Product Information

High Voltage SMA6800M Series Driver IC for Small Brushless DC Motor Applications

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Abstract

Conventional single-chip IGBT-based driver ICs for low-capacity motors have drawbacks such as large switching losses and limited allowable power dissipation. An alternative, described in this note, is the inverter power module (IPM) SMA6800M Series, which is designed for use in low-capacity motors such as air conditioner fans.

The SMA6800M Series uses power MOSFET chips to achieve low loss levels. Highly integrated multichip technology is used to combine the driving circuitry with a high voltage monolithic IC, allowing packaging in a small SIP. This package is ideally suited for equipment requiring compact size and high efficiency. Because this is a standard Sanken package, these power modules are readily available from the high-volume Sanken SMA package production line.

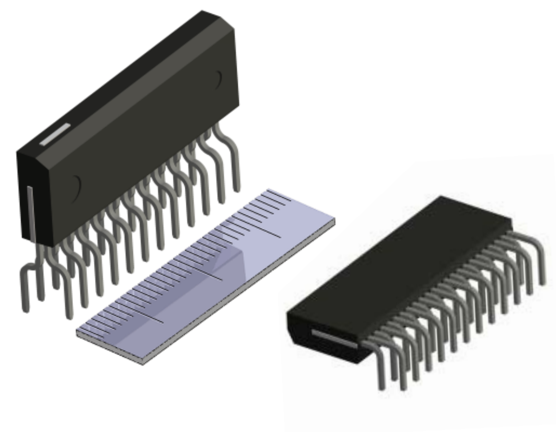

Figure 1. SMA6800M Series packages are fully molded SIPs, offering both vertical and horizontal mount options, in a compact configuration.

Introduction

Triggered by the Kyoto Protocol of 1997, optimized high-efficiency power management systems have been introduced into the Japan residential electric appliance market to help achieve greater energy savings. In accordance with the global need for energy saving, home electric appliances in Japan are now required to indicate their energy saving levels on product labeling. This movement has lead to technological changes; for example, AC motors are increasingly being replaced by higher efficiency brushless DC motors (BLDC).

In order to drive the brushless DC motors, a 3-phase full bridge inverter and driver IC are required. For low-capacity fan motors in room air conditioners, a commonly-used product has been a combination of drive IC and protection functions with the 3-phase full bridge circuit, integrated on a single chip. However, these single-chip solutions have the disadvantages of large switching losses and limited allowable power dissipation.

To overcome those disadvantages, Sanken has developed a multichip driver IC. Although the driver IC consists of six MOSFET chips, two pre-driver IC chips, and three bootstrap diode chips, a small package size is successfully achieved. This size advantage, together with its low losses, has resulted in this family of devices, the SMA6820 Series, being adopted for assembly into various air conditioners.

Product Structure

The physical configurations of the SIP options are shown in figure 1. The SIP packages for these devices have 24 pins and 1.27 mm pin pitch. The resin case is 31 mm in width, 10 mm in height, and 4 mm in thickness.

All performance characteristics given are typical values for circuit or system baseline design only and are at the nominal operating voltage and an ambient temperature of 25°C, unless otherwise stated.

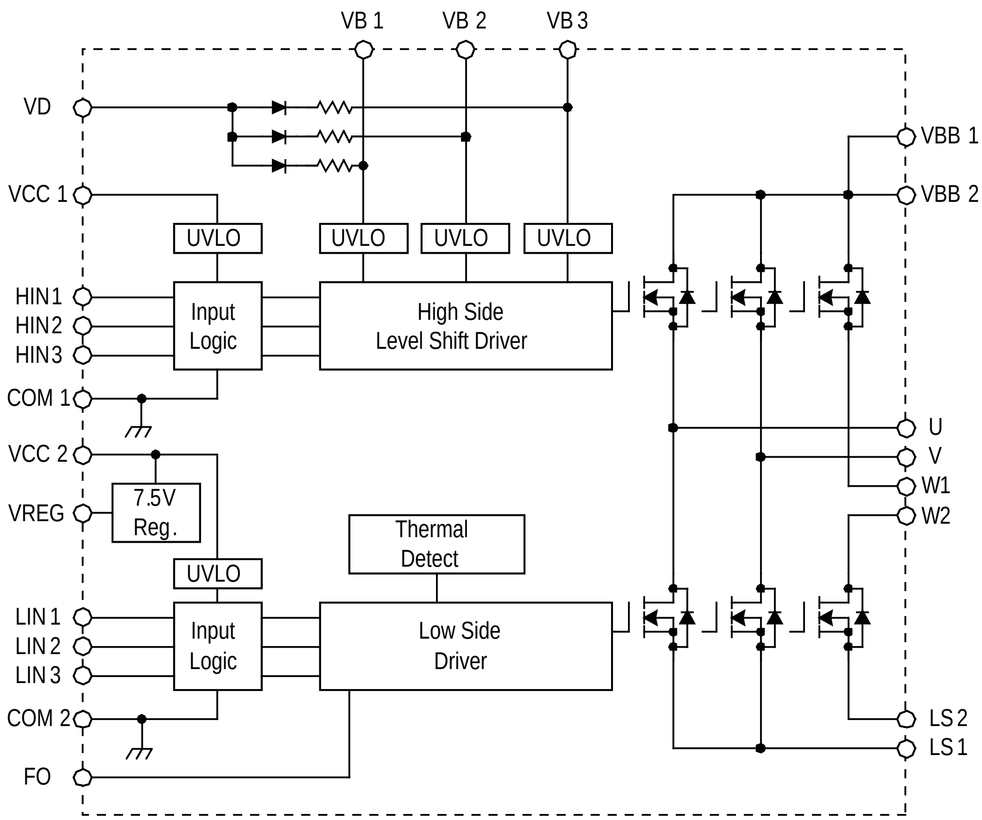

Figure 2. SMA6820M Series Phase Block Diagram. These devices support high-side and low-side three-phase MOSFET output drivers.

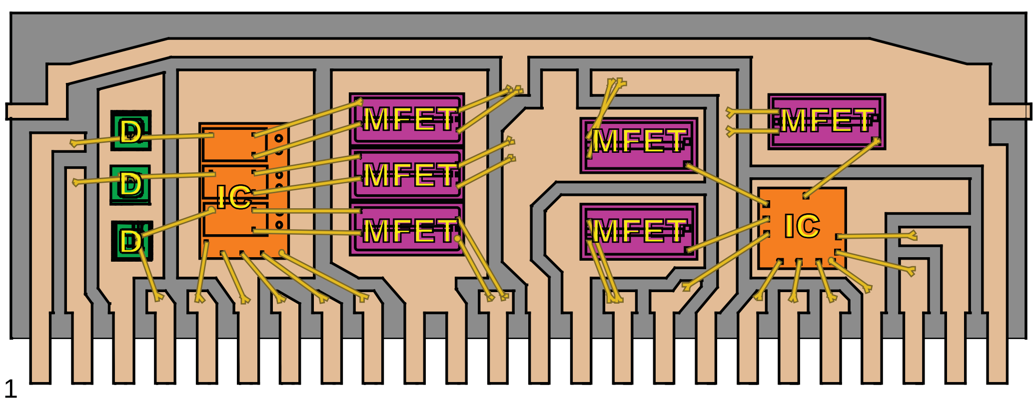

Figure 3. SMA6820M Series Internal Layout. D are the three bootstrap diodes and resistors, MFET are the six power MOSFETs in the full bridge, and IC are the two pre-driver logic integrated circuits.

The block diagram of the SMA6820 Series high voltage 3-phase motor driver is shown in figure 2. The interior layout is shown in figure 3. In the layout, you can see how the power MOSFET chips, IC pre-driver chips, and bootstrap diodes with matched limiting resistors are soldered to the die pads, and gold wires make the electrical connections between the pads and the leadframe. Additional description of this structure is found in the Mounting Technology section in this note.

The MOSFET is superior to the IGBT in terms not only of switching loss, but also surge tolerance and avalanche breakdown level, as shown in the table 1 specifications, which apply to the SMA6820MP Series. These products have a rated current of 2.5 A, MOSFET breakdown voltage of 500 V, and a MOSFET on-resistance of 2.0 Ω.

Table 1. Electrical Characteristics

Characteristic	Symbol	SMA6821MP			SMA6822MP			SMA6823MP			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Logic Supply Voltage	V_{CC}	13.5	15	16.5	13.5	15	16.5	13.5	15	16.5	V
Logic Supply Current	I_{CC}	–	4	6	–	4	6	–	4	6	mA
Undervoltage Lock Out, High Side	V_{UVHL}	9.0	10.0	11.0	9.0	10.0	11.0	9.0	10.0	11.0	V
	V_{UVHH}	9.5	10.5	11.5	9.5	10.5	11.5	9.5	10.5	11.5	V
	V_{UVHhys}	–	0.5	–	–	0.5	–	–	0.5	–	V
Undervoltage Lock Out, Low Side	V_{UVLL}	10.0	11.0	12.0	10.0	11.0	12.0	10.0	11.0	12.0	V
	V_{UVLH}	10.5	11.5	12.5	10.5	11.5	12.5	10.5	11.5	12.5	V
	V_{UVLhys}	–	0.5	–	–	0.5	–	–	0.5	–	V
Overtemperature Detection Threshold Temperature, Activation	T_{DH}	135	150	165	135	150	165	135	150	165	°C
Overtemperature Detection Threshold Temperature, Deactivation	T_{DL}	105	120	135	105	120	135	105	120	135	°C
Output Voltage for Regulator	V_{REG}	6.75	7.5	8.25	6.75	7.5	8.25	6.75	7.5	8.25	V
Bootstrap Diode Forward Voltage	V_{FBD}	–	1.1	1.3	–	1.1	1.3	–	1.1	1.3	V
Bootstrap Diode Series Resistor	R_{BD}	–	22	–	–	22	–	–	22	–	Ω
MOSFET Breakdown Voltage	V_{DSS}	250	–	–	500	–	–	500	–	–	V
MOSFET Leakage Current	I_{DSS}	–	–	100	–	–	100	–	–	100	µA
MOSFET On State Resistance	$R_{DS(on)}$	–	1.4	1.8	–	3.6	4.0	–	2.0	2.4	Ω
MOSFET Diode Forward Voltage	V_{SD}	–	1.0	1.5	–	1.0	1.5	–	1.0	1.5	V
MOSFET Diode Recovery Time	t_{rr}	–	50	–	–	75	–	–	75	–	ns
Switching Time, High Side	$t_{dH(on)}$	–	650	–	–	550	–	–	650	–	ns
	t_{rH}	–	100	–	–	100	–	–	100	–	
	$t_{dH(off)}$	–	370	–	–	420	–	–	520	–	
	t_{fH}	–	10	–	–	30	–	–	50	–	
Switching Time, Low Side	$t_{dL(on)}$	–	600	–	–	570	–	–	700	–	ns
	t_{rL}	–	100	–	–	100	–	–	100	–	
	$t_{dL(off)}$	–	300	–	–	450	–	–	580	–	
	t_{fL}	–	10	–	–	30	–	–	40	–	

Loss Characteristics

A comparison of loss characteristics was made between products of manufacturers using IGBTs and the SMA6800M Series products, which use MOSFETs. The results, shown in figure 4, demonstrate that the losses in products using MOSFETs are lower than the losses generated in products using IGBTs. These results were taken over the full range of the application output currents (0.8 A or less) for an outdoor fan motor (maximum rating 500 V).

The losses in power devices are divided into two types: normal losses and switching losses. The switching losses of MOSFETs are lower than those of IGBTs over the entire operating range, and this is the main differentiating factor between the two.

Heat Dissipation

With respect to heat dissipation, there are differences between single-chip products and multichip products. Because these types of packages do not have heatsink tabs, heat generated from the electrically active elements is mostly dissipated through the resin case and the leads.

In a single-chip product, heat is concentrated in the area of the one IC. In a multichip product, the various sources of heat can be dispersed laterally. In addition, the MOSFETs can be mounted on pads that are separated from the pads of the ICs (see figure 3), so the heat from the various elements can be conducted away along separate paths through the case and pins.

As shown in figure 5, with the single-chip product, heat is concentrated at the chip mounting location, worsening heat dissipation and resulting in an overall higher temperature rise in the product. Because heat sources are dispersed in the multichip product, the highest temperature, which occurs in the area of the triple-MOSFET chip, is only 70% of the single-chip product highest temperature. This helps to provide good overall heat dissipation characteristics.

Mounting Technology

The mounting technology that enables the multichip structure to be accommodated in a small package, while providing excellent power loss and heat dissipation characteristics, is based on several advanced technologies.

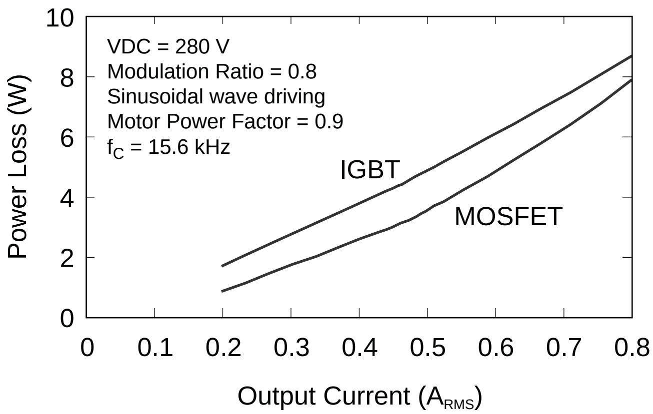

Figure 4. Comparison of MOSFET and IGBT Losses

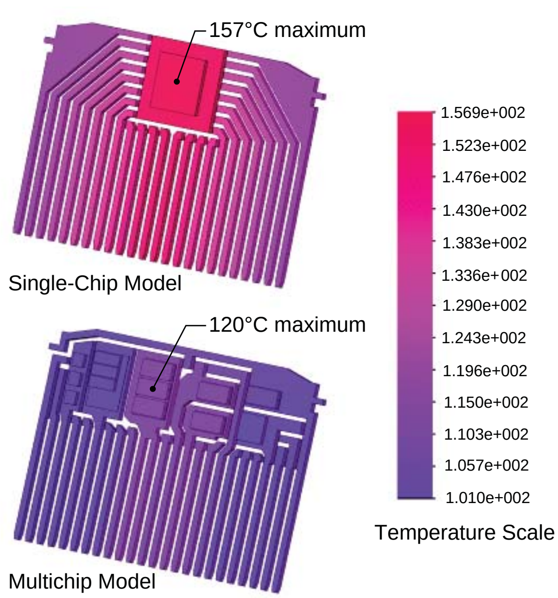

Figure 5. Thermal Analysis Simulation, Leadframe

Bond Stitch on Ball (BSOB)

BSOB bonding technology has been adopted, in preference to the more conventional wedge bonding methods, to save space and to provide a more reliable bond. The two types of bond are illustrated in figure 6.

One important consideration is that, with the wedge bonding method, measures must be taken to protect against damage in the area of the bond pad. These considerations are summarized in table 2.

In the conventional wedge bonding system, wiring is connected between the ICs and the MOSFETs through intermediate substrates. In such a design, the leadframe could not be accommodated in the SMA package due to the size of the additional lateral areas required on the leadframe. By using the BSOB system, direct wiring between the ICs and the MOSFETs can be made, eliminating the intermediate substrates. Because the space for the intermediate substrate is no longer required, the leadframe can be reduced to fit into the small SMA package. A comparison of typical layouts is shown in figure 7.

Triple-MOSFET chip

In the conventional design, if the MOSFETs are mounted as separate die, space between the die would be required for the bonding machine. The SMA6280M design provides an alternative: one chip composed of three MOSFETs is used to dispense with the dicing of the high-side MOSFET which has the same drain potential. As a result, the mounting space for these MOSFETs can be reduced by approximately 15% compared to the conventional design. The comparison is illustrated in figure 8. This composite structure also lessens the chip-mounting times.

High heat-dissipation molding resin

Because the small package has no tab for heat dissipation, it is required that high heat-dissipation molding resin be used for the case. For this purpose, the type of filler material and its volume

Table 2. Bonding Comparison

Bonding System	Countermeasures
Wedge bonding (conventional system)	Barrier layers of interface metals and other measures are required to prevent damage
BSOB	No specific measure is required for pad section to prevent damage

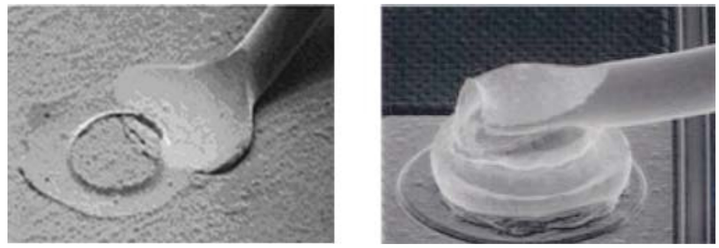

Figure 6. Illustration of bonding methods: (A) the conventional method, wedge bonding, and (B) the BSOB method used in the SMA6820M Series.

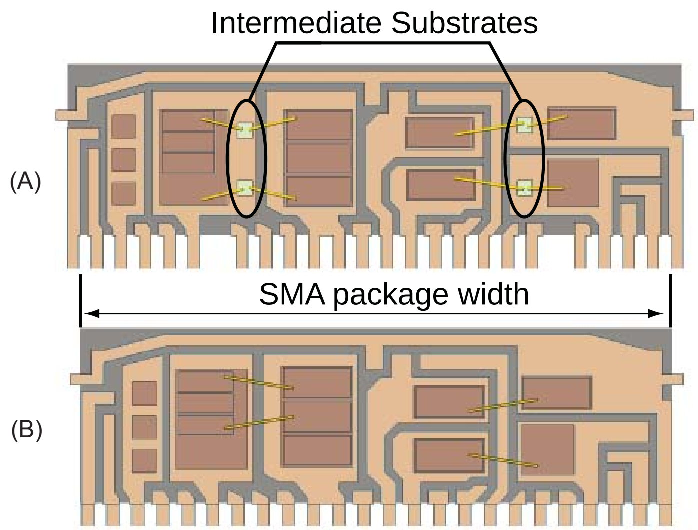

Figure 7. Size reduction from (A) the conventional method, wedge bonding, to (B) the BSOB method, allowing small SMA package use.

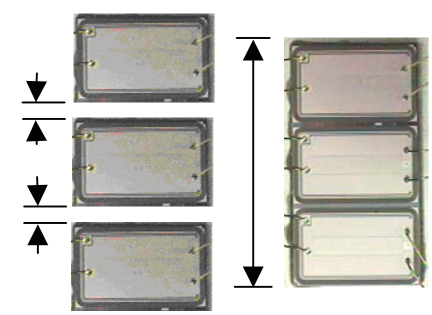

Figure 8. Spacing reduction from: (A) the conventional method, wedge bonding, in which space for mounting equipment is required between die, and (B) the triple-MOSFET chip in the SMA6820M Series.

are optimized. As a result, the thermal conductivity is improved by approximately 10% compared with conventional resins.

A comparison of the surface temperatures of the high heat-dissipation resin of the SMA6820M Series and those of the conventional resin are shown in figure 9. The high heat-dissipation resin has temperatures lower than those of the conventional resin, thus proving that it has better heat radiation rate than the conventional resin.

Development of Product Lineup

For applications requiring products having 3 A or more as a rated current, the SLA6800 Series has been added to the product lineup. It has identical package width and thickness, but also is provided with an aluminum heatsink tab. This 3 A product uses IGBTs, and has been widely adopted as a power device for such applications as refrigerators, dishwashers, and other types of appliances.

In the SLA6800 Series devices, a total 14 chips including six IGBT chips, six fast-recovery diode (FRD) chips and two logic chips are accommodated in one package. The internal layout is shown in figure 10. As far as this level of the rated current is concerned, there is no other product which is housed in a package of equivalent size. Therefore this product is in demand for those applications where down-sizing is required.

Summary

As described in this note, Sanken is now able to accommodate a composite structure of multiple MOSFETs plus multiple logic chips in one small package that has excellent loss and heat dissipation characteristics. Consequently, the developed product is widely adopted for use as the driver IC for air conditioners.

Sanken is continuing to engage in developing ICs that have multiple functions and low loss/low heat resistance to continue to meet our customers' needs.

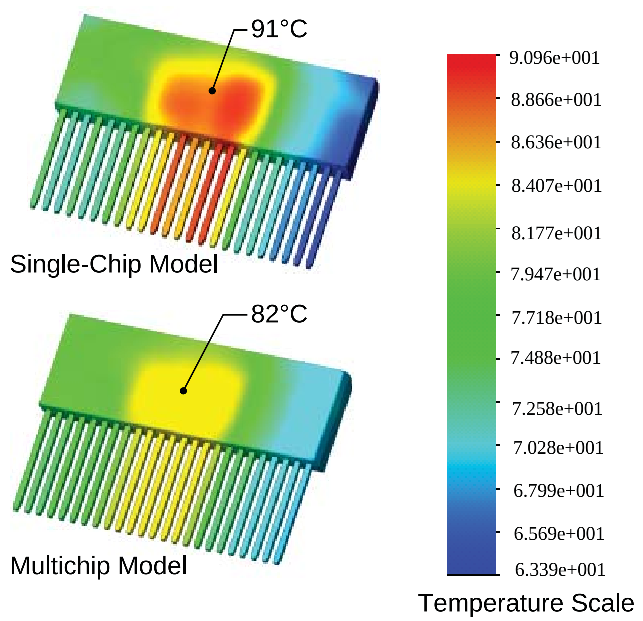

Figure 9. Thermal Analysis Simulation, Package Surface

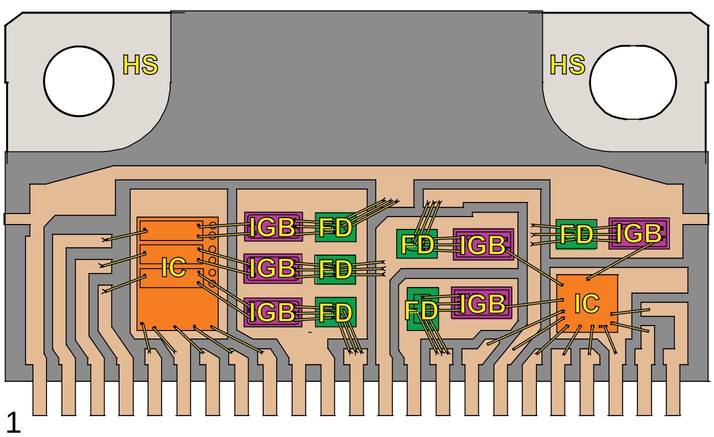

Figure 10. SMA6800 Series Internal Layout. HS are the heatsink tab, FD the six fast recovery diodes, IGB are the six power IGBTs in the full bridge, and IC are the two pre-driver logic integrated circuits.

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