High-Side Intelligent Power Switch Technology

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1. Introduction

Power devices have been used in automobile electronics for various systems such as automatic transmission, anti-skid brakes etc. Recently, these conventional power devices, power transistors and power MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor), have been replaced by so called intelligent power devices which are able to detect load and power supply status and have self-protection functions. Power devices are required to be of the MOS gate type with small power loss. Therefore, power MOSFETs will be mainly used in the output stage of intelligent power devices. Specifically, those power devices(1) should have the following features.

(1) Internal detection and protection circuits for overheat, overcurrent(2) and overvoltage
(2) Internal detection and protection circuits for short circuit and open circuit at the load side
(3) High surge resistance
(4) Low On-state resistance of the power device

In the automobile field where there is strong demand for intelligent power devices, Fuji Electric has developed intelligent power switches (IPS) which have an even higher performance/cost ratio. High-side IPS technology specially used as a high-side switch (switch installed for the load on the high-potential side) and application examples are introduced.

2. Process Technology

To achieve a high performance/cost ratio, Fuji Electric utilizes self-isolation technology in its high-side IPS. A cross section of the high-side IPS made from a self-isolated CDMOS process is shown in **Fig. 1**(3). **Figure 2** shows the processing steps. This technology was based on the power MOSFET manufacturing process with the addition of process steps for CMOS-IC formation. The CMOS logic circuit and high precision analog circuit can be integrated on the same substrate as the vertical power MOSFET of the output stage. In addition, this technology minimizes the number of process steps, and achieves high-side IPS with a high performance/cost ratio.

Fig. 1 Chip cross section

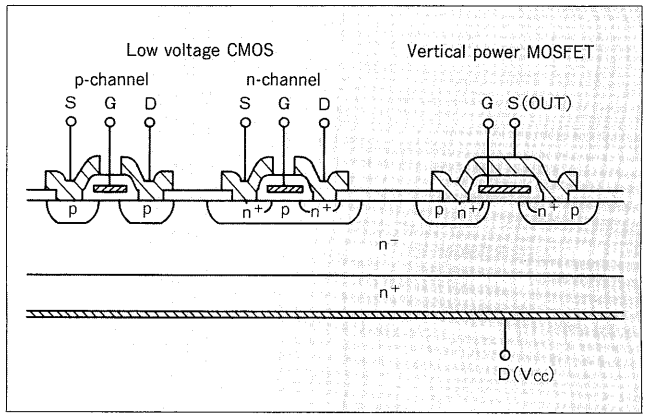
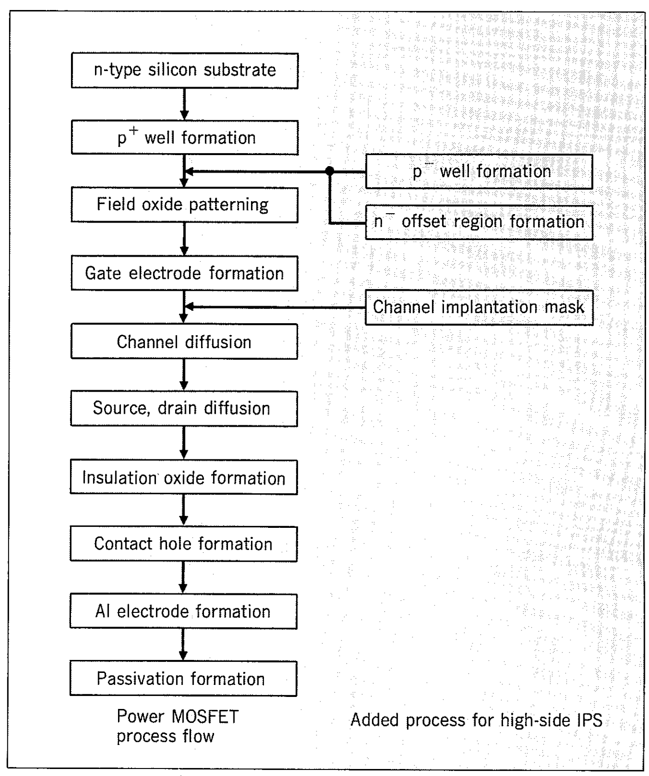


Fig. 2 Self-isolated CDMOS processing steps



3. Technology for Elementary Devices

Using a self-isolated process for high-side IPS, in order to realize various essential functions and circuits, it is necessary that high voltage lateral CMOS devices are integrated on the same substrate as the power MOSFETs for the output stage. These CMOS devices should be able to withstand voltage of the same level as the power MOSFETs.

Fuji Electric solved this problem by developing high-voltage CMOS devices with the structures[4] shown in **Figs. 3** and **4**.

The representative characteristics of lateral high voltage CMOS devices of the 60V and 120V classes are shown in **Table 1**. Output characteristics of the 60V class are shown in **Fig. 5**. Output characteristics of a power MOSFET on the same substrate are also shown in **Fig. 5(c)** for comparison. High voltage CMOS devices show better breakdown voltage characteristics than the power MOSFET, which has the same performance as an independent power MOSFET.

The high-side IPSs with a high performance/cost ratio could be realized by using these high-voltage devices.

Fig. 3 Cross section of a p-channel MOSFET structure

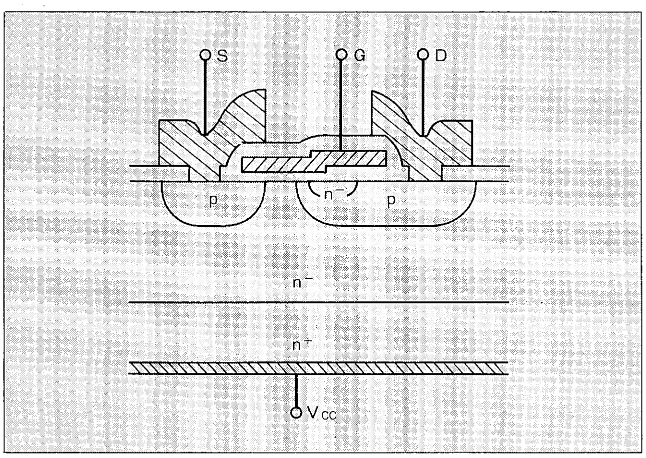


Fig. 4 Cross section of an n-channel MOSFET structure

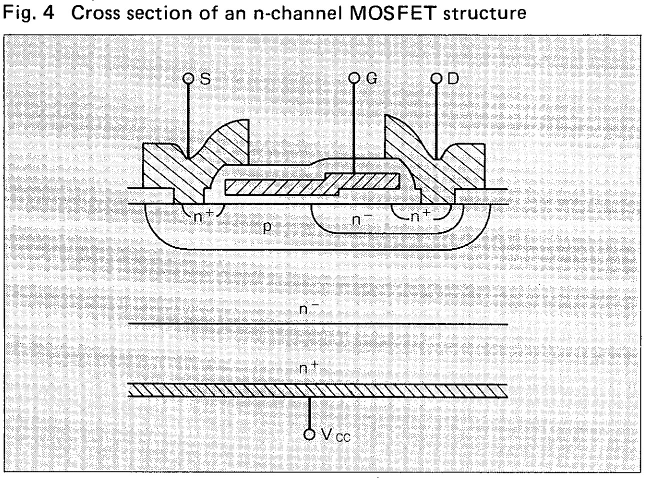
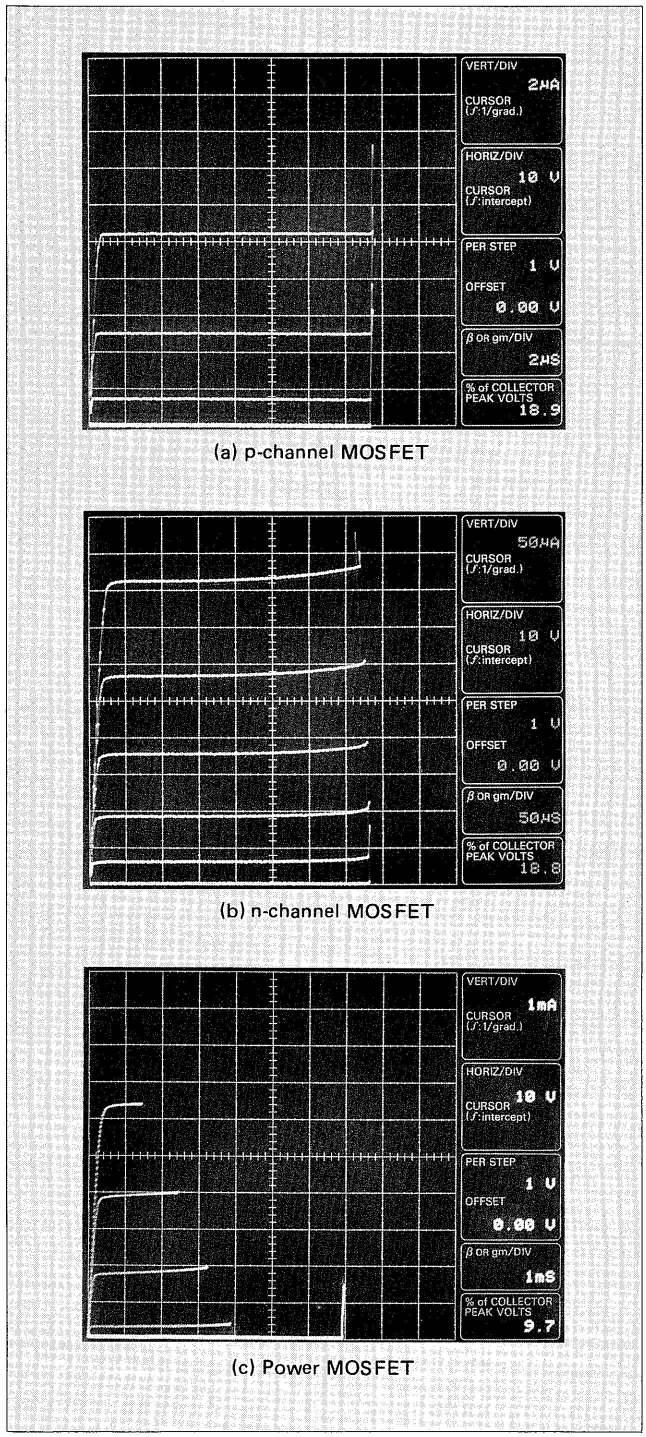


Table 1 Characteristics of high-voltage devices with self-isolation technology

Elementary device (lateral type)		Characteristic	Value (standard)	Unit
60V class	p-channel MOSFET	BV_{DSS}	70	V
		V_{TH}	1.5	V
	n-channel MOSFET	BV_{DSS}	70	V
		V_{TH}	1.0	V
120V class	p-channel MOSFET	BV_{DSS}	130	V
		V_{TH}	1.5	V
	n-channel MOSFET	BV_{DSS}	130	V
		V_{TH}	1.0	V

Fig. 5 Output characteristics of 60V class MOSFETs



4. An Application Example of Self-Isolated High-Side IPS (F5017H)

A high-side IPS "F5017H" with a 60V/6A rating was developed by using 60V class elementary devices.

The main features are as follows.

(1) With an integrated drive circuit, this IPS can be directly driven from the microcomputer.

(2) Overheat, overcurrent, and overvoltage protection functions are integrated.

(3) Functions are integrated to detect and protect against output short circuits caused by IPS output lines grounded to the body, and open loads caused by a dislodged connector.

(4) Output terminals are provided for load condition and protection status signals.

(5) Operation without cooling fins is possible due to the low ON resistance of the power MOSFET in the output stage.

(6) High surge resistance

(7) When the input terminal is disconnected, an integrated function turns off the output.

(8) A clamping circuit is integrated to control the kick-back voltage and to achieve high speed operation of a solenoid.

Figure 6 is a photograph of an IPS. Insulation at mounting is easy because of the TO-220-5 pin full molding type package. **Figure 7** shows a block diagram of the internal circuit.

The absolute maximum ratings are shown in **Table 2** and the electrical characteristics are shown in **Table 3.**

Figure 8 shows the voltage and current waveforms during switching with an inductive load of 10mH.

Fig. 6 Appearance of self-isolated IPS (F5017H)

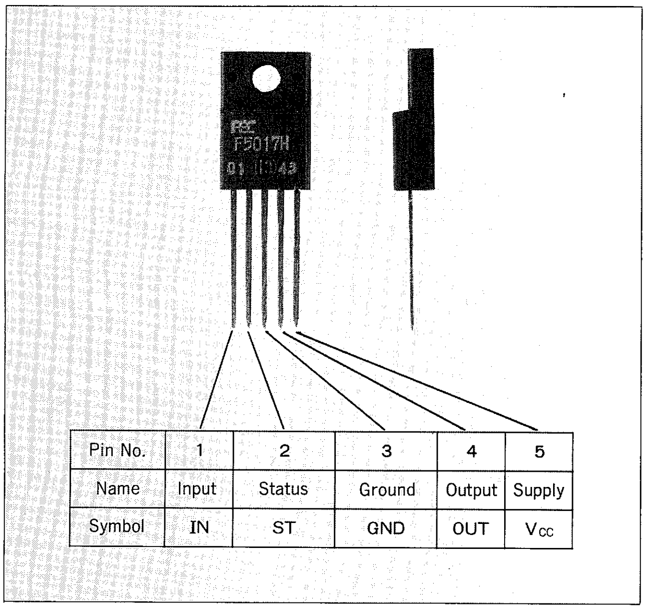


Fig. 7 Block diagram of self-isolated IPS (F5017H)

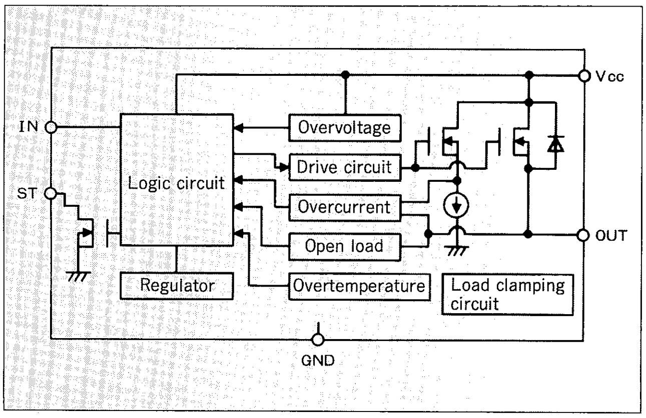


Table 2 Maximum ratings (T_c= 25°C)

Item	Symbol	Test conditions	Ratings	Units
Drain-source voltage	V_{DS}	(V_{CC} – OUT) 0.25ms	60	V
Supply voltage	V_{CC}	DC/0.25ms	33/60	V
Output current	I_D		6	A
Input voltage	V_{IN}	DC	–0.3 to 33.3	V
Max. power dissipation	P_D	T_C = 25°C T_a = 25°C	30 2	W
Max. channel temperature	T_j		150	°C
Storage temperature range	T_{st}		–55 to 150	°C
Max. status current	I_{ST}		5	mA

Table 3 Electrical characteristics and truth table

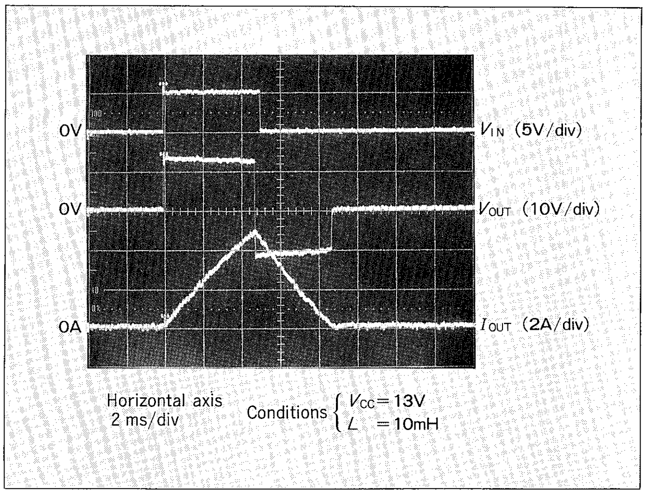
(a) Electrical characteristics (T_C = 25°C)

Item	Symbol	Test conditions	Spec. Min.	Spec. Typ.	Spec. Max.	Units
Operating voltage	V_{CC}		5	13	28	V
Stand-by current	I_{CC}	V_{IN} = 0		1	3	mA
Input voltage	V_{IN} (H)			2.6	3.5	V
Input voltage	V_{IN} (L)		1.5	2.4		V
On-state resistance	R_{DS} (on)			130	160	mΩ
Overcurrent detection	I_{OC}		6	9	12	A
Overtemperature detection	T_{trip}		150	175	200	°C
Overvoltage detection	V_{DDS}		28	30	33	V
Open load detection	R_{Lopen}		5	10	30	kΩ
Switching time	t_{on} t_{off}	R_L = 4.3Ω		40 20	80 40	μs
Output clamping voltage	V_{clamp}			11		V

(b) Truth table

Pin \ Mode	Normal operation	Over-temperature	Over-current	Over-voltage	Open load
IN	L H	L H	L H	L H	L H
ST	L H	L L	L L	L H	H H
OUT	L H	L L	L L	L L	H H

Fig. 8 Switching waveforms for inductive load of 10mH



5. Conclusion

The technology for high-side IPS elementary devices developed for the automobile and their applications have been introduced. In the automobile field, however, even higher performance and lower prices are required. We intend to meet customer needs by promptly evaluating market demands and developing processing technology with an even higher performance/cost ratio in the future.

References

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