Present Status and Prospects of Fuji Electric's IC Products and Technologies

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1. Introduction

Fuji Electric has been expanding its line of IC (integrated circuit) products by focusing on power supply ICs and developing high-voltage CMOS IC (complementary metal oxide semiconductor IC) technology as core technology, based on the incorporation of the key concepts of added power, intelligence, and analog circuitry.

To cope with recent increased demand for environmental conservation, and energy savings in particular, Fuji Electric has developed low power consumption, high-voltage CMOS analog technology. This technology contributes to extending the available standby time in power supply ICs for cellular phones, and allows longer operation time in digital still cameras (DSCs) through meticulous power management.

In the field of high voltage technology, Fuji Electric has developed highly reliable device and process technologies, which enable the incorporation of 700 V power MOSFETs (metal oxide semiconductor field effect transistors) into ICs.

In addition, Fuji Electric's proprietary sensor integration technology is applied to AF (autofocus) ICs with built-in photodiode-based photosensors for use in cameras, and to pressure sensor ICs with built-in piezoelectric strain gauges for use in automobiles.

This paper introduces new products that utilize these technologies, with a particular emphasis on power supply ICs.

2. Present Status of Fuji Electric's ICs

2.1 IC products

2.1.1 Power supply ICs

As described above, Fuji Electric has developed IC products with emphasis on power supply ICs. The development concepts are low power consumption, high current, high accuracy, multi-functionality, and low costs. Based on these concepts, Fuji Electric has been developing easy-to-use, high value-added products based on a "Customer First" policy.

Table 1 lists Fuji Electric's CMOS products. In the field of power supply ICs, to comply with such AC-DC converter requirements as low-power standby operation, lower noise due to power factor correction, and higher efficiency, Fuji Electric has developed the FA 3641/3647, a PWM (pulse width modulation) control IC that is provided with a function to suppress switching loss by reducing switching frequencies during light loads. With regard to power factor control, Fuji Electric has newly developed the FA5501, a peak-current mode control IC, utilizing CMOS technology. This IC performs power factor correction suitable for lighting apparatus and small-sized power supplies through incorporating various protection functions in a small 8-pin package. For details, refer to the separate paper "CMOS Power Factor Control IC" in this special issue.

For application to worldwide power supplies, Fuji Electric has also developed the FA5701/5702, a single-chip power IC with a built-in 700 V high voltage MOSFET. This IC is provided in a DIP (dual in-line package)-6 package with reduced external parts and various built-in protection functions, suitable for small-sized AC adapters used for cellular phones and other electronic devices. In particular, this IC was engineered for enhanced reliability through adopting a double metal shield structure which provides the plastic mold package with the ability to withstand a more than 1,000-hour pressure cooker bias test (PCBT). For details of the 700 V single-chip power IC and related device technology, refer to the separate paper "Power Supply IC for Low Power AC Adapters" in this special issue.

In the field of DC-DC converters, Fuji Electric has developed and commercialized 1- and 2-channel general-purpose DC-DC converter ICs which utilize high voltage CMOS technology that allows direct MOSFET driving. In addition, Fuji Electric has developed highly integrated multi-channel custom ICs for use in video cameras and DSCs. Application of cell-based design technology and provision of comprehensive after-sales service enable those ICs to meet customers' requirements such as customization and short lead-time development.

Small size, light weight, thin profile, and low power consumption are increasingly required of elec-

Table 1 List of general-purpose power supply ICs
(a) AC-DC converters

Model name		D_{max} (%)	Circuit application			MOS drive	Operating mode		Protection circuit			No. of pins
			Flyback	Forward	Power factor correction		Voltage	Current	OCP	OVP	OTP	
MOS	FA13842	96	○			○		○				8 pins
	FA13844	48		○		○		○				8 pins
	FA3641/3647	70	○			○	○		○	○		8 pins
	FA5510/5511 FA5514/5515	46/70	○	○		○	○		○	○		8 pins
	FA5501				○	○			○	○		8 pins
	FA5502				○	○			○	○		16 pins
	FA5701	70	○			Built-in 700 V MOS		○	○	○	○	6 pins
	FA5702	50	○			Built-in 700 V MOS		○	○		○	6 pins

(b) DC-DC converters

Model name		No. of channels	D_{max} (%)	Voltage range			Circuit application				MOS drive	No. of pins
				2.5 to 18 V	2.5 to 5.5 V	10 to 25 V	Step down	Step up	Inverter	Flyback		
MOS	FA3675F	6	Optional setting	○			○	○	○	○	○	48 pins
	FA3676F	6	Optional setting	○			○	○	○	○	○	48 pins
	FA3698F	6	Optional setting	○			○	○	○	○	○	48 pins
	FA3630V	2	Optional setting		○		○	○	○	○	○	16 pins
	FA13843	1	96					○	○	○	○	8 pins
	FA13845	1	48			○		○	○	○	○	8 pins
	FA3686V	2	85	○		○		○	○	○	○	16 pins
	FA3687V	2	Optional setting	○			○	○	○	○	○	16 pins
	FA7700	1	90	○				○		○	○	8 pins
	FA7701	1	100	○			○				○	8 pins
	FA7703/7704	2	Optional setting	○			○	○	○	○	○	16 pins
	FA3629AV	3	Channel 1 = 87		2.5 to 5.8 V			○	○	○	Built-in n-channel MOSFET (1 channel only)	16 pins
			Channel 2 = 87					○	○	○		
			Channel 3 = 86				○		○			
	FA3635P	1	Optional setting			10 to 45 V	○		○			8 pins
	FA3685P	1	Optional setting			○	○		○			8 pins

tronic devices, particularly of power supplies for liquid crystal display panels of notebook-sized personal computers. To meet these requirements, Fuji Electric has commercialized the FA3686/3687, a high-frequency switching power supply IC (300 kHz to 1.5 MHz), which allows a reduction in size of external parts such as transformers and coils through the utilization of high-frequency PWM technology.

In addition, Fuji Electric has developed a single-chip multi-output, system power supply IC with a built-in low-power, high-PSRR (power supply ripple reduction ratio) series regulator, which performs charging control of a lithium-ion battery, and serves as a power supply for amplifiers, radio communication, and analog circuits in portable electronic equipment such as cellular phones. Fuji Electric has also developed the FA3705, a single-chip power supply IC with a built-in charge pump circuit and series regulator for applications in which voltage step-up is required. For details, refer to the separate paper "Charge Pump Booster IC" in this special issue.

As described above, Fuji Electric has been developing and commercializing a wide range of power supply ICs for AC-DC and DC-DC converters in a system power source, to meet customers' various customization requirements.

2.1.2 PDP driver ICs

In addition to power supply ICs, Fuji Electric has developed PDP (plasma display panel) driver ICs utilizing high-voltage technology. Those driver ICs include address driver ICs using 85 to 150 V C/DMOS (complementary double diffused MOS) devices, and scan driver ICs with built-in 200 V IGBT (insulated gate bipolar transistor) output stages using SOI (sili-

con on insulator) substrates.

2.1.3 AFICs

Fuji Electric has developed small-sized AF module ICs in newly designed packages, which integrate optical modules and IC packages, thereby substantially reducing costs. These AF module ICs utilize Fuji Electric's proprietary sensor application technology to meet the requirements for cameras, such as smaller size, lower power consumption, and higher power zoom.

2.1.4 Pressure sensors

In the past, Fuji Electric has developed and commercialized single-chip pressure sensors for automobiles, which integrated sensing gauges and amplifying and adjusting circuits. In 2000, Fuji Electric commercialized pressure sensors with integrated low-pass filters as an anti-EMI (electromagnetic interference) measure, to cope with the increasingly severe EMI environment of automobiles.

Fuji Electric has recently developed new-type resin-mold package pressure sensors, with built-in EPROMs (erasable programmable read only memories), which allow more accurate and stable trimming.

2.2 Technological development

2.2.1 Process device technology

A characteristic of Fuji Electric's process device technology is the addition of various analog options to high voltage CMOS technology. As listed in Table 2, p- and n-offset diffusion, n-Zener diffusion, depletion diffusion, and high-resistance, low-temperature-coefficient, polysilicon resistance formation are added to the basic 1 μm design rule CMOS processes, thereby allowing various built-in devices listed in Table 3.

Table 2 Process flow

Process flow	STD flow	Option
n-well diffusion	○	
p-well diffusion	○	
p-offset diffusion		○
n-offset diffusion		○
n-Zener diffusion		○
Field oxidation	○	
Channel diffusion	○	
Depletion diffusion		○
Gate electrode formation	○	
Source drain diffusion	○	
High-resistance, low temp. coefficient polysilicon		○
Contact formation	○	
No.1 metal formation	○	
No.2 metal formation		○
Passivation film	○	

2.2.2 Design technology

As IC design technology, Fuji Electric possesses analog-digital hybrid design technology based on PWM circuitry technology for power supply ICs. Automated design and cell-based design have been applied to analog IC design to reduce design lead times. Basic circuit blocks (13 circuits, 21 blocks) are available as CMOS analog macro-cells,, including reference voltage circuits and constant current circuits. Additional basic circuit blocks are being one by one after their performance has been verified.

The functions required for application specific power supply ICs used in portable electronic equipment and other devices are determined largely by the application. In many cases, the requirements for custom ICs are ultimately based on specifications specific to each customer. The cell-based design of custom ICs allows for short development lead-times, and an engineering sample can be completed within only three months.

Corner simulation technology, an improved circuit simulation technology, has been introduced to enhance design quality, with consideration given to all various combinations of corner models, variation in the performance of passive elements, and ambient temperatures. In addition, full-chip simulation using a behavior model has been adopted to verify the performance of the whole IC circuit and to carry out quality-oriented design.

3. Future Prospects

Fuji Electric is determined to improve its high-voltage analog CMOS IC technology and to supply highly functional power management ICs, including power supply ICs, to meet customers' needs.

Table 4 shows a technological development roadmap of power supply ICs. In the field of AC-DC converters, Fuji Electric will develop power supply IC technology that minimizes power consumption to satisfy the growing demand for lower power consumption.

In the future, power factor correction ICs will

Table 3 Device characteristics

Device / Item	CMOS		High voltage MOS (60 V)		High voltage DMOS (60 V)		High voltage DMOS (30 V)	
	NMOS	PMOS	Low V_{th} NMOS	Low V_{th} PMOS	Low on-state resistance NDMOS	Low on-state resistance PDMOS	Low on-state resistance NDMOS	Low on-state resistance PDMOS
V_{th}	0.5 V	0.5 V	0.5 V	0.5 V	1.0 V	1.0 V	1.0 V	1.0 V
BV_{dss}	11 V	11 V	90 V	75 V	87 V	75 V	43 V	47 V
$R_{on} \times A$	–	–	–	–	0.124 Ω · mm^2	0.315 Ω · mm^2	0.066 Ω · mm^2	0.205 Ω · mm^2

Table 4 Technology roadmap of power supply ICs

Item		2000	2001	2002	2003
Circuit design technology	AC–DC	Power factor correction control Peak current mode control / average current mode control	With standby mode Current mode / voltage mode control		
	DC–DC	Cell base for DC-DC converters 1.0/0.6 μm	Low noise switching circuit	Low-voltage start-up cell	
		Multichannel		High frequency switching system Small-sized, high-efficiency power management ICs	
	Battery management	LiB's remaining battery charge measurement accuracy: 1 % Consumption current: 125 μA		Integration of protective switches for LiB	
	Digital control power supply			Next-generation power supply control technology	
Device process technology	Low on-state resistance device	700 V high-reliability power ICs		700 V lower on-state resistance devices	
		Lateral trench power MOS (TLPM)	n-channel TLPM/30 V	p-channel TLPM	
				100 V TLPM	
		Trench MOS process / high-reliability oxide film		Lower-resistance metal electrode (power Al, Cu)	
	High-reliability analog CMOS process	1.0 μm analog CMOS / 700 V, 60 V, 30 V			
			0.6 μm analog CMOS / 30 V		

increase in importance for reducing harmonic noise and power loss. Fuji Electric has developed peak-current mode CMOS ICs, and hereafter, will develop average-current mode ICs.

In the field of DC-DC converters, Fuji Electric will expand analog cells and improve cell-based design technology to reduce design lead-time. In the future, the operating voltage of high-performance CPUs (central processing units) and ASICs (application specific ICs) is expected to decrease. To comply with this trend, Fuji Electric will develop low-noise switching power supply technology, essential for PWM switching power supplies, which efficiently produces low voltages from battery voltage. Fuji Electric is promoting the development of higher switching frequencies to reduce the size of reactors and transformers, and hence the size of power supplies. Fuji Electric has already developed 3 to 6 MHz high-frequency switching technology and will improve upon this technology for practical applications.

The development of low on-state resistance devices is essential for power IC technology. As described in the separate paper "Low On-Resistance Trench Lateral Power MOS Technology," Fuji Electric has developed low on-state resistance trench lateral power MOS devices. Fuji Electric plans to enhance the quality of these devices and commercialize them. For the core technology of high-voltage analog CMOS process technology, Fuji Electric will promote fine process, transitioning from 1 μm to 0.6 μm design rules, and will promote total cost reduction.

4. Conclusion

This paper summarized the present status and future prospects of Fuji Electric's ICs, with an emphasis on power supply ICs. In the future, Fuji Electric is determined to develop and manufacture high value-added products, utilizing low power consumption, high-accuracy CMOS technology integrated with high-voltage, high-current power IC technology and intelligent functions using sensors and digital circuits.

Reference

(1) Komori, T. Present Status and Prospects of Fuji Electric's IC technology and Products. Fuji Electric Review. vol.46, no.4, 2000, p.110-113.