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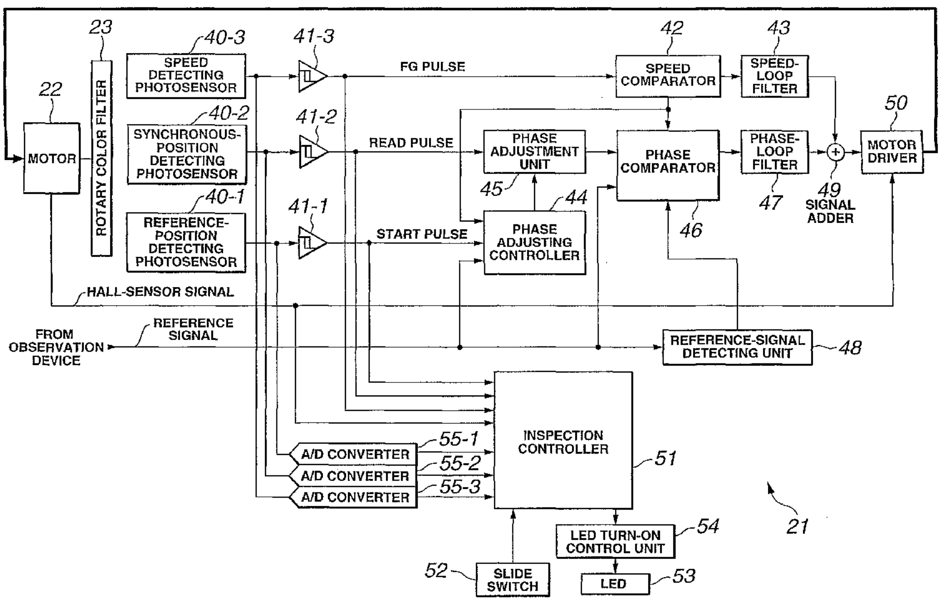
(54) **Title:** ENDOSCOPE LIGHT SOURCE DEVICE



(57) **Abstract:** An endoscope light-source device includes a rotation-speed comparator (42), a phase adjusting controller (44), a phase adjustment unit (45), and a motor driver (50). The rotation speed comparator detects and compares the rotation speed of a rotary color filter (23). The phase adjusting controller detects the phase difference between a rotation-position detection signal of the rotary color filter and a reading signal for reading a captured-image signal from a solid-state image pickup device when the speed comparator determines that the rotary color filter reaches a predetermined speed. The phase adjustment unit delays the phase of the rotation position detection signal of the rotary color filter based on the phase difference detected by the phase adjusting controller.

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DESCRIPTION

ENDOSCOPE LIGHT SOURCE DEVICE

Technical Field

The present invention relates to endoscope light-source devices used for electronic endoscope apparatuses. More particularly, the present invention relates to an endoscope light-source device that controls the rotation speed of a rotary color filter for sequentially emitting illumination light having different wavelength ranges in synchronization with the timing of reading a captured-image signal generated by picking up an image based on the illumination light.

Background Art

In recent years, electronic endoscope apparatuses having image pickup means of compact, high-definition-pixel solid-state image pickup devices have been widely in use. As methods employed for electronic endoscope apparatuses having the image pickup means of such solid-stage image pickup devices, a one-time pass image pickup method and a field-sequential image pickup method are available for generating color captured images of observed areas.

In the one-time pass image pickup method, a color image signal is obtained by causing color filters to divide light of an observed area illuminated with white light into the three primary colors, i.e., red (R), green (G), and blue (B), by simultaneously generating respective image signals using solid-state image pickup devices corresponding to the three primary colors, and by combining the image signals.

In the field-sequential image pickup method, a color image signal is obtained by sequentially projecting illumination light having different wavelength ranges (the three primary colors: red (R), green (G), and blue (B)) onto an observed area through a rotary color filter and by combining image signals, which have respective wavelength ranges, of images captured by a single solid-state image pickup device based on the illumination light.

In the field-sequential image pickup method, the rotary color filter has three-primary-color filters, which are arranged at predetermined intervals, and light-shielding portions, which are respectively arranged between the corresponding three-primary-color filters. Three-primary-color illumination light is sequentially emitted through the three-primary-color filters to illuminate an observed area, an image of which is captured by the solid-state image pickup device so that light reflected from the observed area is subjected to photoelectric conversion. During a period when electrical charge obtained by the photoelectric conversion by the solid-state image pickup device is read as a captured-image signal, the illumination light is shielded by the light-shielding portions.

During a period when the captured-image signal generated by the solid-state image pickup device is read, in order to ensure that the illumination light is prevented from being projected onto the solid-state image pickup device, the rotary color filter needs to be controlled such that the rotational drive thereof is synchronized with the reading of the captured-image signal output from the solid-state image pickup device and the phase thereof is constant.

A servo control for performing phase matching between the reading of each captured-image signal generated by the solid-state image pickup device and the cycle of the rotational drive of the rotary color filter has been proposed. For example, a motor control apparatus for controlling the reading of a captured-image signal and the phase of the rotary color filter includes Japanese Unexamined Patent Application Publication No. 8-107879 (hereinafter referred to as Patent Document 1). Wherein, the rotation speed of a motor for rotationally driving the rotary color filter is controlled by counting the cycle of rotation pulses of the motor based on a reference clock signal such that the cycle of the rotation pulses is equal to a predetermined rotation pulse cycle. Also, the rotary color filter has a light exposure period in which light is transmitted and a light shielding period in which light is shielded. Thus, in order that a captured-image electrical charge stored through the exposure of the solid-state image pickup device during the light exposure period is read during the light exposure period to generate a captured-image signal, light reflected from a silk-type reflector that is provided on a rotary color filter and that indicates a reading reference position is read by a sensor and the phase of a signal of the read reference position read by the sensor is compared with the phase of vertical synchronization signal of the read captured-image signal.

A light source device having a built-in motor drive control device for rotationally driving the rotary color filter, used in such a conventional electronic endoscope apparatus, for sequentially projecting three-primary-color illumination light, causes a variation in rotational drive phase of the rotary color filter relative to a reading signal for the solid-state image pickup device, depending on the characteristics of components. Thus, alignmental adjustment is performed before shipment from a factory.

In addition, the motor control device disclosed in Patent Document 1 described above requires a long light-shielding period, considering variations in alignmental adjustment, in order to ensure that the rotary color filter shields light during a read period of the solid-state image pickup device. As a result, the light exposure period is reduced.

Also, when a component is replaced due to a breakdown or a life cycle, the alignmental adjustment needs to be carried out again.

That is, when the field-sequential image pickup method is used for an electronic endoscope apparatus, a motor control device, which is provided for a rotary color filter in a light source device, for matching the reading of a captured-image signal from a solid-state image pickup device with the cycle of rotational drive of the rotary color filter has a variation in the rotation phase difference depending on each individual motor control device because of variations in components. As a result, the motor control device requires alignmental adjustment before shipment from a factory. Also, when the period in which the rotary color filter shields light is extended considering variations in the alignmental adjustment, the light-exposure period is reduced. Further, when a component is replaced due to a breakdown or a life cycle, the alignmental adjustment of the phase needs to be carried out again.

In view of the above-described problems, an object of the present invention is to provide an endoscope light-source device that ensures the servo-control of the rotation speed and phase of a rotary color filter relative to the reading of a captured-image signal from a solid-state image pickup device, that eliminates a need for alignmental adjustment for variations in components, and that is robust against characteristic changes in the components.

Disclosure of Invention

The present invention provides an endoscope light-source device that is used for an electronic endoscope apparatus having a solid-state image pickup device for capturing an image of an observed area illuminated with illumination light that has different wavelength ranges and is sequentially emitted through a rotary color filter. The endoscope light-source device includes: a driving section for rotating the rotary color filter; a rotation-position detecting section for detecting a rotation position of the rotary color filter rotated by the driving section; a phase-difference detecting section for detecting a phase difference between a reading signal for reading a captured-image signal from the solid-state image pickup device and the rotation-position signal; and a phase delaying section for delaying the rotation-position signal in accordance with the phase difference detected by the phase-difference detecting section.

Brief Description of the Drawings

Fig. 1 is a constitutional diagram showing the schematic configuration of an electronic endoscope apparatus using an endoscope light-source device according to the present invention.

Fig. 2 is a block diagram showing the overall configuration of the electronic endoscope apparatus using the endoscope light-source device according to the present invention.

Fig. 3 is a plan view showing the configuration of a rotary color filter for use in an endoscope light-source device according a first embodiment of the present invention.

Fig. 4 is a block diagram illustrating the configuration of a motor control circuit for use in the endoscope light-source device according to the first embodiment of the present invention.

Fig. 5 is a flow chart illustrating the processing operation of an inspection controller of the endoscope light-source device according to the first embodiment of the present invention.

Figs. 6A to 6H are waveform diagrams showing processing operation timings of the inspection controller of the endoscope light-source device according to the first embodiment of the present invention.

Figs. 7A to 7I are waveform diagrams illustrating operation timings of a motor control servo of the endoscope light-source device according to the first embodiment of the present invention.

Fig. 8 is a plan view illustrating the configuration of a rotary color filter for use in an endoscope light-source device according to a second embodiment of the present invention.

Fig. 9 is a block diagram showing the configuration of a motor control circuit for use in the endoscope light-source device according to the second embodiment of the present invention.

Fig. 10 is a flow chart illustrating the rotation control of the rotary color filter of the motor control circuit for use in the endoscope light-source device according to the second embodiment of the present invention.

Fig. 11 is a flow chart illustrating the inspection operation of a speed and synchronous-position detecting photosensor for combined use and a reference-position detecting photosensor in the motor control circuit for use in the endoscope light-source device according to the second embodiment of the present invention.

Fig. 12 is a flow chart illustrating the inspection operation of the speed and synchronous-position detecting photosensor for combined use and the reference-position detecting photosensor in the motor control circuit for use in the endoscope light-source device according to the second embodiment of the present invention.

Figs. 13A to 13J are waveform diagrams illustrating operation timings of a motor control servo of the endoscope light-source device according to the second embodiment of the present invention.

Best Mode for Implementing the Invention

Embodiments of the present invention will be described below with reference to the accompanying drawings.

(First Embodiment)

First, an endoscope light-source device according to a first embodiment of the present invention will be described with reference to Figs. 1 to 7.

Fig. 1 is a constitutional diagram showing the schematic configuration of an electronic endoscope apparatus using an endoscope light-source device according to the present embodiment. Fig. 2 is a block diagram showing the overall configuration of the electronic endoscope apparatus using the endoscope light-source device according to the present embodiment. Fig. 3 is a plan view showing the configuration of a rotary color filter for use in the endoscope light-source device according to a first embodiment of the present embodiment. Fig. 4 is a block diagram showing the configuration of a motor control circuit for use in the endoscope light-source device according to the present embodiment. Fig. 5 is a flow chart illustrating the processing operation of an inspection controller in the endoscope light-source device according to the present embodiment. Figs. 6A to 6H are waveform diagrams showing processing operation timings of the inspection controller in the endoscope light-source device according to the present embodiment. Figs. 7A to 7I are waveform diagrams illustrating operation timings of a motor control servo in the endoscope light-source device according to the present embodiment.

As shown in Fig. 1, an electronic endoscope apparatus using an endoscope light-source device according to the present embodiment includes an endoscope unit 10, which has a main unit 11 and an endoscope insert unit 12, an observation device 14, a light source device 15, and a color monitor 16. The main unit 11 of the endoscope unit 10 is connected to the observation device 14 and the light source device 15 via a connection unit 17. The endoscope insert unit 12 is inserted into a living body 13. The color monitor 16 is connected to the observation device 14.

Illumination light produced and emitted by the light source device 15 is introduced into a light guide 25 (shown in Fig. 2), which is provided in the connection unit 17, and the main unit 11 and the endoscope insert unit 12 of the endoscope unit 10, and is projected from a distal end of the endoscope insert unit 12.

The illumination light emitted by the light source device 15 and projected from the distal end of the endoscope insert portion 12 illuminates an observed area in the living body 13 and an image of the observed area is converted by a solid-state image pickup device 26 (hereinafter referred to as a "CCD: charge coupled device"), which is disposed at the distal end of the endoscope insert unit 12 and is shown in Fig. 2, into a captured-image signal.

The observation device 14 includes a CCD driver 27 (shown in Fig. 2) and a video processing circuit 28. The CCD driver 27 drives and controls the CCD 26, and the video processing circuit 28 processes the captured-image signal, which is generated by the CCD 26, and generates and outputs a video signal according to an NTSC method or the like. The video signal generated by the observation device 14 is supplied to the color monitor 16 and the image of the observed area is displayed on the screen thereof.

The configurations of the endoscope insert unit 12, the observation device 14, and the light source device 15 of the electronic endoscope apparatus configured as described above will now be described in detail with reference to Fig. 2.

The light source device 15 includes: a lamp 20, of which turning on and off are controlled by a lamp turn-on control circuit which is not shown; a rotary color filter 23; a motor 22 for driving and rotating the rotary color filter 23; a motor control circuit 21 for controlling the rotational drive of the motor 22; and an illumination lens 24 that converges the three-primary-color illumination light, which has been transmitted through the corresponding color filters of the rotary color filter 23, and emits the resulting light. The rotary color filter 23 has color filters for the three primary colors, i.e., red (R), green (G), and blue (B), and light-shielding portions arranged between the corresponding color filters. The R, G, and B color filters transmit the R, G, and B colors of the illumination light emitted by the lamp 20.

That is, the motor 22 is driven under the control of the motor control circuit 21, so that the rotary color filter 23 is rotationally driven. The illumination light emitted by the lamp 20 is transmitted through the R, G, and B color filters of the rotary color filter 23 and the resulting illumination light is emitted from the illumination lens 24.

The illumination light that has transmitted through the R, G, and B color filters and that has emitted from the illumination lens 24 is projected into one end of the light guide 25, which is provided in the connection unit 17, the main unit 11, and the endoscope insert unit 12, and is introduced into the light guide 25 and is emitted to the living body 13 from the other end of the light guide 25, i.e., a distal end portion of the endoscope insert unit 12. Light reflected from the observed area is projected onto an image capturing surface of the CCD 26, which is disposed at the distal end portion of the endoscope insert unit 12, and is subjected to photoelectric conversion.

The observation device 14 includes the CCD driver 27 and the video processing circuit 28. The CCD driver 27 drives and controls the CCD 26, which is disposed at the distal end portion of the endoscope insert unit 12, such that the CCD 26 performs photo-electric conversion to produce electrical charge for the observed area. The video processing circuit 28 reads the electrical charge and processes a captured-image signal.

That is, the CCD driver 27 drives and controls the CCD 26 for converting photo-electrically light reflected from the observed area intermittently illuminated with R, G, and B field-sequential light transmitted through the R, G, and B color filters of the rotary color filter 23 and the light-shielding portions arranged among the corresponding color filters. The video processing circuit 28 controls the reading of R, G, and B captured-image signals that are photo-electrically converted by the CCD 26, while the light-shielding portions of the rotary color filter 23 are shielding the illumination light.

The video processing circuit 28 combines the R, G, and

B color captured-image signals, which have been sequentially read from the CCD 26, to produce, for example, a standard video signal according to the NTSC method, and outputs the video signal to the color monitor 16. Based on the video signal, the color monitor 16 displays the observed-area color image on the monitor screen thereof.

Further, the video processing circuit 28 of the observation device 14 outputs a reference signal to the motor control circuit 21 of the light source device 15. The reference signal is used to synchronize the timing of reading photoelectric conversion charge of the CCD 26 and the timing of shielding the R, G, and B illumination light transmitted through the rotary color filter 23. The reference signal is, for example, a vertical synchronization signal of the video signal generated by the video processing circuit 28.

The configuration of the rotary color filter 23 will now be described with reference to Fig. 3.

The rotary color filter 23 has a disc shape. Along the outer periphery portion of the rotary color filter 23, an R color filter 30r for transmitting red light, a G color filter 30g for transmitting green light, and a B color filter 30b for transmitting blue light, as well as light-shielding portions are sequentially provided. The light-shielding portions are arranged among the corresponding R, G, and B color filters 30r, 30g, and 30b. The light-shielding portions are arranged such that they prevent the illumination light from the lamp 20 from being transmitted to the illumination lens 24, for example, during a period when an R captured-image signal, which results from the photoelectric conversion by the CCD 26 based on the illumination light of the R color filter 30r, is read.

At the inner periphery portion of the rotary color filter 23, silk-type reflectors (hereinafter simply referred to as "silks") are disposed serving as three types of marks for detection of the rotational state of the rotary color filter 23.

The silks, which are provided on the rotary color filter 23 so as to serve as three types of marks, are arranged in three types of concentric circles with different diameters such that the outer circumferences and the inner circumferences of the silks that are provided at different diameters do not overlap each other.

Of the three concentric circles of the rotary color filter 23, the innermost peripheral circle has one reference-position detecting silk 31 for identifying the reference position of the rotary color filter 23.

Of the three concentric circles, the circle outside the innermost peripheral circle, which has the reference-position detecting silk 31, has three synchronous-position detecting silk 32-1 to 32-3 for synchronization with the reference signal sent from the observation device 14. The synchronous-position detecting silk 32-1 to 32-3 are arranged in a plane perpendicular to the rotation axis of the rotary color filter 23 at the same angle about the rotation axis.

Of the three concentric circles, the circle that is located outside the outermost circumference of the synchronous-position detecting silks 32-1 to 32-3 and that is located inside the inner circumference of the color filters 30r, 30b, and 30g, and the light-shielding portion has 12 speed detecting silks 33-1 to 33-12 for determining the rotation speed of the rotary color filter 23. The speed detecting silks 33-1 to 33-12 are arranged in the plane perpendicular to the rotation axis of the rotary color filter 23 at the same angle about the rotation axis.

The configuration of the motor control circuit 21, which is provided in the light source device 15, for controlling the rotation of the motor 22 for rotationally driving the rotary color filter 23 having the configuration described above will now be described with reference to Fig. 4.

In order to detect the rotational state of the rotary color filter 23 rotationally driven by the motor 22, three types of photosensors 40-1 to 40-3 for detecting the three types of silks 31, 32-1 to 32-3, and 33-1 to 33-12, which are concentrically arranged on the rotary color filter 23, are provided in the motor control circuit 21.

Specifically, the photosensor 40-1 serves as a reference-position detecting photosensor for detecting one reference-position detecting silk 31, which is provided at the innermost periphery of the rotary color filter 23, and the photosensor 40-2 serves as a synchronous-position detecting photosensor for detecting the three synchronous-position detecting silk 32-1 to 32-3, which are provided at the outer circumference side of the reference-position detecting silk 31. Further, the photosensor 40-3 serves as a speed detecting photosensor for detecting the 12 speed detecting silks 33-1 to 33-12, which are provided at the outer circumference side of the synchronous-position detecting silk 32-1 to 32-3.

Waveform shaping circuits 41-1 to 41-3, such as Schmidt trigger circuits, are provided. Thus, upon detecting the reference-position detecting silk 31, the synchronous-position detecting silk 32-1 to 32-3, and the speed detecting silks 33-1 to 33-12, the three types of photosensors 40-1 to 40-3 output respective analog waveforms. Upon receiving the analog waveforms, the waveform shaping circuits 41-1 to 41-3 convert the analog waveforms into respective digital pulses.

That is, the speed detecting photosensor 40-3 detects the speed detecting silks 33-1 to 33-12 of the rotary color filter 23, and the waveform shaping circuit 41-3 converts the analog waveform into FG pulses, which are digital pulses, and outputs the FG pulses to a speed comparator 42.

The speed comparator 42 determines the time difference between the cycle of the FG pulses and a preset target cycle, and outputs any time difference to a speed-loop filter 43 as an error voltage.

The speed comparator 42 has a function for determining whether the FG pulse cycle is close to the target cycle and whether the error voltage indicating the time difference is not greater than the upper limit of the error voltage or is not smaller than the lower limit thereof.

That is, when the motor 22 is rotationally driven upon the supply of power and the rotation speed of the rotary color filter 23 reaches a predetermined value, the speed comparator 42 determines whether the cycle of the FG pulses provided by the speed detecting silks 33-1 to 33-12 reaches a speed comparable range that allows comparison with a predetermined cycle. The speed comparator 42 outputs a determination-result signal, which indicates whether the FG pulse cycle is within or without the speed comparison range, to a phase adjusting controller 44 and a phase comparator 46, which are described below.

The speed-loop filter 43 adjusts the level and frequency characteristics of the error voltage that is output from the speed comparator 42 and that indicates the time difference between the FG pulse cycle and the target cycle, and outputs the adjusted voltage.

That is, the speed detecting photosensor 40-3 and the waveform shaping circuit 41-3 are means for detecting the rotation speed of the rotary color filter 23 and for generating a control signal for rotationally driving the rotary color filter 23 at a predetermined speed.

The reference-position detecting photosensor 40-1 detects the reference-position detecting silk 31 of the rotary color filter 23, and the waveform shaping circuit 41-1 converts the detected result into digital-pulsed START pulses, and the START pulses are output to the phase adjusting controller 44.

In addition to the START pulses, the determination-result signal, supplied from the speed comparator 42 and indicating by the FG pulse cycle whether the rotational drive of rotary color filter 23 is within or without the speed comparable range, and the reference signal supplied from the observation device 14 are supplied to the phase adjusting controller 44.

The phase adjusting controller 44 operates in response to the detection-result signal supplied from the speed comparator 42 and indicating that the FG pulse cycle is within the speed comparison range. Further, in accordance with the reference signal supplied from the observation device 14, the phase adjusting controller 44 is in a standby state until a predetermined number of START pulses are received and the synchronization of the START pulses with the reference signal becomes stable.

That is, upon receiving a predetermined number of START pulses, the phase adjusting controller 44 measures, just once, the phase difference between the phase of the reference signal relative to the START pulses and a preset target phase, and outputs the measured phase difference to a phase adjustment unit 45.

That is, the reference-position detecting photosensor 40-1, the waveform shaping circuit 41-1, and the phase adjusting controller 44 are means for detecting the number of rotations of the rotary color filter 23.

The synchronous-position detecting photosensor 40-2 detects the synchronous-position detecting silk 32-1 to 32-3 of the rotary color filter 23, and the waveform shaping circuit 41-2 converts the detected result into digital-pulsed READ pulses, which are then input in the phase adjustment unit 45. In response to the READ pulses, the phase adjustment unit 45 generates pulses that are delayed in phase from the READ pulses and to output that pulses to the phase comparator 46, so as to cancel the phase difference between the phase of the reference signal relative to the START pulses and the preset target phase, the phase difference being output from the phase adjusting controller 44.

That is, the reference-position detecting photosensor 40-1, the waveform shaping circuit 41-1, the synchronous-position detecting photosensor 40-2, and the waveform shaping circuit 41-2 are means for detecting the rotational position of the rotary color filter 23.

The phase comparator 46 operates in response to the determination-result signal supplied from speed comparator 42 and indicating that the FG pulse cycle is within the speed comparable range. During the reception of the reference signal, the phase comparator 46 compares the phase of the reference signal with the phase of the pulses that are received from the phase adjustment unit 45 and that are delayed in phase from the READ pulses and to output the resulting phase difference as an error voltage to a phase-loop filter 47.

When the signal received from the speed comparator 42 indicates that the FG pulse cycle is without the speed comparable range, the phase comparator 46 does not output the error signal to the phase-loop filter 47.

The phase-loop filter 47 adjusts the level and frequency characteristics of the signal received from the phase comparator 46 and to output the adjusted signal.

A reference-signal detecting unit 48 controls the phase comparator 46 in accordance with the presence or absence of the reference signal output from the observation device 14.

Outputs from the speed-loop filter 43 and the phase-loop filter 47 are added by a signal adder 49 and the resulting output is supplied to a motor driver 50.

This motor driver 50 uses a signal supplied from a hall sensor provided at the motor 22 and the output supplied from the signal adder 49 to generate a drive signal for driving and controlling the motor 22, and outputs the drive signal.

The motor control circuit 21 further includes an inspection controller 51 for inspecting the reference-position detecting photosensor 40-1, the synchronous-position detecting photosensor 40-2, and the speed detecting photosensor 40-3 to check whether or not they are operating properly.

The inspection controller 51 has a photosensor inspection processor, which is described below. Respective digital signals, which are converted by analog/digital converters (hereinafter referred to as "A/D converters") 55-1 to 55-3 from the respective outputs from the reference-position detecting photosensor 40-1, the synchronous-position detecting photosensor 40-2, and the speed detecting photosensor 40-3, are input to the inspection controller 51, in conjunction with the START, READ, and FG pulses output from the waveform shaping circuits 41-1 to 41-3. Further, the inspection controller 51 is connected to a slide switch 52, described blow, for setting the start of inspection, and is connected to an LED 53 for displaying an inspection result via an LED turn-on control unit 54 for controlling the turning on of the LED 53.

The operation of the light source device 15 having the above-described motor control circuit 21 will now be described.

When a power supply, not shown, for the light source device 15 is turned on, the speed comparator 42 outputs an initial value. This initial value is supplied to the motor driver 50 via the speed-loop filter 43 and the signal adder 49. The motor driver 50 then generates an output signal for maximum rotation operation of the motor 22 and supplies the output signal to the motor 22.

That is, immediately after the power supply is turned on, in order to start the maximum rotational drive of the motor 22, the motor driver 50 is controlled by the speed comparator 42 via the speed-loop filter 43 and the signal adder 49 so as to perform a maximum rotation operation. During the start of the rotational drive, when the speed detecting photosensor 40-3 detects the speed detecting silks

33-1 to 33-12, the FG pulse cycle significantly differs from the predetermined target cycle value and is thus the speed comparable range, since the FG pulses converted by the waveform shaping circuit 41-3 are not output.

The signal without a speed comparable range supplied from the speed comparator 42 puts the phase comparator 46 into a non-operating and non-outputting state.

As a result, the signal adder 49 controls the motor driver 50 in accordance with the control signal supplied from the speed-loop filter 43 and indicating the maximum rotation operation of the motor 22, thereby controlling the rotational drive of the motor 22 to rotate the rotary color filter 23.

When the initial value that is output from the speed comparator 42 immediately after the turning on of the power supply causes the rotational drive of the motor 22 to thereby rotate the rotary color filter 23, the speed detecting photosensor 40-3 detects the speed detecting silks 33-1 to 33-12, which are provided on the rotary color filter 23, and the waveform shaping circuit 41-3 outputs the digitized FG pulses to the speed comparator 42.

When the cycle of the FG pulses, generated as a result of the detection of the rotational drive of the motor 22, is without the speed comparable range, the speed comparator 42 continuously outputs, to the speed-loop filter 43, the control signal for the maximum rotation operation of the motor 22.

When the FG pulse cycle approaches the predetermined target cycle and becomes fast to be within the speed comparable range, the speed comparator 42 outputs, to the phase adjusting controller 44 and the phase comparator 46, the signal indicating that the FG pulse cycle is within the speed comparable range.

Further, when the FG pulse cycle is within the speed comparable range, the speed comparator 42 compares the FG pulse cycle with the predetermined target cycle. When the comparison shows a time difference, the speed comparator 42 generates an error signal indicating the time difference and outputs the error signal to the motor driver 50 via the speed-loop filter 43 and the signal adder 49. As described above, a feed back control is performed on the motor 22 such that the FG pulse cycle approaches the predetermined target cycle.

On the other hand, when the observation device 14 is not connected and the reference signal is not input, the reference-signal detecting unit 48 performs control for stopping the operation of the phase comparator 46. Consequently, the motor driver 50 controls the rotational drive of the motor 22 in accordance with the signal within the speed comparable range control that is output and supplied from the speed comparator 42.

Next, when the reference signal output from the observation device 14 is input to the reference-signal detecting unit 48, the reference-signal detecting unit 48 drives the phase comparator 46.

The synchronous-position detecting photosensor 40-2 detects the synchronous-position detecting silk 32-1 to 32-3, which are provided on the rotary color filter 23, and the waveform shaping circuit 41-2 converts the detected result into the digitized READ pulses, which are then input in the phase comparator 46 via the phase adjustment unit 45.

The phase adjustment unit 45 generates pulses that are delayed from the READ pulses based on an initial value. The phase comparator 46 compares the phase of the pulses, delayed from the READ pulses by the phase adjustment unit 45 based on the initial value, with the phase of the reference signal, and then outputs a result of the comparison as an error signal to the phase-loop filter 47.

Signals output from the phase-loop filter 47 and the speed-loop filter 43 are added by the signal adder 49 and the resulting signal is supplied to the motor driver 50. The rotational drive of the motor 22 is controlled as described above, so that the rotary color filter 23 is rotated in synchronization with the reference signal output from the observation device 14.

After the synchronization of the rotary color filter 23 with the reference signal output from the observation device 14 becomes stable and the FG pulse cycle is also within the speed comparable range, the reference-position detecting photosensor 40-1 further detects the reference-position detecting silk 31 of the rotary color filter 23 and outputs a detection signal, which is then digitized by the waveform shaping circuit 41-1 to produce the START pulses. The phase adjusting controller 44 counts the START pulses by a predetermined number, and then measures the phase of the START pulses and the reference signal output from the observation device 14, in order to stabilize the phase relationship between the START pulses and the reference signal.

The phase adjusting controller 44 outputs the phase difference between the START pulse phase and the target phase of the reference signal, which are measured by the phase adjustment unit 45.

That is, in response to the READ pulses, the phase adjustment unit 45 outputs the pulses delayed in phase from the READ pulses to the phase comparator 46 so as to cancel the phase difference between the START pulse phase and the preset target phase of the reference signal, the phase difference being output from the phase adjusting controller 44.

In this manner, the measuring of the START pulse phase and the reference signal phase by the phase adjusting controller 44 and the setting of the phase adjustment value by the phase adjustment unit 45 are performed once, after the power supply is turned on. This allows the rotation of the rotary color filter 23 with the rotation position thereof being constant in response to the reference signal output from the observation device 14.

Figs. 7A to 7I show the relationships of the phase-adjusted START pulses, the reference signal, the READ pulses having a phase adjusted by the phase adjustment unit 45, the pattern of light emitted by the light source device 15, the pattern of CCD reading by the CCD driver 27 in the observation device 14, and so on.

Next, how the inspection controller 51 operates on inspections of the reference-position detecting photosensor 40-1, the synchronous-position detecting photosensor 40-2, and the speed detecting photosensor 40-3 will be described with reference to Figs. 5 and 6A to 6H.

After the power supply for the light source device 15 is turned on, the slide switch 52 is operated to input a photosensor-inspection start instruction to the inspection controller 51.

In step S1, the inspection controller 51 activates the photosensor inspection processor to start inspection. In step S2, the number of digital pulsed FG pulses, which are provided by conversion in the waveform shaping circuit 41-3 after detection by the speed detecting photosensor 40-3, is counted during a period of one cycle of the digital pulsed START pulses, which are provided by conversion by the waveform shaping circuit 41-1 after detection by the reference-position detecting photosensor 40-1 (see Figs. 6A to 6C).

In step S2, when the counting result of the number of FG pulses during one cycle of the START pulses shows a value other than a predetermined number, for example, a value other than "12", it is determined that a detection failure of the speed detecting photosensor 40-3 is occurring and the process proceeds to step S8. In step S8, the inspection controller 51 drives and controls the LED turn-on control unit 54 to turn off the LED 53. The process then proceeds to step S10, in which the photosensor inspection ends.

In step S2, when it is determined that the number of FG pulses during one cycle of the START pulses is equal to the predetermined number of pulses, in step S3, the number of digital pulsed READ pulses, which are provided by conversion by the waveform shaping circuits 41-2 after detection by the synchronous-position detecting photosensor 40-2, is counted during a period of one cycle of the digital pulsed START pulses, which are provided by conversion by the waveform shaping circuit 41-1 after detection by the reference-position detecting photosensor 40-1 (see Figs. 6D to 6F).

In step S3, when the counting result of the number of READ pulses during one cycle of the START pulses shows a value other than a predetermined number, for example, a value other than "3", it is determined that a detection failure of the synchronous-position detecting photosensor 40-2 is occurring and the process in step S8 and the subsequent processes are executed.

When it is determined in step S3 that the number of READ pulses during one cycle of the START pulses is equal to the predetermined number of pulses, an output from the speed detecting photosensor 40-3 is checked in step S4.

More specifically, in the output checking of the speed detecting photosensor 40-3, an output from the speed detecting photosensor 40-3 is converted by the A/D converter 55-3 in synchronization with the FG pulses and the resulting signal is sampled, and then a determination is made as to whether the sampled output satisfies a threshold of the high (H) level or low (L) level of the waveform shaping circuit 41-3. Fig. 6C shows the timings of the FG pulses and A/D conversion points.

When it is determined in step S4 that the output from the speed detecting photosensor 40-3 does not satisfy the threshold of the H/L level of the waveform shaping circuit

41-3, the process in step S8 and the subsequent processes are executed.

When it is determined in step S4 that the output from the speed detecting photosensor 40-3 satisfies the threshold of the H/L level of the waveform shaping circuit 41-3, an output from the synchronization-position detecting photosensor 40-2 is checked in step S5.

More specifically, in the output checking of the synchronous-position detecting photosensor 40-2, an output from the synchronous-position detecting photosensor 40-2 is converted by the A/D converter 55-2 in synchronization with the READ pulses and the resulting signal is sampled, and then a determination is made as to whether the sampled output satisfies a threshold of the high (H) level or low (L) level of the waveform shaping circuit 41-2. Fig. 6F shows the timings of the READ pulses and A/D conversion points.

When it is determined in step S5 that the output from the synchronization-position detecting photosensor 40-2 does not satisfy the threshold of the H/L level of the waveform shaping circuit 41-2, the process in step S8 and the subsequent processes are executed.

When it is determined in step S5 that the output from the synchronization-position detecting photosensor 40-2 satisfies the threshold of the H/L level of the waveform shaping circuit 41-2, an output from the reference-position detecting photosensor 40-1 is checked in step S6.

More specifically, in the output checking of the reference-position detecting photosensor 40-1, an output from the reference-position detecting photosensor 40-1 is converted by the A/D converter 55-1 in synchronization with the START pulses and the resulting signal is sampled, and then a determination is made as to whether the sampled output satisfies a threshold of the high (H) level or low (L) level of the waveform shaping circuit 41-1. Figs. 6G and 6H show the timings of the START pulses and A/D conversion points.

When it is determined in step S6 that the output from the reference-position detecting photosensor 40-1 does not satisfy the threshold of the H/L level of the waveform shaping circuit 41-1, the process in step S8 and the subsequent processes are executed.

When it is determined in step S6 that the output from the reference-position detecting photosensor 40-1 satisfies the threshold of the H/L level of the waveform shaping circuit 41-1, a Hall-sensor signal output from the motor 22 is checked in step S7.

In the checking of the hall-sensor signal output from the motor 22, when a three-phase motor is used for the motor 22, as shown in Figs. 7G to 7I, three types of signals that are shifted in phase from each other by 120° during one rotation of the motor 22 are output.

The three types of motor hall-sensor outputs are checked with reference to the START pulses as to whether the phases of the three types of signals are shifted in order.

When there is a problem with the hall-sensor outputs, the process in step S8 and the subsequent processes are executed. On the other hand, when it is determined that the hall sensor outputs are detected in a predetermined phase order, in step S9, the inspection controller 51 controls the LED 53 to be continuously turned on via the LED turn-on control unit 54, completes all the photosensor inspection, and displays a message indicating that there is no problem.

The series of the inspection processes described above is performed only once, after the slide switch 52 sends a signal indicating the start of inspection to the inspection controller 51. When the slide switch 52 sends a signal indicating a return to a normal mode to the inspection controller 51, the LED 53 is turned off and the operation returns to the normal mode. No further inspection is performed until when the slide switch 52 sends another signal indicating the start of inspection to the inspection controller 51.

As described above, in the endoscope light-source device according to this embodiment, after the power supply therefor is turned on, the phase adjustment is automatically performed once on the rotary color filter relative to the reference signal for a captured-image signal, the reference signal being output from the observation device. This can eliminate a need for adjustment before shipment from a factory and during component replacement, and can ensure that the rotary color filter shields the illumination light during the period of reading a signal from the solid-state image pickup device.

In addition, the present embodiment can readily detect output parameters of the photosensors for detecting the reference position, synchronous position, and rotation speed of the rotary color filter, and can facilitate output inspection before shipment from a factory and during component replacement.

(Second Embodiment)

An endoscope light-source device according to a second embodiment of the present invention will now be described with reference to Figs. 8 to 13J.

Fig. 8 is a plan view showing the configuration of a rotary color filter for use in an endoscope light-source device according to a second embodiment of the present invention. Fig. 9 is a block diagram showing the configuration of a motor control circuit for use in the endoscope light-source device according to the second embodiment. Fig. 10 is a flow chart illustrating the rotation synchronization and phase adjustment of the rotary color filter which are performed by the motor control circuit for use in the endoscope light-source device according to second embodiment. Figs. 11 and 12 are flow charts illustrating the inspection operation of a speed and synchronous-position detecting photosensor for combined use and a reference-position detecting photosensor in the motor control circuit for use in the endoscope light-source device according to the second embodiment. Figs. 13A to 13J are waveform diagrams illustrating the rotation synchronization and phase adjustment of the rotary color filter of the motor control circuit for use in the endoscope light-source device according to the second embodiment.

In Figs. 8 to 13J, the same elements shown in Figs. 1 to 7I are denoted with the same reference numerals, and detail descriptions thereof are omitted.

As shown in Fig. 8, a rotary color filter 23' for use in an endoscope light-source device according to a second embodiment has at the outermost periphery an R color filter 30r, G color filter 30g, and B color filter 30b, which are arranged at predetermined intervals, and light-shielding portions, which are respectively arranged between the corresponding R, G, and B color filters, 30r, 30g, and 30b.

At the inner circumference side of the R, G, and B color filters 30r, 30g, and 30b and the light-shielding portions, 12 speed and synchronous-position detecting silk for combined use 90-1 to 90-12 are arranged in a plane perpendicular to the rotation axis of the rotary color filter 23' at the same angle about the rotation axis. Further, at the inner circumference side of the speed and synchronous-position detecting silks for combined use 90-1 to 90-12, a reference-position detecting silk 31 indicating the reference position of the rotary color filter 23' is provided.

The speed and synchronous-position detecting silks for combined use 90-1 to 90-12 of the rotary color filter 23' serve as both the speed detecting silks 33-1 to 33-12 and the synchronous-position detecting silks 32-1 to 32-3 of the above-described rotary color filter 23. The reference-position detecting silk 31 and the speed and synchronous-position detecting silks for combined use 90-1 to 90-12 are arranged in concentric circles having different diameters from each other such that the inner circumference and the outer circumference of the circles do not overlap each other.

The configuration of a motor control circuit 21' used in this embodiment will now be described with reference to FIG. 9.

The rotary color filter 23' is rotationally driven by a motor 22. A reference-position detecting photosensor 40-1 for detecting the reference-position detecting silk 31 and a speed and synchronous-position detecting photosensor for combined use 40-4 for reading the speed and synchronous-position detecting silks for combined use 90-1 to 90-12 are provided so as to face the rotary color filter 23'.

Waveform shaping circuits 41-1 and 41-4, such as Schmidt trigger circuits, are provided. Thus, upon detecting the reference-position detecting silk 31 and the speed and synchronous-position detecting silks for combined use 90-1 to 90-12, the corresponding reference-position detection photosensor 40-1 and the synchronous-position detecting photosensor 40-4 generate and output respective analog waveforms. Upon receiving the analog waveforms, the waveform shaping circuits 41-1 and 41-4 convert the analog waveforms into respective digital pulses.

The signal detected by the speed and synchronous-position detecting photosensor for combined use 40-4 is converted by the waveform shaping circuit 41-4 into digital pulsed FG pulses, which are then output to a divider circuit 65 and an FG pulse counter 60.

The signal detected by the reference-position detecting photosensor 40-1 is converted in the waveform shaping circuit 41-1 into digital-pulsed START pulses, which are then output to the divider circuit 65, a START pulse counter 62, and a phase difference counter 63.

Based on the START pulses output from the waveform shaping circuit 41-1, the divider circuit 65 divides the frequency of the FG pulses output from the waveform shaping circuit 41-4 to generate READ pulses, which is used by a phase comparator 46, described below, for synchronization with the reference signal output from the observation device 14. The READ pulses generated in the divider circuit 65 are output to the phase comparator 46 via a phase adjustment unit 45.

The FG pulse counter 60 measures the cycle of the FG pulses that are generated in the waveform shaping circuit 41-4 after detecting at the speed and synchronous-position detecting photosensor for combined use 40-4.

The FG pulse cycle measured by the FG pulse counter 60 is output to a computer unit (CPU), not shown, having an arithmetic unit, a RAM, a ROM in which a program is stored, and so on via a CPU bus, not shown.

The CPU computes the time difference between a result of the FG pulse cycle measured by the FG pulse counter 60 and a target cycle of the FG pulses, and outputs, as an error voltage, the computational result to a speed-loop filter 43 via a speed-comparison-result output unit 61 that is connected to the CPU bus, which is not shown.

The speed-comparison-result output unit 61 outputs to the phase comparator 46 a signal within/without the speed comparable range indicating whether the error voltage, which indicates the time difference, computed by the CPU, between the FG pulse cycle and the target cycle of the FG pulses, is not greater than the upper limit of the error voltage or is not smaller than the lower limit thereof.

The START pulse counter 62 counts the number of START pulses that are generated in the waveform shaping circuit 41-1 after being detected at the reference-position detecting photosensor 40-1.

The phase difference counter 63 counts the phase difference between the START pulse and the reference signal output from the observation device 14.

The counting results obtained by the START pulse counter 62 and the phase difference counter 63 are output to the CPU, not shown, via the CPU bus, not shown. The CPU computes the difference between the counter value counted by the phase difference counter 63 and a predetermined target value to generate a control signal for canceling the phase difference between the counted value and the target value, and sends the control signal to the phase adjustment unit 45 via the CPU bus, not shown, thereby performing control for delaying the phase of the READ pulses having a frequency divided by the divider circuit 65.

That is, the phase adjustment unit 45 outputs the READ pulses, which have been adjusted such that the phase difference between the START pulses and the reference signal becomes the target value, to the phase comparator 46.

The motor control circuit 21' includes an inspection controller 66 having a built-in inspection processor for inspecting and adjusting the levels of voltages output from the photosensors 40-1 and 40-4 and for inspecting a signal output from a hall sensor provided at the motor 22.

The inspection controller 66 is connected to a communication controller 68, A/D converters 55-1 and 55-4, D/A converters 58-1 and 58-2, and a nonvolatile RAM 69. The communication controller 68 performs a setting of the starting of inspection made by an inspection connector 67 and communicates a notification of the inspection result, which are provided by the inspection processor, with an external control apparatus, such as a PC, in accordance with an RS232C communication method or the like. The A/D converters 55-1 and 55-4 convert analog voltages output from the reference-position detecting photosensor 40-1 and the speed and synchronous-position detecting photosensor for combined use 40-4 into respective digital signals and send the digital signals to the inspection controller 66, which, in turn, generates digital adjustment values for adjusting outputs from the photosensors 40-1 and 40-4. The D/A converters 58-1 and 58-2 convert the digital adjustment values into respective analog voltages and output the analog voltages. The nonvolatile RAM 69 stores the values for adjusting the outputs from the photosensors 40-1 and 40-4.

In accordance with respective outputs from the D/A converters 58-1 and 58-2, a reference-position detecting photosensor output adjusting unit 59-1 and a speed and synchronous-position detecting photosensor for combined use output adjusting unit 59-2 adjust the respective outputs from the reference-position detecting photosensor 40-1 and the speed and synchronous-position detecting photosensor for combined use 40-4.

The motor rotational drive control operation of a light source device 15 having the motor control circuit 21' described above will now be described with reference to Fig. 10.

When a power supply, not shown, for the light source device 15 is turned on, a program, which is stored in the ROM in the CPU, not shown, for rotation synchronization and phase adjustment of the rotary color filter 23' is read and an initialization process included in the program is executed in step S21.

More specifically, in the initialization process in step S21, in order to rotate and drive the motor 22 from a stationary state, an output for maximum rotational drive of the motor 22 is set to the speed-comparison-result output unit 61, and then the maximum rotational drive output is supplied to the speed-loop filter 43, a signal adder 49, and a motor driver 50, thereby starting the rotational drive of the motor 22.

The speed-comparison-result output unit 61 also generates a signal indicating that the speed is without the speed comparable range when the motor 22 is not rotated, and outputs the signal without the speed comparable range to the phase comparator 46, thereby putting the phase comparator 46 into the non-operating state.

As a result, in accordance with the maximum rotational drive output supplied from the CPU, the motor 22 starts rotational drive to thereby rotate the rotary color filter 23'.

When the motor 22 starts rotational drive in the initialization process in step S21, the CPU, in step S22, is put into a standby state for waiting for the input of the FG pulses that are digitized by the waveform shaping circuit 41-4 after the speed and synchronous-position detecting photosensor for combined use 40-4 detects the speed and synchronous-position detecting silks for combined use 90-1 to 90-12 of the rotary color filter 23'.

In the standby state for the input of the FG pulses in step S22, when the rotary color filter 23' is rotated, the speed and synchronous-position detecting photosensor for combined use 40-4 detects the speed and synchronous-position detecting silks for combined use 90-1 to 90-12, and the FG pulses digitized by the waveform shaping circuit 41-4 are input to the FG pulse counter 60, the FG pulse counter 60 counts the cycle of the FG pulses.

When the FG pulse counter 60 have counted the cycle of the FG pulses, in step S23, the CPU reads the FG pulse cycle counted by the FG pulse counter 60. In step S24, the CPU performs computation for comparing the read FG pulse cycle with a target cycle of the FG pulses, thereby performing rotation-speed comparison of the rotary color filter 23'.

That is, when the comparison shows small or no difference between the FG pulse cycle counted by the FG pulse counter 60 and the target cycle of the FG pulses, this means that the motor 22 and the rotary color filter 23' are rotationally driven at a target rotation speed.

The speed comparison result, obtained by the computation for determining the difference between the FG pulses and the target cycle in step S24, is output to the speed-comparison-result output unit 61. The motor 22 is controlled to perform maximum rotational drive until the FG pulse cycle approaches the target cycle. When the FG pulse cycle approaches the target cycle, a motor-drive feedback control is performed in accordance with the FG pulse cycle.

That is, when the FG pulse cycle does not reach the target cycle and is determined to be without the speed comparable range, the CPU outputs to the speed-comparison-result output unit 61 a maximum rotational drive control signal for driving the motor 22 at a target speed, and also outputs the signal without the speed comparable range to the phase comparator 46. The process then proceeds to step S22.

When the FG pulse cycle approaches the target cycle and is determined in step S25 to be within the speed comparable range, in step S26, a determination is made as to whether the reference signal from the observation device 14 is input. When it is determined that the reference signal is not input, the process returns to step S22. In this case, a reference-signal detecting unit 48 stops the operation of the phase comparator 46.

In this non-operating state of the phase comparator 46, the motor 22 is continuously controlled such that the FG pulse cycle counted by the FG pulse counter 60 reaches the target cycle value.

In step S26, when the reference-signal detecting unit 48 acknowledges the supply of the reference signal from the observation device 14, the phase comparator 46 operates to compare the phase of the reference signal output from the observation device 14 with pulses that are obtained by delaying the READ pulses based on an initial value of the phase adjustment unit 45, the READ pulses being generated, at the divider circuit 65, by dividing the frequency of the

FG pulses by the START pulses. The phase comparator 46 outputs a result of the phase comparison as an error voltage to the phase-loop filter 47.

The initial value that is used in the phase adjustment unit 45 to delay the READ pulses is set by the CPU.

The error voltage output from the phase-loop filter 47 and an output sent from the speed-loop filter 43 are added by the signal adder 49. In accordance with the resulting signal, the motor driver 50 drives and controls the motor 22, so that the rotary color filter 23' is rotationally driven in synchronization with the reference signal from the observation device 14.

When the synchronization of the rotary color filter 23' with the reference signal output from the observation device 14 becomes stable and the FG pulse cycle counted by the FG pulse counter 60 is also within the speed comparable range, in step S27, the number of input START pulses counted by the START pulse counter 62 is obtained.

When the number of input START pulses does not reach a preset value, the process returns to S22 in order to wait for stabilization of the phase relationship between the START pulses and the reference signal.

In response to the START pulses, the phase difference counter 63 starts counting in accordance with a reference clock signal. In response to the reference signal, the phase difference counter 63 stops the counting, stores a counter value, and is reset.

When the number of input START pulses exceeds the preset value, in step S28, the CPU, which is not shown, checks for the stopping of the phase difference counter 63, and in step S29, the CPU resets the START pulse counter 62. In step S30, the CPU reads a counter value immediately before the resetting of the phase difference counter 63.

In step S31, a determination is made as to whether the reading of the counter value of the phase difference counter 63 by the CPU is performed after turning on the power supply.

That is, when a first counter value is read after turning on the power supply, in step S32, the CPU computes the difference between the counter value and a target value and outputs the computed difference to the phase adjustment unit 45.

The phase adjustment unit 45 outputs to the phase comparator 46 pulses having a phase delayed from the READ pulses so as to cancel the phase difference between the counted value of the START pulses and the reference signal and the target value and the phase difference being output from the CPU, not shown.

When the CPU reads a second counter value or a subsequent counter value of the phase difference counter 63 after turning on the power supply, a determination is made in step S33 as to whether the counter value is within the target range. When it is determined that the counter value is within the target value range, a value to be output to the phase adjustment unit 45 is not updated in step S34. On the other hand, when it is determined that the counter value is without the target value range, an output to be output to the phase adjustment unit 45 is updated in step S35.

Thus, when the rotation of the rotary color filter 23' is in a stable state, almost no updating is performed on a value to be output to the phase adjustment unit 45, which can eliminate loop in addition instability that results from the addition of the third loop to the speed loop and the phase loop.

Figs. 13A to 13J show the relationships of the above-described START pulses, the reference signal, the READ pulses, the READ pulses having a phase adjusted by the phase adjustment unit 45, the pattern of light emitted from the light source device 15, and the pattern of CCD reading made by the CCD driver 27 in the observation device 14.

A phase adjustment value before turning on the power supply may be stored in a nonvolatile RAM so that the phase adjustment value stored in the nonvolatile RAM can be used as the initial value.

The inspection operation of the photosensors 40-1 and 40-4 using the inspection controller 66 of the motor control circuit 21' of the light source device 15 will now be described with reference to Figs. 11 and 12.

After the power supply for the light source device 15 is turned on, when an instruction for causing the inspection controller 66 to start a photosensor inspection operation is sent to the inspection controller 66 from an external control apparatus, such as a PC, that is connected to the inspection connector 67, via the communication controller 68 according to communication using an RS232C or the like, the photosensor inspection processor in the inspection controller 66 is activated and driven in step S41.

Next, in step S42, the number of FG pulses during one cycle of the START pulses is counted. When the counting number of FG pulses is not equal to a predetermined number, which is, for example, "12", in step S68, the inspection controller 66 sends a notification indicating an inspection result NG to the external control apparatus, such as a PC, that is connected to the inspection connector 67, via the communication controller 68. In step S69, the photosensor inspection ends.

When the number of FG pulses is equal to the predetermined number in step S42, the number of READ pulses during one cycle of the START pulses is counted in step S43. When the counting number of READ pulses is not equal to a predetermined number, which is, for example, "3", the process proceeds to steps S68 and S69, in which the photosensor inspection ends.

On the other hand, when the counting value of the READ pulses is equal to the predetermined number, in step S44, an output from the speed and synchronous-position detecting photosensor for combined use 40-4 is checked.

More specifically, in the output checking of the speed and synchronous-position detecting photosensor for combined use 40-4, an output from the speed and synchronous-position detecting photosensor for combined use 40-4 is converted by the A/D converter 55-4 in synchronization with the input of the FG pulses and the resulting signal is sampled, and then a determination is made as to whether the sampled output satisfies a threshold of the H/L level of the waveform shaping circuit 41-4. The timings of the FG pulses and A/D conversion points are analogous to those illustrated in the first embodiment with reference to Figs. 6A to 6C.

When it is determined in step S44 that the output from the speed and synchronous-position detecting photosensor for combined use 40-4 does not satisfy the threshold of the H/L level, the process proceeds to step S48 and steps subsequent thereto, in which processes for adjusting the output of the speed and synchronous-position detecting photosensor for combined use 40-4 are executed.

More specifically, in step S48, a determination is made as to whether an H output level of the speed and synchronous-position detecting photosensor for combined use 40-4 is larger than an H level threshold. When it is determined that the H output level is smaller than the H level threshold, a determination is made in step S53 as to whether an L output level of the speed and synchronous-position detecting photosensor for combined use 40-4 is smaller than an L level threshold. When it is determined that the H output level is larger than the L level threshold, the processes in steps S68 and S69 are executed, since the output of the speed and synchronous-position detecting photosensor for combined use 40-4 cannot be adjusted.

When the result of the determination in step S48 shows that the H output level is larger than the H level threshold, a determination is made in S49 as to whether the current output adjustment value is larger than a default value. When it is determined that the output adjustment value is larger than the default value, the process in step S68 and the subsequent processes are executed. On the other hand, when it is determined that the output adjustment value is smaller than the default value, a determination is made in step S50 as to whether the current output adjustment value is larger than an adjustment minimum value. When it is determined that the output adjustment value is smaller than the adjustment minimum value, the process in step S68 and the subsequent processes are executed. When it is determined that the output adjustment value is larger than the adjustment minimum value, in step S51, the output adjustment value is reduced by "1". In step S52, the resulting output adjustment value is sent to the speed and synchronous-position detecting photosensor for combined use output adjusting unit 59-2 via the D/A converter 58-2, so that the speed and synchronous-position detecting photosensor for combined use output adjusting unit 59-2 adjusts the output of the speed and synchronous-position detecting photosensor for combined use 40-4. The output adjustment value is also stored in the nonvolatile RAM 69. The processes after step S42 are then repeated.

When it is determined in step S53 that the L output level of the speed and synchronous-position detecting photosensor for combined use 40-4 is smaller than the L level threshold, a determination is made in step S54 as to whether the current output adjustment value is smaller than a default value. When it is determined that the output adjustment value is smaller than the default value, the process in S68 and the subsequent processes are executed. When it is determined that the output adjustment value is larger than the default value, a determination is made in step S55 as to whether the output adjustment value is smaller than an adjustment maximum value. When it is determined that the output adjustment value is larger than the adjustment maximum value, the process in S68 and the subsequent processes are executed. When it is determined that the output adjustment value is smaller than the adjustment maximum value, in step S56, the output adjustment value is increased by "1". In step S57, the resulting output adjustment value is sent to the speed and synchronous-position detecting photosensor for combined use output adjusting unit 59-2 via the D/A converter 58-2, so that the speed and synchronous-position detecting photosensor for combined use output adjusting unit 59-2 adjusts the output of the speed and synchronous-position detecting photosensor for combined use 40-4. The output adjustment value is then stored in the nonvolatile RAM 69. The processes after step S42 are then repeated.

When it is determined in step S44 that the output of the speed and synchronous-position detecting photosensor for combined use 40-4 satisfies the threshold of the H/L level, an output from the reference-position detecting photosensor 40-1 is checked in step S45.

More specifically, in the output checking of the reference-position detecting photosensor 40-1, an output from the reference-position detecting photosensor 40-1 is converted by the A/D converter 55-1 in synchronization with the START pulses and the resulting signal is sampled, and then a determination is made as to whether the sampled output satisfies a threshold of the H/L level of the waveform shaping circuit 41-1. The timings of the START pulses and A/D conversion points are analogous to those illustrated in the first embodiment with reference to Figs. 6G and 6H.

When it is determined in step S45 that the output of the reference-position detecting photosensor 40-1 does not satisfy the threshold of the H/L level, the process in step S58 and the subsequent processes are executed for adjusting the output of the reference-position detecting photosensor 40-1.

Specifically, in step S58, a determination is made as to whether an H output level of the reference-position detecting photosensor 40-1 is larger than an H level threshold. When it is determined that the H output level is smaller than the H level threshold, a determination is made in step S63 as to whether an L output level of the reference-position detecting photosensor 40-1 is smaller than a L level threshold. When it is determined that the L output level is larger than the L level threshold, the process in step S68 and the subsequent processes are executed, since the output of the reference-position detecting photosensor 40-1 cannot be adjusted.

When the result of the determination in step S58 shows that the H output level is larger than the H level threshold, a determination is made in step S59 as to whether the current output adjustment value is larger than a default value. When it is determined that the output adjustment value is larger than the default value, the process in step S68 and the subsequent processes are executed. When it is determined that the output adjustment value is smaller than the default value, a determination is made in step S60 as to whether the output adjustment value is larger than an adjustment minimum value. When it is determined that output adjustment value is smaller than the adjustment minimum value, the process in step S68 and the subsequent processes are executed. When it is determined that the output adjustment value is larger than the adjustment minimum value, in step S61, the output adjustment value is reduced by "1". In step S62, the resulting output adjustment value is sent to the reference-position detecting-photosensor output adjusting unit 59-1 via the D/A converter 58-1, so that reference-position detecting-photosensor output adjusting unit 59-1 adjusts the output of the reference-position detecting photosensor 40-1. The output adjustment value is then stored in the nonvolatile RAM 69. The processes after step S42 are then repeated.

When it is determined in step S63 that the L output level of the reference-position detecting photosensor 40-1 is smaller than the L level threshold, a determination is made in step S64 as to whether the current output adjustment value is smaller than a default value. When it is determined that the current output adjustment value is smaller than the default value, the process in S68 and the subsequent processes are executed. When it is determined that the current output adjustment value is larger than the default value, a determination is made in step S65 as to whether the current output adjustment value is smaller than an adjustment maximum value. When it is determined that the current output adjustment value is larger than the adjustment maximum value, the process in S68 and the subsequent processes are executed. When it is determined that the current output adjustment value is smaller than the adjustment maximum value, in step S66, the output adjustment value is increased by "1". In step S67, the resulting output adjustment value is sent to the reference-position detecting-photosensor output adjusting unit 59-1 via the D/A converter 58-1, so that the reference-position detecting-photosensor output adjusting unit 59-1 adjusts the output of the reference-position detecting photosensor 40-1. The output adjustment value is then stored in the nonvolatile RAM 69. The processes after step S42 are then repeated.

When it is determined in step S45 that the output of the reference-position detecting photosensor 40-1 satisfies the threshold of the H/L level, in step S46, a hall-sensor signal output from the motor 22 is checked.

In the checking of the hall-sensor signal output from the motor 22, when a three-phase motor is used for the motor 22, as shown in Figs. 13H to 13J, three types of signals that are shifted in phase from each other by 120° during one rotation of the motor 22 are output.

The three types of motor hall-sensor outputs are checked with reference to the START pulses as to whether the phases of the three types of signals are shifted in order.

When there is a problem with the hall-sensor outputs, the process in step S68 and the subsequent processes are executed. On the other hand, when it is determined that the hall sensor outputs are detected in a predetermined phase order, in step S47, in order to show that there is no problem in all the inspection, the inspection controller 66 sends a notification indicating an OK result to the external control apparatus, such as a PC, that is connected to the inspection connector 67, via the communication controller 68. In step S69, the photosensor inspection ends.

The series of the inspection processes described above is performed only once, after the signal indicating the start of inspection is input to the inspection controller 66 via the inspection connector 67 and the communication controller 68. When a signal indicating a return to a normal mode is input to the inspection controller 66 via the inspection connector 67 and the communication controller 68, the inspection controller 66 returns to the normal mode. No further inspection is performed until when another signal indicating the start of inspection is input to the inspection controller 66.

As described above, in the endoscope light-source device according to the second embodiment, after the power supply is turned on, the phase of the rotary color filter is automatically adjusted relative to the phase of the reference signal for the captured-image signal, the reference signal being output from the observation device. Further, the phase adjustment between the reference signal output from the observation device and the START pulses provided by the reference-position detection silks of the color filter is constantly performed. As a result, the second embodiment can also deal with a change in the reference signal after the power supply is turned on. In addition, the second embodiment can readily detect output parameters of the various photosensors for detecting the reference position, synchronous position, and rotation speed of the rotary color filter and can facilitate output inspection before shipment from a factory and during component replacement.

As described above, in the endoscope light-source devices according to the two embodiments, after the power supply for the light-source device is turned on, the phase of the rotary color filter is automatically adjusted relative to the phase of the reference signal for a captured-image signal, the reference signal being output from the observation device. This can eliminate a need for adjustment before shipment from a factory and during component replacement, and can ensure that the rotary color filter shields the illumination light during the period of reading a signal from the solid-state image pickup device. In addition, the embodiments can readily detect output parameters of the detectors for detecting the rotation of the rotary color filter and can facilitate output inspection before shipment from a factory and during component replacement.

While the embodiments of the present invention have been described above, the present invention is not limited to the illustrated embodiments, and thus it is apparent that various changes and modifications can be made thereto without departing from the sprit and scope of the present invention.

Industrial Applicability

The present invention provides an endoscope light-source device that is used for an electronic endoscope apparatus and that controls the rotation speed of a rotary color filter for sequentially emitting illumination light having different wavelength ranges in synchronization with the timing of reading a captured-image signal generated based on the illumination light.

Cross Reference to Related Applications

This application is based upon and claims the benefit of priority from (1) the prior Japanese Patent Application No. 2003-039995, filed on February 18, 2003, the entire contents of which (1) are incorporated herein by reference.

CLAIMS

1. An endoscope light-source device used for an electronic endoscope apparatus having a solid-state image pickup device for capturing an image of an observed area illuminated with illumination light that has different wavelength ranges and that is sequentially emitted through a rotary color filter, the endoscope light-source device comprising:

a driving section for rotating the rotary color filter;

a rotation-position detecting section for detecting a rotation position of the rotary color filter rotated by the driving section and for providing a rotation-position signal indicating the rotation position of the rotary color filter;

a phase-difference detecting section for detecting a phase difference between a reading signal for reading a captured-image signal from the solid-state image pickup device and the rotation-position signal; and

a phase delaying section for delaying the rotation-position signal in accordance with the phase difference detected by the phase-difference detecting section.

2. The endoscope light-source device according to claim 1, wherein the phase-difference detecting section and the phase delaying section perform phase adjustment based on the phase difference between the reading signal and the rotation-position signal, only when the rotation of the rotary color

filter is started.

3. The endoscope light-source device according to claim 1, further comprising a number-of-rotations detecting section for detecting the number of rotations of the rotary color filter, wherein the phase-difference detecting section and the phase delaying section perform phase adjustment based on the phase difference between the reading signal and the rotation-position signal, for each plurality of rotations of the rotary color filter when the number-of-rotations detecting section detects the number of rotations, so that a target value for the adjustment has a range.

4. The endoscope light-source device according to claim 1 or 2, further comprising:

a rotation-speed detecting section for detecting a rotation speed of the rotary color filter;

an output comparing section for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting section and the rotation-position detecting section comprises the respective detectors; and

a determination displaying section for displaying a determination result indicating whether or not the detectors operate properly in accordance with a result of the comparison performed by the output comparing section.

5. The endoscope light-source device according to claim 1

or 2, further comprising:

a rotation-speed detecting section for detecting a rotation speed of the rotary color filter;

an output comparing section for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting section and the rotation-position detecting section comprises the respective detectors; and

an output adjusting section for adjusting the output values of the detectors in accordance with a result of the comparison performed by the output comparing section.

6. An endoscope light-source device used for an electronic endoscope apparatus having a solid-state image pickup device for capturing an image of an observed area illuminated with illumination light that has different wavelength ranges and that is sequentially emitted through a rotary color filter, the endoscope light-source device comprising:

a driving section for rotating the rotary color filter;

a rotation-speed detecting section for detecting a rotation speed of the rotary color filter rotated by the driving section;

a rotation-position detecting section for detecting a rotation position of the rotary color filter;

a speed comparing section for comparing the rotation speed detected by the rotation-speed detecting section with a predetermined rotation speed to determine whether the rotation speed is within or without a speed comparable range;

a phase-difference determining section for determining a phase difference between a reading signal for reading a captured-image signal from the solid-state image pickup device and the rotation-position signal, when the rotation speed is within the speed comparable range; and

a phase delaying section for delaying the rotation-position signal in accordance with the phase difference determined by the phase-difference determining section.

7. The endoscope light-source device according to claim 6, wherein the phase-difference determining section and the phase delaying section perform phase adjustment based on the phase difference between the reading signal and the rotation-position signal, only when the rotation of the rotary color filter is started.

8. The endoscope light-source device according to claim 6, further comprising a number-of-rotations detecting section for detecting the number of rotations of the rotary color filter, wherein the phase-difference determining section and the phase delaying section perform phase adjustment based on the phase difference between the reading signal and the rotation-position signal, for each plurality of rotations of

the rotary color filter when the number-of-rotation detecting section detects the number of rotations, so that a target value for the adjustment has a range.

9. The endoscope light-source device according to claim 6 or 7, further comprising:

a rotation-speed detecting section for detecting a rotation speed of the rotary color filter;

an output comparing section for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting section and the rotation-position detecting section comprises the respective detectors; and

a determination displaying section for displaying a determination result indicating whether or not the detectors operate properly in accordance with a result of the comparison performed by the output comparing section.

10. The endoscope light-source device according to claim 6 or 7, further comprising:

a rotation-speed detecting section for detecting a rotation speed of the rotary color filter;

an output comparing section for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting section and the rotation-position detecting section comprises the respective detectors; and an output adjusting section for adjusting the output values of the detectors in accordance with a result of the comparison performed by the output comparing section.

11. An endoscope light-source device used for an electronic endoscope apparatus having a solid-state image pickup device for capturing an image of an observed area illuminated with illumination light that has different wavelength ranges and that is sequentially emitted through a rotary color filter, the endoscope light-source device comprising:

driving means for rotating the rotary color filter;

rotation-position detecting means for detecting a rotation position of the rotary color filter rotated by the driving means;

phase-difference detecting means for detecting a phase difference between a reading signal for reading a captured-image signal from the solid-state image pickup device and the rotation-position signal; and

phase delaying means for delaying the rotation-position signal in accordance with the phase difference detected by the phase-difference detecting means.

12. The endoscope light-source device according to claim 11, further comprising:

rotation-speed detecting means for detecting a rotation speed of the rotary color filter;

output comparing means for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting means and the rotation-position detecting means comprises the respective detectors; and

determination displaying means for displaying a determination result indicating whether or not the detectors operate properly in accordance with a result of the comparison performed by the output comparing means.

13. The endoscope light-source device according to claim 11, further comprising:

rotation-speed detecting means for detecting a rotation speed of the rotary color filter;

output comparing means for comparing output values of detectors with corresponding predetermined values, wherein the rotation-speed detecting means and the rotation-position detecting means comprises the respective detectors; and

output adjusting means for adjusting the output values of the detectors in accordance with a result of the comparison performed by the output comparing means.

14. An endoscope light-source device used for an electronic endoscope apparatus having a solid-state image pickup device for capturing an image of an observed area illuminated with illumination light that has different wavelength ranges and that is sequentially emitted through a rotary color filter, the endoscope light-source device

comprising:

driving means for rotating the rotary color filter;

rotation-speed detecting means for detecting a rotation speed of the rotary color filter rotated by the driving means;

rotation-position detecting means for detecting a rotation position of the rotary color filter;

speed comparing means for comparing the rotation speed detected by the rotation-speed detecting means with a predetermined rotation speed to determine whether the rotation speed is within or without a speed comparable range;

phase-difference determining means for determining a phase difference between a reading signal for reading a captured-image signal from the solid-state image pickup device and the rotation-position signal, when the rotation speed is within the speed comparable range; and

phase delaying means for delaying the rotation-position signal in accordance with the phase difference determined by the phase-difference determining means.

FIG.1

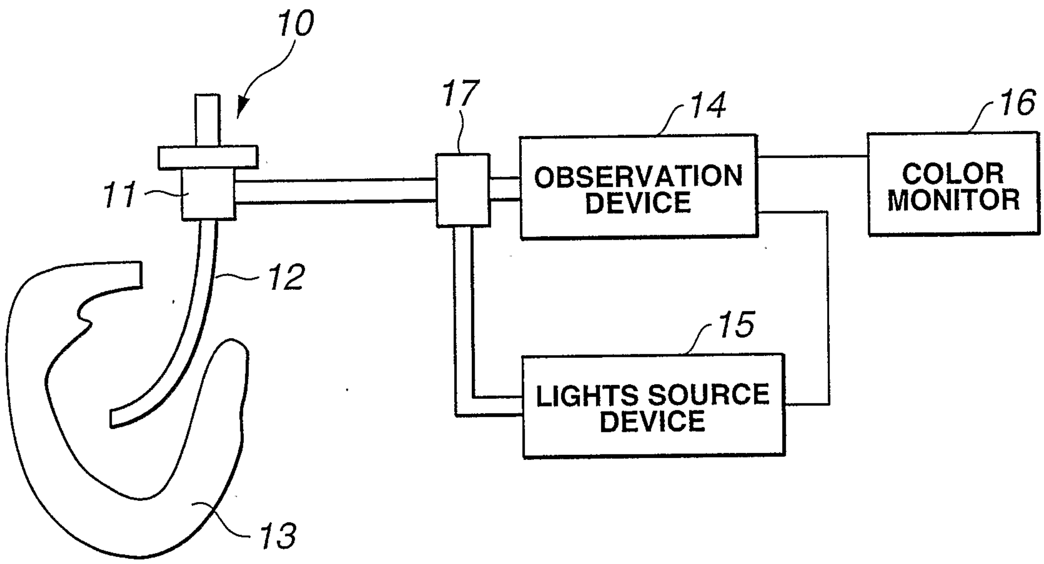
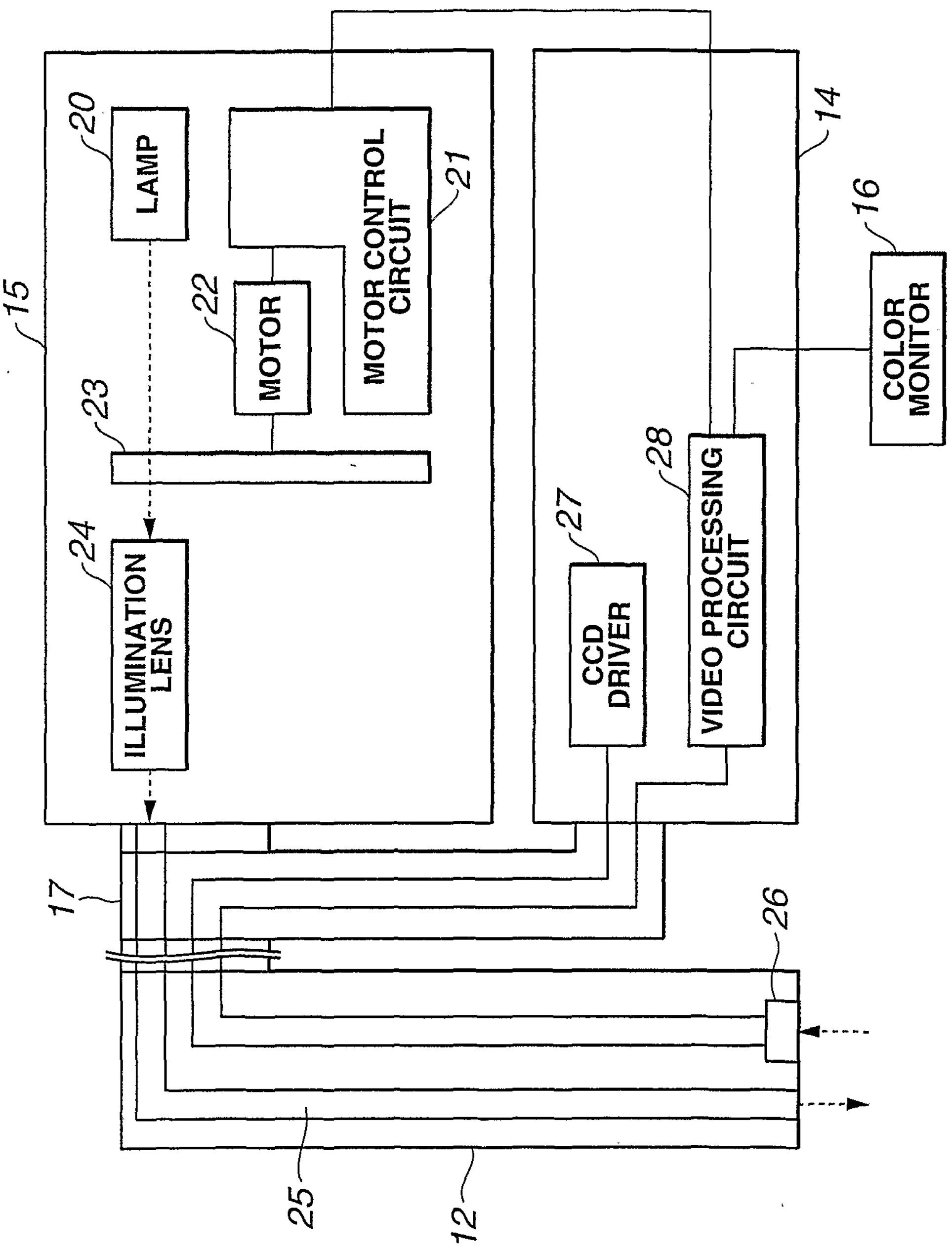

10
11
12
13
17
14
OBSERVATION DEVICE
16
COLOR MONITOR
15
LIGHTS SOURCE DEVICE

FIG.2



LAMP
20
MOTOR CONTROL CIRCUIT
21
MOTOR
22
15
23
ILLUMINATION LENS
24
14
COLOR MONITOR
16
CCD DRIVER
27
VIDEO PROCESSING CIRCUIT
28
17
26
25
12

FIG.3

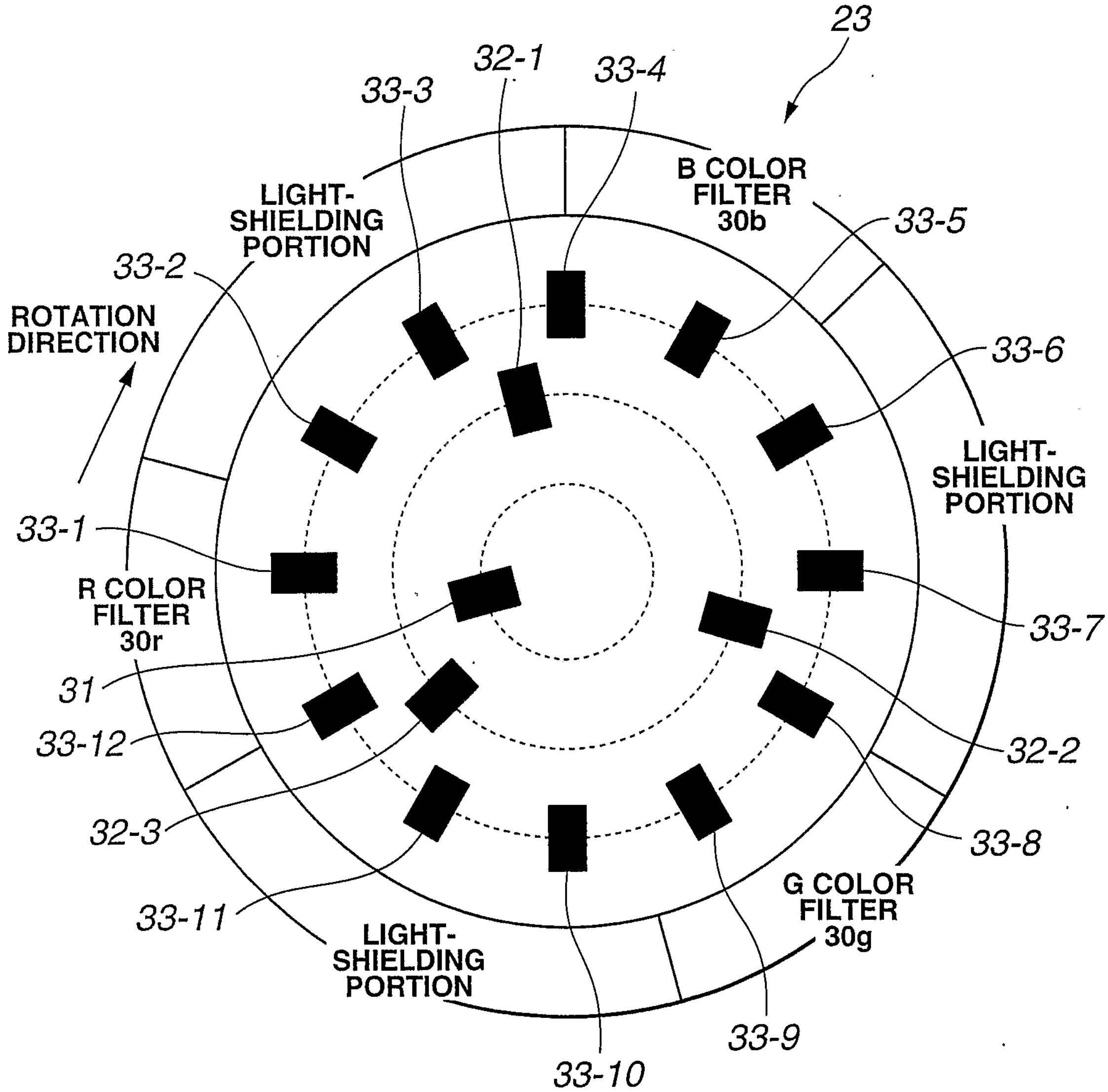

23
32-1
33-3
33-4
B COLOR FILTER 30b
LIGHT-SHIELDING PORTION
33-5
33-2
ROTATION DIRECTION
33-6
LIGHT-SHIELDING PORTION
33-1
R COLOR FILTER 30r
33-7
31
32-2
33-12
32-3
33-8
33-11
G COLOR FILTER 30g
LIGHT-SHIELDING PORTION
33-9
33-10

FIG.4

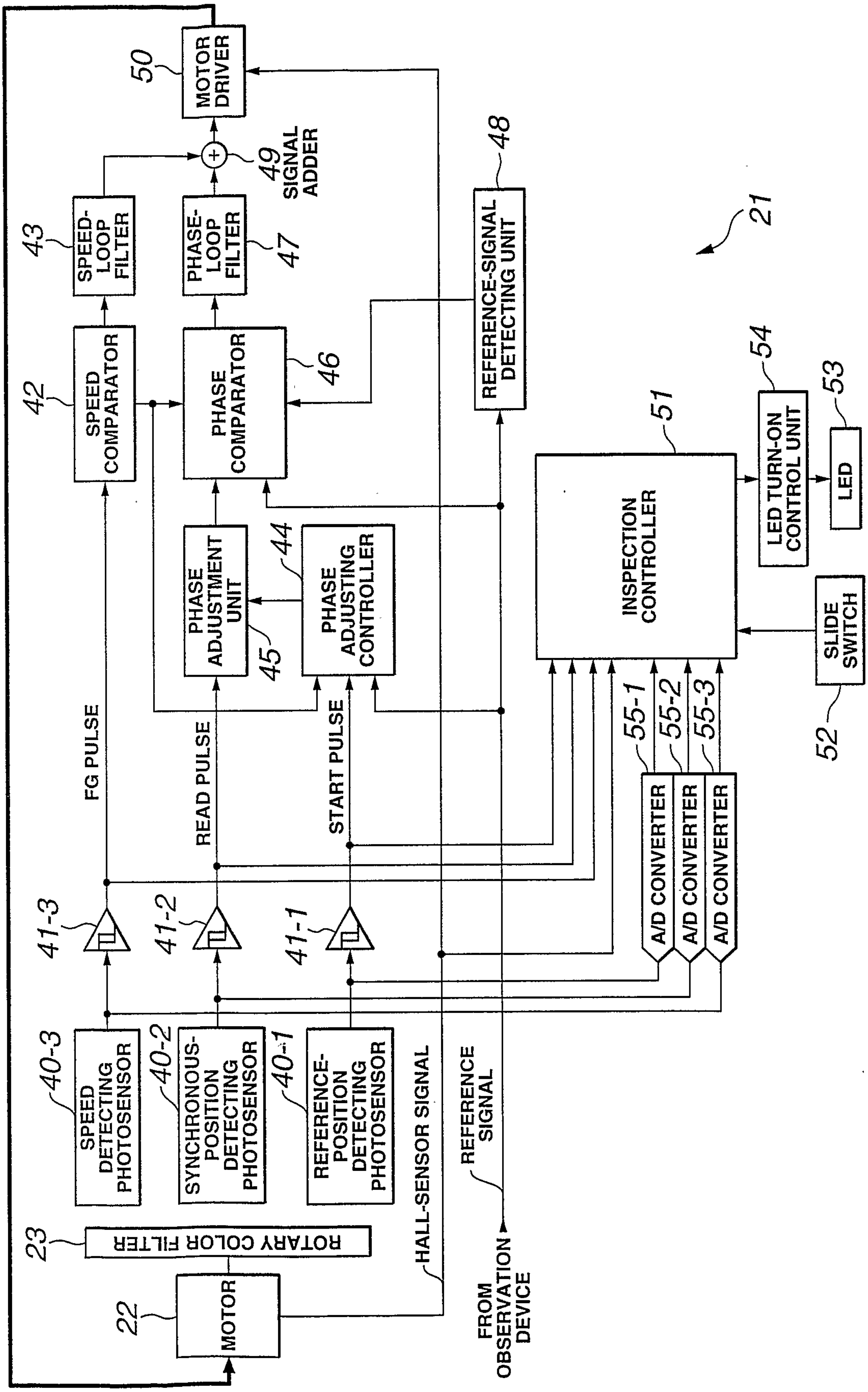
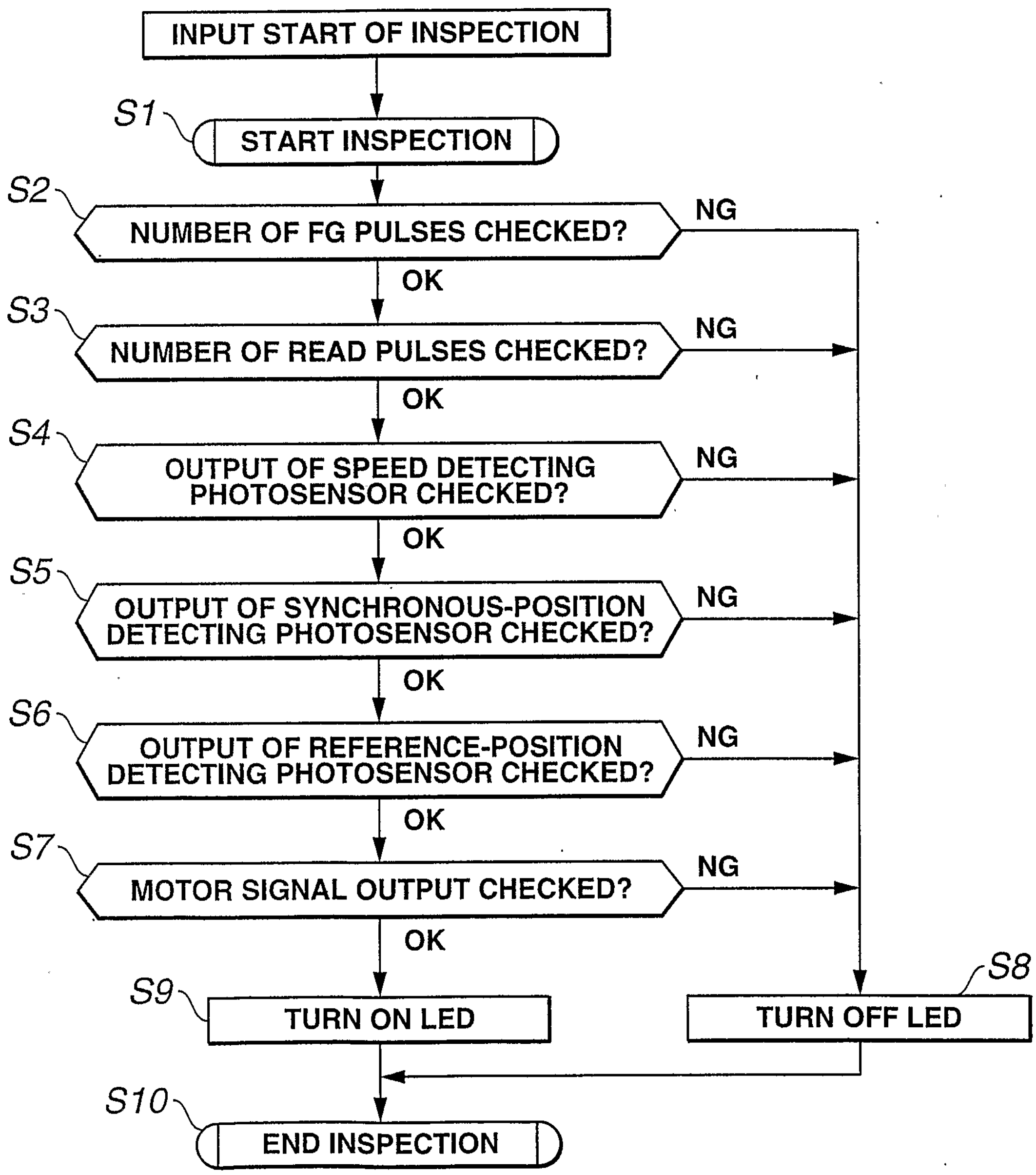

MOTOR DRIVER
50
SIGNAL ADDER
49
SPEED-LOOP FILTER
43
PHASE-LOOP FILTER
47
REFERENCE-SIGNAL DETECTING UNIT
48
21
SPEED COMPARATOR
42
PHASE COMPARATOR
46
54
LED TURN-ON CONTROL UNIT
53
LED
51
INSPECTION CONTROLLER
SLIDE SWITCH
52
PHASE ADJUSTMENT UNIT
45
PHASE ADJUSTING CONTROLLER
44
FG PULSE
READ PULSE
START PULSE
55-1
55-2
55-3
A/D CONVERTER
A/D CONVERTER
A/D CONVERTER
41-3
41-2
41-1
40-3
SPEED DETECTING PHOTOSENSOR
40-2
SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR
40-1
REFERENCE-POSITION DETECTING PHOTOSENSOR
HALL-SENSOR SIGNAL
REFERENCE SIGNAL
23
ROTARY COLOR FILTER
22
MOTOR
FROM OBSERVATION DEVICE

FIG.5


INPUT START OF INSPECTION
S1
START INSPECTION
S2
NUMBER OF FG PULSES CHECKED?
NG
OK
S3
NUMBER OF READ PULSES CHECKED?
NG
OK
S4
OUTPUT OF SPEED DETECTING PHOTOSENSOR CHECKED?
NG
OK
S5
OUTPUT OF SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR CHECKED?
NG
OK
S6
OUTPUT OF REFERENCE-POSITION DETECTING PHOTOSENSOR CHECKED?
NG
OK
S7
MOTOR SIGNAL OUTPUT CHECKED?
NG
OK
S9
TURN ON LED
S8
TURN OFF LED
S10
END INSPECTION

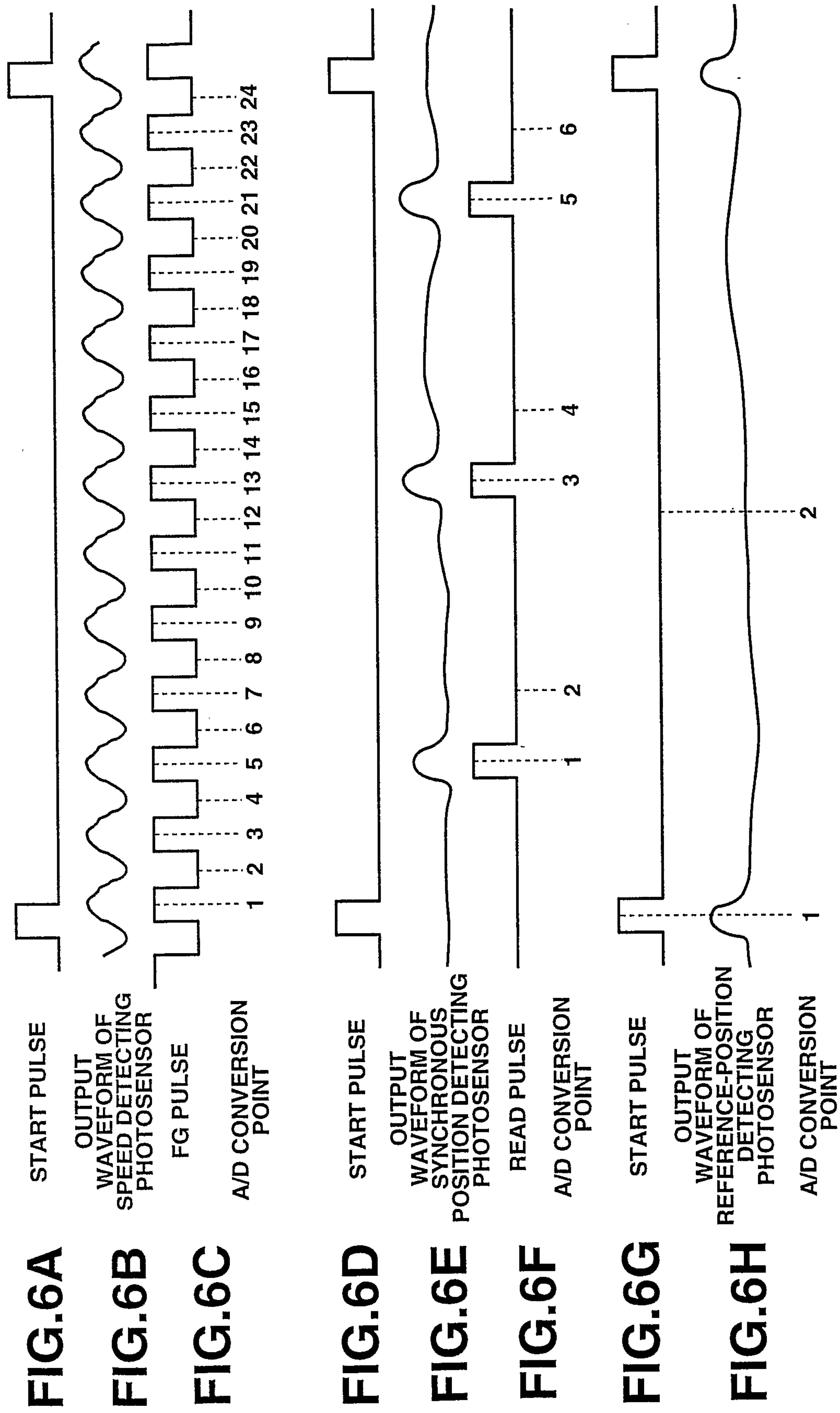


FIG.6A START PULSE
FIG.6B OUTPUT WAVEFORM OF SPEED DETECTING PHOTOSENSOR
FIG.6C FG PULSE
A/D CONVERSION POINT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
FIG.6D START PULSE
FIG.6E OUTPUT WAVEFORM OF SYNCHRONOUS POSITION DETECTING PHOTOSENSOR
FIG.6F READ PULSE
A/D CONVERSION POINT
1 2 3 4 5 6
FIG.6G START PULSE
FIG.6H OUTPUT WAVEFORM OF REFERENCE-POSITION DETECTING PHOTOSENSOR
A/D CONVERSION POINT
1 2

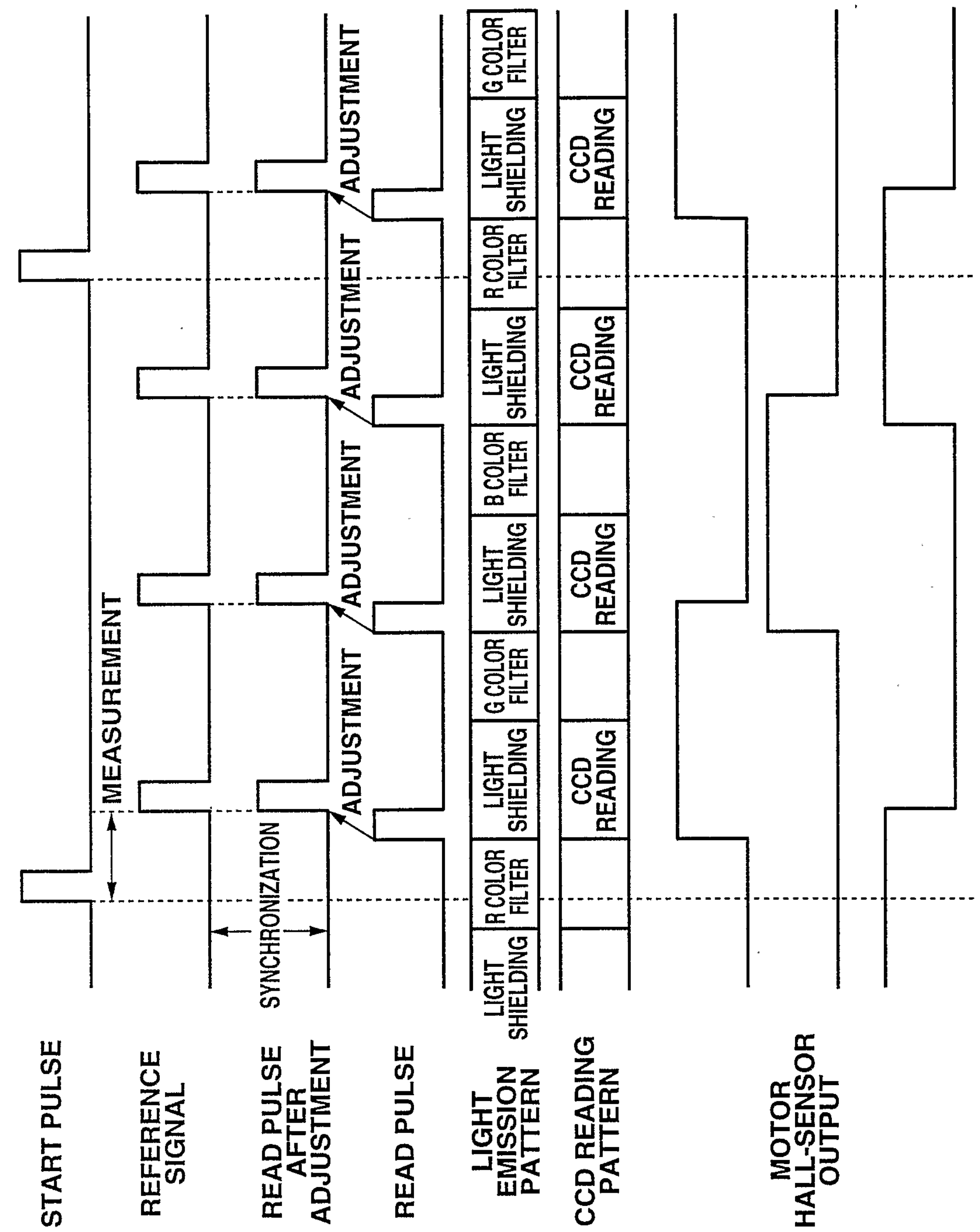


FIG.7A FIG.7B FIG.7C FIG.7D FIG.7E FIG.7F FIG.7G FIG.7H FIG.7I

FIG.8

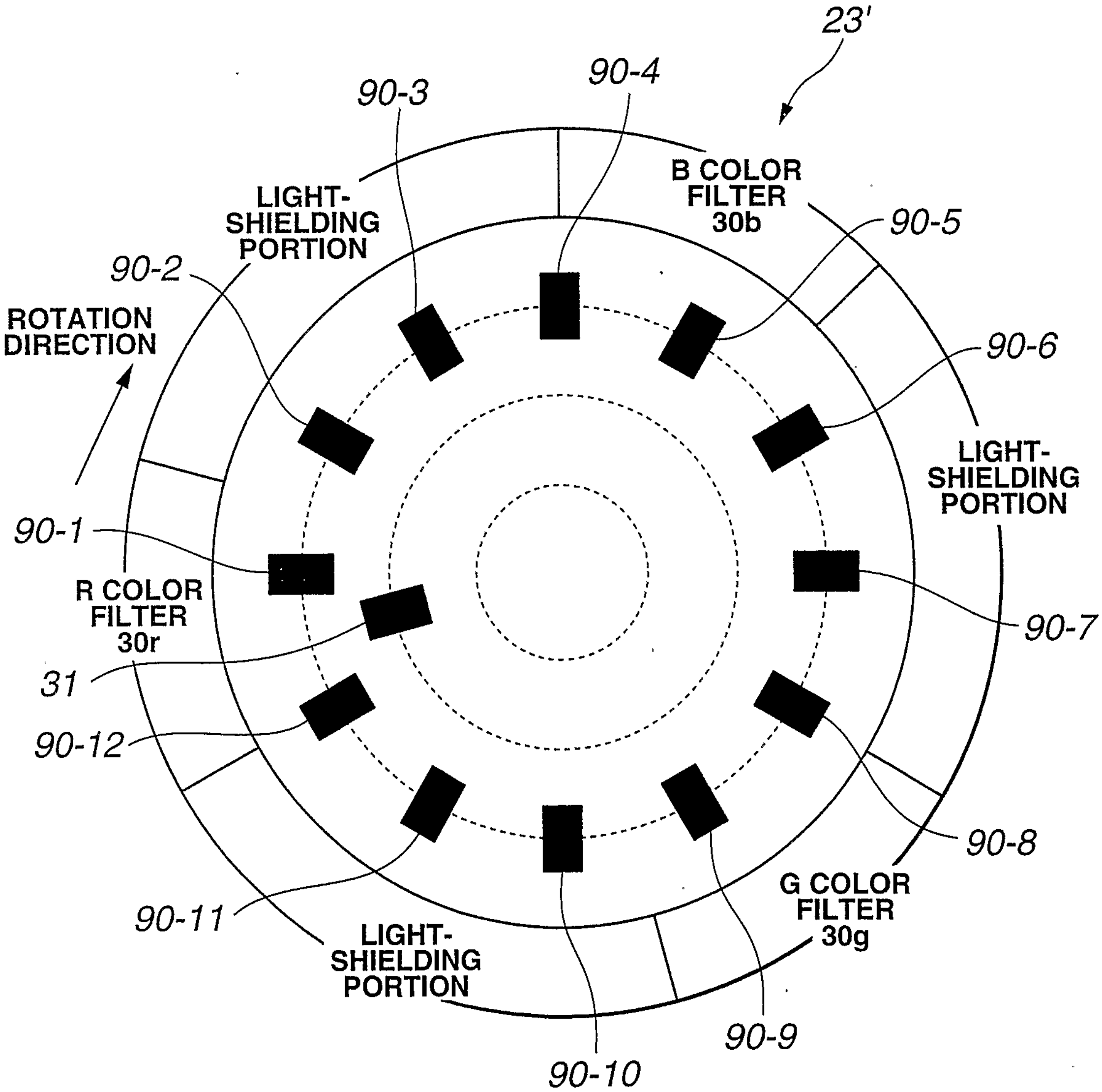
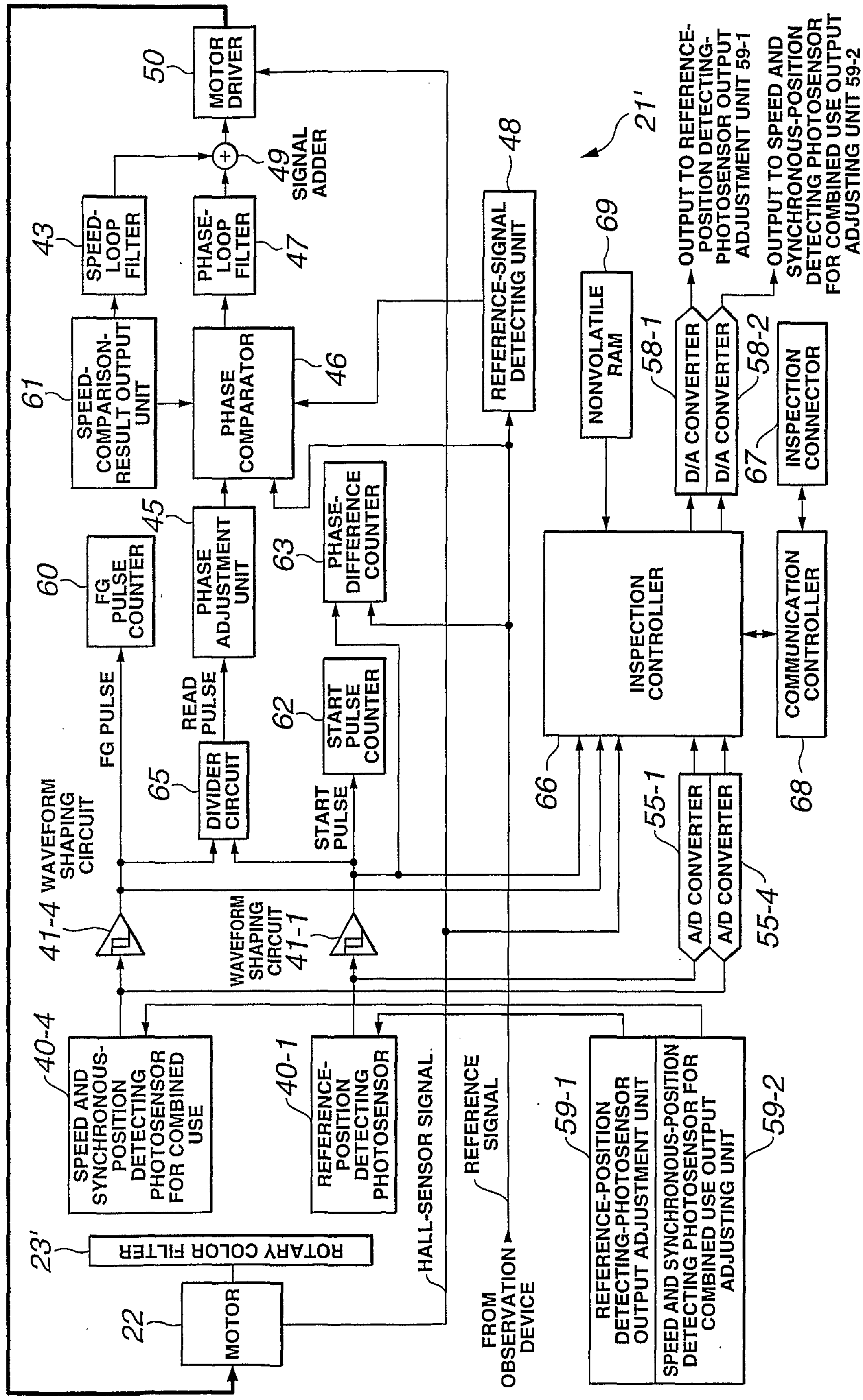

23'
90-4
90-3
B COLOR
FILTER
30b
LIGHT-
SHIELDING
PORTION
90-5
90-2
ROTATION
DIRECTION
90-6
LIGHT-
SHIELDING
PORTION
90-1
R COLOR
FILTER
30r
90-7
31
90-12
90-8
G COLOR
FILTER
30g
90-11
LIGHT-
SHIELDING
PORTION
90-9
90-10

FIG.9



21'
22 MOTOR
23' ROTARY COLOR FILTER
HALL-SENSOR SIGNAL
REFERENCE SIGNAL
FROM OBSERVATION DEVICE
40-4 SPEED AND SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR FOR COMBINED USE
40-1 REFERENCE-POSITION DETECTING PHOTOSENSOR
41-4 WAVEFORM SHAPING CIRCUIT
41-1 WAVEFORM SHAPING CIRCUIT
FG PULSE
READ PULSE
START PULSE
60 FG PULSE COUNTER
65 DIVIDER CIRCUIT
62 START PULSE COUNTER
45 PHASE ADJUSTMENT UNIT
63 PHASE-DIFFERENCE COUNTER
61 SPEED-COMPARISON-RESULT OUTPUT UNIT
46 PHASE COMPARATOR
43 SPEED-LOOP FILTER
47 PHASE-LOOP FILTER
49 SIGNAL ADDER
50 MOTOR DRIVER
48 REFERENCE-SIGNAL DETECTING UNIT
69 NONVOLATILE RAM
66 INSPECTION CONTROLLER
58-1 D/A CONVERTER
58-2 D/A CONVERTER
55-1 A/D CONVERTER
55-4 A/D CONVERTER
67 INSPECTION CONNECTOR
68 COMMUNICATION CONTROLLER
OUTPUT TO REFERENCE-POSITION DETECTING-PHOTOSENSOR OUTPUT ADJUSTMENT UNIT 59-1
OUTPUT TO SPEED AND SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR FOR COMBINED USE OUTPUT ADJUSTING UNIT 59-2
59-1 REFERENCE-POSITION DETECTING-PHOTOSENSOR OUTPUT ADJUSTMENT UNIT
59-2 SPEED AND SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR FOR COMBINED USE OUTPUT ADJUSTING UNIT

FIG.10

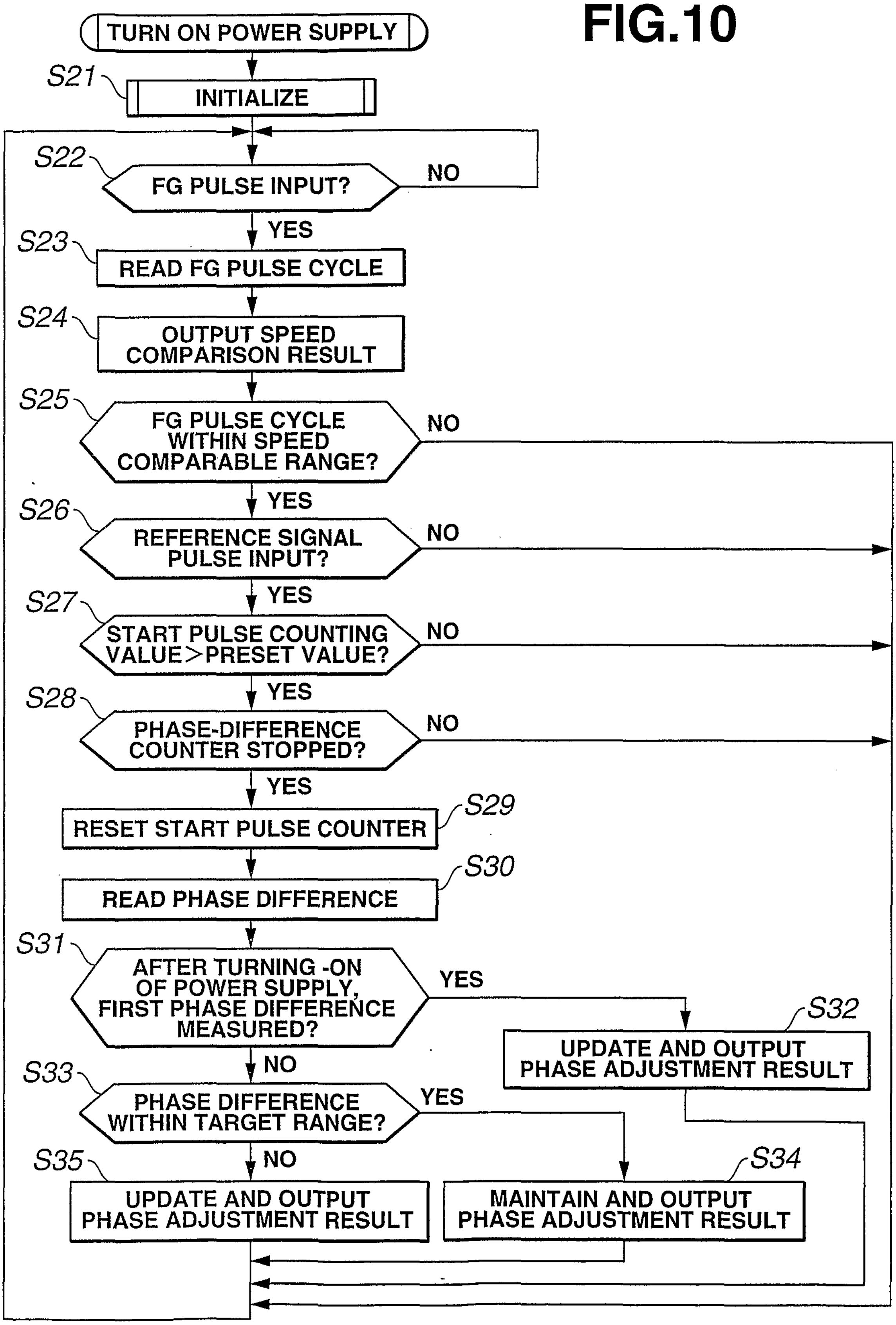

TURN ON POWER SUPPLY
S21
INITIALIZE
S22
FG PULSE INPUT?
NO
YES
S23
READ FG PULSE CYCLE
S24
OUTPUT SPEED COMPARISON RESULT
S25
FG PULSE CYCLE WITHIN SPEED COMPARABLE RANGE?
NO
YES
S26
REFERENCE SIGNAL PULSE INPUT?
NO
YES
S27
START PULSE COUNTING VALUE>PRESET VALUE?
NO
YES
S28
PHASE-DIFFERENCE COUNTER STOPPED?
NO
YES
RESET START PULSE COUNTER
S29
READ PHASE DIFFERENCE
S30
S31
AFTER TURNING -ON OF POWER SUPPLY, FIRST PHASE DIFFERENCE MEASURED?
YES
S32
UPDATE AND OUTPUT PHASE ADJUSTMENT RESULT
NO
S33
PHASE DIFFERENCE WITHIN TARGET RANGE?
YES
NO
S35
UPDATE AND OUTPUT PHASE ADJUSTMENT RESULT
S34
MAINTAIN AND OUTPUT PHASE ADJUSTMENT RESULT

FIG.11

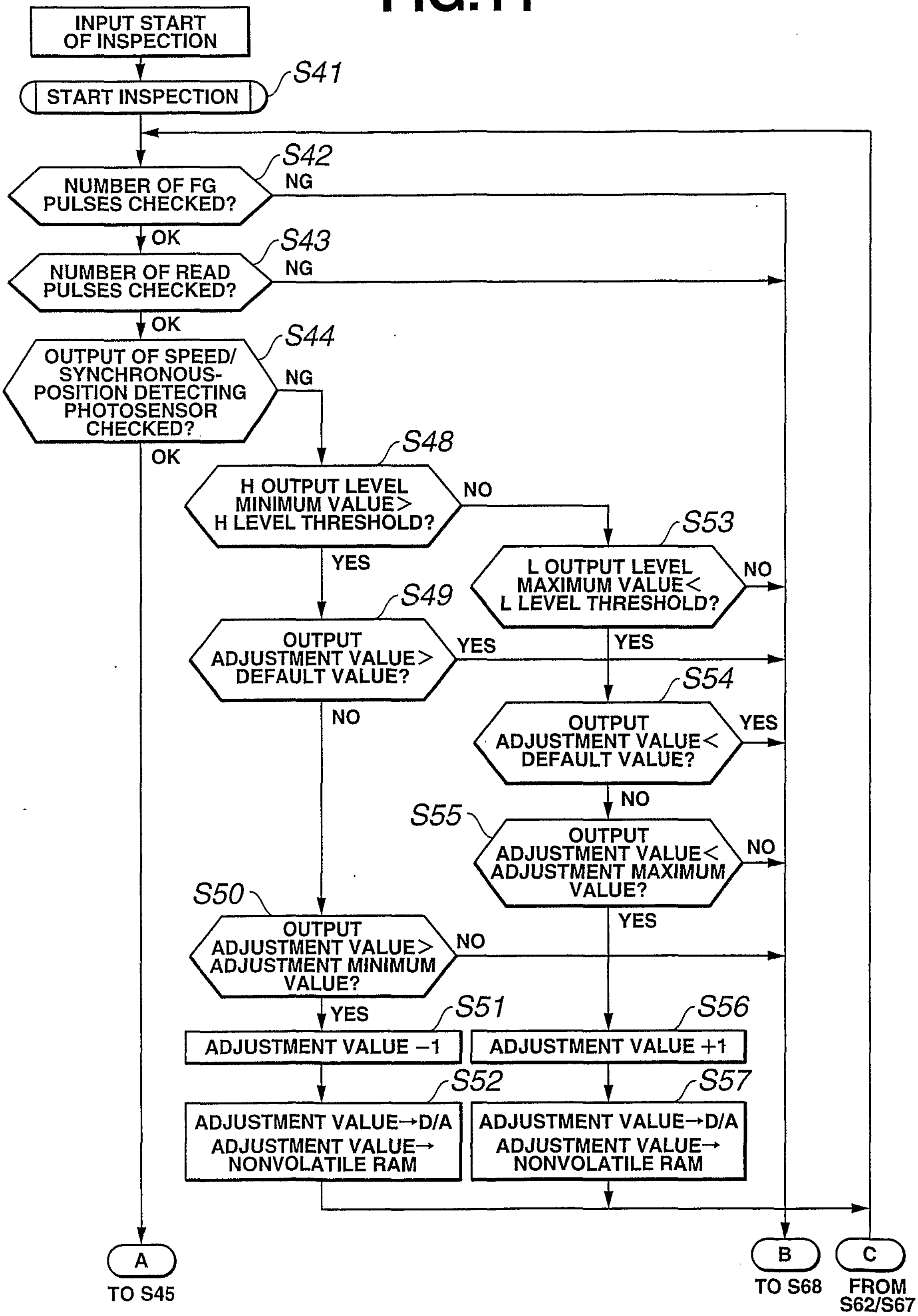
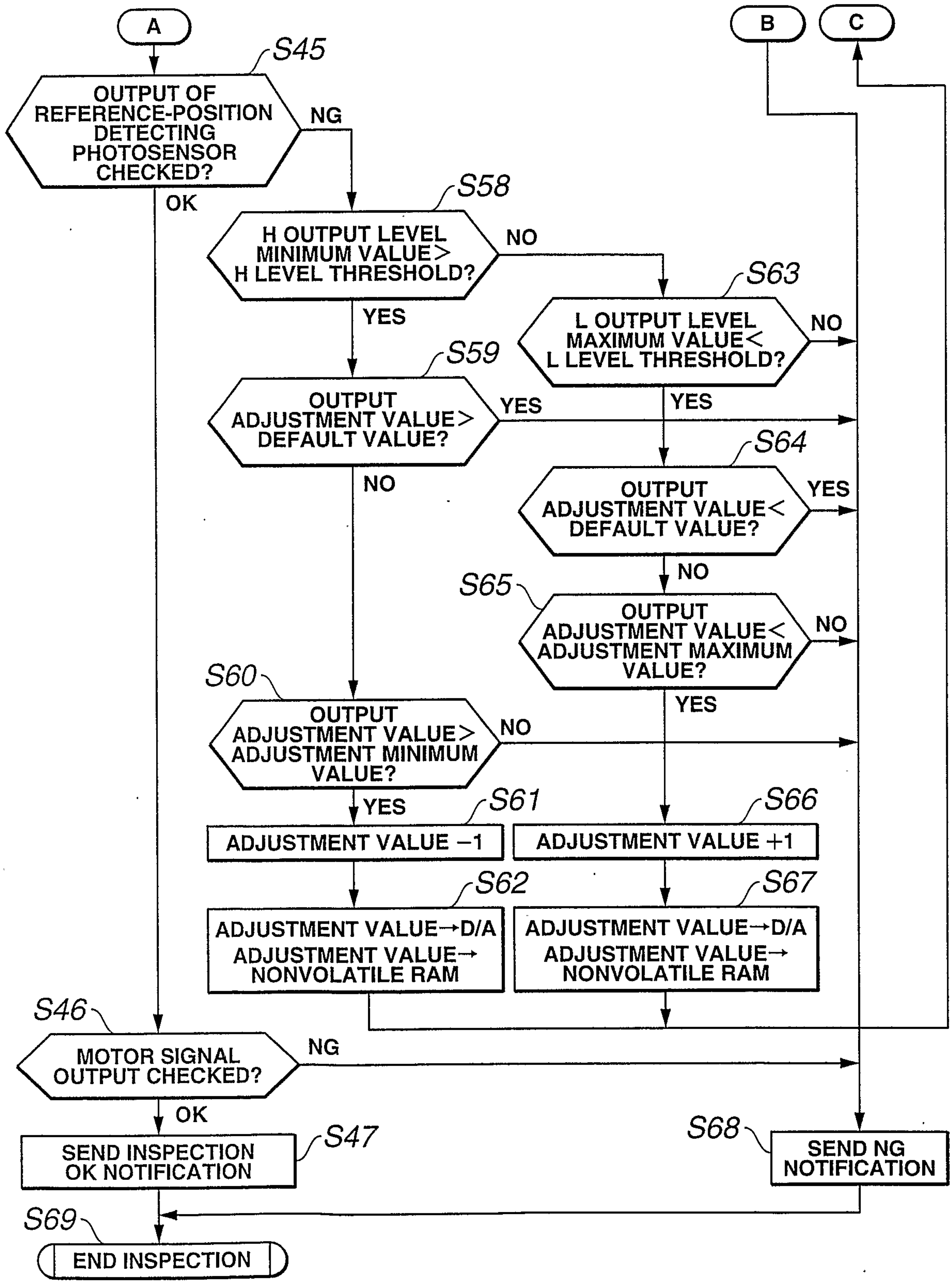

INPUT START OF INSPECTION
S41
START INSPECTION
S42
NUMBER OF FG PULSES CHECKED?
NG
OK
S43
NUMBER OF READ PULSES CHECKED?
NG
OK
S44
OUTPUT OF SPEED/ SYNCHRONOUS-POSITION DETECTING PHOTOSENSOR CHECKED?
NG
OK
S48
H OUTPUT LEVEL MINIMUM VALUE> H LEVEL THRESHOLD?
NO
YES
S53
L OUTPUT LEVEL MAXIMUM VALUE< L LEVEL THRESHOLD?
NO
YES
S49
OUTPUT ADJUSTMENT VALUE> DEFAULT VALUE?
YES
NO
S54
OUTPUT ADJUSTMENT VALUE< DEFAULT VALUE?
YES
NO
S55
OUTPUT ADJUSTMENT VALUE< ADJUSTMENT MAXIMUM VALUE?
NO
YES
S50
OUTPUT ADJUSTMENT VALUE> ADJUSTMENT MINIMUM VALUE?
NO
YES
S51
ADJUSTMENT VALUE −1
S56
ADJUSTMENT VALUE +1
S52
ADJUSTMENT VALUE→D/A ADJUSTMENT VALUE→ NONVOLATILE RAM
S57
ADJUSTMENT VALUE→D/A ADJUSTMENT VALUE→ NONVOLATILE RAM
A
TO S45
B
TO S68
C
FROM S62/S67

FIG.12


A
B
C
S45
OUTPUT OF REFERENCE-POSITION DETECTING PHOTOSENSOR CHECKED?
NG
OK
S58
H OUTPUT LEVEL MINIMUM VALUE> H LEVEL THRESHOLD?
NO
YES
S63
L OUTPUT LEVEL MAXIMUM VALUE< L LEVEL THRESHOLD?
NO
YES
S59
OUTPUT ADJUSTMENT VALUE> DEFAULT VALUE?
YES
NO
S64
OUTPUT ADJUSTMENT VALUE< DEFAULT VALUE?
YES
NO
S65
OUTPUT ADJUSTMENT VALUE< ADJUSTMENT MAXIMUM VALUE?
NO
YES
S60
OUTPUT ADJUSTMENT VALUE> ADJUSTMENT MINIMUM VALUE?
NO
YES
S61
ADJUSTMENT VALUE −1
S66
ADJUSTMENT VALUE +1
S62
ADJUSTMENT VALUE→D/A
ADJUSTMENT VALUE→ NONVOLATILE RAM
S67
ADJUSTMENT VALUE→D/A
ADJUSTMENT VALUE→ NONVOLATILE RAM
S46
MOTOR SIGNAL OUTPUT CHECKED?
NG
OK
S47
SEND INSPECTION OK NOTIFICATION
S68
SEND NG NOTIFICATION
S69
END INSPECTION

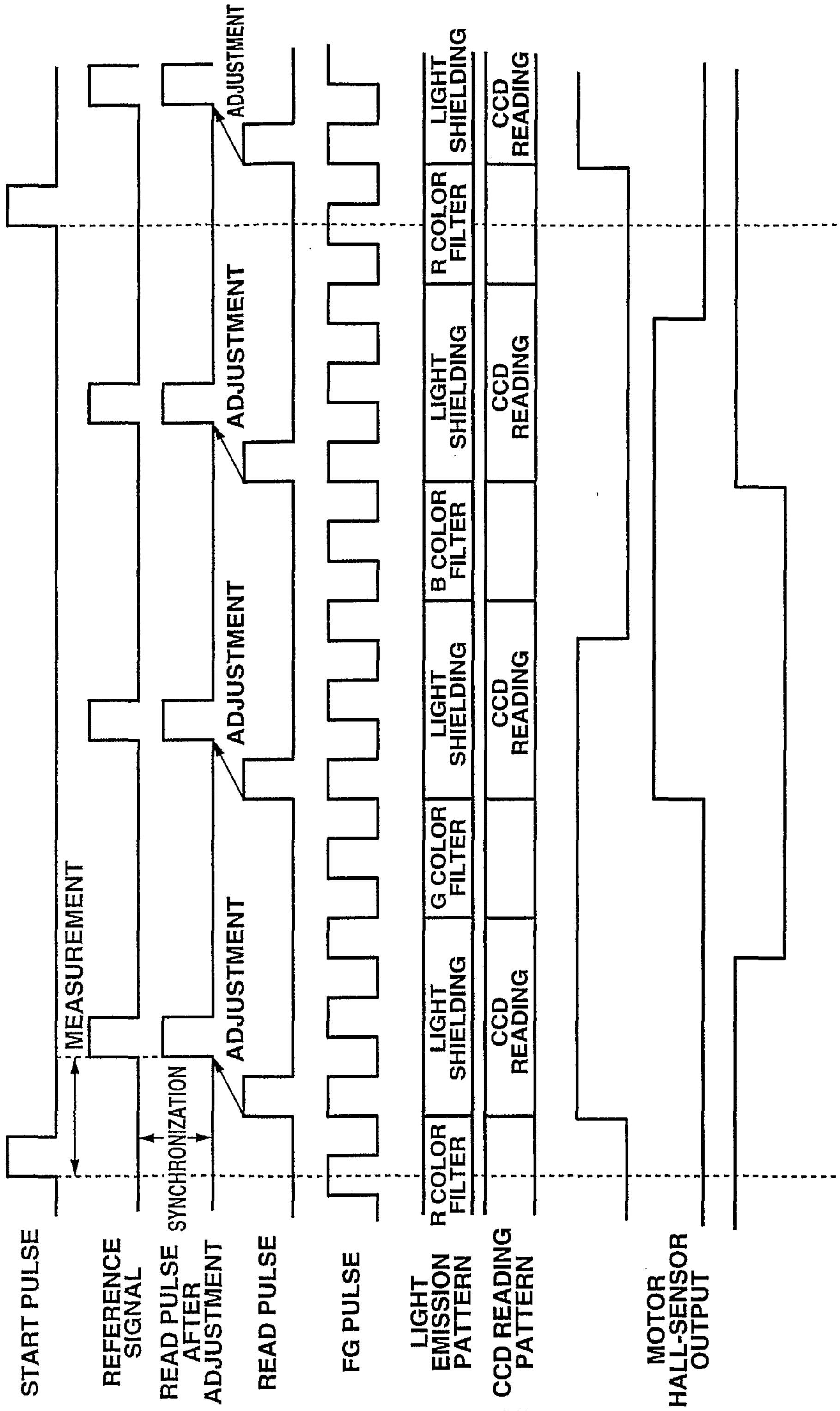


FIG.13A
FIG.13B
FIG.13C
FIG.13D
FIG.13E
FIG.13F
FIG.13G
FIG.13H
FIG.13I
FIG.13J

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP2004/001652

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B1/045 A61B1/06 G02B23/24 H02P9/00 H04N9/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B G02B H02P H04N

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 713 683 A (NAGASAKI TATSUO ET AL) 15 December 1987 (1987-12-15) column 3, line 47 -column 4, line 10 column 4, line 60 -column 5, line 19 figures 4,5,8	1,3,5,6, 11,13,14
A		8
X	US 4 998 163 A (SALVATI JOHN R) 5 March 1991 (1991-03-05) column 2, line 10-68; figure 1	1,2,11
X	US 4 523 224 A (LONGACRE JR ANDREW) 11 June 1985 (1985-06-11) abstract; figure 1 column 1, line 27-47	1,2,11

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

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Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2004	16/06/2004

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP2004/001652

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 733 246 A (FORKEY RICHARD E) 31 March 1998 (1998-03-31) column 6, line 7-32 column 7, line 35 -column 8, line 7 figures 1,3A,3B -----	1,11

INTERNATIONAL SEARCH REPORT

nformation on patent family members

International Application No
PCT/JP2004/001652

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4713683	A	15-12-1987	JP	6046811	B	15-06-1994
			JP	61061587	A	29-03-1986
			DE	3530775	A1	13-03-1986
US 4998163	A	05-03-1991	NONE			
US 4523224	A	11-06-1985	DE	3344287	A1	28-06-1984
			GB	2132387	A ,B	04-07-1984
			JP	59151591	A	30-08-1984
US 5733246	A	31-03-1998	DE	69527571	D1	05-09-2002
			DE	69527571	T2	03-04-2003
			EP	0682451	A2	15-11-1995
			JP	8079581	A	22-03-1996
			SG	30380	A1	01-06-1996
			TW	387560	Y	11-04-2000