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AUTO-FOCUS IC

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1. FOREWORD

In the advance of electronification of cameras, most cameras being sold today are provided with auto-focus (AF) as a standard function.

Roughly, there are two types of AF: active type which radiates infrared rays from the camera and checks the reflection angle from the object and passive type which focuses the image of the object on a linear image sensor and processes that image signal. The importance of the passive type is being steadily recognized because of the following special features, especially about the middle grade and high grade camera at which a high magnification zooming function is advancing.

(1) No limitation of measurable range.

(2) Available to systems with interchangeable lenses or zooming functions.

For popularization of passive type which has been regarded as expensive and complex, Fuji Electric has developed small and high performance AFICs integrating photo-sensors and quantizing unit (A-D converter) and processing circuits on one chip for several years while cooperating with users.

Currently, the series shown in *Table 2* are available and several other types are under development. An FB6213T chip photograph is shown in *Fig. 1* as an example of these.

These types use Fuji Electric's original technology throughout and are highly original products.

Table 1 Comparison of passive type and active type

Type	Passive type	Active type
Advantages	• Measurable up to infinite distance • No need for radiation of infrared rays or ultrasonic rays • Available to through the lens type auto-focus → No parallax between taking lens and AF system	• Available to very low illuminated object • Comparatively simple construction

Dis-advantages	• Auto-focus difficult in dark places
	• Distance measurement of the following objective is difficult:
	  • Low contrast
	  • Repeated pattern
		• Measurable distance is limited (up to the range of the infrared rays)
		• Parallax between taking lens and auto-focus system

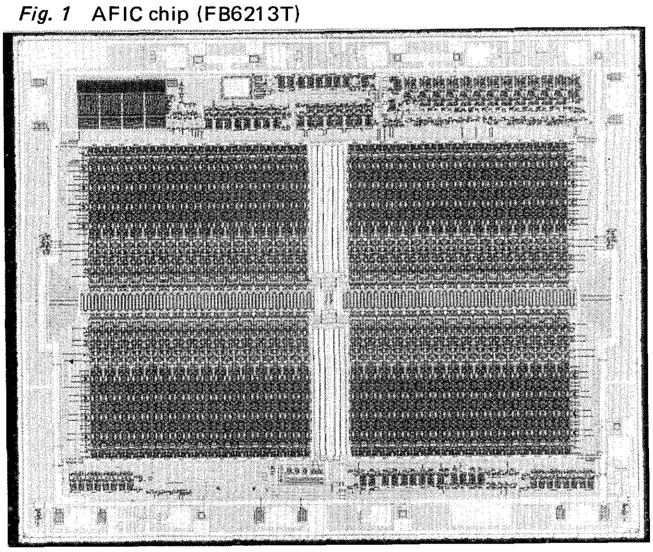


Fig. 1 AFIC chip (FB6213T)

Table 2 AFIC type series

Item	FB6203	FB6213	FB6204	FB6214	FB6206	FB6207
Number of sensors/array	64	64	48	48	48	24
Sensor pitch (μm)	24	24	24	24	24	24
Distance between centers of two photo-sensor arrays (mm)	1,856	1,856	3.5	3.5	2.8	2.8
Number of pins	24	16	16	16	16	16
Supply voltage (V)	4~6	4~6	4~6.5	4~6.5	3~7	3~7
Data format	8 bits parallel	1 bit serial	1 bit serial	1 bit serial	5 bits parallel	4 bits parallel
Package	Ceramic package	Clear mold package	Ceramic package	Clear mold package	Clear mold package	Clear mold package

Fig. 2 Optical system of triangulation range finding system

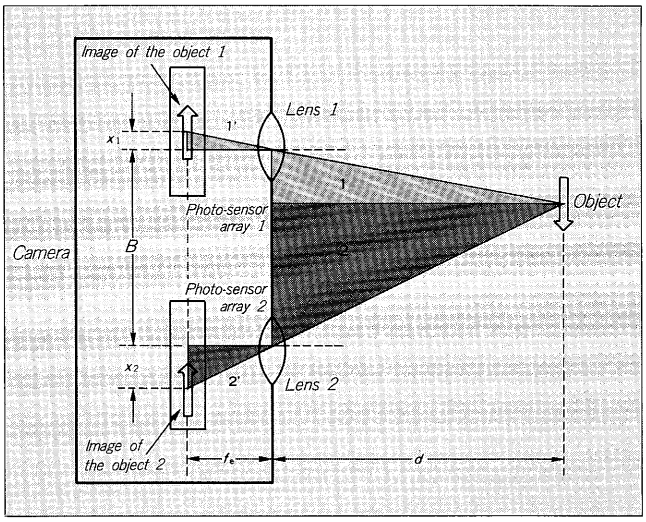


Fig. 3 Basic Architecture of AFIC

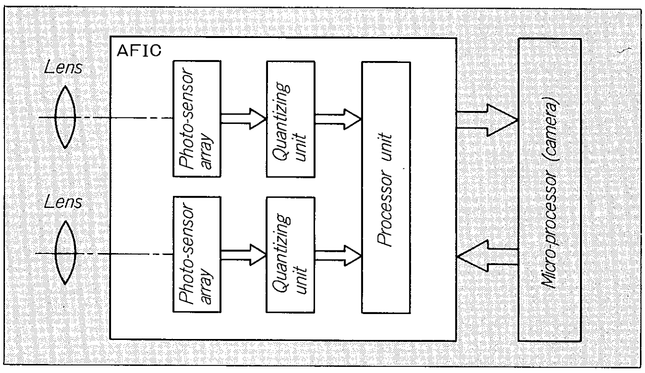


Fig. 4 Photo-sensor basic circuit and its timing chart

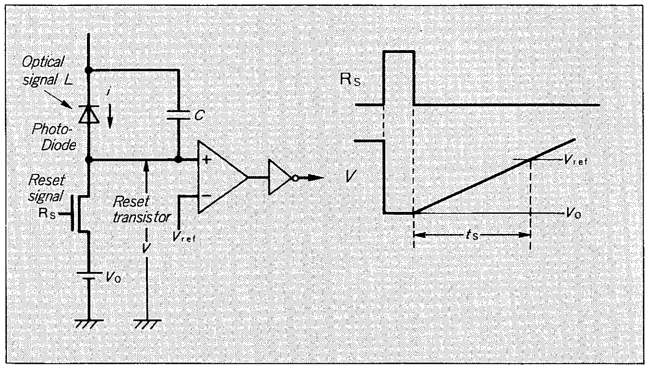
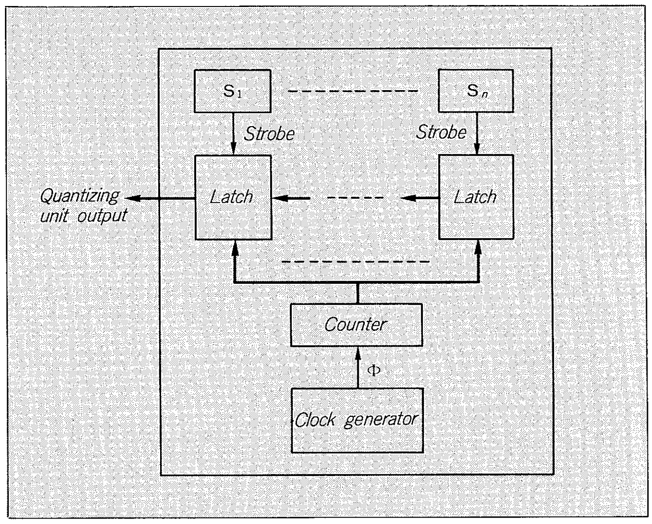


Fig. 5 Quantizing unit architecture



Technology of AFIC, especially quantizing technology, is introduced below.

2. RANGE FINDING PRINCIPLE

The optical system of the triangulation range finding system used in this AFIC, which is typical passive type AF, is shown in *Fig. 2*.

Object images 1 and 2 are focused on photo-sensor arrays 1 and 2 by lenses 1 and 2. Here, because triangles 1 and 1′ and 2 and 2′ are similar respectively, distance d between the object and the camera is found from the following equation:

Since B and f_e are constants, distance d up to the image can be found by detecting x. x is the relative displacement of the two images from the position when the object is an infinite distance, that is, when the two images are at the intersection of the optical axis and the photo-sensor arrays.

3. ARCHITECTURE

3.1 Basic architecture

The basic architecture of the AFIC is shown in *Fig. 3*. The main features of this basic architecture is integrating the sensor unit, quantizing unit and processing unit on one chip (conventionally they are on 2 or 3 chips), and it contributes to improvement of miniaturization and processing speed.

The role of the three blocks shown in the basic architecture is as follows: the photo-sensors convert the optical image signal to an analog electric signal and the quantizing unit digitizes this signal and the processsing unit detects the above-described relative displacement x from the quantized image signal.

The roles of the photo-sensor and quantizing unit are to transmit the information included in the optical signal as much as possible to the pocessing unit which is to use the information in image signal as much as possible.
much as possible.

Each block is described next.

3.2 Photo-sensor

The basic circuit of photo-sensor and its timing chart are shown in *Fig. 4*. Photocurrent i proportional to the luminous intensity of the optical signal L (image element) is generated by the photo-diode which is used as the photoelectric cell. The reset transistor is turned on temporarily by the signal Rs at the beginning of operation and potential V is initialized to V_0. Thereafter, potential V rises with integration of optical current i by capacitance C (photo-diode junction capacitance) and reaches the required potential V_{ref}. The time t_s until potential V reaches V_{ref} is given by the following equation and is defined as the sensor response time.

$$t_s = C \cdot (V_{ref} - V_0)/i$$

Since the output of the sensor to the quantizing unit of the next stage is this t_s, this photo-sensor is said to convert the optical signal L to time base signal t_s.

With systems that use a CCD, there are many cases where a supply voltage of 10V or greater is necessary, but this photo-sensor is operable at a low supply voltage of about 4V, thanks to the above mentioned architecture and CMOS design.

3.3 Quantizing unit

3.3.1 Architecture

The architecture of the quantizing unit is shown in *Fig. 5*. A 6~8 bits latch circuit (a kind of memory) is connected to each sensor (S_1, · · · , S_n) and the data of the counter is recorded when the connected sensor responds.

This value is the found quantized data and the time difference ($t_s - T$) of the response time T of the fastest sensor of all the sensors and the response time t_s of each sensor was measured by using clock Φ.

The latch group is configured so that it looks like an ordinary RAM from the viewpoint of the processing unit so that the quantized data can be read by the processing unit.

An example of "optical signal → response time → quantized data" conversion is shown in *Fig. 6*. As shown

Fig. 6 Example of image signal quantization

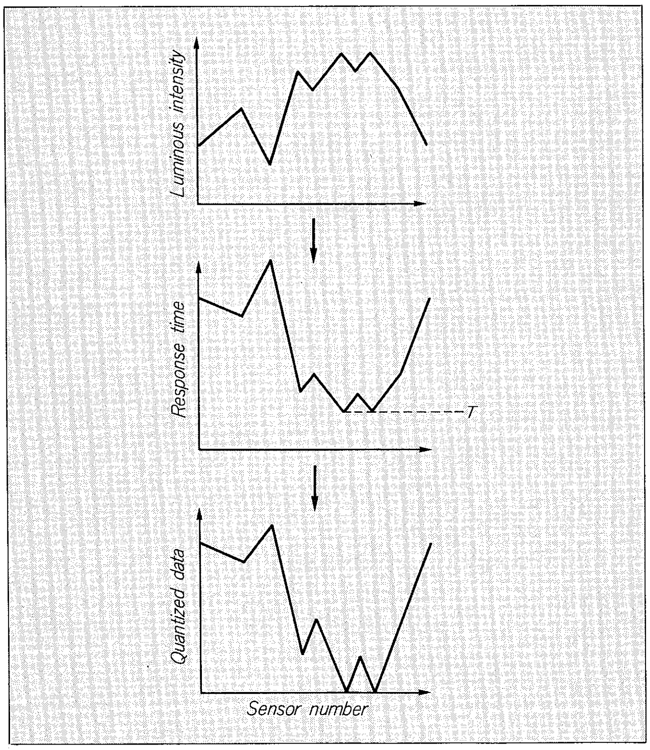


Fig. 7 Clock generator

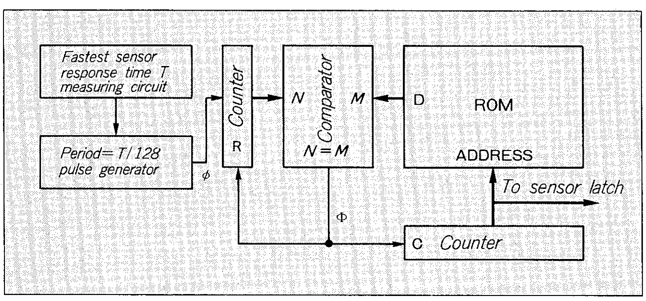


Fig. 8 Relation between sensor operation and clock Φ

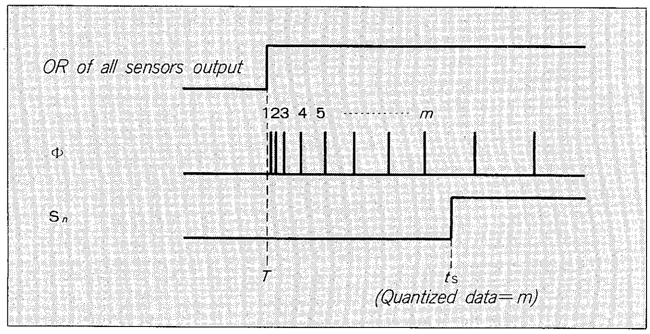


Fig. 9 Conversion characteristics of quantization

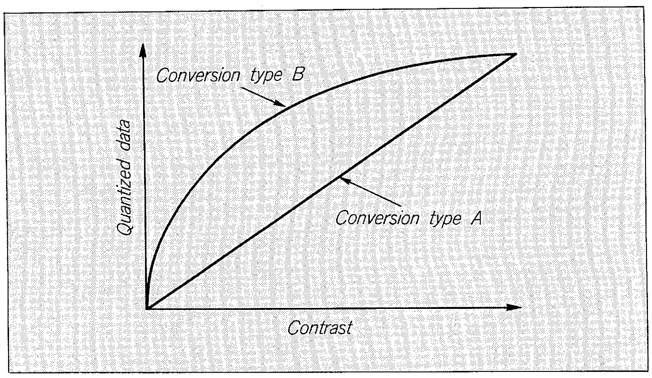


Fig. 10 Clear mold package

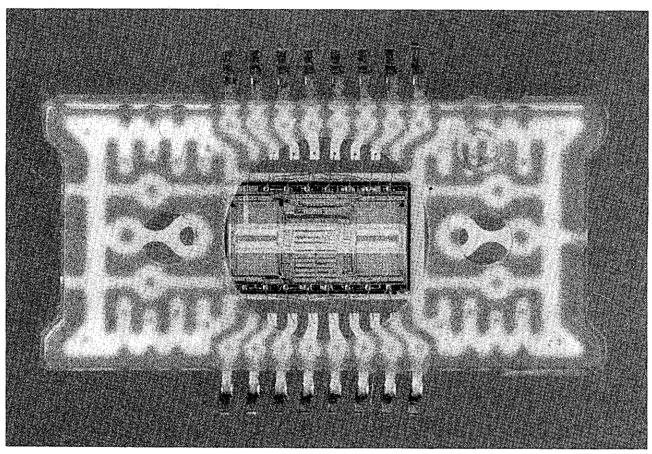
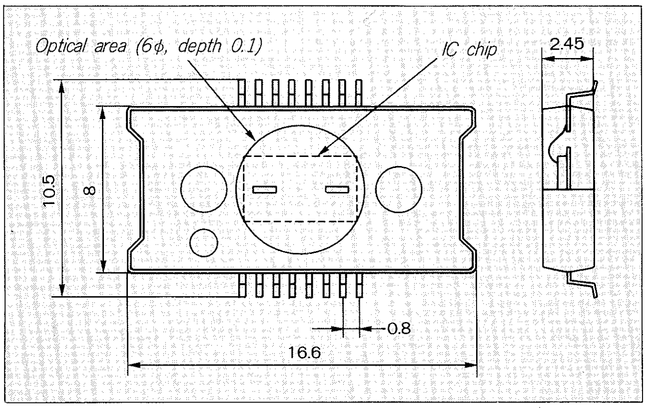


Fig. 11 Clear mold package



in *Fig. 6*, the sensor responding the strongest luminous intensity becomes the quantizing operation reference.

3.3.2 Quantizing clock

The architecture of the clock generator that generates clock Φ is shown *Fig. 7*.

The dynamic range of the luminous intensity of the image is about 10^6, but a clock with a period of T/N (in the example of *Fig. 7*, $N = 128$) is generated as the base clock of the following stages so that a constant quantizing accuracy is obtained for any luminous intensity, that is, any response time T.

The each period of clock Φ is determined by the ROM data.

Although not shown in *Fig. 5*, an OR gate using $S_1, \cdots, S_n$ as inputs is added to the clock generator and clock Φ starts operation from the time the OR gate output becomes H, that is, from the time T that fastest sensor responds. This is shown in *Fig. 8*.

As can be understood from the previous description, the quantization conversion characteristic depends on the periods of clock Φ, that is, the ROM data. In other words, conversion characteristics (examples are shown in *Fig. 9*) can be freely set by changing the ROM data.

3.4 Processing unit

An algorithm which finds the previously mentioned relative displacement from the two image signals of the object is implemented. Abstract of this architecture is as follows: each part of the image signal is read from the latches of the quantizing unit and the part with the highest correlation of the two image signals is detected. The relative displacement is determined by the position of this part in the sensor array and is output as the AF signal.

3.5 Package

As shown in *Table 2* and *Fig. 10*, a clear mold package is used with the Fuji Electric AFIC. This clear mold package was originally developed by Fuji Electric and its outward form is shown in *Fig. 11*. This package has the same outline dimensions and is compatible with the SOP ceramic package used with the FB6204.

4. CONCLUSION

Fuji Electric's AFIC was outlined above with emphasis placed on the description of quantization.

In the near future, we plan improvement of the performance of the photo-sensor and development of an AF module with combining an AFIC and optical system and other developments to meet the needs of the market.

We wish to thank the many camera related users for their assistance related to problems of optics, etc. in the development of the AFIC.