



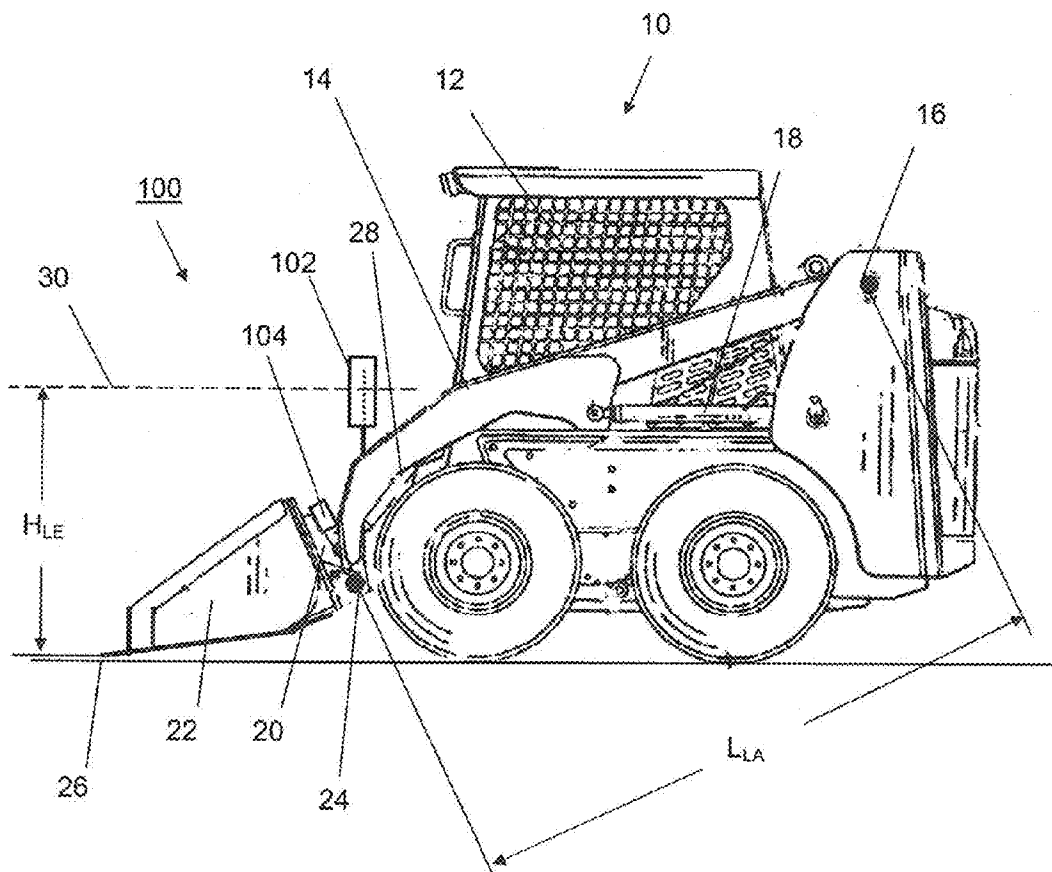
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(19) **United States**(12) **Patent Application Publication****Funk et al.**(10) **Pub. No.: US 2016/0273196 A1**(43) **Pub. Date: Sep. 22, 2016**(54) **AUTOMATIC LEVELING CONTROL SYSTEM**(71) Applicants: **Benjamin Jesse Funk**, Wymark (CA);
Fred Funk, Neville (CA)(72) Inventors: **Benjamin Jesse Funk**, Wymark (CA);
Fred Funk, Neville (CA)(21) Appl. No.: **14/661,225**(22) Filed: **Mar. 18, 2015****Publication Classification**(51) **Int. Cl.**
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(57)

ABSTRACT

An automatic leveling control system for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite is provided. A single laser receiver is mounted to one of two lift arms of the machine. The laser receiver is configured to receive a laser signal from a laser plane generator and to provide a height signal. A tilt sensor is mounted to a work attachment mounting structure and is configured to sense a tilt angle of the work attachment mounting structure and to provide a tilt angle signal and a lateral tilt signal in dependence on lateral tilt of the machine. A controller is configured for generating a control signal based on the height signal, the tilt angle signal and the lateral tilt signal and for communicating the control signal to the machine to adjust at least one of a height of the lift arms and the tilt angle of the work attachment mounting structure such that a grading edge of the work attachment is maintained at elevation as the machine is propelled about the worksite.



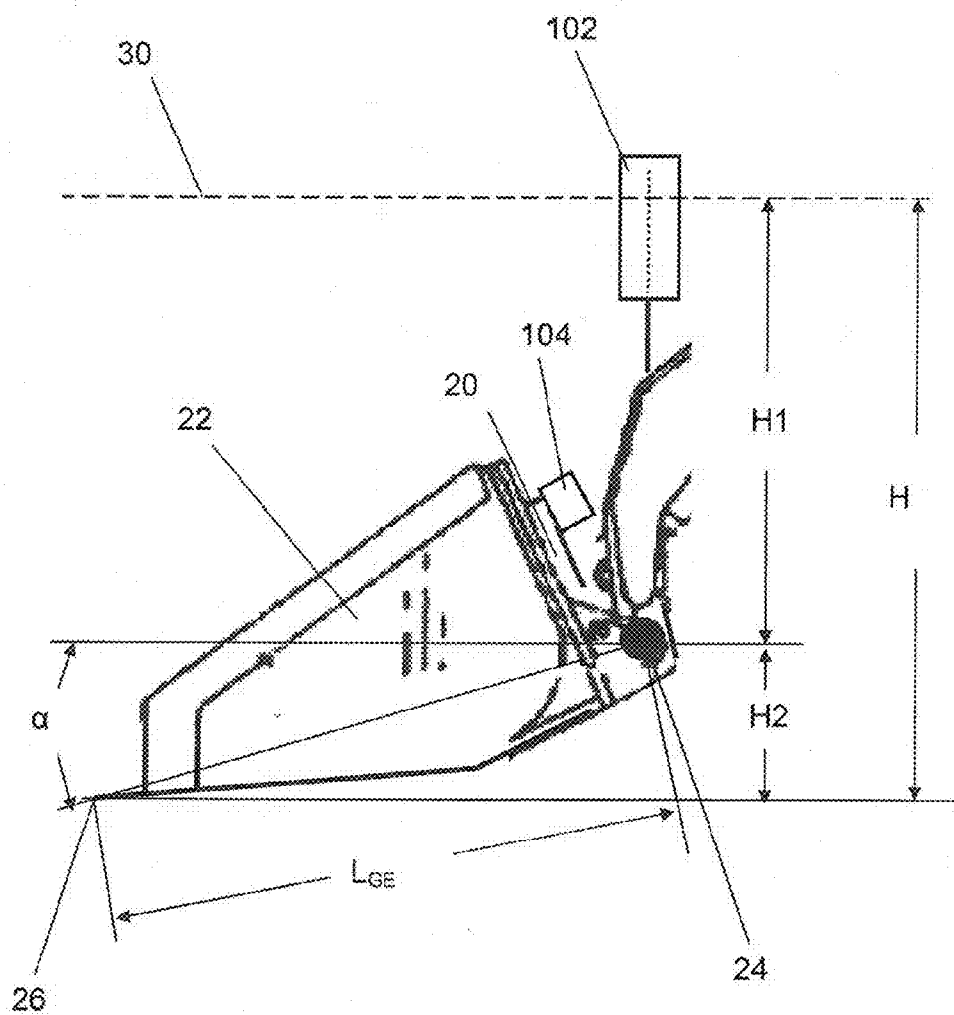


Figure. 1b

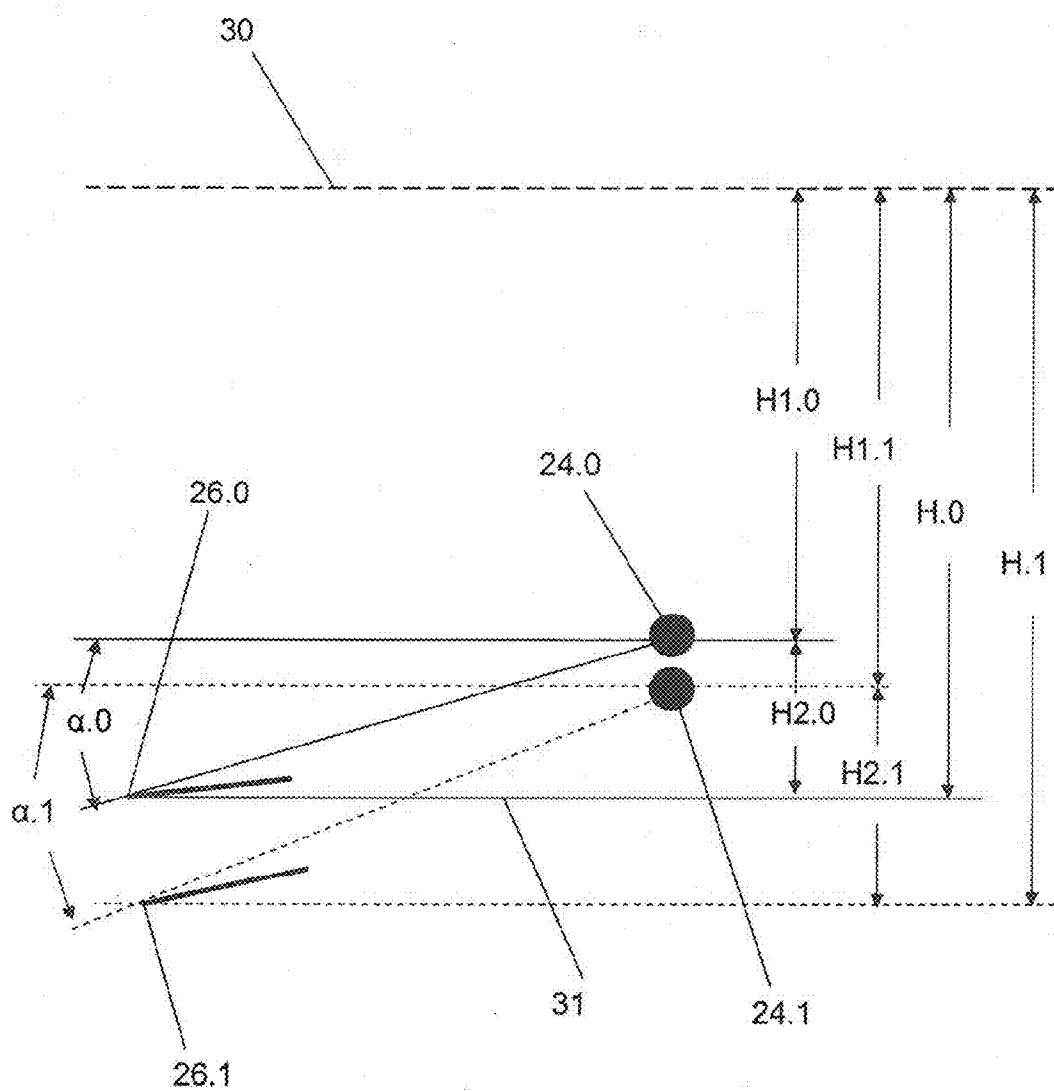


Figure. 1c

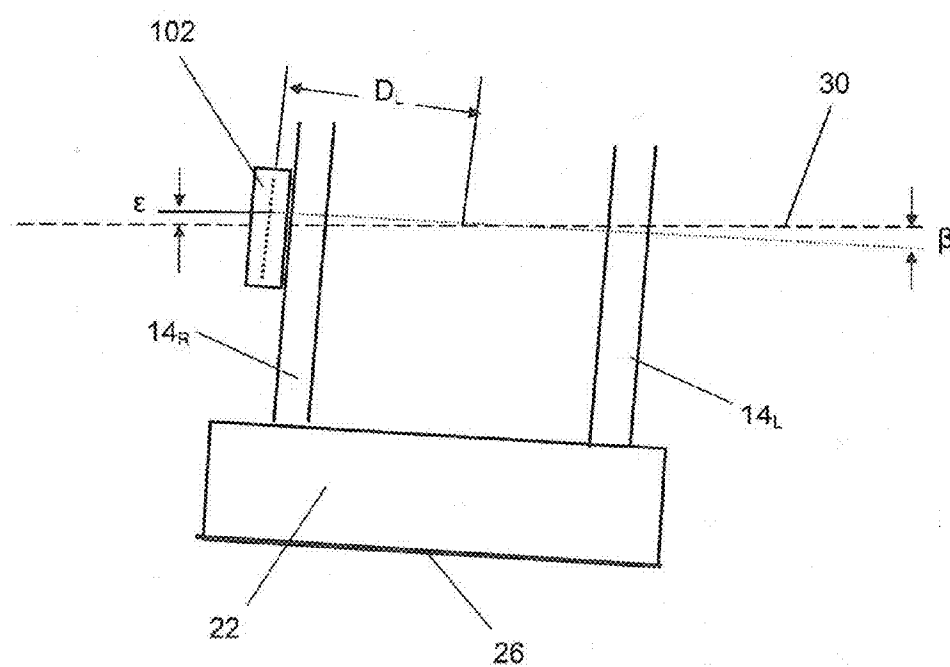


Figure. 1d

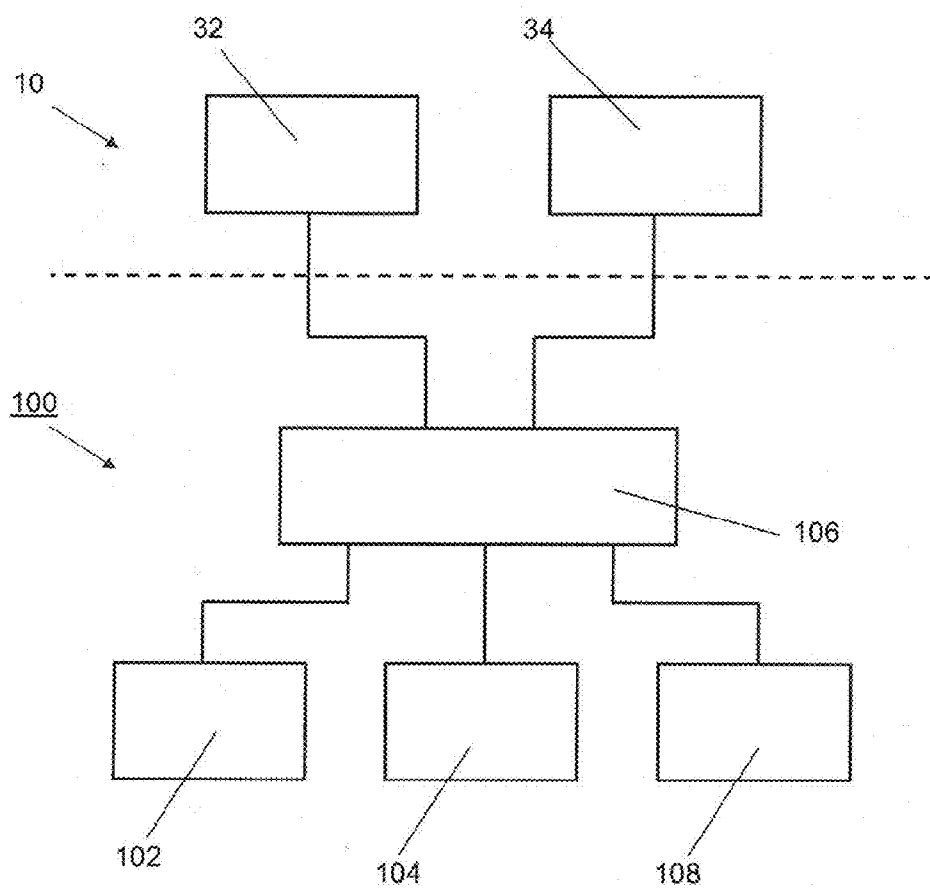


Figure. 2a

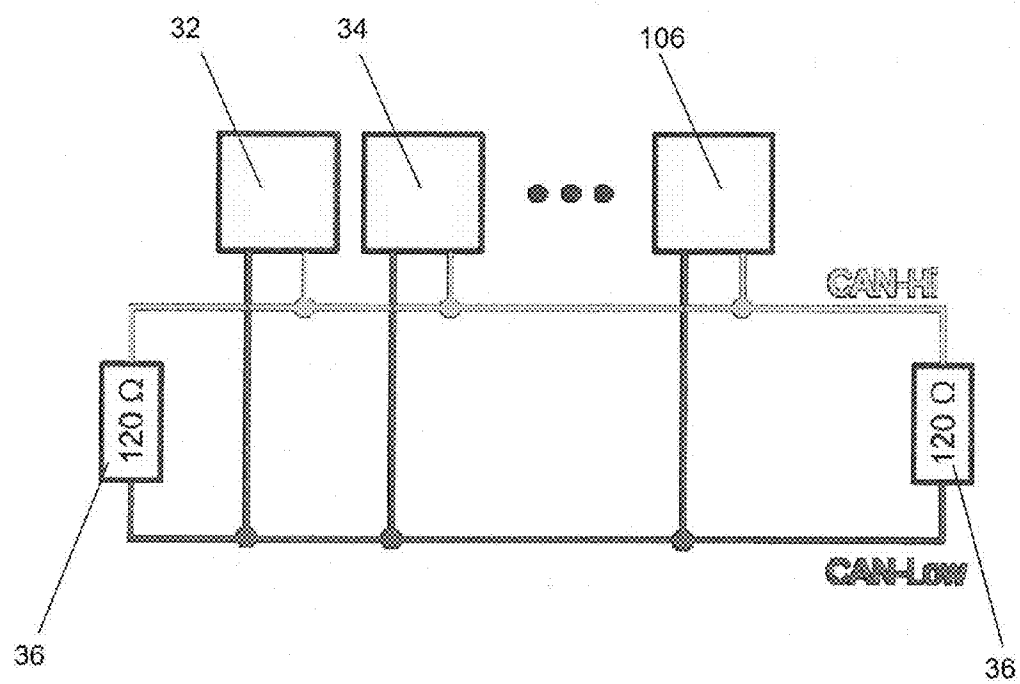
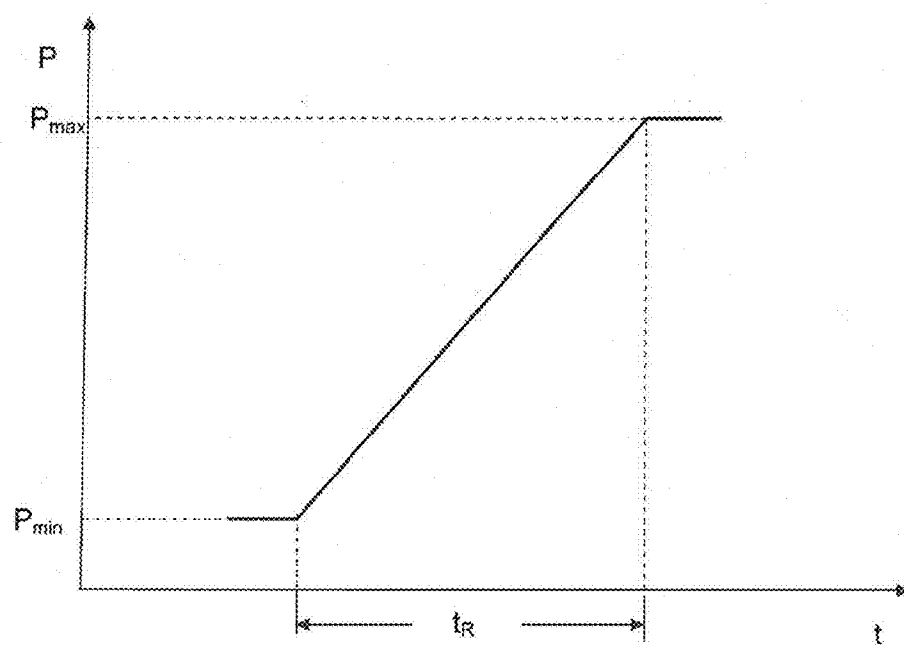


Figure. 2b

**Figure. 3**

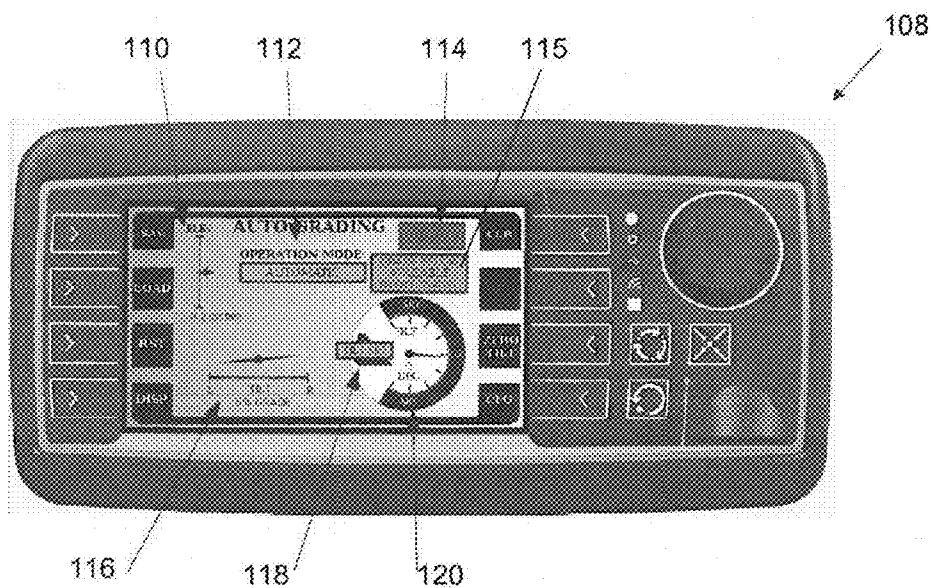


Figure. 4a

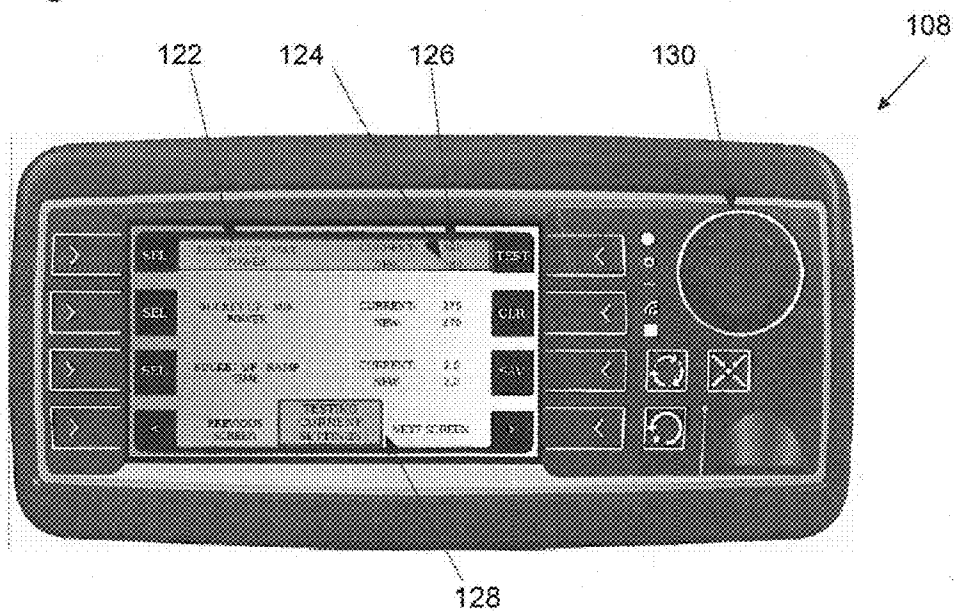
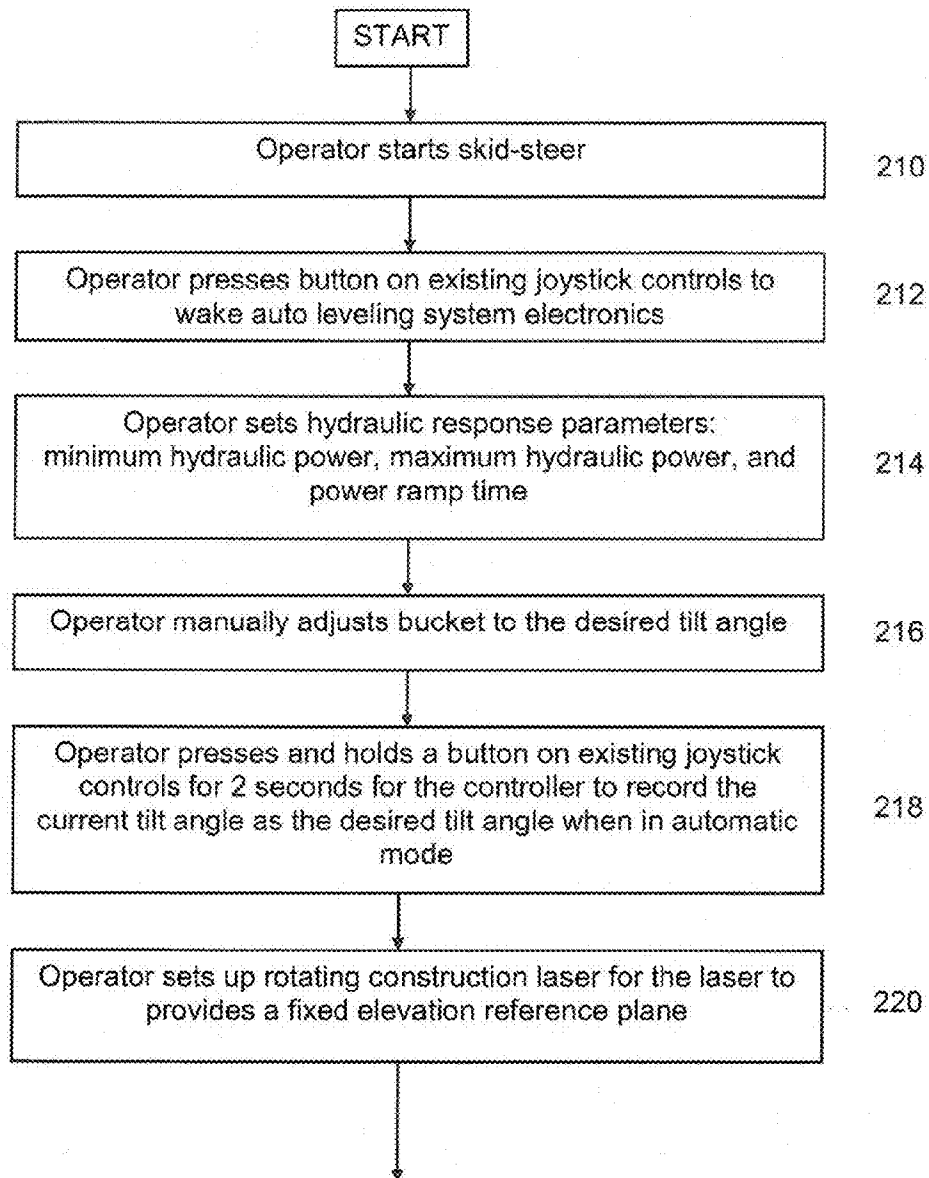


Figure. 4b

**Figure. 5**

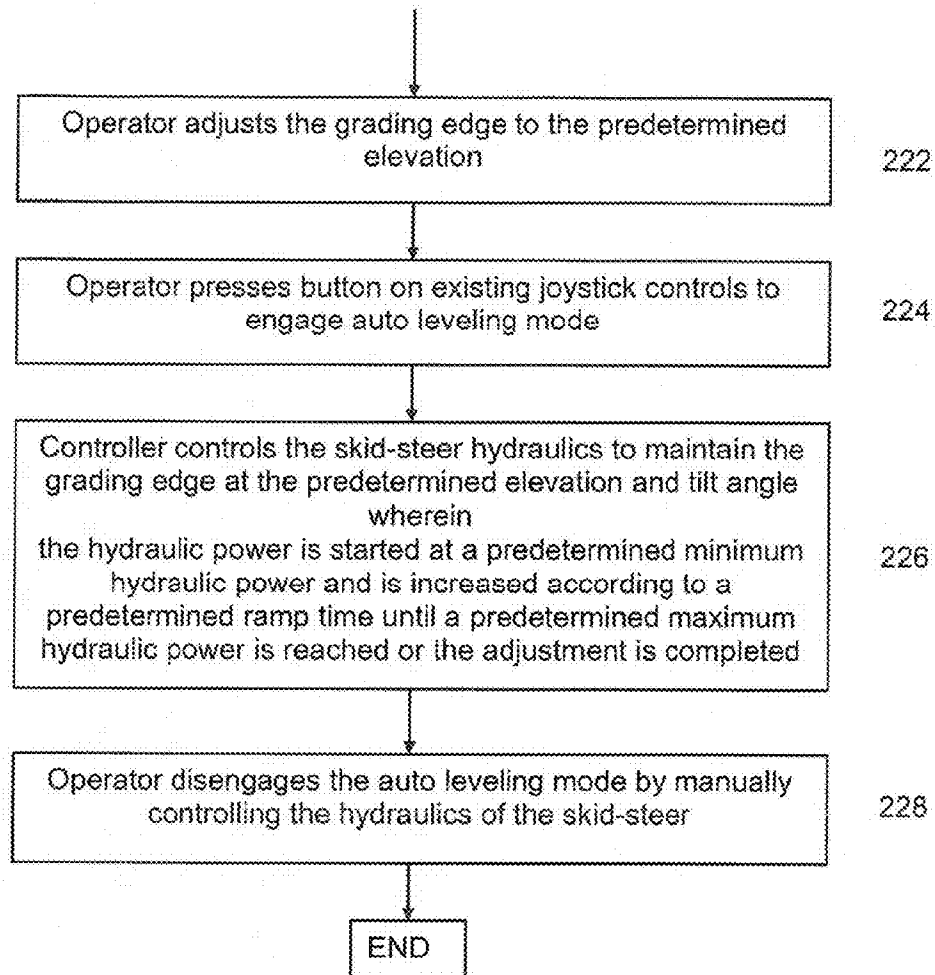


Figure. 5 Continued

AUTOMATIC LEVELING CONTROL SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates to grading implements, and more particularly, to an automatic leveling control system for maintaining a grading edge at a predetermined elevation during movement over uneven terrain.

BACKGROUND OF THE INVENTION

[0002] Worksite preparations often include grading the ground to be level. Particularly, prior to the construction of concrete floors and foundations, the ground has to be leveled with high accuracy to ensure structural integrity of the same. Typically, such grading work is done with a skid-steer having a worker continually check the level, using a rotating construction laser and a laser receiver, and direct the skid-steer operator.

[0003] Alternatively, a skid-steer automatic laser grading attachment is used. The skid-steer automatic laser grading attachment comprises a grading blade mounted to a stabilizing boom and wheels and is mounted to the attachment mounting structure of the skid-steer. One or two laser receivers are mounted via booms to the grading blade for detecting the laser beam of a rotating construction laser for controlling the elevation of the grading blade. Unfortunately, the skid-steer automatic laser grading attachment is expensive, difficult to operate in small spaces and to transport due to its large size and weight, and is not able to dig, push or carry a large amount of material at a time. An attachment that allowed for the movement of a larger amount of material in a shorter time by more efficient leveling activity would be desirable.

[0004] Other existing automatic laser grading systems lack the accuracy for preparing the ground prior to the construction of concrete floors and foundations and are difficult to implement, in particular as a retro-fit. Prior art systems are not integrated to the earth moving equipment—for example in prior art skid steer equipment, the automatic leveling systems consist of customized bucket attachments powered by the auxiliary hydraulics on the skid steer unit. None of them use the factory produced excavation attachments with the full power primary hydraulics and as such their utility or power is limited. These attachments, while accurate, are expensive and bulky in addition to their minimized utility.

[0005] Another major difficulty in designing an accurate integrated automatic leveling control system is the control of the hydraulic system of the skid steer, since the amount of power required to move the hydraulics at a certain speed can vary substantially dependent on, for example, solenoid valve heating and bucket weight/loading. It is desirable to provide an integrated automatic leveling control system that is sufficiently compact and accurate for preparing the ground prior to the construction of concrete floors and foundations.

[0006] It is also desirable to provide an automatic leveling control system that is implementable as a retro-fit to a pre-existing skid steer unit, which ideally does not rely upon custom bucket attachments. It is also desirable to provide an automatic leveling control system that enables customization of the hydraulic response of the grading equipment.

SUMMARY OF THE INVENTION

[0007] Accordingly, one object of the present invention is to provide an automatic leveling control system that is suffi-

ciently accurate for preparing the ground prior to the construction of concrete floors and foundations.

[0008] Another object of the present invention is to provide an automatic leveling control system that is implementable as a retro-fit, which would in installation be completely integrated to the skid steer unit.

[0009] Another object of the present invention is to provide an automatic leveling control system that enables customization of the hydraulic response of the grading equipment.

[0010] Another object of the invention is to be able to potentially use the skid steer machine, with the existing buckets, forks or the like, without having to switch the attachment on the skid steer unit to enter into auto leveling mode—being able to enter into leveling mode from the operator position in the unit, using an integrated control modification to the pre-existing hydraulic system and attachments on the skid steer unit is the most desirable implementation of the present invention.

[0011] According to one aspect of the present invention, there is provided an automatic leveling control system for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite. A single laser receiver is mounted to one of two lift arms of the machine. The laser receiver is configured to receive a laser signal from a laser plane generator associated with a predetermined level and to provide a height signal in dependence thereupon.

[0012] A tilt sensor is mounted to a work attachment mounting structure. The work attachment mounting structure is pivotally movable mounted to a front end portion of the lift arms and has the work attachment mounted thereto. The tilt sensor is configured to sense a tilt angle of the work attachment mounting structure and to provide a tilt angle signal in dependence thereupon. The tilt sensor is further configured to sense a lateral tilt of the machine and to provide a lateral tilt signal in dependence thereupon.

[0013] A controller is connected to the laser receiver and the tilt sensor. The controller is configured for generating a control signal based on the height signal, the tilt angle signal and the lateral tilt signal and for communicating the control signal to the machine to adjust at least one of a height of the lift arms and the tilt angle of the work attachment mounting structure such that a grading edge of the work attachment is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite.

[0014] According to another aspect of the present invention, there is provided an automatic leveling control system for a machine having a work attachment adapted for grade leveling as the machine is propelled about a worksite. A level grade is achieved by movement of the unit around the work surface by maintaining the working edge of the work attachment in a desired plane in relation to a laser plane projected at the worksite. A laser receiver is mounted to the machine. The laser receiver is configured to receive a laser signal from a laser plane generator associated with a predetermined level and to provide a height signal in dependence thereupon.

[0015] An automotive programmable logic controller is connected to the laser receiver. The controller is configured for generating a control signal based on the height signal and for communicating the control signal via DC electric current to the hydraulic valves of the machine, to adjust the work attachment such that a grading edge thereof is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite.

[0016] According to yet another aspect of the present invention, there is provided an automatic leveling control method for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite. At least a sensor signal associated with a predetermined level is received at a controller. Using the controller, a control signal based on the at least a sensor signal is generated and communicated to at least a hydraulic actuator of the machine to adjust the work attachment such that a grading edge thereof is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite. The control signal is determined such that hydraulic power for adjusting the work attachment is started at a predetermined minimum hydraulic power and is increased according to a predetermined ramp time until a predetermined maximum hydraulic power is reached or the adjustment is completed. If the adjustment of the work attachment is not completed by the time that the maximum hydraulic power is reached, the maximum hydraulic power is maintained until the adjustment of the work attachment is completed.

[0017] The advantage of the present invention is that it provides an automatic leveling control system that is sufficiently accurate for preparing the ground prior to the construction of concrete floors and foundations.

[0018] A further advantage of the present invention is that it provides an integrated and automatic leveling control system that is implementable as a retro-fit.

[0019] A further advantage of the present invention is that it provides an automatic leveling control system that enables customization of the hydraulic response of the grading equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] A preferred embodiment of the present invention is described below with reference to the accompanying drawings, in which:

[0021] FIG. 1a is a simplified block diagram illustrating a side view of a skid-steer with an automatic leveling control system according to a preferred embodiment of the invention;

[0022] FIG. 1b is a simplified block diagram illustrating a side view of a bucket of the skid-steer with the automatic leveling control system according to a preferred embodiment of the invention;

[0023] FIG. 1c is a simplified block diagram illustrating in a side view the displacement of the bucket of the skid-steer with the automatic leveling control system according to a preferred embodiment of the invention;

[0024] FIG. 1d is a simplified block diagram illustrating in a front view the lateral tilt of the bucket and the laser receiver of the skid-steer with the automatic leveling control system according to a preferred embodiment of the invention;

[0025] FIGS. 2a and 2b are simplified block diagrams illustrating the automatic leveling control system according to a preferred embodiment of the invention connected to the control network of the skid-steer;

[0026] FIG. 3 is a simplified block diagram illustrating the increase of hydraulic power for adjusting the bucket in an automatic leveling control method according to a preferred embodiment of the invention;

[0027] FIGS. 4a and 4b are simplified block diagrams illustrating an HMI of the automatic leveling control system

according to a preferred embodiment of the invention with the display being in home mode and configuration mode, respectively; and,

[0028] FIG. 5 is a simplified flow diagram illustrating an automatic leveling control method according to a preferred embodiment of the invention.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0029] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described.

[0030] While the description of the preferred embodiments hereinbelow is with reference to automatic leveling using a skid-steer digging bucket, it will become evident to those skilled in the art that the embodiments of the invention are not limited thereto, but is also adaptable for use with various other attachments having a suitable front edge or working surface such as, for example, other types of buckets and blades, as well as for use with other types of machines such as, for example, front loaders and bulldozers.

[0031] Referring to FIGS. 1a to 1d, 2a, and 2d, an automatic leveling control system 100 according to a preferred embodiment of the invention is provided. Hereinbelow, the automatic leveling control system 100 is implemented using a skid-steer 10 having a digging bucket 22 as work attachment with its digging edge being adapted as grading edge 26 for leveling as the skid-steer 10 is propelled about a worksite. Laser receiver 102 is mounted to one of two lift arms 14 of the skid-steer 10 using a conventional fastening technique, preferably, a removable magnetic mount. The laser receiver 102 is configured to receive a laser signal 30 from a laser plane generator such as, for example, a rotating construction laser (not shown), associated with a predetermined level 31 and to provide a signal indicative of height H1 in dependence thereupon. To provide sufficient accuracy, the laser receiver 102 is, preferably, mounted in proximity to the digging bucket 22, for example, to a front end portion of the lift arm 14, as illustrated in FIGS. 1a and 1b. Preferably, the laser receiver 102 is an off-the-shelf construction laser receiver.

[0032] Tilt sensor 104 is mounted to work attachment mounting structure 20, which is pivotally movable mounted at pivot 24 to a front end portion of the lift arms 14 and has the digging bucket 22 mounted thereto, using a conventional fastening technique, preferably, a removable magnetic mount. The tilt sensor 104 is configured to sense a tilt angle of the work attachment mounting structure 20, which is indicative of a tilt angle of the digging bucket 22, for example angle α between a line connecting the pivot 24 with the grading edge 26 and a parallel to the laser plane 30, and to provide a tilt angle signal in dependence thereupon. Height H2 can then be calculated based on the tilt angle α and the length L_{GE} between the pivot 24 and the grading edge 26. The tilt sensor 104 is further configured to sense a lateral tilt β of the skid-steer 10 and to provide a lateral tilt signal in dependence thereupon. Preferably, the tilt sensor 104 is an off-the-shelf tilt sensor.

[0033] Controller 106 is connected to the laser receiver 102 and the tilt sensor 104. The controller 106 is configured for generating a control signal based on the height signal, the tilt

angle signal and the lateral tilt signal and for communicating the control signal to the skid-steer hydraulic control controlling actuation of hydraulic cylinders **18**, **28** to adjust at least one of a height of the lift arms **14** and the tilt angle of the work attachment mounting structure **20** such that the grading edge **26** is maintained at an elevation substantially corresponding to the predetermined level **31** as the machine is propelled about the worksite. The adjustment is determined, for example, based on the geometry illustrated in FIG. **1c** and the length of the lift arm L_{LA} between the pivots **16** and **24** using standard trigonometry. For example, the predetermined elevation **31**—position “0” of the pivot **24** and the grading edge **26**—is set prior to starting the automatic leveling and respective signal data indicative of $H1.0$ and $\alpha.0$ are received at the controller **106** from the laser receiver **102** and the tilt sensor **104**. Heights $H2.0$ and $H.0$ are then determined therefrom. As the skid-steer **10** is propelled over un-even terrain, the pivot **24** and the grading edge **26** are moved to current position “1” and signal data indicative of $H1.1$ and $\alpha.1$ are received at the controller **106** which then determines heights $H2.1$ and $H.1$ therefrom. The controller **106** then calculates the necessary adjustment of the tilt angle of the digging bucket **22** and the height of the lift arm **14** based on the difference between $\alpha.1$ and $\alpha.0$ and the difference between $H.1$ and $H.0$.

[0034] When being propelled over un-even terrain, the skid-steer **10** experiences lateral tilt β , resulting in a different elevation of the lift arms **14**. For example, the right hand side lift arm **14_R** is elevated higher than the left hand side lift arm **14_L**, as illustrated in FIG. **1d**, resulting in error ϵ of the height $H1$ measured by the laser sensor **102** mounted to the right hand side lift arm **14_R**. Knowing the distance D_L of the laser receiver **102** from the center between the right hand side lift arm **14_R** and the left hand side lift arm **14_L**, the error ϵ can be determined based on the measured lateral tilt β . Preferably, the lateral tilt β is displayed to the operator, giving the operator the opportunity to control the lateral accuracy of the leveling and, for example, the opportunity to stop the automatic leveling process if the lateral tilt β is above a threshold.

[0035] Mounting the tilt sensor **104** to the work attachment mounting structure **20**, enables grading using different work attachments mounted thereto without having to remove/re-attach the tilt sensor **104**. For example, a first pass of coarse grading is performed using a digging bucket to be able to move larger quantities of material, followed by a second pass of fine grading using a grading blade. For facilitating the change to a different work attachment, data indicative of the geometries of the different work attachments—in particular, the distance L_{GE} —could be stored, for example, in the form of a look-up table, in non-volatile memory of the controller **106**. Some embodiments may contain geometric lookup tables, and others may not, and it will be understood that both such approaches are contemplated within the scope of the present invention.

[0036] It is noted, that most present-day machines such as skid-steers, loaders, etc. have a work attachment mounting structure to enable use of the machine with different work attachments. Alternatively, for example, in the absence of a work attachment mounting structure, the tilt sensor **104** is mounted to the work attachment itself.

[0037] As illustrated in FIG. **2a**, the automatic leveling control system **100** comprises the controller **106** connected to the laser receiver **102**, the tilt sensor **104** and a Human-Machine Interface (HMI) **108** using conventional wiring,

with the controller **106** being disposed in the engine compartment of the skid-steer **10** and the HMI **108** being disposed in the cab **12** of the skid-steer **10**. Preferably, the controller **106** is a Programmable Logic Controller (PLC) for executing executable commands preferably stored in non-volatile memory such as, for example, flash-memory.

[0038] Further preferably, the PLC is an off-the-shelf automotive PLC having CAN interfaces which are easily connected to the two-wire CANBUS network of the skid-steer **10**. It is noted that CANBUS is a standard communications protocol developed for, and widely used in, the automotive industry. Typically, the CANBUS protocol only specifies a source address, thus enabling a CAN device, once connected to the network, to immediately access the communications of every device of the network. The automotive PLC having CAN interfaces is easily connected to the CANBUS network of the skid-steer **10** by unplugging one of the terminator resistors **36**, which are connected via standard automotive connectors to an end of the network, connecting the controller **106** via a “Y” connector to the network and the terminator resistor **36**, as illustrated in FIG. **2b**.

[0039] The controller **106** is then able to actuate the hydraulic valves on the skid steer directly via DC electric current. The skid steer would have its own hydraulic control unit in most cases, which is bypassed by creating a shared electrical Y connection directly to the hydraulic valves.

[0040] The integration or reading of other control inputs on the human interface of the skid steers also shown—for example the joystick buttons **34** of the skid-steer **10**. In the current embodiment shown, nothing is actually broadcast on the CAN network of the skid steer and in fact the purpose of accessing an interface to that network is to listen for hydraulic commands being broadcast from the operator moves the joysticks or other controls on the unit. Given the interface to the CAN network and the ability of the controller of the present invention to listen in on all internal skid steer communications and signals however, a lot more could be done with this information in future versions and embodiments of the system, to enhance capability, or accuracy thereof.

[0041] Some skid steer units may include binary or on off electrical switches in the controls of the skid steer including joysticks or other human control interface. Some of those switches, or other buttons in the human interface, may broadcast on the CAN network, of the power unit, and others may not and may simply comprise on off electrical switches requiring tie-ins or Y connections for the wiring of the controller.

[0042] Employment of an off-the-shelf automotive PLC having CAN interfaces substantially facilitates connection of the automatic leveling control system **100** to the control network of an existing machine since most present-day machines such as skid-steers, loaders, etc. have a two-wire CANBUS network. The use of existing work attachments, the employment of only two sensors—which are easily mounted—and the use of an off-the-shelf automotive PLC having CAN interfaces substantially facilitates employment of the automatic leveling control system **100** as a retro-fit.

[0043] A major problem in designing an accurate automatic leveling control system is the control of the skid-steer's hydraulic system, since the amount of power required to move the hydraulics at a certain speed can vary substantially, dependent on, for example, solenoid valve heating and bucket weight/loading. This problem is addressed by an automatic leveling control method according to a preferred embodiment of the invention. After determining the adjustments to be

made as described hereinabove, the controller 106 generates a control signal and communicates the same to the hydraulic control 32 of the skid-steer 10 for actuating at least one of the hydraulic cylinders 18, 28 to adjust the digging bucket 22 such that the grading edge 26 is maintained at an elevation substantially corresponding to the predetermined level 31 as the machine is propelled about the worksite. The controller 106 determines the control signal such that hydraulic power for adjusting the digging bucket 22 is started at a predetermined minimum hydraulic power P_{min} and is increased according to a predetermined ramp time t_R until a predetermined maximum hydraulic power P_{max} is reached, as illustrated in FIG. 3, or the adjustment is completed. If the adjustment of the digging bucket 22 is not completed by the time that the predetermined maximum hydraulic power P_{max} is reached, maximum hydraulic power will be maintained until the adjustment of the digging bucket 22 is completed.

[0044] Preferably, the minimum hydraulic power P_{min} , the ramp time t_R , and the maximum hydraulic power P_{max} are predetermined for each of the different movements of the work attachment 22:

- [0045] moving lift arms 14 up;
- [0046] moving the lift arms 14 down;
- [0047] tilting the grading edge 26 up; and,
- [0048] tilting the grading edge 26 down.

[0049] Further preferably, the minimum hydraulic power P_{min} , the ramp time t_R , and the maximum hydraulic power P_{max} are adjustable by the operator using the HMI 108, in order to customize the hydraulic response.

[0050] Referring to FIGS. 4a and 4b, a preferred embodiment of the HMI 108 is provided, with FIG. 4a illustrating a home screen mode of the display and FIG. 4b illustrating a configuration screen mode of the display, respectively.

[0051] In home screen mode the display shows:

[0052] 110—The real-time elevation of the skid-steer lift arms 14.

[0053] 112—The current operating mode of the automatic leveling system (manual/automatic).

[0054] While in manual mode, the automatic leveling system does not make any hydraulic adjustments.

[0055] While in automatic mode, the automatic leveling system does make hydraulic adjustments as described hereinabove.

[0056] The automatic mode is engaged by pressing, for example, the bottom right button on the left skid-steer joystick.

[0057] 114—Over current, indicating an electrical short in the wiring.

[0058] 115—Grade below available lift arm travel.

[0059] 116—Real-time side-to-side machine tilt angle β .

[0060] 118—Temporary banner showing that the desired bucket tilt angle $\alpha.0$ has been recorded.

[0061] The tilt angle $\alpha.0$ is set by the following procedure:

[0062] manually positioning the bucket 22 to the desired tilt angle $\alpha.0$;

[0063] press and hold the top right button of the left skid-steer joystick for 3 seconds; and,

[0064] the banner flashes when the tilt angle has been successfully recorded.

[0065] 120—Real-time bucket angle $\alpha.1$.

[0066] The home screen buttons are:

[0067] SAV—Saves the current hydraulic and tilt settings to the controller in non-volatile memory.

[0068] LOAD—Loads the previously saved hydraulic and tilt settings from non-volatile memory.

[0069] RST—Resets the controller to factory defaults.

[0070] DISP—Adjusts screen brightness.

[0071] CLR—Clears error codes.

[0072] ZERO TILT—Zeroes the tilt angle on the display only. This allows the operator to see the true bucket angle.

[0073] CFG—Navigates to the hydraulic configuration screens.

[0074] Procedure for modifying the hydraulic parameters in configuration screen mode:

[0075] Press the SEL button that corresponds to the parameter you wish to modify. For the example in

[0076] FIG. 4b, press the top left SEL button. Selection will show green highlight 122.

[0077] Turn the Rotary Encoder 130 to change the New Setpoint 124 parameter.

[0078] Press the SAV button to save all New Setpoints 124 to the Current Setpoints 126 on the screen.

[0079] The configuration screen buttons are:

[0080] SEL—Select the parameter to be modified.

[0081] TEST—Have the controller activate the hydraulics according to the parameters on the current screen. While the test is active, the Testing Banner will appear 128.

[0082] CLR—Resets the New Setpoint parameters to equal the Current Setpoint parameters.

[0083] SAV—Saves the New Setpoints on screen to the Current Setpoints.

[0084] <—Navigate to the previous screen.

[0085] >—Navigate to the next screen.

[0086] There are four sets of hydraulic parameters that can be adjusted with each set corresponding to one movement of the work attachment 22, as described hereinabove. Each set has its own screen as illustrated in FIG. 4b.

[0087] Preferably, the controller 106 is mounted in the engine compartment of the skid-steer 10 while the HMI 108 is mounted inside the operator cab 12 such that the operator can view the display during operation of the skid-steer 10. Alternatively, the controller 106 is disposed in the cab 12, for example, in a single housing with the HMI 108. Optionally, the display and the control buttons of the HMI 108 are integrated in a touch-screen.

[0088] Referring to FIG. 5, an automatic leveling control method according to a preferred embodiment of the invention is provided:

[0089] 210—The operator starts the skid-steer 10.

[0090] 212—The operator presses a button on the existing joystick controls 34 to wake the auto leveling system electronics.

[0091] 214—The operator sets hydraulic response parameters:

minimum hydraulic power, maximum hydraulic power, and power ramp time.

[0092] 216—The operator manually adjusts bucket 22 to the desired tilt angle $\alpha.0$.

[0093] 218—The operator presses and holds a button on existing joystick 34 controls for 3 seconds for the controller 106 to record the current tilt angle as the desired tilt angle $\alpha.0$ when in automatic mode.

[0094] 220—The operator sets up rotating construction laser for the laser to provide a fixed elevation reference plane 30.

[0095] 222—The operator adjusts the grading edge 26 to the predetermined elevation 31.

[0096] 224—The operator presses button on existing joystick controls 34 to engage auto leveling mode.

[0097] 226—The controller 106 controls the skid-steer hydraulics 32 to maintain the grading edge 26 at the predetermined elevation 31 and tilt angle α_0 , wherein the hydraulic power is started at a predetermined minimum hydraulic power and is increased according to a predetermined ramp time until a predetermined maximum hydraulic power is reached or the adjustment is completed.

[0098] 228—The operator disengages the auto leveling mode by manually controlling the hydraulics 32 of the skid-steer 10.

[0099] The present invention has been described herein with regard to preferred embodiments. However, it will be obvious to persons skilled in the art that a number of variations and modifications can be made without departing from the scope of the invention as described herein.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An automatic leveling control system for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite, the system comprising:

- a. a single laser receiver mounted to one of two lift arms of the machine, the laser receiver being configured to receive a laser signal from a laser plane generator associated with a predetermined level and to provide a height signal in dependence thereupon;
- b. a tilt sensor mounted to a work attachment mounting structure, the work attachment mounting structure being pivotally movable mounted to a front end portion of the lift arms and having the work attachment mounted thereto, the tilt sensor being configured to sense a tilt angle of the work attachment mounting structure and to provide a tilt angle signal in dependence thereupon, the tilt sensor further being configured to sense a lateral tilt of the machine and to provide a lateral tilt signal in dependence thereupon;
- c. a controller connected to the laser receiver and the tilt sensor, the controller being configured for generating a control signal based on the height signal, the tilt angle signal and the lateral tilt signal and for communicating the control signal to the machine to adjust at least one of a height of the lift arms and the tilt angle of the work attachment mounting structure such that a grading edge of the work attachment is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite.

2. The system according to claim 1 wherein the laser receiver is mounted to a front end portion of the lift arm.

3. The system according to claim 1 wherein the controller is an automotive programmable logic controller having CAN interfaces connected to a CAN network of the machine.

4. The system according to claim 3 wherein the controller is connected to at least a button of a joystick of the machine.

5. The system according to claim 3 comprising a human-machine interface connected to the controller.

6. An automatic leveling control system for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite, the system comprising:

- a. a laser receiver mounted to the machine, the laser receiver being configured to receive a laser signal from a

laser plane generator associated with a predetermined level and to provide a height signal in dependence thereupon;

- b. an automotive programmable logic controller connected to the laser receiver, the controller being configured for generating a control signal based on the height signal and for communicating the control signal to the machine to adjust the work attachment such that a grading edge thereof is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite.

7. The system according to claim 6 wherein the controller is connected to at least a button of a joystick of the machine.

8. The system according to claim 6 comprising a human-machine interface connected to the controller.

9. The system according to claim 6 wherein the laser receiver is mounted to a lift arm of the machine.

10. The system according to claim 9 comprising a tilt sensor mounted to a work attachment mounting structure, the work attachment mounting structure being pivotally movable mounted to a front end portion of the lift arms and having the work attachment mounted thereto, the tilt sensor being configured to sense a tilt angle of the work attachment mounting structure and to provide a tilt angle signal in dependence thereupon, the tilt sensor further being configured to sense a lateral tilt of the machine and to provide a lateral tilt signal in dependence thereupon.

11. An automatic leveling control method for a machine having a work attachment adapted for leveling as the machine is propelled about a worksite, the method comprising:

- a. using a controller, receiving at least a sensor signal associated with a predetermined level;
- b. using the controller, generating a control signal based on the at least a sensor signal and communicating the control signal to at least a hydraulic actuator of the machine to adjust the work attachment such that a grading edge thereof is maintained at an elevation substantially corresponding to the predetermined level as the machine is propelled about the worksite,

wherein the control signal is determined such that hydraulic power for adjusting the work attachment is started at a predetermined minimum hydraulic power and is increased according to a predetermined ramp time until a predetermined maximum hydraulic power is reached or the adjustment is completed.

12. The method according to claim 11 comprising receiving from a human-machine interface connected to the controller data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time.

13. The method according to claim 12 comprising receiving from the human-machine interface first data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for moving a grading edge of the work attachment in an upward direction and second data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for moving the grading edge of the work attachment in a downward direction.

14. The method according to claim 12 comprising receiving from the human-machine interface:

- a. first data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for moving lift arms of the machine in an upward direction;

- b. second data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for moving the lift arms of the machine in a downward direction;
 - c. third data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for tilting a grading edge of the work attachment in an upward direction; and,
 - fourth data indicative of the minimum hydraulic power, the maximum hydraulic power, and the ramp time for tilting the grading edge of the work attachment in a downward direction.
- 15.** The method according to claim **14** comprising:
- a. moving the work attachment to a predetermined tilt angle;
 - b. sensing the predetermined tilt angle; and,
 - c. communicating to the controller data indicative of the predetermined tilt angle.
- 16.** The method according to claim **15** comprising moving the grading edge of the work attachment to the predetermined level.
- 17.** The method according to claim **16** comprising adjusting the work attachment such that the grading edge is maintained at an elevation substantially corresponding to the predetermined level and at the predetermined tilt angle as the machine is propelled about the worksite.

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