

FSBM20SH60A

SPM™ (Smart Power Module)

General Description

FSBM20SH60A is an advanced smart power module (SPM) that Fairchild has newly developed and designed to provide very compact and high performance ac motor drives mainly targeting high speed low-power inverter-driven application like washing machines. It combines optimized circuit protection and drive matched to low-loss IGBTs. Highly effective short-circuit current detection/protection is realized through the use of advanced current sensing IGBT chips that allow continuous monitoring of the IGBTs current. System reliability is further enhanced by integrated under-voltage lock-out protection. The high speed built-in HVIC provides opto-coupler-less IGBT gate driving capability that further reduce the overall size of the inverter system design. In addition the incorporated HVIC facilitates the use of single-supply drive topology enabling the FSBM20SH60A to be driven by only one drive supply voltage without negative bias. Inverter current sensing application can be achieved due to the divided negative dc terminals.

Features

- UL Certified No. E209204
- 600V-20A 3-phase IGBT inverter bridge including control ICs for gate driving and protection
- Divided negative dc-link terminals for inverter current sensing applications
- Single-grounded power supply due to built-in HVIC
- Typical switching frequency of 15kHz
- Inverter power rating of 1.5kW / 100~253 Vac
- Isolation rating of 2500Vrms/min.
- Very low leakage current due to using ceramic substrate
- Adjustable current protection level by varying series resistor value with sense-IGBTs

Applications

- AC 100V ~ 253V 3-phase inverter drive for small power (1.5kW) ac motor drives
- Home appliances applications requiring high switching frequency operation like washing machines drive system
- Application ratings:
 - Power : 1.5kW / 100~253 Vac
 - Switching frequency : Typical 15kHz (PWM Control)
 - 100% load current : 8A (Irms)
 - 150% load current : 12A (Irms) for 1 minute

External View

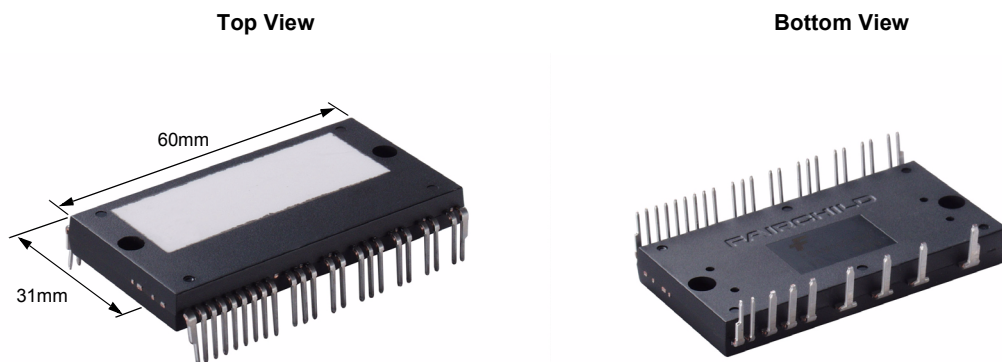


Fig. 1.

Integrated Power Functions

- 600V-20A IGBT inverter for 3-phase DC/AC power conversion (Please refer to Fig. 3)

Integrated Drive, Protection and System Control Functions

- For inverter high-side IGBTs: Gate drive circuit, High voltage isolated high-speed level shifting
Control circuit under-voltage (UV) protection
Note) Available bootstrap circuit example is given in Figs. 13 and 14.
- For inverter low-side IGBTs: Gate drive circuit, Short-Circuit (SC) protection
Control supply circuit under-voltage (UV) protection
- TFault signaling: Corresponding to a SC fault (Low-side IGBTs) or a UV fault (Low-side control supply circuit)
- Input interface: 5V CMOS/LSTTL compatible, Schmitt trigger input

Pin Configuration

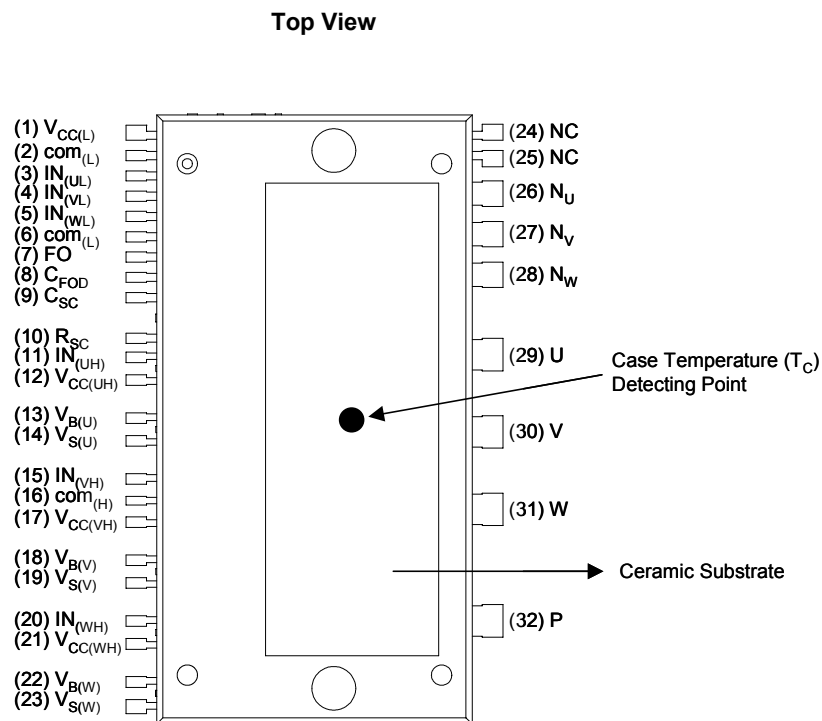


Fig. 2.

Pin Descriptions

| Pin Number | Pin Name | Pin Description |
|------------|--------------|---|
| 1 | $V_{CC(L)}$ | Low-side Common Bias Voltage for IC and IGBTs Driving |
| 2 | $COM_{(L)}$ | Low-side Common Supply Ground |
| 3 | $IN_{(UL)}$ | Signal Input for Low-side U Phase |
| 4 | $IN_{(VL)}$ | Signal Input for Low-side V Phase |
| 5 | $IN_{(WL)}$ | Signal Input for Low-side W Phase |
| 6 | $COM_{(L)}$ | Low-side Common Supply Ground |
| 7 | V_{FO} | Fault Output |
| 8 | C_{FOD} | Capacitor for Fault Output Duration Time Selection |
| 9 | C_{SC} | Capacitor (Low-pass Filter) for Short-Circuit Current Detection Input |
| 10 | R_{SC} | Resistor for Short-Circuit Current Detection |
| 11 | $IN_{(UH)}$ | Signal Input for High-side U Phase |
| 12 | $V_{CC(UH)}$ | High-side Bias Voltage for U Phase IC |
| 13 | $V_{B(U)}$ | High-side Bias Voltage for U Phase IGBT Driving |
| 14 | $V_{S(U)}$ | High-side Bias Voltage Ground for U Phase IGBT Driving |
| 15 | $IN_{(VH)}$ | Signal Input for High-side V Phase |
| 16 | $COM_{(H)}$ | High-side Common Supply Ground |
| 17 | $V_{CC(VH)}$ | High-side Bias Voltage for V Phase IC |
| 18 | $V_{B(V)}$ | High-side Bias Voltage for V Phase IGBT Driving |
| 19 | $V_{S(V)}$ | High-side Bias Voltage Ground for V Phase IGBT Driving |
| 20 | $IN_{(WH)}$ | Signal Input for High-side W Phase |
| 21 | $V_{CC(WH)}$ | High-side Bias Voltage for W Phase IC |
| 22 | $V_{B(W)}$ | High-side Bias Voltage for W Phase IGBT Driving |
| 23 | $V_{S(W)}$ | High-side Bias Voltage Ground for W Phase IGBT Driving |
| 24 | NC | No Connection |
| 25 | NC | No Connection |
| 26 | N_U | Negative DC-Link Input for U Phase |
| 27 | N_V | Negative DC-Link Input for V Phase |
| 28 | N_W | Negative DC-Link Input for W Phase |
| 29 | U | Output for U Phase |
| 30 | V | Output for V Phase |
| 31 | W | Output for W Phase |
| 32 | P | Positive DC-Link Input |

Internal Equivalent Circuit and Input/Output Pins

Bottom View



Note:

- 1) Inverter low-side is composed of three sense-IGBTs including freewheeling diodes for each IGBT and one control IC which has gate driving, current sensing and protection functions.
- 2) Inverter power side is composed of four inverter dc-link input pins and three inverter output pins.
- 3) Inverter high-side is composed of three normal-IGBTs including freewheeling diodes and three drive ICs for each IGBT.

Fig. 3.

Absolute Maximum Ratings ($T_J = 25^\circ\text{C}$, Unless Otherwise Specified)**Inverter Part**

| Item | Symbol | Condition | Rating | Unit |
|------------------------------------|------------------------|---|-----------|------------------|
| Supply Voltage | V_{PN} | Applied between P- N_U , N_V , N_W | 450 | V |
| Supply Voltage (Surge) | $V_{PN(\text{Surge})}$ | Applied between P- N_U , N_V , N_W | 500 | V |
| Collector-Emitter Voltage | V_{CES} | | 600 | V |
| Each IGBT Collector Current | $\pm I_C$ | $T_C = 25^\circ\text{C}$ | 20 | A |
| Each IGBT Collector Current | $\pm I_C$ | $T_C = 100^\circ\text{C}$ | 14 | A |
| Each IGBT Collector Current (Peak) | $\pm I_{CP}$ | $T_C = 25^\circ\text{C}$, Instantaneous Value (Pulse) | 40 | A |
| Collector Dissipation | P_C | $T_C = 25^\circ\text{C}$ per One Chip | 59 | W |
| Operating Junction Temperature | T_J | (Note 1) | -20 ~ 125 | $^\circ\text{C}$ |

Note:

1. It would be recommended that the average junction temperature should be limited to $T_J \leq 125^\circ\text{C}$ ($@T_C \leq 100^\circ\text{C}$) in order to guarantee safe operation.

Control Part

| Item | Symbol | Condition | Rating | Unit |
|--------------------------------|----------|--|---------------------|------|
| Control Supply Voltage | V_{CC} | Applied between $V_{CC(UH)}$, $V_{CC(VH)}$, $V_{CC(WH)} - \text{COM}_{(H)}$, $V_{CC(L)} - \text{COM}_{(L)}$ | 20 | V |
| High-side Control Bias Voltage | V_{BS} | Applied between $V_{B(U)} - V_{S(U)}$, $V_{B(V)} - V_{S(V)}$, $V_{B(W)} - V_{S(W)}$ | 20 | V |
| Input Signal Voltage | V_{IN} | Applied between $IN_{(UH)}$, $IN_{(VH)}$, $IN_{(WH)} - \text{COM}_{(H)}$ $IN_{(UL)}$, $IN_{(VL)}$, $IN_{(WL)} - \text{COM}_{(L)}$ | -0.3 ~ $V_{CC}+0.3$ | V |
| Fault Output Supply Voltage | V_{FO} | Applied between $V_{FO} - \text{COM}_{(L)}$ | -0.3 ~ $V_{CC}+0.3$ | V |
| Fault Output Current | I_{FO} | Sink Current at V_{FO} Pin | 5 | mA |
| Current Sensing Input Voltage | V_{SC} | Applied between $C_{SC} - \text{COM}_{(L)}$ | -0.3 ~ $V_{CC}+0.3$ | V |

Total System

| Item | Symbol | Condition | Rating | Unit |
|---|-----------------------|---|-----------|------------------|
| Self Protection Supply Voltage Limit (Short-Circuit Protection Capability) | $V_{PN(\text{PROT})}$ | $V_{CC} = V_{BS} = 13.5 \sim 16.5\text{V}$ $T_J = 25^\circ\text{C}$, Non-repetitive, less than $6\mu\text{s}$ | 400 | V |
| Module Case Operation Temperature | T_C | Note Fig.2 | -20 ~ 100 | $^\circ\text{C}$ |
| Storage Temperature | T_{STG} | | -20 ~ 125 | $^\circ\text{C}$ |
| Isolation Voltage | V_{ISO} | 60Hz, Sinusoidal, AC 1 minute, Connection Pins to Heat-sink Plate | 2500 | V_{rms} |

Absolute Maximum Ratings

Thermal Resistance

| Item | Symbol | Condition | Min. | Typ. | Max. | Unit |
|-------------------------------------|----------------|---|------|------|------|------|
| Junction to Case Thermal Resistance | $R_{th(j-c)Q}$ | Each IGBT under Inverter Operating Condition | - | - | 2.1 | °C/W |
| | $R_{th(j-c)F}$ | Each FWDi under Inverter Operating Condition | - | - | 3.3 | °C/W |
| Contact Thermal Resistance | $R_{th(c-f)}$ | Ceramic Substrate (per 1 Module) Thermal Grease Applied (Note 3) | - | - | 0.06 | °C/W |

Note:

- For the measurement point of case temperature(T_C), please refer to Fig. 2.
- The thickness of thermal grease should not be more than 100um.

Electrical Characteristics ($T_J = 25^\circ\text{C}$, Unless Otherwise Specified)

Inverter Part

| Item | Symbol | Condition | Min. | Typ. | Max. | Unit | |
|--|---------------|--|-------------------------------------|------|------|------|---------------|
| Collector - Emitter Saturation Voltage | $V_{CE(SAT)}$ | $V_{CC} = V_{BS} = 15V$ $V_{IN} = 0V$ | $I_C = 20A, T_J = 25^\circ\text{C}$ | - | - | 2.5 | V |
| FWDi Forward Voltage | V_{FM} | $V_{IN} = 5V$ | $I_C = 20A, T_J = 25^\circ\text{C}$ | - | - | 2.5 | V |
| Switching Times | t_{ON} | $V_{PN} = 300V, V_{CC} = V_{BS} = 15V$ $I_C = 20A, T_J = 25^\circ\text{C}$ $V_{IN} = 5V \leftrightarrow 0V$, Inductive Load (High, Low-side) | | - | 0.35 | - | us |
| | $t_{C(ON)}$ | | | - | 0.16 | - | us |
| | t_{OFF} | | | - | 0.75 | - | us |
| | $t_{C(OFF)}$ | | | - | 0.23 | - | us |
| | t_{tr} | | (Note 4) | | - | 0.13 | - |
| Collector - Emitter Leakage Current | I_{CES} | $V_{CE} = V_{CES}, T_J = 25^\circ\text{C}$ | | - | - | 250 | μA |

Note:

- t_{ON} and t_{OFF} include the propagation delay time of the internal drive IC. $t_{C(ON)}$ and $t_{C(OFF)}$ are the switching time of IGBT itself under the given gate driving condition internally. For the detailed information, please see Fig. 4.

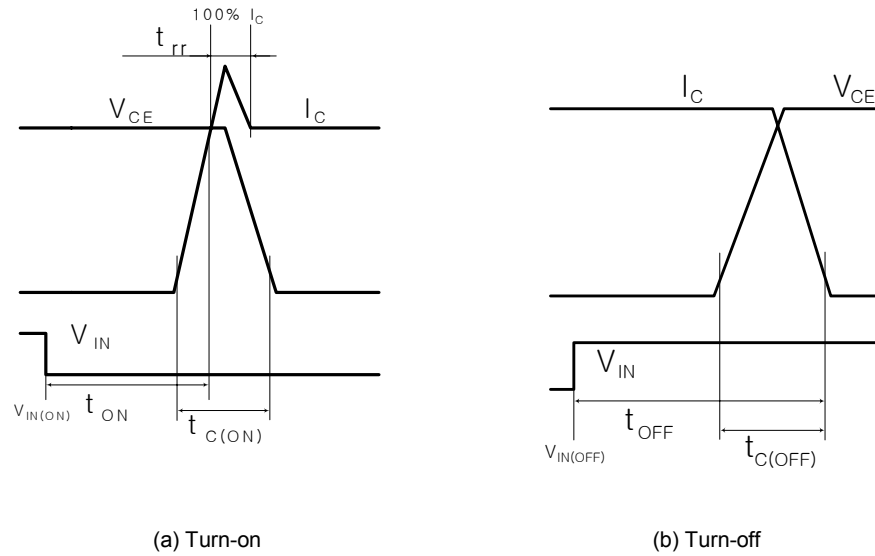


Fig. 4. Switching Time Definition

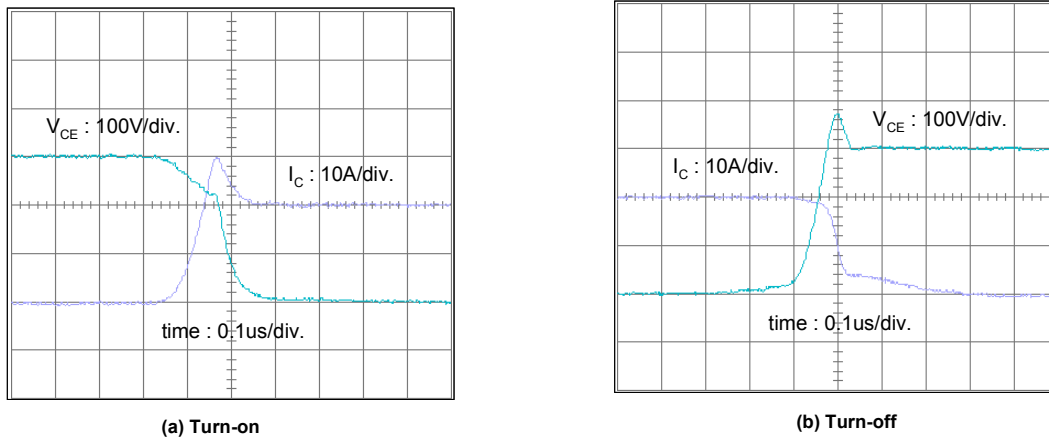


Fig. 5. Experimental Results of Switching Waveforms
 Test Condition: $V_{dc}=300V$, $V_{cc}=15V$, $L=500\mu H$ (Inductive Load), $T_J=25^\circ C$

Electrical Characteristics (T_J = 25°C, Unless Otherwise Specified)

Control Part

| Item | Symbol | Condition | Min. | Typ. | Max. | Unit | |
|--|----------------------|--|--|------|------|------|----|
| Quiescent V _{CC} Supply Current | I _{QCCL} | V _{CC} = 15V IN _(UL, VL, WL) = 5V | V _{CC(L)} - COM _(L) | - | - | 26 | mA |
| | I _{QCCH} | V _{CC} = 15V IN _(UH, VH, WH) = 5V | V _{CC(UH)} , V _{CC(VH)} , V _{CC(WH)} - COM _(H) | - | - | 130 | µA |
| Quiescent V _{BS} Supply Current | I _{QBS} | V _{BS} = 15V IN _(UH, VH, WH) = 5V | V _{B(U)} - V _{S(U)} , V _{B(V)} - V _{S(V)} , V _{B(W)} - V _{S(W)} | - | - | 420 | µA |
| Fault Output Voltage | V _{FOH} | V _{SC} = 0V, V _{FO} Circuit: 4.7kΩ to 5V Pull-up | 4.5 | - | - | V | |
| | V _{FOL} | V _{SC} = 1V, V _{FO} Circuit: 4.7kΩ to 5V Pull-up | - | - | 1.1 | V | |
| Short-Circuit Trip Level | V _{SC(ref)} | V _{CC} = 15V (Note 5) | 0.45 | 0.51 | 0.56 | V | |
| Sensing Voltage of IGBT Current | V _{SEN} | R _{SC} = 50 Ω, R _{SU} = R _{SV} = R _{SW} = 0 Ω and I _C = 30A (Note Fig. 6) | 0.45 | 0.51 | 0.56 | V | |
| Supply Circuit Under-Voltage Protection | UV _{CCD} | Detection Level | 11.5 | 12 | 12.5 | V | |
| | UV _{CCR} | Reset Level | 12 | 12.5 | 13 | V | |
| | UV _{BSD} | Detection Level | 7.3 | 9.0 | 10.8 | V | |
| | UV _{BSR} | Reset Level | 8.6 | 10.3 | 12 | V | |
| Fault Output Pulse Width | t _{FOD} | C _{FOD} = 33nF (Note 6) | 1.4 | 1.8 | 2.0 | ms | |
| ON Threshold Voltage | V _{IN(ON)} | High-Side | Applied between IN _(UH) , IN _(VH) , IN _(WH) - COM _(H) | - | - | 0.8 | V |
| OFF Threshold Voltage | V _{IN(OFF)} | | | 3.0 | - | - | V |
| ON Threshold Voltage | V _{IN(ON)} | Low-Side | Applied between IN _(UL) , IN _(VL) , IN _(WL) - COM _(L) | - | - | 0.8 | V |
| OFF Threshold Voltage | V _{IN(OFF)} | | | 3.0 | - | - | V |

Note:

- Short-circuit current protection is functioning only at the low-sides. It would be recommended that the value of the external sensing resistor (R_{SC}) should be selected around 50 Ω in order to make the SC trip-level of about 30A at the shunt resistors (R_{SU}, R_{SV}, R_{SW}) of 0Ω. For the detailed information about the relationship between the external sensing resistor (R_{SC}) and the shunt resistors (R_{SU}, R_{SV}, R_{SW}), please see Fig. 6.
- The fault-out pulse width t_{FOD} depends on the capacitance value of C_{FOD} according to the following approximate equation : C_{FOD} = 18.3 × 10⁻⁶ × t_{FOD}[F]

Recommended Operating Conditions

| Item | Symbol | Condition | Values | | | Unit |
|--|----------------------|---|----------|------|------|------|
| | | | Min. | Typ. | Max. | |
| Supply Voltage | V _{PN} | Applied between P - N _U , N _V , N _W | - | 300 | 400 | V |
| Control Supply Voltage | V _{CC} | Applied between V _{CC(UH)} , V _{CC(VH)} , V _{CC(WH)} - COM _(H) , V _{CC(L)} - COM _(L) | 13.5 | 15 | 16.5 | V |
| High-side Bias Voltage | V _{BS} | Applied between V _{B(U)} - V _{S(U)} , V _{B(V)} - V _{S(V)} , V _{B(W)} - V _{S(W)} | 13.5 | 15 | 16.5 | V |
| Blanking Time for Preventing Arm-short | t _{dead} | For Each Input Signal | 3 | - | - | µs |
| PWM Input Signal | f _{PWM} | T _C ≤ 100°C, T _J ≤ 125°C | - | 15 | - | kHz |
| Input ON Threshold Voltage | V _{IN(ON)} | Applied between IN _(UH) , IN _(VH) , IN _(WH) - COM _(H) , IN _(UL) , IN _(VL) , IN _(WL) - COM _(L) | 0 ~ 0.65 | | | V |
| Input OFF Threshold Voltage | V _{IN(OFF)} | Applied between IN _(UH) , IN _(VH) , IN _(WH) - COM _(H) , IN _(UL) , IN _(VL) , IN _(WL) - COM _(L) | 4 ~ 5.5 | | | V |

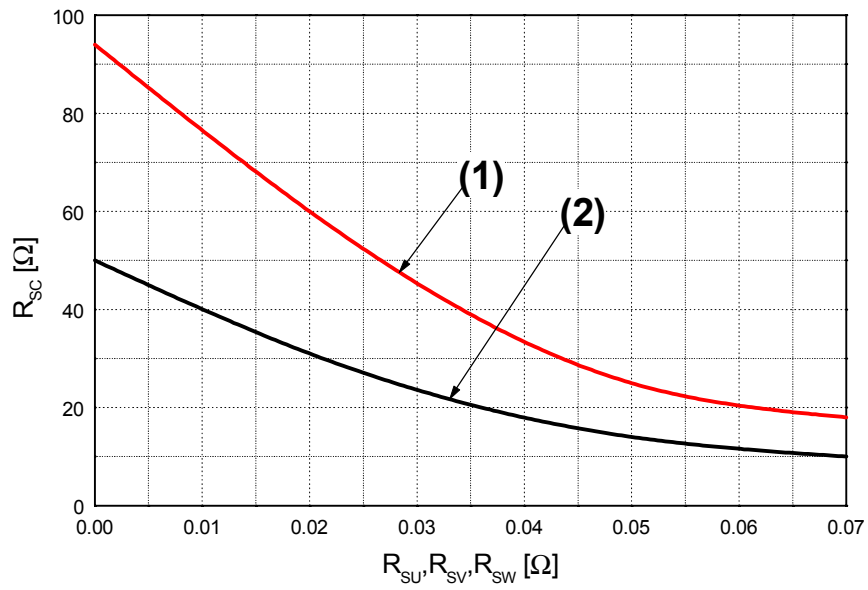


Fig. 6. R_{sc} Variation by change of Shunt Resistors (R_{SU}, R_{SV}, R_{SW}) for Short-Circuit Protection
 (1) @ around 100% Rated Current Trip ($I_C = 20A$)
 (2) @ around 150% Rated Current Trip ($I_C = 30A$)

Mechanical Characteristics and Ratings

| Item | Condition | Limits | | | Unit | |
|------------------|--------------------------------------|---------------------|------|------|------|-------|
| | | Min. | Typ. | Max. | | |
| Mounting Torque | Mounting Screw: M4 (Note 7 and 8) | Recommended 10Kg•cm | 8 | 10 | 12 | Kg•cm |
| | | Recommended 0.98N•m | 0.78 | 0.98 | 1.17 | N•m |
| Ceramic Flatness | Note Fig.7 | 0 | - | +120 | um | |
| Weight | | - | 35 | - | g | |

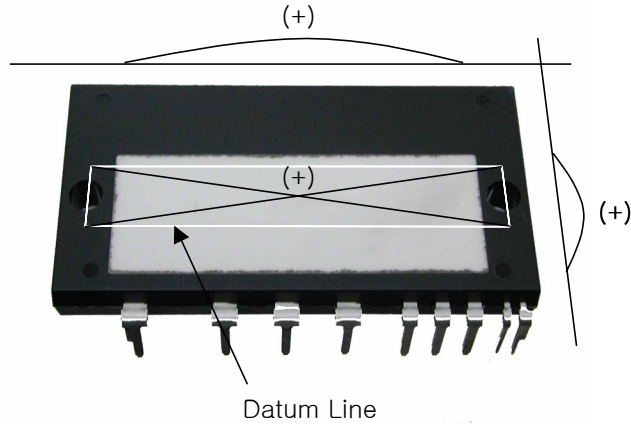


Fig. 7. Flatness Measurement Position of The Ceramic Substrate

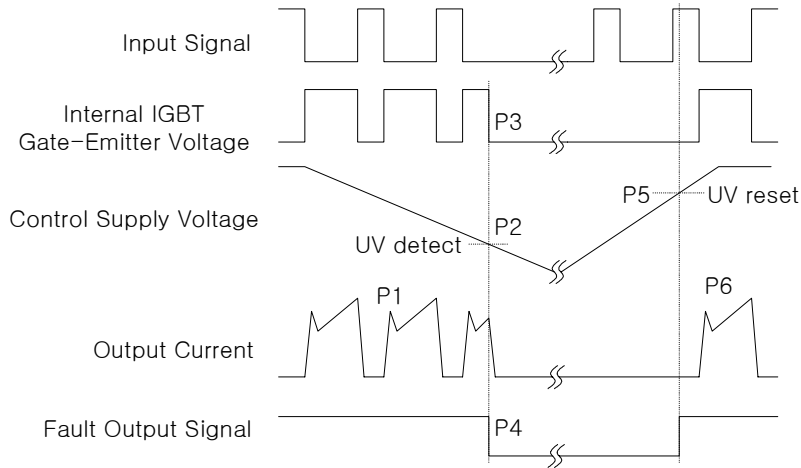
Note:

- 7. Do not make over torque or mounting screws. Much mounting torque may cause ceramic cracks and bolts and AI heat-fin destruction.
- 8. Avoid one side tightening stress. Fig.8 shows the recommended torque order for mounting screws. Uneven mounting can cause the SPM ceramic substrate to be damaged.



Fig. 8. Mounting Screws Torque Order

Time Charts of SPMs Protective Function



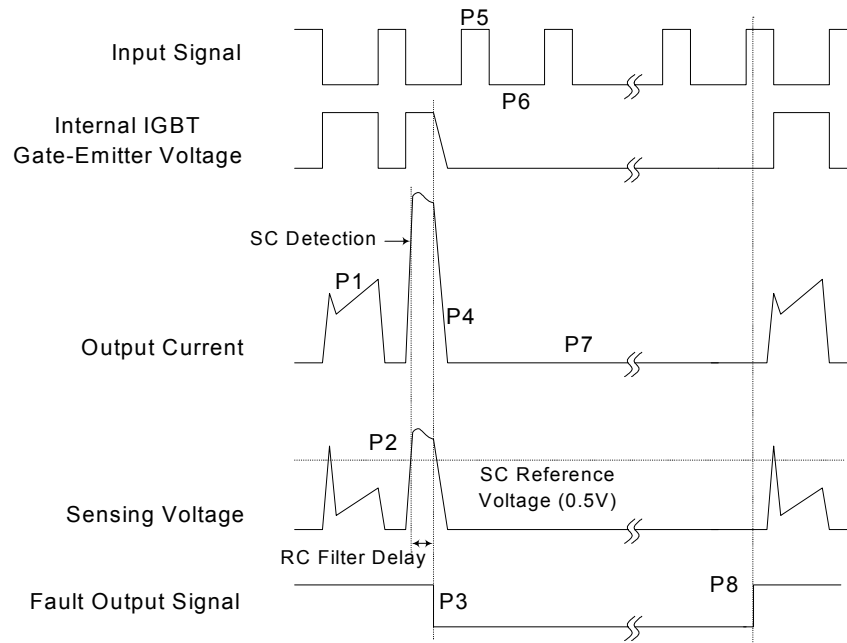
- P1 : Normal operation - IGBT ON and conducting current
- P2 : Under-Voltage detection
- P3 : IGBT gate interrupt
- P4 : Fault signal generation
- P5 : Under-Voltage reset
- P6 : Normal operation - IGBT ON and conducting current

Fig. 9. Under-Voltage Protection (Low-side)



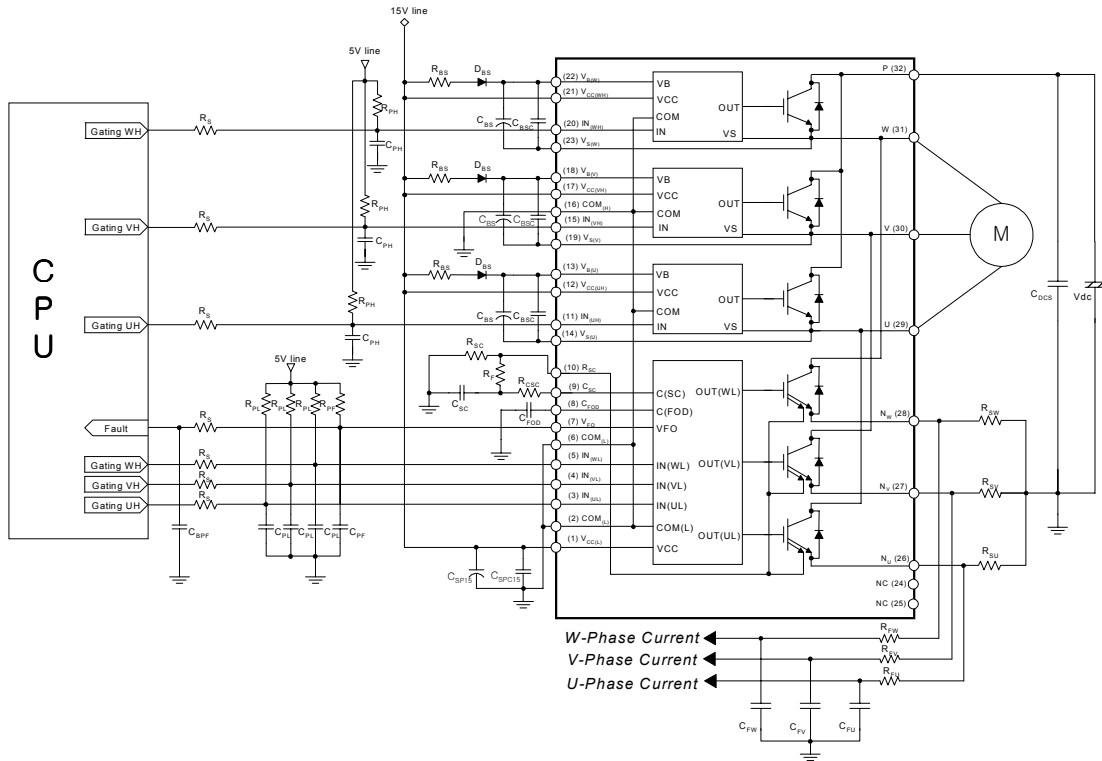
- P1 : Normal operation - IGBT ON and conducting current
- P2 : Under-Voltage detection
- P3 : IGBT gate interrupt
- P4 : No fault signal
- P5 : Under-Voltage reset
- P6 : Normal operation - IGBT ON and conducting current

Fig. 10. Under-Voltage Protection (High-side)



- P1 : Normal operation - IGBT ON and conducting current
- P2 : Short-Circuit current detection
- P3 : IGBT gate interrupt / Fault signal generation
- P4 : IGBT is slowly turned off
- P5 : IGBT OFF signal
- P6 : IGBT ON signal - but IGBT cannot be turned on during the fault Output activation
- P7 : IGBT OFF state
- P8 : Fault Output reset and normal operation start

Fig. 11. Short-Circuit Current Protection (Low-side Operation only)



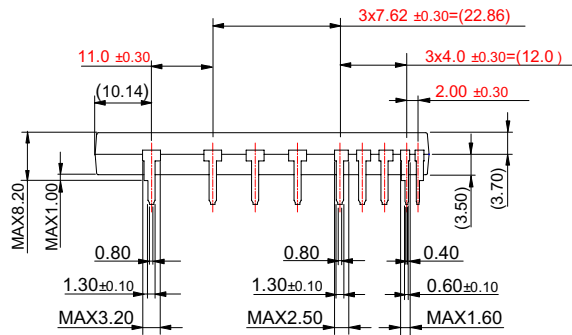
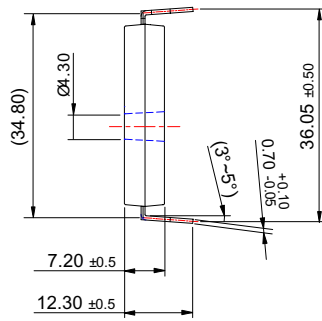
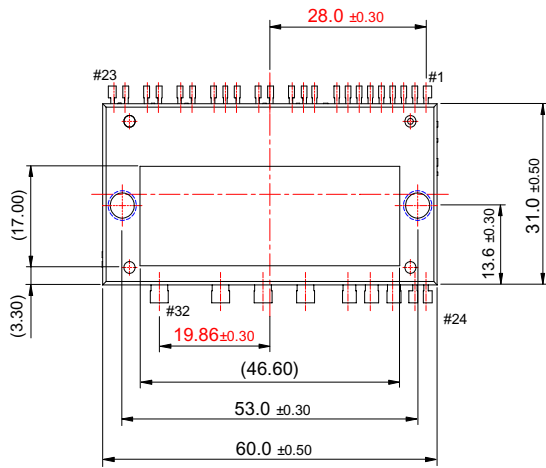
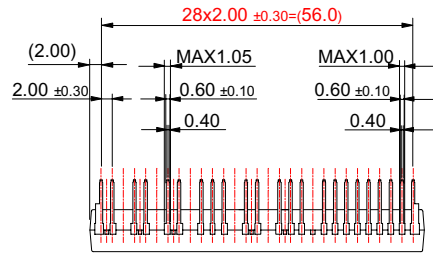
Note:

- 1) $R_{PL}C_{PL}/R_{PH}C_{PH} / R_{PF}C_{PF}$ coupling at each SPM input is recommended in order to prevent input signals' oscillation and it should be as close as possible to each SPM input pin.
- 2) By virtue of integrating an application specific type HVIC inside the SPM, direct coupling to CPU terminals without any opto-coupler or transformer isolation is possible.
- 3) V_{FO} output is open collector type. This signal line should be pulled up to the positive side of the 5V power supply with approximately 4.7k Ω resistance. Please refer to Fig. 14.
- 4) C_{SP15} of around 7 times larger than bootstrap capacitor C_{BS} is recommended.
- 5) V_{FO} output pulse width should be determined by connecting an external capacitor (C_{FOD}) between C_{FOD} (pin8) and $COM_{(L)}$ (pin2). (Example : if $C_{FOD} = 33$ nF, then $t_{FO} = 1.8$ ms (typ.)) Please refer to the note 6 for calculation method.
- 6) Each input signal line should be pulled up to the 5V power supply with approximately 4.7k Ω (at high side input) or 2k Ω (at low side input) resistance (other RC coupling circuits at each input may be needed depending on the PWM control scheme used and on the wiring impedance of the system's printed circuit board). Approximately a 0.22~2nF by-pass capacitor should be used across each power supply connection terminals.
- 7) To prevent errors of the protection function, the wiring around R_{SC} , R_F and C_{SC} should be as short as possible.
- 8) In the short-circuit protection circuit, please select the $R_F \cdot C_{SC}$ time constant in the range 3~4 μ s.
- 9) To enhance the noise immunity, C_{SC} pin should be connected to the external circuit through a series resistor, R_{CSC} , which is approximately 390 Ω . R_{CSC} should be connected to C_{SC} pin as close as possible.
- 10) Each capacitor should be mounted as close to the pins of the SPM as possible.
- 11) To prevent surge destruction, the wiring between the smoothing capacitor and the P&N pins should be as short as possible. The use of a high frequency non-inductive capacitor of around 0.1~0.22 μ F between the P&N pins is recommended.
- 12) Relays are used at almost every systems of electrical equipments of home appliances. In these cases, there should be sufficient distance between the CPU and the relays. It is recommended that the distance be 5cm at least.

Fig. 14. Typical Application Circuit

Detailed Package Outline Drawings

SPM32-AA



Dimensions in Millimeters

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| Bottomless™ | FASTr™ | MicroFET™ | QFET® | SyncFET™ |
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| CROSSVOLT™ | GlobalOptoisolator™ | MICROWIRE™ | QT Optoelectronics™ | TINYOPTO™ |
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| EcoSPARK™ | HiSeC™ | MSXPro™ | RapidConfigure™ | UHC™ |
| E ² CMOS™ | I ² C™ | OCX™ | RapidConnect™ | UltraFET® |
| EnSigna™ | ImpliedDisconnect™ | OCXPro™ | SILENT SWITCHER® | VCX™ |
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| Across the board. Around the world.™ | OPTOPLANAR™ | SPM™ | | |
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