

# 500V / 600V High Voltage 3-phase Motor Driver ICs SIM6800M Series

## Data Sheet

### Description

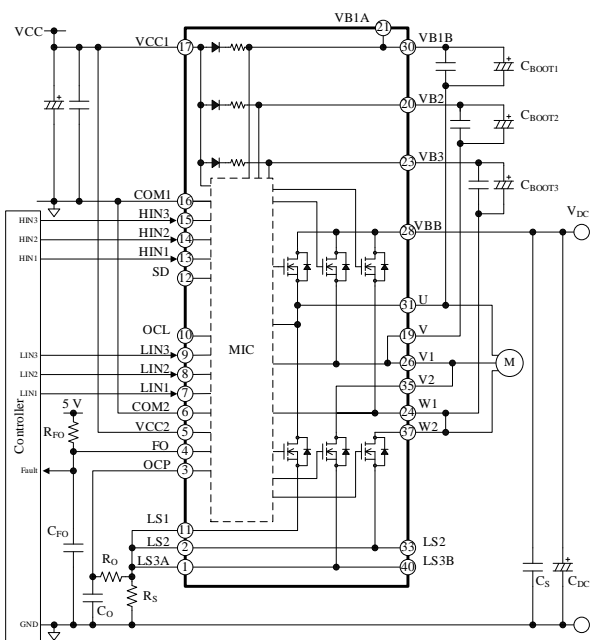
The SIM6800M series are high voltage 3-phase motor driver ICs in which transistors, a pre-driver IC (MIC), and bootstrap circuits (diodes and resistors) are highly integrated.

These products can run on a 3-shunt current detection system and optimally control the inverter systems of small- to medium-capacity motors that require universal input standards.

### Features

- Built-in Bootstrap Diodes with Current Limiting Resistors (60 Ω)
- CMOS-compatible Input (3.3 V or 5 V)
- Bare Lead Frame: Pb-free (RoHS Compliant)
- Isolation Voltage: 1500 V (for 1 min)  
UL-recognized Component (File No.: E118037)  
(SIM6880M UL Recognition Pending)
- Fault Signal Output at Protection Activation (FO Pin)
- High-side Shutdown Signal Input (SD Pin)
- Protections Include:
  - Overcurrent Limit (OCL): Auto-restart
  - Overcurrent Protection (OCP): Auto-restart
  - Undervoltage Lockout for Power Supply High-side (UVLO\_VB): Auto-restart
  - Low-side (UVLO\_VCC): Auto-restart
  - Thermal Shutdown (TSD): Auto-restart

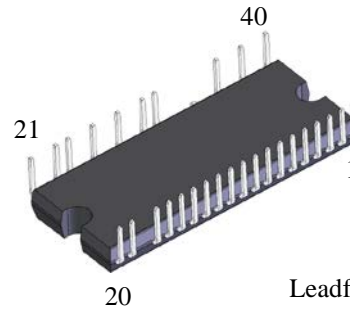
### Typical Application (SIM681xM)



### Package

DIP40

Mold Dimensions: 36.0 mm × 14.8 mm × 4.0 mm



Leadform 2971

Not to scale

### Selection Guide

| V <sub>DSS</sub> /V <sub>CES</sub> | I <sub>O</sub> | Feature                                  | Part Number |
|------------------------------------|----------------|--|-------------|
| 500 V                              | 2.0 A          | Power MOSFET                             | SIM6811M    |
|                                    | 2.5 A          |  | SIM6812M    |
|                                    | 3.0 A          |  | SIM6813M    |
| 600 V                              | 3.0 A          | IGBT with FRD, low switching dissipation | SIM6880M    |
|                                    | 5.0 A          | IGBT with FRD, low switching dissipation | SIM6822M    |
|                                    | 5.0 A          | IGBT with FRD, low noise                 | SIM6827M    |

### Applications

For motor drives such as:

- Refrigerator Compressor Motor
- Fan Motor and Pump Motor for Washer and Dryer
- Fan Motor for Air Conditioner, Air Purifier, and Electric Fan

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## SIM6800M Series

### 1. Absolute Maximum Ratings

Current polarities are defined as follows: current going into the IC (sinking) is positive current (+); current coming out of the IC (sourcing) is negative current (-).

Unless specifically noted,  $T_A = 25\text{ }^\circ\text{C}$ , COM1 = COM2 = COM.

| Parameter                                 | Symbol          | Conditions   | Rating     | Unit             | Remarks              |
|---|-----------------|--|------------|------------------|----------------------|
| Main Supply Voltage (DC)                  | $V_{DC}$        | VBB-LSx  | 400        | V                | SIM681xM             |
|   |                 |  | 450        |                  | SIM682xM<br>SIM6880M |
| Main Power Voltage (Surge)                | $V_{DC(SURGE)}$ | VBB-LSx  | 450        | V                | SIM681xM             |
|   |                 |  | 500        |                  | SIM682xM<br>SIM6880M |
| IGBT / Power MOSFET Breakdown Voltage     | $V_{DSS}$       | $V_{CC} = 15\text{ V}$ ,<br>$I_D = 1\text{ }\mu\text{A}$ , $V_{IN} = 0\text{ V}$                           | 500        | V                | SIM681xM             |
|   | $V_{CES}$       | $V_{CC} = 15\text{ V}$ ,<br>$I_C = 1\text{ mA}$ , $V_{IN} = 0\text{ V}$                                    | 600        |                  | SIM682xM<br>SIM6880M |
| Logic Supply Voltage                      | $V_{CC}$        | VCCx-COM   | 20         | V                |                      |
|   | $V_{BS}$        | VB1B-U,<br>VB2-V,<br>VB3-W1  | 20         |                  |                      |
| Output Current <sup>(1)</sup>             | $I_O$           | $T_C = 25\text{ }^\circ\text{C}$ ,<br>$T_J < 150\text{ }^\circ\text{C}$                                    | 2          | A                | SIM6811M             |
|   |                 |  | 2.5        |                  | SIM6812M             |
|   |                 |  | 3          |                  | SIM6813M<br>SIM6880M |
|   |                 |  | 5          |                  | SIM6822M<br>SIM6827M |
| Output Current (Pulse)                    | $I_{OP}$        | $T_C = 25\text{ }^\circ\text{C}$ ,<br>$V_{CC} = 15\text{ V}$ ,<br>$P_W \leq 1\text{ ms}$ ,<br>single pulse | 3          | A                | SIM6811M             |
|   |                 |  | 3.75       |                  | SIM6812M             |
|   |                 |  | 4.5        |                  | SIM6813M<br>SIM6880M |
|   |                 |  | 7.5        |                  | SIM6822M<br>SIM6827M |
| Input Voltage                             | $V_{IN}$        | HINx-COM,<br>LINx-COM  | -0.5 to 7  | V                |                      |
| FO Pin Voltage                            | $V_{FO}$        | FO-COM   | -0.5 to 7  | V                |                      |
| OCP Pin Voltage                           | $V_{OCP}$       | OCP-COM  | -10 to 5   | V                |                      |
| SD Pin Voltage                            | $V_{SD}$        | SD-COM   | -0.5 to 7  | V                |                      |
| Operating Case Temperature <sup>(2)</sup> | $T_{C(OP)}$     |  | -30 to 100 | $^\circ\text{C}$ |                      |
| Junction Temperature <sup>(3)</sup>       | $T_J$           |  | 150        | $^\circ\text{C}$ |                      |
| Storage Temperature                       | $T_{STG}$       |  | -40 to 150 | $^\circ\text{C}$ |                      |
| Isolation Voltage <sup>(4)</sup>          | $V_{ISO(RMS)}$  | Between surface of the case and each pin; AC, 60 Hz, 1 min   | 1500       | V                |                      |

<sup>(1)</sup> Should be derated depending on an actual case temperature. See Section 15.4.

<sup>(2)</sup> Refers to a case temperature measured during IC operation.

<sup>(3)</sup> Refers to the junction temperature of each chip built in the IC, including the controller IC (MIC), transistors, and fast recovery diodes.

<sup>(4)</sup> Refers to voltage conditions to be applied between the case and all pins. All pins have to be shorted.

## SIM6800M Series

### 2. Recommended Operating Conditions

Unless specifically noted, COM1 = COM2 = COM.

| Parameter                                  | Symbol           | Conditions                  | Min.  | Typ. | Max.  | Unit         | Remarks                          |
|--|------------------|-----------------------------|-------|------|-------|--------------|----------------------------------|
| Main Supply Voltage                        | $V_{DC}$         | VBB-COM                     | —     | 300  | 400   | V            |                                  |
| Logic Supply Voltage                       | $V_{CC}$         | VCCx-COM                    | 13.5  | 15.0 | 16.5  | V            |                                  |
|  | $V_{BS}$         | VB1B-U,<br>VB2-V,<br>VB3-W1 | 13.5  | —    | 16.5  | V            |                                  |
| Input Voltage<br>(HINx, LINx, OCP, SD, FO) | $V_{IN}$         |                             | 0     | —    | 5.5   | V            |                                  |
| Minimum Input Pulse Width                  | $t_{IN(MIN)ON}$  |                             | 0.5   | —    | —     | $\mu$ s      |                                  |
|  | $t_{IN(MIN)OFF}$ |                             | 0.5   | —    | —     | $\mu$ s      |                                  |
| Dead Time of Input Signal                  | $t_{DEAD}$       |                             | 1.5   | —    | —     | $\mu$ s      |                                  |
| FO Pin Pull-up Resistor                    | $R_{FO}$         |                             | 3.3   | —    | 10    | k $\Omega$   |                                  |
| FO Pin Pull-up Voltage                     | $V_{FO}$         |                             | 3.0   | —    | 5.5   | V            |                                  |
| FO Pin Noise Filter Capacitor              | $C_{FO}$         |                             | 0.001 | —    | 0.01  | $\mu$ F      |                                  |
| Bootstrap Capacitor                        | $C_{BOOT}$       |                             | 1     | —    | 220   | $\mu$ F      |                                  |
| Shunt Resistor                             | $R_S$            | $I_p \leq 3$ A              | 390   | —    | —     | m $\Omega$   | SIM6811M                         |
|  |                  | $I_p \leq 3.75$ A           | 270   | —    | —     |              | SIM6812M                         |
|  |                  | $I_p \leq 4.5$ A            | 270   | —    | —     |              | SIM6813M<br>SIM6880M             |
|  |                  | $I_p \leq 7.5$ A            | 150   | —    | —     |              | SIM6822M<br>SIM6827M             |
| RC Filter Resistor                         | $R_O$            |                             | —     | —    | 100   | $\Omega$     |                                  |
| RC Filter Capacitor                        | $C_O$            |                             | 1000  | —    | 2200  | pF           | SIM6822M<br>SIM6827M<br>SIM6880M |
|  |                  |                             | 1000  | —    | 10000 |              | SIM6811M<br>SIM6812M<br>SIM6813M |
| PWM Carrier Frequency                      | $f_C$            |                             | —     | —    | 20    | kHz          |                                  |
| Operating Case Temperature                 | $T_{C(OP)}$      |                             | —     | —    | 100   | $^{\circ}$ C |                                  |

## SIM6800M Series

### 3. Electrical Characteristics

Current polarities are defined as follows: current going into the IC (sinking) is positive current (+); current coming out of the IC (sourcing) is negative current (-).

Unless specifically noted,  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{CC} = 15\text{ V}$ ,  $\text{COM1} = \text{COM2} = \text{COM}$ .

#### 3.1 Characteristics of Control Parts

| Parameter   | Symbol               | Conditions  | Min.   | Typ.   | Max.   | Unit          | Remarks |
|---|----------------------|---|--------|--------|--------|---------------|---------|
| <b>Power Supply Operation</b>                           |                      |   |        |        |        |               |         |
| Logic Operation Start Voltage                           | $V_{CC(\text{ON})}$  | VCCx-COM  | 10.5   | 11.5   | 12.5   | V             |         |
|   | $V_{BS(\text{ON})}$  | VB1B-U,<br>VB2-V,<br>VB3-W1   | 9.5    | 10.5   | 11.5   | V             |         |
| Logic Operation Stop Voltage                            | $V_{CC(\text{OFF})}$ | VCCx-COM  | 10.0   | 11.0   | 12.0   | V             |         |
|   | $V_{BS(\text{OFF})}$ | VB1B-U,<br>VB2-V,<br>VB3-W1   | 9.0    | 10.0   | 11.0   | V             |         |
| Logic Supply Current                                    | $I_{CC}$             | VCC1 = VCC2,<br>VCC pin current in 3-phase operation                              | —      | 3.2    | 4.5    | mA            |         |
|   | $I_{BS}$             | VB1B-U or VB2-V or<br>VB3-W1; HINx = 5 V;<br>VBx pin current in 1-phase operation | —      | 140    | 400    | $\mu\text{A}$ |         |
| <b>Input Signal</b>                                     |                      |   |        |        |        |               |         |
| High Level Input Threshold Voltage (HINx, LINx, SD, FO) | $V_{IH}$             |   | —      | 2.0    | 2.5    | V             |         |
| Low Level Input Threshold Voltage (HINx, LINx, SD, FO)  | $V_{IL}$             |   | 1.0    | 1.5    | —      | V             |         |
| High Level Input Current (HINx, LINx)                   | $I_{IH}$             | $V_{IN} = 5\text{ V}$   | —      | 230    | 500    | $\mu\text{A}$ |         |
| Low Level Input Current (HINx, LINx)                    | $I_{IL}$             | $V_{IN} = 0\text{ V}$   | —      | —      | 2      | $\mu\text{A}$ |         |
| <b>Fault Signal Output</b>                              |                      |   |        |        |        |               |         |
| FO Pin Voltage at Fault Signal Output                   | $V_{FOL}$            | $V_{FO} = 5\text{ V}$ , $R_{FO} = 10\text{ k}\Omega$                              | 0      | —      | 0.5    | V             |         |
| FO Pin Voltage in Normal Operation                      | $V_{FOH}$            | $V_{FO} = 5\text{ V}$ , $R_{FO} = 10\text{ k}\Omega$                              | 4.8    | —      | —      | V             |         |
| <b>Protection</b>                                       |                      |   |        |        |        |               |         |
| OCL Pin Output Voltage (L)                              | $V_{OCL(L)}$         |   | 0      | —      | 0.5    | V             |         |
| OCL Pin Output Voltage (H)                              | $V_{OCL(H)}$         |   | 4.5    | —      | 5.5    | V             |         |
| Current Limit Reference Voltage                         | $V_{LIM}$            |   | 0.6175 | 0.6500 | 0.6825 | V             |         |
| OCP Threshold Voltage                                   | $V_{TRIP}$           |   | 0.9    | 1.0    | 1.1    | V             |         |
| OCP Hold Time   | $t_p$                |   | 20     | 25     | —      | $\mu\text{s}$ |         |
| OCP Blanking Time                                       | $t_{BK(\text{OCP})}$ |   | —      | 2      | —      | $\mu\text{s}$ |         |
| Current Limit Blanking Time                             | $t_{BK(\text{OCL})}$ |   | —      | 2      | —      | $\mu\text{s}$ |         |

## SIM6800M Series

| Parameter                 | Symbol   | Conditions | Min. | Typ. | Max. | Unit | Remarks |
|---------------------------|----------|------------|------|------|------|------|---------|
| TSD Operating Temperature | $T_{DH}$ |            | 135  | 150  | —    | °C   |         |
| TSD Releasing Temperature | $T_{DL}$ |            | 105  | 120  | —    | °C   |         |

### 3.2 Bootstrap Diode Characteristics

| Parameter                       | Symbol     | Conditions               | Min. | Typ. | Max. | Unit          | Remarks |
|---------------------------------|------------|--------------------------|------|------|------|---------------|---------|
| Bootstrap Diode Leakage Current | $I_{LBD}$  | $V_R = 500\text{ V}$     | —    | —    | 10   | $\mu\text{A}$ |         |
| Bootstrap Diode Forward Voltage | $V_{FB}$   | $I_{FB} = 0.15\text{ A}$ | —    | 1.0  | 1.3  | V             |         |
| Bootstrap Diode Series Resistor | $R_{BOOT}$ |                          | 45   | 60   | 75   | $\Omega$      |         |

### 3.3 Thermal Resistance Characteristics

| Parameter  | Symbol             | Conditions                        | Min. | Typ. | Max. | Unit | Remarks              |
|--|--------------------|-----------------------------------|------|------|------|------|----------------------|
| Junction-to-Case Thermal Resistance <sup>(1)</sup> | $R_{J-C}$          | All power MOSFETs operating       | —    | —    | 3.6  | °C/W | SIM681xM             |
|  | $R_{(J-C)Q}^{(2)}$ | All IGBTs operating               | —    | —    | 3.6  | °C/W | SIM682xM<br>SIM6880M |
|  | $R_{(J-C)F}^{(3)}$ | All freewheeling diodes operating | —    | —    | 4.2  | °C/W | SIM682xM<br>SIM6880M |
| Junction-to-Ambient Thermal Resistance             | $R_{J-A}$          | All power MOSFETs operating       | —    | —    | 25   | °C/W | SIM681xM             |
|  | $R_{(J-A)Q}$       | All IGBTs operating               | —    | —    | 25   | °C/W | SIM682xM<br>SIM6880M |
|  | $R_{(J-A)F}$       | All freewheeling diodes operating | —    | —    | 29   | °C/W | SIM682xM<br>SIM6880M |

<sup>(1)</sup> Refers to a case temperature at the measurement point described in Figure 3-1, below.

<sup>(2)</sup> Refers to steady-state thermal resistance between the junction of the built-in transistors and the case. For transient thermal characteristics, see Section 15.1.

<sup>(3)</sup> Refers to steady-state thermal resistance between the junction of the built-in freewheeling diodes and the case.

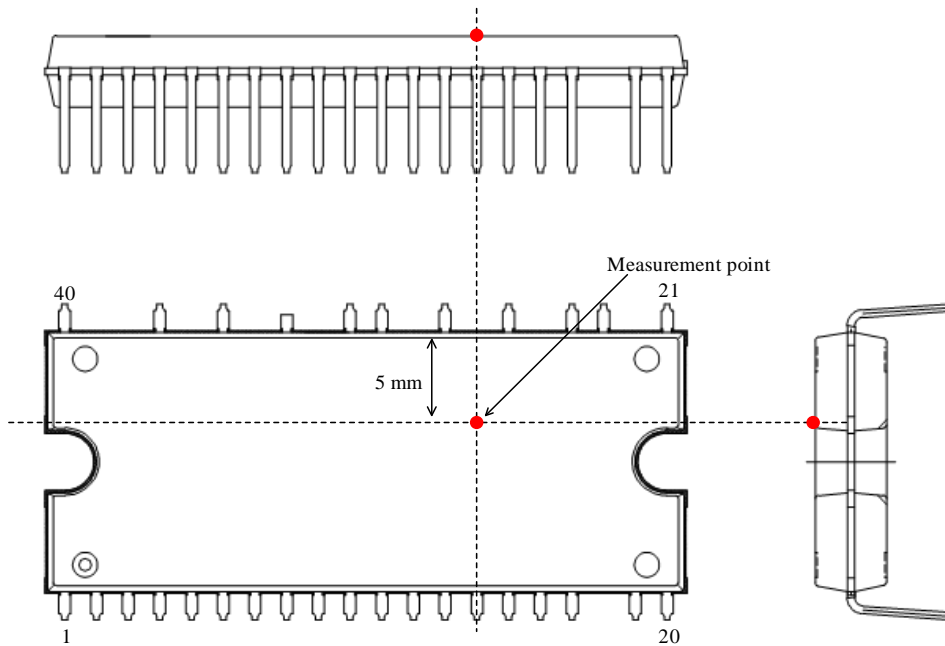


Figure 3-1. Case Temperature Measurement Point

### 3.4 Transistor Characteristics

Figure 3-2 provides the definitions of switching characteristics described in this and the following sections.

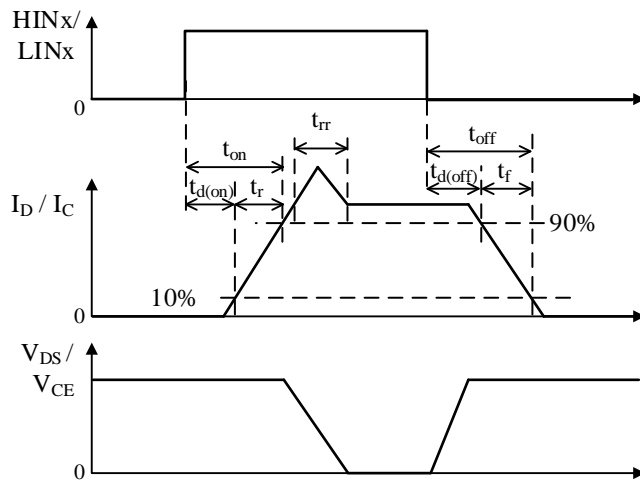


Figure 3-2. Switching Characteristics Definitions



## SIM6800M Series

### 3.4.1 SIM6811M

| Parameter                                   | Symbol       | Conditions  | Min. | Typ. | Max. | Unit          |
|---|--------------|---|------|------|------|---------------|
| Drain-to-Source Leakage Current             | $I_{DSS}$    | $V_{DS} = 500\text{ V}, V_{IN} = 0\text{ V}$  | —    | —    | 100  | $\mu\text{A}$ |
| Drain-to-Source On Resistance               | $R_{DS(ON)}$ | $I_D = 1.0\text{ A}, V_{IN} = 5\text{ V}$   | —    | 3.2  | 4.0  | $\Omega$      |
| Source-to-Drain Diode Forward Voltage       | $V_{SD}$     | $I_{SD} = 1.0\text{ A}, V_{IN} = 0\text{ V}$  | —    | 1.0  | 1.5  | V             |
| <b>High-side Switching</b>                  |              |   |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$     | $V_{DC} = 300\text{ V}, I_C = 1.0\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 150  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$  |   | —    | 770  | —    | ns            |
| Rise Time                                   | $t_r$        |   | —    | 70   | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$ |   | —    | 690  | —    | ns            |
| Fall Time                                   | $t_f$        |   | —    | 30   | —    | ns            |
| <b>Low-side Switching</b>                   |              |   |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$     | $V_{DC} = 300\text{ V}, I_C = 1.0\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 150  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$  |   | —    | 690  | —    | ns            |
| Rise Time                                   | $t_r$        |   | —    | 90   | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$ |   | —    | 650  | —    | ns            |
| Fall Time                                   | $t_f$        |   | —    | 50   | —    | ns            |

### 3.4.2 SIM6812M

| Parameter                                   | Symbol        | Conditions   | Min. | Typ. | Max. | Unit          |
|---|---------------|--|------|------|------|---------------|
| Drain-to-Source Leakage Current             | $I_{CES}$     | $V_{DS} = 500\text{ V}, V_{IN} = 0\text{ V}$   | —    | —    | 100  | $\mu\text{A}$ |
| Drain-to-Source On Resistance               | $V_{CE(SAT)}$ | $I_D = 1.25\text{ A}, V_{IN} = 5\text{ V}$   | —    | 2.0  | 2.4  | $\Omega$      |
| Source-to-Drain Diode Forward Voltage       | $V_F$         | $I_{SD} = 1.25\text{ A}, V_{IN} = 0\text{ V}$  | —    | 1.0  | 1.5  | V             |
| <b>High-side Switching</b>                  |               |  |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 1.25\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 140  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$   |  | —    | 910  | —    | ns            |
| Rise Time                                   | $t_r$         |  | —    | 100  | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$  |  | —    | 700  | —    | ns            |
| Fall Time                                   | $t_f$         |  | —    | 40   | —    | ns            |
| <b>Low-side Switching</b>                   |               |  |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 1.25\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 155  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$   |  | —    | 875  | —    | ns            |
| Rise Time                                   | $t_r$         |  | —    | 110  | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$  |  | —    | 775  | —    | ns            |
| Fall Time                                   | $t_f$         |  | —    | 35   | —    | ns            |

## SIM6800M Series

### 3.4.3 SIM6813M

| Parameter                                   | Symbol       | Conditions  | Min. | Typ. | Max. | Unit          |
|---|--------------|---|------|------|------|---------------|
| Drain-to-Source Leakage Current             | $I_{DSS}$    | $V_{DS} = 500\text{ V}, V_{IN} = 0\text{ V}$  | —    | —    | 100  | $\mu\text{A}$ |
| Drain-to-Source On Resistance               | $R_{DS(ON)}$ | $I_D = 1.5\text{ A}, V_{IN} = 5\text{ V}$   | —    | 1.4  | 1.7  | $\Omega$      |
| Source-to-Drain Diode Forward Voltage       | $V_{SD}$     | $I_{SD} = 1.5\text{ A}, V_{IN} = 0\text{ V}$  | —    | 1.0  | 1.5  | V             |
| <b>High-side Switching</b>                  |              |   |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$     | $V_{DC} = 300\text{ V}, I_C = 1.5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 170  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$  |   | —    | 820  | —    | ns            |
| Rise Time                                   | $t_r$        |   | —    | 100  | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$ |   | —    | 810  | —    | ns            |
| Fall Time                                   | $t_f$        |   | —    | 50   | —    | ns            |
| <b>Low-side Switching</b>                   |              |   |      |      |      |               |
| Source-to-Drain Diode Reverse Recovery Time | $t_{rr}$     | $V_{DC} = 300\text{ V}, I_C = 1.5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 180  | —    | ns            |
| Turn-on Delay Time                          | $t_{d(on)}$  |   | —    | 760  | —    | ns            |
| Rise Time                                   | $t_r$        |   | —    | 130  | —    | ns            |
| Turn-off Delay Time                         | $t_{d(off)}$ |   | —    | 750  | —    | ns            |
| Fall Time                                   | $t_f$        |   | —    | 50   | —    | ns            |

### 3.4.4 SIM6880M

| Parameter                               | Symbol        | Conditions  | Min. | Typ. | Max. | Unit |
|---|---------------|---|------|------|------|------|
| Collector-to-Emitter Leakage Current    | $I_{CES}$     | $V_{CE} = 600\text{ V}, V_{IN} = 0\text{ V}$  | —    | —    | 1    | mA   |
| Collector-to-Emitter Saturation Voltage | $V_{CE(SAT)}$ | $I_C = 3.0\text{ A}, V_{IN} = 5\text{ V}$   | —    | 1.85 | 2.30 | V    |
| Diode Forward Voltage                   | $V_F$         | $I_F = 3.0\text{ A}, V_{IN} = 0\text{ V}$   | —    | 2.0  | 2.4  | V    |
| <b>High-side Switching</b>              |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 3.0\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 100  | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 880  | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 120  | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 740  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 210  | —    | ns   |
| <b>Low-side Switching</b>               |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 3.0\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 100  | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 820  | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 140  | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 660  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 200  | —    | ns   |

## SIM6800M Series

### 3.4.5 SIM6822M

| Parameter                               | Symbol        | Conditions  | Min. | Typ. | Max. | Unit |
|---|---------------|---|------|------|------|------|
| Collector-to-Emitter Leakage Current    | $I_{CES}$     | $V_{CE} = 600\text{ V}, V_{IN} = 0\text{ V}$  | —    | —    | 1    | mA   |
| Collector-to-Emitter Saturation Voltage | $V_{CE(SAT)}$ | $I_C = 5\text{ A}, V_{IN} = 5\text{ V}$   | —    | 1.75 | 2.2  | V    |
| Diode Forward Voltage                   | $V_F$         | $I_F = 5\text{ A}, V_{IN} = 0\text{ V}$   | —    | 2.0  | 2.4  | V    |
| <b>High-side Switching</b>              |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 80   | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 740  | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 70   | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 570  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 100  | —    | ns   |
| <b>Low-side Switching</b>               |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 80   | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 690  | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 100  | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 540  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 100  | —    | ns   |

### 3.4.6 SIM6827M

| Parameter                               | Symbol        | Conditions  | Min. | Typ. | Max. | Unit |
|---|---------------|---|------|------|------|------|
| Collector-to-Emitter Leakage Current    | $I_{CES}$     | $V_{CE} = 600\text{ V}, V_{IN} = 0\text{ V}$  | —    | —    | 1    | mA   |
| Collector-to-Emitter Saturation Voltage | $V_{CE(SAT)}$ | $I_C = 5\text{ A}, V_{IN} = 5\text{ V}$   | —    | 1.75 | 2.2  | V    |
| Diode Forward Voltage                   | $V_F$         | $I_F = 5\text{ A}, V_{IN} = 0\text{ V}$   | —    | 2.0  | 2.4  | V    |
| <b>High-side Switching</b>              |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 100  | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 1030 | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 180  | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 590  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 150  | —    | ns   |
| <b>Low-side Switching</b>               |               |   |      |      |      |      |
| Diode Reverse Recovery Time             | $t_{rr}$      | $V_{DC} = 300\text{ V}, I_C = 5\text{ A},$<br>inductive load,<br>$V_{IN} = 0 \rightarrow 5\text{ V}$ or $5 \rightarrow 0\text{ V},$<br>$T_J = 25\text{ }^\circ\text{C}$ | —    | 100  | —    | ns   |
| Turn-on Delay Time                      | $t_{d(on)}$   |   | —    | 1030 | —    | ns   |
| Rise Time                               | $t_r$         |   | —    | 240  | —    | ns   |
| Turn-off Delay Time                     | $t_{d(off)}$  |   | —    | 540  | —    | ns   |
| Fall Time                               | $t_f$         |   | —    | 150  | —    | ns   |

**4. Mechanical Characteristics**

| Parameter                            | Conditions      | Min.  | Typ. | Max.  | Unit | Remarks |
|--------------------------------------|-----------------|-------|------|-------|------|---------|
| Heatsink Mounting Screw Torque       | *               | 0.294 | —    | 0.441 | N·m  |         |
| Flatness of Heatsink Attachment Area | See Figure 4-1. | 0     | —    | 60    | μm   |         |
| Package Weight                       |                 | —     | 5.2  | —     | g    |         |

\* When mounting a heatsink, it is recommended to use a metric screw of M2.5 and a plain washer of 6.0 mm (φ) together at each end of it. For more details about screw tightening, see Section 13.2.

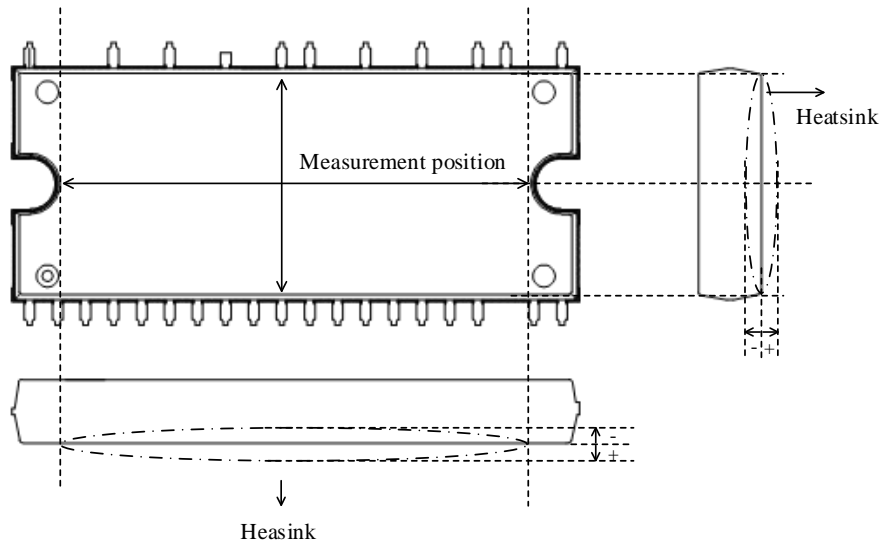


Figure 4-1. Flatness Measurement Position

**5. Insulation Distance**

| Parameter | Conditions                                   | Min. | Typ. | Max. | Unit | Remarks |
|-----------|--|------|------|------|------|---------|
| Clearance | Between heatsink* and leads. See Figure 5-1. | 1.5  | —    | 2.1  | mm   |         |
| Creepage  |  | 1.7  | —    | —    | mm   |         |

\* Refers to when a heatsink to be mounted is flat. If your application requires a clearance exceeding the maximum distance given above, use an alternative (e.g., a convex heatsink) that will meet the target requirement.

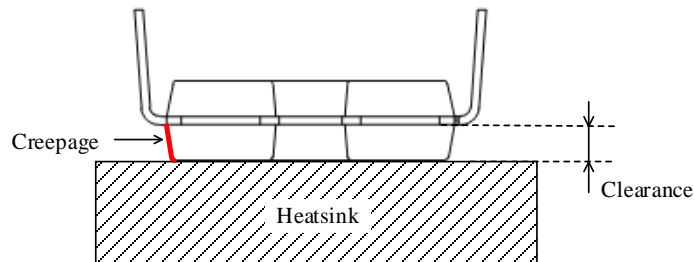


Figure 5-1. Insulation Distance Definitions

**6. Truth Table**

Table 6-1 is a truth table that provides the logic level definitions of operation modes.

In the case where HINx and LINx signals in each phase are high at the same time, both the high- and low-side transistors become on (simultaneous on-state). Therefore, HINx and LINx signals, the input signals for the HINx and LINx pins, require dead time setting so that such a simultaneous on-state event can be avoided.

After the IC recovers from a UVLO\_VCC condition, the low-side transistors resume switching in accordance with the input logic levels of the LINx signals (level-triggered), whereas the high-side transistors resume switching at the next rising edge of an HINx signal (edge-triggered).

After the IC recovers from a UVLO\_VB condition, the high-side transistors resume switching at the next rising edge of an HINx signal (edge-triggered).

Table 6-1. Truth Table for Operation Modes

| Mode  | HINx | LINx | High-side Transistor | Low-side Transistor |
|---|------|------|----------------------|---------------------|
| Normal Operation  | L    | L    | OFF                  | OFF                 |
|   | H    | L    | ON                   | OFF                 |
|   | L    | H    | OFF                  | ON                  |
|   | H    | H    | ON                   | ON                  |
| External Shutdown Signal Input<br>FO = Low Level                | L    | L    | OFF                  | OFF                 |
|   | H    | L    | ON                   | OFF                 |
|   | L    | H    | OFF                  | OFF                 |
|   | H    | H    | ON                   | OFF                 |
| Undervoltage Lockout for<br>High-side Power Supply<br>(UVLO_VB) | L    | L    | OFF                  | OFF                 |
|   | H    | L    | OFF                  | OFF                 |
|   | L    | H    | OFF                  | ON                  |
|   | H    | H    | OFF                  | ON                  |
| Undervoltage Lockout for<br>Low-side Power Supply<br>(UVLO_VCC) | L    | L    | OFF                  | OFF                 |
|   | H    | L    | OFF                  | OFF                 |
|   | L    | H    | OFF                  | OFF                 |
|   | H    | H    | OFF                  | OFF                 |
| Overcurrent Protection (OCP)                                    | L    | L    | OFF                  | OFF                 |
|   | H    | L    | ON                   | OFF                 |
|   | L    | H    | OFF                  | OFF                 |
|   | H    | H    | ON                   | OFF                 |
| Overcurrent Limit (OCL)<br>(OCL = SD)                           | L    | L    | OFF                  | OFF                 |
|   | H    | L    | OFF                  | OFF                 |
|   | L    | H    | OFF                  | ON                  |
|   | H    | H    | OFF                  | ON                  |
| Thermal Shutdown (TSD)  | L    | L    | OFF                  | OFF                 |
|   | H    | L    | ON                   | OFF                 |
|   | L    | H    | OFF                  | OFF                 |
|   | H    | H    | ON                   | OFF                 |

7. Block Diagrams

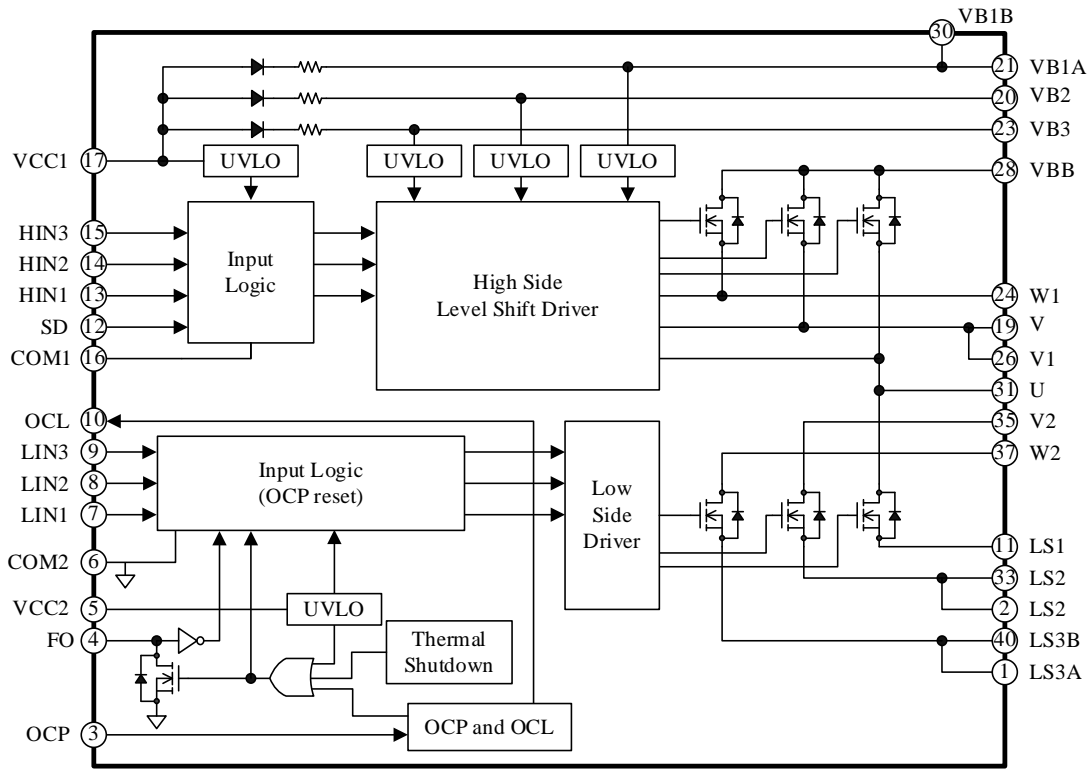


Figure 7-1. SIM681xM

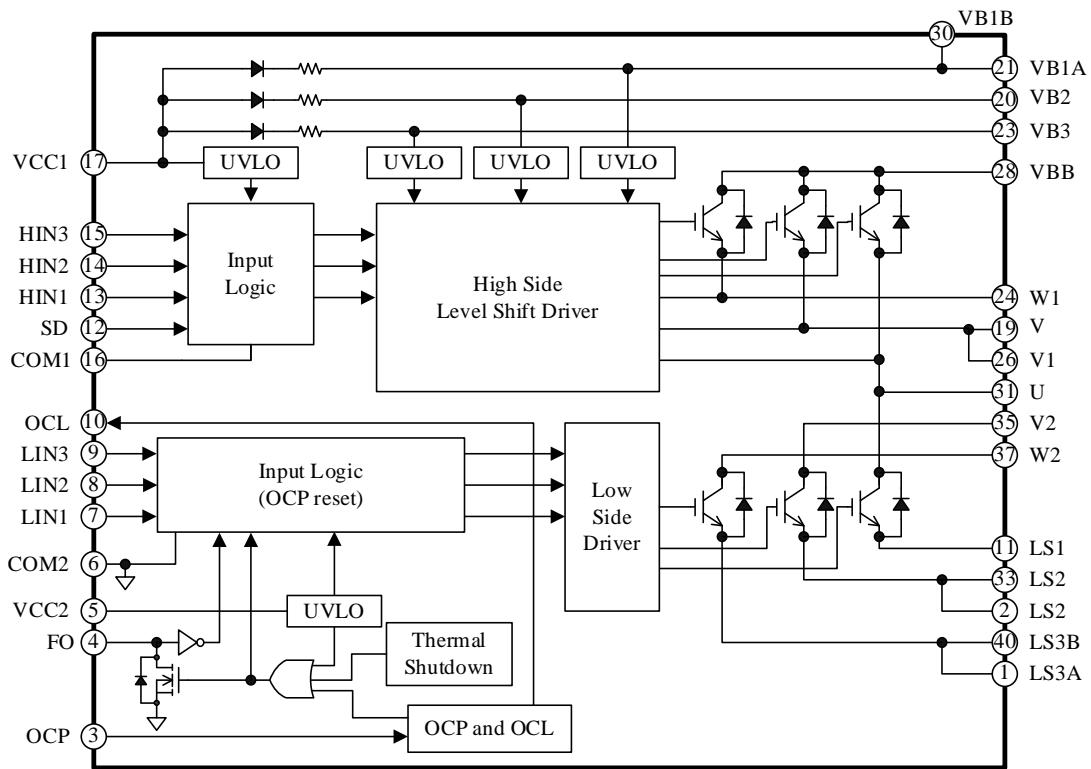
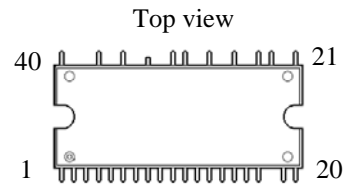
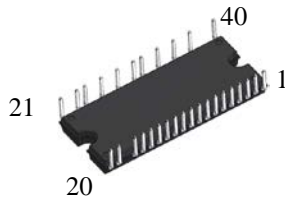


Figure 7-2. SIM682xM or SIM688xM

**8. Pin Configuration Definitions**



| Pin Number | Pin Name | Description  |
|------------|----------|--|
| 1          | LS3A     | W-phase IGBT emitter, or power MOSFET source               |
| 2          | LS2      | V-phase IGBT emitter, or power MOSFET source               |
| 3          | OCF      | Overcurrent protection signal input                        |
| 4          | FO       | Fault signal output and shutdown signal input              |
| 5          | VCC2     | Low-side logic supply voltage input                        |
| 6          | COM2     | Low-side logic ground                                      |
| 7          | LIN1     | Logic input for U-phase low-side gate driver               |
| 8          | LIN2     | Logic input for V-phase low-side gate driver               |
| 9          | LIN3     | Logic input for W-phase low-side gate driver               |
| 10         | OCL      | Overcurrent limit signal input                             |
| 11         | LS1      | U-phase IGBT emitter, or power MOSFET source               |
| 12         | SD       | High-side shutdown signal input                            |
| 13         | HIN1     | Logic input for U-phase high-side gate driver              |
| 14         | HIN2     | Logic input for V-phase high-side gate driver              |
| 15         | HIN3     | Logic input for W-phase high-side gate driver              |
| 16         | COM1     | High-side logic ground                                     |
| 17         | VCC1     | High-side logic supply voltage input                       |
| 18         | —        | (Pin removed)  |
| 19         | V        | Bootstrap capacitor connection for V-phase                 |
| 20         | VB2      | V-phase high-side floating supply voltage input            |
| 21         | VB1A     | U-phase high-side floating supply voltage input            |
| 22         | —        | (Pin removed)  |
| 23         | VB3      | W-phase high-side floating supply voltage input            |
| 24         | W1       | W-phase output (connected to W2 externally)                |
| 25         | NC       | (No connection)  |
| 26         | V1       | V-phase output (connected to V2 externally)                |
| 27         | —        | (Pin removed)  |
| 28         | VBB      | Positive DC bus supply voltage                             |
| 29         | NC       | (No connection)  |
| 30         | VB1B     | U-phase high-side floating supply voltage input            |
| 31         | U        | U-phase output   |
| 32         | —        | (Pin removed)  |
| 33         | LS2      | (Pin trimmed) V-phase IGBT emitter, or power MOSFET source |
| 34         | —        | (Pin removed)  |
| 35         | V2       | V-phase output (connected to V1 externally)                |
| 36         | NC       | (No connection)  |
| 37         | W2       | W-phase output (connected to W1 externally)                |
| 38         | —        | (Pin removed)  |
| 39         | —        | (Pin removed)  |
| 40         | LS3B     | W-phase IGBT emitter, or power MOSFET source               |

**9. Typical Applications**

CR filters and Zener diodes should be added to your application as needed. This is to protect each pin against surge voltages causing malfunctions, and to avoid the IC being used under the conditions exceeding the absolute maximum ratings where critical damage is inevitable. Then, check all the pins thoroughly under actual operating conditions to ensure that your application works flawlessly.

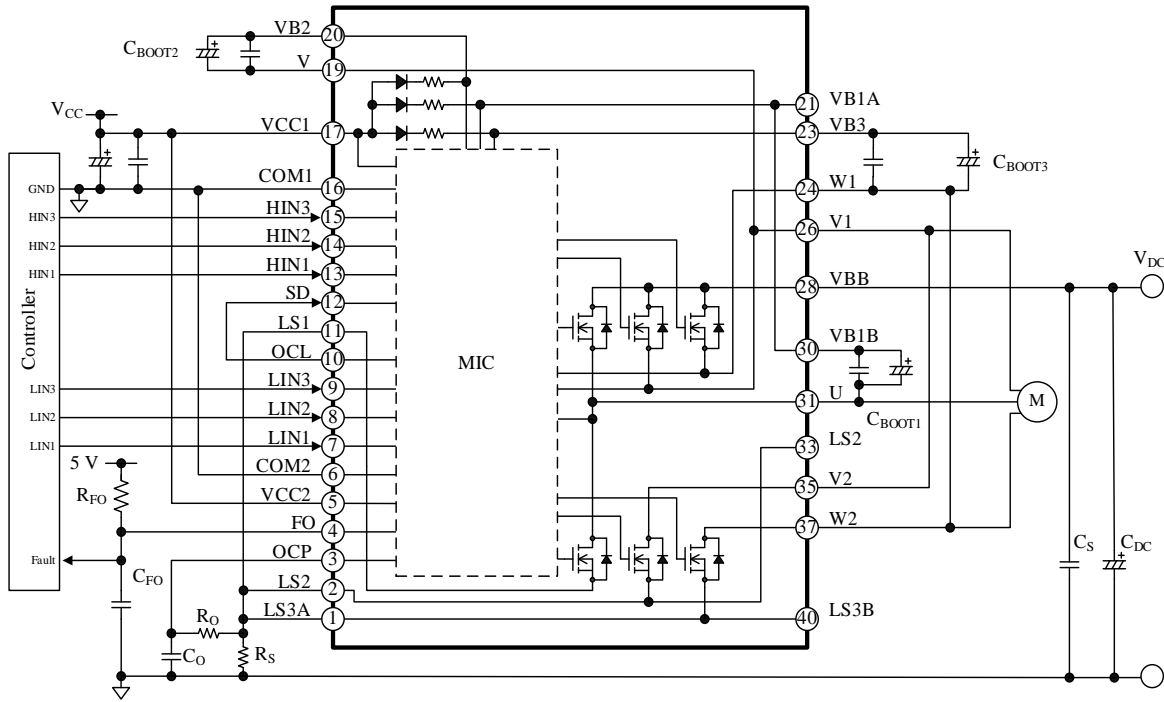


Figure 9-1. SIM681xM Typical Application Using a Single Shunt Resistor

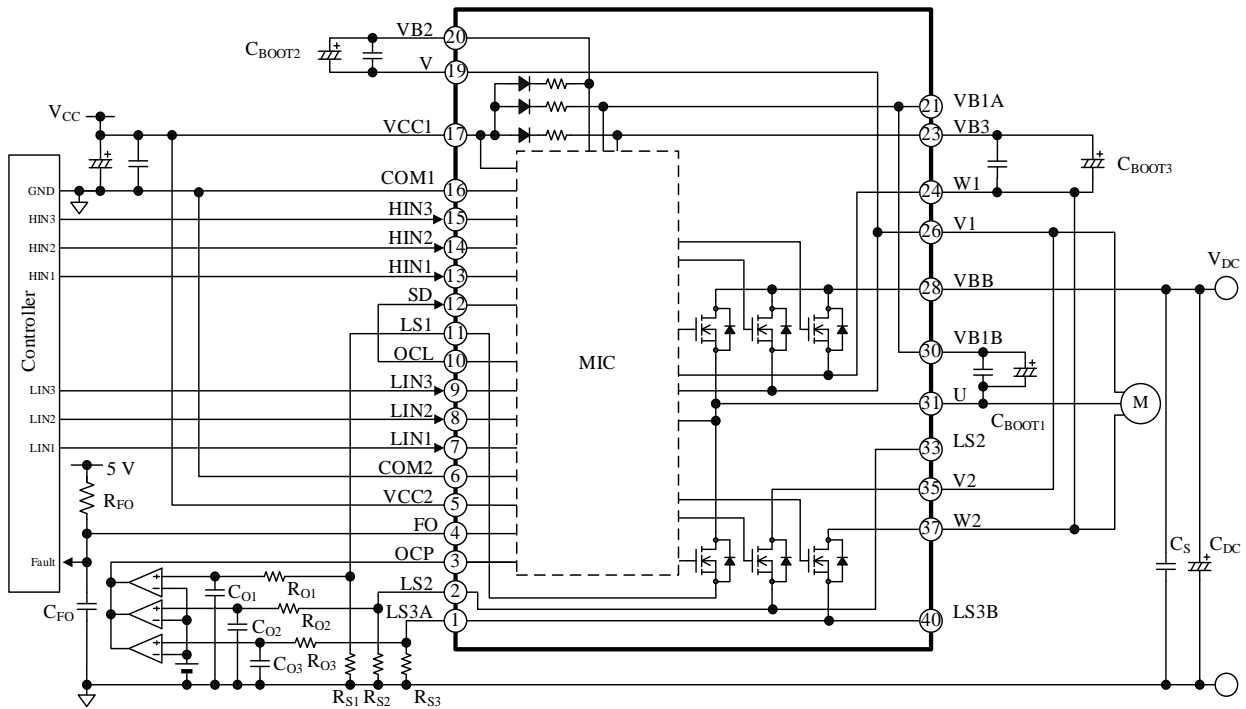
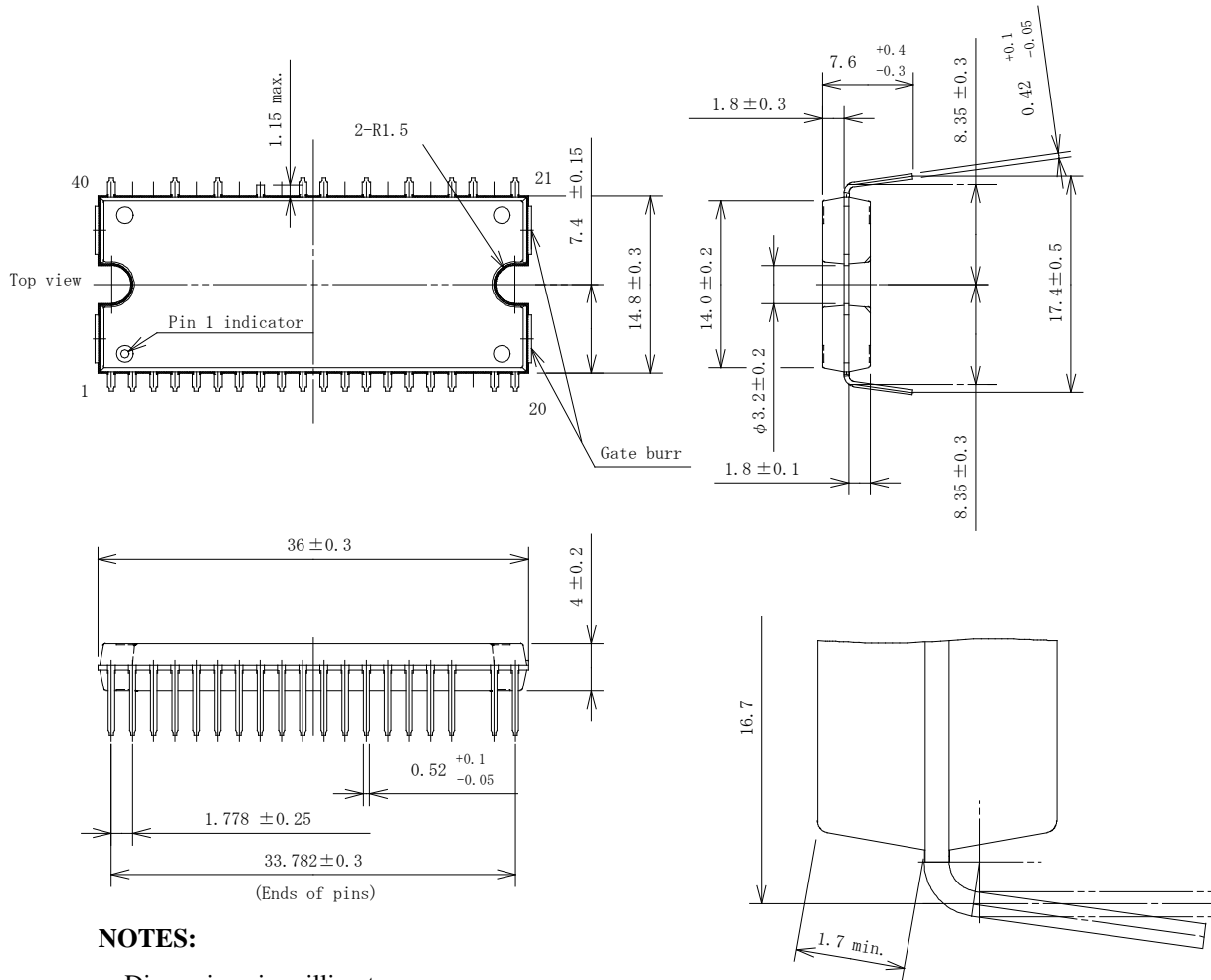


Figure 9-2. SIM681xM Typical Application Using Three Shunt Resistors



**10. Physical Dimensions**

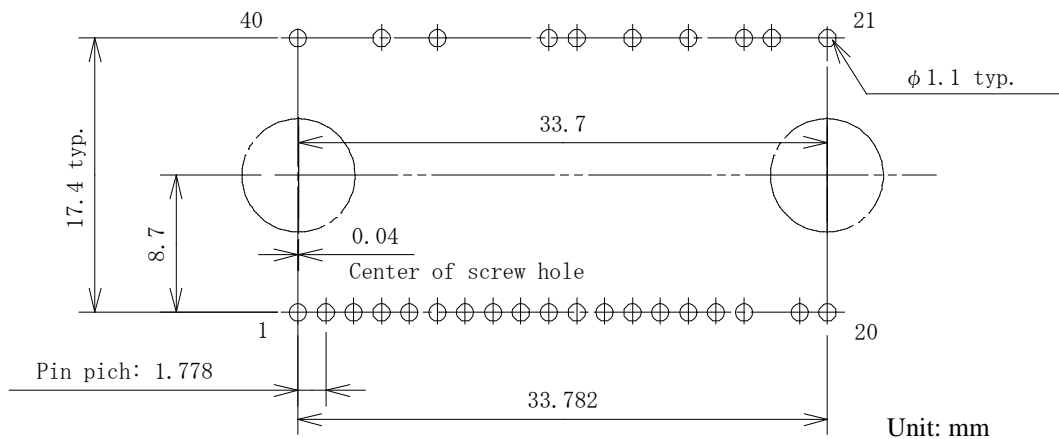
**• DIP40 Package**



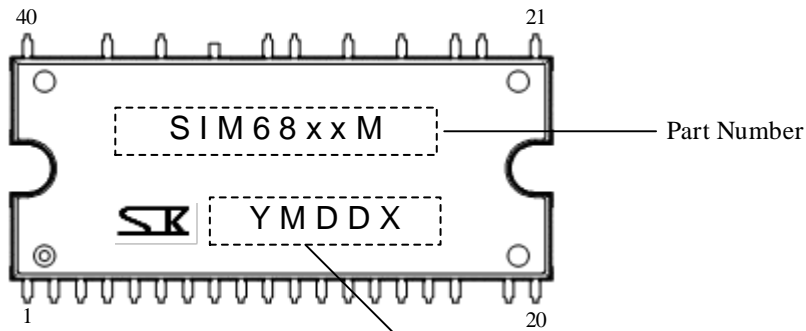
**NOTES:**

- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- The leads illustrated above are for reference only, and may not be actual states of being bent.
- Maximum gate burr height is 0.3 mm.

**• Reference Through Hole Size and Layout**



**11. Marking Diagram**



Lot Number:

Y is the last digit of the year of manufacture (0 to 9)

M is the month of the year (1 to 9, O, N, or D)

DD is the day of the month (01 to 31)

X is the control number

**12. Functional Descriptions**

Unless specifically noted, this section uses the following definitions:

- All the characteristic values given in this section are typical values.
- All the circuit diagrams listed in this section represent the type of IC that incorporates power MOSFETs. All the functional descriptions in this section are also applicable to the type of IC that incorporates IGBTs.
- For pin and peripheral component descriptions, this section employs a notation system that denotes a pin name with the arbitrary letter “x”, depending on context. Thus, “the VCCx pin” is used when referring to either or both of the VCC1 and VCC2 pins.
- The COM1 pin is always connected to the COM2 pin.

**12.1 Turning On and Off the IC**

The procedures listed below provide recommended startup and shutdown sequences. To turn on the IC properly, do not apply any voltage on the VBB, HINx, and LINx pins until the VCCx pin voltage has reached a stable state ( $V_{CC(ON)} \geq 12.5 \text{ V}$ ).

It is required to fully charge bootstrap capacitors,  $C_{BOOTx}$ , at startup (see Section 12.2.2).

To turn off the IC, set the HINx and LINx pins to logic low (or “L”), and then decrease the VCCx pin voltage.

**12.2 Pin Descriptions**

**12.2.1 U, V, V1, V2, W1, and W2**

These pins are the outputs of the three phases, and serve as the connection terminals to the 3-phase motor. The V1 and W1 pins must be connected to the V2 and W2 pins on a PCB, respectively.

The U, V (V1) and W1 pins are the grounds for the VB1A (VB1B), VB2, and VB3 pins.

The U, V and W1 pins are connected to the negative nodes of bootstrap capacitors,  $C_{BOOTx}$ . The V pin is internally connected to the V1 pin.

Since high voltages are applied to these output pins (U, V, V1, V2, W1, and W2), it is required to take measures for insulating as follows:

- Keep enough distance between the output pins and low-voltage traces.
- Coat the output pins with insulating resin.

**12.2.2 VB1A, VB1B, VB2, and VB3**

These pins are connected to bootstrap capacitors for the high-side floating supply.

In actual applications, use either of the VB1A or VB1B pin because they are internally connected. Voltages across the VBx and these output pins should be maintained within the recommended range (i.e., the Logic Supply Voltage,  $V_{BS}$ ) given in Section 2.

A bootstrap capacitor,  $C_{BOOTx}$ , should be connected in each of the traces between the VB1A (VB1B) and U pins, the VB2 and V pins, the VB3 and W1 (W2) pins.

For proper startup, turn on the low-side transistor first, then fully charge the bootstrap capacitor,  $C_{BOOTx}$ .

For the capacitance of the bootstrap capacitors,  $C_{BOOTx}$ , choose the values that satisfy Equations (1) and (2). Note that capacitance tolerance and DC bias characteristics must be taken into account when you choose appropriate values for  $C_{BOOTx}$ .

$$C_{BOOTx} (\mu\text{F}) > 800 \times t_{L(OFF)} \tag{1}$$

$$1 \mu\text{F} \leq C_{BOOTx} \leq 220 \mu\text{F} \tag{2}$$

In Equation (1), let  $t_{L(OFF)}$  be the maximum off-time of the low-side transistor (i.e., the non-charging time of  $C_{BOOTx}$ ), measured in seconds.

Even while the high-side transistor is off, voltage across the bootstrap capacitor keeps decreasing due to power dissipation in the IC. When the VBx pin voltage decreases to  $V_{BS(OFF)}$  or less, the high-side undervoltage lockout (UVLO\_VB) starts operating (see Section 12.3.3.1). Therefore, actual board checking should be done thoroughly to validate that voltage across the VBx pin maintains over 11.0 V ( $V_{BS} > V_{BS(OFF)}$ ) during a low-frequency operation such as a startup period.

As Figure 12-1 shows, a bootstrap diode,  $D_{BOOTx}$ , and a current-limiting resistor,  $R_{BOOTx}$ , are internally placed in series between the VCC1 and VBx pins.

Time constant for the charging time of  $C_{BOOTx}$ ,  $\tau$ , can be computed by Equation (3):

$$\tau = C_{BOOTx} \times R_{BOOTx} \tag{3}$$

where  $C_{BOOTx}$  is the optimized capacitance of the bootstrap capacitor, and  $R_{BOOTx}$  is the resistance of the current-limiting resistor ( $60 \Omega \pm 25\%$ ).

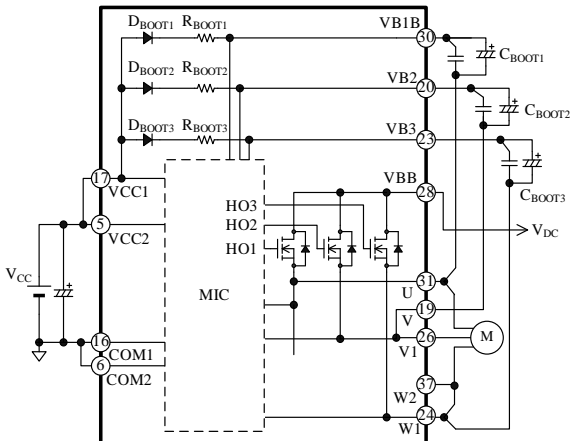


Figure 12-1. Bootstrap Circuit

Figure 12-2 shows an internal level-shifting circuit. A high-side output signal, HO<sub>x</sub>, is generated according to an input signal on the HIN<sub>x</sub> pin. When an input signal on the HIN<sub>x</sub> pin transits from low to high (rising edge), a “Set” signal is generated. When the HIN<sub>x</sub> input signal transits from high to low (falling edge), a “Reset” signal is generated. These two signals are then transmitted to the high-side by the level-shifting circuit and are input to the SR flip-flop circuit. Finally, the SR flip-flop circuit feeds an output signal, Q (i.e., HO<sub>x</sub>).

Figure 12-3 is a timing diagram describing how noise or other detrimental effects will improperly influence the level-shifting process. When a noise-induced rapid voltage drop between the VB<sub>x</sub> and output pins (U, V, or W1; hereafter “VB<sub>x</sub>-HS<sub>x</sub>”) occurs after the Set signal generation, the next Reset signal cannot be sent to the SR flip-flop circuit. And the state of an HO<sub>x</sub> signal stays logic high (or “H”) because the SR flip-flop does not respond. With the HO<sub>x</sub> state being held high (i.e., the high-side transistor is in an on-state), the next LIN<sub>x</sub> signal turns on the low-side transistor and causes a simultaneously-on condition, which may result in critical damage to the IC. To protect the VB<sub>x</sub> pin against such a noise effect, add a bootstrap capacitor, C<sub>BOOTx</sub>, in each phase. C<sub>BOOTx</sub> must be placed near the IC, and be connected between the VB<sub>x</sub> and HS<sub>x</sub> pins with a minimal length of traces. To use an electrolytic capacitor, add a 0.01 μF to 0.1 μF bypass capacitor, C<sub>Px</sub>, in parallel near these pins used for the same phase.

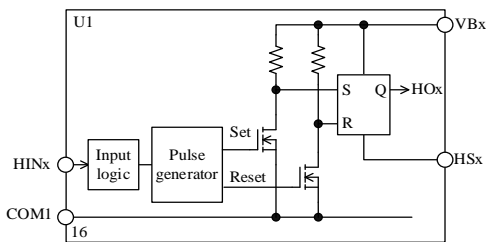


Figure 12-2. Internal Level-shifting Circuit

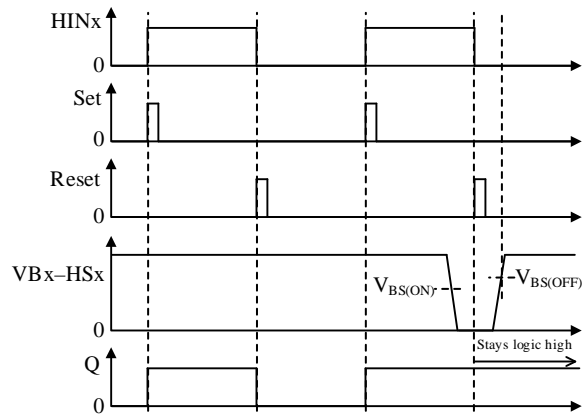


Figure 12-3. Waveforms at VB<sub>x</sub>-HS<sub>x</sub> Voltage Drop

### 12.2.3 VCC1 and VCC2

These are the power supply pins for the built-in control IC. The VCC1 and VCC2 pins must be externally connected on a PCB because they are not internally connected. To prevent malfunction induced by supply ripples or other factors, put a 0.01 μF to 0.1 μF ceramic capacitor, C<sub>VCC</sub>, near these pins. To prevent damage caused by surge voltages, put an 18 V to 20 V Zener diode, DZ, between the VCC<sub>x</sub> and COM<sub>x</sub> pins.

Voltages to be applied between the VCC<sub>x</sub> and COM<sub>x</sub> pins should be regulated within the recommended operational range of V<sub>CC</sub>, given in Section 2.

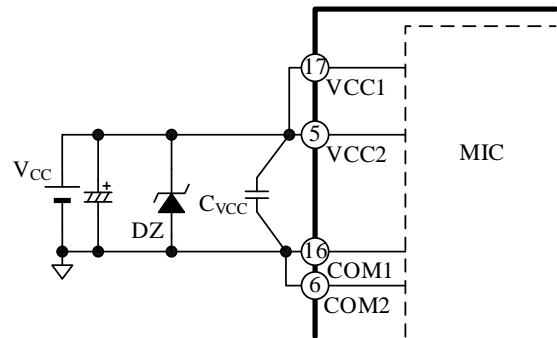


Figure 12-4. VCC<sub>x</sub> Pin Peripheral Circuit

### 12.2.4 COM1 and COM2

These are the logic ground pins for the built-in control IC. The COM1 and COM2 pins should be connected externally on a PCB because they are not internally connected. Varying electric potential of the logic ground can be a cause of improper operations. Therefore, connect the logic ground as close and short as possible to shunt resistors, R<sub>Sx</sub>, at a single-point ground (or star ground) which is separated from the power ground (see Figure 12-5).

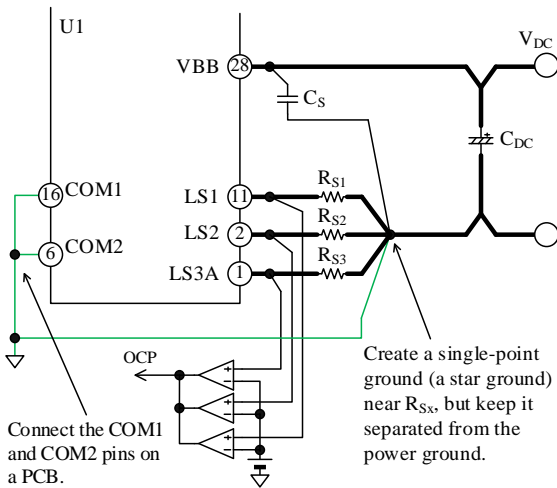


Figure 12-5. Connections to Logic Ground

### 12.2.5 HIN1, HIN2, and HIN3; LIN1, LIN2, and LIN3

These are the input pins of the internal motor drivers for each phase. The HINx pin acts as a high-side controller; the LINx pin acts as a low-side controller.

Figure 12-6 shows an internal circuit diagram of the HINx or LINx pin. This is a CMOS Schmitt trigger circuit with a built-in 20 kΩ pull-down resistor, and its input logic is active high.

Input signals across the HINx–COMx and the LINx–COMx pins in each phase should be set within the ranges provided in Table 12-1, below. Note that dead time setting must be done for HINx and LINx signals because the IC does not have a dead time generator.

The higher PWM carrier frequency rises, the more switching loss increases. Hence, the PWM carrier frequency must be set so that operational case temperatures and junction temperatures have sufficient margins against the absolute maximum ranges, specified in Section 1.

If the signals from the microcontroller become unstable, the IC may result in malfunctions. To avoid this event, the outputs from the microcontroller output line should not be high impedance.

Also, if the traces from the microcontroller to the HINx or LINx pin (or both) are too long, the traces may be interfered by noise. Therefore, it is recommended to add an additional filter or a pull-down resistor near the HINx or LINx pin as needed (see Figure 12-7).

Here are filter circuit constants for reference:

- $R_{IN1x}$ : 33 Ω to 100 Ω
- $R_{IN2x}$ : 1 kΩ to 10 kΩ
- $C_{INx}$ : 100 pF to 1000 pF

Care should be taken when adding  $R_{IN1x}$  and  $R_{IN2x}$  to the traces. When they are connected to each other, the input voltage of the HINx and LINx pins becomes

slightly lower than the output voltage of the microcontroller.

Table 12-1. Input Signals for HINx and LINx Pins

| Parameter             | High Level Signal                    | Low Level Signal                     |
|-----------------------|--------------------------------------|--------------------------------------|
| Input Voltage         | $3\text{ V} < V_{IN} < 5.5\text{ V}$ | $0\text{ V} < V_{IN} < 0.5\text{ V}$ |
| Input Pulse Width     | $\geq 0.5\ \mu\text{s}$              | $\geq 0.5\ \mu\text{s}$              |
| PWM Carrier Frequency | $\leq 20\text{ kHz}$                 |                                      |
| Dead Time             | $\geq 1.5\ \mu\text{s}$              |                                      |

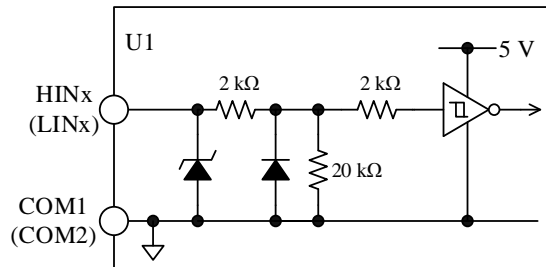


Figure 12-6. Internal Circuit Diagram of HINx or LINx Pin

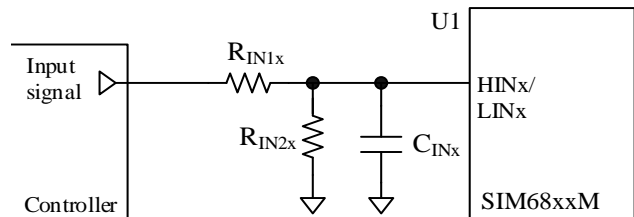


Figure 12-7. Filter Circuit for HINx or LINx Pin

### 12.2.6 VBB

This is the input pin for the main supply voltage, i.e., the positive DC bus. All of the IGBT collectors (power MOSFET drains) of the high-side are connected to this pin. Voltages between the VBB and COMx pins should be set within the recommended range of the main supply voltage,  $V_{DC}$ , given in Section 2.

To suppress surge voltages, put a 0.01 μF to 0.1 μF bypass capacitor,  $C_S$ , near the VBB pin and an electrolytic capacitor,  $C_{DC}$ , with a minimal length of PCB traces to the VBB pin.

12.2.7 LS1, LS2, LS3A, and LS3B

These are the emitter (source) pins of the low-side IGBTs (power MOSFETs). For current detection, the LS1, LS2, and LS3 (LS3B) pins should be connected externally on a PCB via shunt resistors,  $R_{Sx}$ , to the COMx pin. In actual applications, use either of the LS3A or LS3B pin because they are internally connected.

When connecting a shunt resistor, place it as near as possible to the IC with a minimum length of traces to the LSx and COMx pins. Otherwise, malfunction may occur because a longer circuit trace increases its inductance and thus increases its susceptibility to improper operations. In applications where long PCB traces are required, add a fast recovery diode,  $D_{RSx}$ , between the LSx and COMx pins in order to prevent the IC from malfunctioning.

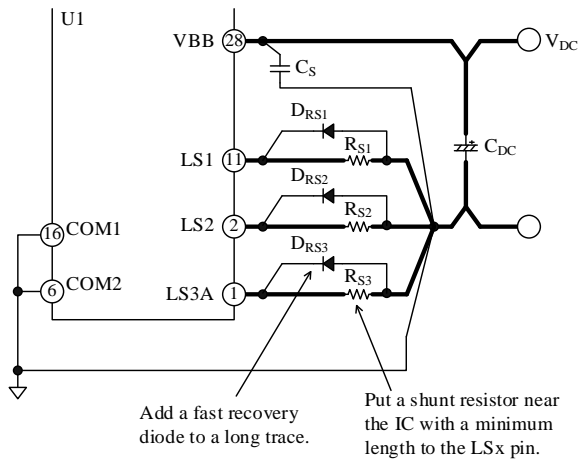


Figure 12-8. Connections to LSx Pin

12.2.8 OCP and OCL

The OCP pin serves as the input for the overcurrent protections which monitor the currents going through the output transistors.

In normal operation, the OCL pin logic level is low. In case one or more of the protections listed below are activated by an OCP input signal, the OCL pin logic level becomes high. If the OCL pin is connected to the SD pin so that the SD pin will respond to the OCL input signal, the high-side transistors can be turned off when the protections (OCP and OCL) are activated.

• Overcurrent Limit (OCL)

When the OCP pin voltage exceeds the Current Limit Reference Voltage,  $V_{LIM}$ , the OCL pin logic level becomes high. While the OCL is in working, the output transistors operate according to an input signal (HINx or LINx). If the OCL pin is connected to the SD pin, the high-side transistors can be turned off. For a more detailed OCL description, see Section 12.3.4.

• Overcurrent Protection (OCP)

This function detects inrush currents larger than those detected by the OCL. When the OCP pin voltage exceeds the OCP Threshold Voltage,  $V_{TRIP}$ , the IC operates as follows: the OCL pin = logic high, the low-side transistors = off, the FO pin = logic low.

In addition, if the OCL pin is connected to the SD pin, the high-side transistors can be turned off. For a more detailed OCP description, see Section 12.3.5.

12.2.9 SD

When a 5 V or 3.3 V signal is input to the SD pin, the high-side transistors turn off independently of any HINx signals. This is because the SD pin does not respond to a pulse shorter than an internal filter of 3.3  $\mu$ s (typ.).

The SD-OCL pin connection, as described in Section 12.2.8, allows the IC to turn off the high-side transistors at OCL or OCP activation. Also, inputting the inverted signal of the FO pin to the SD pin permits all the high- and low-side transistors to turn off, when the IC detects an abnormal condition (i.e., some or all of the protections such as TSD, OCP, and UVLO are activated).

12.2.10 FO

This pin operates as the fault signal output and the low-side shutdown signal input. Sections 12.3.1 and 12.3.2 explain the two functions in detail, respectively. Figure 12-9 illustrates an internal circuit diagram of the FO pin and its peripheral circuit.

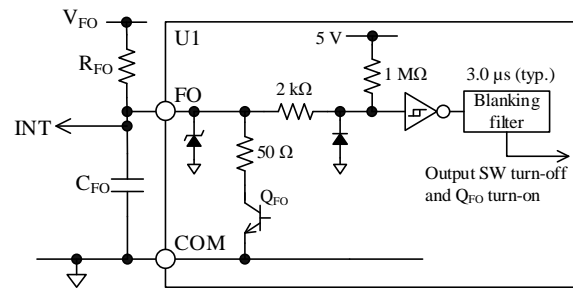


Figure 12-9. Internal Circuit Diagram of FO Pin and Its Peripheral Circuit

Because of its open-collector nature, the FO pin should be tied by a pull-up resistor,  $R_{FO}$ , to the external power supply. The external power supply voltage (i.e., the FO Pin Pull-up Voltage,  $V_{FO}$ ) should range from 3.0 V to 5.5 V. When the pull-up resistor,  $R_{FO}$ , has a too small resistance, the FO pin voltage at fault signal output becomes high due to the saturation voltage drop of a built-in transistor,  $Q_{FO}$ . Therefore, it is recommended to use a 3.3 k $\Omega$  to 10 k $\Omega$  pull-up resistor. To suppress noise, add a filter capacitor,  $C_{FO}$ , near the IC with minimizing a trace length between the FO and COMx pins.



To avoid the repetition of OCP activations, the external microcontroller must shut off any input signals to the IC within an OCP hold time,  $t_p$ , which occurs after the internal transistor ( $Q_{FO}$ ) turn-on.  $t_p$  is 15  $\mu s$  where minimum values of thermal characteristics are taken into account. (For more details, see Section 12.3.5.) Our recommendation is to use a 0.001  $\mu F$  to 0.01  $\mu F$  filter capacitor.

**12.3 Protection Functions**

This section describes the various protection circuits provided in the SIM6800M series. The protection circuits include the undervoltage lockout for power supplies (UVLO), the overcurrent protection (OCP), and the thermal shutdown (TSD). In case one or more of these protection circuits are activated, the FO pin outputs a fault signal; as a result, the external microcontroller can stop the operations of the three phases by receiving the fault signal. The external microcontroller can also shut down IC operations by inputting a fault signal to the FO pin.

In the following functional descriptions, “HOx” denotes a gate input signal on the high-side transistor, whereas “LOx” denotes a gate input signal on the low-side transistor..

**12.3.1 Fault Signal Output**

In case one or more of the following protections are actuated, an internal transistor,  $Q_{FO}$ , turns on, then the FO pin becomes logic low ( $\leq 0.5 V$ ).

- 1) Low-side undervoltage lockout (UVLO\_VCC)
- 2) Overcurrent protection (OCP)
- 3) Thermal shutdown (TSD)

While the FO pin is in the low state, all the low-side transistors turn off. In normal operation, the FO pin outputs a high signal of 5 V. The fault signal output time of the FO pin at OCP activation is the OCP hold time ( $t_p$ ) of 25  $\mu s$  (typ.), fixed by a built-in feature of the IC itself (see Section 12.3.5). The external microcontroller receives the fault signals with its interrupt pin (INT), and must be programmed to put the HINx and LINx pins to logic low within the predetermined OCP hold time,  $t_p$ .

**12.3.2 Shutdown Signal Input**

The FO pin also acts as the input pin of shutdown signals. When the FO pin becomes logic low, all the low-side transistors turn off.

The voltages and pulse widths of the shutdown signals to be applied between the FO and COMx pins are listed in Table 12-2.

Table 12-2. Shutdown Signals

| Parameter         | High Level Signal      | Low Level Signal       |
|-------------------|------------------------|------------------------|
| Input Voltage     | $3 V < V_{IN} < 5.5 V$ | $0 V < V_{IN} < 0.5 V$ |
| Input Pulse Width | —                      | $\geq 6 \mu s$         |

**12.3.3 Undervoltage Lockout for Power Supply (UVLO)**

In case the gate-driving voltages of the output transistors decrease, their steady-state power dissipations increase. This overheating condition may cause permanent damage to the IC in the worst case. To prevent this event, the SIM6800M series has the undervoltage lockout (UVLO) circuits for both of the high- and low-side power supplies in the monolithic IC (MIC).

**12.3.3.1. Undervoltage Lockout for High-side Power Supply (UVLO\_VB)**

Figure 12-10 shows operational waveforms of the undervoltage lockout for high-side power supply (i.e., UVLO\_VB).

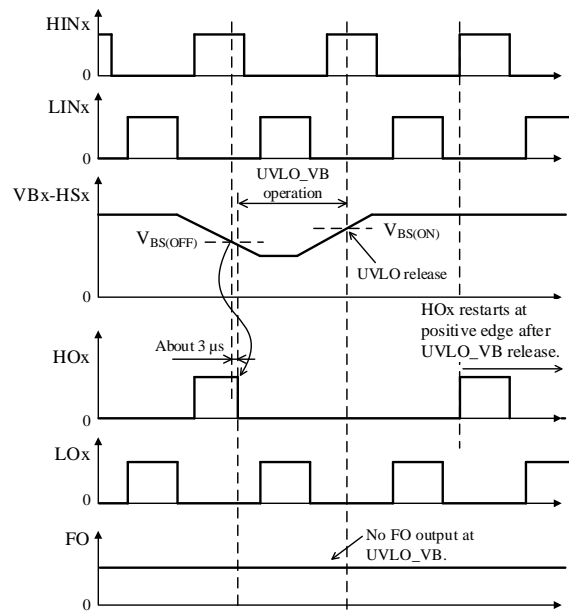


Figure 12-10. UVLO\_VB Operational Waveforms

When the voltage between the VBx and output pins (VBx–HSx shown in Figure 12-10) decreases to the Logic Operation Stop Voltage ( $V_{BS(OFF)}$ , 10.0 V) or less, the UVLO\_VB circuit in the corresponding phase gets

activated and sets an HOx signal to logic low. When the voltage between the VBx and HSx pins increases to the Logic Operation Start Voltage ( $V_{BS(ON)}$ , 10.5 V) or more, the IC releases the UVLO\_VB operation. Then, the HOx signal becomes logic high at the rising edge of the first input command after the UVLO\_VB release. Any fault signals are not output from the FO pin during the UVLO\_VB operation. In addition, the VBx pin has an internal UVLO\_VB filter of about 3  $\mu$ s, in order to prevent noise-induced malfunctions.

**12.3.3.2. Undervoltage Lockout for Low-side Power Supply (UVLO\_VCC)**

Figure 12-11 shows operational waveforms of the undervoltage lockout for low-side power supply (i.e., UVLO\_VCC).

When the VCC2 pin voltage decreases to the Logic Operation Stop Voltage ( $V_{CC(OFF)}$ , 11.0 V) or less, the UVLO\_VCC circuit in the corresponding phase gets activated and sets both of HOx and LOx signals to logic low. When the VCC2 pin voltage increases to the Logic Operation Start Voltage ( $V_{CC(ON)}$ , 11.5 V) or more, the IC releases the UVLO\_VCC operation. Then, the IC resumes the following transmissions: an LOx signal according to an LINx pin input command; an HOx signal according to the rising edge of the first HINx pin input command after the UVLO\_VCC release. During the UVLO\_VCC operation, the FO pin becomes logic low and sends fault signals. In addition, the VCC2 pin has an internal UVLO\_VCC filter of about 3  $\mu$ s, in order to prevent noise-induced malfunctions.

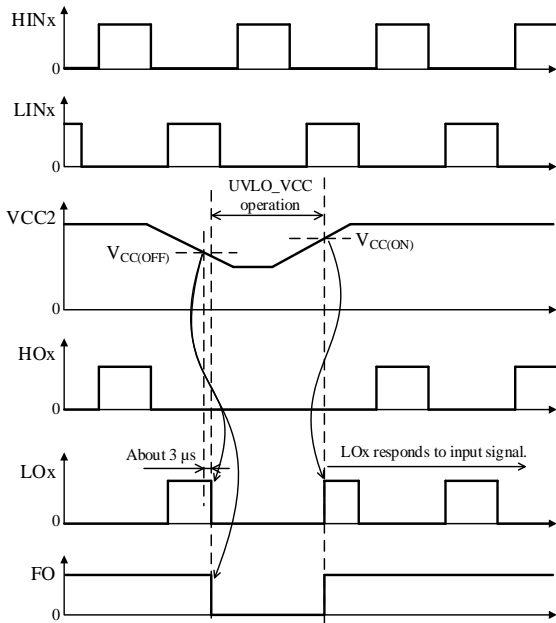


Figure 12-11. UVLO\_VCC Operational Waveforms

**12.3.4 Overcurrent Limit (OCL)**

The overcurrent limit (OCL) is a protection against relatively low overcurrent conditions. Figure 12-12 shows an internal circuit of the OCP and OCL pins; Figure 12-13 shows OCL operational waveforms.

When the OCP pin voltage increases to the Current Limit Reference Voltage ( $V_{LIM}$ , 0.6500 V) or more, and remains in this condition for a period of the Current Limit Blanking Time ( $t_{BK(OCP)}$ , 2  $\mu$ s) or longer, the OCL circuit is activated. Then, the OCL pin goes logic high.

During the OCL operation, the gate logic levels of the low-side transistors respond to an input command on the LINx pin. To turn off the high-side transistors during the OCL operation, connect the OCL and SD pins on a PCB. The SD pin has an internal filter of about 3.3  $\mu$ s (typ.).

When the OCP pin voltage falls below  $V_{LIM}$  (0.6500 V), the OCL pin logic level becomes low. After the OCL pin logic has become low, the high-side transistors remain turned off until the first low-to-high transition on an HINx input signal occurs (i.e., edge-triggered).

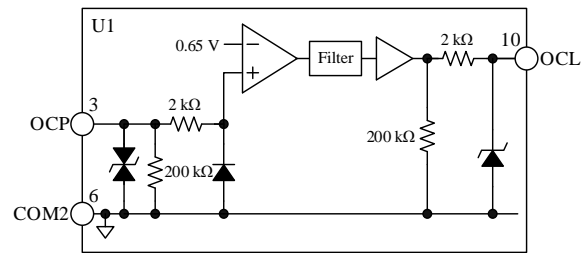


Figure 12-12. Internal Circuit of OCP and OCL Pins

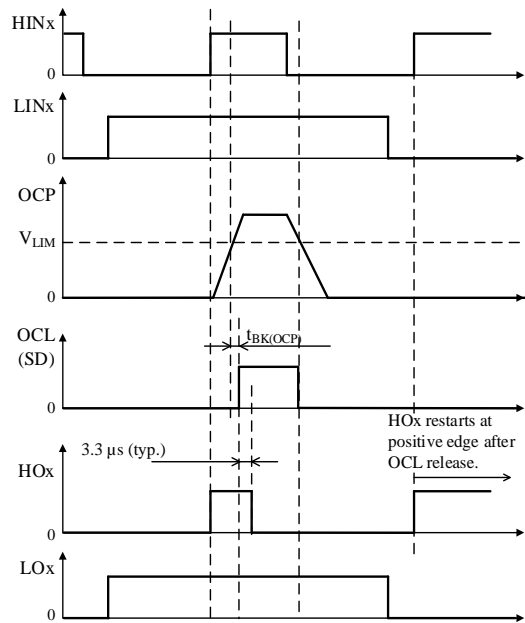


Figure 12-13. OCL Operational Waveforms (OCL = SD)



### 12.3.5 Overcurrent Protection (OCP)

The overcurrent protection (OCP) is a protection against large inrush currents (i.e., high di/dt). Figure 12-14 is an internal circuit diagram describing the OCP pin and its peripheral circuit.

The OCP pin detects overcurrents with voltage across external shunt resistors,  $R_{Sx}$ . Because the OCP pin is internally pulled down, the OCP pin voltage increases proportionally to a rise in the currents running through the shunt resistors,  $R_{Sx}$ .

Figure 12-15 is a timing chart that represents operation waveforms during OCP operation. When the OCP pin voltage increases to the OCP Threshold Voltage ( $V_{TRIP}$ , 1.0 V) or more, and remains in this condition for a period of the OCP Blanking Time ( $t_{BK}$ , 2  $\mu$ s) or longer, the OCP circuit is activated. The enabled OCP circuit shuts off the low-side transistors and puts the FO pin into a low state. Then, output current decreases as a result of the output transistors turn-off. Even if the OCP pin voltage falls below  $V_{TRIP}$ , the IC holds the FO pin in the low state for a fixed OCP hold time ( $t_p$ ) of 25  $\mu$ s (typ.). Then, the output transistors operate according to input signals.

The OCP is used for detecting abnormal conditions, such as an output transistor shorted. In case short-circuit conditions occur repeatedly, the output transistors can be destroyed. To prevent such event, motor operation must be controlled by the external microcontroller so that it can immediately stop the motor when fault signals are detected.

For proper shunt resistor setting, your application must meet the following:

- Use the shunt resistor that has a recommended resistance,  $R_{Sx}$  (see Section 2).
- Set the OCP pin input voltage to vary within the rated OCP pin voltages,  $V_{OCP}$  (see Section 1).
- Keep the current through the output transistors below the rated output current (pulse),  $I_{OP}$  (see Section 1).

It is required to use a resistor with low internal inductance because high-frequency switching current will flow through the shunt resistors,  $R_{Sx}$ . In addition, choose a resistor with allowable power dissipation according to your application.

When you connect a CR filter (i.e., a pair of a filter resistor,  $R_O$ , and a filter capacitor,  $C_O$ ) to the OCP pin, care should be taken in setting the time constants of  $R_O$  and  $C_O$ . The larger the time constant, the longer the time that the OCP pin voltage rises to  $V_{TRIP}$ . And this may cause permanent damage to the transistors. Consequently, a propagation delay of the IC must be taken into account when you determine the time constants. For  $R_O$  and  $C_O$ , their time constants must be set to the values listed in Table 12-3. And place  $C_O$  as close as possible to the IC with minimizing a trace length between the OCP and COMx pins.

Note that overcurrents are undetectable when one or more of the U, V/V1/V2, and W1/W2 pins or their traces

are shorted to ground (ground fault). In case any of these pins falls into a state of ground fault, the output transistors may be destroyed.

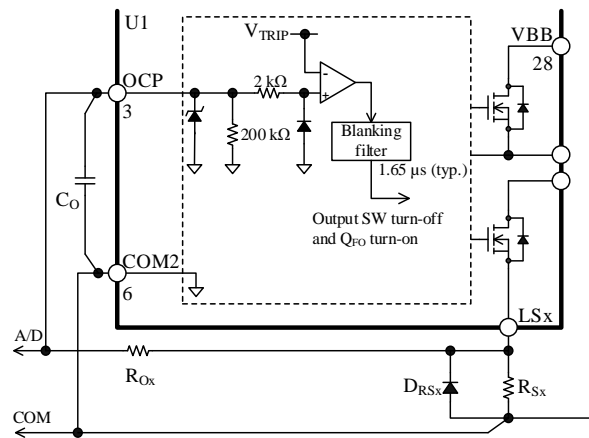


Figure 12-14. Internal Circuit Diagram of OCP Pin and Its Peripheral Circuit

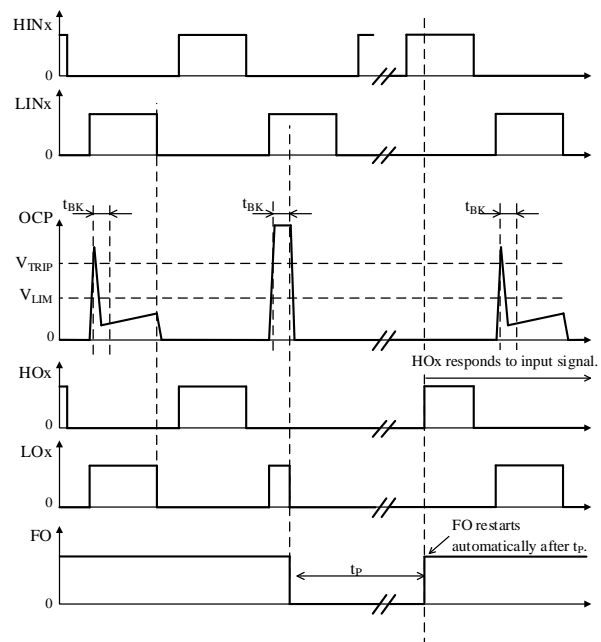


Figure 12-15. OCP Operational Waveforms

Table 12-3. Reference Time Constants for CR Filter

| Part Number        | Time Constant ( $\mu$ s) |
|--------------------|--------------------------|
| SIM681x            | $\leq 2$                 |
| SIM682x<br>SIM688x | $\leq 0.2$               |

12.3.6 Thermal Shutdown (TSD)

The SIM6800M series incorporates a thermal shutdown (TSD) circuit. Figure 12-16 shows TSD operational waveforms. In case of overheating (e.g., increased power dissipation due to overload, a rise in ambient temperature at the device, etc.), the IC shuts down the low-side output transistors.

The TSD circuit in the monolithic IC (MIC) monitors temperatures (see Section 7). When the temperature of the monolithic IC (MIC) exceeds the TSD Operating Temperature ( $T_{DH}$ , 150 °C), the TSD circuit is activated.

When the temperature of the monolithic IC (MIC) decreases to the TSD Releasing Temperature ( $T_{DL}$ , 120 °C) or less, the shutdown condition is released. The output transistors then resume operating according to input signals.

During the TSD operation, the FO pin becomes logic low and transmits fault signals.

Note that junction temperatures of the output transistors themselves are not monitored; therefore, do not use the TSD function as an overtemperature prevention for the output transistors.

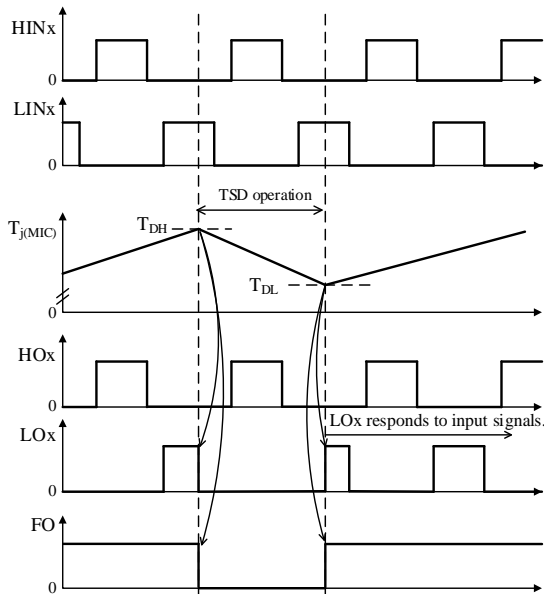


Figure 12-16. TSD Operational Waveforms

13. Design Notes

13.1 PCB Pattern Layout

Figure 13-1 shows a schematic diagram of a motor driver circuit. The motor driver circuit consists of current paths having high frequencies and high voltages, which also bring about negative influences on IC operation, noise interference, and power dissipation. Therefore, PCB trace layouts and component placements play an important role in circuit designing.

Current loops, which have high frequencies and high voltages, should be as small and wide as possible, in order to maintain a low-impedance state. In addition, ground traces should be as wide and short as possible so that radiated EMI levels can be reduced.

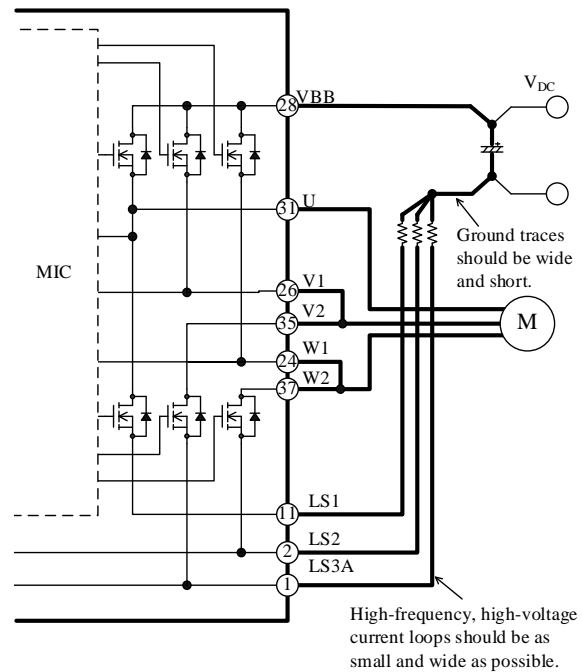


Figure 13-1. High-frequency, High-voltage Current Paths

13.2 Considerations in Heatsink Mounting

The following are the key considerations and the guidelines for mounting a heatsink:

- It is recommended to use a pair of a metric screw of M2.5 and a plain washer of 6.0 mm ( $\phi$ ). To tighten the screws, use a torque screwdriver. Tighten the two screws firstly up to about 30% of the maximum screw torque, then finally up to 100% of the prescribed maximum screw torque. Perform appropriate tightening within the range of screw torque defined in Section 4.



**14. Calculating Power Losses and Estimating Junction Temperatures**

This section describes the procedures to calculate power losses in switching transistors, and to estimate a junction temperature. Note that the descriptions listed here are applicable to the SIM6800M series, which is controlled by a 3-phase sine-wave PWM driving strategy.

For quick and easy references, we offer calculation support tools online. Please visit our website to find out more.

- DT0026: SIM681xM Calculation Tool  
[http://www.semicon.sanken-ele.co.jp/en/calc-tool/sim681xm\\_caltool\\_en.html](http://www.semicon.sanken-ele.co.jp/en/calc-tool/sim681xm_caltool_en.html)
- DT0027: SIM682xM and SIM6880M Calculation Tool  
[http://www.semicon.sanken-ele.co.jp/en/calc-tool/sim682xm\\_caltool\\_en.html](http://www.semicon.sanken-ele.co.jp/en/calc-tool/sim682xm_caltool_en.html)

**14.1 IGBT**

Total power loss in an IGBT can be obtained by taking the sum of steady-state loss,  $P_{ON}$ , and switching loss,  $P_{SW}$ . The following subsections contain the mathematical procedures to calculate these losses ( $P_{ON}$  and  $P_{SW}$ ) and the junction temperature of all IGBTs operating.

**14.1.1 IGBT Steady-state Loss,  $P_{ON}$**

Steady-state loss in an IGBT can be computed by using the  $V_{CE(SAT)}$  vs.  $I_C$  curves, listed in Section 15.3.1. As expressed by the curves in Figure 14-1, linear approximations at a range the  $I_C$  is actually used are obtained by:  $V_{CE(SAT)} = \alpha \times I_C + \beta$ . The values gained by the above calculation are then applied as parameters in Equation (4), below. Hence, the equation to obtain the IGBT steady-state loss,  $P_{ON}$ , is:

$$\begin{aligned}
 P_{ON} &= \frac{1}{2\pi} \int_0^\pi V_{CE(SAT)}(\varphi) \times I_C(\varphi) \times DT \times d\varphi \\
 &= \frac{1}{2} \alpha \left( \frac{1}{2} + \frac{4}{3\pi} M \times \cos\theta \right) I_M^2 \\
 &\quad + \frac{\sqrt{2}}{\pi} \beta \left( \frac{1}{2} + \frac{\pi}{8} M \times \cos\theta \right) I_M . \tag{4}
 \end{aligned}$$

Where:

- $V_{CE(SAT)}$  is the collector-to-emitter saturation voltage of the IGBT (V),
- $I_C$  is the collector current of the IGBT (A),
- DT is the duty cycle, which is given by

$$DT = \frac{1 + M \times \sin(\varphi + \theta)}{2},$$

M is the modulation index (0 to 1),  
 $\cos\theta$  is the motor power factor (0 to 1),  
 $I_M$  is the effective motor current (A),  
 $\alpha$  is the slope of the linear approximation in the  $V_{CE(SAT)}$  vs.  $I_C$  curve, and  
 $\beta$  is the intercept of the linear approximation in the  $V_{CE(SAT)}$  vs.  $I_C$  curve.

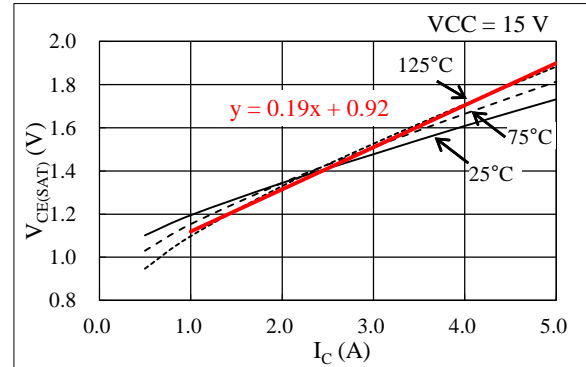


Figure 14-1. Linear Approximate Equation of  $V_{CE(SAT)}$  vs.  $I_C$  Curve

**14.1.2 IGBT Switching Loss,  $P_{SW}$**

Switching loss in an IGBT can be calculated by Equation (5), letting  $I_M$  be the effective current value of the motor:

$$P_{SW} = \frac{\sqrt{2}}{\pi} \times f_c \times \alpha_E \times I_M \times \frac{V_{DC}}{300} . \tag{5}$$

Where:

- $f_c$  is the PWM carrier frequency (Hz),
- $V_{DC}$  is the main power supply voltage (V), i.e., the VBB pin input voltage, and
- $\alpha_E$  is the slope of the switching loss curve (see Section 15.3.2).

**14.1.3 Estimating Junction Temperature of IGBT**

The junction temperature of all IGBTs operating,  $T_J$ , can be estimated with Equation (6):

$$T_J = R_{(J-C)Q} \times \{(P_{ON} + P_{SW}) \times 6\} + T_C . \tag{6}$$

Where:

- $R_{(J-C)Q}$  is the junction-to-case thermal resistance ( $^{\circ}C/W$ ) of all the IGBTs operating, and
- $T_C$  is the case temperature ( $^{\circ}C$ ), measured at the point defined in Figure 3-1.

## 14.2 Power MOSFET

Total power loss in a power MOSFET can be obtained by taking the sum of the following losses: steady-state loss,  $P_{RON}$ ; switching loss,  $P_{SW}$ ; the steady-state loss of a body diode,  $P_{SD}$ . In the calculation procedure we offer, the recovery loss of a body diode,  $P_{RR}$ , is considered negligibly small compared with the ratios of other losses.

The following subsections contain the mathematical procedures to calculate these losses ( $P_{RON}$ ,  $P_{SW}$ , and  $P_{SD}$ ) and the junction temperature of all power MOSFETs operating.

### 14.2.1 Power MOSFET Steady-state Loss, $P_{RON}$

Steady-state loss in a power MOSFET can be computed by using the  $R_{DS(ON)}$  vs.  $I_D$  curves, listed in Section 15.3.1. As expressed by the curves in Figure 14-2, linear approximations at a range the  $I_D$  is actually used are obtained by:  $R_{DS(ON)} = \alpha \times I_D + \beta$ . The values gained by the above calculation are then applied as parameters in Equation (7), below. Hence, the equation to obtain the power MOSFET steady-state loss,  $P_{RON}$ , is:

$$\begin{aligned}
 P_{RON} &= \frac{1}{2\pi} \int_0^\pi I_D(\varphi)^2 \times R_{DS(ON)}(\varphi) \times DT \times d\varphi \\
 &= 2\sqrt{2}\alpha \left( \frac{1}{3\pi} + \frac{3}{32} M \times \cos\theta \right) I_M^3 \\
 &\quad + 2\beta \left( \frac{1}{8} + \frac{1}{3\pi} M \times \cos\theta \right) I_M^2.
 \end{aligned} \tag{7}$$

Where:

- $I_D$  is the drain current of the power MOSFET (A),
- $R_{DS(ON)}$  is the drain-to-source on-resistance of the power MOSFET ( $\Omega$ ),
- $DT$  is the duty cycle, which is given by

$$DT = \frac{1 + M \times \sin(\varphi + \theta)}{2},$$

- $M$  is the modulation index (0 to 1),
- $\cos\theta$  is the motor power factor (0 to 1),
- $I_M$  is the effective motor current (A),
- $\alpha$  is the slope of the linear approximation in the  $R_{DS(ON)}$  vs.  $I_D$  curve, and
- $\beta$  is the intercept of the linear approximation in the  $R_{DS(ON)}$  vs.  $I_D$  curve.

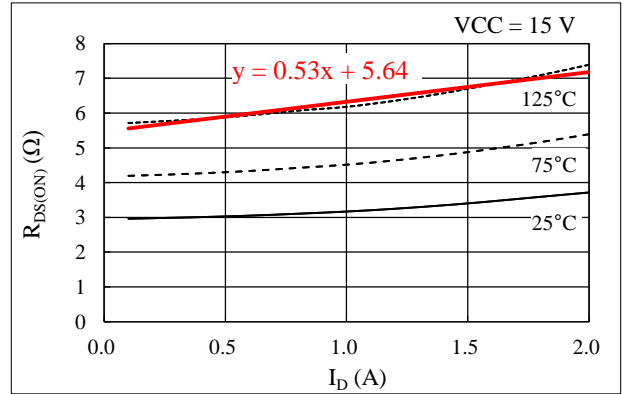


Figure 14-2. Linear Approximate Equation of  $R_{DS(ON)}$  vs.  $I_D$  Curve

### 14.2.2 Power MOSFET Switching Loss, $P_{SW}$

Switching loss in a power MOSFET can be calculated by Equation (8), letting  $I_M$  be the effective current value of the motor:

$$P_{SW} = \frac{\sqrt{2}}{\pi} \times f_C \times \alpha_E \times I_M \times \frac{V_{DC}}{300}. \tag{8}$$

Where:

- $f_C$  is the PWM carrier frequency (Hz),
- $V_{DC}$  is the main power supply voltage (V), i.e., the VBB pin input voltage, and
- $\alpha_E$  is the slope of the switching loss curve (see Section 15.3.2).

### 14.2.3 Body Diode Steady-state Loss, $P_{SD}$

Steady-state loss in the body diode of a power MOSFET can be computed by using the  $V_{SD}$  vs.  $I_{SD}$  curves, listed in Section 15.3.1. As expressed by the curves in Figure 14-3, linear approximations at a range the  $I_{SD}$  is actually used are obtained by:  $V_{SD} = \alpha \times I_{SD} + \beta$ . The values gained by the above calculation are then applied as parameters in Equation (9), below. Hence, the equation to obtain the body diode steady-state loss,  $P_{SD}$ , is:

$$\begin{aligned}
 P_{SD} &= \frac{1}{2\pi} \int_0^\pi V_{SD}(\varphi) \times I_{SD}(\varphi) \times (1 - DT) \times d\varphi \\
 &= \frac{1}{2} \alpha \left( \frac{1}{2} - \frac{4}{3\pi} M \times \cos\theta \right) I_M^2 \\
 &\quad + \frac{\sqrt{2}}{\pi} \beta \left( \frac{1}{2} - \frac{\pi}{8} M \times \cos\theta \right) I_M.
 \end{aligned} \tag{9}$$

Where:

$V_{SD}$  is the source-to-drain diode forward voltage of the power MOSFET (V),

$I_{SD}$  is the source-to-drain diode forward current of the power MOSFET (A),

DT is the duty cycle, which is given by

$$DT = \frac{1 + M \times \sin(\varphi + \theta)}{2},$$

M is the modulation index (0 to 1),

$\cos\theta$  is the motor power factor (0 to 1),

$I_M$  is the effective motor current (A),

$\alpha$  is the slope of the linear approximation in the  $V_{SD}$  vs.  $I_{SD}$  curve, and

$\beta$  is the intercept of the linear approximation in the  $V_{SD}$  vs.  $I_{SD}$  curve.

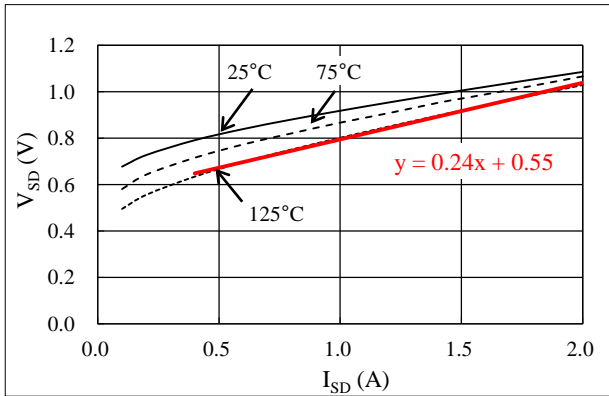


Figure 14-3. Linear Approximate Equation of  $V_{SD}$  vs.  $I_{SD}$  Curve

#### 14.2.4 Estimating Junction Temperature of Power MOSFET

The junction temperature of all power MOSFETs operating,  $T_j$ , can be estimated with Equation (10):

$$T_j = R_{J-C} \times \{(P_{ON} + P_{SW} + P_{SD}) \times 6\} + T_C. \quad (10)$$

Where:

$R_{J-C}$  is the junction-to-case thermal resistance ( $^{\circ}\text{C}/\text{W}$ ) of all the power MOSFETs operating, and

$T_C$  is the case temperature ( $^{\circ}\text{C}$ ), measured at the point defined in Figure 3-1.

**15. Performance Curves**

**15.1 Transient Thermal Resistance Curves**

The following graphs represent transient thermal resistance (the ratios of transient thermal resistance), with steady-state thermal resistance = 1.

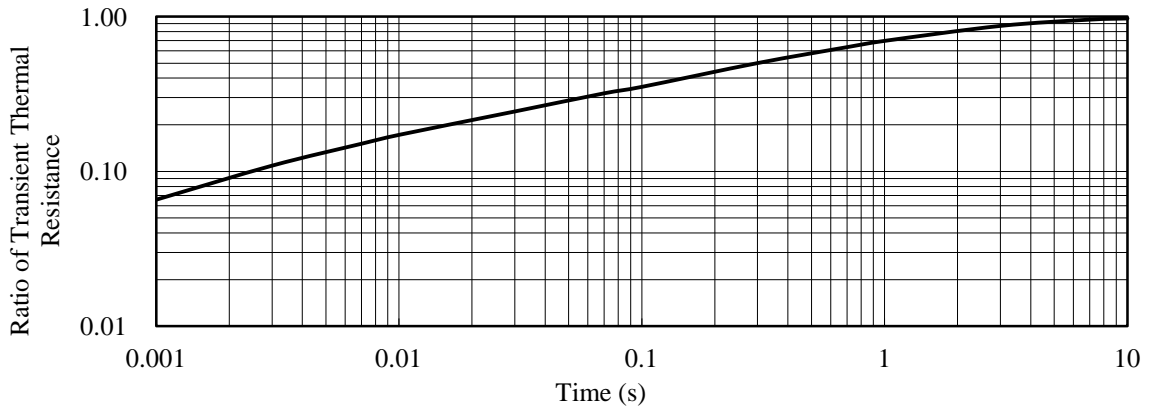


Figure 15-1. Transient Thermal Resistance Curve: SIM681xM

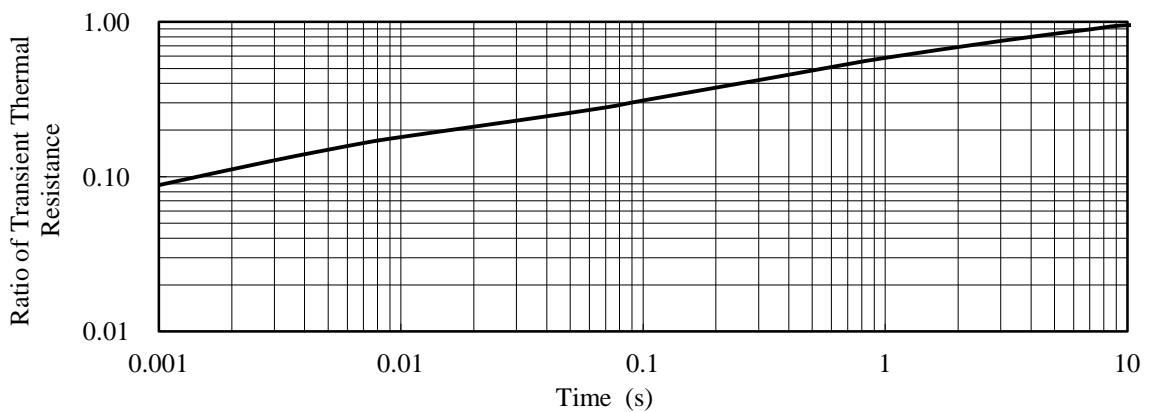


Figure 15-2. Transient Thermal Resistance Curve: SIM682xM

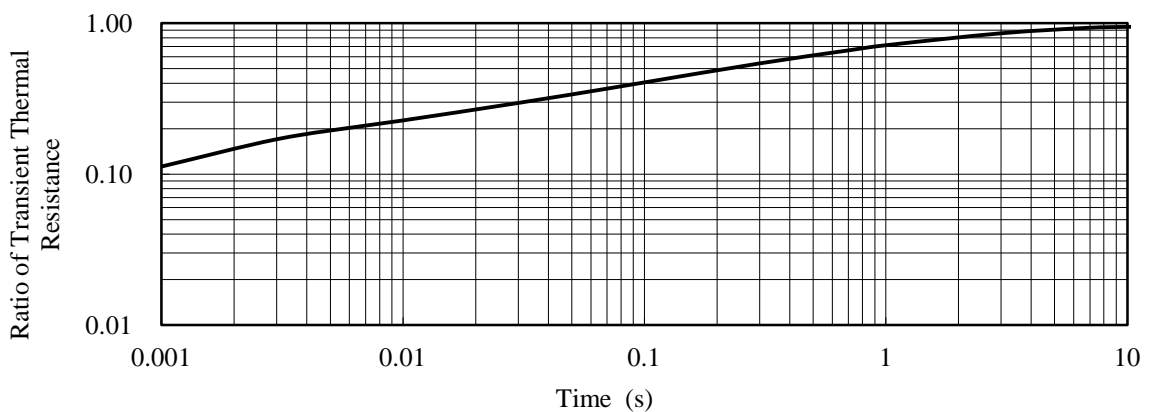


Figure 15-3. Transient Thermal Resistance Curve: SIM6818M



**15.2 Performance Curves of Control Parts**

Figure 15-4 to Figure 15-28 provide performance curves of the control parts integrated in the SIM6800M series, including variety-dependent characteristics and thermal characteristics.  $T_J$  represents the junction temperature of the control parts.

Table 15-1. Typical Characteristics of Control Parts

| Figure Number | Figure Caption  |
|---------------|---|
| Figure 15-4   | Logic Supply Current, $I_{CC}$ vs. $T_C$ ( $IN_x = 0$ V)  |
| Figure 15-5   | Logic Supply Current, $I_{CC}$ vs. $T_C$ ( $IN_x = 5$ V)  |
| Figure 15-6   | VCCx Pin Voltage, $V_{CC}$ vs. Logic Supply Current, $I_{CC}$ curve                               |
| Figure 15-7   | Logic Supply Current (1-phase) $I_{BS}$ vs. $T_C$ ( $HIN_x = 0$ V)                                |
| Figure 15-8   | Logic Supply Current (1-phase) $I_{BS}$ vs. $T_C$ ( $HIN_x = 5$ V)                                |
| Figure 15-9   | VBx Pin Voltage, $V_B$ vs. Logic Supply Current, $I_{BS}$ ( $HIN_x = 0$ V)                        |
| Figure 15-10  | Logic Operation Start Voltage, $V_{BS(ON)}$ vs. $T_C$   |
| Figure 15-11  | Logic Operation Stop Voltage, $V_{BS(OFF)}$ vs. $T_C$   |
| Figure 15-12  | Logic Operation Start Voltage, $V_{CC(ON)}$ vs. $T_C$   |
| Figure 15-13  | Logic Operation Stop Voltage, $V_{CC(OFF)}$ vs. $T_C$   |
| Figure 15-14  | UVLO_VB Filtering Time vs. $T_C$  |
| Figure 15-15  | UVLO_VCC Filtering Time vs. $T_C$   |
| Figure 15-16  | High Level Input Threshold Voltage, $V_{IH}$ vs. $T_C$  |
| Figure 15-17  | Low Level Input Threshold Voltage, $V_{IL}$ vs. $T_C$   |
| Figure 15-18  | Input Current at High Level ( $HIN_x$ or $LIN_x$ ), $I_{IN}$ vs. $T_C$                            |
| Figure 15-19  | High-side Turn-on Propagation Delay vs. $T_C$ (from $HIN_x$ to $HO_x$ )                           |
| Figure 15-20  | Low-side Turn-on Propagation Delay vs. $T_C$ (from $LIN_x$ to $LO_x$ )                            |
| Figure 15-21  | Minimum Transmittable Pulse Width for High-side Switching, $t_{HIN(MIN)}$ vs. $T_C$               |
| Figure 15-22  | Minimum Transmittable Pulse Width for Low-side Switching, $t_{LIN(MIN)}$ vs. $T_C$                |
| Figure 15-23  | SD Pin Filtering Time vs. $T_C$   |
| Figure 15-24  | FO Pin Filtering Time vs. $T_C$   |
| Figure 15-25  | Current Limit Reference Voltage, $V_{LIM}$ vs. $T_C$  |
| Figure 15-26  | OCP Threshold Voltage, $V_{TRIP}$ vs. $T_C$   |
| Figure 15-27  | OCP Hold Time, $t_p$ vs. $T_C$  |
| Figure 15-28  | OCP Blanking Time, $t_{BK(OCP)}$ vs. $T_C$ ; Current Limit Blanking Time, $t_{BK(OCL)}$ vs. $T_C$ |

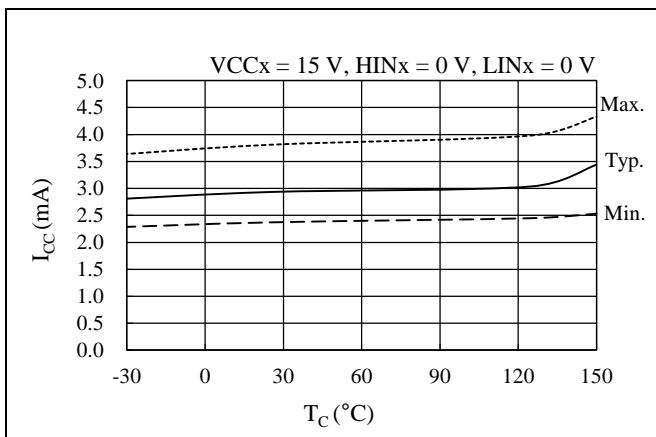


Figure 15-4. Logic Supply Current,  $I_{CC}$  vs.  $T_C$  ( $IN_x = 0$  V)

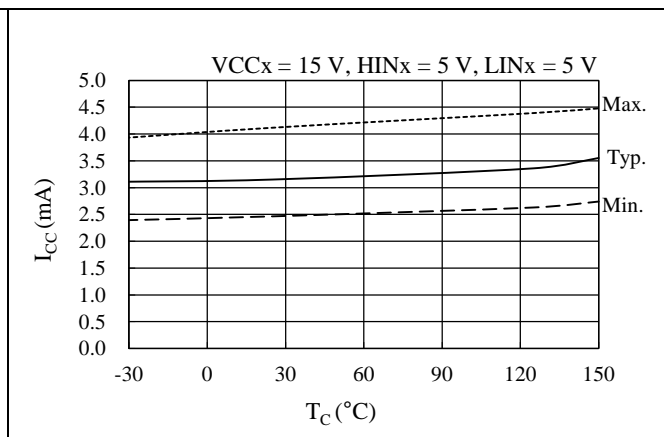


Figure 15-5. Logic Supply Current,  $I_{CC}$  vs.  $T_C$  ( $IN_x = 5$  V)



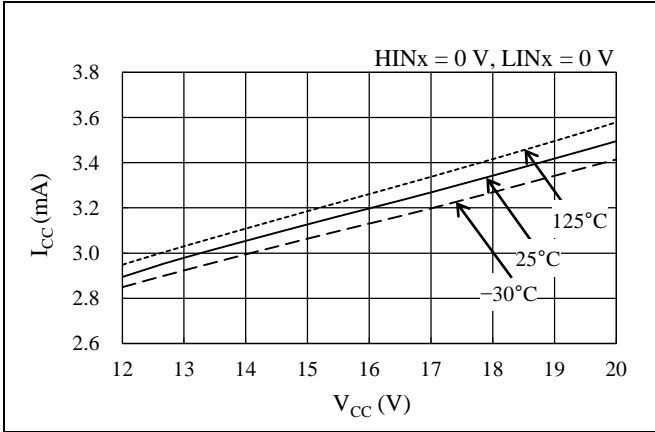


Figure 15-6. VCCx Pin Voltage,  $V_{CC}$  vs. Logic Supply Current,  $I_{CC}$  curve

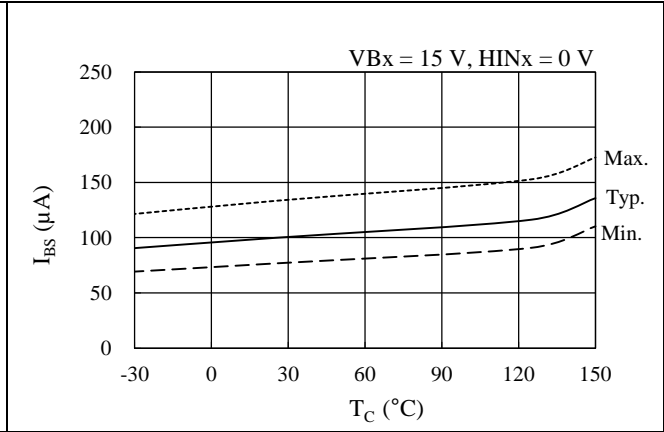


Figure 15-7. Logic Supply Current (1-phase)  $I_{BS}$  vs.  $T_C$  ( $HIN_x = 0 V$ )

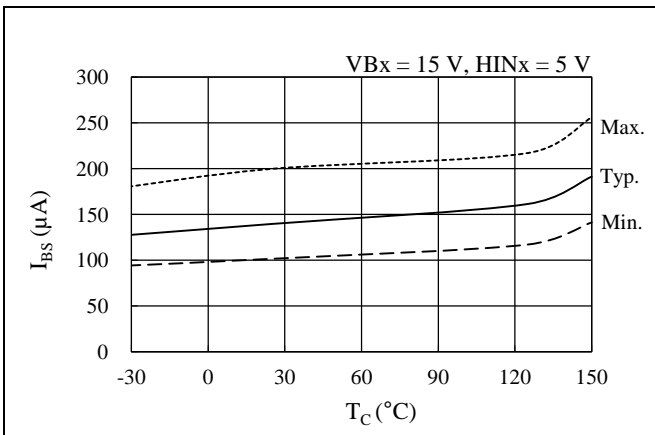


Figure 15-8. Logic Supply Current (1-phase)  $I_{BS}$  vs.  $T_C$  ( $HIN_x = 5 V$ )

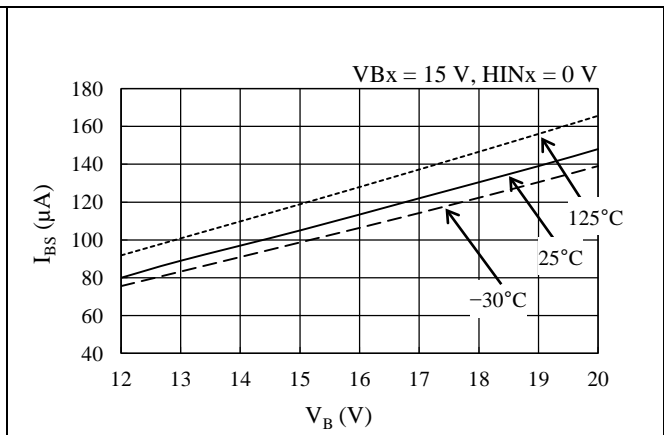


Figure 15-9. VBx Pin Voltage,  $V_B$  vs. Logic Supply Current,  $I_{BS}$  ( $HIN_x = 0 V$ )

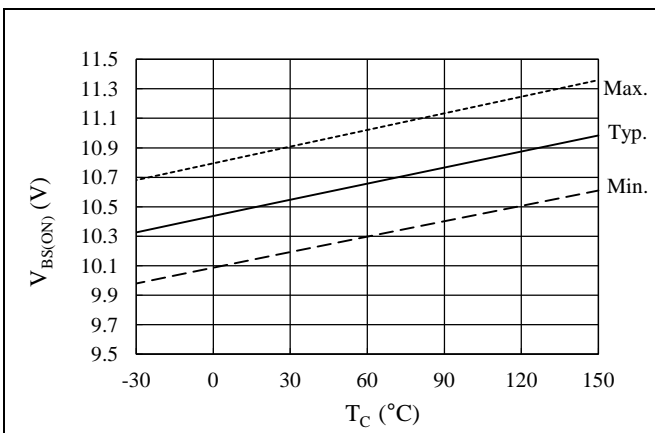


Figure 15-10. Logic Operation Start Voltage,  $V_{BS(ON)}$  vs.  $T_C$

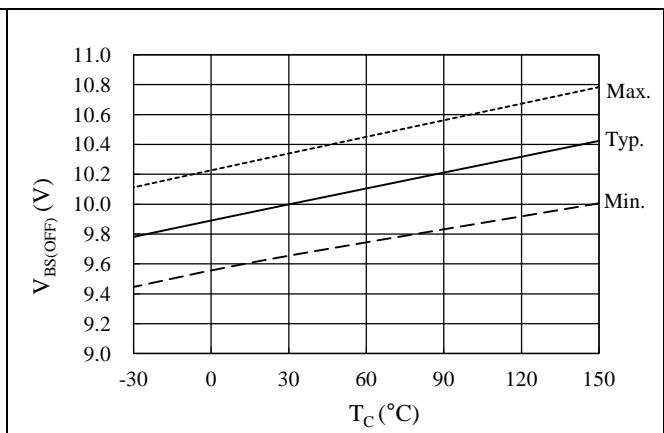


Figure 15-11. Logic Operation Stop Voltage,  $V_{BS(OFF)}$  vs.  $T_C$

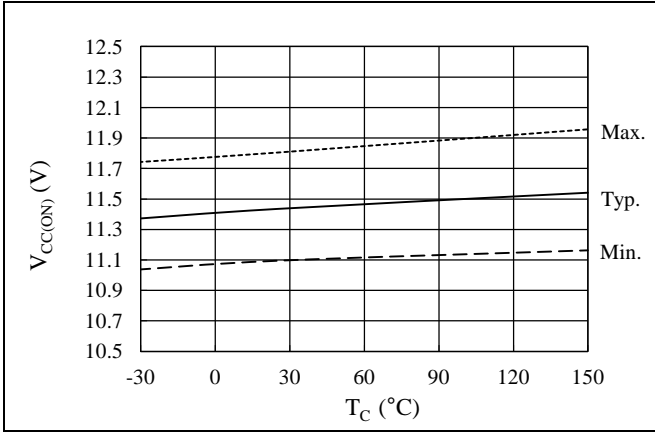


Figure 15-12. Logic Operation Start Voltage,  $V_{CC(ON)}$  vs.  $T_C$

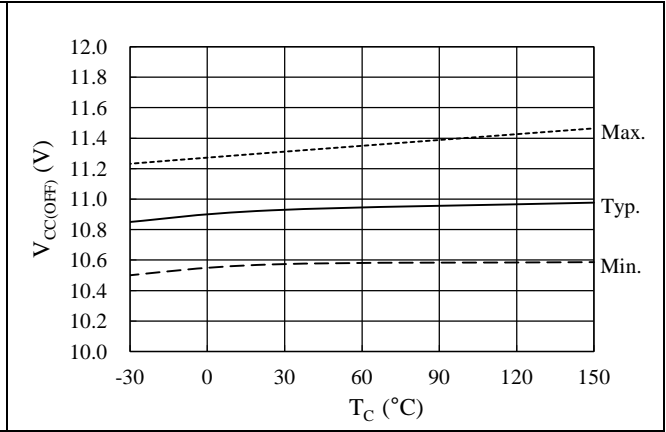


Figure 15-13. Logic Operation Stop Voltage,  $V_{CC(OFF)}$  vs.  $T_C$

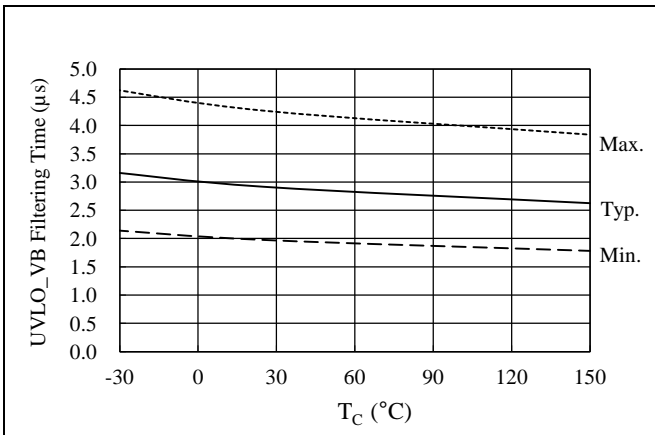


Figure 15-14. UVLO\_VB Filtering Time vs.  $T_C$

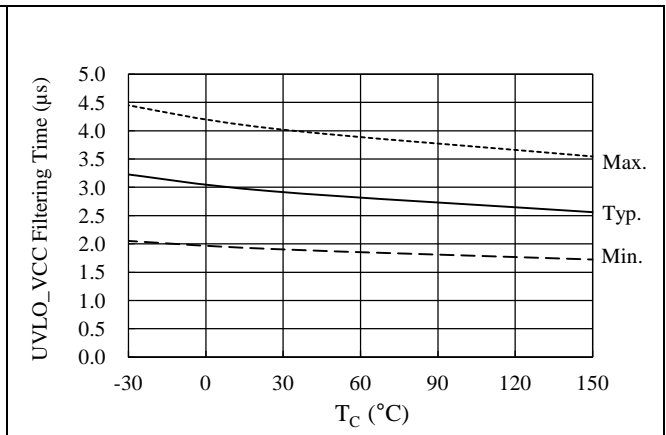


Figure 15-15. UVLO\_VCC Filtering Time vs.  $T_C$

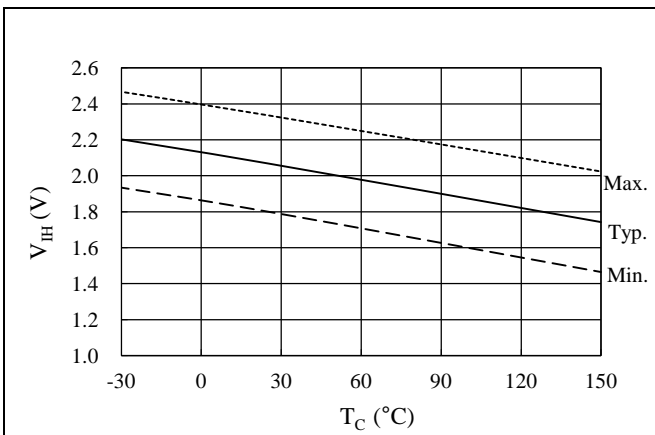


Figure 15-16. High Level Input Threshold Voltage,  $V_{IH}$  vs.  $T_C$

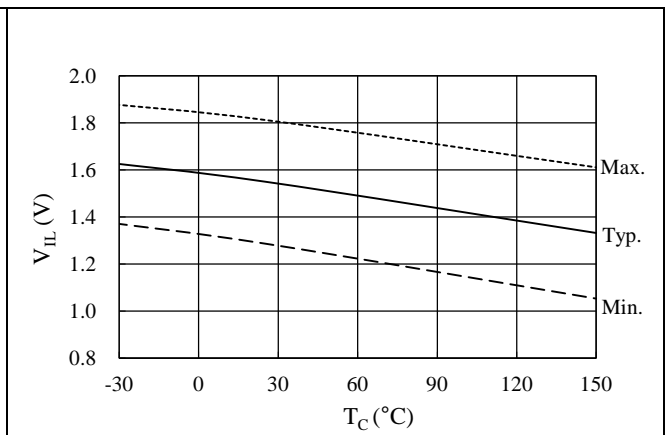


Figure 15-17. Low Level Input Threshold Voltage,  $V_{IL}$  vs.  $T_C$

# SIM6800M Series

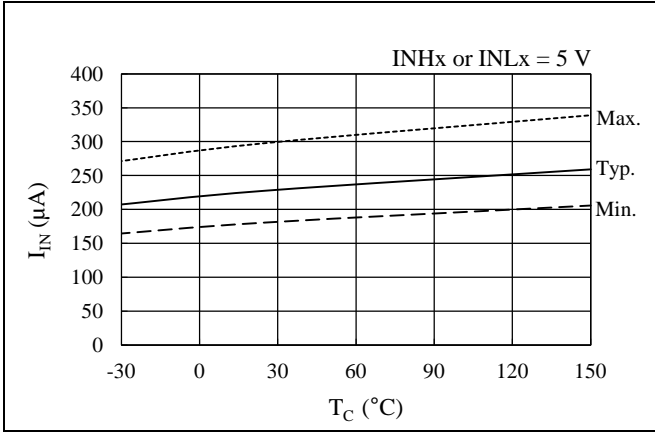


Figure 15-18. Input Current at High Level (INHx or LINx),  $I_{IN}$  vs.  $T_C$

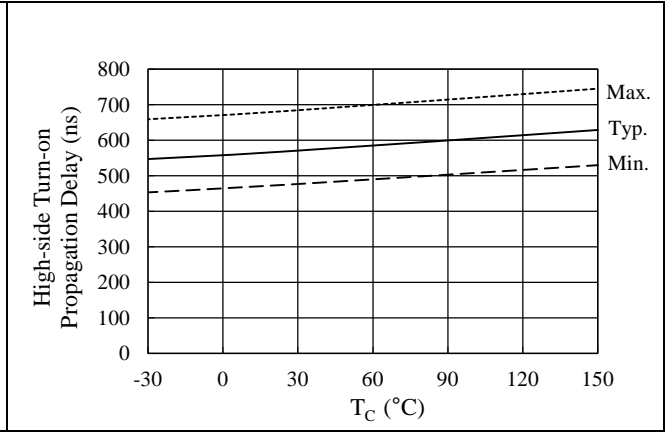


Figure 15-19. High-side Turn-on Propagation Delay vs.  $T_C$  (from HINx to HOx)

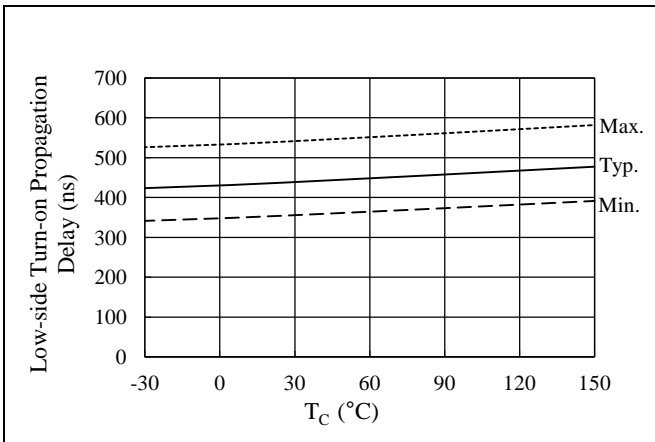


Figure 15-20. Low-side Turn-on Propagation Delay vs.  $T_C$  (from LINx to LOx)

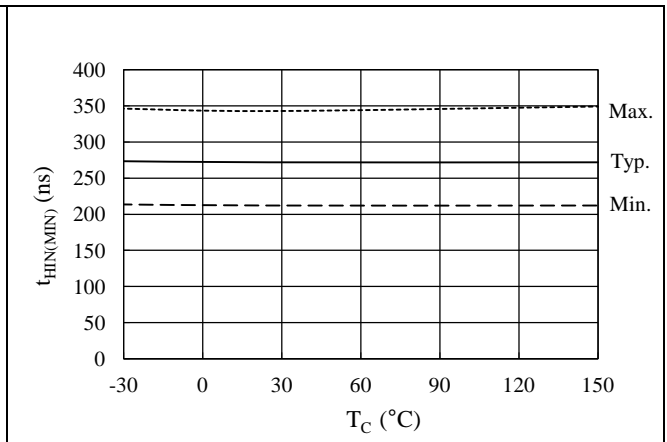


Figure 15-21. Minimum Transmittable Pulse Width for High-side Switching,  $t_{HIN(MIN)}$  vs.  $T_C$

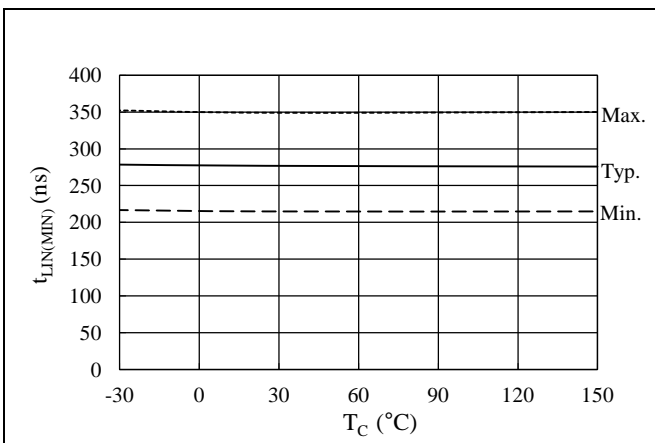


Figure 15-22. Minimum Transmittable Pulse Width for Low-side Switching,  $t_{LIN(MIN)}$  vs.  $T_C$

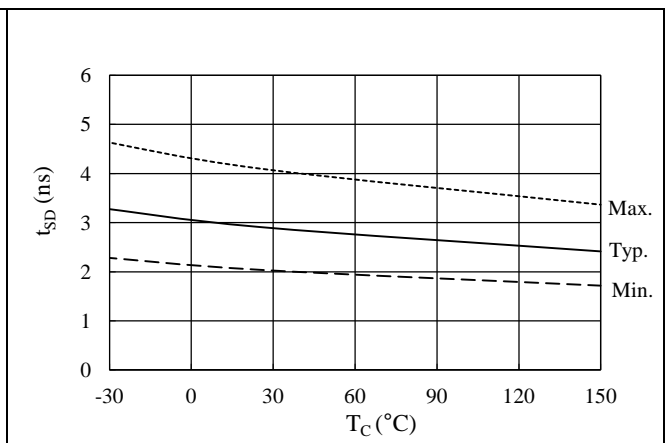


Figure 15-23. SD Pin Filtering Time vs.  $T_C$

# SIM6800M Series

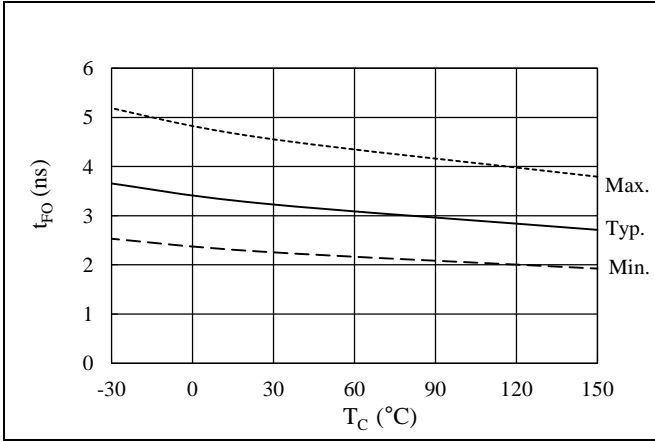


Figure 15-24. FO Pin Filtering Time vs. T<sub>C</sub>

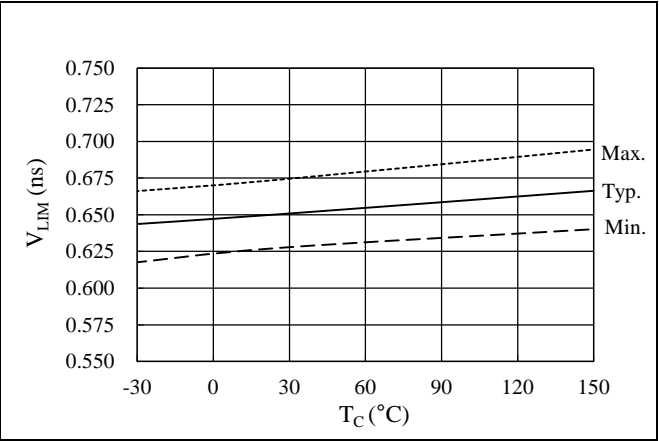


Figure 15-25. Current Limit Reference Voltage, V<sub>LIM</sub> vs. T<sub>C</sub>

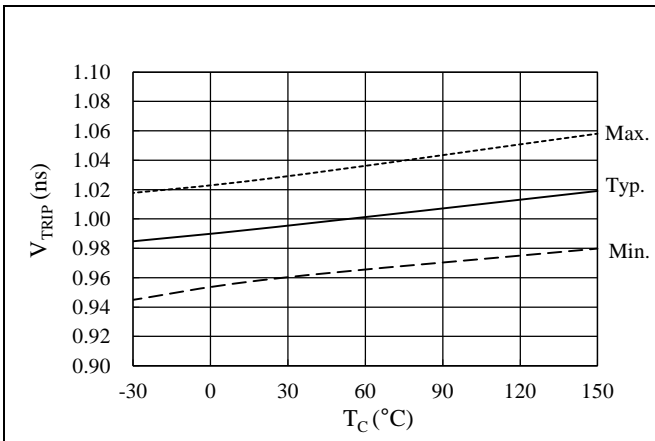


Figure 15-26. OCP Threshold Voltage, V<sub>TRIP</sub> vs. T<sub>C</sub>

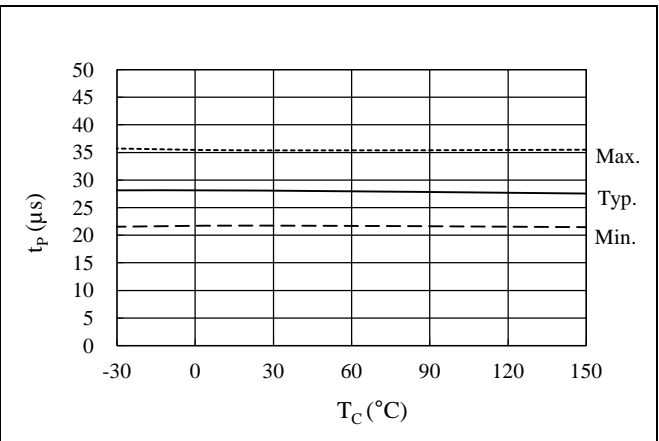


Figure 15-27. OCP Hold Time, t<sub>p</sub> vs. T<sub>C</sub>

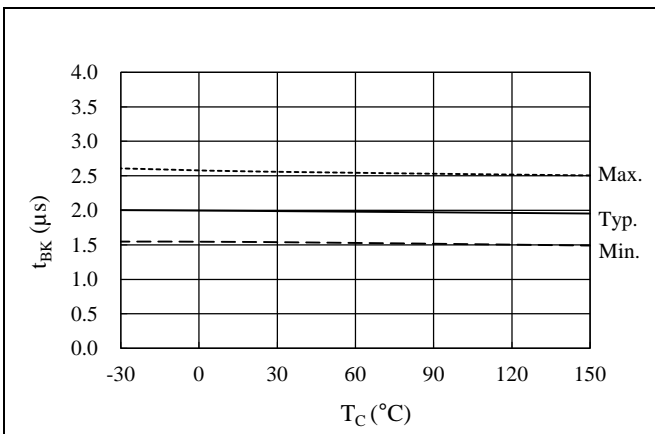


Figure 15-28. OCP Blanking Time, t<sub>BK(OCP)</sub> vs. T<sub>C</sub>; Current Limit Blanking Time, t<sub>BK(OCL)</sub> vs. T<sub>C</sub>

**15.3 Performance Curves of Output Parts**

**15.3.1 Output Transistor Performance Curves**

**15.3.1.1. SIM6811M**

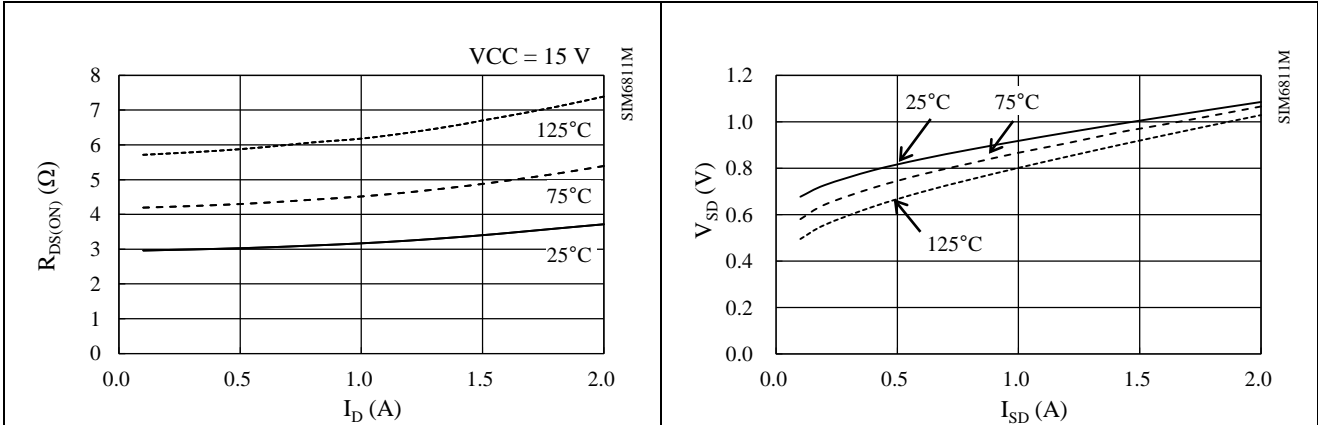


Figure 15-29. Power MOSFET  $R_{DS(ON)}$  vs.  $I_D$

Figure 15-30. Power MOSFET  $V_{SD}$  vs.  $I_{SD}$

**15.3.1.2. SIM6812M**

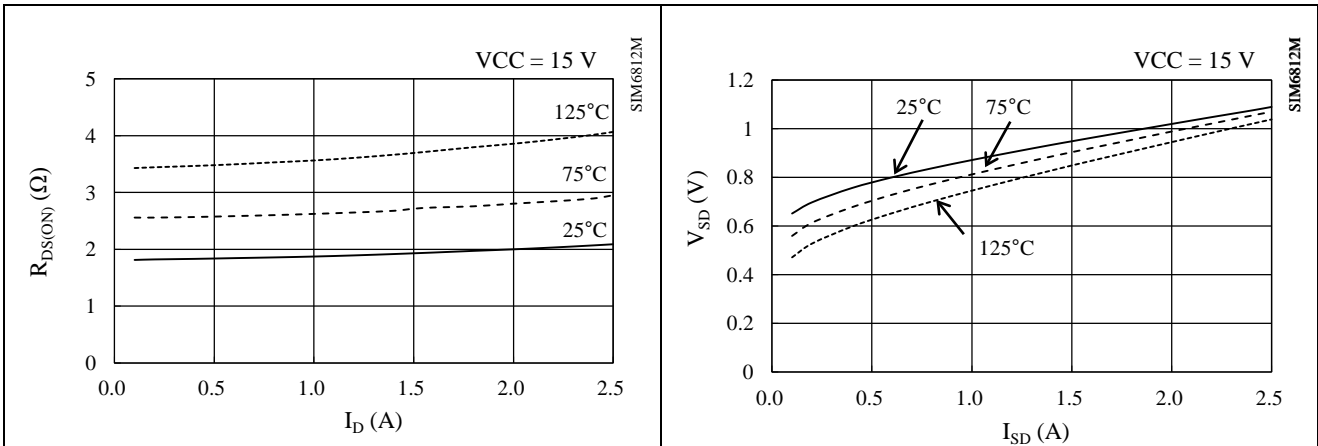


Figure 15-31. Power MOSFET  $R_{DS(ON)}$  vs.  $I_D$

Figure 15-32. Power MOSFET  $V_{SD}$  vs.  $I_{SD}$

**15.3.1.3. SIM6813M**

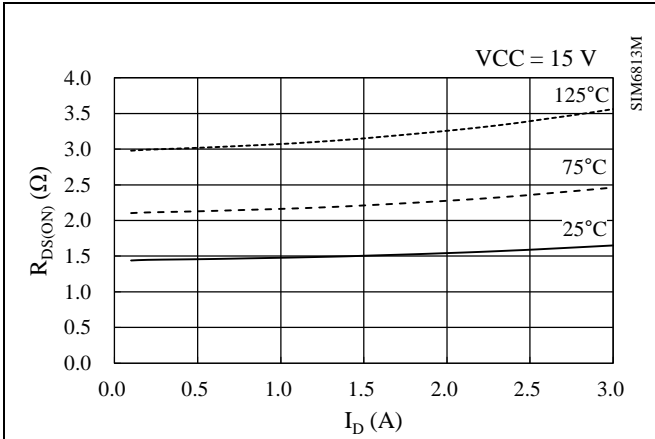


Figure 15-33. Power MOSFET  $R_{DS(ON)}$  vs.  $I_D$

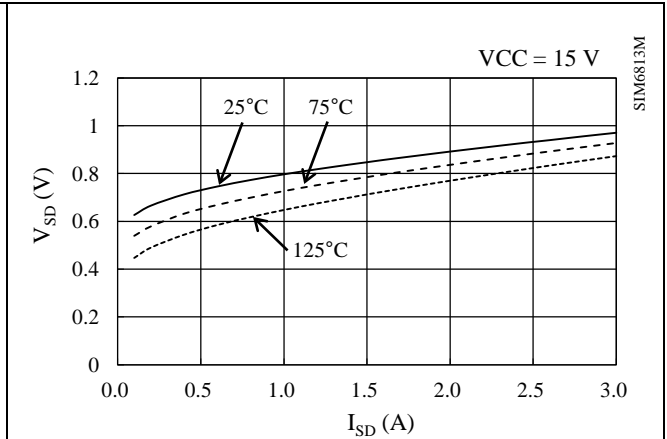


Figure 15-34. Power MOSFET  $V_{SD}$  vs.  $I_{SD}$

**15.3.1.4. SIM6880M**

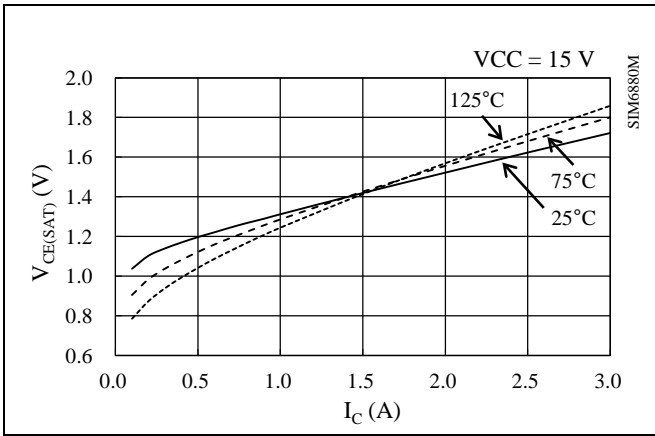


Figure 15-35. IGBT  $V_{CE(SAT)}$  vs.  $I_C$

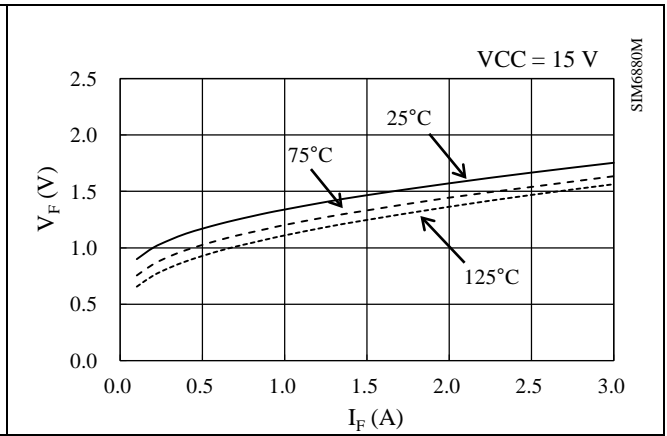


Figure 15-36. FRD  $V_F$  vs.  $I_F$

**15.3.1.5. SIM6822M and SIM6827M**

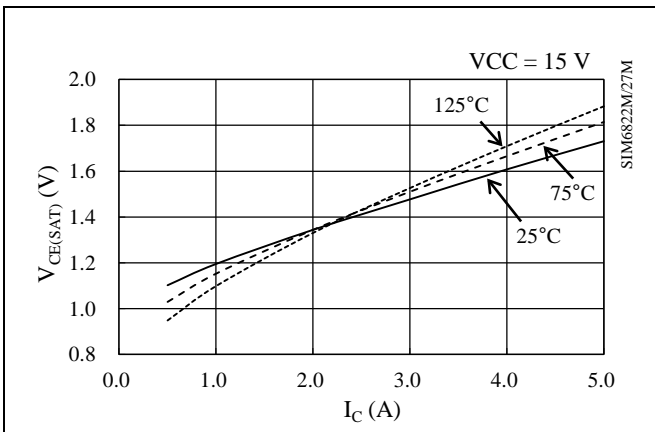


Figure 15-37. IGBT  $V_{CE(SAT)}$  vs.  $I_C$

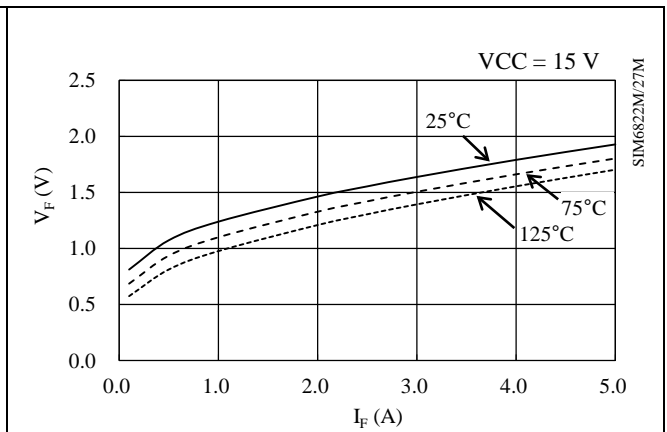


Figure 15-38. FRD  $V_F$  vs.  $I_F$

## SIM6800M Series

### 15.3.2 Switching Losses

Conditions:  $V_{BB} = 300\text{ V}$ , half-bridge circuit with inductive load.  
Switching Loss,  $E$ , is the sum of turn-on loss and turn-off loss.

#### 15.3.2.1. SIM6811M

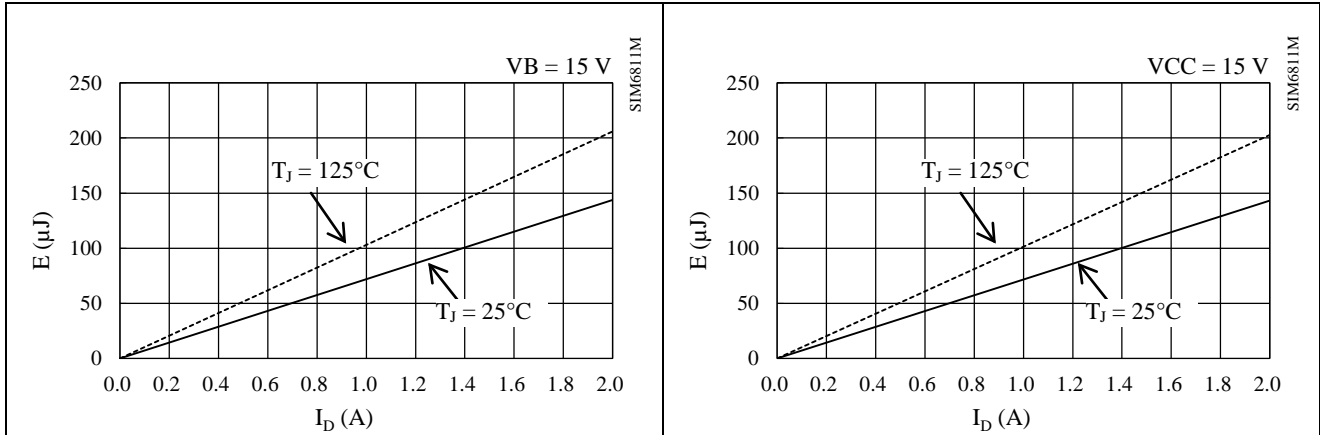


Figure 15-39. High-side Switching Loss

Figure 15-40. Low-side Switching Loss

#### 15.3.2.2. SIM6812M

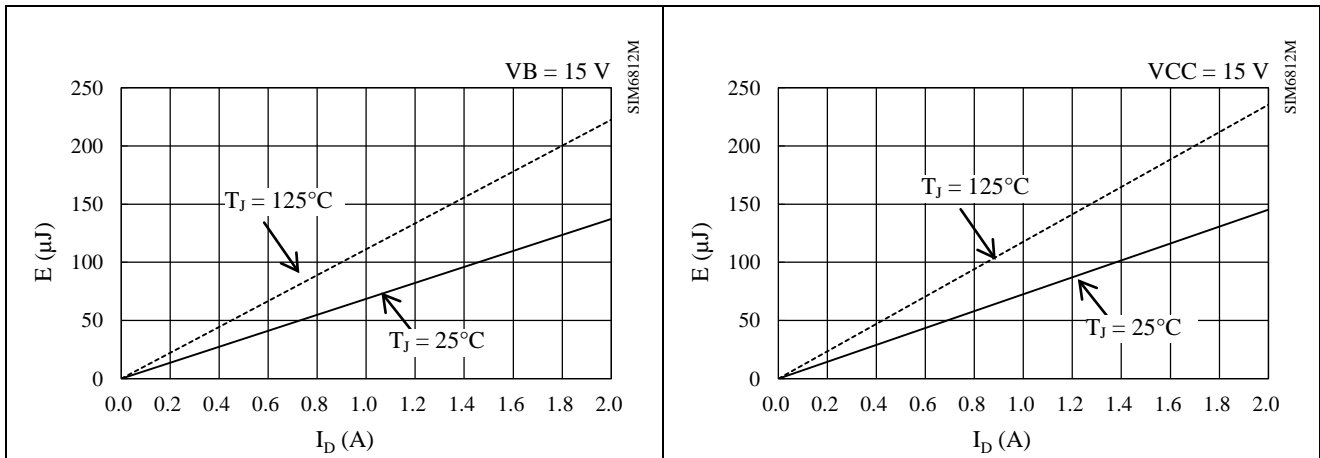


Figure 15-41. High-side Switching Loss

Figure 15-42. Low-side Switching Loss

**15.3.2.3. SIM6813M**

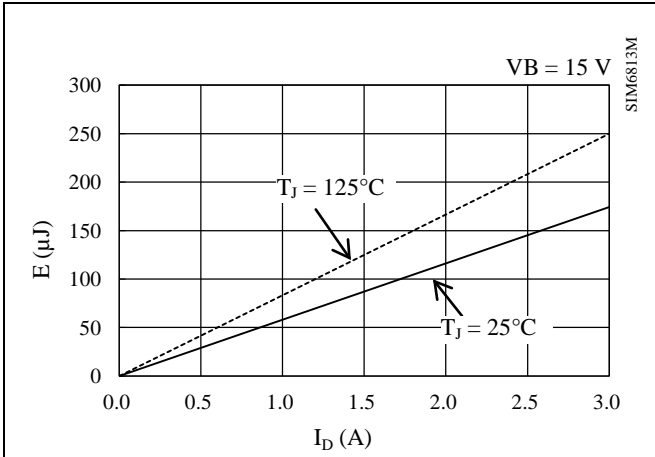


Figure 15-43. High-side Switching Loss

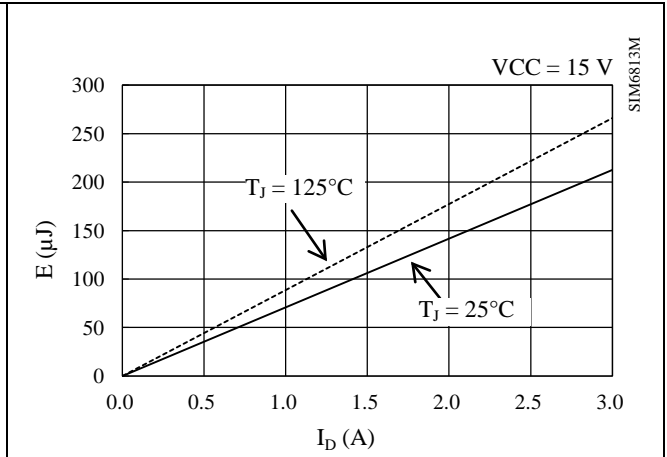


Figure 15-44. Low-side Switching Loss

**15.3.2.4. SIM6880M**

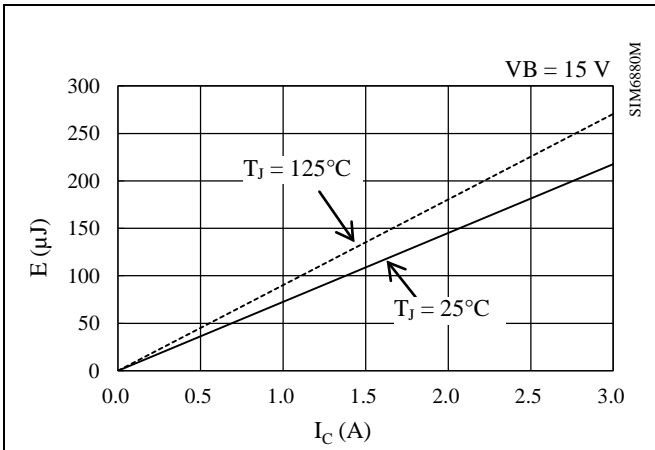


Figure 15-45. High-side Switching Loss

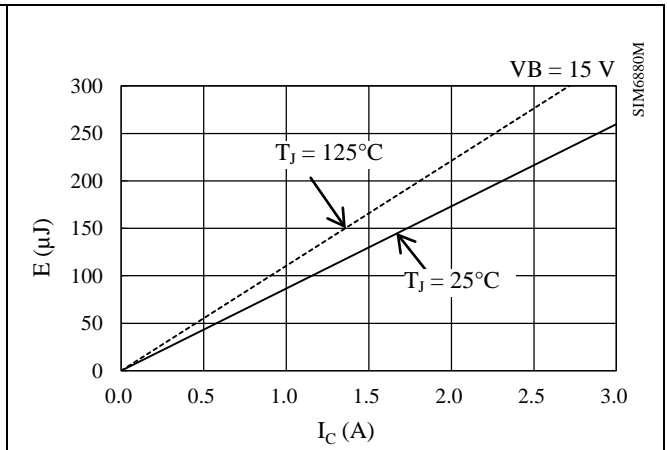


Figure 15-46. Low-side Switching Loss



15.3.2.5. SIM6822M

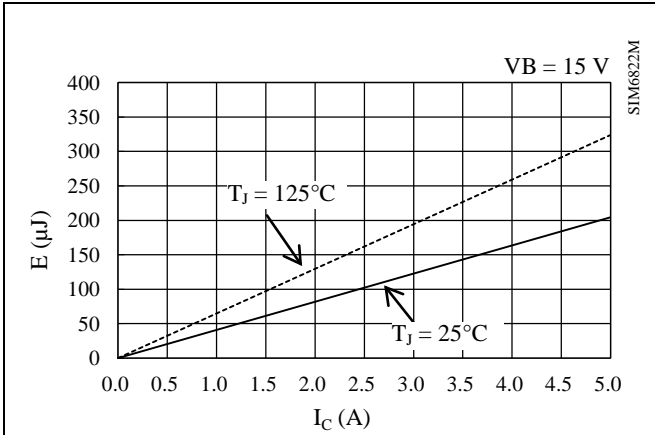


Figure 15-47. High-side Switching Loss

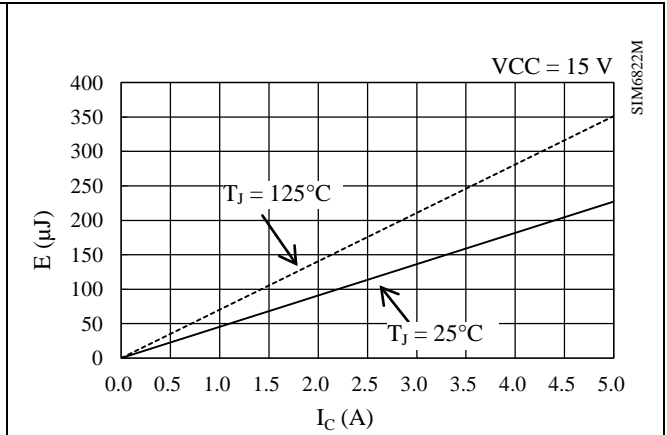


Figure 15-48. Low-side Switching Loss

15.3.2.6. SIM6827M

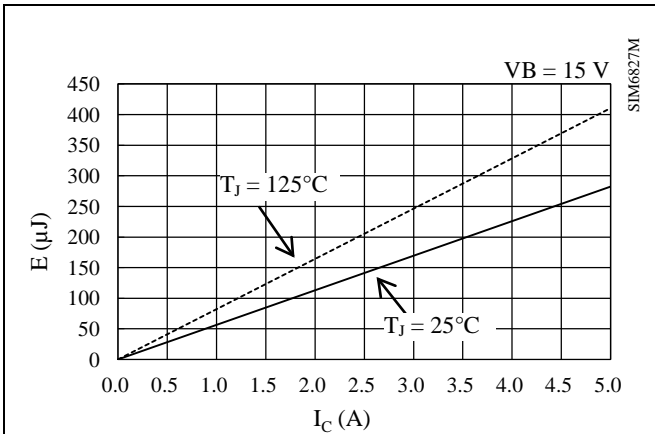


Figure 15-49. High-side Switching Loss

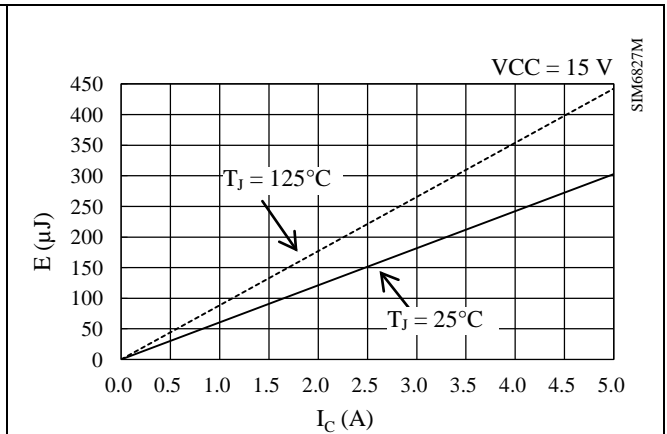


Figure 15-50. Low-side Switching Loss

**15.4 Allowable Effective Current Curves**

The following curves represent allowable effective currents in 3-phase sine-wave PWM driving with parameters such as typical  $R_{DS(ON)}$  or  $V_{CE(SAT)}$ , and typical switching losses.

Operating conditions: VBB pin input voltage,  $V_{DC} = 300$  V; VCC pin input voltage,  $V_{CC} = 15$  V; modulation index,  $M = 0.9$ ; motor power factor,  $\cos\theta = 0.8$ ; junction temperature,  $T_J = 150$  °C.

**15.4.1 SIM6811M**

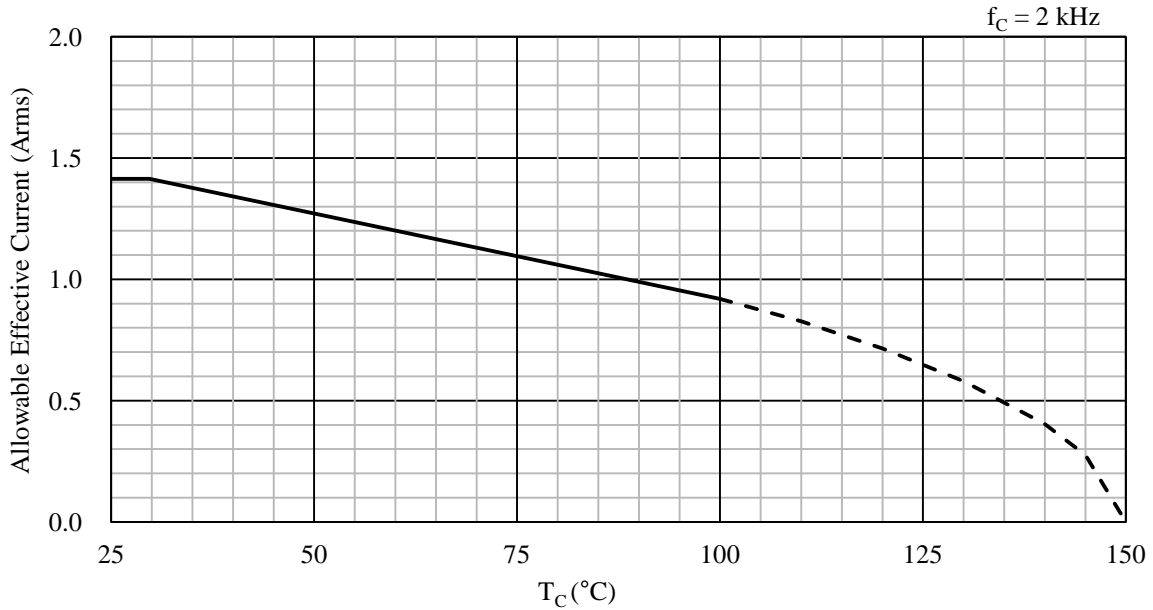


Figure 15-51. Allowable Effective Current ( $f_C = 2$  kHz): SIM6811M

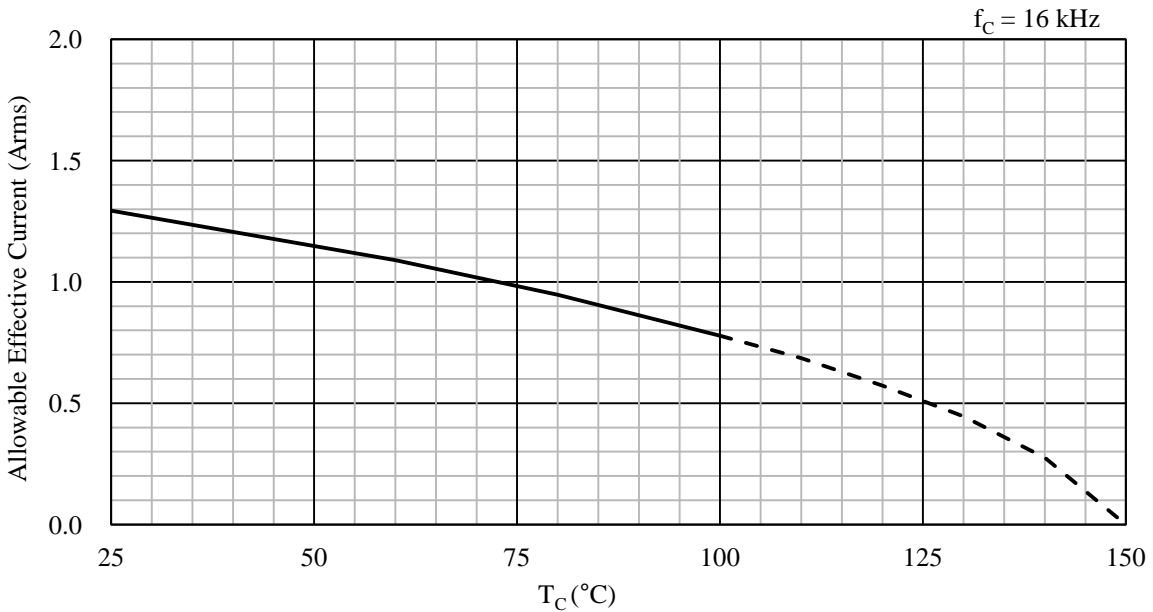


Figure 15-52. Allowable Effective Current ( $f_C = 16$  kHz): SIM6811M

15.4.2 SIM6812M

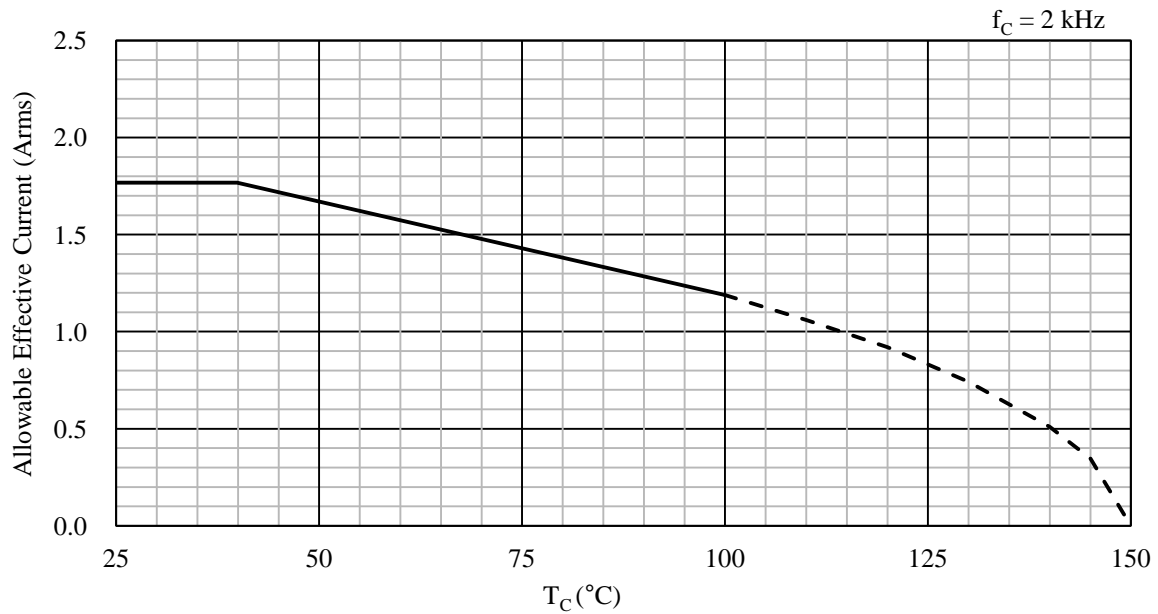


Figure 15-53. Allowable Effective Current ( $f_c = 2 \text{ kHz}$ ): SIM6812M

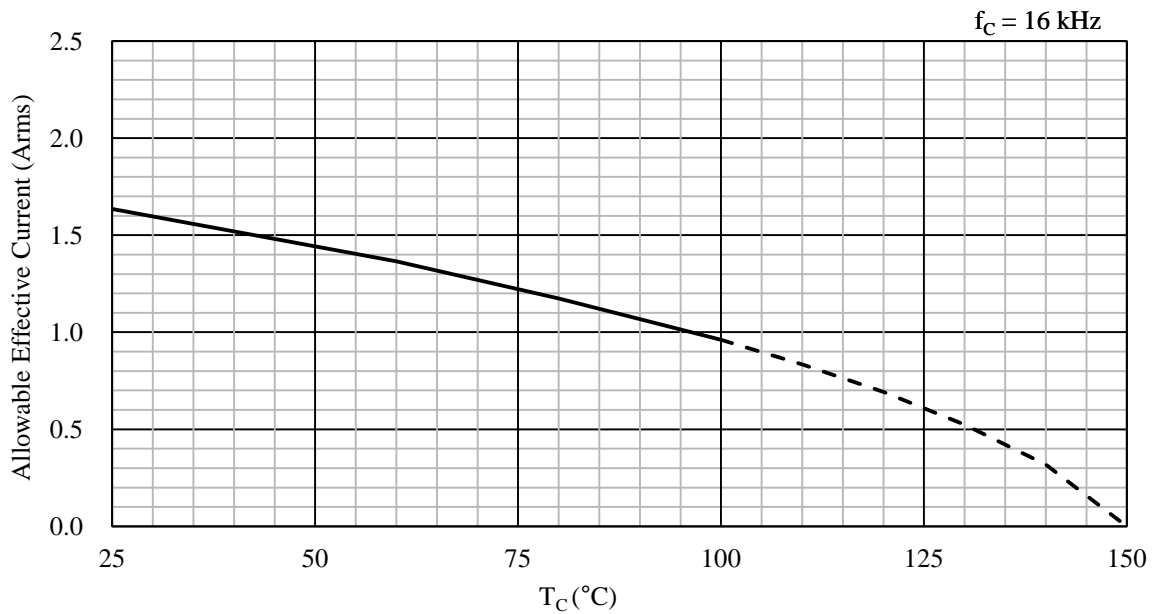


Figure 15-54. Allowable Effective Current ( $f_c = 16 \text{ kHz}$ ): SIM6812M

15.4.3 SIM6813M

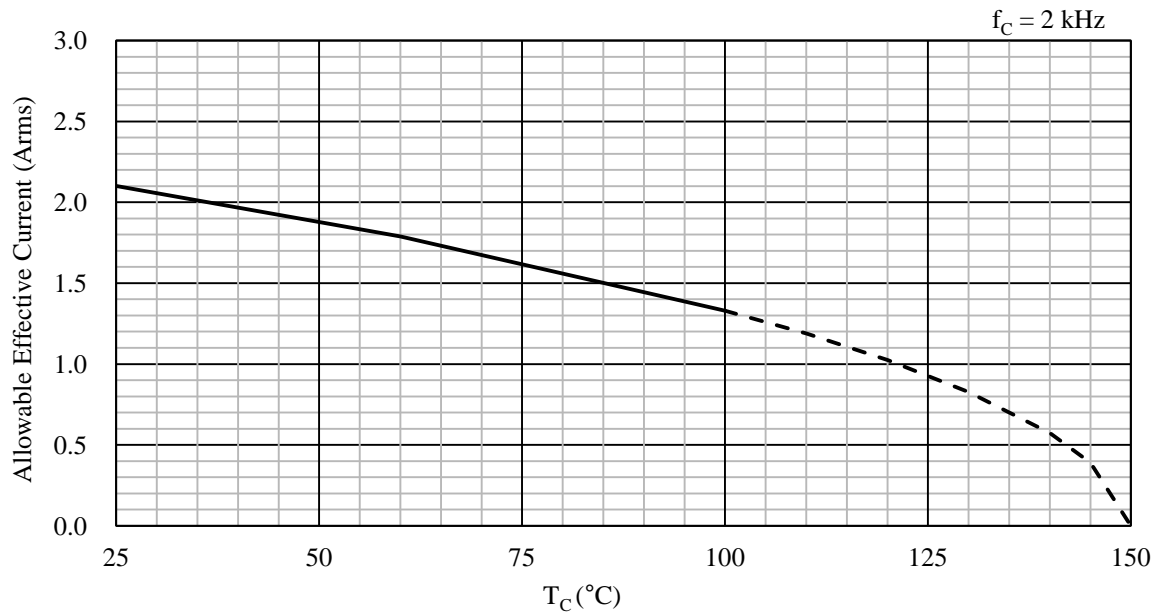


Figure 15-55. Allowable Effective Current ( $f_c = 2$  kHz): SIM6813M

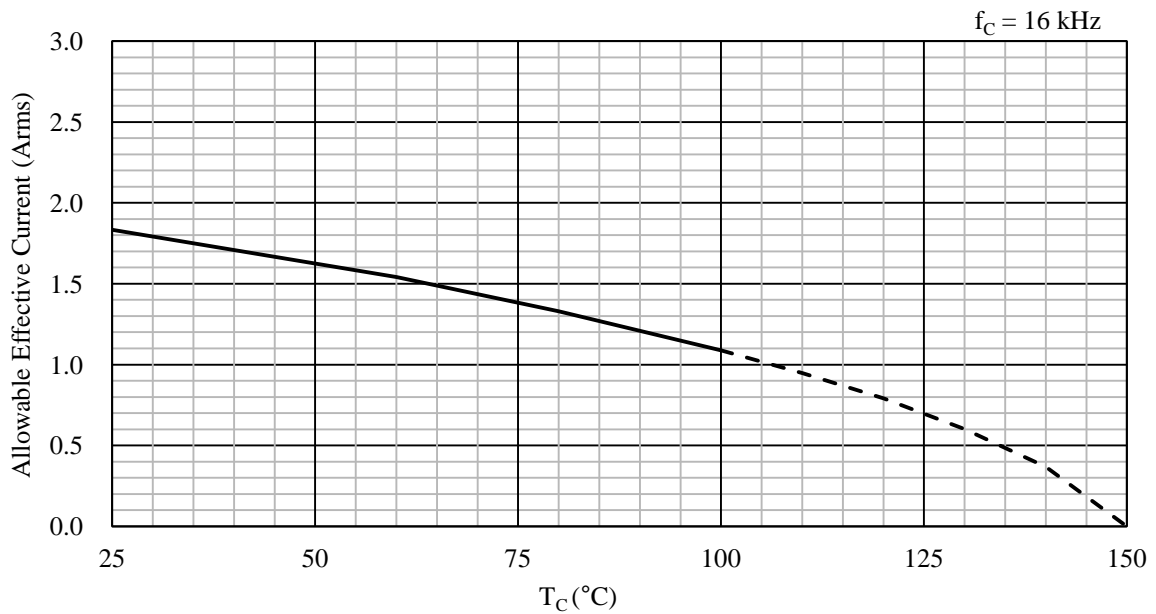


Figure 15-56. Allowable Effective Current ( $f_c = 16$  kHz): SIM6813M

15.4.4 SIM6880M

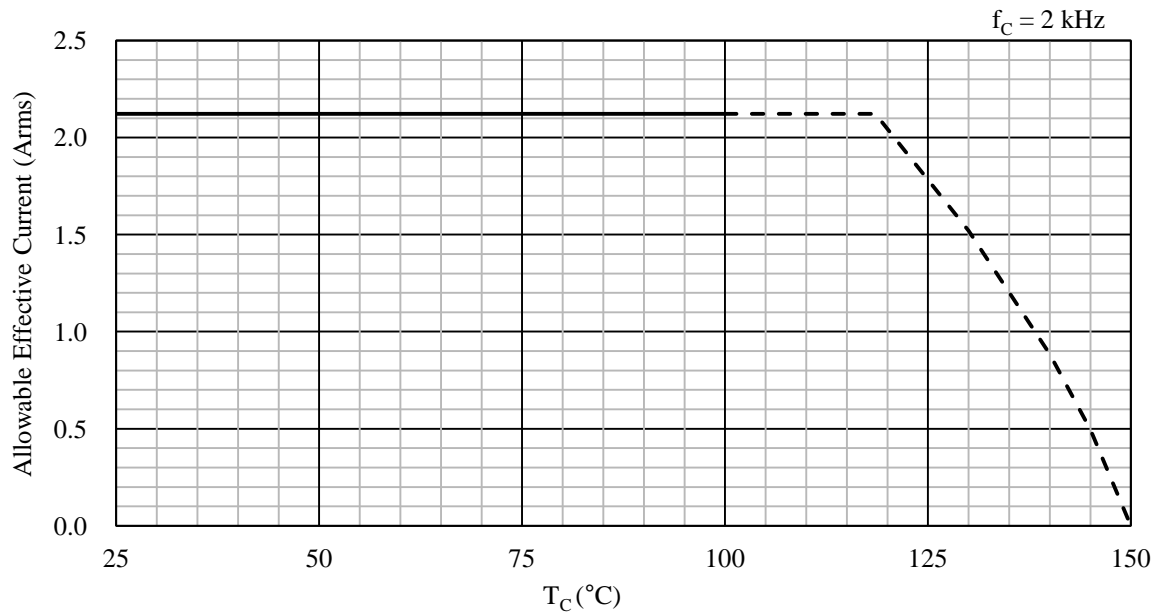


Figure 15-57. Allowable Effective Current (f<sub>C</sub> = 2 kHz): SIM6880M

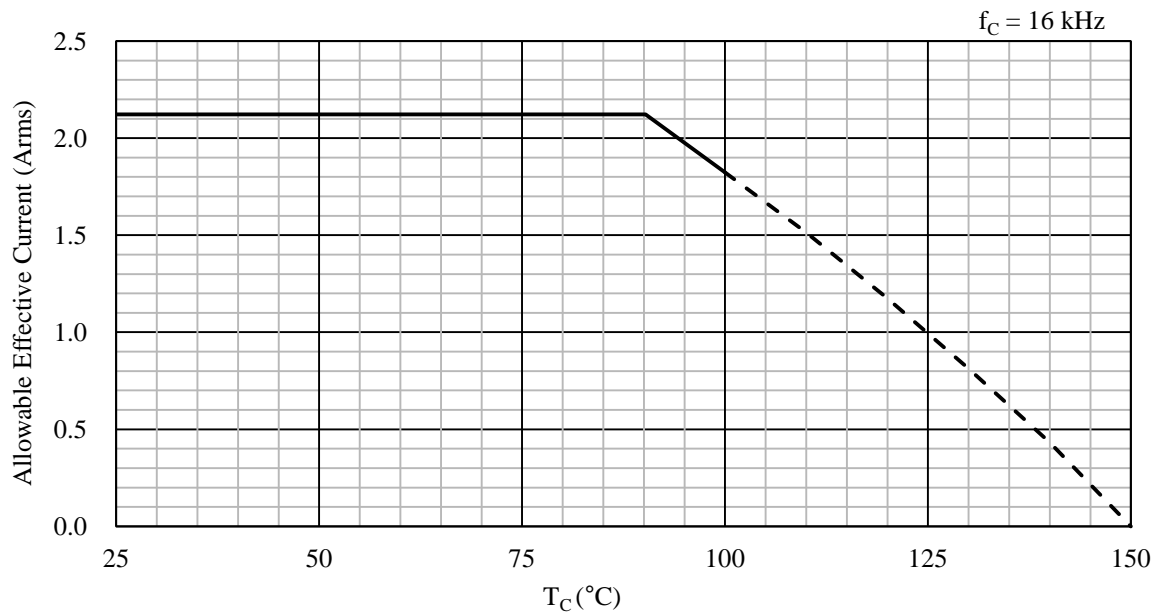


Figure 15-58. Allowable Effective Current (f<sub>C</sub> = 16 kHz): SIM6880M

15.4.5 SIM6822M

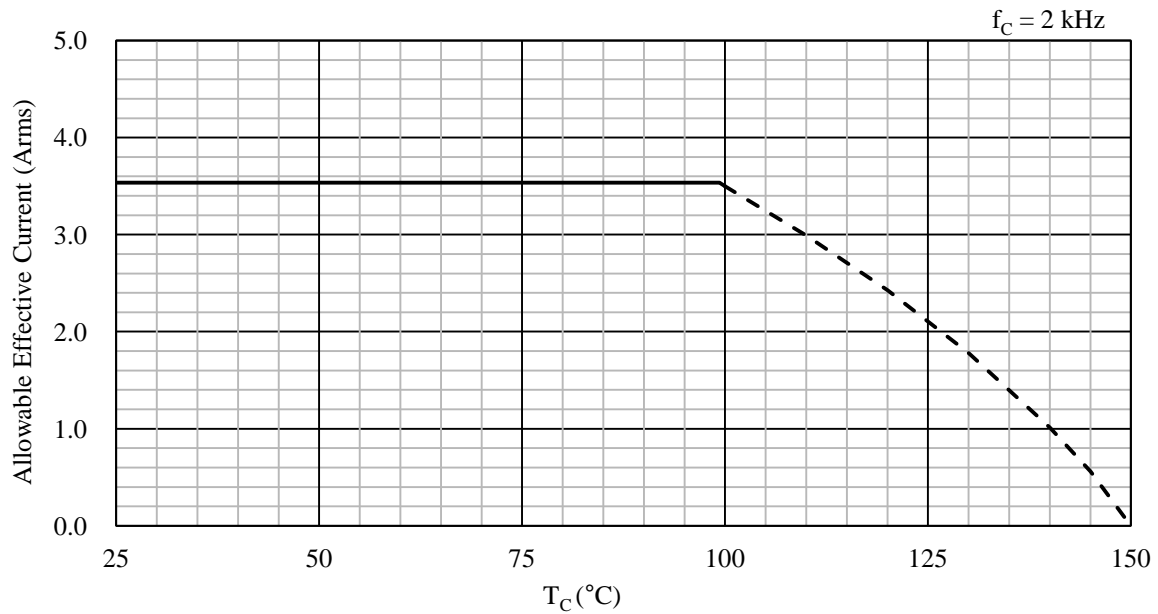


Figure 15-59. Allowable Effective Current ( $f_c = 2$  kHz): SIM6822M

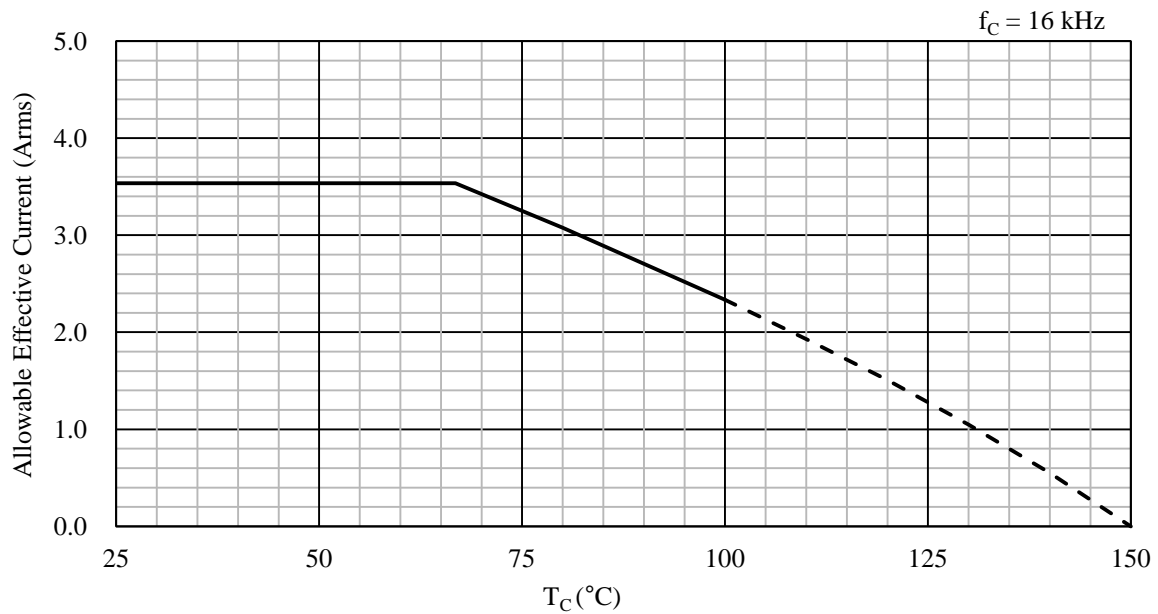


Figure 15-60. Allowable Effective Current ( $f_c = 16$  kHz): SIM6822M

15.4.6 SIM6827M

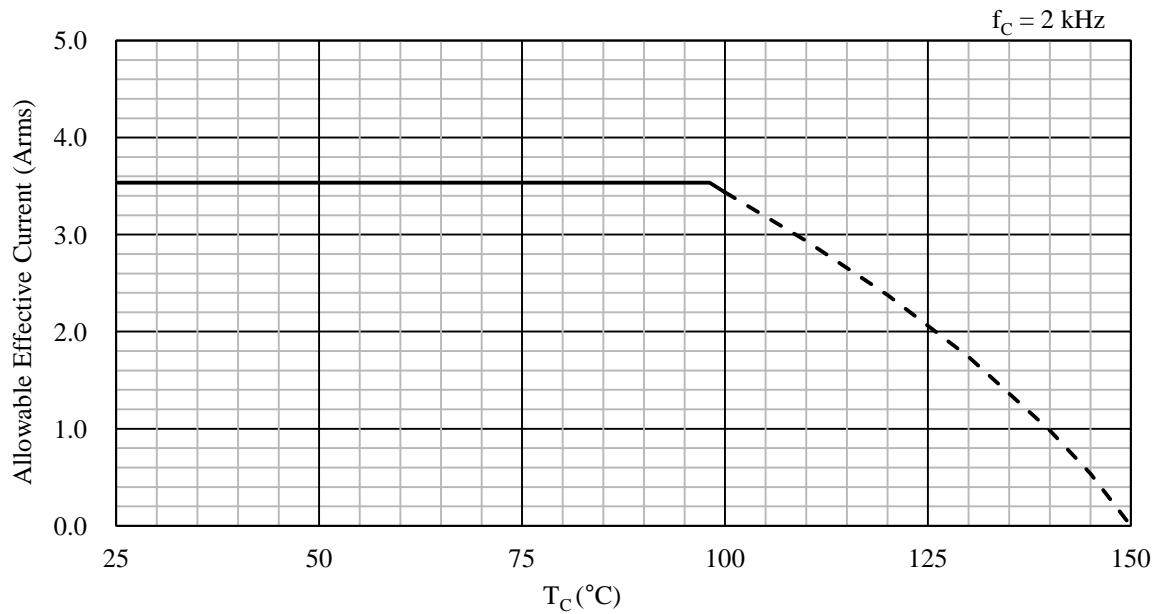


Figure 15-61. Allowable Effective Current ( $f_c = 2$  kHz): SIM6827M

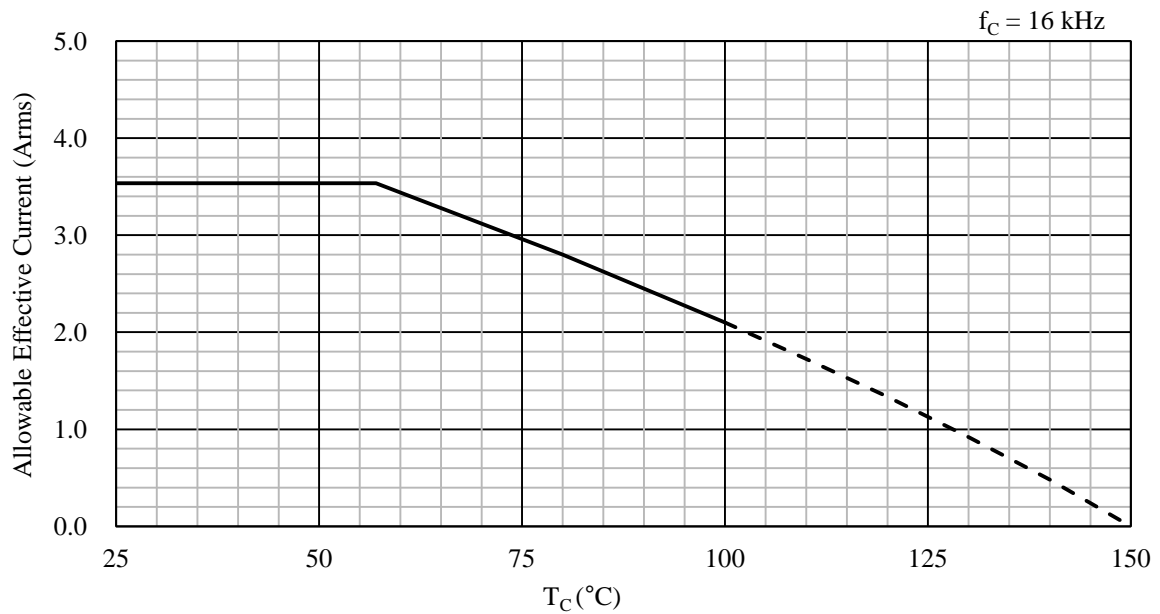


Figure 15-62. Allowable Effective Current ( $f_c = 16$  kHz): SIM6827M

**15.5 Short Circuit SOAs (Safe Operating Areas)**

This section provides the graphs illustrating the short circuit SOAs of the SIM6800M series devices whose output transistors consist of built-in IGBTs.

Conditions:  $V_{DC} \leq 400\text{ V}$ ,  $13.5\text{ V} \leq V_{CC} \leq 16.5\text{ V}$ ,  $T_J = 125\text{ }^\circ\text{C}$ , 1 pulse.

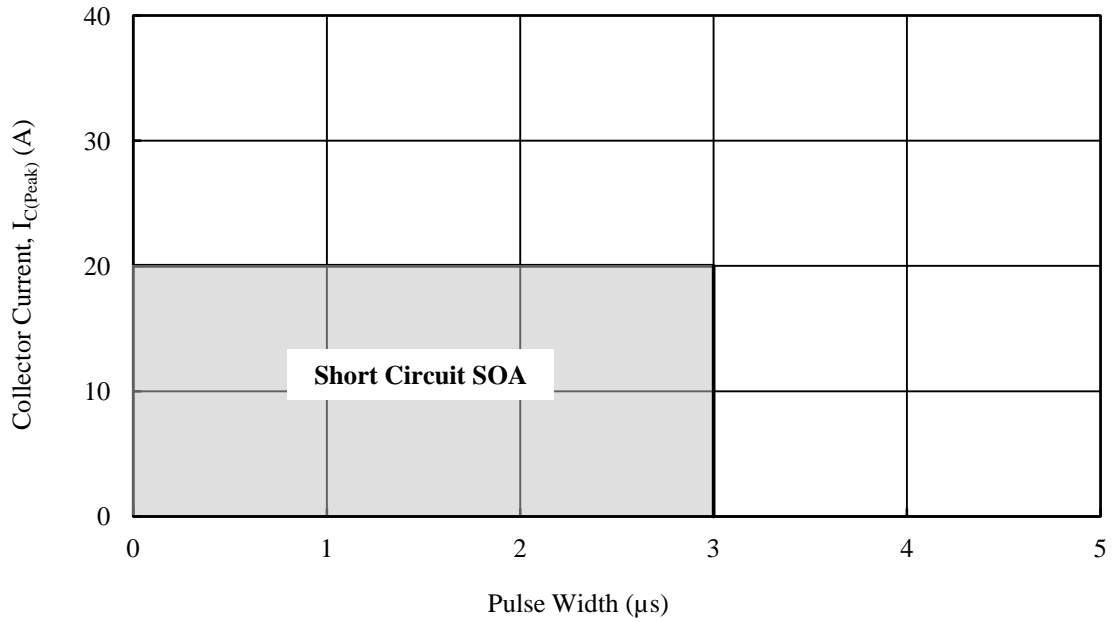


Figure 15-63. Short Circuit SOA: SIM6880M



Figure 15-64. Short Circuit SOA: SIM6822M, SIM6827M



**16. Pattern Layout Example**

This section contains the schematic diagrams of a PCB pattern layout example using an SIM6800M series device. For more details on through holes, see Section 10.

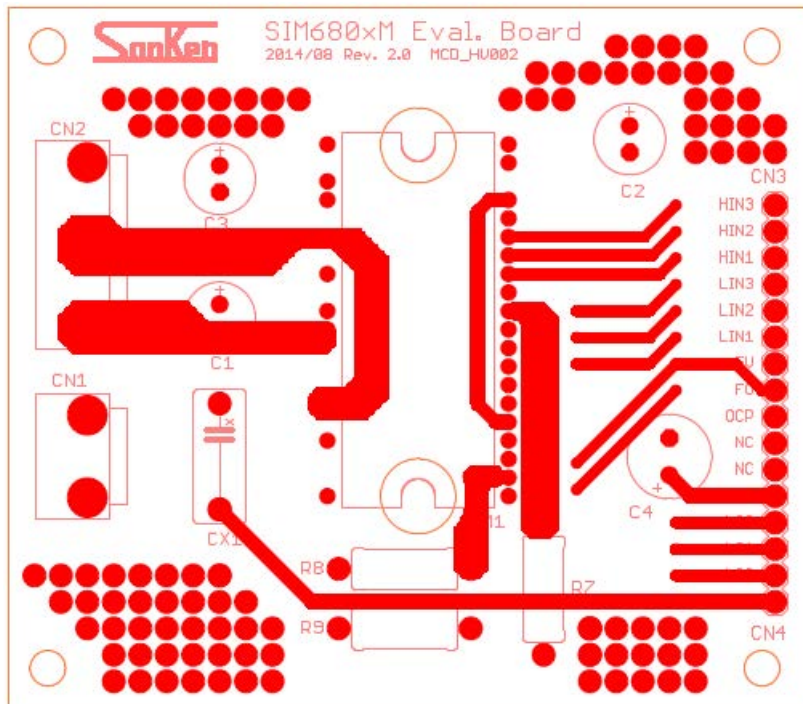


Figure 16-1. Top View

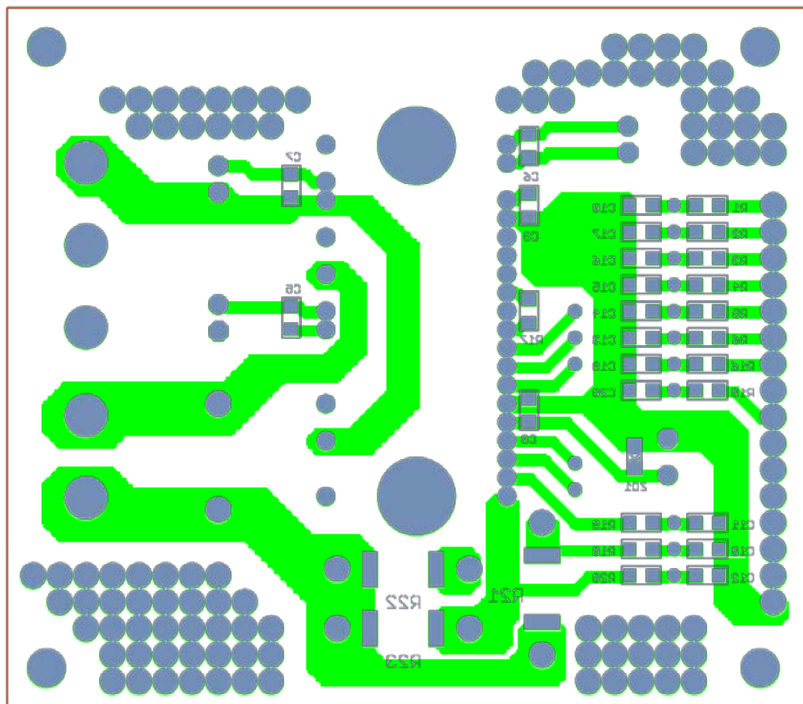


Figure 16-2. Bottom View

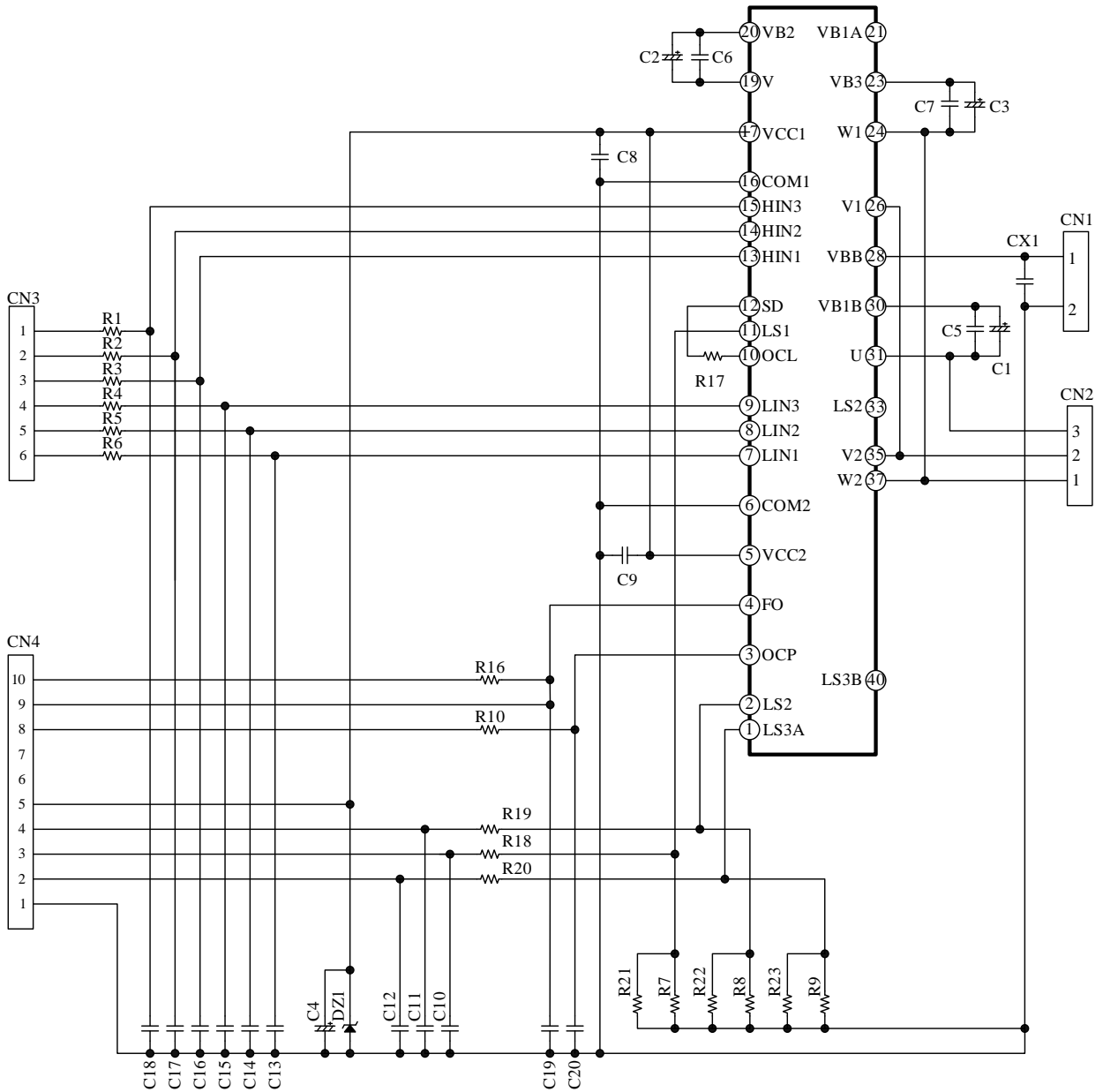


Figure 16-3. Circuit Diagram of PCB Pattern Layout Example

## SIM6800M Series

### 17. Typical Motor Driver Application

This section contains the information on the typical motor driver application listed in the previous section, including a circuit diagram, specifications, and the bill of the materials used.

- **Motor Driver Specifications**

|                               |                |
|-------------------------------|----------------|
| IC                            | SIM6822M       |
| Main Supply Voltage, $V_{DC}$ | 300 VDC (typ.) |
| Rated Output Power            | 500 W          |

- **Circuit Diagram**

See Figure 16-3.

- **Bill of Materials**

| Symbol | Part Type    | Ratings              | Symbol | Part Type   | Ratings                |
|--------|--------------|----------------------|--------|-------------|------------------------|
| C1     | Electrolytic | 47 $\mu$ F, 50 V     | R3     | General     | 100 $\Omega$ , 1/8 W   |
| C2     | Electrolytic | 47 $\mu$ F, 50 V     | R4     | General     | 100 $\Omega$ , 1/8 W   |
| C3     | Electrolytic | 47 $\mu$ F, 50 V     | R5     | General     | 100 $\Omega$ , 1/8 W   |
| C4     | Electrolytic | 100 $\mu$ F, 50 V    | R6     | General     | 100 $\Omega$ , 1/8 W   |
| C5     | Ceramic      | 0.1 $\mu$ F, 50 V    | R7*    | Metal plate | 0.15 $\Omega$ , 2 W    |
| C6     | Ceramic      | 0.1 $\mu$ F, 50 V    | R8*    | Metal plate | 0.15 $\Omega$ , 2 W    |
| C7     | Ceramic      | 0.1 $\mu$ F, 50 V    | R9*    | Metal plate | 0.15 $\Omega$ , 2 W    |
| C8     | Ceramic      | 0.1 $\mu$ F, 50 V    | R10    | General     | 100 $\Omega$ , 1/8 W   |
| C9     | Ceramic      | 0.1 $\mu$ F, 50 V    | R16    | General     | 3.3 k $\Omega$ , 1/8 W |
| C10    | Ceramic      | 100 pF, 50 V         | R17    | General     | 0 k $\Omega$ , 1/8 W   |
| C11    | Ceramic      | 100 pF, 50 V         | R18    | General     | 100 $\Omega$ , 1/8 W   |
| C12    | Ceramic      | 100 pF, 50 V         | R19    | General     | 100 $\Omega$ , 1/8 W   |
| C13    | Ceramic      | 100 pF, 50 V         | R20    | General     | 100 $\Omega$ , 1/8 W   |
| C14    | Ceramic      | 100 pF, 50 V         | R21    | General     | Open                   |
| C15    | Ceramic      | 100 pF, 50 V         | R22    | General     | Open                   |
| C16    | Ceramic      | 100 pF, 50 V         | R23    | General     | Open                   |
| C17    | Ceramic      | 100 pF, 50 V         | ZD1    | Zener diode | $V_Z = 21$ V (max.)    |
| C18    | Ceramic      | 100 pF, 50 V         | IPM1   | IC          | SIM6822M               |
| C19    | Ceramic      | 0.01 $\mu$ F, 50 V   | CN1    | Pin header  | Equiv. to B2P3-VH      |
| C20    | Ceramic      | 100 pF, 50 V         | CN2    | Pin header  | Equiv. to B2P5-VH      |
| CX1    | Film         | 0.033 $\mu$ F, 630 V | CN3    | Connector   | Equiv. to MA06-1       |
| R1     | General      | 100 $\Omega$ , 1/8 W | CN4    | Connector   | Equiv. to MA10-1       |
| R2     | General      | 100 $\Omega$ , 1/8 W |        |             |                        |

\* Refers to a part that requires adjustment based on operation performance in an actual application.

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