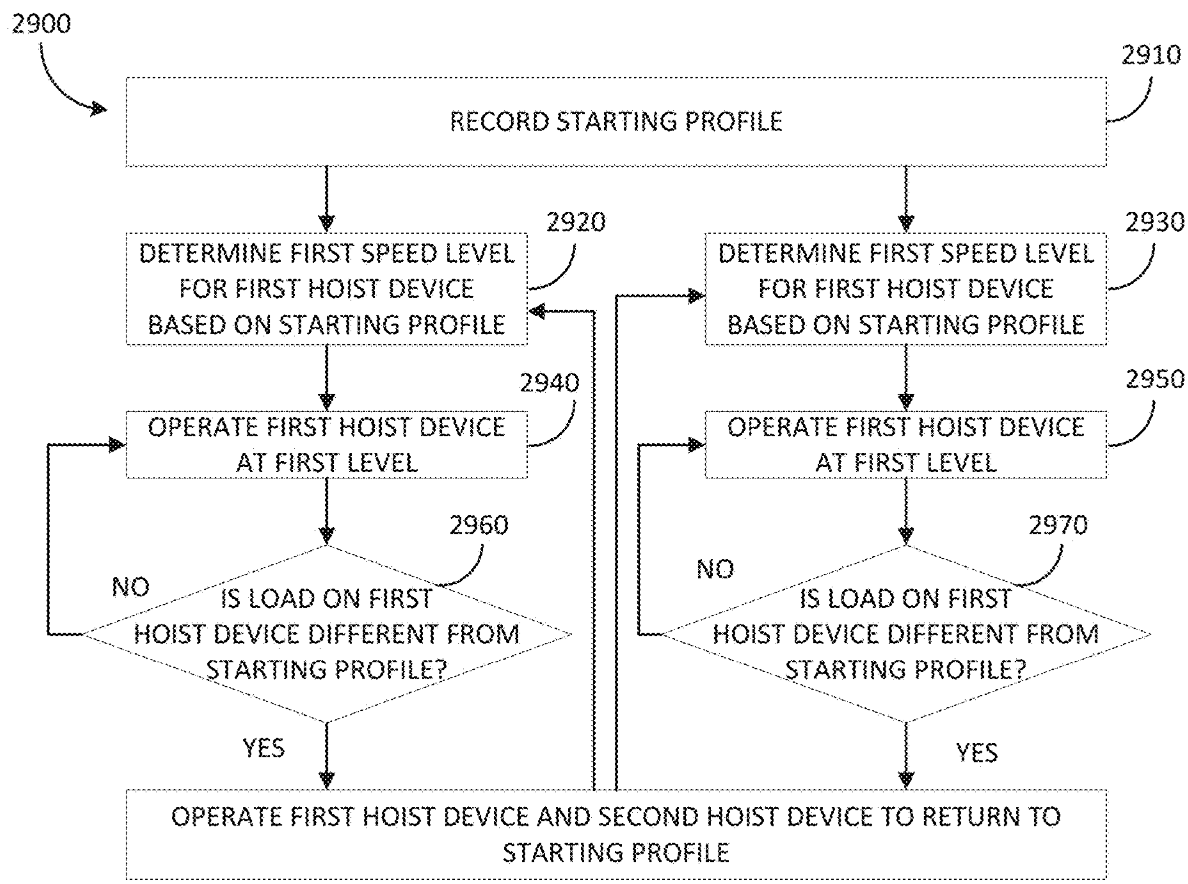

2900
2910
RECORD STARTING PROFILE
2920
DETERMINE FIRST SPEED LEVEL FOR FIRST HOIST DEVICE BASED ON STARTING PROFILE
2930
DETERMINE FIRST SPEED LEVEL FOR FIRST HOIST DEVICE BASED ON STARTING PROFILE
2940
OPERATE FIRST HOIST DEVICE AT FIRST LEVEL
2950
OPERATE FIRST HOIST DEVICE AT FIRST LEVEL
2960
NO
IS LOAD ON FIRST HOIST DEVICE DIFFERENT FROM STARTING PROFILE?
YES
2970
NO
IS LOAD ON FIRST HOIST DEVICE DIFFERENT FROM STARTING PROFILE?
YES
OPERATE FIRST HOIST DEVICE AND SECOND HOIST DEVICE TO RETURN TO STARTING PROFILE

FIG. 29C

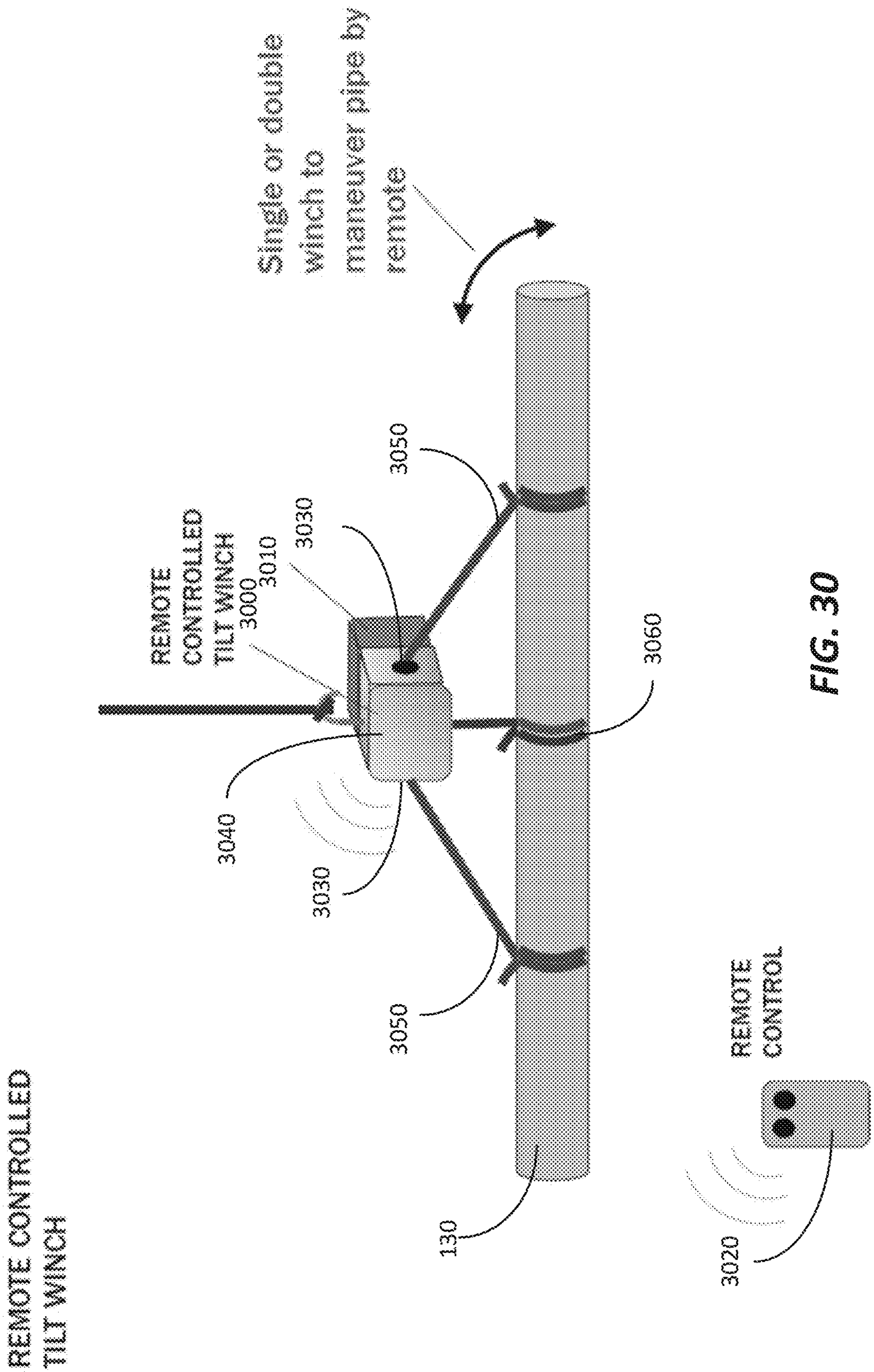

REMOTE CONTROLLED TILT WINCH
REMOTE CONTROLLED TILT WINCH
3000
3010
3030
3050
3060
3040
3030
3050
Single or double winch to maneuver pipe by remote
130
REMOTE CONTROL
3020

FIG. 30

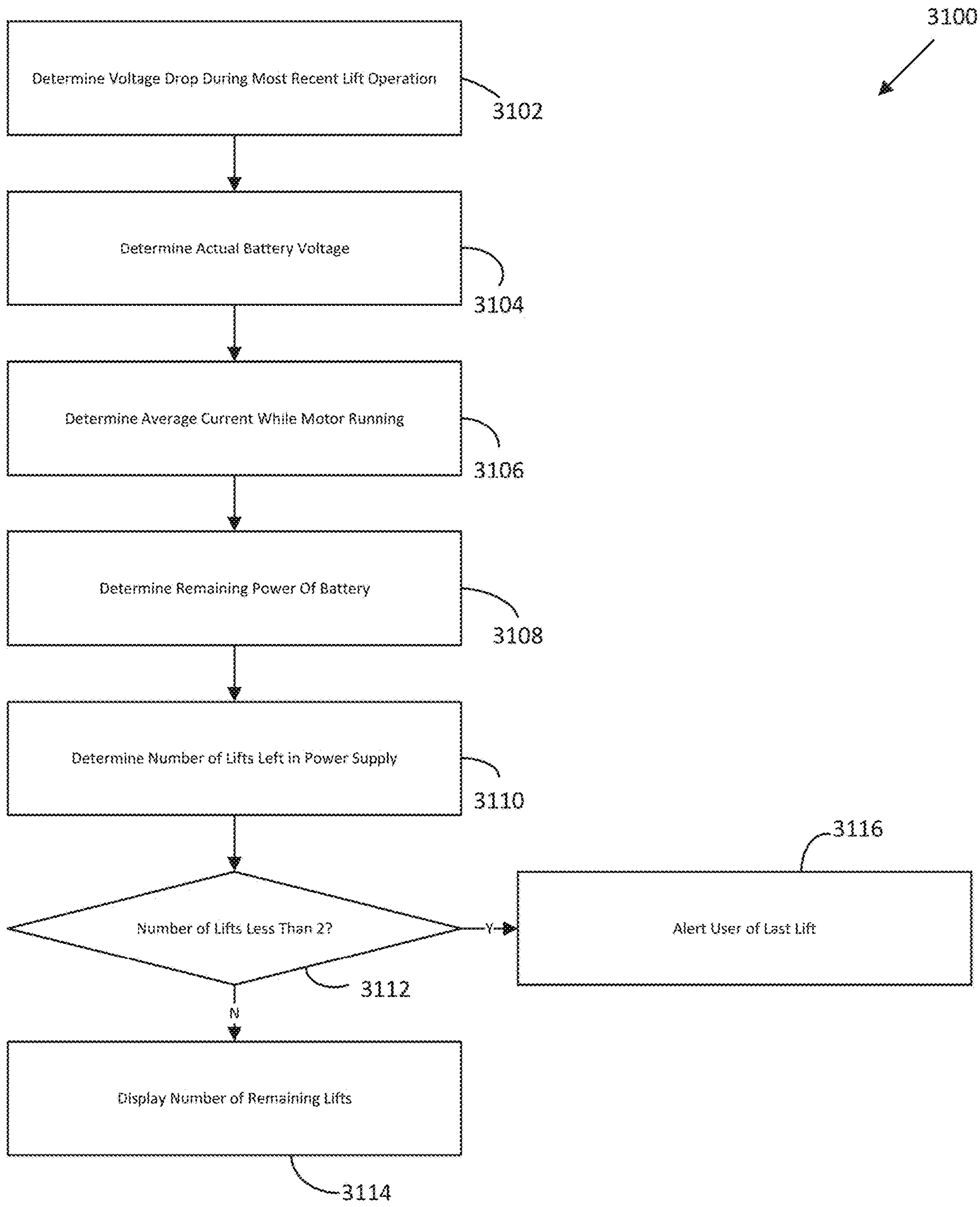

3100
Determine Voltage Drop During Most Recent Lift Operation
3102
Determine Actual Battery Voltage
3104
Determine Average Current While Motor Running
3106
Determine Remaining Power Of Battery
3108
Determine Number of Lifts Left in Power Supply
3110
Number of Lifts Less Than 2?
3112
Y
N
Alert User of Last Lift
3116
Display Number of Remaining Lifts
3114

FIG. 31

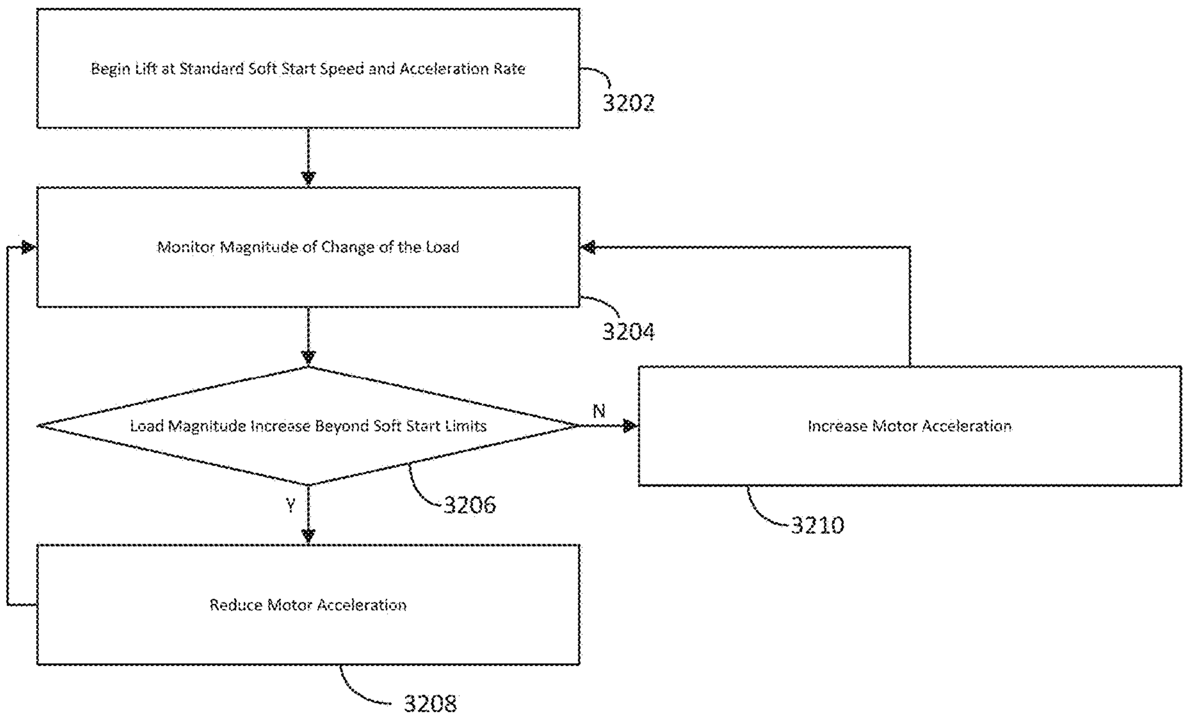

Begin Lift at Standard Soft Start Speed and Acceleration Rate
3202
Monitor Magnitude of Change of the Load
3204
Load Magnitude Increase Beyond Soft Start Limits
N
Y
3206
Increase Motor Acceleration
3210
Reduce Motor Acceleration
3208

FIG. 32

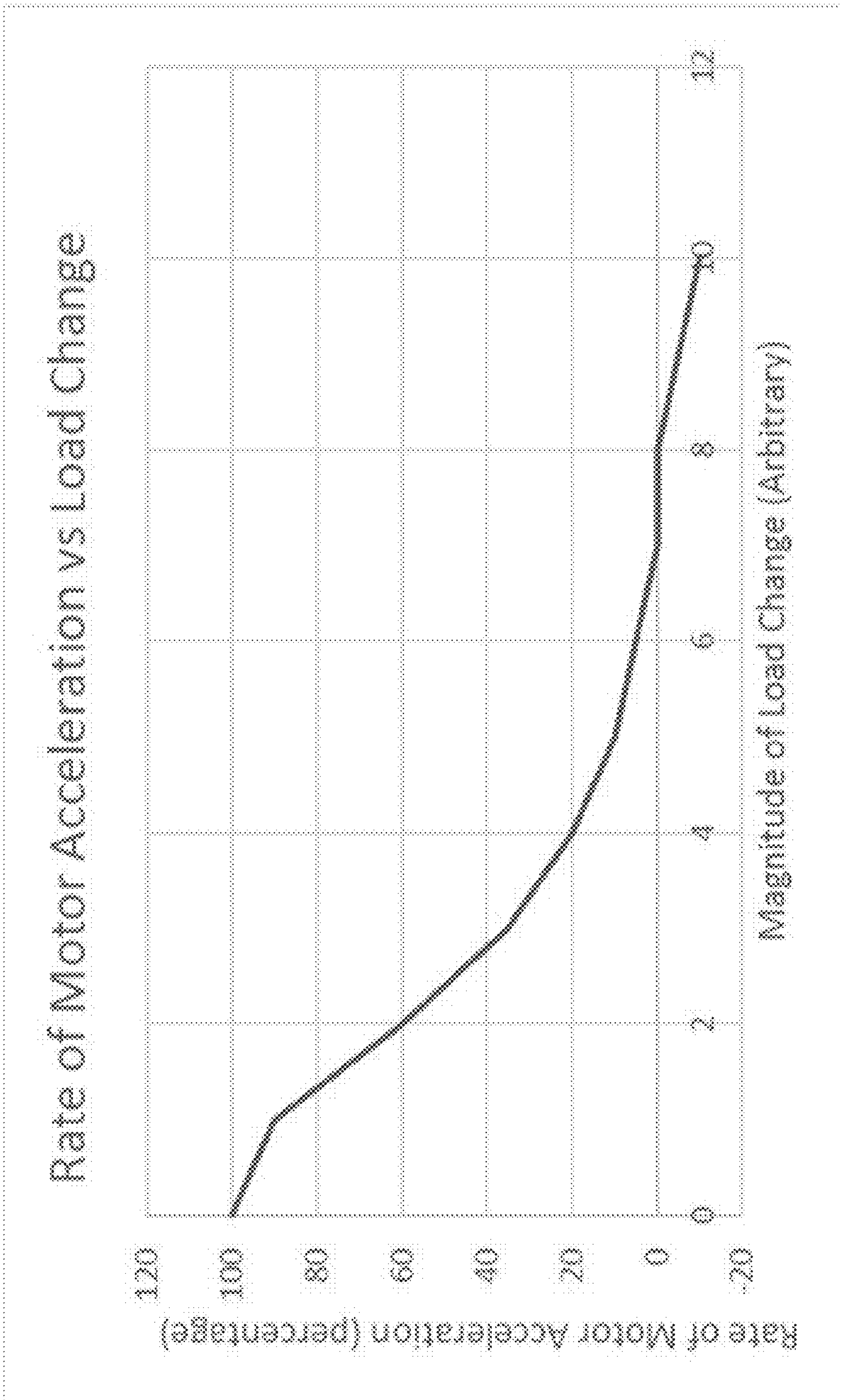

Rate of Motor Acceleration vs Load Change
Rate of Motor Acceleration (percentage)
Magnitude of Load Change (Arbitrary)
120
100
80
60
40
20
0
-20
0
2
4
6
8
10
12

FIG. 33

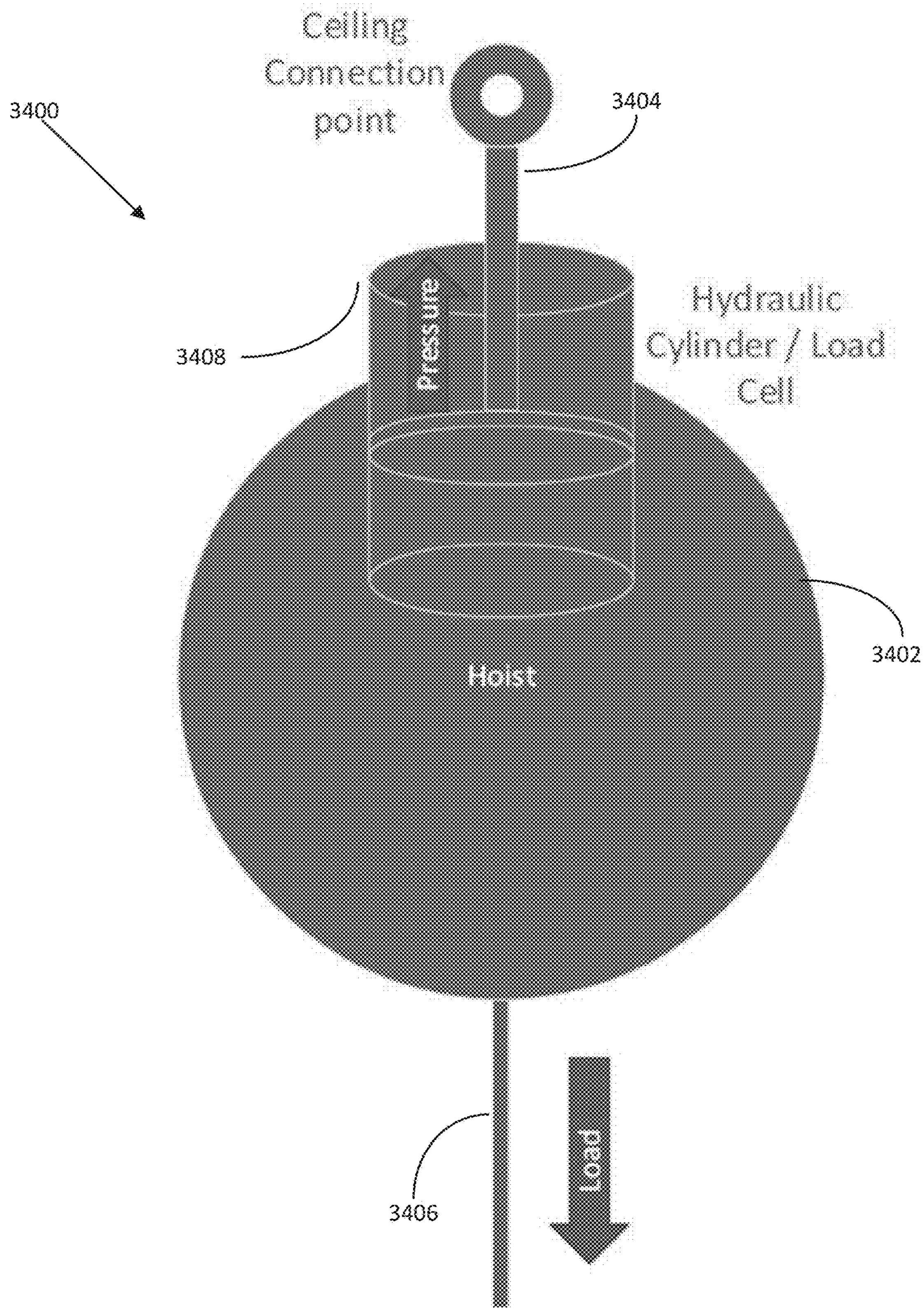

Ceiling
Connection
point
3400
3404
Pressure
Hydraulic
Cylinder / Load
Cell
3408
Hoist
3402
Load
3406

FIG. 34

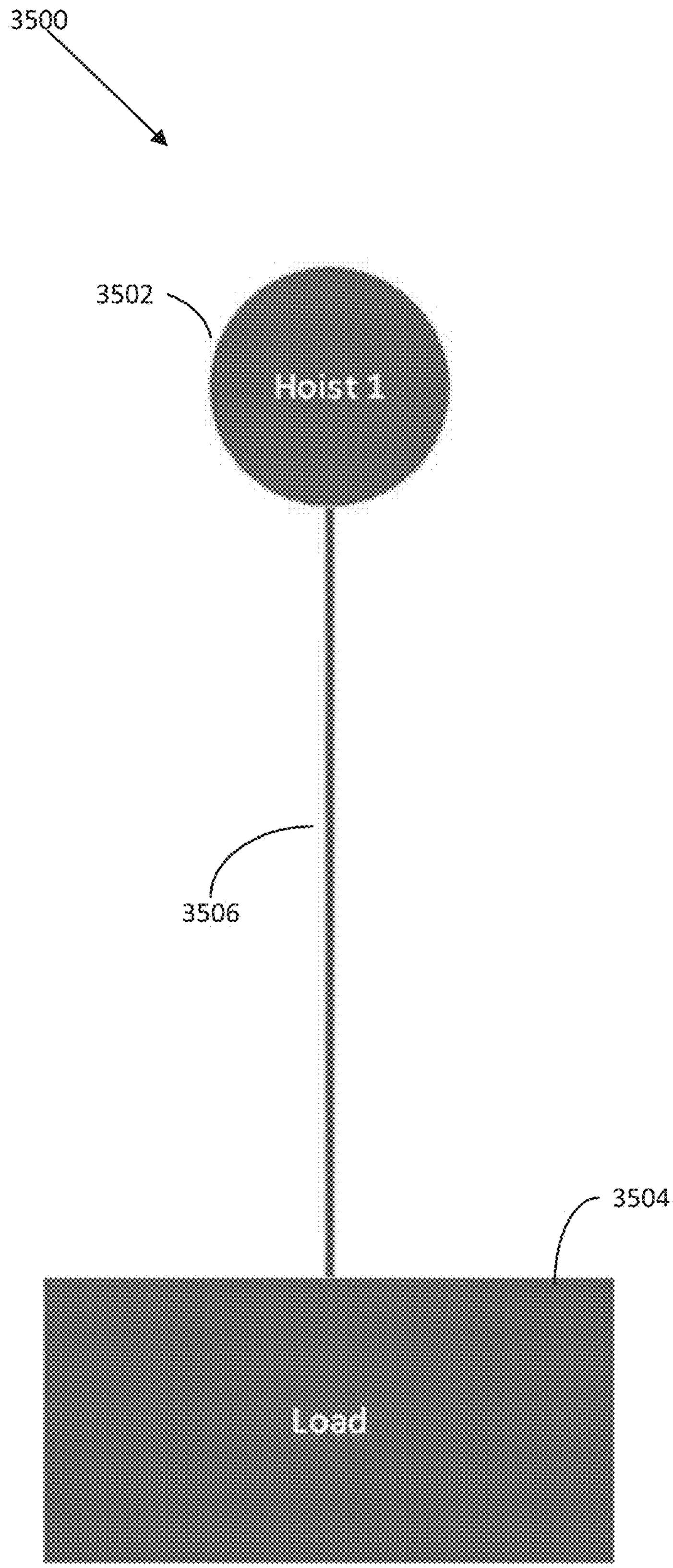


FIG. 35

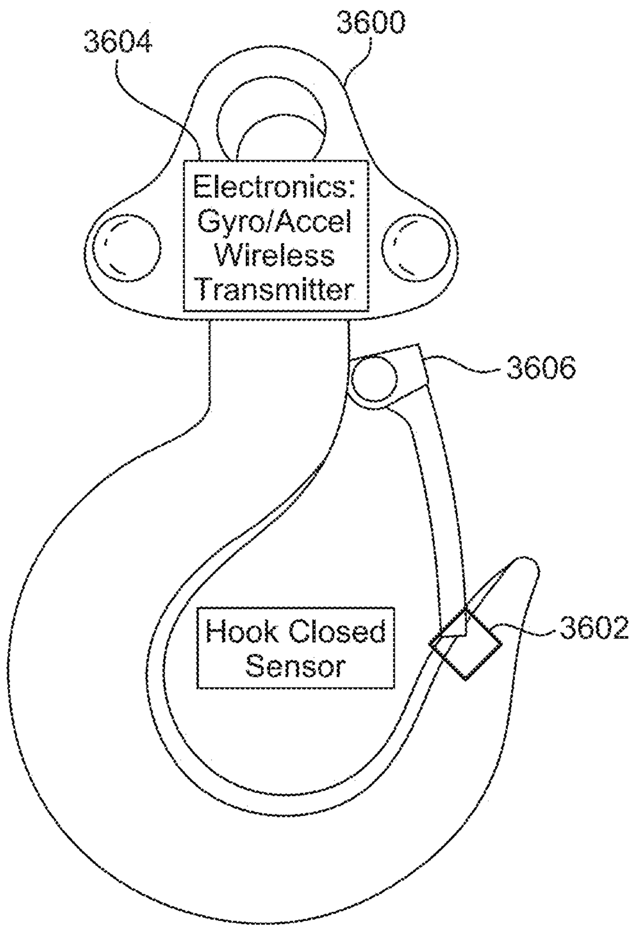

3604
3600
Electronics:
Gyro/Accel
Wireless
Transmitter
3606
Hook Closed
Sensor
3602

FIG. 36

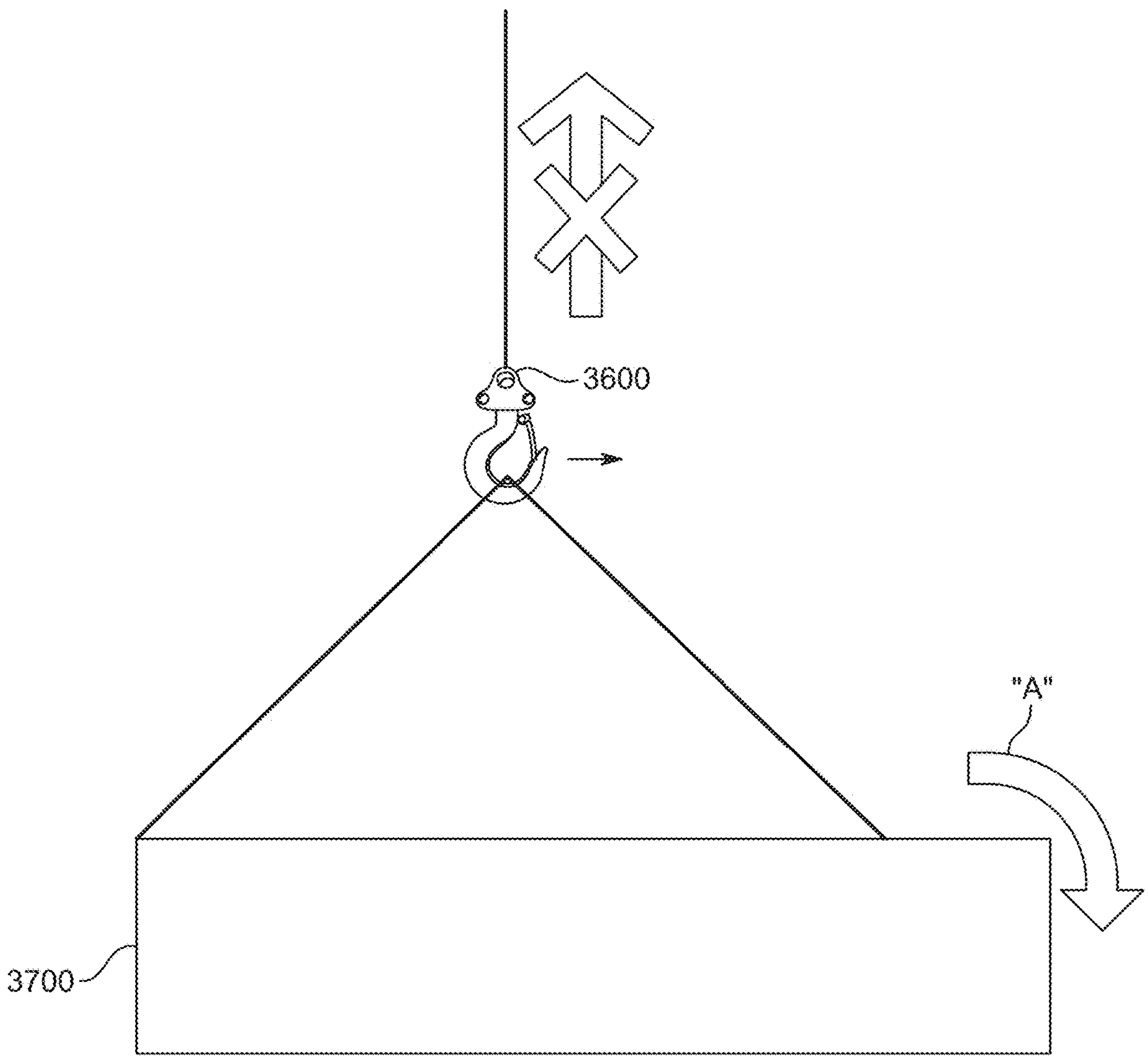


FIG. 37

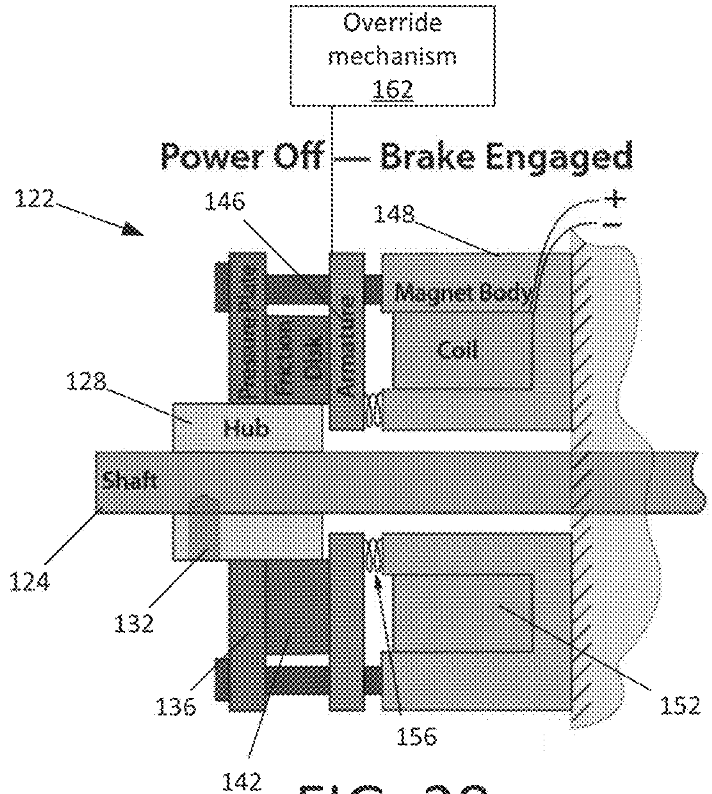

Override
mechanism
162
Power Off — Brake Engaged
122
146
148
+
-
Magnet Body
Armature
Coil
128
Hub
Shaft
124
132
136
142
156
152

FIG. 38

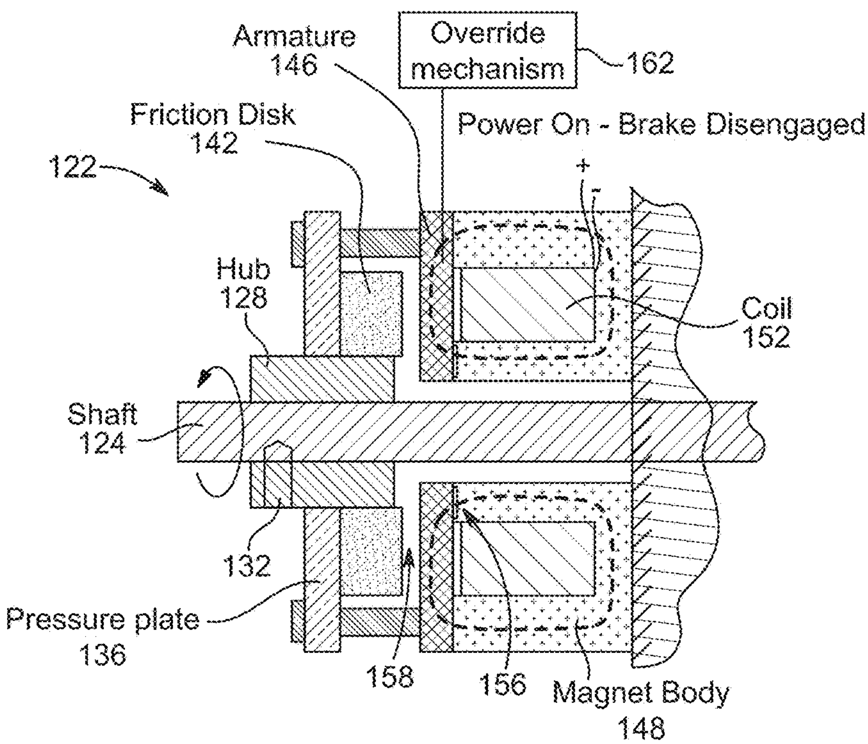

Armature
146
Override
mechanism
162
Friction Disk
142
Power On - Brake Disengaged
122
+
-
Hub
128
Coil
152
Shaft
124
132
Pressure plate
136
158
156
Magnet Body
148

FIG. 39

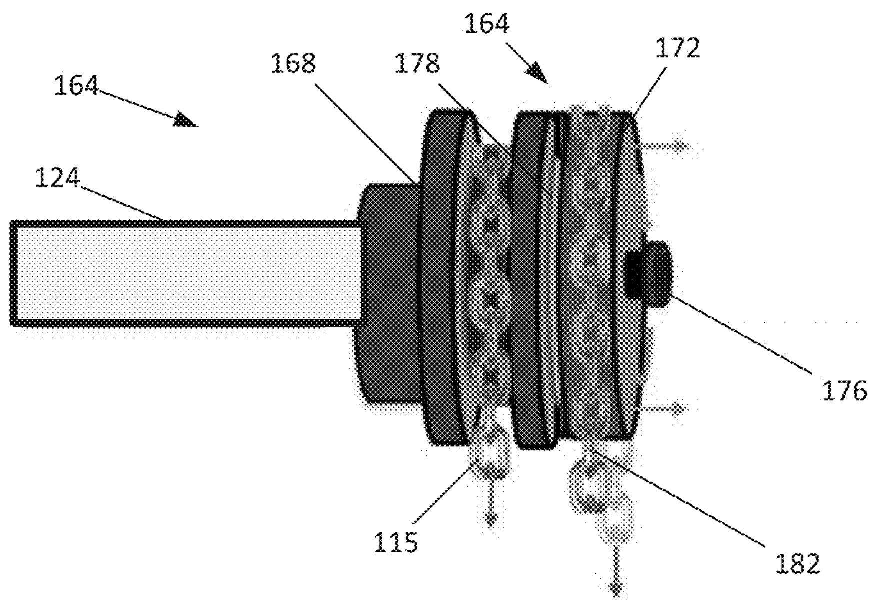

164
168
178
164
172
124
176
115
182

FIG. 40

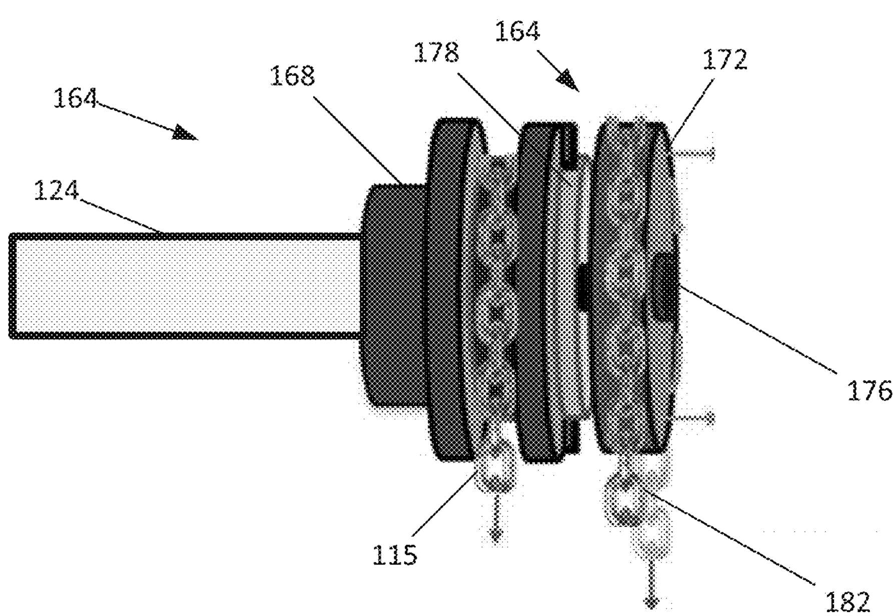

164
178
172
164
168
124
176
115
182

FIG. 41

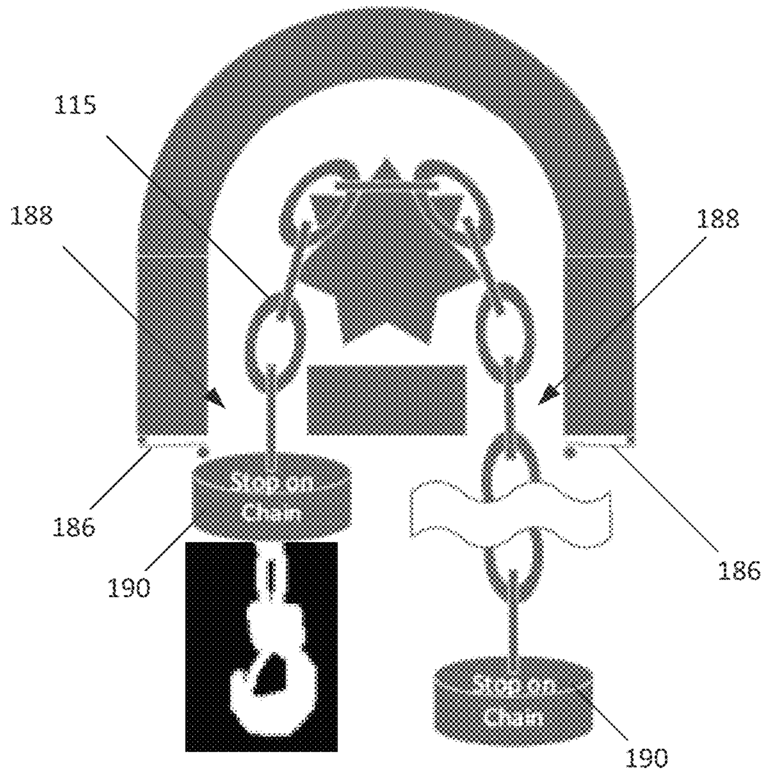


FIG. 42

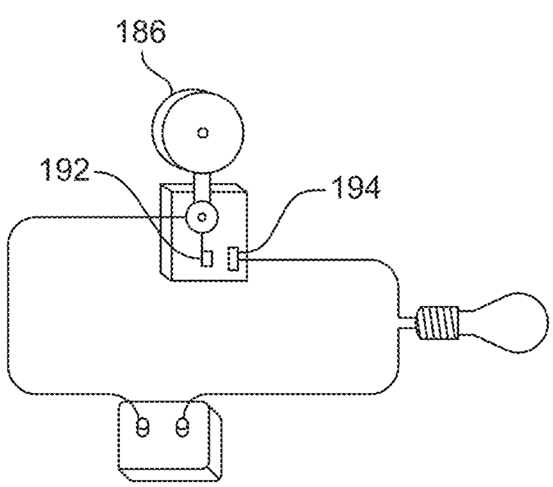


FIG. 43A

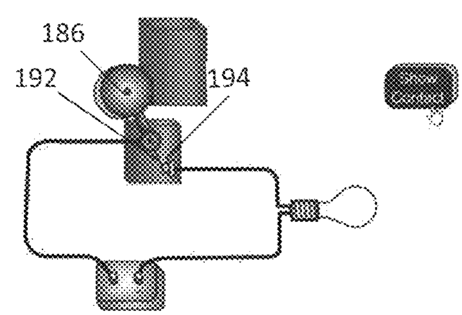


FIG. 43B

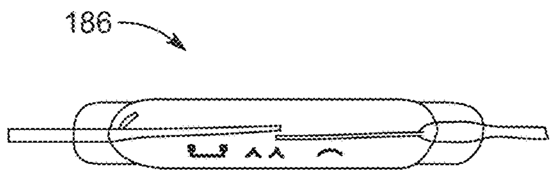


FIG. 44A

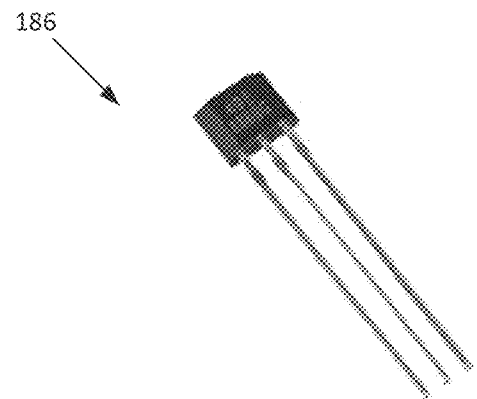


FIG. 44B

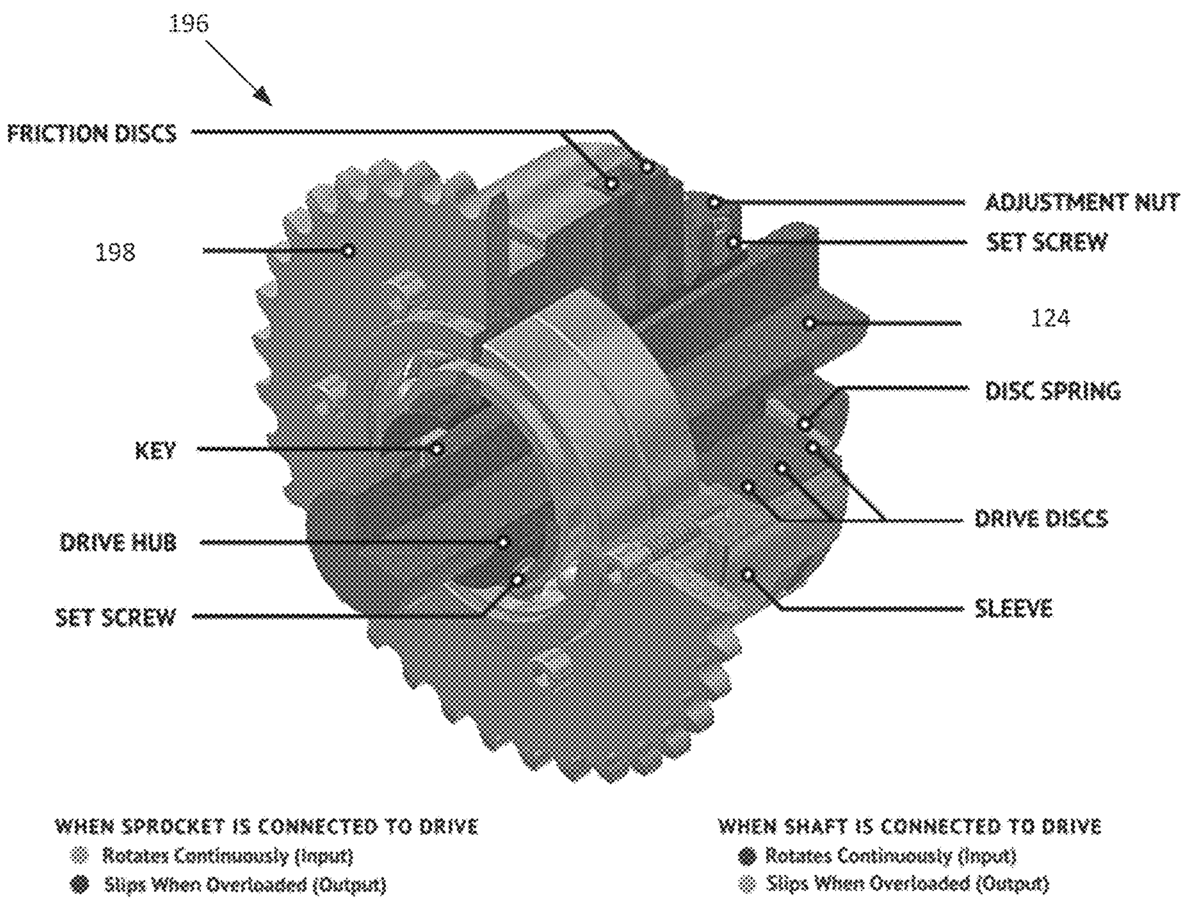


FIG. 44C

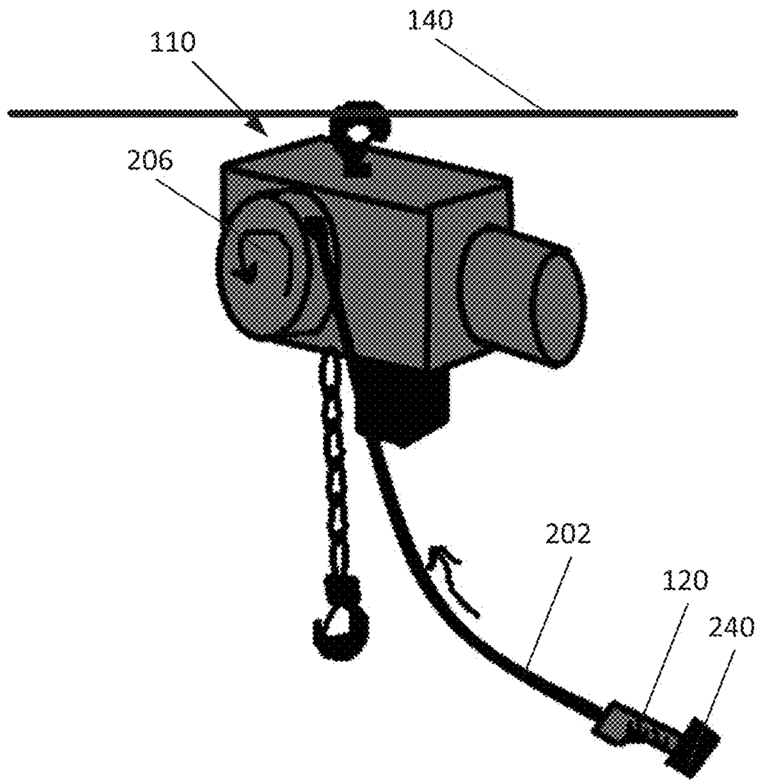


FIG. 45

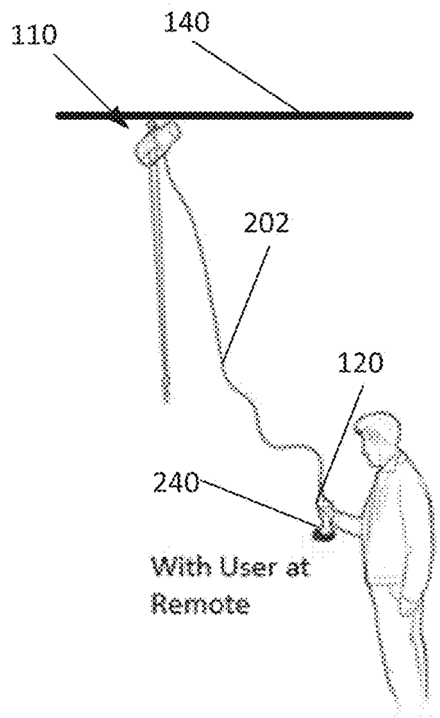


FIG. 46

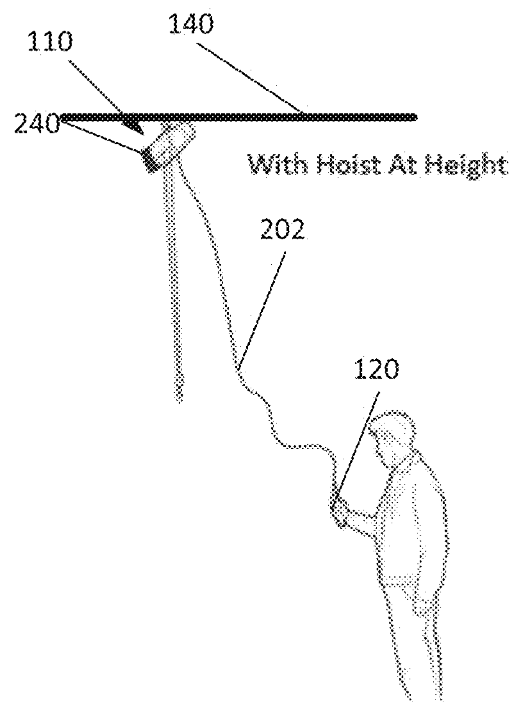


FIG. 47

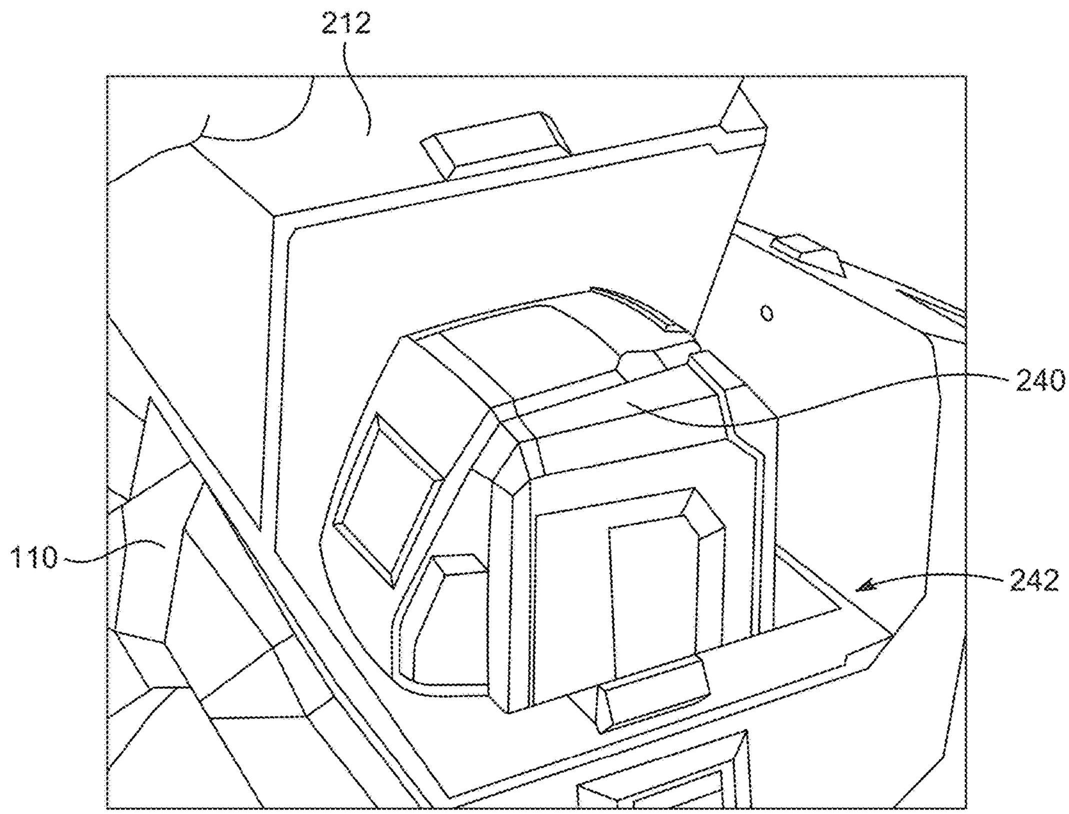

212
240
110
242

FIG. 48

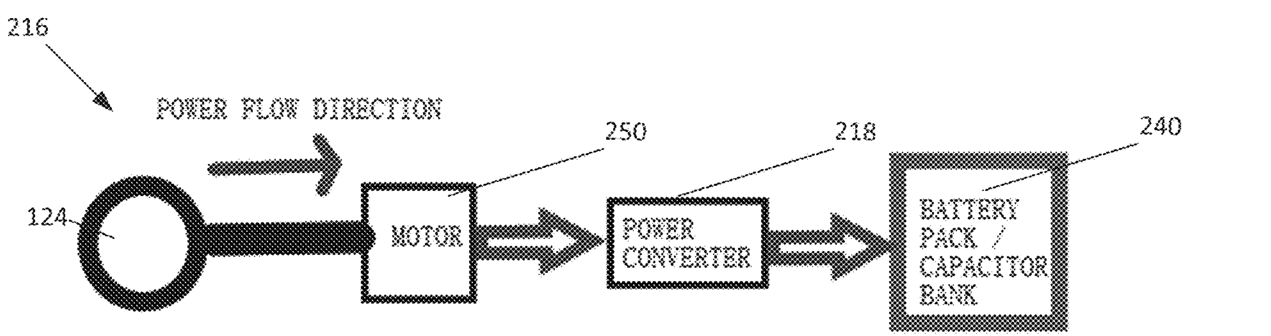

216
POWER FLOW DIRECTION
250
218
240
124
MOTOR
POWER CONVERTER
BATTERY PACK / CAPACITOR BANK

FIG. 49

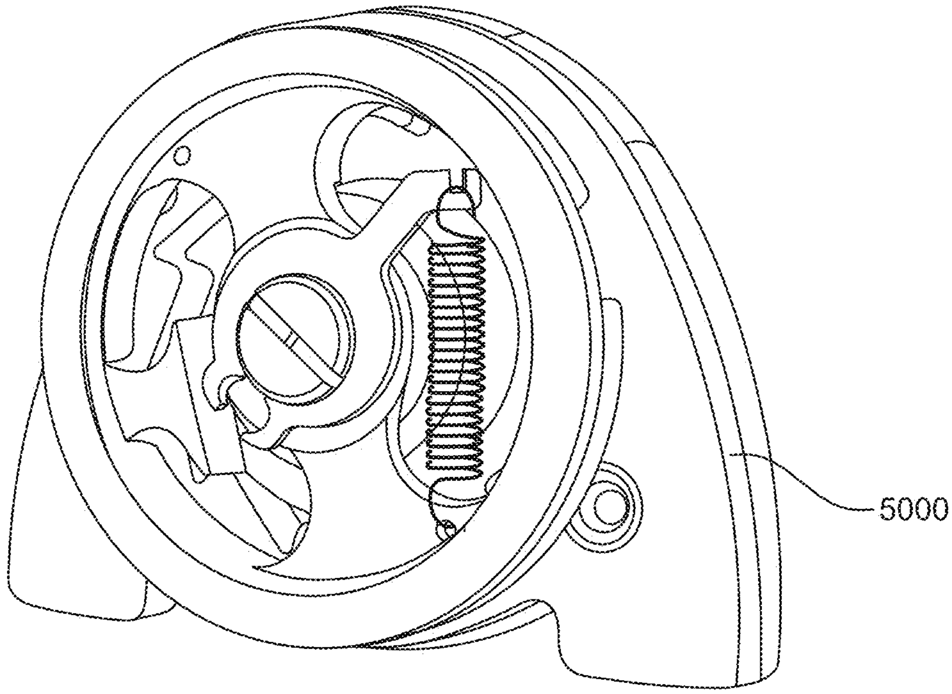


FIG. 50

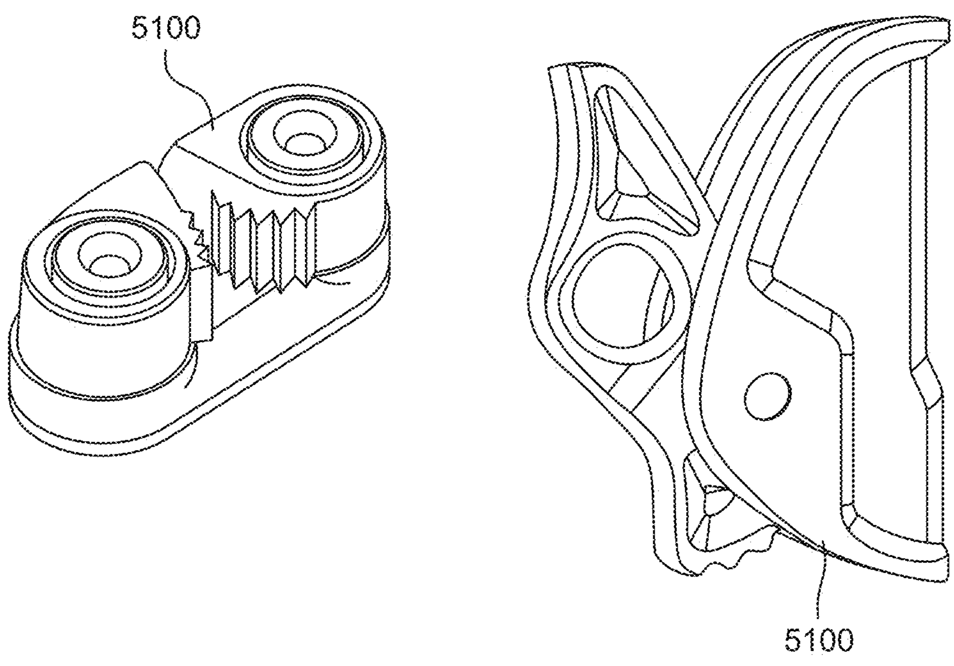


FIG. 51

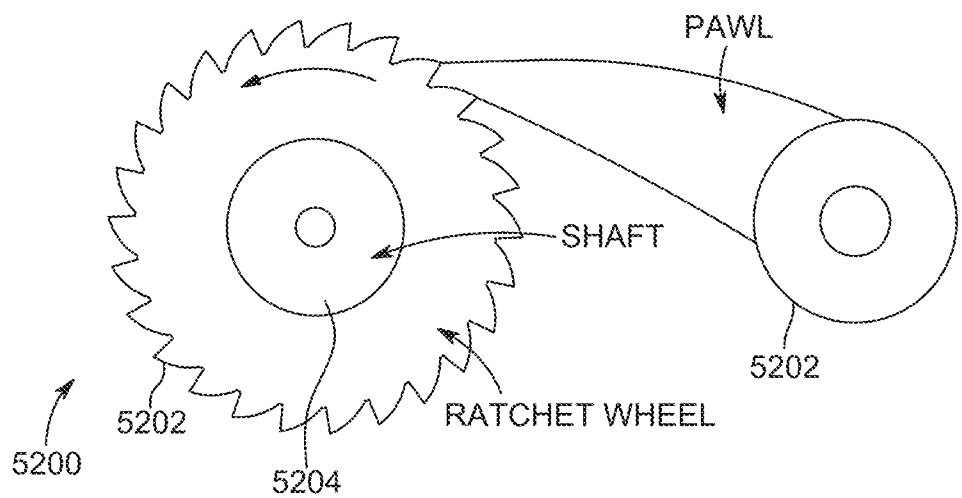


FIG. 52A

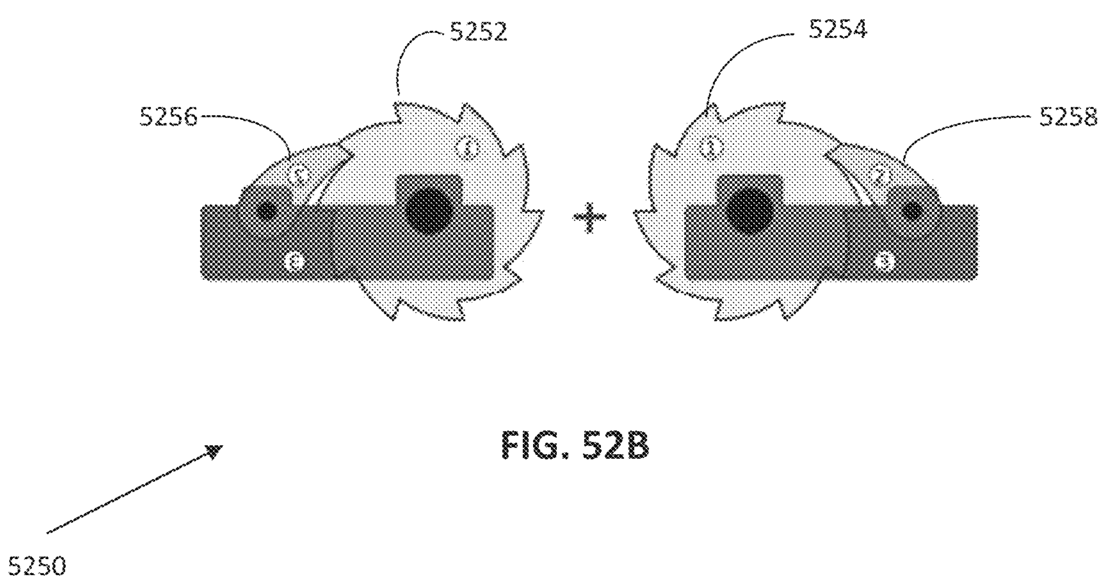


FIG. 52B

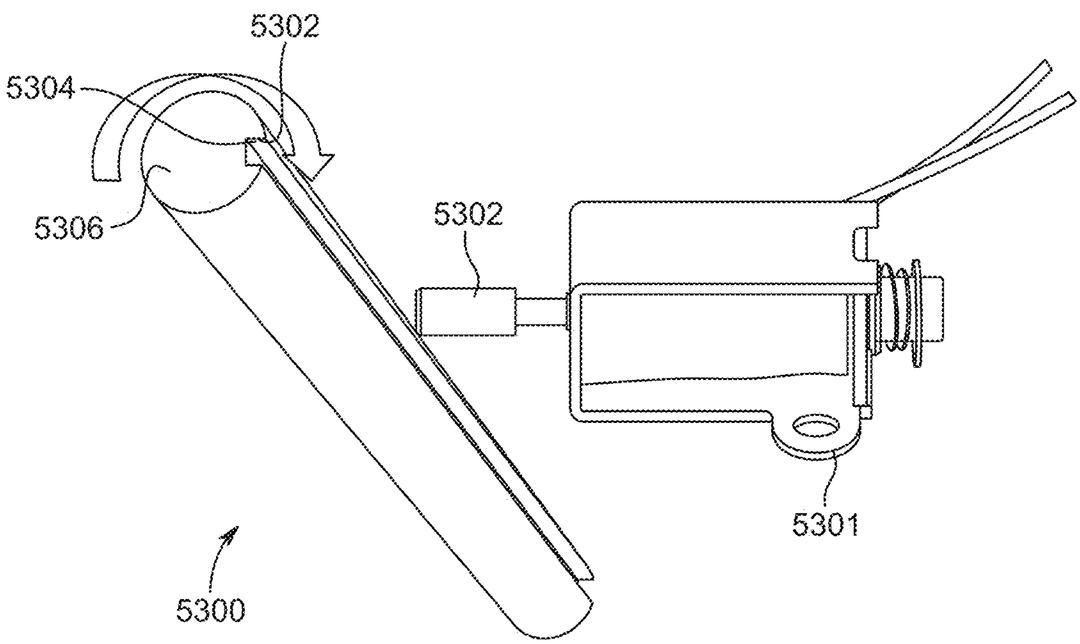

5302
5304
5306
5302
5301
5300

FIG. 53

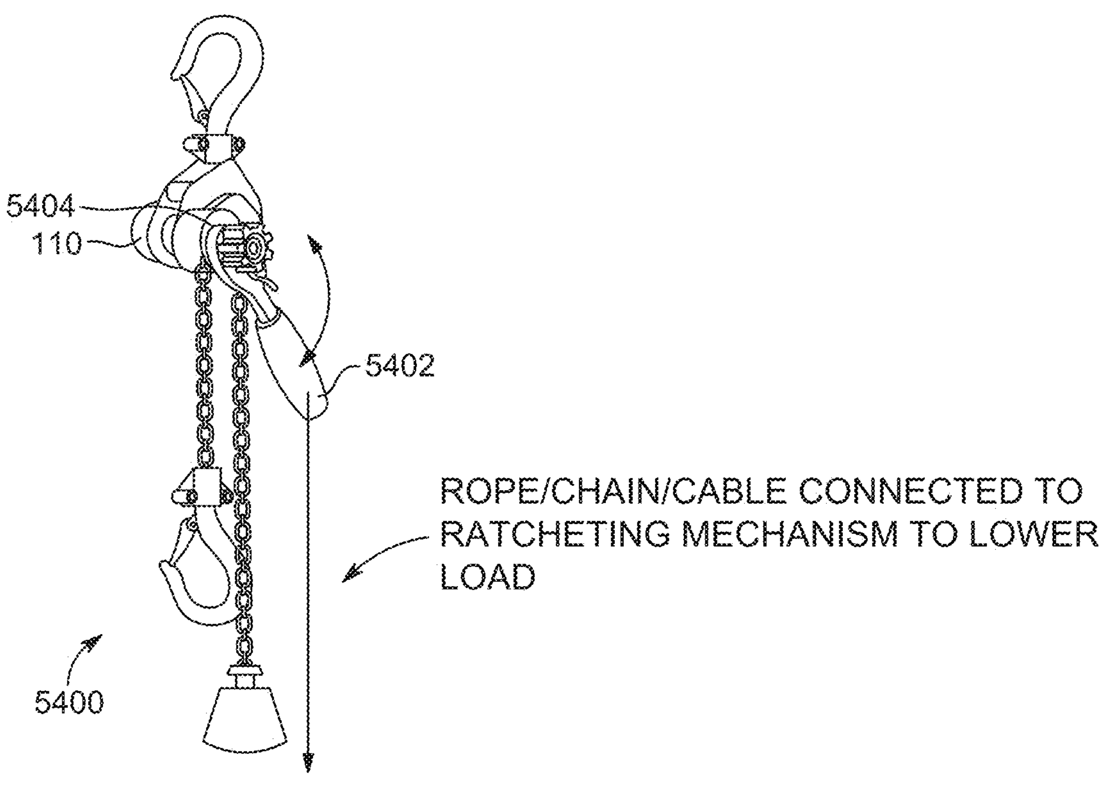

5404
110
5402
ROPE/CHAIN/CABLE CONNECTED TO RATCHETING MECHANISM TO LOWER LOAD
5400

FIG. 54

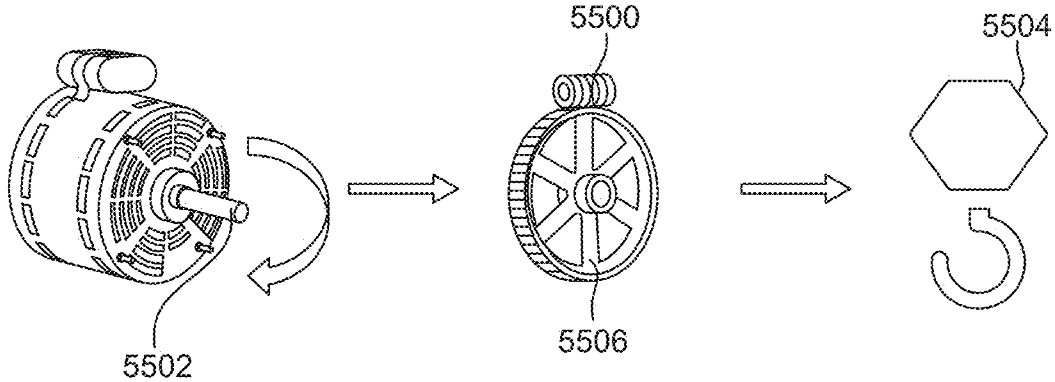

5500
5504
5502
5506

FIG. 55

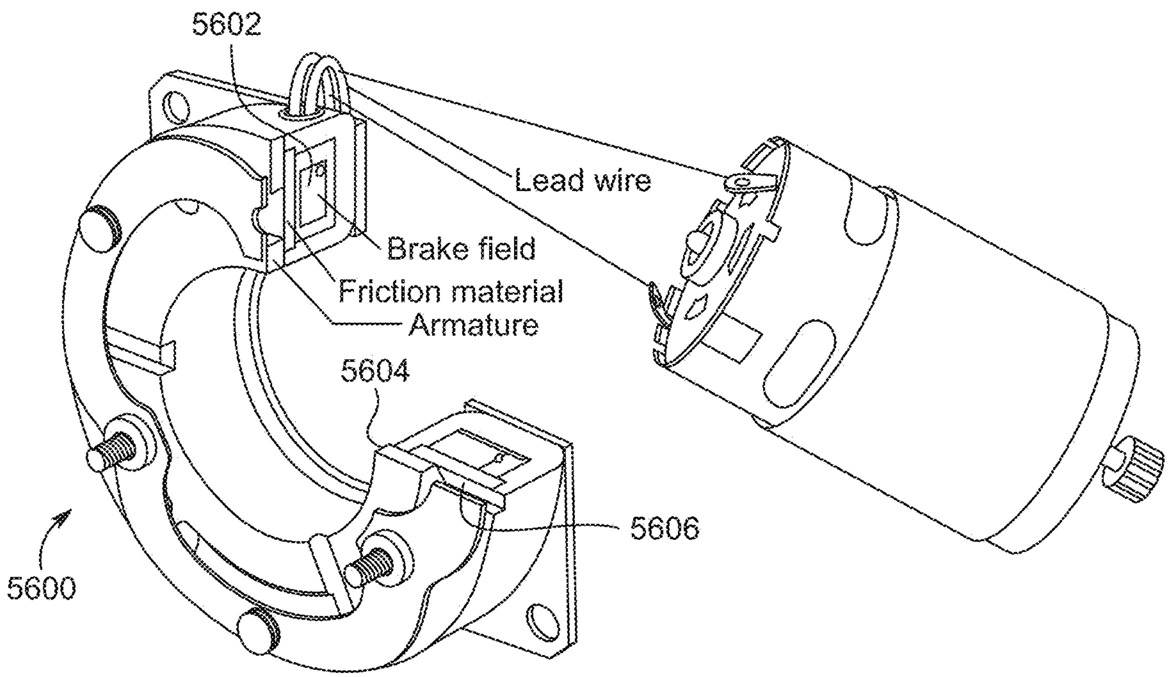

5602
Lead wire
Brake field
Friction material
Armature
5604
5606
5600

FIG. 56

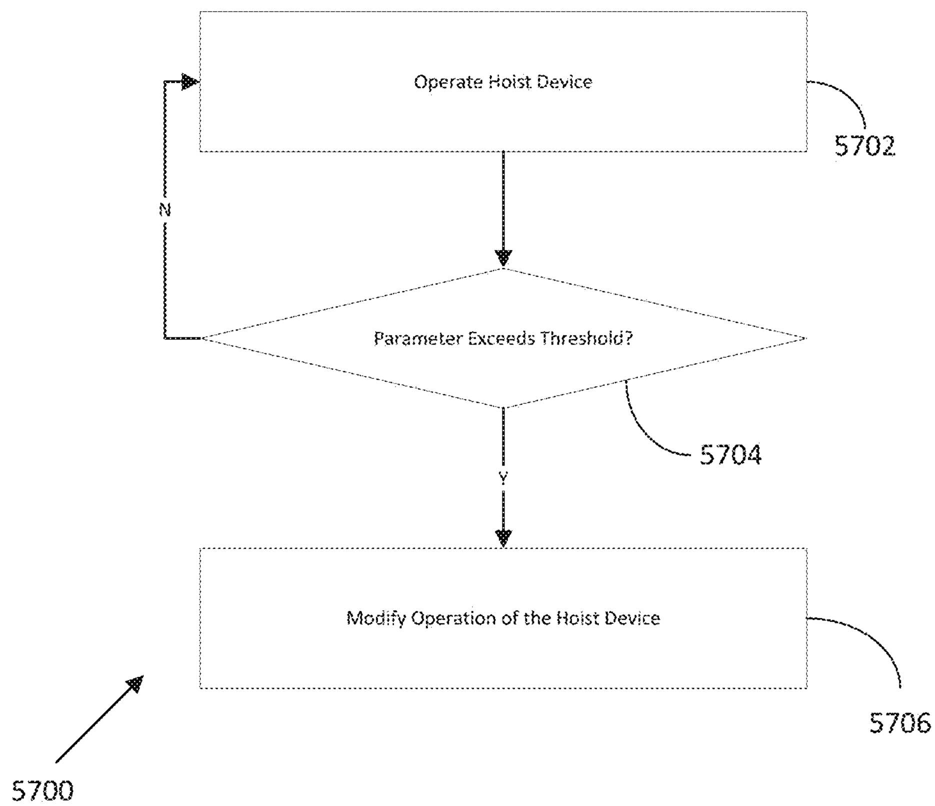

Operate Hoist Device
5702
N
Parameter Exceeds Threshold?
5704
Y
Modify Operation of the Hoist Device
5706
5700

FIG. 57

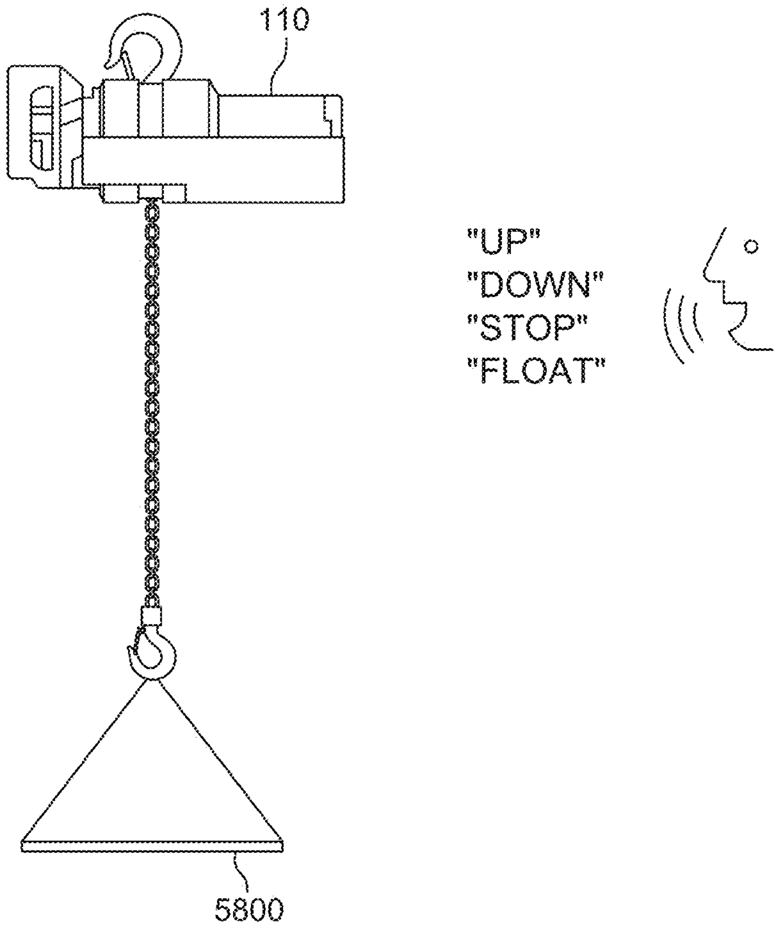


FIG. 58

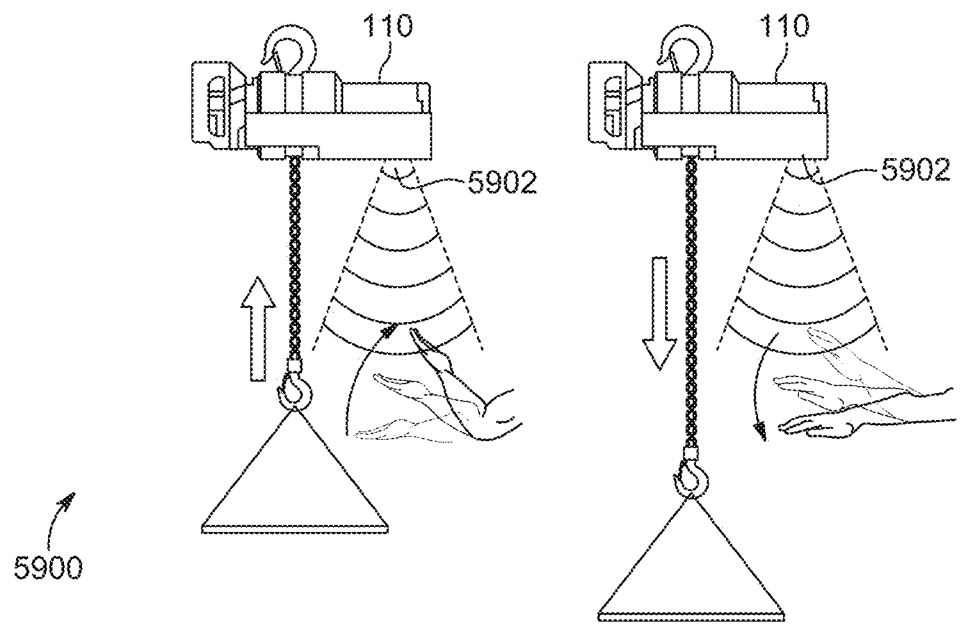


FIG. 59

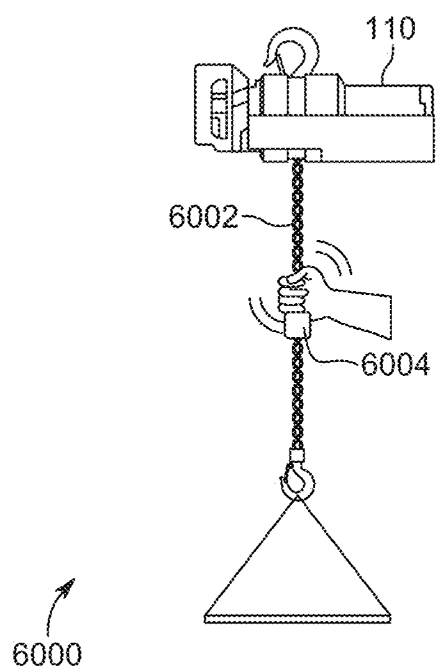


FIG. 60

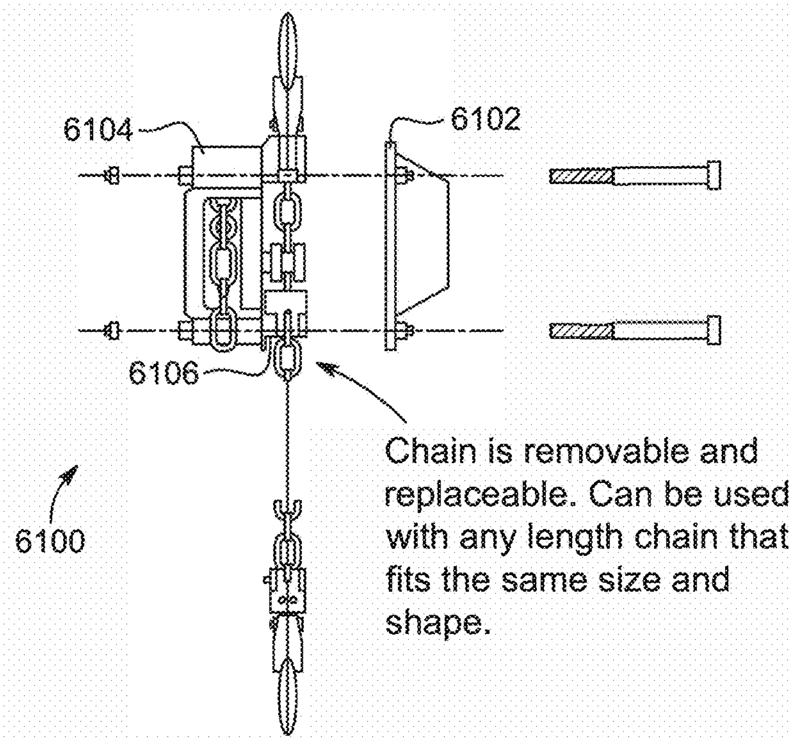

6104
6102
6106
Chain is removable and replaceable. Can be used with any length chain that fits the same size and shape.
6100

FIG. 61

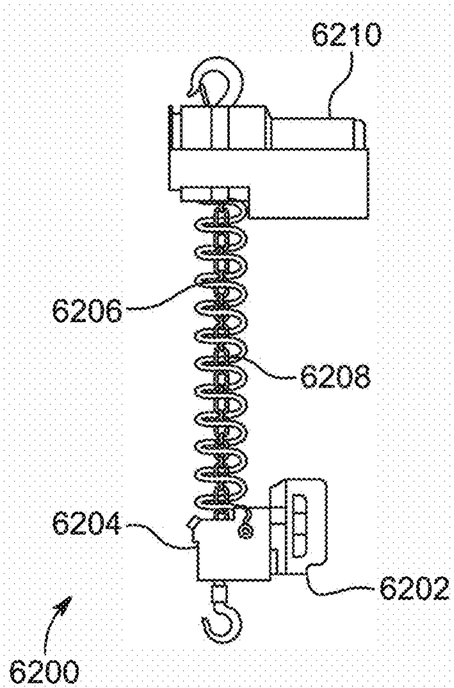

6210
6206
6208
6204
6202
6200

FIG. 62

WIRELESS HOIST SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national phase filing under 35 U.S.C. § 371 of International Application No. PCT/US2020/039908, filed Jun. 26, 2020, which claims priority to U.S. Provisional Patent No. 62/868,297, filed Jun. 28, 2019, U.S. Provisional Patent No. 62/951,394, filed Dec. 20, 2019, and U.S. Provisional Patent No. 62/965,676, filed Jan. 24, 2020, the entire contents of all of which are incorporated by reference herein.

FIELD

This application relates to a wireless hoist system and is directed to wirelessly controlling hoist devices for moving workpieces as well as other hoist systems.

BACKGROUND

Hoist devices are used for lifting or lowering workpieces. The hoist devices may be manually operated, electrically or pneumatically driven, and may use chain or chain rope to move the workpieces.

SUMMARY

For complex movements, precise placements, or moving complex objects (for example, in terms of weight distribution and shape), two or more hoist devices can be used to move the workpiece from one location to another location. The hoist devices may be moved in a coordinated manner by multiple users to ensure that the workpiece is not damaged. However, without communication between the hoist devices, the hoist systems are prone to user error in coordinating the hoist devices.

One embodiment provides a wireless hoist system including a first hoist device having a first motor and a first wireless transceiver and a second hoist device having a second motor and a second wireless transceiver. The first hoist device and the second hoist device are configured to be coupled to a workpiece to raise or lower the workpiece. The wireless hoist system also includes a controller in wireless communication with the first wireless transceiver of the first hoist device and the second wireless transceiver of the second hoist device. The controller is configured to receive user input and determine a first operation parameter and a second operation parameter based on the user input. The controller is also configured to provide, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device and provide, wirelessly, a second control signal indicative of the second operation parameter to the second hoist device. The first hoist device operates based on the first control signal and the second hoist device operates based on the second control signal.

In some examples, the controller communicates with the first hoist device over a first wireless channel and wherein the controller communicates with the second hoist device over a second wireless channel.

In some examples, the system further comprises a third hoist device, and the first hoist device is further configured to: determine a third operation parameter based on the first operation parameter; and provide a third control signal indicative of the third operation parameter to the third hoist device, wherein the third hoist device operates based on the third control signal.

In some examples, the controller communicates with the first hoist device over a first wireless channel, and the first hoist device communicates with the third hoist device over a second wireless channel.

In some examples, the first hoist device further comprises: a chain connectable to the workpiece to raise and lower the workpiece, the first motor coupled to the chain to release and retract the chain; a sensor for detecting a chain length of the chain indicative of a length of chain released from the first hoist device; and a motor drive coupled to the sensor and the motor and configured to: receive the chain length from the sensor; receive the first control signal from the controller; and drive the motor based on the first control signal and the chain length.

In some examples, the motor drive is further configured to: receive a level input from a level, the level placed on the workpiece and the level input indicating an angle of the level with respect to ground, wherein driving the motor is further based on the level input.

In some examples, the controller is further configured to: receive a level input from a level, the level placed on the workpiece and the level input indicating an angle of the level with respect to ground, wherein determining the first control signal and the second control signal are further based on the level input.

In some examples, the first operation parameter includes one or more selected from a group consisting of: speed, direction, and chain length.

In some examples, the user input is a desired movement of the workpiece.

In some examples, the user input includes a position of the first hoist device, a position of the second hoist device, and a desired end position of the workpiece.

Another embodiment provides a wireless hoist system including a first hoist device having a first motor and a first wireless transceiver and a second hoist device having a second motor and a second wireless transceiver. The first hoist device and the second hoist device are configured to be coupled to a workpiece to raise or lower the workpiece. The wireless hoist system also includes a controller in wireless communication with the first wireless transceiver of the first hoist device and the second wireless transceiver of the second hoist device. The controller is configured to receive user input and determine a first operation parameter based on the user input. The controller is also configured to provide, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device and provide, wirelessly, a second control signal indicative of the first operation parameter to the second hoist device. The first hoist device operates based on the first control signal and the second hoist device operates based on the second control signal.

In some examples, the first control signal is provided to the first hoist device in response to determining that a first channel associated with the first hoist device is enabled, and the second control signal is provided to the second hoist device in response to determining that a second channel associated with the second hoist device is enabled.

In some examples, the system further comprises a third hoist device including a third motor and a third wireless transceiver, and the third hoist device is associated with a third channel. Further, the controller, in response to determining that the third channel is disabled, does not provide a control signal indicative of the first operation parameter to the third hoist device.

Another embodiment provides a wireless hoist system including a first hoist device having a first motor and a first wireless transceiver. The first hoist device is configured to be coupled to a workpiece to raise or lower the workpiece. The wireless hoist system also includes a level configured to be placed on the workpiece, to sense an angle of the level with respect to gravitational pull when the level is on the workpiece and to wirelessly output a level signal indicative of the angle. The wireless hoist system further includes a controller in wireless communication with the first wireless transceiver of the first hoist device and the level. The controller is configured to receive user input and determine a first operation parameter based on the user input. The controller is also configured to receive the level signal and provide, wirelessly to the first hoist device, a first control signal that is based on the first operation parameter and the level signal. The first hoist device operates based on the first control signal.

In some examples, the system further comprises a second hoist device including a second motor and a second wireless transceiver, and the second hoist device is configured to be coupled to the workpiece to raise or lower the workpiece. Further, the controller is configured to: determine a second operation parameter based on the user input, and provide, wirelessly to the second hoist device, a second control signal that is based on the second operation parameter and the level signal. Further, the second hoist device operates based on the second control signal.

Another embodiment provides a wireless hoist system including a first hoist device having a first motor and a first wireless transceiver and a second hoist device having a second motor and a second wireless transceiver. The second wireless transceiver is in wireless communication with the first wireless transceiver and the first hoist device and the second hoist device are configured to be coupled to a workpiece to raise or lower the workpiece. The wireless hoist system also includes a controller in wireless communication with the first wireless transceiver of the first hoist device. The controller is configured to receive user input and determine a first operation parameter based on the user input. The controller is also configured to provide, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device. The first hoist device is configured to provide, wirelessly, a second control signal to the second hoist device and the second control signal is based on the first control signal. The first hoist device operates based on the first control signal and the second hoist device operates based on the second control signal.

In some examples, the first wireless transceiver, the second wireless transceiver, and the controller communicate via an RF communication protocol. The RF communication protocol uses dual identifiers, one broadcast from the controller, and an individual identifier for each of the first wireless transceiver and the second wireless transceiver.

In some examples, the RF communication protocol initiates a pairing between the controller and the first wireless transceiver. The pairing includes broadcasting a first pairing signal from the controller to the first wireless transceiver, wherein the first pairing signal includes an identifier of the controller, and storing, at the first wireless transceiver, the identifier of the controller. The pairing also includes transmitting, by the first wireless transceiver in response to receiving the pairing signal, an identifier of the first wireless transceiver, storing at the controller the identifier of the first wireless transceiver, and generating a paired identifier including at least the identifier of the controller and the identifier of the first wireless transceiver for performing future communications between the controller and the first wireless transceiver.

In some examples, the RF communication protocol initiates a pairing between the controller and the second wireless transceiver. The pairing includes broadcasting a second pairing signal from the controller to the second wireless transceiver, wherein the second pairing signal includes an identifier of the controller, and storing, at the second wireless transceiver, the identifier of the controller. The pairing also includes transmitting, by the second wireless transceiver in response to receiving the pairing signal, an identifier of the second wireless transceiver, storing at the controller the identifier of the second wireless transceiver, and generating a paired identifier including at least the identifier of the controller and the identifier of the second wireless transceiver for performing future communications between the controller and the second wireless transceiver.

Another embodiment includes a hoist device having a power source, a motor having an output shaft, a transmission coupled to the output shaft, and a controller configured to control an operation of the motor. The transmission is configured to interface with a chain, and to transfer rotational motion of the output shaft of the motor to the chain to one of release or retract the chain. The hoist device is configured to one of raise and lower a workpiece coupled to the chain based on a user command signal received at the controller

In some examples, the hoist device also includes a limit sensor configured to detect an end of the chain. The limit sensor is further configured to provide an input to the controller to stop the motor in response to detecting the end of the chain.

In some examples, the limit sensor is one or more of a mechanical limit switch, a hall sensor, a time-of-flight sensor, a chain speed sensor, an ultrasonic pulse transceiver, and a distance run sensor.

In some examples, the limit sensor is configured to detect a change in the size of one or more links in the chain indicating the end of the chain.

In some examples, the limit sensor is configured to detect a change in the color of one or more links in the chain indicating the end of the chain.

In some examples, the limit sensor is a mechanical limit switch configured to be actuated by a feature of the chain used to indicate the end of the chain.

In some examples, the hoist device includes a wireless transceiver and a remote controller in communication with the wireless transceiver.

In some examples, the controller is configured to determine a distance between the hoist device and the remote controller using a distance determination protocol. The distance determination protocol includes receiving, from the remote controller, a data packet including a sent time message, determining a receive time at the data packet using the controller, and determining a distance between the remote controller and the hoist device. The distance is determined based on the speed of the transmission and the difference between the receive time and the sent time.

In some examples, a first internal clock of the remote controller and a second internal clock of the controller are synchronized.

In some examples, the remote controller includes a display device configured to display one or more parameters associated with the hoist device.

In some examples, the parameters include one or more of an overload condition, an ability to complete lift condition, a system health, an individual hoist battery charge level, a remote battery charge level, a secured load indication, and a distance between the hoist device and the remote controller.

In some examples, the remote controller further includes an input to provide a variable speed input to the controller for controlling a speed of the motor.

In some examples, the controller is additionally configured to determine a magnitude of a load associated with the workpiece, and control a rate of acceleration of the motor based on the determined magnitude. The rate of acceleration is reduced in response to an increase in the magnitude of the load.

In some examples, the hoist device includes a load detection device in communication with the controller.

In some examples, the load detection device is a hydraulic cylinder coupled between the hoist device and a hoist support point, the hydraulic cylinder including a pressure sensor in communication with the controller.

In some examples, the pressure sensor outputs a pressure reading indicative of a load coupled to the hoist device.

In some examples, the load detection device is a load cell coupled between the hoist device and a hoist support point, the load cell configured to communicate a load reading to the controller.

In some examples, the load detection device is a current sensor configured to determine a current consumption of the motor, wherein the current consumption is indicative of a load coupled to the hoist device.

In some examples, the load detection device is a speed sensor configured to determine a speed of the motor and in communication with the controller. The controller is configured to determine a load based on a decrease in speed of the motor from a no-load speed.

In some examples, the hoist device further includes a load hook coupled to a first end of the chain. The load hook is configured to couple the workpiece to the chain.

In some examples, the load hook includes a security hasp. The security hasp comprises an electronic sensor to determine whether the hasp has been closed.

In some examples, the load hook includes a motion sensor configured to determine a change in a balance of the workpiece when the workpiece is suspended.

In some examples, the motion sensor is one or more of an accelerometer and a gyroscope.

In some examples, the controller is further configured to determine a number of lifts remaining in the power supply based on one or more parameters of the power supply, a current draw during a lifting operation, and a voltage drop during the lifting operation.

In some examples, the controller is configured to receive redundant data signals containing commands from the remote controller in communication with the hoist device.

In some examples, the controller monitors the redundant data signals from the remote controller to verify the accuracy of a received command.

In some examples, the controller is configured to evaluate commands received from the remote controller to verify that the commands are within a predetermined specification.

In some examples, the remote controller includes one or more double activation inputs requiring a user to perform two independent actions in order to transmit a command associated with the user actions.

In some examples, the remote controller includes one or more triple activation inputs requiring a user to perform three independent actions in order to transmit a command associated with the user actions.

In some examples, one of the activation inputs is a capacitive hand sensor for sensing the presence of a user's hand.

In some examples, the hoist device includes a mechanical brake configured to stop and maintain a position of the workpiece during a lifting operation or a lowering operation.

In some examples, the mechanical brake is a friction brake.

In some examples, the friction brake is actuated based on a command from the controller.

In some examples, hoist device includes an electro-mechanical brake configured to stop and maintain a position of the workpiece during a lifting operation or a lower operation.

In some examples, the electro-mechanical brake is controller based on an output from the controller.

In some examples, the hoist device includes a chain locking device configured to prevent movement of the workpiece during a loss of power.

In some examples, the chain locking device includes a first pawl configured to engage a first ratchet wheel of the transmission to prevent operation of the hoist device in a first direction.

In some examples, the first pawl is moved into and out of engagement with the first ratchet wheel by one or more solenoid devices.

In some examples, the solenoid is configured to move the first pawl into engagement with the ratchet wheel when power is removed to the solenoid device.

In some examples, the chain locking device further includes a second pawl configured to engage a second ratchet wheel of the transmission to prevent operation of the hoist device in a second direction.

In some examples, the chain locking device includes a worm gear coupled to one or more gears of the transmission to prevent movement of the load by preventing undesired movement of a main drive gear of the transmission.

In some examples, the chain locking device is an inertial lock configured to prevent movement of the chain if a speed of the chain release exceeds a predetermined speed.

In some examples, the controller is configured to stop operation of the hoist device when a voice command indicting a stop is received by one or more components of the hoist device.

In some examples, the controller is configured to determine a distance between the remote controller and the hoist device.

In some examples, the controller is configured to not accept commands from the remote controller when the determined distance exceeds a predetermined threshold.

In some examples, the remote controller uses a line-of-sight communication signal to communicate with the hoist device.

In some examples, the hoist device further includes a manual hoist input configured to accept a manual operating mechanism. The manual operating mechanism interfaces with one or more ratcheting interfaces of the transmission to allow a user to manually raise or lower the workpiece using the manual operating mechanism.

In some examples, the controller is configured to stop an operation of the hoist device in response to determining a current increase that exceeds a predetermined threshold.

In some examples, the controller is configured to stop an operation of the hoist device in response to determining a current decrease that exceeds a predetermined threshold.

In some examples, the power source is a removable battery pack.

In some examples, the removable battery pack is a power tool battery pack.

Other aspects of the application will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless hoist system in accordance with some embodiments.

FIG. **2**A illustrates a hoist device of the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **2**B is a block diagram of a hoist device of the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **3** is a block diagram of a hoist controller of the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIGS. **4**A-**4**C illustrate example implementations of the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **5** illustrates an example implementation of the wireless hoist system of FIG. **1** to install a workpiece in accordance with some embodiments.

FIGS. **6**A-**6**B illustrate an example implementation of the wireless hoist system of FIG. **1** with different mounting positions of the hoist devices of FIG. **1** in accordance with some embodiments.

FIG. **7** is a flowchart of a method for operating the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **8** is a block diagram of a communication scheme of the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **9** is a flowchart of the communication scheme of FIG. **8** in accordance with some embodiments.

FIG. **10** is a flowchart of another method for operating the wireless hoist system of FIG. **1** in accordance with some embodiments.

FIG. **11** illustrates an example implementation of the wireless hoist system of FIG. **1** with a hoist controller in communication with two or more hoist devices in accordance with some embodiments.

FIG. **12** illustrates another example implementation of the wireless hoist system of FIG. **1** with control of one or more hoist devices to maintain a desired angle in accordance with some embodiments.

FIG. **13** illustrates a block diagram for the implementation of the wireless hoist system shown in FIG. **12**.

FIG. **14** illustrates a control diagram for the implementation of the wireless hoist system shown in FIG. **12**.

FIG. **15** is a flowchart of a method for operating the wireless hoist system of FIGS. **12**-**14** in accordance with some embodiments.

FIG. **16** illustrates an example implementation of the wireless hoist system of FIG. **1** with a hoist controller in communication with a single hoist device in accordance with some embodiments.

FIG. **17** illustrates a block diagram for the implementation of the wireless hoist system shown in FIG. **16**.

FIG. **18** illustrates a control diagram for the implementation of the wireless hoist system shown in FIG. **16**.

FIG. **19** is a flowchart of a method for operating the wireless hoist system of FIG. **16** in accordance with some embodiments.

FIG. **20** illustrates a wireless hoist system including a handheld remote controller in accordance with some embodiments.

FIG. **21** is a schematic of the handheld remote controller of FIG. **20** in accordance with some embodiments.

FIG. **22** is a schematic of a hoist device of the wireless hoist system of FIG. **20** in accordance with some embodiments.

FIG. **23** illustrates an indication system of the wireless hoist system of FIG. **20** in accordance with some embodiments.

FIG. **24** is a graphical user interface of a smart telephone used as the handheld remote controller of FIG. **20** in accordance with some embodiments.

FIGS. **25**A, **25**B, and **25**C illustrate the handheld remote controller of FIG. **20** in accordance with some embodiments.

FIGS. **26**A and **26**B illustrate a method for calculating a distance between a controller and a hoist device of FIG. **1** and FIG. **20** in accordance with some embodiments.

FIGS. **27**A and **27**B illustrate a method for synchronizing clocks of the controller and the hoist device of FIG. **1** and FIG. **20** in accordance with some embodiments.

FIGS. **28**A, **28**B, **28**C, and **28**D illustrate exchange of signals between a controller and a hoist devices of FIG. **1** and FIG. **20** using a proprietary RF communication protocol in accordance with some embodiments.

FIGS. **29**A, **29**B, and **29**C illustrate an example of multiple hoist load balancing in accordance with some embodiments.

FIG. **30** illustrates a tilt winch system that may be used with the hoist system of FIG. **1** in accordance with some embodiments.

FIG. **31** is a flow chart illustrating a process for determining a last lift for a DC battery powered hoist device in accordance with some embodiments.

FIG. **32** is a flow chart illustrating a process for controlling a soft start function of a motor in accordance with some embodiments.

FIG. **33** is a data plot illustrating the relationship between motor acceleration and magnitude of a load in a hoist system in accordance with some embodiments.

FIG. **34** illustrates a system for determining a magnitude of a load on a chain hoist in accordance with some embodiments.

FIG. **35** illustrates a system for determining a dynamic loading of a hoist system in accordance with some embodiments.

FIG. **36** illustrates a smart hook for use with a hoist system in accordance with some embodiments.

FIG. **37** illustrates a system incorporating the smart hook of FIG. **36** in accordance with some embodiments.

FIG. **38** illustrates an electromechanical brake in the engaged position.

FIG. **39** illustrates the electromechanical brake in the disengaged position.

FIG. **40** illustrates a manual operation mechanism operably coupled to the motor shaft of the hoist device in a first position.

FIG. **41** illustrates a manual operation mechanism operably coupled to the motor shaft of the hoist device in a second position.

FIG. **42** illustrates a limit switch mechanism for the hoist device.

FIG. **43**A illustrates the limit switch mechanism for the hoist device according to one embodiment.

FIG. **43**B illustrates the limit switch mechanism of FIG. **43**A when a stop interacts with the limit switch mechanism.

FIG. **44**A illustrates the limit switch mechanism for the hoist device according to another embodiment.

FIG. **44**B illustrates the limit switch mechanism for the hoist device according to another embodiment.

FIG. **44**C illustrates a hard stop or overloading clutch mechanism for the hoist device.

FIG. **45** illustrates a hoist controller operably coupled the hoist device via a retractable cord.

FIG. **46** illustrates a user operating the hoist device of FIG. **45**.

FIG. **47** illustrates user operating the hoist device according to another embodiment.

FIG. **48** illustrates a power supply storage compartment for a hoist device.

FIG. **49** illustrates a regenerative braking mechanism for a hoist device.

FIG. **50** illustrates an inertial locking device for a hoist device, according to some embodiments.

FIG. **51** illustrates cam locks for a hoist device, according to some embodiments.

FIG. **52**A illustrates a mechanical ratchet/clutch system for a hoist device, according to some embodiments.

FIG. **52**B illustrates a two-way ratchet clutch system for a hoist device, according to some embodiments.

FIG. **53** illustrates a solenoid based locking system for a hoist device, according to some embodiments.

FIG. **54** illustrates a ratcheting mechanism for a hoist device, according to some embodiments.

FIG. **55** illustrates a worm gear mechanism for a hoist device, according to some embodiments.

FIG. **56** illustrates an electromechanical brake for a hoist device, according to some embodiments.

FIG. **57** illustrates a process for modifying the operation of the hoist device, according to some embodiments.

FIG. **58** illustrates a hoist device configured to receive voice commands, according to some embodiments.

FIG. **59** illustrates a motion activated hoist system, according to some embodiments.

FIG. **60** illustrates a chain controller hoist system, according to some embodiments.

FIG. **61** illustrates a modular hoist device, according to some embodiments.

FIG. **62** illustrates a remotely powered hoist system, according to some embodiments.

Before any embodiments are explained in detail, it is to be understood that the included embodiments are not to be limited to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The embodiments are capable of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limited. The use of "including," "comprising" or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. The terms "mounted," "connected" and "coupled" are used broadly and encompass both direct and indirect mounting, connecting and coupling. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings, and can include electrical connections or couplings, whether direct or indirect. Additionally, as used herein with a list of items, "and/or" means that the items may be taken all together, in sub-sets, or as alternatives (for example, "A, B, and/or C" means A; B; C; A and B; B and C; A and C; or A, B, and C).

It should be noted that a plurality of hardware and software based devices, as well as a plurality of different structural components may be utilized to implement the described embodiments. Furthermore, and as described in subsequent paragraphs, the specific configurations illustrated in the drawings are intended as example embodiments and other alternative configurations are possible. The terms "processor" "central processing unit" and "CPU" are interchangeable unless otherwise stated. Where the terms "processor" or "central processing unit" or "CPU" are used as identifying a unit performing specific functions, it should be understood that, unless otherwise stated, those functions can be carried out by a single processor, or multiple processors arranged in any form, including parallel processors, serial processors, tandem processors or cloud processing/cloud computing configurations.

It should be understood that although certain drawings illustrate hardware and software located within particular devices, these depictions are for illustrative purposes only. In some embodiments, the illustrated components may be combined or divided into separate software, firmware and/or hardware. For example, instead of being located within and performed by a single electronic processor, logic and processing may be distributed among multiple electronic processors. Regardless of how they are combined or divided, hardware and software components may be located on the same computing device or may be distributed among different computing devices connected by one or more networks or other suitable communication links.

DETAILED DESCRIPTION

FIG. **1** illustrates one example embodiment of a wireless hoist system **100** including a plurality of hoist devices **110**, for example, a first hoist device **110**A and a second hoist device **110**B, a hoist controller **120**, and a workpiece **130**. The first hoist device **110**A and the second hoist device **110**B are mounted on a support surface **140**. The support surface **140** is, for example, a ceiling, wall, beam, or another structure of a work shop. The first hoist device **110**A and the second hoist device **110**B may be singularly referred to as a hoist device **110**. The hoist controller **120** is, for example, a hand-held device such as a joystick controller (see FIGS. **20** and **25**A-C), a smart telephone (see FIG. **24**), a tablet computer, and the like.

The first hoist device **110**A is connected to the workpiece **130** by a first chain **115**A of the first hoist device **110**A. The second hoist device **110**B is connected to the workpiece **130** by a second chain **115**B of the second hoist device **110**B. The first hoist device **110**A and the second hoist device **110**B move the workpiece **130** by operating the first chain **115**A and the second chain **115**B respectively. The first chain **115**A and the second chain **115**B may be singularly referred to as a chain **115**. The hoist controller **120** can control one or more of the first hoist device **110**A and the second hoist device **110**B (for example, the plurality of hoist devices **110**) to move the workpiece **130** between different locations. FIG. **1** illustrates only one example embodiment of the wireless hoist system **100**. The wireless hoist system **100** may include more or fewer components and may perform functions other than those explicitly disclosed herein.

FIG. **2**A illustrates one example embodiment of the hoist device **110**. The hoist device **110** may be mounted to the support surface **140** (see FIG. **1**). The hoist device **110** includes a first hook **204** used for mounting the hoist device **110** to a support surface, such as the support surface **140**. In some embodiments, other mounting elements, for example, fasteners, may be used to mount the hoist device **110** to the support surface **140**. The hoist device **110** also includes a second hook **208** used for connecting the hoist device **110** to the workpiece **130**. The hoist device **110** releases and retracts the chain **115** to raise and lower a workpiece, such as the workpiece **130**. In other embodiments, the hoist device **110** may be mounted to a floor or other ground level support, and a pulley or other device may be coupled to the support surface **140**, and coupled via the chain **115**. Operation of the hoist device **110** releases and retracts the chain to raise and lower the workpiece via the pulley. By mounting the hoist device to the floor or other ground level support, more convenient access to the hoist is provided, thereby allowing maintenance to be performed without a lift or removing the hoist from the support surface **140**.

FIG. **2**B is a block diagram of one example embodiment of the hoist device **110**. The hoist device **110** includes a hoist electronic processor **210** (for example, a motor drive), a hoist memory **220**, a hoist transceiver **230** (for example, a first wireless transceiver and a second wireless transceiver), a hoist power source **240**, a hoist motor **250** (for example, a first motor and a second motor), and one or more hoist sensors **260**. The hoist electronic processor **210** communicates with the hoist memory **220**, the hoist transceiver **230**, the hoist motor **250**, and the one or more hoist sensors **260** over one or more control and/or data buses (for example, hoist communication buses **270**). FIGS. **2**A-**2**B illustrates only one example embodiment of a hoist device **110**. The hoist device **110** may include more or fewer components and may perform functions other than those explicitly described herein.

In some embodiments, the hoist electronic processor **210** is implemented as a microprocessor with separate memory, such as the hoist memory **220**. In other embodiments, the hoist electronic processor **210** may be implemented as a microcontroller (with hoist memory **220** on the same chip). In other embodiments, the hoist electronic processor **210** may be implemented using multiple processors. In addition, the hoist electronic processor **210** may be implemented partially or entirely as, for example, a field-programmable gate array (FPGA), and application specific integrated circuit (ASIC), and the like and the hoist memory **220** may not be needed or be modified accordingly. In the example illustrated, the hoist memory **220** includes non-transitory, computer-readable memory that stores instructions that are received and executed by the hoist electronic processor **210** to carry out functionality of the hoist device **110** described herein. The hoist memory **220** may include, for example, a program storage area and a data storage area. The program storage area and the data storage area may include combinations of different types of memory, such as read-only memory and random-access memory.

The hoist transceiver **230** enables wireless communication between the hoist device **110** and other devices, for example, other hoist devices **110**, the hoist controller **120** and the like. In some embodiments, the hoist transceiver **230** includes a combined transmitter and receiver, while in other embodiments, the hoist transceiver **230** includes a separate transmitter and receiver.

The hoist power source **240** may be a DC power source, for example, a power tool battery pack coupled to the hoist device **110**, or may be an AC power source, for example, a power cord that plugs into an AC outlet (for example, a wall outlet). In one example, the hoist power source **240** is an M18 REDLITHIUM Battery Pack sold and marketed by Milwaukee®. The hoist power source **240** provides operating electric power to the hoist motor **250** and other electrical components, for example, the hoist electronic processor **210**, the hoist transceiver **230**, and the like. The electrical connections between the hoist power source **240** and other components of the hoist device **110** are not shown to simplify the illustration. The hoist motor **250** is, for example, an AC motor, a brushless DC motor, a brushed motor, or the like, powered by the hoist power source **240**. The hoist motor **250** is controlled by the hoist electronic processor **210** to release or retract the chain **115** from the hoist device **110**. The hoist device **110** includes a transmission mechanism for connecting the output shaft of the hoist motor **250** to the chain **115**. The one or more hoist sensors **260** include, for example, a length sensor to detect the amount of chain **115** released, a tension sensor to detect the tension in the chain **115**, a resolver to detect motor position, a torque or current sensor to detect torque of the hoist motor **250**, and the like.

FIG. **3** is a block diagram of one example embodiment of the hoist controller **120**. The hoist controller **120** includes a controller electronic processor **310**, a controller memory **320**, a controller transceiver **330**, a user interface **340**, and a power source **345**. The hoist controller **120** may include a housing (shown diagrammatically at least in FIG. **1**) that supports the elements of the hoist controller **120** described herein. The controller electronic processor **310** communicates with the controller memory **320**, the controller transceiver **330**, and the user interface **340** over one or more control and/or data buses (for example, controller communication buses **350**). FIG. **3** illustrates only one example embodiment of a hoist controller **120**. The hoist controller **120** may include more or fewer components and may perform functions other than those explicitly described herein.

The controller electronic processor **310**, the controller memory **320**, and the controller transceiver **330** may implemented similarly as the hoist electronic processor **210**, the hoist memory **220**, and the hoist transceiver **230**. The controller transceiver **330** enables wireless communication between the hoist controller **120** and other devices, for example, the plurality of hoist devices **110**. The hoist controller **120** and the plurality of hoist devices **110** may communicate over, for example, a Bluetooth network, a Wi-Fi network, or the like. The hoist controller **120** and the plurality of hoist devices **110** may communicate over the same channel or different channels as further described below.

The user interface **340** may include one or more input devices (for example, pushbutton, a trigger, a joystick, a keyboard, and the like), one or more output devices (for example, light emitting diodes (LEDs), a speaker, a display, and the like), and/or one or more input/output devices (for example, a touch screen display). The hoist controller **120** may receive control inputs (for example, a user input) from a user through the user interface **340**. For example, the user may move the joystick to control release or retraction of the chain **115** from one or more of the hoist devices **110**.

The power source **345** is coupled to and powers the components of the hoist controller **120** including the controller electronic processor **310**, the controller memory **320**, the controller transceiver **330**, and the user interface **340**. The electrical connections between the power source **345** and other components of the hoist controller **120** are not illustrated to simplify the illustration. In some embodiments, the power source **345** is a DC power source including, for example, one or more battery cells (e.g., AA type, AAA type, 9V type) or a battery pack including one or more battery cells (e.g., a power tool battery pack or a USB power source). In one example, the power source **345** is an M12 Battery Pack sold and marketed by Milwaukee®. The DC power source, in contrast to a corded AC power source, increases the portability and mobility of the hoist controller **120**. However, in some embodiments, the power source **345** is an AC power supply circuit that receives AC power via a cord coupled to an AC power source (e.g., a wall outlet), converts the AC power to DC power (e.g., via a rectifier or power switching elements), and outputs DC power.

FIGS. **4A-4C** illustrate several example implementations of the wireless hoist system **100**. The wireless hoist system **100** is used to lift or lower the workpiece **130** using the first hoist device **110**A and the second hoist device **110**B. The first chain **115**A and the second chain **115**B are coupled to different locations on the workpiece **130** to place the workpiece at an angle. In FIG. **4**A, the workpiece **130** is lifted or lowered at an angle from ground (for example, a non-zero angle from the ground). The first hoist device **110**A and the second hoist device **110**B are controlled by the hoist controller **120** to have differing chain lengths to maintain the non-zero angle. In FIG. **4**B, the workpiece **130** is lifted or lowered at a level angle (for example, 0 degrees from the ground). The first hoist device **110**A and the second hoist device **110**B are controlled by the hoist controller **120** to have the same chain length to maintain the level angle. In FIG. **4**C, the wireless hoist system **100** is used to lift or lower a workpiece **130** having an irregular shape such that the first hoist device **110**A and the second hoist device **110**B may have different chain lengths to maintain the angle of lift of the workpiece **130**.

FIG. **5** illustrates another example implementation of the wireless hoist system **100**. The wireless hoist system **100** is used to lift the workpiece **130** from a first location **510** and install the workpiece **130** at a second location **520**. The first chain **115**A and the second chain **115**B are coupled at the same location or at nearby locations to install the workpiece **130**. Particularly, the first hoist device **110**A and the second hoist device **110**B work together to move the workpiece **130** vertically and laterally to install the workpiece **130** at the second location **520**.

FIGS. **6**A-**6**B illustrate different mounting positions of the hoist devices **110**. The first hoist device **110**A is mounted to a first support surface **610** (for example, a ceiling) of a workshop and the second hoist device **110**B is mounted to a second support surface **620** (for example, a wall) of the workshop. The mounting location of the first hoist device **110**A and the second hoist device **110**B may be varied depending on the installation location **520** and barriers in the workshop.

FIG. **7** illustrates a flowchart of one example method **700** of operating the wireless hoist system **100**. In the example illustrated, the method **700** includes receiving, at user interface **340** of the hoist controller **120**, user input (at block **710**). A user of the wireless hoist system **100** controls the hoist devices **110** using the hoist controller **120**. The user provides control inputs to the hoist controller **120** over the user interface **340**. For example, the user interface **340** includes a joystick controller and the user moves the joystick controller to produce movements of the workpiece through the hoist devices **110**. The user interface **340** may receive user input from the user including several operational parameters for the work to be performed by the wireless hoist system **100**. The user input may include a desired movement of the workpiece **130**, for example, a direction of movement, a speed of movement, a start point, an end point, or the like of the workpiece **130**. The user interface **340** may also receive as user input from the a position of the first hoist device **110**A, a position of the second hoist device **110**B, and a desired end position of the workpiece **130**.

The method **700** includes determining, using the controller electronic processor **310**, a first operation parameter and a second operation parameter based on the user input (at block **720**). The first operation parameter corresponds to the first hoist device **110**A and the second operation parameter corresponds to the second hoist device **110**B. The controller electronic processor **310** receives the user input, for example, the desired movement of the workpiece, the positions of the hoist devices **110** and the workpiece, and determines the operation parameters of the first hoist device **110**A and the second hoist device **110**B based on the user input. For example, the controller electronic processor **310** receives a desired movement of the workpiece as the user input and determines a direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A and a direction and/or speed of movement and/or chain length of the second chain **115**B of the second hoist device **110**B. The direction and/or speed of movement and/or chain length of the first chain **115**A corresponds to the first operation parameter and the direction and/or speed of movement and/or chain length of the second chain **115**B corresponds to the second operation parameter. In another example, the controller electronic processor **310** receives the respective positions of the first hoist device **110**A and the second hoist device **110**B and the desired end position of the workpiece as the user input and determines the direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A and the direction and/or speed of movement and/or chain length of the second chain **115**B of the second hoist device **110**B. In this example, the controller electronic processor **310** may also use the respective chain lengths of the first chain **115**A and the second chain **115**B from the first hoist device **110**A and the second hoist device **110**B for determining the first operation parameter and the second operation parameter. For example, the controller electronic processor **310** may determine the initial position of the workpiece based on the positions of the hoist devices **110** (which may be entered in a set up stage) and the respective chain lengths (which may be determined using the respective sensors **260**). The controller electronic processor **310** finds the distance and direction between the initial position determined above and the desired end position received from the user input. The positions of the hoist devices **110** and the initial positions of the workpiece may, for example, be provided or determined with respect to a common reference point (e.g., a point on the floor) or multiple reference points with known relative positions. The controller electronic processor **310** uses the distance and direction to calculate the direction and/or speed of movement and/or chain length of the first chain **115**A and the second chain **115**B. For example, the positions may be expressed one of various formats, such as using the Cartesian coordinate system or another coordinate system. Then, for example, the direction and chain length for each hoist device **110** to move a workpiece from an initial position to an end position may be calculated by determining differences between the coordinates of the initial and end positions with respect to the positions of the hoist devices **110**.

The method **700** includes providing, wirelessly using the controller electronic processor **310**, a first control signal indicative of the first operation parameter to the first hoist device **110**A (at block **730**). The controller electronic processor **310** provides the control signals that correspond to the first operation parameter via the controller transceiver **330** to the first hoist device **110**A. The first hoist device

110A receives the first control signal over the hoist transceiver 230 (that is, the first wireless transceiver). The first hoist device 110A operates based on the first control signal. That is, the first hoist device 110A controls the hoist motor 250 (that is, the first motor) of the first hoist device 110A based on the first control signal. For example, the hoist electronic processor 210 of the first hoist device 110A controls the hoist motor 250 of the first hoist device 110A to match the direction, chain length, and/or speed indicated by the first control signal.

The method 700 also includes providing, wirelessly using the controller electronic processor 310, a second control signal indicative of the second operation parameter to the second hoist device 110B (at block 740). The controller electronic processor 310 provides the control signals that correspond to the second operation parameter via the controller transceiver 330 to the second hoist device 110B. The second hoist device 110B receives the second control signal over the hoist transceiver 230 (that is, the second wireless transceiver). The second hoist device 110B operates based on the second control signal. That is, the second hoist device 110B controls the hoist motor 250 (that is, the second motor) of the second hoist device 110B based on the second control signal. For example, the hoist electronic processor 210 of the second hoist device 110B controls the hoist motor 250 of the second hoist device 110B to match the direction, chain length, and/or speed indicated by the second control signal.

In some embodiments, the method 700 may include determining the first operation parameter based on the user input rather than both the first operation parameter and the second operation parameter at block 720. This embodiment may be applicable in, for example, situations where the first hoist device 110A and the second hoist device 110B include similar operation to move the workpiece as shown in FIGS. 1 and 4A-C. In these embodiments, the method 700 further includes providing, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device 110A (at block 730) and providing, wirelessly, a second control signal indicative of the first operation parameter to the second hoist device 110B (at block 740).

In some embodiments, the user may provide signals continuously until the workpiece 130 reaches the desired end position. For example, the user may move the joystick controller until the workpiece 130 reaches the desired end position. In these embodiment, the method 700 repeats to continuously provide the first control signal and the second control signal (which may vary over time) to the first hoist device 110A and the second hoist device 110B until the user terminates providing the user input (e.g., releases the joystick). In some embodiments, the user may provide the desired end position along with other inputs and the method 700 may continuously provide the first control signal and the second controls signal until the desired end position is reached. Alternatively, the method 700 may provide the first control signal and the second control signal once to the first hoist device 110A and the second hoist device 110B and the first hoist device 110A and the second hoist device 110B operate until the workpiece 130 is at the desired location.

As shown in FIG. 8, the hoist controller 120 communicates with different hoist devices 110 over different wireless communication channels 810. For example, the hoist controller 120 communicates with the first hoist device 110A over a first channel 810A (i.e., first wireless channel), with the second hoist device 110B over a second channel 810B (i.e., a second wireless channel), and so on. Communicating with different hoist devices 110 over different communication channels 810 prevents interference between the different hoist devices. The user may selectively activate the channels 810 depending on the implementation of the wireless hoist system 100. For example, for a certain time period or operation, the user may activate only the first channel 810A to enable communication with the first hoist device 110A and deactivate all other channels 810. A wireless network may operate over a certain radio signal frequency bandwidth. That is the wireless network includes a minimum radio frequency and a maximum radio frequency and the wireless network utilizes the band of frequencies between the minimum and the maximum radio frequency to send and receive radio signals. The wireless bandwidth may be further divided into several channels, for example, by dividing the bandwidth into smaller frequency intervals. For example, a 20 MHz wireless band may be divided into several 5 GHz channels. A host device may communicate with several other devices over a single channel or over the complete range of the wireless network. However, communicating over a single channel or the complete range of the wireless network may cause interference between different communication paths (i.e., communication paths between the host device and guest devices) or may require special addressing to avoid interference. By communicating with different devices over different channels, interference and special addressing may be avoided.

FIG. 9 illustrates a flowchart of a method 900 of communication between the hoist controller 120 and the plurality of hoist devices 110. In the example illustrated, the method 900 includes reading, using the controller electronic processor 310, a direction and speed input from a user over the user interface 340 (at block 910). A user may input the desired direction and speed for moving the workpiece 130 using the user interface 340. The method 900 also includes determining, using the controller electronic processor 310, whether the first channel 810A is enabled (at block 920). When the first channel 810A is enabled, the method 900 includes providing, using the controller electronic processor 310 via the controller transceiver 330 and the first channel 810A, the direction and speed information to the first hoist device 110A (at block 930). That is, the first control signal is provided to the first hoist device 110A in response to determining that a first channel 810A associated with the first hoist device 110A is enabled. The method 900 similarly includes determining whether the other channels 810 are enabled (at blocks 935 and 945) and providing the direction and speed information to the respective hoist devices 110 when the respective channels 810 are enabled (at blocks 940 and 950). The second control signal is provided to the second hoist device 110B in response to determining that a second channel 810B associated with the second hoist device 110B is enabled. When a channel 810 is disabled (not enabled), the hoist controller 120 does not provide a direction and speed information to the hoist device 110 associated with the disabled channel. That is, the hoist controller 120, in response to determining that the third channel is disabled, does not provide a control signal indicative of the first operation parameter to the third hoist device 110.

FIGS. 10-11 illustrate one example implementation of the wireless hoist system 100 where two or more hoist devices 110 are controlled by the hoist controller 120 to install a workpiece 130. In the example illustrated, the hoist controller 120 communicates wirelessly with the first hoist device 110A over a first wireless communication channel 810A and communicates with the second hoist device 110B over a second wireless communication channel 810B.

FIG. 10 illustrates a method 1000 for the wireless hoist system 100. In the example illustrated, the method 1000 includes receiving, using the controller electronic processor **310**, a first position of the first hoist device **110**A (at block **1010**). The method **1000** also includes receiving, using the controller electronic processor **310**, a second position of the second hoist device **110**B (at block **1020**). A user may enter the first position data and the second position data using the user interface **340**. The position may be represented in various coordinate system formats (e.g., Cartesian) using a common reference point or multiple reference points with known or indicated relative positions.

The method **1000** further includes connecting the first hoist device **110**A to the workpiece **130** (at block **1030**) and connecting the second hoist device **110**B to the workpiece **130** (at block **1040**). The user may connect the first hoist device **110**A and the second hoist device **110**B to the workpiece **130** using the second hooks of the first hoist device **110**A and the second hoist device **110**B respectively.

The method **1000** includes calculating, using the controller electronic processor **310**, a workpiece position based on the first position, the second position, and chain length information (at block **1050**). As discussed above, the controller electronic processor **310** receives the first position information and the second position information from the user through the user interface **340**. Additionally, the hoist controller **120** communicates with the first hoist device **110**A to determine the released chain length of the first chain **115**A (determined by the first hoist device **100**A based on sensors **260**) and communicates with the second hoist device **110**B to determine the released chain length of the second chain **115**B (determined by the first hoist device **100**A based on sensors **260**). The controller electronic processor **310** determines the workpiece position based on the position information of the hoist devices **110** and the respective chain lengths.

The method **1000** also includes receiving, using the controller electronic processor **310**, a desired workpiece location (at block **1060**). The user may enter the desired workpiece location using the user interface **340**. For example, the location may be specified using the same coordinate system used to specify the first and second hoist positions. Based on the workpiece position and the desired workpiece location, the hoist controller **120** may automatically provide control signals to the first hoist device **110**A and the second hoist device **110**B (at block **1070**). FIG. **11** illustrates an example technique to implement block **1070** in which the hoist controller **120** provides a user desired workpiece position to the first hoist device **110**A and the second hoist device **110**B.

The control of the first hoist device **110**A and the second hoist device **110**B based on the first control signal and the second control signal is further explained with respect to FIG. **11**. The first hoist device **110**A includes a proportional-integral-derivative (PID) controller **1110**, for example, implemented by the hoist electronic processor **210** of the first hoist device **110**A. The PID controller **1110** or the hoist electronic processor **210** forms the motor drive of the first hoist device **110**A. The PID controller **1110** is coupled to a length/speed sensor **1120** (for example, a sensor for detecting chain length). The PID controller **1110** receives sensor data from the length/speed sensor **1120**. For example, the PID controller **1110** receives chain length information from the length/speed sensor **1120** indicating the amount of chain released from the first hoist device **110**A. The PID controller **1110** also receives the first control signal from the hoist controller **120**. The PID controller **1110** controls the motor **1130** (for example, the motor **250** of the first hoist device **110**A) based on the first control signal and the chain length information to install the workpiece **130**.

Similarly, the second hoist device **110**B includes a proportional-integral-derivative (PID) controller **1140**, for example, implemented by the hoist electronic processor **210** of the second hoist device **110**B. The PID controller **1140** or the hoist electronic processor **210** forms the motor drive of the second hoist device **110**B. The PID controller **1140** is coupled to a length/speed sensor **1150** (for example, a sensor for detecting chain length). The PID controller **1140** receives sensor data from the length/speed sensor **1150**. For example, the PID controller **1140** receives chain length information from the length/speed sensor **1150** indicating the amount of chain released from the second hoist device **110**B. The PID controller **1140** also receives the second control signal from the hoist controller **120**. The PID controller **1140** controls the motor **1160** (for example, the motor **250** of the second hoist device **110**B) based on the second control signal and the chain length information to install the workpiece **130**.

FIGS. **12**, **13**, and **14** illustrate one example implementation of the wireless hoist system **100** where one or more hoist devices **110** are controlled by the hoist controller **120** to install a workpiece **130**. The wireless hoist system **100** additionally includes a level sensor **1200** mounted to the workpiece **130** to measure an angle or orientation of the workpiece **130** with respect to gravitational pull (or ground). In the example illustrated, the hoist controller **120** communicates wirelessly with the first hoist device **110**A over a first wireless communication channel **810**A, communicates with the second hoist device **110**B over a second wireless communication channel **810**B, and communicates with the level sensor **1200** over a third wireless communication channel **810**C. The level sensor **1200** may include an electronic processor, memory, and transceiver (e.g., each similar to similarly named components of the hoist controller **120**), as well as a sensor (e.g., accelerometer, gyroscope, or the like) configured to generate level data and that is in communication with the electronic processor. The electronic processor of the level sensor **1200** may receive level data from the level sensor and communicate the level data to other devices (e.g., the hoist controller **120** or hoist device **110**) via the transceiver of the level sensor **1200**.

FIG. **15** illustrates a flowchart of one example method **1500** of operating the wireless hoist system **100** of FIGS. **12-14**. In the example illustrated, the method **1500** includes receiving, at user interface **340** of the hoist controller **120**, user input (at block **1510**). A user of the wireless hoist system **100** controls the hoist devices **110** using the hoist controller **120**. The user provides control inputs to the hoist controller **120** over the user interface **340**. For example, the user interface **340** includes a joystick controller and the user moves the joystick controller to produce movements of the workpiece through the hoist devices **110**. The user interface **340** may receive user input from the user including several operational parameters for the work to be performed by the wireless hoist system **100**. The user input may include a desired movement of the workpiece **130**, for example, a direction of movement, a speed of movement, a start point, an end point, or the like of the workpiece **130**. The user input may also include a position of the first hoist device **110**A, a desired angle of the level **1200**, a desired end position of the workpiece **130**, and the like.

The method **1500** includes determining, using the controller electronic processor **310**, a first operation parameter based on the user input (at block **1520**). The first operation parameter may correspond to the operation of the first hoist device **110**A and/or the second hoist device **110**B. The controller electronic processor **310** receives the user input, for example, the desired movement of the workpiece, the desired angle of the level **1200**, the positions of the hoist devices **110** and the workpiece, and determines the operation parameters of the first hoist device **110**A and/or the second hoist device **110**B based on the user input. For example, the controller electronic processor **310** receives a desired movement of the workpiece as the user input and determines a direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A and the second chain **115**B of the second hoist device **110**B. The direction and/or speed of movement and/or chain length of the first chain **115**A and the second chain **115**B corresponds to the first operation parameter. In another example, the controller electronic processor **310** receives the respective positions of the first hoist device **110**A and the second hoist device **110**B and the desired end position of the workpiece as the user input and determines the direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A and/or the second chain **115**B of the second hoist device **110**B. In this example, the controller electronic processor **310** may also use the respective chain lengths of the first chain **115**A and the second chain **115**B from the first hoist device **110**A and the second hoist device **110**B for determining the first operation parameter. For example, the controller electronic processor **310** may determine the initial position of the workpiece based on the positions of the hoist devices **110** and the respective chain lengths. The controller electronic processor **310** finds the distance and direction between the initial position determined above and the desired end position received from the user input. The controller electronic processor **310** uses the distance and direction to calculate the direction and/or speed of movement and/or chain length of the first chain **115**A and the second chain **115**B.

The method **1500** includes receiving, from the level sensor **1200**, the level signal (at block **1530**). As described above, the level sensor **1200** measures an angle of the level sensor against the gravitational pull and continuously provides the measured angle to the hoist controller **120**. The method **1500** includes providing, wirelessly using the controller electronic processor **310**, a first control signal indicative of the first operation parameter and the level signal to the first hoist device **110**A (at block **1540**). The controller electronic processor **310** provides the control signals that correspond to the first operation parameter and the level signal via the controller transceiver **330** to the first hoist device **110**A. The first hoist device **110**A receives the first control signal over the hoist transceiver **230** (that is, the first wireless transceiver). The first hoist device **110**A operates based on the first control signal. That is, the first hoist device **110**A controls the hoist motor **250** (that is, the first motor) of the first hoist device **110**A based on the first control signal. For example, the hoist electronic processor **210** of the first hoist device **110**A controls the hoist motor **250** of the first hoist device **110**A to match the direction, chain length, and/or speed indicated by the first control signal. The first control signal may take into account the desired level angle provided by the user through the user input and indicate the direction, chain length, and/or speed such that the user desired level angle is maintained during the operation. The method **1500** may repeat until the workpiece **130** is installed at the desired location. Additionally, in some embodiments, in addition to providing a first control signal indicative of the first operation parameter and level signal to the first hoist device, in block **1540**, the controller **120** may provide a second control signal indicative of a second operation parameter and level signal to the second hoist device **110**B using similar principals of operation.

FIG. **14** illustrates another control diagram for the wireless hoist system **100** that may be used to implement the method **1500**, as well as additional methods. The diagram of FIG. **14** includes determining, using the controller electronic processor **310**, a desired parameter information (for example, a desired angle of the workpiece **130** and a desired speed of operation). The controller electronic processor **310** further provides, via a communication channel, control signals indicating the desired parameter information to the first hoist device **110**A and the second hoist device **110**B. For the first hoist device **110**A, the PID controller **1110** receives the control signals from the hoist controller **120** and the chain length and/or motor speed information from the length/speed sensor **1120** and controls the motor **1130** based on the control signals and the sensor signals to install the workpiece **130**. Similarly, for the second hoist device **110**B, the PID controller **1140** receives the control signals from the hoist controller **120** and the chain length and/or motor speed information from the length/speed sensor **1150** and controls the motor **1160** based on the control signals and the sensor signals to install the workpiece **130**. In some embodiments, rather than receiving the level signal through the hoist controller **120**, the first hoist device **110**A and/or the second hoist device **110**B may communicate directly with the level sensor **1200** over a separate channel to receive the level signal and adjust the operation accordingly.

FIGS. **16-18** illustrate one example implementation of the wireless hoist system **100** where the hoist controller **120** sends commands to a first hoist device **110** to install a workpiece **130**, and the first hoist device **110** relays or generates further commands for at least the second hoist device **110**B or provides operational information (e.g., motor speed, chain length) that form that basis for operation of the second hoist device **110**B. In the example illustrated, the hoist controller **120** communicates wirelessly with the first hoist device **110**A. The first hoist device **110**A in turn communicates with the second hoist device **110**B to install the workpiece **130**. For example, the hoist controller **120** communicates with the first hoist device **110**A over a first wireless communication channel **810**A and the first hoist device **110**A communicates with the second hoist device **110**B over a second wireless communication channel **810**B.

FIG. **19** illustrates a flowchart of one example method **1900** of operating the wireless hoist system **100** of FIGS. **16-18**. In the example illustrated, the method **1900** includes receiving, at user interface **340** of the hoist controller **120**, user input (at block **1910**). A user of the wireless hoist system **100** controls the hoist devices **110** using the hoist controller **120**. The user provides control inputs to the hoist controller **120** over the user interface **340**. For example, the user interface **340** includes a joystick controller and the user moves the joystick controller to produce movements of the workpiece through the hoist devices **110**. The user interface **340** may receive user input from the user including several operational parameters for the work to be performed by the wireless hoist system **100**. The user input may include a desired movement of the workpiece **130**, for example, a direction of movement, a speed of movement, a start point, an end point, or the like of the workpiece **130**. The user input may also include a position of the first hoist device **110**A, a desired angle of the level **1200**, a desired end position of the workpiece **130**, and the like.

The method **1900** includes determining, using the controller electronic processor **310**, a first operation parameter based on the user input (at block **1920**). The first operation parameter may correspond to the operation of the first hoist device **110**A. The controller electronic processor **310** receives the user input, for example, the desired movement of the workpiece, the desired angle of the level **1200**, the positions of the hoist devices **110** and the workpiece, and determines the operation parameter of the first hoist device **110**A based on the user input. For example, the controller electronic processor **310** receives a desired movement of the workpiece as the user input and determines a direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A. The direction and/or speed of movement and/or chain length of the first chain **115**A corresponds to the first operation parameter. In another example, the controller electronic processor **310** receives the respective positions of the first hoist device **110**A and the second hoist device **110**B and the desired end position of the workpiece as the user input and determines the direction and/or speed of movement and/or chain length of the first chain **115**A of the first hoist device **110**A and/or the second chain **115**B of the second hoist device **110**B. In this example, the controller electronic processor **310** may also use the respective chain lengths of the first chain **115**A and the second chain **115**B from the first hoist device **110**A and the second hoist device **110**B for determining the first operation parameter. For example, the controller electronic processor **310** may determine the initial position of the workpiece based on the positions of the hoist devices **110** (e.g., received in a set up stage) and the respective chain lengths (determined by respective sensors **260** of the hoist devices **110**). The controller electronic processor **310** finds the distance and direction between the initial position determined above and the desired end position received from the user input. The controller electronic processor **310** uses the distance and direction to calculate the direction and/or speed of movement and/or chain length of the first chain **115**A.

The method **1900** includes providing, wirelessly using the controller electronic processor **310**, a first control signal indicative of the first operation parameter to the first hoist device **110**A (at block **1930**). The controller electronic processor **310** provides the control signals that correspond to the first operation parameter via the controller transceiver **330** to the first hoist device **110**A. The first hoist device **110**A receives the first control signal over the hoist transceiver **230** (that is, the first wireless transceiver). The first hoist device **110**A operates based on the first control signal. That is, the first hoist device **110**A controls the hoist motor **250** (that is, the first motor) of the first hoist device **110**A based on the first control signal. For example, the hoist electronic processor **210** of the first hoist device **110**A controls the hoist motor **250** of the first hoist device **110**A to match the direction, chain length, and/or speed indicated by the first control signal.

The method **1900** also includes providing, wirelessly using the first hoist device **110**A, a second control signal to the second hoist device **110**B (at block **1940**). The hoist electronic processor **210** provides the second control signal based on the first control signal via the hoist transceiver **230** to the first hoist device **110**A to the second hoist device **110**B. The second hoist device **110**B receives the second control signal over the hoist transceiver **230** (that is, the second wireless transceiver). The first hoist device **110**A determines, for example, a second operation parameter as described in the method **700** that corresponds to the operation of the second hoist device **110** based on the first control signal received from the hoist controller **120**. The second hoist device **110**B operates based on the second control signal. That is, the second hoist device **110**B controls the hoist motor **250** (that is, the second motor) of the second hoist device **110**B based on the second control signal. For example, the hoist electronic processor **210** of the second hoist device **110**B controls the hoist motor **250** of the second hoist device **110**B to match the direction, chain length, and/or speed indicated by the second control signal.

As shown in the control diagram of FIG. **18**, some embodiments of the wireless hoist system **100** include determining, using the controller electronic processor **310**, desired parameter information. For example, the user may input a desired speed and position information into the hoist controller **120** using the user interface **340**. The method also includes providing, using the controller electronic processor **310** via the first communication channel **810**A, control signals indicating the desired parameter information to the first hoist device **110**A. The PID controller **1110** of the first hoist device **110**A receives the control signals from the hoist controller **120** and the chain length and/or motor speed information from the length/speed sensor **1120** (for example, the one or more hoist sensors **260** of the first hoist device **110**A) and controls the motor **1130** (for example, the motor **250** of the first hoist device **110**A) based on the control signals and the sensor signals to install the workpiece **130**.

The first hoist device **110**A also provides, using the hoist electronic processor **210**A, a speed of the first hoist device **110**A to the second hoist device **110**B. The first hoist device **110**A communicates with the second hoist device **110**B over the second wireless communication channel **810**B to provide the speed information to the second hoist device **110**B. The PID controller **1140** of the second hoist device **110**B receives the speed information from the first hoist device **110**A and the chain length and/or motor speed information from the length/speed sensor **1150** (for example, one or more hoist sensors **260** of the second hoist device **110**B) and controls the motor **1160** (for example, the motor **250** of the second hoist device **110**B) based on the speed signals and the sensor signals to install the workpiece **130**. In some embodiments, if the speed or acceleration exceeds a predetermined maximum value, the hoist controller **120** may stop operation of the hoist device. Examples of the predetermined threshold may be 20% above a normal operating value. However, threshold values of more than 20% or less than 20% are also contemplated.

While some of the embodiments are described herein with respect to a single (first) hoist device **110** or with respect to a first and second hoist device **110**, in some embodiments, two, three, or more hoist devices **110** are included. For example, the wireless hoist system **100** may include a third hoist device **110**. Continuing the method **700**, the controller electronic processor **310** also determines a third operation parameter based on the user input (at block **720**), and the method **700** further includes providing a third control signal indicative of the third operation parameter to the third hoist device **110**. Turning to the method **1900**, with a third hoist device, an additional block may be included (e.g., after block **1940**) in which a third control signal is provided to the third hoist device using the first (or second) hoist device **110**. The third hoist device **110** operates based on the third control signal. In these embodiments, the hoist controller **120** communicates with the first hoist device **110**A over a first wireless channel **810**, the first hoist device **110**A communicates with the second hoist device **110**B over a second wireless channel **810**B (as previously described), and the first hoist device **110**A (or the second hoist device **110**B) communicates with the third hoist device **110** over a third wireless communication channel **810**C. As another example, the method **1500** may also operate with a third hoist device

110, in which the third hoist device 110 operates with the first and second hoist devices 110 and level 1400 similar to the manner in which the second hoist device 110 is described as operating with the first hoist device 110 and level 1400.

FIG. 20 illustrates a handheld remote controller 2000 that may be used as the controller 120 in the various hoist systems described herein. In the example illustrated, the handheld remote controller 2000 includes a housing 2010, a variable speed trigger 2020, direction control pushbuttons 2030, and a communication channel pushbutton matrix 2040. The handheld remote controller 2000 is in the form of a joystick remote such as that used in flight simulators and video game controller. The handheld remote controller 2000 may communicate with one or more hoist devices 110 using one or more communication protocols (for example, Bluetooth®, ZigBee®, and the like).

The housing 2010 may be an elongated tubular housing that includes grip portion 2012 and a top portion 2014. The variable speed trigger 2020 is provided on the top portion 2014 just above the grip portion 2012. The direction control pushbuttons 2030 are provided on top of the top portion 2014. The grip portion 2012 and the top portion 2014 are arranged and sized such that a user holding the handheld remote controller 2000 using the grip portion 2012 may use the index finger to pull or release the variable speed trigger 2020 and may use the thumb to push the direction control pushbuttons 2030 provided on the top portion 2014. Accordingly, the handheld remote controller 2000 is designed for single-handed user operation.

The variable speed trigger 2020 is used to control a speed of operation of the hoist devices 110. Particularly, the speed of the hoist devices varies from zero to a maximum speed, where the maximum speed corresponds to a maximum pulling amount of the variable speed trigger 2020. The speed of the hoist devices 110 is therefore controlled by varying the pulling amount of the variable speed trigger 2020. The variable speed trigger 2020 includes a body with a spring biased member such that the user can pull the variable speed trigger 2020 from an original position by asserting pressure on the variable speed trigger 2020 and the trigger 2020 returns to the original position when the user releases the variable speed trigger 2020. In some embodiments, a sense pad and wiper are provided in the handheld remote controller 2000 to determine a pulling amount of the variable speed trigger 2020. The wiper is attached to the variable speed trigger 2020 such that the wiper moves with the variable speed trigger 2020 on the sense pad. The resistance of the sense pad changes based on the position of the wiper on the sense pad. This resistance of the sense pad is detected by the controller electronic processor 310 to determine the pulling amount of the trigger. In other embodiments, a Hall-sensor design or an optical sensor design may be used to determine the pulling amount of the variable speed trigger 2020.

In some embodiments, the variable speed trigger 2020 is configured to prevent a "lock on" condition, such as where the trigger becomes stuck in a position, resulting in a user being unable to disengage a previously commanded operation. In some examples, the variable speed trigger (or other inputs on the remote controller 2000) may be contaminated by debris, tolerance, or misuse. In some embodiment, rubber boots or other protective coverings may be added to the variable speed trigger 2020 or other inputs on the remote controller 2000, which can provide protection from contaminants, as well as mechanical wear.

The remote controller 2000 may further include one or more devices to reduce accidental operation of the remote controller 2000. These devices may include kill switches, trigger/actuator guards, and double and/or triple activation triggers/switches/hand sensors. Double/triple activation triggers/switches/hand sensors are configured to require multiple operations by a user to generate a command. For example, a user may have to depress a grip sensor on the remote controller 2000 as well as depress the variable speed trigger 2020 to effectuate the desired output. Example grip sensors may include capacitive sensors, pressure sensors, etc. In other embodiments, an accelerometer may be used to detect a motion in conjunction with an operation of an input, such as via the variable speed trigger 2020, which can be used as an additional input.

The remote controller 2000 may further include safety inputs such as a kill switch or emergency stop button to stop all movement of the hoist device 110. In one embodiment, the remote controller 2000 (and/or the hoist device) may include microphone or other audio input configured to recognize a vocal command or indicator related to stopping operation of the hoist device 110. For example, the audio input may be configured to recognize a yell/raised voice/loud noise and stop the operation of the hoist device. In some examples, environmental sounds, such as transient noises, scraping noises, or other sounds indicating undesired operation and or potential interference with the load may also be determined via the audio input. In one embodiment, a controller of the remote controller 2000 (such as described below) may be configured to process the audio input. In other embodiments, the hoist controller 120 is configured to process the audio input. In one embodiment, additional safety sensors, such as pinch sensors, may be placed onto the workpiece 130 which can output a signal to the remote controller 2000 and/or hoist controller 120. For example, a person guiding the workpiece into position may activate the pinch sensor by applying a force in order to stop movement of the hoist system 100. In other examples, the pinch sensor may be actuated if the workpiece 130 comes into contact with an object, and thereby stops operation of the hoist device 110.

The direction control pushbuttons 2030 are used to control a direction of operation of the hoist devices 110. The direction control pushbuttons 2030 include an up direction pushbutton 2030A and a down direction push button 2030B. The user may press down on one of the direction control pushbuttons 2030 to select a direction of operation of the hoist devices 110. In one embodiments, a user may be required to keep one of the direction control pushbuttons 2030 to be pressed down for the duration of operation of the hoist device 110. For example, the user may be required to actuate both a direction control pushbutton 2030 and the variable speed trigger 2020 to operate the hoist device 110. In this embodiments, the release of either the direction control pushbutton 2030 or the variable speed trigger 2020 may stop the operation of the hoist devices 110. In other embodiments, the user may press the direction control pushbutton 2030 at the start of the operation and the hoist devices 110 are operated in the selected direction without needing continuous actuation of the direction control pushbutton 2030.

In one embodiment, the hoist controller 120 is configured to receive commands from the remote controller 2000. The hoist controller 120 may be configured with one or more safety interlocks to prevent undesired operation of the hoist device. For example, the hoist controller may be configured to monitor one or more electronic signals from the remote controller 2000 and verify that the electronic signals (e.g. commands) are valid and within specification. In some embodiments, in response to determining that the electronic signals are not valid, the hoist controller **120** does not execute the requested command associated with the received signal. Where the hoist controller **120** is executing a command (e.g. moving a load up or down, etc.) and receives a subsequent electronic signal from the remote controller **2000** that is determined to be invalid, the hoist controller **120** stops the current operation and waits for a further valid electronic signal from the remote controller **2000** that is determined to be valid. Similarly, in some examples, the remote controller **2000** is configured to transmit redundant signals for all commands input by a user. The hoist controller **120** may be configured to monitor for the redundant command signals from the remote controller **2000**, and stop a current operation and/or prevent the commanded operation where the redundant signals are not valid. The hoist controller **120** may determine that redundant commands are invalid based on receiving only one of the two redundant signals and/or receiving different commands for each of the redundant commands.

In other examples, the hoist controller **120** is configured to provide one or more safety interlocks related to commands received from a remote source, such as remote controller **2000**. For example, when a command has been received by the hoist controller (such as UP or DOWN), the hoist controller will perform that operation only for as long as the command is issued. For example, if the hoist controller **120** receives an UP command the hoist controller **120** commands the hoist to raise the load up. If an issue is encountered, such as a mechanical issue, loss of power, loss of communication with remote controller **2000**, etc., the hoist controller **120** will stop the operation. However, as the last valid received command was an UP command, the hoist controller will prevent the load from being lowered (e.g. a DOWN operation). Similarly, if the last command received was a DOWN command, the hoist controller **120** will either operate the hoist device **110** in a DOWN mode, or stop operation in the event of an issue, but will not allow for an UP operation to be executed until a valid UP command is received.

The communication channel pushbutton matrix **2040** may include a plurality of communication channel pushbuttons each corresponding to one communication channel of the handheld remote controller **2000**. Each communication channel may be programmed to communicate with a single hoist device **110**. In the example illustrated, the communication channel pushbutton matrix includes four communication channel pushbuttons to communicate with four separate hoist devices **110** (individually identified as **110**A-D). The user may select one or more hoist devices **110** for control by the handheld remote controller **2000** by pressing the corresponding communication channel pushbutton. In the example illustrated, the user selected a first communication channel pushbutton **2040**A and a second communication channel pushbutton **2040**B for simultaneous control of a first hoist device **110**A and a second hoist device **110**B corresponding to the first communication channel pushbutton **2040**A and the second communication channel pushbutton **2040**B. Each communication channel pushbutton may also including a light indicator (e.g., an LED) to illuminate to indicate that the communication channel pushbutton is selected. In one embodiment, a communication channel pushbutton illuminates to indicate that the communication channel pushbutton is selected and is not illuminated when the communication channel pushbutton is not selected. In another embodiments, a communication channel pushbutton is illuminated in a first color (e.g., green) to indicate the communication channel pushbutton is selected and is illuminated in a second color (e.g., red) different that the first color to indicate that the communication channel pushbutton is not selected.

FIG. **21** illustrates a schematic of the handheld remote controller **2000**. In the example illustrated, the handheld remote controller **2000** includes the controller power source **345**, an electronic controller **2042** (including the controller electronic processor **310** and the controller memory **320**), the controller transceiver **330**, the variable speed trigger **2020**, the direction control pushbuttons **2030**, and the communication channel pushbutton matrix **2040**. The power source **345** is, for example, one or more AAA batteries that are inserted into the housing **2010** of the handheld remote controller **2000**. The power source **345** provides operating power for the electrical components of the handheld remote controller **2000**.

The controller transceiver **330** is, for example, a Bluetooth® chip, a radio-frequency (RF) transceiver chip, and the like. The controller transceiver **330** includes an antenna **335** for transmitting and receiving signals from the hoist devices **110**. The controller transceiver **330** is coupled to the controller electronic processor **310** to receive control signals from the controller electronic processor **310** for transmission and for providing signals from the hoist devices **110** to the controller electronic processor **310**.

The variable speed trigger **2020** is coupled to the controller electronic processor **310** to provide speed control signals to the controller electronic processor **310**. As described above, the variable speed trigger **2020** provided an indication of the amount to which the variable speed trigger **2020** is pulled to the controller electronic processor. The direction control pushbuttons **2030** are coupled to the controller electronic processor **310** to provide actuation signals to the controller electronic processor **310**.

For example, the first direction control pushbutton **2030**A provides a signal when the first direction control pushbutton **2030**A is pressed and does not provide any signal when the first direction control pushbutton is not pressed. The first direction control pushbutton **2030**A may continue to provide the signal as long as the first direction control pushbutton **2030**A remains pressed. In one example, when the first direction control pushbutton **2030**A is pressed, the first direction control pushbutton **2030**A closes a circuit forming a current path from the controller electronic processor **310** to ground and drawing a current from the controller electronic processor **310**. When the controller electronic processor **310** detects that a current is being drawn from the port connected to the first direction control pushbutton **2030**A, the controller electronic processor **310** determines that the first direction control pushbutton **2030**A is pressed. When the first direction control pushbutton **2030**A is released, the circuit is opened terminating the current draw from the controller electronic processor **310**.

Similarly, the second direction control pushbutton **2030**B provides a signal when the second direction control pushbutton **2030**B is pressed and does not provide any signal when the second direction control pushbutton is not pressed. The second direction control pushbutton **2030**B may continue to provide the signal as long as the second direction control pushbutton **2030**B remains pressed. In one example, when the second direction control pushbutton **2030**B is pressed, the first direction control pushbutton **2030**B closes a circuit forming a current path from the controller electronic processor **310** to ground and drawing a current from the controller electronic processor **310**. When the controller electronic processor **310** detects that a current is being drawn from the port connected to the first direction control pushbutton **2030**B, the controller electronic processor **310** determines that the first direction control pushbutton **2030**A is pressed. When the second direction control pushbutton **2030**B is released, the circuit is opened terminating the current draw from the controller electronic processor **310**. In the example illustrated, the first direction control pushbutton **2030**A corresponds to UP and the second direction control pushbutton **2030**B corresponds to DOWN.

The communication channel pushbutton matrix **2040** is coupled to the controller electronic processor **310** to provide control signals to the controller electronic processor **310**. The communication channel pushbutton matrix **2040** includes four communication channel pushbuttons **2040**A, **2040**B, **2040**C, **2040**D. The communication channel pushbuttons operate similar as the direction control pushbuttons **2030**A as described above. However, at least in some embodiments, the communication channel pushbuttons are toggle switches such that the communication channel pushbuttons can be pressed once to turn a communication channel on and once to turn the communication channel off. That is, the communication channel pushbuttons need not be pressed continuously.

The communication channel pushbutton matrix **2040** also includes a plurality of indicators **2045**A, **2045**B, **2045**C, **2045**D corresponding to the four communication channel pushbuttons. The plurality of indicators receive control signals from the controller electronic processor **310**. In some embodiments, an indicator is illuminated or its color is changed (e.g., red to green) when a corresponding one of the communication channel pushbutton is activated.

FIG. **22** illustrates a schematic of the hoist device **110**. In the example illustrated, the hoist device **110** includes the hoist power source **240**, a hoist electronic controller **2047** (including the hoist electronic processor **210** and the hoist memory **220**), and the hoist transceiver **230**. The power source **345** is, for example, a power tool battery pack that includes a terminal block and couples to a terminal block on a housing of the hoist device **110**. The power source **345** provides operating power for the electrical components of the hoist device **110**, including the motor **250** (not shown in FIG. **22**). Although the hoist electronic controller **2047** is illustrated as including two control boards in FIG. **22**, in some embodiments, the hoist electronic controller **2047** is a single control board including the hoist electronic processor **210** and the hoist memory **220**. For ease of description, the processors of the control boards of the hoist electronic controller **2047** will be collectively referred to as the hoist electronic processor **210**.

The hoist transceiver **230** is, for example, a Bluetooth® chip, a radio-frequency (RF) transceiver chip, and the like. The hoist transceiver **230** includes an antenna **235** for transmitting and receiving signals from the handheld remote controller **2000**. The hoist transceiver **230** is coupled to the hoist electronic processor **210** to receive signals from the hoist electronic processor **210** for transmission and for providing control signals from the handheld remote controller **2000** to the hoist electronic processor **210**.

Referring back to FIG. **20**, each communication channel pushbutton may be programmed to communicate with a single hoist device **110**. Particularly, a Bluetooth® address or a radio-frequency address of each hoist device **110** may be hard coded into the controller electronic processor **310** (e.g., permanently or semi-permanently stored in the hoist memory **220**) and associated with the corresponding one of the communication channel pushbutton. Each coded hoist device **110** may only be activated when the corresponding communication channel pushbutton is pressed and the corresponding LED is illuminated. Selecting more than one hoist device **110** allows for each of the selected hoist devices **110** to be controlled simultaneously with the handheld remote controller **2000**. Additionally, as further discussed above, the activated hoist devices **110** may communicate with each other to coordinate movement of a workpiece **130**. In some embodiments, for added safety, the hoist devices **110** may be configured to stop operation when no signals are received from the handheld remote controller **2000**.

In some embodiments, rather than being hardcoded, each communication channel pushbutton may be paired on-the-fly with a hoist device **110**. The pairing operation may be performed similar to Bluetooth® pairing or other RF communication protocol pairing. This allows for additional flexibility in the system by allowing a user to use the same handheld remote controller **2000** with several hoist devices **110**. Additionally, a lost or broken handheld remote controller **2000** may be easily replaced by pairing a new handheld remote controller **2000** with the hoist devices **110**.

In some embodiments, each hoist devices **110** may be paired with only one handheld remote controller **2000** at a time. For example, each hoist device may be store only one active address of a handheld remote controller **2000** at a time. Accordingly, the hoist device **110** can avoid receiving multiple control signals or conflicting control signals from different handheld remote controllers **2000** at the same time.

In some embodiments, each indicator **2045** associated with communication channel pushbutton may illuminate in a different color (e.g., one of red, blue, yellow, and green). The hoist device **110** may include similar indicators **2050** on the device. Referring to FIG. **23**, when a hoist device **110** is successfully paired with a communication channel pushbutton, the indicator **2045** corresponding to the communication channel pushbutton and the indicator **2050** on hoist device **110** may illuminate with the same color. This allows a user to easily identify the correspondence between each communication channel pushbutton and the hoist devices **110**.

In some embodiments, the controller transceiver **330** may be configured to transmit on unique frequencies that are not associated with other devices within a certain range of the hoist device **110**. In one embodiment, the controller transceiver **330** is configured to listen for other signal operating at or near the operating frequency of the remote controller **2000** and/or hoist devices **110**, and perform an action if a potential interfering signal is detected. In one embodiment, the controller transceiver **330** may stop operation and generate an alert to a user indicating that the operating frequency is in use by other devices. The user may then change the operating frequency of the controller transceiver **330**, or the user may disable the interfering device (or modify the operating frequency thereof). In other embodiments, the controller transceiver may automatically switch to a different frequency that is different from the interfering frequency. For example, the controller transceiver **330** may use frequency hopping whenever interference is detected. Further the controller transceiver **330** may also control the other wireless transceivers associated with the hoist devices **110** to switch frequencies accordingly.

In one embodiment, the controller transceiver **330** is configured to pair with the one or more hoist devices **110** using an encrypted communication protocol to prevent other devices from interfering with the communications between the remote controller **2000** and the hoist devices **110**. Additionally, as described above, the hoist controller **120** may perform redundant checks of the commands received from the remote controller **2000** to ensure the commands are valid. In other examples, the controller transceiver **330** is configured to send multiple signals (either redundant or dissimilar), which are checked by the by the hoist controller **120** for accuracy and verification before executing the command.

In other examples, the controller transceiver **330** and/or the hoist controller **120** performs time based signal quality and/or accuracy checks of all received signals. The time based signal checks evaluate signals over a period of time to verify that the signals are acceptable and verifiable. This can aid in discriminating between noise and actual signals. In other embodiments, the receiving device (i.e. the controller transceiver **330** and/or the hoist controller **120**) may evaluate a strength of the received signal, and only execute a command associated with the received signal based on the signal strength being above as signal strength threshold. In one embodiment, the controller transceiver **330** and/or the hoist controller **120** may use received signal strength-based location determination algorithms (RSSI) and will only execute commands with the associated received signals are within a threshold distance. In a further embodiment, the controller transceiver **330** may be configured to only interface with the hoist controller **120** via line of sight communications, such as infrared (IR) or other line of sight communication protocols.

Referring to FIGS. **21** and **22**, the hoist devices **110** provide indications of speed, direction, and load to each other simultaneously operated hoist device **110** as well as to the handheld remote controller **2000**. Referring to FIGS. **4**A-**4**C, the speed and load information may be used to move a workpiece **130** in unison as further described below. Referring to FIG. **5**, the speed and load information may also be used such that each hoist device **110** moves at a different speed and direction to move a workpiece **130** from a first location to a second location.

In some embodiments, a smart telephone may also be used in place of or in addition to the handheld remote controller **2000**. FIG. **24** illustrates a user interface **2400** on the smart telephone that allows for operation of the connected hoist devices. In the example illustrated, the user interface **2400** is provided on a touch screen such that different portions or different pages of the touch screen form different user input (for example, a variable speed trigger **2020**, direction control pushbuttons **2030**, and communication channel pushbutton matrix **2040**). In some embodiments, the smart telephone is configured to communicate with the hoist device **110** to configure the hoist device **110**, to retrieve operational data (e.g., logged data indicating usage, faults, and the like), and to transmit operational data and location information related to the hoist device **110** to a remote server. The location information may be determined from a GPS receiver on-board the smart phone, and attached to the operational information and identity of the hoist device when being sent to the remote server. Because the smart phone is communicating with the hoist device **110** via a local, short-range wireless communication protocol, the location information of the smart phone is an acceptable stand-in as a location of the hoist device **110**. The remote server may, in turn, provide the received information to another client device (e.g., another smart phone or a personal computer) such that location and operational data related to a fleet of hoist devices **110** may be tracked and monitored.

FIGS. **25**A through **25**C illustrate another embodiment of the handheld remote controller **2000**. In the example illustrated, the handheld remote controller **2000** includes the variable speed trigger **2020**, the communication channel pushbutton matrix **2040**, a system health indicator **2500**, a remote controller battery indicator **2510**, and a speed dial **2520**. The variable speed trigger **2020** is provided on a side of the housing **2010** of the handheld remote controller **2000**. The communication channel pushbutton matrix **2040** includes, for example, four translucent communication channel pushbuttons with LEDs or other illumination devices provided below the communication channel pushbuttons.

Referring to FIG. **25**B, the LEDs of the communication channel pushbuttons may be illuminated in different colors and flashing patterns to indicate different statuses of their respective associated hoist devices **110**. For example, the LEDs may be turned off to indicate that a hoist device **110**A is inactive due to power loss, due to the hoist device **110** not selected for operation, or the like. The LEDs may be flashed in a first color (e.g., orange) to indicate an error status of a corresponding hoist device **110**. The LED may be illuminated in the first color without flashing to indicate that the hoist device has not been secured, which may be indicated, for example, when a smart hook **3600** indicates to the remote controller **2000** that a hook latch **3606** is open (refer see to FIG. **36**). The LEDs may be flashed in a second color (e.g., red) to indicate that the corresponding hoist device **110** is overloaded. The LEDs may be illuminated in the second color without flashing to indicate that the hoist power source **240** of the corresponding hoist device **110** is depleted below operations level (or has a dead battery). The LEDs may be flashed in a third color (e.g., green) to indicate that the corresponding hoist device **110** has low battery. The LEDs may be illuminated in the third color without flashing to indicate that the corresponding hoist device **110** is active and operating normally. The LEDS may also be used for other warnings and alerts, for example, overload warnings and the like.

Referring to FIG. **25**A, the system health indicator **2500** may provide an indication of the overall system health of the hoist system **100**. The system health indicator **2500** include three LEDs illuminated in a single color or multiple colors. The system health indicator **2500** may illuminate all three LEDs to indicate that all components are functioning correctly. One or more of the LEDs may not be illuminated to indicate that one or more components of the system **100** may not functioning correctly. The remote controller battery indicator **2510** provides an indication of the battery level of the controller power source **345**. In the example illustrated, the remote controller battery indicator **2510** includes four LEDs, which may be illuminated to correspond to the current battery level of the controller power source **345** (e.g., four illuminated for full charge, three illuminated for ¾ charge, two illuminated for ½ charge, 1 illuminated for ¼ charge, and none illuminated for no charge).

Referring to FIG. **25**C, the variable speed trigger **2020** may be implemented using a dual trigger design having a first trigger **2020**A and a second trigger **2020**B. The first trigger **2020**A is provided below the top portion **2014** to be operated by an index finger of the user and the second trigger **2020**B is provided above the top portion **2014** to be operation by a thumb of the user. In some embodiments, the amount of trigger pull of the two triggers **2020**A-B correspond to the PWM duty cycle (ranging from 0-100%) of the signal used to drive the hoist motor(s) **250** being controlled by the handheld remote controller **2000**. The PWM duty cycle that drives the hoist motor(s) **250** is directly proportional to the speed of the hoist motor(s). In some embodiments, the pulling amount of the first trigger **2020**A is mapped to the entire range of the PWM duty cycle such that, for each 10% of total potential trigger travel, the PWM duty cycle increases from 10%, until the first trigger **2020**A is fully depressed (100%), at which point, the PWM duty cycle is set to 100%. In some embodiments, the pulling amount of the second trigger **2020**B is mapped to a reduced range of the PWM duty cycle such that, for each 10% of total potential trigger travel, the PWM duty cycle increases by 1%, until the first trigger **2020**A is fully depressed (100%), at which point, the PWM duty cycle would be 10%. In some embodiments, the sum of the duty cycles indicated by the two triggers **2020** is totaled, capped at 100%, to determine the PWM duty cycle to drive the hoist motor(s) **250**. Thus, for example:

- when the first trigger **2020**A is fully released (indicating 0% duty cycle), and the second trigger **2020**B is fully depressed (indicating+10% duty cycle), the total PWM duty cycle is set to 10%;
- when the first trigger **2020**A is pulled halfway (indicating 50% duty cycle), and the second trigger **2020**B is pulled halfway (indicating+5% duty cycle), the total PWM duty cycle is set to 55%; and
- when the first trigger **2020**A is fully depressed (indicating 100% duty cycle) the total PWM duty cycle is set to 100% regardless of the pull amount of the second trigger **2020**B.

Accordingly, at least in some embodiments, the first trigger **2020**A provides more variation in speed for each successive amount of pulling and has a larger range of control (e.g., 0-100% duty cycle), while the second trigger **2020**B provides less variation in speed for each successive amount of pulling and has a lower range of control (e.g., 0-10% duty ratio). In some embodiments, the first trigger **2020**A may be used for larger movements (for example, larger distances) of a workpiece **130** and the second trigger **2020**B is used for finer movement (for example, small distances) of the workpiece **130**. In another embodiment, the first trigger **2020**A and the second trigger **2020**B are not used concurrently and, rather, for example, one trigger signal is ignored when the other is already activated.

In some embodiments, rather than varying motor speed based on an amount of depression of a trigger of the remote controller **120** or **2000**, the speed dial **2520** or another speed selector input button or slider may be used to set certain speeds (for example, low, medium, and high speeds) of the hoist motor **250**. In some embodiments, a smart telephone may be used to program the speed dial **2520** to certain speeds. These set speeds may be used as desired speeds in a closed-loop control function implemented by the hoist electronic processor **210** such that the set speeds are held substantially constant. In other words, the hoist electronic processor **210** measures speed of the motor **250**, compares to the desired speed, and adjusts current flow to the motor (e.g., by adjusting a PWM duty cycle driving the motor) to maintain the speed of the motor **250** at the desired speed. In other embodiments, an open loop control function is implemented by the hoist electronic processor **210** such that the desire speed maps to a particular current flow to the motor **250** (e.g., a particular PWM duty cycle), which is then used to drive the motor **250**.

In some embodiments, the hoist device **110** may be provided with a worklight to illuminate a working surface, a workpiece **130**, or an area in which a workpiece **130** is being moved. For example, the worklight may direct light toward the workpiece, as well as the surrounding area. The hoist device **110** may also include indicators to provide visible notifications and/or a speaker to provide audible notifications (for example, beeps, alarms, voice notifications, and the like to a user). The indicators and speaker may be used in conjunction with other techniques and methods described herein to provide the different notifications, alarms, or indications.

In some embodiments, the hoist system **100** may impose a distance limitation on the hoist devices **110** and the controller **120**. Particularly, to ensure that signals may be accurately received by the hoist devices **110**, the hoist system **100** may prevent operation of the hoist devices **110** when the distance between the controller **120** and the hoist device **110** is more than a predetermined amount. The controller **120** may determine the distance between the controller **120** and the hoist device **110** using a propagation delay of a roundtrip signal from the controller **120** to the hoist device.

FIGS. **26**A and **26**B illustrate a method for calculating a distance between the controller and the hoist device **110**. FIG. **26**B is a flowchart of an example method **2600** for determining a distance between the controller **120** and the hoist device **110**. In the example illustrated, the method **2600** includes synchronizing clocks of the controller **120** and the hoist device **110** (at block **2610**). The clocks may be synchronized at the time of pairing the controller to the hoist device **110**. In some embodiments, both the controller **120** and the hoist device **110** may include a Global Positioning System (GPS) to receive a universal time. The clocks of the controller **120** and the hoist device **110** are then synchronized to the universal time. In some embodiments, the clocks are synchronized according to the method provided in FIGS. **27**A and **27**B and further described below.

The method **2600** also includes transmitting, using the controller **120**, a timing signal including a first time to the hoist device **110** (at block **2620**). The controller **120** may record the first time and embed the first time into the timing signal, for example, by time stamping the timing signal. The first time corresponds to the time at which the timing signal is transmitted from the controller **120**.

The method **2600** includes receiving, at the hoist device **110**, the timing signal at a second time from the controller **120** (at block **2630**). The hoist device **110** may record the time at which the timing signal was received by the hoist device **110**. The method **2600** further includes determining, using the hoist electronic processor **210**, the distance between the controller **120** and the hoist device **110** based on the first time and the second time (at block **2640**). In one example, the hoist electronic processor **210** determines the distance by calculating the propagation time and multiplying the propagation time with a known speed of transmission (that is, speed of light). The hoist electronic processor **210** calculates the propagation time by subtracting the first time from the second time. In some embodiments, the hoist electronic processor **210** may adjust the propagation time to account for processing delays by the controller **120** and/or the hoist device **110**.

The method **2600** includes determining, using the hoist electronic processor **210**, whether the distance between the controller **120** and the hoist device **110** is below a predetermined threshold (at block **2650**). The hoist electronic processor **210** compares the distance between the controller **120** and the hoist device **110** to the predetermined amount. When the distance between the controller **120** and the hoist device **110** is below the predetermined threshold, the method **2600** includes allowing the controller **120** to control operation of the hoist device **110** (at block **2660**). When the distance between the controller **120** and the hoist device **110** is above the predetermined threshold, the method **2600** includes performing a predetermined action (at block **2670**). The predetermined action may include providing an indication on the hoist device **110** and/or providing an indication on the controller **120**. The indication informs the user that the controller **120** is not within an operating distance of the hoist device. The predetermined action may also include preventing the controller **120** from operating the hoist device **110**. For example, the hoist device **110** may ignore commands from the controller **120** until the method **2600** is executed again and the distance is determined to be below the predetermined threshold.

FIGS. **27**A and **27**B provide a method **2700** for synchronizing the clocks of the controller **120** and the hoist device **110**. The method **2700** includes transmitting, using the controller **120**, a transmission signal at a first time to the hoist device **110** (at block **2710**). The controller electronic processor **310** records the first time. The method **2700** also includes receiving, at the controller **120**, a reply signal at a second time from the hoist device **110** (at block **2720**). The hoist device **110** provides the reply signal in response to receiving the transmission signals. The method **2700** further includes determining, using the controller electronic processor **310**, a timing offset based on the first time and the second time (at block **2730**). The controller electronic processor **310** calculates the timing offset by dividing the propagation delay by two. The propagation delay represents the time taken for a roundtrip signal from the controller **120** to the hoist device **110** and back to the controller **120**. Accordingly, the timing offset represents the time taken by a signal to reach the hoist device **110** from the controller **120**. The propagation delay is calculated by subtracting the first time from the second time. The propagation delay may be adjusted by subtracting the processing delay introduced by the hoist device **110**. The controller **120** may be preprogrammed with the processing delay of the hoist device **110**. The method **2600** further includes transmitting, using the controller **120**, a synchronization signal including a third time and the timing offset to the hoist device **110** (at block **2740**). The third time represents the time at which the controller **120** transmits the synchronization signal. The hoist device **110** synchronizes the clock of the hoist device **110** to the third time increased by the timing offset such that the clock of the hoist device **110** is synchronized to the clock of the controller **120**.

In some embodiments, the controller **120** and the hoist devices **110** use a Bluetooth® communication protocol to exchange control and other signals. In other embodiments, the handheld remote controller **2000** and the hoist devices **110** may use a proprietary radio-frequency (RF) communication protocol to exchange control and other signals.

FIGS. **28**A through **28**D illustrate exchange of signals between the controller **120** and the hoist devices **110** using the proprietary RF communication protocol. The proprietary RF communication protocol uses dual identifiers, one broadcast from the controller **120** and an individual identifier for each hoist device **110**. FIG. **28**D illustrates a pairing process between the controller **120** and a hoist device **110**. The pairing may be initiated on either device or may be initiated simultaneously on both devices. During the pairing process, the controller **120** broadcasts a pairing signal including an identifier of the controller **120** to the hoist device **110**. The hoist device **110** stores the identifier of the controller **120** and responds with an identifier of the hoist device **110** and/or the identifier of the controller **120**. The controller **120** stores the identifier of the hoist device **110**. The pairing process is now complete and the controller **120** and the hoist device **110** use a new identifier that is generated to include both the identifier of the controller **120** and the identifier of the hoist device **110** for further communication. In other embodiments, the RF communication protocol may use other method of communication, for example, a separate communication channel may be used for each hoist device **110**.

FIG. **28**A illustrates a communication methodology between the controller **120** and the hoist device **110**. In one embodiment, the controller **120** transmits a first broadcast signal to a first hoist device **110**A. As shown in FIG. **28**C, the first broadcast signal includes a first identifier corresponding to the controller **120** and the first hoist device **110**A (for example, a combination of the identifier of the controller **120** and the identifier of the first hoist device **110**A), a command (for example, specifying a speed, a direction, and/or the like), a timestamp (for example, for distance calculation), padding, and checksum (for signal accuracy verification). In response to receiving the first broadcast signal, the first hoist device **110**A transmits a first service packet to the controller **120**. As shown in FIG. **28**C, the service packet includes a first identifier, a distance of the first hoist device **110** from the controller **120**, an operation in progress (for example, a direction and speed), statuses (for example, sensor readings (e.g., load, speed, and/or the like)), and a checksum (for signal accuracy verification). In this embodiment, the controller **120** transmits a second broadcast signal to a second hoist device **110**B after receiving the first service packet and transmits a third broadcast signal to the third hoist device **110**C after receiving a second service packet from the second hoist device **110**B. In other embodiments, the controller **120** may simultaneously or in quick succession transmit the first broadcast signal, the second broadcast signal, and the third broadcast signal. The controller **120** receives the first service packet, the second service packet, and the third service packet from the first hoist device **110**A, the second hoist device **110**B, and the third hoist device **110**C respectively. The first service packet, the second service packet, and the third service packet are received in response to the first broadcast signal, the second broadcast signal, and the third broadcast signal respectively. In some embodiments, the RF communication protocol may use a different strategy for a stop command from the controller **120** to a hoist device **110**. Particularly, in contrast to the operation signals, the controller **120** may repeatedly provide a stop signal to the hoist device **110** until a service packet acknowledging the stop command is received from the hoist device **110**. Although described with the proprietary RF communication protocol, the methodology described above may be used with other communication protocols, for example, Bluetooth®, Wi-Fi™, ZigBee®, 4G, 5G, Infrared, and the like. Additionally, rather than using a dual identifier, the RF communication methodology described above may use a channel identifier and may establish communication between the controller **120** and each hoist device **110** over a separate channel.

In some embodiments, rather than individually communicating with each hoist device **110**, the controller **120** may communicate with a single hoist device **110**, which in turn communicates with other hoist devices **110**. For example, as shown in FIG. **28**B, the first hoist device **110**A, the second hoist device **110**B, and the third hoist device **110**C are daisy-chained together. In this example, the controller **120** provides control signals for each of the hoist devices to the first hoist device **110**A. The first hoist device **110**A extracts the control signals for the first hoist device **110**A and transmits the control signals for the second hoist device **110**B and the third hoist device **110**C to the second hoist device **110**B. Similarly, the second hoist device **110**B extracts the controls signals for the second hoist device **110**B and transmits the control signals for the third hoist device

110C to the third hoist device 110C. The first hoist device 110A, the second hoist device 110B, and the third hoist device 110C then operate using the control signals received from the controller 120. A similar communication scheme may be used with respect to the embodiments of FIGS. 16-17.

In some embodiments, two or more hoist devices 110 may be tethered together for concurrent operation. Tethering may be performed on a user interface of the hoist devices 110 and/or on the user interface of the handheld remote controller 2000. In some embodiments, tethering may also be performed on a connected smart telephone device running an application designed to function with the hoist device system described herein. When two or more hoist devices 110 are tethered together, the hoist devices 110 may exchange operation and control signals to work in unison to perform a task.

FIGS. 29A through 29C illustrate an example of multiple hoist load balancing performed when lifting a single workpiece 130 using two or more hoist devices 110. In the example illustrated in FIGS. 29A through 29C, a first hoist device 110A and a second hoist device 110B are used for lifting workpiece 130 and a method 2900 is described with respect to two hoist devices 110. However, the method 2900 is equally applicable for any number of hoist devices working together and/or in unison to lift a single workpiece 130. FIG. 29C is a flowchart of an example method 2900 for multiple hoist load balancing.

In the example illustrated in FIG. 29C, the method 2900 includes recording a starting profile (at block 2910). The starting profile varies based on the desired lifting profile of a workpiece 130. Referring to FIG. 29A, when the workpiece 130 has equal weight distribution and is to be raised at a horizontal level (i.e., zero degrees from ground), the starting profile includes the load and speed on the first hoist device 110A being equal to the load and speed on the second hoist device 110B. Referring to FIG. 29B, when the load is not equally distributed or when the workpiece 130 is to be lifted at an angle different than a horizontal angle, the load and speed on each hoist device 110 may be different. In this example, at the beginning of the lifting operation, the first hoist device 110A records a load (e.g., based on a load sensor) on the first hoist device 110A and the second hoist device 110B records a load on the second hoist device 110B. In some embodiments, the first hoist device 110A and the second hoist device 110B provide the load signals to a controller 120 that may monitor the load on each hoist device 110.

The method 2900 includes determining a corresponding first speed level for a first hoist device 110A based on a load on the first hoist device 110A and a load on the second hoist device 110B (at block 2920). The method 2900 also includes determining a corresponding second speed level for a second hoist device 110B based on the load on the first hoist device 110A and the load on the second hoist device 110B (at block 2930). The first speed level and the second speed level are selected to maintain the starting load profile on each of the hoist devices 110 throughout the lifting process. Accordingly, the ratio between the first speed level and the second speed level is inversely proportional to the ratio between the load on the first hoist device 110A and the load on the second hoist device 110B.

The method 2900 includes operating the first hoist device 110A at the first speed level (at block 2940) and operating the second hoist device 110B at the second speed level (at block 2950). The method 2900 maintains the first speed level and the second speed level as long as the load on the first hoist device 110A and the load on the second hoist device 110B are consistent with the starting profile (e.g., within a predetermined percentage or other threshold of the starting profile).

The method 2900 includes determining whether the load on the first hoist device 110A is different from the starting profile (at block 2960) and determining whether the load on the second hoist device 110B is different from the starting profile (2970). When the load on the first hoist device 110A and the load on the second hoist device 110B are consistent with the starting profile (e.g., within a predetermined percentage or other threshold of the starting profile), the method 2900 returns to blocks 2940 and 2950 to maintain current operation.

When the load on the first hoist device 110A and/or the load on the second hoist device 110B are inconsistent with the starting profile (e.g., the load is outside of a predetermined percentage or other threshold of the starting profile), the method 2900 includes operating the first hoist device 110A and the second hoist device 110B to return to the starting profile (at block 2980). For example, the method 2900 may halt operation, then then may operate one or both of the first hoist device 110A and the second hoist device 110B to return to the starting profile. Once returned to the starting profile, the method 2900 returns to blocks 2920 and 2930 to continue operation. In some embodiments, rather than returning to starting profile, the method 2900 may include determining new speed levels based on the new load profile and operating the hoist devices 110 based on the new speed levels. For example, if the first hoist device 110A detects an increased load (which should correspond to the second hoist device 110B detecting a decreased load), in block 2980, the first hoist device 110A may be controlled to increase its speed and/or the second hoist device 110B may be controlled to decrease its speed to shift more of the load to the second hoist device 110B and return to the starting profile. Similarly, if the first hoist device 110A detects an decreased load (which should correspond to the second hoist device 110B detecting an increased load), in block 2980, the first hoist device 110A may be controlled to decrease its speed and/or the second hoist device 110B may be controlled to increase its speed to shift more of the load to the first hoist device 110A and return to the starting profile.

In some embodiments, the two paths between recording the starting profile block 2910 and the operating to return to the starting profile block 2980 (i.e., the path with blocks 2920, 2940, and 2960 and the path with blocks 2930, 2950, and 2970) may be executed in parallel so each of the first hoist device 110A and the second hoist device 110B may be continually adjusting motor speed to maintain the starting profile.

FIG. 30 illustrates tilt winch 3000 that may be used with a hoist device 110 to lift a workpiece 130. The tilt winch 3000 is powered by a winch power source 3010. The winch power source 3010 may be similar to the hoist power source 240, for example, a power tool battery pack. The tilt winch 3000 may be controlled by a winch controller 3020, which may be a stand-alone controller or may be integrated into the controller 120. The tilt winch 3000 may be attached to a hook of the hoist device 110 and may communicate with the hoist device 110 and the controller 120 to operate in conjunction with the hoist device 110.

The tilt winch 3000 include two rope openings 3030 provided on each side of a housing 3040 of the tilt winch 3000. The rope openings 3030 provide an outlet for a rope 3050 that may be pulled in and let out by the tilt winch 3000. The tilt winch 3000 may include a motor similar to the motor of the hoist device **110** to adjust a length of the rope **3050**. The rope **3050** may be tied on each side of a workpiece **130**. The tilt winch **3000** is then operated (e.g., the winch motor is controlled) to adjust a length and/or tension of the rope **3050** on each side of the tilt winch **3000**. In some embodiments, a third opening may be provided on the bottom of the winch housing **3040** to allow a second rope **3060** to be pulled in or let out. The second rope **3060** may be provided in addition to the rope **3050** or alternatively in lieu of the rope **3050**. The length and tension in the second rope **3060** may similar be adjusted as the rope **3050** using the winch controller **3020**.

Turning now to FIG. **31**, a flowchart illustrating a process **3100** for determining a last lift for a DC battery powered hoist device, such as hoist device **110**. In some embodiments, the process **3100** is executed by an electronic processor of one of the herein-described hoist systems, such as the hoist electronic processor **210** or the controller electronic processor **310**. At process block **3102**, the electronic processor determines a voltage drop of the power source, such as hoist power source **240**. The voltage drop may be the voltage drop from the beginning of the lift until the end of the lift (e.g. when the motor stops). At process block **3104**, the electronic processor determines an actual voltage level of the battery. At process block **3106**, the electronic processor determines an average current of the motor during a lift. At process block **3108**, the electronic processor determines the remaining power in the power source. In one embodiment, the remaining power in the power source is determined by multiplying the difference between the actual voltage of the battery and a minimum voltage of the power source by the power of a standard lift. In one example, the minimum voltage may be stored in a memory of the electronic processor. The minimum voltage may be communicated to the electronic processor by the power source in some instances. Power of a standard lift may be calculated as the average current divided by the determined voltage drop during a lift.

At process block **3110**, the number of lifts left in the power supply is determined by dividing the determined power left in the power source in process block **3108**, by the power of a standard lift. If the number of remaining lifts is determined to be less than 2 at process block **3112**, a user is alerted that only one lift remains in the power source. In some embodiments, the alert may be a visual alert provided on the remote controller **2000**, described above. For example, the alert may be presented via one or more LEDs, or via a user interface, such as an LCD screen. In other embodiments, audio or tactile alerts may be provided to the user, either alone, or in combination with the above described visual alerts. If the number of lifts is not less than two, the number of remaining lifts is displayed for the user at process block **3114**. For example, the remaining lifts may be displayed via a user interface of the remote controller **2000**.

As an example, if the minimum voltage of the power source is 14V, the voltage drop is 0.5 VDC, the actual voltage of the power source is 16V, and the average current is 10 A, then the remaining power can be calculated as: 16V−14V*(10 A/0.5)=40 W. Then, based on the power of a standard lift being 20 W, the remaining lifts can be calculated as: 40 W/20 W=2.

Turning now to FIG. **32**, a process **3200** for controlling a soft start function of a motor, such as the motor of the hoist device **110**. The soft start function may be controlled by an electronic processor of one of the herein-described hoist systems, such as the hoist electronic processor **210** or the controller electronic processor **310**. In one embodiment, the soft start function is configured to ramp up the acceleration of the motor at less than full speed to reduce in-rush current, as well as to reduce undue strain on the motor. At process block **3202**, the hoist device begins the lift and the electronic processor begins accelerating the motor at a standard soft-start level. In some embodiments, this is a predefined acceleration. In other embodiments, a user is able to select the soft-start acceleration rate within a range of acceleration rates (e.g., using a wirelessly connected smart phone or a user interface on the remote controller **120**, **2000**). The electronic processor may be configured to control the acceleration and speed of the motor by varying a pulse width modulation ("PWM") signal to the motor. By increasing or decreasing the duty cycle of the PWM output to the motor, the controller can increase or decrease, respectively, the acceleration and speed of the motor.

The electronic processor then monitors a magnitude of a change in the load being lifted at process block **3204**. In some embodiments, the magnitude of the load may be determined based on a load sensor output. The load sensors could monitor pressure in a hydraulic fluid, or a strain on a load bearing chain or other connection between the load and the hoist device **110**. In other examples, a current of the motor **250** may be used to determine a magnitude of the load being lifted by the hoist device **110**. At process block **3206**, the electronic processor determines if the load magnitude has increased beyond a soft-start limit. In some embodiments, the soft-start limit is a ratio of motor acceleration to load. In response to the load magnitude increasing beyond the soft-start limit, the electronic processor reduces the acceleration of the motor **250** (e.g., by reducing the PWM duty cycle that controls driving of the motor **250**) at process block **3208**. In one embodiment, the electronic processor reduces the acceleration such that the acceleration is inversely proportional to the magnitude of load change, as shown in FIG. **33**. After reducing the motor acceleration, the electronic processor returns to monitoring the magnitude of change of the load at process block **3204**.

In response to determining that the load magnitude has not increased beyond the soft-start limits, the electronic processor increases the motor acceleration (e.g., by increasing the PWM duty cycle that controls driving of the motor **250**) at process block **3210**. In some embodiments, the acceleration is not increased beyond a predetermined level, such as an acceleration limit specified by the predetermined soft-start ramp. The controller then resumes monitoring the magnitude of change of the load at process block **3204**.

Turning now to FIG. **34**, an example system for determining a magnitude of a load on a chain hoist, such as hoist system **100**, is shown, according to some embodiments. Generally, load sensing within a chain hoist can be done using one or more of static and dynamic measurements. FIG. **34** provides an illustration of a static load determination system **3400**. To obtain a static load value, the measurement must be taken once the load has been lifted, and is free hanging from the hoist **3402**. As described above, the hoist **3402** may be coupled to a support (e.g. ceiling, structural beams, etc.) via a first connection **3404**. It should be understood that the hoist **3402** may be similar to the hoist device **110** or other hoist devices described herein. The first connection **3404** may be a chain, a wire cable, straps, rope, and the like. A load is then suspended from the hoist **3402** via a second connection **3406**, such as a chain or wire cable. As shown in FIG. **34**, a load sensing device **3408** may be coupled on the first connection **3404** between the connection point and the hoist **3402**. In one embodiment, the sensing device **3408** is a hydraulic cylinder that is placed between the first connection **3404** and the hoist **3402**. As the load is increased, the pressure within the hydraulic cylinder increases, and the pressure is then measured by one or more pressure sensors within the hydraulic cylinder, and that pressure is provided to one or more other devices, such as the hoist electronic processor **210** or controller electronic processor **310**. In other embodiments, the load sensing device **3408** includes one or more strain or load sensors configured to sense a load or strain in the first connection **3404**. In some examples, the strain or load sensors may be located on the second connection **3406** to detect a force applied to the second connection **3406** by the load. In still further examples, the load sensing device **2408** is a tensionmeter applied to either the first connection **3404** or the second connection **3406** to detect a change in tension of the connection. One or more sensors within the tensionmeter may detect an amount of tension caused by the load, and transmit that data to the hoist electronic processor **210** or controller electronic processor **310**.

Turning now to FIG. **35**, a system **3500** for determining a dynamic loading of the hoist **3502** is shown, according to some embodiments. Dynamic load measurements allow for a magnitude of load to be determined while the load is in motion, e.g. being raised or lowered by the hoist **3502**. As shown in FIG. **35**, the hoist **3502** is coupled to a load **3504** via a load connection **3506**. It should be understood that the hoist **3502** may be similar to the hoist device **110** or other hoist devices described herein. Also, the load connection **3506** may be a chain, a wire cable, or other applicable connection for use with the hoist **3502**.

In order to determine a dynamic load value, an electronic processor, such as the hoist electronic processor **210** described above, of the hoist **3502** may compare an actual speed of the hoist motor to an expected speed. The difference between the expected speed and the actual speed is proportional to the load. In some examples, the hoist **3502** may control a motor to raise and lower the load **3504**. The hoist **3502** may control the speed of the motor by varying the duty cycle of a PWM cycle. For a no-load condition, the expected speed at a given duty cycle is known by the electronic processor (e.g., from experimental testing and storing values in the hoist memory **220** at manufacture). The electronic processor may further receive a speed feedback signal from the motor **250** (e.g., from associated Hall sensors providing signals indicating motor speed). The electronic processor then can be configured to determine the difference between the expected speed (e.g. the no-load speed) and the actual speed to determine a magnitude of the load.

In other examples, motor current may be used in lieu of motor speed. For example, the electronic processor may measure a current measured when lifting load at a given PWM duty cycle. The electronic processor then correlates the measured current at the determined duty cycle to determine the magnitude of the load. In one example, the electronic processor may access a look up table to determine a load magnitude based on the measured current and determined PWM duty cycle applied to the motor. In some embodiments, the hoist **3502** may only use static measurements or dynamic measurements. However, in some embodiments, the hoist **3502** may use both static and dynamic load measurements to provide additional verification of the load magnitude.

Turning now to FIG. **36**, a smart load hook **3600** for use with a hoist, such as hoist device **110** is shown, according to some embodiments. The smart hook **3600** includes a hook mouth closed sensor **3602** and an electronics module **3604**. The hook mouth closed sensor **3602** may be configured to provide an indication to one or more of the electronic processors herein-described, such as the hoist electronic processor **210** or the controller electronic processor **310**, that the hook latch or hasp **3606** of the hook **3600** is closed, thereby securing the load. The hook mouth closed sensor **3602** may be in electronic communication with the electronics module **3604**. The electronics module **3604** may include one or more sensors, such as gyroscopes, accelerometers, etc. The electronics module **3604** may further include a wireless transmitter for communicating with one or both of the hoist device **110** and the hoist controller **120**. The wireless transmitter may utilize Bluetooth, Bluetooth Low Energy ("BLE"), Wi-Fi, ZigBee, RF, 4G, 5G, IR, or any other applicable wireless communication protocol. In other examples, the electronics module **3604** may use a wired communication protocol to transmit data to one or both of the hoist device **110** and the hoist controller **120**, or other external device.

The sensors in the smart hook **3600** may be configured to determine if the load is imbalanced. For example, the accelerometer and/or gyroscope of the electronics module **3604** can detect orientations or movements of the smart hook **3600** that can indicate an imbalance of the load (e.g. the smart hook is not on dead center of the load during a lift). This can be seen in FIG. **37**, whereby a load **3700** is off center, causing a movement in direction "A," which translates to a lateral motion of the smart hook **3600**. This movement may be detected by the sensors within the electronics module **3604**. The electronics module may transmit the sensor data, along with the mouth closed sensor data to one or both of the hoist device **110** and the hoist controller **120**, or other external device using the wireless transmitter of the electronics module **3604**. In response, the hoist device **110**, the hoist controller **120**, or both may take a responsive action, such as stopping the motor **250** or generating an alert (e.g., illuminating an LED of the hoist controller **120** or the hoist device **110**) to notify a user.

FIGS. **38-41** illustrate backup manual operation mechanisms for the hoist device **110** (FIG. 2A). FIGS. **38** and **39** illustrate an electromagnetic brake **122** attached to an output shaft **124** of the hoist motor **250**. The electromagnetic brake **122** may be controlled by the user via the hoist controller **120**. The electromagnetic brake **122** includes a hub **128** surrounding the output shaft **124**, a set screw **132** to couple the hub **128** to the motor shaft **124**, a pressure plate **136**, a friction disk **142**, an armature **146**, a magnetic body **148**, and a coil **152** positioned within the magnetic body **148**. When the hoist device **110** is powered off or the electromagnetic brake **122** is engaged, the armature **146** is urged against the friction disk **142** by a biasing member **156** (e.g., a coil spring), to restrict movement of the output shaft **124**.

When the hoist device **110** is powered on, a magnetic flux is formed between the coil **152**, the magnet body **148**, and the armature **146** to compress the biasing member **156** so the armature **146** disengages with the friction disk **142**. As a result, an air gap **158** is formed between the armature **146** and the friction disk **142** to allow the output shaft **124** to rotate. In some embodiments, an electromagnetic brake **122** may include an override mechanism **162** that is operably coupled to the armature **146** to allow a user to manually close the armature **146** to disengage the electromagnetic brake **122**. For example, the override mechanism **162** may be a lever integrated with the electromagnetic brake assembly **122**, or may be adjusted using a screw driver or other tools. Manually disengaging the electromagnetic brake **122** may allow the user to adjust the length of the chain **115** to adjust the positioning of the workpiece (FIG. **1**) coupled to the chain **115** when the hoist motor **250** is deactivated.

FIGS. **40** and **41** illustrate a manual operation mechanism **164** that may be coupled to the output shaft **124** of the hoist motor **250**. The manual operation mechanism **164** includes an output device **168** that moves the chain **115**, a hand wheel **172** operably coupled to the output device **168** via a threaded shaft **176**, and a ratchet **178** positioned between the threaded shaft **176** and the hand wheel **172**. A second chain or lever **182** (e.g., a hand chain) is coupled to the hand wheel **172** to allow the user to rotate the hand wheel **172** relative the output device **168**. If the user desires to manually adjust the position of the workpiece **130** attached to the chain **115**, the user may grasp and pull the second chain **182**, which causes the hand wheel **172** to rotate on the threaded shaft **176**. As the second chain **182** is driven up the shaft **176** (41. 4), the second chain **182** disengages the hand wheel **172** from a slip clutch positioned between the output device **168** and the hand wheel **172**, while the ratchet **178** remains stationary. As a result, the threaded shaft **176** rotates the output device **168** to lower the chain **115** to allow the user to manually adjust the length of the chain **115** via the second chain **182**. If the user releases the second chain **182**, the second chain **182** will stop moving and the ratchet **178** engaged with the motor shaft **124** to stop movement and suspend the workpiece **130** on the chain **115**. In other embodiments, other tools may be used in place of the second chain **182** to manually adjust the positioning of the chain **115**.

In some embodiments, a ratcheting device, such as a ratcheting socket may be coupled to manual operation mechanism **164** to allow a user to manually adjust the position of the workpiece **130** attached to the chain **115**, thereby eliminating the need for a second chain or lever **182** to be permanently attached to the manual operation mechanism **164**. In some embodiments, the manual operation mechanism **164** and/or the hoist motor **250** may include a fitting to allow for a user to couple a powered device or hand operated device to adjust the position of the workpiece **130** attached to the chain **115**. The fitting may be various types of fittings, such as square fittings, hex fittings, 12 point drive fittings, etc. By using a powered device or a hand crank connected to the fitting, the manual operation mechanism **164** allows the load to be lowered even when power to the hoist motor **250** is removed.

FIGS. **42**-**44**C illustrate auto stop features for the hoist device **110**. The auto stop features discussed below may be used together or separately from each other to automatically stop the hoist device **110** when the chain **115** reaches end of travel on either end. The auto stop feature may provide the necessary detection of end of chain **115** for normal operation of the hoist device **110** and in cases where the hoist device **110** may fail (e.g., if the motor **250** loses power during a lift).

As illustrated in FIG. **42**, the hoist device **110** includes a limit switch **186** positioned adjacent each chain receiving opening **188** on the hoist device **110**. The chain **115** may include a stop **190** adjacent each end of the chain **115** that interacts with the limit switches **186** to provide a signal to the hoist device **110**, that the chain **115** is near the end of travel. When the hoist device **110** receives the signal, the hoist electronic processor **210** (FIG. **2**B) deactivates the hoist motor **250**. It should be appreciated that the limit switch **186** may include mechanical limit switches (FIGS. **43**A and **43**B), Hall-effect sensors, distance run measurement, speed measurement, and/or the like. Additionally, the hoist transceiver **230** may communicate with the hoist controller **120** (e.g., a joystick controller (see FIGS. **20** and **25**A-C), a smart telephone (see FIG. **24**), a tablet computer, and the like) to alert the user that the limit switch **186** was actuated. The user may also adjust the sensitivity or configuration of the limit switch **186** via the hoist controller **120**. For example, the hoist controller **120** may track the number of times that the limit switch **186** is actuated to determine when the limit switch **186** should be repaired, changed, or tested. The hoist transceiver **230** may further communicate other warnings or alerts (e.g., low battery, speed, overload, etc.) to the hoist controller **120** using devices such as LED indicators, buzzer(s), and/or the like. Additionally, the hoist controller **120** may allow the user to set a constant speed of operation.

As illustrated in FIGS. **43**A and **43**B, the limit switch **186** may be a mechanical limit switch that is used to detect the presence of an object when physical contact is made between the object (e.g., the stop **190**) and the limit switch **186**. The limit switch **186** may include a lever **192** that is moved to close a set of electrical contacts **194** when the stop **190** actuates the limit switch **186** (FIG. **43**B). The engagement of the lever **192** with the electrical contacts **194** completes a circuit, which sends a signal to the hoist electronic processor **210** (FIG. **2**B) to deactivate the hoist motor **250**.

In other embodiments, the limit switch **186** may be an electromechanical rotary limit switch to automatically stop travel when a set number of revolutions or rotational position is reached. The hoist device **110** may have a preset number of revolutions that correlate to the maximum distance the chain **115** can travel or the minimum distance the chain **115** can travel. In other embodiments, the limit switch **186** may detect the number of chain links to automatically stop the hoist device **110** when a predetermined number of chain links has been detected. In some embodiments, the hoist controller **120** or a separate device (e.g., a smart phone) is configured to communicate with the hoist device **110** to set the limits for travel of the chain **115**. For example, the user may control the hoist device **110** to move the chain **115** to a desired maximum limit (whether upper or lower limit), and then press a button the user interface of the hoist controller or device, which causes transmission of a signal to the hoist device **110** to store the current chain **115** position as a limit (whether in terms of a rotational position of a rotary encoder or chain link). Then, during later operation, the hoist device **110** is configured to stop driving the motor **250** when the chain **115** reaches the limit previously set. A similar process can be used to set both the upper limit and lower limit.

In other embodiments, the limit switch **186** may include an ultrasonic pulse generator and receiver. The ultrasonic pulse generator may be configured to transmit an ultrasonic pulse along the length of chain. The ultrasonic pulse may return to the ultrasonic receiver after reaching the end of chain, and a time to return may be determined and used to determine a length of chain between the hoist device **110** and the end of the chain **115**. In other embodiments, a change in frequency of the ultrasonic pulse may be used to determine the length of chain **115** remaining. In one embodiment, the limit switch **186** may be a time-of-flight ("ToF") sensor configured to detect a time-of-flight of a signal from the hoist device **110** to the end of the chain. In one embodiment, the time of flight may be a laser or ultrasonic time-of-flight sensor. For example, a laser emitter on the hoist device **110** may configured to transmit a laser output which is received by a receiving device at the end of the chain. The ToF sensor may be configured to determine a length of the chain based on the measured time of flight of the laser signal. In other embodiments, the ToF sensor is a radio TOF sensor. The hoist device **110** may have a radio transceiver in communication with a second radio transceiver located at the end of the chain **115**. Radio signals may be transmitted and received from both radio transceivers, and the associated time of flight for the signals to be received after being transmitted (or transmitted and subsequently received) may be used to determine a length of the chain **115**.

In still further embodiments, the limit switch **186** may include a weight sensor to weigh the non-loaded length of the chain **115**. For example, a storage device, such as a bag may hold the excess (non-loaded) chain **115**. The limit switch **186** may measure the weight of the chain in the storage device and determine a length of loaded and unloaded chain **115** based on the weight.

As illustrated in FIGS. **44**A and **44**B, the limit switch **186** may be a reed switch (FIG. **44**A) or Hall sensor (FIG. **44**B) used as proximity switch that detects a magnetic field. In such an embodiment, the chain **115** may include a magnetic device attached to each end of the chain **115** to produce a magnetic field. For example, the stops **190** may be configured to include a magnet. As a result, the reed switch or Hall sensor, when acted upon by a magnetic field as the end of the chain **115** becomes proximate to the reed switch or Hall sensor, functions to detect the nearby end of the chain **115** and send a signal to the hoist electronic processor **210** (FIG. **2**B) to deactivate the hoist motor **250**.

In other embodiments, as illustrated in FIG. **44**C, the hoist device **110** may include a hard stop or overload limiting clutch **196** that is coupled to the output shaft **124**. The clutch **196** may include a sprocket **198** that is operably coupled to the output shaft **124**. In some embodiments, the sprocket **198** may be connected to an output device that drives the chain **115**. When the chain **115** abruptly stops or hits the body of the wireless hoist device **110**, the clutch **196** detects an overload condition that causes the output shaft **124** to slip relative to the sprocket **198** (e.g., the sprocket **198** continuously rotates). In other embodiments, the output shaft **124** may be connected to the output device that drives the chain **115**. Therefore, when the clutch **196** detects the overload condition, the sprocket **198** slips relative to the output shaft **124** (e.g., the output shaft **124** continuously rotates). In either case, the slippage between the output shaft **124** and the sprocket **198** causes the chain **115** to stop ascending or descending.

In some examples, other auto-stop devices may be used with the hoist device **110**. In one example, the chain **115** may be painted, coated, or otherwise made to have different colors near the ends of the chain **115**. A sensor, such as an imaging sensor, an infrared sensor, or other sensor within the hoist device **110** may be configured to detect the color change and stop the operation of the hoist device **110** before the end of the chain is reached. In other embodiments, the ends of the chain **115** may be sized differently (e.g. larger or smaller links), which can be detected by the hoist device **110** and subsequently cause the hoist device **110** to stop before the end of the chain is reached.

FIGS. **45**-**47** illustrate the hoist controller **120** attached to the hoist device **110** via a retractable cord **202**. The cord **202** may be attached to the hoist device **110** via a rotatable reel **206** on the hoist device **110**. The user may adjust the length of the cord **202** relative to the hoist device **110**. As a result, the length of the cord **202** may be adjusted to account for different installation heights for the hoist device **110** when the hoist device **110** is attached to a support surface **140**. Additionally, the cord **202** may be retracted and wrapped around the reel **206** when the hoist device **110** is not in use.

With reference to FIGS. **45** and **46**, the power supply **240** of the hoist device **110** may be coupled to the hoist controller **120**. As a result, the user may remove and replace the power supply **240** (e.g., with another, fully charged power supply **240**) while the hoist device **110** remains suspended from the support surface **140**.

In other embodiments, as illustrated in FIGS. **47** and **48**, the power source **240** may be coupled to and positioned onboard the hoist device **110**. As a result, the weight of the power source **240** is supported by the hoist device **110**, resulting in the controller **120** having a reduced weight. The hoist device **110** may include a power source storage area **242** (FIG. **48**) to secure and enclose the power source **240** within the hoist device **110**. The power source storage area **242** includes a door **212** that is pivotally coupled to the hoist body to allow the user to selectively access the power source **240** (e.g., to replace the power source **240**). The door **212** protects the power supply **240** from the environment while the hoist device **110** in operation.

With reference to FIG. **49**, the hoist device **110** may further include a regenerative braking mechanism **216** for use with the hoist motor **250**. The regenerative braking mechanism **216** includes a power converter **218** that converts kinetic energy created during operation of the hoist device **110** into electrical energy that can be stored in the power supply **240**. For example, FIG. **49** illustrates the power flow through the hoist device **110** using the regenerative braking mechanism **216**. When motor shaft **124** rotates the chain **115** of the hoist device **110** to lower a suspended workpiece **130** (FIG. **2**A), the regenerative braking mechanism **216** may reduce the speed of the workpiece **130** as it is lowered by using the kinetic energy of the workpiece **130** to drive the power converter **218**, which in turn produces electricity for storage in the power supply **240**. In some embodiments, the hoist device **110** may include a separate capacitor bank that is operably coupled to the power supply **240** to store the energy. The regenerative braking mechanism may reduce heat loss, increase efficiency of the hoist device **110**, and reduce wear of mechanical brake components to extend the life of the components. The power converter **218** may be, for example, a generator in which the rotating motor shaft, being driven at least in part by gravitational forces pulling on the load, drives a rotor of the generator, which induces current in a stator of the generator. The induced current is then provided to the battery pack **240** or capacitor bank.

To prevent uncontrolled descending of the workpiece **130** following the motor **250** losing power (such as a battery being discharged), the hoist device **110** includes redundant and fail-safe systems to allow for the load to be safely lowered. Turning now to FIG. **50**, an inertial locking device **5000** is shown. The inertial locking device **5000** is configured to stop rotation of the hoist motor **250**, the transmission, or the output shaft of the hoist device **110** when an inertia of the load exceeds a predetermined value. The predetermined value may be set to engage the inertial locking device **5000** when a load is determined to be free falling. As shown in FIG. **50**, the inertial locking device **5000** is a mechanical device. However, in some embodiments the inertial locking device **5000** may be an electronic inertial locking device **5000** including one or more inertia sensors coupled to an electronically activated inertial lock.

Turning now to FIG. **51**, cam locks **5100** may be installed on the chain **115** or cable to prevent a load from free falling. The cam locks **5100** may be configured to apply a force to the chain **115** and/or cable when the load descends at a speed that is sufficient to engage the cam locks **5100**. Upon the cam locks **5100** being engaged, they prevent additional cable or chain from passing through the cam locks **5100**, thereby stopping the motion. To disengage the cam locks **5100**, the load must be slightly raised and then lowered at a speed below the engagement speed of the cam locks **5100**. In some embodiments, the cam locks **5100** are coupled to the hoist device **110**. However, in other embodiments, the cam locks may be coupled to a support structure external to the hoist device **110**.

FIG. **52**A illustrates a mechanical ratchet/clutch system **5200**. The mechanical ratchet/clutch system **5200** includes a ratchet wheel **5202** coupled to a drive shaft **5204** of the hoist device **110**. However, in some examples, the ratchet wheel **5202** may be coupled to other stages of the drive train, or the output of the hoist device **110**. The ratchet/clutch system **5200** further includes a pawl **5206** configured to engage with the ratchet wheel. The pawl **5206** is configured to engage with the ratchet wheel **5202** to prevent rotation of the shaft **5204** in a first direction. The first direction is a direction associated with lowering a load. In some embodiments, the pawl **5206** engages the ratchet wheel **5202** unless disengaged, thereby preventing movement of the drive shaft **5204**. The ratchet/clutch system **5200** may further be used to prevent a free fall of the hoist device **110** during a loss of power or other condition.

FIG. **52**B illustrates a two-way ratchet clutch **5250** that locks in the opposite direction that the load is moving. The two-way ratchet clutch has a first ratchet **5252** and a second ratchet **5254**. The first ratchet **5252** engages with a first pawl **5256**, and the second ratchet **5254** engages with a second pawl **5258**. Depending on the direction the load is moving, the associated ratchet **5252**, **5254** moves in the direction of the load, but the other ratchet **5252**, **5254** is locked to prevent the load from moving in the opposite direction. Where the load is stationary, both ratchets **5252**, **5454** are locked, such as via a directional lever that opens one direction with rotation, or via a solenoid (not shown). In one embodiment, the ratchets **5252**, **5254** are installed on the drive shaft of a hoist motor. However, in some examples, the ratchets may be installed on any part of the drive train. This mechanism can prevent the load from moving if power is removed from the hoist by mechanically locking the drive shaft.

In some embodiment, the above ratchet clutches **5200**, **5250** may be coupled to one or more sprockets within the hoist device **110** that are coupled to the drive shaft. In some embodiments, the ratchet clutches **5200**, **5250** may be coupled to a final sprocket in direct connection with the chain holding the load, as described above. Thus, in the event of a drive shaft malfunction (e.g. drive shaft becomes loose, etc.), the ratchet clutches **5200**, **5250** engage the final sprocket to prevent movement of the load.

FIG. **53** illustrates a solenoid based locking system **5300** to prevent the load from being lowered when power is removed from the hoist device **110**. The solenoid based locking system **5300** uses a solenoid **5301** driven pin **5302** that interfaces with a slot or hole **5304** in the drive shaft **5306**, to prevent movement of the drive shaft **5306**. In one embodiment, the solenoid **5301** may be configured to remove the pin **5302** from the slot or hole **5304** in the drive shaft **5306** when power is applied to the solenoid **5301**. Accordingly, when power is removed from the solenoid **5301**, the pin **5302** is released, causing interaction with the slot or hole **5304** in the drive shaft **5306**, thereby preventing movement of the load when power is lost.

FIG. **54** illustrates a ratcheting mechanism **5400** that can be used to manually lower or raise a load of the hoist device **110** in the event of a power loss. A manual ratchet handle **5402** may be attached to a ratchet input **5404** of the hoist device **110**. A user may manually actuate the manual ratchet handle **5402** to raise or lower the load. In one embodiment, the ratchet input **5404** may be coupled to one or more gears within the hoist device **110** to allow for a force reduction such that the user can easily manipulate the load via the manual ratchet handle.

In some embodiments, the hoist device **110** may include a transmission, as described above, having a high enough gear reduction ratio such that the friction created by the gearing is not overcome by a load attached to the hoist. In other embodiments, the hoist device **110** may use a continuous drive train to eliminate clutches that may be susceptible to failure during operation. As shown in FIG. **55**, in some embodiments, the hoist device may incorporate a worm gear **5500** between the drive shaft **5502** and the load **5504**. The worm gear drive is configured to prevent back driving or free rotation of the system by ensuring that the worm gear drive is in constant contact with the main drive gear **5506** such that the main drive gear cannot move without a corresponding movement of the worm gear **5500**. In some embodiments, a separate worm gear drive motor may be used to control movement of the worm gear.

As described above, it is important to ensure that when a stop command is transmitted by the remote, or other safety sensor within the hoist system, such as hoist device **110**, that the hoist is stopped and the load must come to rest as quickly as possible. In some embodiments, a mechanical brake may be used to stop the operation of the hoist device **110**. For example, friction brakes, ratcheting brakes (similar to those shown in FIGS. **52**A and **52**B, above) disc brakes, and the like may be used to brake the hoisting device, such as by preventing operation of a drive shaft of the motor.

As shown in FIG. **56**, an electromechanical brake **5600** may be used to stop the movement of the hoist device **110**, and bring a load to rest. In one embodiment, the electromechanical brake **5600** may be placed on a drive shaft of a motor, such as drive shaft **5204** described above. The electromechanical brake **5600** may include a brake field area **5602**, an armature **5604**, and a friction material **5606**. Based on the configuration of the electromechanical brake, the friction material **5606** is put into contact with the motor shaft based on a movement of the armature **5604**. In one embodiment, when power is applied to the brake field area **5602**, the armature **5604** moves in response to magnetic repulsion to put the friction material **5606** in contact with the drive shaft, thereby restricting or preventing the movement of the drive shaft. In some embodiments, the armature **5604** may be biased to place to the friction material **5606** in contact with the drive shaft when no power is applied to the brake field area **5602**. Thus, when power is applied to the brake field area **5602**, the armature **5604** is moved towards the brake field area **5602** based on magnetic attraction. In one embodiment, the power applied to the motor is routed through the electromagnetic brake **5600** such that if power is lost to the motor, the armature **5604** is released, causing the friction material **5606** to contact the drive shaft to prevent movement of the drive shaft during a loss of power.

In some examples, a braking mechanism, such as those described above, may be controlled via a remote control, such as remote control **2000**. In one embodiment, the remote control **2000** may be configured to transmit multiple, redundant braking commands when a braking input is received from a user. The redundant braking commands may then be provided to a controller, such as controller **120** described above, as described above.

Turning now to FIG. **57**, a flowchart illustrating a process **5700** for modifying the operation of a hoist device, such as hoist device **110**, when conditions outside of the normal operating conditions are determined is shown, according to some embodiments. At process block **5702** the hoist device **110** is operate in a normal operating mode. At process block **5704** a controller, such as hoist controller **120**, determines if one or more operating parameters exceed various thresholds indicating an undesirable operating condition. In one embodiment, the operating parameters may be a force and/or current parameter. The hoist controller **120** may determine whether the force/current parameter experiences a sudden spike or increase in measure load that exceeds a predetermined threshold, thereby indicating a possible increase in load such as if the load has come into contact with another object during a lifting operation. In other examples, the hoist controller **120** determines whether the force/current parameter falls below a minimum threshold, thereby indicating a sudden lightening of the load. In other embodiments, various other operating parameters are evaluated by the hoist controller **120**, such as those described above, to determine if the operating parameters exceeds various threshold values.

In response to determining that the measured parameters do not exceed one of the predetermined thresholds, the hoist controller **120** continues to operate the hoist device **110** at process block **5702**. In response to determining that the measured parameters do exceed one of the predetermined thresholds, the operation of the hoist device is modified at process block **5706**. In one example, where the force/current parameter is determined to exceed a threshold value indicating a sudden increase in load, the hoist controller **120** stops operation of the hoist device **110**. In some embodiments, the hoist controller **120** stops the operation of the hoist device for a predetermined time period, such as one minute. However, predetermined time periods of more than one minute or less than one minute are also contemplated. In other embodiments, the hoist controller **120** stops operation of the hoist device until a user override is received by the hoist controller **120**. Similarly, the hoist controller **120** may stop operation of the hoist device **110** in response to the force/current parameter being determined to be below a predetermined threshold. In other embodiments, the hoist controller **120** may retract the load a predetermined amount to relieve the load of a potential impact or pinch point. For example, the hoist controller **120** may control the hoist device **110** to retract the load by six inches. However, retraction distances of more than six inches or less than six inches are also contemplated. After the hoist device retracts the load by the predetermined amount, the load controller **120** may again evaluate one or more operational parameters, such as those described above, to determine whether the adverse operational condition has been resolved. If the measured operational parameters still exceed the predetermined thresholds, the hoist controller **120** may instruct the host device **110** to stop.

Turning now to FIG. **58**, a hoist device, such as hoist device **110** is shown attached to a load **5800**. The hoist device **110** may be configured to receive one or more voice commands to control an operation of the hoist device **110**. In one embodiment, a microphone or audio input on the hoist controller **120** receives the voice command. In other embodiments, the microphone may be coupled to a remote controller, such as remote controller **2000** described above. In still further embodiments, the microphone may be remote from the hoist device, such as a user worn microphone. In other examples, the microphone may be integrated into a user device, such as a smartphone, smartwatch, or other personal electronic device. In one embodiment, the user must repeat the commands within a specified time frame to maintain the current operating mode of the hoist device **110**. For example, if a user desires the load to be lifted upwards, the user would issue a voice command such as "UP." To maintain the upward movement, the user is required to re-issue the voice command within a predetermined time period, such as three seconds. However, predetermined time periods of more than three seconds and less than three seconds are also contemplated. In response to the user not issuing a subsequent command within the predetermined time period, the hoist device **110** will stop (e.g. hold the load in the current position). This is the same for all voice commands, other than the "STOP" command, which will maintain its condition (e.g. stopped) until a subsequent command is issued. Example voice commands may include, UP, DOWN, STOP, FLOAT, and the like.

Turning now to FIG. **59**, a motion activated hoist system **5900** is shown, according to some embodiments. The motion activated hoist system **5900** includes a hoist device, such as hoist device **110**. The hoist device may include one or more sensing devices **5902** for detecting a movement of a user, such as their hand, arm, leg, etc. In one embodiment, the one or more sensing devices may include a time of flight (ToF) sensor, a camera sensor, an IR sensor, or other applicable sensing device. The sensing devices **5902** may be in communication with a controller, such as hoist controller **120**, described above. The sensing devices **5902** are configured to interpret motions of a user into hoist commands. For example, as the user may move their hand or arm in an upward direction to provide an "UP" instruction. Similarly, the user may move their hand or arm in a downward direction to provide a "DOWN" instruction. Based on the sensed motion provided by the user and sensed via the sensing devices **5902**, the hoist controller **120** is configured to control the operation of the hoist device **110**. While UP and DOWN commands are described above, it is contemplated that multiple other gesture commands may be used to control other operations of the hoist.

Turning now to FIG. **60**, a chain controlled hoist system **6000** is shown, according to some embodiments. The hoist system **6000** may include a hoist device, such as hoist device **110**, described above. The hoist system **6000** further includes a load chain **6002** having one or more embedded sensors **6004** for sensing a user touching or moving the load chain **6002**. In one example, the embedded sensors **6004** are one or more of capacitive sensors, inductive sensors, and the like. In one embodiment, the embedded sensors **6004** are in communication with a controller, such as hoist controller **120**, described above. The sensors may be configured to sense a user manipulating the chain with their hand or other extremity. Manipulating the chain may include jerking, jolting, pushing, pulling, or otherwise moving the chain to indicate that the user wishes the hoist device **110** to stop. This can allow a user to stop the hoist device **110** by moving the chain, in the event that it is not convenient to operate a control on the remote, such as an emergency stop ("E-STOP"). By utilizing an inductive or capacitive sensor, inadvertent movement of the load chain will not by itself cause the hoist device **110** to stop. Rather, the sensors must first determine a human touch via the embedded sensors **6004**

Turning now to FIG. **61**, a modular hoist device **6100** is shown, according to some embodiments. The modular hoist device consists of a drive portion **6102** and a chain portion **6104**. The drive portion **6102** may operate similarly to the hoist device **110** described above. The chain portion **6104** may include an interface to couple to the drive portion **6102** to allow the drive portion to control the movement of a chain

6106 within the chain portion 6104. This can allow for user to quickly modify the hoist device 6100 to have different lengths of chain as needed. This can reduce the need to have multiple hoist devices with multiple chain lengths.

Turning now to FIG. 62, a remotely powered hoist system 6200 is shown. The remotely powered hoist system 6200 is configured to have the removable power source 6202 (e.g. battery pack) interface with a receptacle 6204 at a load end of the chain 6206. A power cable 6208 may be coupled between the receptacle 6204 and a hoist device 6210. The power cable is configured to provide power from the removable power source 6202 to the host device 6210. By placing the removable power source 6202 at the end of the chain 6206, a user can more easily exchange power sources when needed without having to gain access to the hoist device 6210, which may require ladders, lifts or other equipment to access.

Thus, various embodiments described herein provide for a wireless hoist system. Various features and advantages are set forth in the following claims.

What is claimed is:

1. A wireless hoist system comprising:

a first hoist device including a first motor and a first wireless transceiver;

a second hoist device including a second motor and a second wireless transceiver, wherein the first hoist device and the second hoist device are configured to be coupled to a workpiece to raise or lower the workpiece; and

a controller configured to wirelessly communicate with the first wireless transceiver of the first hoist device and the second wireless transceiver of the second hoist device, the controller configured to:

receive user input,

determine a first operation parameter and a second operation parameter based on the user input, and

provide, wirelessly, a first control signal indicative of the first operation parameter to the first hoist device,

provide, wirelessly, a second control signal indicative of the second operation parameter to the second hoist device, and

receive a level input from a level sensor, the level sensor coupled to the workpiece and configured to indicate an angle of the level with respect to ground;

wherein the first hoist device is configured to operate based on the first control signal and the level input, and

wherein the second hoist device is configured to operate based on the second control signal and the level input.

2. The wireless hoist system of claim **1**, wherein the controller is configured to communicate with the first hoist device over a first wireless channel and wherein the controller is configured to communicate with the second hoist device over a second wireless channel.

3. The wireless hoist system of claim **1**, wherein the first hoist device further comprises:

a chain connectable to the workpiece to raise and lower the workpiece, the first motor coupled to the chain to release and retract the chain;

a sensor for detecting a chain length of the chain indicative of a length of chain released from the first hoist device; and

a motor drive coupled to the sensor and the motor and configured to:

receive the chain length from the sensor,

receive the first control signal from the controller, and

drive the motor based on the first control signal and the chain length.

4. The wireless hoist system of claim **1**, wherein the first operation parameter includes one or more selected from a group consisting of: speed, direction, and chain length.

5. The wireless hoist system of claim **1**, wherein the user input is a desired movement of the workpiece.

6. The wireless hoist system of claim **1**, wherein the user input includes a position of the first hoist device, a position of the second hoist device, and a desired end position of the workpiece.

7. A wireless hoist system comprising:

a first hoist device having a first motor and a first wireless transceiver;

a second hoist device having a second motor and a second wireless transceiver, wherein the second wireless transceiver is in wireless communication with the first wireless transceiver, and the first hoist device and the second hoist device are configured to be coupled to a workpiece to raise or lower the workpiece, wherein the first hoist device is coupled to the workpiece by a first chain and the second hoist device is coupled to the workpiece by a second chain;

a controller in wireless communication with the first wireless transceiver of the first hoist device, wherein the controller is configured to:

receive user input and determine a first operation parameter based on the user input,

provide, wirelessly, a first control signal to the first hoist device,

provide, wirelessly, a second control signal to the second hoist device, wherein the second control signal is based on the first control signal,

wherein, the first hoist device operates based on the first control signal and the second hoist device operates based on the second control signal, and

wherein the first hoist device further includes:

a sensor for detecting a chain length of the first chain indicative of a length of chain released from the first hoist device; and

a motor drive coupled to the sensor and the first motor and configured to:

receive the detected chain length from the sensor,

receive the first control signal from the controller, and

drive the first motor based on the first control signal and the chain length.

8. The hoist system of claim **7**, wherein the first wireless transceiver, the second wireless transceiver, and the controller communicate via an RF communication protocol, wherein the RF communication protocol uses dual identifiers, one broadcast from the controller, and an individual identifier for each of the first wireless transceiver and the second wireless transceiver.

9. A hoist device, comprising:

a power source;

a motor having an output shaft;

a transmission coupled to the output shaft and configured to interface with a chain, wherein the transmission transfers rotational motion of the output shaft of the motor to the chain to one of release or retract the chain; and

a controller configured to:

control an operation of the motor; and

determine a number of lifts remaining in the power source based on one or more parameters of the power source;

wherein the hoist device is configured to one of raise and lower a workpiece coupled to the chain based on a user command signal received at the controller.

10. The hoist device of claim **9**, further comprising a limit sensor configured to detect an end of the chain, wherein the limit sensor is further configured to provide an input to the controller to stop the motor in response to detecting the end of the chain.

11. The hoist device of claim **9**, further comprising:

a wireless transceiver;

a remote controller in communication with the wireless transceiver.

12. The hoist device of claim **11**, wherein the controller is configured to determine a distance between the hoist device and the remote controller using a distance determination protocol, the hoist system configured to:

receive, from the remote controller, a data packet including a sent time message,

determine, at the controller, a receive time of the data packet, and

determine the distance between the remote controller and the hoist device based on the speed of the transmission and the difference between the receive time and the sent time.

13. The hoist device of claim **12**, wherein a first internal clock of the remote controller and a second internal clock of the controller are synchronized.

14. The hoist device of claim **11**, wherein the remote controller includes a display device configured to display one or more parameters associated with the hoist device.

15. The hoist device of claim **14**, wherein the parameters include one or more of an overload condition, an ability to complete lift condition, a system health, an individual hoist battery charge level, a remote battery charge level, a secured load indication, and a distance between the hoist device and the remote controller.

16. The hoist device of claim **11**, wherein the remote controller further comprises an input to provide a variable speed input to the controller for controlling a speed of the motor.

17. The hoist device of claim **9**, wherein one or more parameters of the power supply include a current draw during a lifting operation and a voltage drop during the lifting operation.

18. The hoist device of claim **9**, wherein the hoist device includes an electro-mechanical brake configured to maintain a position of the workpiece during a lifting operation or a lowering operation.

19. The hoist device of claim **9**, wherein the controller is configured to stop operation of the hoist device when a voice command indicating a stop is received by one or more components of the hoist device.

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