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(54) CCD Imager

(57) A CCD imager includes a CCD (1), a line memory (2), a subtracter (3), a comparator (4), a constant voltage source (5) and two switches (S1, S2). Using the subtracter (3), a smear signal produced by the CCD (1) is removed from the video signal. When the video signal from CCD exceeds a predetermined level indicating that the charge accumulated in the CCD is regulated to the maximum available voltage with the excess charge being drained away, the video signal from the CCD before being subtracted is selected. Accordingly, an image having no undesirable dark spot within the bright area can be reproduced.

Fig. 5

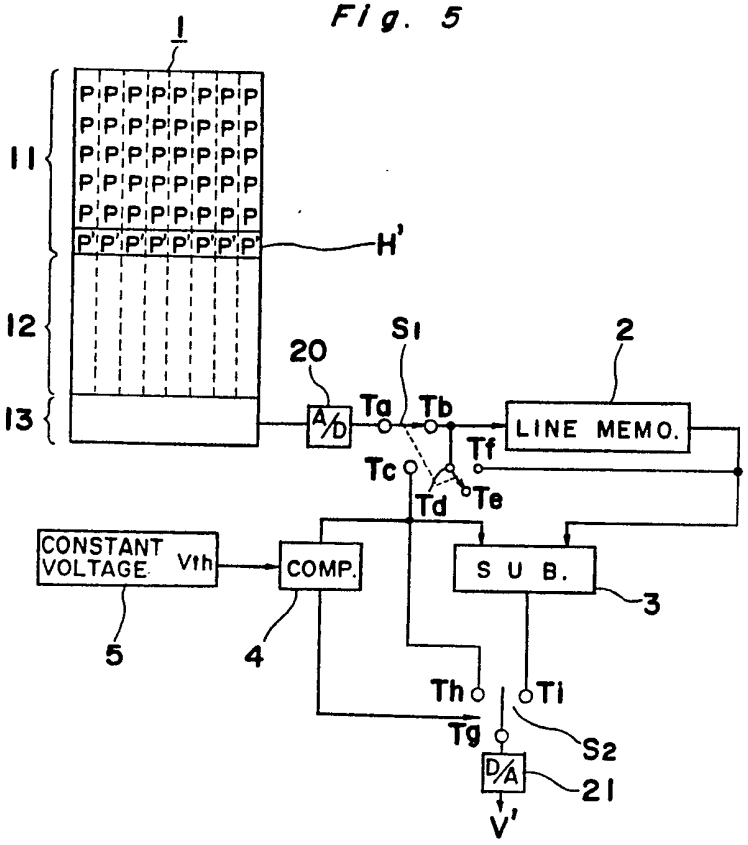

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Fig. 1 PRIOR ART

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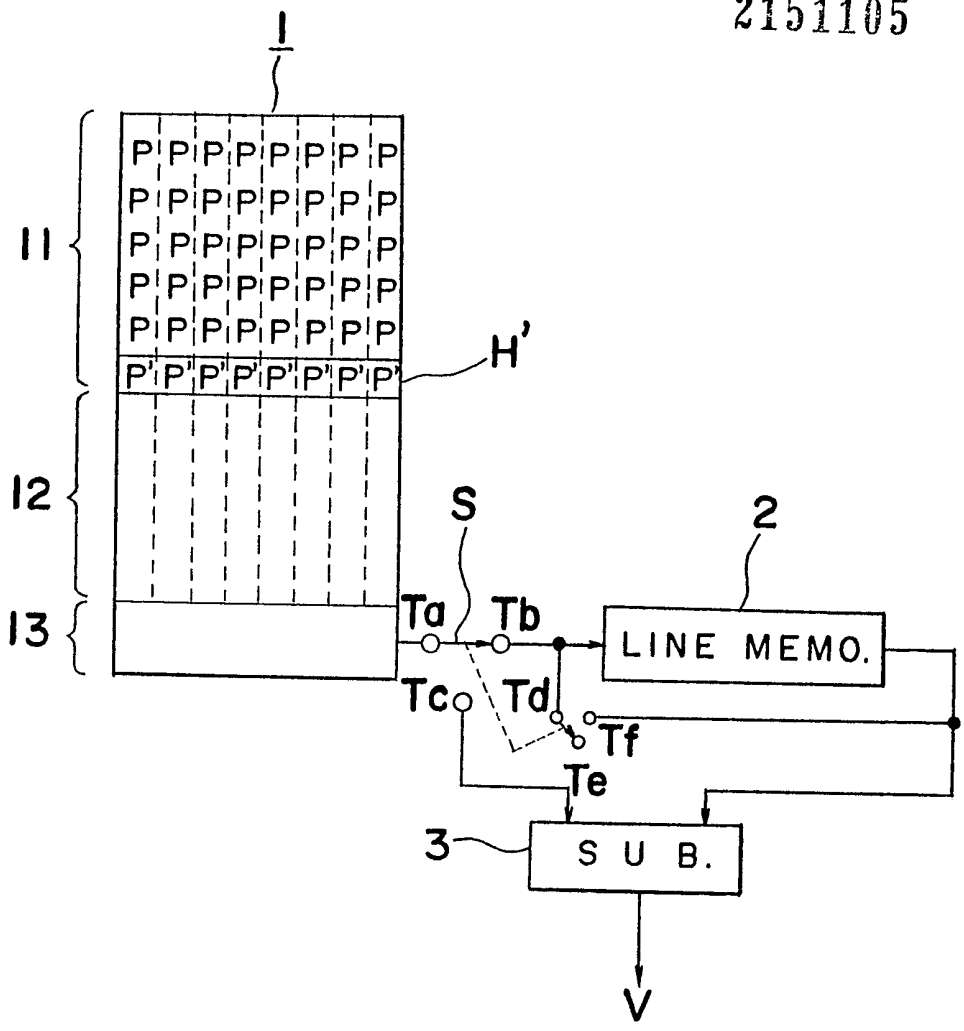

Fig. 2 PRIOR ART

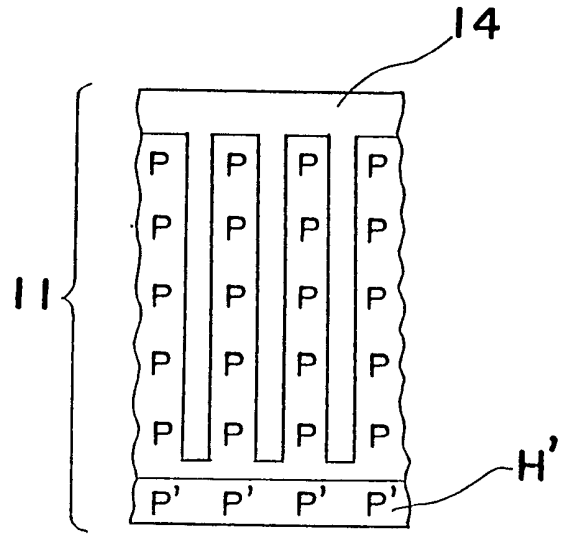

Fig. 3a

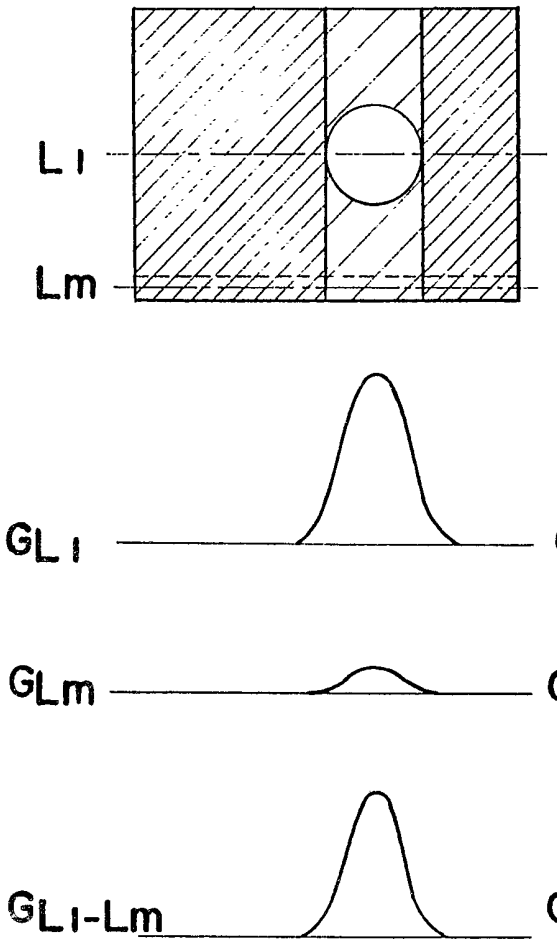

Fig. 4a

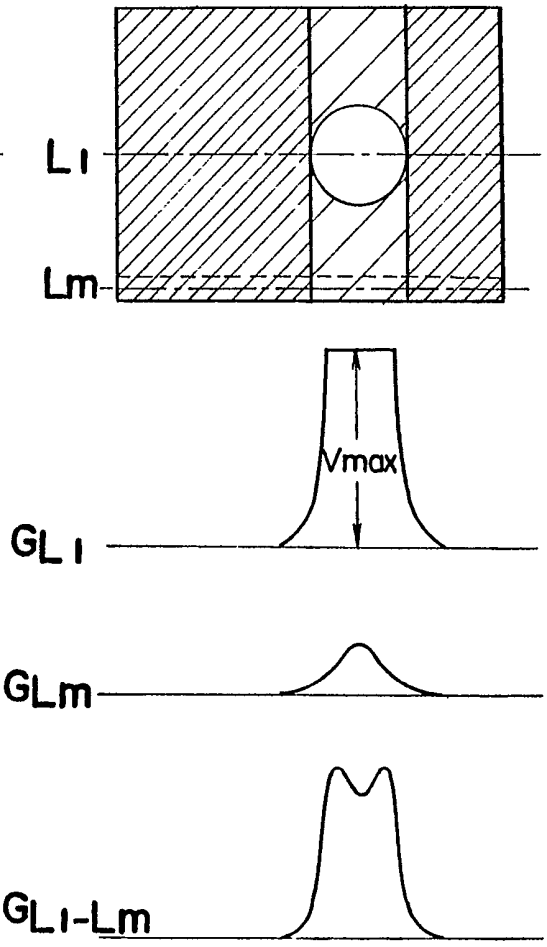

Fig. 3b

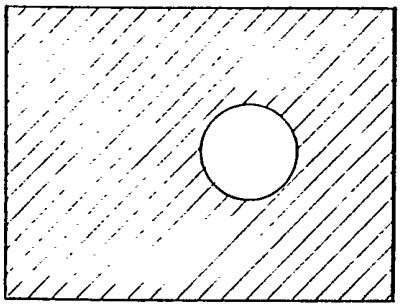

Fig. 4b

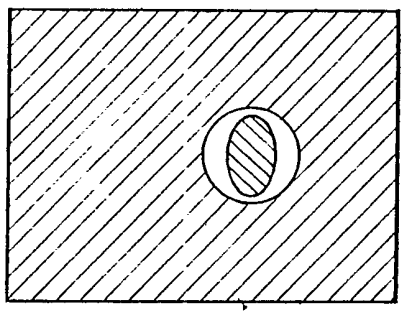

Fig. 5

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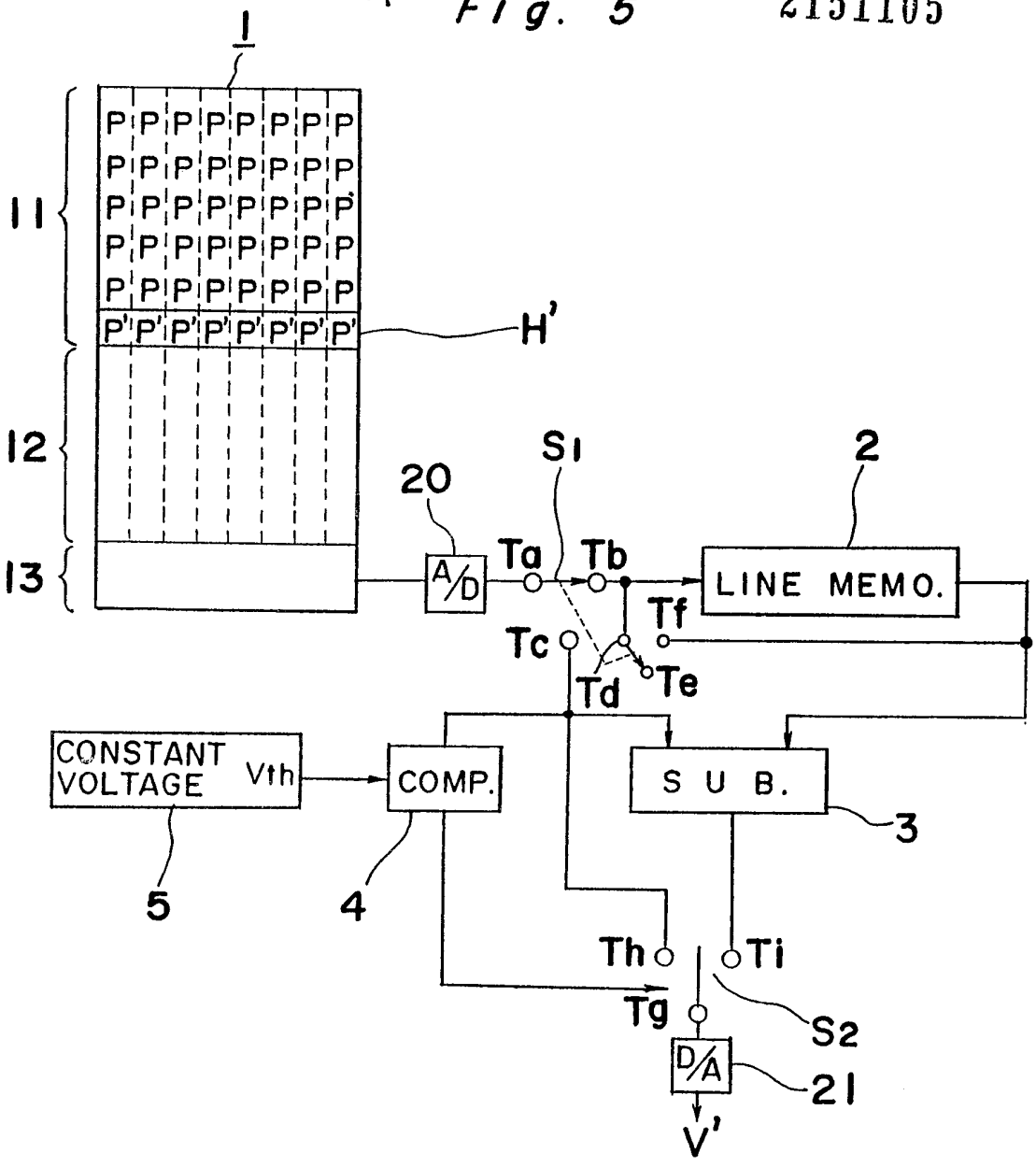


Fig. 6

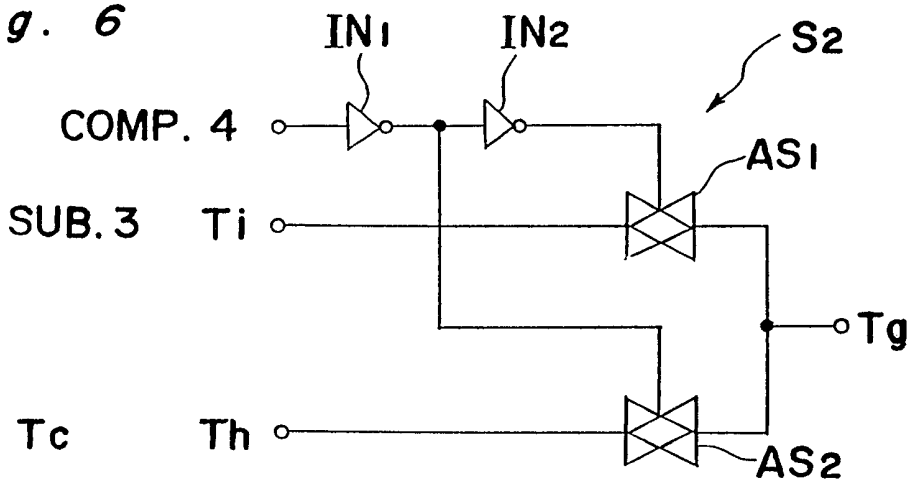


Fig. 7a

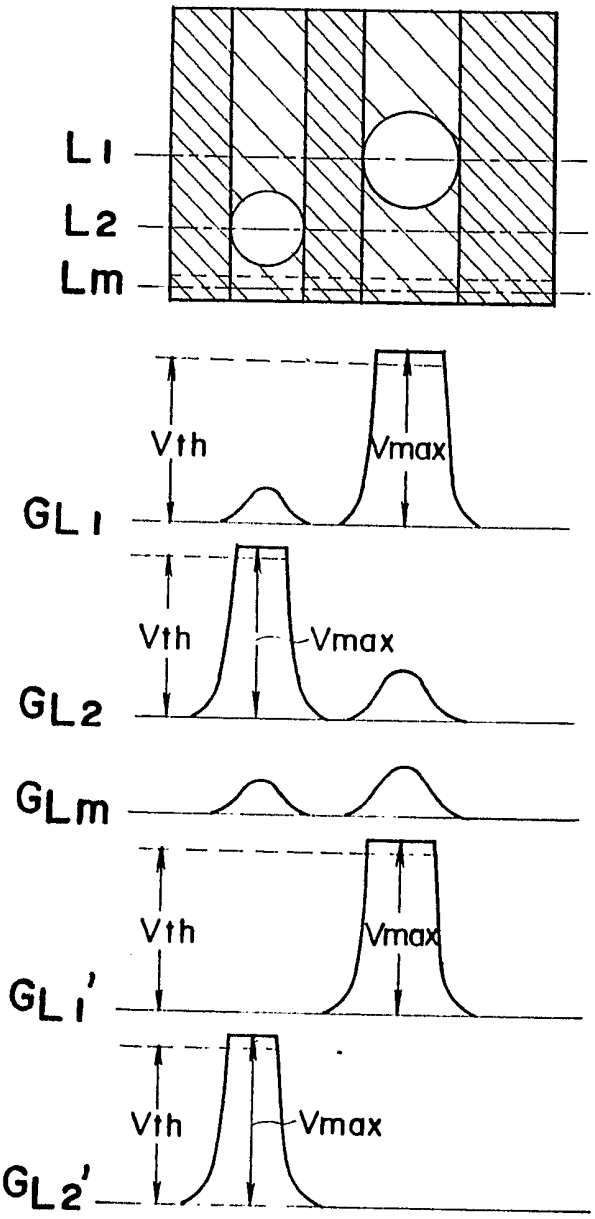
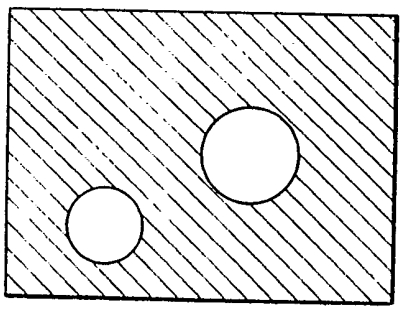


Fig. 7b



SPECIFICATION

CCD imager

The present invention relates to an imager employing CCD (charge-coupled device) and, more particularly, to an improvement in an imager which reduces the smear on a reproducing image.

Recently, many improvements have been made to an imager for use, for example, in a television camera, and one of which is the employment of a solid state CCD in place of the imaging tube, resulting in a compact size of the camera.

Such a solid state imager is defined by a plurality of photoelectric transducers aligned in two directions orthogonal to each other. When an image is formed on the solid state imager, each photoelectric transducer stores a charge which is in relation to the intensity of the impinged light thereon, thereby forming a charge pattern of one field. The charge pattern is transferred to a register, from which a charge signal is read out serially. When the image formed on the solid state imager has a bright portion, such as a bright spot light, an extra charge will be added, during the transfer of the charged pattern, to the photoelectric transducers on which the bright spot light is traced. Such an extra charge will result in an unpleasant smear in the reproduced image.

Conventionally, there have been proposed a number of arrangements which can reduce the smear. Such an arrangement is disclosed, for example, in U.S. Patent Specification No. 4,010,319 or in japanese Patent LaidOpen Application No. 17276/82.

One arrangement of a prior art CCD imager is shown in Figure 1 of the accompanying drawings. The imager includes a frame transfer type CCD 1 having a first register 11, a second register 12, and a readout resistor 13. In the first register 11 defining an imaging area, photoelectric transducers P′ in the bottom row are masked and the other photoelectric transducers P are provided to receive light image. The second register 12 which defines a storage area and the readout register 13 are also masked. When the clock pulse is applied to the CCD 1, an image integration period (for example, 16.1 milliseconds) and an image transfer period (for example 0.5 millisecond) are repeated alternately. It is assumed that a scene having one bright circle spot is projected on the first register 11.

Before the first integration period starts, a "field" with no image information appears in first register 11 as if a "field" is pulled down across first register 11 in the manner of pulling down a blind. The first register 11 receives light even during the period when the "field" is pulled down. Accordingly, the photoelectric transducers P′ in the last row H′ carry a signal obtained by the quick scan of the new field vertically across the light receiving area. When the image formed on the field has no outstanding bright portion, the signal in the last row H′ is so low that it can be disregarded. On the contrary, when the image on the field has a bright portion, such as a bright spot, a photoelectric transducer will be integrated to a small degree even during the period when the field scans across that bright spot. Thus, in such a case, the charge distribution along line L*m* shown in Figure 3a of the accompanying drawings which extends through the masked last row H′ has a small mount as indicated by the curve G_{Lm}. Since such a small mount appears on, and added to, every horizontal line a vertical smear will appear in that field. Thus, the signal shown by the curve G_{Lm} is called a smear signal.

During the first integration period, photoelectric transducers P are integrated, each charged to a level relative to the brightness of the received light. Accordingly, the received image is changed to a charge pattern on photoelectric transducers P. The charge distribution along line L1 shown in Figure 3a which intersects the spot image is indicated by the curve G_{L1}.

Then, in the first transfer period, which corresponds to the vertical blanking period of the commercial television system, the charge signals which have accumulated one "field" are transferred, in parallel, in the column direction from register 11 to resistor 12, such that the charge in the photoelectric transducer P in the first row from the top are transferred to those in the second row, and so on. During the transfer period, a next new field appears in first register 11 as the same manner described above, in the blind pull down manner.

Then, in the second integration period, the charge pattern is formed in the same manner described above, and at the same time, the signals stored in the second register 12 are readout through the readout register 13 serially such that the first readout line signal, which is the smear signal carried in the last row H′ in photoelectric transducers P′, is transferred and stored in line memory 2. After the readout of the smear signal, switch S changes its connection from the condition shown in Figure 1 to such that terminal T*a* is connected to terminal T*c* and terminal T*d* is connected to terminal T*f*. Accordingly, the readout signal through terminals T*a* and T*c* and the smear signal from line memory 2 are transferred at the same time to subtracter 3 at which the readout signal is subtracted by the smear signal. The subtracted result, such as indicated by the curve $G_{L1-Lm'}$ is produced from the subtracter 3. When the subtraction is carried out for each horizontal line signal, an image without a smear, such as shown in Figure 3b of the accompanying drawings can be reproduced.

According to the prior art CCD imager de-

scribed above, a problem arises when the imager is provided with an overflow drain, bus, for the reduction of the blooming. Figure 2 of the accompanying drawings diagrammatically illustrates an arrangement of an overflow drain 14 interleaving the aligned photoelectric transducers P. When a very bright image is impinged, photoelectric transducers generate much more charge signal than can be stored at that location. The excess charge tends to spread to the adjacent locations along the charge-coupled channel, resulting as "blooming" of the image. But when the overflow drain 14 is provided, the excess charge, which is above a predetermined level Vmax, flows through the overflow drain 14, thereby eliminating undesirable blooming.

In the case where the overflow drain 14, or the like arrangement which reduces the blooming, is employed in combination with the above described smear reducing arrangement, a problem arises as explained below.

When a very bright image, such as a very bright spot light as shown in Figure 4a of the accompanying drawings, impinges on the CCD array, the charge distribution along line L1 would have a flat top, restricting the maximum voltage to Vmax, as indicated by the curve G_{L1}. When the smear signal shown by the curve G_{Lm} is subtracted from the line signal along line L1, the flat top will be recessed, as shown by the curve G_{L1-Lm}, providing a dark portion at the centre of the spot, as illustrated in Figure 4b of the accompanying drawings.

It is an object of the present invention to solve the above described problem by providing an improved CCD imager which can reduce the smear and, at the same time, which can reduce the blooming around a bright image without producing any dark portion at the centre of the bright image.

According to the present invention there is provided a CCD imager including:

(a) a CCD having a plurality of photoelectric transducers aligned vertically and horizontally, with at least one horizontal line being masked, said CCD producing unmasked horizontal line signals obtained from unmasked horizontal lines and a masked horizontal line signal obtained from said at least one masked horizontal line;

(b) a line memory for storing said masked horizontal line signal and for producing said masked horizontal line signal repeatedly and serially;

(c) a subtracter for subtracting said masked horizontal line signal from each unmasked horizontal line signal and for producing a subtracted signal;

(d) a constant voltage source for producing a threshold voltage;

(e) a comparator for comparing said unmasked horizontal line signal with said threshold voltage and for producing a first signal when said unmasked horizontal line signal is below said threshold voltage and a second signal when the same is above said threshold voltage; and

(f) a switch means coupled to said comparator for permitting said subtracted signal to pass therethrough when said first signal is produced, and for permitting said unmasked horizontal line signal to pass therethrough when said second signal is produced.

The present invention will now be described in greater detail by way of example with reference to the remaining figures of the accompanying drawings, wherein:

Figure 5 is a circuit diagram of a preferred form of a CCD imager;

Figure 6 is a circuit diagram of the switch arrangement shown in Figure 5;

Figure 7a is a diagrammatic view showing vertical smears appearing on a reproduced image of very bright spots, and also showing graphs of charge distribution along particular lines L1, L2 and L*m*, and a produced video signal; and

Figure 7b is a diagrammatic view showing a reproduced image with the smear being removed without any unwanted dark portion within the bright portion.

Referring to Figure 5, the CCD imager further includes over the known CCD imager shown in Figure 1, a comparator 4 coupled with a constant voltage source 5 and a switch S2. Thus, it will be appreciated that the CCD imager of Figure 5 has an overflow drain, such as the overflow drain 14 shown in Figure 2, which prevents the blooming.

The switch S2 is provided with terminals T*g*, T*h* and T*i*. The terminal T*h* is connected to the terminal T*c* of the switch S1, the terminal T*i* is connected to the subtracter 3, and the terminal T*g* is an output which is either connected to the terminal T*h* or T*i*. The switch S2 is controlled by the output signal from the comparator 4.

The comparator 4 has one of its inputs connected to the terminal T*c* of the switch S1 for receiving the readout signal from the CCD 1 when the switch S1 connects the terminals T*a* and T*c* together. Another input of the comparator 4 is connected to the constant voltage source 5 for receiving a threshold voltage Vth, which is a little below the voltage Vmax of the overflow drain. The output of the comparator 4 is connected to the switch S2.

The operation of the CCD imager shown in Figure 5 is described below with the assumption that the image CCD 1 includes two bright circle spots, as shown in Figure 7a.

When the readout signal from the CCD 1 as obtained from the terminal T*c* is smaller than the threshold level Vth, that is when the image corresponding to that signal has a brightness below a certain level, such as shown by round-top mountains in the curves G_{L1} and G_{L2} in Figure 7a, the comparator 4

produces a signal for effecting the switch S2 to connect its terminals T*i* and terminal T*g* together, thereby producing a subtracted video signal from the output terminal T*g*. Accordingly, a video signal without smear is produced from the terminal T*g*.

On the contrary, when the readout signal from the CCD 1 as obtained from the terminal T*c* is greater than that of the threshold level Vth, that is when the image corresponding to that signal has a brightness above a certain level, such as shown by flat-top mountains in the curves G_{L1} and G_{L2} in Figure 7a, the comparator 4 produces a signal for effecting the switch S2 to connect the terminals T*h* and terminal T*g* together, thereby producing a video signal without being subtracted from the output terminal T*g*. Accordingly, an image having no undesirable dark spot within the bright area can be reproduced.

In Figure 7a, the curves G_{L1}, G_{L2} and G_{Lm} show video signals obtained along the lines L1, L2 and L*m*, respectively, before the unwanted smear signals are removed. When the signal shown by the curve G_{L1} is processed in the circuit of Figure 5, it is changed to the signal shown by the curve $G_{L1'}$ in which the round-top mountain is eliminated, but no change in the flat-top mountain. A similar change is seen in the signal shown by the curve G_{L2}. Thus, by the use of signals such as shown by the curves $G_{L1'}$ and $G_{L2'}$, the reproduced image has no smear and no dark spot within the bright area, as shown in Figure 7b.

Referring to Figure 6, one preferred embodiment of the switch S2 is shown, which is formed by a logic circuit. The terminal T*i* is connected to an analog switch AS1. Similarly, the terminal T*h* is connected to an analog switch AS2. The outputs of the analog switches AS1 and AS2 are connected to each other and further to the output terminal T*g*. A line from the comparator 4 is connected to an inverter IN1 which is connected to another inverter IN2 and also to a control terminal of the analog switch AS2. The output of the inverter IN2 is connected to a control terminal of the analog switch AS1.

The comparator 4 in combination with the switch S2 of Figure 6 is designed to operate such that when the readout signal from the CCD 1 as obtained from the terminal T*c* is smaller than the threshold level Vth, that is when the image corresponding to that signal has a brightness below a certain level, the comparator 4 produces a HIGH signal. Thus, the inverter IN1 produces a LOW signal to break the analog switch AS2, and the inverter IN2 produces a HIGH signal to make the analog switch AS1. Thus, a subtracted video signal is transmitted through the terminal T*i* and the analog switch AS1 to the output terminal T*g*.

On the contrary, when the readout signal from the CCD 1 as obtained from the terminal T*c* is greater than that of the threshold level Vth, that is when the image corresponding to that signal has a brightness above a certain level, the comparator 4 produces a LOW signal. Thus, the inverter IN1 produces a HIGH signal to make the analog switch AS2, and the inverter IN2 produces LOW to break the analog switch AS1. Thus, a video signal without being subtracted is produced from the output terminal T*g*.

According to one embodiment of the present invention, the signals applied to the circuits 2, 3, 4 and 5 shown in Figure 5 can be processed in a digital form. In such a case, an analog-to-digital converter 20 is inserted between the CCD 1 and the switch S1, and a digital-to-analog converter 21 is connected after the output terminal T*g*, as shown in Figure 5.

CLAIMS

1. A CCD imager including:

(a) a CCD having a plurality of photoelectric transducers aligned vertically and horizontally, with at least one horizontal line being masked, said CCD producing unmasked horizontal line signals obtained from unmasked horizontal lines and a masked horizontal line signal obtained from said at least one masked horizontal line;

(b) a line memory for storing said masked horizontal line signal and for producing said masked horizontal line signal repeatedly and serially;

(c) a subtracter for subtracting said masked horizontal line signal from each unmasked horizontal line signal and for producing a subtracted signal;

(d) a constant voltage source for producing a threshold voltage;

(e) a comparator for comparing said unmasked horizontal line signal with said threshold voltage and for producing a first signal when said unmasked horizontal line signal is below said threshold voltage and a second signal when the same is above said threshold voltage; and

(f) a switch means coupled to said comparator for permitting said subtracted signal to pass therethrough when said first signal is produced, and for permitting said unmasked horizontal line signal to pass therethrough when said second signal is produced.

2. A CCD imager according to claim 1, wherein said switch means is in the form of a logic circuit having a pair of analog switches.

3. A CCD imager constructed substantially as herein described with reference to and as illustrated in Figures 5 to 7 of the accompanying drawings.

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