Autofocus Modules with MOS Analog Sensors

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1. Introduction

In the compact camera market, competition for higher performance and miniaturization with a built-in zoom function is a matter of great concern. In particular, the relative merits of autofocus (AF) systems largely influence performance of compact cameras.

In the past, Fuji Electric developed small and light AF modules with high performance, combining an optical system and a single chip autofocus IC (AFIC) with an analog-to-digital (A-D) converter for sensor data for autofocus calculation. We have continued production of the modules since 1992 with favorable market acceptance.

But the advent of new type cameras (cameras based on the advanced photo system) accelerated the breakthrough of camera miniaturization and Fuji Electric was required to further miniaturize the AF modules.

Table 1 Line-up of AF modules with MOS analog sensors

Item \ Type	FM6256T34	FM6254T34	FM6255T40
Applied AFIC	FB6256T	FB6254T	FB6255T
Number of terminals (pins)	24	24	16
Target camera	Compact camera LS: zoom × (3 or more)	Compact camera LS: zoom × (2 or more)	
Baseline length *B* (mm)	5.566	5.566	5.566
Focal length *f* (mm)	10.7	10.7	6.1
Number of photodiodes	2 × 234	2 × 130	2 × 130
Photosensor pitch (μm)	12	21	12
Sensor response (V/s) (standard source A: 5EV)	180	220	180
Full view angle of sensor area (degrees)	10.0	10.0	10.0
DC power supply voltage (V)	3.0 to 6.0	4.0 to 6.0	4.0 to 6.0

For meeting this marker requirement, AF modules with analog sensor data output have been developed. Their configuration and structure will be introduced here.

In contrast with conventional AF modules of digital sensor data output, modules with MOS (metal-oxide semiconductor) analog sensors have the following features:

(1) Miniaturization of the modules can be realized, since a difference in the sensor circuits allows photodiode sensor pitches to decrease.
(2) The IC chip sizes have been scaled down, thus, cost reduction can be achieved with omission of A-D conversion and AF data processing circuits.

Table 1 shows the line-up of AF modules with MOS

Fig.1 Block diagram of the AFIC with MOS analog sensors

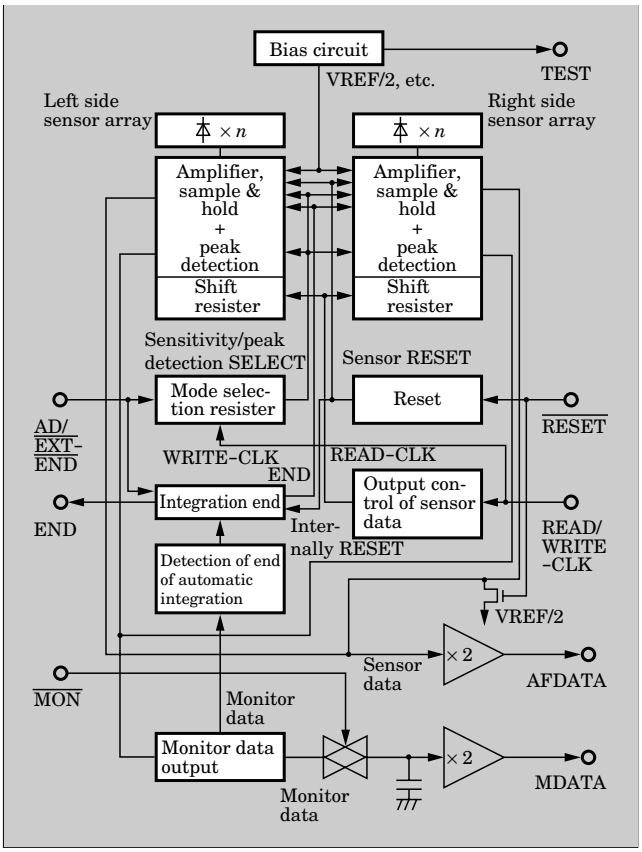


Fig.2 Example of sensor data output

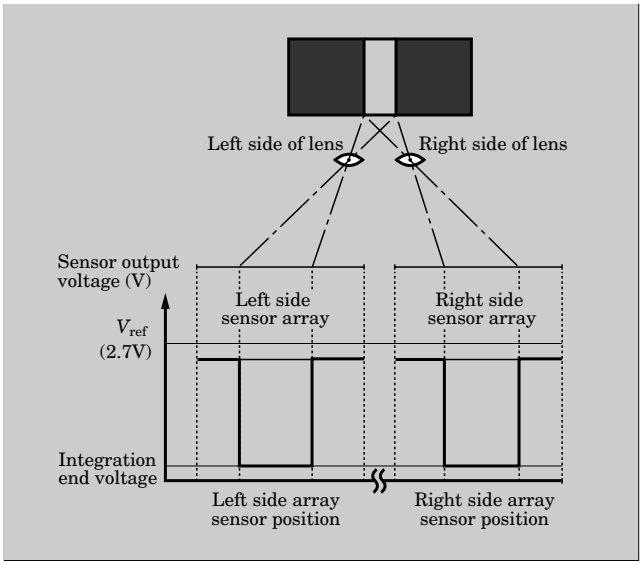
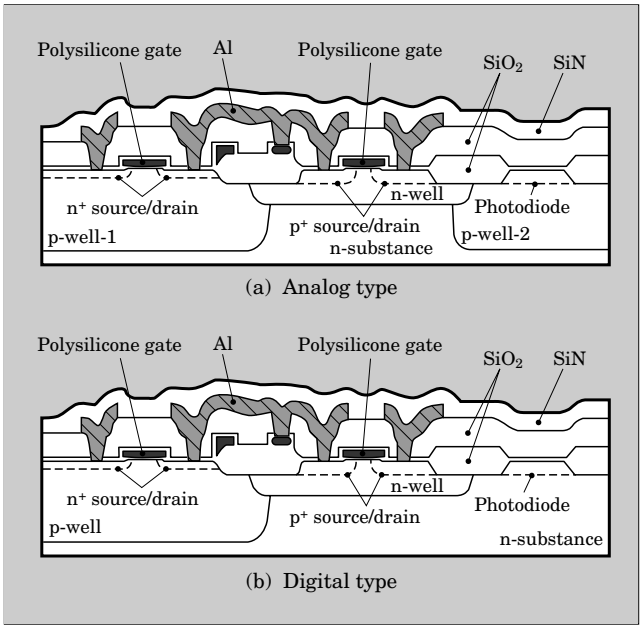


Fig.3 Structure of the photodiode



analog sensors.

2. Circuit Configuration of the Analog AFIC

Figure 1 shows a block diagram of an AFIC with MOS analog sensors.

Detailed explanation is abbreviated, but this IC is configured so that each photo current of photodiodes on the left and right side sensor arrays is converted to an amplified voltage through integrator and amplifier circuits, both composed of MOS transistors. The voltage is then sampled and held as sensor data.

Operation of the integrator circuit starts at the initial reference voltage Vref and the output voltage descends according to its integral time. On receiving the integration end signal, the voltage is sampled and held at that time. After synchronization with an external clock signal, each pixel's sensor data is selected and output. As shown in Fig. 2, the output sensor voltage of the pixel projected by a light part of an object image is low but that projected by a dark part of the image approximates to Vref.

Fig.4 Spectral sensitivity characteristics

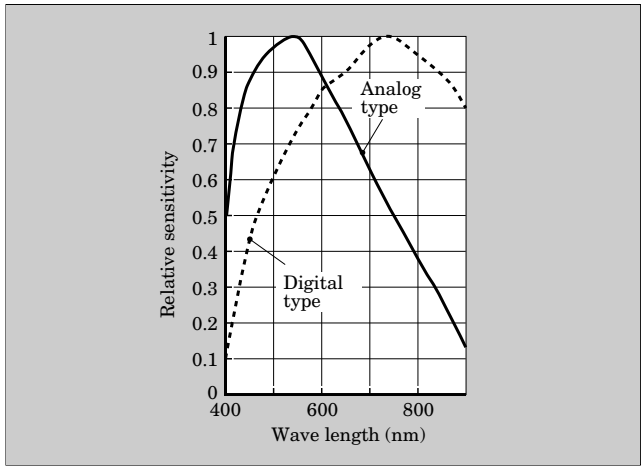


Fig.5 Miniaturization of modules with reduced sensor pitch

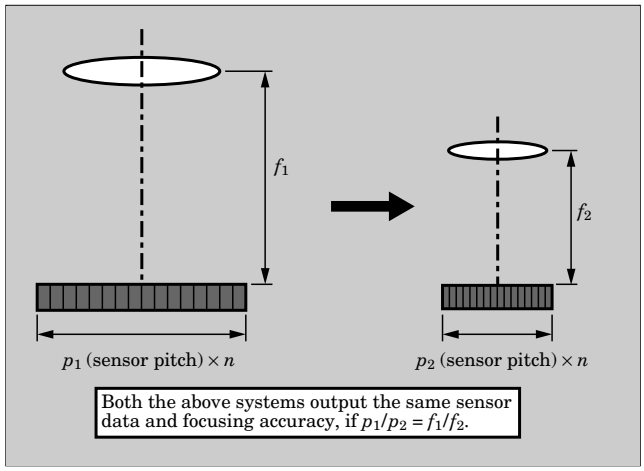
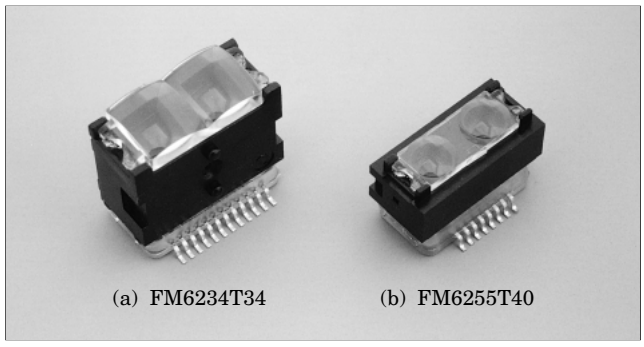


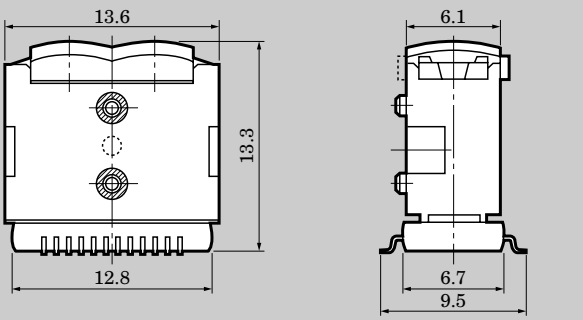
Fig.6 External view of the AF modules



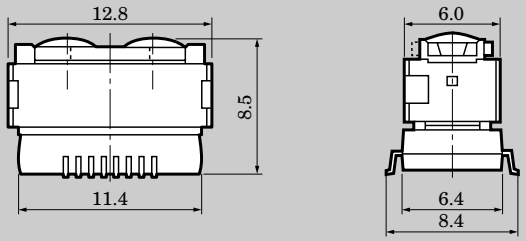
3. Structure and Characteristics of the Photodiode

In the MOS analog sensor, the photodiode struc-

Fig.7 Comparison of external dimensions of the AF modules



(a) FM6234T34 (Sensor pitch : 21μm)



(b) FM6255T40 (Sensor pitch : 12μm)

ture which had been used in conventional digital types was modified by altering the above-mentioned sensor circuitry. Figure 3 shows the structure with a transistor part in a cross section of the IC chip. In contrast to the conventional digital types, the photodiode is configured to be electrically isolated from a substrate. This allows the influence of carriers generated in the substrate to decrease. As a result, any noise in the image data is reduced.

As shown in Fig. 4, this structural modification of the photodiode also changes its spectral sensitivity characteristics. Namely, since the carriers generated from a deep region of the substrate are absorbed at a junction between the substrate and the p-well-2, the sensitivity for light with a long wave length is decreased in comparison with the digital type. As the dynamic range of the spectral sensitivity characteristics narrows, the influence due to chromatic aberration of lenses is reduced and more sharpened image signal has been achieved.

4. Miniaturization of Modules

Previous digital AFICs were configured with a sensor pitch of 21μm. But the recently developed analog ICs have realized a shorter sensor pitch of 12μm due to a difference in configuration of the sensor circuit. In the AF modules, the left and right side of the lenses are configured to project the object images on the bilateral sensor arrays. Therefore, as shown in Fig. 5, if the sensor pitch is reduced and the focal length f of the lenses is decreased according to the reduction ratio, the ratio of the object image size to the sensor pitch does not changes. Thus, the same accuracy can be obtained in autofocus performance.

FM6255T40 is the first AF modules with the 12μm sensor pitch and, though its volume is about half that of the FM6234T34 digital AF module, almost the same focusing accuracy is realized. Figure 6 shows pictures of the FM6255T40 and FM6234T34 modues. Their external dimesnions are compared in Fig. 7.

5. Conclusion

Fuji Electric's AF modules with MOS analog sensors have been introduced. For meeting the user's needs Fuji Electric will continue to develop advanced AF modules and to provide more originative products.