

ANALOG-TO-DIGITAL CONVERTER FOR A CAMERA

This invention relates to analog-to-digital converters for cameras.

5 In automatic cameras brightness and range information of an object to be photographed has to be converted to a digital signal. For example, in Japanese Laid Open Patent Specification No. 60-164728, there is proposed a digital photometric device where an object
10 brightness detector R_t and a capacitor C are coupled in series with each other, and clock pulses are counted from the time when a photometric process is started until the voltage across the capacitor C reaches a reference voltage. However, this device is
15 disadvantageous in that measuring accuracy is reduced due to variations in the capacitance of the capacitor C and variations in the reference voltage. Another problem is that since a comparator is used for comparing the capacitor voltage with the reference voltage and
20 this comparator has three transistors T_1 , T_2 , T_3 connected in series with a power supply V_e as shown in Figure 6, the power supply has to produce a high voltage which is three times the threshold voltage of each of the transistors.

25 The present invention seeks to provide an analog-

to-digital converter for a camera, which has high conversion accuracy and which can be driven by a relatively low voltage.

5 According to the present invention, there is provided an analog-to-digital converter for a camera, comprising pulse output means alternately and selectively connectable to one of a pair or pairs of signal generating means, the ratio of whose signals is indicative of the value of a physical quantity,
10 computing means for computing the ratio of pulse durations of two pulse signals from the pulse output means which is a one shot multi-vibrator, memory means storing values of the physical quantity related to ratios, and means to apply the computed ratio to the
15 memory means to derive a stored value of the physical quantity in digital form.

Preferably, the converter includes a clock pulse source producing two series of clock pulses at different

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frequencies, the computing means including a pre-settable counter for counting clock pulses of the lower frequency from the source for a duration determined by the pulse signals from the pulse output means due to one
5 signal generating means to pre-set a count in the pre-settable counter, and for counting clock pulses of the higher frequency from the source for a duration determined by the pulse signals from the pulse output means due to the other signal generating means, comparing the
10 latter count with the pre-set count and issuing a signal to another counter for each completed count to provide a computed ratio.

The signal generating means may comprise means to generate a reference signal and means to generate a
15 measurement signal dependent upon a physical quantity to be measured.

Alternatively, the signal generating means may comprise means to generate the sum of two measurement signals and means to generate the difference of the two
20 measurement signals, the measurement signals being

dependent upon a physical quantity to be measured.

Conveniently, one pair of signal generating means comprises means to generate a reference signal and means to generate a measurement signal dependent upon a
5 physical quantity to be measured, and the other pair of signal generation means comprises means to generate the sum of two measurement signals and means to generate the difference of the two measurement signals, the measurement signals being dependent upon another
10 physical quantity to be measured.

The computing means may include a pre-settable counter for counting clock pulses for a duration determined by the pulse signals from the pulse output means.

15 The analog-to-digital converter may include oscillator means for producing clock pulses for the

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computing means. The oscillator means may produce a first series of clock pulses of one frequency and a second series of clock pulses of a second frequency.

5 In one embodiment the measurement signal generating means includes switch means for selectively passing the measurement signal to the pulse output means.

The measurement signal generating means may include means for determining the brightness of an object to be photographed. Additionally or
10 alternatively, the measurement signal generating means may include means for determining the distance of an object to be photographed.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:-

15 Figure 1 is a block diagram of one embodiment of an analog-to-digital converter according to the present invention;

Figure 2 is a timing chart to illustrate the operation of the analog-to-digital converter of Figure
20 1;

Figure 3 is a block diagram of another embodiment of an analog-to-digital converter according to the present invention;

Figure 4 is a diagram explaining the operation of
25 a rangefinder circuit of the analog-to-digital converter

of Figure 3;

Figure 5 is a block diagram of a third embodiment of an analog-to-digital converter according to the present invention; and

5 Figure 6 is a circuit diagram of a conventional photometric circuit.

Figure 1 shows an embodiment of an analog-to-digital converter according to the present invention. The analog-to-digital converter comprises a one-shot
10 multivibrator 1 having a NOR gate 1a, a capacitor 1b, and an inverter 1c connected in series. One input terminal of the NOR gate 1a is connected to the output terminal of the inverter 1c, and the other input terminal of the NOR gate 1a is coupled to a trigger
15 circuit 2. A voltage V_e is applied selectively through switches 5,6 interlinked to a release button (not shown) of the camera, a reference resistor 3, and a light detector 4 having a photoresistive conversion capability. A pulse duration ratio computing circuit 7
20 comprises an AND gate 7a having one input terminal supplied with a main pulse signal from the one-shot multivibrator 1 and the other input terminal supplied selectively with a clock signal CK1 of a lower repetition frequency and a clock signal CK2 of a higher
25 repetition frequency, a presettable counter 7b supplied

with the clock signal from the AND gate 7a, and a counter 7c for counting a count-up signal from the counter 7b. Both the clock signals CK1 and CK2 are provided by a clock oscillator 9. The pulse duration ratio computing circuit 7 serves to compute the ratio between the numbers of two clock signals. A data memory circuit 8 stores exposure values corresponding to and addressable by the outputs from the pulse duration ratio computing circuit 7 as shown in Table 1.

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TABLE 1

	Zone	Tx / Ts	Object Brightness
	0	- 0.55	- 15 3/4
	1	0.55 - 0.66	15 3/4 - 15 1/4
	2	0.66 - 0.78	15 1/4 - 14 3/4
15	3	0.78 - 0.91	14 3/4 - 14 1/4
	4	0.91 - 1.08	14 1/4 - 13 3/4
	5	1.08 - 1.28	13 3/4 - 13 1/4
	6	1.28 - 1.58	13 1/4 - 12 3/4
	7	1.58 - 1.89	12 3/4 - 12 1/4
	8	1.89 - 2.29	12 1/4 - 11 3/4
	9	2.29 - 2.80	11 3/4 - 11 1/4
20	10	2.80 - 3.43	11 1/4 - 10 3/4
	11	3.43 - 4.22	10 3/4 - 10 1/4
	12	4.22 - 5.14	10 1/4 - 9 3/4
	13	5.14 - 6.29	9 3/4 - 9 1/4
	14	6.29 - 7.54	9 1/4 - 8 3/4
	15	7.54 -	8 3/4 - 8 1/4

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Operation of the analog-to-digital converter of

Figure 1 will now be described with reference to a timing diagram shown in Figure 2.

When the release button is depressed to a first position in order to measure the brightness of an object to be photographed, the switch 5 is turned on to allow the voltage V_e to be applied through the reference resistor 3 to the one-shot multivibrator 1, and a trigger signal is applied from the trigger circuit 2.

The multivibrator 1 then issues a pulse P_s having a duration determined by the time constant of the capacitor 1b and the reference resistor 3. The pulse P_s is applied to the pulse duration ratio computing circuit 7 to open the gate 7a, thus allowing the clock pulses CK_1 to be applied to the presettable counter 7b which presets a number of clock pulses equal to the pulse duration. The pulse duration T_s of the pulse P_s is expressed by:

$$T_s = R_s \cdot C \cdot \ln \frac{V_e - V_{th}}{V_e}$$

where R_s is the resistance of the reference resistor 3, C is the capacitance of the capacitor, V_e the power supply voltage, and V_{th} the threshold voltage of the inverter 1c. The pulse duration T_s is thus proportional to the resistance of the reference resistor 3.

After the pulse P_s is terminated, the switch 5 is turned OFF and the switch 6 is turned ON to permit the

voltage V_e to be applied through the light detector 4 to the multivibrator 1, and a trigger signal, is applied from the trigger circuit 2. The multivibrator 1 then produces a pulse P_x having a time duration T_x , expressed below, proportional to the resistance R_x of the light detector 4 which resistance is proportional to object brightness:

$$R_x.C.\ell n \frac{V_e - V_{th}}{V_e} \tau$$

The pulse P_x is applied to the pulse duration ratio computing circuit 7 to open the gate 7a which allows the clock pulses CK_2 to be impressed on the presettable counter 7b. The presettable counter 7b starts counting the clock pulses CK_2 , and issues a count-up signal each time the count reaches a preset value which has been set on the pulse P_s , so that the counter 7c counts up.

The count in the counter 7c is indicative of the ratio of the pulse durations of the pulse signals P_s , P_x , i.e.:

$$\begin{aligned} \frac{T_x}{T_s} &= \frac{R_x.C.\ell n \frac{V_e - V_{th}}{V_e}}{R_s.C.\ell n \frac{V_e - V_{th}}{V_e}} \\ &= \frac{R_x}{R_s} \end{aligned}$$

Therefore, the count is only related to the resistance of the reference resistor 3 and the light detector 4

while the capacitance C of the capacitor 1b, the power supply voltage V_e , and the threshold voltage V_{th} are cancelled out. Accordingly, the count is of high accuracy and free from influences due to variations in the power supply voltage V_e , the threshold voltage V_{th} which varies with the power supply voltage, and the capacitance of the capacitor which varies with time and temperature.

However, photometric errors due to variations in the linearity (so-called γ characteristics) of a CdS light detector with respect to variations in the amount of incident light cannot be removed.

The resistance of the light detector 4 has been referred to as R_x . The resistance R_x of a CdS light detector and object brightness are related by the following equation:

$$R_x = R_0 \times 2^{\gamma(n-x)}$$

where, R_0 is the resistance at a reference brightness $\underline{n}$, and x is the object brightness. Therefore, when γ varies, so does R_x . Since γ is an exponent of 2, it greatly affects R_x .

It is possible to measure the CdS resistance to give and divide the same in order to make its variations small. It is also possible to make a large number of divisions so that the variation in each division is

substantially zero.

Therefore, correct brightness can be obtained by storing values corresponding to pulse duration ratios inherent in γ in the respective divisions. The value of
 5 a desired division can be determined by selecting the corresponding one of as many terminals as the number of divisions. The values according to the divisions are stored in the data memory circuit.

The computed value is applied to the data memory
 10 circuit 8 to access a corresponding address for obtaining object brightness information which is employed as a parameter for exposure control.

Figure 3 illustrates a second embodiment of an analog-to-digital converter according to the present
 15 invention. A rangefinder circuit 10 is operable on the principle of trigonometric survey. The rangefinder circuit 10 has a bias voltage generator 10a for applying a reference voltage to the neutral point of a position sensitive device (PsD) 10b which produces current from
 20 opposite ends, which currents are converted by operational amplifiers 10c, 10d, respectively shunted by feedback resistors R_f , to voltage signals $v_1 = R_f \times i_1$, $v_2 = R_f \times i_2$, respectively. These voltage signals are applied respectively to inverting amplifiers 10e, 10f
 25 which produce an added signal $V_1 = v_1 + v_2$ and a

subtracted signal $V_2 = v_2 - v_1$, respectively. Denoted at 10g is a light-emitting element, and 11, 12 are condensing lenses.

5 Assuming that the distance to the object to be photographed is indicated by L (Figure 4), the length of the PSD 10b is indicated by d , the distance from the light emitting element to the neutral point of the PSD 10b is indicated by b , and the distance between the position where a light spot is formed and the neutral point of the PSD 10b is indicated by x (Figure 4), the output currents from the output terminals of the PSD 10b are indicated by $i_1 = (d - 2x)/2d \cdot F$, $i_2 = (d + 2x)/2d \cdot F$, respectively, where F indicates the intensity of the light spot which is determined by the distance L to the object to be photographed and the reflectivity thereof.

Since the distance x between the neutral point and the light spot is expressed by $f \cdot b/L$ if the focal length of the lens 11 is indicated by f , the distance x is given by:

$$\frac{i_2 - i_1}{i_1 + i_2} = \frac{1}{L} \cdot \frac{2fb}{d}$$

Consequently, the distance L to the object is expressed by:

$$25 \quad L = K \cdot (i_1 + i_2) / (i_2 - i_1)$$

Inasmuch as this proportionality equation does not contain the light intensity at the light spot as a

factor, the distance can be detected irrespective of the reflectivity of the object and variations in the output from the light emitting element.

The rangefinder circuit 10 has respective added and subtracted signal output terminals p, m connected to a switching circuit 13 and a voltage-to-current converter 17 to the one-shot multivibrator 1 so that the added and subtracted signals will be applied alternately to the multivibrator 1.

When the switching circuit 13 is connected to the output terminal p , the voltage-to-current converter 17 issues a current $I_1 = k(i_1 + i_2)$, and when the switching circuit 13 is connected to the output terminal m , the voltage-to-current converter 17 issues a current $I_2 = k(i_2 - i_1)$, where k is a constant determined by resistors R_C, R_S of the voltage-to-current converter 17.

TABLE 2

Zone	T_2 / T_1	Distance (m)
0	- 64/40	- 0.96
1	64/40 - 64/35	0.96 - 1.09
2	64/35 - 64/30	1.09 - 1.28
3	64/30 - 64/25	1.28 - 1.54
4	64/25 - 64/20	1.54 - 1.92
5	64/20 - 64/15	1.92 - 2.56
6	64/15 - 64/10	2.56 - 3.84
7	64/10 -	3.84 -

A data memory circuit 14 stores data distances (see Table 2) corresponding to the pulse duration ratios

and addressable by the output signals from the pulse duration ratio computing circuit 7.

When the release button, for example, is depressed in order to measure the distance to the object to be photographed, the added signal V1 from the rangefinder circuit 10 is applied through the switching circuit 13 to the voltage-to-current converter 17 which issues the signal $I1 = k(i1 + i2)$ to the one-shot multivibrator 1, which is also supplied with a trigger signal from the trigger circuit 2.

The multivibrator 1 then issues a pulse P1 having a duration determined by the values of the capacitor 1b and the current I1. The pulse P1 is applied to the pulse duration ratio computing circuit 7 to open the gate 7a, which allows the clock pulses CK1 to the presettable counter 7b which presets the number of clock pulses equal to the pulse duration. The pulse duration T1 of the pulse P1 is expressed by:

$$T1 = \frac{1}{I1} \cdot C V_{th} = \frac{1}{k(i1 + i2)} \cdot C V_{th}$$

which is proportional to $(i1 + i2)$.

Upon completion of the pulse P1 based on the added signal V1, the switching circuit 13 is operated to apply the subtracted signal V2 from the rangefinder circuit 10 to the voltage-to-current converter 17, which then applies the signal $I2 = k(i2 - i1)$ to the multivibrator

1, which is also supplied with a trigger pulse.

The multivibrator 1 then produces a pulse P2 having a time duration T2, expressed below, proportional to the current I2;

$$T_2 = \frac{1}{I_2} \cdot C \cdot V_{th} = \frac{1}{k(i_2 - i_1)} \cdot C \cdot V_{th}$$

The pulse P2 is applied to the pulse duration ratio computing circuit 7 to open the gate 7a which permits the clock pulses CK2 to be applied to the presettable counter 7b.

The presettable counter 7b issues a count-up signal each time its count reaches a preset value, and the count-up signals are counted by the counter 7c. The count in the counter 7c is indicative of the ratio between the pulse signals P1, P2, i.e.:

$$\begin{aligned} \frac{T_2}{T_1} &= \frac{\frac{1}{k(i_2 - i_1)} \cdot C \cdot V_{th}}{\frac{1}{k(i_1 + i_2)} \cdot C \cdot V_{th}} \\ &= \frac{(i_1 + i_2)}{(i_2 - i_1)} \end{aligned}$$

and hence is proportional to the distance L. The count is only related to (i1 + i2) and (i2 - i1) while the capacitance C of the capacitor 1b, the power supply voltage Ve, and the threshold voltage Vth are cancelled out. Accordingly, the count is of high accuracy and free from influences due to variations in the power

supply voltage V_e , the threshold voltage V_{th} which varies with the power supply voltage, and the capacitance of the capacitor 1b which varies with time and temperature.

The computed value is applied to the data memory circuit 14 to access a corresponding address for obtaining object distance information which is employed as a parameter for focal distance control and exposure control.

Figure 5 shows a third embodiment of an analog-to-digital converter according to the present invention. The reference resistor 3 and the light detector 4 of the photometric circuit, and the rangefinder circuit 10 are connected to the one-shot multivibrator 1 through a measurement mode switching circuit 15. By operating the measurement mode switching circuit 15 in response to the release button, for example, measured photometric and distance values can be converted by the common one-shot multivibrator 1 to a pulse duration ratio to access a data memory circuit 16 which stores object brightness and distance data for producing a digital signal. The arrangement of this embodiment is of reduced cost.

While the pulse duration ratio computing circuit is composed of a combination of counters in the above embodiments, a pulse duration ratio computing circuit of

other design may be employed. Either the reference value or the measured value may be applied first to the pulse duration ratio computing circuit. A silicon photodiode may be used as the light detector.

5 With the embodiments of the present invention described above, since there are provided pulse output means alternately selectively connectable to a reference signal generating element and a measurement signal generating element which serve as elements for defining
10 pulse durations, and means for computing the ratio of the pulse duration of two pulse signals from the pulse output means, a measured value can be highly accurately converted to a digital signal free from time- and temperature-dependent variations while cancelling out
15 circuit constants such as the capacitance of a capacitor constituting a time-constant circuit and the supply voltages.

Inasmuch as pulse durations are compared, no comparator is required, and the power supply voltage can
20 be lowered as much as possible.

The pulse duration ratios are used as addresses and the measured values corresponding to the pulse duration ratios are stored as data in memory means. Therefore, device variations can be compensated for
25 simply by varying the data to be stored according to

characteristics and tolerances of the detector and circuit components. Consequently, parameters for camera control can be obtained with high accuracy without the need for highly accurate circuit components.

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C L A I M S

1. An analog-to-digital converter for a camera,
comprising pulse output means alternately and
5 selectively connectable to one of a pair or pairs of
signal generating means, the ratio of whose signals is
indicative of the value of a physical quantity,
computing means for computing the ratio of pulse
durations of two pulse signals from the pulse output
10 means which is a one shot multi-vibrator, memory means
storing values of the physical quantity related to
ratios, and means to apply the computed ratio to the
memory means to derive a stored value of the physical
quantity in digital form.

15 2. A converter as claimed in claim 1, including
a clock pulse source producing two series of clock
pulses at different frequencies, the computing means
including a pre-settable counter for counting clock
pulses of the lower frequency from the source for a
20 duration determined by

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the pulse signals from the pulse output means due to one signal generating means to pre-set a count in the pre-settable counter, and for counting clock pulses of the higher frequency from the source for a duration determined by the pulse signals from the pulse output means due to the other signal generating means, comparing the latter count with the pre-set count and issuing a signal to another counter for each completed count to provide a computed ratio.

3. A converter as claimed in claim 1 or 2, in which the signal generating means comprises means to generate a reference signal and means to generate a measurement signal dependent upon a physical quantity to be measured.

4. A converter as claimed in claim 1 or 2, in which the signal generating means comprises means to generate the sum of two measurement signals and means to generate the difference of the two measurement signals, the measurement signals being dependent upon a physical quantity to be measured.



5. A converter as claimed in claim 1 or 2, in which one pair of signal generating means comprises means to generate a reference signal and means to generate a measurement signal dependent upon a physical quantity to be measured, and the other pair of signal generation means comprises means to generate the sum of two measurement signals and means to generate the difference of the two measurement signals, the measurement signals being dependent upon another physical quantity to be measured.

6. A converter as claimed in claim 1 or in any of claims 3, 4 and 5, as appendant to claim 1, in which the computing means includes a pre-settable counter for counting clock pulses for a duration determined by the pulse signals from the pulse output means.

7. A converter as claimed in claim 1 or claim 6, including oscillator means for producing clock pulses for the computing means.

8. A converter as claimed in claim 7, as appendant to claim 6, in which the oscillator means produces a first series of clock pulses of one frequency and a second series of clock pulses of a second frequency.



9. A converter as claimed in claim 3 or 5, or in any claim appendant to claim 3 or 5, including switch means for selectively passing the measurement signal to the pulse output means.

5 10. A converter as claimed in claim 3 or 5, or in any claim appendant to claim 3 or 5, in which the measurement signal generating means includes means for determining the brightness of an object to be photographed.

10 11. A converter as claimed in claim 4 or 5, or in any claim appendant to claim 4 or 5, in which the sum and difference measurement signal generating means includes means for determining the distance of an object to be photographed.

15 12. An analog-to-digital converter for a camera, substantially as herein described with reference to and as shown in Figures 1 and 2 of the accompanying drawings.

20 13. An analog-to-digital converter for a camera, substantially as herein described with reference to and as shown in Figures 3 and 4 of the accompanying drawings.



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14. An analog-to-digital converter for a camera,
substantially as herein described with reference to and
as shown in Figure 5 of the accompanying drawings.

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