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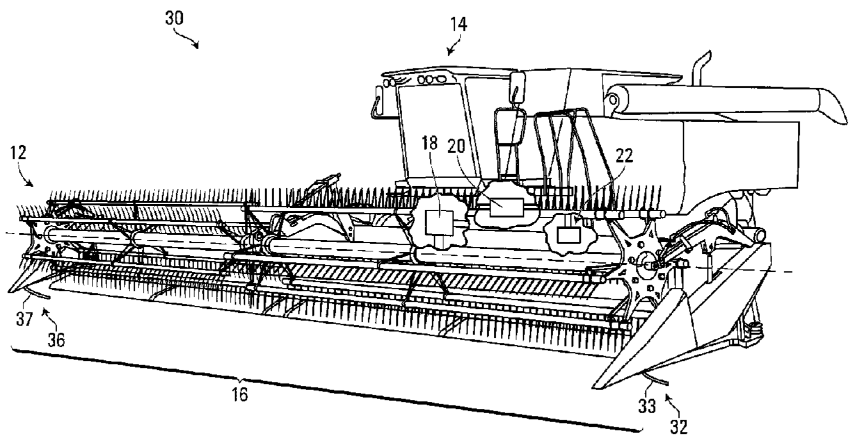


(57) Abrégé/Abstract:
A method, apparatus, and system for producing at least one control signal for controlling a positioning system having a positioning response time is disclosed. The apparatus includes a processor configured to receive at least one position signal representing a position of the agricultural implement and to receive at least one desired position signal representing at least one desired position of the agricultural implement. The apparatus is also operably configured to derive the control signal from a difference between the position and the desired position, and produce the control signal for receipt by the positioning system. The control signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

ABSTRACT

A method, apparatus, and system for producing at least one control signal for controlling a positioning system having a positioning response time is disclosed. The apparatus includes a processor configured to receive at least one position signal representing a position of the agricultural implement and to receive at least one desired position signal representing at least one desired position of the agricultural implement. The apparatus is also operably configured to derive the control signal from a difference between the position and the desired position, and produce the control signal for receipt by the positioning system. The control signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

CONTROLLING A POSITIONING SYSTEM FOR AN AGRICULTURAL IMPLEMENT

BACKGROUND

1. Field

This invention relates to positioning systems for agricultural implements and more particularly to conditioning or producing control signals for controlling a positioning system for an agricultural implement and/or producing position signals representing positioning of the agricultural implement.

2. Description of Related Art

An agricultural implement such as a harvesting header on a combine or a spray boom on a power unit may be driven across a field. During use, it may be desirable to control a position of the implement relative to a propulsion unit and thereby control a position of the implement relative to the ground or to crops on the field. Accurate control of the position of the implement may result in higher crop yields for harvesting and improved efficiency in spraying, for example.

Some agricultural control systems may sense a height or separation distance of the implement above the ground and produce control signals for causing a positioning system to move the implement relative to the propulsion unit, based on the sensed height. However, when a positioning system receives a control signal and is directed to move the implement, there may be a response time before the positioning system is able to cause the implement to reach a fixed or generally non-transient position. Some agricultural control systems may not take into account the response time when producing the control signals for controlling the implement position.

Further, agricultural control systems may sense the position of the implement periodically. Some control systems do not sense positioning frequently enough such that the control signals they produce can maintain accurate control of the implement. Accordingly, some agricultural control systems are constantly causing the agricultural implement to overshoot a desired setpoint position which may result in constant “hunting”.

Further, some sensing systems may not be configured to sense changes in the ground at an intermediate position on the agricultural implement.

SUMMARY

In accordance with one disclosed aspect there is provided an apparatus for conditioning at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to the at least one control signal. The apparatus includes at least one processor configured to intercept the at least one control signal, and in response to the intercept of the at least one control signal, produce at least one output signal for receipt by the positioning system instead of the at least one control signal. The at least one output signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

The at least one processor may be configured to cause a first active time of the plurality of active times to have a length equal to a first active time length.

The first active time length may be between about 10 and about 40 milliseconds.

The first active time length may be about 20 milliseconds.

The at least one processor may be configured to determine the first active time length.

The at least one processor may be configured to receive at least one system information signal representing system information, and derive the first active time length from the system information.

The system information may include a controller identifier identifying the controller.

The system information may include user-defined speed information representing a desired speed at which the user wishes the positioning system to move the agricultural implement.

The system information may include at least one of hydraulic pressure information representing a hydraulic pressure associated with the positioning system, travel speed information representing a travel speed of the agricultural implement, acceleration information representing acceleration of the agricultural implement, fill level information representing a fill level and associated mass of the frame, engine speed information representing an engine speed of an engine powering the positioning system, hydraulic fluid temperature information representing a hydraulic fluid temperature of a hydraulic fluid reservoir of the positioning system, fuel consumption rate information representing a fuel consumption rate and associated engine load of the positioning system, and an implement identifier identifying the agricultural implement and an associated inertia.

The at least one processor may be configured to cause a first inactive time following the first active time to have a first inactive time length.

The first inactive time length may be between about 280 milliseconds and about 310 milliseconds.

The first inactive time length may be about 300 milliseconds.

The controller may be associated with a sampling interval, and the at least one processor is configured to cause the first inactive time length to be equal to a difference between the active time length and the sampling interval.

The at least one processor may be configured to determine whether the at least one control signal meets a continuous control criterion, produce at least one continuous control signal representing the at least one control signal for receipt by the positioning system when the at least one control signal meets the continuous control criterion, and produce the at least one output signal only if the at least one control signal does not meet the continuous control criterion.

The at least one processor may be configured to determine whether the at least one control signal meets the continuous control criterion by determining whether the at least one control signal is configured to move the agricultural implement for more than a threshold control time.

The threshold control time may be between about 1.0 seconds and about 2.0 seconds.

The threshold control time may be about 1.5 seconds.

The at least one processor may be configured to receive the at least one control signal at a first time, produce a first set of output signal portions in response to the at least one control signal received at the first time, the first set of output signal portions representing an active time of the plurality of active times followed by an inactive time of the plurality of inactive times, receive the at least one control signal at a second time following the inactive time represented by the first set of output signal portions, and produce a second set of output signal portions in response to the at least one control signal received at the second time, the second set of output signal portions representing an active time of the plurality of active times followed by an inactive time of the plurality of inactive times.

The at least one processor may be configured to receive at least one position signal representing at least one position of the agricultural implement, receive at least one desired position signal representing the at least one desired position of the agricultural implement, and derive the at least one control signal from at least one difference between the at least one position and the at least one desired position.

In accordance with another disclosed aspect there is provided a method for conditioning at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to the at least one control signal. The method involves intercepting the at least one control signal, and in response to intercepting the at least one control signal, producing at least one output signal for receipt by the positioning system instead of the at least one control signal. The at least one output signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

A method of operating an agricultural implement on an agricultural vehicle may involve causing a controller of the agricultural implement to produce at least one control signal for causing a positioning system to move the agricultural implement up or down relative to the ground or to not move the agricultural implement up or down. The method involves executing the method above to intercept the at least one control signal and to produce the at least one output signal and causing the at least one output signal to be provided to the positioning system instead of the at least one control signal produced by the controller. The method further involves causing the positioning system to move the agricultural implement up or down or to stay in a current position, in response to the at least one output signal.

In accordance with another disclosed aspect there is provided a non-transitory computer-readable medium having stored thereon codes which, when executed by at least one processor, cause the at least one processor to condition at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to the at least one control signal. The codes, when executed by the at least one processor, cause the at least one processor to intercept the at least one control signal, and in response to the intercept of the at least one control signal, produce at least one output signal for receipt by the positioning system instead of the at least one control signal. The at least one output signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

In accordance with another disclosed aspect there is provided an agricultural implement control system for moving an agricultural implement up and down or for holding the agricultural implement at a height above the ground over which an agricultural vehicle is driven, the agricultural implement control system. The system includes a positioning system operably configured to move the agricultural implement up or down or to not move the agricultural implement up or down, in response to at least one control signal. The system also includes a controller operably configured to produce the at least one control signal, and a conditioner operably configured to intercept the at least one control signal, and in response to the intercept of the at least one control signal, produce at least one output signal for receipt by the positioning system instead of the at least one control signal. The at least one output signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to a positioning response time for causing the agricultural implement to respond to the at least one control signal.

In accordance with another disclosed aspect there is provided a vehicle including the agricultural implement control system above.

In accordance with another disclosed aspect there is provided an apparatus for producing at least one control signal for controlling a positioning system, the positioning system having a positioning response time for causing an agricultural implement to move in response to the at least one control signal. The apparatus includes at least one processor configured to receive at least one position signal representing at least one position of the agricultural implement, receive at least one desired position signal representing at least one desired position of the agricultural implement, derive the at least one control signal from at least one difference between the at least one position and the at least one desired position, and produce the at least one control signal for receipt by the positioning system. The at least one control signal represents a plurality of active times during which the positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which the positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times. Each of the plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to the positioning response time.

In accordance with another disclosed aspect there is provided a vehicle including the agricultural implement control system above.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention,

Figure **1** is a perspective view of an agricultural apparatus including a system for controlling movement of an agricultural implement according to one embodiment of the invention;

Figure **2** is a schematic view of the system of Figure **1** according to one embodiment;

Figure **3** is a schematic view of the system of Figure **1** according to one embodiment;

Figure **4** is a side view of the apparatus of Figure **1**;

Figure **5** is a schematic view of a processor circuit for implementing a conditioner included in the system of Figure **1**;

Figure **6A** is a representation of an exemplary portion of a lift control signal;

Figure **6B** is a representation of an exemplary portion of a drop control signal;

Figure **7** is a flowchart depicting blocks of code for directing the conditioner shown in Figure **5** to facilitate signal conditioning;

Figure **8** is a flowchart depicting sub-blocks of code included in the blocks of code shown in Figure **7**;

Figure **9** is a representation of an exemplary controller signal record used by the processor circuit of Figure **5**;

Figure **10** is a flowchart depicting sub-blocks of code included in the blocks of code shown in Figure **7**

Figure **11**A is a representation of an exemplary portion of a conditioned lift control signal;

Figure **11**B is a representation of an exemplary portion of a conditioned drop control signal;

Figure **12** is a representation of an exemplary signal time record used by the processor circuit of Figure **5**;

Figure **13** is a schematic view of portion of the system of Figure **1** according to one embodiment;

Figure **14** is a flowchart depicting blocks of code for directing the conditioner shown in Figure **5** to facilitate time length determining;

Figure **15** is a representation of an exemplary system information record used by the processor circuit of Figure **5**;

Figure **16** is a flowchart depicting sub-blocks of code included in the blocks of code shown in Figure **14**;

Figure **17** is a representation of an exemplary controller time length record used by the processor circuit of Figure **5**;

Figure **18** is a flowchart depicting blocks of code for directing the conditioner shown in Figure **5** to facilitate continuous control override;

Figure **19** is a flowchart depicting sub-blocks of code included in the blocks of code shown in Figure **18**;

Figure **20** is a representation of an exemplary threshold time record used by the processor circuit of Figure **5**;

Figure **21** is a schematic view of a system for controlling movement of an agricultural implement according to one embodiment of the invention;

Figure **22** is a schematic view of a processor circuit for implementing a controller/conditioner included in the system of Figure **21**;

Figure **23** is a flowchart depicting blocks of code for directing the controller/conditioner shown in Figure **22** to facilitate signal producing;

Figure **24** is a representation of an exemplary sensed height record used by the processor circuit of Figure **22**;

Figure **25** is a representation of an exemplary desired height record used by the processor circuit of Figure **22**;

Figure **26** is a schematic view of a system for controlling movement of an agricultural implement according to one embodiment of the invention;

Figure **27** is a perspective view of an agricultural apparatus including the system of Figure **26**;

Figure **28** is a schematic view of a processor circuit for implementing a modifier included in the system of Figure **26**;

Figure **29** is a flowchart depicting blocks of code for directing the modifier shown in Figure **28** to facilitate position signal modifying;

Figure **30** is a representation of an exemplary position record used by the processor circuit of Figure **28**;

Figure **31** is a representation of an exemplary representative position record used by the processor circuit of Figure **28**; and

Figure **32** is a representation of an exemplary representative position record used by the processor circuit of Figure **28**.

DETAILED DESCRIPTION

Referring to Figure **1**, an agricultural apparatus in accordance with one embodiment is shown at **30**. In the embodiment shown, the agricultural apparatus **30** is an agricultural combine harvester including a header **12**, which acts as an agricultural implement, mounted to a propulsion and processing unit **14** (hereinafter referred to as a "propulsion unit"), which acts as a frame.

In various embodiments, the header **12** is configured to harvest crop material from crops growing in a field while the apparatus **30** is driven across the field by the propulsion unit **14**. The header **12** is configured to collect the crop material and transfer the crop material to the propulsion unit **14** which may be configured to process the crop material.

In various embodiments, the header **12** may be able to efficiently harvest the crop material when the header **12** is kept at a constant height or separation distance close to the ground, without striking the ground. As the apparatus **30** travels over the ground, the ground may have inconsistencies and undulations and therefore in order to keep the header **12** at a constant height relative to the ground, in various embodiments, the apparatus has a sensor system **16** to sense changes in the ground, which may act as a reference surface. The apparatus **30** then controls a position of the header **12** relative to the propulsion unit **14** to maintain the header at a constant or desired height above the reference surface.

Referring to Figure **2**, to control the position of the header **12**, the apparatus **30** shown in Figure **1** includes a system **10** for controlling movement of the agricultural implement relative to the frame. The system **10** includes a controller system **11** including the sensor system **16**, a controller **18**, and a positioning system **22**. The controller system **11** may be a known controller system such as supplied by a manufacturer of the apparatus for controlling movement of the agricultural implement.

Referring to Figure **2**, the sensor system **16** is configured to sense a position of the agricultural implement and to transmit position signals representing the sensed position to the controller **18**. The controller **18** receives the position signals representing the sensed position and compares the sensed position to a desired position to determine a difference. The controller **18** then produces control signals, based on the difference. The controller **18** is configured to transmit the control signals to the positioning system **22** which may control hydraulic actuators, for example to cause movement of the agricultural implement towards a desired position relative to the frame.

The positioning system **22** has a positioning response time for causing the agricultural implement to respond to the control signals. In cases where the positioning system has a positioning response time that results in excessive movement or “hunting” for the desired position, according to the teachings herein the system **10** is provided with a signal conditioner **20**, which is configured to condition the control signals transmitted by the controller **18** and normally received by the positioning system **22**. The conditioner **20** is configured to intercept the control signals transmitted by the controller **18** and to transmit conditioned control signals or output signals to the positioning system **22** instead of the control signals, in response to the control signals transmitted by the controller **18**.

The conditioned control signals may represent a plurality of active times during which the positioning system **22** is instructed to move the agricultural implement towards a desired position and a plurality of inactive times during which the positioning system **22** is instructed not to move, with each active time being followed by a respective one of the inactive times. In some embodiments the conditioner **20** may be configured to cause the inactive times to be sufficiently long to permit the agricultural implement to settle into a fixed position due to the positioning response time of the positioning system **22**. In some embodiments, the agricultural implement may be considered to be in a fixed position when the agricultural implement is generally non-transient or when the agricultural implement would not substantially change its general position, given further time. In some embodiments, an oscillating agricultural implement may be considered to have settled into a fixed position.

Referring back to Figure **1**, the system **10** of Figure **2** is mounted on the apparatus **30**. In the embodiment shown, the sensor system **16** includes left, and right sensors **32** and **36** located at first and second locations on left and right ends respectively of the header **12**.

Referring to Figures **1** and **3**, the sensors **32** and **36** are configured to send left and right position signals **40** and **44** representing left and right sensed positions or heights of respective locations on the header **12** relative to the ground to the controller **18**. In some embodiments, the sensors **32** and **36** may each include a sensing arm or paddle (shown at **33** and **37** in Figure **1**) and a Hall Effect sensor configured to sense a rotational angle of the sensing arm.

In various embodiments the left and right position signals **40** and **44** may be electrical signals which have a voltage level representing a sensed position or height measured by their respective sensor. For example, the voltage level of the left and right position signals **40** and **44** may be between a low voltage level and a high voltage level, with a low voltage level representing **0**% of a maximum sensed height and high voltage level representing **100**% of the maximum sensed height. For example, in some embodiments, the low voltage level may be about **1** Volt and the high voltage level may be about **4** Volts. However, in various other embodiments, the high and low voltage levels of the left and right position signals **40** and **44** may be other voltage levels.

In the embodiment shown, the sensors **32** and **36** have a minimum sensed height of about **0** inches and a maximum sensed height of about **18** inches. However, in various embodiments, the sensors **32** and **36** may sense other ranges of heights.

In various embodiments, the sensors **32** and **36** may transmit the left and right position signals **40** and **44** to the controller **18** using electrical wires, for example, coupled to a respective one of the sensors **32** and **36** at one end and to the controller **18** at another end.

Referring still to Figure **3**, in various embodiments, the controller **18** may be configured to receive or sample the left and right position signals **40** and **44** representing the left and right sensed heights of the header **12.** In some embodiments, the controller **18** may be configured to sample the position signals periodically, such as once every about **320** ms, for example. The controller **18** is configured to compare each of the left and right sensed heights with desired left and right heights respectively to determine differences between the sensed heights and the desired heights. In some embodiments, the controller **18** may be configured to receive signals representing the desired left and right heights from memory and/or via an I/O interface of the controller **18**, for example. The desired heights may be about **2**", for example.

The controller **18** may, based on the differences between the sensed heights and the desired heights, produce lift and drop control signals **46** and **48** for causing the positioning system **22** to move the header **12** towards the desired heights.

For example, in some embodiments, the controller **18** may be configured to determine a left difference between the left sensed height and the left desired height and to determine a right difference between the right sensed height and the right desired height. When at least one of the left and right differences represents a sensed height that is less than a desired height and has an absolute value that is greater than a threshold difference, the controller **18** may produce the lift and drop control signals **46** and **48** such that, if the control signals were transmitted to the positioning system **22**, the control signals would cause the positioning system **22** to cause the header **12** to be raised relative to the propulsion unit **14** shown in Figure **1**. If neither of the left and right differences represents a sensed height that is less than a desired height and has an absolute value that is greater than the threshold difference and at least one of the left and right differences represents a sensed height that is greater than a desired height and has an absolute value that is greater than a threshold difference, the controller **18** may produce the lift and drop control signals **46** and **48** such that, if the control signals were transmitted to the positioning system **22**, the control signals would cause the positioning system **22** to drop (i.e. lower) the header **12** relative to the propulsion unit **14** shown in Figure **1**. If the left and right differences are both within a threshold range, the controller **18** may produce the lift and drop control signals **46** and **48** to cause the positioning system **22** to not change the height of the header **12** relative to the propulsion unit **14** shown in Figure **1**.

As discussed above, the controller **18** may be configurable to transmit the lift and drop control signals **46** and **48** directly to the positioning system **22** but, in the embodiment shown in Figure **3**, the conditioner **20** is configured to intercept the lift and drop control signals **46** and **48**.

Referring to Figure **3**, the conditioner **20** is configured to intercept the lift and drop control signals **46** and **48** produced by the controller **18** and to produce and transmit conditioned lift and drop control or output signals **50** and **52** to the positioning system **22** instead of the control signals. The conditioned lift and drop output signals **50** and **52** represent a plurality of active times during which the positioning system **22** is instructed to move the header **12** shown in Figure **1** towards the desired position and a plurality of inactive times during which the positioning system **22** is instructed not to move, with each active time being followed by a respective one of the plurality of inactive times. In various embodiments the conditioner **20** may be configured to cause the inactive times to be sufficiently long to permit the header **12** shown in Figure **1** to settle into a fixed position due to a positioning response time of the positioning system **22**.

In various embodiments, by causing each active time to be followed by a respective inactive time wherein the positioning system is allowed to settle into a fixed position, the conditioner **20** may allow the controller **18** to sample the left and right position signals **40** and **44** and thus sense heights during a time when the header **12** is generally non-transient or has reached a fixed position. In various embodiments, this non-transient height sensing may facilitate more accurate height sensing and thus better control of the position of the header **12** than would be provided by simply transmitting the lift and drop control signals directly from the controller to the positioning system.

Referring to Figure **3**, the positioning system **22** is configured to receive the conditioned lift and drop output signals **50** and **52** from the conditioner **20** and to cause hydraulic actuators to move the header **12** shown in Figure **1** in accordance with the conditioned output signals.

Figure **4** shows a side view of the apparatus **30** without the header **12** attached, showing elements of the positioning system **22**, in accordance with one embodiment. Referring to Figure **4**, the positioning system **22** includes a feeder house **60** pivotally connected to the propulsion unit **14** at pivot point **62**. The positioning system **22** also includes a height controlling hydraulic system including a height-controlling hydraulic cylinder **64** connected at one end to the feeder house **60** and at the other end to the propulsion unit **14**. The height controlling hydraulic system may include a "lift" valve, such as, for example, a solenoid controlled valve which may be controlled using the conditioned lift output signal **50** and a "drop" valve, such as, for example, a solenoid controlled valve, which may be controlled using the conditioned drop output signal **52**. When the lift valve is opened and the drop valve is closed, the height-controlling hydraulic cylinder **64** extends. Conversely, when the lift valve is closed and the drop valve is opened, the height-controlling hydraulic cylinder **64** retracts.

The header **12** shown in Figure **1** is mounted to a front portion **66** of the feeder house **60** shown in Figure **4**. Extension of the height-controlling hydraulic cylinder **64** causes the front portion **66** (and thus the header **12** shown in Figure **1** when attached to the front portion **66**) to move upward relative to the propulsion unit **14** in the direction of arrow **67**. Conversely, retraction of the height-controlling hydraulic cylinder **64** may cause the front portion **66** (and thus the header **12** shown in Figure **1** when attached to the front portion **66**) to move downward relative to the propulsion unit **14** in the direction of arrow **69**.

As discussed above, in various embodiments, each time the positioning system **22** is instructed to move, there may be a positioning response time before the positioning system **22** finishes moving and reaches a generally non-transient or fixed position. In various embodiments, the positioning response time may be due to a variety of factors such as, for example, weight and momentum of the feeder house **60** and/or the header **12**, time required for valves of the height-controlling hydraulic cylinder **64** to open and/or close after being commanded to do so, and/or float in the height-controlling hydraulic cylinder.

Referring back to Figure **3**, in various embodiments, the system **10** may optionally include system sensors **47** for sensing system information and transmitting system information signals **49** representing the system information to the conditioner **20**. In some embodiments, the conditioner **20** may be configured to adjust properties of the lift and drop output signals **50** and **52** based on the system information. For example, as will be described in further detail below, in various embodiments, the conditioner **20** may be configured to determine active and inactive time lengths for the lift and drop output signals **50** and **52** based on the system information.

Processor Circuit - Conditioner

Referring to Figure **5**, a processor circuit for implementing the conditioner **20** shown in Figure **1** according to one embodiment is shown generally at **200**. The processor circuit **200** includes a conditioner processor **202**, a program memory **204**, a variable memory **206**, and an input output ("I/O") interface **212**, all of which are in communication with the conditioner processor **202**. For example, the conditioner processor **202** may be an ARM™ Cortex™-M3 processor.

Program codes for directing the conditioner processor **202** to carry out various functions are stored in the program memory **204**. The program memory **204** may be implemented as any form of computer-readable memory or storage medium, such as, for example, read only memory (ROM), random access memory (RAM), a hard disk drive (HDD), solid state memory, a network drive, flash memory, removable memory, and/or a combination thereof, for example.

In various embodiments, the variable memory **206** may be implemented in RAM, a hard drive, solid state memory, a network drive, flash memory, a memory stick or card, removable memory, any other form of computer-readable memory or storage medium and/or any combination thereof.

In various embodiments, the program memory **204** includes a block of codes **220** for directing the conditioner processor **202** to perform signal conditioning functions a block of codes **222** for directing the conditioner processor **202** to perform time length determining functions, and a block of codes **224** for directing the conditioner processor **202** to perform continuous control functions. The program memory **204** also includes at least one memory location **236** for storing controller time information and at least one memory location **238** for storing threshold time information.

The variable memory **206** may include a plurality of storage locations including locations **230** for storing controller signal information, locations **232** for storing time length information, and locations **234** for storing system information.

The I/O interface **212** includes input ports **250** and **252** for receiving control signals such as, for example, the lift and drop control signals **46** and **48**, and output ports **260** and **262** for producing and transmitting the conditioned output signals **50** and **52** to the positioning system. In the embodiment shown, the I/O interface also includes input ports **254**, **256**, **258**, **259**, **263**, **264**, **266**, **268**, **270**, **272**, and **274** for receiving user input signals, pressure signals, travel speed signals, engine speed signals, temperature signals, fuel consumption signals, acceleration signals, fill level signals, implement identifier signals, controller identifier signals, and user control signals, respectively. In various embodiments, the I/O interface **212** may include an analog to digital converter in communication with the input ports and a digital to analog converter in communication with the output ports, for example.

Each of the input ports and output ports shown in Figure **5** are shown as single ports which are distinct and separate. However, in various embodiments, one or more of the input and output ports may be implemented using one or more ports.

Referring to Figures **6A** and **6B** exemplary representations of the lift and drop control signals **46** and **48** during a time period, in accordance with one embodiment, are shown. The lift control signal **46** affects control of the lift valve of the height hydraulic system and the drop control signal **48** affects control of the drop valve of the height hydraulic system.

In various embodiments, a high voltage level of V_H on the lift control signal **46** shown in Figure **6A**, if communicated to the lift valve of the height hydraulic system shown in Figure **4** may cause the lift valve to open and a low voltage level of V_L, if communicated to the lift valve of the height hydraulic system may cause the lift valve to close. Similarly, a low voltage level of V_L on the drop control signal **48** shown in Figure **6B**, if communicated to the drop valve of the height hydraulic system may cause the drop valve to close and a high voltage level of V_H if communicated to the drop valve of the height hydraulic system may cause the drop valve to open. The voltage levels V_H and V_L may vary depending on a type of the controller **18** shown in Figure **3**. For example, in some embodiments, for some controllers, the high voltage level of V_H may be about **12** volts and the low voltage level V_L may be about **0** volts.

In various embodiments, the lift and drop control signals **46** and **48**, which are represented in accordance with one embodiment in Figures **6A** and **6B**, and shown in context in Figure **3**, may fall within one of three control states at a given time. In an up control state, the lift control signal **46** has a high voltage level of V_H and the drop control signal **48** has a low voltage level of V_L. When the lift and drop control signals **46** and **48** are in the up control state, the lift and drop control signals **46** and **48**, if communicated to the positioning system **22**, cause the lift valve to open and the drop valve to close such that the height-controlling hydraulic cylinder **64** shown in Figure **4** extends and thus raises the header **12** shown in Figure **1**.

In a down control state, the lift control signal **46** has a low voltage level of V_L and the drop control signal **48** has a high voltage level of V_H. When the lift and drop control signals **46** and **48** are in the down control state, the lift and drop control signals **46** and **48**, if communicated to the positioning system **22**, cause the lift valve to close and the drop valve to open such that the hydraulic cylinder **64** shown in Figure **4** retracts and thus lowers the header **12** shown in Figure **1**.

In an off control state both of the lift and drop control signals **46** and **48** have a low voltage level of V_L. Accordingly, when the lift and drop control signals **46** and **48** are in the off control state, the lift and drop control signals **46** and **48**, if communicated to the positioning system **22**, cause both the lift valve and the drop valve to close such that the hydraulic cylinder **64** shown in Figure **4** does not move and the positioning system **22** holds the header **12** shown in Figure **1** at a constant height relative to the propulsion unit.

Signal Conditioning

Referring to Figure **5**, the signal conditioning block of codes **220** of the processor circuit **200** are shown in greater detail in Figure **7**, and include a first block **302** which directs the conditioner processor **202** shown in Figure **5** to intercept control signals by causing the I/O interface **212** to receive the lift and drop control signals **46** and **48** via the input ports **250** and **252** shown in Figure **5**. Block **302** is shown in greater detail in Figure **8** wherein it is seen that block **302** includes block **322** which directs the conditioner processor **202** to sample the lift and drop control signals **46** and **48** at the input ports **250** and **252** of the I/O interface **212** shown in Figure **5**. For example, block **322** of Figure **8** may be executed at time t_1 shown in Figures **6A** and **6B** and block **322** may direct the conditioner processor **202** to cause the I/O interface **212** shown in Figure **5** to sample the lift and drop control signals **46** and **48** at time t_1 such that the sampled voltage levels of the lift and drop control signals **46** and **48** are V_H and V_L respectively.

Referring back to Figure **8**, block **324** then directs the conditioner processor **202** shown in Figure **5** to store controller signal information representing the lift and drop control signals **46** and **48** in memory. In one embodiment, block **324** may direct the conditioner processor **202** to store the controller signal information in a controller signal record representing the lift and drop control signals **46** and **48** in locations **230** of the variable memory **206** shown in Figure **5**.

A representation of an exemplary controller signal record is shown at **340** in Figure **9**. The controller signal record **340** includes a lift valve field **342** and a drop valve field **344** for storing respective Boolean representations of the lift and drop control signals **46** and **48** which were sampled at input ports **250** and **252** respectively of the I/O interface **212** shown in Figure **5** at time t_1. The controller signal record **340** shown in Figure **9** also includes a time field **346** for storing a representation of the time at which the lift and drop control signals **46** and **48** were sampled.

In various embodiments, the time field **346** shown in Figure **9** may store a representation of time that may be established by a real time clock or be relative based on a microprocessor clock rate and a cycle count. In various embodiments, the units of measure for the representation of time may be accurate to between microseconds and milliseconds. In the embodiment shown in Figure **9**, the time field **346** stores a value having a format of YYYYMMDDHHMiMiSSTTT, where YYYY represents the year, MM represents the month, DD represents the day of the month, HH represents the hour, MiMi represents the minute, SS represents the second, and TTT represents the thousandths of a second. In some embodiments, the time field **346** may store other representations of time which may, for example, include less information than is shown in Figure **9**. For example, in various embodiments, the time field **346** may not include representations of the year, month, day, hour, or minute.

In various embodiments, block **324** of Figure **8** may direct the conditioner processor **202** shown in Figure **5** to store a value of TRUE in the lift valve field **342** of Figure **9** when the lift control signal **46** received at the input port **250** shown in Figure **5** represents a voltage of V_H and to store a value of FALSE in the lift valve field **342** when the lift control signal represents a voltage of V_L. Similarly, block **324** may direct the conditioner processor **202** to store a value of TRUE in the drop valve field **344** when the drop control signal **48** received at the input port **252** represents a voltage of V_H and to store a value of FALSE in the drop valve field **344** when the drop control signal represents a voltage of V_L.

For example when block **322** of Figure **8** is executed at time t_1 shown in Figure **6A**, the lift control signal **46** sampled at the input port **250** shown in Figure **5** has a voltage of V_H and the drop control signal **48** received at the input port **252** has a voltage of V_L. Accordingly, block **324** may direct the conditioner processor **202** to store a value of TRUE in the lift valve field **342** and a value of FALSE in the drop valve field **344**, as shown in Figure **9**. In various embodiments, block **324** may direct the conditioner processor **202** to store the controller signal record **340** shown in Figure **9** in locations **230** of the variable memory **206** shown in Figure **5**.

Referring back to Figure **7**, after block **302** has been executed, block **304**, directs the conditioner processor **202** shown in Figure **5** to cause the I/O interface **212** shown in Figure **5** to produce and transmit at least one conditioned output signal, in this embodiment two conditioned output signals (such as shown in Figures **11**A and **11**B), to the positioning system **22** shown in Figure **3** instead of the lift and drop control signals, wherein the conditioned output signals represent an active time (e.g. **368**) during which the positioning system **22** is instructed to move the header **12** shown in Figure **1** towards a desired position and an inactive time (e.g. **370**) following the active time during which the positioning system **22** is instructed not to move, wherein the inactive time (e.g. **370**) is sufficiently long to permit the header **12** to settle into a fixed position due to the positioning response time of the positioning system **22**.

In various embodiments, the length of the active time (e.g. **368**) and the inactive time (e.g. **370**) enables the controller **18** to sample the left and right position signals **40** and **44** and update the control signals **46** and **48** when the header **12** has reached a fixed position. Once block **304** is complete, the conditioner processor **202** is directed back to block **302**. Figure **7** thus depicts an endless loop with timings based on known controller **18** and/or positioning system **22** performance, as described in further detail below.

Referring to Figure **10**, block **304** includes blocks of code beginning with block **381** which directs the conditioner processor **202** to cause the I/O interface **212** shown in Figure **5** to set the lift and drop output signals **50** and **52** at the output ports **260** and **262** to a voltage of V_L.

Block **382** of Figure **10** then directs the conditioner processor **202** shown in Figure **5** to retrieve controller signal information from locations **230** of the variable memory **206**. In the embodiment shown, block **382** directs the conditioner processor **202** to retrieve the most recently stored controller signal record **340** as shown in Figure **9**, from locations **230** of the variable memory **206** shown in Figure **5**.

Block **384** of Figure **10** then directs the conditioner processor **202** shown in Figure **5** to determine whether the contents of the lift valve field **342** of the controller signal record **340** retrieved at block **382** are set to TRUE. If at block **384**, the conditioner processor **202** determines that the contents of the lift valve field are set to TRUE, block **384** directs the conditioner processor **202** to block **386**. If the conditioner processor **202** determines that the contents of the lift valve field are not set to TRUE, block **384** directs the conditioner processor **202** to block **390**.

When block **386** of Figure **10** is executed, block **386** directs the conditioner processor **202** to cause the output port **260** of the I/O interface **212** shown in Figure **5** to produce a lift output signal having a voltage of V_H for the active time **368** as shown in Figure **11**A and a voltage of V_L for the inactive time **370**. A first lift signal portion **364** of the lift output signal **50** is thus transmitted to the positioning system **22** shown in Figure **3**.

In the embodiment shown, a signal time record **420** as shown in Figure **12** is stored in locations **234** of the variable memory **206** shown in Figure **5**. The signal time record **420** includes an active time length field **422** for storing a representation of an active time length and an inactive time length field **424** for storing a representation of an inactive time length. In some embodiments, the signal time record **420** may be initialized by a manufacturer of the conditioner **20**, for example. In some embodiments, as described in further detail below, the signal time record **420** may be derived from system information.

Referring back to Figure **10**, block **386** directs the conditioner processor **202** to read the active time length field **422** of the signal time record **420** shown in Figure **12** and to cause the I/O interface **212** shown in Figure **5** to cause the output port **260** to produce a low level voltage V_H for an active time having a length corresponding to the contents of the active time length field. Block **386** similarly directs the conditioner processor **202** to read the inactive time length field **424** of the signal time record **420** and cause the I/O interface **212** to cause the output port **260** to produce a low level voltage V_L for an inactive time having a length corresponding to the contents of the inactive time length field.

Referring to Figure **11A**, in the embodiment shown, block **386** has directed the conditioner processor **202** to cause the conditioned lift output signal to have the first lift signal portion **364** having the active time **368** having a voltage of V_H and a length of **20** ms, corresponding to the value stored in the active time length field **422** of the signal time record **420** shown in Figure **12**. In some embodiments, the active time **368** has a length between **10** ms and **40** ms. Block **386** has also directed the conditioner processor **202** to cause the first lift signal portion **364** to have the inactive time **370** having a voltage of V_L and a length of **300** ms, corresponding to the value stored in the inactive time length field **424** of the signal time record **420** shown in Figure **12**. In some embodiments, the inactive time **370** has a length between **280** ms and **310** ms.
The conditioned drop output signal **52** shown in Figure **11**B remains unchanged during the active and inactive times **368** and **370** of the first lift signal portion **364** and thus the drop output signal **52** includes a first drop signal portion **366** having a voltage of V_L, as was set at block **381** of Figure **10**.

If at block **384** of Figure **10**, the conditioner processor **202** shown in Figure **5** determines that the lift valve field is not set to TRUE, or, upon completion of block **386**, the conditioner processor **202** is directed to block **390**.

Block **390** directs the conditioner processor **202** shown in Figure **5** to determine whether a drop valve field of the controller signal record retrieved at block **382** is set to TRUE. If so, the conditioner processor **202** is directed to block **392**. If at block **390**, the conditioner processor **202** determines that the drop valve field is not set to TRUE, i.e. is set to FALSE, block **390** directs the conditioner processor **202** to end the process.

Block **392** of Figure **10** is generally similar to block **386**, except that block **392** directs the conditioner processor **202** to cause the output port **262** of the I/O interface **212** shown in Figure **5** to produce the conditioned drop output signal.

When the positioning system **22** shown in Figure **3** receives the conditioned lift and drop output signals **50** and **52** shown in Figures **11A** and **11B** during the active time **368**, the output signals are in an up control state and so the positioning system **22** is instructed to open the lift valve and close the drop valve of the height hydraulic system shown in Figure **4** and thus raise the header **12** shown in Figure **1**.

Referring to Figure **11A**, at time t_2, the conditioner processor **202** causes the output **260** to cause the lift output signal **50** to transition from V_H to V_L and thus the positioning system **22** shown in Figure **4** is instructed to close the lift valve. Closing of the lift valve may not occur instantaneously after the conditioned lift output signal changes at time t_2 due to its response time and even after the lift valve is closed, the header **12** shown in Figure **1** may continue to move, due to various factors, such as, for example, momentum and/or float in the height hydraulic system shown in Figure **4**. Accordingly, the header **12** shown in Figure **1** may continue to move during a positioning response time **372** shown in Figure **11A** at the beginning of the inactive time **370** until the header **12** settles into a fixed position.

The inactive time length field **424** should be set to represent a time length that is greater than the positioning response time **372**, such that block **386** directs the conditioner processor **202** to cause the conditioned lift output signal **50** to have an inactive time having a sufficient length to include a stable time **373** during which the header **12** has settled into a fixed position. The length of the active time may be sufficiently short and the length of the inactive time may be sufficiently long and suitable delays can be provided by codes in blocks **302** or **304** to facilitate the controller **18** sampling the left and right position signals **40** and **44** and during the stable time **373**.

For example, after block **304** of Figure **7** has been executed and the first lift and drop signal portions **364** and **366** as shown in Figures **11A** and **11B** have been produced, the codes of block **304** may cause the conditioner processor **202** to execute at time t_3, for example, block **302** which directs the conditioner processor **202** to sample the lift and drop signals and store a controller signal record having a lift valve field set to TRUE and a drop valve field set to FALSE in accordance with the lift and drop signals as seen at t_3 in Figures **6A** and **6B**.

As shown in Figure **10** block **304** then directs the conditioner processor **202** to cause the outputs **260** and **262** of the I/O interface **212** to produce a second lift signal portion **400** and a second drop signal portion **402** shown in Figures **11A** and **11B** on the output ports **260** and **262** respectively. Referring to Figure **11A**, the second lift signal portion **400** includes an active time **375** and an inactive time **376**.

Blocks **302** and **304** of Figure **7** are then executed again, this time at time t_4 shown in Figures **6A**, **6B**, **11A** and **11B**. Blocks **302** and **304** direct the conditioner processor **202** to cause the outputs **260** and **262** of the I/O interface **212** to produce a third lift signal portion **404** as shown in Figure **11A** and a third drop signal portion **406** as shown in Figure **11B**. Referring to Figure **11A**, the third lift signal portion **404** includes an active time **374** and an inactive time **378**.

Blocks **302** and **304** of Figure **7** are then executed at time t_5 shown in Figures **6A**, **6B**, **11A** and **11B** and at this time (t_5), the controller **18** shown in Figure **3** has determined that a representative sensed height is greater than a desired representative height and so the controller **18** has set the lift and drop control signals **46** and **48** into a drop control state by setting the lift and drop control signals **46** and **48** to V_L and V_H respectively, as shown in Figures **6A** and **6B**.

Therefore, when the conditioner processor **202** executes block **324** of Figure **8**, at time t_5, the conditioner processor **202** stores a controller signal record having a lift valve field set to FALSE and a drop valve field set to TRUE.

Referring to Figure **10**, block **384** directs the conditioner processor **202** to block **390**, which directs the conditioner processor **202** to block **392**. Block **392** directs the conditioner processor **202** to cause the output **262** of the I/O interface **212** to produce a fourth drop signal portion **410** having an active time **412** and inactive time **414** respectively, while the output port **260** transmits a fourth lift signal portion **408**.

Referring to Figures **11**A and **11**B, during the active time **412**, the output signals **50** and **52** are in a drop control state and the positioning system **22** is instructed to open the drop valve of the height hydraulic system to retract the cylinder, causing the header **12** shown in Figure **1** to be lowered. In various embodiments, the inactive time **414** may be greater than a positioning response time of the positioning system **22**. The active time **412** and the inactive time **414** shown in Figures **11**A and **11**B should be set to sufficient lengths to facilitate the controller **18** sampling the left and right position signals **40** and **44** shown in Figure **3** and updating the control signals **46** and **48** during a stable time.

In effect blocks **302** and **304** of Figure **7** are executed in a continuous loop such that the conditioner processor **202** shown in Figure **5** effectively intercepts the lift and drop control signals **46** and **48** produced by the controller **18** and produces the lift and drop output signals **50** and **52**.

More particularly, blocks **302** and **304** of Figure **7**, when executed a plurality of times during the time period shown in Figures **11**A and **11**B, direct the conditioner processor **202** to produce the lift and drop output signals **50** and **52** shown in Figures **11**A and **11**B representing a plurality of active times including the active times **368**, **375**, **374**, and **412** during which the positioning system **22** shown in Figure **4** is instructed to move and a plurality of inactive times including the inactive times **370**, **376**, **378**, and **414** during which the positioning system **22** shown in Figure **4** is instructed not to move, each active time **368**, **375**, **374**, and **412** being followed by a respective one of the plurality of inactive times **370**, **376**, **378**, and **414**, wherein each of the plurality of inactive times **370**, **376**, **378**, and **414** is sufficiently long to permit the header **12** shown in Figure **1** to settle into a fixed position due to the positioning response time of the positioning system **22**.

Blocks **302** and **304** thus direct the conditioner processor **202** to condition the lift and drop control signals **46** and **48** transmitted by the controller **18,** normally received by the positioning system **22**, and configured to cause movement of the header **12** relative to a frame towards a desired position, by producing the conditioned lift and drop signals.

<u>Time Length Determining</u>

In various embodiments, the conditioner **20** shown in Figure **3** may be configured to improve performance of the system **10** by determining, based on system information, lengths for the active times and the inactive times to be represented by the output signals. For example, in various embodiments, the conditioner **20** shown in Figures **1-3** and **5** may be configured to receive system information from the system sensors **47** via the system information signals **49** and to determine the lengths of the active times and/or inactive times based on the received system information.

Referring to Figure **13**, in the embodiment shown, the system sensors **47** include a user input device **480** for receiving user input, a hydraulic pressure sensor **482**, such as a hydraulic pressure sensor on a combine main pump output, for sensing pressure in a reservoir configured to control the height hydraulic cylinder **64** shown in Figure **4**, a travel speed sensor **484**, such as a GPS true ground speed sensor, for sensing a travel speed of the apparatus **30** shown in Figure **1**, an engine speed sensor **486**, such as an engine RPM sensor, for sensing an engine speed for an engine that provides power to the positioning system **22** shown in Figure **4**, a hydraulic temperature sensor **498**, such as a hydraulic temperature sensor at the reservoir configured to control the height hydraulic cylinder **64**, for sensing a temperature of the hydraulic fluid contained in the reservoir, a fuel consumption sensor **488**, such as an engine fuel flow meter, for sensing a rate at which the engine that provides power to the positioning system **22** is consuming fuel, an accelerometer **490**, such as a vertical accelerometer on the header **12** shown in Figure **1**, for sensing acceleration of the header **12**, fill level sensors **492**, such as a hopper fill level sensor on the propulsion unit **14** shown in Figure **1**, for sensing a fill level of the propulsion unit **14**, an implement identifier device **494** for identifying the header **12** shown in Figure **1**, and a controller identifier device **496** for identifying the controller **18** shown in Figure **3**.

Referring still to Figure **13**, in various embodiments, the user input device **480** is configured to transmit a user input signal **481** representing received user input to the conditioner **20**.

In some embodiments, a user may wish to modify system performance or speed with which the system **10** shown in Figure **3** responds to changes in the sensed environment. The user may use the user input device **480** shown in Figure **13** to produce the user input signal **481** representing a user-defined speed with which the user wishes the system **10** to respond to changes in the sensed environment. For example, the active time lengths may be altered by the user input. The user input device **480** may include a speed control switch for example or jumper wire on a circuit board on which the conditioner processor **202** is mounted, for example for varying a voltage of the user input signal **481** between a high voltage and a low voltage where a high voltage may indicate that the user wishes that the system **10** shown in Figure **3** respond quickly using longer active times where a low voltage may indicate that the user wishes that the system respond more slowly using shorter active times.

In other embodiments, the user input device **480** shown in Figure **13** may include push buttons on a user display unit and the user-defined speed may be represented by a value, such as, for example a value between **0** and **100**.

The hydraulic pressure sensor **482** is configured to transmit a pressure signal **483** representing the sensed pressure to the conditioner **20**. In various embodiments, the pressure signal **483** represents pressure between about **100** and **5000** PSI. The travel speed sensor **484** is configured to transmit a travel speed signal **485** representing the sensed travel speed to the conditioner **20**. In various embodiments, the travel speed signal **485** represents speed between about **0** km/h and **30** km/h. The engine speed sensor **486** is configured to transmit an engine speed signal **487** representing the sensed engine speed to the conditioner **20**. In various embodiments, the engine speed signal **487** represents engine speed between about **500** and **4000** RPM.

The hydraulic temperature sensor **498** is configured to transmit a temperature signal **499** representing the sensed temperature to the conditioner **20.** The hydraulic temperature sensor **498** may be located in a position on the apparatus **30** shown in Figure **1** that facilitates accurate sensing of a working temperature of the hydraulic fluid. For example, the hydraulic temperature sensor maybe located at a valve of the hydraulic height cylinder **64** shown in Figure **4**. In various embodiments, the temperature signal **499** represents temperature between about **0** and **200** Celsius.

The fuel consumption sensor **488** is configured to transmit a fuel consumption signal **489** representing the sensed fuel consumption rate to the conditioner **20**. In various embodiments, the fuel consumption signal **489** represents a fuel consumption rate between about **0** and **20** L/hr.

The accelerometer **490** is configured to transmit an acceleration signal **491** representing the sensed acceleration to the conditioner **20**. In various embodiments, the acceleration signal **491** represents one or more sensed acceleration between about **0** and **245** m/s^2. The fill level sensor **492** is configured to transmit a fill level signal **493** representing the sensed fill level to the conditioner **20**. In various embodiments, the fill level signal **493** represents fill level between **0** and **100**%.

The implement identifier device **494** is configured to transmit an implement identifier signal **495** representing the implement identifier to the conditioner **20**. In various embodiments, the implement identifier signal **495** represents an implement identifier between **0000** and FFFF. The controller identifier device **496** is configured to transmit a controller identifier signal **497** representing the controller identifier to the conditioner **20**. In various embodiments, the controller identifier signal **497** represents a controller identifier between **0000** and FFFF.

In some embodiments, a device may act as the user input device **480**, the accelerometer **490**, the implement identifier device **494**, and/or the controller identifier device **496**. For example, in some embodiments, a user may use push buttons on a user display unit of the device to set the user-input, implement identifier, and controller identifier.

In some embodiments, the pressure signal **483**, travel speed signal **485**, engine speed signal **487**, temperature signal **499**, fuel consumption signal **489**, and fill level signal **493** may be transmitted on an electrical system or controller area network bus (CAN bus) of the propulsion unit **14** shown in Figure **1**. For example, any or all of the sensors, such as the hydraulic pressure sensor **482**, travel speed sensor **484**, engine speed sensor **486**, hydraulic temperature sensor **498**, fuel consumption sensor **488**, and/or fill level sensors **492** may be an existing machine sensor that is included in the propulsion unit **14** and produces a respective signal on the electrical system or CAN bus of the propulsion unit **14** shown in Figure **1**.

In the embodiment shown, the signals **481**, **483**, **485**, **487**, **499**, **489**, **491**, **493**, **495**, and **497** shown in Figure **13** may act as the system information signals **49** shown in Figure **3**. Each of the signals, **481**, **483**, **485**, **487**, **499**, **489**, **491**, **493**, **495**, and **497** may be one or more analog voltage signals having a voltage proportional to the sensed or measured value. In some embodiments, the signals may be digital signals representing sensed or measured values in binary hexadecimal code for example.

Referring to Figure **14**, a flowchart depicting the block of codes **222** for directing the processor circuit **200** shown in Figure **5** to perform time length determining functions is shown. In various embodiments, the block of codes **222** may be executed periodically. For example, in some embodiments, the block of codes **222** may be executed once upon startup of the conditioner **20**. In other embodiments, the block of codes **222** may be executed once every minute, for example.

Referring to Figure **14**, block **502** directs the conditioner processor **202** shown in Figure **5** to determine system information by directing the conditioner processor **202** to cause the I/O interface **212** to receive the system information signals **481**, **483**, **485**, **487**, **499**, **491**, **493**, **495** and **497** at the input ports **254**, **256**, **258**, **259**, **263**, **264**, **266**, **268**, **270**, **272** and **274** respectively and to store a representation of the system information in locations **234** of the variable memory **206** shown in Figure **5**. The system information may be stored as a system information record as shown in Figure **15**.

Referring to Figure **15**, an exemplary system information record is shown at **540**. In the embodiment shown, the system information record **540** includes a user input field **542** for storing a representation of user-defined speed, a hydraulic pressure field **544** for storing a representation of sensed pressure, a travel speed field **546** for storing a representation of sensed travel speed, an engine speed field **548** for storing a representation of sensed engine speed, a hydraulic temperature field **549** for storing a representation of sensed temperature of hydraulic fluid, an engine fuel consumption rate field **550** for storing a representation of a sensed fuel consumption rate, an acceleration field **554** for storing a representation of sensed acceleration, a fill level field **556** for storing a representation of a sensed fill level, an implement identifier field **558** for storing a representation of an implement identifier, and a controller identifier field **559** for storing a representation of a controller identifier. In the embodiment shown in Figure **15**, the acceleration field **554** stores a plurality of representations of sensed accelerations over a time period, which is shown as a graph in Figure **15**.

Referring back to Figure **14**, after block **502** has been completed, block **504** directs the conditioner processor **202** to determine time length information from the system information stored in the system information record **540** shown in Figure **15** and stored in locations **234** of the variable memory **206** shown in Figure **5** and to store the derived time length information in locations **232** of the variable memory **206**.

Block **504** is shown in greater detail in Figure **16** and includes a first block **582** which directs the conditioner processor **202** to determine a base active time length and a base inactive time length. In some embodiments, block **582** may direct the conditioner processor **202** to determine a base active time length based on the contents of the controller identifier field **559** of the system information record **540** shown in Figure **15**. For example, block **582** may direct the conditioner processor **202** to read the controller identifier from the controller identifier field **559** of the system information record **540** and use it to find a controller time length record stored in location **236** in the program memory **204** shown in Figure **5**. An exemplary representation of a controller time length record, in accordance with one embodiment of the invention, is shown at **600** in Figure **17** and includes a controller identifier field **602** for storing a controller identifier, a base active time length field **606**, a minimum active time length field **608**, a maximum active time length field **610** and a cycle time length or sampling interval field **612**.

The base active time length field **606** shown in Figure **17** stores an active time that facilitates accurate control by the controller identified by the controller identifier field **602** in base conditions (e.g., average expected values for system information). The minimum active time length field **608** and maximum active time length field **610** represent minimum and maximum active times that can facilitate control by the controller identified by the controller identifier field **602**. The cycle time length field **612** stores a value representing a sampling interval time between the controller identified by the controller identifier field **602** sampling the position signals and updating the control signals.

Block **582** of Figure **16** directs the conditioner processor **202** of Figure **5** to derive a base active time length from the base active time length field **606** shown in Figure **17** and to derive a base inactive time length by subtracting the base active time length from the cycle time length stored in the cycle time length field **612**. Use of these base active and inactive times by the conditioner **20** causes the controller **18** shown in Figure **3** to sample position signals and update control signals during inactive times (e.g. during the inactive times **370**, **376**, **378**, and **414** shown in Figures **11**A and **11**B).

In various embodiments, a manufacturer of the conditioner **20** may conduct experiments employing various active time lengths when using the conditioner **20** to condition signals produced by the controller **18** to produce output signals for causing the positioning system **22** to move an average agricultural implement such as the header **12**. In various embodiments, for example, the manufacturer may find that under normal conditions (i.e., average expected values for system information), the conditioner **20** best facilitates accurate control when the active time length is **20** ms. Accordingly, in various embodiments, the manufacturer may store in the controller time length record **600**, a base active time length of **20** ms. Similarly, the manufacturer may determine minimum and maximum active time lengths through experimentation.

For universal application of the conditioner **20**, the controller time length information location **236** of the program memory **204** shown in Figure **5** may store a plurality of controller active time length records for a plurality of different controllers identified by respective controller identifiers. In various embodiments, a user can provide input via the controller identifier device **496** shown in Figure **13** or the controller identifier device **496** may be included in the controller **18** shown in Figures **1**-**3** such that the controller identifier device **496** identifies the controller with which the conditioner is to be used and the time length determining codes will automatically determine appropriate active time and inactive time lengths, cycle time etc. for the identified controller, using the controller active time length record corresponding to the identified controller. Block **582** directs the conditioner processor **202** to store derived base active and base inactive time lengths in the active and inactive time length fields **422** and **424** in the signal time record **420** shown in Figure **12** and stored in locations **232** of the variable memory **206** shown in Figure **5**.

In some embodiments, the flowchart shown in Figure **16** may end after block **582**. In other embodiments, the process may continue at block **584**, which directs the conditioner processor **202** to adjust values stored in the active time length field **422** and the inactive time length field **424** of the signal time record **420** shown in Figure **12** using information from the system information record **540** shown in Figure **15**.

For example, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the user input field **542** of the system information record **540** shown in Figure **15**. When the user input field **542** stores a value of TRUE, this indicates that the user-defined speed is high and thus the user wishes that the system **10** shown in Figure **3** react quickly. Therefore, block **584** may direct the conditioner processor **202** to increase the active time length stored in the active time length field **422** in response to the user input field **542** of the system information record **540** shown in Figure **15** being set to TRUE.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the hydraulic pressure field **544** and/or the engine speed field **548** of the system information record **540** shown in Figure **15**. High hydraulic pressure and low engine speed may indicate high loads that may result in low hydraulic power. Accordingly, block **584** may direct the conditioner processor **202** to compensate for low hydraulic power by increasing the active time length stored in the active time length field **422** when the hydraulic pressure field **544** and the engine speed field **548** represent high hydraulic pressure and low engine speed and thus represent low hydraulic power.
In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the travel speed field **546** of the system information record

540 shown in Figure **15**. High travel speed may indicate that faster lift rates are required. Accordingly, block **584** may direct the conditioner processor **202** to increase the active time length stored in the active time length field **422** when the travel speed field **546** represents high travel speed.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the engine speed field **548** of the system information record **540** shown in Figure **15**. Low engine speed may indicate reduced available hydraulic power and slower hydraulic system functions. Accordingly, block **584** may direct the conditioner processor **202** to compensate for the low power by increasing the active time length stored in the active time length field **422** when the engine speed field **548** represents low engine speed.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the temperature field **549** of the system information record **540** shown in Figure **15**. High hydraulic temperature may result in lower hydraulic power that may result in low hydraulic function whereas low hydraulic temperature may result in higher hydraulic power. Accordingly, block **584** may direct the conditioner processor **202** to increase the active time length stored in the active time length field **422** when the temperature field **549** represents high temperature and/or to decrease the active time length stored in the active time length field **422** when the temperature field **549** represents low temperature.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the engine fuel consumption rate field **550** and the travel speed field **546** of the system information record **540** shown in Figure **15**. In various embodiments, fuel consumption rate may be indicative of engine load. High travel speed at low engine load may indicate that the apparatus **30** shown in Figure **1** is traveling downhill. Low travel speed at high engine load may indicate that the apparatus **30** shown in Figure **1** is traveling uphill. In some embodiments, it may be desirable to slow down auto header height functions when traveling up or down hill, for stability.

Accordingly, in some embodiments, block **584** may direct the conditioner processor **202** to decrease the active time length stored in the active time length field **422** when the engine fuel consumption rate field **550** and the travel speed field **546** indicate that the apparatus **30** shown in Figure **1** is traveling up or down hill. Thus, in some embodiments, block **584** may direct the conditioner processor **202** to decrease the active time length stored in the active time length field **422** when the engine fuel consumption rate field **550** represents high consumption and the travel speed field **546** represents low speed or when the engine fuel consumption rate field **550** represents low consumption and the travel speed field **546** represents high speed.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the acceleration field **554** of the system information record **540** shown in Figure **15**. High frequency acceleration may be used to determine roughness of terrain. For example, in various embodiments, the roughness of the terrain may be classified as “soft”, “medium” or “hard”. A high level of high frequency acceleration may indicate that the terrain is rough or hard. In some embodiments, it may be desirable to have slower control and thus shorter active times in rough or hard terrain. Accordingly, block **584** may direct the conditioner processor **202** to decrease the active time length stored in the active time length field **422** when the acceleration field **554** represents a high level of high frequency acceleration.

Low frequency acceleration may be used to determine a pitching motion of the apparatus **30** shown in Figure **1**. Accordingly, block **584** may direct the conditioned processor **202** to decrease the active time length stored in the active time length field **422** when the acceleration field **554** represents a low frequency accelerator.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the fill level field **556** of the system information record **540** shown in Figure **15**. The fill level may be indicative of a mass of the propulsion unit **14**. For example, fill level of crop load may add several tons to an operating mass of the propulsion unit **14** shown in Figure **1** as it fills. High mass of the propulsion unit **14** may indicate that header height control is able to be more aggressive without causing the apparatus **30** shown in Figure **1** to pitch. Accordingly, block **584** may direct the conditioner processor **202** to increase the active time length stored in the active time length field **422** when the fill level field **556** represents a high fill level and thus a large mass of the propulsion unit **14**. In various embodiments, the mass of the propulsion unit may be derived from both the fill level and a capacity of the propulsion unit. Accordingly, an amount by which the active time is varied may depend not only on the fill level but also on a capacity of the propulsion unit **14**, which may be determined, for example, using the contents of the controller identifier field **559** of Figure **15**, which may correspond to a type of propulsion unit, and a lookup table stored in the program memory **204** shown in Figure **5**, for example.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to vary the contents of the active time length field **422** of the signal time record **420** shown in Figure **12** based on contents of the implement identifier field **558** of the system information record **540** shown in Figure **15**. In various embodiments, the implement identifier may be associated with an inertia of the agricultural implement identified by the implement identifier, for example, by a lookup table stored in the program memory **204** of the conditioner processor circuit **200** shown in Figure **5**. Block **584** may direct the conditioner processor **202** to look up in the look up table, an inertia of the agricultural implement using the implement identifier from the implement identifier field **558**. High inertia may indicate that the agricultural implement is difficult to move. Accordingly, block **584** may direct the conditioner processor **202** to increase the active time length stored in the active time length field **422** when the implement identifier field **558** stores an implement identifier associated with a high inertia.

In some embodiments, block **584** of Figure **16** may direct the conditioner processor **202** to read the minimum and maximum active time length fields **608** and **610** of the controller time length record **600** shown in Figure **17** and limit the adjustments to the active time length to keep the active time length between the minimum and maximum active time lengths.

In some embodiments, block **584** may direct the conditioner processor **202** to vary the contents of the inactive time length **424** of the signal time record **420** shown in Figure **12** to equal a difference between the times represented by the cycle time length field **612** of the controller time length record **600** shown in Figure **17** and the updated active time length field **422**, such that the sum of the active time length and the inactive time length remains equal to the cycle time length.

Accordingly, the conditioner processor **202** may be directed to store adjusted or updated time length information in locations **232** of the variable memory **206** shown in Figure **5**. As described above, the conditioner processor **202** may be directed to use the time length information stored in the locations **232** of the variable memory **206** when producing the output signals **50** and **52**. Accordingly, the conditioner processor **202** may be directed to use updated time length information, which has been determined using the process depicted by the flowchart shown in Figure **14**, when producing the output signals **50** and **52**.

Continuous Control

Referring to Figure **1**, in various embodiments, a user may wish to control the positioning system **22** manually, such as, for example, when the user is finished harvesting and wishes to raise the header **12**. In such embodiments, for example, the user causes the controller **18** to continuously transmit output signals **50** and **52** (shown in Figure **3**) that are in the up control state to raise the header **12** or to continuously transmit output signals **50** and **52** in the down control state to lower the header **12**. The conditioner **20** may normally condition the signals before transmitting output signals to the positioning system **22**.

However, when the user wishes to manually raise or lower the header **12**, in various embodiments, conditioning the continuous control signals may cause the positioning system to move slower than is necessary.

Accordingly, in some embodiments, referring to Figure **3**, the conditioner **20** may be configured to determine whether the control signals **46** and **48** represent continuous or manual control by a user and, if the control signals **46** and **48** represent continuous or manual control, to transmit output signals to the positioning system **22**, which are not conditioned. In various embodiments, the conditioner **20** may be configured to simply relay representations of the control signals as output signals to the positioning system **22** when the control signals represent continuous or manual control.
Referring to Figure **18**, block of codes **224** shown in Figure **5** for directing the processor circuit **200** to perform continuous control override functions is shown in greater detail. The blocks of code **224** may be executed after block **302** and before block **304** shown in Figure **7** is executed.

Referring to Figure **18**, block **622** directs the conditioner processor **202** to determine whether the control signals meet a continuous control criterion. For example this criterion may be met when the lift and drop control signals **46** and **48** are in an up control state or in a down control state and have not changed for a certain threshold period of time. In various embodiments, during normal automatic control of the positioning system **22** by the controller **18**, the controller may not keep the lift and drop control signals **46** and **48** in an up or down control state for longer than the threshold period of time, due to the speed of the system **10** shown in Figure **3**. Accordingly, when the control signals **46** and **48** have not changed in greater than the threshold period of time, this may be indicative of manual user control.

Referring to Figure **19**, in some embodiments, block **622** includes sub-blocks of code including block **642** which directs the conditioner processor **202** to retrieve control signals for the last threshold period of time. This is done by directing the conditioner processor **202** to retrieve a threshold control time from a threshold time record **660** such as shown in

Figure **21** from location **238** of the program memory **204**. The threshold time record **660** may include a threshold time field **662** representing a threshold time period to be used in determining whether continuous control criterion are met.

Block **642** of Figure **19** may direct the conditioner processor **202** shown in Figure **5** to retrieve all controller signal records from locations **230** of the variable memory **206** that include time fields representing times within the time represented by the threshold time record **660** shown in Figure **20**. Accordingly, where the threshold time field **662** stores a time of **1.5** seconds, block **642** may direct the conditioner processor **202** to retrieve controller signal records that include time fields representing times that are within **1.5** seconds of a current time. In some embodiments, the threshold time may be between about **1.0** seconds and about **2.0** seconds.

Block **644** of Figure **19** then directs the conditioner processor **202** to read the lift and drop valve fields of the controller signal records retrieved in block **642** to determine whether the lift and drop valve fields store equal values for each of the controller signal records retrieved. If the lift and drop values indicated in each of the retrieved records are equal, block **644** directs the conditioner processor **202** to determine that the control signals **46** and **48** meet the continuous control criterion and the conditioner processor **202** is directed to continue at block **624** of Figure **18**.

In some embodiments, block **644** of Figure **19** may direct the conditioner processor **202** of Figure **5** to first determine whether the lift and drop valve fields store all FALSE values, and if the conditioner processor **202** determines that the lift and drop valve fields store all false values, then block **644** directs the conditioner processor to determine that the control signals **46** and **48** do not meet the continuous control criterion and directs the conditioner processor **202** to end the process.
If the lift and drop values are not equal, block **644** of Figure **19** directs the conditioner processor **202** of Figure **5** to determine that the control signals **46** and **48** do not meet the continuous control criterion and directs the conditioner processor **202** to end as shown in Figures **18** and **19**.

In some embodiments, the value stored in the threshold time field **662** of the threshold time record **660** shown in Figure **20** may be set by a manufacturer of the conditioner **20** for example. The value stored in the threshold time field **662** may represent a time that the manufacturer has found through experimentation, for example to indicate that a user has taken control of the controller **18**. In various embodiments, the time represented by the threshold time field **662** may be large enough such that when the controller **18** is automatically controlling the position of the header **12** shown in Figure **2** during normal use (i.e., while travelling along a field and harvesting crop), block **644** of the flowchart shown in Figure **18** would not direct the conditioner processor to continue at block **624** of the flowchart shown in Figure **19**.

Referring back to Figure **18**, after block **622** has been executed, if the control signals meet the continuous control criterion, block **624** directs the conditioner processor **202** shown in Figure **5** to produce continuous control signals representing received control signals to the positioning system **22**. For example, block **624** may direct the conditioner processor **202** to set the lift and drop output signals **50** and **52** at the output ports **260** and **262** to respective voltages representing the received control signals. More particularly, block **624** may direct the conditioner processor **202** to retrieve a most recent controller signal record from the locations **230** of the variable memory **206** shown in Figure **5** and cause the output ports **260** and **262** to set the lift and drop output signals **50** and **52** to voltages representing the values of the lift and drop valve fields respectively of the retrieved controller signal record. For example, where the lift and drop valve fields store values of TRUE and FALSE respectively, block **624** may direct the conditioner processor **202** shown in Figure **5** to cause the output ports **260** and **262** of the I/O interface **212** to set the lift output signal **50** to V_H and the drop output signal **52** to V_L.

After block **624** is completed, the conditioner processor **202** is directed to return to block **622**. If at block **622**, the conditioner processor **202** determines that the control signals do not meet the continuous control criterion, the process ends, otherwise block **624** is repeated until the control signals do not meet the continuous control criterion.

In embodiments where the continuous control block of codes **220** is executed after block **302** and before block **304**, once execution of the continuous control block of codes **220** has ended , the conditioner processor **202** is directed to execute block **304**. Accordingly, in some embodiments, block **304** is executed only if block **622** determines that the control signals do not meet the continuous control criterion.

In some embodiments, block **622** of Figure **18** may direct the conditioner processor **202** shown in Figure **5** to determine that the control signals meet the continuous control criterion in other ways than as described above with reference to Figure **19**. For example, in some embodiments, the controller **18** may produce a user control signal **650** that may be intercepted or received at port **274** of the I/O interface **212** of the processor circuit **200** shown in Figure **5**. In such embodiments, the control signals received by the conditioner may include the lift control signal **46**, the drop control signal **48** and the user control signal **650**.

For example, the controller **18** may be configured to set the user control signal **650** shown in Figure **5** to V_H when a user is manually controlling the controller **18** and to set the user control signal to V_L when a user is not manually controlling the controller **18**. Block **622** may direct the conditioner processor **202** to determine whether the control signals meet the continuous control criterion by determining whether the user control signal **650** received at the input port **272** shown in Figure **5** is set to V_H. In such embodiments, if the user control signal **650** is set to V_H, block **622** may direct the conditioner processor **202** to determine that the control signals meet the continuous control criterion.

Lateral Tilt

Referring back to Figure **4**, in some embodiments, the positioning system **22** may include a tilt hydraulic cylinder for controlling a lateral tilt of the header **12** shown in Figure **1**. Extension of the tilt hydraulic cylinder may cause the front portion **66** of the feeder house **60** shown in Figure **4** to tilt laterally from left to right (i.e., to rotate the front portion **66** about a pivot point of the front portion by raising a left side of the front portion **66** and lowering a right side of the front portion).

In some embodiments, the controller **18** may be configured to produce tilt control signals in addition to the signals already described, based on the received left and right position signals **40** and **44**. The tilt control signals may be configured to control the tilt hydraulic cylinder and thus cause the positioning system **22** to control a lateral tilt of the header **12** shown in Figure **1**. In some embodiments, the controller **18** may be configured to cause the tilt control signals to direct the positioning system **22** to tilt the header **12** such that the heights of the left and right sensors **32** and **36** are equal. In some embodiments, the controller **18** may be configured to transmit the tilt control signals directly to the positioning system **22**. In some embodiments, the controller **18** may transmit the tilt control signals to the conditioner **20**, and the conditioner **20** may relay the tilt control signals to the positioning system **22**. In some embodiments, the conditioner **20** may condition the tilt control signals generally as described above having regard to the lift and drop control signals **46** and **48** shown in Figure **3**.

<u>Variable Valve Hydraulic Cylinders</u>

In various embodiments, other types of height control may be used generally as described above. For example, a height-controlling hydraulic cylinder generally similar to the height-controlling hydraulic cylinder **64** shown in Figure **4** may include, instead of the solenoid controlled lift and drop valves, current controlled variable lift and drop valves. The current controlled variable lift and drop valves may be configured to control a flow of fluid through the valves in proportion to a current applied to inputs on the valves, for example. In some embodiments, the conditioner **20** may be configured to transmit conditioned output signals representing a plurality of active times during which one of the current controlled variable lift and drop valves is caused to open fully and a plurality of inactive times during which the current controlled variable lift and drop valves are caused to close, with each active time being followed by a respective one of the inactive times. The inactive times may be sufficiently long to permit the agricultural implement to settle into a fixed position due to the positioning response time of the positioning system **22**.

Controller/Conditioner Processor Circuit

Referring to Figure **21**, in alternative embodiments, functions of the controller **18** and the conditioner **20** shown in Figures **1-3** and described above may be integrated into a single controller/conditioner **680** in a system **682** shown in accordance with one embodiment in Figure **21**. The system **682** may be generally similar to the system **10** shown in Figure **3**, except that the system **682** includes the controller/conditioner **680** in place of the controller **18** and the conditioner **20** shown in Figures **1-3**. The system **682** shown in Figure **21** includes the sensor system **16** and the positioning system **22** of Figures **1-3**. In various embodiments, the system **682** may also include the system sensors **47** of Figure **3**.

The sensors **32** and **36** are configured to produce left and right position signals **40** and **44** representing sensed positions or heights of the header **12** shown in Figure **1** and the controller/conditioner **680** is configured to receive the left and right position signals **40** and **44** and to receive desired position signals representing desired positions or heights of the header **12**. In various embodiments, the controller/conditioner **680** is configured to determine a difference between the sensed heights and the desired heights, to derive conditioned lift and drop output signals **684** and **686** from the difference and to transmit the conditioned lift and drop output signals **684** to the positioning system **22**.

The lift and drop output signals **684** and **686** are as earlier described and represent a plurality of active times during which the positioning system **22** is instructed to move a header such as the header **12** shown in Figure **1** towards the desired height and a plurality of inactive times during which the positioning system **22** is instructed not to move, each active time being followed by a respective one of the plurality of inactive times, wherein each of the plurality of inactive times is sufficiently long to permit the header **12** shown in Figure **1** to settle into a fixed position due to the positioning response time of the positioning system **22**.

Referring to Figure **22**, a schematic view of a controller/conditioner processor circuit for implementing the controller/conditioner **680** shown in Figure **21** according to one embodiment is shown generally at **700**.

In various embodiments similar aspects of the controller/conditioner processor circuit **700** shown in Figure **22** may be implemented generally similarly to that described above in connection with the processor circuit **200** shown in Figure **5**.

Referring to Figure **22**, the controller/conditioner processor circuit **700** includes a controller/conditioner processor **702**, a program memory **704**, a variable memory **706**, and an input output ("I/O") interface **712**, all of which are in communication with the controller/conditioner processor **702**.

The program memory **704** includes a block of codes **720** for directing the controller/conditioner processor **702** to perform signal producing functions and a block of codes **722** for directing the controller/conditioner processor **702** to perform time length determining functions. The program memory **704** may also include at least one location **736** for storing controller time information.

The variable memory **706** includes a plurality of storage locations including locations **726** for storing sensed height information, locations **728** for storing desired height information, locations **730** for storing controller signal information, locations **732** for storing time length information, and locations **734** for storing system information.

The I/O interface **712** may include input ports **750** and **752** for receiving the left and right position signals **40** and **44** and output ports **760** and **762** for producing and transmitting the output signals **684** and **686**. In the embodiment shown, the I/O interface **712** also includes input ports **754**, **756**, **758**, **759**, **763**, **764**, **766**, **768**, **770**, and **772** for receiving user input signals, pressure signals, travel speed signals, engine speed signals, temperature signals, fuel consumption signals, acceleration signals, fill level signals, implement identifier signals, and controller identifier signals, respectively such as described previously. In some embodiments, the I/O interface **712** may also include input ports **774** and **776** for receiving desired position signals.

Controller/Conditioner Signal Producing

Referring to Figure **23**, block of codes **720** for directing the controller/conditioner processor circuit **700** shown in Figure **22** to produce conditioned lift and drop output signals is shown.

The block of codes **720** begins with block **802** which directs the controller/conditioner processor **702** shown in Figure **22** to receive position signals. In various embodiments, block **802** may direct the controller/conditioner processor **702** to cause the I/O interface **712** to receive the left and right position signals **40** and **44** shown in Figure **21** via the input ports **750**, and **752** shown in Figure **22**. In some embodiments, block **802** may direct the controller/conditioner processor **702** to convert the position signals into values representing heights or separation distances and to store the values in the locations **726** of the variable memory **706**.

In some embodiments, block **802** may direct the controller/conditioner processor **702** shown in Figure **22** to store the representations of the heights as digital values representing heights of between **0** inches and **18** inches. Block **802** directs the controller/conditioner processor to store the representations in a sensed height record **820,** such as shown in Figure **24**, in locations **726** of the variable memory **706**. The sensed height record **820** includes a left sensed height field **822** and a right sensed height field **826** for storing representations of the heights represented by the signals **40** and **44** respectively.

Referring to Figure **23**, block **804** then directs the controller/conditioner processor to receive a desired position signal representing a desired position. In some embodiments, a desired height input device may be in communication with the input ports **774** and **776** of the I/O interface **712** shown in Figure **22**. In various embodiments, the desired height input device may include one or more user controllable voltage sources for producing one or more desired position signals having voltages representing desired heights for the left and right sensors **32** and **36**, shown in Figure **21** for example.

Referring back to Figure **23**, in some embodiments, block **804** may direct the controller/conditioner processor **702** shown in Figure **22** to cause the input ports **774** and

776 of the I/O interface **712** to receive left and right desired position signals **830** and **832** having voltages representing desired heights for the left and right sensors **32** and **36**. Block **804** may direct the controller/conditioner processor **702** to store in the locations **728** of the variable memory **706** shown in Figure **22**, a desired height record **840** as shown in Figure **25** including a left desired height field **842** and a right desired height field **844** storing values based on the received left and right desired height signals **830** and **832** .

Block **806** of Figure **23** then directs the controller/conditioner processor **702** shown in Figure **22** to derive controller signal information from differences between the desired positions and the sensed positions. For example, block **806** may direct the controller/conditioner processor **702** to determine a left difference between a left sensed height represented by the left sensed height field **822** of the sensed height record **820** shown in Figure **24** and a left desired height represented by the left desired height field **842** of the desired height record **840** shown in Figure **25**. Block **806** may also direct the controller/conditioner processor **702** to determine a right difference between the right sensed height represented by the right sensed height field **824** and the right desired height represented by the right desired height field **844** of the desired height record **840** shown in Figure **25**.

Referring back to Figure **23**, block **806** directs the controller/conditioner processor **702** to store a controller signal record having an up control state in locations **730** of the variable memory **706** shown in Figure **22** (having a lift valve field set to TRUE and a drop valve field set to FALSE) if at least one of the left and right differences represents a sensed height that is less than a desired height and the difference has magnitude greater than a threshold difference. If neither of the left and right differences represents a sensed height that is less than a desired height and has magnitude greater than the threshold difference and at least one of the left and right differences represents a sensed height that is more than a desired height and has a magnitude greater than the threshold difference then block **806** directs the controller/conditioner processor **702** to store a controller signal record having a down control state in locations **730** of the variable memory **706** shown in Figure **22** (having a lift valve field set to FALSE and a drop valve field set to TRUE). Otherwise, block **806** directs the controller/conditioner processor **702** to store a controller signal record having an off control state in locations **730** of the variable memory **706** shown in Figure **22** (having a lift valve field and drop valve field set to FALSE)

Block **806** thus directs the controller/conditioner processor **702** to store a controller signal record having an up control state in locations **730** of the variable memory **706** shown in Figure **22** if one of the left and right differences represents a sensed height less than a desired height by more than the threshold difference, regardless of the contents of the other of the left and right differences. This may facilitate the controller/conditioner **680** directing the positioning system **22** to avoid a collision between an agricultural implement and the ground.

In various embodiments, the threshold difference may be set by a manufacturer of the controller/conditioner. In some embodiments, the threshold difference may between **0** and **1** inch and may represent a height difference of about **0.5** inches, for example.

Block **808** of Figure **23** directs the controller/conditioner processor **702** to cause the I/O interface **712** to produce at least one output signal to be provided to the positioning system **22** shown in Figure **21** wherein the at least one output signal represents an active time during which the positioning system **22** is instructed to move the header **12** shown in Figure **1** towards a desired position and an inactive time following the active time during which the positioning system **22** is instructed not to move, wherein the inactive time is sufficiently long to permit the header **12** to settle into a fixed position due to the positioning response time of the positioning system **22**. In some embodiments, block **808** may direct the controller/conditioner processor **702** to cause the output ports **760** and **762** to transmit the output signals **684** and **686** to the positioning system **22** shown in Figure **21**. Block **808** may be generally similar to block **304** shown in Figure **7** as discussed above. After block **808** has completed, the controller/conditioner processor has completed a cycle and may be directed to return to block **802** to begin a new cycle.

In some embodiments, blocks of code for directing the controller/conditioner processor circuit **700** shown in Figure **22** to perform time length determining may be encoded in the block of codes **722** shown in Figure **22**. In various embodiments, the blocks of code similar to those shown at **222** in Figure **14**, except that they may be configured to direct the controller/conditioner processor **702** to perform the process. In various embodiments, for the time length determining encoded in the block of codes **722** shown in Figure **22**, steps relating to the controller identifier signals may be omitted and the controller time length information may include a single controller time length record associated with the controller/conditioner **680**. In such embodiments, the controller time length record associated with the controller/conditioner may include a cycle time length field representing a base cycle time length that facilitates accurate control of an average positioning system. Further, the controller time length record may not need to include a controller identifier field.

<u>Sensor System Including a Modifier</u>

A field over which an agricultural implement is driven may include ground inconsistencies such as, for example, bumps and hills. In various embodiments, a user may wish to be able to sense a position of the agricultural implement relative to the ground at an intermediate location on the agricultural implement. For example, a user may wish to sense a position of the agricultural implement relative to the ground between left and right sensors, which may act as first and second sensors, to avoid driving the agricultural implement into a bump that is located between the left and right sensors.

Referring to Figure **26** there is shown a system **940** according to another embodiment that is generally similar to the system **10** shown in Figures **1** and **3** except that the system **940** includes a different sensor system **950** in place of the sensor system **16**. The different sensor system **950** shown in Figure **26** is configured to transmit first and second representative position signals **970** and **972** to the controller **18**, which may be received and handled generally as described above in the same way as the left and right position signals **40** and **44** shown in Figures **3** and **21**. Accordingly, the sensor system **950** may be configured to be substitutable for the sensor system **16** shown in Figures **3** and **21**, for example

The different sensor system **950** includes first and second sensors **952** and **956**, an intermediate or central sensor **954**, and a modifier **960**. Figure **28** shows an agricultural apparatus in accordance with one embodiment, which includes the first, intermediate, and second sensors **952**, **954**, and **956**. In the embodiment shown, the agricultural apparatus **1000** is an agricultural combine harvester including a header **1002** mounted to a propulsion unit **1004**.

Referring to Figure **27**, the first and second sensors **952** and **956** are mounted to an underside of the header **1002** at first and second spaced apart locations on the header **1002**. The first and second sensors **952** and **956** are located at opposite ends of the header **1002** and act as left and right sensors. The first and second sensors **952** and **956** sense first and second positions or separation distances of the header **1002** relative to the ground at the first and second locations respectively. The first and second sensors **952** and **956** may be generally similar to the left and right sensors **32** and **36** shown in Figure **1**.

Referring still to Figure **27**, the intermediate sensor **954** is mounted to an underside of the header **1002** at an intermediate location disposed generally between the first and second sensors **952** and **956**. The intermediate sensor **954** senses an intermediate position or separation distance of the header **1002** relative to the ground at the intermediate location. The intermediate sensor **954** may be generally similar to the first and second sensors **952** and **956**.

Referring back to Figure **26**, the first, intermediate, and second sensors **952**, **954**, and **956** produce first, intermediate, and second position signals **962**, **964**, and **966** respectively, representing the first, intermediate, and second positions of the first, intermediate and second locations of the header **1002** relative to the ground.
The modifier **960** receives the first, intermediate, and second position signals **962**, **964**, and **966** and, when the intermediate position meets a reference surface proximity criterion, transmits to the controller at least one modified representative position signal representing at least one modified position that differs from the first and second positions.

The reference surface proximity criterion may be met for example when the intermediate position is indicative of the header **1002** shown in Figure **27** getting close to the ground and the modifier **960** may, when the intermediate position meets the reference surface proximity criterion, cause the first representative position signal **970** to represent a position closer to the ground than the first position and/or cause the second representative position signal **972** to represent a position closer to the ground than the second position.

Accordingly, in various embodiments, when the intermediate position is indicative of the header **1002** shown in Figure **27** getting close to the ground, the modifier **960** modifies the first and second representative position signals **970** and **972** such that the controller **18** is more likely to cause the header **1002** to be raised. In various embodiments, this may facilitate avoidance of impact of the header **1002** with the ground.

Referring to Figure **28**, a modifier processor circuit for implementing the modifier **960** shown in Figure **26** according to one embodiment is shown generally at **1040**. The modifier processor circuit **1040** includes a modifier processor **1042**, a program memory **1044**, a variable memory **1046**, and an I/O interface **1048**, all of which are in communication with the modifier processor **1042**.

The program memory **1044** includes a block of codes **1050** for directing the modifier processor **1042** to perform position signal modifying functions. The variable memory **1046** includes a plurality of storage locations including locations **1066** for storing position information and locations **1068** for storing representative position information. The I/O interface **1048** includes input ports **1080**, **1082,** and **1084** for receiving the second, intermediate, and first position signals **966, 964,** and **962** and output ports **1090** and **1092** for producing and transmitting the first and second representative position signals **970** and **972**. Similar elements of the modifier processor circuit **1040** shown in Figure **28** may be implemented generally similarly to those described above in connection with the processor circuit **200** shown in Figure **5**.

Referring to Figure **29**, the block of codes **1050** for directing the modifier processor circuit **1040** shown in Figure **28** to perform position signal modifying functions, begins with block **1112** which directs the modifier processor **1042** shown in Figure **28** to receive at least one signal representing the first, second, and intermediate positions relative to the ground of the first, second, and intermediate locations respectively of the header **1002** shown in Figure **27**. Block **1112** directs the modifier processor **1042** shown in Figure **28** to cause the I/O interface **1048** to receive the first, intermediate, and second position signals **962, 964,** and **966** via the input ports **1084**, **1082,** and **1080** shown in Figure **28** and to store a position record based on the first, intermediate, and second position signals in the locations **1066** of the variable memory **1046** shown in Figure **28**.

Referring to Figure **30**, an exemplary position record is shown at **1140** and includes a first position field **1142**, a second position field **1144**, and an intermediate position field **1146**. Block **1112** directs the modifier processor **1042** to store digital representations of positions represented by the first, second, and intermediate position signals **962**, **966**, and **964** shown in Figure **26** in the first, second, and intermediate position fields **1142**, **1144**, and **1146** of the position record **1140**. The digital representations act as representations of the first position, the second position, and the intermediate position of the first, second, and intermediate locations of the header **1002** shown in Figure **27**.

Referring back to Figure **29**, block **1114** then directs the modifier processor **1042** of Figure **28** to determine whether the intermediate position meets a reference surface proximity criterion. To do this, block **1114** directs the modifier processor **1042** to retrieve a threshold intermediate value from the variable memory **1046**. The threshold intermediate value represents a threshold intermediate distance under which the header **1002** shown in Figure **27** is considered to be close to the ground. The threshold intermediate value may be previously set by a user of the modifier **960** such as, for example, by an input device. The threshold intermediate value may represent a separation distance of about **0.5** inches, for example.

Block **1114** of Figure **29** directs the modifier processor **1042** of Figure **28** to determine whether the intermediate position represented by the intermediate position field **1146** of the position record **1140** shown in Figure **30** represents a separation distance that is less than the threshold intermediate distance represented by the threshold intermediate value. If the intermediate position represents a separation distance that is less than the threshold intermediate distance, block **1114** of Figure **29** directs the modifier processor **1042** to proceed to block **1116**. If the intermediate position represents a separation distance that is not less than the threshold intermediate distance, block **1114** directs the modifier processor **1042** to proceed to block **1118**.

In an alternative embodiment, the reference surface proximity criterion may be met only if the intermediate position represents a separation distance of less than the threshold intermediate distance for more than a threshold period of time, such as **3** seconds, for example.

In the embodiment shown in Figure **30**, the intermediate position field **1146** contains a representation of an intermediate position of **0.3** inches relative to the ground which represents an intermediate separation distance of **1.5** inches which is less than the threshold intermediate distance of **0.5** inches. Thus, block **1114** of Figure **29** directs the modifier processor **1042** of Figure **28** to proceed to block **1116**.

Referring to Figure **29**, block **1116** directs the modifier processor **1042** of Figure **28** to produce and transmit to the positioning system at least one modified representative position signal representing at least one modified position that differs from the first and second positions.

In some embodiments, block **1116** directs the modifier processor **1042** to determine an intermediate deviation by determining a difference between the intermediate position and the threshold intermediate distance. In the embodiment shown in Figure **30**, the intermediate position field **1146** represents a separation distance of **0.3** inches. As discussed above, the threshold intermediate value represents a separation distance of **0.5** inches and so block **1116** directs the modifier processor **1042** to determine that the intermediate deviation is **0.5** inches – **0.3** inches = **0.2** inches. The intermediate deviation determined at block **1116** represents a proximity of the intermediate location of the header **1002** shown in Figure **27** to the ground.

Referring still to Figure **29**, block **1116** then directs the modifier processor **1042** to derive a representative position record, such as exemplary representative position record **1180** shown in Figure **31,** and to store the representative position record **1180** in locations **1068** of the variable memory **1046** shown in Figure **28**.

Referring to Figure **31**, the representative position record **1180** includes a first representative position field **1182** for storing representation of a first representative position and a second representative position field **1184** for storing a representation of a second representative position.

Referring to Figure **29**, block **1116** directs the modifier processor **1042** to store in the first representative position field **1182** of the representative position record **1180** shown in Figure **31**, a representation of a difference between the first position represented by the first position field **1142** of the position record **1140** shown in Figure **30** and the intermediate deviation discussed above. Accordingly, where the first position field **1142** represents **1.3** inches of separation distance and the intermediate deviation is **0.2** inches, as calculated above, block **1116** directs the modifier processor **1042** to store a representation of the difference (i.e., **1.1** inches) in the first representative position field **1182** shown in Figure **31**. In some embodiments, block **1116** may direct the modifier processor **1042** to scale the intermediate deviation up or down before subtracting it from the first position represented by the first position field **1182** and storing the difference in the first representative position field **1182** shown in Figure **31**.

Block **1116** similarly directs the modifier processor **1042** to store in the second representative position field **1184** a representation of a difference between the second position represented by the second position field **1144** of the position record **1140** shown in Figure **30** and the intermediate deviation. The positions represented by the contents of the first and second representative position fields **1182** and **1184** differ from the first and second positions and act as modified positions.

Block **1116** directs the modifier processor **1042** to cause the output ports **1090** and **1092** of the I/O interface shown in Figure **28** to cause the first and second representative position signals **970** and **972** to represent the modified positions represented by the first and second representative position fields **1182** and **1184** shown in Figure **31**. In various embodiments, block **1116** may direct the modifier processor **1042** to cause the output ports **1090** and **1092** to set the first and second representative position signals **970** and **972** to respective voltages representing the modified positions represented by the first and second representative position fields **1182** and **1184**.

In various embodiments, the modified positions represent an offset of the first and second positions wherein a magnitude of the offset is based on a proximity of the intermediate position to the ground. In various embodiments, because the modified positions represent positions that are closer to the ground than the first and second positions, the controller **18** shown in Figure **26** receiving the first and second representative position signals **970** and **972** may be more likely to cause the positioning system **22** to move the header **1002** shown in Figure **27** upwards in response to the first and second representative position signals **970** and **972** than if the controller **18** received the first and second position signals **962** and **966**.

In some embodiments, the intermediate position may not meet the reference surface proximity criterion. For example, the intermediate position represented by the intermediate position field **1146** shown in Figure **30** may be greater than the threshold intermediate distance and thus block **1114** of Figure **29** directs the modifier processor **1042** of Figure **28** to proceed to block **1118**.

Block **1118** of Figure **29** directs the modifier processor **1042** of Figure **28** to produce and transmit to the controller **18** shown in Figure **26** at least one representative position signal representing the first and the second positions.

In various embodiments, block **1118** of Figure **29** directs the modifier processor **1042** of Figure **28** to derive a representative position record, such as exemplary representative position record **1200** as shown in Figure **32,** and to store the representative position record **1200** in locations **1068** of the variable memory **1046** shown in Figure **28**. Referring to Figure **32**, the representative position record **1200** has the same format as the representative position record **1180** shown in Figure **31**. Block **1118** of Figure **29** directs the modifier processor **1042** of Figure **28** to copy the representations of the first and second positions from the first and second position fields **1142** and **1144** of the position record **1140** shown in Figure **30** into first and second representative position fields **1202** and **1204** of the representative position record **1200** shown in Figure **32**.

Block **1118** of Figure **29** then directs the modifier processor **1042** of Figure **28** to cause the output ports **1090** and **1092** of the I/O interface shown in Figure **28** to cause the first and second representative position signals **970** and **972** to represent the positions represented by the first and second representative position fields **1202** and **1204** shown in Figure **32**. Accordingly, block **1118** directs the modifier processor **1042** to relay the first and second positions represented by the received first and second positions signals **962** and **966** on to the controller **18** shown in Figure **26**.

Referring to Figure **29**, after block **1116** or block **1118** has been executed, the modifier processor **1042** is directed to return to block **1112**.

Alternatively, a sensor system similar to the sensor system **950** shown in Figure **26** may include one or more intermediate sensors. For example, the sensor system may include two or more intermediate sensors configured to sense respective intermediate positions of respective intermediate locations of the header **1002** shown in Figure **27**. In such an embodiment, the modifier **960** is configured to apply a selection criterion to the intermediate positions represented by intermediate sensor signals to select one of the intermediate positions and then use it as the intermediate position in the process shown in Figure **29**. For example, applying the selection criterion may involve selecting the intermediate position that represents a separation distance that is closest to the ground.

In an alternative embodiment, the header **1002** shown in Figure **27** includes a cutter bar that is configured to be pushed up by rising ground or terrain. In such an embodiment, a hydraulic pressure sensor for sensing hydraulic pressure in a hydraulic cylinder coupled to the cutter bar may act as the intermediate sensor. The pressure sensor may sense position or height of the header **1002** by sensing backpressure or differential pressure in the hydraulic cylinder coupled to the cutter bar.

While the above has been described having regard to an agricultural combine harvester including a header, which acts as an agricultural implement, mounted to a propulsion and processing unit, in various embodiments, similar methods, systems and apparatuses to those described above may be used in connection with other agricultural implements, such as, for example, a spray boom on a power unit.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An apparatus for conditioning at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to said at least one control signal, the apparatus comprising at least one processor configured to:

intercept said at least one control signal; and

in response to said intercept of said at least one control signal, produce at least one output signal for receipt by the positioning system instead of said at least one control signal, said at least one output signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to said positioning response time.

2. The apparatus of claim **1** wherein said at least one processor is configured to cause a first active time of said plurality of active times to have a length equal to a first active time length.

3. The apparatus of claim **2** wherein the first active time length is between about **10** and about **40** milliseconds.

4. The apparatus of claim **3** wherein the first active time length is about **20** milliseconds.

5. The apparatus of claim **2** wherein said at least one processor is configured to determine said first active time length.

6. The apparatus of claim **5** wherein said at least one processor is configured to:

receive at least one system information signal representing system information; and

derive the first active time length from the system information.

7. The apparatus of claim **6** wherein the system information comprises a controller identifier identifying the controller.

8. The apparatus of claim **6** wherein the system information includes user-defined speed information representing a desired speed at which the user wishes the positioning system to move the agricultural implement.

9. The apparatus of claim **6** wherein the system information comprises at least one of:

hydraulic pressure information representing a hydraulic pressure associated with the positioning system;

travel speed information representing a travel speed of the agricultural implement;

acceleration information representing acceleration of the agricultural implement;

fill level information representing a fill level and associated mass of the frame;

engine speed information representing an engine speed of an engine powering the positioning system;

hydraulic fluid temperature information representing a hydraulic fluid temperature of a hydraulic fluid reservoir of the positioning system;

fuel consumption rate information representing a fuel consumption rate and associated engine load of the positioning system; and

an implement identifier identifying the agricultural implement and an associated inertia.

10. The apparatus of claim **2** wherein said at least one processor is configured to cause a first inactive time following said first active time to have a first inactive time length.

11. The apparatus of claim **10** wherein the first inactive time length is between about **280** milliseconds and about **310** milliseconds.

12. The apparatus of claim **11** wherein the first inactive time length is about **300** milliseconds.

13. The apparatus of claim **11** wherein the controller is associated with a sampling interval, and wherein said at least one processor is configured to cause said first inactive time length to be equal to a difference between the active time length and the sampling interval.

14. The apparatus of claim **11** wherein said at least one processor is configured to:

determine whether the at least one control signal meets a continuous control criterion;

produce at least one continuous control signal representing said at least one control signal for receipt by said positioning system when the at least one control signal meets the continuous control criterion; and

produce said at least one output signal only if the at least one control signal does not meet the continuous control criterion.

15. The apparatus of claim **14** wherein said at least one processor is configured to determine whether the at least one control signal meets the continuous control criterion by determining whether the at least one control signal is configured to move the agricultural implement for more than a threshold control time.

16. The apparatus of claim **15** wherein the threshold control time is between about 1.0 seconds and about 2.0 seconds.

17. The apparatus of claim **15** wherein the threshold control time is about 1.5 seconds.

18. The apparatus of claim **1** wherein said at least one processor is configured to:

receive the at least one control signal at a first time;

produce a first set of output signal portions in response to said at least one control signal received at said first time, said first set of output signal portions representing an active time of the plurality of active times followed by an inactive time of the plurality of inactive times;

receive the at least one control signal at a second time following the inactive time represented by the first set of output signal portions; and

produce a second set of output signal portions in response to said at least one control signal received at said second time, said second set of output signal portions representing an active time of the plurality of active times followed by an inactive time of the plurality of inactive times.

19. The apparatus of claim **1** wherein said at least one processor is configured to:

receive at least one position signal representing at least one position of the agricultural implement;

receive at least one desired position signal representing the at least one desired position of the agricultural implement; and

derive said at least one control signal from at least one difference between said at least one position and said at least one desired position.

20. A method for conditioning at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to said at least one control signal, the method comprising:

intercepting said at least one control signal; and

in response to intercepting said at least one control signal, producing at least one output signal for receipt by the positioning system instead of said at least one control signal, said at least one output signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to said positioning response time.

21. A method of operating an agricultural implement on an agricultural vehicle, the method comprising:

causing a controller of the agricultural implement to produce at least one control signal for causing a positioning system to move the agricultural implement up or down relative to the ground or to not move the agricultural implement up or down;

executing the method of claim **20** to intercept said at least one control signal and to produce said at least one output signal and causing said at least one output signal to be provided to said positioning system instead of said at least one control signal produced by said controller; and

causing the positioning system to move the agricultural implement up or down or to stay in a current position, in response to said at least one output signal.

22. A non-transitory computer-readable medium having stored thereon codes which, when executed by at least one processor, cause the at least one processor to condition at least one control signal transmitted by a controller and normally received by a positioning system and configured to cause movement of an agricultural implement relative to a frame towards at least one desired position, the positioning system having a positioning response time for causing the agricultural implement to respond to said at least one control signal, wherein the codes, when executed by the at least one processor, cause the at least one processor to:

intercept said at least one control signal; and

in response to said intercept of said at least one control signal, produce at least one output signal for receipt by the positioning system instead of said at least one control signal, said at least one output signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to said positioning response time.

23. An agricultural implement control system for moving an agricultural implement up and down or for holding the agricultural implement at a height above the ground over which an agricultural vehicle is driven, the agricultural implement control system comprising:

a positioning system operably configured to move the agricultural implement up or down or to not move the agricultural implement up or down, in response to at least one control signal;

a controller operably configured to produce said at least one control signal; and

a conditioner operably configured to:

intercept said at least one control signal; and

in response to said intercept of said at least one control signal, produce at least one output signal for receipt by the positioning system instead of said at least one control signal, said at least one output signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to a positioning response time for causing the agricultural implement to respond to said at least one control signal.

24. A vehicle comprising the agricultural implement control system of claim **23**.

25. An apparatus for producing at least one control signal for controlling a positioning system, the positioning system having a positioning response time for causing an agricultural implement to move in response to said at least one control signal, the apparatus comprising at least one processor configured to:

receive at least one position signal representing at least one position of the agricultural implement;

receive at least one desired position signal representing at least one desired position of the agricultural implement;

derive said at least one control signal from at least one difference between said at least one position and said at least one desired position; and

produce said at least one control signal for receipt by said positioning system, said at least one control signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to said positioning response time.

26. An agricultural implement control system for moving an agricultural implement up and down or for holding the agricultural implement at a height above the ground over which an agricultural vehicle is driven, the agricultural implement control system comprising:

a positioning system operably configured to move the agricultural implement up or down or to not move the agricultural implement up or down, in response to at least one control signal;

a controller operably configured to produce said at least one control signal; and

a conditioner comprising an apparatus according to claim **1**, the conditioner operably configured to:

intercept said at least one control signal; and

in response to said intercept of said at least one control signal, produce at least one output signal for receipt by the positioning system instead of said at least one control signal, said at least one output signal representing a plurality of active times during which said positioning system is instructed to move the agricultural implement towards the at least one desired position and a plurality of inactive times during which said positioning system is instructed not to move, each active time being followed by a respective one of the plurality of inactive times;

wherein each of said plurality of inactive times has a respective time length determined to permit the agricultural implement to settle into a fixed position due to a positioning response time for causing the agricultural implement to respond to said at least one control signal.

27. A vehicle comprising the agricultural implement control system of claim **26**.

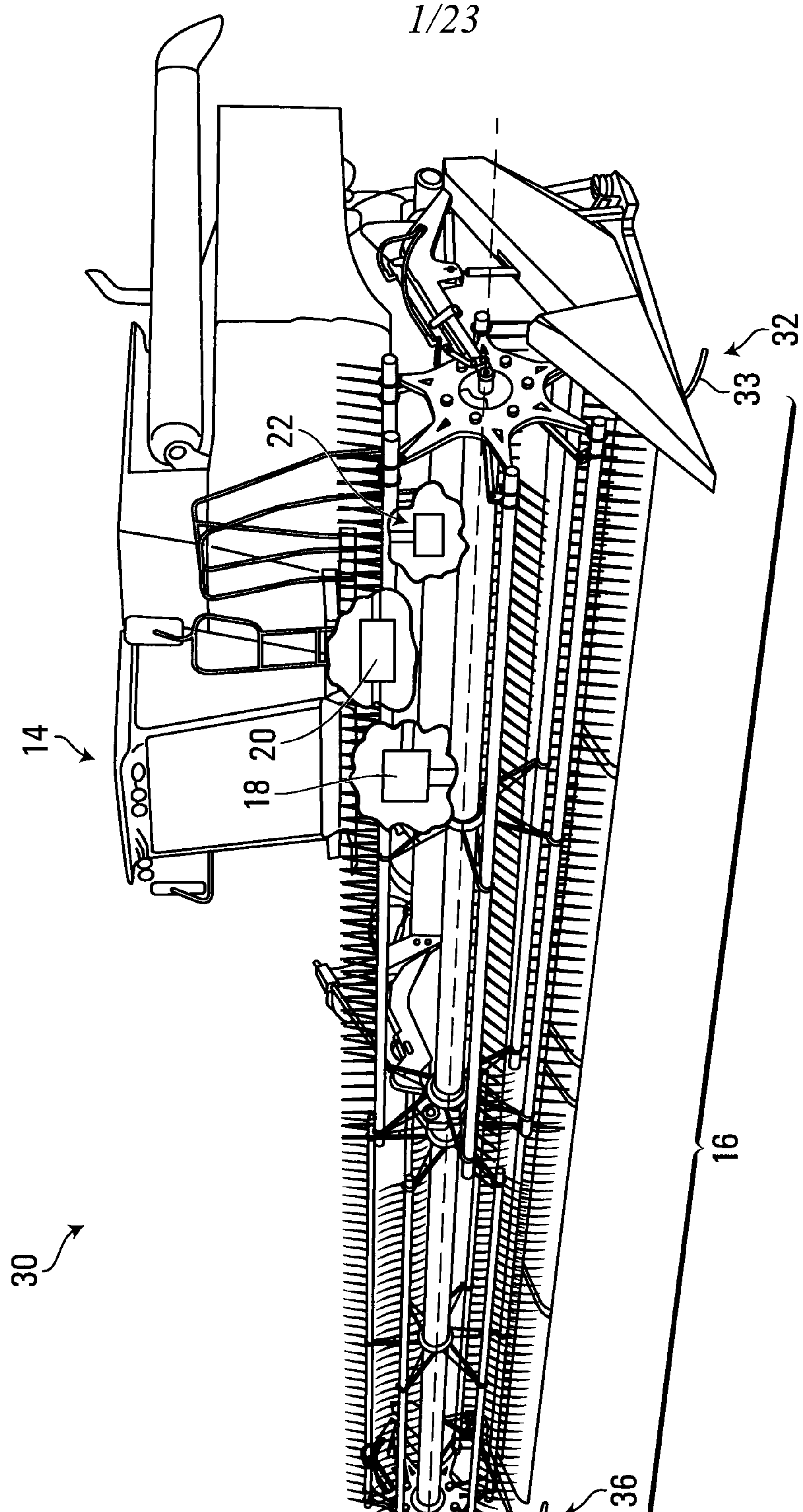


FIG. 1

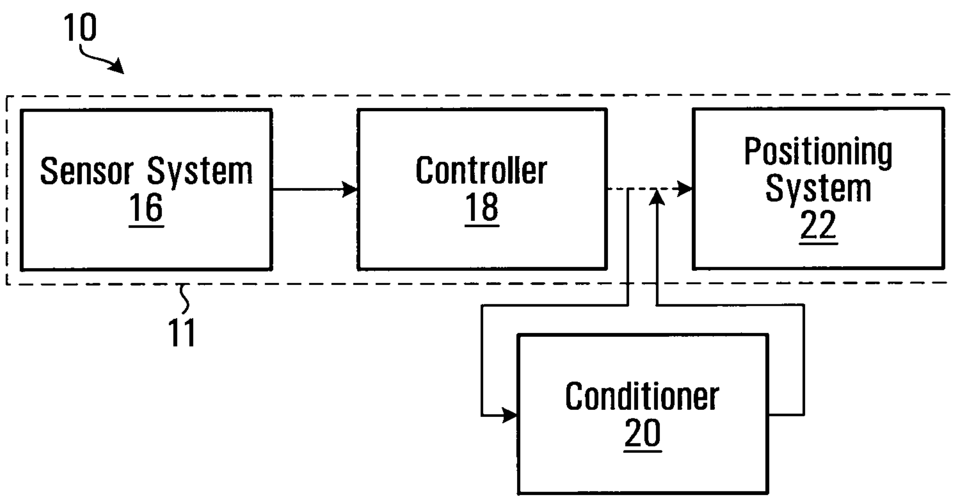

10
Sensor System
16
Controller
18
Positioning
System
22
11
Conditioner
20

FIG. 2

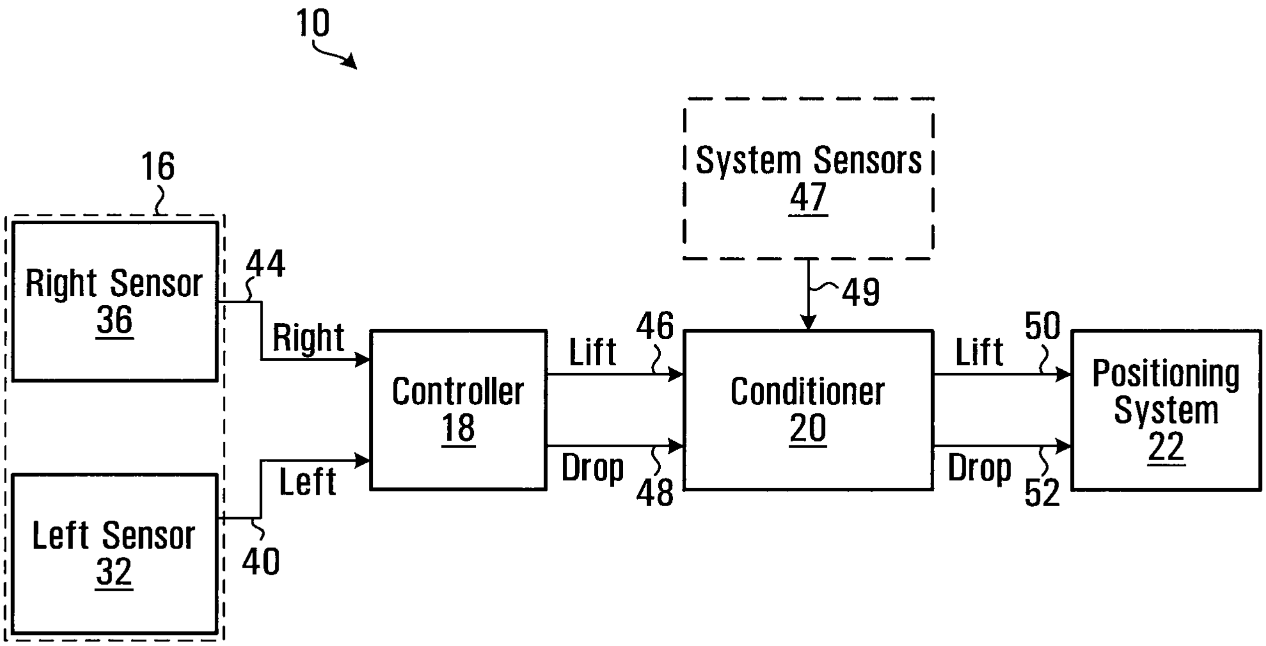

10
16
Right Sensor
36
Left Sensor
32
44
40
Right
Left
Controller
18
Lift
Drop
46
48
System Sensors
47
49
Conditioner
20
Lift
Drop
50
52
Positioning
System
22

FIG. 3

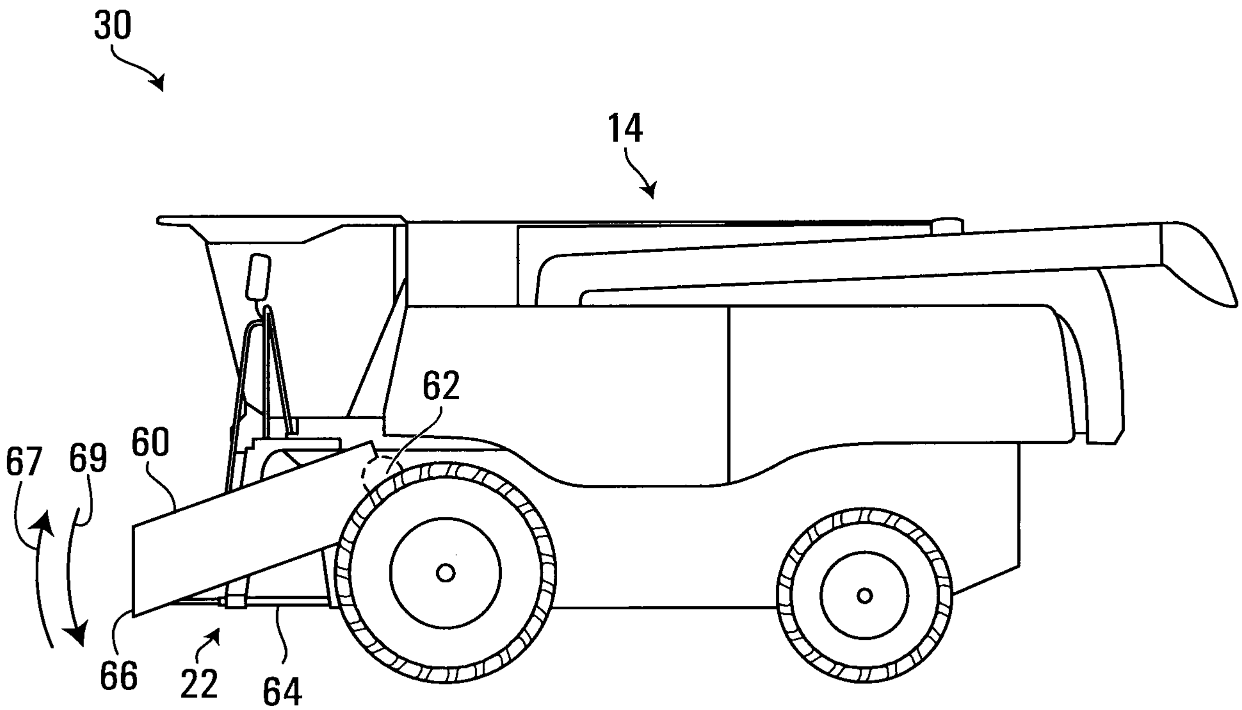


FIG. 4

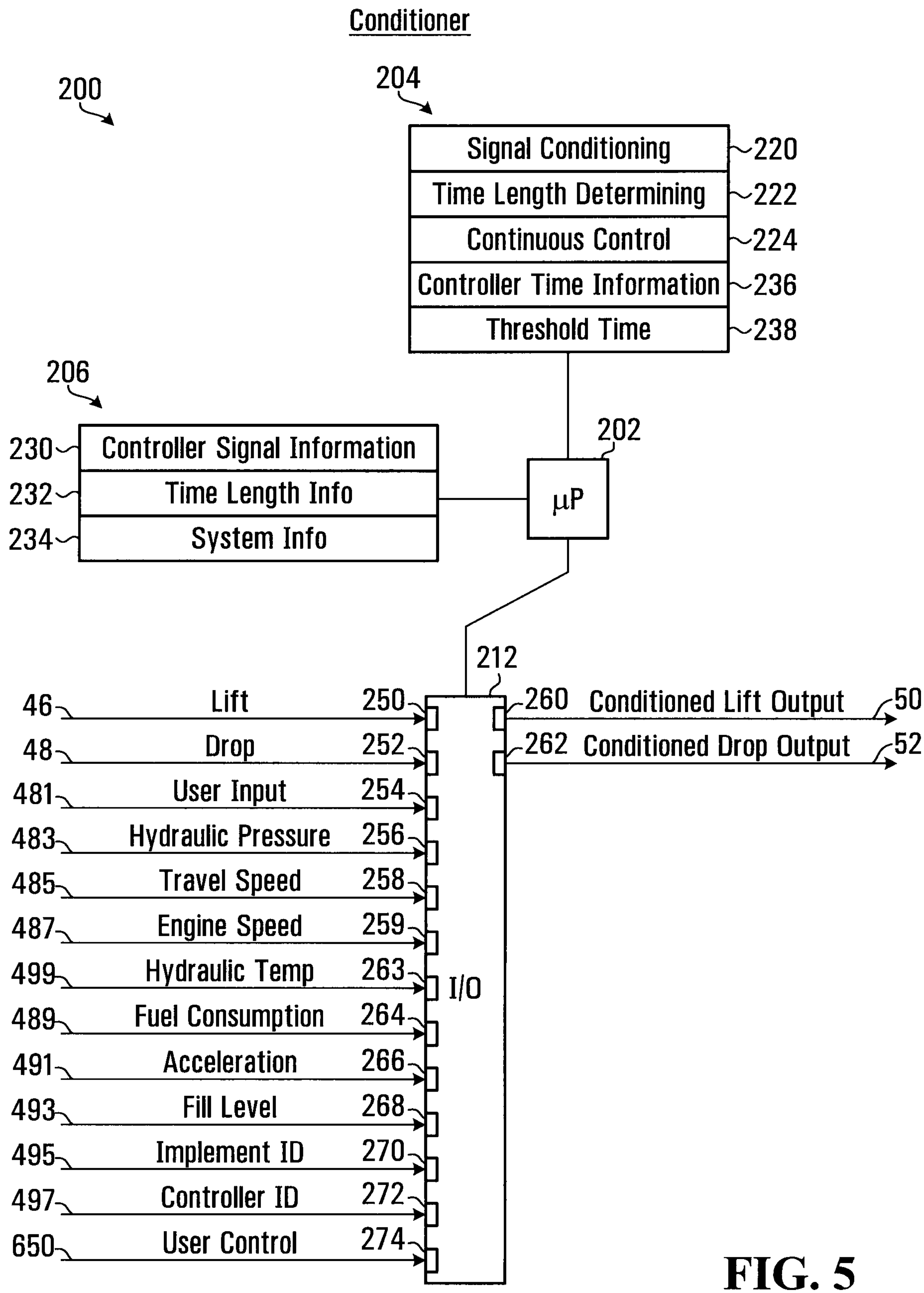

Conditioner
200
204
Signal Conditioning
220
Time Length Determining
222
Continuous Control
224
Controller Time Information
236
Threshold Time
238
206
230
Controller Signal Information
232
Time Length Info
234
System Info
202
μP
212
I/O
46
Lift
250
48
Drop
252
481
User Input
254
483
Hydraulic Pressure
256
485
Travel Speed
258
487
Engine Speed
259
499
Hydraulic Temp
263
489
Fuel Consumption
264
491
Acceleration
266
493
Fill Level
268
495
Implement ID
270
497
Controller ID
272
650
User Control
274
260
Conditioned Lift Output
50
262
Conditioned Drop Output
52

FIG. 5

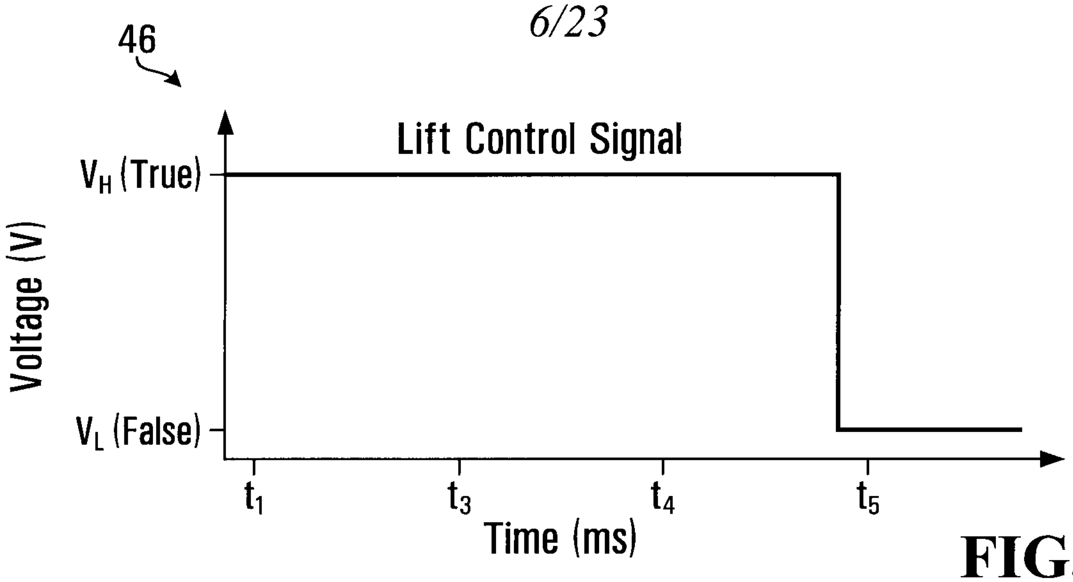


FIG. 6A

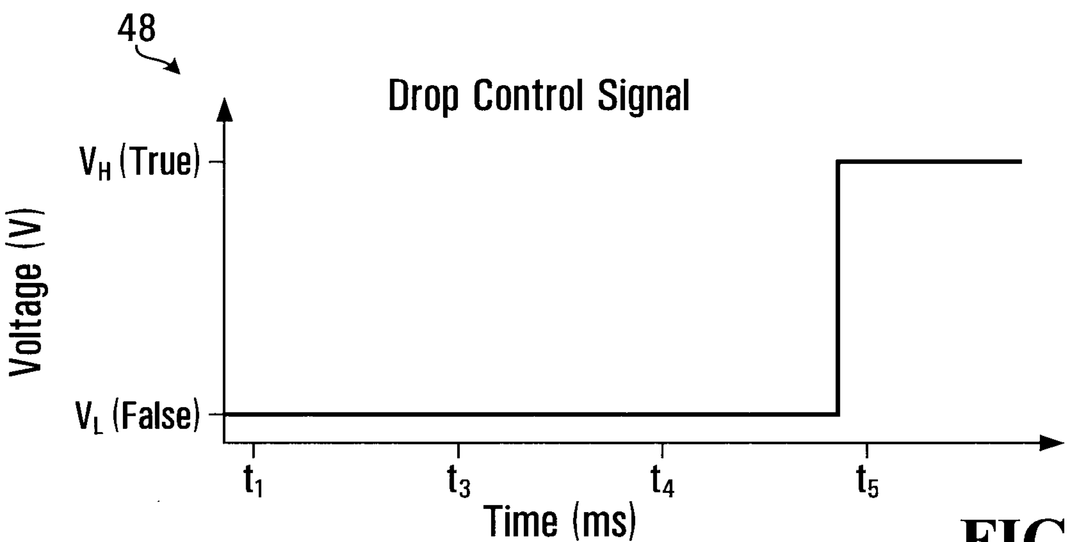


FIG. 6B

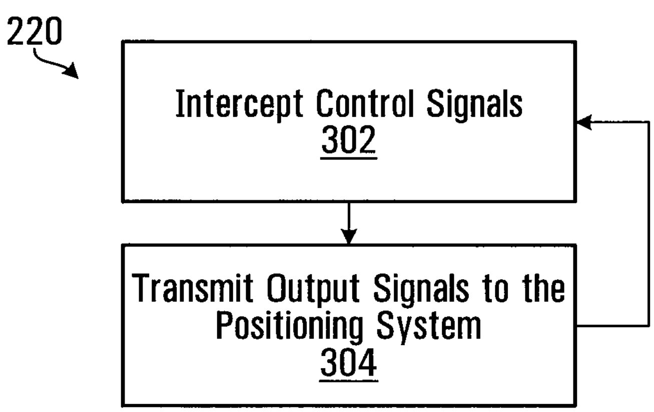


FIG. 7

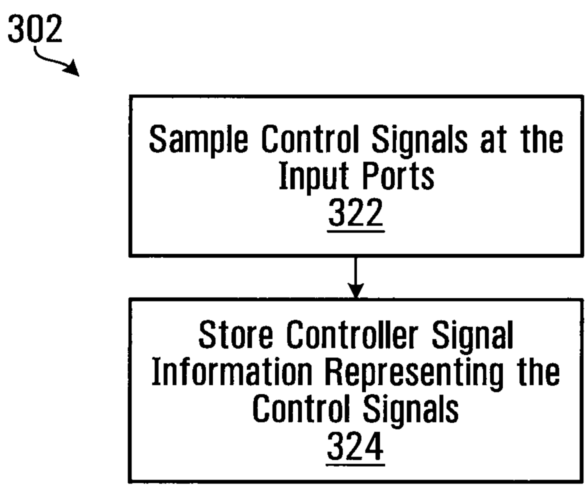


FIG. 8

340

Controller Signal Record

342	Lift Valve Field	TRUE
344	Drop Valve Field	FALSE
346	Time	20150228121512345

FIG. 9

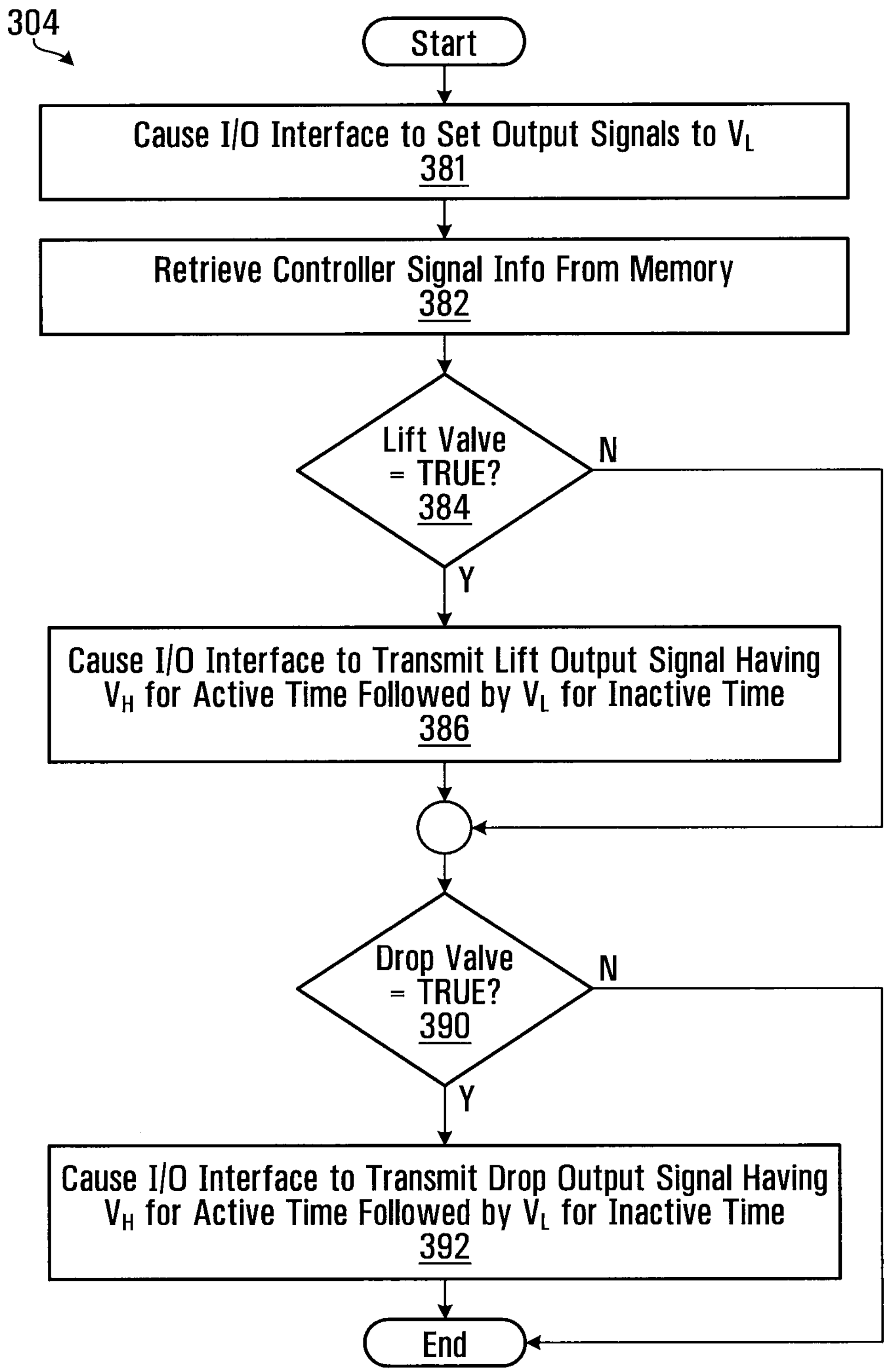

304
Start
Cause I/O Interface to Set Output Signals to V_L
381
Retrieve Controller Signal Info From Memory
382
Lift Valve = TRUE?
384
N
Y
Cause I/O Interface to Transmit Lift Output Signal Having V_H for Active Time Followed by V_L for Inactive Time
386
Drop Valve = TRUE?
390
N
Y
Cause I/O Interface to Transmit Drop Output Signal Having V_H for Active Time Followed by V_L for Inactive Time
392
End

FIG. 10

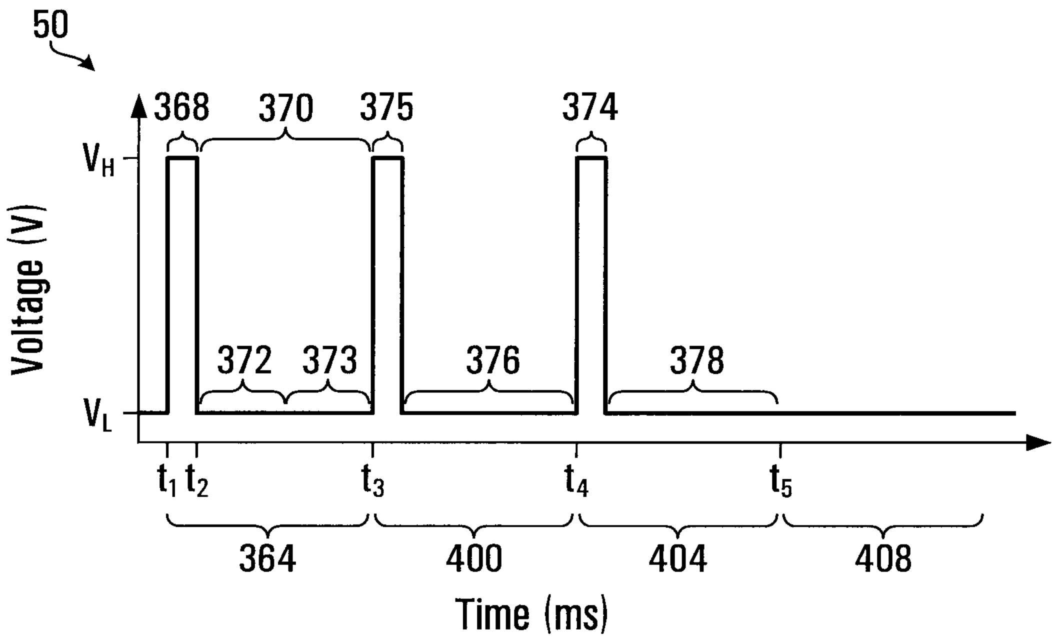


FIG. 11A

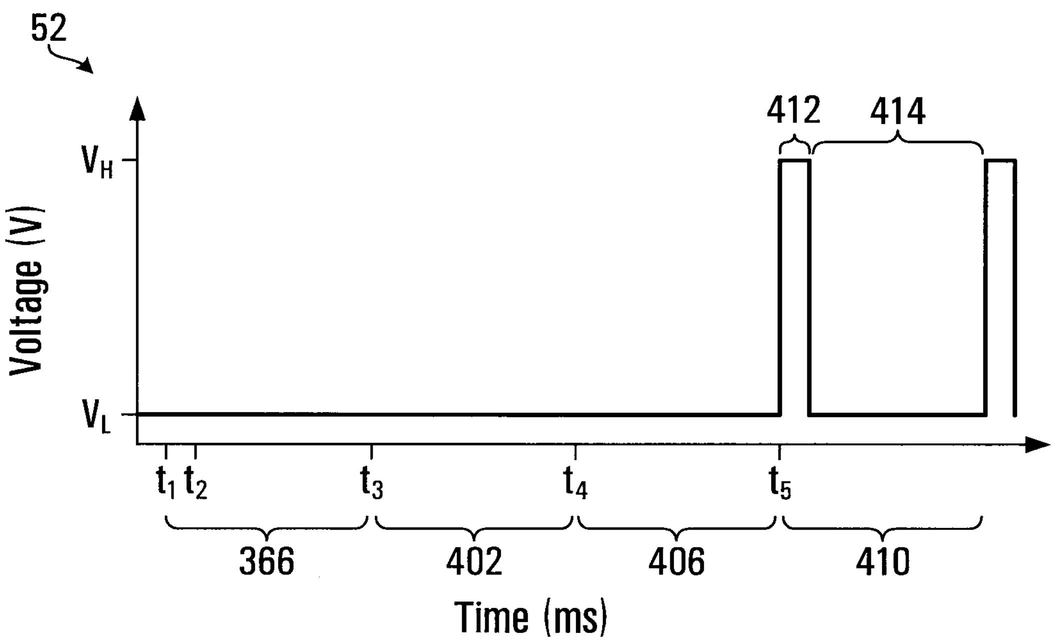


FIG. 11B

420

Signal Time Record

422~ Active Time 20ms
424~ Inactive Time 300ms

FIG. 12

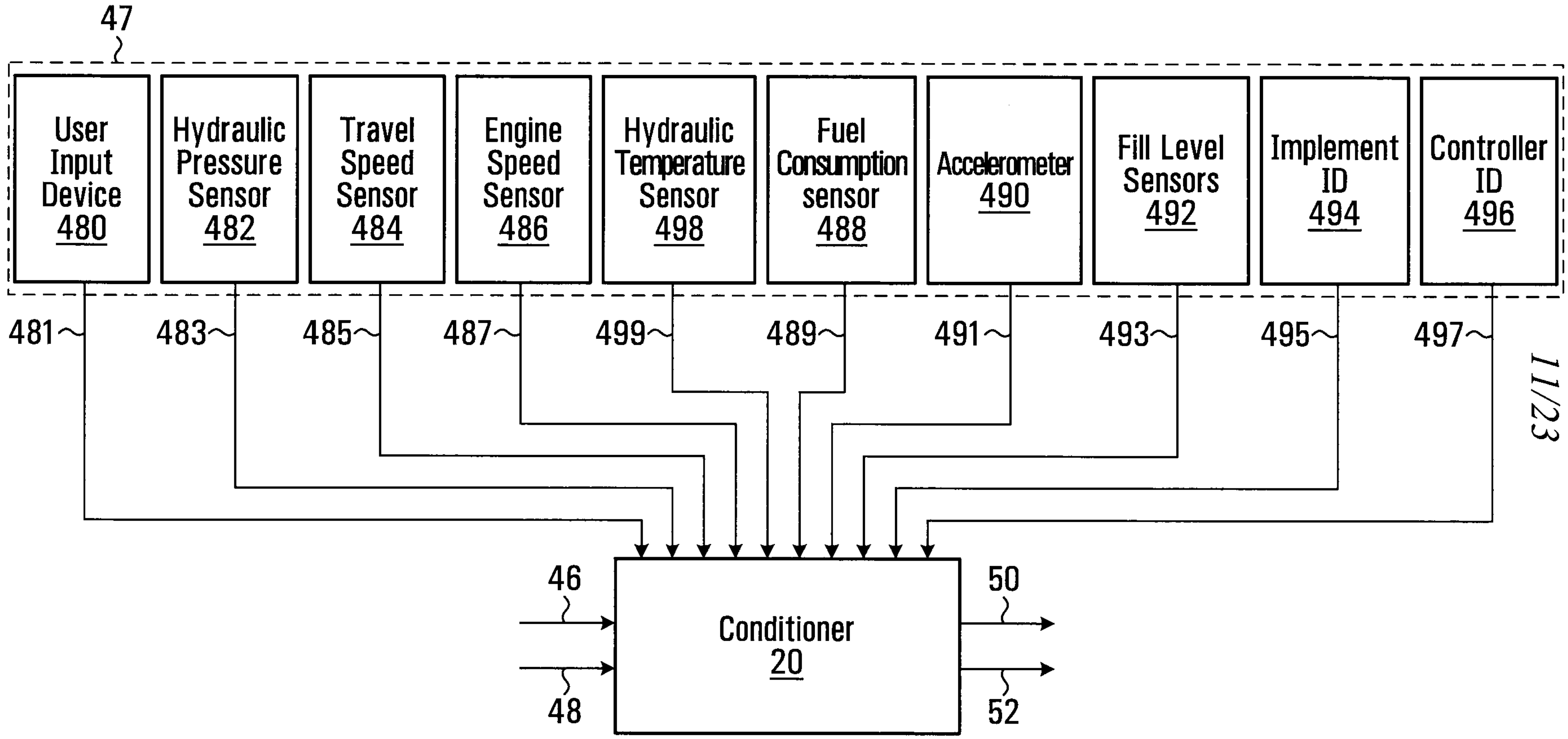

47
User Input Device 480
Hydraulic Pressure Sensor 482
Travel Speed Sensor 484
Engine Speed Sensor 486
Hydraulic Temperature Sensor 498
Fuel Consumption sensor 488
Accelerometer 490
Fill Level Sensors 492
Implement ID 494
Controller ID 496
481
483
485
487
499
489
491
493
495
497
46
48
Conditioner 20
50
52

FIG. 13

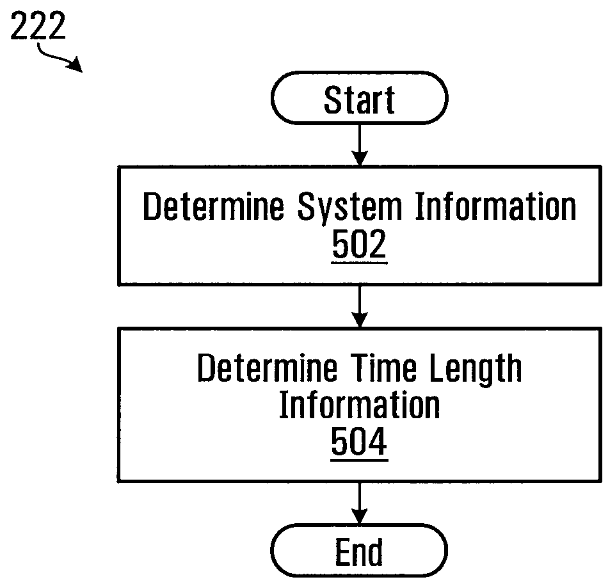

222
Start
Determine System Information
502
Determine Time Length
Information
504
End

FIG. 14

540

System Information Record

542	User Input	TRUE
544	Hydraulic Pressure	2000 PSI
546	Travel Speed	15 km/h
548	Engine Speed	1000 RPM
549	Hydraulic Temperature	100°c
550	Fuel Consumption Rate	10 L/h
554	Acceleration	
556	Fill Level	50%
558	Implement ID	A30F
559	Controller ID	11FF

FIG. 15

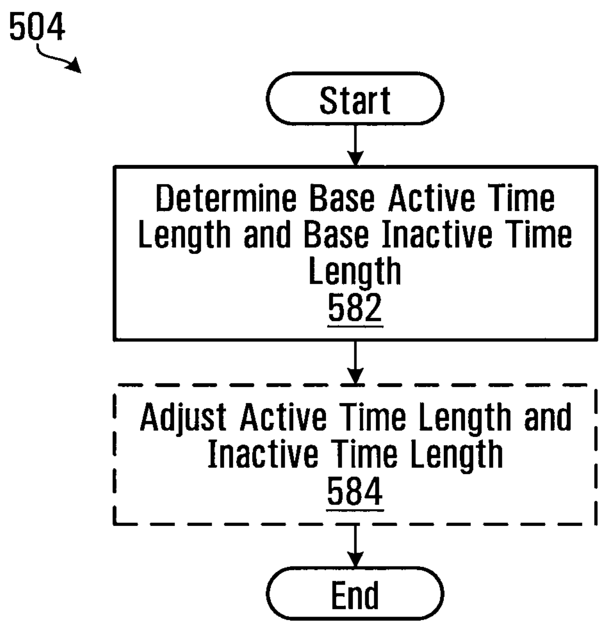


FIG. 16

CA 3062675 2019-11-22

600

Controller Time Length Record

602	Controller ID	11FF
606	Base Active Time Length	20ms
608	Minimum Active Time Length	10ms
610	Maximum Active Time Length	40ms
612	Cycle Time Length	320ms

FIG. 17

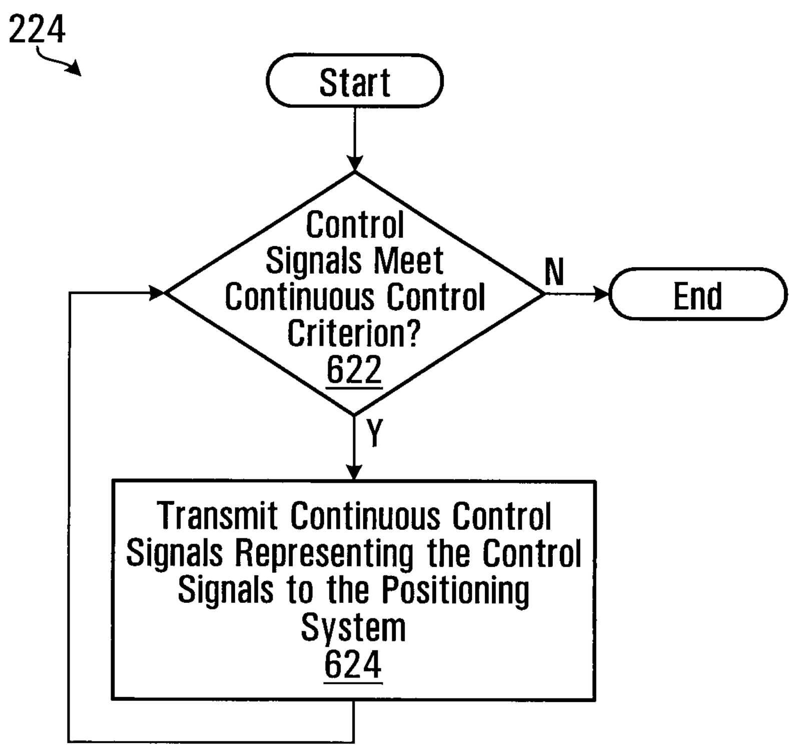


FIG. 18

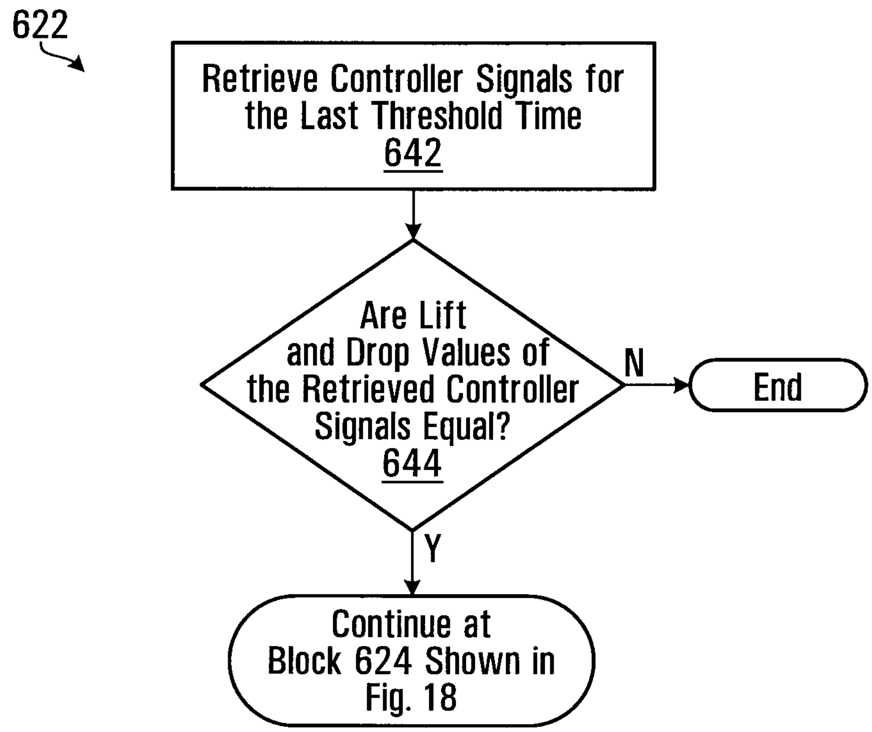


FIG. 19

660

Threshold Time Record

662∼ Threshold Time 1.5s

FIG. 20

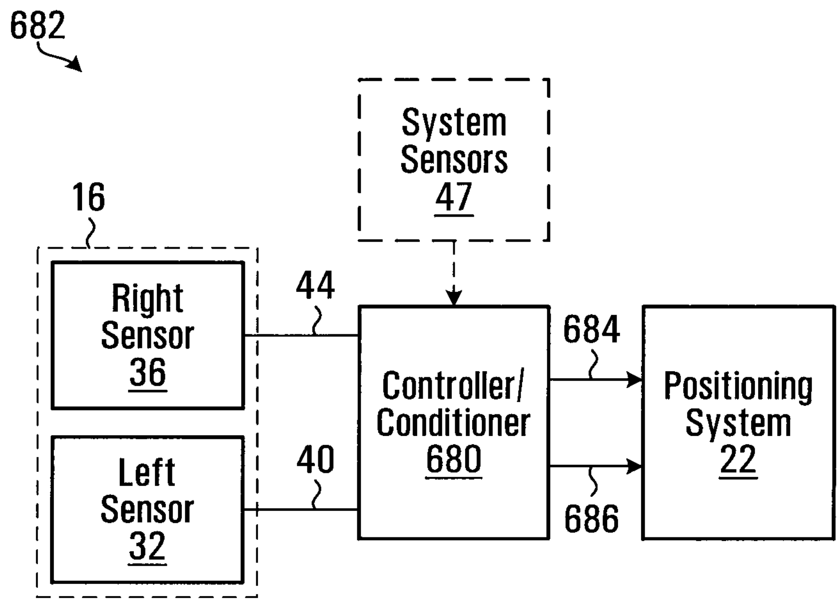

682
System
Sensors
47
16
Right
Sensor
36
44
Controller/
Conditioner
680
684
Positioning
System
22
Left
Sensor
32
40
686

FIG. 21

Controller/Conditioner

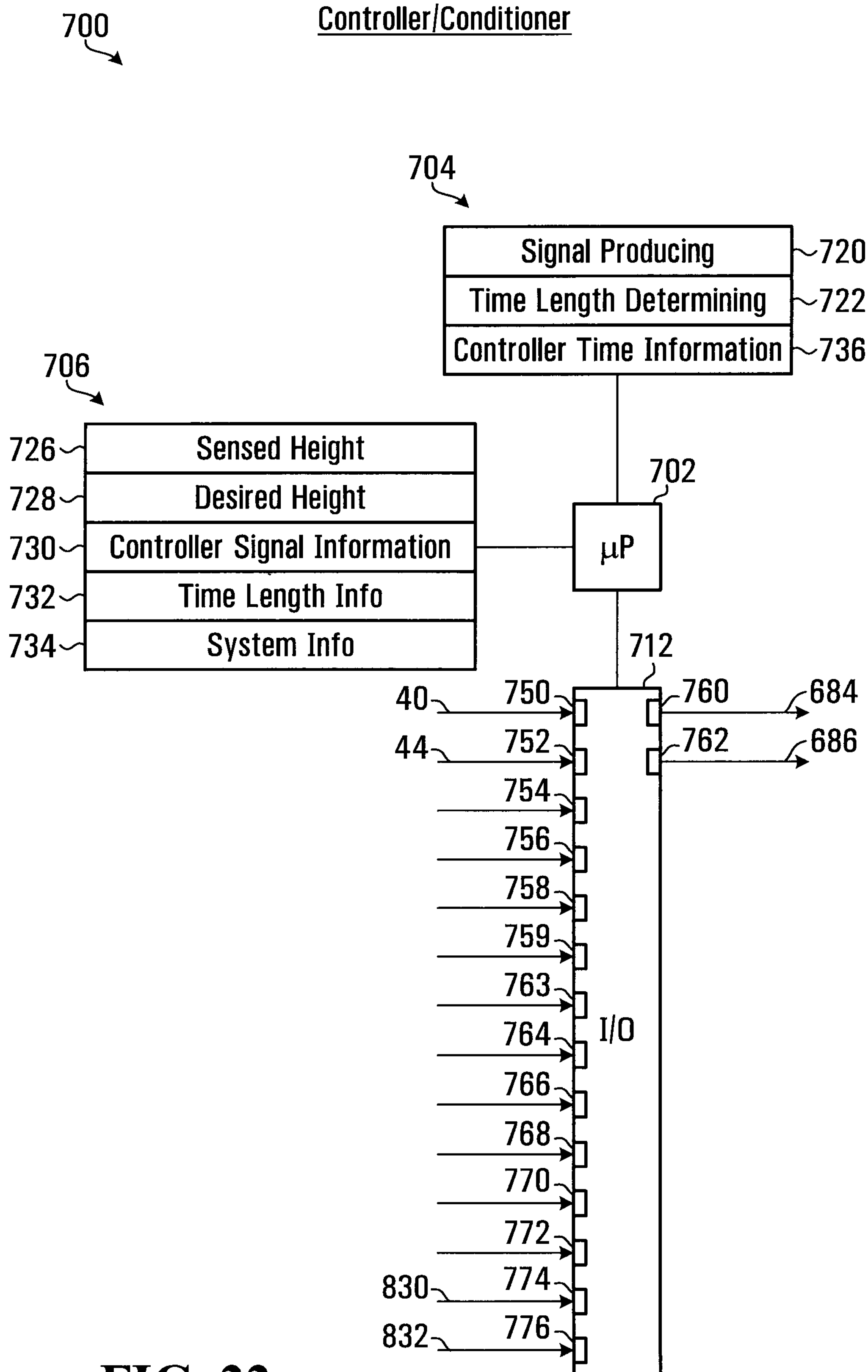


FIG. 22

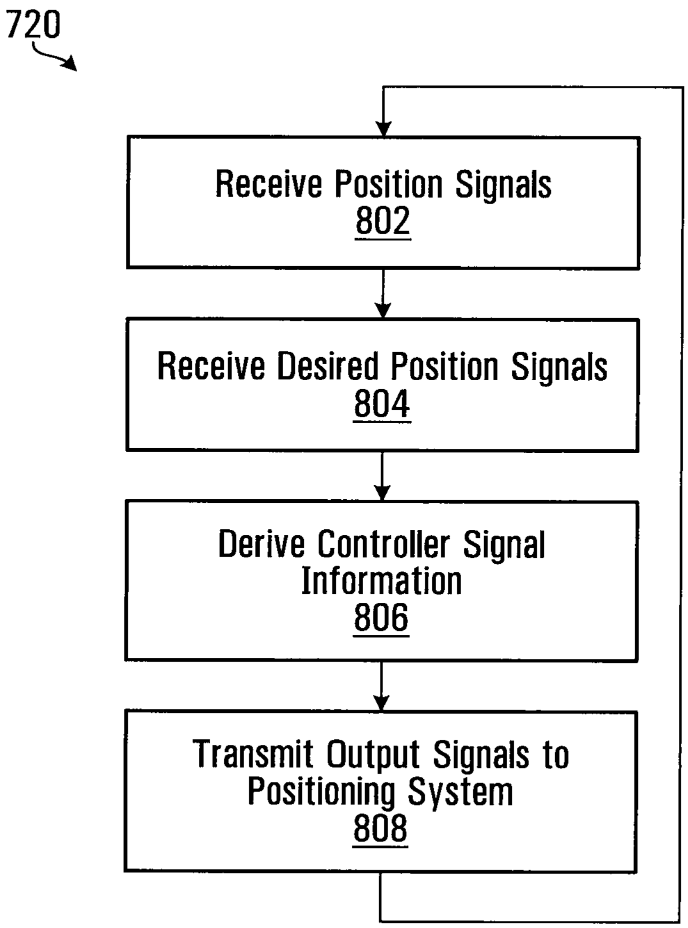

720
Receive Position Signals
802
Receive Desired Position Signals
804
Derive Controller Signal
Information
806
Transmit Output Signals to
Positioning System
808

FIG. 23

820

Sensed Height Record

822~ Left Sensed Height 1.3 inches
826~ Right Sensed Height 2.0 inches

FIG. 24

840

Desired Height Record

842~ Left Desired Height 2.0 inches
844~ Right Desired Height 2.0 inches

FIG. 25

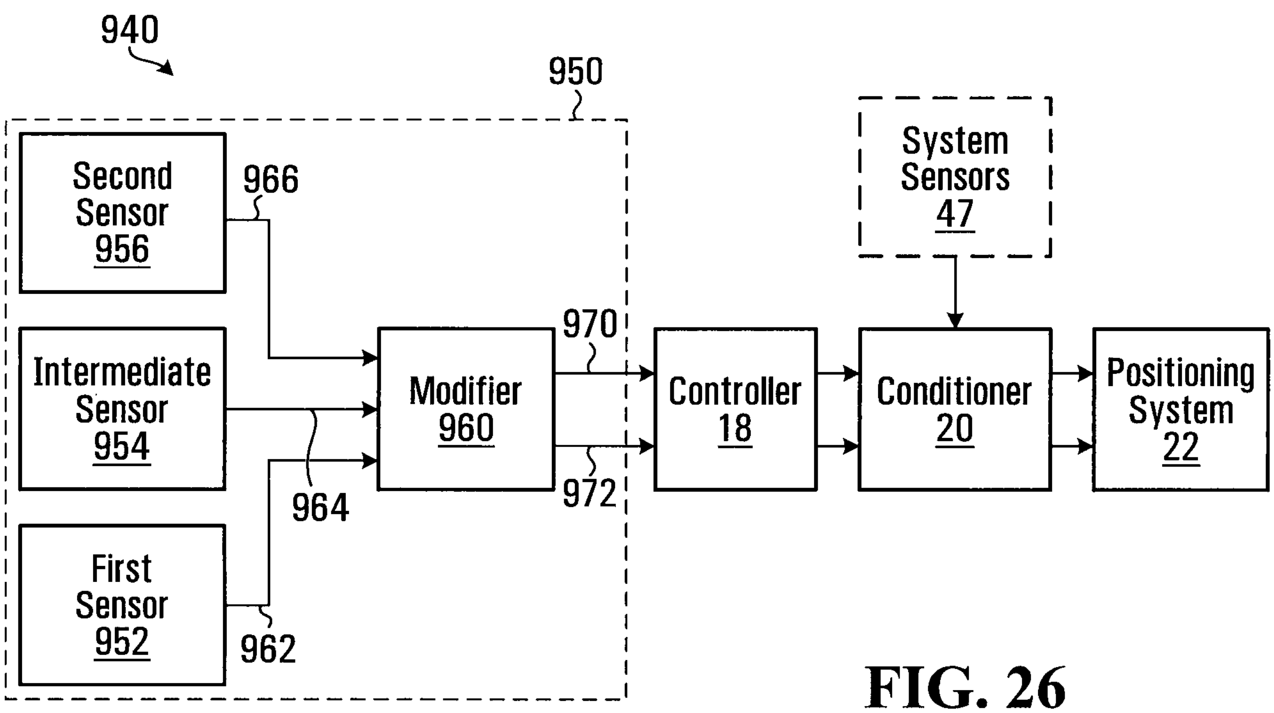


FIG. 26

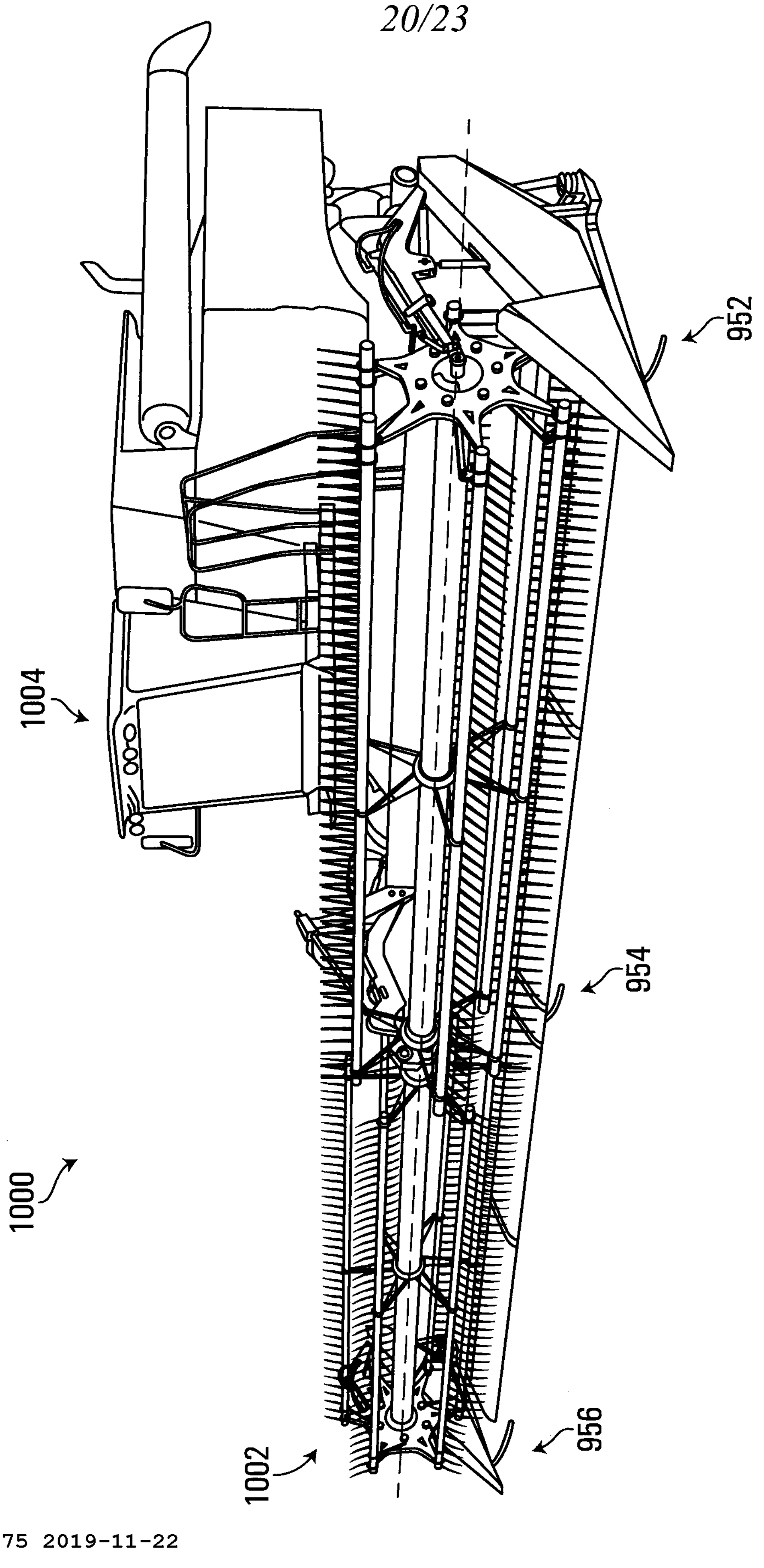


FIG. 27

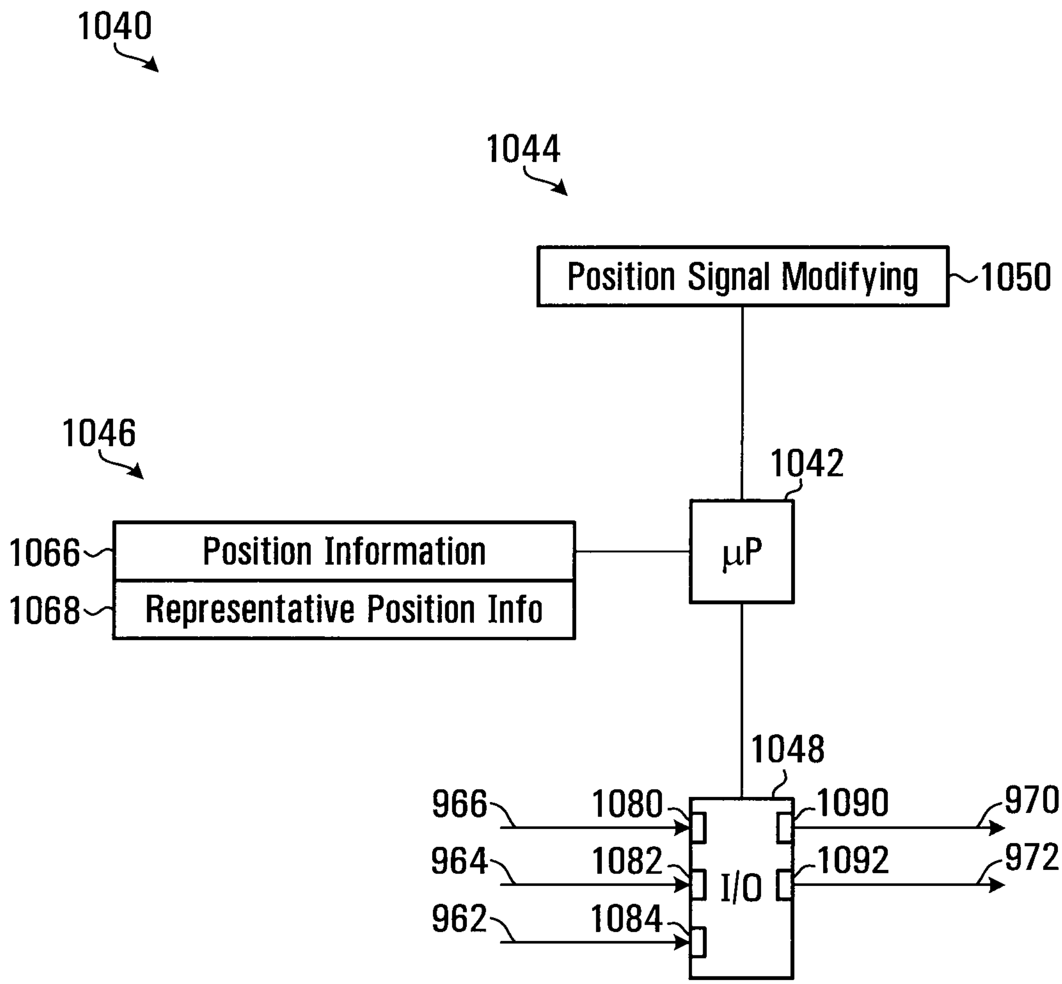

1040
1044
Position Signal Modifying
1050
1046
1042
1066
Position Information
1068
Representative Position Info
μP
1048
966
1080
1090
970
964
1082
I/O
1092
972
962
1084

FIG. 28

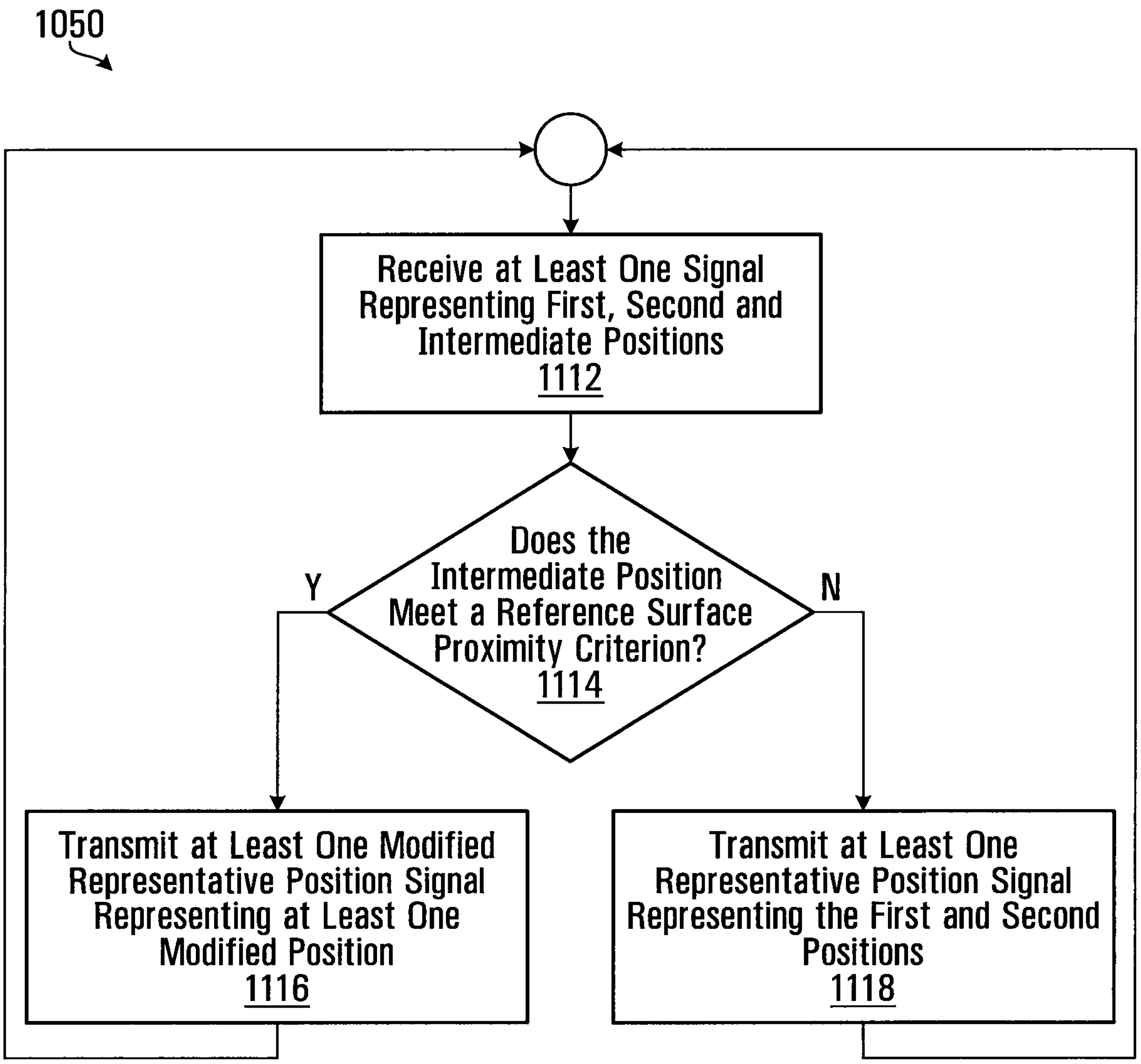

1050
Receive at Least One Signal Representing First, Second and Intermediate Positions
1112
Does the Intermediate Position Meet a Reference Surface Proximity Criterion?
1114
Y
N
Transmit at Least One Modified Representative Position Signal Representing at Least One Modified Position
1116
Transmit at Least One Representative Position Signal Representing the First and Second Positions
1118

FIG. 29

1140

Position Record

1142	First Position	1.3 inches
1144	Second Position	2.0 inches
1146	Intermediate Position	0.3 inches

FIG. 30

1180

Representative Position Record

1182	First Representative Position	1.1 inches
1184	Second Representative Position	1.8 inches

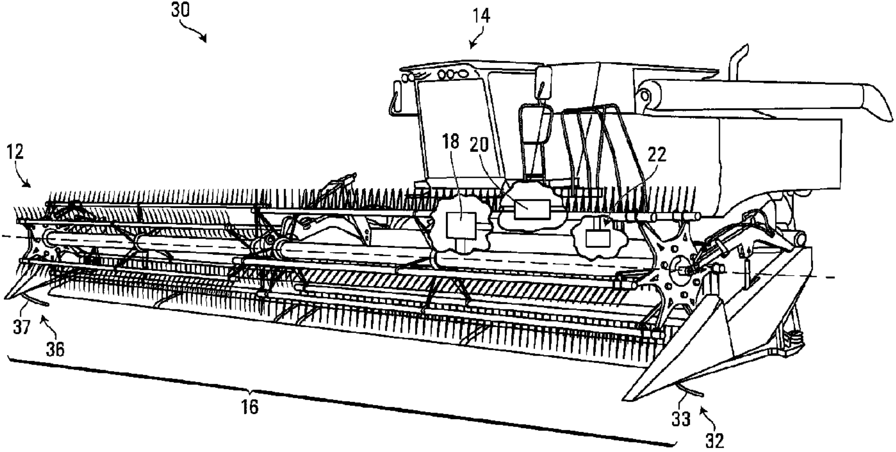
FIG. 31

1200

Representative Position Record

1202	First Representative Position	1.3 inches
1204	Second Representative Position	2.0 inches

FIG. 32


30
14
12
18
20
22
37
36
16
33
32