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(54) **POSITION DETECTION UNIT, AND LENS APPARATUS, IMAGE PICKUP APPARATUS, AND LENS COMMAND APPARATUS EACH INCLUDING THE POSITION DETECTION UNIT**

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(21) Appl. No.: **15/848,805**

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(30) **Foreign Application Priority Data**

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H04W 4/02 (2006.01)

(52) **U.S. Cl.**
CPC ***H04W 4/023*** (2013.01); ***H04W 4/027*** (2013.01)

(57) **ABSTRACT**

A position detector of a mover relative to a stator includes: an output unit outputting displacement signals including a first signal in a first period and a second signal in a period longer than the first period, while switching among the displacement signals, according to a change in the position of the mover; and a deriver that derives an absolute position as the position of the mover based on the displacement signals, and derives a relative position as a displacement amount with respect to a predetermined absolute position of the mover, wherein in deriving the absolute position, the signal output unit outputs the first signal, the second signals, and the first signal in this order, and the deriver derives the absolute position based on the displacement signals, in deriving the relative position, the position deriver derives the relative position based on the first signal and the second signals.

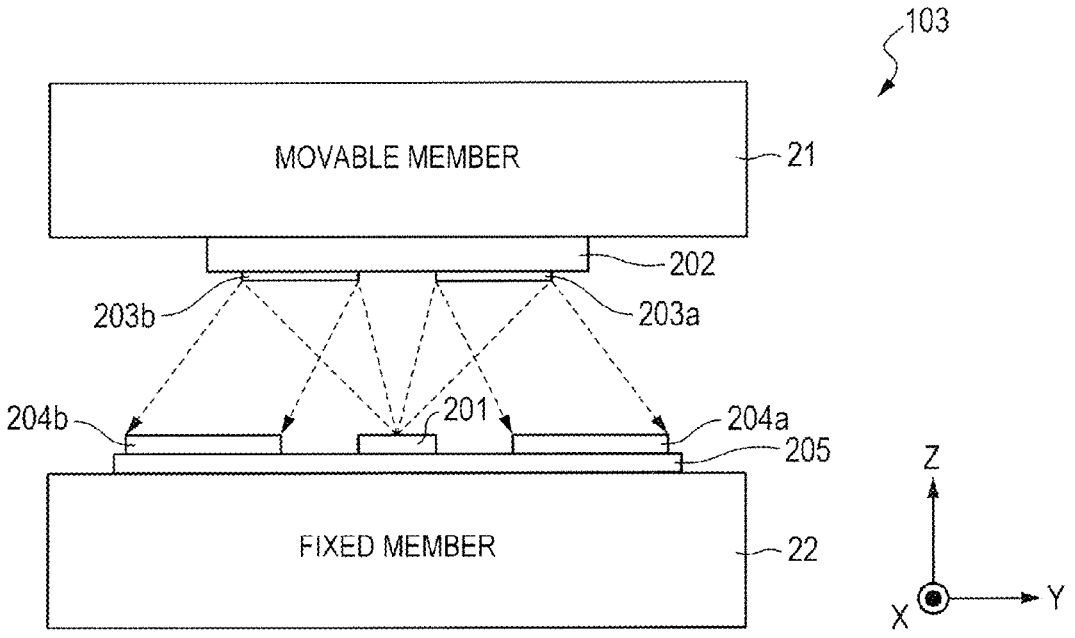


FIG. 1

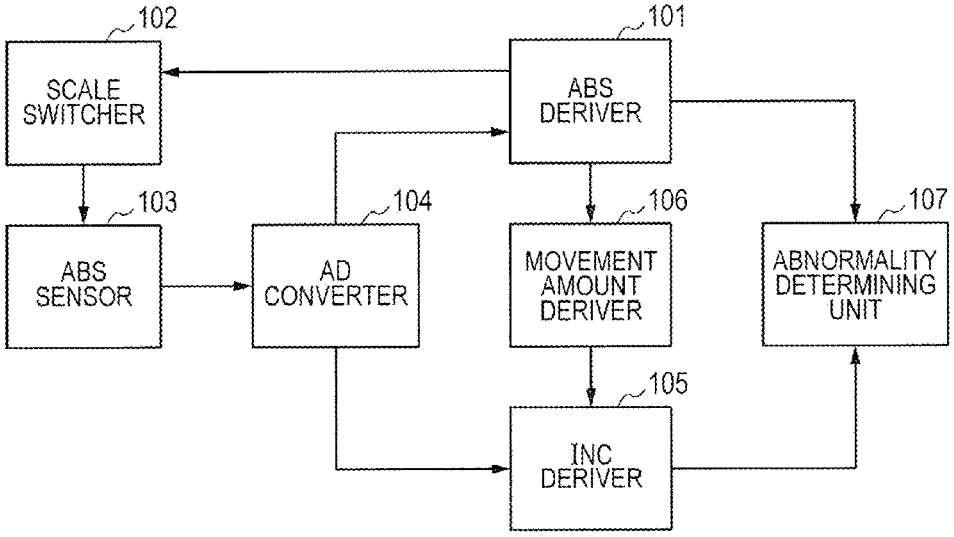

102
SCALE SWITCHER
101
ABS DERIVER
103
ABS SENSOR
104
AD CONVERTER
106
MOVEMENT AMOUNT DERIVER
107
ABNORMALITY DETERMINING UNIT
105
INC DERIVER

FIG. 2

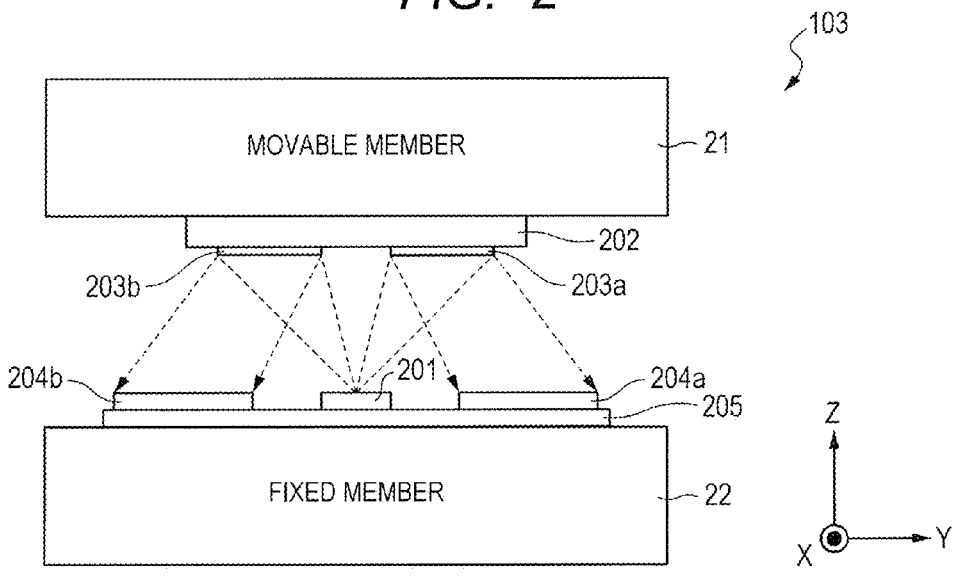

103
MOVABLE MEMBER
21
202
203b
203a
204b
201
204a
205
FIXED MEMBER
22
Z
X
Y

FIG. 3

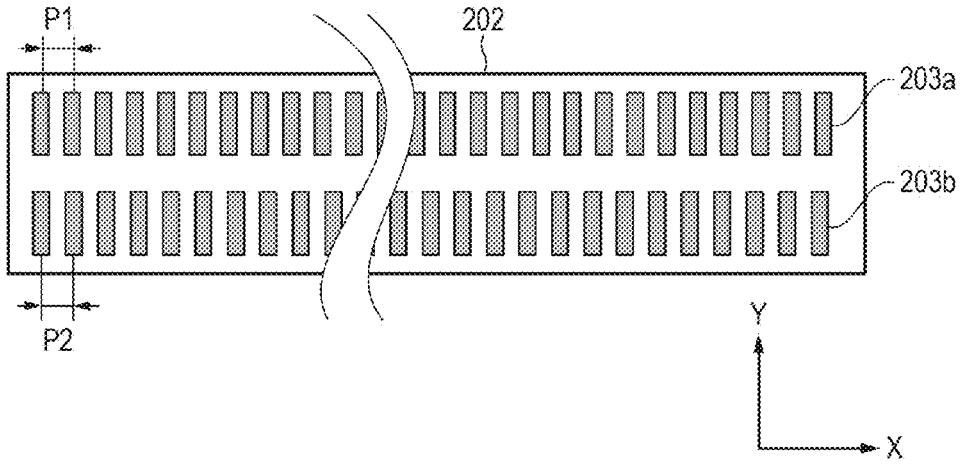

P1
202
203a
203b
P2
Y
X

FIG. 4

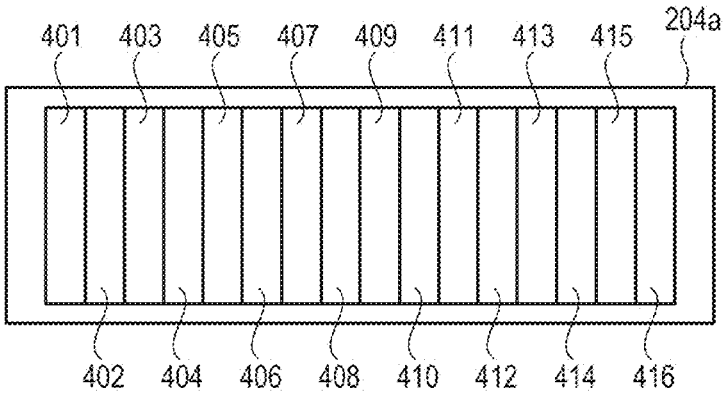

401
403
405
407
409
411
413
415
204a
402
404
406
408
410
412
414
416

FIG. 5

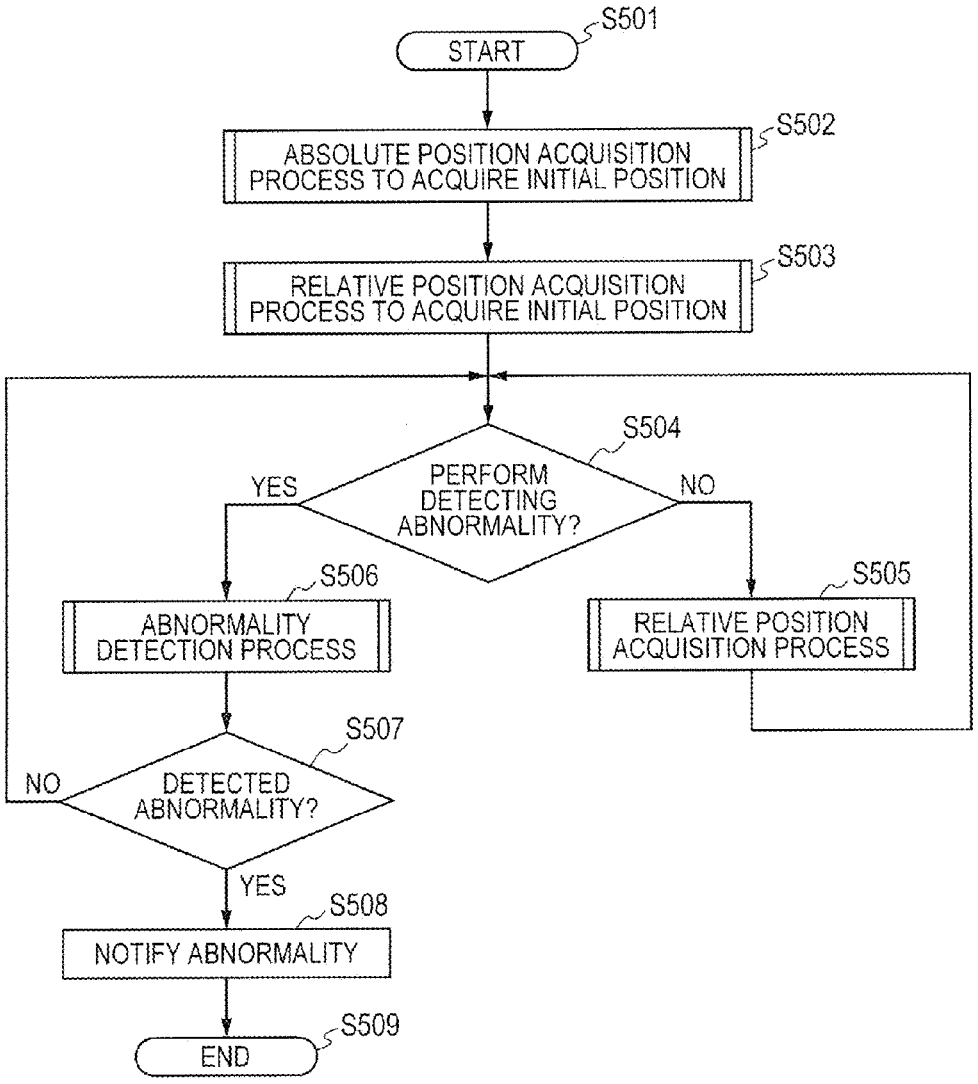

S501
START
S502
ABSOLUTE POSITION ACQUISITION PROCESS TO ACQUIRE INITIAL POSITION
S503
RELATIVE POSITION ACQUISITION PROCESS TO ACQUIRE INITIAL POSITION
S504
PERFORM DETECTING ABNORMALITY?
YES
NO
S506
ABNORMALITY DETECTION PROCESS
S505
RELATIVE POSITION ACQUISITION PROCESS
S507
DETECTED ABNORMALITY?
NO
YES
S508
NOTIFY ABNORMALITY
S509
END

FIG. 6

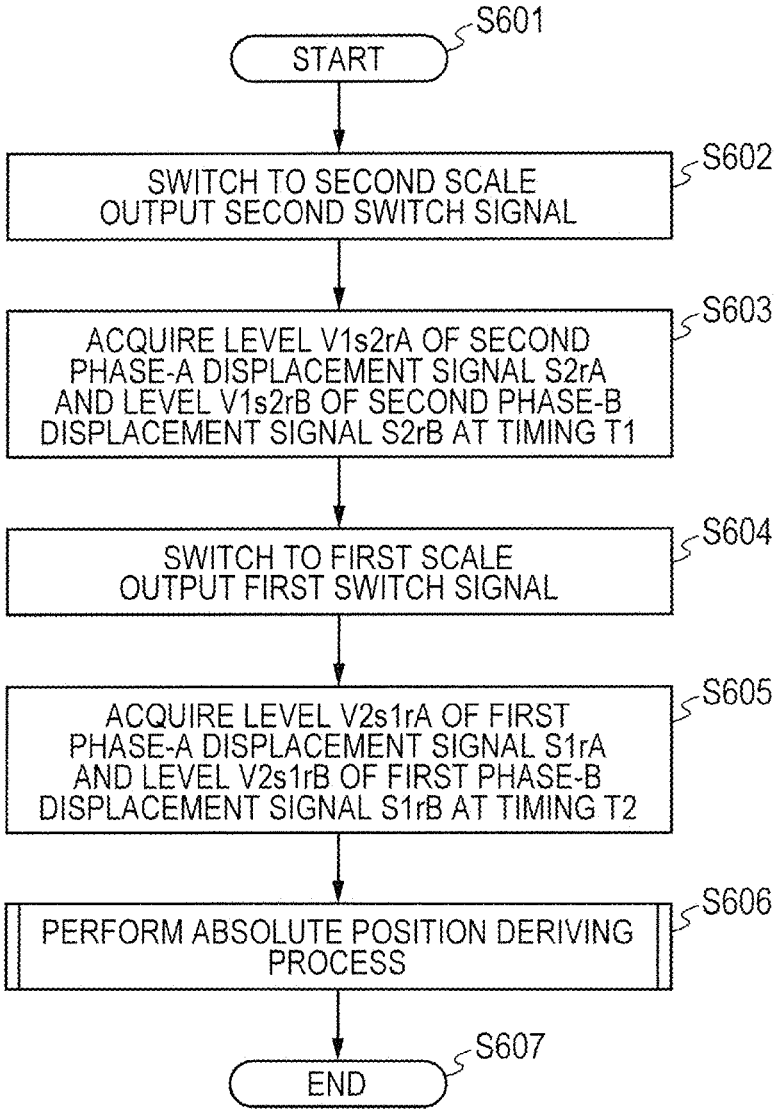

S601
START
S602
SWITCH TO SECOND SCALE
OUTPUT SECOND SWITCH SIGNAL
S603
ACQUIRE LEVEL V1s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V1s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB AT TIMING T1
S604
SWITCH TO FIRST SCALE
OUTPUT FIRST SWITCH SIGNAL
S605
ACQUIRE LEVEL V2s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V2s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB AT TIMING T2
S606
PERFORM ABSOLUTE POSITION DERIVING PROCESS
S607
END

FIG. 7

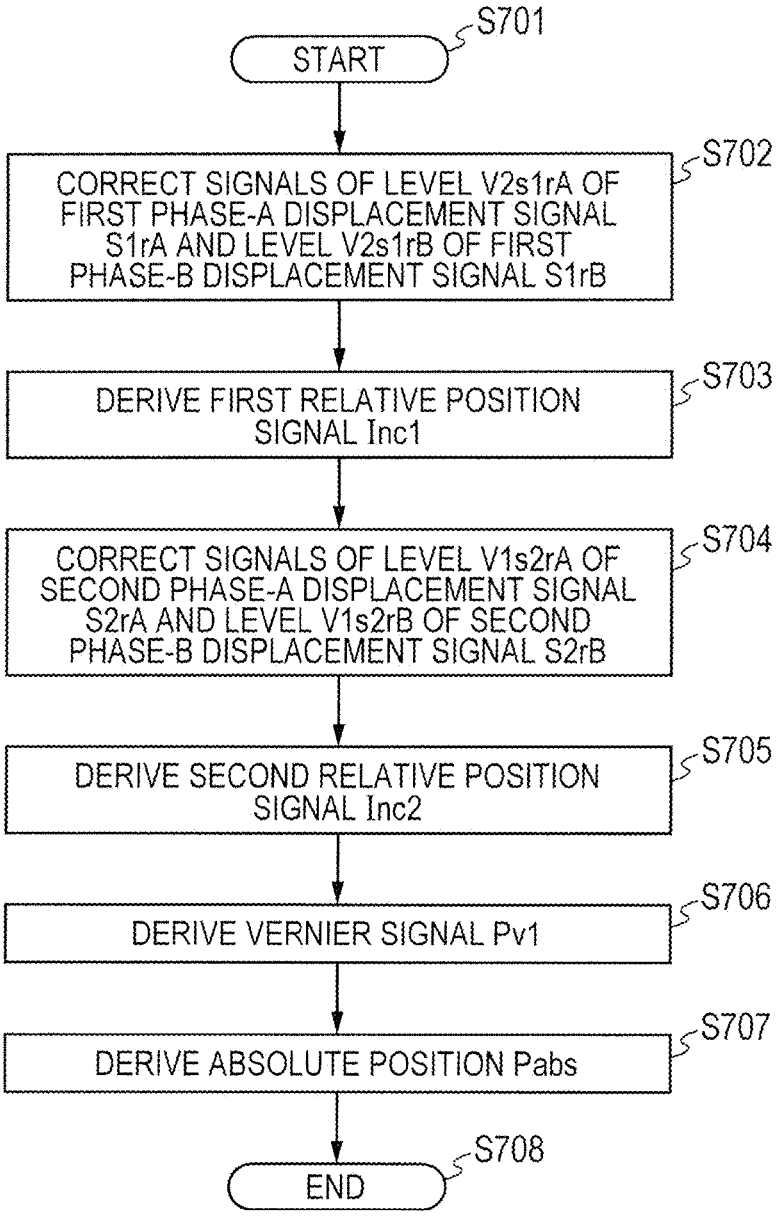

S701
START
S702
CORRECT SIGNALS OF LEVEL V2s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V2s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB
S703
DERIVE FIRST RELATIVE POSITION SIGNAL Inc1
S704
CORRECT SIGNALS OF LEVEL V1s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V1s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB
S705
DERIVE SECOND RELATIVE POSITION SIGNAL Inc2
S706
DERIVE VERNIER SIGNAL Pv1
S707
DERIVE ABSOLUTE POSITION Pabs
S708
END

FIG. 8A Atan1

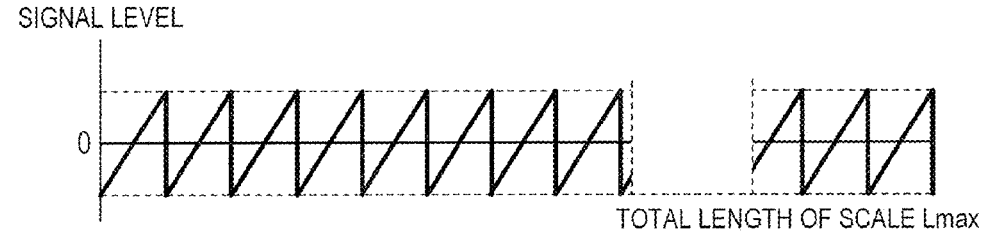


FIG. 8B Inc1

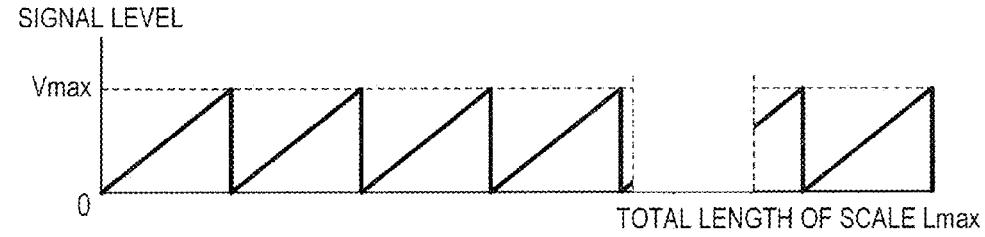


FIG. 8C Inc2

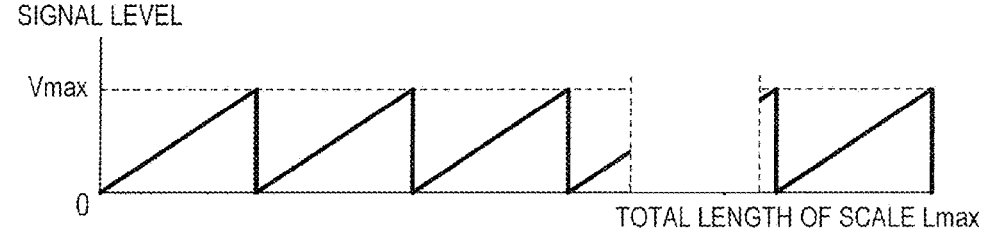


FIG. 8D Pv1

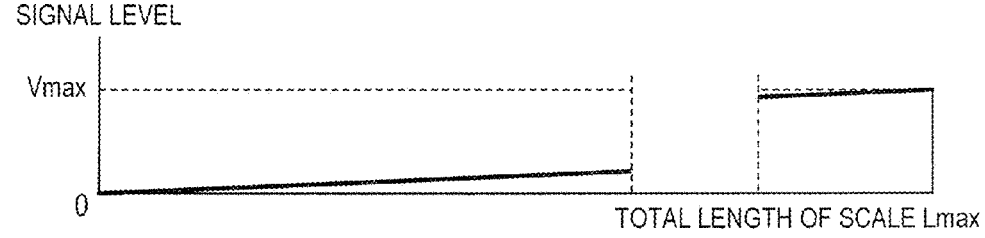


FIG. 9A

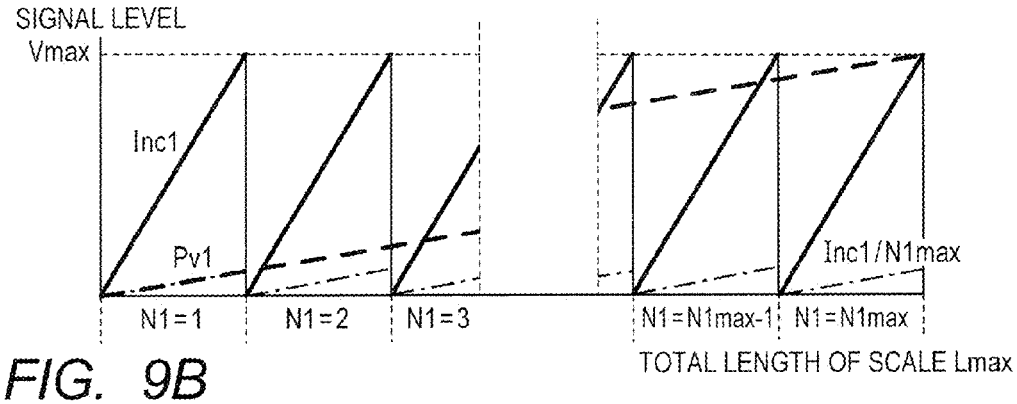


FIG. 9B

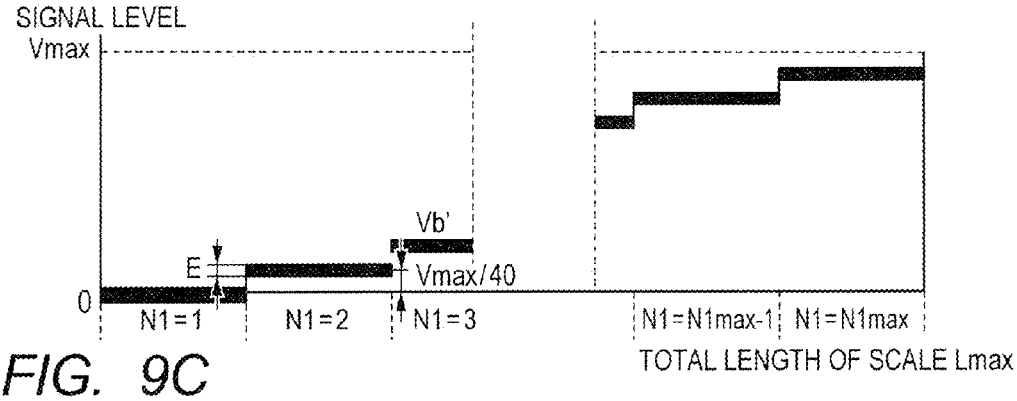


FIG. 9C

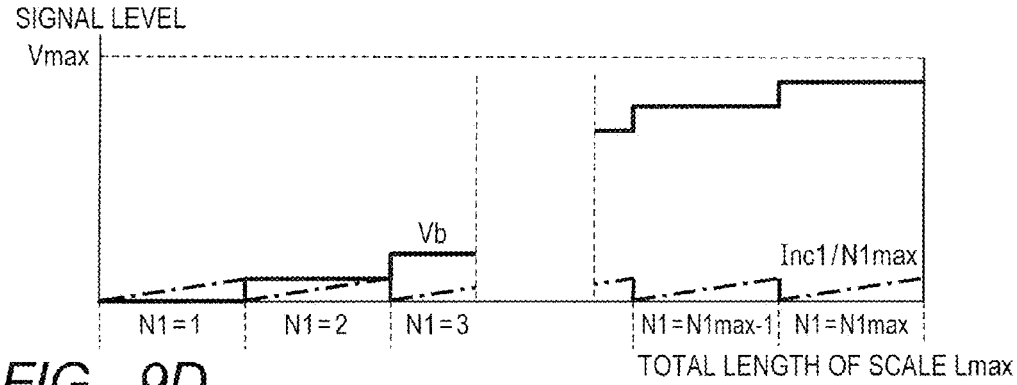


FIG. 9D

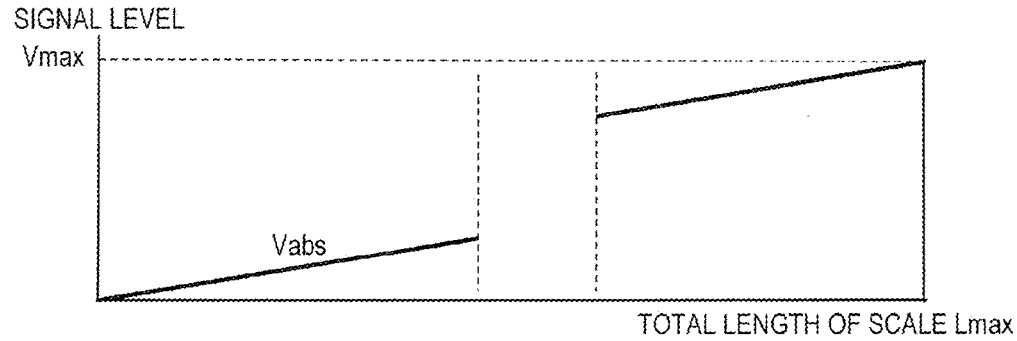


FIG. 10

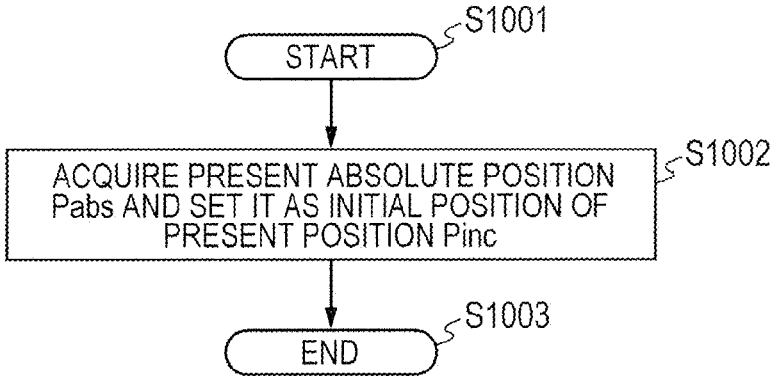

S1001
START
ACQUIRE PRESENT ABSOLUTE POSITION Pabs AND SET IT AS INITIAL POSITION OF PRESENT POSITION Pinc
S1002
S1003
END

FIG. 11

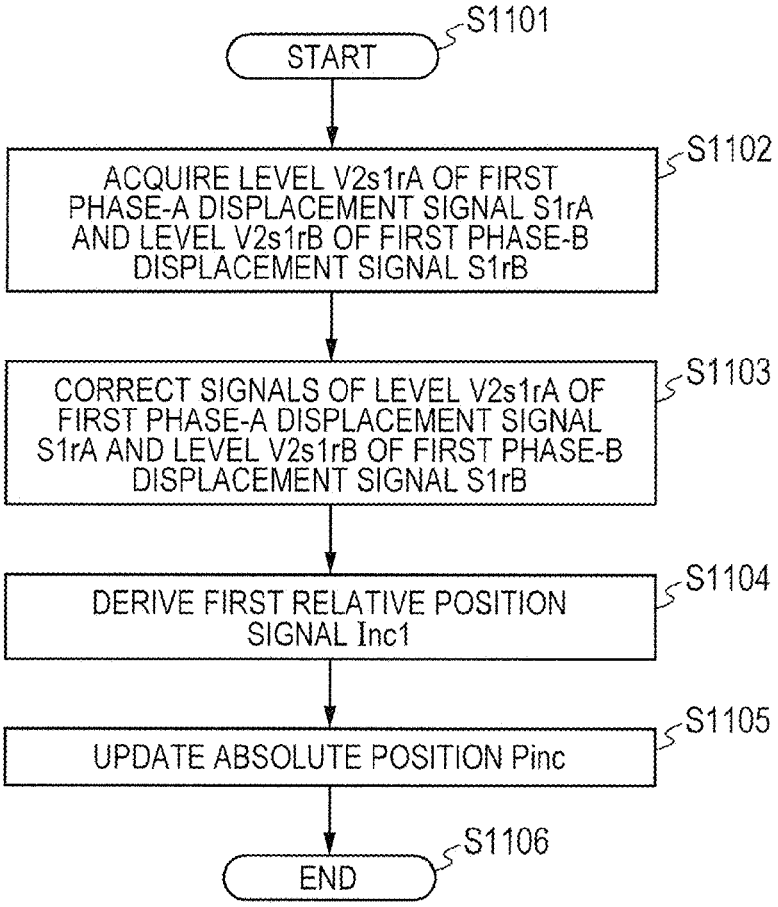

S1101
START
ACQUIRE LEVEL V2s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V2s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB
S1102
CORRECT SIGNALS OF LEVEL V2s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V2s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB
S1103
DERIVE FIRST RELATIVE POSITION SIGNAL Inc1
S1104
UPDATE ABSOLUTE POSITION Pinc
S1105
END
S1106

FIG. 12

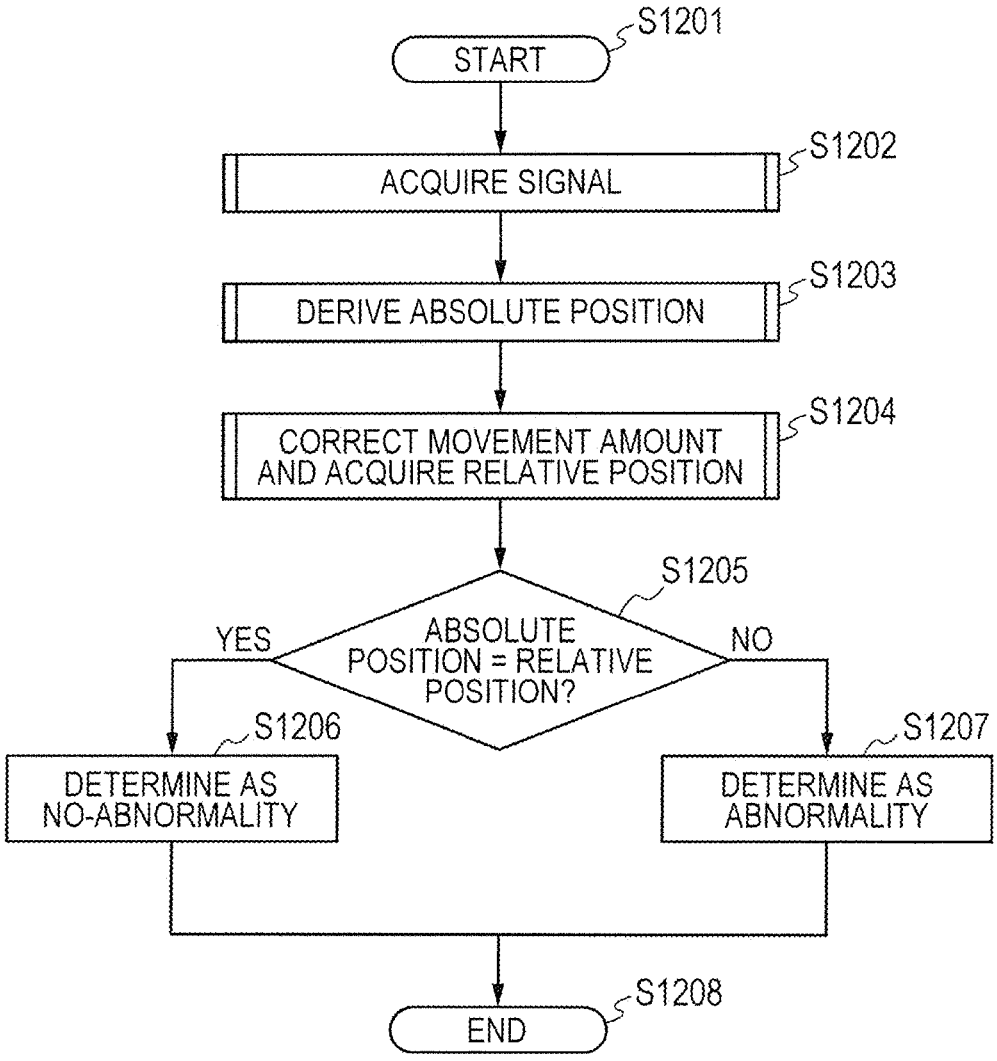

S1201
START
S1202
ACQUIRE SIGNAL
S1203
DERIVE ABSOLUTE POSITION
S1204
CORRECT MOVEMENT AMOUNT AND ACQUIRE RELATIVE POSITION
S1205
ABSOLUTE POSITION = RELATIVE POSITION?
YES
NO
S1206
DETERMINE AS NO-ABNORMALITY
S1207
DETERMINE AS ABNORMALITY
S1208
END

FIG. 13

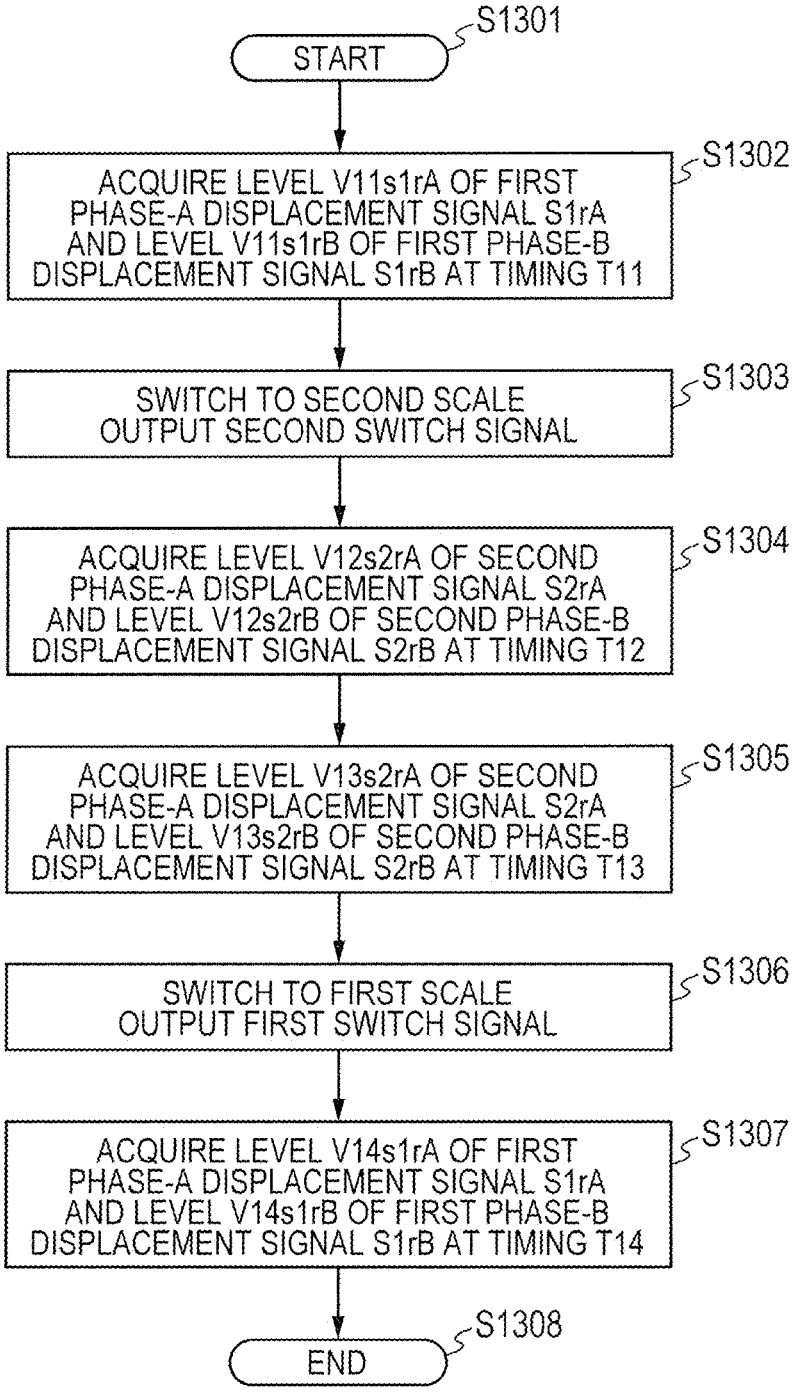

S1301
START
S1302
ACQUIRE LEVEL V11s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V11s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB AT TIMING T11
S1303
SWITCH TO SECOND SCALE OUTPUT SECOND SWITCH SIGNAL
S1304
ACQUIRE LEVEL V12s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V12s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB AT TIMING T12
S1305
ACQUIRE LEVEL V13s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V13s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB AT TIMING T13
S1306
SWITCH TO FIRST SCALE OUTPUT FIRST SWITCH SIGNAL
S1307
ACQUIRE LEVEL V14s1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V14s1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB AT TIMING T14
S1308
END

FIG. 14

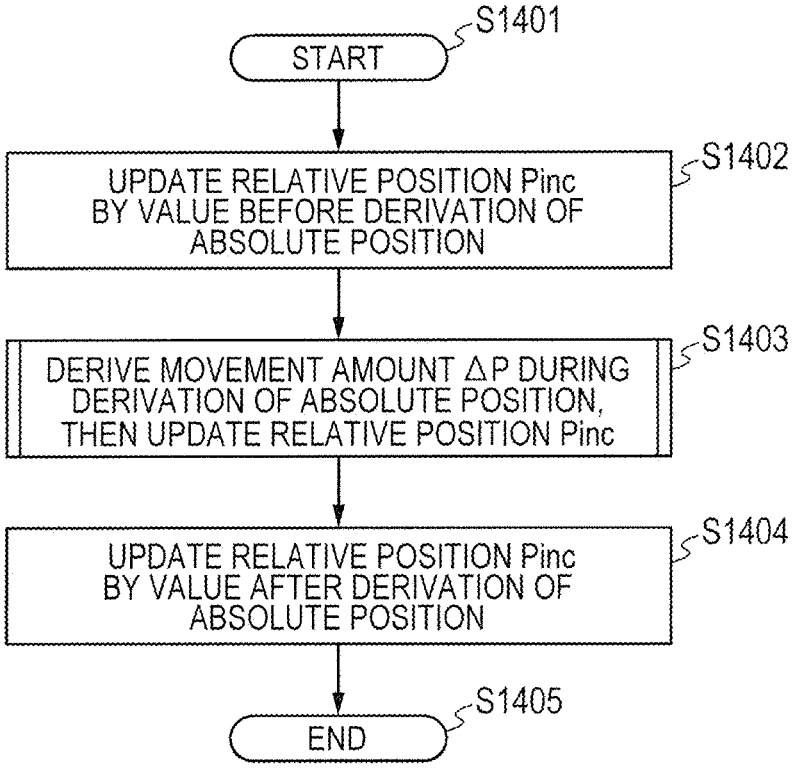

S1401
START
UPDATE RELATIVE POSITION Pinc BY VALUE BEFORE DERIVATION OF ABSOLUTE POSITION
S1402
DERIVE MOVEMENT AMOUNT ΔP DURING DERIVATION OF ABSOLUTE POSITION, THEN UPDATE RELATIVE POSITION Pinc
S1403
UPDATE RELATIVE POSITION Pinc BY VALUE AFTER DERIVATION OF ABSOLUTE POSITION
S1404
END
S1405

FIG. 15

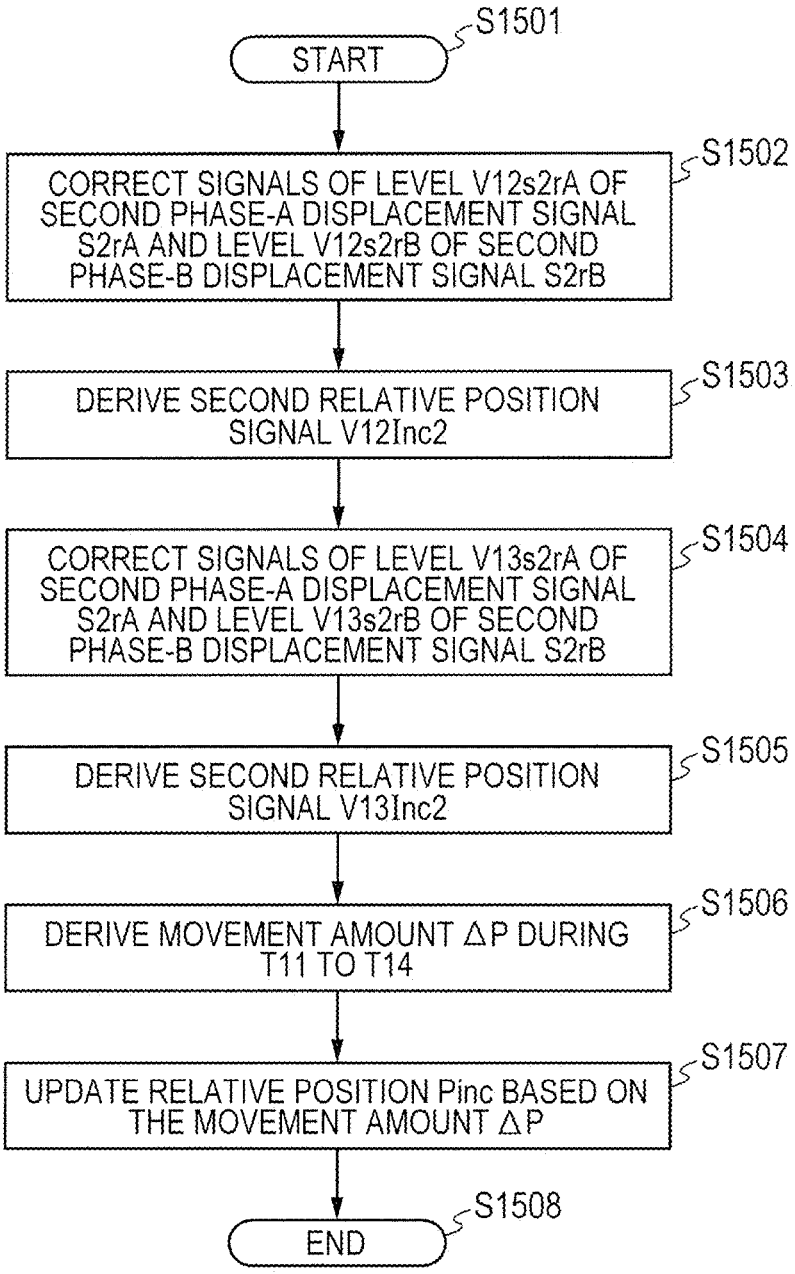

S1501
START
S1502
CORRECT SIGNALS OF LEVEL V12s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V12s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB
S1503
DERIVE SECOND RELATIVE POSITION SIGNAL V12Inc2
S1504
CORRECT SIGNALS OF LEVEL V13s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V13s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB
S1505
DERIVE SECOND RELATIVE POSITION SIGNAL V13Inc2
S1506
DERIVE MOVEMENT AMOUNT ΔP DURING T11 TO T14
S1507
UPDATE RELATIVE POSITION Pinc BASED ON THE MOVEMENT AMOUNT ΔP
S1508
END

FIG. 16A

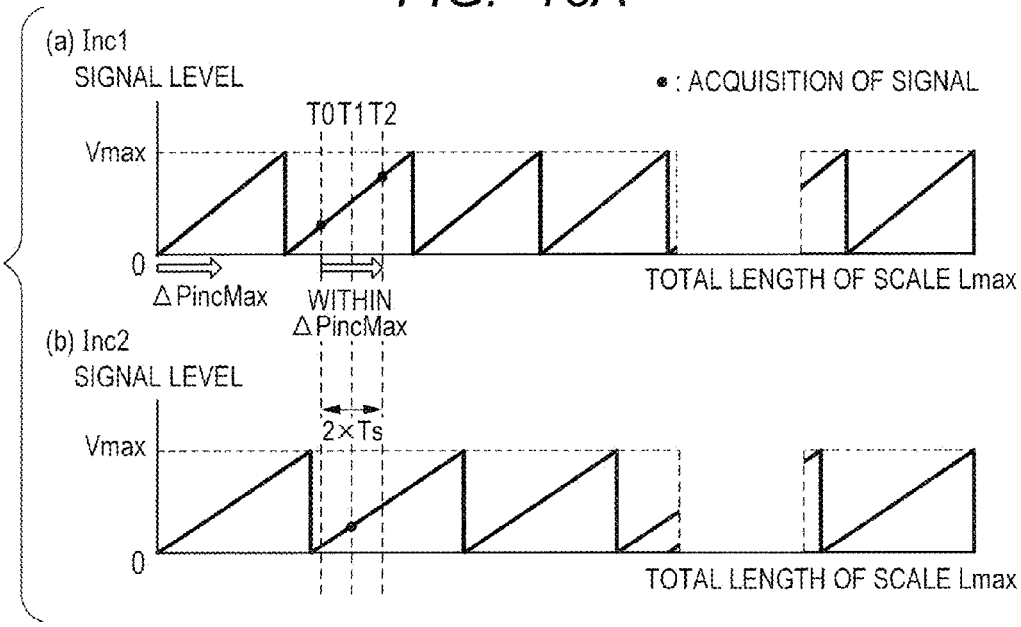


FIG. 16B

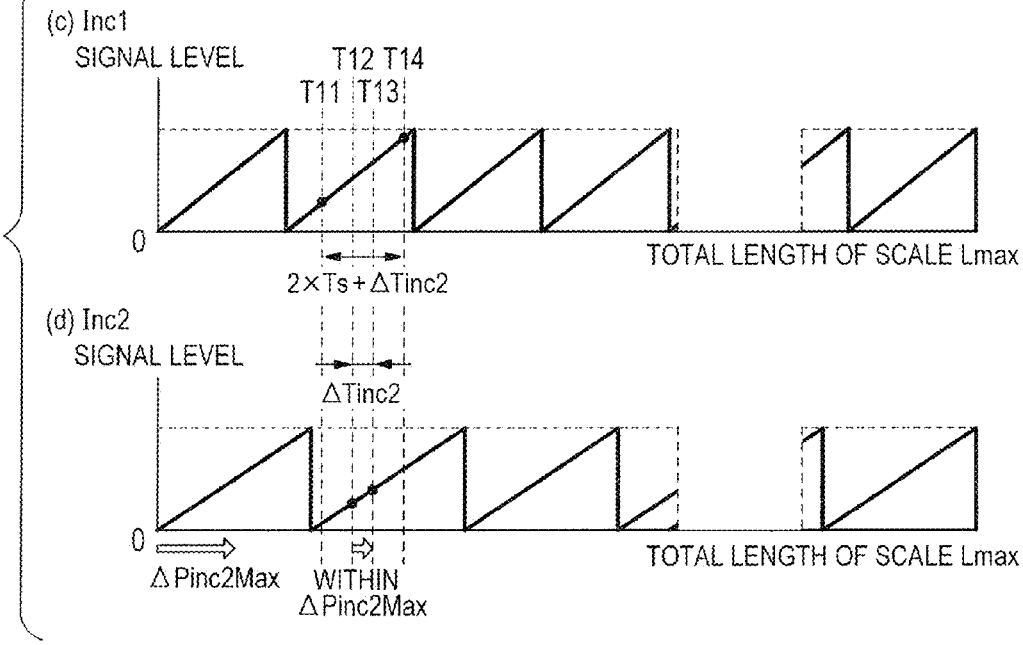


FIG. 17

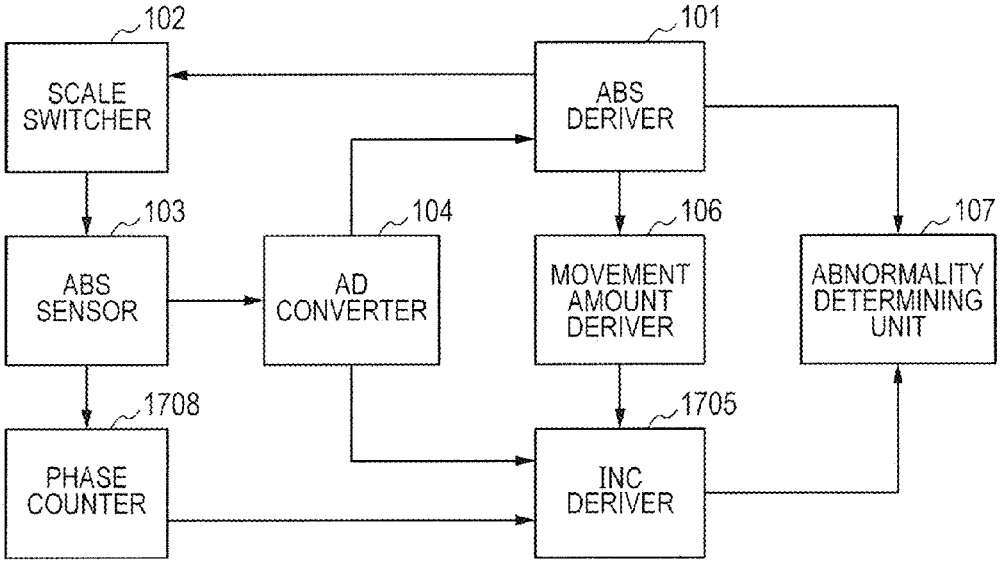

102
SCALE SWITCHER
101
ABS DERIVER
103
ABS SENSOR
104
AD CONVERTER
106
MOVEMENT AMOUNT DERIVER
107
ABNORMALITY DETERMINING UNIT
1708
PHASE COUNTER
1705
INC DERIVER

FIG. 18

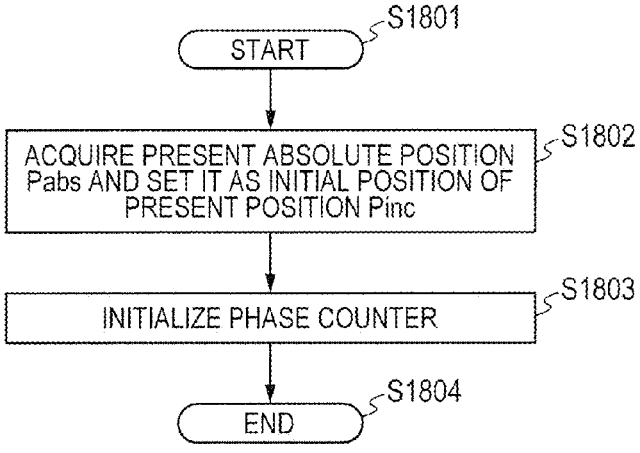

S1801
START
ACQUIRE PRESENT ABSOLUTE POSITION Pabs AND SET IT AS INITIAL POSITION OF PRESENT POSITION Pinc
S1802
INITIALIZE PHASE COUNTER
S1803
END
S1804

FIG. 19

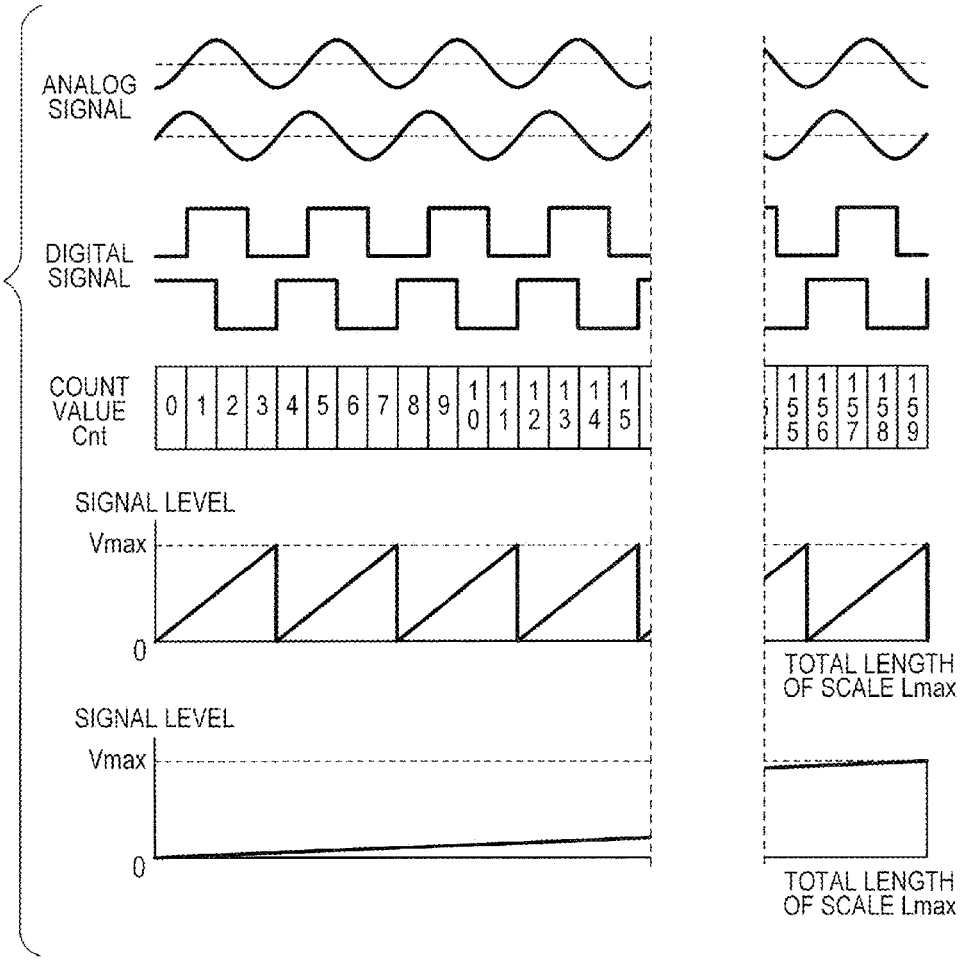

ANALOG SIGNAL
DIGITAL SIGNAL
COUNT VALUE Cnt
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
155 156 157 158 159
SIGNAL LEVEL
Vmax
0
TOTAL LENGTH OF SCALE Lmax
SIGNAL LEVEL
Vmax
0
TOTAL LENGTH OF SCALE Lmax

FIG. 20

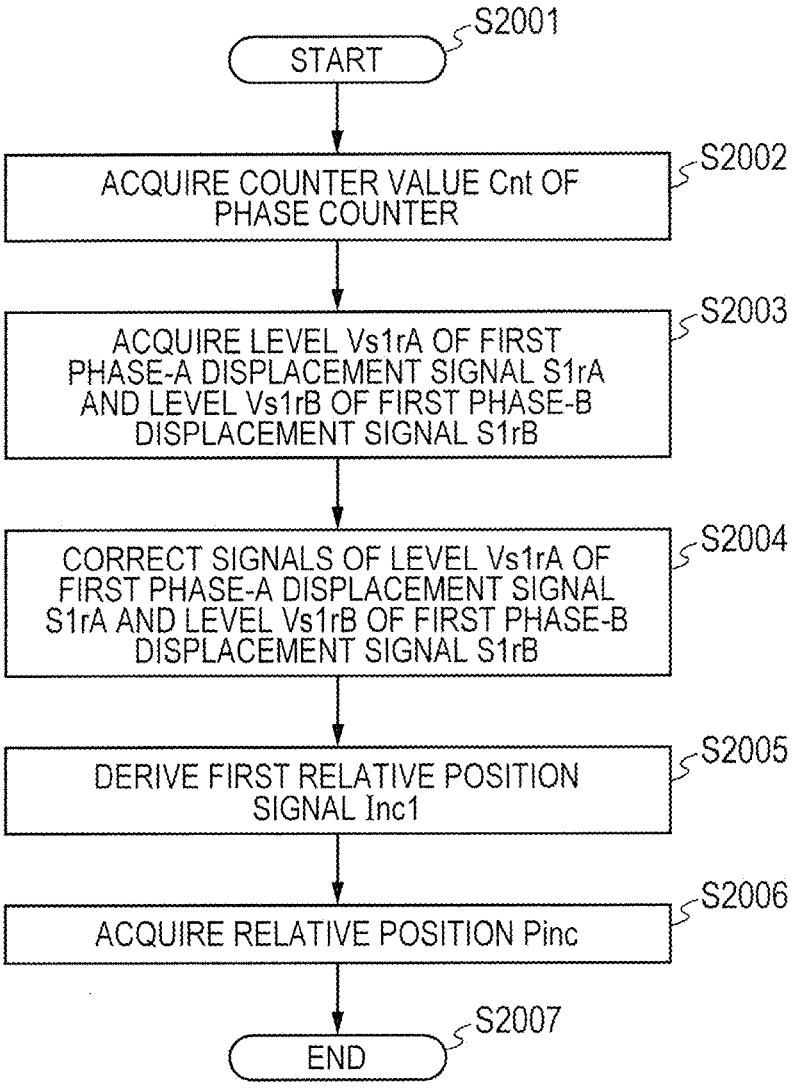

S2001
START
S2002
ACQUIRE COUNTER VALUE Cnt OF PHASE COUNTER
S2003
ACQUIRE LEVEL Vs1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL Vs1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB
S2004
CORRECT SIGNALS OF LEVEL Vs1rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL Vs1rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB
S2005
DERIVE FIRST RELATIVE POSITION SIGNAL Inc1
S2006
ACQUIRE RELATIVE POSITION Pinc
S2007
END

FIG. 21

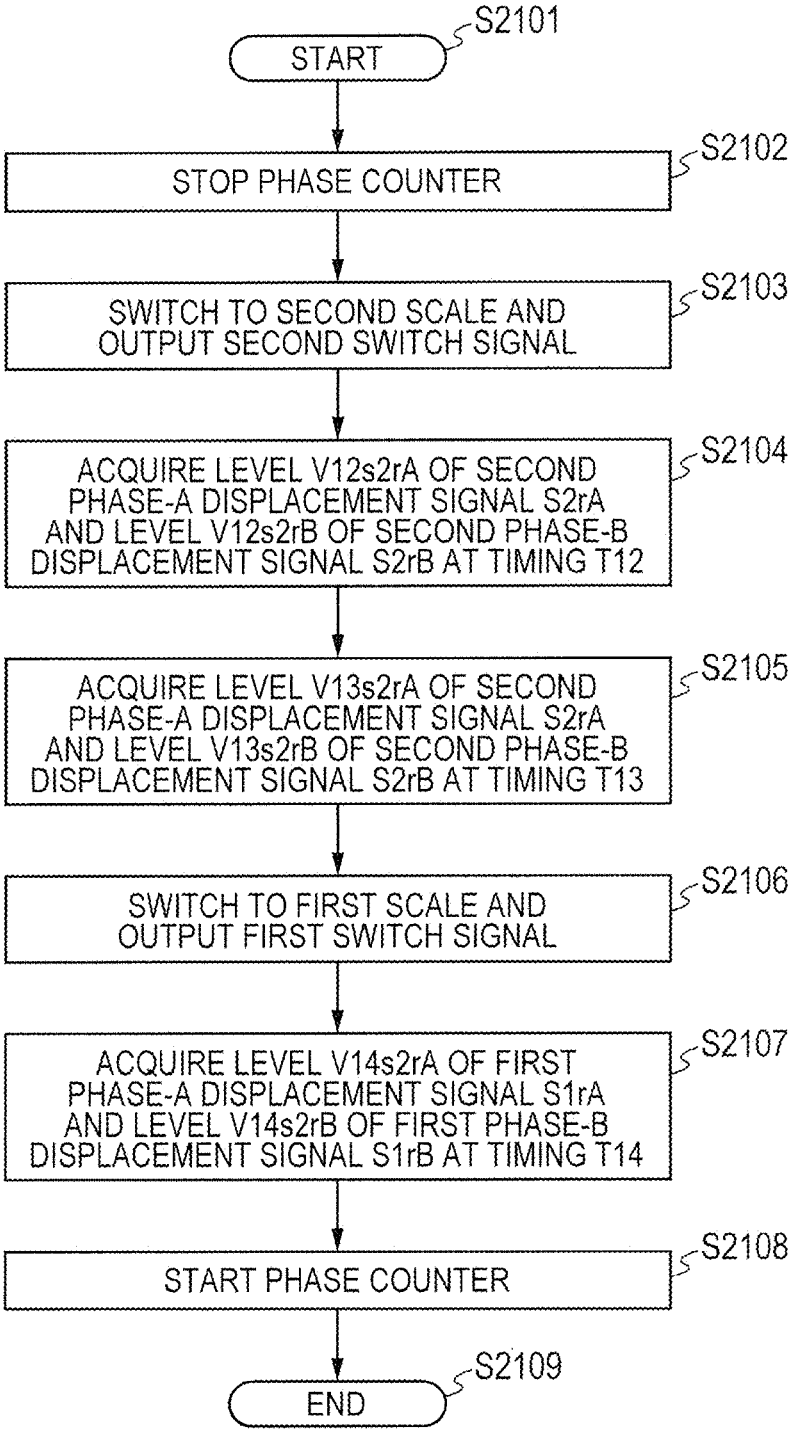

S2101
START
S2102
STOP PHASE COUNTER
S2103
SWITCH TO SECOND SCALE AND OUTPUT SECOND SWITCH SIGNAL
S2104
ACQUIRE LEVEL V12s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V12s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB AT TIMING T12
S2105
ACQUIRE LEVEL V13s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V13s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB AT TIMING T13
S2106
SWITCH TO FIRST SCALE AND OUTPUT FIRST SWITCH SIGNAL
S2107
ACQUIRE LEVEL V14s2rA OF FIRST PHASE-A DISPLACEMENT SIGNAL S1rA AND LEVEL V14s2rB OF FIRST PHASE-B DISPLACEMENT SIGNAL S1rB AT TIMING T14
S2108
START PHASE COUNTER
S2109
END

FIG. 22

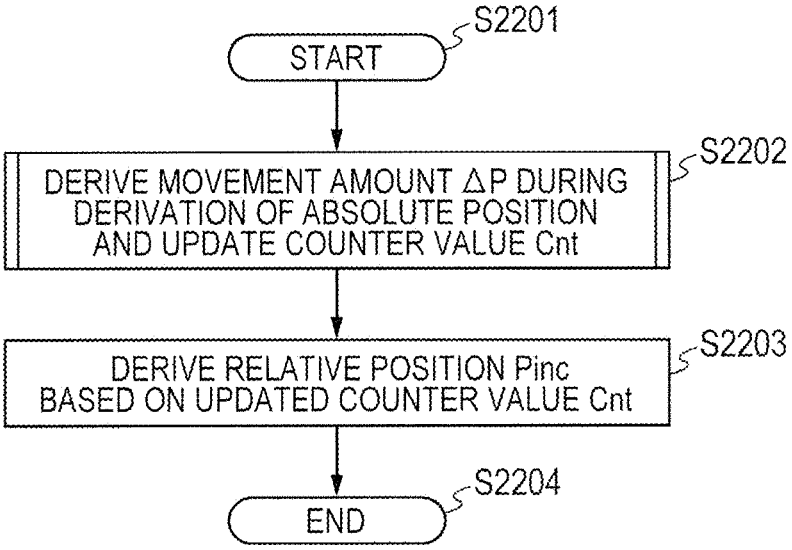

S2201
START
DERIVE MOVEMENT AMOUNT ΔP DURING DERIVATION OF ABSOLUTE POSITION AND UPDATE COUNTER VALUE Cnt
S2202
DERIVE RELATIVE POSITION Pinc BASED ON UPDATED COUNTER VALUE Cnt
S2203
END
S2204

FIG. 23

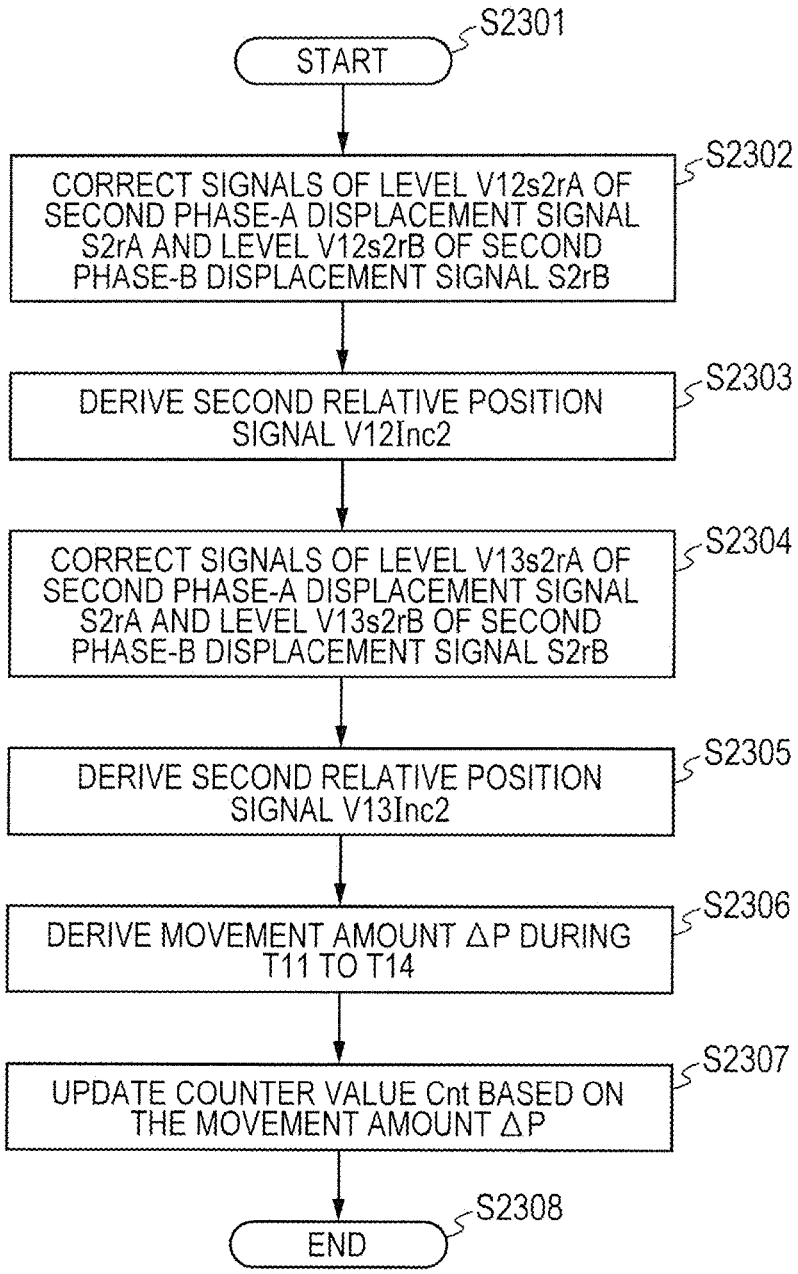

S2301
START
S2302
CORRECT SIGNALS OF LEVEL V12s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V12s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB
S2303
DERIVE SECOND RELATIVE POSITION SIGNAL V12Inc2
S2304
CORRECT SIGNALS OF LEVEL V13s2rA OF SECOND PHASE-A DISPLACEMENT SIGNAL S2rA AND LEVEL V13s2rB OF SECOND PHASE-B DISPLACEMENT SIGNAL S2rB
S2305
DERIVE SECOND RELATIVE POSITION SIGNAL V13Inc2
S2306
DERIVE MOVEMENT AMOUNT ΔP DURING T11 TO T14
S2307
UPDATE COUNTER VALUE Cnt BASED ON THE MOVEMENT AMOUNT ΔP
S2308
END

FIG. 24A

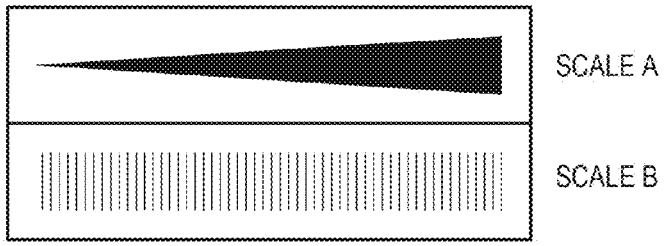


FIG. 24B

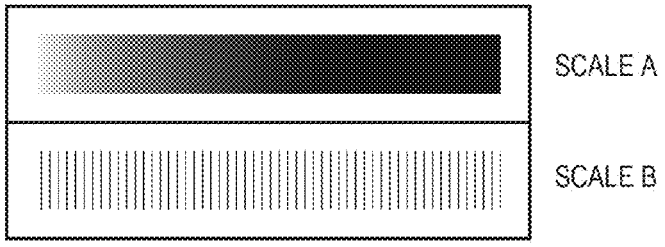


FIG. 24C

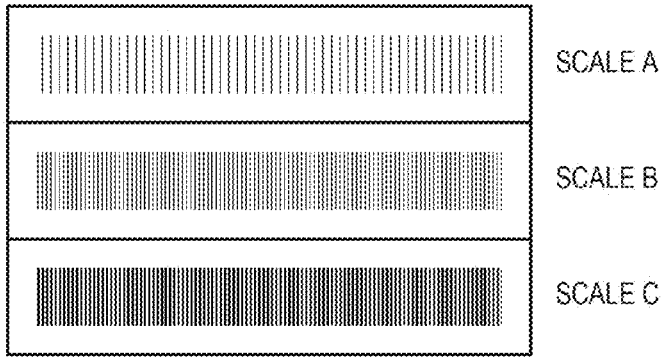
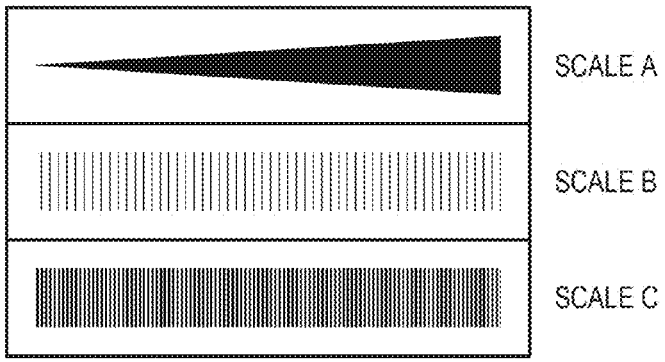


FIG. 24D



POSITION DETECTION UNIT, AND LENS APPARATUS, IMAGE PICKUP APPARATUS, AND LENS COMMAND APPARATUS EACH INCLUDING THE POSITION DETECTION UNIT

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a position detection apparatus for detecting the position of a movable member, and particularly to a position detection apparatus for detecting the position of a movable member based on a plurality of signals, and a lens apparatus, an image pickup apparatus, and a lens command apparatus each including the position detection apparatus.

Description of the Related Art

[0002] An absolute encoder capable of determining an absolute position by measurement as well as an incremental encoder for measuring a relative moving distance is known as an apparatus for measuring a moving distance of an object.

[0003] Japanese Patent Application Laid-Open No. 2013-088191 discloses a Vernier type absolute encoder configured to acquire a signal by switching among detection states of a plurality of periodic signals to derive an absolute position. After the absolute position has been derived, a relative position is derived by using only one of the periodic signals with reference to the derived absolute position.

[0004] Japanese Patent Application Laid-Open No. 2010-249720 discloses a code-type absolute encoder that compares an absolute position derived by an absolute position generator and a relative position relatively derived from an absolute position reference based on an incremental signal and detects abnormality.

[0005] If the absolute encoder having the configuration disclosed in Japanese Patent Application Laid-Open No. 2013-088191 performs abnormality detection as described in Japanese Patent Application Laid-Open No. 2010-249720, there arises the following problem.

[0006] In the Vernier type absolute encoder, a relative position is derived by using only one periodic signal, whereas an absolute position is derived by using a plurality of periodic signals. However, the configuration disclosed in Japanese Patent Application Laid-Open No. 2013-088191 needs to switch a signal to be detected in order to acquire a plurality of periodic signals, and thus, a periodic signal for deriving a relative position cannot be acquired while the signal is being switched. Specifically, the relative position deriving process needs to be stopped while a plurality of periodic signals are being acquired in order to derive an absolute position, and thus, a relative position deriving unit cannot detect a positional change while the relative position deriving process is stopped. That is, the absolute position and the relative position cannot be derived at the same time.

SUMMARY OF THE INVENTION

[0007] A position detection apparatus according to the present invention is a position detection apparatus for detecting a position of a movable member relative to a fixed member and includes: a signal output unit that outputs a plurality of displacement signals including a first signal that changes in a first period and a second signal that changes in a period longer than the first period, while switching among the plurality of displacement signals, in accordance with a change in the position of the movable member relative to the fixed member; and a position deriver that derives an absolute position as the position of the movable member relative to the fixed member based on the plurality of displacement signals output from the signal output unit, and derives a relative position as a displacement amount with respect to a predetermined absolute position of the movable member relative to the fixed member, wherein in deriving the absolute position, the signal output unit outputs the first signal, a plurality of the second signals, and the first signal in this order, and the position deriver derives the absolute position based on the plurality of displacement signals in deriving the relative position, the position deriver derives the relative position based on the first signal and the plurality of the second signals.

[0008] According to the present invention, in the position detection apparatus, a highly reliable position detection unit that can achieve size reduction of a circuit configuration and can detect an absolute position and a relative position at the same time accurately can be provided.

[0009] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a block diagram illustrating a configuration according to a first embodiment.

[0011] FIG. **2** is a cross-sectional view of an ABS sensor.

[0012] FIG. **3** is a plan view of a scale unit according to the first embodiment.

[0013] FIG. **4** is a plan view of a light receiver.

[0014] FIG. **5** is a flowchart showing the entire process in the first embodiment.

[0015] FIG. **6** is a flowchart showing signal acquisition for acquiring an initial position.

[0016] FIG. **7** is a flowchart showing deriving of an absolute position for acquiring the initial position.

[0017] FIG. **8**A is a graph showing a signal Atan 1.

[0018] FIG. **8**B is a graph showing a first relative position signal.

[0019] FIG. **8**C is a graph showing a second relative position signal.

[0020] FIG. **8**D is a graph showing a Vernier signal.

[0021] FIG. **9**A shows waveforms of Inc**1**, Pv**1**, and Inc/N**1**max in a synchronous operation.

[0022] FIG. **9**B shows a waveform of Vb' in the synchronous operation.

[0023] FIG. **9**C shows a waveform of Vb in the synchronous operation.

[0024] FIG. **9**D shows a waveform of Vabs in the synchronous operation.

[0025] FIG. **10** is a flowchart showing an initialization operation for deriving a relative position.

[0026] FIG. **11** is a flowchart showing deriving of the relative position.

[0027] FIG. **12** is a flowchart showing an abnormality detection operation.

[0028] FIG. **13** is a flowchart showing signal acquisition in the abnormality detection operation.

[0029] FIG. **14** is a flowchart showing movement amount correction.

[0030] FIG. **15** is a flowchart showing details of the movement amount correction.

[0031] FIG. **16**A is a graph showing an operation of the movement amount correction and shows signal acquisition positions.

[0032] FIG. **16**B is a graph showing an operation of the movement amount correction and signal acquisition positions.

[0033] FIG. **17** is a block diagram illustrating a configuration according to a second embodiment.

[0034] FIG. **18** is a flowchart showing an initialization operation for deriving a relative position.

[0035] FIG. **19** shows graphs showing a relationship between an input signal and a count value of a phase counter.

[0036] FIG. **20** is a flowchart showing deriving of a relative position.

[0037] FIG. **21** is a flowchart showing signal acquisition in an abnormality detection operation.

[0038] FIG. **22** is a flowchart showing movement amount correction.

[0039] FIG. **23** is a flowchart showing details of the movement amount correction

[0040] FIG. **24**A illustrates one of various scale units.

[0041] FIG. **24**B illustrates another one of various scale units.

[0042] FIG. **24**C illustrates still another one of various scale units.

[0043] FIG. **24**D illustrates yet another one of various scale units.

DESCRIPTION OF THE EMBODIMENTS

[0044] Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

First Embodiment

[0045] With reference to FIGS. **1** to **16**B, a position detection unit according to a first embodiment of the present invention will be described.

[0046] FIG. **1** is a block diagram illustrating a configuration of the position detection unit according to the first embodiment of the present invention. In FIG. **1**, an ABS deriver **101** is an arithmetic section for deriving an absolute position Pabs that is a displacement amount (relative to a predetermined reference position) of a movable member relative to a fixed member, based on a signal output from the ABS sensor **103**. A scale switcher (switcher) **102** is a scale switcher that switches between two types of signal outputs generated based on two types of track patterns sequentially output from the ABS sensor **103**. An ABS sensor (signal detection unit) **103** is an absolute position sensor that outputs a signal for deriving an absolute position of the movable member relative to the fixed member. An inner configuration and an output signal of the ABS sensor **103** will be described later. An AD converter **104** is an AD converter that converts an analog signal output from the ABS sensor **103** to a digital signal. An INC deriver **105** is an arithmetic section that derives a relative position Pinc based on a displacement amount from a reference position.

[0047] The movement amount deriver **106** is a movement amount deriver that derives and corrects a movement amount in which the movable member moves while the movement amount deriver **106** acquires the two types of signals acquired by the ABS deriver **101**. The movement amount correcting process will be specifically described.

[0048] The abnormality determining unit **107** is a determination unit that determines whether the position detection unit has abnormality or not, based on Pabs as an arithmetic result in the ABS deriver **101** and Pinc as an arithmetic result in the INC deriver **105**.

[0049] The ABS deriver **101**, the INC deriver **105**, the movement amount deriver **106**, and the abnormality determining unit **107** are provided in, for example, one CPU.

[0050] Then, an inner configuration and an output signal of the ABS sensor **103** will be described.

[0051] FIG. **2** is a cross-sectional view of the ABS sensor **103**. In FIG. **2**, the movable member **21** is a movable unit that moves in an X-axis direction that is perpendicular to the drawing sheet, relative to the fixed member **22**. A light source **201** is a light-emitting unit, and is, for example, an LED. A scale unit **202** is a scale unit including two evenly spaced track patterns **203***a* and **203***b* having different numbers of slits in the entire length thereof. Each of light receivers **204***a* and **204***b* is a light receiver that receives light emitted from the light source **201** and reflected on an associated one of the track patterns **203***a* and **203***b*, and is composed of, for example, a photodiode array. A signal processing circuit **205** is a signal processing circuit that performs processing on signals received by the light receivers **204***a* and **204***b* and outputs a signal of one of the track patterns **203***a* and **203***b* in accordance with a switch signal of the scale switcher **102**.

[0052] In this embodiment, the movable member **21** includes the scale unit **202**, and the fixed member **22** includes the light source **201** and the light receivers **204***a* and **204***b*. However, the present invention is not limited to this example, and the scale unit **202** may be included in one of the fixed member or the movable member with the light source **201** and the light receivers **204***a* and **204***b* being included in the other. The same holds for the embodiment below.

[0053] FIG. **3** is a plan view of the scale unit **202** according to this embodiment. FIG. **3** illustrates a reflection-type slit pattern (reflection pattern array) as an example. The scale unit **202** includes two track patterns, that is, a first track pattern **203***a* and a second track pattern **203***b*. When light from the light source **201** strikes reflection portions (black portions in FIG. **3**) of the track patterns **203***a* and **203***b*, the light is respectively reflected toward the light receivers **204***a* and **204***b*. The reflection portions of the first track pattern **203***a* are formed to be evenly spaced from each other at a pitch P**1**. The reflection portions of the second track pattern **203***b* are formed to be evenly spaced from each other at a pitch P**2**. In this embodiment, P**1** is selected in such a way that **40** reflection portions are provided for the total length Lmax of the scale, that is, 40 periods are provided for the total length Lmax. On the other hand, P**2** is selected in such a way that 39 reflection portions are provided for the total length Lmax of scale, that is, 39 periods are provided for the total length Lmax.

[0054] FIG. **4** is a plan view of the light receiver **204***a*. The light receiver **204***b* has a configuration similar to that of the light receiver **204***a*. In the light receiver **204***a*, 16 photodiodes **401** to **416** are arranged at regular intervals in a horizontal direction. The photodiodes **401**, **405**, **409**, and **413** are electrically connected to one another, and will be hereinafter referred to as a phase-a. The group of the

photodiodes **402**, **406**, **410**, and **414** will be hereinafter referred to as a phase-b. Similarly, the group of the photodiodes **403**, **407**, **411**, and **415** will be hereinafter referred to as a phase-c, and the group of the photodiodes **404**, **408**, **412**, and **416** will be hereinafter referred to as a phase-d. Description of this embodiment is based on the premise that the pitch of four photodiodes (e.g., the pitch from the photodiode **401** to the photodiode **404**) in the light receiver **204***a* is twice as large as the pitch P1 of the reflection portions of the first track pattern **203***a*. Here, the distance twice as large as the distance from the light source **201** to the reflection portions of the first track pattern **203***a* is equal to the distance from the light source **201** to the light receiver **204***a*. Thus, the width of reflected light received by the light receiver **204***a* is twice as large as the width of the reflection portions. Accordingly, the pitch of four photodiodes in the light receiver **204***a* corresponds to one period of the pattern of the first track pattern **203***a*.

[0055] When the light receiver **204***a* receives light from the light source **201** reflected on the first track pattern **203***a*, each of the photodiode groups of the phase-a, the phase-b, the phase-c, and the phase-d outputs photocurrent in accordance with the amount of received light. Here, with movement of the scale unit **202** in the X-axis direction, the photodiode groups of the phase-a, the phase-b, the phase-c, and the phase-d output currents (periodic signals) that vary in accordance with a phase relationship in which the phase-b shifts 90°, the phase-c shifts 180°, and the phase-d shifts 270° with respect to the phase-a. The signal processing circuit **205** converts an output current to a voltage with a current-to-voltage converter. Then, the signal processing circuit **205** obtains a differential component between the phase-a and the phase-c and a differential component between the phase-b and the phase-d, with a differential amplifier. Thereafter, the signal processing circuit **205** generates a first phase-A displacement signal S1*r*A that is a phase-A displacement signal of the first track pattern **203***a* and a first phase-B displacement signal S1*r*B that is a phase-B displacement signal of the first track pattern **203***a*, from the differential component between the phase-a and the phase-c and the differential component between the phase-b and the phase-d. The phases of the phase-A displacement signal and the phase-B displacement signal are shifted from each other by 90°. In a similar manner, the light receiver **204***b* generates a second phase-A displacement signal S2*r*A that is a phase-A displacement signal of the second track pattern **203***b* and a second phase-B displacement signal S2*r*B that is a phase-B displacement signal of the second track pattern **203***b*.

[0056] Here, the signal processing circuit **205** outputs either the first phase-A displacement signal S1*r*A and the first phase-B displacement signal S1*r*B or the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B, in accordance with the switch signal from the scale switcher **102**. In this manner, the signal from the signal processing circuit **205** is output with switching in accordance with the switch signal from the scale switcher **102** so that a processing load of the signal processing circuit **205** is reduced, thereby achieving high-speed processing, power conservation, and size reduction.

[0057] In the foregoing manner, the ABS sensor **103** outputs either the first phase-A displacement signal S1*r*A and the first phase-B displacement signal S1*r*B or the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B, in accordance with the switch signal from the scale switcher **102**.

[0058] An operation of this embodiment will be described with reference to FIGS. **5** to **15**. FIG. **5** shows an operation flow of this embodiment.

[0059] The process starts in S**501**, and proceeds to S**502**. The start of the process is, for example, power-on of equipment.

[0060] In S**502**, an absolute position acquisition process for acquiring an initial position is performed, and the process proceeds to S**503**. The absolute position acquisition process for acquiring the initial position will be described in detail below.

[0061] In S**503**, an initialization process for acquiring a relative position is performed, and the process proceeds to S**504**. The initialization process for acquiring the relative position will be described in detail below.

[0062] In S**504**, it is determined whether abnormality detection is performed or not. If the abnormality detection is not performed, the process proceeds to S**505**, and otherwise, the process proceeds to S**506**. Whether the abnormality detection is performed or not may be determined by notification with, for example, an unillustrated switch or may be determined at regular intervals.

[0063] In S**505**, the detected position is updated by the relative position acquisition process, and the process returns to S**504**.

[0064] In S**506**, an abnormality detection process is performed, and the process proceeds to S**507**. The abnormality detection process will be described later.

[0065] In S**507**, it is determined whether abnormality is detected or not. If abnormality is not detected, the process proceeds to S**504**, and otherwise, the process proceeds to S**508**.

[0066] In S**508**, notification of abnormality is issued, and the process proceeds to S**509**. The notification of abnormality is performed by, for example, an unillustrated LED.

[0067] S**509** is the end of the process.

[0068] Subsequently, with reference to FIGS. **6** and **7**, an absolute position deriving process for acquiring an initial position in the operation flow according to this embodiment will be described.

[0069] The process starts in S**601**, and proceeds to S**602**.

[0070] In S**602**, the ABS deriver **101** outputs a second switch signal for switching to a second scale to the scale switcher **102**, and the process proceeds to S**603**. In response to the second switch signal, the scale switcher **102** instructs the ABS sensor **103** to output a signal of a second track pattern, and the ABS sensor **103** outputs signals S2*r*A and S2*r*B of the second track pattern. The signals S2*r*A and S2*r*B of the second track pattern are converted to digital signals by the AD converter **104**, and output to the ABS deriver **101**.

[0071] In S**603**, a signal level V1*s*2*r*A of a second phase-A displacement signal S2*r*A and a signal level V1*s*2*r*B of a phase-B displacement signal S2*r*B at timing T1 of S**603** output from the AD converter **104** are acquired, and the process proceeds to S**604**.

[0072] In S**604**, the ABS deriver **101** outputs a first switch signal for switching to a first scale to the scale switcher **102**, and the process proceeds to S**605**. In response to the first switch signal, the scale switcher **102** instructs the ABS sensor **103** to output a signal of a first track pattern, and the ABS sensor **103** outputs signals S1*r*A and S1*r*B of the first track pattern. The signals S1*r*A and S1*r*B of the first track

pattern are converted to digital signals by the AD converter **104**, and output to the ABS deriver **101**.

[0073] In S**605**, a signal level V**2***s***1***r*A of the first phase-A displacement signal S**1***r*A and a signal level V**2***s***1***r*B of the phase-B displacement signal S**1***r*B at timing T**2** of S**605** output from the AD converter **104**, and the process proceeds to S**606**.

[0074] In S**606**, an absolute position Pabs is derived based on signals of the track patterns acquired in S**603** and S**605**, and the process proceeds to S**607**. A method for deriving an absolute position will be described later.

[0075] S**607** is the end of the process.

[0076] In the foregoing manner, an initial position of the movable member is determined.

[0077] A time interval between time T**1** and time T**2** will be hereinafter referred to as a signal acquisition delay time Ts. The signal acquisition delay time Ts is set as a time necessary for sufficiently stabilizing an output signal after switching of the scale by the scale switcher **102**.

[0078] Then, the method for deriving an absolute position will be described. The absolute position is derived by the ABS deriver **101**. FIG. **7** shows a flow in which an absolute position is derived.

[0079] In S**701**, the process starts and proceeds to S**702**.

[0080] In S**702**, a signal level V**2***s***1***r*A of the first phase-A displacement signal S**1***r*A and a signal level V**2***s***1***r*B of the phase-B displacement signal S**1***r*B at time T**2** acquired in S**605** shown in FIG. **6** are corrected.

[0081] Here, the first phase-A displacement signal S**1***r*A and the first phase-B displacement signal S**1***r*B can have different signal offsets and signal amplitudes. If an absolute position is derived using such signals without change, an error might occur in the derived absolute position Pabs. Thus, signal correction is needed.

[0082] In this embodiment, as described above, the pitch of four photodiodes (e.g., the pitch from the photodiode **401** to the photodiode **404**) in the light receiver **204***a* is twice as large as the pitch P**1** of the reflection portions of the first track pattern **203***a*. Thus, the first phase-A displacement signal S**1***r*A and the first phase-B displacement signal S**1***r*B can be respectively expressed as Expressions (1) and (2):

$$S1rA:\ a1\times\cos\theta+s1 \tag{1}$$

$$S1rB:\ a2\times\mathrm{SIN}\ \theta+s2 \tag{2}$$

where a**1** and s**1** are respectively an amplitude and an offset of the first phase-A displacement signal S**1***r*A, a**2** and s**2** are respectively an amplitude and an offset of the first phase-B displacement signal S**1***r*B, and 0 is a phase of a signal. The first phase-A displacement signal S**1***r*A has a maximum value of s**1**+a**1**, a minimum value of s**1**−a**1**, a signal amplitude of a**1**, and an average value of s**1**. Similarly, the phase-B displacement signal S**1***r*B has a maximum value of s**2**+a**2**, a minimum value of s**2**−a**2**, signal amplitude of a**2**, and an average value of s**2**. Using these values, the first phase-A displacement signal S**1***r*A and the first phase-B displacement signal S**1***r*B expressed by Expressions (1) and (2) are corrected so that the corrected first phase-A displacement signal S**1***c*A and first phase-B displacement signal S**1***c*B can be expressed as Expressions (3) and (4):

$$S1cA:\ ((a1\times\mathrm{COS}\ \theta+s1)-a2=a1\times a2\times\mathrm{COS}\ \theta \tag{3}$$

$$S1cB:\ ((a2\times\mathrm{SIN}\ \theta+s2)-s2)\times a1=a1\times a2\times\mathrm{SIN}\ \theta \tag{4}$$

[0083] Consequently, offsets of the first phase-A displacement signal S**1***r*A and the first phase-B displacement signal S**1***r*B are removed, and a first phase-A displacement signal S**1***c*A and a first phase-B displacement signal S**1***c*B having the same signal amplitude are obtained.

[0084] In the foregoing manner, the first phase-A displacement signal S**1***r*A and the first phase-B displacement signal S**1***r*B are corrected in S**702**, and the process proceeds to S**703**.

[0085] In S**703**, using the corrected first phase-A displacement signal S**1***c*A and first phase-B displacement signal S**1***c*B, a first relative position signal Inc**1** having 40 periods with respect to the total length of the scale with an amplitude Vmax as shown in FIG. **8**B is derived, and the process proceeds to S**704**. In FIGS. **8**A to **8**D, the abscissa represents a position relative to the total length Lmax of the scale, and the ordinate represents a corresponding signal level.

[0086] First, using the corrected first phase-A displacement signal S**1***c*A and first phase-B displacement signal S**1***c*B, an arc tangent operation is performed so that a signal Atan 1 as shown in FIG. **8**A is derived. Here, the first track pattern **203***a* is a pattern having 40 periods with respect to the total length Lmax of the scale. Thus, the signal Atan 1 has 80 periods with respect to the total length of the scale.

[0087] Next, a first relative position signal Inc**1** having 40 periods with respect to the total length of scale and having an amplitude Vmax is derived from Atan 1. Specifically, the first relative position signal Inc**1** is derived by applying gain to the signal Atan 1 so that the amplitude of Atan 1 is Vmax/2, and by adding Vmax/2 when the phase is in the range from 180° to 360° where the signal level when the phase of S**1***r*B is 0° is defined as 0 (zero). Thus, the first relative position signal Inc**1** is a sawtooth wave having 40 periods with respect to the total length Lmax of scale as shown in FIG. **8**B.

[0088] As described above, in S**702** and S**703**, a signal level V**2***inc***1** of the first relative position signal Inc**1** at T**2** is derived from the signal level V**2***s***1***r*A of the first phase-A displacement signal S**1***r*A and the signal level V**2***s***1***r*B of the phase-B displacement signal S**1***r*B at T**2**, and the process proceeds to S**704**.

[0089] In S**704**, the signal level V**1***s***2***r*A of the second phase-A displacement signal S**2***r*A and the signal level V**1***s***2***r*B of the phase-B displacement signal S**2***r*B at T**1** acquired in S**603** in FIG. **6** are corrected.

[0090] Here, since the light receiver **204***b* has the same configuration as that of the light receiver **204***a*, the pitch of four photodiodes (e.g., the pitch from the photodiode **401** to the photodiode **404**) in the light receiver **204***b* is twice as large as the pitch P**1** of the reflection portions of the first track pattern **203***a*. Here, the pitch P**1** of the reflection portions of the first track pattern **203***a* is different from the pitch P**2** of the reflection portions of the second track pattern **203***b*. Accordingly, the pitch of four photodiodes (e.g., the pitch from the photodiode **401** to the photodiode **404**) in the light receiver **204***b* is not twice as large as the pitch P**2** of the reflection portions of the second track pattern **203***b*. Consequently, the second phase-A displacement signal S**2***r*A and the second phase-B displacement signal S**2***r*B shift from 90° in phase relationship.

[0091] Thus, the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B are expressed by Expressions (5) and (6) as follows:

$$S2rA:\ b1\times\mathrm{COS}\ \theta+t1 \tag{5}$$

$$S2rB:\ b2\times\mathrm{SIN}\ (\theta+\alpha)+t2 \tag{6}$$

where b**1** and t**1** are respectively an amplitude and an offset of the second phase-A displacement signal S2*r*A, b**2** and t**2** are respectively an amplitude and an offset of the second phase-B displacement signal S2*r*B, θ is a phase of a signal, and α is the amount of phase shift. In a manner similar to S**602**, when the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B are corrected, the corrected second phase-A displacement signal S2*c*A' and second phase-B displacement signal S2*c*B' are expressed by Expressions (7) and (8) as follows:

$$S2cA':\ \{(b1\times\mathrm{COS}\ \theta+t1)-t1\}\times b2=b1\times b2\times\mathrm{COS}\ \theta \tag{7}$$

$$S2cB':\ \{(b2\times\mathrm{SIN}\ (\theta+\alpha)+t26)-t2\}b1=b1\times b2\times\mathrm{SIN}\ (\theta+\alpha) \tag{8}$$

[0092] Consequently, the offsets t**1** and t**2** of the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B are removed, and the second phase-A displacement signal S2*c*A' and the second phase-B displacement signal S2*c*B' having the same signal amplitude are obtained.

[0093] Then, a process in which a phase difference between the second phase-A displacement signal S2*c*A' and the second phase-B displacement signal S2*c*B' is set at 90° will be described using Expressions (7) and (8).

[0094] Differences and sums in Expressions (7) and (8) are expressed by Equations (9) and (10) as follows:

$$b1\times b2\times(\mathrm{SIN}(\theta+\alpha)-\mathrm{COS}\theta)=b1\times b2\times 2\times\mathrm{SIN}\{(\alpha-90)/2\}\times\mathrm{COS}\{\theta+(\alpha+90)/2\} \tag{9}$$

$$b1\times b2\times(\mathrm{SIN}(\theta+\alpha)+\mathrm{COS}\theta)=b1\times b2\times 2\times\mathrm{COS}\{(\alpha-90)/2\}\times\mathrm{SIN}\{\theta+(\alpha+90)/2\} \tag{10}$$

[0095] In this manner, the phase differences in Equations (9) and (10) are 90°.

[0096] Since amplitudes in Equations (9) and (10) are different from each other, amplitudes are next corrected so as to derive the second phase-A displacement signal S2*c*A and the second phase-B displacement signal S2*c*B having the same signal amplitude. Equation (9) is multiplied by COS{(α−90)/2} as a part of the amplitude in Equation (10), and Equation (10) is multiplied by SIN{(α−90)/2} as a part of the amplitude in Equation (9). Then, Expressions (11) and (12) are obtained as follows:

[0097] Second phase-A displacement signal S2*c*A:

$$b1\times b2\times 2\times\mathrm{SIN}\{(\alpha-90)/2\}\times\mathrm{COS}\{(\alpha-90)/2\}\times\mathrm{COS}\{\theta+(\alpha+90)/2\} \tag{11}$$

[0098] Second phase-B displacement signal S2*c*B:

$$b2\times b2\times 2\times\mathrm{SIN}\{(\alpha-90)/2\}\times\mathrm{COS}\{(\alpha-90)/2\}\times\mathrm{SIN}\{\theta+(\alpha+90)/2\} \tag{12}$$

[0099] Consequently, the offsets of the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B are removed, the second phase-A displacement signal S2*c*A and the second phase-B displacement signal S2*c*B having the same signal amplitude and a phase difference of 90° are obtained.

[0100] In this manner, the second phase-A displacement signal S2*r*A and the second phase-B displacement signal S2*r*B are corrected in S**704**, and then, the process proceeds to S**705**.

[0101] In S**705**, an operation similar to that in S**703** is performed using the corrected second phase-A displacement signal S2*c*A and second phase-B displacement signal S2*c*B, and a second relative position signal Inc**2** is derived. Here, the second track pattern **203***b* has a pattern in which 39 periods are provided with respect to the total length Lmax of scale. Thus, the second relative position signal Inc**2** is a sawtooth wave having 39 periods with respect to the total length Lmax of scale as shown in FIG. **8**C. In FIGS. **8**A to **8**D, the abscissa represents a position relative to the total length Lmax of scale, and the ordinate represents a corresponding signal level.

[0102] In this manner, in S**704** and S**705**, a signal level V**1***inc***2** of the second relative position signal Inc**2** at T**1** is derived from the signal level V**1***s***2***r*A of the second phase-A displacement signal S**2***r*A and the signal level V**1***s***2***r*B of the phase-B displacement signal S**2***r*B at T**1**, and the process proceeds to S**706**.

[0103] For convenience of description, deriving of the first relative position signal at time T**2** is performed first, and then, deriving of the second relative position signal at time T**1** is performed. However, the present invention is, of course, not limited to this order, and deriving of the second relative position signal at time T**1** may be performed first.

[0104] In S**706**, a Vernier signal Pv**1** as shown in FIG. **8**D is derived from the signal level V**2***inc***1** of the first relative position signal Inc**1** at T**2** and the signal level V**1***inc***2** of the second relative position signal Inc**2** at T**1**. The Vernier signal Pv**1** is obtained by calculating a difference between Inc**1** and Inc**2** and adding Vmax if the difference is a negative value.

[0105] Here, since the difference in period between the first relative position signal Inc**1** and the second relative position signal Inc**2** with respect to the total length Lmax of scale is 1 (one), the Vernier signal Pv**1** is a sawtooth wave having a period with respect to the total length Lmax.

[0106] As described above, the Vernier signal Pv**1** is derived in S**706**, and the process proceeds to S**707**.

[0107] In S**707**, an absolute position Pabs is derived.

[0108] Here, since S**1***r*A, S**1***r*B, S**2***r*A, and S**2***r*B include noise components due to disturbance or other factors, Inc**1**, Inc**2**, and Pv**1** derived from these signals also include noise components. To correct the noise components, a synchronous operation of the Vernier signal Pv**1** and the first relative position signal Inc**1** is performed.

[0109] FIGS. **9**A to **9**D show how a wavelength changes with the synchronous operation.

[0110] In FIGS. **9**A to **9**D, the abscissa represents a position relative to the total length Lmax of scale, and the ordinate represents a corresponding signal level. The maximum value of the signal level is indicated as Vmax. In addition, N1 indicates an ordinal number of a period including a region from the start of scaling, and N1max is defined as the number of periods (maximum value of N1) in the total length Lmax. In this embodiment, since the first track pattern **203***a* has 40 periods with respect to the total length Lmax of scale, N1max is 40 and N1 is a natural number from 1 (one) to 40, both inclusive.

[0111] FIG. **9**A shows waveforms of Inc**1**, Pv**1**, and Inc**1**/N**1**max. If a difference between Pv**1** and Inc**1**/N**1**max at the same inclination as Pv**1** is taken, a stepped waveform having an error component E and shown in FIG. **9**B is generated. A signal Vb' of the waveform shown in FIG. **9**B is expressed as Equation (13) below. In Equation (13), the signal level corresponding to one step of the stepped waveform is Vmax/N**1**max.

$$Vb'=Pv1-(Inc1/N1\max) \tag{13}$$

[0112] Then, the error component E of the waveform shown in FIG. **9**B is removed by rounding, a waveform shown in FIG. **9**C is obtained. A signal Vb of the waveform shown in FIG. **9**C is expressed by Equation (14) as follows:

$$Vb=\mathrm{Round}[Vb'\times(N1\max/V\max)]\times(V\max/N1\max) \tag{14}$$

where Round [ ] is a function for rounding off to the first decimal place.

[0113] The error component E can be expressed by Equation (15):

$$E=[pV1-(Inc1/n1\max)]-Vb \tag{15}$$

[0114] A waveform of Inc**1**/N**1**max is added to the waveform shown in FIG. **9**C so that a signal Vabs showing an absolute position from which the error component E is removed and which is shown in FIG. **9**D is generated.

[0115] This synchronous operation is performed by an operation expressed by Equation (16) as follows:

$$Vabs=Vb+(Inc1/N1\max) \tag{16}$$

[0116] The synchronous operation is performed in the foregoing manner so that a signal obtained by synchronizing the Vernier signal Pv**1** as a higher-order signal and the first relative position signal Inc**1** as a lower-order signal is derived as the signal Vabs indicating an absolute position.

[0117] From the signal Vabs indicating the absolute position, the absolute position Pabs is expressed by Equation (17):

$$Pabs=Vabs\times(L\max/V\max) \tag{17}$$

[0118] As described above, in S**707**, when the absolute position Pabs at T**2** is derived from the Vernier signal Pv**1** and the signal level V**2***inc***1** of the first relative position signal Inc**1** at T**2**, the process proceeds to S**708**, and then is finished.

[0119] In the foregoing manner, the absolute position Pabs can be derived.

[0120] Next, referring to FIG. **10**, an initialization process in deriving a relative position in the operation flow of this embodiment will be described.

[0121] The process starts in S**1001**, and proceeds to S**1002**.

[0122] In S**1002**, an absolute position Pabs derived immediately previously is acquired as an initial value of a relative position Pinc, and the process proceeds to S**1003**.

[0123] S**1003** is the end of the process.

[0124] With this process, a reference position in deriving a relative position is determined.

[0125] Subsequently, referring to FIG. **11**, a process of deriving a relative position in the operation flow of this embodiment will be described.

[0126] The process starts in S**1101**, and proceeds to S**1102**.

[0127] In S**1102**, a first phase-A displacement signal S**1***r*A and a phase-B displacement signal S**1***r*B are acquired, and the process proceeds to S**1103**. Details of the process in S**1102** are similar to those of S**605** shown in FIG. **6**.

[0128] In S**1103**, the first phase-A displacement signal S**1***r*A and the phase-B displacement signal S**1***r*B are corrected, and the process proceeds to S**1104**. Details of the process in S**1103** are similar to those of S**702** shown in FIG. **7**.

[0129] In S**1104**, a first relative position signal Inc**1** is derived by using the corrected first phase-A displacement signal S**1***c*A and first phase-B displacement signal S**1***c*B, and the process proceeds to S**1105**. Details of the process in S**1104** are similar to those of S**703** shown in FIG. **7**.

[0130] In S**1105**, the relative position Pinc is updated based on the first relative position signal Inc**1** derived in S**1104**, and the process proceeds to S**1106**.

[0131] Specifically, a previous relative position signal Inc**1**A is derived from a previous position PincA by using Equation (18) as follows:

$$Inc1A=(PincA\times(V\max/L\max)\times N1\max) \bmod (N1\max) \tag{18}$$

where operator mod represents a residue.

[0132] It should be noted that in order to omit this operation, Inc**1** obtained when the previous position PincA is derived may be stored as Inc**1**A together with PincA.

[0133] Subsequently, a relative position displacement signal ΔInc**1** as a difference between the relative position signal Inc**1**A and the Inc**1**B as the relative position signal Inc**1** derived in S**1104** are derived:

$$\Delta Inc1=Inc1B-Inc1A, \text{ when } -V\max/2\leq Inc1B-Inc1A\leq V\max/2$$

$$\Delta Inc1=Inc1B-Inc1A+V\max, \text{ when } Inc1B-Inc1A<-V\max/2$$

$$\Delta Inc1=Inc1B-Inc1A-V\max, \text{ when } Inc1B-Inc1A>V\max/2 \tag{19}$$

[0134] Lastly, Pinc is updated using Equation (20) as follows:

$$Pinc=PincA+((\Delta Inc1/N1\max)\times(L\max/V\max)) \tag{20}$$

[0135] S**1106** is the end of the process.

[0136] In this relative position detecting process, if the position greatly moves in a sampling interval ΔTinc**1** with the previous relative position, the amount of change cannot be correctly detected, and a positional shift occurs disadvantageously.

[0137] A maximum change amount ΔPinc**1**Max in which the position can move within the sampling interval ΔTinc**1** of the relative position operation and no positional shift occurs can be obtained by Equation (21) as follows:

$$\Delta Pinc1\mathrm{Max}=(L\max/N1\max)/2 \tag{21}$$

[0138] Thus, it is necessary to derive a relative position with a sampling interval ΔTinc**1** in which the position does not move to a distance greater than or equal to ΔPinc**1**Max.

[0139] Referring to FIGS. **12** to **15**, an abnormality detection process in the operation flow of this embodiment will be described.

[0140] The process starts in S**1201**, and proceeds to S**1202**.

[0141] In S**1202**, displacement signals at various timings used in the abnormality detection process are acquired, and the process proceeds to S**1203**. The signal acquisition process will be described in detail later.

[0142] In S**1203**, an absolute position is derived, and the process proceeds to S**1204**. The deriving of the absolute position will be described later.

[0143] In S**1204**, a correction process of correcting a movement amount in the relative position acquisition process and the absolute position acquisition process (within a time in which the absolute position is derived) is performed, and the process proceeds to S**1205**. The correction process of correcting the movement amount in the relative position acquisition process and the absolute position acquisition process will be described.

[0144] In S**1205**, the absolute position derived in S**1203** and the relative position derived in S**1204** are compared. If these positions coincide with each other, the process proceeds to S**1206**, and otherwise, the process proceeds to S**1207**.

[0145] In S**1206**, it is determined that no abnormality occurs, and the process proceeds to S**1208**.

[0146] In S**1207**, it is determined that abnormality occurs, and the process proceeds to S**1208**.

[0147] S**1208** is the end of the process.

[0148] Thereafter, the signal acquisition process performed in S**1202** will be described with reference to FIG. **13**.

[0149] The process starts in S**1301**, and proceeds to S**1302**.

[0150] S**1302** is a process similar to S**605**. Specifically, a signal level V**11***s***1***r*A of the first phase-A displacement signal S**1***r*A and a signal level V**11***s***1***r*B of the phase-B displacement signal S**1***r*B at timing T**11** of S**1302** output from the AD converter **104** are acquired, and the process proceeds to S**1303**.

[0151] S**1303** and S**1304** are processes similar to S**602** and S**603**. Specifically, a signal level V**12***s***2***r*A of the second phase-A displacement signal S**2***r*A and a signal level V**12***s***2***r*B of the phase-B displacement signal S**2***r*B at timing T**12** of S**1304** are acquired, and the process proceeds to S**1305**.

[0152] S**1305** is a process similar to S**603**. Specifically, a signal level V**13***s***2***r*A of the second phase-A displacement signal S**2***r*A and a signal level V**13***s***2***r*B of the phase-B displacement signal S**2***r*B at timing T**13** of S**1305** are acquired, and the process proceeds to S**1306**.

[0153] S**1306** and S**1307** are processes similar to S**604** and S**605**. Specifically, a signal level V**14***s***1***r*A of the first phase-A displacement signal S**1***r*A and a signal level V**14***s***1***r*B of the phase-B displacement signal S**1***r*B at timing T**14** of S**1307** are acquired, and the process proceeds to S**1308**.

[0154] S**1308** the end of the process.

[0155] A time interval between time T**11** and time T**12** and a time interval between time T**13** and time T**14** are a signal acquisition delay time Ts, and equal to each other. A time interval ΔTinc**2** between time T**12** and time T**13** will be described later.

[0156] Then, a process of deriving an absolute position in S**1203** will be described.

[0157] In the process of deriving an absolute position, an absolute position Pabs is derived in a manner similar to the process flow shown in FIG. **7**, by using V**14***s***1***r*A and V**14***s***1***r*B acquired in S**1307** shown in FIGS. **13** and V**13***s***2***r*A and V**13***s***2***r*B acquired in S**1305** shown FIG. **13**.

[0158] Subsequently, the correction process of correcting the movement amount in the relative position acquisition process and the absolute position acquisition process in S**1203** will be described with reference to FIG. **14**. A correction of the movement amount (displacement amount) in the absolute position acquisition process is a correction of the amount of movement (amount of displacement) in a time in which a periodic signal for detecting a relative position (displacement amount from a predetermined absolute position) cannot be continuously detected during the process (within a time) of deriving the absolute position.

[0159] The process starts in S**1401**, and proceeds to S**1402**.

[0160] In S**1402**, the relative position Pinc is updated based on V**11***s***1***r*A and V**11***s***1***r*B acquired in S**1302** shown in FIG. **13**, and the process proceeds to S**1403**. The process of updating the relative position Pinc is similar to S**1103**, S**1104**, and S**1105**, and thus, description thereof is not repeated.

[0161] In S**1403**, a movement amount AP from time T**11** to time T**14** is derived by using V**12***s***2***r*A and V**12***s***2***r*B acquired in S**1304** shown in FIGS. **13** and V**13***s***2***r*A and V**13***s***2***r*B acquired in S**1305** is derived, the relative position Pinc is updated, and the process proceeds to S**1404**. The deriving of the movement amount ΔP and the process of updating the relative position Pinc will be described later.

[0162] In S**1404**, the relative position Pinc is updated based on the relative position Pinc updated in S**1403** and V**14***s***1***r*A and V**14***s***1***r*B acquired in S**1307**, and the process proceeds to S**1405**. The process of updating the relative position Pinc is similar to that in S**1402**, and description thereof is not repeated.

[0163] S**1405** is the end of the process.

[0164] In the following description, a relative position before the update in S**1402**, the relative position updated in S**1402**, the relative position updated in S**1403**, and the relative position updated in S**1404** will be hereinafter respectively referred to as Pinc**11**, Pinc**12**, Pinc**13**, and Pinc**14**.

[0165] Subsequently, deriving of the movement amount AP and the process of updating the relative position Pinc, that is, the process of deriving the relative position Pinc**13** from the relative position Pinc**12**, as features of the present invention, will be described.

[0166] The process starts in S**1501**, and the process proceeds to S**1502**.

[0167] In S**1502**, V**12***s***2***r*A and V**12***s***2***r*B acquired in S**1304** shown in FIG. **13** are corrected, and the process proceeds to S**1503**. Details of the process in S**1502** are similar to those in S**704** shown in FIG. **7**.

[0168] In S**1503**, a second relative position signal V**12**Inc**2** is derived using the signals corrected in S**1502**, and the process proceeds to S**1504**. Details of the process in S**1503** are similar to those in S**705** shown in FIG. **7**.

[0169] In S**1504** and S**1505**, in a manner similar to S**1502** and S**1503**, a second relative position signal V**13**Inc**2** is derived from V**13***s***2***r*A and V**13***s***2***r*B acquired in S**1305** shown in FIG. **13**, and the process proceeds to S**1506**.

[0170] In S**1506**, a movement amount AP from time T**11** to time T**14** is derived by using V**12**Inc**2** and V**13**Inc**2**, and the process proceeds S**1507**.

[0171] Specifically, the amount of change ΔInc**2** in a time interval ΔTinc**2** that is a time interval from time T**12** to time T**13** is derived from V**12**Inc**2** and V**13**Inc**2**, by Equation (22) as follows:

$$\Delta Inc2 = V13Inc2 - V12Inc2, \text{ when } -V\max/2 \leq V13Inc2 - V12Inc2 \leq V\max/2$$

$$\Delta Inc2 = V13Inc2 - V12Inc2 + V\max, \text{ when } V13Inc2 - V12Inc2 < -V\max/2$$

$$\Delta Inc2 = V13Inc2 - V12Inc2 - V\max, \text{ when } V13Inc2 - V12Inc2 > V\max/2 \quad (22)$$

[0172] In the process of deriving the change amount ΔInc**2**, if the position greatly moves in the time interval ΔTinc**2**, the change amount cannot be correctly detected, and a positional shift occurs.

[0173] A maximum change amount ΔPinc**2**Max with which the position can move in the time interval ΔTinc**2** and no positional shift occurs, can be obtained by Equation (23) as follows:

$$\Delta Pinc2\text{Max} = (L\max/N2\max)/2 \quad (23)$$

[0174] Thus, it is necessary to perform S**1304** and S**1305** shown in FIG. **13** with the time interval ΔTinc**2** in which the position does not move to ΔPinc**2**Max or more.

[0175] A change amount ΔInc**2'** from time T**11** to time T**14** can be derived by using the time interval ΔTinc**2** and the signal acquisition delay time Ts from Equation (24) as follows:

$$\Delta Inc2' = (\Delta Inc2/\Delta Tinc2) \times (2 \times Ts + \Delta Tinc2) \quad (24)$$

[0176] Then, a movement amount ΔP as a position is derived by Equation (25) as follows:

$$\Delta P = ((\Delta Inc2'/N2\max) \times (L\max/V\max)) \quad (25)$$

[0177] In this manner, a movement amount AP is derived.

[0178] In S**1507**, a relative position Pinc**13** is derived from the relative position Pinc**12** by using the movement amount ΔP, and the process proceeds to S**1508**.

[0179] Specifically, the relative position Pinc**13** is derived by Equation (26) as follows:

$$Pinc13 = Pinc12 + \Delta P \quad (26)$$

[0180] S**1508** is the end of the process.

[0181] In the process described above, the movement amount in the time interval from time T**11** to time T**14** in which Inc**1** cannot be acquired because of deriving of the absolute position can be derived from Inc**2** different from Inc**1**. Based on this movement amount, the relative position can be corrected so that a relative position can be correctly derived.

[0182] Advantages obtained by deriving a movement amount in a time interval in which Inc**1** cannot be acquired because of deriving of an absolute position and correcting Pinc will now be described.

[0183] In a case where the present invention is not applied in the configuration of this embodiment, to derive an absolute position in a state in which a relative position is derived, an output signal needs to be at least switched in the following manner. That is, as shown in FIG. **16**A, the output signal is switched from a state in which a first displacement signal is output to a state in which a second displacement signal is output at time T**0**, and a second displacement signal is acquired at time T**1**. Thereafter, the output signal is switched to the state in which the first displacement signal is output again, and the first displacement signal is acquired at time T**2**. At this time, the time during which the process of deriving the relative position is stopped is at least twice as long as the signal acquisition delay time Ts.

[0184] If the position moves to a distance greater than or equal to a change amount ΔPinc**1**Max of a position in which movement is allowed during sampling of a relative position operation in a time 2×Ts during which the process of deriving the relative position is stopped, a shift occurs in an obtained relative position. Consequently, an abnormality detection process using a comparison between the absolute position and the relative position cannot be normally performed.

[0185] On the other hand, in the process described in this embodiment, as shown in FIG. **16**B, the time during which the process of deriving the relative position as expressed by Equation (22) is stopped is 2×Ts+ΔTinc**2**. However, since the movement amount ΔP in the time period in which the process of deriving the relative position is stopped is derived by acquiring a signal using the time interval ΔTinc**2**, the relative position can be normally derived as long as the movement amount in the time interval ΔTinc**2** is within ΔPinc**2**Max. As a result, an abnormality detection process using a comparison between the absolute position and the relative position can be normally performed.

[0186] In this embodiment, the movement amount ΔP in the time period during which the process of deriving the relative position is stopped is derived by using only ΔInc**2** acquired in this period.

[0187] However, similar advantages can be obtained by acquiring Inc**1** twice immediately before and immediately after stopping of the process of deriving the relative position to derive ΔInc**1** and then performing an operation on the movement amount ΔP. It should be noted that a time during which the process of deriving the relative position is actually stopped can be derived by deriving the movement amount in the time period during which the process of deriving the relative position is stopped using Inc**2**.

[0188] After the movement amount has been corrected, the relative position is derived based on the relative position Pinc**13** subjected to the correction of the movement amount and the relative position Pinc**14** is updated. Thus, the relative position Pinc**13** subjected to the correction of the movement amount is allowed to have a certain degree of an error. Specifically, the relative position Pinc**13** only needs to be corrected within the range of ±ΔPinc**1**Max from an actual position in order to update Pinc**14** to the actual position in the subsequent process of deriving the relative position.

[0189] Here, from Equations (21) and (23), Equation (27) is established as follows:

$$\Delta Pinc2\text{Max} = (N1\max/N2\max) \times \Delta Pinc1\text{Max} \quad (27)$$

[0190] In this embodiment, since N**1**max is 40 and N**2**max is 39, the change amount with which no positional shift occurs in deriving the movement amount ΔP is larger in the case of ΔPinc**2**Max than in the case of ΔPinc**1**Max. Thus, the case of deriving the movement amount using Inc**2** is more advantageous for deriving the movement amount. That is, the case of deriving the movement amount using Inc**2** can achieve relative position detection with which a positional shift is less likely to occur.

[0191] To increase the accuracy, a movement amount may be derived from each of ΔInc**1** immediately before stopping of the process of deriving the relative position, ΔInc**2** in the middle of the stopping, and ΔInc**1** immediately after the stopping, and the obtained movement amounts are averaged so as to derive a movement amount ΔP for use in correction.

Second Embodiment

[0192] A second embodiment of the present invention will be described with reference to FIGS. **17** to **23**.

[0193] FIG. **17** is a block diagram illustrating a configuration according to the second embodiment. Description of components shown in FIG. **17** having similar structures as those in the first embodiment will not be repeated.

[0194] A position detection apparatus according to this embodiment includes a phase counter **1708** that counts a phase change of a signal, and uses a count value obtained by the phase counter **1708** in deriving a relative position, as a feature of this embodiment. The phase counter **1708** is a counter that converts an analog signal from an ABS sensor **103** to a digital signal using, for example, a comparator and counts a phase change. The phase counter will be described in detail later.

[0195] An INC deriver **1705** is an arithmetic section that derives a relative position Pinc from a signal from the AD converter **104** and the count value of the phase counter **1708**.

[0196] An ABS deriver **101**, the INC deriver **1705**, a movement amount deriver **106**, an abnormality determining unit **107**, and the phase counter **1708** are provided in, for example, one CPU.

[0197] Next, an operation flow according to the second embodiment will be described.

[0198] First, since the operation flow of the entire process is similar to that of the first embodiment shown in FIG. **5**, and thus, description thereof will not be repeated.

[0199] An absolute position acquisition process for acquiring an initial position is also similar to that of the first embodiment shown in FIGS. **6** and **7**, and thus, description thereof will not be repeated.

[0200] Thereafter, an initialization process for acquiring a relative position will be described with reference to FIG. **18**.

[0201] The process starts in S**1801**, and proceeds to S**1802**.

[0202] In S**1802**, a process similar to that in S**1002** shown in FIG. **10** in the first embodiment is performed, and the process proceeds to S**1803**.

[0203] In S**1803**, the phase counter **1708** is initialized, and the process proceeds to S**1804**.

[0204] S**1804** is the end of the process.

[0205] The initialization of the phase counter **1708** will be described.

[0206] FIG. **19** shows an analog signal of a first track pattern from the ABS sensor **103**, a digital signal converted by, for example, the comparator, and a count value Cnt of the phase counter. In FIG. **19**, a first relative position signal Inc**1** and a correspondence with a position P are also shown.

[0207] The count value Cnt is initialized in such a manner that the count value Cnt is 0 (zero) when the position P is 0 (zero). The count value has four counts in one period of an analog signal of the first track pattern, and specifically obtained by Equation (28) as follows:

$$Cnt=\text{integer portion of }(Pabs\times N1\max\times 4/L\max) \tag{28}$$

[0208] Specifically, when the position P is 0 (zero), the count value Cnt is 0 (zero), and when the position P is the total length Lmax of scale, the count value Cnt is N1max×4−1.

[0209] In this manner, a count value can be correctly determined as an initial position.

[0210] Thereafter, the phase counter is started. The function of the phase counter is the function incorporated in, for example, the CPU, and is not specifically described here.

[0211] Then, a relative position acquisition process will be described with reference to FIG. **20**.

[0212] The process starts in S**2001**, and proceeds to S**2002**.

[0213] In S**2002**, a count value Cnt of the phase counter is acquired, and the process proceeds to S**2003**.

[0214] In S**2003**, S**2004**, and S**2005**, processes similar to those in S**605**, S**702**, and S**703** are performed, and the process proceeds to S**2006**.

[0215] In S**2006**, a relative position Pinc is derived based on the count value Cnt acquired in S**2002** and the first relative position signal Inc**1** derived in S**2005**, and the process proceeds to S**2007**.

[0216] Specifically, first, a phase shift between the count value Cnt and the first relative position signal Inc**1** is corrected using Equation (29) as follows:

$$\begin{aligned} Cnt = Cnt(Cnt \bmod 4 - (\text{integer portion of } Inc1/V\max\times 4) = 0) = \\ Cnt - 1(Cnt \bmod 4 - (\text{integer portion of } Inc1/V\max\times 4) = \\ 1 \text{ or } -3) = \\ Cnt + 1\,(Cnt \bmod 4 - (\text{integer portion of } Inc1/V\max\times 4) = \\ 3 \text{ or } -1) = Cnt(Cnt \bmod 4 - \\ (\text{integer portion of } Inc1/V\max\times 4) = 2 \text{ or } -2) \end{aligned} \tag{29}$$

[0217] As shown in this equation, correction can be performed as long as the phase shift between the count value Cnt and the first relative position signal Inc**1** is within ±1. On the other hand, correction cannot be performed if the phase shift is ±2. However, the phase shift can be reduced within at least ±1 by acquiring the count value Cnt and the first relative position signal Inc**1** substantially at the same time.

[0218] Thereafter, Pinc is derived by Equation (30) as follows:

$$Pinc=((\text{integer portion of } Cnt/4)\times V\max+Inc1)/N1\max\times(L\max/V\max) \tag{30}$$

[0219] S**2007** is the end of the process.

[0220] Subsequently, an abnormality detection process will be described.

[0221] The entire flow of the abnormality detection process is the same as that shown in FIG. **12**.

[0222] The signal acquisition process shown in FIG. **12** will be described with reference to FIG. **21**.

[0223] The process starts in S**2101**, and proceeds to S**2102**.

[0224] In S**2102**, the phase counter is stopped, and the process proceeds to S**2103**. This process is necessary for preventing a displacement of a signal in switching to a first scale from being counted. The timing at which the phase counter is stopped in S**2102** is indicated as T**11**.

[0225] S**2103** and S**2104** are similar to S**602** and S**603**. Specifically, a signal level V**12***s***2***r*A of a second phase-A displacement signal S**2***r*A and a signal level V**12***s***2***r*B of a phase-B displacement signal S**2***r*B at timing T**12** of S**2104** are acquired, and the process proceeds to S**2105**.

[0226] A process in S**2105** is similar to that in S**603**, a signal level V**13***s***2***r*A of the second phase-A displacement

signal S2*r*A and a signal level V13*s*2*r*B of the phase-B displacement signal S2*r*B at timing T13 of S2105 are acquired, and the process proceeds to S2106.

[0227] S2106 and S2107 are similar to S604 and S605. Specifically, a signal level V14*s*1*r*A of the first phase-A displacement signal S1*r*A and a signal level V14*s*1*r*B of the phase-B displacement signal S1*r*B at timing T14 of S2107 are acquired, and the process proceeds to S2108.

[0228] In S2108, the phase counter is started, and the process proceeds to S2109.

[0229] S2109 is the end of the process.

[0230] A time interval between time T11 and time T12 and a time interval between time T13 and time T14 are a signal acquisition delay time Ts, and equal to each other. A time interval ΔTinc2 between time T12 and time T13 is similar to that in the first embodiment, and description will not be repeated.

[0231] In the absolute position deriving process shown in FIG. 12, in a manner similar to the process flow shown in FIG. 7, an absolute position Pabs is derived by using V14*s*1*r*A and V14*s*1*r*B acquired in S2107 shown in FIGS. 21 and V13*s*2*r*A and V13*s*2*r*B acquired in S2105 shown in FIG. 13.

[0232] A correction process of correcting a movement amount in the relative position acquisition process and the absolute position acquisition process shown in FIG. 12 will be described with reference to FIGS. 22 and 23.

[0233] The process starts in S2201, and proceeds to S2202.

[0234] In S2202, a movement amount AP from time T11 to time T14 is derived by using V12*s*2*r*A and V12*s*2*r*B acquired in S2104 shown in FIGS. 21 and V13*s*2*r*A and V13*s*2*r*B acquired in S2105, the count value Cnt is updated, and the process proceeds to S2203. The process of updating the count value Cnt will be described later. The deriving of the movement amount ΔP is similar to that in the first embodiment, and description thereof is not repeated.

[0235] In S2203, a relative position Pinc is derived from the count value Cnt updated in S2202 and V14*s*1*r*A and V14*s*1*r*B acquired in S2107, and the process proceeds to S2204. The process of deriving the relative position Pinc is similar to those in S2004, S2005, and S2006, and description thereof is not repeated.

[0236] S2204 is the end of the process.

[0237] Subsequently, the process of updating the count value Cnt, which is a feature of the present invention, will be described with reference to FIG. 23.

[0238] The process starts in S2301, and the process proceeds to S2302.

[0239] S2302 to S2306 are similar to S1502 to S1506 of the first embodiment shown in FIG. 15, and the process proceeds to S2307.

[0240] In S2307, the count value Cnt is updated using the movement amount ΔP, and the process proceeds to S2308.

[0241] Specifically, the count value Cnt is updated by Equation (31) as follows:

$$Cnt=Cnt+(\text{integer portion of } \Delta P\times N1\max\times 4/L\max) \quad (31)$$

[0242] After this process, in generating a relative position Pinc in S2203, a correction process of correcting a phase shift between the count value Cnt and the first relative position signal Inc1 expressed by Equation (29) is performed. Thus, Cnt updated by Equation (31) only needs to be within the range from the count value at an actual position to ±1, and AP does not need to be highly accurately derived.

[0243] S2308 is the end of the process.

[0244] In the foregoing process, a movement amount in the time interval from time T11 to time T14 during which the phase counter needs to be stopped in order to derive an absolute position can be derived. In addition, the phase counter can be updated based on the movement amount to derive a relative position accurately.

[0245] As described above, in the time period during which deriving of the relative position is stopped, a movement amount in this period is derived and corrected in deriving the relative position so that the relative position can be correctly derived even when deriving of the relative position is stopped.

[0246] The configuration described in this embodiment uses an encoder with two track patterns having different pitches. However, the present invention is not limited to this example.

[0247] For example, as illustrated in FIGS. 24A and 24B, similar advantages can be obtained in the case of two signals one of which is a periodic signal and the other is a signal that monotonously increases or monotonously decreases with respect to the position of the movable member.

[0248] As illustrated in FIG. 24C, the present invention is also applicable to a configuration using three or more encoders.

[0249] For example, in a position detection unit having a configuration in which three types of signals, i.e., dense, intermediate, and sparse signals, are acquired in the order of intermediate, sparse, intermediate, and dense signals so that an absolute positions are acquired based on sparse, intermediate, and dense signals, and a movement amount is derived based on intermediate signals acquired twice. Of course, signals may be acquired in the order of sparse, intermediate, sparse, and dense signals so that an absolute position is acquired based on sparse, intermediate, and dense signals and a movement amount is derived based on sparse signals acquired twice. In this case, the CPU (including the ABS deriver, the INC deriver, the movement amount deriver, and the abnormality determining unit) controls a scale switcher (switcher) so as to output an instruction specifying a desired one of dense, intermediate, and sparse signals to be output to the ABS sensor.

[0250] Advantages of the present invention can be obtained with a configuration in which each of a dense signal and a sparse signal is acquired twice so that a correction amount is approximated by using the sparse signal and the accuracy is enhanced by using the dense signal.

[0251] In the illustrated embodiments, the correction amount is derived based on a specific periodic signal obtained twice at different timings. Alternatively, the correction amount may be derived based on a specific periodic signal acquired a plurality of times at different timings. The correction amount may be derived based on a plurality of periodic signals acquired a plurality of times at different timings. For example, in the encoder for acquiring the absolute position based on the sparse, intermediate, and dense signals described above, a correction amount may be derived based on the sparse signal and the intermediate signal (one or more signals) acquired a plurality of times at different timings so as to enhance the accuracy.

[0252] Furthermore, as illustrated in FIG. 24D, similar advantages can be obtained in a configuration using a

combination of a plurality of periodic signals and a signal that monotonously increases or monotonously decreases.

[0253] In the illustrated embodiments, an optical encoder is used as the encoder. However, the present invention is not limited to this example, and a magnetic or capacitance encoder may be used.

[0254] In addition, the position detection apparatus for deriving an absolute position has been described as an example. Alternatively, similar advantages can be obtained by a position detection apparatus having a plurality of periods with respect to the entire range.

[0255] The position detection apparatus according to the present invention described in the embodiments may be applied to a lens apparatus including a movable optical member. Then, a small-size lens apparatus that can detect an absolute position and a relative position with accuracy can be obtained.

[0256] A small-size image pickup apparatus that can detect an absolute position and a relative position accurately can be obtained with a configuration characterized by including the lens apparatus including a movable optical member having the position detection apparatus according to the present invention, and an image pickup element that receives light from the lens apparatus.

[0257] In addition, a small-size lens command apparatus that can detect an absolute position and a relative position accurately can be obtained with a configuration in which a lens command apparatus for driving and operating a lens apparatus including a movable optical member includes the position detection apparatus according to the present invention.

[0258] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0259] This application claims the benefit of Japanese Patent Application No. 2014-228844, filed Nov. 11, 2014, which is hereby incorporated by reference herein in its entirety.

1-10. (canceled)

11. A position detection apparatus for detecting a position of a first member relative to a second member, the apparatus comprising:

a sensor configured to selectively output a first signal that changes in a first period in accordance with a change in the position and a second signal that changes in a period longer than the first period in accordance with a change in the position; and

a processor configured to obtain an initial position based on the output first and second signals, and obtain a displacement amount from the initial position based on the output first signal,

wherein the processor is configured to obtain the displacement amount based on a plurality ones of the output second signal.

12. The position detection apparatus according to claim **11**, wherein the processor is configured to obtain the displacement amount based on the output first signal and the plurality ones of the output second signal.

13. The position detection apparatus according to claim **11**, wherein

the sensor is configured to selectively output the first signal and the second signal with switching thereof, and the processor is configured to obtain the plurality of ones of the output second signal without the switching.

14. The position detection apparatus according to claim **11**, wherein

the sensor includes

a first pattern array having a first period and a second pattern array having a second period different from the first period fixed to one of the first member and the second member, and

a plurality of light receivers fixed to the other of the first member and the second member and configured to receive light reflected by the first and second pattern arrays.

15. The position detection apparatus according to claim **11**, wherein

the sensor includes

a pattern fixed to one of the first member and the second member,

a light receiver fixed to the other of the first member and the second member and configured to receive light reflected by the pattern to output, as the second signal, a signal that monotonously increases or decreases in accordance with the change.

16. The position detection apparatus according to claim **11**, further comprising:

a counter configured to count a change of a signal obtained by the first signal,

wherein the processor is configured to obtain the displacement amount based on a count value obtained by the counter.

17. The position detection apparatus according to claim **11**, further comprising:

a switcher configured to output a switching signal to the sensor,

wherein the sensor is configured to selectively output the first signal and the second signal in accordance with the switching signal.

18. The position detection apparatus according to claim **11**,

wherein the processor is configured to obtain the displacement amount based on a displacement amount in a time in which the sensor outputs a first one of the first signal, the plurality of ones of the second signal, and a second one of the first signal in this order, and on the first one of the output first signal, the processor being configured to obtain the displacement amount in the time based on the plurality of ones of the output second signal.

19. A lens apparatus comprising:

a movable optical member; and

a position detection apparatus for detecting a position of a first member, as the movable optical member, relative to a second member, the position detection apparatus comprising:

a sensor configured to selectively output a first signal that changes in a first period in accordance with a change in the position and a second signal that changes in a period longer than the first period in accordance with a change in the position; and

a processor configured to obtain an initial position based on the output first and second signals, and obtain a displacement amount from the initial position based on the output first signal,

wherein the processor is configured to obtain the displacement amount based on a plurality ones of the output second signal.

20. An image pickup apparatus comprising:

a lens apparatus comprising:

a movable optical member; and

a position detection apparatus for detecting a position of a first member, as the movable optical member, relative to a second member, the position detection apparatus comprising:

a sensor configured to selectively output a first signal that changes in a first period in accordance with a change in the position and a second signal that changes in a period longer than the first period in accordance with a change in the position; and

a processor configured to obtain an initial position based on the output first and second signals, and obtain a displacement amount from the initial position based on the output first signal,

wherein the processor is configured to obtain the displacement amount based on a plurality ones of the output second signal; and

an image pickup element configured to receive light from the lens apparatus.

21. A lens command apparatus for operating a lens apparatus including a movable optical member, the lens command apparatus comprising:

a position detection apparatus for detecting a position of a first member, for operating the lens apparatus, relative to a second member,

the position detection apparatus comprising:

a sensor configured to selectively output a first signal that changes in a first period in accordance with a change in the position and a second signal that changes in a period longer than the first period in accordance with a change in the position; and

a processor configured to obtain an initial position based on the output first and second signals, and obtain a displacement amount from the initial position based on the output first signal,

wherein the processor is configured to obtain the displacement amount based on a plurality ones of the output second signal.

22. A position detection apparatus for performing detection of a position of a first member relative to a second member, the apparatus comprising:

a sensor configured to selectively output a plurality of displacement signals that change with respective periods different from each other in accordance with a change in the position; and

a processor configured to obtain a plurality of periodic signals, with respective periods different from each other, based on the output plurality of displacement signals, to obtain a first position as the position of the first member relative to the second member based on the plurality of periodic signals, and to obtain a relative position relative to the first position based on a first periodic signal of the plurality of periodic signals,

wherein the processor is configured to obtain, after the relative position is obtained, a first value as a value of the first periodic signal, second and third values as values of a second periodic signal of the plurality of periodic signals, a fourth value as a value of the first periodic signal in this order, to obtain a second position as a position of the first member relative to the second member based on at least one of the second and third values, and the fourth value, and to obtain an updated value of the relative position based on the first, second and third values.

23. The position detection apparatus according to claim **22**, wherein a period of the first periodic signal is shorter than a period the second periodic signal.

24. The position detection apparatus according to claim **22**, wherein a period of the first periodic signal is the shortest of a plurality of periods of the plurality of periodic signals.

25. The position detection apparatus according to claim **22**, wherein a period of the second periodic signal is the longest of a plurality of periods of the plurality of periodic signals.

26. The position detection apparatus according to claim **22**, wherein

the sensor includes

a plurality of pattern arrays, having a respective plurality of periods different from each other, arranged with one of the first member and the second member, and

a light receiver arranged with the other of the first member and the second member and configured to receive light reflected by the plurality of pattern arrays.

27. The position detection apparatus according to claim **22**, wherein

the sensor includes

a pattern arranged with one of the first member and the second member,

a light receiver arranged with the other of the first member and the second member and configured to receive light reflected by the pattern to output, as the second signal, a signal that monotonously increases or decreases in accordance with the change.

28. The position detection apparatus according to claim **22**, further comprising:

a counter configured to perform count based on the plurality of displacement signals,

wherein the processor is configured to obtain the relative position based on the count.

29. The position detection apparatus according to claim **22**, further comprising:

a switcher configured to output a switching signal to the sensor,

wherein the sensor is configured to selectively output the plurality of displacement signals in accordance with the switching signal.

30. The position detection apparatus according to claim **22**, wherein the processor is configured to obtain the updated value based on a displacement amount obtained based on the second and third values, and on the first value.

31. The position detection apparatus according to claim **22**, wherein the processor is configured to detect abnormality of the detection based on the second position and the updated value.

32. A lens apparatus comprising:

a movable optical member; and

a position detection apparatus for detecting a position of a first member, as the movable optical member, relative to a second member, the position detection apparatus comprising:

a sensor configured to selectively output a plurality of displacement signals that change with respective

periods different from each other in accordance with a change in the position; and

a processor configured to obtain a plurality of periodic signals, with respective periods different from each other, based on the output plurality of displacement signals, to obtain a first position as the position of the first member relative to the second member based on the plurality of periodic signals, and to obtain a relative position relative to the first position based on a first periodic signal of the plurality of periodic signals,

wherein the processor is configured to obtain, after the relative position is obtained, a first value as a value of the first periodic signal, second and third values as values of a second periodic signal of the plurality of periodic signals, a fourth value as a value of the first periodic signal in this order, to obtain a second position as a position of the first member relative to the second member based on at least one of the second and third values, and the fourth value, and to obtain an updated value of the relative position based on the first, second and third values.

33. An image pickup apparatus comprising:

a lens apparatus, comprising:

a movable optical member; and

a position detection apparatus for detecting a position of a first member, as the movable optical member, relative to a second member, the position detection apparatus comprising:

a sensor configured to selectively output a plurality of displacement signals that change with respective periods different from each other in accordance with a change in the position; and

a processor configured to obtain a plurality of periodic signals, with respective periods different from each other, based on the output plurality of displacement signals, to obtain a first position as the position of the first member relative to the second member based on the plurality of periodic signals, and to obtain a relative position relative to the first position based on a first periodic signal of the plurality of periodic signals,

wherein the processor is configured to obtain, after the relative position is obtained, a first value as a value of the first periodic signal, second and third values as values of a second periodic signal of the plurality of periodic signals, a fourth value as a value of the first periodic signal in this order, to obtain a second position as a position of the first member relative to the second member based on at least one of the second and third values, and the fourth value, and to obtain an updated value of the relative position based on the first, second and third values; and

an image pickup element configured to receive light from the lens apparatus.

34. A command apparatus for operating a lens apparatus including a movable optical member, the command apparatus comprising:

a position detection apparatus, defined in claim **22**, for detecting a position of a first member, for operating the lens apparatus, relative to a second member, the position detection apparatus comprising:

a sensor configured to selectively output a plurality of displacement signals that change with respective periods different from each other in accordance with a change in the position; and

a processor configured to obtain a plurality of periodic signals, with respective periods different from each other, based on the output plurality of displacement signals, to obtain a first position as the position of the first member relative to the second member based on the plurality of periodic signals, and to obtain a relative position relative to the first position based on a first periodic signal of the plurality of periodic signals,

wherein the processor is configured to obtain, after the relative position is obtained, a first value as a value of the first periodic signal, second and third values as values of a second periodic signal of the plurality of periodic signals, a fourth value as a value of the first periodic signal in this order, to obtain a second position as a position of the first member relative to the second member based on at least one of the second and third values, and the fourth value, and to obtain an updated value of the relative position based on the first, second and third values.

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