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(54) Control of Television Camera Sensitivity

(57) Sensitivity control of a television camera having a broad dynamic range is carried out by constituting a sensitivity control unit by an iris control unit 11 of a lens system 1, a sensitivity control unit 14 of an image pickup tube 2 and a gain control unit (figure 1, 16 not shown) of an image signal amplification circuit 5.

The sensitivity is controlled, in the case of falling light levels, by first adjusting the iris control 11, once this is at it maximum range the pickup tube control 14 is adjusted until it reaches its maximum level when the gain control unit (16) is operated. In the case of rising light levels the opposite procedure would be enhanced.

FIG. 4

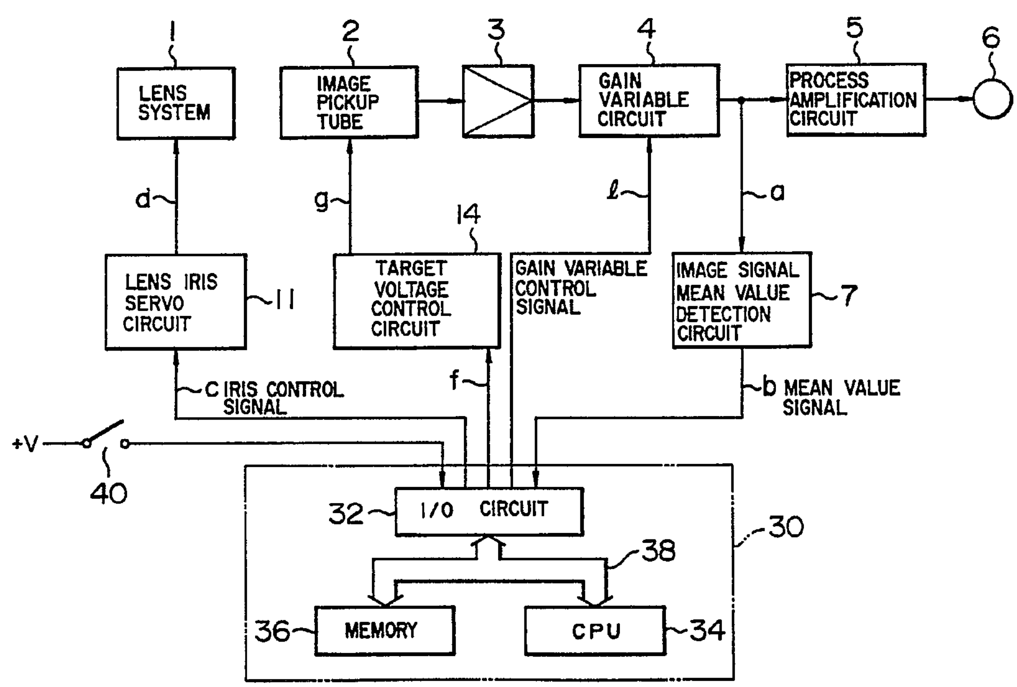

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FIG. 1

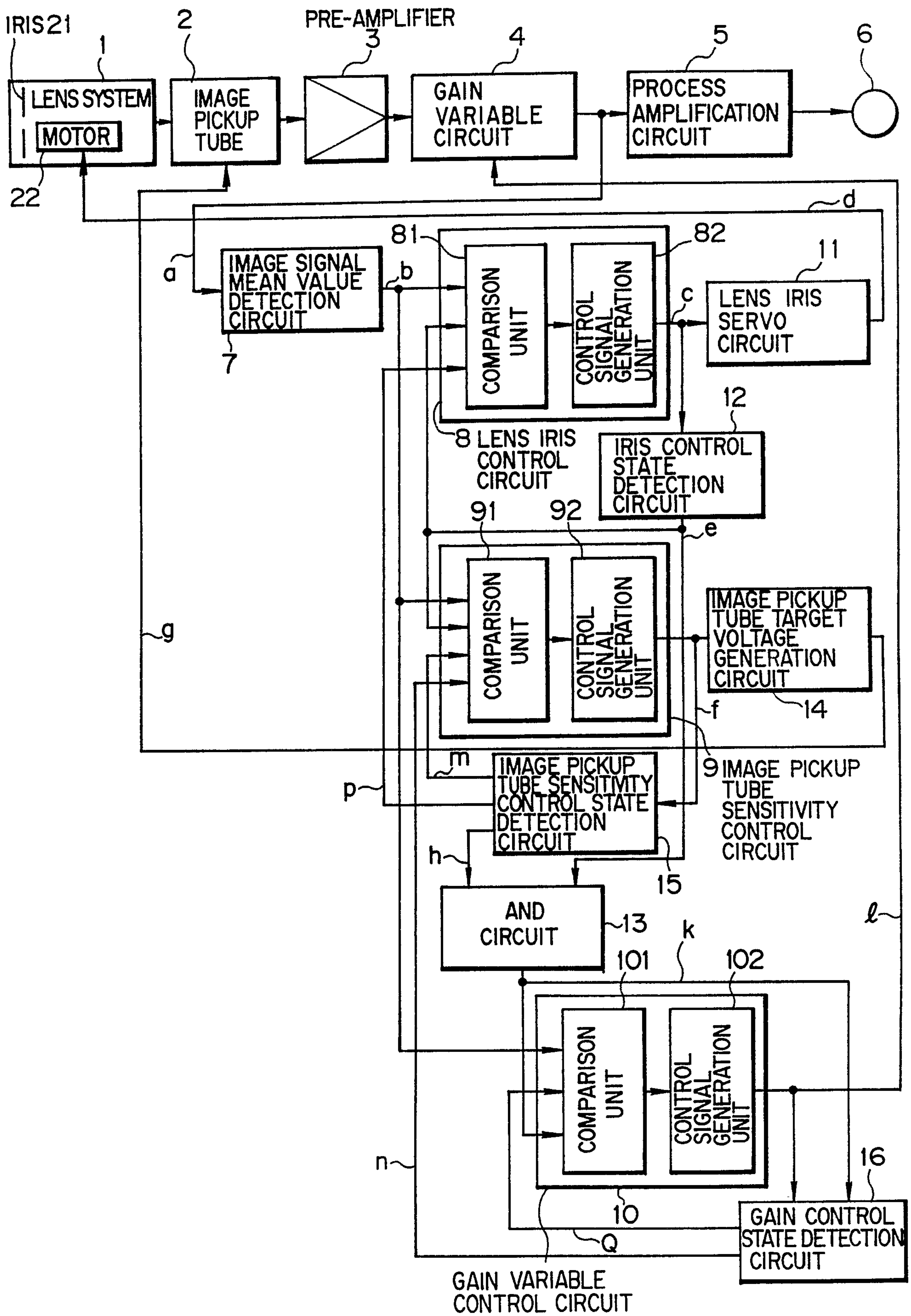

IRIS 21
LENS SYSTEM
MOTOR
22
1
2
IMAGE PICKUP TUBE
PRE-AMPLIFIER
3
4
GAIN VARIABLE CIRCUIT
5
PROCESS AMPLIFICATION CIRCUIT
6
d
a
IMAGE SIGNAL MEAN VALUE DETECTION CIRCUIT
7
b
81
82
COMPARISON UNIT
CONTROL SIGNAL GENERATION UNIT
c
11
LENS IRIS SERVO CIRCUIT
8 LENS IRIS CONTROL CIRCUIT
12
IRIS CONTROL STATE DETECTION CIRCUIT
91
92
e
COMPARISON UNIT
CONTROL SIGNAL GENERATION UNIT
IMAGE PICKUP TUBE TARGET VOLTAGE GENERATION CIRCUIT
14
f
g
9 IMAGE PICKUP TUBE SENSITIVITY CONTROL CIRCUIT
m
p
IMAGE PICKUP TUBE SENSITIVITY CONTROL STATE DETECTION CIRCUIT
15
h
AND CIRCUIT
13
ℓ
k
101
102
COMPARISON UNIT
CONTROL SIGNAL GENERATION UNIT
n
10
16
GAIN CONTROL STATE DETECTION CIRCUIT
Q
GAIN VARIABLE CONTROL CIRCUIT

FIG. 2

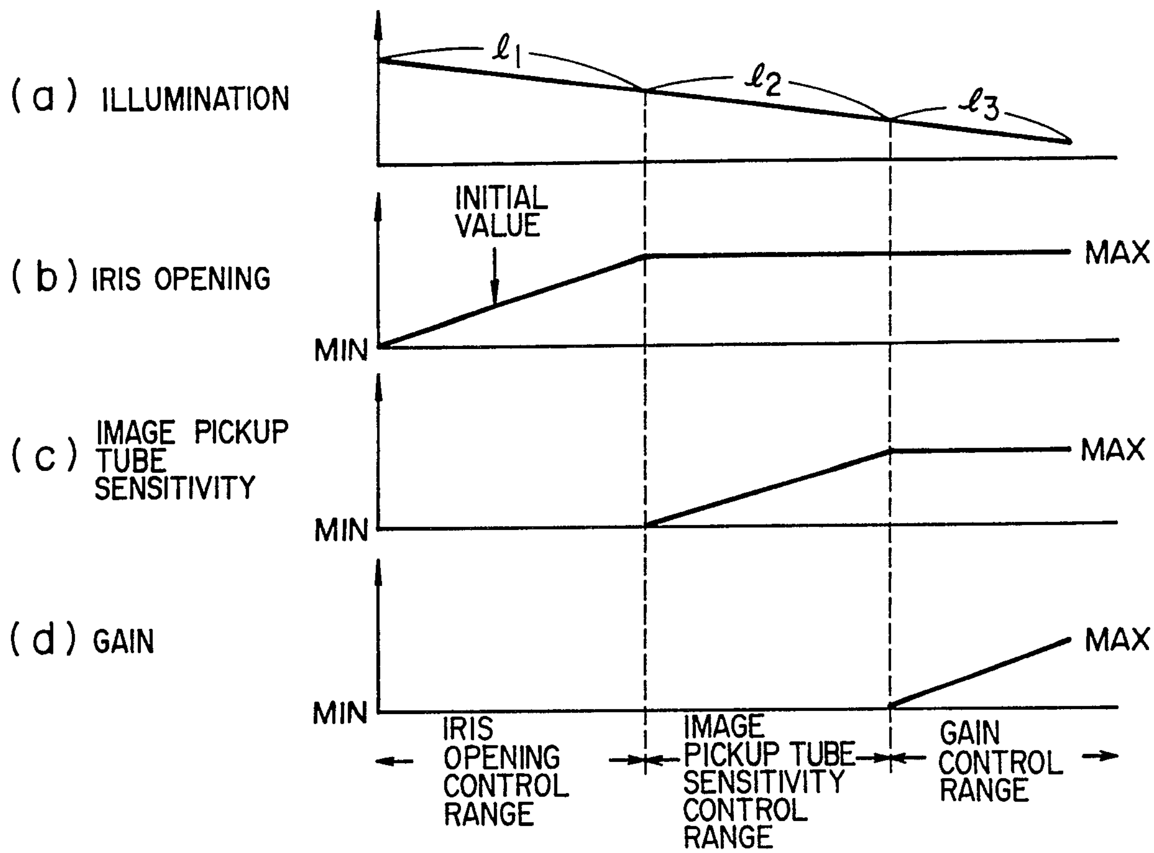

(a) ILLUMINATION
ℓ_1
ℓ_2
ℓ_3
(b) IRIS OPENING
INITIAL VALUE
MAX
MIN
(c) IMAGE PICKUP TUBE SENSITIVITY
MAX
MIN
(d) GAIN
MAX
MIN
IRIS OPENING CONTROL RANGE
IMAGE PICKUP TUBE SENSITIVITY CONTROL RANGE
GAIN CONTROL RANGE

FIG. 3

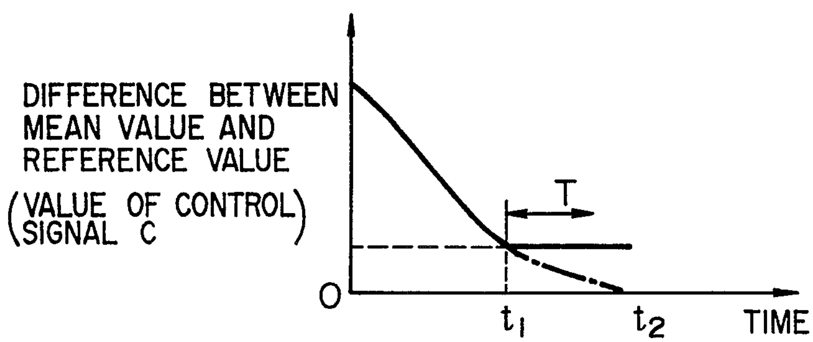
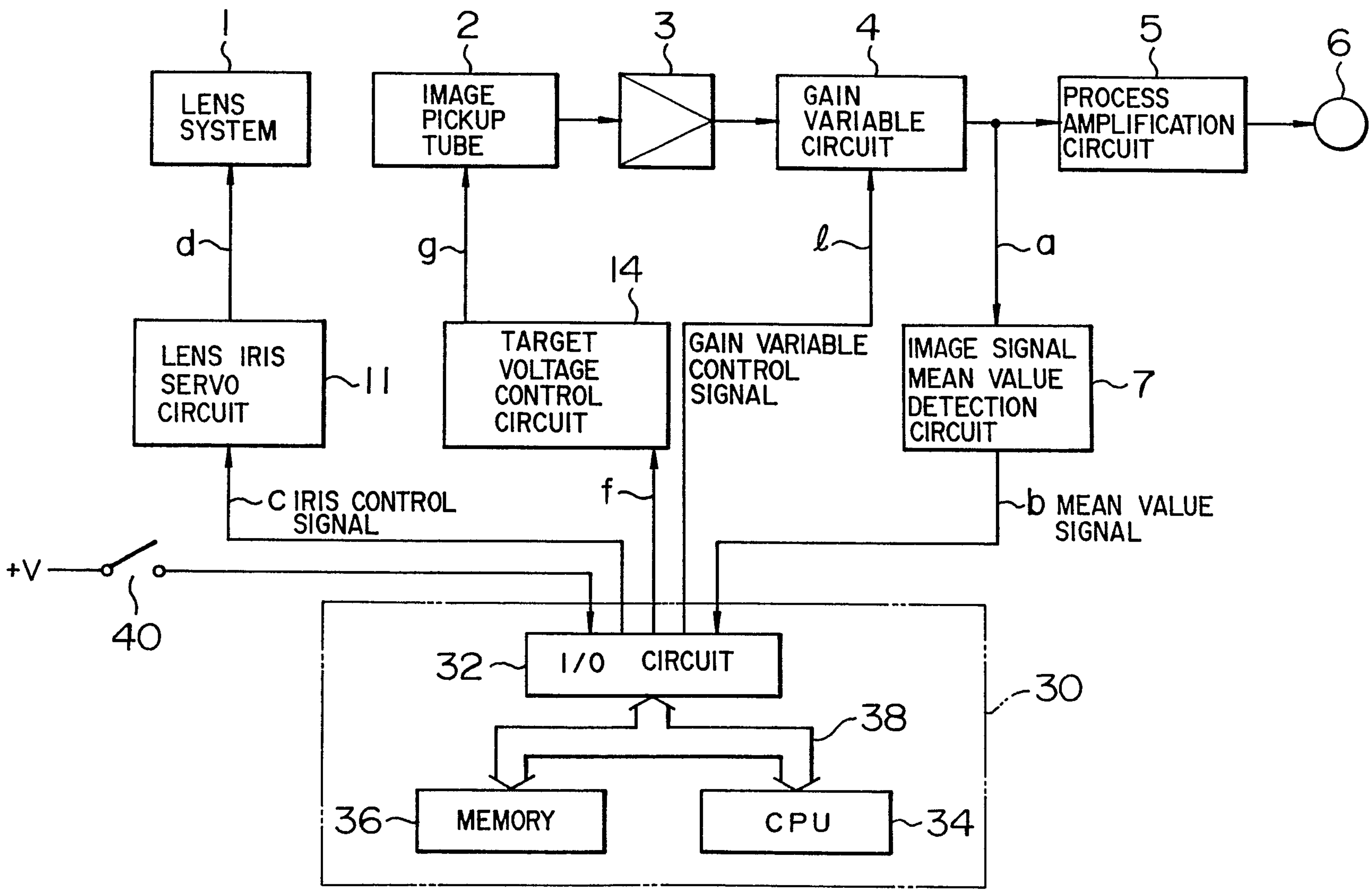
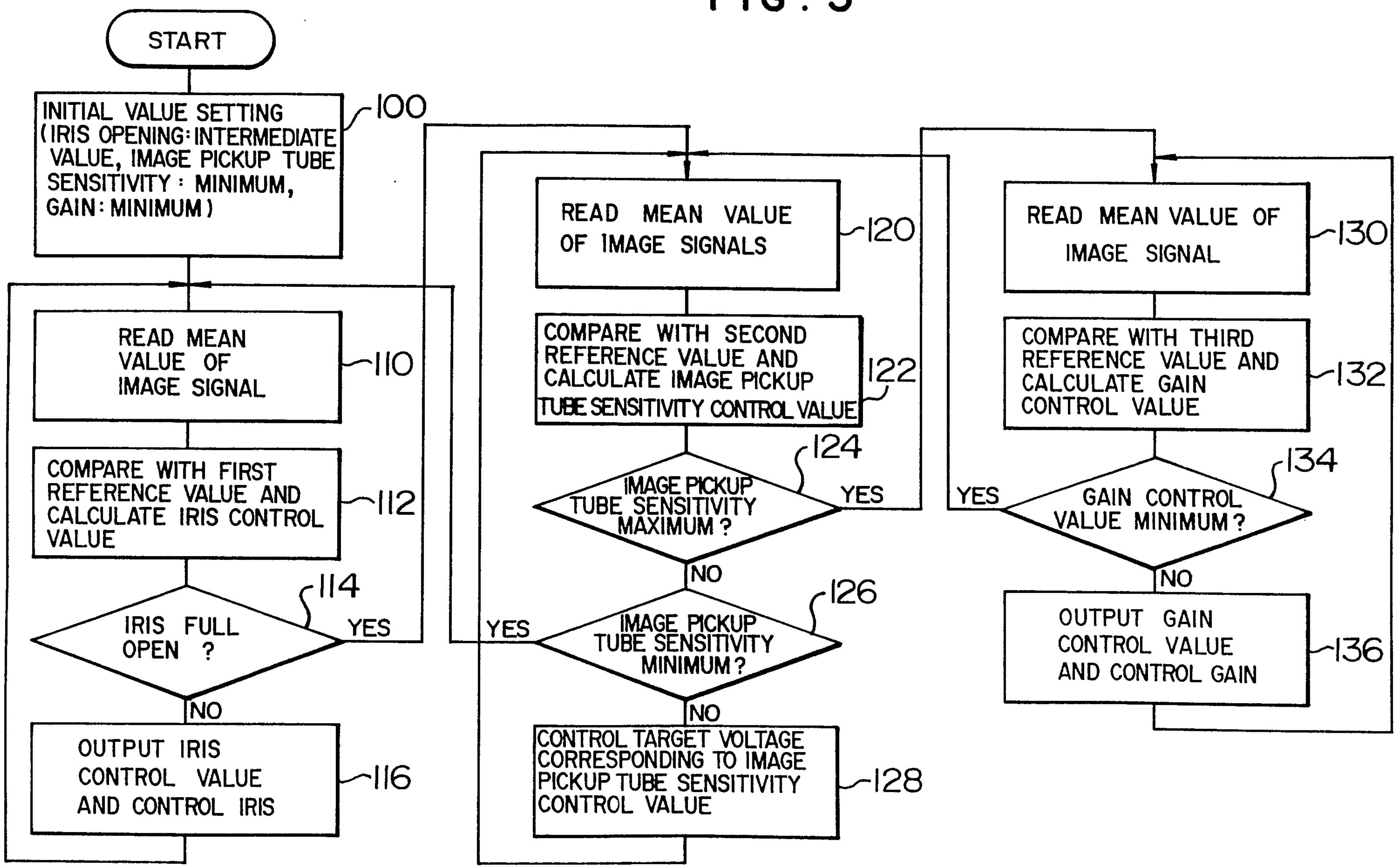

DIFFERENCE BETWEEN MEAN VALUE AND REFERENCE VALUE
(VALUE OF CONTROL SIGNAL C)
T
O
t_1
t_2
TIME

FIG. 4



1
LENS SYSTEM
2
IMAGE PICKUP TUBE
3
4
GAIN VARIABLE CIRCUIT
5
PROCESS AMPLIFICATION CIRCUIT
6
d
g
ℓ
a
14
LENS IRIS SERVO CIRCUIT
11
TARGET VOLTAGE CONTROL CIRCUIT
GAIN VARIABLE CONTROL SIGNAL
IMAGE SIGNAL MEAN VALUE DETECTION CIRCUIT
7
C IRIS CONTROL SIGNAL
f
b MEAN VALUE SIGNAL
+V
40
32
I/O CIRCUIT
30
38
36
MEMORY
CPU
34

FIG. 5


START
INITIAL VALUE SETTING (IRIS OPENING: INTERMEDIATE VALUE, IMAGE PICKUP TUBE SENSITIVITY : MINIMUM, GAIN: MINIMUM)
100
READ MEAN VALUE OF IMAGE SIGNAL
110
COMPARE WITH FIRST REFERENCE VALUE AND CALCULATE IRIS CONTROL VALUE
112
IRIS FULL OPEN ?
114
YES
NO
OUTPUT IRIS CONTROL VALUE AND CONTROL IRIS
116
READ MEAN VALUE OF IMAGE SIGNALS
120
COMPARE WITH SECOND REFERENCE VALUE AND CALCULATE IMAGE PICKUP TUBE SENSITIVITY CONTROL VALUE
122
IMAGE PICKUP TUBE SENSITIVITY MAXIMUM ?
124
YES
NO
IMAGE PICKUP TUBE SENSITIVITY MINIMUM ?
126
YES
NO
CONTROL TARGET VOLTAGE CORRESPONDING TO IMAGE PICKUP TUBE SENSITIVITY CONTROL VALUE
128
READ MEAN VALUE OF IMAGE SIGNAL
130
COMPARE WITH THIRD REFERENCE VALUE AND CALCULATE GAIN CONTROL VALUE
132
GAIN CONTROL VALUE MINIMUM ?
134
YES
NO
OUTPUT GAIN CONTROL VALUE AND CONTROL GAIN
136

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TELEVISION CAMERA AND SENSITIVITY CONTROL METHOD THEREOF

This invention relates to a television camera capable of sensitivity control over a broad dynamic range for the change of a quantity of incident light from an object the intensity of illumination of which changes from a low intensity to a high intensity and vice versa, and a sensitivity control method of the television camera.

Television cameras in general are provided with sensitivity control means (gain control means) for holding an output image signal at a substantially predetermined level even when the quantity of incident light changes with the change of the intensity of illumination of an object.

Sensitivity control means for controlling an opening of an iris of a lens system and sensitivity control means for controlling the gain of an image signal amplification circuit are known as the prior art examples of the sensitivity control means of the television cameras, and these means have been put into practical application.

Auto-iris means which detects the change of an image signal level which changes with the change of the quantity of incident light into the television camera (the detection includes the mean value detection, peak value detection and their combination), and automatically controls the lens iris so that the level of this detection signal attains a predetermined value, has been used widely as the means for effecting the sensitivity control of the television camera by controlling the lens iris described above.

On the other hand, JP-A-3-1773 (reference 1) discloses an image pickup apparatus which controls the gain of an image signal amplification circuit when an opening degree of the iris of the lens system exceeds a predetermined value.

Recently, a high sensitivity image pickup tube, which multiplies a signal charge by an avalanche amplification effect of the signal charge at a target by applying a high voltage as a target voltage to a signal electrode, has been put into practical application by the improvement of the target of the image pickup tube. Further, another feature of this image pickup tube resides in that the sensitivity can be controlled by changing the target voltage.

Such a high sensitivity image pickup tube is disclosed in the following references, for example:

"Hosoh-Gijutsu", Vol. 43, No. 6, 1990, June, pp. 135 - 140 (reference 2);

T. Yoshida et al., "Super-High Sensitivity HARPICON Color Camera", The Institute of Television Engineers of Japan Technical Report, Vol. 14, No. 66, pp. 21 - 26 (Reference 3); and F. Okano et al., "The HARP High-Sensitivity Hand-held HDTV Camera", SMPTE Journal, Aug., 1990, pp. 612 - 619 (reference 4).

However, the drop of a signal-to-noise ratio (S/N) of an image signal occurs when control is indiscreetly executed by the means for effecting the sensitivity control by controlling the gain of the image signal amplification circuit described above. Similarly, shot noise increases and the S/N drops when control is made by the means for effecting the sensitivity control by changing the target voltage of the image pickup tube described above. In other words, these means yet involve the problem that a skilled operator must make a suitable control of the gain or the target voltage through a manual operation in match with the intensity of illumination of an object while viewing a screen to be shot.

In the case of a television camera for monitor use which shoots those objects the intensity of illumination of which changes from a high intensity in the daytime to a low intensity at night and vice versa and an underwater camera for shooting objects above the sea having a high intensity and objects at the depth of the sea having a low intensity, sensitivity control must be carried out over a broad dynamic range in match with the intensity of illumination of the objects, but the television camera exists at a position spaced apart from the operator. Accordingly, manual sensitivity control cannot be made, so that setting of the gain control of the image signal amplification circuit and setting of the target voltage control of the image pickup tube are set to predetermined fixed values, respectively, and the sensitivity control is executed only by the control of the lens iris which can be remote-controlled. As a result, the sensitivity control can be made appropriately by the lens iris control within the illumination range which is in match with the set gain and target voltage values, but outside this illumination range, suitable sensitivity control cannot be made, so that the image signal output becomes excessively high or low and in some cases, the drop of image quality is invited due to deterioration of the S/N.

In the image pickup apparatus disclosed in the reference (1), on the other hand, control is carried out by increasing the opening degree of the iris with the drop of the intensity of illumination of the object and increasing the gain of the image signal amplification circuit when the opening of the iris exceeds a predetermined opening. However, this method involves the critical problem that when the gain of the image signal amplification circuit is increased, degradation of image quality is great in the resulting video signals. Accordingly, the gain control must be limited to the minimum.

In the television camera using the high

sensitivity image pickup tube disclosed in the references (2) to (4), the target voltage applied to the signal electrode is manually switched and the sensitivity of the image pickup tube is manually controlled step-wise. In other words, when a desired sensitivity corresponding to the intensity of illumination of the object corresponds to a voltage between two discrete voltages, a desired sensitivity cannot be obtained. Further, a target voltage higher than a necessary level might be impressed and in such a case, degradation of the image pickup tube and hence, reduction of its service life, might be promoted.

The present invention aims at providing a television camera capable of effecting a sensitivity control over a broad dynamic range by shooting the images of an object the intensity of illumination of which changes from a high intensity to a low intensity, and a sensitivity control method of such a television camera.

According to an aspect of the present invention, there is provided a sensitivity control method in a television camera including lens system having an iris for controlling a quantity of light incident from an object to be shot, for forming an image of the incident light passing through the iris as an optical image on an image pickup tube; the image pickup tube for converting photoelectrically the optical image to image signals; an amplifier for amplifying the image signal from the image pickup tube; and a signal processing circuit for generating a video signal on the basis of the image signal from the amplifier and outputting it to the outside; which includes a step of continuously controlling an opening of the iris, the sensitivity of the image pickup tube and the gain of the amplifier in a predetermined sequence.

According to an example of the present invention, when the intensity of illumination of an object drops from a high intensity to a low intensity, the opening of the lens iris, which does not invite deterioration of image quality for the image signals, is first executed, and then the sensitivity control is made so as to increase the quantity of incident light and to keep an image signal output level.

When the opening degree of the iris reaches a predetermined opening (full open state) and the sensitivity control by the lens iris cannot be made any longer, control is switched to the next sensitivity control.

For example, the sensitivity control for increasing the sensitivity of the image pickup tube is carried out next by controlling the sensitivity of the image pickup tube, that is, a target voltage, which does not relatively invite degradation of image quality for the image signals.

When the arrival of the sensitivity control by the control of the target voltage of the image pickup tube at its limit is detected, control is switched likewise to the next sensitivity control.

Next, the sensitivity control by controlling the gain of the image signal amplification circuit, for example, is carried out. In this way, three kinds of sensitivity controls, that is, iris opening control, the image pickup tube sensitivity control and the gain control, are appropriately switched automatically and continuously in such a sequence which less affects image quality, in accordance with the intensity of illumination of the object, so that sensitivity control having a broad dynamic range can be achieved.

When the intensity of illumination of the object increases from a low intensity to a high intensity, the sensitivity control is carried out in the reverse sequence to the sequence described above.

The sequence of the three kinds of sensitivity controls can be changed appropriately and can be executed.

As a result, the opening degree of the iris of the lens system, the sensitivity of the image pickup tube (target voltage) and the gain of the image signal amplification circuit can be controlled appropriately and continuously in accordance with the change of the intensity of illumination of the object. In consequence, the object the intensity of illumination of which changes from a high intensity to a low intensity can be shot under the state where degradation of image quality least occurs.

Further, according to another example of the present invention, the sensitivity of the image pickup tube is continuously controlled by changing continuously the target voltage to be applied to the signal electrode of the image pickup tube in accordance with the intensity of illumination of the object.

Accordingly, the target voltage applied to the image pickup tube is continuously variable and can be set to an arbitrary voltage corresponding to the intensity of illumination of the object. Therefore, the sensitivity of the image pickup tube, too, can be changed continuously. For this reason, a desired sensitivity corresponding to the intensity of illumination of the object can always be obtained, the possibility of the application of a target voltage, which is higher than necessary, to the image pickup tube can be eliminated, and degradation of the image pickup tube and reduction of its service life can be prevented.

In the drawings:

Fig. 1 is a block diagram showing the construction of a television camera according to one embodiment of the present invention;

Fig. 2 is a conceptual view useful for explaining the basic concept of sensitivity control in the camera according to the present invention;

Fig. 3 is an explanatory view useful for explaining the sensitivity control operation in the camera according to the present invention;

Fig. 4 is a block diagram showing the construction of a television camera according to another embodiment of the present invention; and

Fig. 5 is a flowchart useful for explaining the operation in the embodiment shown in Fig. 4.

Hereinafter, preferred embodiments of the present invention will be explained in detail with reference to the accompanying drawings.

To begin with, the first embodiment of the present invention will be explained with reference to Figs. 1 to 3. Fig. 1 is a block diagram showing the construction of the first embodiment of the present invention. Incident light from an object passes through a lens system 1 and is formed as an optical image by an image pickup tube 2. This optical image is photoelectrically converted to an image signal by the image pickup tube 2. After the image signal is amplified to a necessary level by a pre-amplification circuit 3, it passes through a gain control circuit 4 as a part of a process amplification circuit 5 as a signal processing circuit, for example. This gain control circuit is to control the level of the amplified image signal. Then, the process control circuit 5 executes various signal processings to obtain a video signal, and outputs the video signal from a video signal output terminal 6 to the outside.

The lens system 1 includes an iris 21 for controlling light quantity (light power) of light incident from the object into the image pickup tube, and its opening is controlled by a motor 22. Any of the image pickup tubes disclosed in the afore-mentioned references (2) to (4) may be used for this image pickup tube 2 with the proviso that, in the present invention, the sensitivity of the image pickup tube can be continuously changed by changing continuously a voltage (target voltage) to be impressed on a signal electrode of the image pickup tube 2.

The video signal output a of the gain control circuit 4 is also applied to an image signal mean value detection circuit 7, which determines the mean value of the image signals and outputs a mean value signal representing the mean value 6 of the image signals to a lens iris control circuit 8, an image pickup tube sensitivity control circuit 9 and a gain variable control circuit 10.

Here, the mean value represented by this mean value signal b corresponds to the intensity of illumination of the object, and increases or decreases in accordance with the increase or decrease of the intensity of illumination. The value which corresponds to this intensity of illumination of the object may be the peak value of the image signal from the gain variable circuit 4, or a level which is lower by a predetermined proportion (for example, 30%) from the peak value of the image signal, or the sum of one of these values and the mean value described above at a suitable ratio.

Any of the output image signal of the image pickup tube 2, the output image signal of the pre-amplifier and the output video signal of the process amplification circuit 5 may be used by the same method as described above as the signal corresponding to the intensity of illumination of the object.

The basic concept of the sensitivity control of the television camera according to the present invention will be explained hereby with reference to Fig. 2. First of all, the opening of the iris 21 of the lens system 1, the sensitivity of the image pickup tube 2 (target voltage of the image pickup tube) and the gain of the gain variable circuit 4 are initially set to respective values in response to turn-on of the power supply of the television camera. For example, the opening of the iris of the lens system is set to an intermediate value, the sensitivity of the image pickup tube (target voltage), to a minimum value and the gain of the gain variable circuit 4, to a minimum value. The opening of the iris is controlled in accordance with the intensity of illumination of the object so that an image signal having a predetermined level can be obtained from an image signal output terminal 6 under this initial setting state. When the intensity of illumination of the object is greater with respect to this iris opening state (intermediate value), for example, the iris opening is decreased to the minimum value (IRIS CLOSE). When the intensity of illumination is smaller, on the other hand, the iris opening is so controlled as to reach the maximum value (IRIS OPEN). When the intensity of illumination of the object changes to a smaller value and exceeds the control range of the iris under this condition, the control shifts to the sensitivity control (target voltage control) of the image pickup tube 2 while the iris opening is kept at the maximum value. Then, the sensitivity (target voltage) of the image pickup tube is controlled to an optimum value between the minimum and maximum values in accordance with the change of the intensity of illumination of the object. When the intensity of illumination of the object further changes to a smaller value and comes out from the control range of the sensitivity of the image pickup tube under this condition, the control shifts to the control of the gain of the gain variable circuit 4 under the state where the sensitivity (target voltage) of the image pickup tube is kept at the maximum value. Then, the gain of the gain variable circuit 4 is controlled to an optimum value between the minimum and maximum values in accordance with the change of the intensity of illumination of the object. In other words, when the intensity of illumination of the object exists within the range ℓ_1, the iris opening is controlled from MIN to MAX while the image pickup tube sensitivity and the gain are kept at the minimum values. When the intensity of illumination exists within the range ℓ_2, the image pickup tube sensitivity is controlled from MIN to MAX while the iris opening and the gain are kept at the maximum value and the minimum value, respectively, and when the intensity exists within the range ℓ_3, the gain is controlled from MIN to MAX while the iris opening and the image pickup tube sensitivity are kept at their maximum values.

Incidentally, the opening of the iris, the sensitivity (target voltage) of the image pickup tube and the gain of the gain variable circuit 4 may be set to their minimum values, respectively, as the initial set values.

Next, the construction and operation of the embodiment shown in Fig. 1, which executes control on the basis of the basic concept described above, will be explained.

Incidentally, each constituent element shown in Fig. 1 is connected to the power supply of the television camera, not shown, through a switch which is not shown, either.

First of all, initial setting described above is effected in response to turn-on of a power switch of the television camera, not shown in the drawing. Namely, the lens iris servo circuit 11 applies a lens iris control signal d which sets the opening of the iris 21 to an intermediate value, to a motor 22 in response to turn-on of the power switch, and sets the opening of the iris

21 to the intermediate value. The target voltage control circuit 14 applies a target voltage g which sets the sensitivity of the image pickup tube 2 to the minimum value (that is, the minimum value of the target voltage), to the signal electrode of the image pickup tube 2 in response to turn-on of the power switch, and sets the sensitivity of the image pickup tube 2 to the minimum value. Further, the gain variable control circuit 10 applies a gain variable control signal ℓ which sets the gain of the gain variable circuit 4 to the minimum value, to the gain variable circuit 4, and sets its gain to the minimum value.

Under this state, the mean value signal b from the image signal mean value detection circuit 7 is applied to the lens iris control circuit 8, the image pickup tube sensitivity control circuit 9 and the gain variable control circuit 10. Under the initial setting state, however, the image pickup tube sensitivity control circuit 9 and the gain variable control circuit 10 do not execute their operations corresponding to the mean value signal b, that is, the later-appearing comparison operation, but are kept under the operation lock state until a detection signal e and a control signal k are applied, respectively, as will be described elsewhere. The lens iris control circuit 8, the image pickup tube sensitivity control circuit 9 and the gain variable control circuit 10 includes a comparison unit 81, 91, 101 and a control signal generation unit 82, 92, 102, respectively.

Under the initial setting condition, therefore, only the lens iris control circuit 8 is operative, and its comparison unit 81 compares the mean value of the image signals represented by the inputted mean value signal b with a first reference value which is set in advance to the control circuit 8 to obtain the difference, and applies this difference to the control signal generation unit 82. The control signal generation unit 82 calculates an iris control deviation value corresponding (proportional, for example) to this difference, and applies the control signal c representing this control deviation value to the lens iris servo circuit 11. In other words, the control signal generation unit 82 outputs the control signal c the polarity of which is positive and the value (level) of which corresponds to the difference when the mean value described above is smaller than the first reference value, and outputs the control signal c the polarity of which is negative and the value (level) of which corresponds to the difference when the mean value is greater than the first reference value.

Here, the first reference value is, for example, 30% of the rated voltage of the image signals obtained at the image signal output terminal 6.

The lens iris servo circuit 11 applies the iris control signal d corresponding to this control signal c to the motor 22, and controls the iris 21 to a suitable opening.

In other words, when the mean value described above is smaller than the first reference value, the servo circuit 11 normally rotates the motor 22 by an angle corresponding to the difference, for example, in response to the iris control signal d, so as to increase the opening of the iris 21, and when the mean value is smaller than the first reference value, on the other hand, the servo circuit 11 reversely rotates the motor 22 by an angle corresponding to the difference, for example, so as to reduce the opening of the iris 21.

The lens iris control circuit 8 repeats such operations in predetermined intervals (e.g. 50 ms), for example, until the mean value of the image signals a coincides with the first reference value. When the mean value coincides with the first reference value, the value of the control signal c from the control signal generation unit 82 becomes zero (0). At this time, the iris 21 is controlled to a suitable opening.

By the way, the operations of the control unit and control signal generation unit of the lens iris control circuit 8 also hold true of the image pickup tube sensitivity control circuit 9 and the gain variable control circuit 10.

The control signal c from the lens iris control circuit 8 is also applied to the iris control state detection circuit 12 which detects the control state of the lens iris such as the full open state of the iris 21, for example.

Next, the operation when the intensity of illumination of the object drops under the state where the iris 21 has a suitable opening will be explained.

When the intensity of illumination of the object drops, the mean value described above becomes smaller than the first reference value as already described, and the opening of the iris 21 is increased by an angle corresponding to this difference.

Let's consider the case where the intensity of illumination of the object further drops and the mean value of the mean value signal b does not reach the first reference value even when the opening of the iris 21 is increased to the maximum (full open), that is, when the intensity of illumination of the object falls out of the control range of the iris. In such a case, the iris control state detection circuit 12 detects the full-open state of the iris 21 from the control signal c supplied thereto in the following way. Namely, when the intensity of illumination of the object drops and the mean value becomes lower than the first reference value as described above, a control signal c having a value corresponding to the difference is outputted, and the motor 22 is rotated in accordance with the iris control signal d corresponding to this control signal c so as to increase the opening of the iris 21. This operation is repeated to gradually increase the opening of the iris and to gradually decrease the difference between the mean value and the first reference value (that is, the value of the control signal c). Here, if the iris control state detection circuit 12 is provided with an integration circuit which has set upper and lower limit values and integrates the value of the control signal c, the integration value represents the value corresponding to the opening of the iris 21. Accordingly, it is possible to detect that the integration value attains the value corresponding to the full-open state of the iris 21, and in this case, the detection circuit 12 outputs the detection signal e that represents that the opening of the iris 21 is maximal (full open).

Another method of detecting the full-open state of the iris 21 is as follows. Namely, the control signal c having a value corresponding to the difference between the mean value and the first reference value is outputted, and the motor 22 is rotated in accordance with the iris control signal d to increase the opening of the iris 21. When these operations are repeated, the difference between the mean value and the first reference value (that is, the value of the control signal c) gradually decreases as shown in Fig. 3 until finally, it converges to 0 at a time t2 (one-dot-chain line in Fig. 3). However, when the opening of the iris 21 reaches the maximum before the difference reaches 0 at a time t1, for example, the difference does not decrease any longer after the time t1 but remains constant. Accordingly, the iris control state detection circuit 12 detects the state where the value of the control signal c does not decrease for a predetermined time T but remains constant, then judges that the opening of the iris is the maximum (full open), and outputs the detection signal e. Incidentally, this predetermined time T may be counted by a built-in timer, or the number of times of the output of the control signal c may be counted because the control signal c is outputted in the predetermined time interval as described above.

When the iris control state detection circuit 12 detects that the intensity of illumination of the object is out of the control range of the iris 21 (iris full open), a detection signal e is supplied to the iris control circuit 8, locks the operation of this circuit 8, and keeps the iris 21 under the full open state. This detection signal e is also supplied to the image pickup tube sensitivity control circuit 9 and to the AND circuit 13.

Accordingly, the image pickup tube sensitivity control circuit 9 is released from the operation lock state in response to the detection signal e, and enters the operative state. Accordingly, its comparison unit 91 compares the mean value represented by the mean value signal b from the mean value detection circuit 7 with the second reference value set to the control circuit 9, and applies a signal representing the difference to the control signal generation unit 92. The control signal generation unit 92 calculates an image pickup tube sensitivity control deviation value (that is, a target voltage deviation value) corresponding to this difference, and applies an image pickup tube sensitivity control signal f representing this control deviation value to the image pickup tube target value control circuit 14. In other words, when the mean value is smaller than the second reference value, the control signal generation unit 92 outputs the control signal f the polarity of which is positive and the value (level) of which corresponds to the difference, and when the mean value is greater than the second reference value, it outputs the control signal f the polarity of which is negative and the value (level) of which corresponds to the difference.

Here, the second reference value may be equal to the first reference value described already.

The image pickup tube target voltage control circuit 14 adds a voltage value corresponding to the value of the control signal f to the target voltage used for the previous control (when the control signal f is positive), subtracts the former from the latter (when the control signal f is negative), to obtain the target voltage g in either case, and applies this target voltage g to the signal electrode of the image pickup tube 2. Incidentally, the target voltage used for the previous control is the minimum value under the initial setting state. In this way, the target voltage of the image pickup tube 2 is continuously increased in accordance with the drop of the intensity of illumination of the object and control is so made as to continuously increase the sensitivity of the image pickup tube 2 until the mean value of the mean value signal b coincides with the second reference value.

The control signal f from the image pickup sensitivity control circuit 9 is also applied to the image pickup tube sensitivity control state detection circuit 15 for detecting the control state of the sensitivity of the image pickup tube (that is, the state where the target voltage is the maximum and the minimum).

Here, when the intensity of illumination of the object further drops and the mean value represented by the mean value signal b does not coincide with the second reference value even when the target voltage is increased to the maximum (that is, when the intensity of illumination is out of the control range of the image pickup tube sensitivity), the image pickup tube sensitivity control state detection circuit 15 detects from the control signal f applied thereto at this time that the target voltage reaches the maximum value.

In other words, this detection circuit 15 has the integration circuit having set upper and lower limit values in the same way as the detection circuit 12 does, and this integration circuit integrates the values of the control signals f, so that its integration value represents the value corresponding to the target voltage. Accordingly, the detection circuit 15 may output detection signals h, m (p) representing that the target voltage is the maximum and minimum, respectively, by detecting that the integration value reaches the values corresponding to the maximum and minimum values of the target voltage, respectively.

The detection signal m is supplied to the image pickup tube sensitivity control circuit 9, locks the operation of this image pickup tube control circuit 9 and holds the sensitivity of the image pickup tube (target voltage) at the maximum value.

The detection signal e representing the open state of the lens iris is supplied from the iris control state detection circuit 12 to an AND circuit 13 and the detection signal h representing the maximum state of the image pickup tube sensitivity is supplied from the image pickup tube sensitivity control state detection circuit 15. In such a case, the AND circuit 13 outputs a control signal k to the gain variable control circuit 10.

Accordingly, the gain variable control circuit 10 is released from the operation lock state in response to the control signal k and enters the operative state. Accordingly, its comparison unit 101 compares the mean value represented by the mean value signal b from the mean value detection circuit 7 with a third reference value set to the control circuit 10, and applies a signal representing the difference to the control signal generation unit 102. The control signal generation unit 102 calculates a gain control deviation corresponding to this difference and applies a gain variable control signal ℓ corresponding to this control deviation value to the gain variable circuit 4. In other words, when the mean value is smaller than the third reference value, the control signal generation unit 102 outputs the control signal ℓ the polarity of which is positive and the value (level) of which corresponds to the difference, and when the former is greater than the latter, the control signal generation unit 102 outputs the control signal ℓ the polarity of which is negative and the value (level) of which corresponds to the difference.

Here, the third reference value may be equal to the first or second reference values described already.

The gain variable circuit 4 changes its gain in accordance with the polarity and value of the control signal ℓ so as to continuously increase the gain thereof in accordance with the drop of the intensity of illumination of the object and to increase the gain until the mean value of the mean value signal b coincides with the third reference value.

Next, the operation of each control circuit when the intensity of illumination of the object changes from a low intensity to a high intensity from the state described above, will be explained.

When the illumination of the object gradually rises, the value of the gain variable control signal 1 outputted from the gain variable control circuit 10, which corresponds to the difference between the mean value of the mean value signal b of the image signal mean value detection circuit 7 inputted to the gain variable control circuit 10, and the third reference value, changes to the opposite polarity to the case of the drop of the intensity of illumination of the object. Accordingly, the gain of the gain variable circuit 4 drops in accordance with the intensity of illumination of the object, and the gain is controlled so that the mean value represented by the mean value signal b coincides with the third reference value.

Incidentally, since the lens iris control circuit 8 and the image pickup tube sensitivity control 9 are under the lock state in this case, they do not operate in response to this mean value signal b. Consequently, the iris 21 is fully opened and the image pickup tube sensitivity is at the maximum sensitivity.

When the intensity of illumination further rises and the mean value represented by the mean value signal b does not coincide with the third reference value even when the gain of the image signal is set to the minimum (when the intensity of illumination is out of the gain control range), the gain control state detection circuit 16 for detecting the gain control state (for example, the minimum gain state) of the gain variable circuit 4 detects from the gain variable control signal ℓ and the control signal K at this time that the gain of the gain variable circuit 4 reaches the minimum value.

In other words, the detection circuit 16 has the integration circuit having set upper and lower limit values in the same way as the detection circuits 12, 15 do, and this integration circuit integrates the value of the control signal ℓ, so that the integration value represents a value corresponding to the gain of the gain variable circuit 4. Accordingly, the detection circuit 16 may output a detection signal representing that the gain becomes minimal, by detecting that the integration value reaches the minimum value or in other words, the value corresponding to the minimum value of the gain of the gain variable circuit 4, and that the control signal k is inputted to the detection circuit 16.

The reason why the detection circuit 16 is allowed to operate in response to the control signal k is to prevent the possible problem that the detection signal n is applied to the image pickup tube sensitivity control circuit 9 and renders this circuit 9 operative, when the sensitivity of the camera is controlled only by the opening control of the iris under the state where the gain of the gain variable circuit 4 is minimal and the sensitivity of the image pickup tube 2 is the lowest.

This detection signal o is supplied to the gain variable control circuit 10, locks the operation of this circuit 10 and keeps the gain under the minimum state.

Further, the output detection signal n of this gain control state detection circuit 16 is supplied to the image pickup tube sensitivity control circuit 9, releases the image pickup tube target voltage g which has been kept at the maximum value, renders the image pickup tube sensitivity control circuit 9 operative, and sensitivity of the image pickup tube 2 is controlled by reducing the target voltage g in accordance with the intensity of illumination of the object, until the mean value coincides with the second reference value.

When the intensity of illumination of the object further rises and the target voltage, that is, the sensitivity, of the image pickup tube 2 drops to the minimum in the same way as described above, the image pickup tube sensitivity control state detection circuit 15 outputs a detection signal p representing that the target voltage, that is, the sensitivity, of the image pickup tube 2 is the lowest, and applies this signal p to the image pickup tube sensitivity control circuit 9, locks this circuit 9, and further applies it to the iris control circuit 8. In consequence, the lens iris control circuit 8 is released from the lock state, where the iris has so far been kept under the full open state, is rendered operative, and controls the iris in accordance with the intensity of illumination of the object. Incidentally, the gain variable control circuit 10 is kept locked.

In the embodiment described above, the iris control state detection circuit judges the iris opening on the basis of the iris control signal c, but it may judge by a signal from a sensor directly detecting the opening of the iris.

Similarly, though the image pickup tube

sensitivity state detection circuit 15 judges the image pickup tube sensitivity on the basis of the image pickup tube sensitivity control signal f, the target voltage of the image pickup tube 2 may be directly detected for the purpose of judgement.

Furthermore, though the gain control state detection circuit 6 judges the gain of the gain variable circuit 4 on the basis of the gain variable control signal ℓ, the gain of the gain variable circuit 4 may be detected for judgement.

Next, another embodiment of the present invention will be described with reference to Figs. 4 and 5. Fig. 4 is a block diagram showing the construction of another embodiment of the present invention. In Fig. 4, like reference numerals will be used to identify like constituent elements as in Fig. 1, and their explanation will be omitted. In this embodiment, the lens iris control circuit 8, the iris control state detection circuit 12, the image pickup tube sensitivity control circuit 9, the image pickup tube sensitivity control state detection circuit 15, the AND circuit 13, the gain variable control circuit 10 and the gain control state detection circuit 16 shown in Fig. 1 comprise a microcomputer 30, and the sensitivity control method of the television camera is substantially the same as the control method of the embodiment described above.

The microcomputer 30 includes an input/output (I/O) circuit 32, a central processing unit (CPU) 34, a memory 36 such as a RAM (random access memory), a ROM (read-only memory), etc., and a bus 38 for connecting these members. The I/O circuit 32 of the microcomputer 32 inputs the mean value signal b from the image signal mean value detection circuit 7, applies this signal b to the CPU 34, and also applies the iris control signal c, the image pickup tube sensitivity control signal f corresponding to the target voltage g and the gain variable control signal ℓ, that are determined by the CPU 34, to the lens iris servo circuit 11, the image pickup tube target voltage control circuit 14 and the gain variable circuit 4, respectively. Further, the I/O circuit 32 is connected to the power switch 40 of the television camera and detects turn-on and -off of this switch. Though not shown in the drawing, each of these members is connected to the power supply through the switch.

Fig. 5 is a flowchart useful for explaining an example of the operation of this embodiment. Hereinafter, the operation of this embodiment will be described with reference to this flowchart.

First, initial setting is effected in response to turn-on of the power switch 40 (step 100). In other words, the iris control signal c, the image pickup tube sensitivity control signal f and the gain variable control signal ℓ are applied from the I/O circuit 32 to the iris servo circuit 11, the image pickup tube target voltage control circuit 14 and the gain variable circuit

4, respectively, so that the opening of the iris assumes an intermediate value, the sensitivity of the image pickup tube (target voltage) is the minimum value and the gain of the gain variable circuit 4, too, is the minimum.

Next, the mean value signal b is read at the step 110, and the mean value represented by the mean value signal b thus read is compared with the first reference value for controlling the iris and the iris control deviation value (±ΔVin) having a polarity and value (a proportional value, for example) corresponding to their difference is calculated at the step 112. Here, a new iris control value (Vin) is obtained by adding the iris control deviation value (ΔVin) to the previous iris control value (Vin-1) stored in the memory 36. This new iris control value (Vin) represents a value corresponding to the present iris opening. Incidentally, the previous iris control value stored in the memory 36 immediately after initial setting is a control value corresponding to the intermediate value of the iris opening.

Next, whether or not this new iris control value (Vin) is a value corresponding to the full open state of the iris is judged (step 114). When it does not correspond to the full open state of the iris (the opening less than full opening), the flow proceeds to the step 116, where the iris control signal c corresponding to this new iris control value is applied to the lens iris servo circuit 11. In this way, the lens iris servo circuit 11 controls the iris to the opening corresponding to the intensity of illumination of the object. The previous iris control value (Vin-1) stored in the memory is updated by this new iris control value (Vin). Thereafter, the flow returns to the step 110.

In this way, the opening of the iris 21 is increased (decreased) when the intensity of illumination of the object drops (rises). When the new iris control value (Vin) obtained at the step 112 is judged as corresponding to the full open state of the iris 21 (step 114), the sensitivity control of the television camera is shifted from the opening control of the iris 21 to the sensitivity control of the image pickup tube 2 while the iris 21 is kept under the full open state. In other words, the flow proceeds to the step 120.

The mean value signal b is read at the step 120. The mean value represented by the mean value signal b thus read is compared with the second reference value for the sensitivity control of the image pickup tube at the step 122, and the image pickup tube sensitivity control deviation value (±ΔVsn) having a polarity and a value (a proportional value, for example) corresponding to their difference is calculated. Here, a new image pickup tube sensitivity control value (Vsn) is obtained by adding the previous image pickup tube sensitivity control value (Vsn-1) stored in the memory 36 to the image pickup tube sensitivity control deviation value (ΔVsn) of this time. This new image pickup tube sensitivity control value (Vsn) represents a value corresponding to the present target voltage. Incidentally, the previous image pickup tube sensitivity control value stored in the memory 36 is a control value corresponding to the minimum value of the image pickup tube sensitivity immediately after initial setting.

Next, whether or not this new image pickup tube sensitivity control value (Vsn) is a value corresponding to the maximum value of the image pickup tube sensitivity is judged (step 124). When it does not correspond to the maximum value of the image pickup tube sensitivity (the sensitivity less than the maximum value), the flow proceeds to the step 126, and whether or not this new image pickup tube sensitivity control value (Vsn) is a value corresponding to the minimum value of the image pickup tube sensitivity is judged (step 126). When it does not correspond to the minimum value of the image pickup tube sensitivity (the sensitivity between the maximum and minimum values), the flow proceeds to the step 128, and the image pickup tube sensitivity control signal f corresponding to the new image pickup tube sensitivity control value (Vsn) is applied to the image pickup tube target voltage control circuit 14. Accordingly, the image pickup tube target voltage control circuit 14 applies the corresponding target voltage g to the image pickup tube 2, and the sensitivity of the image pickup tube 2 is controlled to a sensitivity corresponding to this target voltage g. The previous image pickup tube sensitivity control value (Vsn-1) stored in the memory is updated by this new image pickup tube sensitivity control value (Vsn). Thereafter, the flow returns to the step 120.

In this way, the image pickup tube sensitivity is increased (decreased) when the intensity of illumination of the object drops (increases). Incidentally, when the image pickup tube sensitivity control value (Vsn) obtained at the step 122 is judged as a value corresponding to the minimum value of the image pickup tube sensitivity (step 126), the sensitivity control of the television camera is returned from the control of the image pickup tube sensitivity to the opening control of the iris while the image pickup tube sensitivity is kept at the minimum value. In other words, the flow returns again to the step 110.

On the other hand, when the image pickup tube sensitivity control value (Vsn) obtained afresh at the step 122 is judged as corresponding to a sensitivity exceeding the maximum value of the image pickup tube sensitivity (step 124), the sensitivity control of the television camera is switched from the control of the image pickup tube sensitivity to the gain control of the gain variable circuit 4 while the image pickup tube sensitivity is kept at the maximum value. In other words, the flow proceeds to the step 130.

The mean value signal b is read at this step 130. The mean value represented by the mean value signal b thus read is compared with the third reference value for the gain control at the step 132, and a gain control deviation value (±ΔVgn) having a polarity and a value (a proportional value, for example) corresponding to this difference is calculated. Here, a new gain control value (Vgn) is obtained by adding the previous gain control value (Vgn-1) stored in the memory 36 to the gain control deviation value (ΔVgn) of this time. This new gain control value (Vgn) represents a value corresponding to the present gain of the gain variable circuit 4. Incidentally, the previous gain control value stored in the memory 36 is a control value corresponding to the minimum gain value of the gain variable circuit 4 immediately after initial setting.

Next, whether or not this new gain control value (Vgn) corresponds to the minimum value of the gain of the gain variable circuit 4 is judged (step 134). When it does not correspond to the minimum value of the gain variable circuit 4 (a value between the maximum and minimum values), the flow proceeds to the step 136, and a gain variable control signal ℓ corresponding to this new gain control value (Vgn) is applied to the gain variable circuit. In consequence, the gain of the gain variable circuit 4 is controlled to the gain corresponding to this control signal ℓ. The previous gain control value (Vgn-1) stored in the memory is updated by this new gain control value (Vgn). Thereafter, the flow returns to the step 130.

In this way, the gain of the variable gain circuit 4 is increased (decreased) when the intensity of illumination of the object drops (increases). Incidentally, when the new gain control value (Vgn) obtained at the step 132 is judged as corresponding to the minimum value of the gain of the variable gain circuit 4 (step 134), the sensitivity control of the television camera is returned from the control of the gain to the control of the image pickup sensitivity while the gain is kept at the minimum value. In other words, the flow returns to the step 120.

The present invention is not particularly limited to each of the foregoing embodiments, but can be modified in the following way.

In the foregoing embodiments, when the intensity of illumination of the object drops from the initial setting state, the control is switched to the sensitivity control of the image pickup tube when the opening of the iris reaches the maximum (full open). However, the control may be switched to the sensitivity control of the image pickup tube while keeping the iris at a predetermined opening, when the iris opening reaches a predetermined opening between the full open state and the full closed state.

Similarly, the control is switched to the gain control when the sensitivity of the image pickup tube reaches the maximum in each of the foregoing embodiments. However, the control may be switched to the gain control while keeping the image pickup tube sensitivity at a predetermined sensitivity, when the image pickup tube sensitivity reaches a predetermined sensitivity between the maximum and minimum values. By so doing, degradation rate of the image pickup tube can be lowered and its service life can be extended, without operating the image pickup tube 2 at the maximum target voltage.

In each of the foregoing embodiments, the control is switched to the sensitivity control of the image pickup tube at the minimum value of the gain when the intensity of illumination increases. However, the control may be switched to the image pickup tube sensitivity control while keeping the gain at a predetermined value when the gain drops to this predetermined value between the maximum and minimum values.

Similarly, the control is switched to the iris control when the sensitivity of the image pickup tube drops to the minimum in the foregoing embodiments. However, the control may be switched to the iris control while keeping the image pickup tube sensitivity at a predetermined sensitivity, when the image pickup tube sensitivity reaches this predetermined value between the maximum and minimum values.

When the intensity of illumination of the object drops from the initial setting state in the foregoing embodiments, the control is switched from the iris opening control, the image pickup tube sensitivity control and the gain control in order named. However, the control may be switched in the order of the iris opening control, the gain control and the image pickup tube sensitivity control, and when the intensity of illumination of the object increases, the control may be switched in the reverse sequence to the above. According to this arrangement, the number of times of the image pickup tube sensitivity control can be reduced and consequently, service life of the image pickup tube can be extended.

In the foregoing embodiments, the signal corresponding to the intensity of illumination of the object is obtained as the signal representing the intensity of illumination of the object on the basis of the image signal. However, it is also possible to directly measure the intensity of illumination and to control the sensitivity in accordance with the measurement value.

As described above, the present invention is so constituted as to execute the sensitivity control in accordance with the intensity of illumination of the object in such a manner as to minimize deterioration of the image signals. However, similar operations can also be accomplished even by changing the operation sequence of each control means, and an image pickup tube capable of changing the sensitivity and an image pickup device capable of changing the sensitivity by other methods can of course be used in the present invention.

The present invention can accomplish a television camera capable of shooting the images of the object changing from a high intensity to a low intensity of illumination, with the best image quality, and capable of the sensitivity control over a broad dynamic range.

CLAIMS

1. A television camera comprising:

lens means having an iris for controlling a quantity of light incident from an object to be shot, for forming an image of said incident light passing through said iris as an optical image on an image pickup tube;

said image pickup tube for converting photoelectrically said optical image to image signals;

amplification means for amplifying said image signal from said image pickup tube;

a signal processing circuit for generating a video signal on the basis of said image signal from said amplification means and outputting said video signal to the outside;

iris control means for controlling an opening of said iris;

image pickup tube control means for controlling the sensitivity of said image pickup tube;

gain control means for controlling a gain of said amplification means; and

sensitivity control means for continuously controlling said iris control means, said image pickup tube control means and said gain control means in a predetermined sequence in accordance with an intensity of illumination of said object.

2. A television camera according to Claim 1, wherein said sensitivity control means, has means for obtaining a signal representing the intensity of

illumination of said object on the basis of an output signal from one of said image pickup tube, said amplification means and said signal processing circuit, and continuously controls said iris control means, said image pickup tube control means and said gain control means in a predetermined sequence in accordance with a level of said signal representing the intensity of illumination of said object.

3. A television camera according to Claim 1, wherein said image pickup tube control means continuously controls the sensitivity of said image pickup tube by continuously changing a target voltage applied to a signal electrode of said image pickup tube.

4. A television camera according to Claim 1, wherein, when the intensity of illumination of said object drops, said sensitivity control means, continuously controls said iris control means, said image pickup tube control means and said gain control means in order named.

5. A television camera according to Claim 1, wherein, when the intensity of illumination of said object further drops after the opening of said iris is increased to a first predetermined opening by said iris control means in accordance with the drop of intensity of illumination of said object, said sensitivity control means controls said image pickup tube control means under the state where said iris is kept at said first predetermined opening.

6. A television camera according to Claim 2, wherein, when a signal representing the intensity of illumination of said object is lower than a first predetermined value even after said iris is opened to a first predetermined opening by said iris control means in accordance with the drop of the intensity of illumination of said object, said sensitivity control means controls said image pickup tube control means under the state where said iris is kept at said first predetermined opening.

7. A television camera according to Claim 1, wherein, when the intensity of illumination of said object further drops after the sensitivity of said image pickup tube is increased to a first predetermined sensitivity by said image pickup tube control means in accordance with the drop of the intensity of illumination of said object, said sensitivity control means controls said gain control means under the state where the sensitivity of said image pickup tube is kept at said first predetermined sensitivity.

8. A television camera according to Claim 2, wherein, when a signal representing the intensity of illumination of said object is lower than a second predetermined value even when the sensitivity of said image pickup tube is increased to said first predetermined sensitivity by said image pickup tube control means in accordance with the drop of the intensity of illumination of said object, said sensitivity control means

controls said gain control means under the state where the sensitivity of said image pickup tube is kept at said first predetermined sensitivity.

9. A television camera according to Claim 1, wherein, when the intensity of illumination of said object increases, said sensitivity control means continuously controls said gain control means, said image pickup tube and said iris control means in order named.

10. A television camera according to Claim 1, wherein, when the intensity of illumination of said object further increases after the gain of said amplification means is decreased to a predetermined gain by said gain control means in accordance with the increase of the intensity of illumination of said object, said sensitivity control means controls said image pickup tube control means under the state where the gain of said amplification means is kept at said predetermined gain.

11. A television camera according to Claim 2, wherein, when a signal representing the intensity of illumination of said object is higher than a third predetermined value even when the gain of said amplification means is decreased to a predetermined gain by said gain control means in accordance with the increase of the intensity of illumination of said object, said sensitivity control means controls said image pickup tube control means under the state where the gain of said amplification means is kept at said predetermined gain.

12. A television camera according to Claim 1,

wherein, when the intensity of illumination of said object further increases after the sensitivity of said image pickup tube is decreased to a second predetermined sensitivity by said image pickup tube control means with the increase of the intensity of illumination of said object, said sensitivity control means controls said iris control means under the state where the sensitivity of said image pickup tube is kept at said second predetermined sensitivity.

13. A television camera according to Claim 2, wherein, when a signal representing the intensity of illumination of said object is higher than a second predetermined value even when the sensitivity of said image pickup tube is decreased by said image pickup tube control means in accordance with the increase of the intensity of illumination of said object, said sensitivity control means controls said iris control means under the state where the sensitivity of said image pickup tube is kept at said second predetermined value.

14. A sensitivity control method in a television camera including:

lens means having an iris for controlling a quantity of light incident from an object to be shot, for forming an image of said incident light passing through said iris as an optical image on an image pickup tube;

said image pickup tube for converting photoelectrically said optical image to image signals;

amplification means for amplifying said image signal from said image pickup tube; and

a signal processing circuit for generating a video signal on the basis of said image signal from said amplification means and outputting said video signal to the outside;

said sensitivity control method comprising the step of:

continuously controlling an opening of said iris, the sensitivity of said image pickup tube and the gain of said amplification means in a predetermined sequence.

15. A sensitivity control method in a television camera according to Claim 14, wherein the opening of said iris, the sensitivity of said image pickup tube and the gain of said amplification means are continuously controlled in order named when the intensity of illumination of said object drops.

16. A sensitivity control method in a television camera according to Claim 14, wherein the sensitivity of said image pickup tube is controlled under the state where said iris is kept at a first predetermined opening when the intensity of illumination of said object further drops after the opening of said iris is increased to said first predetermined opening with the decrease of the intensity of illumination of said object.

17. A sensitivity control method in a television camera according to Claim 14, wherein the gain of said amplification means is controlled under the state where

the sensitivity of said image pickup tube is kept at said first predetermined sensitivity when the intensity of illumination of said object further drops after the sensitivity of said image pickup tube is increased to said first predetermined sensitivity with the drop of the intensity of illumination of said object.

18. A sensitivity control method in a television camera according to Claim 14, wherein the gain of said amplification means, the sensitivity of said image pickup tube and the opening of said iris are continuously controlled in order named when the intensity of illumination of said object increases.

19. A sensitivity control method in a television camera according to Claim 18, wherein, when the intensity of illumination of said object further increases after the gain of said amplification means is decreased to a predetermined gain with the increase of the intensity of illumination of said object, the sensitivity of said image pickup tube is controlled under the state where the gain of said amplification means is kept at said predetermined gain.

20. A sensitivity control method in a television camera according to Claim 18, wherein when the intensity of illumination of said object further increases after the sensitivity of said image pickup tube is decreased to a second predetermined sensitivity with the increase of the intensity of illumination of said object, the opening of said iris is controlled under the state where the

sensitivity of said image pickup tube is kept at said second predetermined sensitivity.

21. A television camera substantially as herein described with reference to and as illustrated in Figs. 1 to 3 or Figs. 4 to 5 of the accompanying drawings.

22. A sensitivity method control in a television camera substantially as any one herein described with reference to the accompanying drawings.

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Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) EDOC, WPIL

Documents considered relevant following a search in respect of Claims :-
1, 14

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Category	Identity of document and relevant passages		Relevant to claim(s)
Y	EP 0446647 A2	(SONY) see column 1 lines 29 to 51	1, 14
Y	US 4013833	(ZIMMERMAN) see column 3 lines 46 to 63	1, 14

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