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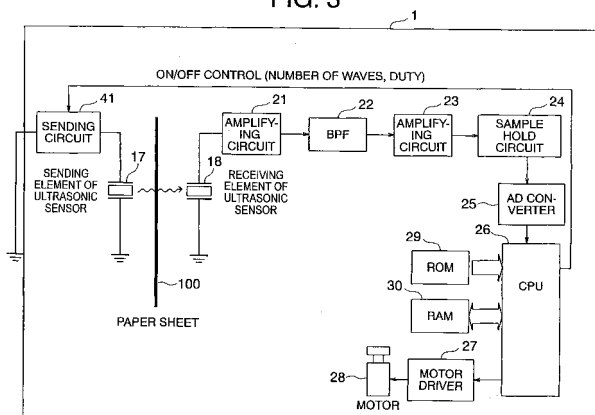
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**(54) PAPER FEEDER**

(57) A sheet feeding apparatus includes a sending element of an ultrasonic sensor (17) for outputting ultrasonic waves, a drive circuit (41) for supplying the sending element of the ultrasonic sensor (17) with a drive signal for driving the sending element, a receiving element of the ultrasonic sensor (18) disposed opposite the sending element of the ultrasonic sensor (17) across a sheet transfer path in the sheet feeding apparatus, and for re-

ceiving the ultrasonic waves, a setting unit (26) for setting a threshold for the detection of transfer of the plurality of paper sheets (100) by using the output of the receiving element of the ultrasonic sensor (18) at the time of stopping of the output of the sending element of the ultrasonic sensor (17) as a basic value, and a detection unit (26) for detecting transfer of the plurality of paper sheets (100) by comparing the output of the receiving element of the ultrasonic sensor (18) with the threshold.

**FIG. 3**



## Description

## Technical Field

**[0001]** This invention generally relates to a sheet feeding apparatus, and particularly to a sheet feeding apparatus which sets a threshold that enables, in double feed detection using ultrasonic waves, the double feed to be detected without fail even in a case that the sensor output is varied by fluctuations in the sensitivity or sound pressure of the ultrasonic sensor and the like.

## Background Art

**[0002]** For use in the front shield device of a sheet-fed press, for example, an ultrasonic detector is known, which detects the transfer or feeding of a plurality of (for example, two) paper sheets (double feed or DF) by using ultrasonic waves. In this ultrasonic detector, ultrasonic waves outputted from a sending element of an ultrasonic sensor are received by a receiving element of the ultrasonic sensor, and it is detected whether there is one fed paper sheet or more according to the level (wave height) of the received ultrasonic waves. That is, when the level of the received ultrasonic waves is higher than a threshold, it is judged that there is only one sheet. On the other hand, when the level is lower than the threshold, it is judged that double feed has occurred (see, for example, Patent Document Reference 1: Japanese Patent Application Laid-Open No. 6-263288 (pp. 2-3)).

**[0003]** However, according to the above-mentioned prior art, adjustment of every individual feeding apparatus is needed because, when each feeding apparatus is shipped, the amplification rate is adjusted with a variable resistance according to the characteristics of its ultrasonic sensor in a state in which a paper sheet is inserted in the device or a threshold for determining double feed detection (hereinafter sometimes referred to as a decision slice value) is determined and applied to the feeding apparatus according to prior evaluation. Moreover, readjustment is needed when ultrasonic sensor has run into trouble and is to be replaced.

**[0004]** Further, in a case that the control is such as to determine the decision slice value uniquely, it is difficult to secure a sufficient margin of operation against variations in the ultrasonic sensor output due to fluctuations in the sensitivity of the ultrasonic sensor or its fitting to the feeding apparatus, ambience or adherence of paper powder. Therefore, it may be impossible to detect double feed when paper sheets of different thickness are consecutively carried.

**[0005]** It is an object of the present invention to provide a sheet feeding apparatus in which a threshold permitting secure detection of double feed even when there are variations in the ultrasonic sensor output due to fluctuations in the sensitivity or sound pressure of the ultrasonic sensor.

## Disclosure of the Invention

**[0006]** A sheet feeding apparatus of the present invention is for detecting transfer of a plurality of paper sheets by using ultrasonic waves. The sheet feeding apparatus includes a sending element of an ultrasonic sensor for outputting ultrasonic waves, a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element, a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves, a setting unit for setting a threshold for the detection of transfer of the plurality of paper sheets by using the output of the receiving element of the ultrasonic sensor at the time of stopping of the output of the sending element of the ultrasonic sensor as a basic value, and a detection unit for detecting transfer of the plurality of paper sheets by comparing the output of the receiving element of the ultrasonic sensor with the threshold.

**[0007]** According to the sheet feeding apparatus of the present invention, since the threshold for detecting transfer of a plurality of paper sheets is set by referencing the output of the receiving element of the ultrasonic sensor at the time of stopping of the output of the sending element of the ultrasonic sensor, the threshold (decision slice value) so set is not fixed. Therefore, it can follow variations in the environment of detection (for example, variations in the sheet feeding apparatus) or in the ultrasonic sensor's own characteristics (for example, aging) and, even after shipment, double feed in the sheet feeding apparatus can be always detected accurately. That is, even in a case that the sensor output varies with fluctuations in the sensitivity, sound pressure or fitting (accuracy) of the ultrasonic sensor, its ambience or adhesion of paper powder, double feed can be detected without fail.

**[0008]** A sheet feeding apparatus of the present invention is for detecting transfer of a plurality of paper sheets by using ultrasonic waves. The sheet feeding apparatus includes a sending element of an ultrasonic sensor for outputting ultrasonic waves, a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element, a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves, an amplifier, comprising an operational amplifier, for amplifying the output of the receiving element of the ultrasonic sensor, and an adjusting unit for forming a control signal for adjusting the output of the amplifier, whereby the reference voltage of the operational amplifier is adjusted.

**[0009]** Further, a sheet feeding apparatus of the present invention is for detecting transfer of a plurality of paper sheets by using ultrasonic waves. The sheet feeding apparatus includes a sending element of an ultrasonic

sensor for outputting ultrasonic waves, a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves, an amplifier for amplifying the output of the receiving element of the ultrasonic sensor, an adjusting unit for forming a control signal for adjusting the output of the amplifier, and a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element. The drive circuit varies the number of waves or the duty ratio of clocks supplied to the sending element of the ultrasonic sensor according to the control signal from the adjusting unit.

**[0010]** According to the sheet feeding apparatus of the present invention, the output value of the receiving element of the ultrasonic sensor is adjusted either by altering the reference voltage of the operational amplifier or altering the frequency of clocks supplied by the drive circuit or the duty ratio. Therefore, at the time of shipping the sheet feeding apparatus, for example, there is no need to adjust the amplification rate of the amplifier of the ultrasonic receiving circuit with a variable resistance. This is also true at the time of replacing the ultrasonic sensor, for example. Even in a case that the ultrasonic receiving circuit comprises a band pass filter, the output of the receiving element of the ultrasonic sensor can be prevented from attenuating.

#### Brief Description of the Drawings

#### **[0011]**

FIG. 1 is a structural diagram of a scanner, showing the schematic structure of a scanner to which a sheet feeding apparatus according to the present invention is applied.

FIG. 2 is a structural diagram of a scanner, showing the schematic structure of a scanner to which a sheet feeding apparatus according to the present invention is applied.

FIG. 3 is a diagram showing one example of structure of an ultrasonic detector.

FIG. 4 is a diagram showing one example of structure of an ultrasonic detector.

FIG. 5A and FIG. 5B are diagrams showing examples of operation by a CPU.

FIG. 6 is a diagram showing one example of operation processing flow at the time of adjustment to determine  $V_{slice}$ .

FIG. 7 is a diagram showing paper sheets and the output transition of a receiving element of the ultrasonic sensor (US sensor).

FIG. 8 is a diagram showing one example of operation processing flow at the time of reading.

FIG. 9 is a diagram showing a sensor reception waveform detected by the CPU.

FIG. 10 is a diagram showing one example of

processing flow to compute the correction value  $\alpha$ . FIG. 11A, FIG. 11B and FIG. 11C are diagrams showing tables to be used for determining the correction value  $\alpha$ .

FIG. 12A and FIG. 12B are diagrams showing examples of device configuration for adjusting the input value of an ultrasonic wave reception sensor.

FIG. 13 is a diagram showing a sequence of adjusting the double feed output level.

FIG. 14 is a diagram showing a sequence of adjusting the double feed output level.

#### Best Mode for Carrying Out the Invention

**[0012]** FIG. 1 and FIG. 2 are structural diagrams of a scanner, showing the schematic structure of a scanner to which a sheet feeding apparatus according to the present invention is applied. Particularly, FIG. 1 shows an external view of the scanner, and FIG. 2 shows a schematic section of a scanner.

**[0013]** This scanner is formed integrally with the sheet feeding apparatus. The sheet feeding apparatus, as shown in FIG. 2, comprises a paper sheet mounting table (shooter) 31, a pick roller 32, a pick arm 33, a separating pad 34, feed rollers 35 and 36, and discharge rollers 37 and 38. And, the sheet feeding apparatus further comprises the sending element of the ultrasonic sensor 17 and the receiving element of the ultrasonic sensor 18 of an ultrasonic detector 1 to be described afterwards. In FIG. 2, the two-dot chain line represents the transfer path of paper sheets 100 and the arrow R represents the reading position of the paper sheets 100.

**[0014]** The paper sheets 100 mounted on the paper sheet mounting table (shooter) 31 are picked by the pick roller 32 in a state of being subjected to an appropriate pressing force by the pick arm 33. Then, the paper sheets 100 are separated one by one sequentially from the bottom by the pick roller 32 and the separating pad 34. The picked paper sheets 100 are further transferred by the pick roller 32 to the feed rollers 35 and 36, transferred by the feed rollers 35 and 36 to their reading position, and discharged by the discharge rollers 37 and 38.

**[0015]** In the transferring process of these paper sheets 100 along the transfer path, a plurality of (usually two) paper sheets 100 which have failed to be separated one by one by the separating pad 34, namely double fed ones are detected by the sending element of the ultrasonic sensor 17 and the receiving element of the ultrasonic sensor 18. For this reason, the sending element of the ultrasonic sensor 17 and the receiving element of the ultrasonic sensor 18 are located upstream on the transfer path from the reading position as shown in FIG. 2. Particularly, the sending element of the ultrasonic sensor 17 and the receiving element of the ultrasonic sensor 18 are positioned downstream or upstream from the feed rollers 35 and 36 in the vicinity of the rollers 35 and 36. This enables double fed paper sheets 100 to be detected before they reach the reading position, and to proceed nec-

essary process (for example, stopping of transfer).

**[0016]** Additionally, the scanner shown in FIG. 1 and FIG. 2 is one example of image processing apparatus to which the sheet feeding apparatus according to the present invention is applied. The present invention can be applied sheet feeding apparatus for not only scanners but also copying machines, facsimile machines and the like.

**[0017]** FIG. 3 and FIG. 4 show one example of structure of ultrasonic detector which is provided in the sheet feeding apparatus according to the present invention. In FIG. 3, the ultrasonic detector 1 detects the transfer of a plurality of paper sheets 100 by using ultrasonic waves. The ultrasonic detector 1 of the sheet feeding apparatus comprises the sending element of the ultrasonic sensor 17, its drive circuit (sending circuit; the same applies hereinafter) 41, the receiving element of the ultrasonic sensor 18, a setting unit (26) for setting the threshold for the transfer of a plurality of paper sheets 100 (double feed), and a detection unit (26) for detecting the transfer of a plurality of paper sheets 100.

**[0018]** The sending element of the ultrasonic sensor 17 outputs ultrasonic waves. The drive circuit 41 supplies the sending element of the ultrasonic sensor 17 with a drive signal to drive the sensor 17. The drive circuit 41 comprises a circuit (capable of ON/OFF control) oscillating at a frequency near the resonance frequency of the sending element of the ultrasonic sensor 17. The receiving element of the ultrasonic sensor 18 is disposed opposite the sending element of the ultrasonic sensor 17 across the sheet transfer path in the sheet feeding apparatus, and receives the ultrasonic waves. The setting unit uses the output of the receiving element of the ultrasonic sensor 18 at the time of the stopping of the output of the sending element of the ultrasonic sensor 17 by the drive circuit 41 as a basic value, and sets a threshold for the detection of the transfer of a plurality of paper sheets 100. The detection unit compares the output of the receiving element of the ultrasonic sensor 18 with the threshold, and detects the transfer of a plurality of paper sheets 100.

**[0019]** The ultrasonic detector 1 further comprises an (first-stage) amplifying circuit 21, a BPF (band pass filter) 22, an (second-stage) amplifying circuit 23, a sample hold (S&H) circuit 24, an AD converter 25, a CPU 26, a motor driver 27, a motor 28, a ROM 29 and RAM 30. They make a receiving circuit 14 shown in FIG. 4. That is, the receiving element of the ultrasonic sensor 18 outputs an electric signal corresponding to the ultrasonic wave received from the sending element of the ultrasonic sensor 17. And, the electric signal is amplified by the amplifying circuit 21, and is cleared of noise by the BPF 22 after the amplification. And, the signal cleared of noise is further amplified by the amplifying circuit 23. Then, after the sample hold circuit 24 samples and holds (SH) the peak value of the signal, the AD converter 25 converts that value (analog signal) into a digital value (digital signal). This digital signal (input signal) is inputted to (the

setting unit and detection unit of) the CPU 26 and analyzed. In other words, the setting unit and the detection unit (see FIG. 5) which are realized by setting and detection processing programs set on the CPU 26 (and hardware) analyze the input signal. The setting and detection processing programs are stored into, for example, the ROM 29 and/or the RAM 30. The CPU 26 (namely the detection unit), in double feed detection, for example, sends a drive signal to the motor driver 27 to have the motor 28 driven and to have the transfer of (a plurality of) paper sheets 100 stopped.

**[0020]** The ultrasonic detector 1 comprises a sending circuit (drive circuit) 41. The sending circuit 41 comprises a drive IC 13, a resistance frequency adjusting oscillator (OSC) 15 and a variable resistor 16 shown in FIG. 4.

**[0021]** The drive IC 13 shown in FIG. 4 is a drive circuit which supplies the sending element of the ultrasonic sensor 17 with a drive signal to drive it. This causes the sending element of the ultrasonic sensor 17 to output an ultrasonic wave. The receiving element of the ultrasonic sensor 18 receives this ultrasonic wave, and outputs a detection signal according to the intensity of the received ultrasonic wave. For example, when no paper sheet 100 is present between the sending element of the ultrasonic sensor 17 and the receiving element of the ultrasonic sensor 18, the receiving element of the ultrasonic sensor 18 detects a signal of a certain level (referred to usual level). When one paper sheet 100 is present between them, the receiving element of the ultrasonic sensor 18 detects a signal of a level below the usual level but higher than a prescribed threshold (referred to normal level). When two (or more) paper sheets 100 are present between them, the receiving element of the ultrasonic sensor 18 detects a signal of a level below the usual level and the above-mentioned threshold (referred to abnormal level).

**[0022]** For example, in advance of transferring paper sheets 100, the drive IC 13 is so controlled that the receiving element of the ultrasonic sensor 18 can receive a signal of the usual level (actually a signal equal to or higher than the usual level). That is, based on the ultrasonic wave received by the receiving element of the ultrasonic sensor 18, the drive IC 13 is so controlled as to match the drive frequency of the drive signal with the resonance frequency of the sending element of the ultrasonic sensor 17, as will be described afterwards (without using a variable resistor).

**[0023]** FIG. 5A shows one example of setting unit and FIG. 6 shows a flow of processing for setting at the time of setting the threshold.

**[0024]** As described above, the setting unit sets (generates) the threshold (decision slice value or  $V_{\text{slice}}$ ) for the detection of transfer of a plurality of paper sheets 100 by using the output of the receiving element of the ultrasonic sensor 18 when the output of the sending element of the ultrasonic sensor 17 is stopped by the drive circuit 41, as the basic value. In this example, the threshold is determined by adding a fixed value to the output of the

receiving element of the ultrasonic sensor at the time the output of the sending element of the ultrasonic sensor is stopped.

[0025] That is, as shown in FIG. 5A, in the CPU 26, sensor control unit 101 sends a control signal to the sending circuit 41 to stop the oscillation of the sending circuit 41. Also, the sensor control unit 101 applies a prescribed bias voltage to (an operational amplifier 106; see FIG. 12A of) the amplifying circuit 23. In this state, a Vslice generating unit 102 of the CPU 26 repeatedly receives from the AD converter 25 input signals inputted from the receiving element of the ultrasonic sensor 18 tens of times, for example, 32 times, computes their average, and uses it as a basic value Vbase (step S11). That is, it is equal to measure signals at 32 points in one raster, for example. Then, the Vslice generating unit 102 performs a correction to add a correction value  $\alpha$  to the basic value Vbase to generate a threshold Vslice ( $V_{\text{slice}} = V_{\text{base}} + \alpha$ ), and stores it into a register 103 (step S12). The correction value  $\alpha$  is empirically determined for each device to be installed, with the influence of noise and other factors being taken into consideration.

[0026] The correction value  $\alpha$  may be determined in advance, or correction value  $\alpha$  may be determined as a variable value for each apparatus on an ad hoc basis with the sensitivity of the ultrasonic sensor, fluctuations in its sound pressure or fitting, ambience, adhesion of paper powder and other factors being taken into consideration.

[0027] FIG. 7 is a diagram showing paper sheets and the output transition of the receiving element of the ultrasonic sensor (US sensor), illustrating one example of threshold set by the processing so far described. In FIG. 7, the vertical axis represents the output (digital value) of the receiving element of the ultrasonic (US) sensor, and the horizontal axis represents the vertical scanning direction of paper sheets (raster).

[0028] The corrected threshold Vslice is set to a level relative to the basic value Vbase as shown in FIG. 7, and used for detection of double feed. For example, when the transferred paper sheets are two sheets of 45K in ream weight (hereinafter referred to as 45K sheets), the input signal level (Vin) is below the threshold Vslice, and therefore it is judged that double feed has occurred (abnormal feed). When only one of this 45K sheet is transferred, though not shown, the input signal level (Vin) is even higher than in a case of one 135K sheet or one 195K sheet which is heavier in ream weight (or thicker), and surpass the threshold Vslice. Therefore, the state is judged as normal feed. When two 135K or two 195K sheets are transferred, though not shown, the input signal level is even lower than in a case of one 45K sheet, and does not reach the threshold Vslice. Therefore, the state is judged as double feed. When only one 135K or one 195K sheet is transferred, the input signal level surpasses the threshold Vslice as shown in FIG. 7. Therefore, the state is judged as normal feed.

[0029] Even in a case that the transferred sheets are

22K sheets, which are very light in ream weight and thin, double feed can be detected correctly. That is, when only one 22K sheet is transferred, though not shown, the input signal level (Vin) is even higher than in a case of one 135K sheet or the like, and surpasses the threshold Vslice. Therefore, the state is judged as normal feed. When two 22K sheets are transferred, the level of the input signal Vin fluctuates as shown in FIG. 7. However, on the right hand side of FIG. 7, the input signal Vin is lower and below the threshold Vslice. Therefore, the state can be judged as double feed. This is because the input signal becomes significantly low in the vicinity of the position where paper sheets 100 are suppressed by the feed rollers 35 through 38. That is, according to the present invention, double feed can be correctly detected over a broad range.

[0030] FIG. 5B shows an example of detection unit. FIG. 8 shows a flow of processing for detection after the setting of the threshold. FIG. 9 shows a drive pulse outputted by the sending circuit 41 in detecting double feed.

[0031] As described above, the detection unit compares the output of the receiving element of the ultrasonic sensor 18 with the threshold, and detects transfer of a plurality of paper sheets 100. That is, as shown in FIG. 5B, the sensor control unit 101 in the CPU 26 sends a control signal to the sending circuit 41 etc. to oscillate the sending circuit 41. Also, the sensor control unit 101 applies prescribed bias voltage to (the operational amplifier 106 of) the amplifying circuit 23. In this state, comparing unit 104 of the CPU 26 repeatedly receives from the AD converter 25 input signals (digital values) from the receiving element of the ultrasonic sensor 18 tens of times, for example, 32 times, and holds them (step S21).

[0032] Then, as shown in FIG. 9, after the oscillation of the sending circuit 41 (the sending drive pulse) is stopped, signals in a plurality of prescribed positions, for example, at 32 points, are measured. The measuring positions are selected to be, for example, once per the raster or once per a plurality of the rasters. Further, when the output waveform of the receiving element of the ultrasonic sensor 18 becomes gradually larger and reaches the maximum level, that maximum level is sampled and held.

[0033] Next, the sensor control unit 101 or the comparing unit 104 sets the timer for an SH interrupt (step S22), and judges whether or not the interrupt has occurred (step S23). In a case that 32 input signals are to be obtained, for example, as mentioned above, 32 times of the SH interrupt are set to occur. That is, using the SH interrupt as a trigger, consecutive drive pulses on the sending side shown in FIG. 9 are outputted. For example, 32 times of the SH interrupt occur with the lapse of a prescribed length of time, at a rate of one interrupt per the raster. When no interrupt occurs, step S23 is repeated. When an interrupt does occur, the average, for example, a moving average, of the 32 values earlier received and held is computed, and this average is used as the value Vin of the input signal for double feed (DF) detection (step S24).

**[0034]** After that, the comparing unit 104 compares the value  $V_{in}$  of the input signal with the threshold  $V_{slice}$  of the register 103 (step S25), and when  $V_{in} < V_{slice}$  is not satisfied, the state is judged as being normal feed. When  $V_{in} < V_{slice}$  is satisfied, the comparing unit 104 further judges whether  $V_{in} < V_{slice}$  is satisfied a prescribed number of times, for example, 10 times or more (step S26). When  $V_{in} < V_{slice}$  is satisfied 10 times or more, the comparing unit 104 judges that double feed occurs and outputs an error signal. When  $V_{in} < V_{slice}$  is satisfied less than 10 times, the process of the step S22 and its subsequence is repeated.

**[0035]** FIG. 10 and FIG. 11 illustrate an ultrasonic detector 1 in a sheet feeding apparatus, which is another example of the present invention in which the correction value  $\alpha$  is a variable value. That is, although a fixed value is used as the correction value  $\alpha$  in the foregoing example as indicated at the step S12 in FIG. 6, this correction value  $\alpha$  may be a variable value.

**[0036]** In this example, as shown in FIG. 11, the threshold  $V_{slice}$  in the detection of transfer of a plurality of paper sheets is calculated by adding a value  $\alpha$  to an output  $V_{base}$ . The output  $V_{base}$  is an output of the receiving element of the ultrasonic sensor at the time the output of the sending element of the ultrasonic sensor 17 is stopped. The value  $\alpha$  is calculated, correspondingly to the output  $V_t$  of the receiving element of the ultrasonic sensor 18 at the time the sending element of the ultrasonic sensor 17 is driven stepwise by the drive circuit 41, according to a (third) correlation between the output of the receiving element of the ultrasonic sensor 18 and the correction value  $\alpha$  (shown in FIG. 11C). The third correlation is determined by a (first) correlation between the sensitivity and the output  $V_t$  of the receiving element of the ultrasonic sensor 18 (shown in FIG. 11A) and a (second) correlation between the fitting position and the output  $V_t$  of the receiving element of the ultrasonic sensor 18 (shown in FIG. 11B).

**[0037]** In the same way as at the step S11, a bias voltage is applied to measure the basic value  $V_{base}$  (step S31). Next, in a state without paper sheets, the sending element of the ultrasonic sensor 17 is driven stepwise (step S32). That is, the drive circuit 41 applies a single drive pulse to the sending element of the ultrasonic sensor 17. And the resultant output  $V_t$  of the receiving element of the ultrasonic sensor 18 is measured (step S33), a correction value  $\alpha$  corresponding to the output  $V_t$  is calculated by using the third correlation shown in FIG. 11C (step S34), and the threshold  $V_{slice} = V_{base} + \alpha$  is determined by using the correction value  $\alpha$  (step S35).

**[0038]** For example, the correction value  $\alpha$  is determined by using the correlation diagrams shown in FIG. 11A to FIG. 11C as described above. That is, the sensor sensitivity and the sensor output  $V_t$  is in a proportional relationship as shown in FIG. 11A. The sensor fitting position and the sensor output  $V_t$  have the correlation shown in FIG. 11B. From the two correlations shown in FIG. 11A and FIG. 11B, the third correlation is derived

between the sensor output  $V_t$  and the correction value  $\alpha$  shown in FIG. 11C.

**[0039]** FIG. 12A, FIG. 13 and FIG. 14 show a structure of the ultrasonic detector 1 in the other sheet feeding apparatus, which is the other example of the present invention, in which the output of the amplifying circuit 23 is adjusted not by varying an amplification rate with variable resistance, but by using some other units.

**[0040]** That is, the example shown in FIG. 12A and FIG. 13 comprises the amplifying circuit 23, which is an amplifier for amplifying the output of the receiving element of the ultrasonic sensor 18 and comprises the operational amplifier 106, and first adjusting unit which forms a control signal for adjusting the output of the amplifying circuit 23. The first adjusting unit adjusts the reference voltage  $V_{ref}$  of the operational amplifier 106, so that the level of output from the amplifying circuit 23 is adjusted. More specifically, the offset of the operational amplifier 106 is adjusted (optimized for the receiving circuit 14). This first adjusting unit actually comprises the sensor control unit 101 and a voltage adjuster 107. The amplifying circuit 23 is the second-stage amplifier in FIG. 3. The amplifying circuit 23 comprises a fixed resistor 105, the operational amplifier 106 and the voltage adjuster 107 which may be a DA converter, for example. Numeral 108 denotes a fixed resistor. This example makes it possible to absorb fluctuations in resistance and temperature characteristics of the fixed resistors 105 and 108, to omit a manual adjustment at the time of shipment or sensor replacement, and to adapt themselves to status variations with the environment of use.

**[0041]** FIG. 13 shows a process of adjusting the double feed output level. The sensor control unit 101 sets the central value of conversion by the DA converter, which is the voltage adjuster 107, to its intrinsic value (for example, x80 of 256 gradations), and sets the number of burst waves to be applied to the sending element of the ultrasonic sensor 17 to "0" (step S41). That is, the output of the sending element of the ultrasonic sensor 17 is set to "0". In this state, the sensor control unit 101 monitors (takes in) the input value  $V_{in}$  from the receiving element of the ultrasonic sensor 18 (step S42), and judges, after the monitoring, whether or not "the first slice upper limit" > "the input value" is satisfied (step S43). This first slice upper limit is an empirically determined value. When "the first slice upper limit" > "the input value" is not satisfied, the sensor control unit 101 sets the central value of conversion by the DA converter, which is the voltage adjuster 107, to a value shifted by +x01 (step S44), and the process of the step S42 and its subsequence is repeated. When "the first slice upper limit" > "the input value" is satisfied, the sensor control unit 101 further judges whether or not "the input value" > "the first slice lower limit" is satisfied (step S45). This first slice lower limit is an empirically determined value. When "the input value" > "the first slice lower limit" is not satisfied, the sensor control unit 101 sets the central value of conversion by the DA converter, which is the voltage adjuster 107, to a

value shifted by  $\times 01$  (step S46), and the process of the step S42 and its subsequence is repeated. When "the input value" > "the first slice lower limit" is satisfied, the process is ended.

**[0042]** Further, the example shown in FIG. 12A and FIG. 14 comprises second adjusting unit. The second adjusting unit forms a control signal for adjusting the output of the amplifying circuit 23 which amplifies the output of the receiving element of the ultrasonic sensor 18. And, the number of waves (the number of pulses) or the duty ratio of the drive pulses (burst waves) is varied which is supplied by the drive circuit 41 according to a control signal from the second adjusting unit to the sending element of the ultrasonic sensor 17. The input value from the amplifying circuit 23 is thereby adjusted. This second adjusting unit actually comprises the sensor control unit 101 and the sending circuit (drive circuit) 41. This example makes it possible to absorb fluctuations in the sensitivity of the receiving element of the ultrasonic sensor 18, and to prevent from attenuating the sensor output even in a case that the receiving circuit 14 includes a band pass filter.

**[0043]** FIG. 14 shows a process of adjusting the output level. The sensor control unit 101 sets the number of pulses (the number of waves) of drive pulses (burst waves) to be applied to the sending element of the ultrasonic sensor 17 to "1 wave" (step S51). The duty ratio then is set to 50%. In this state, the sensor control unit 101 monitors the input value  $V_{in}$  from the receiving element of the ultrasonic sensor 18 (step S52), and judges, after the monitoring, whether or not "the input value" > "the second slice upper limit" is satisfied (step S53). This second slice lower limit is an empirically determined value, and differs from the first slice lower limit. When "the input value" > "the second slice lower limit" is not satisfied, the sensor control unit 101 sets the number of burst waves to +1 (step S54), and then the process of the step S52 and its subsequence is repeated. When "the input value" > "the second slice lower limit" is satisfied, the sensor control unit 101 monitors the input value  $V_{in}$  from the receiving element of the ultrasonic sensor 18 (step S55), and further judges, after the monitoring, whether or not "the second slice upper limit" > "the input value" is satisfied (step S56). This second slice upper limit is an empirically determined value, and differs from the first slice upper limit. When "the second slice upper limit" > "the input value" is not satisfied, the sensor control unit 101 sets the value of the duty ratio (%) to a value shifted by -1% (step S57), and the process of the step S55 and its subsequence is repeated. When "the second slice upper limit" > "the input value" is satisfied, the process is ended.

**[0044]** Additionally, for comparison with FIG. 12A, one example of adjustment of the input value from a receiving element of the ultrasonic sensor 18 is shown in FIG. 12B. In FIG. 12B, numeral 42 denotes an amplifier circuit, 108 denotes a fixed resistor, 109 denotes a variable resistance, 110 denotes an operational amplifier, and  $V_{ref}$  de-

notes a reference voltage. As shown in FIG. 12B, according to the prior art, the input value from the receiving element of the ultrasonic sensor 18 is adjusted by varying the gain of the operational amplifier 110 with the variable resistance 109. This method, however, requires manual adjustment at the time of shipment or sensor replacement, and cannot adapt to status variations with the environment of use.

## 10 Industrial Applicability

**[0045]** As described above, according to the present invention, the threshold (decision slice value) set in a sheet feeding apparatus, since it is not fixed, can follow variations in the environment of detection or in the ultrasonic sensor's own characteristics and, even after shipment, double feed in the sheet feeding apparatus can be always detected accurately. That is, even in a case that the sensor output varies with fluctuations in the sensitivity, sound pressure or fitting of the ultrasonic sensor, its ambience or adhesion of paper powder, double feed can be detected without fail.

**[0046]** Further, according to the present invention, the input value from the receiving element of the ultrasonic sensor in the sheet feeding apparatus is adjusted either by altering the reference voltage of the operational amplifier or altering the frequency of clocks supplied by the drive circuit or the duty ratio. Therefore, at the time of shipping the sheet feeding apparatus, for example, there is no need to adjust the amplification rate of the amplifier of the ultrasonic receiving circuit with a variable resistance. This is also true at the time of replacing the ultrasonic sensor, for example. Even in a case that the ultrasonic receiving circuit comprises a band pass filter, the output of the receiving element of the ultrasonic sensor can be prevented from attenuating.

## 40 Claims

1. A sheet feeding apparatus for detecting transfer of a plurality of paper sheets by using ultrasonic waves, the apparatus comprising:

- a sending element of an ultrasonic sensor for outputting ultrasonic waves;
- a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element;
- a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves;
- a setting unit for setting a threshold for the detection of transfer of the plurality of paper sheets by using the output of the receiving element of the ultrasonic sensor at the time of stopping of

- the output of the sending element of the ultrasonic sensor as a basic value; and  
a detection unit for detecting transfer of the plurality of paper sheets by comparing the output of the receiving element of the ultrasonic sensor with the threshold. 5
2. The sheet feeding apparatus according to claim 1, wherein the threshold for detecting transfer of the plurality of paper sheets is obtained by adding a fixed value to the output of the receiving element of the ultrasonic sensor at the time of stopping the output of the sending element of the ultrasonic sensor. 10
  3. The sheet feeding apparatus according to claim 1, wherein the threshold for detecting transfer of the plurality of paper sheets is obtained by adding, to the output of the receiving element of the ultrasonic sensor at the time of stopping of the output of the sending element of the ultrasonic sensor, a value calculated, correspondingly to the output of the receiving element of the ultrasonic sensor at the time the sending element of the ultrasonic sensor is driven stepwise by the drive circuit, according to the correlation between the output and a correction value determined based on the correlation between the sensitivity and the output of the receiving element of the ultrasonic sensor and the correlation between the fitting position and the output of the receiving element of the ultrasonic sensor. 15 20 25 30
  4. The sheet feeding apparatus according to claim 1, wherein the output of the receiving element of the ultrasonic sensor at the time of stopping of the output of the sending element of the ultrasonic sensor is the average of a plurality of the outputs. 35
  5. The sheet feeding apparatus according to claim 1, wherein the output of the receiving element of the ultrasonic sensor is the average of a plurality of the outputs. 40
  6. The sheet feeding apparatus according to claim 1, wherein the detection unit judges that, when the output of the receiving element of the ultrasonic sensor is lower than the threshold a prescribed number of times or more often, transfer of the plurality of paper sheets is taking place. 45
  7. The sheet feeding apparatus according to claim 1, wherein the detection unit uses the threshold as a threshold for detecting transfer of the plurality of paper sheets regarding a plurality of types of paper sheets differing in ream weight. 50
  8. The sheet feeding apparatus according to claim 1, further comprising: 55
- a motor for transferring paper sheets,  
wherein the detection unit, in the event of detecting transfer of the plurality of paper sheets, drives the motor to stop the transfer of the paper sheets.
9. The sheet feeding apparatus according to claim 1, further comprising:  
feed rollers for transferring paper sheets to a reading position,  
wherein the sending element of the ultrasonic sensor and receiving element of the ultrasonic sensor are disposed upstream from the reading position on the transfer path and in the vicinity of downstream or upstream from the feed rollers.
  10. The sheet feeding apparatus according to claim 1, further comprising:  
a first amplifying circuit for amplifying the output of the receiving element of the ultrasonic sensor;  
a filter for removing noise from the output of the first amplifying circuit;  
a second amplifying circuit for amplifying the signals cleared of noise;  
a sample hold circuit for sampling and holding the peak value of the output of the second amplifying circuit; and  
an AD converter for converting the value held by the sample hold circuit into a digital signal and inputting it to the setting unit.
  11. A sheet feeding apparatus for detecting transfer of a plurality of paper sheets by using ultrasonic waves, the apparatus comprising:  
a sending element of an ultrasonic sensor for outputting ultrasonic waves;  
a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element;  
a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves;  
an amplifier, comprising an operational amplifier, for amplifying the output of the receiving element of the ultrasonic sensor; and  
an adjusting unit for forming a control signal for adjusting the output of the amplifier, whereby the reference voltage of the operational amplifier is adjusted.
  12. A sheet feeding apparatus for detecting transfer of a plurality of paper sheets by using ultrasonic waves, the apparatus comprising:

a sending element of an ultrasonic sensor for outputting ultrasonic waves;  
a receiving element of the ultrasonic sensor disposed opposite the sending element of the ultrasonic sensor across a sheet transfer path in the sheet feeding apparatus, and for receiving the ultrasonic waves;  
an amplifier for amplifying the output of the receiving element of the ultrasonic sensor;  
an adjusting unit for forming a control signal for adjusting the output of the amplifier; and  
a drive circuit for supplying the sending element of the ultrasonic sensor with a drive signal for driving the sending element, the drive circuit varying the number of waves or the duty ratio of clocks supplied to the sending element of the ultrasonic sensor according to the control signal from the adjusting unit.

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FIG. 1

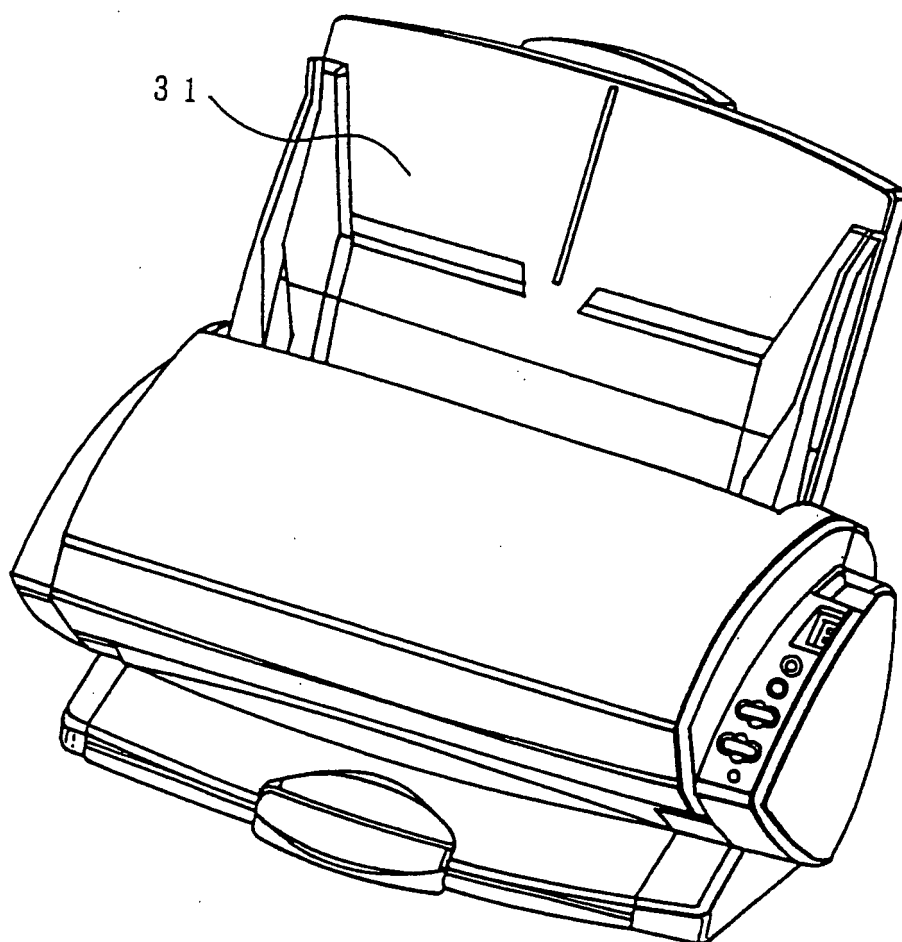


FIG. 2

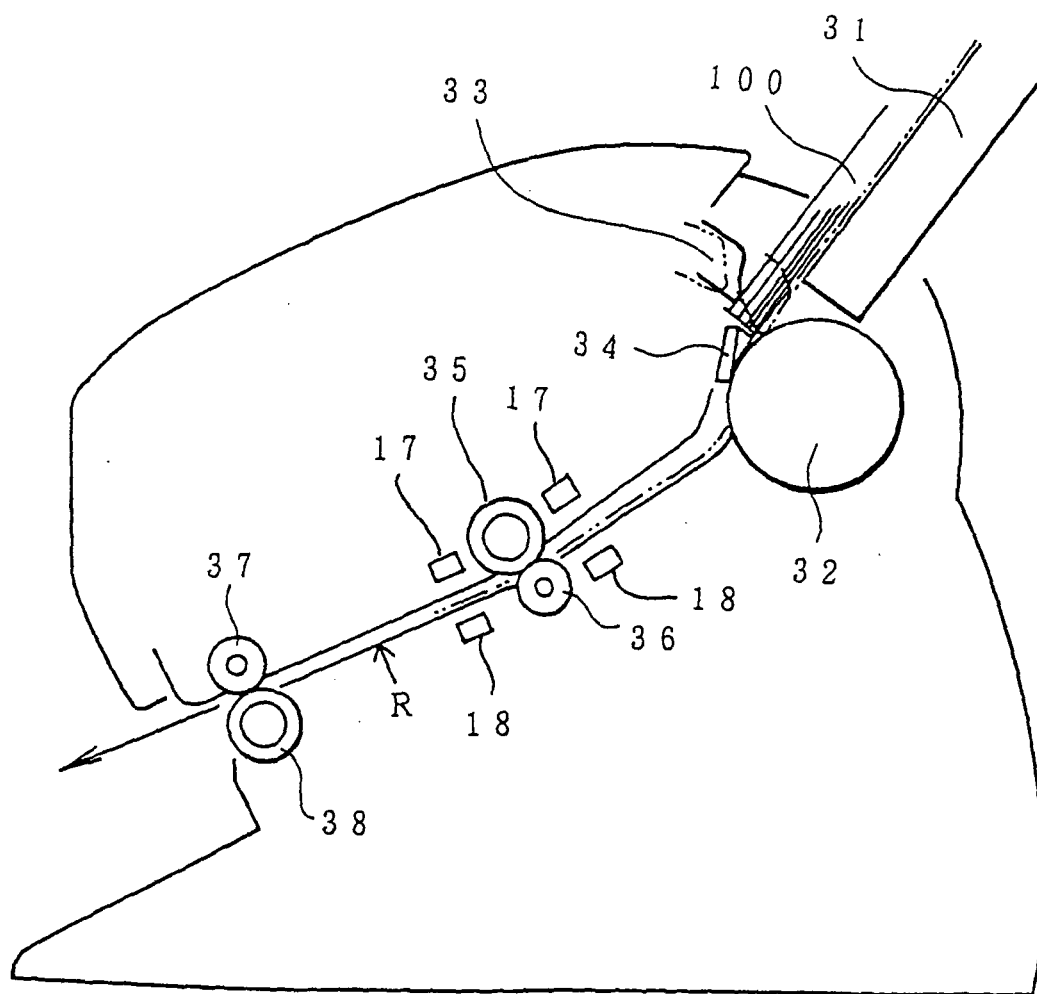


FIG. 3

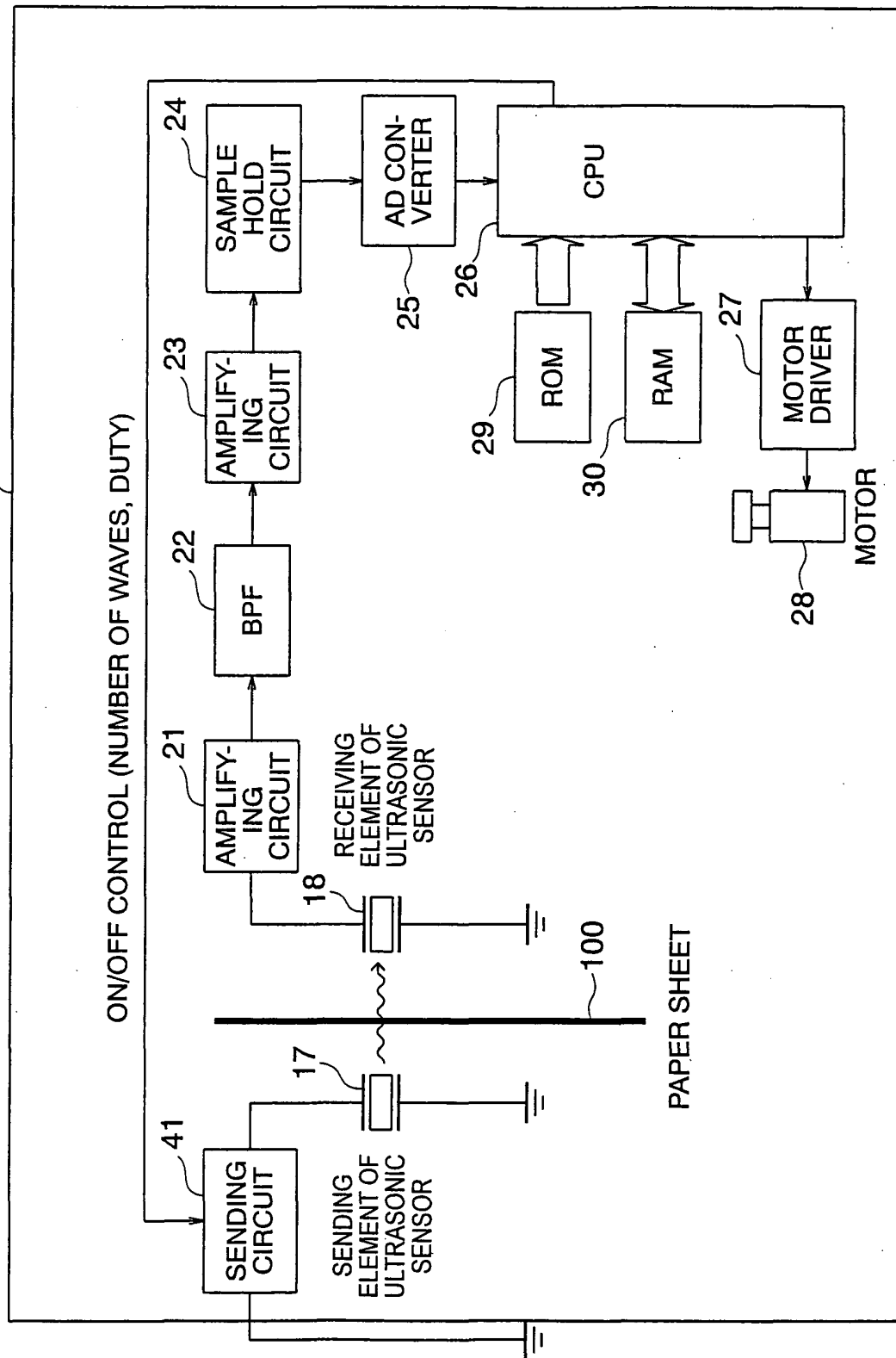


FIG. 4

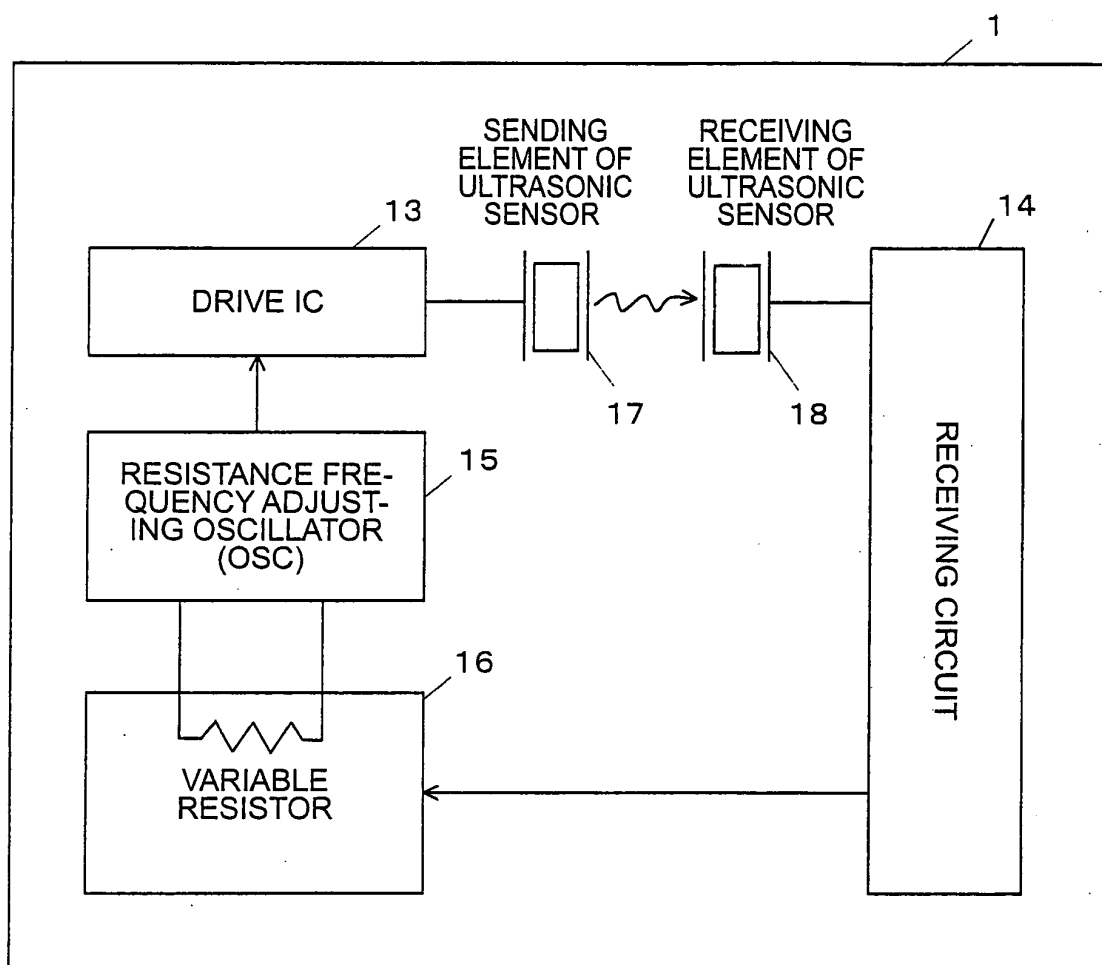


FIG. 5A

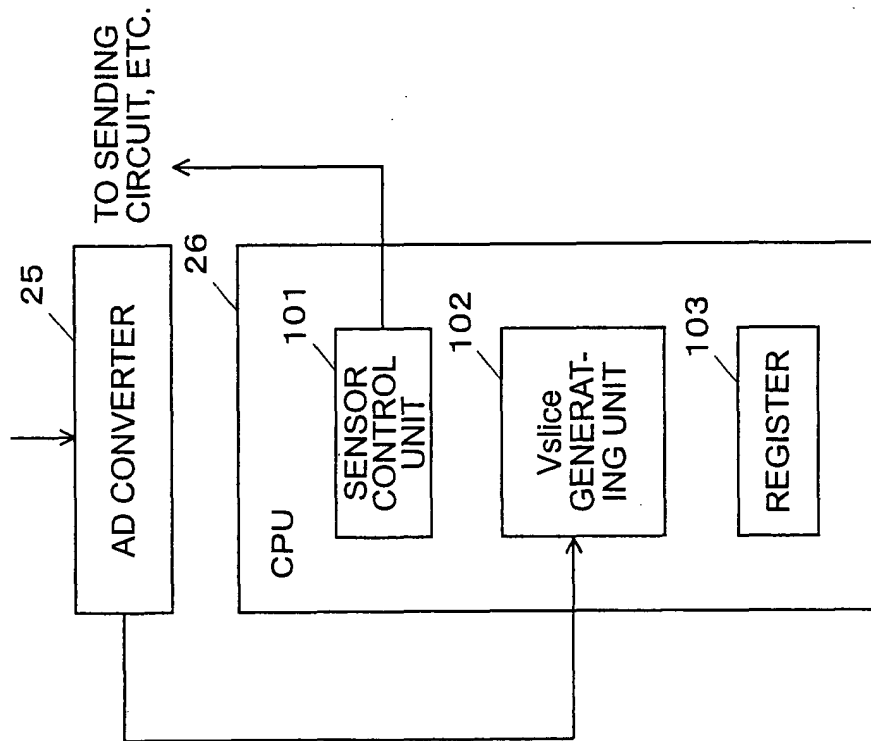


FIG. 5B

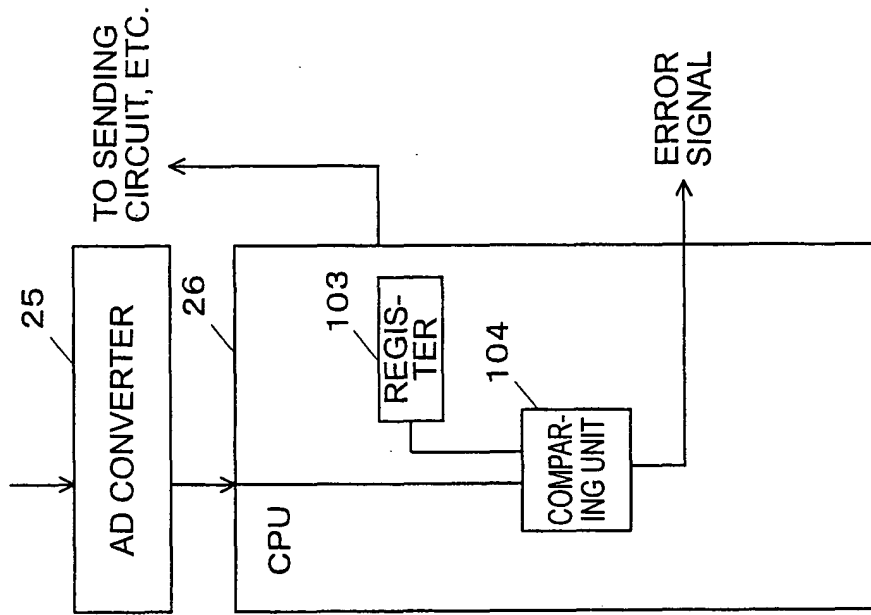


FIG. 6

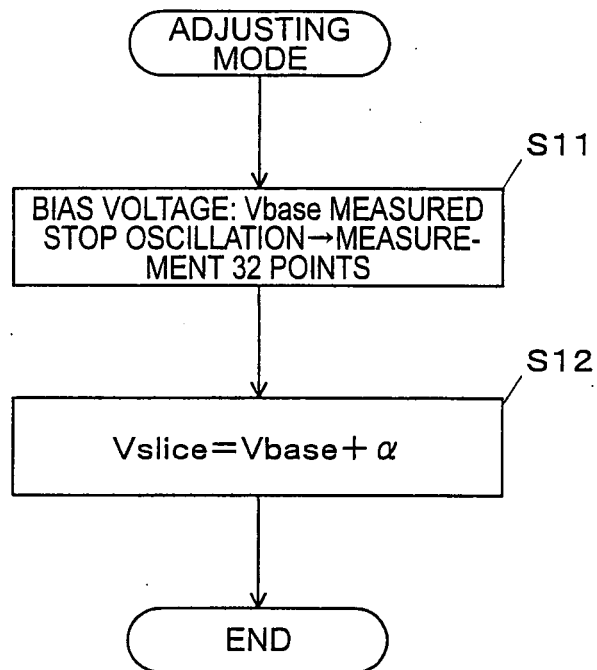
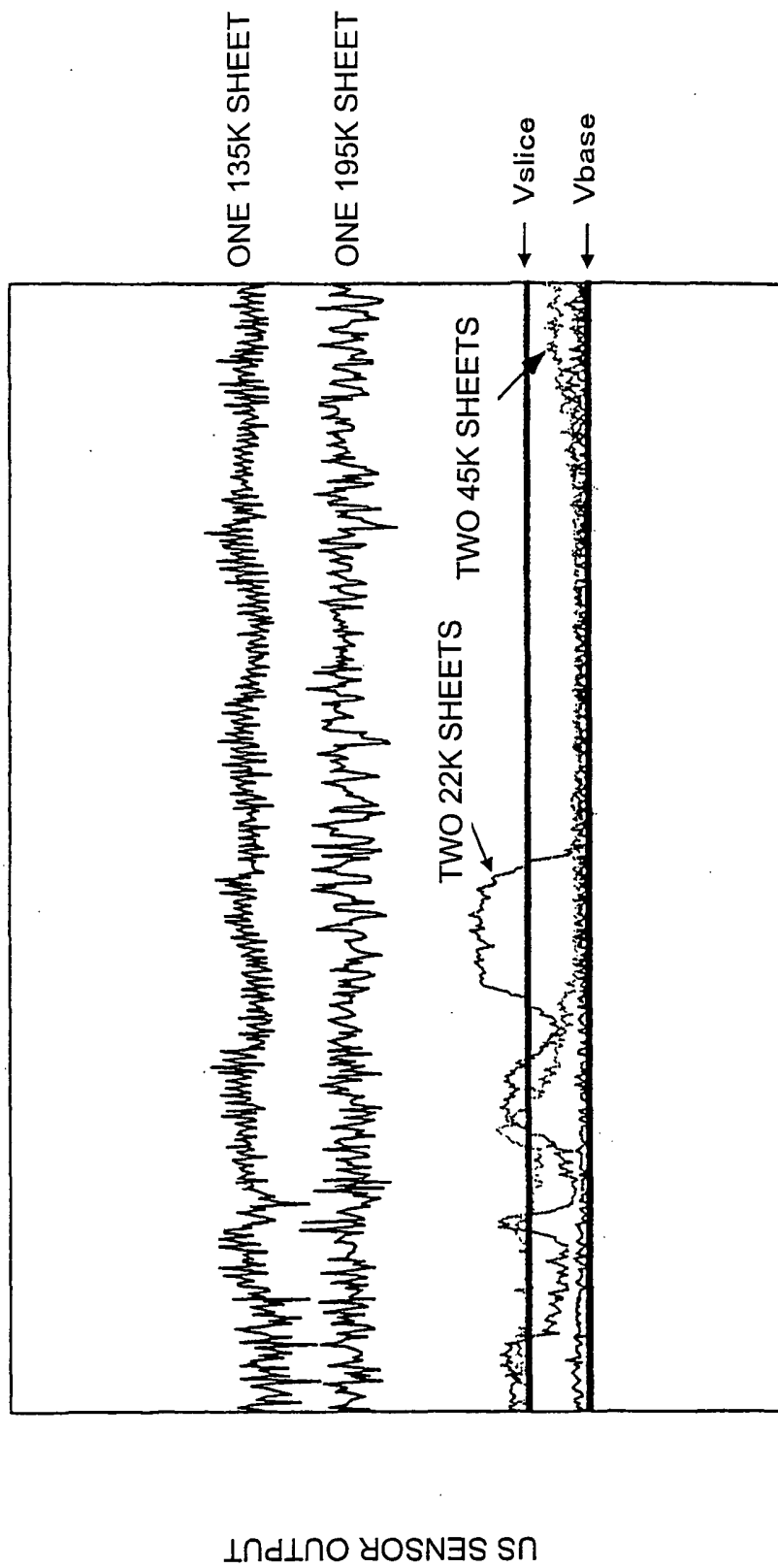


FIG. 7



VERTICAL SHEET SCANNING DIRECTION OF PAPER SHEETS (RASTER)

FIG. 8

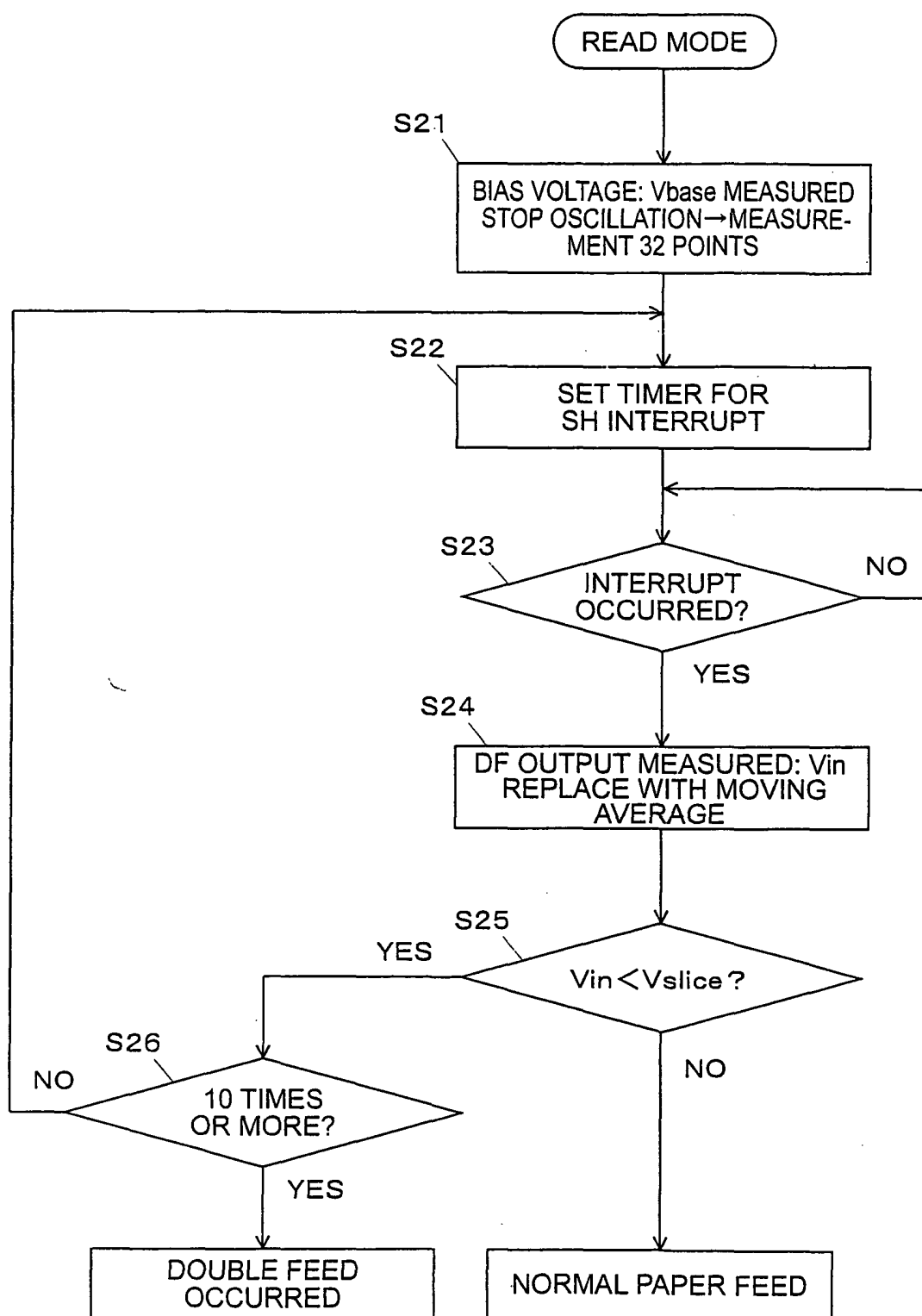


FIG. 9

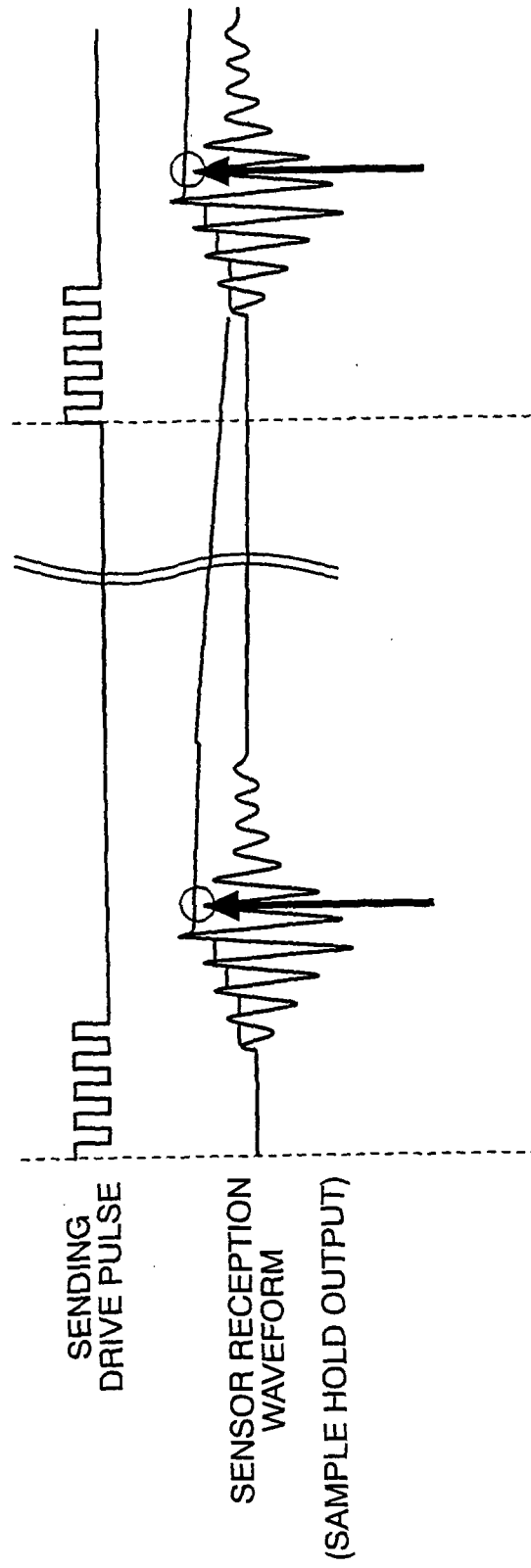


FIG. 10

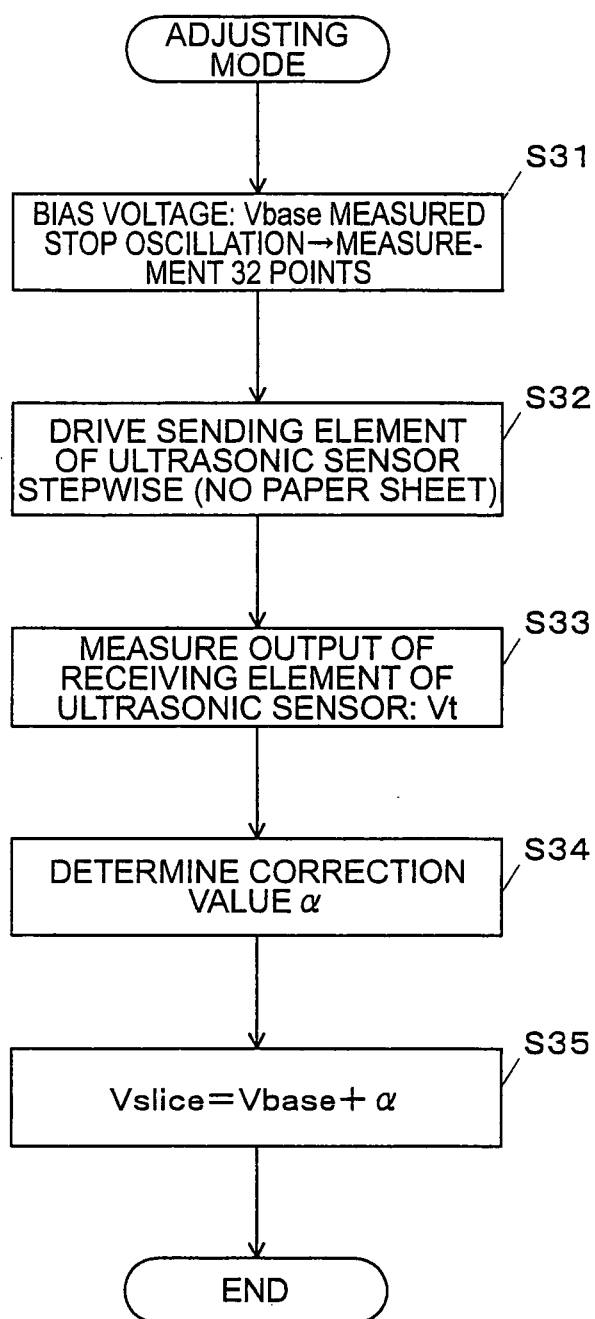


FIG. 11A

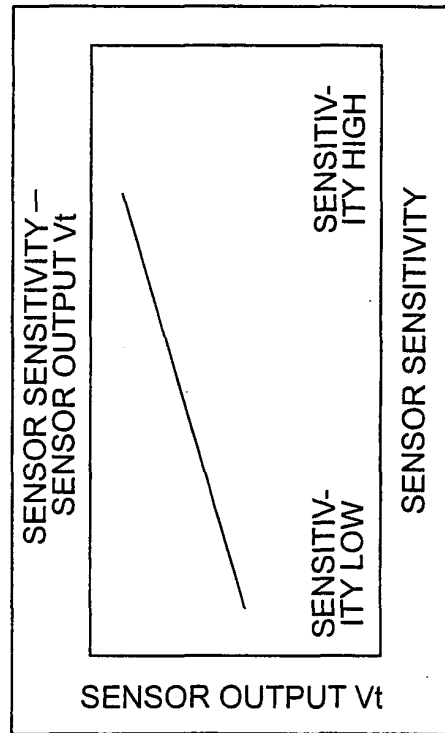


FIG. 11B

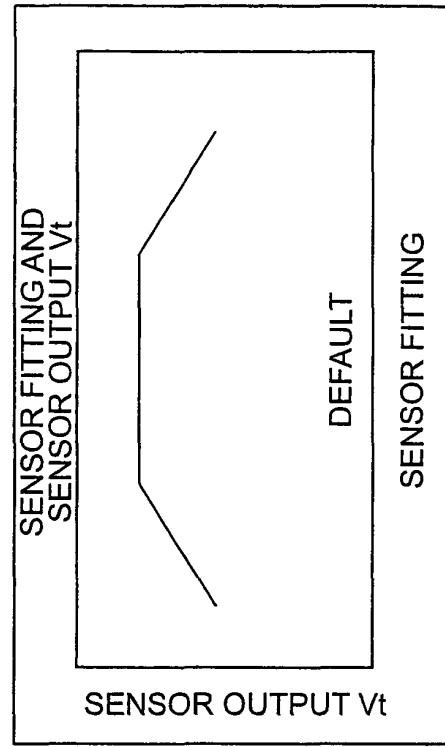


FIG. 11C

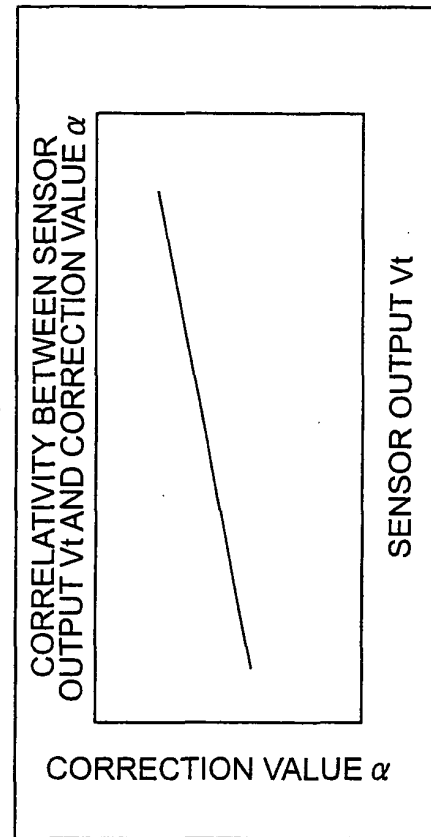


FIG. 12A

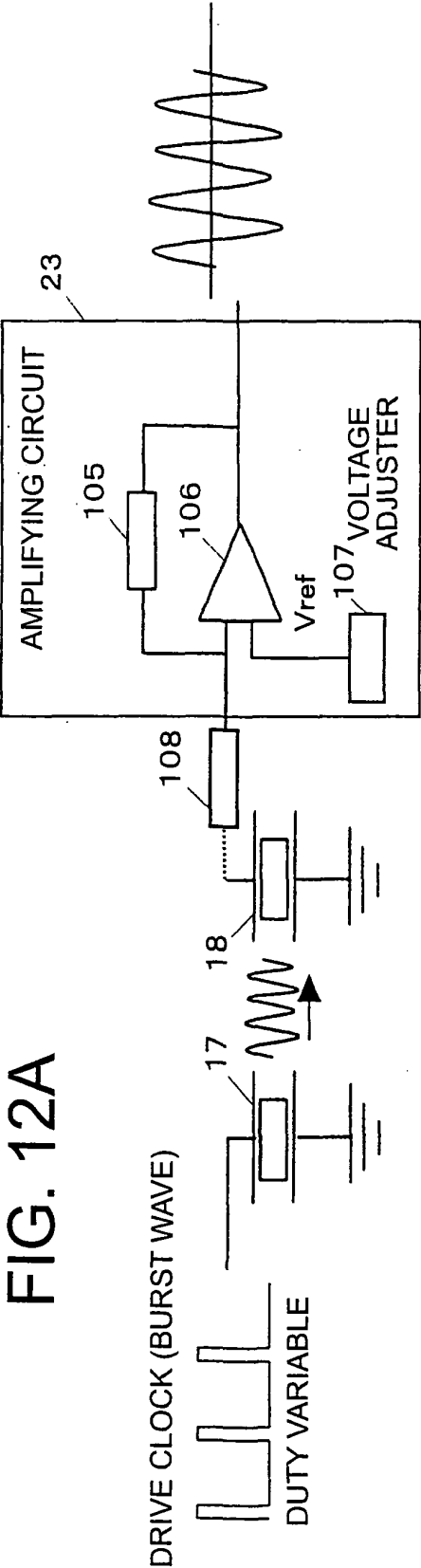


FIG. 12B

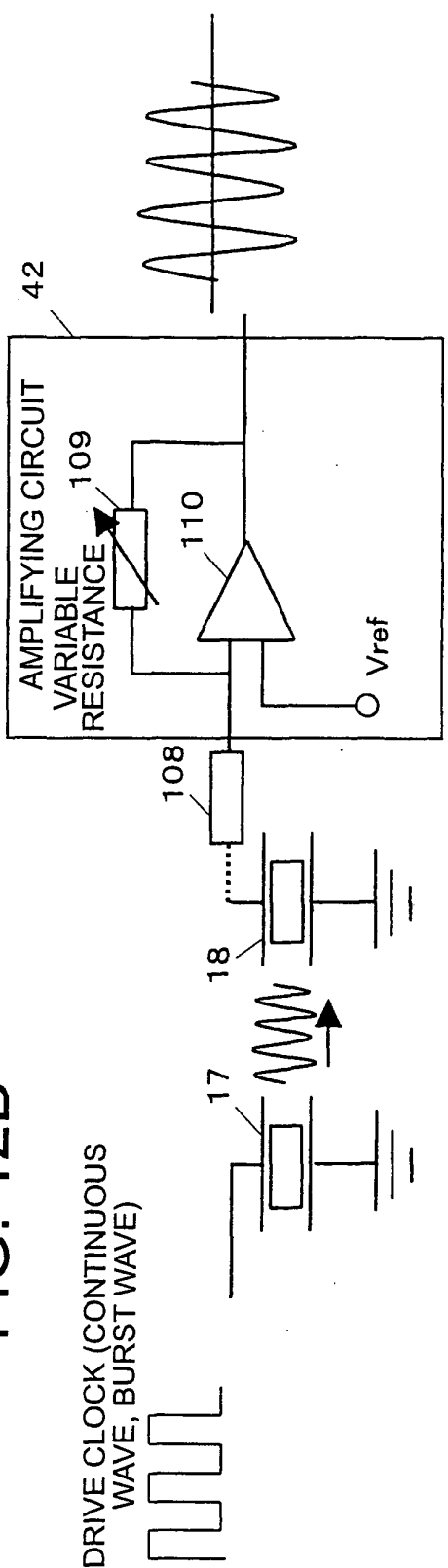


FIG. 13

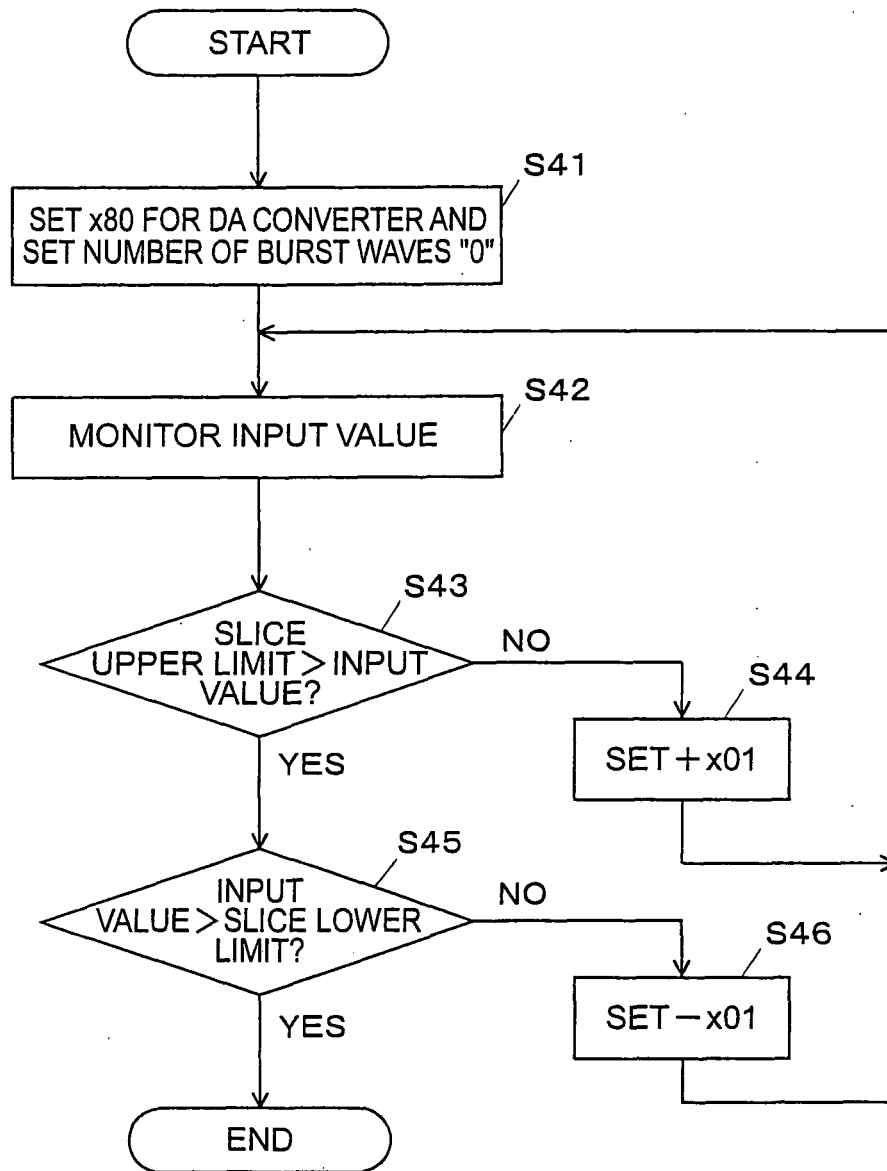
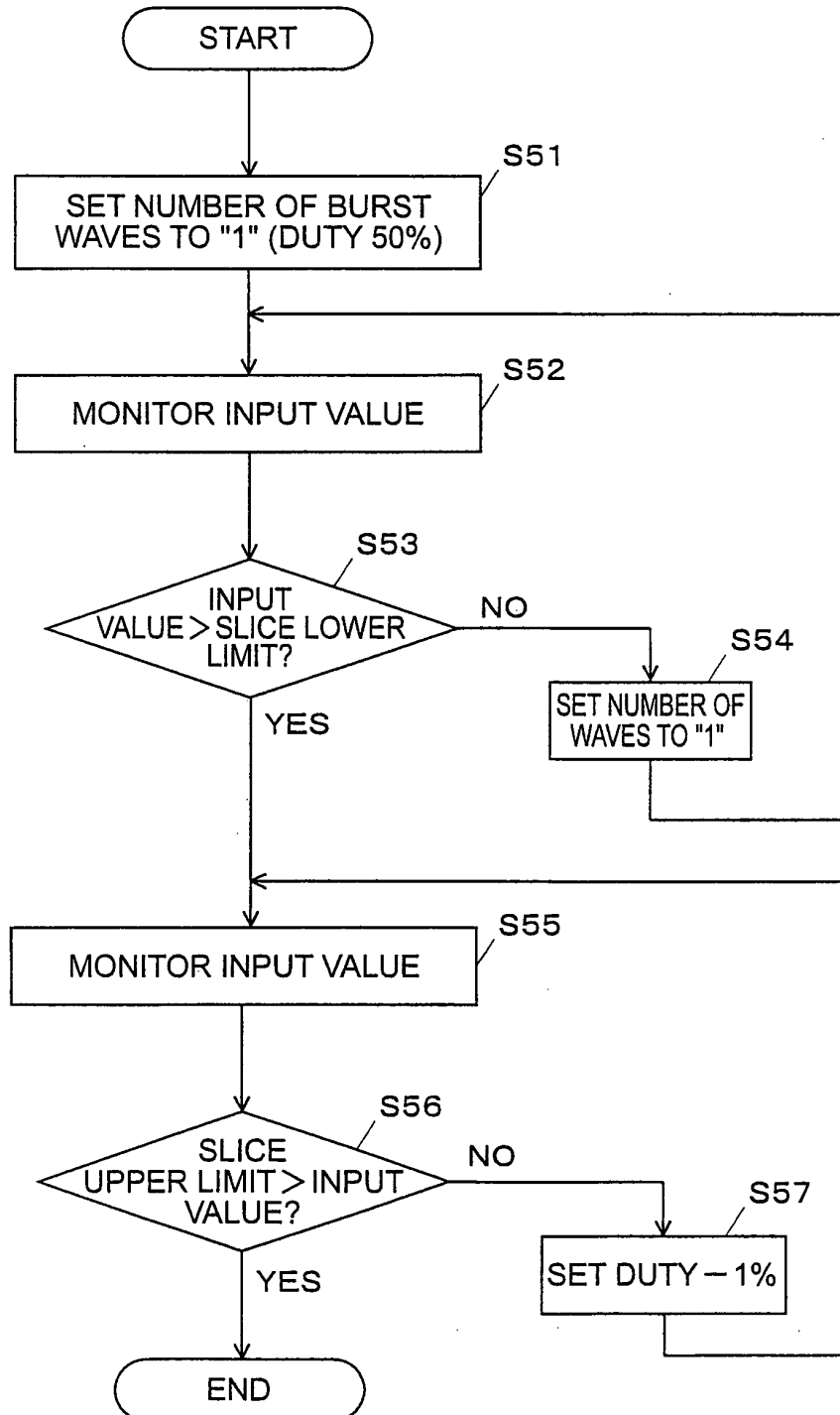


FIG. 14



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/003132

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>Int.Cl. <sup>7</sup> B65H7/12, G01B17/02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                         |                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                         |                                                                                |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br>Int.Cl. <sup>7</sup> B65H7/00-7/20, G01B17/00-17/04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                         |                                                                                |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2004<br>Kokai Jitsuyo Shinan Koho 1971-2004 Toroku Jitsuyo Shinan Koho 1994-2004                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                         |                                                                                |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                         |                                                                                |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                         |                                                                                |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                      | Relevant to claim No.                                                          |
| Y<br>X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | JP 62-70707 A (Sanko Seiki Kabushiki Kaisha),<br>01 April, 1987 (01.04.87),<br>(Family: none)                           | 1-10<br>11, 12                                                                 |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 2000-28358 A (Tokimec Inc.),<br>28 January, 2000 (28.01.00),<br>Par. No. [0024]<br>(Family: none)                    | 1-10                                                                           |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 8-208073 A (Fuji Photo Film Co., Ltd.),<br>13 August, 1996 (13.08.96),<br>Par. Nos. [0030], [0044]<br>(Family: none) | 2                                                                              |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                         |                                                                                |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |                                                                                                                         |                                                                                |
| Date of the actual completion of the international search<br>01 June, 2004 (01.06.04)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                         | Date of mailing of the international search report<br>15 June, 2004 (15.06.04) |
| Name and mailing address of the ISA/<br>Japanese Patent Office                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                         | Authorized officer                                                             |
| Facsimile No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                         | Telephone No.                                                                  |

Form PCT/ISA/210 (second sheet) (January 2004)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/003132

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                            | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | JP 10-338387 A (Copyer Co., Ltd.),<br>22 December, 1998 (22.12.98),<br>Par. Nos. [0004] to [0007]<br>& WO 98/056699 A1 & EP 930259 A1<br>& US 6348697 B1                                                                                                      | 3                     |
| Y         | JP 4-260557 A (Mitsubishi Heavy Industries, Ltd.),<br>16 September, 1992 (16.09.92),<br>Par. No. [0007]<br>(Family: none)                                                                                                                                     | 4                     |
| Y         | CD-ROM of the specification and drawings<br>annexed to the request of Japanese Utility<br>Model application No. 33596/1991(laid-open<br>No. 56851/1993)<br>(Kabushiki Kaisha Kosumo Tekku),<br>27 July, 1993 (27.07.93),<br>Par. No. [0003]<br>(Family: none) | 5                     |
| Y         | JP 10-329964 A (Omron Corp.),<br>15 December, 1998 (15.12.98),<br>Par. No. [0006]<br>(Family: none)                                                                                                                                                           | 6                     |
| Y         | JP 5-40030 A (Kabushiki Kaisha Kosumo Tekku),<br>19 February, 1993 (19.02.93),<br>Par. No. [0037]<br>(Family: none)                                                                                                                                           | 7                     |
| Y         | JP 2002-87641 A (Matsushita Electric Industrial<br>Co., Ltd.),<br>27 March, 2002 (27.03.02),<br>Fig. 2<br>(Family: none)                                                                                                                                      | 9                     |
| A         | JP 55-51375 A (Suzuki Fish Finder Co., Ltd.),<br>15 April, 1980 (15.04.80),<br>(Family: none)                                                                                                                                                                 | 1                     |
| A         | JP 4-323146 A (PFU Ltd.),<br>12 November, 1992 (12.11.92),<br>(Family: none)                                                                                                                                                                                  | 7                     |

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/003132

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-10 relate to the setting of a threshold value for a receiver-side ultrasonic sensor.

Claims 11, 12 relate to adjustment of the output from an amplifier for the receiver-side ultrasonic sensor.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.