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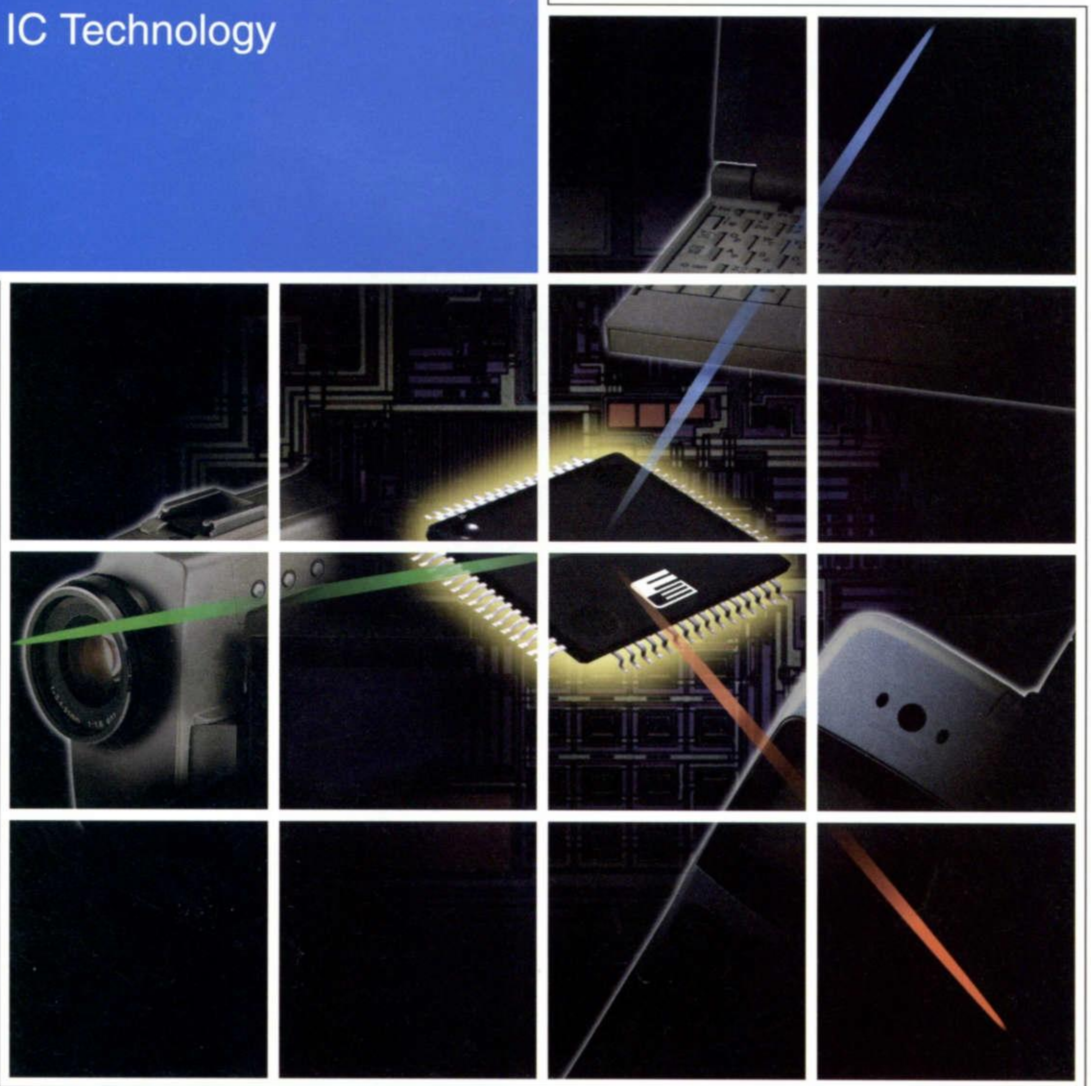
FUJI ELECTRIC REVIEW

2

1999 VOL.45

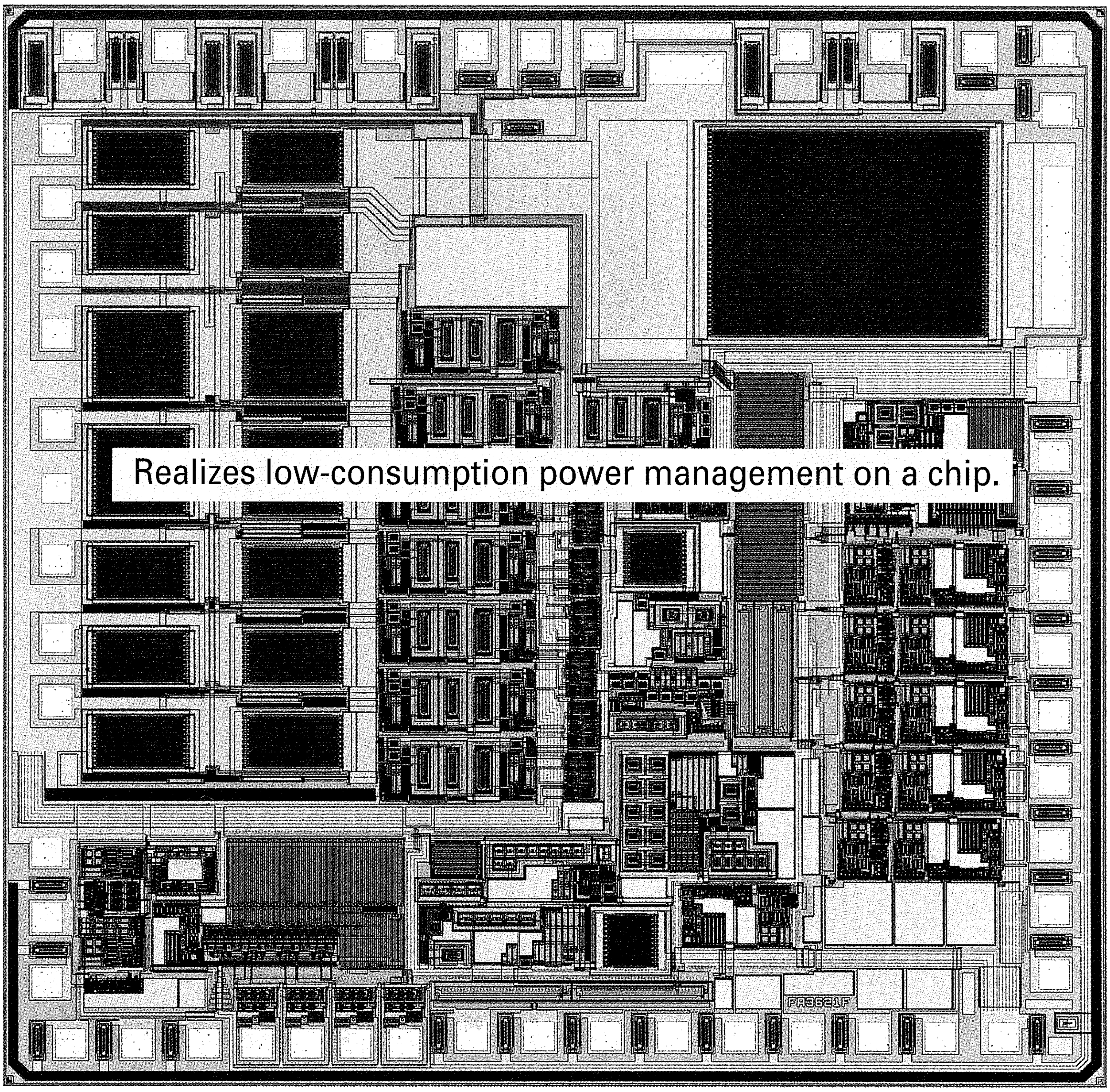
IC Technology



FUJI ELECTRIC

Creating a Better Tomorrow with Trustworthy Technology

Fuji Electric Power IC for Power Supply



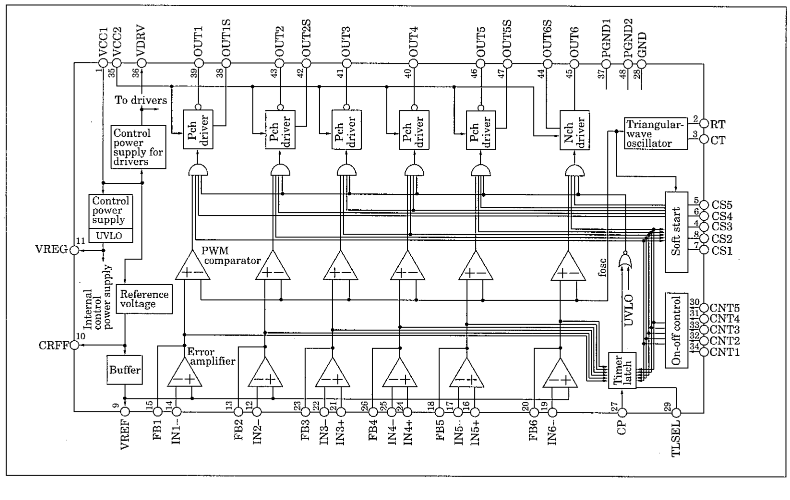
The power IC for power supply units makes multiple responses to multiple requirements.

Examples : 2-channel FA3630V, 3-channel FA3629AV, 6-channel FA3621F, 6-channel FA3675F

Uses : Multiple output power supplies for TFT panels, video cameras, digital cameras, etc.

Features :
- ○ The power MOSFET and controller integrated on a chip using the C/DMOS process to realize a built-in low on-state resistance DMOS output transistor.
- ○ Low power consumption, small size, high efficiency, compatibility with low input voltage (2.5V), and sufficient protective functions against overcurrent, overheat, etc.
- ○ Small outline packages TSSOP-16, SSOP-28, LQFP-48, etc.

Example block diagram with FA3675F



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CONTENTS

Cover Photo:

Recent development in multimedia terminals has been remarkable. Demands for battery type portable terminals such as cellular phones and digital cameras have greatly increased. These require still more improvement in weight, efficiency, and power consumption.

To meet these requirements, Fuji Electric has supplied many control ICs for power supply units based on analog technology with low-power-consumption, high-precision CMOS as key parts for power management.

The cover photo, in which a power supply IC with a built-in output MOSFET is placed in the middle and a video camera and a cellular phone are superposed around the chip, shows the IC playing a vital role in wide applications.

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Present Status and Prospects for Fuji Electric IC Technology

Ken Meguro

1. Introduction

Fuji Electric ICs (integrated circuits) are specialized for specific applications, and have been developed based on distinguished technologies. For example, we have used high-voltage technology [C/DMOS (complementary/double diffused metal-oxide semiconductor) technology] and sensor technology (photodiodes and piezoelectric resistance sensors) to develop controller ICs for power supplies, flat panel display driver ICs (for plasma and liquid crystal displays), auto-focus ICs for cameras, and pressure sensors and hybrid ICs for automobiles.

The semiconductor market has been subjected to boom-and-bust cycles and there is fierce competition. To survive in this environment, it is important for us to refine the distinguished technologies and develop core technologies to supply unique products not available from other companies. An outline of our technologies, examples of our products, and future prospects are described below.

2. Present Status of Fuji Electric ICs

2.1 Process/device technologies

Characteristic features of Fuji Electric's process and device technologies are high voltage and analog-digital hybrid technology. Processes to achieve fine machining as well as high voltage have been developed, and methods of improving analog precision have been developed. Typical processes are as follows (Fig. 1).

(1) Bipolar IC

Because of low cost and high precision, this process has been used for controller ICs in automobile ignition systems, pressure sensors, and ICs for power supplies.

(2) Si-gate CMOSIC

This process, a leader in fine machining, developed into a process for standard logic (5V class) and then into a process for higher voltage ICs. Mass production of CMOSICs with a 0.6µm design rule has been realized. CMOSICs are widely used as analog-digital hybrid ICs for power supplies, cellular phones, automatic focusing, and liquid crystal display drivers. This paper introduces high-voltage CMOSIC technology (30V, 60V, and 120V).

(3) C/DMOSIC

This hybrid process combines DMOS technology with a Si-gate CMOS high-voltage construction and is used for power supply ICs and plasma display driver ICs. This is an effective technology to reduce the size of built-in power MOSFETs (metal-oxide-semiconductor field-effect transistors). Figure 2 shows the DMOSIC on-resistance area efficiency. This paper introduces the plasma display driver IC that uses dielectric isolation technology (SOI) as an example.

In addition, Fuji Electric possesses a bump process (solder and gold) suitable for Bi-CMOSIC and bear chip assembly and can satisfy various customer requests.

2.2 Packaging technology

Plastic molded packages, including DIP (dual inline package), SOP (small outline package), QFP (quad flat package) and TSSOP (thin shrink SOP), fine-pitch and thin packages, are available. CSP (chip size package) is also being investigated. As mentioned before, Fuji Electric possesses a bump process suitable for bear chip assembly and has the complete assembly

Fig.1 Fuji Electric IC process technology

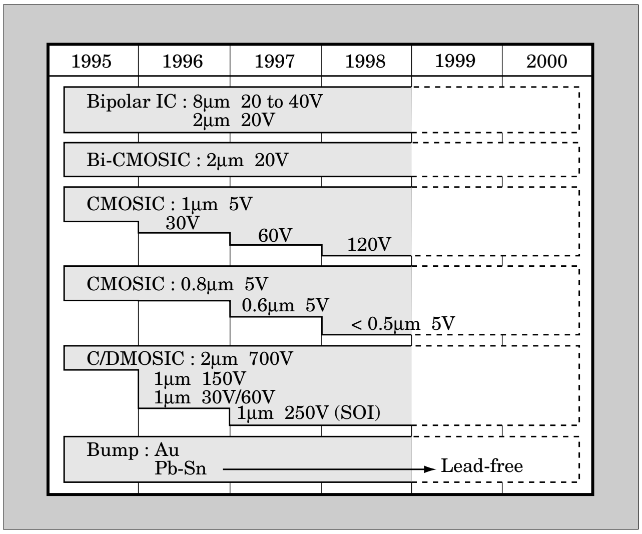


Fig.2 On-resistance area efficiency of Fuji Electric DMOSICs

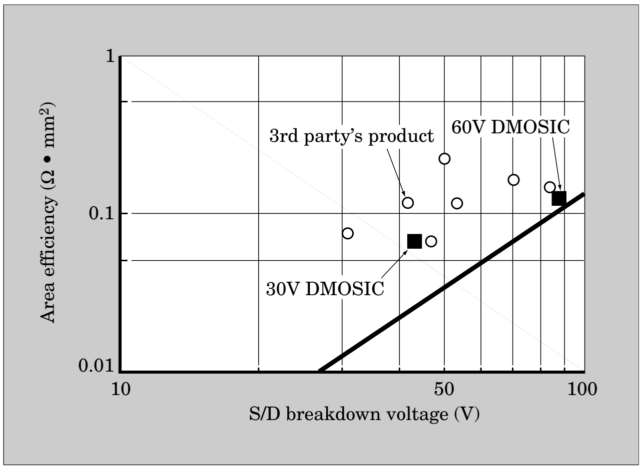


Fig.3 Examples of plastic packages

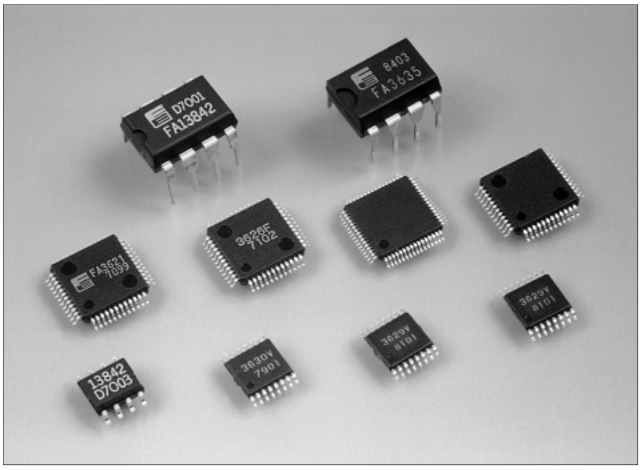
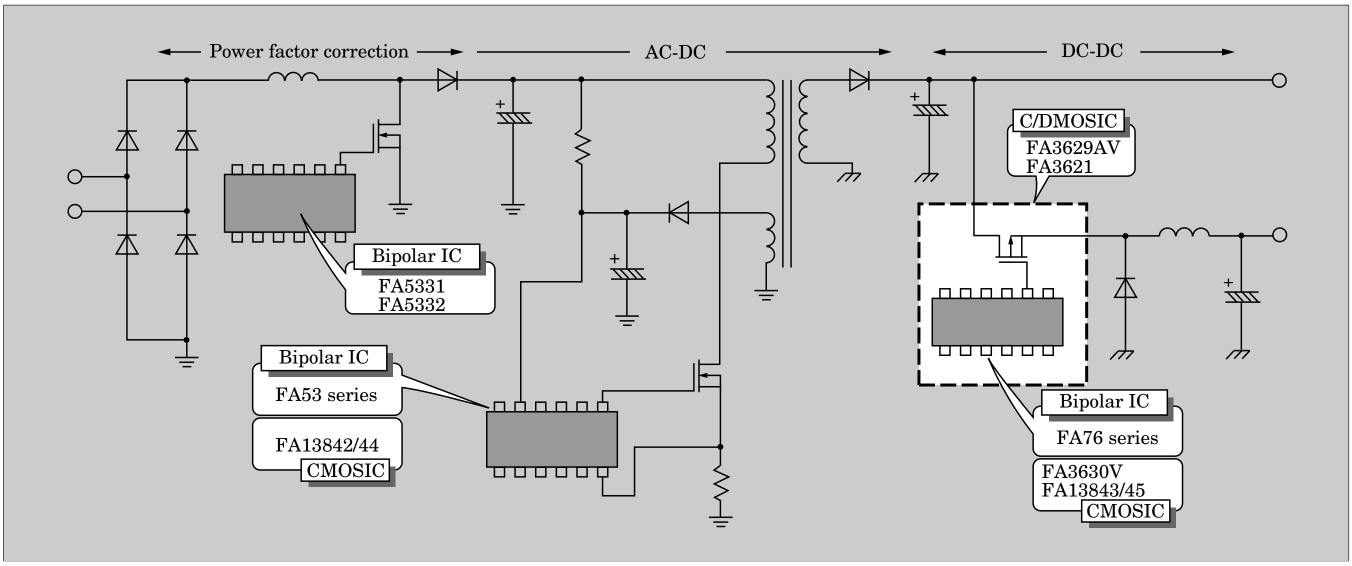


Fig.4 Fuji Electric ICs for power supply and application circuit example



technologies to miniaturize packages (Fig. 3).

Fuji Electric also possesses technologies for modules with lenses and clear resin molded packages for autofocus ICs, and provides a series of high-reliability metal packages and resin-sealed packages for pressure sensors.

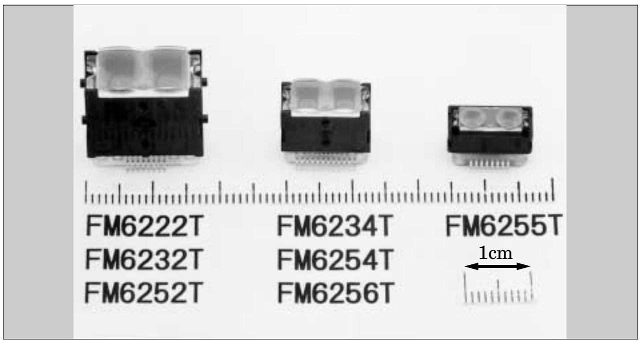
2.3 Fuji Electric ICs

Having started from full-custom ICs, Fuji Electric product development is now focusing on application specific standard product (ASSP) ICs.

A typical product is the power supply IC. In response to the need for resource and energy conservation for global environment protection, a low power consumption CMOS and a power factor correction IC series have been developed (Fig. 4 and Table 1).

Regarding autofocus ICs for cameras, a series of modules with lenses have been developed, and the development of small modules suitable for thin cameras (APS) and low-priced analog sensors (in addition to the conventional digital sensors) has been completed (Fig. 5 and Table 2).

Fig.5 Fuji Electric autofocus IC modules



The color plasma display driver IC has been used to produce large-screen TVs and monitors. This paper introduces an advanced product line of small liquid crystal controllers, as well as pressure sensors used for diesel engines.

Table 1 Fuji Electric ICs for power supplies
(a) AC-DC converter

Classification \ Item		Type number	D_{max}	Application circuits			MOSFET drive	Mode		Protection circuit			Number of pins
				Flyback	Forward	Power factor correction		Voltage	Current	OCP	OVP	OTP	
For control-lers	Bipolar IC	FA5301	100%	○				○		○			16 pins
		FA5304	46%		○		○	○		○	○		8 pins
		FA5305	46%		○		○	○		○	○		8 pins
		FA5310	46%		○		○	○		○	○		8 pins
		FA5311	70%	○			○	○		○	○		8 pins
		FA5314	46%		○		○	○		○	○		8 pins
		FA5315	70%	○			○	○		○	○		8 pins
		FA5316	46%		○		○	○		○	○		8 pins
		FA5317	70%	○			○	○		○	○		8 pins
		FA5321	50%		○		○		○	○	○	○	16 pins
		FA5331	92%			○	○			○	○		16 pins
		FA5332	92%			○	○			○	○		16 pins
	MOSIC	FA13842	96%	○			○		○				8 pins
		FA13844	48%		○		○		○				8 pins

(b) DC-DC converter

Classification \ Item		Type number	Number of channels	Voltage control range				Application circuits			MOS-FET drive	Number of pins
				2.5 to 22V	3.6 to 22V	1.4 to 12V	10 to 50V	Step-down	Step-up	Up & down		
For control-lers	Bipolar IC	FA7610	1		○				○	○		8 pins
		FA7611	2		○			○	○	○		16 pins
		FA7612	1		○			○				8 pins
		FA7613	1	○				○		○		16 pins
		FA7615	2		○			○	○	○		16 pins
		FA7616	2			○			○	○		16 pins
		FA7617	1		○					○		8 pins
		FA7622	2		○			○	○	○	○	20 pins
		FA7630	2		○			○		○	○	20 pins
	MOSIC	FA3630	2	○				○	○	○	○	16 pins
		FA13843	1						○	○	○	8 pins
		FA13845	1						○	○	○	8 pins
For con-trollers with a built-in MOSFET	MOSIC	FA3621	6					○	○	○	○	8 pins
		FA3629	3		○				○	○	○	16 pins
		FA36XX	1				○	○				8 pins

Table 2 Fuji Electric autofocus ICs

Application \ Type	Digital sensor, 21μm-pitch	Analog sensor, 21μm-pitch	Analog sensor, 12μm-pitch
Zoom of 3× or less	FM6234T	FM6254T	FM6255T
Zoom of 3× or greater	FM6232T	FM6252T	(FM6256T)

Note: Products enclosed in parentheses are "under development".

3. Future Prospects

For Fuji Electric ICs to survive in the future, as a matter of course, they must satisfy market needs. Further, it is necessary that they possess unique technology not available from other companies as well as flexible design technology to comply with diversified requirements within a short time. Fuji Electric is working to introduce an IP (intellectual property) core and to develop CAD (computer-aided design) technology, presented in this paper as system design technology.

4. Conclusion

The present status and prospects for Fuji Electric's IC technology have been described. Further with our characteristic technologies, we will continue to develop and supply products that satisfy user needs.

CMOSIC for Current-Mode PWM Power Supply

Hiroshi Maruyama

1. Introduction

In recent years, as energy conservation has become an important environmental protection measure, considerable attention has been given to increasing the efficiency and lowering the power consumption of switching power supplies widely used in electrical and electronic equipment. As a result, the use of products with a remote controller or a timer is increasing, and the use of power supply circuits with standby mode (low power consumption) is increasingly in products normally connected to power supplies in order to reduce the power consumption during standby.

Control ICs manufactured with a bipolar process have been developed for AC-DC converters that transform a commercial AC supply into a DC supply. The power consumption of the control ICs themselves under minimum load conditions in the standby mode has been reduced to targeted levels.

Utilizing high-voltage CMOS process technology accumulated during the development of technologies such as high-voltage driver ICs used in liquid crystal panels and thermal heads for printers, Fuji Electric has developed the FA1384X series of 8-pin CMOS (complementary MOS) ICs for current-mode power supply control. This paper presents an overview of the FA1384X series.

2. Product Outline

Using a bipolar process, Fuji Electric has already developed the series of ICs listed in Table 1 for AC-DC converter control. Recently, Fuji Electric has used a CMOS process to develop 8-pin current-mode power supply control ICs and bring them to market.

This control system maintains a constant peak current for power MOSFETs (metal-oxide-semiconductor field-effect transistors) and is widely used for designing power supplies because it is rarely affected by voltage regulation loop delays, making it easy to design stable power supplies.

Table 2 shows main features of the FA1384X series. Figure 1 shows a diagram of the IC chip.

2.1 Features

The newly developed FA1384X series of 8-pin CMOS ICs for current-mode power supply control have the same pin arrangement and function as the 384X series of other companies, the so-called industrial standard, and is provided with two types of packages, DIP (dual inline package) and SOP (small outline package).

Features of the ICs are listed below.

(1) Reduced electric current due to utilization of a CMOS process

(2) Latching PWM (pulse width modulation) control performs pulse-by-pulse current limiting

(3) UVLO (undervoltage lock out) circuit with hysteresis characteristics

FA13842/44: 16.5V on/9V off
FA13843/45: 9.6V on/9V off

(4) Different product models with different maximum duties are provided for flyback and forward circuits

FA13842/43: 96%
FA13844/45: 48%
Where R_T = 10kΩ, C_T = 3.3nF

2.2 Circuit configuration and devices

Figure 2 shows a block diagram of the FA1384X series.

The block diagram consists of high and low voltage sections. The high voltage section is comprised of a reference voltage generator, a UVLO circuit for undervoltage protection and an output driver circuit connected to a VCC pin. The low voltage section is comprised of an oscillator, an error amplifier and a current sense comparator connected to the reference voltage generator.

2.2.1 Devices

In the manufacturing process, two gate oxide film thicknesses are used for 30V high-voltage MOS devices and 5V low-voltage MOS devices, respectively. CMOS circuits can be configured for both high and low voltages.

Combining a heavily doped region used to create the source and drain in ordinary CMOS processes with a lightly doped region for high voltage use enables

Table 1 IC product series for AC-DC converters

Type (number of pins)	Operating voltage	Maximum operating frequency Maximum duty cycle	Output current	Error amplifier	Reference voltage	Function	Application
FA5301BP/BN (16 pins)	7 to 22V	200kHz Arbitrary	20mA (DC)	Built-in	5V ±5%	External synchronization Overload / overcurrent	CRT monitor display
FA5304AP/AS (8 pins)	10 to 30V	600kHz 46%	±1.5A (peak value)	2.0V ±5%	—	Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply
FA5305AP/AS (8 pins)	10 to 30V	600kHz 46%	±1.5A (peak value)	2.0V ±5%	—	Overload / overvoltage Overcurrent (negative voltage sensing)	General-purpose power supply
FA5310BP/BS (8 pins)	10 to 30V	600kHz 46%	±1.5A (peak value)	—	—	Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply Forward converter
FA5311BP/BS (8 pins)	10 to 30V	600kHz 70%	±1.5A (peak value)	—	—	Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply Flyback converter
FA5314P/S (8 pins)	10 to 30V	600kHz 46%	±1.5A (peak value)	—	—	Overload / overvoltage Overcurrent (negative voltage sensing)	General-purpose power supply Forward converter
FA5315P/S (8 pins)	10 to 30V	600kHz 70%	±1.5A (peak value)	—	—	Overload / overvoltage Overcurrent (negative voltage sensing)	General-purpose power supply Flyback converter
FA5316P/S (8 pins)	10 to 30V	600kHz 46%	±1.0A (peak value)	—	—	Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply Forward converter
FA5317P/S (8 pins)	10 to 30V	600kHz 70%	±1.0A (peak value)	—	—	Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply Flyback converter
FA5321P/M (16 pins)	12 to 27V	500kHz 50%	±1.5A (peak value)	2.4V ±8%	—	Current mode External synchronization Overload / overvoltage Overcurrent (positive voltage sensing)	General-purpose power supply
FA5331P/M (16 pins)	10 to 28V	220kHz 92%	±1.5A (peak value)	1.54V ±4%	5V ±4%	External synchronization Overvoltage / overcurrent	Power factor controller

Table 2 Main features of FA 1384X series

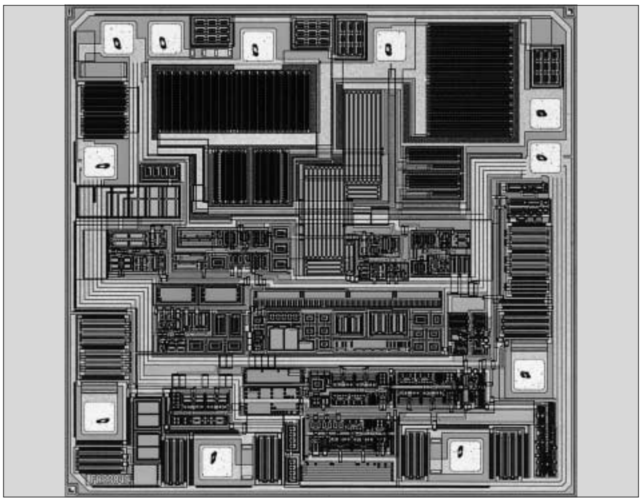
(a) Absolute maximum ratings

Item		Property
Supply voltage		10 to 28V
Output peak current	Source current	400mA
	Sink current	1.0A
Operating frequency		10 to 500kHz
Ambient temperature		– 25 to +85°C
Junction temperature		150°C

(b) Electric characteristics

Item	Property
Start-up current	12μA (standard)
Standby current (V_{CC} = 14V)	2μA (maximum)
Current consumption during operation (C_L = 1,000pF)	3mA (standard)
Reference voltage	5V±5%
Error amp. feedback input voltage	2.5V±4%
Current sense maximum input signal	1V±0.1V
Output rise time (C_L = 1,000pF)	40ns (standard)
Output fall time (C_L = 1,000pF)	20ns (standard)

Fig.1 Chip configuration (FA13842)

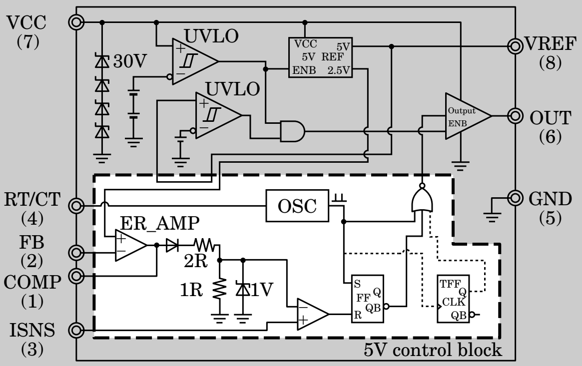


bipolar devices such as npn transistors, pnp transistors and Zener diodes to be configured. A band gap reference voltage circuit with these npn transistors is utilized in the reference voltage generator.

2.2.2 UVLO circuit

The circuit configuration shown in Fig. 3 was

Fig.2 Block diagram



Note: Toggle flip-flop is used only in FA13844 and FA13845.

Fig.3 Undervoltage lockout circuit (UVLO)

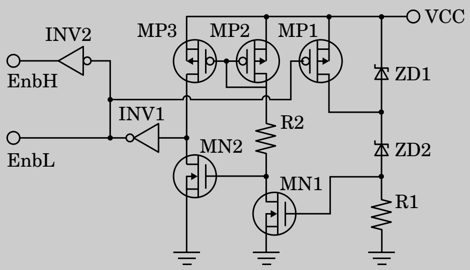
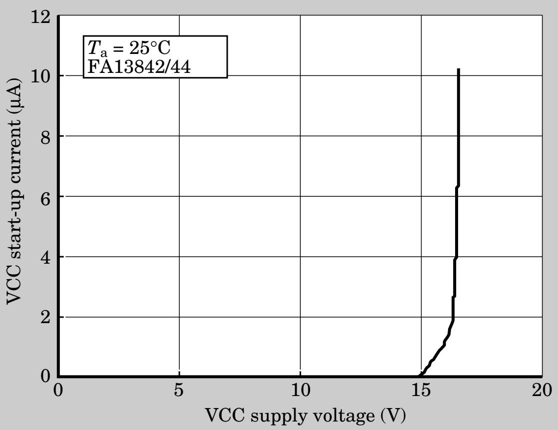


Fig.4 Start-up current



adopted in order to utilize the advantages of the CMOS process and to reduce current consumption before start-up.

Current consumption is almost zero because MN1 is off until VCC voltage exceeds the Zener voltage. Standby current for the entire IC is also almost zero because the bias current of other circuit blocks can be

Fig.5 Output driver circuit

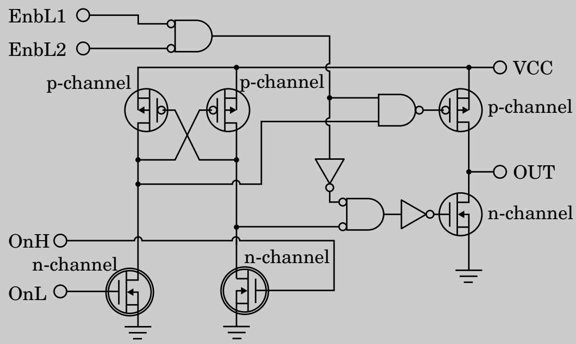
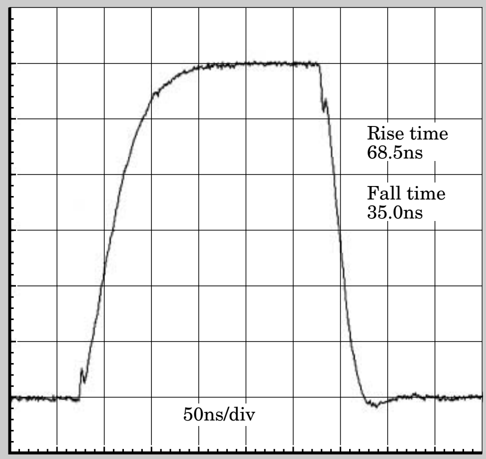


Fig.6 Output terminal voltage waveform



fixed to zero by an output H/L logic signal. Figure 4 shows current consumption characteristics until immediately before start-up. Standby current is almost zero when the VCC supply voltage is less than 14V, and a little over 10µA just before start-up.

As the VCC voltage is raised further, MN1 turns on, reversing the output logic. A bias current begins to flow in each transistor, initiating operation. When MP1 turns on, the voltage hysteresis of the UVLO circuit is determined.

2.2.3 Output driver circuit

The FA1384X series has a built-in output driver circuit with a CMOS inverter configuration. This allows the MOSFET gate voltage for switching to fully swing up to the VCC voltage using a level shifter. When switching between high- and low-levels, the current flowing to GND can be reduced by setting a period of several tens of nanoseconds as the interval when both the p-channel at the VCC side and the n-channel at the GND side are turned off at the same time.

Figure 5 shows a block diagram of the driver circuit. After a 5V-amplitude logic signal (OnH/OnL)

Fig.7 Application circuit

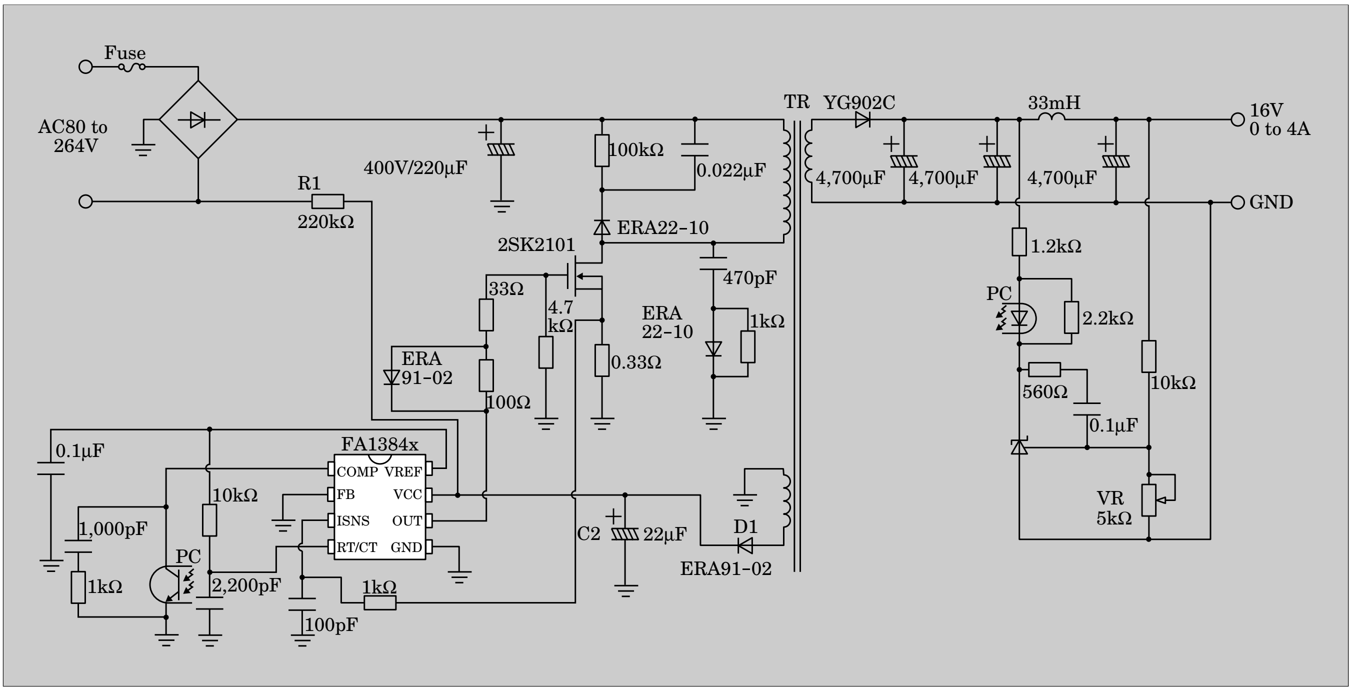
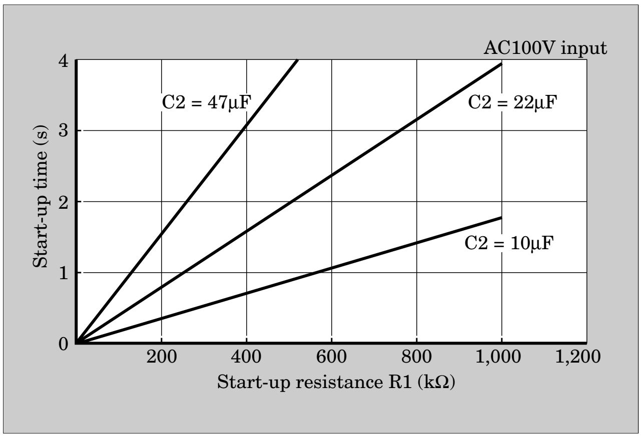


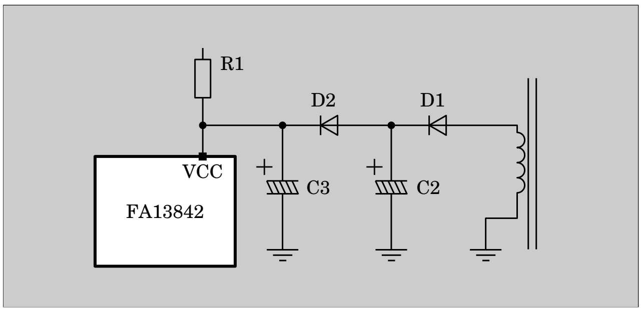
Fig.8 Relationship between start-up time and R1, with C2 as a parameter



from a pulse control section has been expanded up to the VCC voltage, it is logically ANDed with an enable signal from the UVLO circuit to drive the output terminal. When the VCC voltage is less than the start-up voltage, the enable signal is input as a high-level to fix the output driver to a low-level (gate off) irrespective of the control signal conditions.

Figure 6 shows the waveform of the output terminal voltage with a 2,200pF capacitor connected to the output terminal as a load. The rise time is 68.5ns and the fall time is 35ns. The fall time was designed to be shorter than the rise time because in driving the n-channel power MOSFET, faster speed is required for the fall state when the gate turns off than for the rise state when the gate turns on. When VCC voltage is

Fig.9 Auxiliary winding circuit with short start-up time



15V, the on-state resistance is 15Ω at the p-channel source current side and 7.5Ω at the n-channel sink current side.

3. Application Circuits

Figure 7 shows the circuit diagram of an example application of a secondary winding voltage sensing system. The input AC voltage charges an electrolytic capacitor C2. When the voltage reaches the on-threshold voltage, the IC begins operation and current is supplied from the bias winding of the transformer. A large start-up resistance can be set in the newly developed FA1384X because of the small start-up current. Since current continues to flow across the start-up resistor even under the normal operating condition where VCC current is supplied from the bias winding, the resistive loss can be reduced by increasing the resistance of the start-up resistor. However, the smaller the current the longer the start-up time is because more time is required to charge the capacitor C2. Consequently, the values of the resistance and capacitance should be selected in consideration of actual operating conditions.

Figure 8 shows the relationship between start-up time and start-up resistance R1 with capacitance C2 as a parameter.

Figure 9 shows a method to reduce the start-up time even with a high start-up resistance. Decreasing the capacitance of C3 reduces start-up time, and after start-up, current is supplied from C2.

4. Conclusion

This paper presented an overview of the newly developed CMOSICs for current-mode AC-DC converters. CMOS-type ICs have the advantages of being suitable for lower power consumption and are easy to incorporate in logic circuits. In addition to the ICs discussed in this paper, Fuji Electric plans to develop other CMOS-type ICs for switching power supply control.

Control IC for 3-Channel Switching DC-DC Converters

Masayuki Yamadaya

1. Introduction

With the proliferation of portable electronic devices typified by notebook-sized personal computers, importance has been attached to device portability and to longer service life of the batteries installed in these devices.

Consequently, DC-DC converters used as power supplies for these devices require smaller size, lighter weight and higher efficiency.

In addition, these portable electronic devices increasingly require lower operating voltage. Accordingly, control ICs for DC-DC converters must operate at lower voltages.

To meet these market needs Fuji Electric has developed the FA3629AV, a small, light and thin control IC for 3-channel DC-DC converters, mainly aimed at power supplies for liquid crystal displays used in notebook-sized personal computers and other electronic devices. This paper presents an overview of the FA3629AV.

2. Product Overview

The newly developed FA3629AV IC for 3-channel DC-DC converters drives and controls PWM (pulse width modulation) type switching power supplies. This IC has the following features.

(1) TSSOP 16-pin package
(2) Can drive three channels simultaneously, two boost converters and an inverting converter
(3) Built-in n-channel MOSFET (metal-oxide-semiconductor field-effect transistor) as a switching element
(4) Operating voltage: 2.5 to 6.5V
(5) Oscillation frequency: 100kHz to 1MHz
(6) Built-in maximum duty limiting for each channel
(7) Built-in timer and latch type short circuit protection
(8) Built-in soft start circuit, overcurrent limiting circuit, thermal shutdown circuit and undervoltage lockout circuit

The FA3629AV incorporates a MOSFET as well as 3 channels and various protective functions on 16 pins, allowing smaller and thinner DC-DC converters.

Table 1 shows the ratings of the FA3629AV.

3. Internal Circuitry

Figure 1 shows a photograph of the FA3629AV chip and Fig. 2 shows its circuit diagram. Basic circuit blocks use CMOS (complementary MOS) technology and high-voltage sections such as the MOSFET use DMOS (double diffused MOS) technology.

Main circuit blocks are described below.

3.1 Built-in MOSFET

This IC incorporates an n-channel MOSFET, a switching element, in the No. 1 channel, constituting a boost converter. The MOSFET has on-state resistance

Table 1 Ratings of FA3629AV

Item	Condition	Min.	Std.	Max.
Supply voltage (V)		2.5		6.5
Output voltage at OUT1 pin (V)				40
Reference voltage (V)		0.98	1.00	1.02
Oscillation frequency (kHz)		480	550	620
Source current at CS pin (μA)		– 1.2	– 1.0	– 0.8
Sink current at CS3 pin (μA)		0.8	1.0	1.2
Overcurrent sensing current (A)		1.6	2.0	2.2
Thermal shutdown operating temperature (°C)		125	135	145
Undervoltage lockout operating voltage (V)		1.95	2.05	2.15
OUT1 on-state resistance (Ω)	I_{OUT1} = 200mA		0.275	0.3
OUT2, 3 H level on-state resistance (Ω)	I_{OUT} = 150mA	2.6	4.0	5.5
OUT2, 3 L level on-state resistance (Ω)	I_{OUT} = – 150mA	2.0	3.5	5.0
Average current consumption (mA)	f_{OSC} = 500kHz		3.0	3.8

<Note> Unless otherwise indicated, rated values are specified under the condition of a 3.0V supply voltage and 25°C ambient temperature.

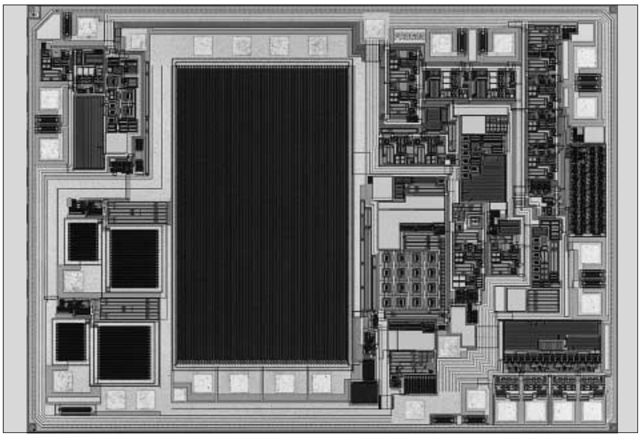
of 0.3Ω (max.) and can provide a current of up to 1.8A. This leads to a reduction in the number of switching elements and to greater output. The OUT1 pin is the drain and the PGND pin the source. Withstand voltage of the OUT1 pin is 40V.

3.2 Output drivers (OUT2 and OUT3 pins)

The No. 2 channel pin is for driving an n-channel MOSFET and the No. 3 channel pin is for driving a p-channel MOSFET. These channels constitute a push-pull construction and form a boost converter and an inverting converter respectively.

In addition, these channels can drive bipolar transistors as switching elements.

Fig.1 Photograph of the FA3629AV



3.3 Basic operating sections (error amplifier and PWM comparator)

Since PWM-type switching power supplies are to be controlled, the basic configuration of the main operating sections is to feed back the output voltage provided from each channel to the error amplifier of each channel and to convert the output of the amplifier into a pulse signal with a comparator to create a driving signal for switching elements.

Each channel has an inverting input pin (IN1-, IN2- or IN3-) and an output pin (FB1, FB2 or FB3) connected to the error amplifier.

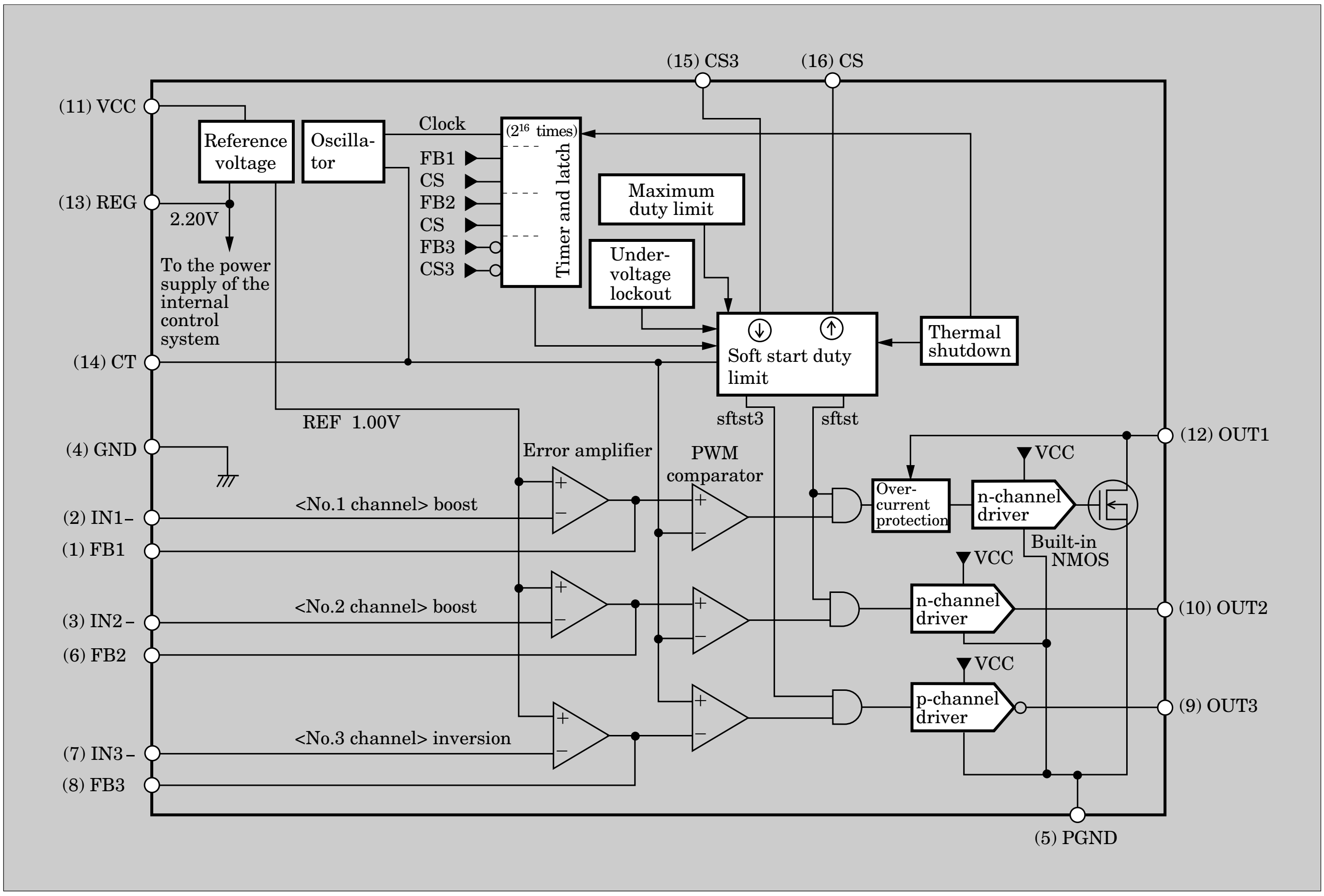
The No. 1 and No. 2 channels constitute boost converters and the No. 3 an inversion booster. This combination is most suitable for the power supply of liquid crystal displays.

In addition, the No. 3 channel utilizes inverted-phase switching (as compared to the other channels). This avoids load concentration during simultaneous operation of the three channels.

3.4 Oscillator

The fundamental frequency of this IC is the

Fig.2 FA3629AV circuit diagram



frequency of the oscillator. Repeated charging and discharging of a timing capacitor by a temperature-compensated built-in power source generates the oscillation ranging from 100 kHz to 1 MHz depending upon capacitance. The oscillation frequency is 550kHz at 150pF.

3.5 Soft start circuit

The IC incorporates a soft start circuit to prevent current flow when the DC-DC converter starts.

Gradual expansion of the pulse signal width in proportion to the charged voltage of a soft start capacitor (connected to CS and CS3 pins) limits the current flow at start-up.

The CS pin is used for the No. 1 and No. 2 channels, and the CS3 pin for the No. 3 channel. These pins can be controlled independently.

3.6 Maximum duty limit

If a boost converter and an inverting converter remain switched on, the heavy current flow may damage the converters. To prevent this, an off-period is forcibly provided for each switching period, in other words, the maximum on-period duty is limited.

For each channel, a maximum duty limit of 86 to 87% of is imposed for an oscillation frequency of 500kHz. Since this is a built-in function, external parts are unnecessary.

3.7 Undervoltage lockout circuit

From the time when the IC is turned on until the internal control power supply is established, switching is halted in order to prevent malfunction.

During operation of this circuit, the soft start capacitor is discharged. The soft start function can be used to return to normal IC operation.

3.8 Overcurrent limiting circuit

This function shortens the switching period to prevent elements and circuits from being damaged when, for some reason, the current of the built-in MOSFET increases.

From the on-state voltage of the built-in MOSFET, this function detects the overcurrent state for each switching operation. If an overcurrent state is detected, the IC is turned off. The detection point is 2.0A for a supply voltage of 3.0V.

Switching is not halted by this function but if the overcurrent state continues for a long time, switching will be halted by a timer and latch circuit to be described later.

3.9 Thermal shutdown circuit

This IC incorporates a MOSFET and has a driving circuit for external switching elements. These elements generate heat when there is a large current flow. The thermal shutdown circuit detects the heat and turns off the IC.

Heat is detected by changes in temperature of an on-state diode. If the chip temperature reaches 135°C, switching is halted.

Fig.3 Schematic diagram of switching operation

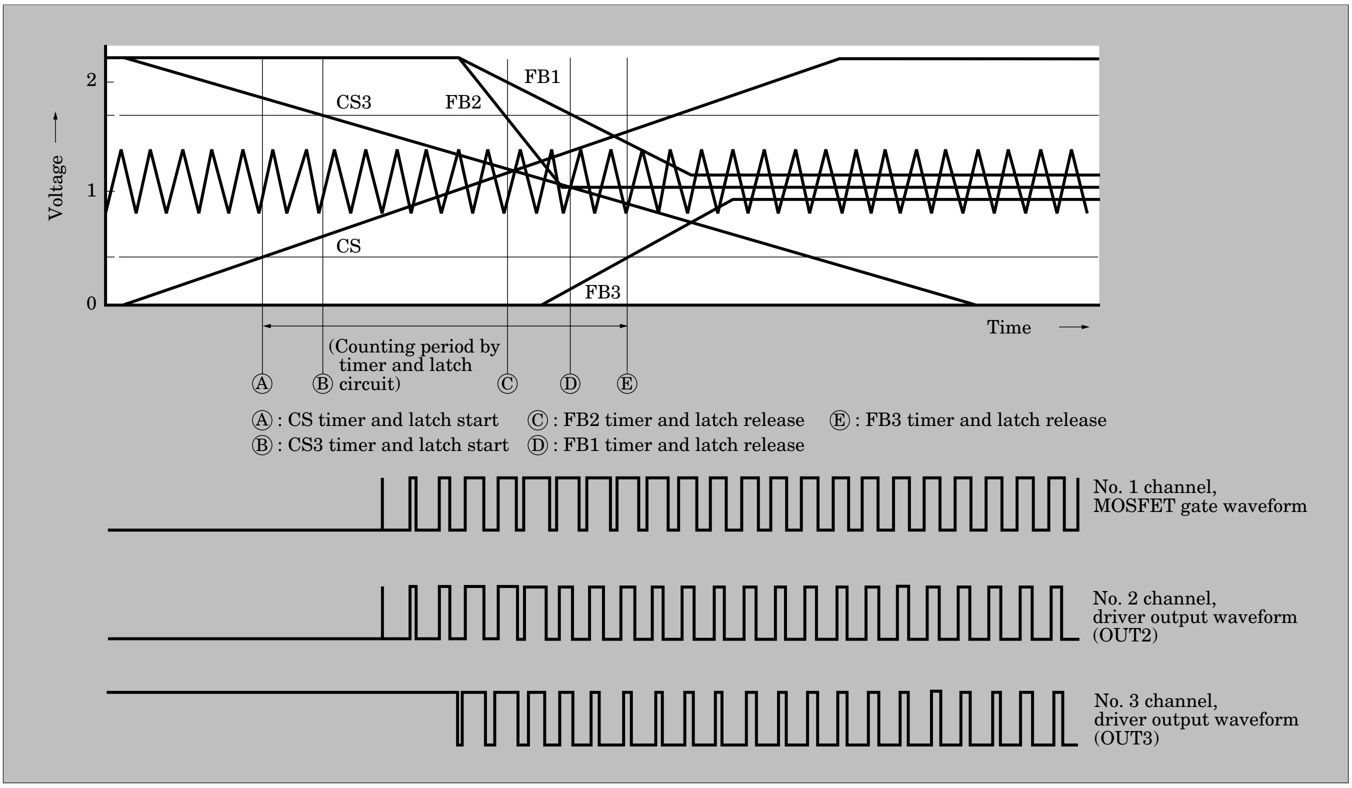
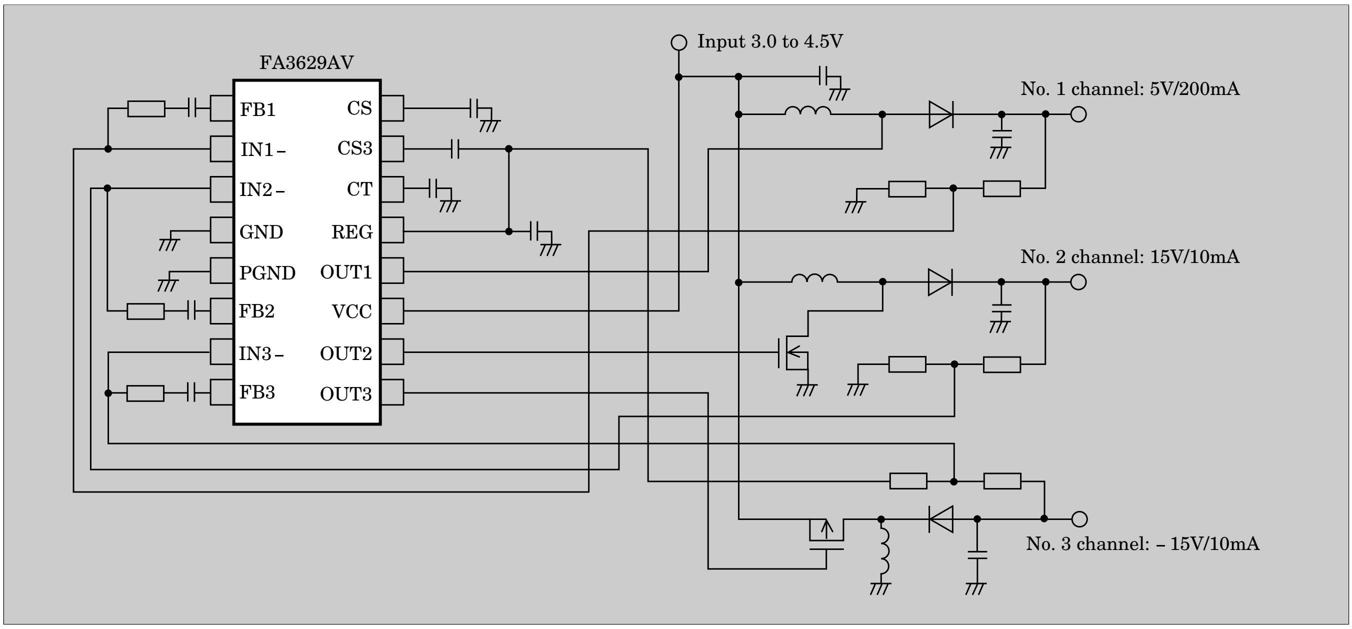


Fig.4 Example application circuit using the FA3629AV



3.10 Timer and latch circuit

The timer and latch circuit detects an abnormal condition when the output voltage of the power supply circuit is less than the specified value for a period of time, and then halts the switching operation.

The charging time of an external capacitor is commonly used to set the time between detecting an abnormal condition and halting the switching operation (hereafter referred to as the “timer-latch time”). To reduce the number of pins and external parts in this IC, however, an internal counter is utilized to set this time.

The counter clock uses the oscillator frequency. When the counterís value reaches 2^{16}, the latch mode is entered and a halt signal is transmitted.

The output voltage of the error amplifier of each channel is used to detect an abnormal condition. When the power supply voltage is below the specified value, the output voltages at FB1 and FB2 reach the voltage level of the FA3629AV’s reference voltage (2.20V), and the voltage at FB3 reaches the ground or zero voltage level to maximize the on-state pulse width of each channel.

Figure 3 shows a schematic diagram of the switching operation.

During start-up operation or when there is an unused channel, the output voltage of the error amplifiers is the same as when there is an abnormal condition. Therefore the pin voltage at the soft start pins (CS, CS3) is detected and input to the timer and latch circuit.

4. Example Application Circuit

Figure 4 shows an example application circuit using the FA3629AV. The No. 1 and No. 2 channels constitute booster converters and the No. 3 channel an inverting converter. This conforms to the general power supply specifications of liquid crystal displays.

The application circuit incorporates an n-channel MOSFET and utilizes a counter type timer and latch circuit. This results in a reduction in the number of parts and mounting surface area.

5. Conclusion

This paper has presented an overview of the FA3629AV, a small size, lightweight and thin shaped control IC for 3-channel DC-DC converters.

Fuji Electric is now developing ICs for power supplies based on CMOS analog technology. Fuji Electric will continue to closely monitor market needs and develop control ICs, in particular, ICs that meet the various requirements of DC-DC converter applications.

Autofocus Modules with MOS Analog Sensors

Makoto Tanaka
Sachiaki Komatsu
Yoshinari Enomoto

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

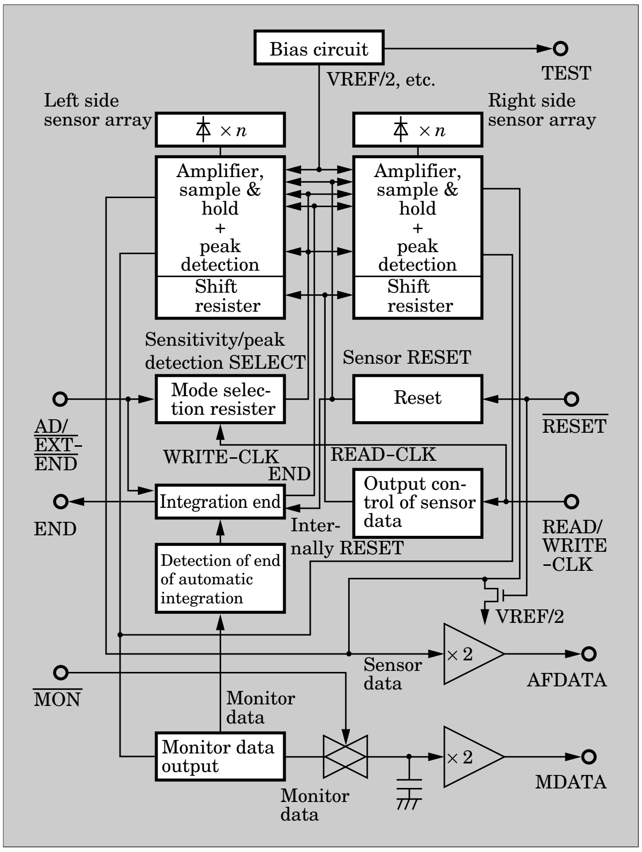


Fig.2 Example of sensor data output

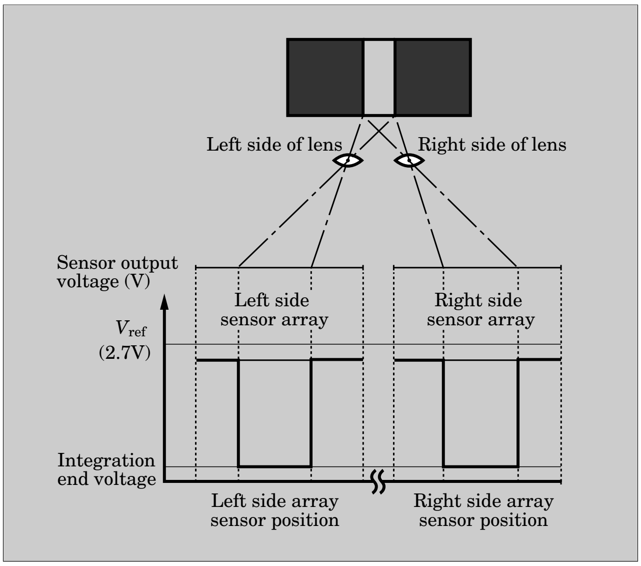
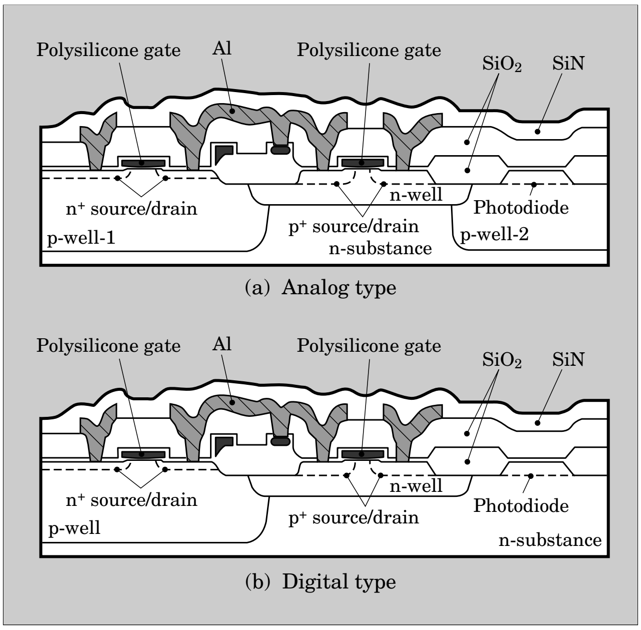


Fig.3 Structure of the photodiode



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

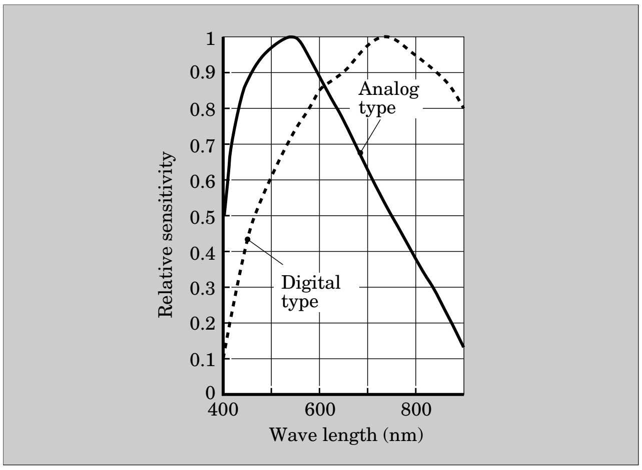


Fig.5 Miniaturization of modules with reduced sensor pitch

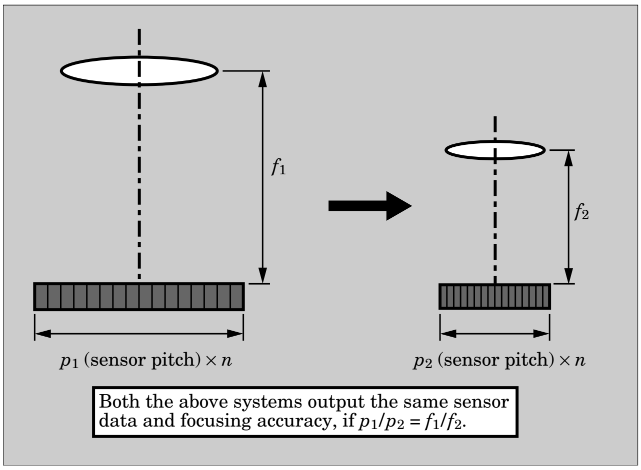
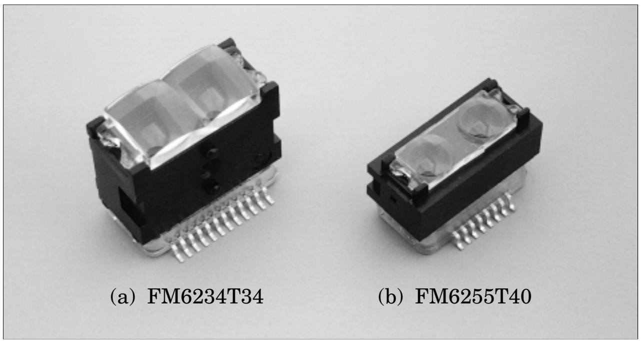


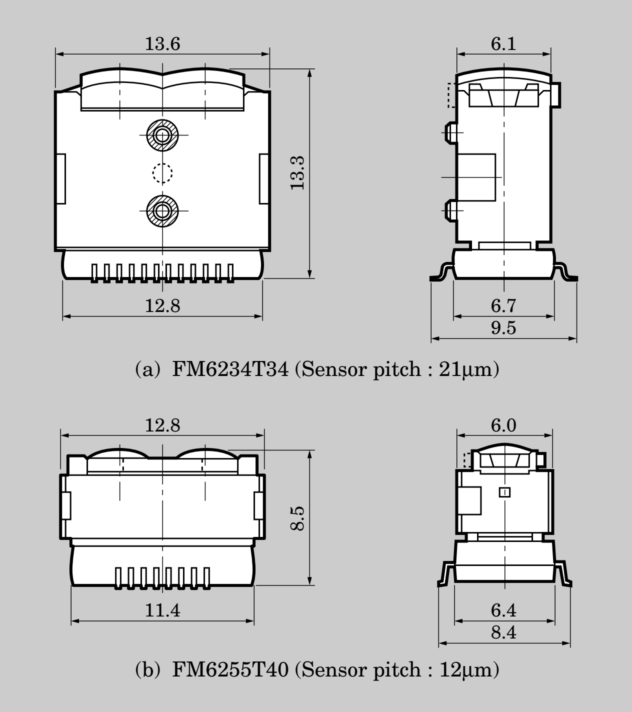
Fig.6 External view of the AF modules



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



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.

Driver ICs for Character Display LCD Controller

Hiroaki Kamo

1. Introduction

In our highly information-oriented society, we have come to rely on electronic display devices. They serve as means of communication and man-machine interfaces in many fields, from general to industrial.

In many kinds of display devices, the liquid crystal display (abbreviated as LCD) is used in a wide range of fields due to its merits of small size, light weight, thin form and low power dissipation. It maintains its position as a next generation general use device, which will succeed LED and CRT displays.

For meeting such market needs, Fuji Electric has continued to produce a series of ICs for LCDs (abbreviated as LCD-IC).

This paper will introduce the production series of driver ICs for character display controllers of small size LCDs (abbreviated as small size LCD-IC) which are chiefly used as display devices in stationary telephones, cellular phones, facsimiles, radio pagers, printers, copying machines, etc.

2. Outline of Products

Fuji Electric has been already mass-producing single chip small size LCD-ICs which have the faculty to drive various LCDs without any additional components. This time, a new production series to meet market needs for a variety of display capacities and low power dissipation have been provided. An outline will be introduced here.

2.1 Features

The principal characteristics of 6-type small size LCD-ICs, now under mass production, are compared in Table 1. These types of IC chips are shown in Figs. 1 through 4.

Within these types of ICs, “FCS2314AK” is produced for LCD panels used in electronic devices like stationary telephones, printers, facsimiles and copying machines. It can display as many as 20 characters per line and its power supply voltage is specified to the 5V system.

Other types of ICs are produced for LCD panels used in hand-held information terminals like cellular phones, PHS (personal handyphone system) and radio pagers, and their power supply voltage is specified to meet the low voltage of the 3V system, driven by a battery. In addition, to eliminate an external power supply circuit, each IC has a charge pump for generating the voltage required to drive an LCD. Among these ICs, “FCS2326K” and “FCS2327K” have achieved low power dissipation and high performance, described below.

2.1.1 Low power dissipation

The ICs for hand-held information terminals are provided with a stand-by mode for low power dissipation, in which a source current to a power supply for driving an LCD is blocked when display is not

Fig.1 Photograph of the FC2306K chip

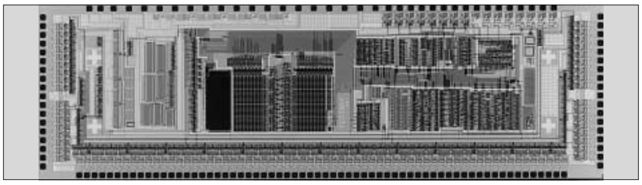


Fig.2 Photograph of the FCS2314AK chip

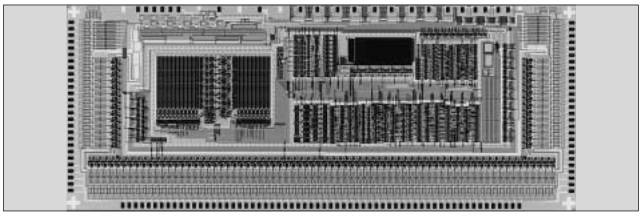


Fig.3 Photograph of the FCS2326K chip

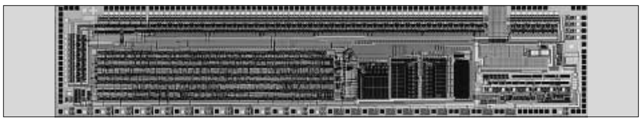
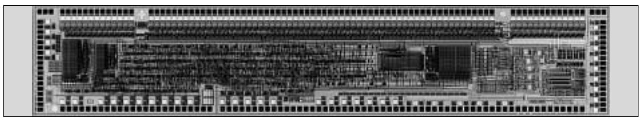


Fig.4 Photograph of the FCS2327K chip



required. But “FC2326K” and “FCS2327K” are designed to accelerate lower power dissipation with the characteristics described below.

(1) Lower frequency oscillator circuit
(2) Built-in power supply circuit with low power dissipation for driving an LCD
(3) Addition of a sleep mode in which the oscillator is paused while a stand-by

These functions greatly help to lengthen battery life of hand-held devices.

2.1.2 High performance

LCD-ICs for hand-held devices generally have an icon (a kind of pictograph) displaying function which can be controlled independently of the display characters and are used for indicating remaining battery capacity of hand-held information terminals. But “FCS2326K” and “FCS2327K” have achieved increased display capacity and better visibility by realizing more icons (116 bits) and double height characters (Fig. 5).

Moreover, adopting asynchronous access (Fig. 6) to an MPU realizes a high speed interface. Many types of optionally available interfaces allow reduction of additional components and facilitated use.

2.1.3 Easy packaging design

(1) Configuring common/segment signal driver circuits with bi-directional shift resisters allows a

Table 1 Principal characteristics of small size LCD-ICs

Items \ Types	FC2306K	FCS2314AK	FC2316K	FCS2326K	FCS2327K
Display capacity (characters × lines)	16 × 2	20 × 2	16 × 4	12 × 2	12 × 3
Duty	1/18	1/8, 1/16	1/34	1/18	1/26
Number of LCD driving output terminals	COM : 18 SEG : 80	COM : 16 SEG : 100	COM : 34 SEG : 80	COM : 18 SEG : 62	COM : 26 SEG : 60
Power supply voltage (V)	2.7 to 5.5	4.5 to 5.5	2.7 to 5.5	2.4 to 3.6	2.7 to 3.6
LCD driving voltage (V)	3.0 to 11.0	3.0 to 5.5	3.0 to 11.0	3.0 to 7.0	3.0 to 11.0
DDRAM (bits) (Maximum characters)	64 × 8 (64)	80 × 8 (80)	64 × 8 (64)	24 × 8 (24)	36 × 8 (36)
CGROM (characters)	240	240	240	240	240
CGRAM (bits)	512	512	512	160	160
PGRAM (bits)	10	—	20	112	72
Interface (bits)	4/8	4/8	4/8	1/4/8	1/4/8
Number of instructions	12	11	12	15	15
RVLCD	Built-in	Built-in	Built-in	Built-in	Built-in
Oscillator frequency (kHz)	250	270	250	33	50
Charge pump	Built-in	—	Built-in	Built-in	Built-in
Electronic variable resistor	—	—	—	Built-in	Built-in
Low current power supply for LCD	—	—	—	Built-in	Built-in
Stand-by mode	Provided	Not Provided	Provided	Provided	Provided
Sleep mode	Not Provided	Not Provided	Not Provided	Provided	Provided
Consumption current (μA)	450 (typ.)	1,500 (typ.)	500 (typ.)	100 (max.)	140 (max.)
Aspect ratio of chip size	1 : 3.14	1 : 2.42	1 : 3.25	1 : 4.64	1 : 5.00

Fig.5 Example of double height character display

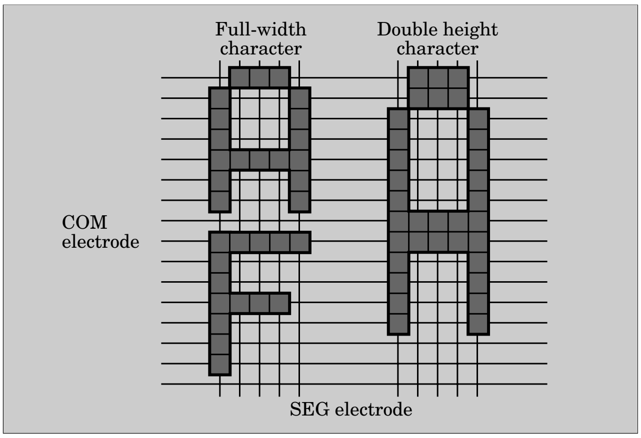
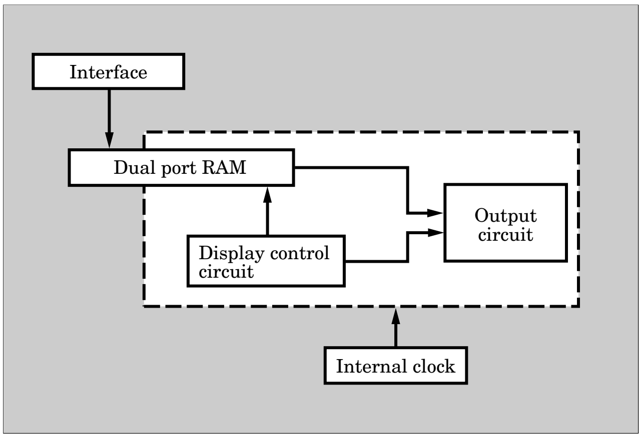


Fig.6 Conceptual rendering of asynchronous access



freer layout of ICs and LCDs, as shown in Fig. 7.

(2) High density packaging is achieved by using gold bump electrode construction applicable for COG (chip on glass) and TAB (tape automated bonding) mounting. Especially in COG mounting, easier handling and higher density packaging are realized by adopting a method (Fig. 8) to efficiently determine an operation mode of the IC through the utilization of ITO (indium tin oxide) wiring.

(3) A chip form desirable for a smaller mounting area (not including the LCD part) has been decided by increasing the aspect ratio of the chip size.

Fig.7 Layout example of ICs and display devices

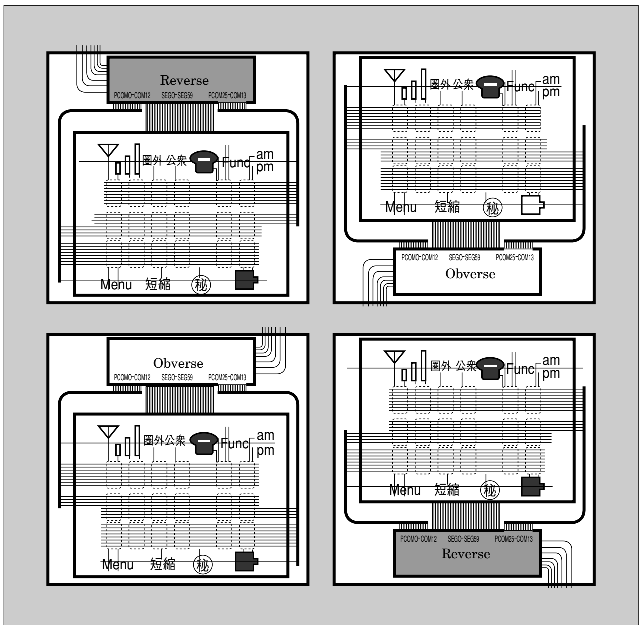


Fig.8 Example of determining operation mode with ITO

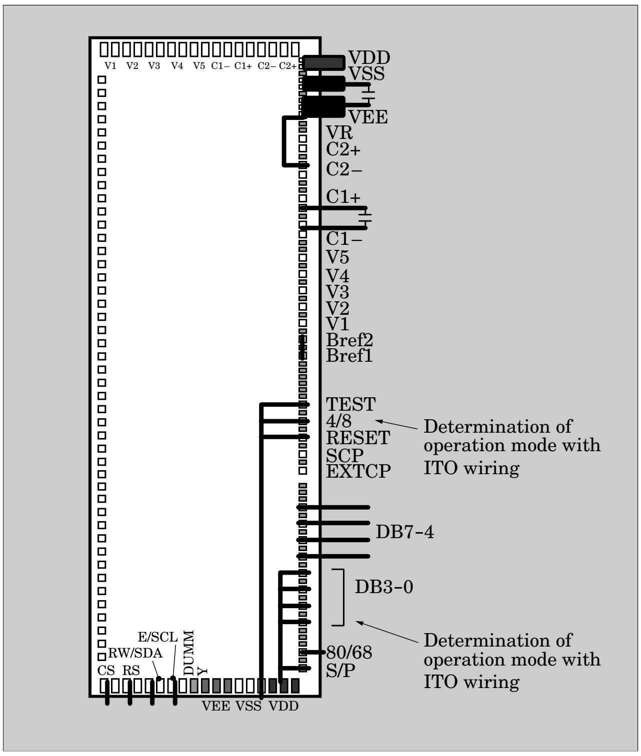


Fig.9 Circuit configuration of the FCS2327K

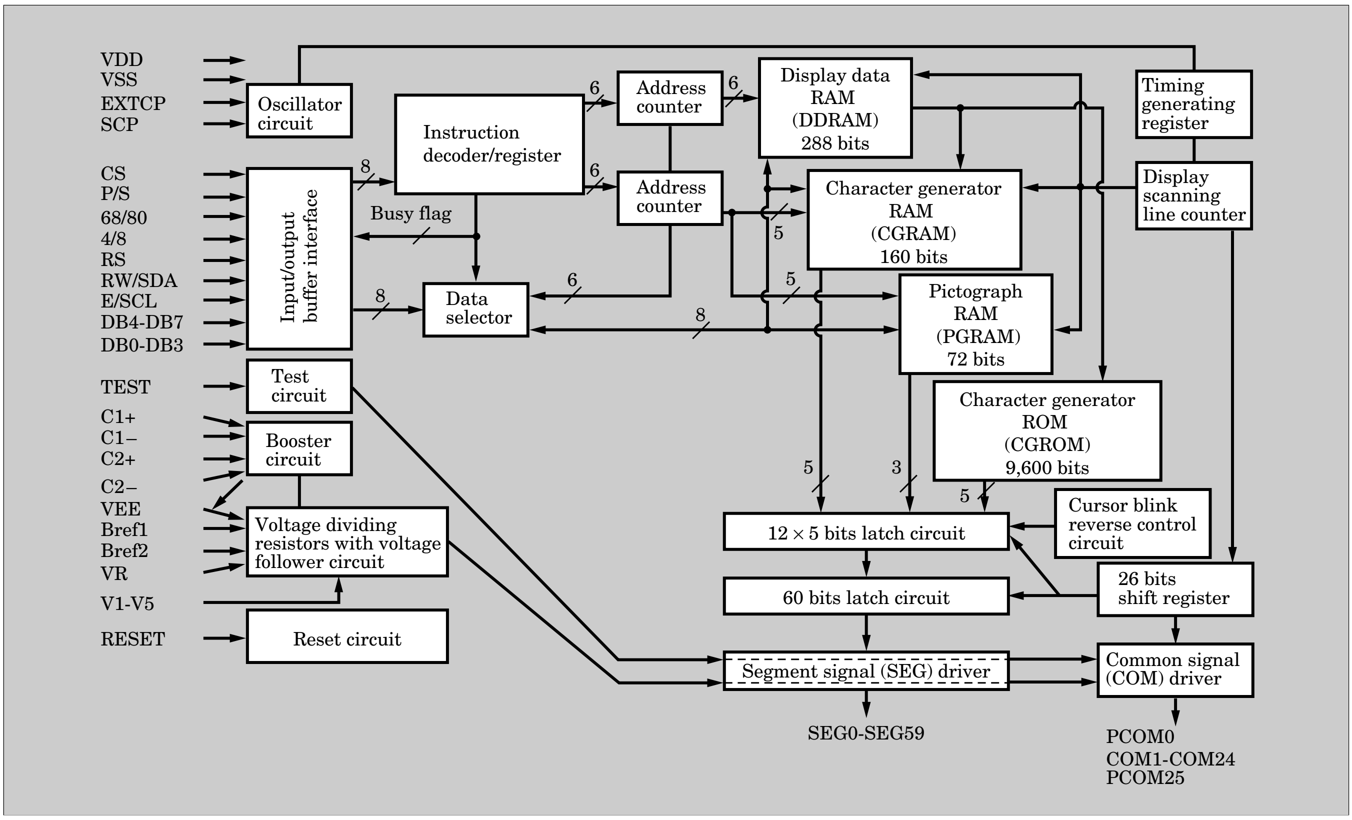


Fig.10 Power supply circuit for the driving LCD

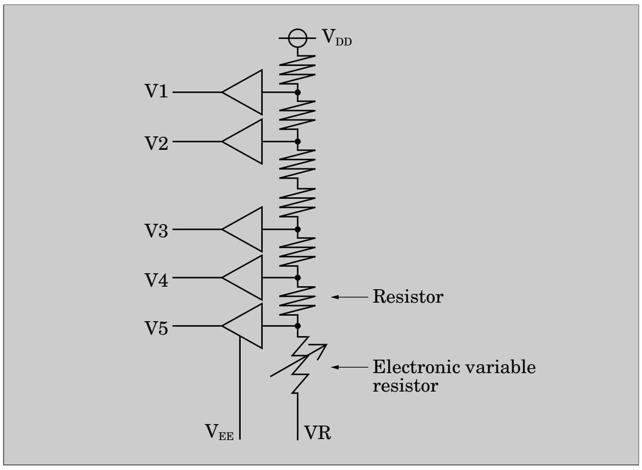
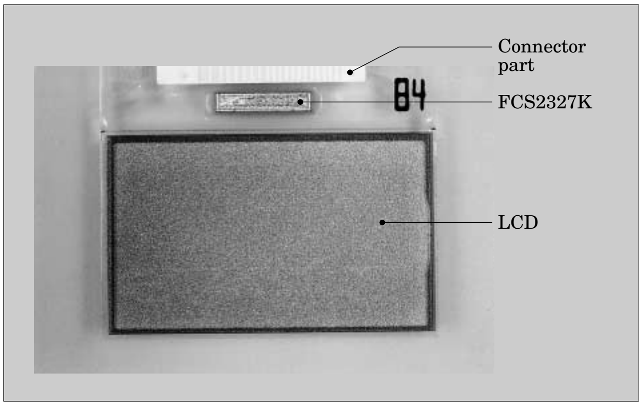


Fig.11 Module mounted with the FCS2327K



2.2 Circuit configuration

As a typical example of driver ICs for the LCD controller, the circuit configuration of "FCS2327K" is shown in Fig. 9.

This IC consists of an interface circuit to the MPU, a control circuit for various display modes or data, ROM/RAM parts for storing display data and a driver circuit for LCD panels.

For realizing low power dissipation, as shown in Fig. 10, the power supply circuit for driving the LCD is configured with a voltage follower circuit. Voltages divided with high resistance are transformed into impedance, and a 5-bit electronic variable resistor adjusts display contrast.

2.3 Application example

An LCD panel capable of displaying 12 characters × 3 lines with "FCS2327K" is shown in Fig. 11 as an application example.

From an externally supplied 3V single power source, the desired LCD driving voltage is generated with the built-in charge pump of this IC and an additional capacitor. It drives the LCD panel through the built-in circuits of the voltage dividing resistor for the LCD driving power supply and the built-in electronic variable resistor for adjusting display contrast.

3. Conclusion

Six types of small size LCD-ICs manufactured by Fuji Electric for displaying characters have been introduced.

As the LCD meets a variety of working environments and multimedia, the market is expected to further expand in the future. Accordingly, lower power dissipation, higher performance and lower cost will be required.

Fuji Electric will promote the manufacture of distinctive LCD-ICs for meeting such market needs.

High-Voltage CMOS Process Technology

Keishirou Kumada
Satoshi Yokoyama

1. Introduction

Fuji Electric has developed processes to fabricate ICs. The process satisfies demands for a display driver IC of up to about 100V for a liquid crystal display (LCD), plasma display panel (PDP) and vacuum fluorescent display (VFD). The power control IC has up to about 40V of high voltage and high current analog signal control.

The ICs are fabricated using the CMOS (complementary MOS) oxide isolation process for driving the LCD, the junction isolation process for driving the PDP and the bipolar process for the power supply.

Besides small size and light weight, there are demands for reduced power consumption for longer battery life for electronic apparatus and devices, especially for the handy type.

An IC used in electronic apparatus and devices, small chip size by using scaling down process, variety of functions to reduce number of parts, low power consumption and low cost are demanded. The CMOS process which uses oxide isolation technology is low in cost when compared with the DMOS (double diffused-MOS) process and bipolar process of junction isolation technology. Also it is favorable for high integration because CMOS process is suitable for scaling down. Fuji Electric has developed devices using the CMOS oxide isolation process for the IC applying to driving LCD, driving PDP and power supply control.

This paper will present a summary of the process and characteristics of the device. The process enables high voltage devices of 30V, 60V and 120V to use the CMOS oxide isolation process.

2. Outline of the Process

Table 1 shows an outline of three processes. One advantage is a simple process based on the logical 1μm rule and another is the possible mounting of the high voltage and logic devices on one chip. These devices can select the process or device depending on the voltage used by the products. Fuji Electric has prepared three high voltage devices of 30V, 60V and 120V for the absolute maximum rating voltage.

Table 1 Classification of CMOS process

Process technology		Geometrical design rules	Absolute maximum ratings for voltage	Polysilicon layer	Metal layer
Polysilicon-gate-CMOS	CMOS Ⅰ	1μm	30V	2 layers	2 layers
	CMOS Ⅱ		60V	2 layers	2 layers
	CMOS Ⅲ		120V	1 layer	1 layer

Table 2 Fabrication process sequence for component device

Process flow	CMOS Ⅰ	CMOS Ⅱ	CMOS Ⅲ
n-well diffusion	○	○	○
p-well diffusion	○	○	○
p-offset diffusion	○	○	○
n-offset diffusion	○	○	○
p-guardring diffusion	○	○	
n-guardring diffusion		○	
Field oxidation	○	○	○
First gate metallization	○	○	○
Second gate metallization	○	○	
Source/drain diffusion	○	○	○
Contact window etching	○	○	○
First interconnections metallization	○	○	○
Second interconnections metallization	○	○	
Passivation film deposition	○	○	○

Table 2 shows the process flow. The process flow for the logic device is identical to the other devices and the addition or elimination of optional flows for high voltage and bipolar devices is possible.

3. Component Devices

Characteristics of each device are shown in Table 3.

Fig.1 Schematic cross section of component devices

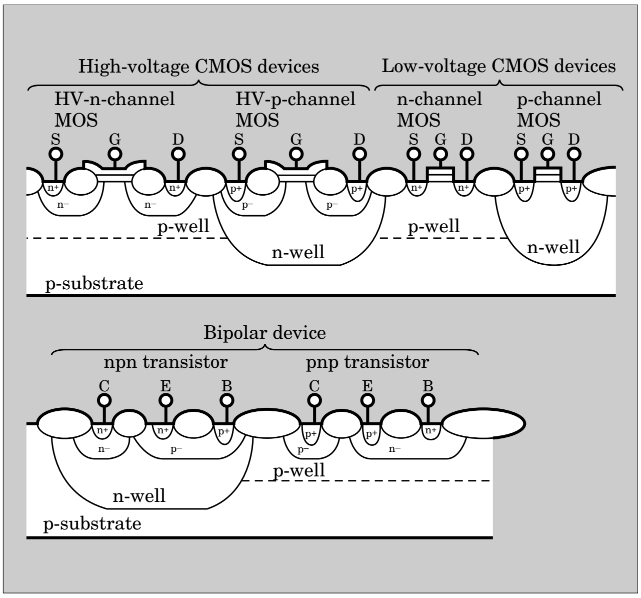


Fig.2 Equipotential plots for the 30V class CMOS device

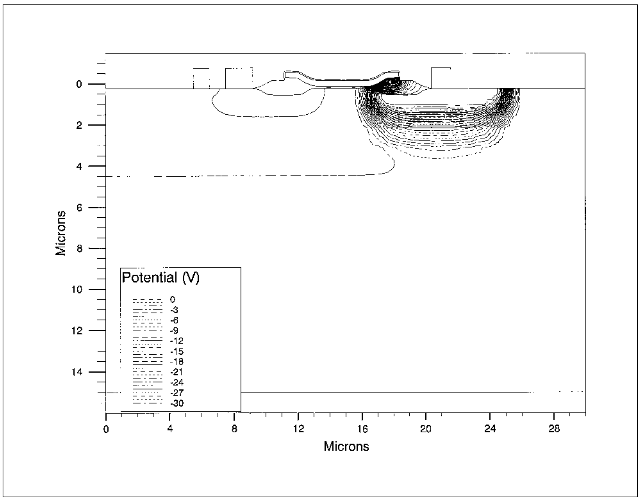


Table 3 Characteristics of component devices

Devices		Charac-teristics	1μm rule CMOS process		
			CMOS Ⅰ	CMOS Ⅱ	CMOS Ⅲ
CMOS	Low-voltage n-channel MOSFET	V_{th} (V)	1.0		
		BV_{dss} (V)	12.0		
	Low-voltage p-channel MOSFET	V_{th} (V)	– 1.0		
		BV_{dss} (V)	– 12.0		
	High-voltage n-channel MOSFET	V_{th} (V)	1.5	2.5	1.0
		BV_{dss} (V)	65.0	80.0	160.0
	High-voltage p-channel MOSFET	V_{th} (V)	– 2.0	– 3.5	– 1.0
		BV_{dss} (V)	– 55.0	– 75.0	– 160.0
Bipolar	npn transistor	h_{FE}	90.0	—	—
		BV_{ceo} (V)	18.0	—	—
	pnp transistor	h_{FE}	35.0	—	—
		BV_{ceo} (V)	80.0	—	—
	Zener diode	V_z (V)	7.5	—	—

3.1 High-voltage CMOS device

Figure 1 shows a cross section of the high voltage CMOS device. Under the high voltage biased between source-drain electrode of CMOS device, punch-through effect, impact ionization, hot-carrier are observed due to the high electric field around the drain region. Punch-through effect reduces the break-down voltage and impact ionization and hot-carrier cause reduction of reliability.

Then, in order to reduce the high electric field of the CMOS, a well-known structure of connected high-concentration diffused layers of the source and drain with a low-concentration diffused layer are adopted. With the low-concentration diffusion layer, the electric field around the drain is lowered, and the breakdown voltage of the device is increase and generation of the hot-carrier is reduced. Figure 2 shows equipotential plots near the drain region in the 30V class device using a two dimensional simulator (ATLAS).

According to the required breakdown voltage of the device, the CMOS has designed to obtain a maximum current while satisfying high voltage by optimizing parameters such as channel length, concentration and depth of the lightly doped diffusion layer and gate oxide thickness.

Figures 3 through 8 show current-voltage characteristics of the high voltage devices.

3.2 Bipolar device

In order to apply the device to a high precision analog circuit, the process flow of the 30V class CMOS has included the production process for the npn transistor, pnp transistor and zener diode as options.

The process cost of these devices can be reduced by using the common use of both the high voltage process sequence.

3.3 Low-voltage device

The low-voltage device has been designed commonly in every process and used as a common device. The design attempted to micronize the device by using the 1μm rule. The IC with higher integration and speed has been realized.

4. Application

Figure 9 shows a photograph of a power control IC chip fabricated by the 30V class CMOS process.

Fig.3 I_d-V_d characteristics of the 30V class n-channel MOSFET

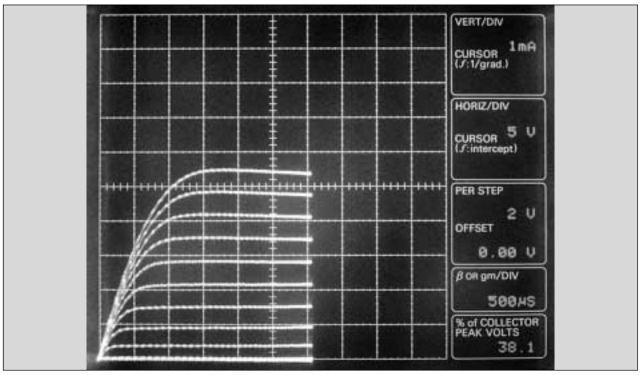


Fig.4 I_d-V_d characteristics of the 30V class p-channel MOSFET

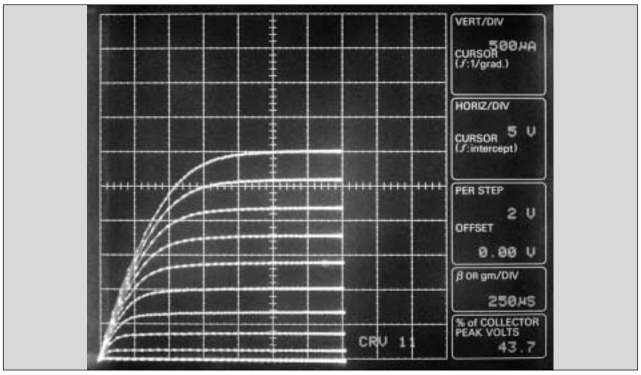


Fig.5 I_d-V_d characteristics of the 60V class n-channel MOSFET

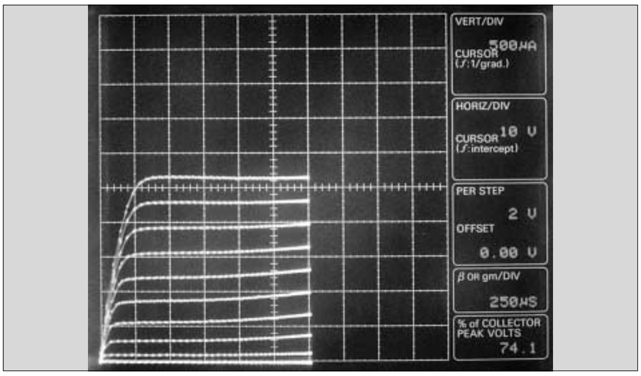


Fig.6 I_d-V_d characteristics of the 60V class p-channel MOSFET

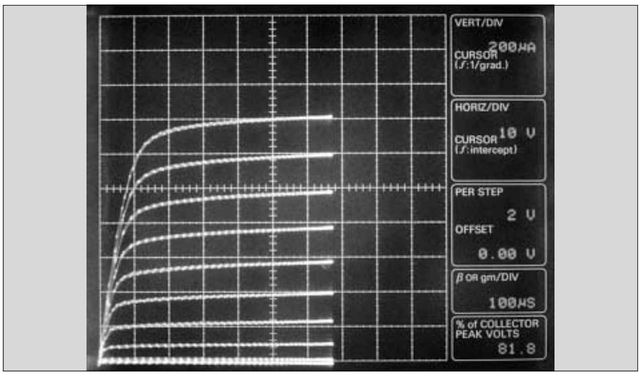


Fig.7 I_d-V_d characteristics of the 120V class n-channel MOSFET

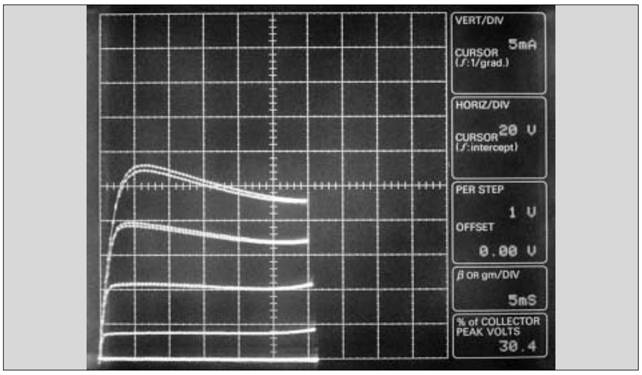


Fig.8 I_d-V_d characteristics of the 120V class p-channel MOSFET

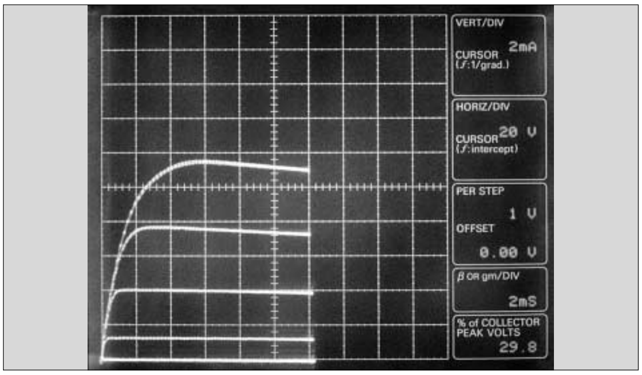
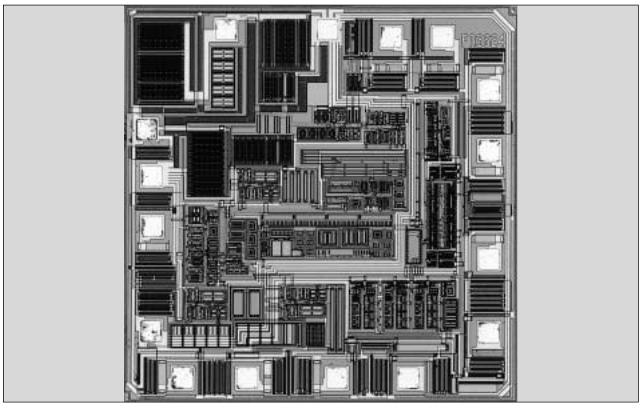


Fig.9 An IC chip fabricated by the 30V class CMOS process



5. Conclusion

This paper introduced the process flows and devices that enable the mounting bipolar device, logic device, and high voltage CMOS devices up to 120V on one chip. All devices are based on the 1μm rule CMOS.

In the future, we will develop micronized process using high voltage device technology and contribute to social requirements by supplying such devices as systematization, small size and lower power consumption.

On-A-Chip Integrated Pressure Sensors for Diesel Engines

Tadayoshi Murakami

1. Introduction

For the production of normal trucks in Japan, the number of gasoline engine cars is decreasing and the number of diesel cars is increasing (Table 1). Even in the extended market for the recent year's RV (recreational vehicle) and MPV (multipurpose vehicle), the ratio of diesel engines in passenger cars is also increasing.

Use of a direct injection system reduces the fuel cost for the gasoline engine. This system is also becoming mainstream in diesel engines. The main characteristics of diesel are a higher heat efficiency and expensive fuel. The cost of fuel is so high that it reduces CO_2 generation and prevents global warming.

Because the exhaust gas of the diesel engine is inferior to the gasoline one, improvements to the catalytic system and combustion using the electronic fuel injection system have been made. Thus, due to a more ideal burning of the gas, generations of not only NO_x but also particulate matter should be sharply reduced.

In the case of diesel engine control, reductions in fuel cost and exhaust gas are achieved by optimum controls that include volume of fuel injection and starting time of fuel injection. Although both fuel cost and engine ability have improved, exhaust gas increases in cases of imperfect engine control. In order to optimize both fuel cost and engine ability, microcomputers have been used to control injection time and the fine mixing ratio of air to fuel.

For that reason, information from various sensors are very important in detecting all signals that indicate engine condition.

The engine has been optimally controlled by the ECU (electronic control unit — the electronic circuit unit for engine control) through these signals.

For optimum control of the fuel injection system, inhalant air volume must be precisely measured and the output pressure signal of the intake manifold transferred to the ECU. Fine volume control of the inhalant air is determined by the pressure and rpm signals in the engine by the ECU.

Fuji Electric has mass-produced the semiconductor pressure sensors used in the measurement of inhalant air pressure of the fuel injection system for the gasoline engine. This paper will present a summary of the semiconductor pressure sensor for the diesel engine.

Table 1 Truck production

(Unit: cars)

Type / Year	Normal trucks		Small size trucks	
	Gasoline engine	Diesel engine	Gasoline engine	Diesel engine
1992	509,694	546,478	410,058	745,268
1993	410,934	510,531	326,475	628,892
1994	431,153	538,307	298,457	606,275
1995	232,514	573,206	304,495	604,825
1996	213,774	568,556	329,500	564,855

2. Features of the Pressure Sensor

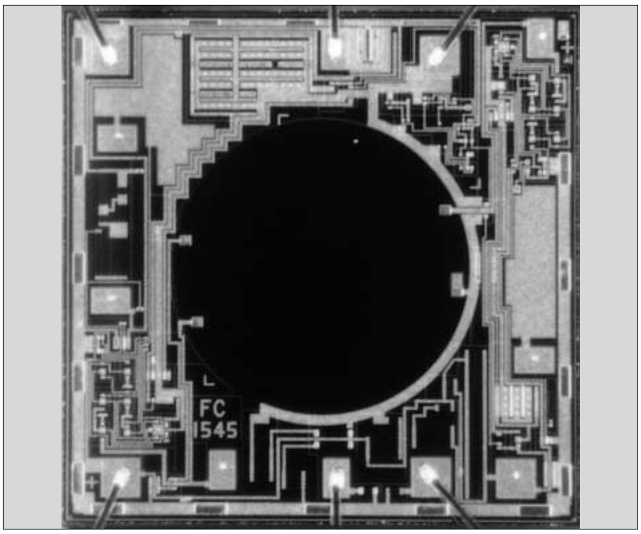
2.1 On-a-chip (single chip) integrated circuit

The pressure sensor manufactured using monolithic integrated circuit technology. The sensing resistor, amplifier and temperature compensatory circuit are all mounted on a single chip only a few mm square. A diaphragm is produced in a thickness of a few tens μm using etching technology of the micromachine. Mechanical displacement (strain) of the diaphragm under different pressures is transferred into an electric signal by a wheastone bridge made from piezoresistance. Although the signal strength is in the few tens of millivolts and there is a strong dependence due to the amplification circuit and the temperature compensatory circuit, we are able to maintain a linear relationship between the output voltage and the mechanical strain, allowing for facilitated control of the circuit. Fuji Electric has mass produced the pressure sensor of the single chip integrated sensor for the automobile's electronic fuel injection unit (Fig. 1). As the single chip integrated circuit sensor is manufactured with a bipolar integrated circuit process and diaphragm etching technology, high mass production, reliability and cost performance are all possible. The sensor can cover a wide pressure range through the thickness of the diaphragm, which can be changed by altering the etching time.

2.2 Function trimming

The chip has 6 thin film resistors for function trimming. The resistors are finely corrected by laser on a chip trimming equipment for amplitude of output voltage, offset trimming and temperature characteristics (offset and sensitivity) generated at the sensing region. Offset trimming and the offset temperature characteristic trimming can be trimmed from both positive and negative. The sensor can be used quickly as a fine pressure sensor by merely connecting it to a power supply.

Fig.1 Surface photograph of on-a-chip integrated pressure sensor



2.3 Package

A small can package is standard for a gasoline engine and has shown satisfactory results and high reliability.

The outer resin case structure which is included in the package can be custom mounted on various forms and adapted to extreme environments such as an engine room.

3. Specification of Characteristics

Table 2 shows the typical characteristics of the pressure sensors for the diesel engine. EPX083, EPX084, EPX068 and EPX059 have been developed for the small car's diesel engine, large car's diesel engine, passenger car, and truck, respectively. The outer resin case package is mounted directly to the engine room.

After connection to a printed circuit board and assembled by the user, the can package is mounted to the engine room.

3.1 Pressure range

As the maximum pressure values are in the range of 250kPa to 400kPa, two diaphragm thicknesses are prepared for up to 300kPa and up to 400kPa sensitivity.

The final sensitivities occur after the thin film resistors on the chip are trimmed by the laser.

3.2 Temperature range

As the can packaged sensor is suitable for use in severe, high temperature environments such as an engine room, it has proven itself on the mass produced gasoline engine without reliability problems between

Table 2 Characteristics of the pressure sensor for the diesel engine

Item \ Type		EPX083	EPX084	EPX068	EPX059
Pressure range (kPa)		20 to 250	50 to 300	20 to 250	50 to 400
Maximum over pressure (kPa)		500	500	500	600
Output voltage range (V)		0.40 to 4.65	0.78 to 4.75	0.5 to 4.5	0.5 to 4.5
Storage temperature (°C)		– 40 to +130	– 40 to +130	– 40 to +125	– 40 to +140
Temperature range (°C)		– 40 to +125	– 40 to +125	– 40 to +125	– 40 to +120
Errors	Pressure (kPa)	±1.48%FS : 50 to 220 ±1.83%FS : 20, 250	±1.89%FS : 70 to 270 ±2.39%FS : 50, 300	±0.87%FS : 100 to 200 ±1.74%FS : 20, 250	±1.00%FS : 70 to 360 ±1.80%FS : 50, 400
	Temperature (°C)	Multiplier 1.00 : 10 to 85 Multiplier 2.00 : – 30/125 Multiplier 3.00 : – 40	Multiplier 1.00 : 20 to 110 Multiplier 1.60 : 125 Multiplier 3.00 : – 40	Multiplier 1.00 : 10 to 85 Multiplier 2.00 : – 40/125	Multiplier 1.00 : 20 to 110 Multiplier 1.60 : 120 Multiplier 3.00 : – 40
Supply voltage range (V)		4.5 to 5.5		4.75 to 5.25	4.5 to 5.5
Supply current (mA max)		10			
Sink currant (mA min)		1			
Source current (mA min)		0.1			
Output impedance (Ω max)		10			
Response time (ms max)		5			
Package		Fig. 2		—	Fig. 3

Fig.2 Outside and cross section of the can package

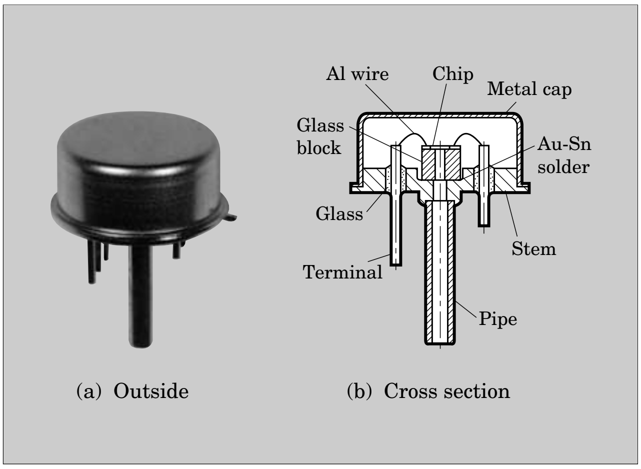
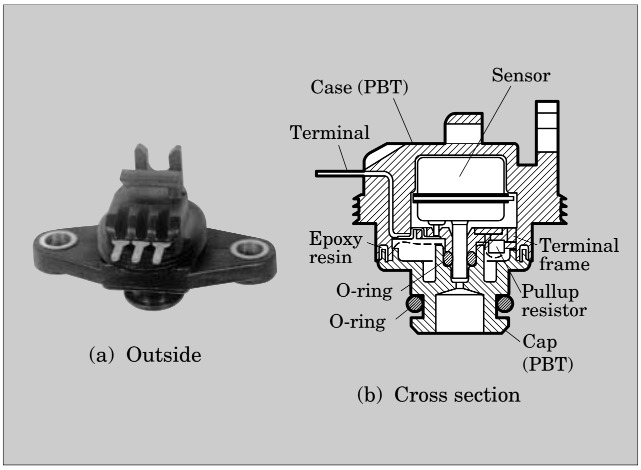


Fig.3 External view and cross section of outer case (EPX059)



the temperature range of − 40°C to +125°C.

3.3 Error

There are various specifications for pressure error. The requirement of high precision has grown strict for the progressive fuel injection control system due to global and environmental demands for a greater reduction in fuel cost and exhaust gas. The pressure error of the outer resin case package is highly precise, to within ±1% FS (full scale). As the sensor has integrated all of the functions on one chip, uniformity of characteristics and higher specification by using the high precision function trimming for the requirement have been accomplished.

3.4 Package

Figure 2 shows the can package sensor. It has had good results when mounted on a gasoline engine and is suitable for use in severe environments. The sensor chip is anodically bonded on a glass block in order to ease the thermal stress of the outer environment. It is then fixed to a Fe-Ni alloy stem with a high melting solder. The sensor has excellent anti-corrosive properties due to the use of Au-Sn high melting solder. The chip is vacuum sealed with a metal cap and is tested by the absolute pressure specification. The outer dimension of the can package is $\phi 15.2 \times 19.6$ (mm).

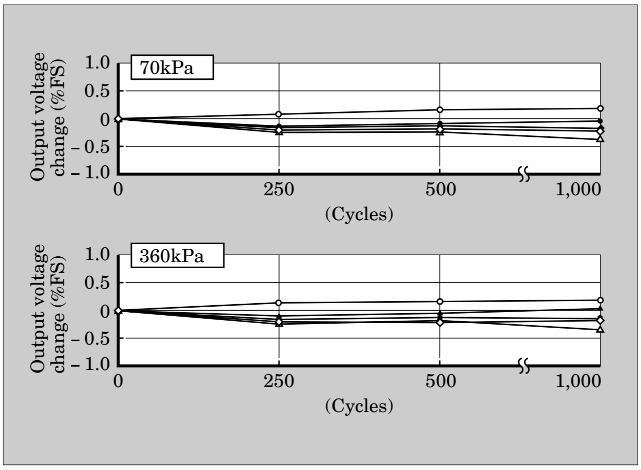
Figure 3 shows the outer case mounted in the engine room. In order to withstand the vibration specific to the diesel engine, the structure is welded through the terminal frame between the edges of the can package and case. The reliability of the welded type is higher than the bonded on the printed circuit board.

Using a low melting solder with the low temperature cycle characteristc of low thermal fatigue, bonding of the pullup resistor for diagnosis is reliable.

3.5 Diagnosis

The check and judging function of the ECU micro

Fig.4 Output voltage change in the thermal shock test of EPX059 (temperature : − 50 to +150°C)



computer determines correct operation of the sensor actuator and wire harness for the engine control system.

Specification of the same functions are also demanded by the pressure sensor. Outer case types such as EPX059 and EPX068 include the required diagnostic functions.

The required specification is that the ECU determines an abnormal state if output voltage is over the standard when the ground (GND) line is in open mode (including the wire harness).

The ECU can also determine an abnormal state such as over the standard output voltage of open or short conditions in the voltage source and output line.

One reason for the necessity of diagnosis is legal limitation. In the state of California in the USA, diagnosis of equipment relating to exhaust gas is carried out to reduce air pollution.

The effects of exhaust gas can be ideally reduced by complete fuel combustion in all driving situations of the car.

But as the required air volume for combustion is calculated by related output voltage of the pressure sensor, the gas is affected by the output of optimum control when an abnormal output voltage is generated.

3.6 Reliability

Results of the reliability test were excellent, and one example of the thermal shock test is shown in Fig. 4. The welded parts and soldered parts of the resistor in the case were all superior and no disconnection was found.

4. Conclusion

Due to the addition of the diesel engine car to the gasoline engine car, the pressure range of the sensor has increased. Increased functions for uses are now possible and further growth is expected. In the future, we will expand uses for the car's fuel tank pressure sensor and oil pressure sensor as well as for fuel injection.

IC Quality Assurance

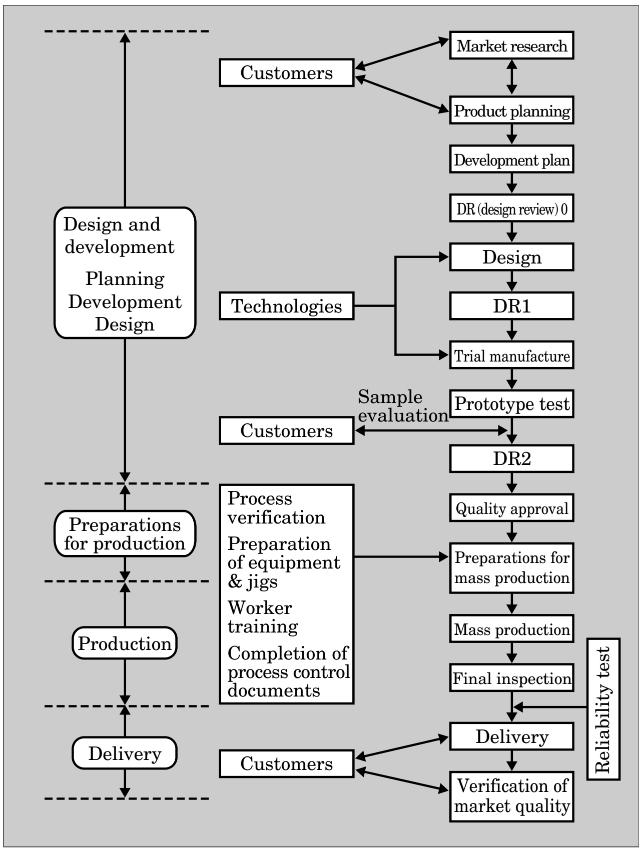
Kozo Kataoka

1. Introduction

The information and communication functions of recent electronics products have become complicated and advanced, and requirements for IC quality and reliability have become stricter. The development and mass production of new products requires establishing new technologies and materials within a short time, resulting in a harsh environment for products.

To meet this situation, Fuji Electric is aggressively pursuing analysis and research. This paper introduces a partial failure analysis of the quality assurance activities described in Chapter 2.

Fig.1 IC quality assurance system



2. Fuji Electric's Quality Assurance Activities

The Matsumoto factory of Fuji Electric received ISO9001 certification in February 1994 and has striv-

Table 1 Modes and causes of IC failures (for CMOSICs)

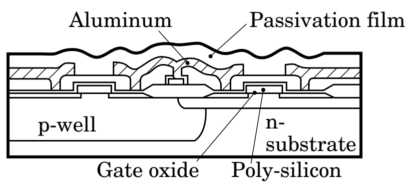
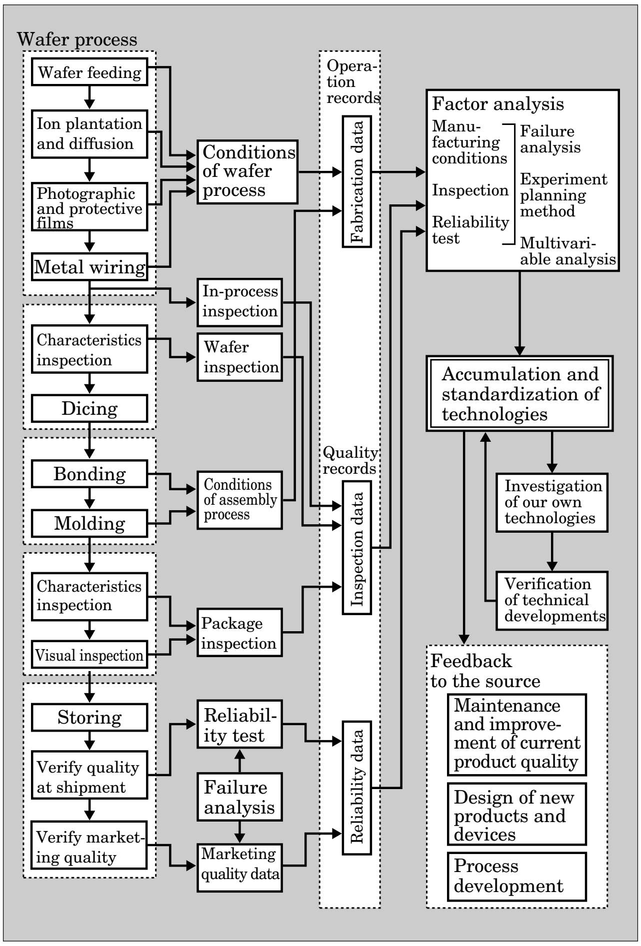
Defective element	Failure mode	Failure cause
Mold	Short Leak Deterioration Open	Moisture, ion impurities, excessive stress
Bonding (die, wire)	Short Leak Open	Migration, Au-Al alloy, mechanical stress
Passivation (surface protection film)	Leak Open	Pinhole, crack, scratch, contamination
Metallization	Short Leak Increase in resistance Malfunction	Scratch, step break, ill pattern, insufficient contact pressure, non-ohmic contact, electromigration, corrosion, thermal break (electrostatic discharge, surge)
Passivation (middle insulation)	Leak Short V_{th}-shift	Pinhole, contamination, electrostatic discharge, surge
Poly-silicon	Leak Short Malfunction	Shape, ill pattern
Gate oxide	Leak Short V_{th}-shift Deterioration	Pinhole, irregular thickness, contamination, electrostatic discharge, surge, hot electron injection
Silicon substrate	Leak Short	Crystal defect, diffusion fault, impurities, micro-crack
IC section		

Fig.2 IC quality information



en to define and improve quality assurance systems. System based quality assurance activities, ranging from development to preparations for production, production, and delivery are described for each stage. The IC quality assurance system is shown in Fig. 1.

(1) Design and development

To achieve the quality and reliability goals of product plans based on market trend and user requirement data, quality requirements and quality information are accurately assessed and analyzed. This information is effectively utilized at every step of the design and development.

(2) Preparation for production

So that the quality goals of the development stage can be realized in the production stage, the process design is thoroughly examined, and the “initial quality” of the first completed products is checked. The relevant supply companies are provided with guidance for quality inspections, so that they can perform the same level of quality assurance as Fuji Electric based on the process design.

(3) Production

Reducing defects through process control (maintenance) and improving defect-free ratios through the continuous analysis of in-process defects (measures for improvement) ensures quality in the production stage. The measuring accuracy of testers and measuring instruments is verified and managed so as not to send a defect to the next process.

(4) Delivery

The assessment of product quality and reliability

Fig.3 Flow chart of IC failure analysis

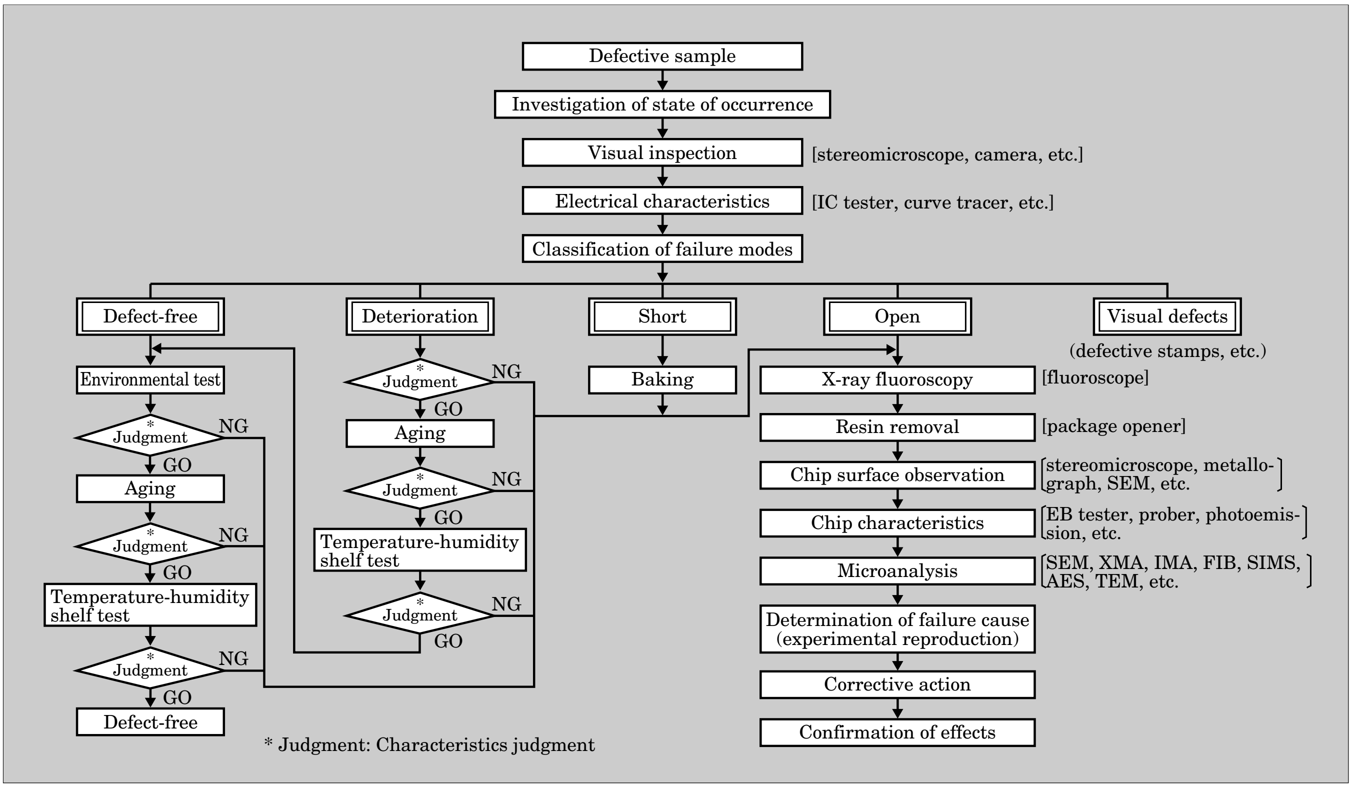


Fig.4 Example analysis with an EB tester

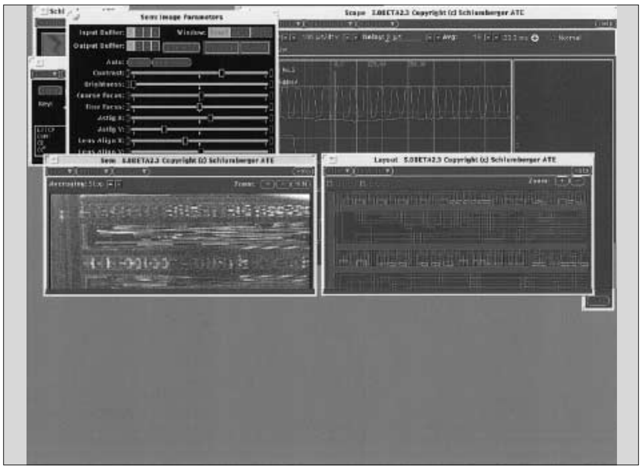
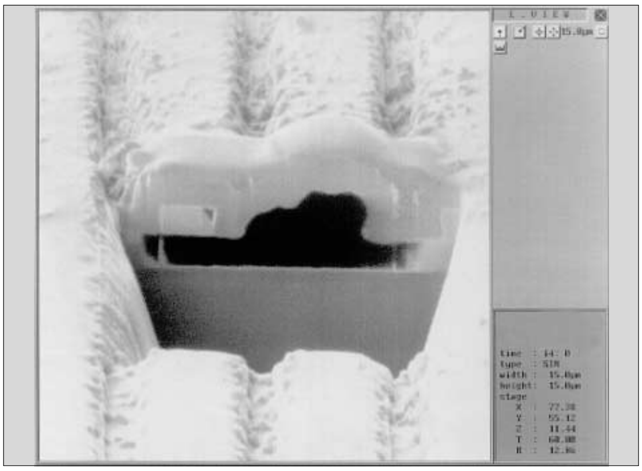


Fig.5 Example analysis with an FIB



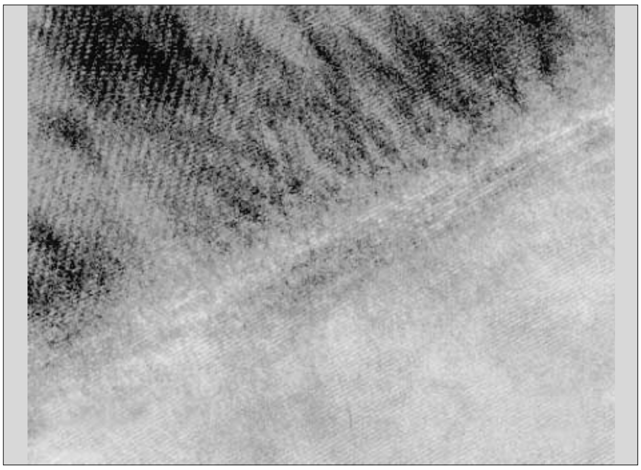
and the failure analysis of defects that occur in the marketplace are important management items.

The four stages from design and development to delivery have been outlined above. A clear understanding of failure mechanisms is essential for reliable IC design. It is necessary to precisely analyze the failures of defects in the marketplace, to collect various data of in-process quality by model types, reliability tests, and marketing quality, and to quickly supply this information in an easy-to-use format. These results are fed back to the sources. This information is utilized for daily quality maintenance and fundamental improvement. We are also making efforts to link this information to new product design and process development.

3. IC Failure Analysis

Table 1 shows typical examples of failure modes and failure causes collected by Fuji Electric. Failure

Fig.6 Example analysis with a TEM



analysis describes the failure mechanisms. Fed back to the source, that information plays an important role in maintaining and improving quality and reliability. Figure 2 shows an example of quality information. Based on the results of failure analysis, manufacturing and inspection data are analyzed, and quality information is fed back to the source. Figure 3 shows a flow chart of IC failure analysis. Typical example analyses are shown in Figs. 4 through 6.

Figure 4 shows an example of analysis with an EB (electron beam) tester. This is a method of analyzing the IC operating state using SEM (scanning electron microscope) contrast images and waveforms. The required time to perform the analysis, and its precision, are improved by linking this with CAD (computer-aided design) data.

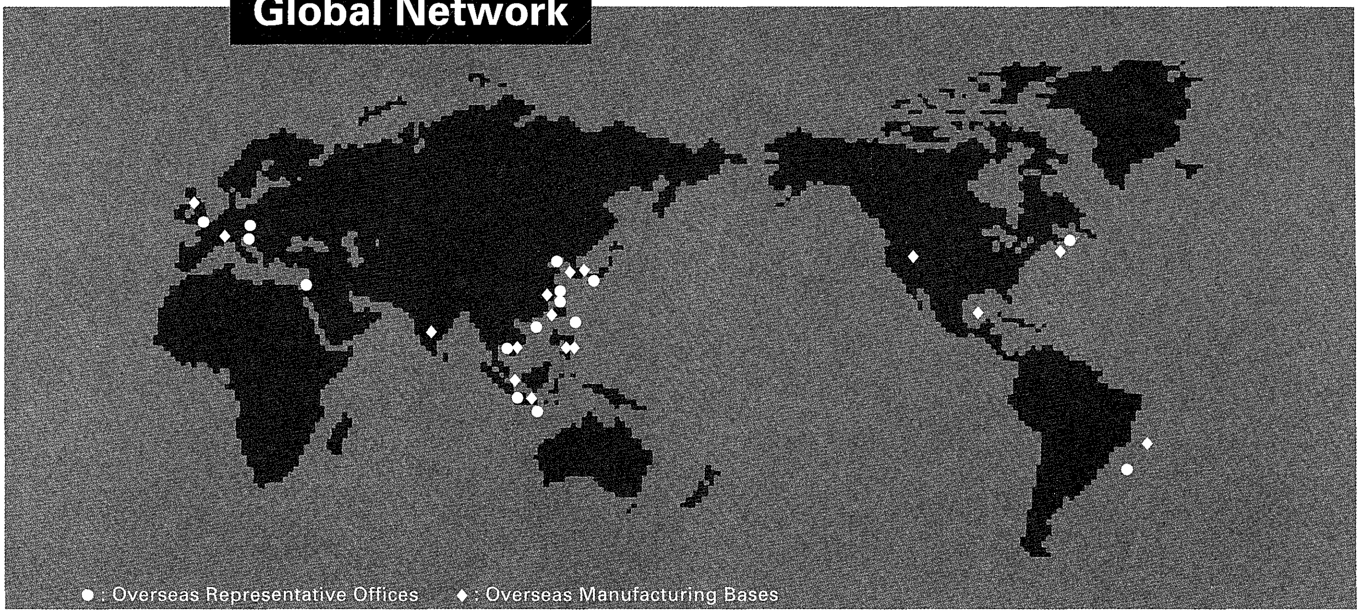
Figure 5 shows an example of analysis with an FIB (focused ion beam). This is a method of inspecting the condition of a cross-section of an IC. In this example, an abnormal form due to foreign matter buried under the metal wiring part is detected.

Figure 6 shows an example of analysis with a TEM (transmission electron microscope). This is a method of analyzing the atomic-level state of materials. In this example, the boundary condition between metals is analyzed.

4. Conclusion

Fuji Electric ICs, developed through close cooperation with the user, have gained in popularity. The trend has been toward high value added products, while the life cycle has become much shorter. Under these circumstances, with its reliable technology and management, Fuji Electric will continue to accumulate and standardize technology and supply high-quality, highly reliable ICs to customers.

Global Network



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