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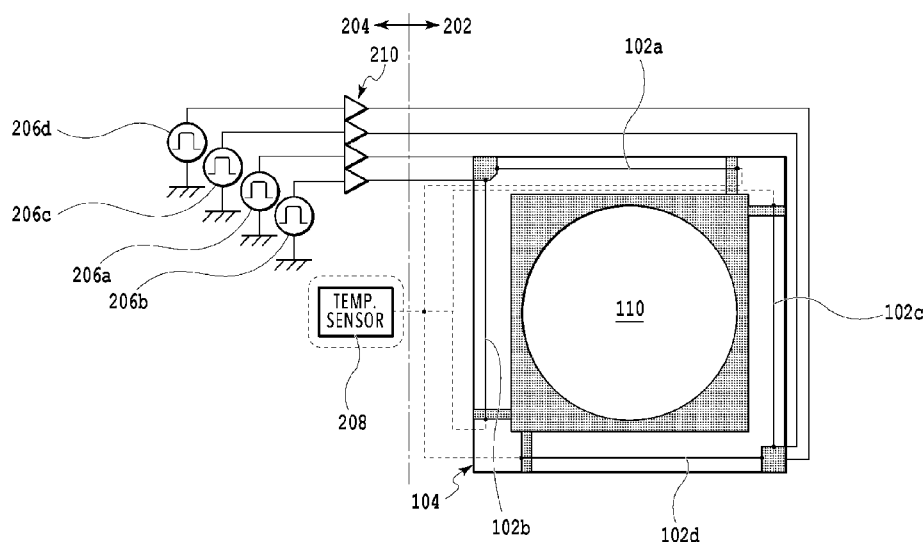


FIG. 1

(57) Abstract: Provided is a PWM driver which can mitigate noise on a camera module which is caused by PWM-controlled OIS/AF actuators. The PWM driver for generating a PWM signal used for driving a lens, comprising: a PWM signal generator configured to generate a reference PWM signal that toggles at a predetermined cycle; a receiving unit configured to receive a mask signal that defines a toggle inhibit period; and a modulation unit configured to generate an actual PWM signal by not toggling a reference PWM signal during the toggle inhibit period defined by the mask signal.



PWM DRIVER, METHOD OF GENERATING PWM SIGNAL, ACTUATOR SYSTEM AND  
CAMERA MODULE

Technical Field

The present invention relates to a PWM driver, a method for generating the PWM signal, an actuator system and a camera module, and more particularly to a PWM driver for generating a PWM signal used to drive a lens, a method for generating the PWM signal, an actuator system and a camera module.

Background Art

Electronic devices such as smartphones and small cameras include an Optical Image Stabilization (OIS) /Auto-Focus (AF) actuator for externally controlling a camera unit. For example, it is known that SMA wires are used as actuators. In this case, the SMA wires are used for OIS driving of an optical image of the camera by driving tilt of a camera unit including lens elements and an image sensor of the camera. In this case, the OIS/AF actuator of the electronic device outputs a signal modulated by PWM (Pulse Width Modulation) signal (hereinafter referred to as "PWM signal"). The PWM signal is a signal that switches between a high (H) state and a low (L) state at a predetermined cycle. In the actuator, the SMA wire is driven by this PWM signal to move the lens elements in the desired direction.

The PWM technique is a good candidate for a control method of driving OIS/AF actuator because it can reduce power consumption of

the camera module. However, repetition of H and L levels of the PWM signals output from the PWM driver raises electric and magnetic noise. Because the OIS/AF actuator is implemented close to an image sensor for moving lens unit, the noise from the PWM driver affects image signals.

#### Summary

The present disclosure provides the method to mitigate noise on a camera module, which is caused by PWM-controlled OIS/AF actuators.

According to the first aspect, there is provided a PWM driver for generating a PWM signal used for driving a lens, comprising:

a PWM signal generator configured to generate a reference PWM signal that toggles at a predetermined cycle;

a receiving unit configured to receive a mask signal that defines a toggle inhibit period; and

a modulation unit configured to generate an actual PWM signal by not toggling a reference PWM signal during the toggle inhibit period defined by the mask signal.

According to this implementation, an actual PWM signal is generated by not toggling a reference PWM signal during the toggle inhibit period. Therefore, it is possible to remove noise impact on AD conversion of the pixel output without restrictions caused by combination of the PWM career frequency and the AD conversion period.

With respect to a possible implementation of the first aspect, the PWM signal generator generates the reference PWM signal based

on movement of the lens.

According to this implementation, a PWM signal can be generated considering movement of the lens such as acceleration, velocity and position of the lens.

With respect to a possible implementation of the first aspect, the generator acquires movement information from a gyro sensor that detects the movement of the lens.

According to this implementation, a PWM signal generator can generate the reference PWM signal based on movement information from a gyro sensor that detects the movement of the lens.

With respect to a possible implementation of the first aspect, the toggle inhibit period is set based on a control signal for analog-digital conversion of an image captured by an image sensor.

According to this implementation, the output level of an actual PWM signal can be maintained during one cycle of the AD conversion operation.

With respect to a possible implementation of the first aspect, the PWM driver further comprises a counter configured to increase or decrease a counter value of a pulse number of a clock according to an H state or an L state of the actual PWM signal, wherein the modulation unit is configured to toggle the actual PWM signal based on the counter value for minimizing an absolute value of the counter value outside of the toggle inhibit period.

According to this implementation, the count number indicates how long H/L state periods of the output are different from those of the reference PWM signal. It is possible to toggle the actual PWM signal considering the result of the measurement.

With respect to a possible implementation of the first aspect, a range of the counter corresponds to a cycle of the reference signal for the analog-digital conversion.

According to this implementation, overflow of a counter can be suppressed.

With respect to a possible implementation of the first aspect, the modulation unit toggles the actual PWM signal when an overflow of the counter value occurs during the toggle prohibition period.

According to this implementation, PWM control with less noise can be continued while reducing an influence of overflow of a counter.

With respect to a possible implementation of the first aspect, the mask signal is generated based on a control signal for analog-digital conversion of an image captured by an image sensor.

According to this implementation, the toggle inhibit period can be set by the mask signal such that a PWM state does not change in one cycle of CDS, and the noise induced by change of the PWM state in AD conversion of the image sensor is suppressed.

With respect to a possible implementation of the first aspect, the toggle inhibit period is set such that the actual PWM signal does not toggle at a period of conversion process of an analog signal of an image captured by an image sensor to digital output.

According to this implementation, the toggle inhibit period can be set such that a PWM state does not change in one cycle of CDS.

With respect to a possible implementation of the first aspect, the PWM driver further comprises a monitor configured to instruct the modulation unit to toggle the actual PWM signal based on the

reference PWM signal and the actual PWM signal.

According to this implementation, the modulation unit can generate an actual PWM signal based on an output from the duty error monitor and a reference PWM signal.

With respect to a possible implementation of the first aspect, the monitor instructs the modulation unit to toggle the actual PWM signal such that the actual PWM signal approaches a duty ratio of the reference PWM signal.

According to this implementation, an average duty ratio can be made the same as the duty ratio of the reference PWM signal.

With respect to a possible implementation of the first aspect, the PWM driver further comprises a mask generation unit configured to generate the mask signal.

According to this implementation, the mask generation unit can be implemented in the PWM driver.

According to the second aspect, there is provided an actuator system, comprising:

the PWM driver according to any one of implementations of the first aspect; and

a lens unit for driving a lens based on an actual PWM signal generated by the actual PWM driver.

According to the third aspect, there is provided a camera module,

the actuator system according to the second aspect; and

an imaging unit configured to capture an image with a lens driven by the actuator system.

According to the fourth aspect, there is provided a method for

generating a PWM signal used to drive a lens, comprising:

generating a reference PWM signal that toggles at a predetermined cycle;

receiving a mask signal that defines a toggle inhibit period;

generating an actual PWM signal by not toggling the reference PWM signal during the toggle inhibit period defined by the mask signal.

According to this implementation, an actual PWM signal is generated by not toggling a reference PWM signal during the toggle inhibit period. Therefore, it is possible to remove noise impact on AD conversion of the pixel output without restrictions caused by combination of the PWM career frequency and an AD conversion period.

With respect to a possible implementation of the fourth aspect, the step of generating the reference PWM signal generates the reference PWM signal based on movement of the lens.

With respect to a possible implementation of the fourth aspect, the step of generating the reference PWM signal obtains movement information from a gyro sensor that detects movement of the lens.

With respect to a possible implementation of the fourth aspect, the toggle inhibit period is set based on a control signal for analog-digital conversion of an image captured by an image sensor.

With respect to a possible implementation of the fourth aspect, the method further comprises:

increasing or decreasing a counter value of a pulse number of a clock according to an H state or an L state of the actual PWM signal, wherein the step of generating the reference PWM signal is

based on the counter value for minimizing an absolute value of the counter value outside of the toggle inhibit period.

With respect to a possible implementation of the fourth aspect, a range of the counter corresponds to a cycle of the reference signal for the analog-digital conversion.

With respect to a possible implementation of the fourth aspect, the step of generating the actual PWM signal toggles the actual PWM signal when an overflow of the counter value occurs during the toggle prohibition period.

With respect to a possible implementation of the fourth aspect, the mask signal is generated based on a control signal for analog-digital conversion of an image captured by an image sensor.

With respect to a possible implementation of the fourth aspect, the toggle inhibit period is set such that the actual PWM signal does not toggle at a period of conversion process of an analog signal of an image captured by an image sensor to digital output.

With respect to a possible implementation of the fourth aspect, the step of generating the actual PWM signal comprises toggling the actual PWM signal based on the reference PWM signal and the actual PWM signal.

With respect to a possible implementation of the fourth aspect, the step of generating the actual PWM signal toggles the actual PWM signal such that the actual PWM signal approaches a duty ratio of the reference PWM signal.

With respect to a possible implementation of the fourth aspect, the method further comprises the step of generating the mask signal.

## Brief Description of Drawings

To describe the technical solutions in the embodiments more clearly, the following briefly describes the accompanying drawings required for describing the present embodiments. Apparently, the accompanying drawings in the following description depict merely some of the possible embodiments, and a person of ordinary skill in the art may still derive other drawings, without creative efforts, from these accompanying drawings, in which:

FIG. 1 illustrates a diagram showing electrical connection of SMA-OIS.

FIG. 2 illustrates a configuration for time division driving.

FIG. 3 illustrates temporal variation of the PWM signal for driving SMA wires.

FIG. 4 illustrates Bode plot of Correlated Double Sampling (CDS) as a filter.

FIG. 5 illustrates a configuration of a CMOS image sensor in which a column ADC of pixel columns performs the CDS.

FIG. 6 illustrates a diagram of signals in the CDS implemented on the CMOS image sensor.

FIG. 7 illustrates a configuration example of lens actuator system.

FIG. 8 illustrates a diagram of signals for performing the CDS in the ADC and a PWM signal for OIS driving.

FIG. 9 illustrates a block diagram of the lens actuator system with a waveform modulator according to one embodiment.

FIG. 10 illustrates a waveform chart for explaining the

waveform operation of the waveform modulator.

FIG. 11 illustrates the relationship between a RAMP signal and an ACT\_PWM signal for AD conversion.

Fig. 12 illustrates a state transition diagram according to one embodiment.

Fig. 13 illustrates a diagram showing operating waveform in the case of overflow of a duty error monitor.

Fig. 14 illustrates a state transition diagram according to one embodiment.

Fig. 15 illustrates a block diagram of a lens actuator system with a waveform modulator.

FIG. 16 illustrates a diagram of signals when the lens actuator system according to one embodiment.

#### Description of Embodiments

To make persons skilled in the art understand the technical solutions in the present disclosure better, the following clearly and completely describes the technical solutions in the embodiments of the present disclosure with reference to the accompanying drawings in the modes of the present disclosure. Apparently, the described embodiments are merely a part rather than all of the embodiments of the present disclosure. All other embodiments obtained by persons of ordinary skill in the art based on the embodiments of the present disclosure without creative efforts shall fall within the protection scope of the present disclosure.

In the following descriptions, control of an SMA actuator using

PWM is described as representative examples.

(First embodiment)

First, operation principle of the present embodiment will be described with reference to FIGS. 1 to 4.

FIG. 1 is a diagram showing electrical connection of SMA-OIS. As shown in FIG. 1, a controller 204 for controlling the OIS and an OIS actuator 202 are connected through conductive lines. Each of Shape Memory Alloy (SMA) wires 102a, 102b, 102c and 102d is connected to one of PWM sources 206a, 206b, 206c and 206d via one of amplifiers 210 for driving.

In order to heat wire, it is available to apply current to the SMA wire by the corresponding one of the PWM sources 206a, 206b, 206c and 206d. Its current should be controlled by a PWM method for lowering its huge power consumption. In addition, a temperature sensor 208 is implemented to this system so as to measure temperature of each wire for improving its control accuracy. The structure which contains a temperature sensor 208 and the plural SMA wires 120 driven by time divided driving (FIGS. 2 and 3) is applied so as to reduce a size of a camera module.

The PWM sources 206a, 206b, 206c and 206d generate PWM signals according to temperatures of the connected SMA wire measured by the temperature sensor 208. This system which is expected to achieve miniature camera module can control the position of a movable unit 110 because each of the SMA wires 102a, 102b, 102c and 102d can shrink its own length by heating.

FIG. 2 shows a configuration for time divided driving. In FIG. 2, SMA wire 304 includes four SMA wires WIRE0, WIRE1, WIRE2, and

WIRE3. The wires WIRE0, WIRE1, WIRE2, and WIRE3 have resistance values  $r_0$ ,  $r_1$ ,  $r_2$ , and  $r_3$ , respectively. One ends of the wires WIRE0, WIRE1, WIRE2, and WIRE3 are connected to the Analog-Digital Converter (ADC) 302 and a temperature sensor 308. If a SMA wire is regarded as a resistance with temperature characteristics, the temperature can be estimated from the output voltage by determining output of divided voltage of the SMA wire and a resistance for measurement included in the temperature sensor 308. This output voltage is converted to a digital value by the ADC 302.

The other end of the SMA wire WIRE0 is connected to a transistor 306a whose gate is connected to a PWM source 206a which outputs a PWM signal PWM0. The other end of the SMA wire WIRE1 is connected to a transistor 306b whose gate is connected to a PWM source 206b which outputs a PWM signal PWM1. The other end of the SMA wire WIRE2 is connected to a transistor 306c having a gate connected to a PWM source 206c which outputs a PWM signal PWM2. The other end of the SMA wire 3 is connected to a transistor 306d having a gate connected to a PWM source 206d which outputs a PWM signal PWM3. When a PWM signal is ON for a gate of a transistor input, current flows. The current from the transistors 306a to 306d are supplied to the SMA wire 304 by opening/closing the transistors 306a to 306d by the PWM sources 206a to 206d.

FIG. 3 shows temporal variation of the PWM signal for driving the SMA wires WIRE0, WIRE1, WIRE2, and WIRE3. As shown in Fig. 3, temperature of each of the SMA wires WIRE0, WIRE1, WIRE2 and WIRE3 should be calculated from ADC input voltage, which is proportional

to a measurement of each of SMA wires. By heating the SMA wires 304 with electricity, a tightening force is generated, and this tightening force is used as a lens-driving force for driving the lens. Here, the length of one period (PWM career period) is the same for the four PWM signals. Further, the four PWM signals become a High state at different timings. Further, the four PWM signals may have different duty ratios. This method generally has the advantages that it is easy to reduce the size and weight of an electronic device and that a relatively large amount of force can be obtained.

Next, the noise generated in the Analog-Digital (AD) conversion used in the image sensor of the camera such as CCD and CMOS image sensor will be described. As such kind of noise, kTC noise,  $V_{th}$  offset and  $1/f$  noise are well known. In order to cancel such noises, Correlated Double Sampling (CDS) is commonly implemented on the ADC of the image sensor. In CDS operation, double-sampling is executed for a reset level (reset sampling) and a signal level (signal sampling), and an output signal is defined as a differential value of the reset and signal sampling. The operation can cancel noises commonly included between the reset sampling and signal sampling. Frequency response of the CDS is defined with a time interval  $T$  between two samplings as follows:

$$|H_{CDS}(f)|^2 = |\sqrt{2} \sin(\pi f T)|^2 \sim \left| \sqrt{2} \frac{1}{1 + j(\frac{1}{\pi f T})} \right|^2 = \left| \sqrt{2} \frac{1}{\sqrt{1 + (\pi f T)^{-2}}} \right|^2$$

FIG. 4 is Bode plot of the CDS as a filter according to the above formula. In the figure, the vertical axis indicates gain

(dB) of the frequency response, and the horizontal axis indicates frequency ( $1/T$ ). Solid lines are drawn by the CDS transfer function. These lines are approximated by broken lines. As shown in FIG. 4, the CDS has a transfer characteristic of a band pass filter. Specifically, it behaves as a high-pass filter in a frequency range under  $1/2T$ , and cancels frequency components of  $n/T$ , completely.

Next, with reference to FIGS. 5 and 6, the CDS implemented in the COMS image sensor will be described. FIG. 5 shows a configuration of a CMOS image sensor in which an ADC of pixel columns performs the CDS. The CMOS image sensor 600 includes a row decoder and driver 608, a pixel array 602, a comparator 604, a counter 605, a buffer 606, a RAMP generator 610 and a counter clock 612. The pixel array 602 includes a plurality of pixels. The pixel is provided with a photodiode and a floating diffusion (FD), and the FD stores the electric charge obtained by the photodiode. The pixel row designated by the signal from the row decoder and driver 608 is driven. The voltage of the pixel output from the pixel array 602 is compared with the voltage of a RAMP signal from the RAMP generator 610 in the comparator 604, and the time at change of comparator output is output to the buffer 606 via the counter 605.

Here, the RAMP signal is a control signal for analog-digital conversion of an image captured by an image sensor. The counter 605 counts the number of pulses from the counter clock 612. Specifically, the counter 605 adds or subtracts the counted number of pulses, to or from the counter value according to the output

value from the comparator 604. The output of the comparator 604 is in the Low state when the voltage of the RAMP signal is higher than the voltage of the pixel output, and is in the High state when the voltage of the RAMP signal is lower than the voltage of the pixel output. In the example shown in FIG. 5, the pixel value is replaced with a digital value by storing the counter value of the counter 605 when the output of the comparator 604 rises in the buffer 606.

FIG. 6 is a diagram of signals in the CDS implemented on the COMS image sensor. In FIG. 6, the upper solid line shows the RAMP signal that is a reference of the AD conversion, and the broken line shows the pixel output (analog input) voltage. The lower solid line shows the output of the comparator 604. The first slope of the RAMP signal starts at time  $t_0$ . The reset operation is performed in the period of Reset Level starting from time  $t_0$ , and the counter 605 performs the countdown operation. Next, when the output level of the comparator 604 rises, the counting is stopped at time  $t_1$ , and the counter value is stored in the buffer 606. Then, the second slope starts at time  $t_2$ . The signal output operation is performed during the Signal Level period starting from time  $t_2$ , and the counter 605 starts counting up. Next, when the output level from the comparator 604 rises, the counting is stopped at time  $t_3$ , and the counter value is stored in the buffer 606. Then, the digital value of the pixel output is acquired by calculating the difference between the two counter values stored in the buffer 606 and obtaining the difference between the digital value. In this way, the CDS is executed, and the noise component

included in the pixel output can be removed.

In FIG. 6, the pixel output may fluctuate as indicated by an arrow 502 due to noise derived from the PWM signal for OIS driving. Due to this fluctuation, the comparison result by the comparator 604 fluctuates, and the rise timing of the output signal also fluctuates within the range indicated by arrows 504 and 506. Fluctuations in the rise timing of the comparator 604 further cause fluctuations in the CDS time interval, resulting in the noise.

Next, with reference to FIG. 7 and FIG. 8, the limitation of PWM control at performing the CDS will be described.

FIG. 7 shows a configuration example of the lens actuator system. The lens actuator system 800 includes a lens unit 808 and a servo controller 814. The lens unit 808 includes a lens 804, an actuator 806 and a gyro sensor 812. The servo controller 814 includes a driver 810, a PWM signal generator 820 and a duty ratio generator 816. In such a configuration, when an image is captured using the lens actuator system 800, an image is input from the lens 804 to the imaging unit 802. The imaging unit 802 includes an image sensor, and the image sensor outputs an image signal DATA based on an analog signal from the lens 804. The imaging unit 802 also outputs the control signal Sctrl to the PWM signal generator 820.

Information on the movement of the lens 804 is obtained by the gyro sensor 812. The gyro sensor 812 outputs the SENS\_OUT signal to the duty ratio generator 816. SENS\_OUT is lens movement information (acceleration, velocity and position of a lens). The

duty ratio generator 816 calculates a duty ratio of the PWM signal to be generated based on the SENS\_OUT signal. The calculated duty ratio is sent to the PWM signal generator 820. The PWM signal generator 820 generates the PWM signal Sdrv0 based on the input duty ratio and the control signal Sctrl, and sends the generated PWM signal Sdrv0 to the driver 810. The driver 810 generates a drive signal Sdrv based on the PWM signal Sdrv0 and outputs it to the actuator 806. The actuator 806 moves the lens 804 based on the drive signal Sdrv to perform OIS control.

FIG. 8 is a waveform chart of signals for performing the CDS in the ADC and a PWM signal for OIS driving. In FIG. 8, the solid line at the top indicates the RAMP signal, and the broken line indicates the pixel output (analog input). The second line shows the output of the comparator. The third line shows the control signal Sctrl. The fourth to sixth signals represent PWM signals with duty ratios of 10%, 40% and 90%, respectively. When the CDS is performed in the ADC, if the PWM signal levels are different at the rise timings t1 and t2 of the comparator output, it may cause noise. Therefore, when drive control is performed with a plurality of PWM signals, the plurality of PWM signals preferably have the same level at the rise timing t1 and t2 of the comparator output during the AD conversion operation period t0.

For driving four SMA wires with the time divided driving, it might be difficult to implement this technique because its maximum pulse width and PWM signal frequency have constraint with AD conversion period.

The present disclosure provides a method to avoid interference

noise generated by a PWM driver without constraints in setting a frequency between a AD conversion operation and a PWM driver.

In this embodiment, a waveform modulator generates an output signal to an actuator or other devices by modulating an output PWM signal for driving these devices under the following rules:

(1) Not to toggle the output PWM signal (H/L), in a toggle inhibit period defined by the MASK signal.

(2) At outside of the toggle inhibit period, (a) set the output PWM signal so as to make its duty ratio to that of a reference PWM signal, or (b) set the output PWM signal to the reference PWM signal if the duty ratio of the output equals to that of the reference PWM signal. Here, the toggle inhibit period should include a CDS period between the start of the reset sampling and the end of the signal sampling (i.e. a CDS period).

According to this embodiment, the waveform modulator comprises a duty error monitor which measures how long H/L state periods of the output are different from those of the reference PWM signal. Then, the waveform modulator generates an actual PWM signal by modulating the reference PWM signal based on an output from the duty error monitor and the MASK signal. Here, the MASK signal indicates an inhibit period to prohibit toggling the output PWM signal (H/L).

FIG. 9 is a block diagram of the lens actuator system with the waveform modulator according to this embodiment. Definition of each signal shown in FIG. 9 is described as set forth below.

MASK is a control signal to define an inhibit period to toggle. SENS\_OUT is lens movement information (acceleration, velocity and

position of a lens). REF\_PWM is a reference PWM signal with a duty ratio determined by servo system. ERR is a flag signal indicating actual duty ratio higher/lower than target duty ratio. Also, ACT\_PWM is a pulse train of an actual PWM signal to move an actuator.

The lens actuator system 900 includes a lens unit 902, a servo controller (PWM driver) 904, and an image sensor with CDS 906. The lens unit 902 includes a lens 908, an actuator 910, and a gyro sensor 912. The servo controller (PWM driver) 904 includes a driver 914, a waveform generator 919, and a PWM signal generator 920. The waveform generator 919 includes a waveform modulator 916 and a duty error monitor 918. In such a configuration, when an image is captured using the camera including the lens actuator system 900, pixel output is input from the lens 908 to the image sensor with CDS 906. The image sensor with CDS 906 is configured to perform conversion process of an analog signal of a captured image to digital output. The image sensor with CDS 906 performs the CDS in the AD conversion for pixel output (analog input) from the lens 908, and outputs an image signal DATA. Also, the image sensor with CDS 906 outputs the MASK signal to the waveform modulator 916.

Information on the movement of the lens 908 is output to the gyro sensor 912. The gyro sensor 912 outputs the SENS\_OUT signal to the PWM signal generator 920 based on the received motion information of the lens 908. The PWM signal generator 920 generates a REF\_PWM signal based on the SENS\_OUT signal and outputs it to the waveform modulator 916 and the duty error

monitor 918. The duty error monitor 918 counts the pulse number of a clock for controlling an imaging unit. Also, the duty error monitor 918 generates an ERR flag based on the REF\_PWM signal and the ACT\_PWM signal from the waveform modulator 916, and outputs the ERR flag to the waveform modulator 916. The waveform modulator 916 generates the ACT\_PWM signal based on the values of the MASK signal, the REF\_PWM signal and the ERR flag. The ACT\_PWM signal is output to the driver 914 and the duty error monitor 918. The driver 914 outputs the input ACT\_PWM signal to the actuator 910. The actuator 910 drives the lens 908 based on the ACT\_PWM signal.

FIG. 10 is a waveform chart for explaining the waveform operation of the waveform modulator. In FIG. 10, the first line is a RAMP signal for the AD conversion. The second signal represents MASK and the third signal represents REF\_PWM. The fourth signal shows the counter value of the counter included in the duty error monitor 918, and the fifth signal shows the value of the ERR flag. Furthermore, the last signal shows the ACT\_PWM signal.

The MASK signal indicates the prohibited period by the H state. During the prohibited period, ACT\_PWM is controlled such that it is not toggled. The prohibition period is set so as to include a period from the start of the reset operation to the end of the signal output operation in one cycle of the AD conversion.

The duty ratio of REF\_PWM is set based on SENS\_OUT from the gyro sensor 912. In this embodiment, the duty ratio is set to 60%.

Referring to the counter value CNT, the duty error monitor 918 counts it up as indicated by an arrow 1002 (t1 to t2) when the reference PWM signal REF\_PWM is L and the waveform modulator 916

outputs H. It also counts it down as indicated by an arrow 1004 (t3 to t4) and 1006 (t5 to t7) when the reference PWM signal REF\_PWM is H and the waveform modulator 916 outputs L. The ERR flag is set to -1 when the counter value is positive, and is set to 1 when the counter value is negative. Thus, when the counter value CNT is positive (ERR=-1), H-level period of the output signal ACT\_PWM is shorter than that of the reference PWM signal REF\_PWM. On the other hand, when the counter value CNT is negative (ERR=+1), L-level period of the output signal is shorter than that of the reference PWM signal REF\_PWM. The waveform modulator 916 selects an output level with reference to the counter value.

The ACT\_PWM signal is in the L state when the ERR flag is -1 (t3), and is in the H state when the ERR flag is +1 (t7) in the toggle inhibit period. Therefore, the ACT\_PWM signal is set as follows:

- (1) When CNT is positive, ACT\_PWM is L
- (2) When CNT is negative, ACT\_PWM is H
- (3) When CNT is "0," the output signal is the same as the reference PWM signal REF\_PWM

According to the above operation, the toggle inhibit period is set such that the actual PWM signal does not toggle at a period of AD conversion process of an analog signal of an image captured by an image sensor to digital output. Therefore, the PWM state does not change in one cycle of CDS, and the noise in AD conversion of the image sensor is suppressed.

FIG. 11 shows the relationship between the RAMP signal and the

ACT\_PWM signal for the AD conversion operation in the period (X) of FIG. 10. In FIG. 11, the output level of ACT\_PWM is maintained during one cycle of an AD conversion operation. Also, as indicated by arrows 1102 and 1104, an average duty ratio is the same as the duty ratio of REF\_PWM. Therefore, the waveform modulator 916 can toggle the actual PWM signal such that the actual PWM signal approaches a duty ratio of the reference PWM signal.

Fig. 12 is a state transition diagram of the present embodiment. There are six states 1301, 1302, 1303, 1304, 1305 and 1306 in FIG. 12. In the three states 1301, 1302 and 1303 on the left side, ACT\_PWM is in the H state. Further, in the three states 1304, 1305, and 1306 on the right side, ACT\_PWM is in the L state. Further, the two central states 1302 and 1305 have CNT of 0. The upper two states 1301 and 1304 have positive CNT, and the lower two states 1303 and 1306 have positive CNT. Further, MASK=φ indicates that the condition is determined regardless of the value of MASK.

For example, in state 1302, ACT\_PWM is in H state and CNT is 0. If REF\_PWM=H, the state is unchanged. Here, when REF\_PWM changes to L, if MASK=H, a transition is made to state 1301, and if MASK=L, a transition is made to state 1305. In the state 1301, if REF\_PWM=H, MASK=L and CNT>0 after decrement of CNT, the transition is made to the state 1304. If REF\_PWM=L and MASK=L, the transition is also made to the state 1304. On the other hand, if REF\_PWM=H, MASK=L and CNT=0 after decrement of CNT, the transition is made to state 1305.

According to the present embodiment, ACT\_PWM is not toggled

when the MASK signal is set to high (H). Here, the "high" means a period of AD conversion with CDS, which is a period from the start of the reset operation to the end of the signal output operation in one cycle of the AD conversion. This means that fluctuation of the edge of the PWM signal does not cause noise in the AD conversion process. Therefore, no noise occurs in the AD conversion operation due to the toggle of ACT\_PWM. Accordingly, it is not necessary to consider restrictions of the relation of PWM career frequency and the AD conversion period.

(Second embodiment)

In a preferable embodiment according to the present disclosure, the counter in the duty error monitor 918 may have capability to count the clock number of a duty control clock of the PWM signal during twice as long as a toggle inhibit period. That is, if the number of pulses in one toggle inhibit period is  $T$  ("Number to Count" in FIG. 13), the value from  $-T$  to  $+T$  should be stored in the counter.

When overflow of the counter may occur, in one embodiment, the waveform modulator 916 may be configured to toggle its output in a case of the counter's overflow in the duty error monitor in order to address the data overflow. In this case, the count number CNT can be toggled even if in the toggle inhibit period. In this case, the actual PWM signal might be toggled, even if it is an inhibit period. However, generally, the countdown in the reset operation starts in the first half of one cycle of AD conversion, and the countup by the signal output operation starts in the second half of one cycle of AD conversion. On the other hand, the toggle due

to the countdown overflow may occur in the latter half of the prohibition period. Therefore, it is possible to reduce the influence of the overflow of the counter value used for monitoring the duty error by controlling the toggle as described above.

Fig. 13 is a diagram showing operating waveform in the case of overflow of the duty error monitor 916 according to this embodiment. In FIG. 13, the range of countable number of the counter value CNT is indicated by an arrow 1406. On the other hand, the range of the actual value is set narrow as indicated by the arrow 1408. The count up of CNT is started from time t0. Since overflow of CNT occurs at time t1, ACT\_PWM changes from the L state to the H state even during the prohibition period, as indicated by an arrow 1404. When there is no overflow of CNT, ACT\_PWM changes to the H state at time t2. Even if it is in the prohibition period, generally, its time t1 is located in the latter half of the AD conversion period when the comparator responds to a large signal input level. In the case of the large signal input level, noise impact on the image signal becomes relatively small.

Fig. 14 is a state transition diagram of the present embodiment. Unlike FIG. 12, when the CNT reaches the maximum value (CNT=MAX) in the state 1301, the state transitions to the state 1304 as indicated by an arrow 1502. Further, when the CNT reaches the minimum value in the state 1306 (CNT=MIN), the state moves to the state 1303 as indicated by an arrow 1504.

According to the present embodiment, PWM control with less noise can be continued while reducing the influence of overflow of

the counter.

(Third Embodiment)

Fig. 15 is a block diagram of a lens actuator system with the waveform modulator according to the third embodiment of the present disclosure. The lens actuator system 1600 has substantially the same configuration as that shown in FIG. 9, except that the waveform generator 919 includes a MASK generator 1602. The MASK generator 1602 generates a MASK signal based on the horizontal sync signal HSYNC output from the image sensor with CDS 906. Since the horizontal synchronization signal HSYNC is a synchronization signal used for AD conversion, the MASK signal can be generated in synchronization with the AD conversion process. Even when the MASK signal is generated by the servo controller (PWM driver) 904, the effect of the present disclosure can be obtained.

FIG. 16 shows a waveform chart of signals when the lens actuator system 1600 according to the present embodiment is applied to driving four SMAs. The PWM signal ACT\_PWM for driving the four wires, that is, the wires WIRE0, WIRE1, WIRE2, and WIRE3 are toggled outside the prohibited period. Comparing the reference PWM signal REF\_PWM and the actual PWM signal ACT\_PWM on each wire, the duty ratios of the two PWM signals are similar.

As described above, according to the present disclosure, a PWM signal is modulated by (1) a MASK signal which modulates the PWM signal for disabling toggle during one cycle of the AD conversion operation, and (2) measurement result of duty ratio error caused by not toggling. The reference PWM signal is toggled so as to

match its duty ratio with a target duty ratio of servo loop based on an error in the duty ratio, considering the toggle inhibit period defined by the MASK signal.

Accordingly, it is possible to remove noise impact on AD conversion of the pixel output without restrictions caused by combination of the PWM carrier frequency and the AD conversion period.

Also, the noise can be easily canceled by monitoring communication channels between an imaging sensor and a lens driver, and modulated PWM signals for driving actuators and so on.

The present disclosure can be applied to system having ADC embedded in various sensors and a PWM actuator existing close to the sensors (e.g. image sensor and lens actuator driven by stepping motor etc.) to reduce emission noise impact due to actuator driving.

The outline descriptions are merely specific implementation manners of the present invention, but are not intended to limit the protection scope of the present invention. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed shall fall within the protection scope of the present invention. Therefore, the protection scope of the present invention shall be subject to the protection scope of the claims.

## CLAIMS

What is Claimed is:

1. A PWM driver for generating a PWM signal used for driving a lens, comprising:

a PWM signal generator configured to generate a reference PWM signal that toggles at a predetermined cycle;

a receiving unit configured to receive a mask signal that defines a toggle inhibit period; and

a modulation unit configured to generate an actual PWM signal by not toggling a reference PWM signal during the toggle inhibit period defined by the mask signal.

2. The PWM driver according to claim 1, wherein the PWM signal generator generates the reference PWM signal based on movement of the lens.

3. The PWM driver according to claim 2, wherein the generator acquires movement information from a gyro sensor that detects the movement of the lens.

4. The PWM driver according to any one of claim 1 to 3, wherein the toggle inhibit period is set based on a control signal for analog-digital conversion of an image captured by an image sensor.

5. The PWM driver according to any one of claims 1 to 4, further comprising a counter configured to increase or decrease a counter value of a pulse number of a clock according to an H state or an L state of the actual PWM signal, wherein the modulation unit is configured to toggle the actual PWM signal based on the counter value for minimizing an absolute value of the counter value outside of the toggle inhibit period.

6. The PWM driver according to claim 5, wherein a range of the counter corresponds to a cycle of the reference signal for the analog-digital conversion.

7. The PWM driver according to claim 6, wherein the modulation unit toggles the actual PWM signal when an overflow of the counter value occurs during the toggle prohibition period.

8. The PWM driver according to any one of claims 1 to 7, wherein the mask signal is generated based on a control signal for analog-digital conversion of an image captured by an image sensor.

9. The PWM driver according to any one of claims 1 to 8, wherein the toggle inhibit period is set such that the actual PWM signal does not toggle at a period of conversion process of an analog signal of an image captured by an image sensor to digital output.

10. The PWM driver according to any one of claims 1 to 9, further comprising a monitor configured to instruct the modulation unit to toggle the actual PWM signal based on the reference PWM signal and the actual PWM signal.

11. The PWM driver according to claim 10, wherein the monitor instructs the modulation unit to toggle the actual PWM signal such that the actual PWM signal approaches a duty ratio of the reference PWM signal.

12. The PWM driver according to any one of claims 1 to 11, further comprising a mask generation unit configured to generate the mask signal.

13. An actuator system, comprising:

the PWM driver according to any one of claims 1 to 12; and

a lens unit for driving a lens based on an actual PWM signal generated by the actual PWM driver.

14. A camera module, comprising:

the actuator system according to claim 13; and

an imaging unit configured to capture an image with a lens driven by the actuator system.

15. A method for generating a PWM signal used to drive a lens, comprising:

generating a reference PWM signal that toggles at a predetermined cycle;

receiving a mask signal that defines a toggle inhibit period; and

generating an actual PWM signal by not toggling the reference PWM signal during the toggle inhibit period defined by the mask signal.

16. The method of claim 15, wherein the step of generating the reference PWM signal generates the reference PWM signal based on movement of the lens.

17. The method according to claim 15 or 16, wherein the step of generating the reference PWM signal obtains movement information from a gyro sensor that detects movement of the lens.

18. The method according to any one of claims 15 to 17, wherein the toggle inhibit period is set based on a control signal for analog-digital conversion of an image captured by an image sensor.

19. The method according to any one of claims 15 to 18, further comprising:

increasing or decreasing a counter value of a pulse number of a

clock according to an H state or an L state of the actual PWM signal, wherein the step of generating the reference PWM signal is based on the counter value for minimizing an absolute value of the counter value outside of the toggle inhibit period.

20. The method according to claim 19, wherein a range of the counter corresponds to a cycle of the reference signal for the analog-digital conversion.

21. The method according to claim 20, wherein the step of generating the actual PWM signal toggles the actual PWM signal when an overflow of the counter value occurs during the toggle prohibition period.

22. The method according to any one of claims 15 to 21, wherein the mask signal is generated based on a control signal for analog-digital conversion of an image captured by an image sensor.

23. The method according to claim 22, wherein the toggle inhibit period is set such that the actual PWM signal does not toggle at a period of conversion process of an analog signal of an image captured by an image sensor to digital output.

24 The method according to any one of claims 15 to 23, wherein the step of generating the actual PWM signal comprises toggling the actual PWM signal based on the reference PWM signal and the actual PWM signal.

25. The method according to claim 24, wherein the step of generating the actual PWM signal toggles the actual PWM signal such that the actual PWM signal approaches a duty ratio of the reference PWM signal.

26. The method according to any one of claims 15 to 25, further

comprising the step of generating the mask signal.

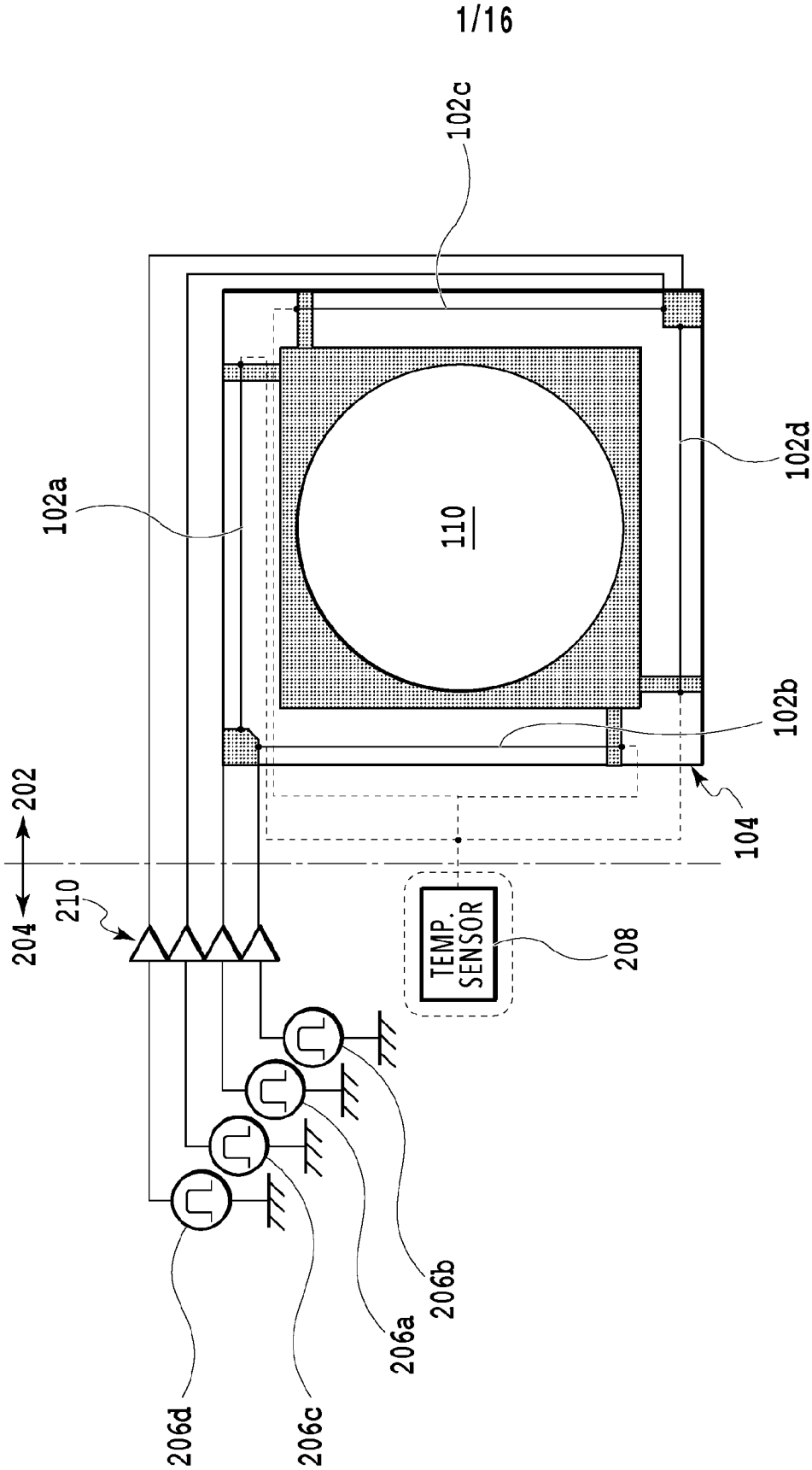


FIG.1

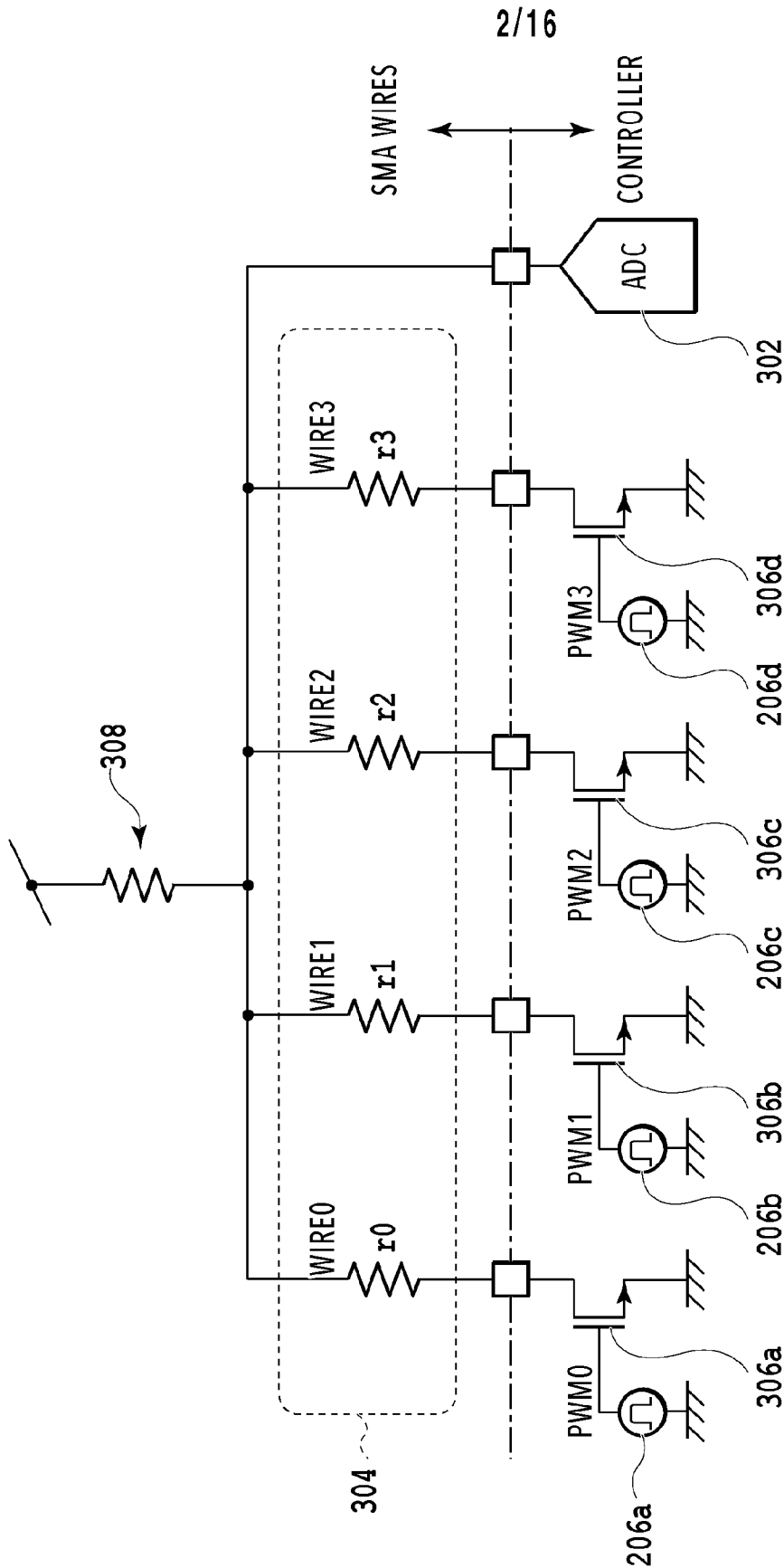


FIG.2

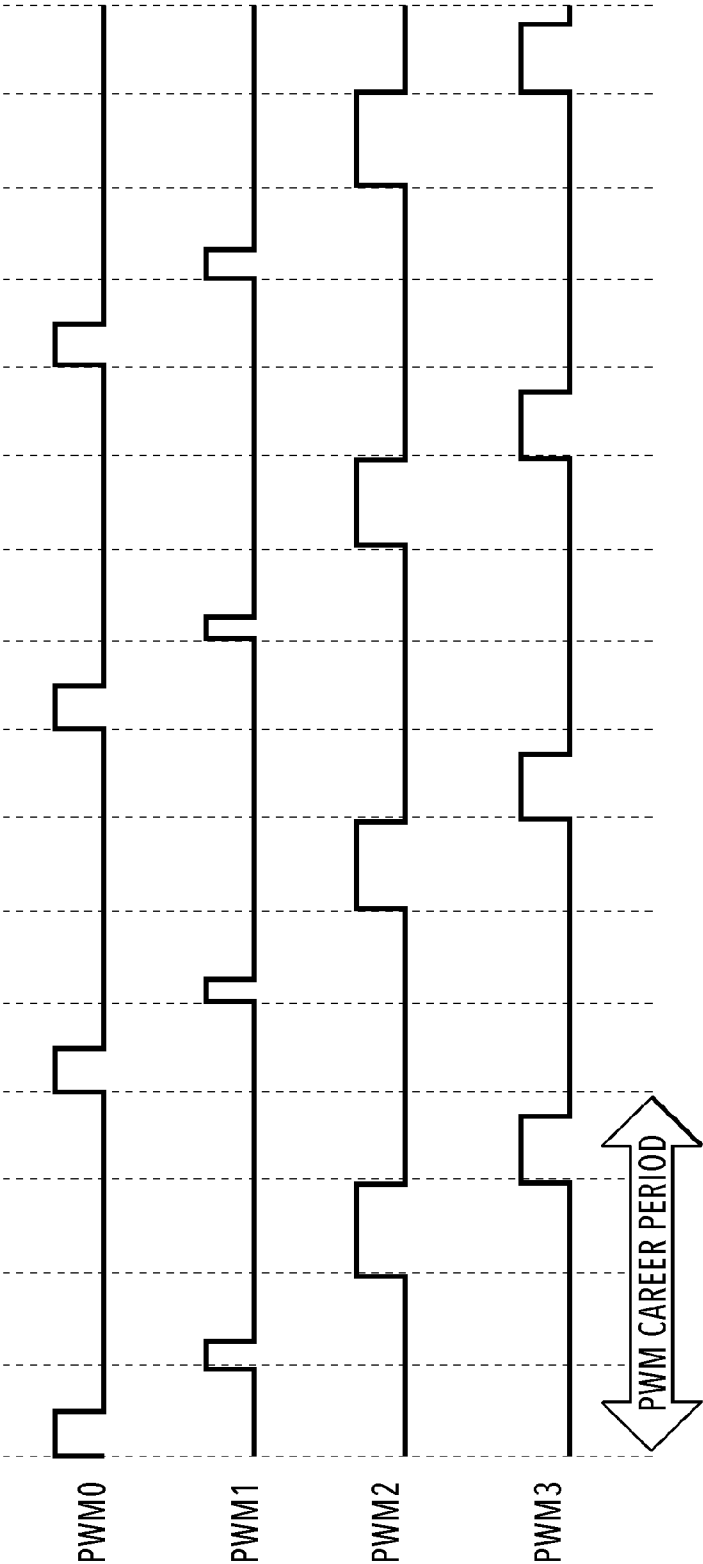


FIG.3

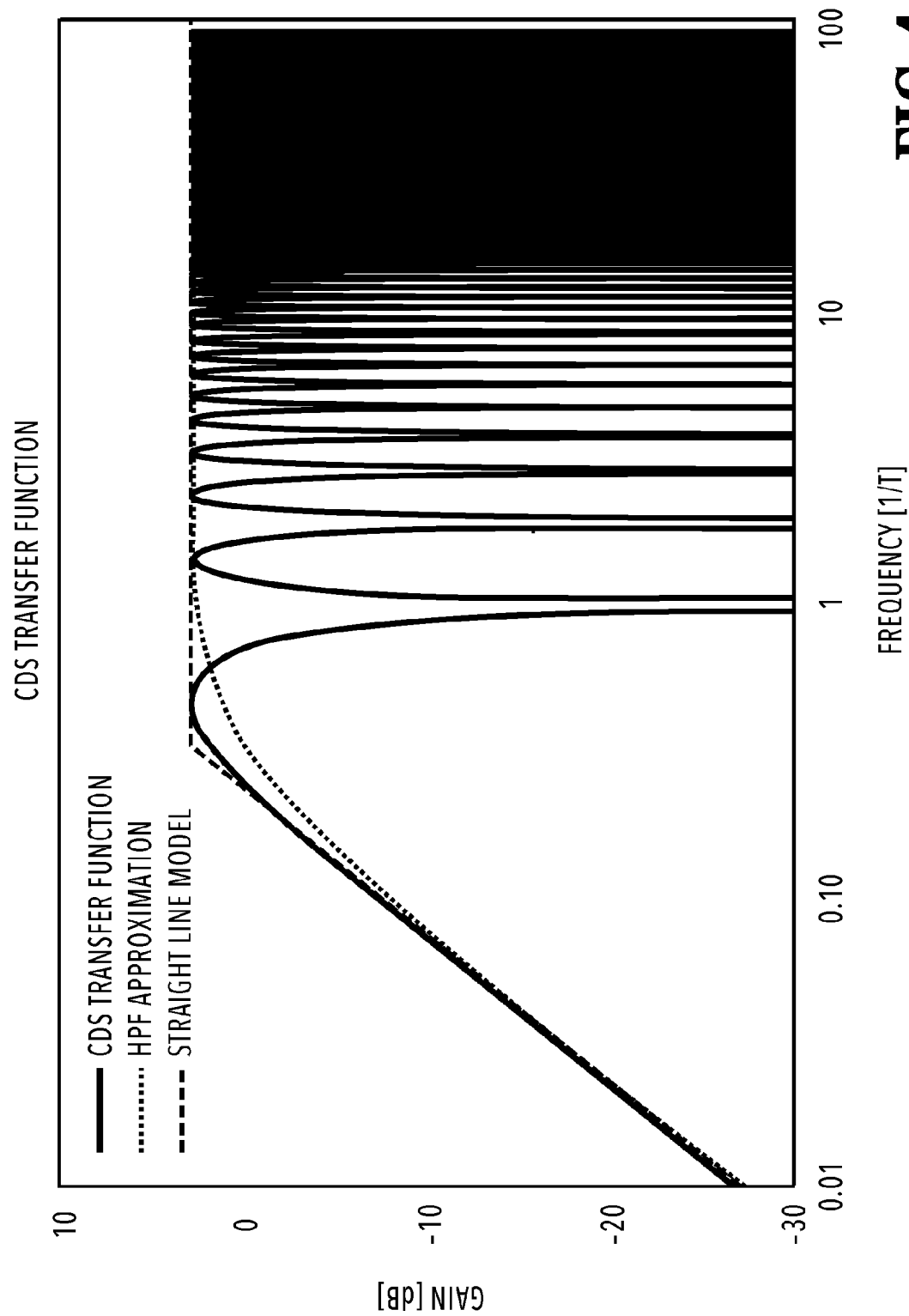
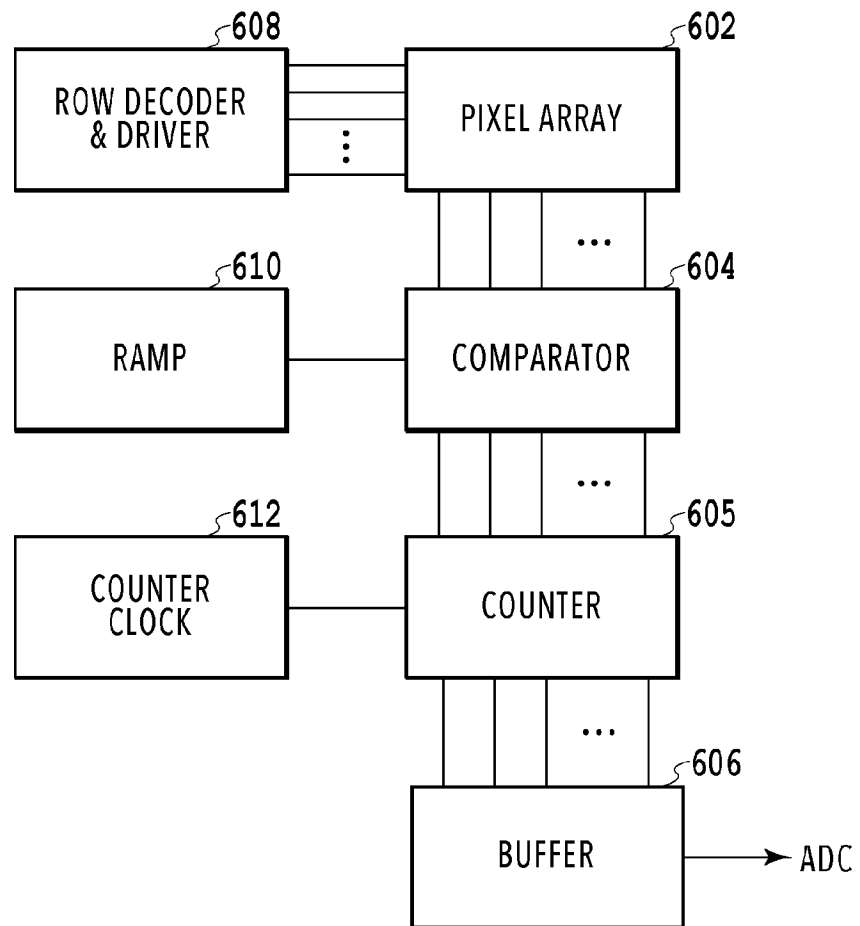


FIG.4

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**FIG.5**

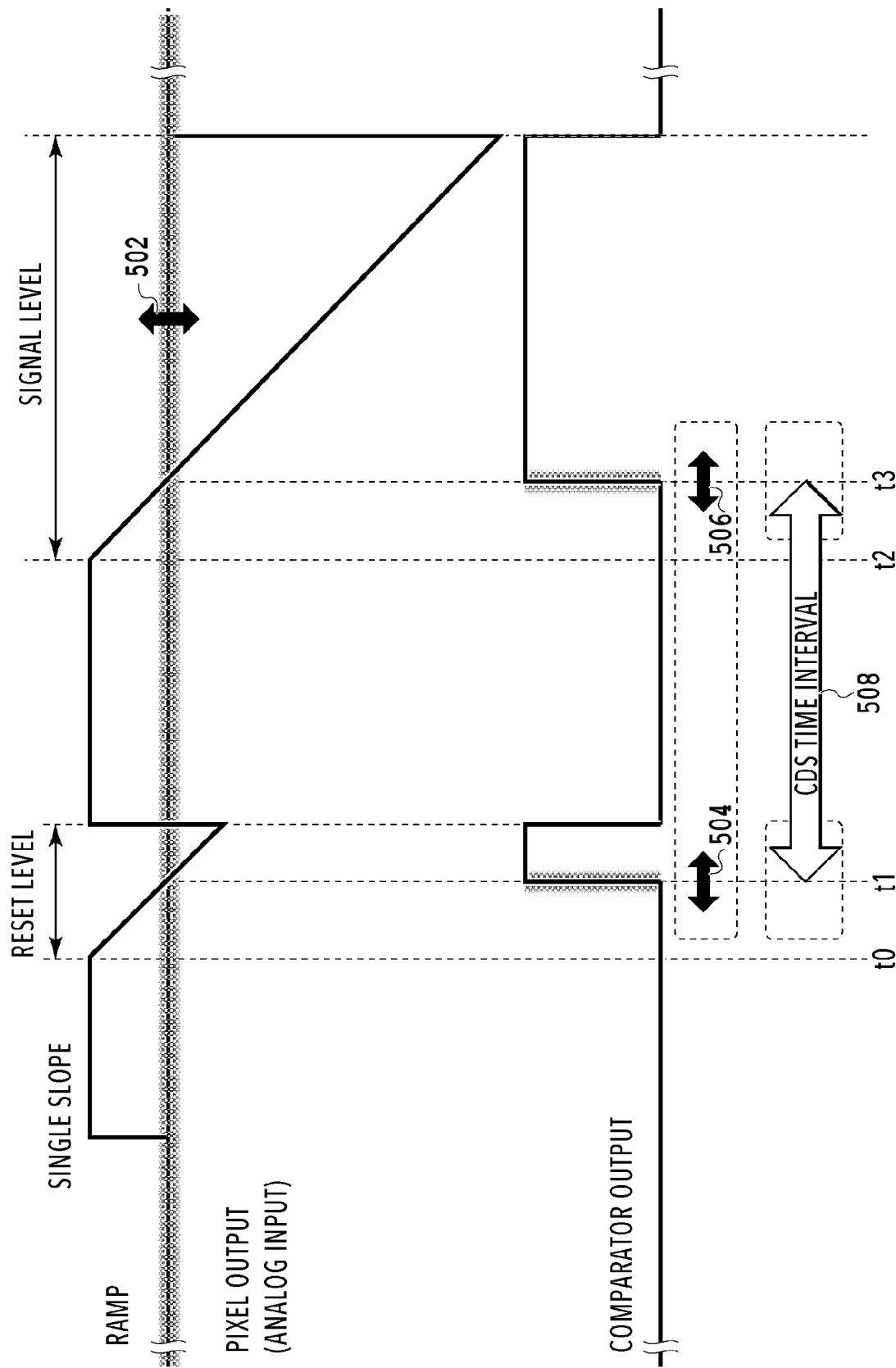
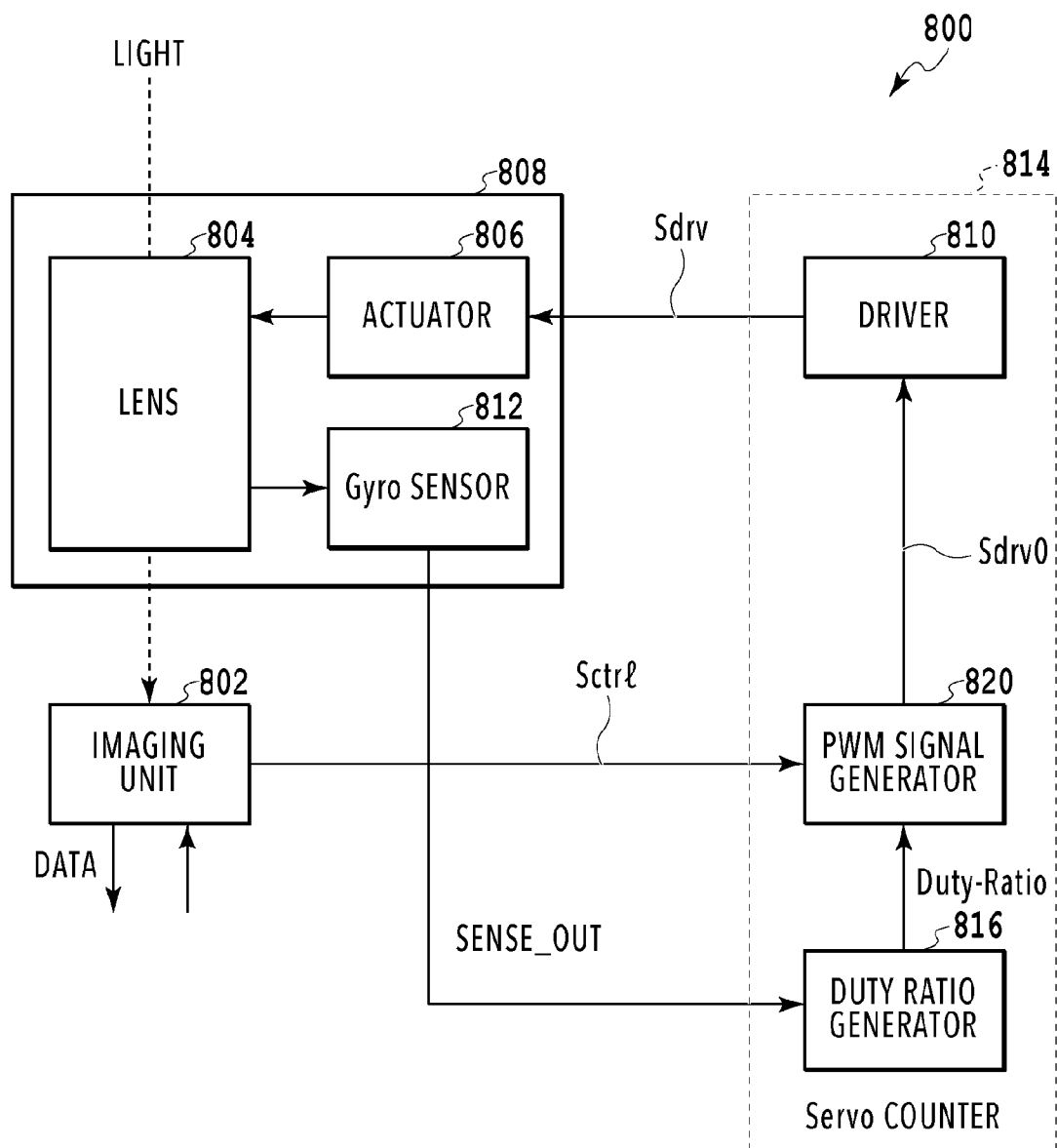


FIG.6

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**FIG.7**

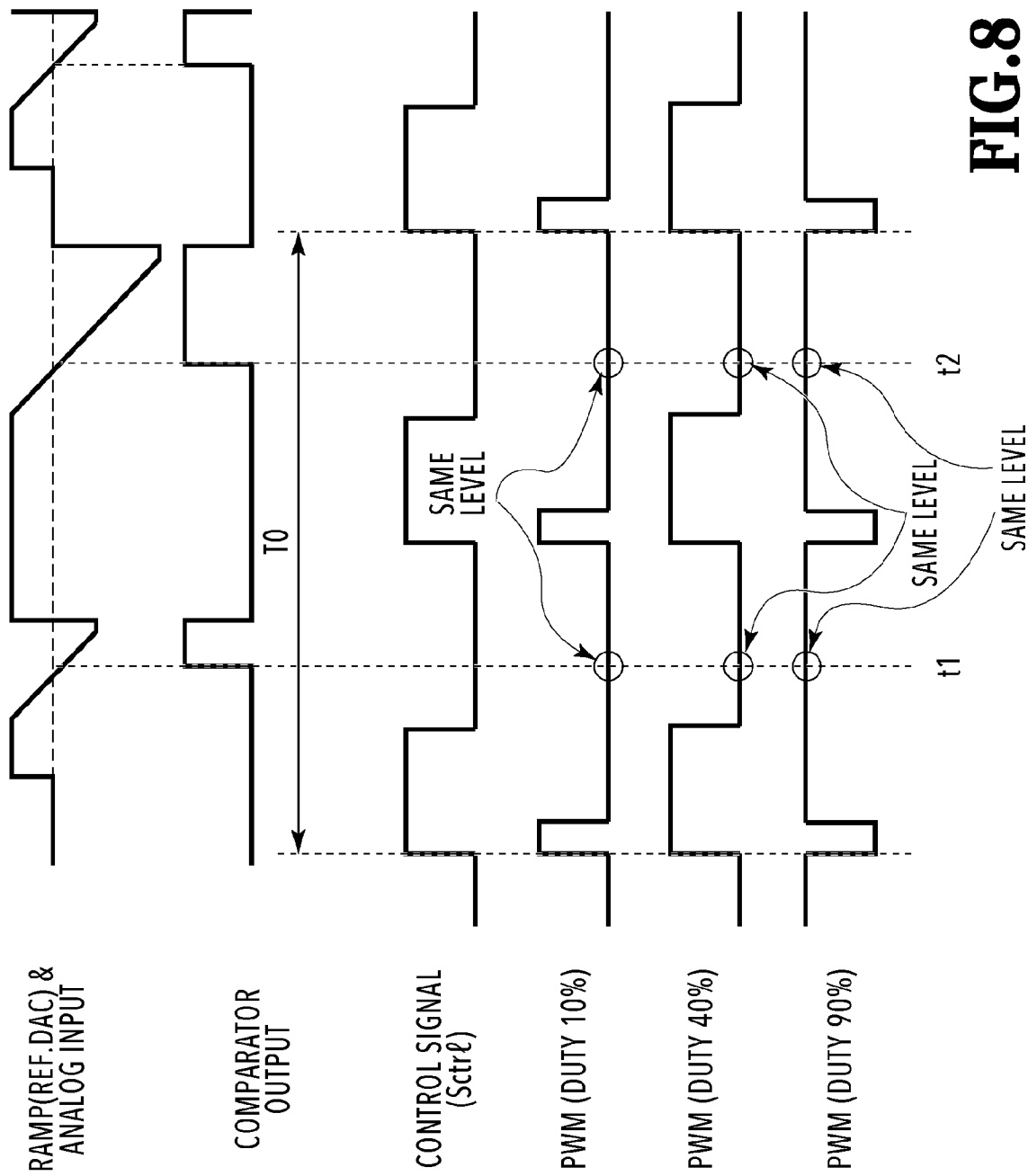


FIG.8

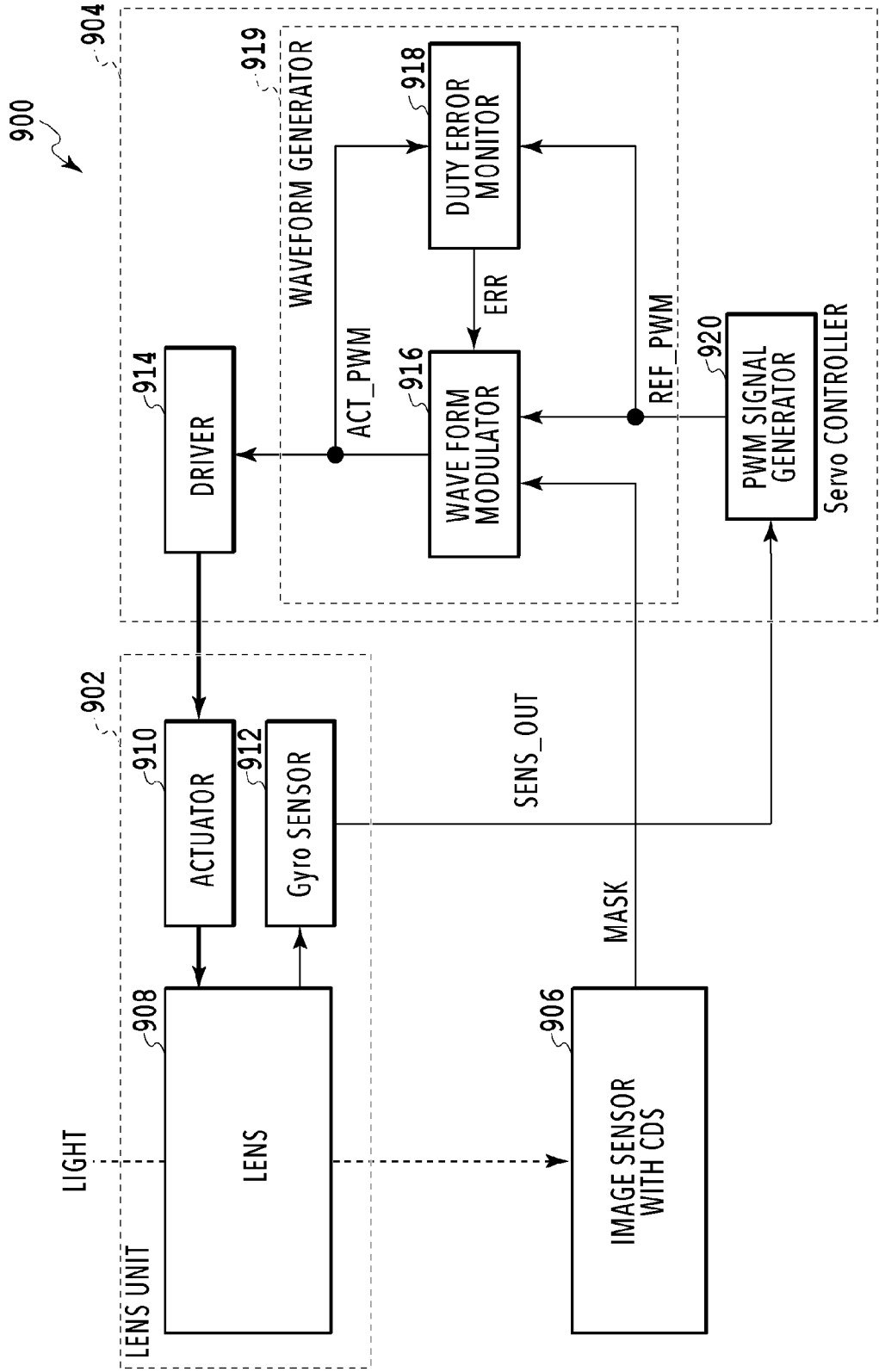


FIG.9

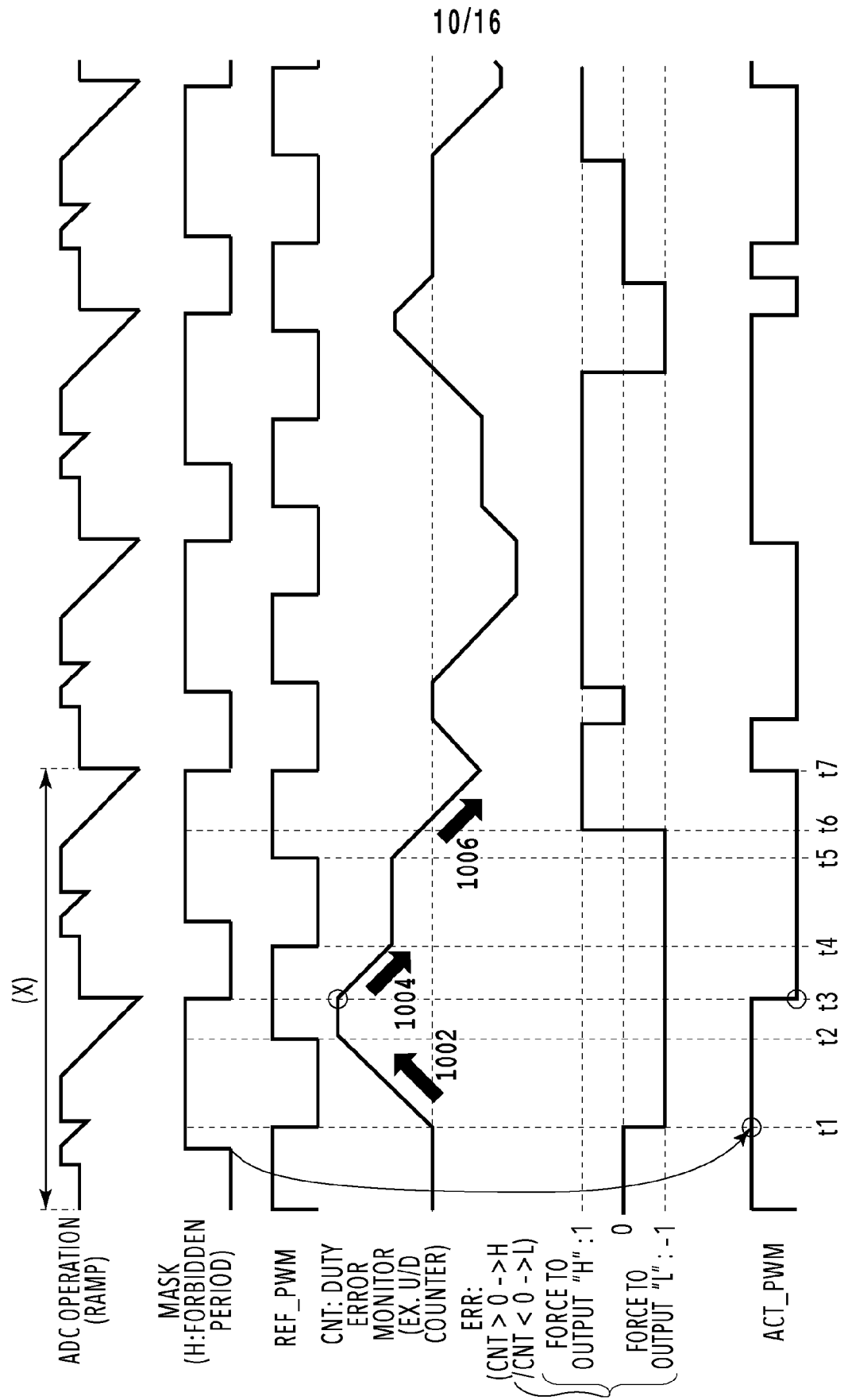


FIG.10

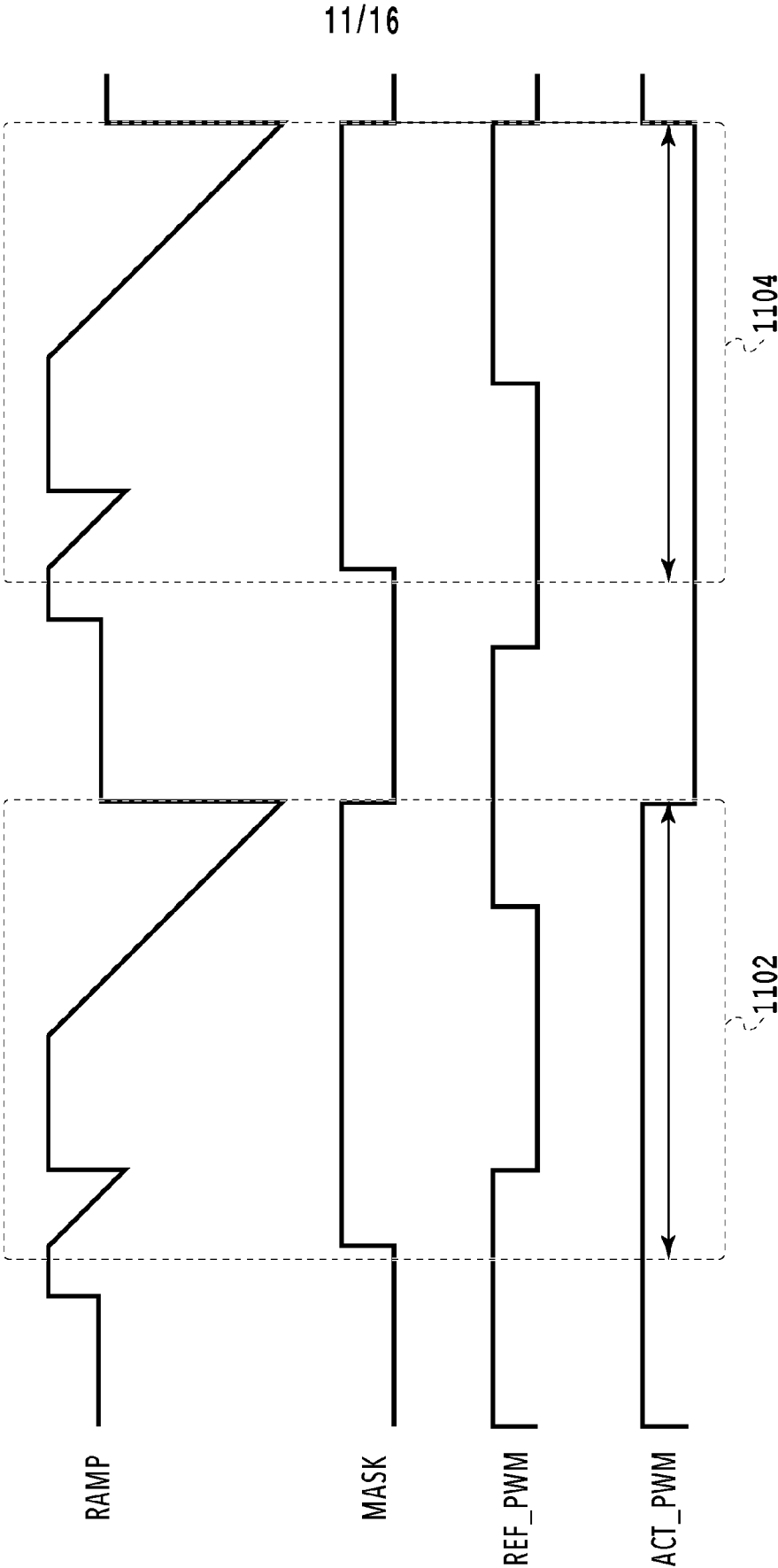


FIG.11

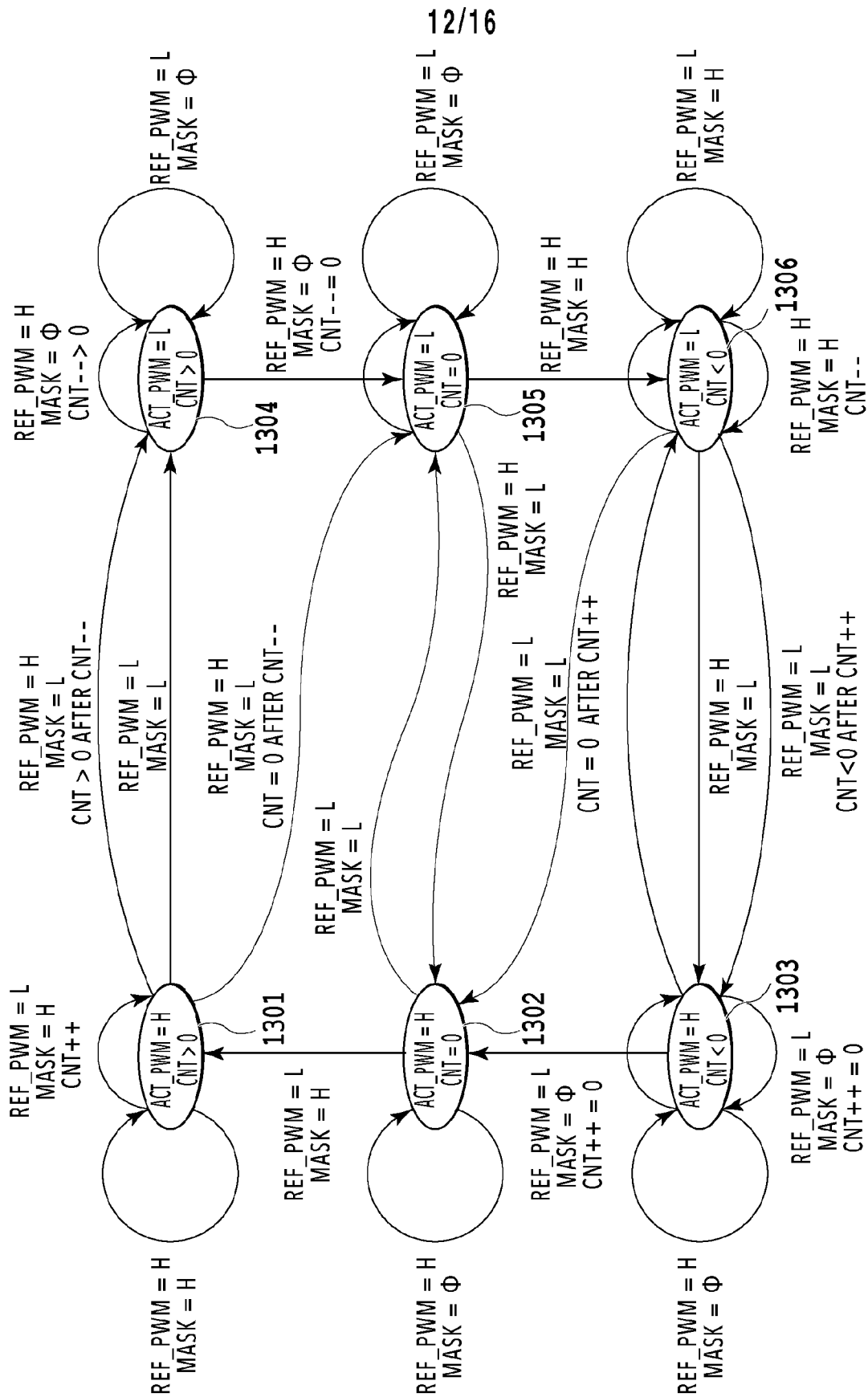


FIG. 12

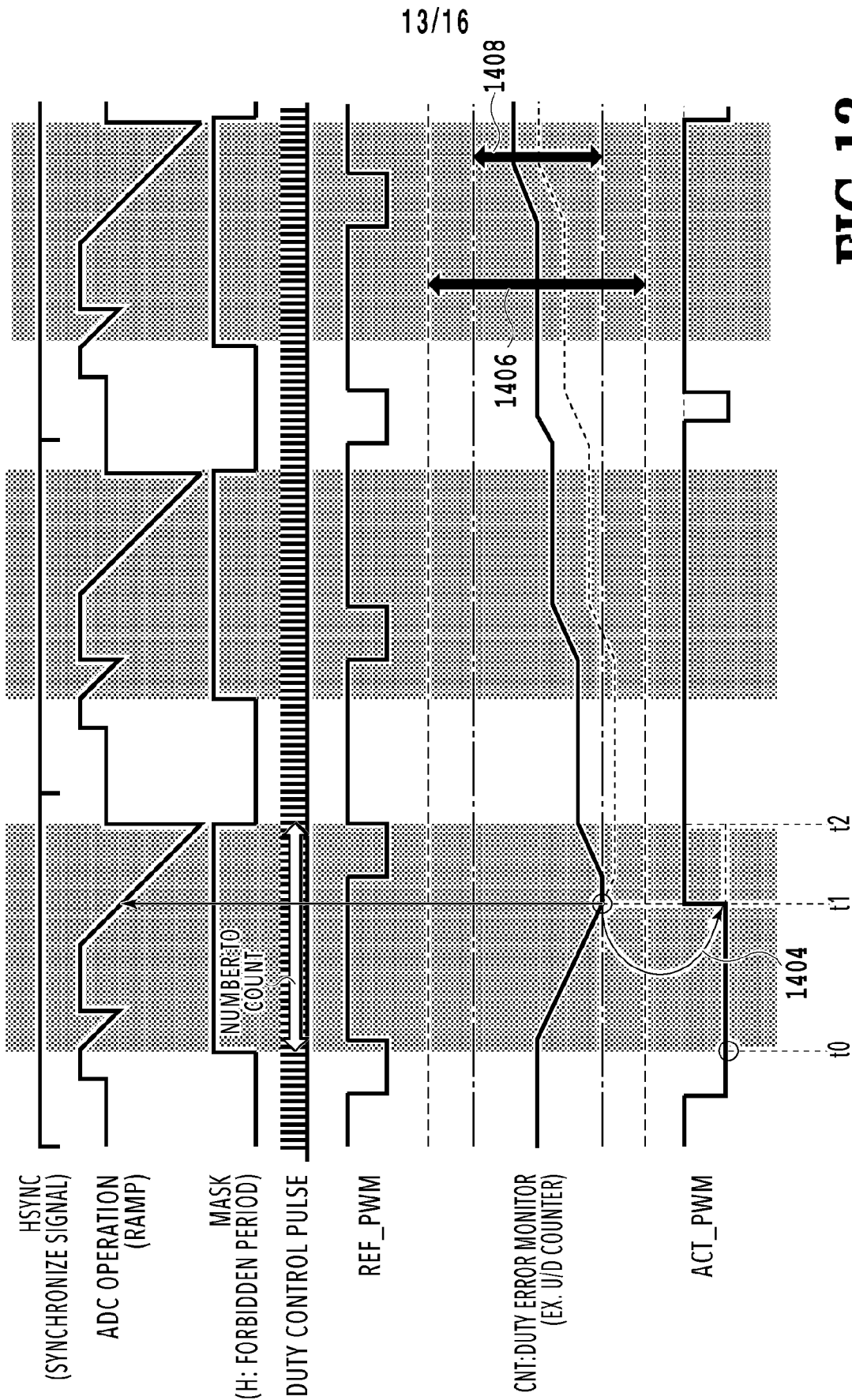


FIG.13

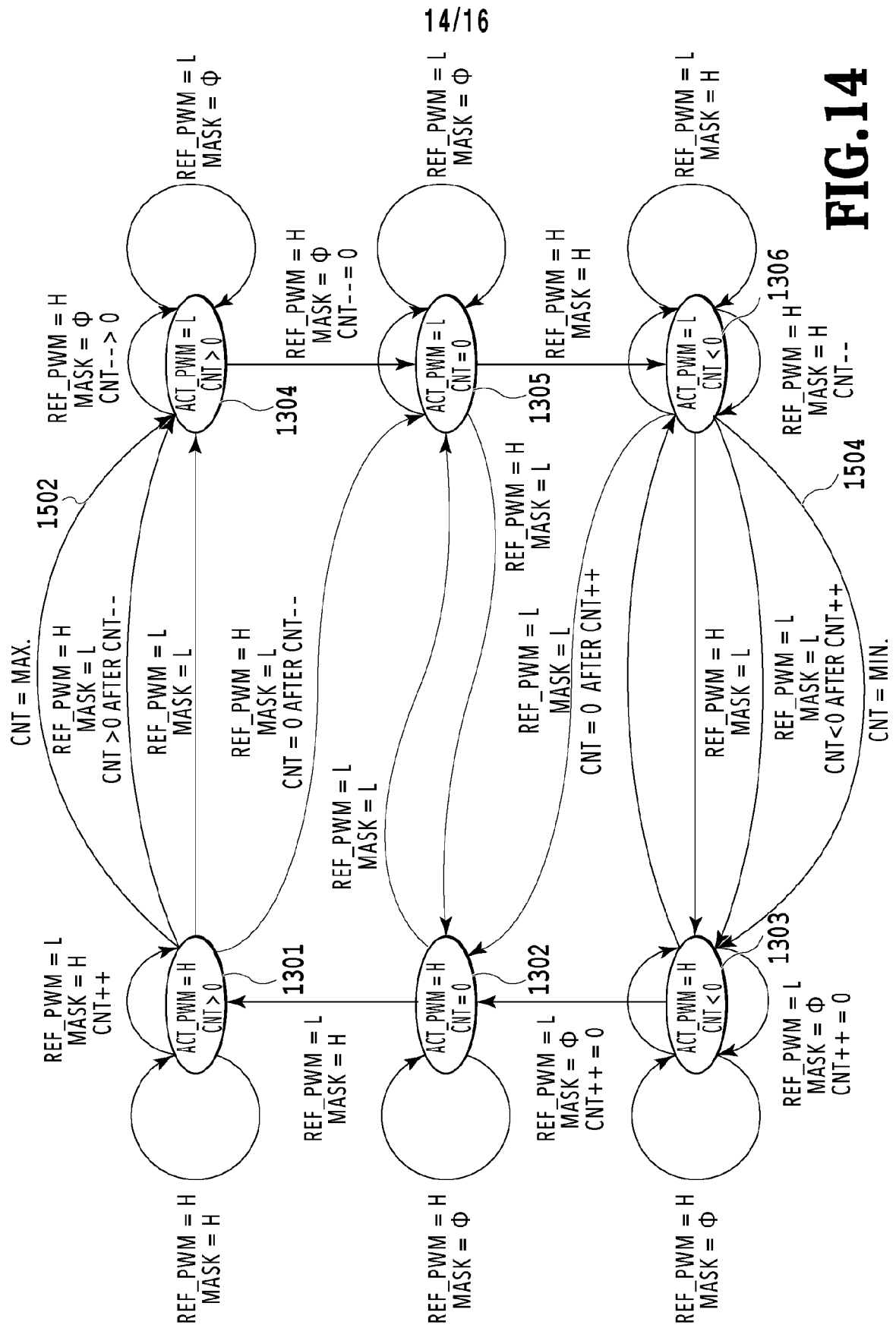


FIG. 14

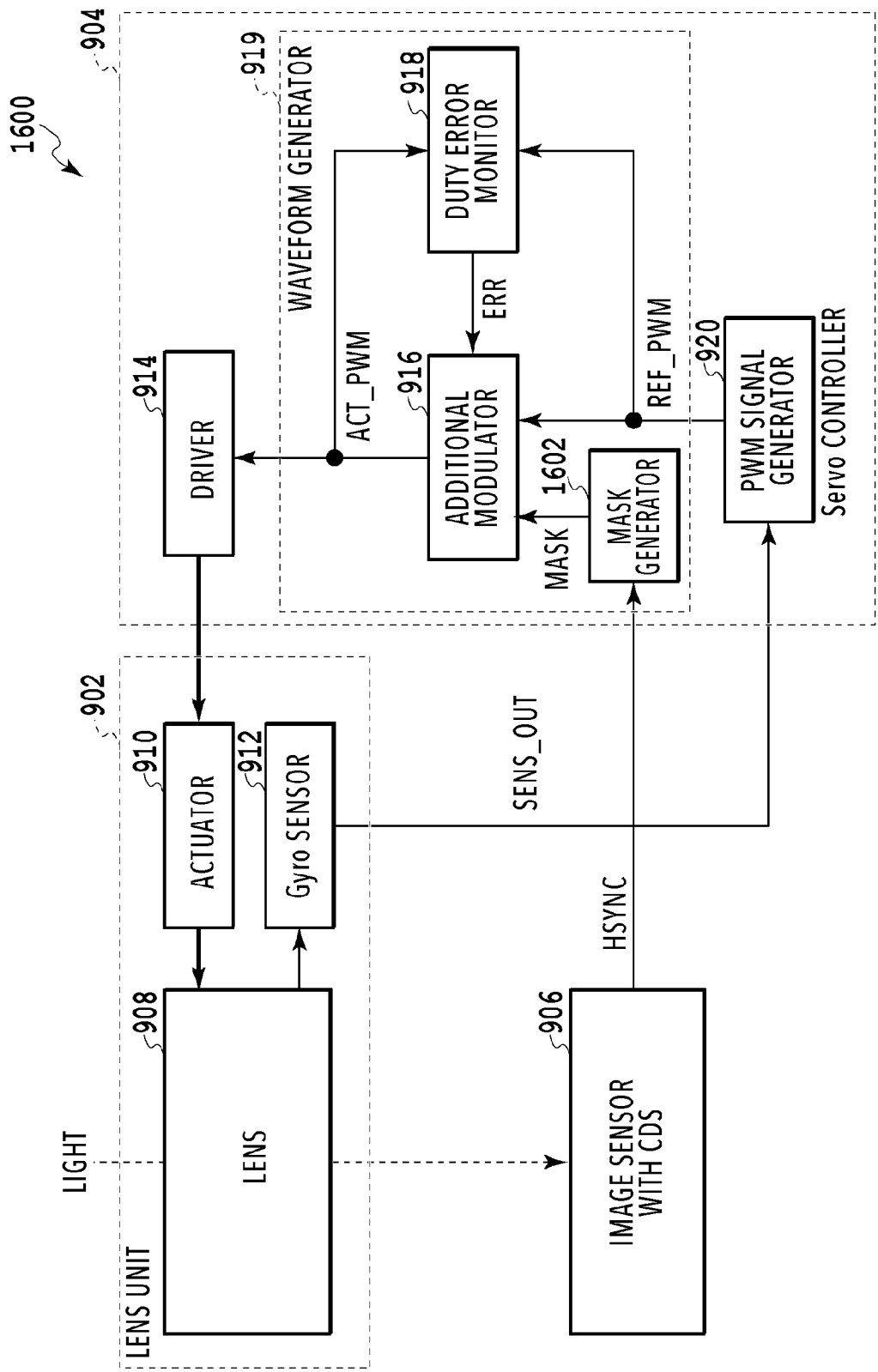


FIG.15

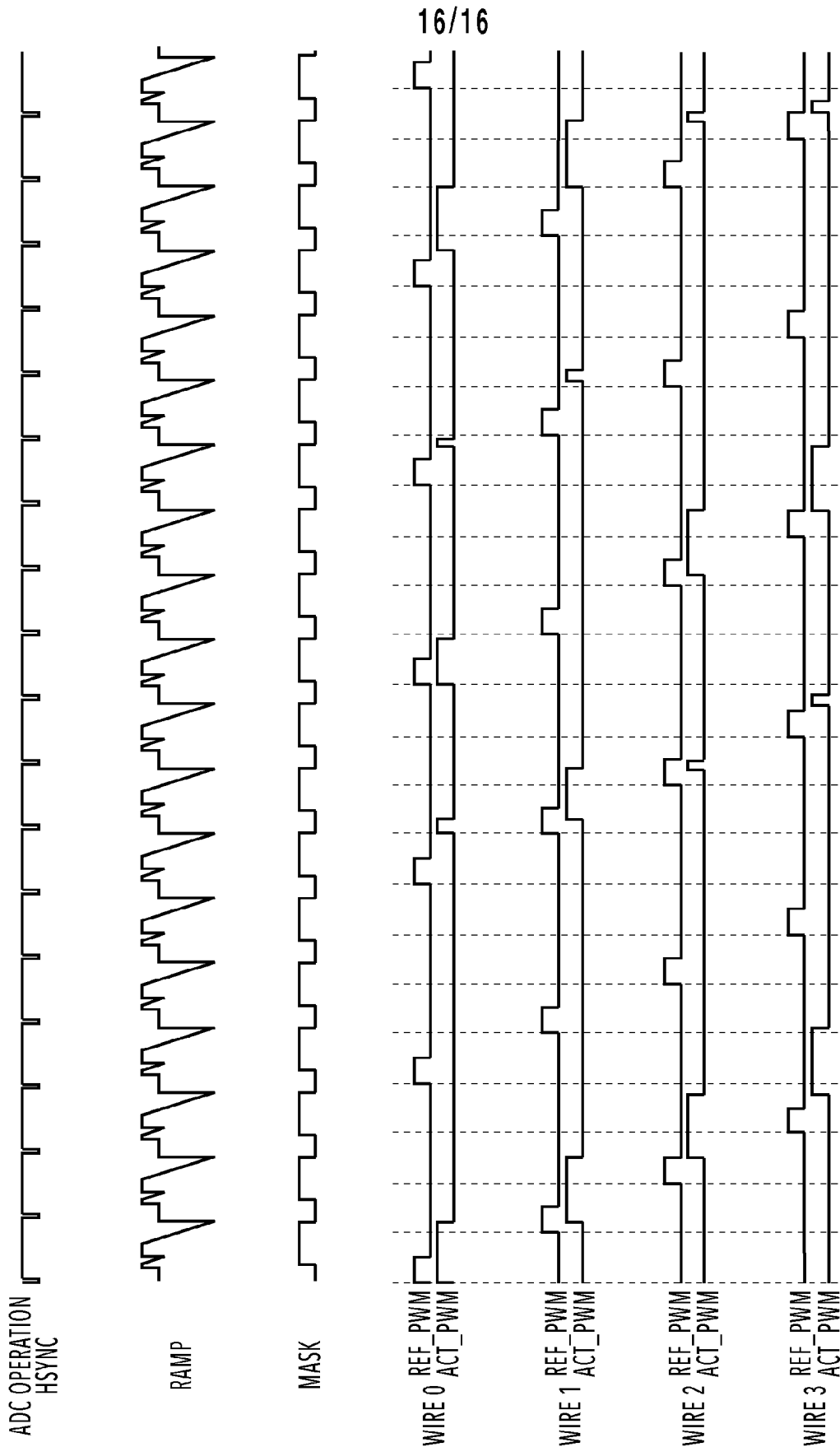


FIG.16

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/105780

**A. CLASSIFICATION OF SUBJECT MATTER**

H04N 5/217(2011.01)i

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)

H04N; G02B

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 practicable, search terms used)

CNPAT, CNKI, EPODOC, WPI: PWM, len, camera, drive, actuator, image, CDS, CMOS, CCD, AD, noise, duty

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                            | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | CN 102340629 A (SONY CORPORATION) 01 February 2012 (2012-02-01)<br>description, paragraphs [0045]-[0088], [0112]-[0150] and figures 1-4, 7-14 | 1-26                  |
| A         | CN 102263532 A (ON SEMICONDUCTOR TRADING, LTD.) 30 November 2011<br>(2011-11-30)<br>the whole document                                        | 1-26                  |
| A         | CN 106375656 A (CANON KABUSHIKI KAISHA) 01 February 2017 (2017-02-01)<br>the whole document                                                   | 1-26                  |
| A         | CN 103379292 A (SONY CORPORATION) 30 October 2013 (2013-10-30)<br>the whole document                                                          | 1-26                  |
| A         | WO 2019221220 A1 (SONY CORPORATION) 21 November 2019 (2019-11-21)<br>the whole document                                                       | 1-26                  |
| A         | US 2017302843 A1 (FUJIFILM CORPORATION) 19 October 2017 (2017-10-19)<br>the whole document                                                    | 1-26                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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

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“&” document member of the same patent family

Date of the actual completion of the international search

27 April 2021

Date of mailing of the international search report

07 May 2021

Name and mailing address of the ISA/CN

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Telephone No. 86-(10)-53961235

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2020/105780**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) | Patent family member(s) |              | Publication date<br>(day/month/year) |                  |
|-------------------------------------------|------------|----|--------------------------------------|-------------------------|--------------|--------------------------------------|------------------|
| CN                                        | 102340629  | A  | 01 February 2012                     | US                      | 8665344      | B2                                   | 04 March 2014    |
|                                           |            |    |                                      | US                      | 2012019680   | A1                                   | 26 January 2012  |
|                                           |            |    |                                      | JP                      | 2012028841   | A                                    | 09 February 2012 |
|                                           |            |    |                                      | JP                      | 5609358      | B2                                   | 22 October 2014  |
| CN                                        | 102263532  | A  | 30 November 2011                     | JP                      | 2011250539   | A                                    | 08 December 2011 |
|                                           |            |    |                                      | TW                      | 201214946    | A                                    | 01 April 2012    |
|                                           |            |    |                                      | KR                      | 101238179    | B1                                   | 28 February 2013 |
|                                           |            |    |                                      | KR                      | 20110129351  | A                                    | 01 December 2011 |
|                                           |            |    |                                      | US                      | 2011291603   | A1                                   | 01 December 2011 |
| CN                                        | 106375656  | A  | 01 February 2017                     | JP                      | 2017028511   | A                                    | 02 February 2017 |
|                                           |            |    |                                      | US                      | 2017026580   | A1                                   | 26 January 2017  |
|                                           |            |    |                                      | US                      | 10218907     | B2                                   | 26 February 2019 |
|                                           |            |    |                                      | CN                      | 106375656    | B                                    | 17 December 2019 |
|                                           |            |    |                                      | JP                      | 6598549      | B2                                   | 30 October 2019  |
| CN                                        | 103379292  | A  | 30 October 2013                      | US                      | 9160940      | B2                                   | 13 October 2015  |
|                                           |            |    |                                      | JP                      | 6019714      | B2                                   | 02 November 2016 |
|                                           |            |    |                                      | US                      | 9712766      | B2                                   | 18 July 2017     |
|                                           |            |    |                                      | US                      | 2016014355   | A1                                   | 14 January 2016  |
|                                           |            |    |                                      | US                      | 2013286265   | A1                                   | 31 October 2013  |
|                                           |            |    |                                      | CN                      | 103379292    | B                                    | 02 January 2018  |
|                                           |            |    |                                      | JP                      | 2013232755   | A                                    | 14 November 2013 |
| WO                                        | 2019221220 | A1 | 21 November 2019                     | CN                      | 112189159    | A                                    | 05 January 2021  |
| US                                        | 2017302843 | A1 | 19 October 2017                      | US                      | 9729773      | B2                                   | 08 August 2017   |
|                                           |            |    |                                      | JP                      | 5851070      | B2                                   | 03 February 2016 |
|                                           |            |    |                                      | JP                      | WO2014156442 | A1                                   | 16 February 2017 |
|                                           |            |    |                                      | US                      | 9973676      | B2                                   | 15 May 2018      |
|                                           |            |    |                                      | CN                      | 105075240    | B                                    | 17 July 2018     |
|                                           |            |    |                                      | CN                      | 105075240    | A                                    | 18 November 2015 |
|                                           |            |    |                                      | WO                      | 2014156442   | A1                                   | 02 October 2014  |
|                                           |            |    |                                      | US                      | 2016006923   | A1                                   | 07 January 2016  |