US 20220308313A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2022/0308313 A1

(43) Pub. Date: Sep. 29, 2022

Yamashita et al.

(54) FOCUS ADJUSTMENT DEVICE, FOCUS ADJUSTMENT METHOD, AND IMAGE CAPTURE APPARATUS

(71) Applicant: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(72) Inventors: **Kouki Yamashita**, Tokyo (JP); **Kengo Takeuchi**, Kanagawa (JP); **Makoto Yokozeki**, Kanagawa (JP)

(21) Appl. No.: **17/699,285**

(22) Filed: **Mar. 21, 2022**

(30) **Foreign Application Priority Data**

Mar. 24, 2021 (JP) 2021-050386

Publication Classification

(51) **Int. Cl.**
G02B 7/36 (2006.01)
H04N 5/232 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 7/36*** (2013.01); ***H04N 5/23212*** (2013.01); *G03B 13/36* (2013.01)

(57) **ABSTRACT**

A focus adjustment device that controls driving of a focus lens included in a lens unit during moving image shooting, is disclosed. The device obtains a drive pattern determined in advance for driving the focus lens to an in-focus position and controls the driving of the focus lens. If the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the device continuously drives the focus lens at the minimum drive speed in the fine-driving section.

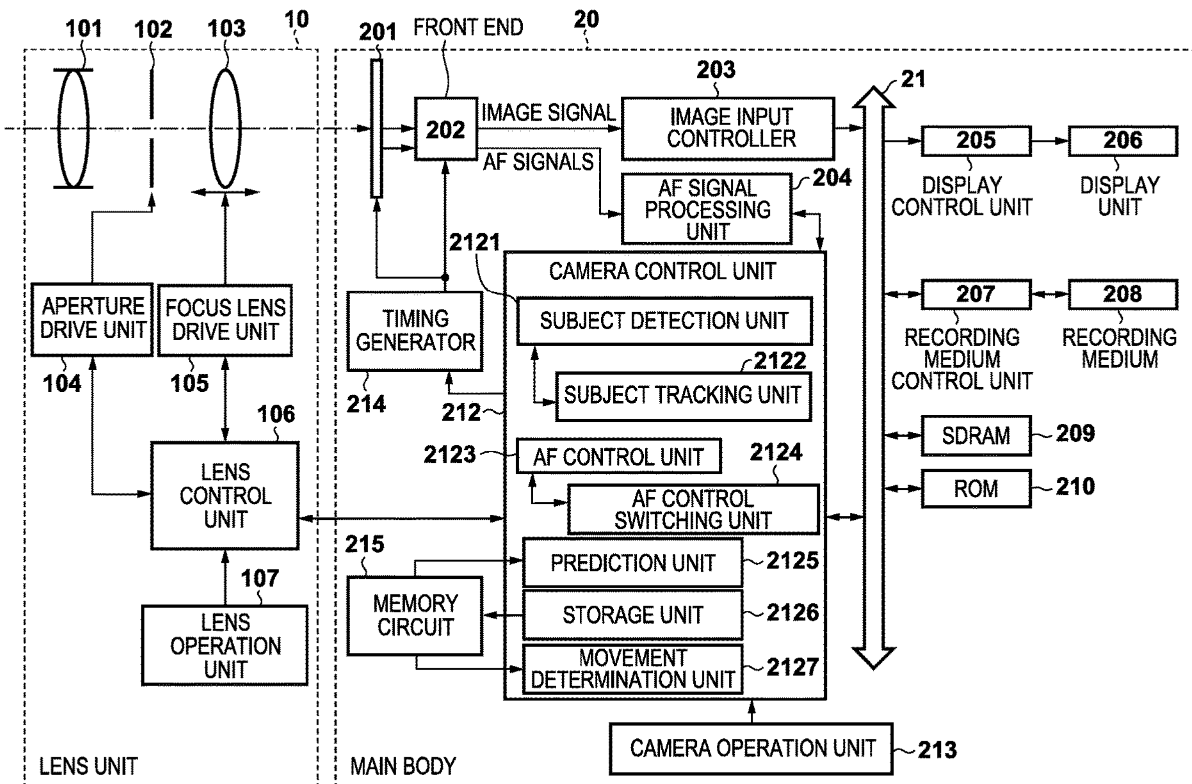
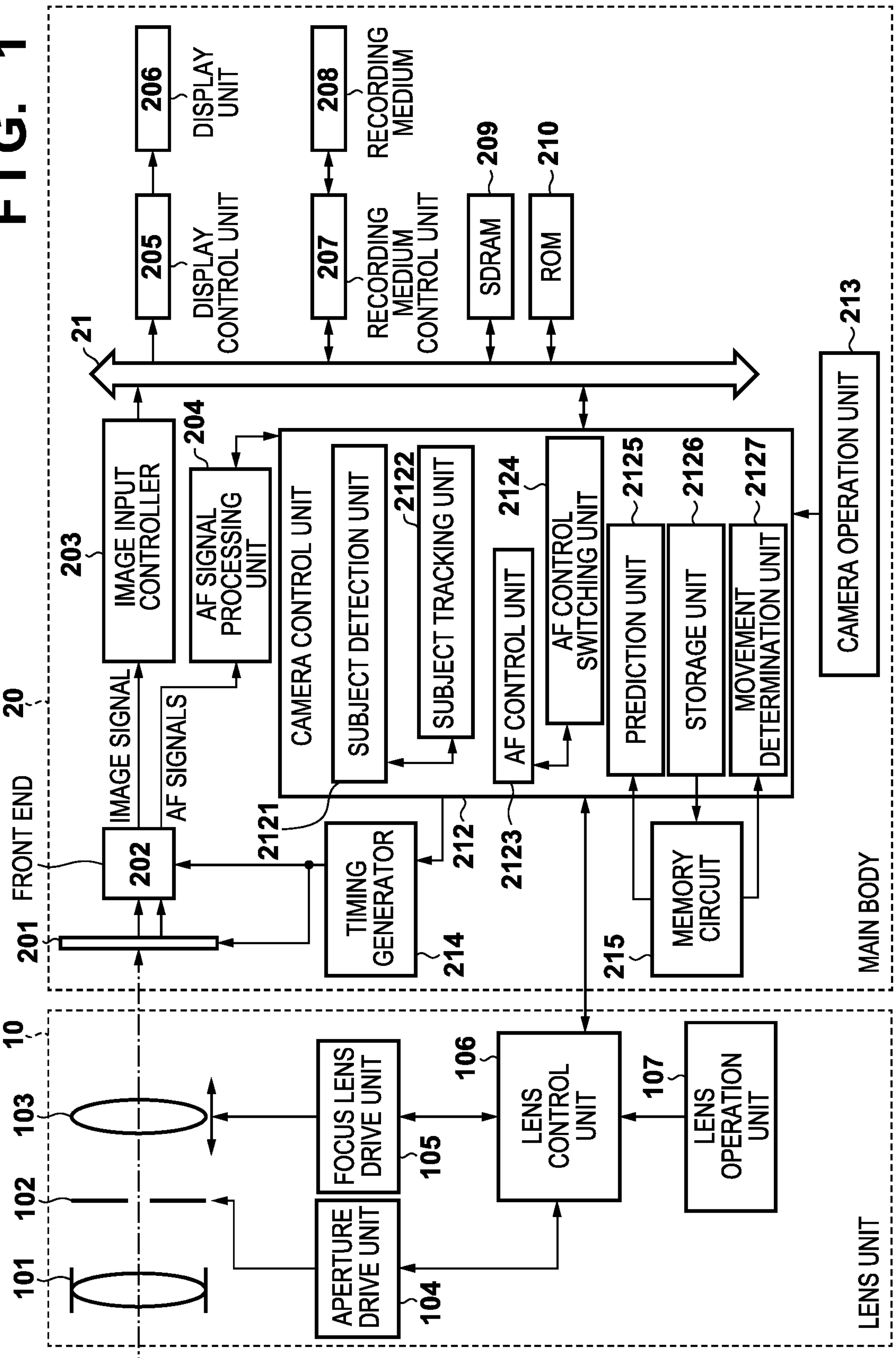


FIG. 1



LENS UNIT
10
101
102
103
APERTURE DRIVE UNIT
104
FOCUS LENS DRIVE UNIT
105
LENS CONTROL UNIT
106
LENS OPERATION UNIT
107
MAIN BODY
20
201
202
FRONT END
IMAGE SIGNAL
AF SIGNALS
IMAGE INPUT CONTROLLER
203
AF SIGNAL PROCESSING UNIT
204
DISPLAY CONTROL UNIT
205
DISPLAY UNIT
206
RECORDING MEDIUM CONTROL UNIT
207
RECORDING MEDIUM
208
SDRAM
209
ROM
210
21
CAMERA CONTROL UNIT
212
SUBJECT DETECTION UNIT
2121
SUBJECT TRACKING UNIT
2122
AF CONTROL UNIT
2123
AF CONTROL SWITCHING UNIT
2124
PREDICTION UNIT
2125
STORAGE UNIT
2126
MOVEMENT DETERMINATION UNIT
2127
CAMERA OPERATION UNIT
213
TIMING GENERATOR
214
MEMORY CIRCUIT
215

F I G. 2

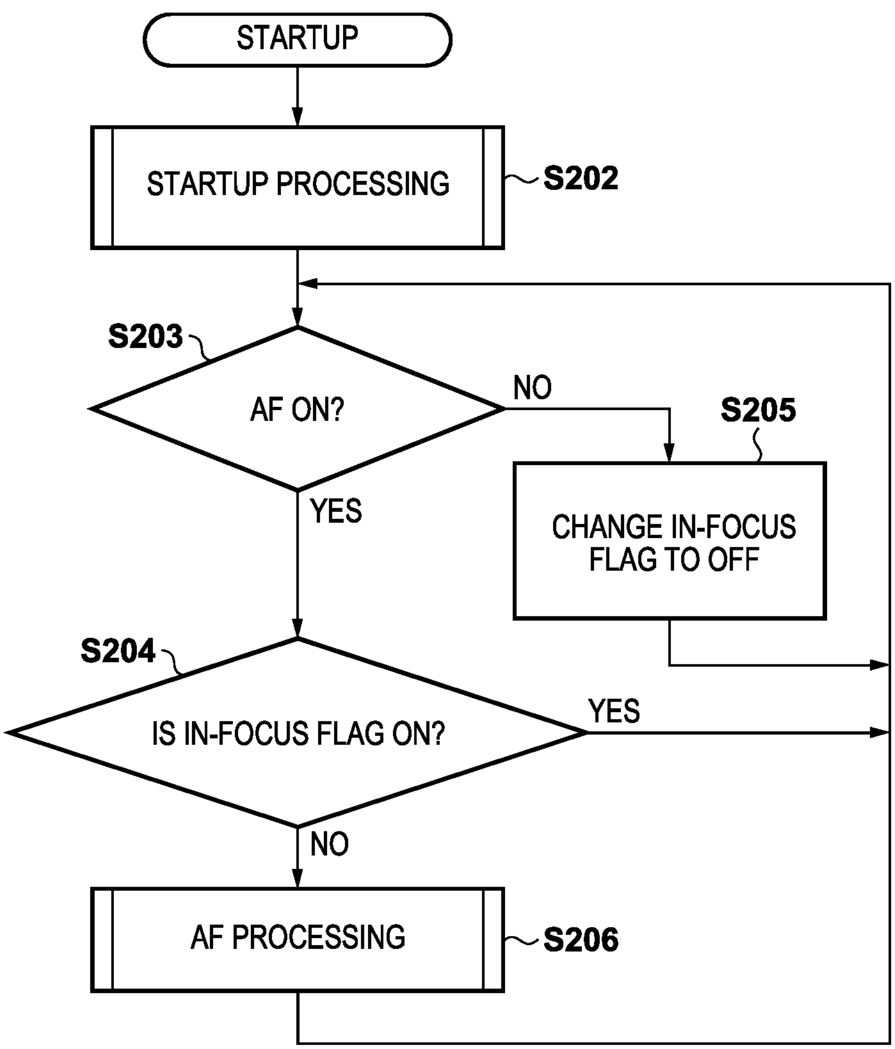

STARTUP
STARTUP PROCESSING
S202
S203
AF ON?
NO
S205
CHANGE IN-FOCUS FLAG TO OFF
YES
S204
IS IN-FOCUS FLAG ON?
YES
NO
AF PROCESSING
S206

FIG. 3

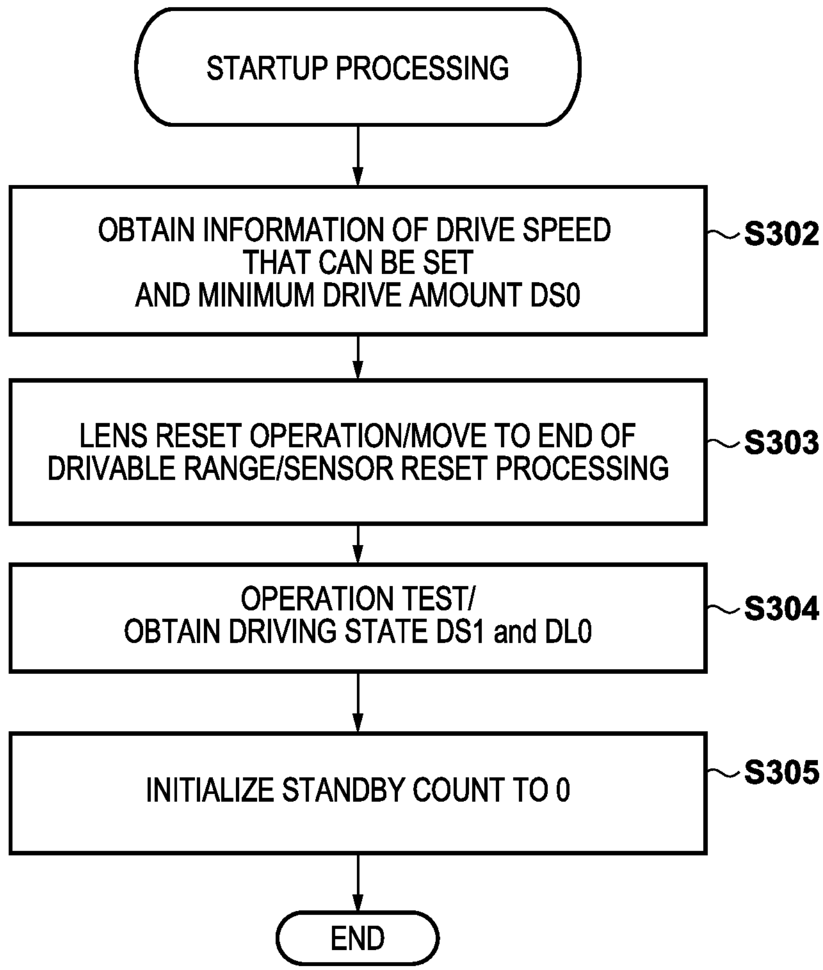

STARTUP PROCESSING
OBTAIN INFORMATION OF DRIVE SPEED THAT CAN BE SET AND MINIMUM DRIVE AMOUNT DS0
S302
LENS RESET OPERATION/MOVE TO END OF DRIVABLE RANGE/SENSOR RESET PROCESSING
S303
OPERATION TEST/ OBTAIN DRIVING STATE DS1 and DL0
S304
INITIALIZE STANDBY COUNT TO 0
S305
END

FIG. 4

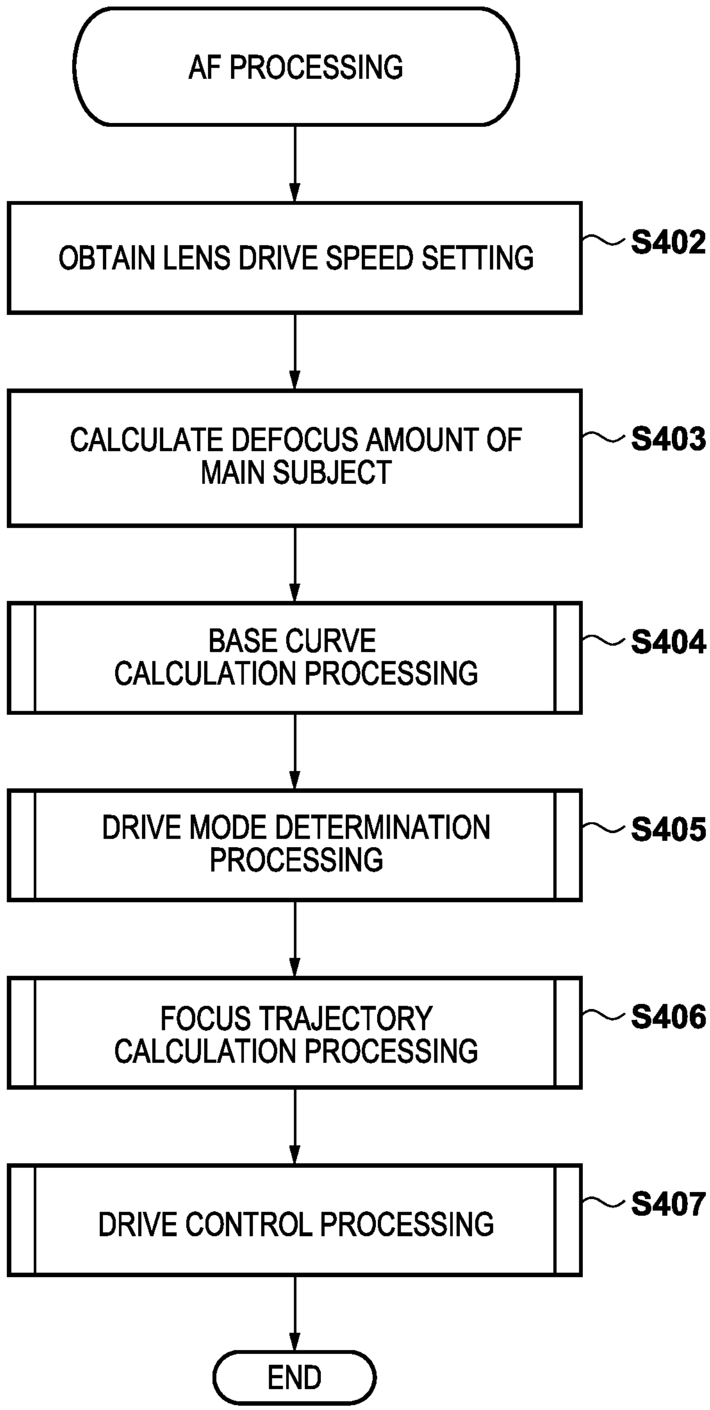
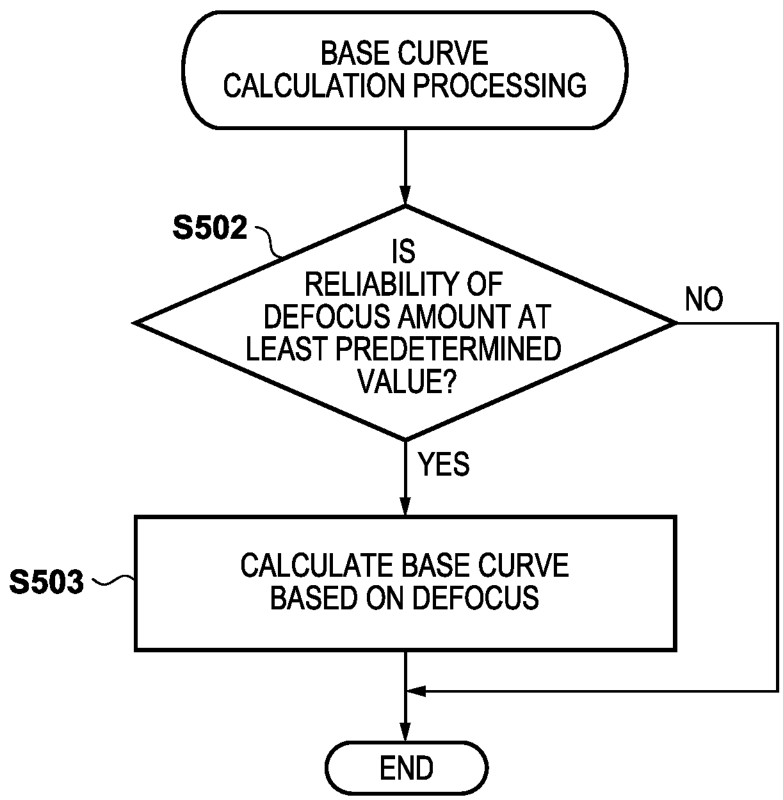

AF PROCESSING
OBTAIN LENS DRIVE SPEED SETTING
S402
CALCULATE DEFOCUS AMOUNT OF MAIN SUBJECT
S403
BASE CURVE CALCULATION PROCESSING
S404
DRIVE MODE DETERMINATION PROCESSING
S405
FOCUS TRAJECTORY CALCULATION PROCESSING
S406
DRIVE CONTROL PROCESSING
S407
END

FIG. 5


BASE CURVE CALCULATION PROCESSING
S502
IS RELIABILITY OF DEFOCUS AMOUNT AT LEAST PREDETERMINED VALUE?
NO
YES
S503
CALCULATE BASE CURVE BASED ON DEFOCUS
END

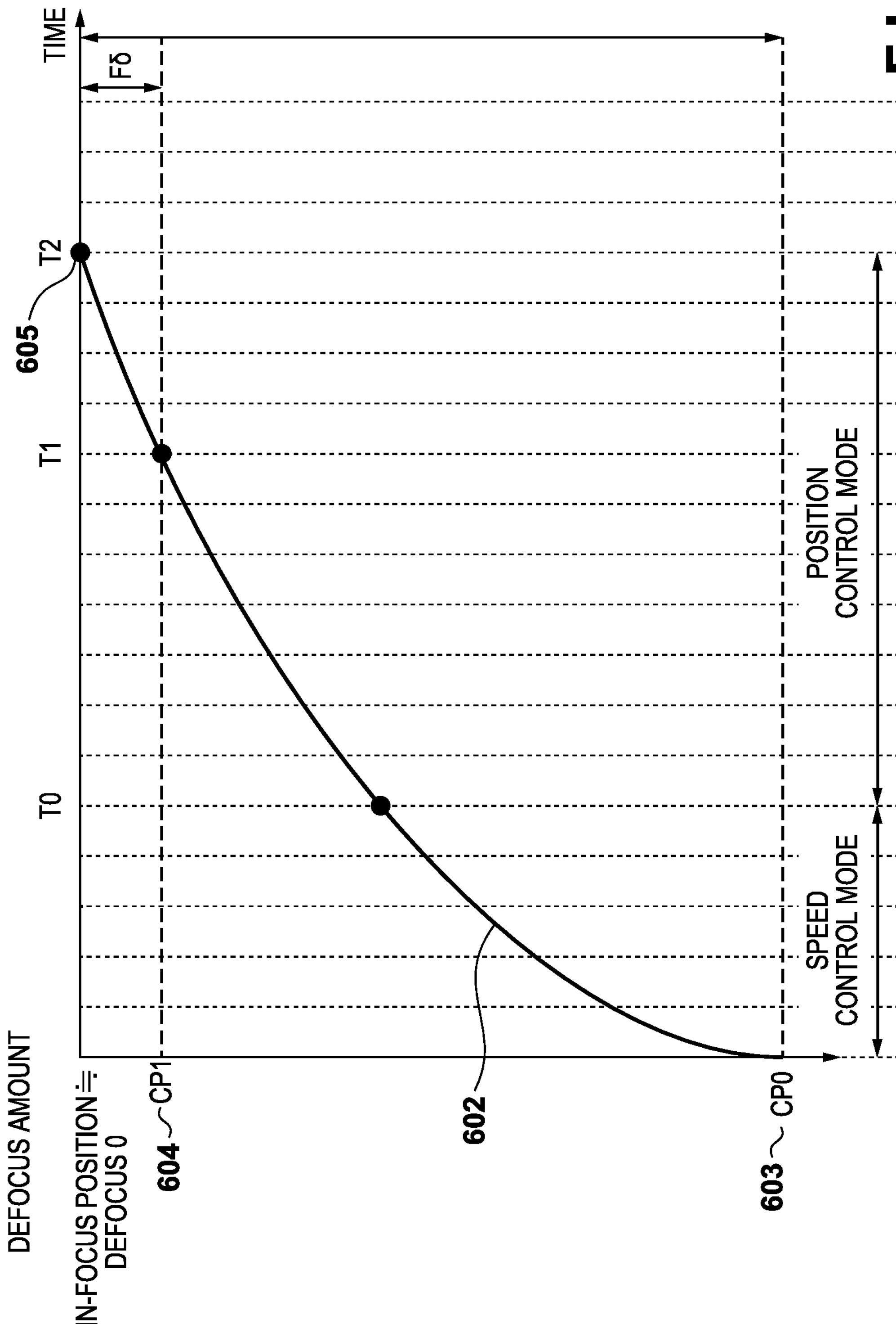

DEFOCUS AMOUNT
IN-FOCUS POSITION ≒ DEFOCUS 0
TIME
Fδ
T0
T1
T2
605
604
CP1
602
603
CP0
SPEED CONTROL MODE
POSITION CONTROL MODE

FIG. 6

FIG. 7

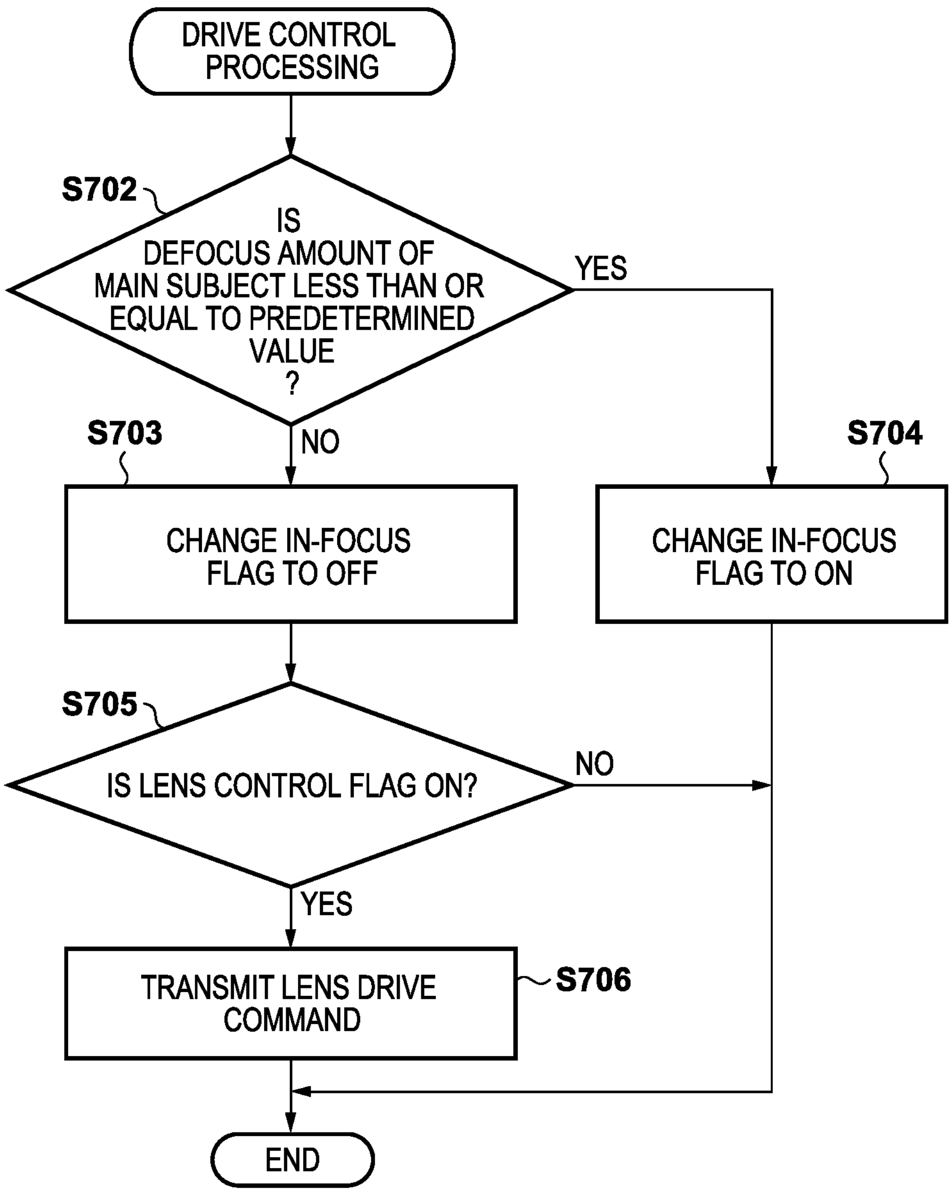

DRIVE CONTROL PROCESSING
S702
IS DEFOCUS AMOUNT OF MAIN SUBJECT LESS THAN OR EQUAL TO PREDETERMINED VALUE ?
YES
NO
S703
CHANGE IN-FOCUS FLAG TO OFF
S704
CHANGE IN-FOCUS FLAG TO ON
S705
IS LENS CONTROL FLAG ON?
NO
YES
TRANSMIT LENS DRIVE COMMAND
S706
END

FIG. 8A

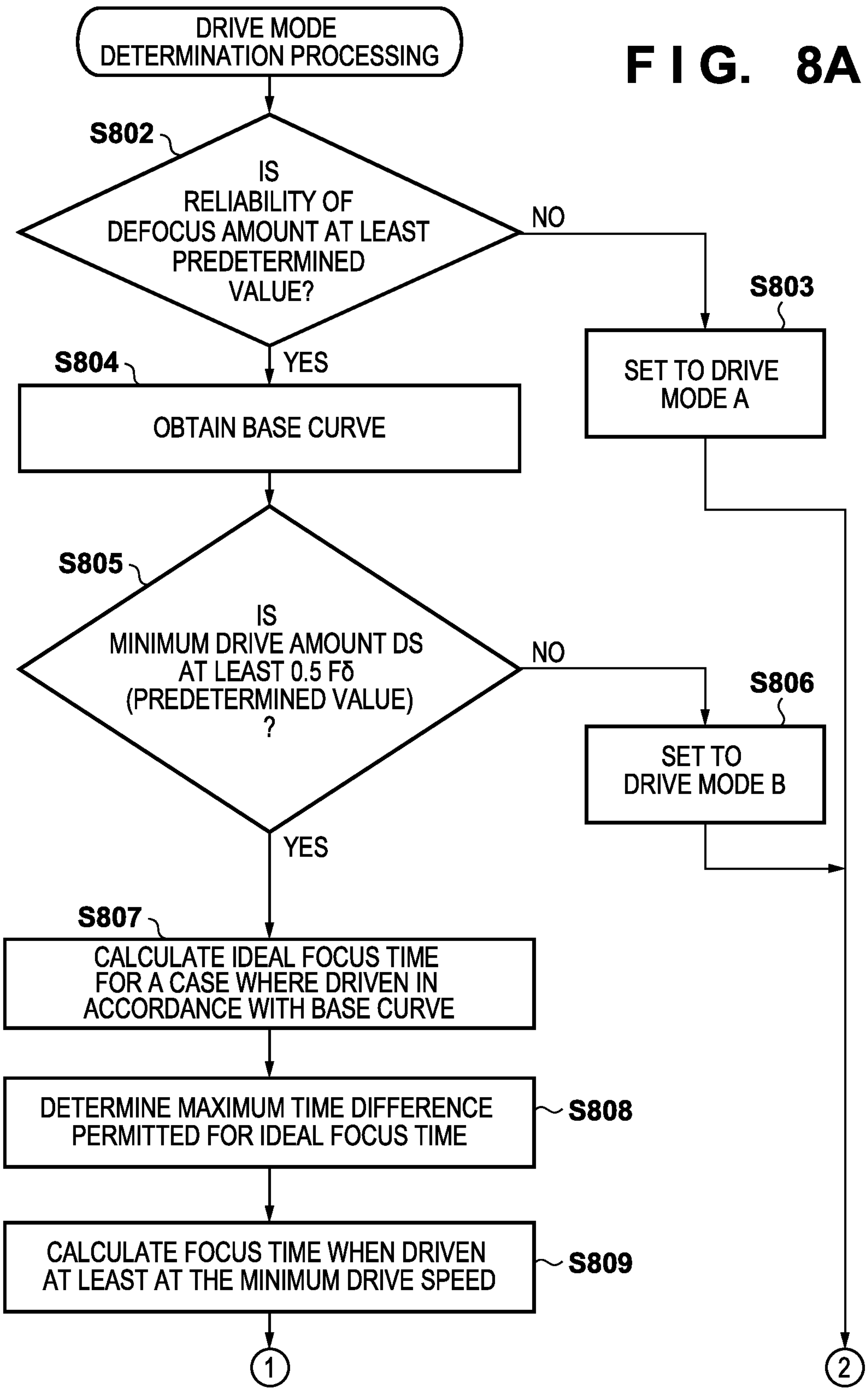

DRIVE MODE DETERMINATION PROCESSING
S802
IS RELIABILITY OF DEFOCUS AMOUNT AT LEAST PREDETERMINED VALUE?
NO
YES
S803
SET TO DRIVE MODE A
S804
OBTAIN BASE CURVE
S805
IS MINIMUM DRIVE AMOUNT DS AT LEAST 0.5 Fδ (PREDETERMINED VALUE) ?
NO
S806
SET TO DRIVE MODE B
YES
S807
CALCULATE IDEAL FOCUS TIME FOR A CASE WHERE DRIVEN IN ACCORDANCE WITH BASE CURVE
DETERMINE MAXIMUM TIME DIFFERENCE PERMITTED FOR IDEAL FOCUS TIME
S808
CALCULATE FOCUS TIME WHEN DRIVEN AT LEAST AT THE MINIMUM DRIVE SPEED
S809
1
2

FIG. 8B

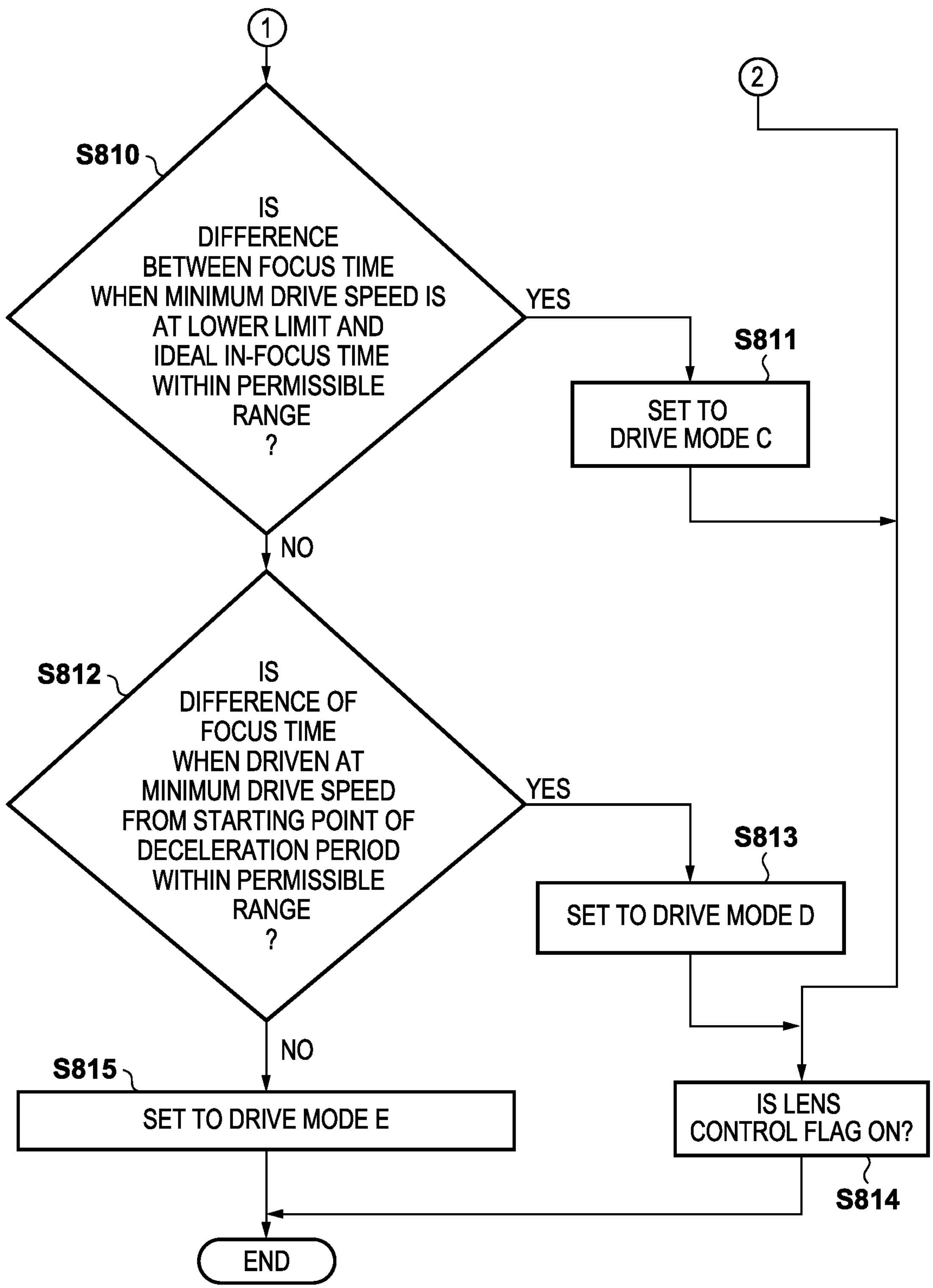

1
2
S810
IS DIFFERENCE BETWEEN FOCUS TIME WHEN MINIMUM DRIVE SPEED IS AT LOWER LIMIT AND IDEAL IN-FOCUS TIME WITHIN PERMISSIBLE RANGE ?
YES
S811
SET TO DRIVE MODE C
NO
S812
IS DIFFERENCE OF FOCUS TIME WHEN DRIVEN AT MINIMUM DRIVE SPEED FROM STARTING POINT OF DECELERATION PERIOD WITHIN PERMISSIBLE RANGE ?
YES
S813
SET TO DRIVE MODE D
NO
S815
SET TO DRIVE MODE E
IS LENS CONTROL FLAG ON?
S814
END

FIG. 9

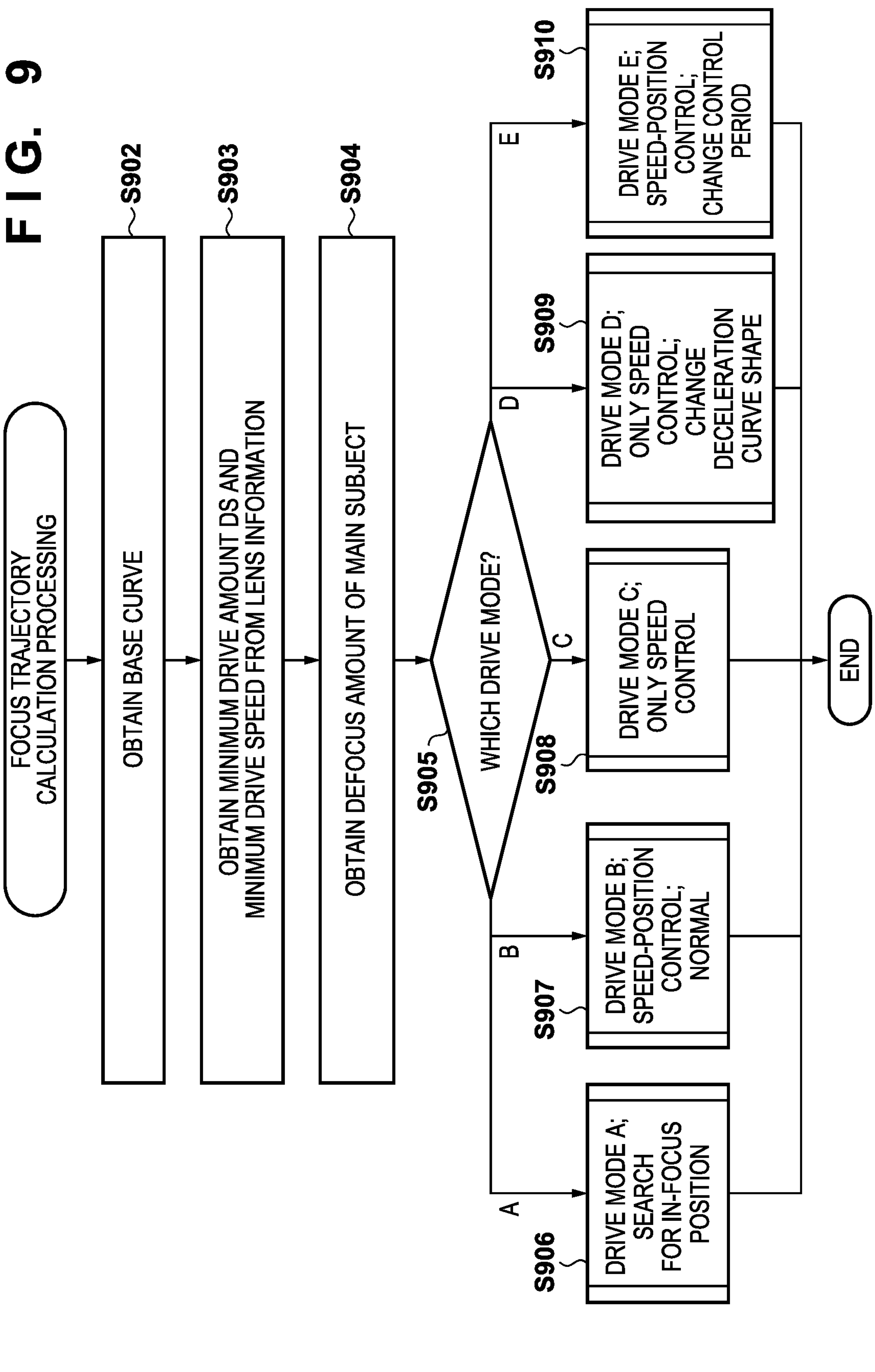

FOCUS TRAJECTORY CALCULATION PROCESSING
S902
OBTAIN BASE CURVE
S903
OBTAIN MINIMUM DRIVE AMOUNT DS AND MINIMUM DRIVE SPEED FROM LENS INFORMATION
S904
OBTAIN DEFOCUS AMOUNT OF MAIN SUBJECT
S905
WHICH DRIVE MODE?
A
B
C
D
E
S906
DRIVE MODE A; SEARCH FOR IN-FOCUS POSITION
S907
DRIVE MODE B; SPEED-POSITION CONTROL; NORMAL
S908
DRIVE MODE C; ONLY SPEED CONTROL
S909
DRIVE MODE D; ONLY SPEED CONTROL; CHANGE DECELERATION CURVE SHAPE
S910
DRIVE MODE E; SPEED-POSITION CONTROL; CHANGE CONTROL PERIOD
END

FIG. 10

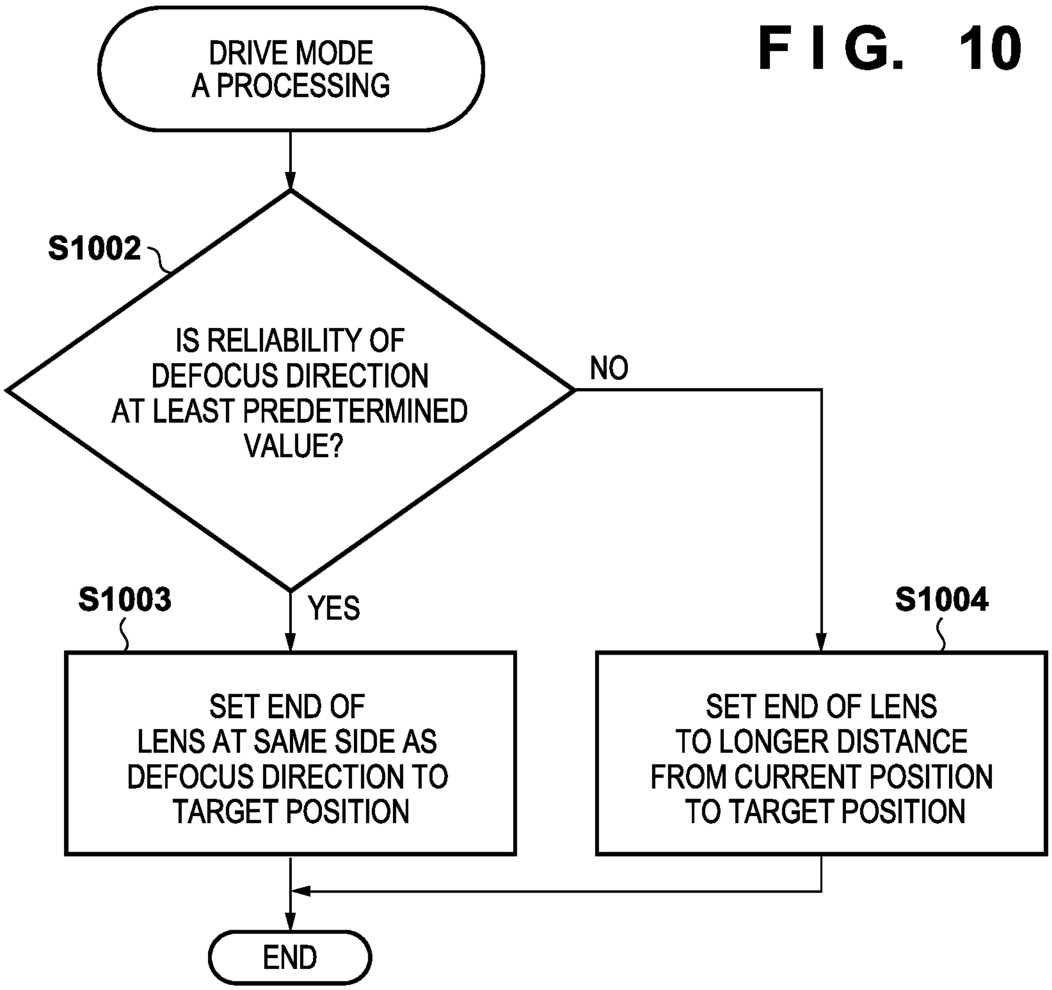

DRIVE MODE A PROCESSING
S1002
IS RELIABILITY OF DEFOCUS DIRECTION AT LEAST PREDETERMINED VALUE?
NO
YES
S1003
SET END OF LENS AT SAME SIDE AS DEFOCUS DIRECTION TO TARGET POSITION
S1004
SET END OF LENS TO LONGER DISTANCE FROM CURRENT POSITION TO TARGET POSITION
END

FIG. 11

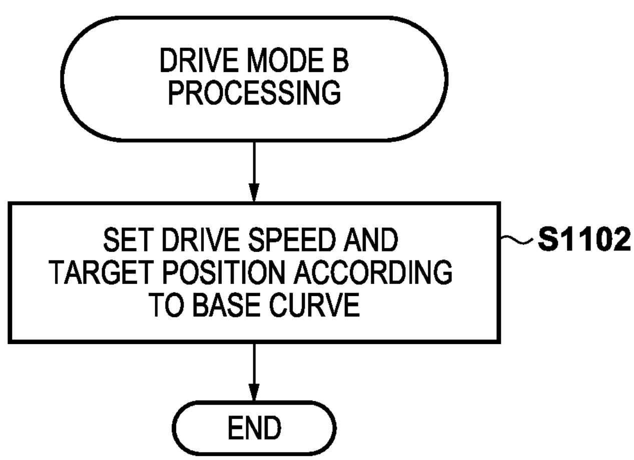
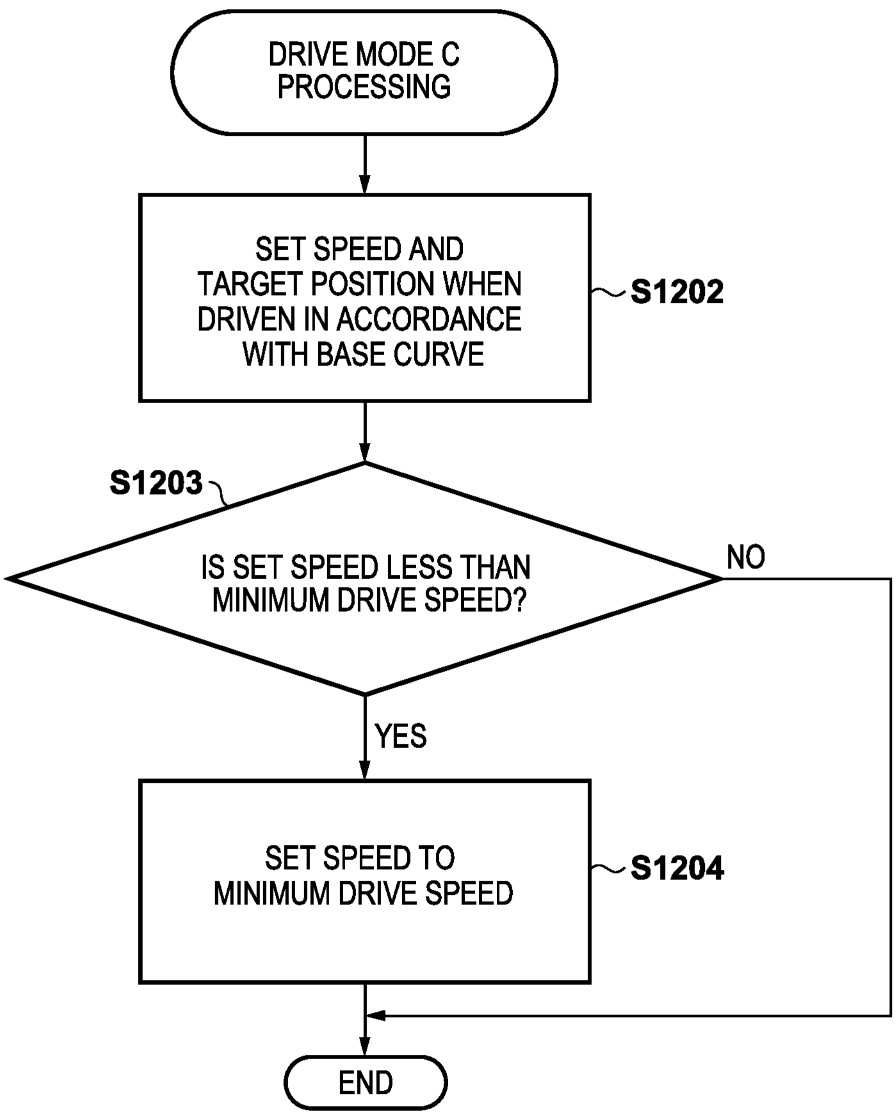

DRIVE MODE B PROCESSING
SET DRIVE SPEED AND TARGET POSITION ACCORDING TO BASE CURVE
S1102
END

FIG. 12


DRIVE MODE C PROCESSING
SET SPEED AND TARGET POSITION WHEN DRIVEN IN ACCORDANCE WITH BASE CURVE
S1202
S1203
IS SET SPEED LESS THAN MINIMUM DRIVE SPEED?
NO
YES
SET SPEED TO MINIMUM DRIVE SPEED
S1204
END

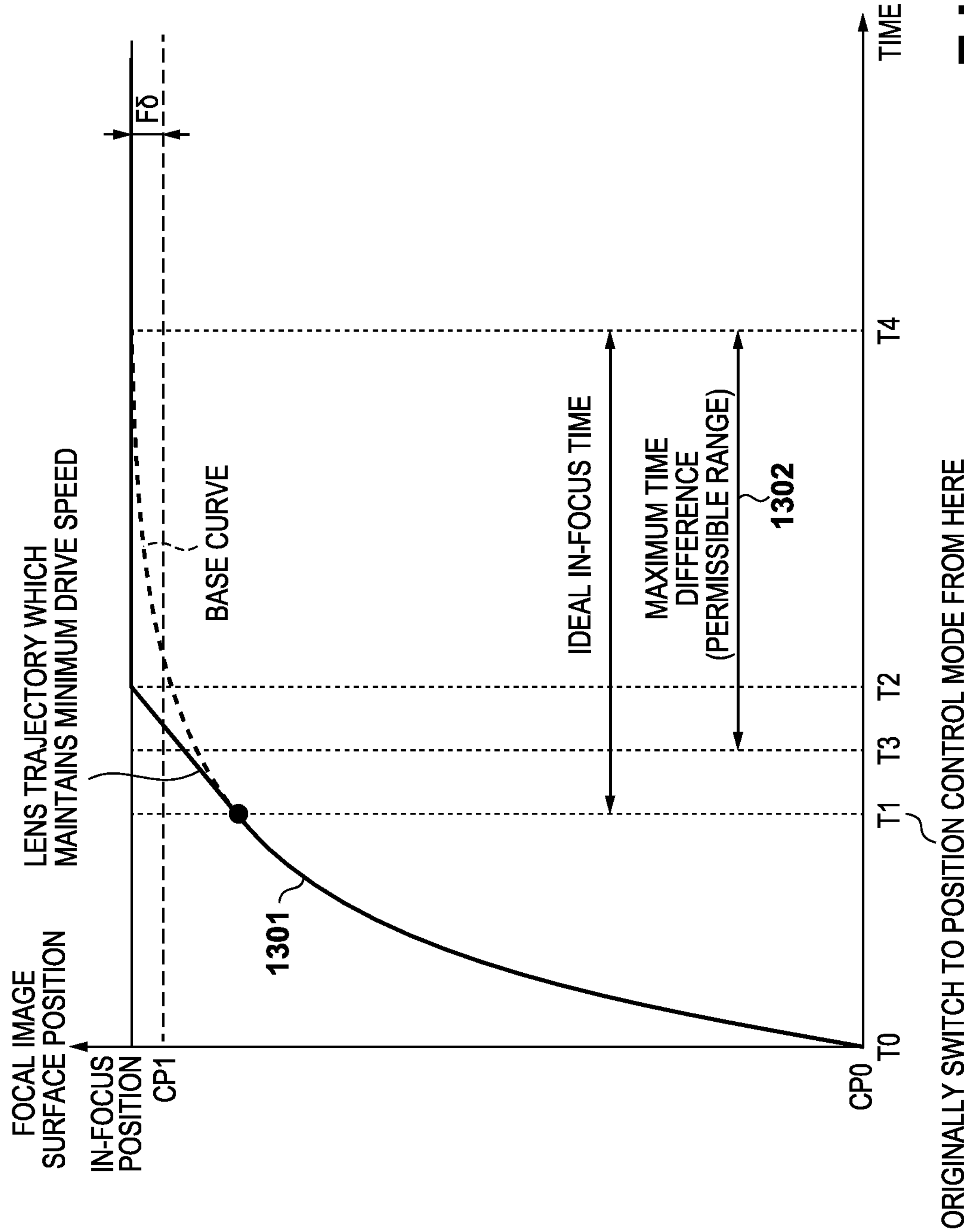

FOCAL IMAGE SURFACE POSITION
IN-FOCUS POSITION
CP1
CP0
T0
T1
T3
T2
T4
TIME
Fδ
LENS TRAJECTORY WHICH MAINTAINS MINIMUM DRIVE SPEED
BASE CURVE
1301
IDEAL IN-FOCUS TIME
MAXIMUM TIME DIFFERENCE (PERMISSIBLE RANGE)
1302
ORIGINALLY SWITCH TO POSITION CONTROL MODE FROM HERE

FIG. 13

FIG. 14

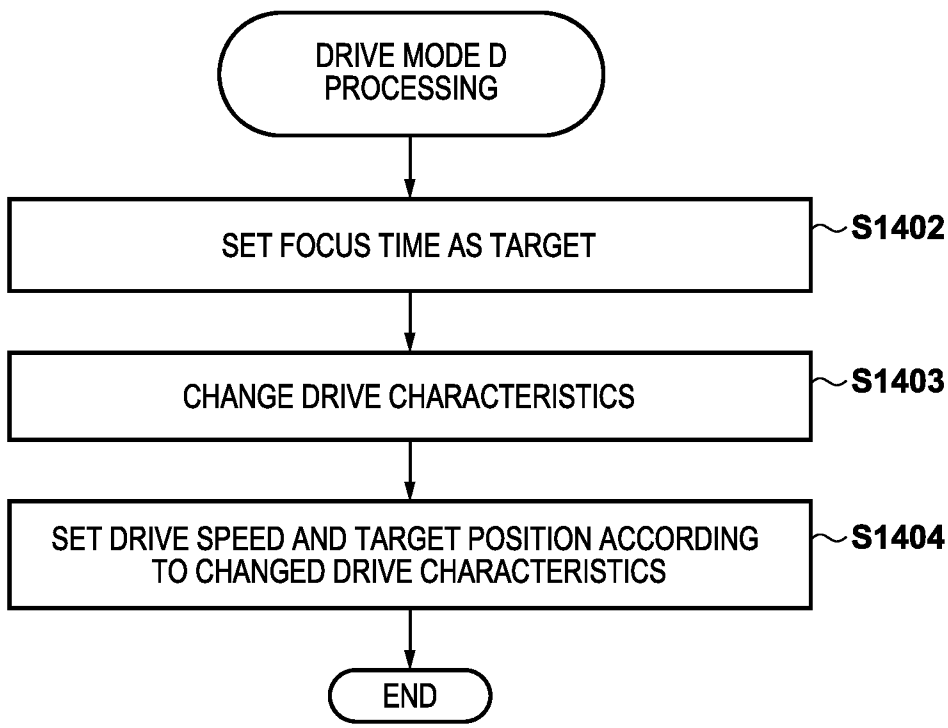

DRIVE MODE D PROCESSING
SET FOCUS TIME AS TARGET
S1402
CHANGE DRIVE CHARACTERISTICS
S1403
SET DRIVE SPEED AND TARGET POSITION ACCORDING TO CHANGED DRIVE CHARACTERISTICS
S1404
END

FIG. 15

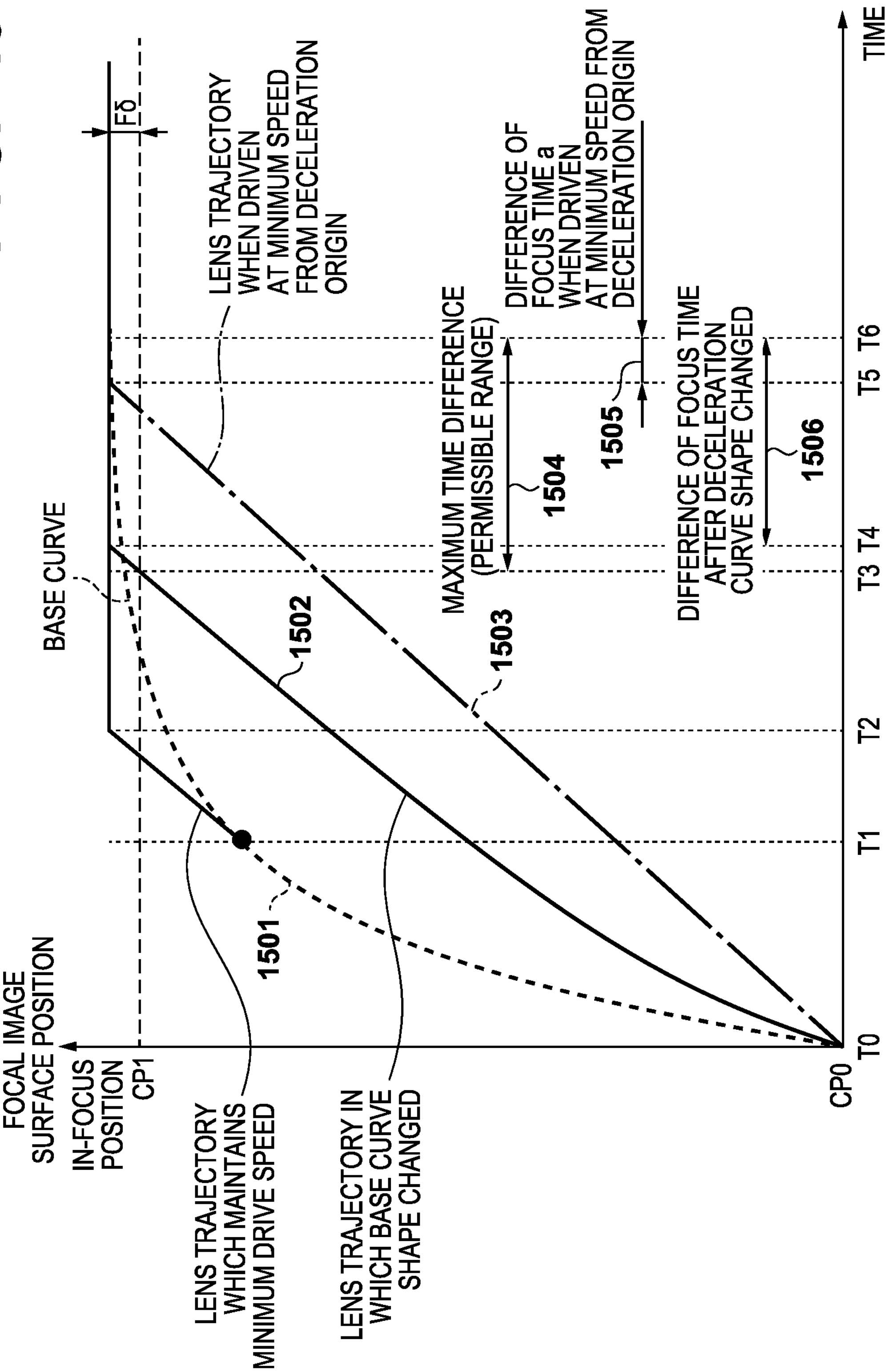

FOCAL IMAGE SURFACE POSITION
IN-FOCUS POSITION CP1
LENS TRAJECTORY WHICH MAINTAINS MINIMUM DRIVE SPEED
LENS TRAJECTORY IN WHICH BASE CURVE SHAPE CHANGED
CP0
T0
T1
T2
T3
T4
T5
T6
TIME
1501
1502
1503
1504
1505
1506
BASE CURVE
LENS TRAJECTORY WHEN DRIVEN AT MINIMUM SPEED FROM DECELERATION ORIGIN
Fδ
MAXIMUM TIME DIFFERENCE (PERMISSIBLE RANGE)
DIFFERENCE OF FOCUS TIME a WHEN DRIVEN AT MINIMUM SPEED FROM DECELERATION ORIGIN
DIFFERENCE OF FOCUS TIME AFTER DECELERATION CURVE SHAPE CHANGED

FIG. 16A

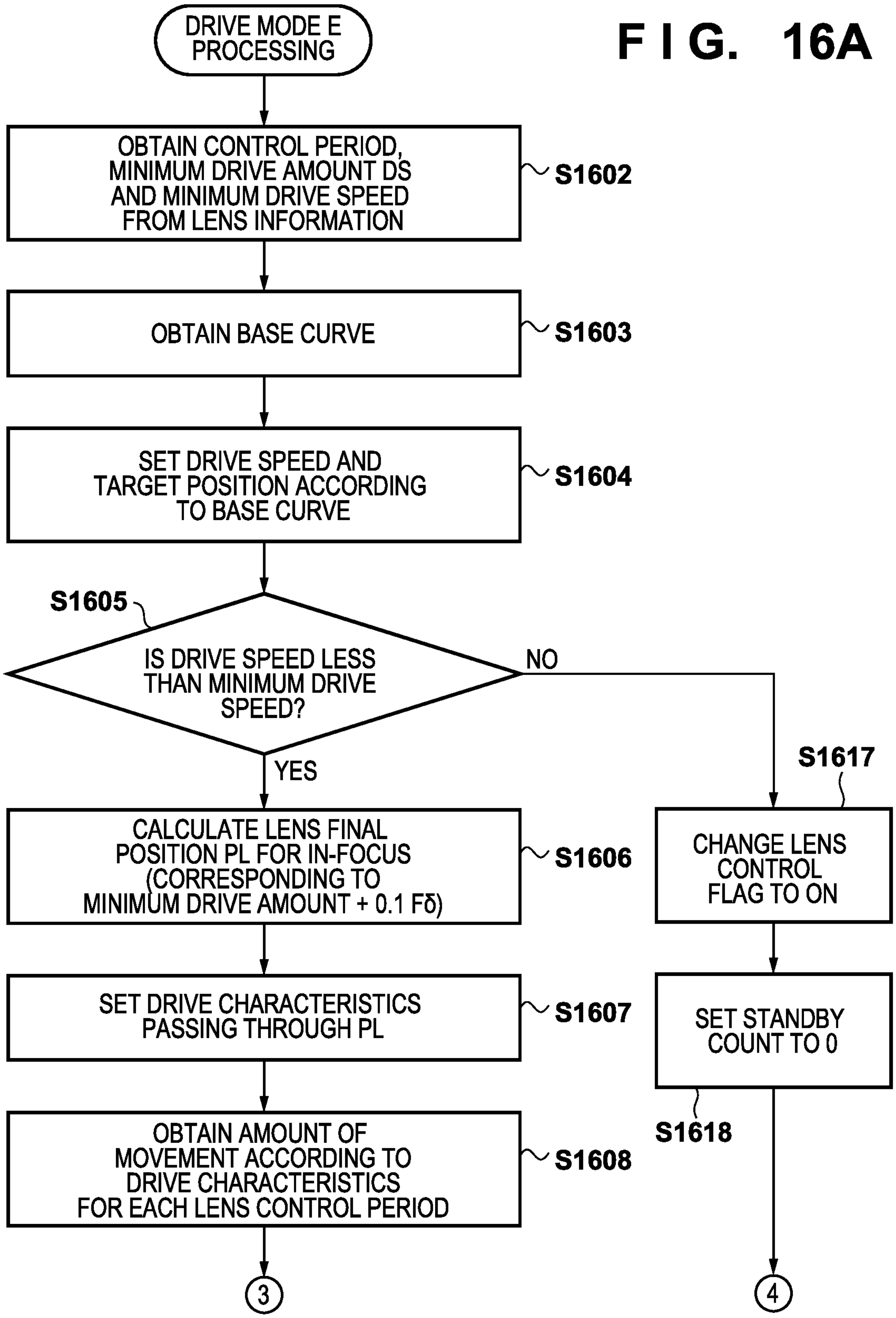

DRIVE MODE E PROCESSING
OBTAIN CONTROL PERIOD, MINIMUM DRIVE AMOUNT DS AND MINIMUM DRIVE SPEED FROM LENS INFORMATION
S1602
OBTAIN BASE CURVE
S1603
SET DRIVE SPEED AND TARGET POSITION ACCORDING TO BASE CURVE
S1604
S1605
IS DRIVE SPEED LESS THAN MINIMUM DRIVE SPEED?
NO
YES
CALCULATE LENS FINAL POSITION PL FOR IN-FOCUS (CORRESPONDING TO MINIMUM DRIVE AMOUNT + 0.1 Fδ)
S1606
SET DRIVE CHARACTERISTICS PASSING THROUGH PL
S1607
OBTAIN AMOUNT OF MOVEMENT ACCORDING TO DRIVE CHARACTERISTICS FOR EACH LENS CONTROL PERIOD
S1608
3
S1617
CHANGE LENS CONTROL FLAG TO ON
SET STANDBY COUNT TO 0
S1618
4

FIG. 16B

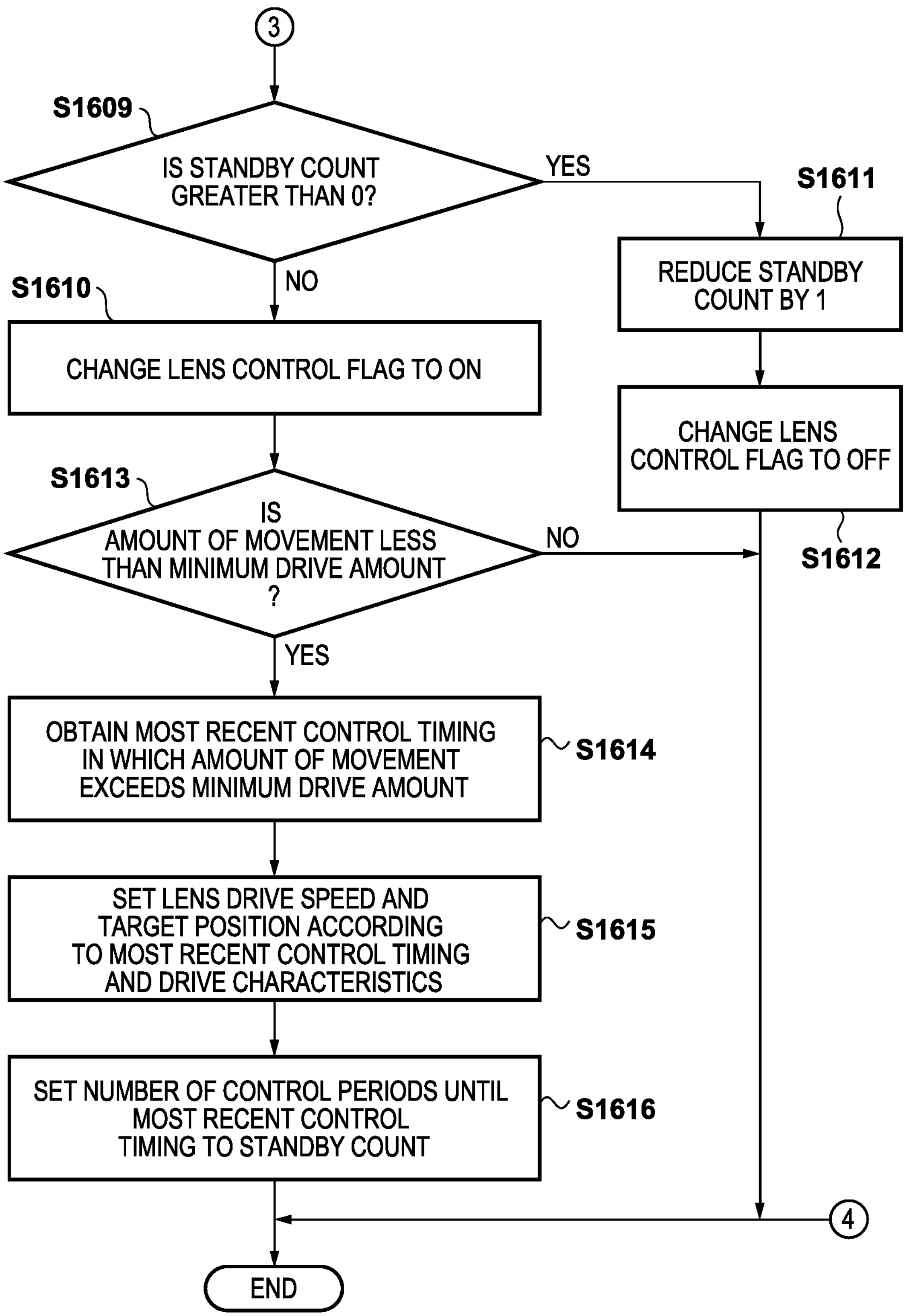
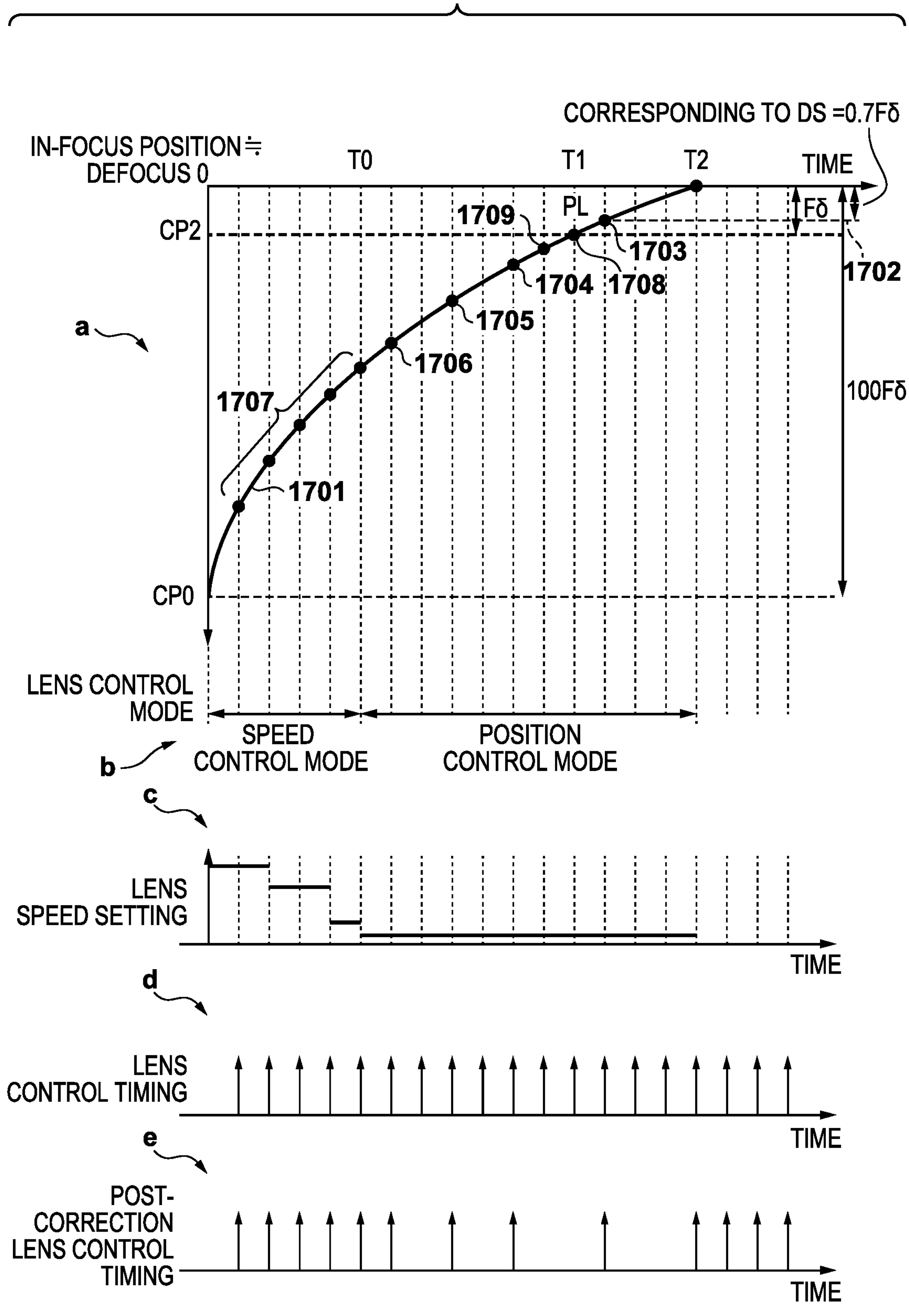

3
S1609
IS STANDBY COUNT GREATER THAN 0?
YES
NO
S1611
REDUCE STANDBY COUNT BY 1
S1610
CHANGE LENS CONTROL FLAG TO ON
CHANGE LENS CONTROL FLAG TO OFF
S1612
S1613
IS AMOUNT OF MOVEMENT LESS THAN MINIMUM DRIVE AMOUNT ?
NO
YES
OBTAIN MOST RECENT CONTROL TIMING IN WHICH AMOUNT OF MOVEMENT EXCEEDS MINIMUM DRIVE AMOUNT
S1614
SET LENS DRIVE SPEED AND TARGET POSITION ACCORDING TO MOST RECENT CONTROL TIMING AND DRIVE CHARACTERISTICS
S1615
SET NUMBER OF CONTROL PERIODS UNTIL MOST RECENT CONTROL TIMING TO STANDBY COUNT
S1616
4
END

FIG. 17



CORRESPONDING TO DS =0.7Fδ
IN-FOCUS POSITION≒
DEFOCUS 0
T0
T1
T2
TIME
Fδ
CP2
PL
1709
1703
1704
1708
1702
a
1705
1706
1707
100Fδ
1701
CP0
LENS CONTROL
MODE
SPEED
CONTROL MODE
POSITION
CONTROL MODE
b
c
LENS
SPEED SETTING
TIME
d
LENS
CONTROL TIMING
TIME
e
POST-
CORRECTION
LENS CONTROL
TIMING
TIME

FIG. 18A

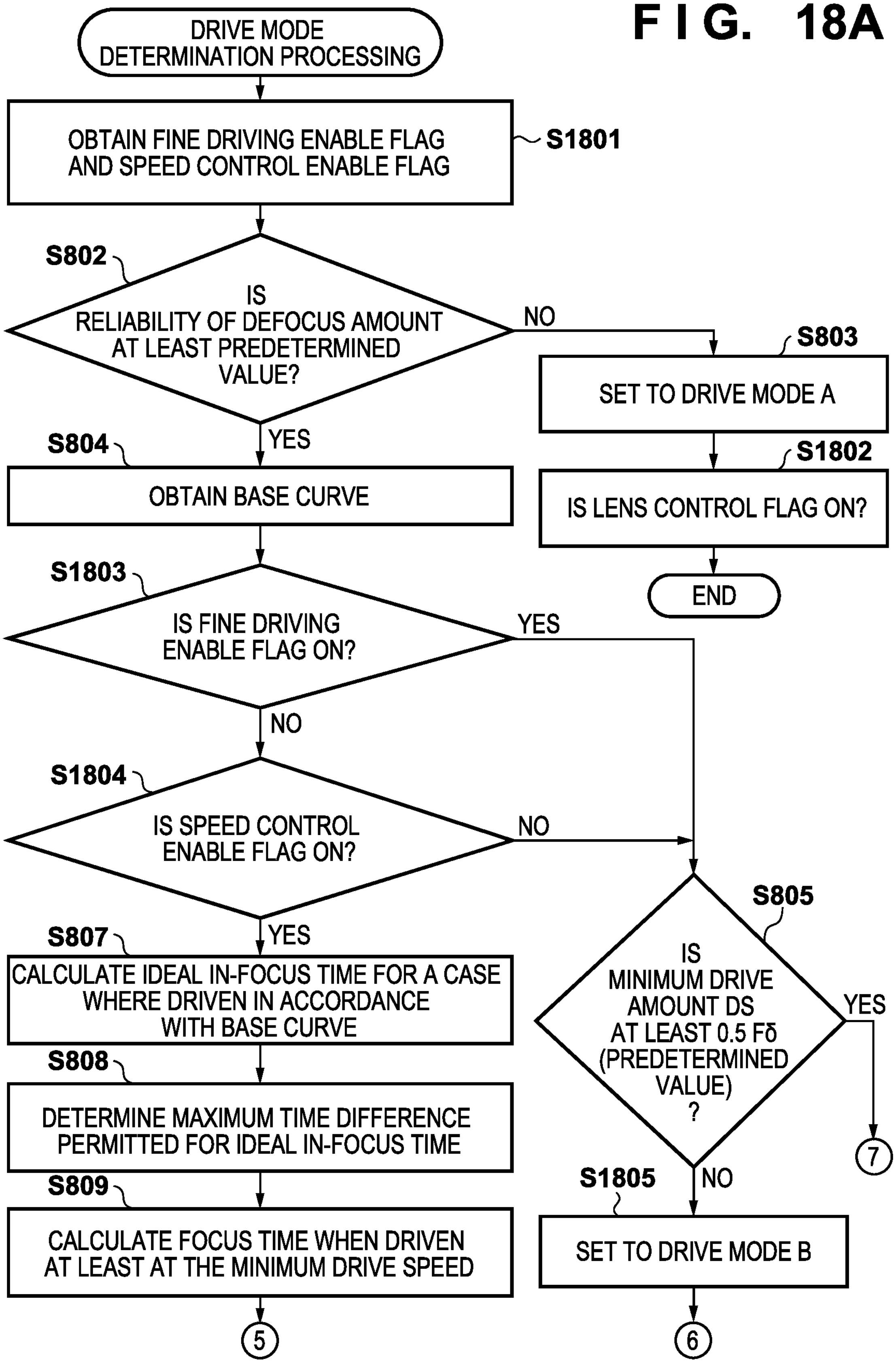
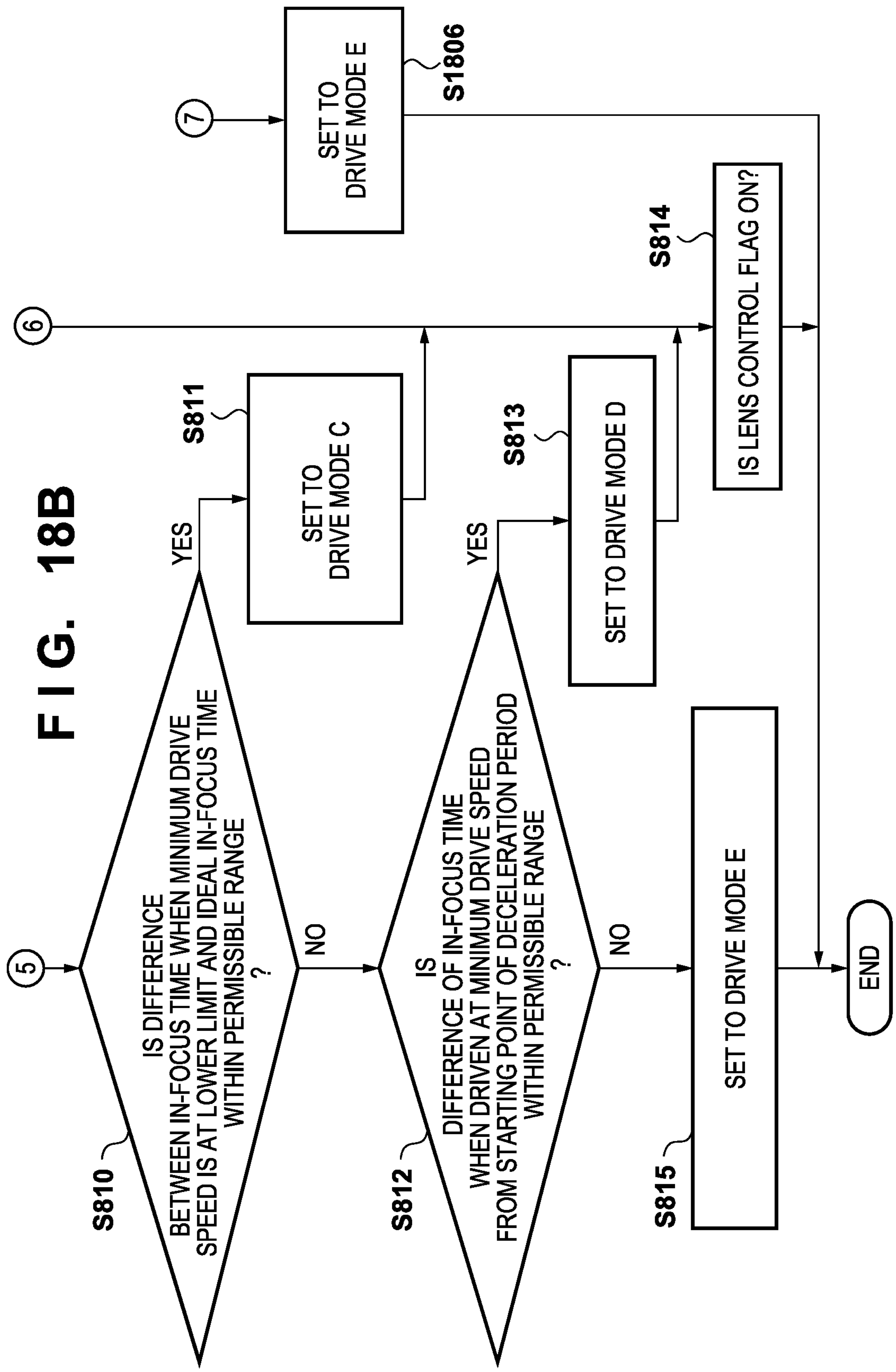

DRIVE MODE DETERMINATION PROCESSING
OBTAIN FINE DRIVING ENABLE FLAG AND SPEED CONTROL ENABLE FLAG
S1801
S802
IS RELIABILITY OF DEFOCUS AMOUNT AT LEAST PREDETERMINED VALUE?
NO
S803
SET TO DRIVE MODE A
S1802
IS LENS CONTROL FLAG ON?
END
YES
S804
OBTAIN BASE CURVE
S1803
IS FINE DRIVING ENABLE FLAG ON?
YES
NO
S1804
IS SPEED CONTROL ENABLE FLAG ON?
NO
YES
S805
IS MINIMUM DRIVE AMOUNT DS AT LEAST 0.5 Fδ (PREDETERMINED VALUE) ?
YES
7
NO
S1805
SET TO DRIVE MODE B
6
S807
CALCULATE IDEAL IN-FOCUS TIME FOR A CASE WHERE DRIVEN IN ACCORDANCE WITH BASE CURVE
S808
DETERMINE MAXIMUM TIME DIFFERENCE PERMITTED FOR IDEAL IN-FOCUS TIME
S809
CALCULATE FOCUS TIME WHEN DRIVEN AT LEAST AT THE MINIMUM DRIVE SPEED
5

FIG. 18B


5
S810
IS DIFFERENCE BETWEEN IN-FOCUS TIME WHEN MINIMUM DRIVE SPEED IS AT LOWER LIMIT AND IDEAL IN-FOCUS TIME WITHIN PERMISSIBLE RANGE ?
YES
NO
S811
SET TO DRIVE MODE C
S812
IS DIFFERENCE OF IN-FOCUS TIME WHEN DRIVEN AT MINIMUM DRIVE SPEED FROM STARTING POINT OF DECELERATION PERIOD WITHIN PERMISSIBLE RANGE ?
YES
NO
S813
SET TO DRIVE MODE D
S815
SET TO DRIVE MODE E
6
S814
IS LENS CONTROL FLAG ON?
7
S1806
SET TO DRIVE MODE E
END

FOCUS ADJUSTMENT DEVICE, FOCUS ADJUSTMENT METHOD, AND IMAGE CAPTURE APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a focus adjustment device, a focus adjustment method, and an image capture apparatus.

Description of the Related Art

[0002] In an image capture apparatus having an autofocus function that automatically drives a focus lens, if the drive speed of the focus lens changes significantly while recording a moving image, the focus condition of the moving image may change suddenly and give an unnatural impression. According to Japanese Patent Laid-Open No. 2018-36509, sudden changes in the drive speed of a focus lens are suppressed by ensuring not to change from a mode in which the drive speed of the focus lens is constant to a mode in which the drive speed of the focus lens is variable, until a defocus amount becomes less than a predetermined value.

[0003] To control the focus condition to change smoothly, it is necessary to drive the focus lens at a low speed when near an in-focus state. On the other hand, the weight of the focus lens, the drive mechanism, and the like vary depending on the lens unit. Accordingly, delay between when a drive command for the focus lens is transmitted and when the focus lens actually starts moving, as well as the change in the drive speed of the focus lens, also vary depending on the lens unit. As such, even if drive control appropriate for one lens unit is applied to another lens unit, it may not be possible to realize the desired drive speed.

SUMMARY OF THE INVENTION

[0004] The present invention in one aspect provides a focus adjustment device, a focus adjustment method, and an image capture apparatus capable of suppressing differences in changes in focus conditions due to differences in lens units by performing appropriate focus lens drive control depending on a respective lens unit.

[0005] According to an aspect of the present invention, there is provided a focus adjustment device that controls driving of a focus lens included in a lens unit during moving image shooting, the focus adjustment device comprising one or more processors that execute a program and thereby function as: an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and a control unit that controls the driving of the focus lens, wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

[0006] According to another aspect of the present invention, there is provided an image capture apparatus comprising: a defocus amount obtainment unit that obtains a defocus amount of a lens unit that is mounted; and a focus adjustment device that drives a focus lens included in the lens unit based on the defocus amount, wherein the focus adjustment device comprising: an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and a control unit that controls the driving of the focus lens, wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

[0007] According to a further aspect of the present invention, there is provided a focus adjustment method executed by a focus adjustment device for controlling driving of a focus lens having a lens unit during moving image shooting, the focus adjustment method comprising: obtaining a drive pattern determined in advance for driving the focus lens to an in-focus position; and controlling the driving of the focus lens, wherein when the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and the lens unit is determined not to be suitable for fine driving of the focus lens, the controlling includes continuously driving the focus lens at the minimum drive speed in the fine-driving section.

[0008] According to another aspect of the present invention, there is provided a non-transitory computer-readable medium storing a program that causes a computer to function as a focus adjustment device comprising: an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and a control unit that controls the driving of the focus lens, wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

[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 an example of the functional configuration of a camera system serving as an example of an image capture apparatus including a focus adjustment device according to an embodiment.

[0011] FIG. **2** is a flowchart pertaining to overall operations.

[0012] FIG. **3** is a flowchart pertaining to startup processing indicated in FIG. **2**.

[0013] FIG. **4** is a flowchart pertaining to AF processing indicated in FIG. **2**.

[0014] FIG. **5** is a flowchart pertaining to base curve calculation processing indicated in FIG. **4**.

[0015] FIG. **6** is a diagram illustrating the base curve calculation processing indicated in FIG. **4**.

[0016] FIG. **7** is a flowchart pertaining to drive control processing indicated in FIG. **4**.

[0017] FIGS. **8**A and **8**B are flowcharts pertaining to drive mode determination processing indicated in FIG. **4**.

[0018] FIG. **9** is a flowchart pertaining to focus trajectory calculation processing indicated in FIG. **4**.

[0019] FIG. **10** is a flowchart pertaining to drive mode A processing.

[0020] FIG. **11** is a flowchart pertaining to drive mode B processing.

[0021] FIG. **12** is a flowchart pertaining to drive mode C processing.

[0022] FIG. **13** is a diagram illustrating drive mode determination processing.

[0023] FIG. **14** is a flowchart pertaining to drive mode D processing.

[0024] FIG. **15** is a diagram illustrating drive mode determination processing.

[0025] FIGS. **16**A and **16**B are flowcharts pertaining to drive mode E processing.

[0026] FIG. **17** is a diagram illustrating focus trajectory calculation processing in drive mode E.

[0027] FIGS. **18**A and **18**B are flowcharts pertaining to drive mode determination processing in a second embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0028] Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention. Multiple features are described in the embodiments, but limitation is not made to an invention that requires all such features, and multiple such features may be combined as appropriate. Furthermore, in the attached drawings, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

[0029] Note that the following embodiments will describe a case where the present invention is applied in an interchangeable lens-type digital video camera. However, the present invention can be applied in any electronic device that can capture moving images using different types of lens units. Examples of such an electronic device include video cameras, computer devices (personal computers, tablet computers, media players, PDAs, and the like), mobile phones, smartphones, game consoles, robots, drones, and dashboard cameras. These are merely examples, however, and the present invention can be applied in other electronic devices as well.

First Embodiment

[0030] A first embodiment of the present invention will be described. FIG. **1** is a block diagram illustrating an example of the functional configuration of a camera system serving as an example of an image capture apparatus including a focus adjustment device according to a first embodiment of the present invention.

[0031] The camera system is an interchangeable lens-type video camera system, and is constituted by a main body **20**, which serves as the image capture apparatus according to the present embodiment, and a lens unit **10** that can be attached to and detached from the main body **20**. The main body **20** and the lens unit **10** are mechanically and electrically connected through respective mount units. A camera control unit **212** in the main body **20** and a lens control unit **106** in the lens unit **10** can send and receive information, commands, and the like by communicating through the mount units.

[0032] The configuration of the lens unit **10** will be described first. A fixed lens **101**, an aperture stop **102**, and a focus lens **103** constitute an optical imaging system. The aperture stop **102** is driven by an aperture drive unit **104**, and controls the amount of light incident on an image sensor **201** (described later). The focus lens **103** is driven along an optical axis by a focus lens drive unit **105** constituted by a DC motor and a control circuit thereof. The focus distance of the imaging optical system changes according to the position of the focus lens **103**.

[0033] The lens control unit **106** controls operations of the aperture drive unit **104** and the focus lens drive unit **105** according to the commands from the camera control unit **212**, and controls the amount by which the aperture stop **102** is open and the position of the focus lens **103**. The drive control of the focus lens (described later) is also realized by the lens control unit **106** controlling the focus lens drive unit **105** according to commands from the camera control unit **212**. The lens control unit **106** also transmits information pertaining to the lens unit, stored in non-volatile memory of the lens control unit **106**, information pertaining to the position of the focus lens, and the like to the camera control unit **212**.

[0034] "Lens operation unit **107**" is a collective term for a group of input devices provided in the lens unit. The lens operation unit **107** includes a switch for changing between AF (autofocus) and MF (manual focus) mode, a focus ring, an aperture ring, a focus limiter, a switch for changing an image stabilization mode, and the like. These are merely examples and are not required, input devices having other functions assigned may be included as well. The operation of the lens operation unit **107** are detected by the lens control unit **106**, and the lens control unit **106** performs control according to the detected operation.

[0035] The lens control unit **106** has, for example, a CPU, ROM, and RAM, and controls each part in the lens unit **10**, communicates with the camera control unit **212**, and so on by loading programs stored in the ROM into the RAM and executing the programs.

[0036] The configuration of the main body **20** will be described next. The image sensor **201** is a CMOS image sensor, for example, in which pixels having photodiodes formed therein are arranged two-dimensionally. The optical imaging system of the lens unit **10** forms an optical image of a subject on an image formation surface of the image sensor **201**. In each pixel of the image sensor **201**, the photodiode generates an electric charge in response to the amount of incident light and generates a pixel signal that converts the amount of charge into a voltage.

[0037] Pixel signals are read out sequentially in, for example, units of pixel lines, by drive pulses output by a timing generator **214** in response to commands from the camera control unit **212**. The series of processing is repeatedly executed, using a period in which pixel signals are read out from all effective pixels in the image sensor **201** as a camera control period.

[0038] Also, the image sensor **201** used in the present embodiment is assumed to be capable of generating a parallax signal pair for implementing image plane phase detection AF. For example, each pixel includes one microlens and two photodiodes A and B, and the photodiodes A and B are configured to receive light fluxes from different partial regions of the exit pupil of the optical imaging system, respectively. For a plurality of pixels in a focus detection region, an A image signal, obtained by concatenating the A signals read out from the photodiode A, and a B image signal, obtained by concatenating the B signals read out from the photodiode B, form a parallax signal pair. By detecting a phase difference of this parallax signal pair and converting the phase difference into a defocus amount and a defocus direction of the optical imaging system, the position of the focus lens can be driven to an in-focus position.

[0039] Note that a normal pixel signal (A+B signal) can be obtained by adding the signals from the photodiodes A and B for each pixel. Normal pixel signals are used to generate image data, and are therefore also called "captured image signals". In contrast, the A signal and the B signal are used for automatic focus detection (autofocus) and are therefore also called "AF signals".

[0040] A front end **202** performs correlated double sampling, gain adjustment, and AD conversion for removing reset noise on the signal read out from the image sensor **201**. The front end **202** outputs these processed signals to an image input controller **203** and an AF signal processing unit **204**, according to the type of signal. Specifically, the front end **202** outputs the A+B signal to the image input controller **203**, and the A signal and B signal to the AF signal processing unit **204**. The AF signal may be read out only from pixels within a preset focus detection region, or from all pixels.

[0041] Note that if the A signal and the A+B signal are read out from the image sensor and the B signal is not read out, the front end **202** outputs a difference between the A+B signal and the A signal as the B signal to the AF signal processing unit **204**. Likewise, if the B signal and the A+B signal are read out from the image sensor and the A signal is not read out, the front end **202** outputs a difference between the A+B signal and the B signal as the A signal to the AF signal processing unit **204**.

[0042] The image input controller **203** applies predetermined image processing to the captured image signal output from the front end **202** and generates image data for display and image data for recording. The predetermined image processing includes color interpolation, white balance adjustment, various types of correction, scaling, encoding, and the like.

[0043] The image input controller **203** stores the generated image data in SDRAM **209** via a bus **21**. The image data for display stored in the SDRAM **209** is read out by a display control unit **205** via the bus **21** and displayed in a display unit **206**. The image data for recording stored in the SDRAM **209** is read out by a recording medium control unit **207** and recorded into a recording medium **208** such as a semiconductor memory card.

[0044] The camera control unit **212** is, for example, a CPU that realizes the functions of the camera system as a whole by loading programs stored in ROM **210** into the SDRAM **209** and executing the programs, and controlling the main body **20** and the lens unit **10**. In the figure, the function blocks of the camera control unit **212** are schematic illustrations of functions realized by the camera control unit **212** executing programs. Note that some of the functions realized by the camera control unit **212** executing programs may be implemented by hardware circuits such as ASICs or the like.

[0045] The ROM **210** is, for example, electrically rewritable non-volatile memory. The ROM **210** stores the programs executed by the camera control unit **212**, various data necessary for executing the programs, various setting values, unique information of the main body **20**, and the like.

[0046] A subject detection unit **2121** in the camera control unit **212** detects a region pertaining to a specific subject (subject region) from the image data stored in the SDRAM **209**, and obtains the position and size of the detected subject region. The subject detection unit **2121** also detects movement of the subject region between frames. The specific subject is, for example, the face of a person or animal, or a region that has a high degree of similarity to a partial region in the screen specified by the user in the camera operation unit **213**.

[0047] A subject tracking unit **2122** is used to track the subject region across frames in cases where the subject region detected by the subject detection unit **2121** is set as the focus detection region. The subject tracking unit **2122** detects the subject region using a different method from that of the subject detection unit **2121**, such as using color information, for example.

[0048] The AF signal processing unit **204**, which serves as a focus detection device, generates the A image signal and the B image signal from the A signal and the B signal output from the front end **202**, and calculates an amount of image shift (phase difference) between the A image signal and the B image signal, as well as a reliability of the amount of image shift. The amount of image shift can be calculated by shifting the A image signal and the B image signal relative to each other, obtaining a correlation amount, and then calculating an amount of shift where the correlation is the highest. The reliability can be calculated based on the correlation amount corresponding to the amount of image shift, the steepness of a change in the correlation amount near the amount of image shift, contrast signals of the A image signal and the B image signal, and the like. The method of calculating the amount of image shift, the reliability thereof, and the like are not particularly limited, and any publicly-known method can be used.

[0049] The generation of the A image signal and the B image signal, and the calculation of the amount of image shift and the reliability thereof, may be executed for a plurality of regions in the screen. For example, in a case such as where AF signals are obtained over the entire screen, the AF signal processing unit **204** can set the focus detection region based on the amount of image shift, and the reliability thereof, obtained for a plurality of regions.

[0050] The AF signal processing unit **204** outputs information on the amount of image shift obtained for the focus detection region, and the reliability thereof, to the camera control unit **212**. An AF control unit **2123** in the camera control unit **212** converts the amount of image shift calculated by the AF signal processing unit **204** into a defocus amount. Then, the AF control unit **2123** transmits, to the lens control unit **106**, a lens drive command including a drive amount and a drive direction of the focus lens determined based on the defocus amount. The lens control unit **106** drives the focus lens **103** by controlling the focus lens drive unit **105** based on the lens drive command. Through this, the focus of the optical imaging system is adjusted such that the focus detection region is in focus.

[0051] An AF control switching unit **2124** switches an operating mode of the AF control unit **2123** based on a determination result from a movement determination unit **2127**, an operation made in the camera operation unit **213**, and the like.

[0052] A prediction unit **2125** predicts the next position for focus detection based on a change in the defocus amount over time. The prediction unit **2125** can be used for the subject tracking function.

[0053] A storage control unit **2126** stores various information pertaining to drive control of the focus lens, including information indicating a drive pattern (drive characteristics) of the focus lens according to the defocus amount obtained for the focus detection region, in a memory circuit **215**. The memory circuit **215** may be a region in the SDRAM **209**.

[0054] The movement determination unit **2127** estimates an amount of movement of the focus lens based on a relationship between an amount of movement of the focus lens **103** instructed to the lens control unit **106** and an actual amount of movement. The AF control unit **2123** controls operations of the AF control switching unit **2124**, the storage control unit **2126**, and the movement determination unit **2127**.

[0055] In the above configuration, the AF signal processing unit **204** and the camera control unit **212** constitute a focus adjustment device according to the embodiment.

[0056] The following will describe, in detail, autofocus operations in the main body **20** when shooting a moving image. The moving image shooting may be moving image shooting for display (e.g., moving image shooting for causing the display unit **206** to function as an EVF), or moving image shooting for recording.

[0057] FIG. **2** is a flowchart illustrating operations of the main body **20** from startup, from the perspective of autofocus operations.

[0058] When startup is instructed by a power switch of the camera operation unit **213** being operated or the like, the camera control unit **212** executes startup processing in step S**202**.

[0059] The startup processing will be described with reference to the flowchart in FIG. **3**. The camera control unit **212** first checks whether the lens unit **10** is mounted. Here, it is assumed that the lens unit **10** is mounted.

[0060] In step S**302**, the camera control unit **212** obtains lens information by communicating with the lens control unit **106**. The lens information includes type information, control period, drive speed information, and minimum drive amount information. The type information is information that can identify the product, such as a model name of the lens unit **10**. The control period is the repetition period of control operations of the lens unit. The drive speed information indicates a drive speed of the focus lens that can be set in the lens unit **10**. The drive speed of the focus lens depends on the weight of the focus lens, the performance of the drive mechanism, and the drive control method, and can vary depending on the model of the lens unit **10**. The minimum drive amount information indicates a minimum drive amount DS**0** of the focus lens.

[0061] When the main body **20** specifies the drive speed of the focus lens to the lens unit **10**, the speed indicated in the drive speed information is specified. Additionally, when specifying the drive amount of the focus lens, a drive amount that is not less than the minimum drive amount DS**0** is specified. The focus lens will not move even if a drive amount less than the minimum drive amount DS**0** is specified.

[0062] For example, assume that the drive amount for the focus lens is expressed as a number of drive pulses, and the minimum drive amount DS**0** is 120 pulses. In this case, even if a drive command specifying **100** pulses as the drive amount is transmitted to the lens control unit **106**, the focus lens will not move.

[0063] In step S**303**, the camera control unit **212** performs a reset operation for the lens unit **10**. Specifically, the camera control unit **212** drives the focus lens **103** to the end of its physical drivable range, and then resets a sensor that measures the position of the focus lens. This resets position information of the focus lens.

[0064] In step S**304**, the camera control unit **212** performs an operation test for the focus lens. Specifically, the camera control unit **212** sets a minimum drive speed among the drive speeds indicated by the drive speed information and a first target drive amount for measuring the actual minimum drive amount, and transmits a focus lens drive command to the lens control unit **106**. The first target drive amount may be, for example, the minimum drive amount DS**0** obtained from the lens unit **10**, but another drive amount may be used. Upon receiving a response to the command from the lens control unit **106**, the camera control unit **212** obtains the actual amount of movement of the focus lens from the lens control unit **106**. The camera control unit **212** stores the actual amount of movement relative to the first target drive amount as movement amount information DS**1**, in the memory circuit **215**, for example.

[0065] The effect of gravity on the focus lens **103** changes depending on the shooting attitude, and particularly the angle in the vertical direction of the optical axis. In addition, variations in the assembly accuracy, component tolerances, and the like exist in the lens unit **10**. On the other hand, the minimum drive amount DS**0** obtained from the lens unit **10** is a design value that assumes specific conditions. Accordingly, the minimum drive amount in a real environment can be different from DS**0**. The actual drive amount is therefore measured when the lens unit operation is reset. The movement amount information DS**1** may be obtained by converting the actual amount of movement obtained for a first target drive amount which is slightly larger than DS**0**.

[0066] Next, the camera control unit **212** sets the minimum drive speed and a second target drive amount defined as greater than the first target drive amount, and transmits a focus lens drive command to the lens control unit **106**. The second target drive amount is defined in order to measure error in the drive amount when the focus lens **103** is moved significantly. The camera control unit **212** then obtains the actual amount of movement, and stores a difference between the second target drive amount and the actual drive amount as drive amount information DLO in, for example, the memory circuit **215**.

[0067] The camera control unit **212** then drives the focus lens back to a default position after the reset operation. This completes the operation test.

[0068] In step S**305**, the camera control unit **212** initializes a standby count to 0 and ends the startup processing. The standby count is a variable that is referenced in processing for extending a real control period. The standby count will be described later.

[0069] Returning to FIG. **2**, once the startup processing ends, the camera control unit **212** executes processing in a shooting standby state. The camera control unit **212** controls each unit such that the display unit **206** functions as an electronic viewfinder (EVF) by, for example, continuously executing moving image recording, generation of the image data for display, and displaying in the display unit **206** based on the image data for display.

[0070] In step S**203**, the camera control unit **212** determines whether autofocus is active. The camera control unit **212** executes step S**204** if autofocus is set to be active through a menu screen or the lens operation unit **107**, and executes step S**205** if autofocus is set to be inactive (manual focus).

[0071] In step S**205**, the camera control unit **212** sets a "in-focus" flag stored in the memory circuit **215** or the SDRAM **209**, for example, to "off" (e.g., 0), and executes step S**203** again.

[0072] In step S**204**, the camera control unit **212** determines whether the "in-focus" flag is on (e.g., 1). If the "in-focus" flag is on, there is no need to perform AF processing, and thus the camera control unit **212** skips step S**206** and executes step S**203**. On the other hand, if the "in-focus" flag is off, the camera control unit **212** executes AF processing in step S**206**.

[0073] In this manner, in step S**203** to step S**206**, for each control period, the camera control unit **212** executes AF processing when autofocus is set to active and the camera is not in the in-focus state.

[0074] The AF processing performed in step S**206** of FIG. **2** will be described next in further detail with reference to the flowchart in FIG. **4**.

[0075] In step S**402**, the camera control unit **212** obtains a lens drive speed setting from the ROM **210**, for example. The lens drive speed setting can be set by the user by operating a menu screen using the camera operation unit **213**, for example. In later processing, the drive speed of the focus lens is determined based on the lens drive speed setting.

[0076] In step S**403**, the camera control unit **212** obtains the defocus amount by causing the AF signal processing unit **204** to detect the amount of image shift for a main subject region. The main subject region may be a focus detection region specified by the user, or may be a region, in the subject region detected by the subject detection unit **2121**, having a position, size, or the like that meet predetermined conditions.

[0077] Subject tracking processing is realized by searching the main subject region over a plurality of frames of a moving image. The following will describe AF processing in which the main subject region is used as the focus detection region, and the focus lens is driven to bring the main subject region into focus.

[0078] In step S**404**, the camera control unit **212** calculates a curve expressing focus lens drive characteristics serving as a reference (a base curve) based on the defocus amount calculated for the main subject region.

[0079] FIG. **5** is a flowchart pertaining to the base curve calculation processing in step S**404**.

[0080] In step S**502**, the camera control unit **212** determines whether the reliability of the defocus amount of the main subject is at least a predetermined value. This determination may be made by comparing a reliability obtained from the AF signal processing unit **204** as the reliability of the amount of image shift used to calculate the defocus amount with the predetermined value. The camera control unit **212** executes step S**503** if the reliability of the defocus amount is determined to be at least the predetermined value, and ends the base curve calculation processing if the reliability of the amount of image shift is determined not to be at least the predetermined value.

[0081] In step S**503**, the camera control unit **212** calculates the base curve based on the defocus amount calculated in step S**402**. The camera control unit **212** calculates the base curve based on reference drive characteristics stored in the memory circuit **215** and the defocus amount calculated in step S**402**. The base curve indicates how to drive the focus lens in each control period, from the current position of the focus lens until the focus lens reaches the in-focus position.

[0082] FIG. **6** is a diagram illustrating an example of a base curve, and indicates a part corresponding to a deceleration period (described later). The horizontal axis represents time, and the vertical axis represents the defocus amount. The upper-left is the origin, and corresponds to a defocus amount of 0 and a drive start time. Note that the defocus amount is converted according to the focus lens position, and the vertical axis can therefore be considered a relative lens position taking the in-focus position as a base point. Note that the defocus amount is assumed to be an absolute value.

[0083] Fδ in the figure indicates a focus range (depth of focus). F represents the aperture value, and δ represents the permissible circle of confusion diameter. The lens is in the in-focus state in a range of Fδ centered on the focus lens position where the defocus amount is 0. Here, the signs indicate the forward side and the back side. A focus lens position **604** corresponding to Fδ is represented by CPT.

[0084] A base curve **602** is designed such that the focus lens arrives at the in-focus position after progressing through an acceleration period, a constant speed period, and a deceleration period. The shape of the base curve **602** changes the manner in which the focus condition changes in response to movement of the focus lens, and thus the visual effects imparted on moving images differ. As such, reference drive characteristics for each visual effect are stored in the memory circuit **215**.

[0085] Here, the calculation of a base curve having a longer deceleration period, which has the effect of slowly switching the subject in focus, will be described as an example.

[0086] Specifically, this base curve is as follows:

[0087] accelerated driving to reach a predetermined speed in a specified period (an acceleration period)

[0088] driving at a constant speed up to a position **603** (CPO) 100 Fδ from the in-focus position (a constant speed period)

[0089] decelerated driving from the position **603** and stopping at the in-focus position (a deceleration period)

Note that the conditions for switching between each period may be changed.

[0090] Of the reference drive characteristics stored in the memory circuit **215**, the camera control unit **212** reads out the reference drive characteristics that produce the corresponding effect. The base curve can then be calculated by scaling the reference drive characteristics according to the current defocus amount. Note that this method is merely an example, and the base curve may be calculated through another method.

[0091] As described above, FIG. **6** illustrates a part of the base curve **602** corresponding to the deceleration period. The slope of the base curve indicates the drive speed of the focus lens. Additionally, the vertical straight lines at equal intervals indicate the control period of the focus lens.

[0092] If it is possible to drive the focus lens to a target position (the in-focus position) along the base curve while keeping the drive speed at at least the minimum speed that can be realized by the speed control that can be specified (the minimum drive speed), the focus lens can be driven while adjusting the drive speed to follow the base curve. However, if the base curve has characteristics where the focus condition (defocus amount) changes gradually with decreased distance from the in-focus position, there will be a section where the speed cannot be kept at at least the minimum drive speed (a fine-driving section). In the fine-driving section, it is necessary to set a target position distanced from the current position by the minimum drive amount, and then repeatedly drive the focus lens by the minimum drive amount and stop the driving.

[0093] A mode in which the focus lens is not stopped until the final target position, and the focus lens is driven while adjusting the drive speed, will be called a "speed control mode". When driving the focus lens according to the base curve, the driving can be performed in the speed control mode everywhere except the fine-driving section. On the other hand, a mode in which the focus lens is driven to the final target position while repeatedly driving the focus lens at the minimum drive amount and stopping the driving will be called a "position control mode". When driving the focus lens according to the base curve, it is necessary to drive the focus lens in the position control mode in the fine-driving section.

[0094] In the example of the deceleration period illustrated in FIG. **6**, it is assumed that the driving continues at the minimum drive amount from the position **603** (CPO) while reducing the drive speed, and that the drive speed reaches the minimum drive speed at time T**0**. In other words, the driving is in the speed control mode until time T**0**. On the other hand, the section from time T**0** onward is the fine-driving section, and the driving therefore transitions to the position control mode. At time T**1**, the focus lens reaches a position **604** at a boundary of the focus range, and at time T**2**, furthermore reaches the in-focus position, where the driving stops. Although the focus lens is driven until reaching the in-focus position in this example, it should be noted that the driving may be stopped at any time after time T**1**, which is when the focus lens enters the focus range.

[0095] When the base curve is calculated in step S**503**, the camera control unit **212** stores the data of the base curve in, for example, the memory circuit **215** or the SDRAM **209**, and ends the base curve calculation processing.

[0096] Returning to FIG. **4**, in step S**405**, the camera control unit **212** performs focus lens drive mode determination processing. The "drive mode" is an operation mode pertaining to the drive speed, the target position, and driving timing of the focus lens. The camera control unit **212** determines the drive mode, among the plurality of drive modes, with which to drive the focus lens.

[0097] In step S**406**, the camera control unit **212** calculates, based on the base curve, control characteristics for actually controlling the driving of the focus lens according to the drive mode determined in step S**405**, and determines the drive speed, the target position, and the driving timing. The processing of step S**405** and S**406** will be described later in detail.

[0098] In step S**407**, the camera control unit **212** performs the drive control processing. The drive control processing performed in step S**407** will be described in detail with reference to the flowchart in FIG. **7**.

[0099] In step S**702**, the camera control unit **212** determines whether the defocus amount (absolute value) of the main subject obtained in step S**403** is at least a predetermined value. The camera control unit **212** executes step S**704** if the defocus amount is determined to be less than or equal to the predetermined value, and executes step S**703** if not. Here, the predetermined value is, for example, a defocus amount corresponding to Fδ.

[0100] In step S**704**, the camera control unit **212** sets the "in-focus" flag stored in, for example, the SDRAM **209** to "on" (1) and ends the drive control processing. This is because if the main subject is in an in-focus state, there is no need to drive the focus lens.

[0101] In step S**703**, the camera control unit **212** changes the "in-focus" flag to "off" (0), and executes step S**705**.

[0102] In step S**705**, the camera control unit **212** determines whether a lens control flag, which is stored in, for example, the SDRAM **209**, is on (1). The camera control unit **212** executes step S**706** if the lens control flag is determined to be on, and ends the drive control processing if not. If the lens control flag is not on, i.e., is off, the focus lens control is not performed.

[0103] In step S**706**, the camera control unit **212** transmits, to the lens control unit **106**, a lens drive command including the drive speed and the target position determined through step S**406**, and ends the drive control processing. Having received the lens drive command, the lens control unit **106** controls the focus lens drive unit **105** according to the drive speed and the target position included in the command, and drives the focus lens **103**. This ends the AF processing illustrated in FIG. **4**. The AF processing steps S**401** to S**408** are repeatedly executed every control period.

[0104] The drive mode determination processing in step S**405** will be described in detail next with reference to the flowcharts in FIGS. **8**A and **8**B.

[0105] In step S**802**, the camera control unit **212** determines whether the reliability of the defocus amount of the main subject is at least a predetermined value. Like step S**502**, this determination may be made by comparing a reliability obtained from the AF signal processing unit **204** as the reliability of the amount of image shift used to calculate the defocus amount with the predetermined value. The magnitude of the predetermined value may be the same as in step S**502**, or different. The camera control unit **212** executes step S**804** if the reliability of the defocus amount is determined to be at least the predetermined value, and executes step S**803** if not.

[0106] In step S**803**, the camera control unit **212** determines a drive mode A for driving the focus lens to a position at which a defocus amount having a high reliability can be obtained, and then executes step S**814**.

[0107] In step S**814**, the camera control unit **212** sets the lens control flag to "on" and ends the drive mode determination processing.

[0108] In step S**804**, the camera control unit **212** obtains the base curve calculated in step S**404** from the memory circuit **215** or the SDRAM **209**, and then executes step S**805**.

[0109] In step S**805**, the camera control unit **212** determines whether the minimum drive amount of the focus lens is at least a predetermined value (e.g., a number of pulses corresponding to 0.5 Fδ). F may be, for example, the aperture value currently set, and δ may be, for example, the pixel pitch of the image sensor **201**. Here, the minimum drive amount may be one of the aforementioned DS**0** and DS**1** (e.g., the greater of the two).

[0110] If the minimum drive amount is determined not to be at least the predetermined value, the camera control unit **212** executes step S**806**. A lens unit **10** in which the minimum drive amount is less than the predetermined value is considered to be suitable for fine driving through the position control mode. Accordingly, in step S**806**, the camera control unit **212** determines a drive mode B suitable for a lens unit which itself is suitable for fine driving.

[0111] In step S**814**, the camera control unit **212** sets the lens control flag to "on" and ends the drive mode determination processing.

[0112] On the other hand, if it is determined in step S**805** that the minimum drive amount is at least the predetermined value, the camera control unit **212** executes step S**807**. A lens unit **10** in which the minimum drive amount is at least the predetermined value is considered not to be suitable for fine driving through the position control mode. Accordingly, the camera control unit **212** executes step S**807** and the subsequent steps, and determines a drive mode B suitable for a lens unit **10** which itself is not suitable for fine driving.

[0113] In step S**807**, the camera control unit **212** calculates an ideal in-focus time for a case where the focus lens is driven using the base curve obtained in step S**804**. Here, the "ideal in-focus time" is a time period it takes for the focus lens to reach the in-focus position from when the position control mode is started, when the focus lens is driven according to the base curve. This corresponds to the length of time from time T**0** to time T**2** (the difference between time T**2** and time T**0**) in the example in FIG. **6**.

[0114] The processing of steps S**808** to S**811** will be described with reference to FIG. **13**. FIG. **13** illustrates the deceleration period in a base curve **1301**, in the same manner as in FIG. **6**. Note that times T**0** to T**4** in FIG. **13** do not correspond to FIG. **6**.

[0115] In step S**808**, the camera control unit **212** determines a maximum time difference permitted for the ideal in-focus time. Here, the maximum time difference is a difference between the ideal in-focus time and a minimum in-focus time that is a minimum time with which the focus lens can be driven to the in-focus position without any noticeable visual difference against the case in which the focus lens is driven to the in-focus position with the ideal in-focus time. This can be obtained experimentally using the ideal in-focus time as a reference, for example.

[0116] For example, in the example illustrated in FIG. **13**, the ideal in-focus time corresponds to the length from time T**1** to time T**4** (T**4**−T**1**). On the other hand, the maximum time difference can be obtained as a predetermined percentage of (T**4**−T**1**). In FIG. **13**, a maximum time difference **1302** is (T**4**−T**3**). Here, to avoid a situation in which the time required to in-focus is later than the ideal in-focus time, the longest in-focus time with which the focus lens can be driven to the in-focus position without any noticeable visual difference against the case in which the focus lens is driven to the in-focus position with the ideal in-focus time is not taken into account.

[0117] Next, in step S**809**, the camera control unit **212** calculates the time required to reach the in-focus position from time T**1** when the focus lens **103** is driven at the minimum speed with the in-focus position as a target, while remaining in a speed-limited mode, even after passing time T**1**, where the mode should be switched to the position control mode. This corresponds to the length from time T**1** to time T**2** in FIG. **13** (T**2**−T**1**).

[0118] In step S**810**, the camera control unit **212** determines whether a in-focus time T**2**, when driving the focus lens at the minimum speed while remaining in the speed control mode even after time T**1** where the mode should be switched to the position control mode, is within a permissible range for the in-focus time under ideal control. Specifically, if the sum of the time obtained in step S**809** (T**2**−T**1**) and the maximum time difference found in step S**808** (T**4**−T**3**) is at least the ideal in-focus time (T**4**−T**1**), the in-focus time T**2** is determined by within the permissible range. Note that the in-focus time T**2** may be determined to be within the permissible range when a difference between the time obtained in step S**809** and the ideal in-focus time is less than the maximum time difference obtained in step S**808**.

[0119] The camera control unit **212** executes step S**811** if it is determined that the difference from the in-focus time when performing ideal driving according to the base curve is within the permissible range even when driving to the in-focus position in the speed control mode, and executes step S**812** if not.

[0120] In step S**811**, the camera control unit **212** determines a drive mode C.

[0121] In step S**814**, the camera control unit **212** sets the lens control flag to "on" and ends the drive mode determination processing.

[0122] The processing of step S**812** will be described with reference to FIG. **15**. In step S**812**, the camera control unit **212** determines whether an in-focus time when the focus lens is driven while remaining at the minimum speed from the start of the deceleration period is within the permissible range for the in-focus time under ideal control. A maximum time difference **1504** defined by the permissible range uses the value determined in step S**808**, in the same manner as in step S**810**. However, for descriptive purposes, this is shorted than the maximum time difference **1302** illustrated in FIG. **13**.

[0123] FIG. **15** illustrates the deceleration period in a base curve **1501**. Time T**0** is the start time of the deceleration period. An example is illustrated in which the in-focus time T**2**, when continuing to drive at the minimum drive speed remaining in the speed control mode even after time T**1** where it is necessary to switch to the position control mode, is not within the permissible range for a in-focus time T**5** under ideal control (time T**3**−T**5**). In such a case, in step S**812**, the camera control unit **212** examines whether changing the start time of the driving at the minimum drive speed to time T**0** will bring the in-focus time into the permissible range (or whether a difference from the in-focus time will be within the permissible range).

[0124] **1503** indicates a lens trajectory when the starting driving at the minimum drive speed from the start time T**0** of the deceleration period of the base curve **1501**. In this case, the focus lens reaches the in-focus position at time T**5**. Time T**5** is within the permissible range (time T**3** to time T**6**) of the in-focus time T**6** under ideal control according to the base curve.

[0125] In this manner, if an in-focus time within the permissible range can be achieved by starting driving at the minimum drive speed from the start time T**0** of the deceleration period in the base curve **1501**, it is thought that characteristics similar to the base curve **1501** can be realized while maintaining the speed control mode. The camera control unit **212** executes step S**813** if it is determined that changing the start time of the driving at the minimum drive speed to time T**0** will make it possible to bring the in-focus time into the permissible range.

[0126] In step S**813**, the camera control unit **212** determines a drive mode D.

[0127] In step S**814**, the camera control unit **212** sets the lens control flag to "on" and ends the drive mode determination processing.

[0128] On the other hand, if an in-focus time within the permissible range cannot be achieved even when starting driving at the minimum drive speed from the start time T**0** of the deceleration period in the base curve **1501**, it is thought that characteristics similar to the base curve **1501** cannot be realized while maintaining the speed control mode. The camera control unit **212** executes step S**815** if it is not determined that changing the start time of the driving at the minimum drive speed to time T**0** will make it possible to bring the in-focus time into the permissible range.

[0129] In step S**815**, the camera control unit **212** determines a drive mode E, and ends the drive mode determination processing.

[0130] The focus trajectory calculation processing in step S**406** will be described in detail next with reference to the flowchart in FIG. **9**.

[0131] In step S**902**, the camera control unit **212** obtains a base curve in the same manner as in step S**804**. If the base curve obtained in step S**804** remains, that base curve may be used.

[0132] In step S**903**, the camera control unit **212** obtains the minimum drive amount DS and the minimum drive speed from the lens information obtained in the startup processing. The minimum drive amount DS is assumed to be one of DS**0**, obtained from the lens unit, and DS**1**, obtained in the lens reset operation (e.g., the greater of the two).

[0133] In step S**904**, the camera control unit **212** obtains the defocus amount for the main subject calculated in step S**403**. This may be calculated anew in step S**904**.

[0134] In step S**905**, the camera control unit **212** finds the drive mode determined in the drive mode determination processing. The camera control unit **212** executes step S**906** if the drive mode A is determined; step S**907**, if the drive mode B is determined; step S**908**, if the drive mode C is determined; step S**909**, if the drive mode D is determined; and step S**910**, if the drive mode E is determined.

[0135] Drive Mode A

[0136] The processing of step S**906** will be described with reference to the flowchart illustrated in FIG. **10**. The drive mode A is determined when the reliability of the defocus amount of the main subject is less than the predetermined value. Accordingly, in the drive mode A, operations are performed according to the reliability of the defocus direction.

[0137] In step S**1002**, the camera control unit **212** determines whether the reliability of the defocus direction detected for the main subject is at least a predetermined value. The reliability of the defocus direction is communicated to the camera control unit **212** from the AF signal processing unit **204** along with the reliability of the amount of image shift. The camera control unit **212** executes step S**1003** if the reliability of the defocus direction is determined to be at least the predetermined value (is reliable), and executes step S**1004** if not.

[0138] In step S**1003**, of both ends of the drivable range of the lens, the camera control unit **212** sets the end of the defocus direction as the target position, and ends the processing of the drive mode A. If the reliability of the defocus direction is high, the in-focus position is searched for by driving the focus lens in the direction that increases the reliability.

[0139] In step S**1004**, of both ends of the drivable range of the lens, the camera control unit **212** sets the end at a longer distance from the current position of the focus lens (the further end) as the target position, and ends the processing of the drive mode A. If the reliability of the defocus direction is not high, an in-focus position having a high reliability is searched for over a broader range.

[0140] Drive Mode B

[0141] The processing of step S**907** will be described with reference to the flowchart illustrated in FIG. **11**. The drive mode B is determined for a lens unit considered to be suitable for fine driving. Accordingly, in the drive mode B, the focus lens is driven such that the drive characteristics indicated by the base curve are realized.

[0142] In step S**1102**, the camera control unit **212** sets the drive speed and the target position according to the base curve, and ends the drive mode B processing.

[0143] Drive Mode C

[0144] The processing of step S**908** will be described with reference to the flowchart illustrated in FIG. **12**. The drive mode C is determined for a lens unit considered to be unsuitable for fine driving. Accordingly, in the drive mode C, the focus lens is continually driven only in the speed control mode (while staying at at least the minimum drive speed), while prioritizing the drive characteristics of the base curve.

[0145] In step S**1202**, the camera control unit **212** sets the drive speed and the target position according to the base curve.

[0146] In step S**1203**, the camera control unit **212** determines whether the drive speed set in step S**1202** is less than the minimum drive speed, executes step S**1204** if so, and ends the drive mode C processing if not.

[0147] In step S**1204**, the camera control unit **212** changes the drive speed to the minimum drive speed. The target position remains unchanged at the in-focus position. Through this, the speed control mode is maintained even after time T**1** in FIG. **13**, and the focus lens is driven as indicated by the solid line. The camera control unit **212** then ends the processing in the drive mode C.

[0148] Drive Mode D

[0149] The processing of step S**909** will be described with reference to the flowchart illustrated in FIG. **14**. The drive mode D is determined when, for a lens unit considered to be unsuitable for fine driving, the difference from the ideal in-focus time does not fall within the permissible range (i.e., exceeds the permissible range) in the drive mode C. Accordingly, in the drive mode D, the focus lens is driven only in the speed control mode (while staying at at least the minimum drive speed) by changing the drive characteristics of the deceleration period in the base curve.

[0150] In step S**1402**, the camera control unit **212** sets a target in-focus time. The drive mode D is determined when an in-focus time within the permissible range can be realized with respect to the ideal in-focus time when the focus lens is driven at the minimum drive speed from the starting point of the deceleration period in step S812.

[0151] In the example of FIG. 15, this corresponds to the in-focus time T5, when the focus lens is driven at the minimum drive speed from time T0, being within the permissible range with respect to the ideal in-focus time T6 (time T3 to T6). If instead of linear drive characteristics (lens trajectory) 1503 that drives at the minimum drive speed from time T0, the drive characteristics are transformed to be similar to the base curve 1501, the in-focus time will be earlier than time T5. Accordingly, the camera control unit 212 can set the target in-focus time to be within the range from time T3 to time T5. Assume, as an example, that time T4 is set as the target in-focus time.

[0152] In step S813, the camera control unit 212 changes the drive characteristics of the deceleration period in the base curve. For example, the camera control unit 212 sets a given time (Tx) from the start time T0 of the deceleration period to the target in-focus time T4 as the start time of constant speed driving at the minimum drive speed. Then, taking a section from time T0 to time Tx as a deceleration drive section down to the minimum drive speed, the camera control unit 212 sets drive characteristics that take the section from time Tx to time T4 as a constant speed driving section at the minimum drive speed. 1502 in FIG. 15 indicates an example of the drive characteristics after the change.

[0153] Note that the drive characteristics are only changed in the deceleration period of the base curve, and the base curve is maintained in the acceleration period and the constant speed period therebefore. Additionally, time Tx may also be set to time T0, in which case the drive speed is faster than the minimum drive speed. Furthermore, the target in-focus time may be set to T5, and constant speed driving may be performed at the minimum drive speed from time T0 (using the drive characteristics indicated by 1503).

[0154] In step S1404, the camera control unit 212 sets the drive speed and the target position according to the post-change drive characteristics, and ends the drive mode D processing.

[0155] Drive Mode E

[0156] The processing of step S910 will be described with reference to the flowcharts illustrated in FIGS. 16A and 16B. The drive mode E is determined when, for a lens unit considered to be unsuitable for fine driving, the difference from the ideal in-focus time does not fall within the permissible range (i.e., exceeds the permissible range) in the drive mode C and the drive mode D. Accordingly, in the drive mode E, driving at less than the minimum drive speed in the speed control mode is realized simulatively by controlling the interval at which the lens drive command is transmitted.

[0157] In step S1602, the camera control unit 212 obtains the lens information. Note that the lens information obtained in the startup processing may be used, or the lens information may be obtained again. The minimum drive amount DS is assumed to be one of DS0 and DS1 (e.g., the greater of the two). Here, the minimum drive speed of the focus lens is assumed to be the same as the image plane speed (movement speed of the image formation surface), which is 10 mm/sec. Furthermore, the control period is assumed to be 1/60, synchronized to the moving image framerate.

[0158] Note that for the minimum drive amount DS, the camera control unit 212 converts a value in units of the drive pulse of the focus lens into a value in units of the depth of focus Fδ. Specifically, the physical drive amount expressed as a number of pulses is converted into an amount of movement of the image plane using the sensitivity of the lens image plane, and is then divided by the current aperture value (F2) and the allowable circle of confusion diameter to calculate a value expressed as DSFδ. DSFδ is an indicator of the minimum drive amount required to move the focus lens.

[0159] In step S1603, the camera control unit 212 obtains a base curve. Abase curve already obtained from other processing may be used again.

[0160] In step S1604, the camera control unit 212 sets the drive speed and the target position according to the base curve.

[0161] In step S1605, the camera control unit 212 determines whether the drive speed set in step S1604 is less than the minimum drive speed, executes step S1606 if so, and executes step S1617 if not.

[0162] In step S1617, the camera control unit 212 sets the lens control flag to "on" and then executes step S1618.

[0163] In step S1618, the camera control unit 212 sets the standby count (described later), which is a variable stored in the SDRAM 209, for example, to 0, and ends the drive mode E processing.

[0164] In steps S1606 to S1609, the camera control unit 212 calculates the drive characteristics for the fine-driving section. The fine-driving section is a section in which drive speed less than the minimum drive speed is required in the speed control mode, and which conventionally is driven in the position control mode.

[0165] Focus trajectory calculation processing in the fine-driving section will be described with reference to FIG. 17.

[0166] FIG. 17 is a diagram illustrating the processing from step S1606 to step S1609, with respect to the base curve illustrated in FIG. 6. In a, CP2 indicates a defocus amount corresponding to the depth of focus Fδ. The minimum drive amount DS is assumed to be 0.7 Fδ. A dotted line 1702 indicates a defocus amount corresponding to 0.7 Fδ. Additionally, b indicates the lens drive mode, and c indicates the drive speed per control period. Until time T0, the focus lens is driven while decelerating in the speed control mode, and from time T0, the focus lens is driven in the position control mode at the minimum drive speed.

[0167] In step S1606, the camera control unit 212 calculates a lens position PL immediately before the in-focus state. The position PL is the lens position when the drive command is last transmitted. Here, a lens position corresponding to a defocus amount (0.8 Fδ), which is obtained by adding an offset amount of 0.1 Fδ to the minimum drive amount DS, is taken as the last lens position PL. Accordingly, the camera control unit 212 calculates a point where the defocus amount is 0.8 Fδ at the timing of the control period, on or near the base curve. 1703 indicates the calculated position PL.

[0168] In step S1607, the camera control unit 212 sets, based on the base curve, drive characteristics 1701 passing through the position PL.

[0169] In step S1608, the camera control unit 212 calculates an amount of movement per control period. In FIG. 17, a lens control timing indicated in d corresponds to the vertical lines in a. The control timing corresponds to the start time of the control period, and the camera control unit 212 normally transmits a drive command to the lens control unit **106** periodically according to the control timing. A difference in the vertical axis coordinates of the intersection of the two adjacent vertical lines and the control characteristics **1701** indicates the amount of movement of the focus lens in the control period defined by the two vertical lines.

[0170] In steps S**1609** to S**1616**, processing for modifying the control timing is performed by excluding control timings in control periods where the amount of movement of the focus lens is lower than the minimum drive amount DS.

[0171] In the control characteristics **1701**, a control timing one previous to the control timing corresponding to a position **1703** is a position **1708**. However, the amount of movement from the position **1708** to **1703** is less than the minimum drive amount DS, and thus the control timing corresponding to the position **1708** is excluded. Furthermore, the amount of movement from a position **1709**, which is one period previous, to **1703** is of course less than the minimum drive amount DS, and thus the control timing corresponding to the position **1709** is excluded as well.

[0172] The amount of movement from a position **1704**, which is yet another period previous, to **1703** is greater than the minimum drive amount DS, and thus the control timing corresponding to the position **1704** is maintained. Likewise, the control timings corresponding to positions **1706** and **1707** are maintained, but the control timing between positions **1704** and **1705**, and the control timing between positions **1705** and **1706**, are excluded.

[0173] The control timing modified in this manner is indicated in e of FIG. **17**. In this manner, by thinning out the control timings of control periods in which the drive amount is less than the minimum drive amount DS, a drive amount that is greater than the minimum drive amount DS can be specified at each control timing. The camera control unit **212** does not transmit lens drive commands to the lens control unit **106** in the control periods in which the control timings have been thinned out.

[0174] The processing of each step will be described hereinafter.

[0175] In step S**1609**, the camera control unit **212** determines whether the standby count is greater than 0, executes step S**1611** if so, and executes step S**1610** if not. The standby count being greater than 0 indicates that the control timing being processed is being thinned out. Accordingly, the camera control unit **212** stops driving the focus lens.

[0176] In step S**1611**, the camera control unit **212** reduces the standby count by **1**.

[0177] In step S**1612**, the camera control unit **212** sets the lens control flag to "off" and ends the drive mode E processing.

[0178] On the other hand, the standby count not being greater than 0 (i.e., being 0) indicates that the control timing being processed is not being thinned out. Accordingly, the camera control unit **212** performs processing for driving the focus lens.

[0179] In step S**1610**, the camera control unit **212** changes the lens control flag to "on" and then executes step S**1613**.

[0180] In step S**1613**, the camera control unit **212** determines whether the amount of movement obtained in step S**1608** is less than the minimum drive amount, executes step S**1614** if so, and ends the drive mode E processing if not.

[0181] If the amount of movement is less than the minimum drive amount, the focus lens is not driven at the control timing being processed, and it is necessary to wait until the control timing when it becomes possible to specify an amount of movement greater than the minimum drive amount. Accordingly, in step S**1614**, the camera control unit **212** sequentially adds the amount of movement of the subsequent control periods to the amount of movement obtained in step S**1608**, and detects the most recent control timing at which the total is at least the minimum drive amount.

[0182] In step S**1615**, the camera control unit **212** sets the drive speed and the target position to be specified for the control timing detected in step S**1614**. The target position is a position distanced from the current position by the amount of movement added in step S**1614**. The drive speed may be the minimum drive speed.

[0183] In step S**1616**, the camera control unit **212** sets the number of control periods to wait until the control timing detected in step S**1614** in the standby count, and ends the drive mode E processing.

[0184] By setting the target position and the drive speed as described above, driving at the minimum drive speed makes it possible to effectively realize driving in which the drive amount per control period is less than the minimum drive amount.

[0185] According to the present embodiment, the drive method is changed according to the focus lens drive characteristics of the lens unit for the fine-driving section, in which it is necessary to drive the focus lens in the position control mode to realize the ideal drive characteristics determined in advance. Specifically, for a lens unit determined to be unsuitable for fine driving of the focus lens, the focus lens is driven in the speed control mode instead of the position control mode for the fine-driving section.

[0186] When driving is performed in position control mode in the fine-driving section, it is necessary to repeatedly drive and stop the focus lens. Accordingly, driving a lens unit that is unsuitable for fine driving in the position control mode will cause a delay in the time until the image comes into focus. On the other hand, in speed control mode, the focus lens is not stopped until the focus lens reaches the in-focus position, which makes it possible to prevent a delay in in-focus time.

[0187] By driving the focus lens in the speed control mode in the fine-driving section, the amount of focus lens movement per unit of time is greater than when driving in the position control mode, resulting in faster focusing than with the ideal drive characteristics. If the difference between the in-focus time when driving in the speed control mode in the fine-driving section and the in-focus time from the ideal drive characteristics exceeds a permissible range, the ideal drive characteristics are changed such that the focus lens can be driven only in the speed control mode, in order to bring the difference in in-focus times within the permissible range. This makes it possible to prevent delays in focusing without greatly changing the visual effect of the moving image.

Second Embodiment

[0188] A second embodiment of the present invention will be described next. The second embodiment is the same as the first embodiment with the exception of the drive mode determination processing (FIGS. **8**A and **8**B), and thus the following descriptions will focus on the differences in the drive mode determination processing.

[0189] FIGS. **18**A and **18**B are flowcharts **4** illustrating the drive mode determination processing according to the present embodiment. Steps carrying out the same processes as those in the first embodiment will be given the same reference signs, and descriptions thereof will be omitted. Additionally, the processing of the determined drive mode may be the same as in the first embodiment, and will therefore not be described.

[0190] In step S**1801**, the camera control unit **212** obtains a fine driving enable flag and a speed control enable flag. These flags may be obtained from the lens unit **10** as lens information, or the type information and the values of these flags may be associated and stored in the ROM **210**, for example, and then obtained by referring to the ROM **210** based on the type information of the mounted lens unit.

[0191] The fine driving enable flag is a flag indicating whether the lens unit is suitable for fine driving. For example, for a lens unit that is not suitable for fine driving, such as, for example, a type of lens unit that uses a DC motor to drive a large focus lens (e.g., a large-format cinema lens), the fine driving enable flag is set to "off".

[0192] The speed control enable flag, for example, is set to "off" for lens units not expected to undergo focus lens driving in the speed control mode (i.e., which does not support a drive command specifying drive speed).

[0193] Steps S**802** to S**804** are the same processing as in the first embodiment.

[0194] After obtaining the base curve in step S**804**, in step S**1803**, the camera control unit **212** determines whether the fine driving enable flag is "on", executes step S**806** if so, and executes step S**1804** if not. A lens unit for which the fine driving enable flag is set to "on" is considered to be capable of driving according to the base curve using the position control mode.

[0195] In step S**1804**, the camera control unit **212** determines whether the speed control enable flag is "on". If the speed control enable flag is determined to be "on", driving in the speed control mode is not possible, and thus the camera control unit **212** executes step S**807**. The processing after step S**807** is the same as in the first embodiment.

[0196] On the other hand, if the speed control enable flag is determined not to be "on", drive modes D and E, which use the speed control mode, cannot be applied, and thus the camera control unit **212** executes step S**806**.

[0197] In step S**805**, the camera control unit **212** determines whether the minimum drive amount DS is at least a predetermined value (at least 0.5 Fδ).

[0198] If the minimum drive amount is determined not to be at least the predetermined value, the camera control unit **212** executes step S**1805**. A lens unit **10** in which the minimum drive amount is less than the predetermined value is considered to be suitable for fine driving through the position control mode. Accordingly, in step S**1805**, the camera control unit **212** determines a drive mode B suitable for a lens unit which itself is suitable for fine driving.

[0199] In step S**814**, the camera control unit **212** sets the lens control flag to "on" and ends the drive mode determination processing.

[0200] On the other hand, if it is determined in step S**805** that the minimum drive amount is at least the predetermined value, the camera control unit **212** executes step S**1806**. A lens unit **10** in which the minimum drive amount is at least the predetermined value is considered not to be suitable for fine driving through the position control mode. Accordingly, in step S**1806**, the camera control unit **212** determines the drive mode E, and ends the drive mode determination processing.

[0201] As described above, according to the second embodiment, control is performed using a modified branching of modes. Although the mode branching is implemented according to the fine driving enable flag and the speed control enable flag obtained from the lens in this example, the branching conditions for each mode may be changed as necessary.

Other Embodiments

[0202] The foregoing embodiments have described a configuration in which the defocus amount is detected by the image plane phase difference detection method. However, the present invention can also be applied in a configuration in which a dedicated phase detection sensor is used to detect the defocus amount.

[0203] In addition, in the foregoing embodiments, whether the lens unit is suitable for fine driving was determined based on the magnitude of the minimum drive amount and the fine driving enable flag. However, it is also possible to determine whether a lens unit is suitable for fine driving based on other criteria. The following are possible examples.

[0204] A delay time from when the drive command is transmitted to when the focus lens starts moving (if at least a predetermined time, the lens is not suitable for fine driving).

[0205] A delay time from when the drive command is transmitted to when the focus lens starts moving/a time from when the drive command is transmitted to when the focus lens reaches a specified speed (if at least a predetermined time, the lens is not suitable for fine driving).

[0206] An actual amount of movement from when the drive command is transmitted to when the focus lens reaches a specified speed/an ideal amount of movement from when the drive command is transmitted to when the focus lens reaches a specified speed (if less than a predetermined amount of movement, the lens is not suitable for fine driving).

[0207] Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

[0208] 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.

[0209] This application claims the benefit of Japanese Patent Application No. 2021-050386, filed on Mar. 24, 2021, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A focus adjustment device that controls driving of a focus lens included in a lens unit during moving image shooting, the focus adjustment device comprising one or more processors that execute a program and thereby function as:

an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and

a control unit that controls the driving of the focus lens,

wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

2. The focus adjustment device according to claim **1**,

wherein if the drive pattern has the fine-driving section and it is determined that the lens unit to be suitable for fine driving of the focus lens, the control unit repeatedly executes fine driving of the focus lens in the fine-driving section.

3. The focus adjustment device according to claim **1**,

wherein for the fine-driving section, if a difference between (i) a time at which the focus lens reaches the in-focus position by continuously driving the focus lens at the minimum drive speed and (ii) a time at which the focus lens reaches the in-focus position by driving the focus lens according to the drive pattern exceeds a permissible range set in advance, the control unit changes the drive pattern and continuously drives the focus lens at the minimum drive speed from a point in time based on the drive pattern after the change so that the difference to be within the permissible range.

4. The focus adjustment device according to claim **3**,

wherein if the difference exceeds the permissible range even after changing the drive pattern or if the lens unit does not support a drive command specifying a drive speed of the focus lens, in the fine-driving section, the control unit changes an interval at which the drive command of the focus lens is transmitted such that the focus lens can be driven using a drive command specifying a drive amount that is not less than a minimum drive amount of the focus lens.

5. The focus adjustment device according to claim **4**,

wherein the control unit changes the interval by skipping transmitting the drive command of the focus lens at a control timing, among periodic control timings set in advance, at which an amount of movement of the focus lens until a next control timing is less than the minimum drive amount of the focus lens.

6. The focus adjustment device according to claim **1**,

wherein the control unit determines whether the lens unit is suitable for fine driving based on a minimum drive amount of the focus lens.

7. The focus adjustment device according to claim **6**,

wherein the minimum drive amount is a minimum drive amount obtained from the lens unit.

8. The focus adjustment device according to claim **6**,

wherein the minimum drive amount is a minimum drive amount obtained during a reset operation of the lens unit.

9. The focus adjustment device according to claim **1**,

wherein the control unit determines whether the lens unit is suitable for fine driving based on the information obtained from the lens unit.

10. The focus adjustment device according to claim **9**,

wherein the information is information indicating whether the lens unit is suitable for fine driving, the information being associated with the lens unit in advance.

11. An image capture apparatus comprising:

a defocus amount obtainment unit that obtains a defocus amount of a lens unit that is mounted; and

a focus adjustment device that drives a focus lens included in the lens unit based on the defocus amount,

wherein the focus adjustment device comprising:

an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and

a control unit that controls the driving of the focus lens,

wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

12. A focus adjustment method executed by a focus adjustment device for controlling driving of a focus lens having a lens unit during moving image shooting, the focus adjustment method comprising:

obtaining a drive pattern determined in advance for driving the focus lens to an in-focus position; and

controlling the driving of the focus lens,

wherein when the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and the lens unit is determined not to be suitable for fine driving of the focus lens, the controlling includes continuously driving the focus lens at the minimum drive speed in the fine-driving section.

13. A non-transitory computer-readable medium storing a program that causes a computer to function as a focus adjustment device comprising:

an obtainment unit that obtains a drive pattern determined in advance for driving the focus lens to an in-focus position; and

a control unit that controls the driving of the focus lens,

wherein if the drive pattern has a fine-driving section in which it is necessary to drive the focus lens at a drive speed less than a minimum drive speed set in advance, and it is determined that the lens unit not to be suitable for fine driving of the focus lens, the control unit continuously drives the focus lens at the minimum drive speed in the fine-driving section.

* * * * *