High-Side 2-in-1 IPS “F5114H” for Automobiles

MORISAWA, Yuka* **TOBISAKA, Hiroshi*** **YASUDA, Yoshihiro***

ABSTRACT

In recent years, electronic control has been advancing in automotive electrical systems based on the keywords of safety, environment, and energy savings. In addition to these keywords, semiconductor products are also required to be compact and highly reliable. Fuji Electric has developed the high-side 2-in-1 intelligent power switch (IPS) “F5114H” for automotive applications to achieve even greater device miniaturization. Fuji Electric has equipped the SSOP-12 package, which has the same external dimensions as the SOP-8 package, with 2 chips that have the same functionality as previous products, allowing for 2 channels on the same mounting area as the previous one channel products. It also utilizes a highly reliable wire that can be used in high temperature environments. These enhancements have made it possible to greatly reduce ECU size.

1. Introduction

In recent years, electronic control has been increasingly used in automotive electrical systems based on the keywords of safety, the environment and energy saving. In addition to these keywords, semiconductor products used in these electrical systems have also been required to be compact and highly reliable.

Fuji Electric has been developing intelligent power switches (IPSs) suitable for electrical systems such as engines, transmissions and brakes. We designed these IPSs by integrating a vertical power metal-oxide-semiconductor field-effect transistor (power MOSFET) used as an output stage and a lateral MOSFET that composes a control/protection circuit on a single chip. We established a product line featuring high-side IPSs in which a semiconductor device is mounted on the power supply side and a load on the ground side, and low-side IPSs with the opposite arrangement. Using IPSs makes it possible to reduce the number of circuit components of an electronic control unit (ECU) while giving a smaller footprint, which leads to a reduction in the size of the ECU itself. In recent years, the application of the 4th-generation IPS device technologies and process technologies[(1)-(2)] has promoted further miniaturization of chips. This paper describes the high-side 2-in-1 IPS “F5114H” for automotive applications developed with the aim of achieving greater miniaturization.

2. Product Overview

The main features of the F5114H are as follows:

(a) Chips of 2 channels mounted on a small SSOP-

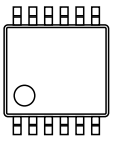
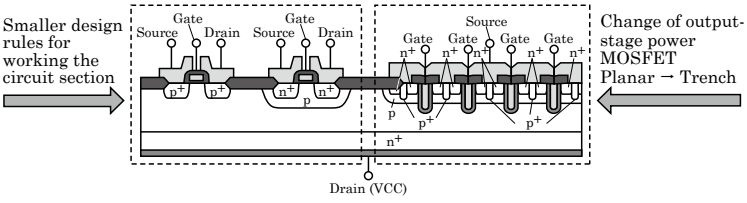
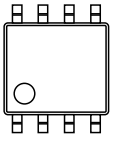
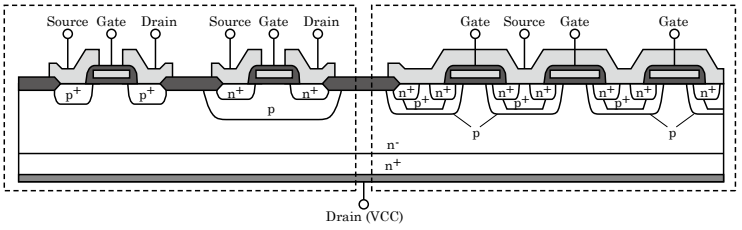
Type	Outline	Package	No. of channels	Device configuration
F5114H (Developed product)		SSOP-12	2	
F5044H (Conventional product)		SOP-8	1	

Fig.1 Outline and device configuration of “F5114H”

* Electronic Devices Business Group, Fuji Electric Co., Ltd.

12 package

(b) Use of highly reliable wire

Figure 1 shows the outline and device configuration of the F5114H. By utilizing the 4th-generation IPS device technologies and process technologies, we changed the output-stage power MOSFET from a conventional planar gate MOSFET into a trench gate MOSFET. As for the circuit section, we applied smaller design rules for the element devices themselves, reduced the wiring area connecting between element devices, and applied multi-metal-layer technology to miniaturize chips. Along with the miniaturization of chips, we mounted 2 chips that have an equivalent functionality as the conventional products on the SSOP-12 package that has the same footprint as the SOP-8 package. This contributes to further miniaturization of electrical systems as well as total cost savings as a result of the reduction in the number of components. For the bonding wire, we adopted materials that can ensure reliability against the temperature rise in the devices themselves due to ECU miniaturization as well as in the operating environment.

3. Characteristics

Figure 2 shows the circuit block diagram, Table 1

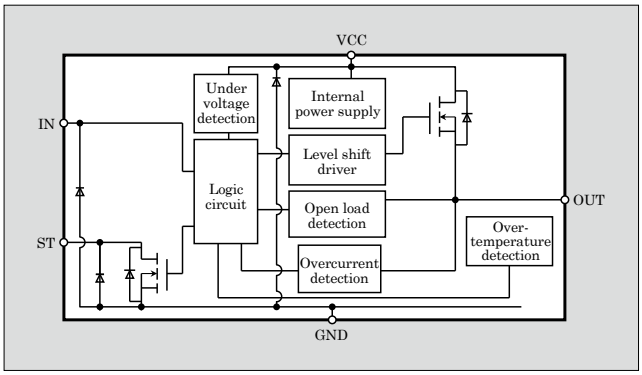


Fig.2 Circuit block diagram of “F5114H” (one channel)

Table 1 Absolute maximum ratings

Item	Symbol	Condition	Rating	
Supply voltage (V)	V_{cc1}	250 ms	—	50
	V_{cc2}	DC	−0.3	35
Output current (A)	I_D	Per channel*	—	1.65
Output voltage (V)	V_{OA}	—	Vcc-50	—
Power dissipation (W)	P_D	*	—	1.5
Input voltage (V)	V_{IN}	DC	−0.5	7
Input current (mA)	I_{IN}	DC	−10	10
Status voltage (V)	V_{ST}	DC	−0.3	7
Status current (mA)	I_{ST}	—	—	5
Junction temperature (°C)	T_j	—	−40	175
Storage temperature (°C)	T_{STG}	—	−55	175

*When mounted on a glass-epoxy 4-layer printed circuit board [10 × 5 × 1.2 (mm)], 2 channels turned on simultaneously

Table 2 Logic table

Mode	IN	ST	OUT
Normal operation	L H	L H	L H
Over-temperature detection	L H	L L	L L
Overcurrent detection	L H	L L	L L
Open load detection	L	H	H
Low-voltage detection	L H	L L	L L
IN input terminal open	L Open	L L	L L

Table 3 Electrical characteristics

Item		Symbol	Condition	Standard value Min.	Max.
Operating voltage (V)		V_{cc}	T_j = −40 to 175 °C	4.5	16
Low-voltage detection (V)		UV_1	V_{IN} = 5 V	2	4.3
Low-voltage recovery (V)		UV_2	V_{IN} = 5 V	2.2	4.5
Standby current (mA)		$I_{cc\,(L)\,1}$	R_L = 10 Ω V_{IN} = 0 V	—	0.6
		$I_{cc\,(L)\,2}$	OUT open V_{IN} = 0 V	—	0.6
Operating current (mA)		$I_{cc\,(H)}$	V_{IN} = 5 V R_L = 1 kΩ	—	5
Input threshold voltage (V)		$V_{IN\,(H)}$	V_{cc} = 4.5 to 16 V R_L = 10 Ω	2.8	—
		$V_{IN\,(L)}$		—	1.5
Input current (μA)		$I_{IN\,(H)}$	V_{IN} = 5 V	5	70
		$I_{IN\,(L)}$	V_{IN} = 0 V	−10	10
On-state resistance (Ω)		$R_{DS\,(on)}$	I_L = 1.5 A T_j = 25 °C	—	0.12
			I_L = 1.5 A T_j = 175 °C	—	0.27
Output leakage current (mA)		I_{OH}	V_{OUT} = Vcc V_{IN} = 0 V	—	2
		I_{OL}	V_{OUT} = 0 V V_{IN} = 0 V	−0.24	—
Overcurrent detection (A)		I_{OC}	V_{cc} = 13 V V_{IN} = 5 V	2	7
Peak current in overcurrent mode (A)		*PeakI*	V_{cc} = 13 V V_{IN} = 5 V	—	16
Periodic cycle in overcurrent mode (ms)		*Per*		—	3
Duty cycle in overcurrent mode (%)		*Duty*		—	40
Over-temperature detection	Detection (°C)	T_{trip1}	V_{IN} = 5 V	—	207
	Recovery (°C)	T_{trip2}		175	—
Turn ON delay time (μs)		t_{ACCON}	V_{cc} = 13 V R_L = 10 Ω V_{IN} = 5 V − 0 V	—	140
Turn OFF delay time (μs)		t_{ACCOFF}		—	140
Turn-on time (μs)		t_{on}		—	120
Turn-off time (μs)		t_{off}		—	70
Status voltage L level (V)		$V_{ST\,(L)}$	V_{IN} = 0 V R_L = 10 Ω I_{st} = 0.6 mA	—	0.5
Status leak current (μA)		I_{STleak}	V_{IN} = 5 V R_L = 10 Ω V_{st} = 7 V	—	10
Status delay (μs)		$t_{ST\,(on)}$	V_{cc} = 13 V R_L = 10 Ω V_{IN} = 5 V − 0 V V_{st} = 5 V	—	200
		$t_{ST\,(off)}$		—	200
Open load detection voltage (V)		V_{OIH}	V_{IN} = 0 V V_{ST} = L -> H	4	—
Open load recovery voltage (V)		V_{OIL}	V_{IN} = 0 V V_{ST} = H -> L	—	1.6

shows the absolute maximum ratings, Table 2 shows the logic table and Table 3 shows the electrical characteristics of the F5114H. In addition to electrical characteristics equivalent to the conventional IPS "F5044H," the F5114H offers the following functions:

(a) Load short-circuit protection function
(b) Low power supply voltage detection function
(c) Current-carrying capability sufficient to support 2 channels

3.1 Load short-circuit protection function

The load short-circuit protection function protects not only the device itself but also the system and load when an overcurrent flows in the output-stage power MOSFET. This function is used to detect overcurrent and reduce the electric power during a load short-circuit, and limit the peak current to a constant level at which the output current is oscillated. This reduces the noises generated from elements even in an abnormal state. The F5114H offers improved product safety through the double-protective functions against overcurrent and over-temperature.

3.2 Low power supply voltage detection function

The product operates under the low power supply voltage conditions including any instantaneous drop in the power supply voltage such as when the engine is started. Even if the power supply voltage drops to 4.5 V, it maintains an on-state resistance almost equivalent to that of the normal voltage of 13 V. Moreover, in the range where the power supply voltage drops below 4.5 V, it is designed to turn off the output immediately when it detects the low voltage, in order to prevent unstable circuit operation. By taking these measures, we ensure an element performance equivalent to that under normal conditions even when the power supply voltage drops.

3.3 Current-carrying capability sufficient to support 2 channels

Compared with the conventional one-channel products, the 2-channel product has 2 chips on a single package. Consequently, there are worries about a decline in the allowable current and allowable watt loss. As a countermeasure, we set the guaranteed junction temperature to 175 °C to prevent the decline of the allowable current and watt loss.

Figure 3 shows the allowable current range of the F5114H. Even when the 2 channels are turned on simultaneously, which is the toughest thermal operating condition, the product ensures the current-carrying capability of I_D=1.65 A (at T_a=25 °C) per channel. It also ensures the allowable watt loss of P_D=1.5 W which is equivalent to that of the conventional products.

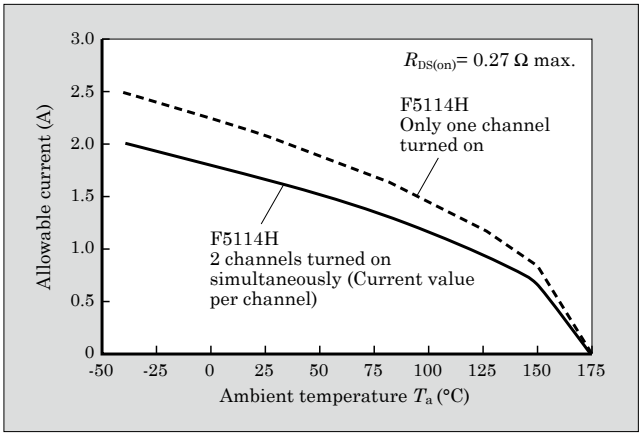


Fig.3 Allowable current range of "F5114H"

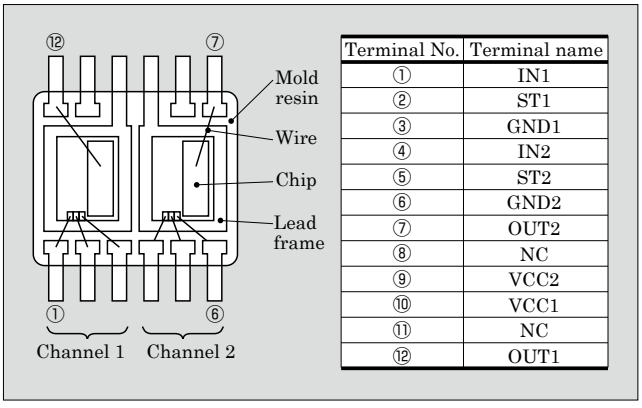
4. Package Features

4.1 Redundant package design

As shown in Fig. 4, the F5114H has a structure with separate lead frames for respective chips in order to allow the functions of each channel to work independently. Components such as the internal power supply and GND circuit are not shared but are allocated individually for the respective channels. This has achieved a redundant design to prevent the operation of one channel from being interfered with even when the other channel abnormally heats up or breaks. Moreover, from a fail-safe standpoint, we designed the terminal arrangement to provide a non connect (NC) terminal between the power supply terminal (VCC) and output terminal (OUT) to reduce the risk of breakdown due to a short-circuit between adjacent terminals. The terminal width and pitch have followed a package design conforming to JEITA EIAJ EDR-7314A*[1]. Lead-free solder (Sn-Ag) is used for the terminal plating.

4.2 Use of highly reliable wire

We have worked to address the temperature rise in the devices themselves due to ECU miniaturization as well as a temperature rise in the operating environ-



Terminal No.	Terminal name
①	IN1
②	ST1
③	GND1
④	IN2
⑤	ST2
⑥	GND2
⑦	OUT2
⑧	NC
⑨	VCC2
⑩	VCC1
⑪	NC
⑫	OUT1

Fig.4 Schematic of internal structure of "F5114H"

*1: JEITA EIAJ EDR-7314A: Integrated circuit package design guideline regarding shrink small outline packages (SSOPs) established by the Japan Electronics and Information Technology Industries Association (JEITA)

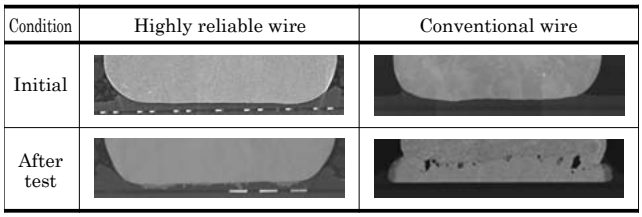


Fig.5 Observation result of cross-section of interface between wire and electrode after high-temperature shelf test

ment. Hence, the guaranteed temperature range of the F5114H is set to T_j=−40 °C to +175 °C[(1)] so that it can be used in environments at higher temperatures than before. Since the period of operation in high-temperature environments is expected to be longer in the future, we need to adopt wire materials that can offer improved reliability at high temperatures.

Figure 5 shows the conditions of the interface between the wire and aluminum electrode pad after they are left in a high-temperature environment for a long period of time. The conventional wire shows a change in the condition of the interface, whereas the highly reliable wire adopted for this product shows almost no change. Thus, we could improve the reliability for use in the higher temperature environments expected in the future.

5. Postscript

This paper described the high-side 2-in-1 IPS "F5114H" for automotive applications. It can help to reduce the footprint and total cost by mounting chips of 2 channels on a package of the same size as the conventional one-channel products with equivalent current-carrying capability ensured. In addition, we adopted highly reliable wire to ensure operation in increasingly severe high-temperature environments. Fuji Electric is committed to contributing to the miniaturization, price reduction and reliability improvement of electrical systems by expanding its IPS product line.

References

(1) Nakagawa, S. et al. One-Chip Linear Control IPS, "F5106H". FUJI ELECTRIC REVIEW. 2013, vol.59, no.4, p.251-254.
(2) Toyoda, Y. et al. "60 V-Class Power IC Technology for an Intelligent Power Switch with an Integrated Trench MOSFET". ISPSD 2013, p.147-150.

Fuji Electric

Innovating Energy Technology