

IMPROVEMENTS IN OR RELATING TO RANGEFINDERS

The present invention relates to automatic rangefinders of a kind wherein a beam of light is projected onto a scene to illuminate a small area on an object in the scene, a linear array of image sensors senses an image of the scene and produces signals indicative of the amplitude of light incident on the sensors, and signal processing electronics detect the location of the spot in the image to determine the distance to the object. More particularly, the present invention relates to improved means for processing the signals and for detecting the location of the image of the illuminated area.

In a known rangefinder, a beam of light is projected onto an object in a scene to illuminate a small area on the object. An image of the scene including the small illuminated area, is formed on a linear array of photosensors. The location of the illuminated area along the linear array is determined, and from that location the range of the object is derived. Such rangefinding devices find application, for example, in automatic focusing cameras.

The general arrangement of elements and the mode of operation of such a known rangefinder will be described with reference to FIG. 1. Means for projecting a beam of light is shown by way of example as a light emitting diode (LED) 10 and a lens 12. The beam is projected along a path 14 to illuminate a small area on an object O₁ in a scene. The scene is imaged by a second lens 16 onto a linear array 18 of photosensors. The signals produced by the photosensors are analyzed by control electronics 20 to determine the position of the small illuminated area in the scene and produce a signal 22 representing the range of the object.

As shown in FIG. 1, the apparent position of the illuminated area in the scene is a function of distance along light path 14 to the object. For an object O_1 located at a distance D_1 from the rangefinding device, the image of the illuminated area will fall on the array 18 at location S_1 . For an object O_2 at a further distance D_2 , the image of the area will fall on the array 18 at location S_2 . By examining the output of the array 18, the control electronics 20 determines (for example, by comparing the outputs of the elements to determine that output which is a maximum) the location of the illuminated area in the scene and thereby the distance to the object.

One way of accomplishing this comparison is described in US-A-4274735. In the device described in US-A-4274735, each signal is compared with all the others by an array of comparators, one comparator for each photosensor in the array, to determine the location of the illuminated area by sensing the largest signal. If the sensor array comprises more than a few photosensors, the use of an array of comparators to determine the maximum signal greatly complicates the signal processing circuitry.

It is an object of the present invention to simplify the signal processing electronics of the rangefinder so that the number of photosensors in the array may reasonably be increased.

According to the present invention, there is provided a device for finding the range of an object in a scene, comprising means for projecting a beam of light for illuminating a small area of the object, a linear array of sensors for viewing the scene and producing signals representing the amplitude of light incident on them from respective

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regions of the scene, means for producing from the first mentioned signals, in response to periodic scanning signals, a series of signals of varying amplitude, signal processing means responsive to
5 said series of signals for detecting the relative location of the illuminated small area in said scene and producing a range signal in response thereto, said signal processing means including counter means advanced in synchronism with said scanning signals
10 for producing a running count representative of the number of signals received in the series, peak detector means responsive to the signals in the series for producing a latch signal each time a new greater signal occurs in said series, and latch
15 means connected to said counter means and responsive to a latch signal for capturing and temporarily holding the current count at the time of receipt of said latch signal, whereby, after said series of signals has been completed, the count held by said
20 latch means represents the location of the image of the illuminated area on the array of sensors.

Preferably, the peak detector means comprises storage means for storing the value of the last greatest signal in said series, comparator
25 means for comparing the value stored in said storage means with the next signal in said series, and producing an output signal in response to the value of said next signal being greater than said last greatest signal, and switch means responsive to said
30 output signal for replacing the value on said storage means with said greater value.

The present invention will now be described, by way of example, with reference to Figs. 2 to 5 of the accompanying drawings, in which:-

FIG. 2 is a schematic block diagram showing the signal processing and control electronics of a rangefinder according to the present invention;

FIG. 3 is an electrical circuit schematic diagram showing the signal processing electronics for peak detecting; and

FIGS. 4 and 5 are timing diagrams useful in explaining the operation of the rangefinder according to the present invention.

Referring first to FIG. 2, overall control of the rangefinder is provided by a programmed microprocessor 100 through conventional driver circuits 102. The microprocessor 100 is supplied with timing signals from a clock circuit 104 and with power through a main power switch 106 from a battery 108. The image sensing portion of the rangefinder includes a serially scanned linear image sensor 109 of the type having an array 110 of photosensors and means for serially addressing the photosensors, such as a CCD shift register 111. Such serially scanned linear image sensors are readily available commercially, and generally require a transfer signal T_1 to actuate a transfer gate 112 to transfer signals generated in the photosensors in parallel to the shift register 111, and a multiphase (e.g. 4-phase) clock signal ϕ_{1-4} to cause the CCD shift register 111 to deliver the signals serially to an output diode 113. The 4-phase clock signals ϕ_{1-4} and the transfer signal T_1 are supplied to the image sensor 109 from output driver circuits 102 under control of microprocessor 100 to

produce output signals from the CCD shift register 111. The signals from the CCD shift register 111 are sampled by a sample and hold circuit 114 and are supplied to a peak detector circuit 115 that
5 produces a pulse each time a signal larger than any previous signal is received from image sensor 109. The output of the peak detector circuit 115 is supplied to a latch circuit 116. Latch circuit 116 is connected to the outputs of a digital counter
10 118. Counter 118 receives a reset signal R and a timing signal Φ_T having the same frequency as the 4-phase clock signals Φ_1 - Φ_4 . The output of the latch circuit 116 is supplied to an input port of microprocessor 100.

15 The driver circuits 102 also power an LED 119 in the beam forming portion of the rangefinder and an output device 120 such as a range display or a range servo. LED 119 preferably emits infra-red light.

FIG. 3 is a more detailed circuit schematic
20 of the signal processing electronics shown in FIG. 2. A portion of the CCD shift register 111 including phase 3 and phase 4 transfer electrodes 130 and 132 respectively, an output gate 122, and output diode 113 is shown.

25 An output amplifier 124 is an on-chip sense and reset amplifier including a sense FET 125 and a reset FET 126. The sense FET 125 is a surface channel device, and the reset FET 126 is a buried channel device. A buried channel FET 128 is
30 connected between the drain of the FET 125 and earth in a constant current configuration for converting the sensed charge on output diode 113 to a voltage at node A. The sample and hold circuit 114, comprising a clamping portion having a series
35 capacitor 139, a clamping FET 140, and a buffer amplifier 141, and a sample and hold portion

comprising a sampling FET 142, a storage capacitor 143, and an amplifier 144, samples the output voltage at node A and holds the voltage at node B.

5 The peak detector circuit 115 comprises a comparator 146, a reference capacitor 148,, a sampling FET switch 150, and a timing FET switch 152. The peak detector circuit 115 also contains a threshold setting portion comprising a preset FET switch 154 connecting capacitor 148 to earth, and a
10 threshold setting FET switch 156 connecting the power supply voltage V_{cc} to capacitor 148 through a resistor 158.

The operation of the rangefinder will now be described with reference to FIGS. 4 and 5. To
15 begin, for example upon closure of main power switch 106 at time t_0 , (see FIG. 4) the microprocessor 100 initializes the photosensor array by transferring any accumulated charge from photosensors in the array 110 into shift register 111 by applying a
20 T_1 transfer pulse to transfer gate 112, (FIG. 4a) while phase 2 (ϕ_2) of the 4-phase clock signal is held high. The 4-phase clock signal ϕ_{1-4} is then applied to the CCD shift register 111 to empty any residual charge therefrom (see FIG. 4b).

25 At time t_1 , the microprocessor 100 turns on LED 119. LED 119 is kept on for a period τ_1 to integrate charge in the photosensors, during which time the signal processing circuitry is initialized to set the threshold of the peak detector. FET switch 154 (see FIG. 3) is turned on
30 momentarily by generating a ϕ_{preset} pulse (see FIG. 4d) to earth capacitor 148. Then, FET switch 156 is closed by a pulse ϕ_{TH} for a period τ_2 (See FIG. 4e) to charge capacitor 148 to a value determined by the
35 time constant of resistor 158 and capacitor 148. At time t_2 , the LED 119 is turned off and the photosignals

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generated by the array 110 are transferred to the CCD shift register 111 by applying a pulse T_1 to transfer gate 112 (see FIG. 4a). The CCD shift register 111 is then read out to generate the range signal by applying the 4-phase clock signal ϕ_{1-4} to the transfer electrodes of the shift register (see FIG. 4b).

Processing of the signals from the CCD shift register 111 will now be described with reference to FIG. 5. The 4-phase clock signals ϕ_{1-4} are shown in FIGS. 5a-d. While the signal charge resides under the phase 3 and phase 4 electrodes, 130 and 132 respectively, (ϕ_3 and ϕ_4 simultaneously high) a reset pulse ϕ_R is applied to buried channel FET reset transistor 126 to prepare the output diode 113 to receive the signal charge. At this point, node A of the output amplifier 124 goes to a high level (200 in FIG. 5f). When the voltage on the phase-3 transfer electrode 130 goes low, some of the signal charge may spill over the output gate onto the output diode 113, and the voltage at node A may go to the intermediate level 202 in FIG. 5f. Finally, when the voltage on the phase-4 transfer gate 132 goes low, all the signal charge is moved to the output diode 113 and the output signal at node A goes to its final signal level 204 as shown in FIG. 5f.

While the signal is at its reset level 200, a clamping pulse ϕ_{CL} (see FIG. 5g) is applied to clamping FET 140, then when the final signal level 204 is present at node A, a sampling pulse $\phi_{S/H}$ is applied to sampling FET 142, thereby storing the signal level present at node A on capacitor 143 while removing any variations due to reset level noise. The output of amplifier 144 at node B follows this signal as shown in FIG. 5i.

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The voltage at node B is a step-wise smooth curve representing the successive values of the output signal (see FIG. 5i). Comparator 146 compares the first sample with a threshold value V_{TH} (see FIG. 5i) stored on reference capacitor 148. If the sampled value is less than the threshold value, the output of comparator 146 at node C remains low. However, if the sampled value exceeds the threshold value, the output at node C goes high. At a point during the sample period, a sampling signal ϕ_S (see FIG. 5j) is applied to FET switch 152. If the voltage at node C is low at this time, the low value will be applied to the gate of FET switch 150 and will have no effect upon the state of the circuit. If, however, the voltage at node C is high, the high value will be applied to the gate of sampling FET switch 150, thereby applying the new higher reference voltage to capacitor 148. The new reference value is equal to the value at node B, thereby causing the output at node C to go low (see FIG. 5k). This process continues, producing a pulse at node C each time a new signal greater than any previous signal is received from the image sensing array.

At the start of the sequence, counter 118 is initialized. Each time a new charge packet is read from the CCD shift register, counter 118 is advanced (see FIG. 2). The pulse train produced by the peak detector circuit 115 at node C is applied to latch circuit 116 which latches the output of counter 118 whenever a new pulse is produced by the peak detector. After all the charge packets in the CCD shift register 111 have been read out, the count held by latch circuit 116 is indicative of the location of the photosensor having the greatest illumination from the LED above the threshold level V_{TH} . At this point, the microprocessor 100 retrieves

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the range data from the latch circuit 116 by interrogating its input port.

The range data are then used in a known manner to drive output device 120 such as a range display or focus servo.

When the rangefinder is employed in an auto-focus camera, and no pulse is produced by the peak detector circuit 115, either because the LED signal from a near object was below the threshold V_{TH} , or the object was beyond the range of the rangefinder, the focus servo drives the lens to the infinity focus position, thereby maximizing the probability that the object will be properly focused since all objects located between one half the hyper focal distance and infinity will be in acceptable focus. Normally, the threshold V_{TH} is set sufficiently high so that there is an acceptably low probability that the rangefinder will indicate an incorrect range due to noise. However, since the photon limited signal-to-noise ratio of the rangefinder is inversely proportional to the square root of the ambient light level, the threshold V_{TH} may be lowered in low ambient light levels, thereby increasing the sensitivity of the rangefinder device while maintaining the same low probability that the rangefinder will trigger on noise.

The maximum ambient light level can easily be determined by setting the threshold V_{TH} at some intermediate value and operating the rangefinder without turning on the LED 119. If a peak greater than V_{TH} is detected, the threshold is raised by some increment, and the process is repeated, until no peak is detected. If no peak is detected at the intermediate threshold value, the threshold is lowered by some increment, and the process is repeated, until a peak is detected. The final threshold value is indicative of the peak ambient

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light level. The threshold setting for operating the rangefinder is then determined as a function of the ambient light level, for example by consulting a look up table stored in computer memory.

5 In the embodiment specifically described above with reference to the drawings, the signals supplied by the sensor 109 are the signals generated by the photosensors in the array 110. It is those signals which are passed to the sample and hold circuit 114. Those signals represent the brightness of
10 portions of the scene including the small area of the object illuminated additionally by LED 119. The rangefinding is achieved by detecting the greatest signal, which is derived from the photosensor having the greatest amplitude of image light. It is
15 assumed that the greatest amplitude of image light is that in which there is a component derived from the LED 119. In most circumstances this assumption gives satisfactory results, particularly when the
20 light being generated by the light source in the above embodiment, the LED 119, and the light being sensed by the sensor, is infrared. However, in some circumstances satisfactory results would not be achieved.

25 In order to ensure that the peak signal detected by the peak detector 115 is indeed derived from light emitted by the LED 119, means may be included for subtracting signals representative of illumination of the scene other than that illumination
30 derived from the LED 119, from signals representative of illumination of the scene by that other illumination and by the LED 119. Such means are known from US-A-4274735 which describes subtracting
35 signals created with the light source off from signals created with the light source on. Also, our

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copending Patent Application No. 8322256 describes
an improved arrangement for removing "background"
signal so that signals are produced which are
representative solely of the illumination provided
5 by the light source of the rangefinder.

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CLAIMS:

1. A device for finding the range of an object in a scene, comprising means for projecting a beam of light for illuminating a small area of the object, a linear array of sensors for viewing the scene and producing signals representing the amplitude of light incident on them from respective regions of the scene, means for producing from the first mentioned signals, in response to periodic scanning signals, a series of signals of varying amplitude, signal processing means responsive to said series of signals for detecting the relative location of the illuminated small area in said scene and producing a range signal in response thereto, said signal processing means including counter means advanced in synchronism with said scanning signals for producing a running count representative of the number of signals received in the series, peak detector means responsive to the signals in the series for producing a latch signal each time a new greater signal occurs in said series, and latch means connected to said counter means and responsive to a latch signal for capturing and temporarily holding the current count at the time of receipt of said latch signal, whereby, after said series of signals has been completed, the count held by said latch means represents the location of the image of the illuminated area on the array of sensors.

2. A device as claimed in claim 1, wherein said peak detector means comprises storage means for storing the value of the last greatest signal in said series, comparator means for comparing the value stored in said storage means with the next signal in said series, and producing an output

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5 signal in response to the value of said next signal
being greater than said last greatest signal; and
switch means responsive to said output signal for
replacing the value on said storage means with said
greater value.

3. A device as claimed in claim 2,
wherein said peak detector means further includes
threshold setting means for storing an initial
threshold value in said storage means.

10 4. A device as claimed in claim 3,
further comprising means for determining said
initial threshold value as a function of ambient
illumination.

15 5. A device as claimed in claim 1
substantially as hereinbefore described with reference
to Figs. 2 to 5 of the accompanying drawings.

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