

# NFL25065L4BT

## SPM<sup>®</sup> 2 32 Series Intelligent Power Module (IPM) Interleaved PFC, 650 V, 50 A

The NFL25065L4BT is a Motion SPM 2 module providing a fully-featured, high-performance Interleaved PFC (Power Factor Correction) input power stage for consumer, medical, and industrial applications. These modules integrate optimized gate drive of the built-in IGBTs to minimize EMI and losses, while also providing multiple on-module protection features including under-voltage lockout, over-current shutdown, thermal monitoring, and fault reporting. These modules also feature a full-wave rectifier and high-performance output diodes for additional space savings and mounting convenience.

### Features

- UL Certified No. E209024 (UL1557)
- 650 V – 50 A 2-Phase Interleaved PFC with Integral Gate Drivers and Protection
- Very Low Thermal Resistance using Al<sub>2</sub>O<sub>3</sub> DBC Substrate
- Low-Loss Field Stop 4<sup>th</sup> Generation IGBT
- Full-Wave Bridge Rectifier and High-Performance Output SiC Boost Diode
- Optimized for 20 kHz Switching Frequency
- Built-in NTC Thermistor for Temperature Monitoring
- Isolation Rating of 2500 Vrms / 1 min
- These Devices are RoHS Compliant

### Typical Applications

- 2-Phase Interleaved PFC Converter (AC 200V Class)
  - ◆ HVAC (Commercial Air-conditioner)

### Integrated Power Functions

- 650 V – 50 A 2-Phase Interleaved PFC for Single-phase AC / DC Power Conversion (refer to Figure 2)

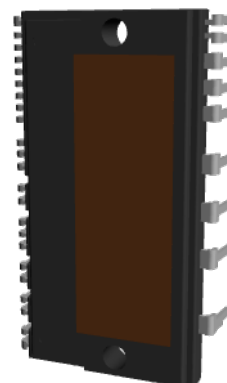
### Integrated Drive, Protection, and System Control Functions

- For IGBTs: Gate-drive Circuit, Over-Current Protection (OCP) Control Circuit, Under-Voltage Lock-Out Protection (UVLO)
- Fault Signaling: Corresponding to UV and OC faults
- Built-in Thermistor: Temperature Monitoring
- Input Interface: Active-HIGH Interface, works with 3.3 V / 5 V Logic, Schmitt-Trigger Input



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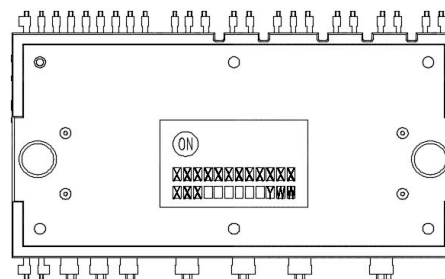
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3D Package Drawing  
(Click to Activate 3D Content)

S32EA-032  
CASE MODEB

### MARKING DIAGRAM



|              |                         |
|--------------|-------------------------|
| ON           | = ON Semiconductor Logo |
| NFL25065L4BT | = Specific Device Code  |
| XXX          | = Lot Number            |
| Y            | = Year                  |
| WW           | = Work Week             |

### ORDERING INFORMATION

See detailed ordering and shipping information on page 7 of this data sheet.

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## PIN CONFIGURATION

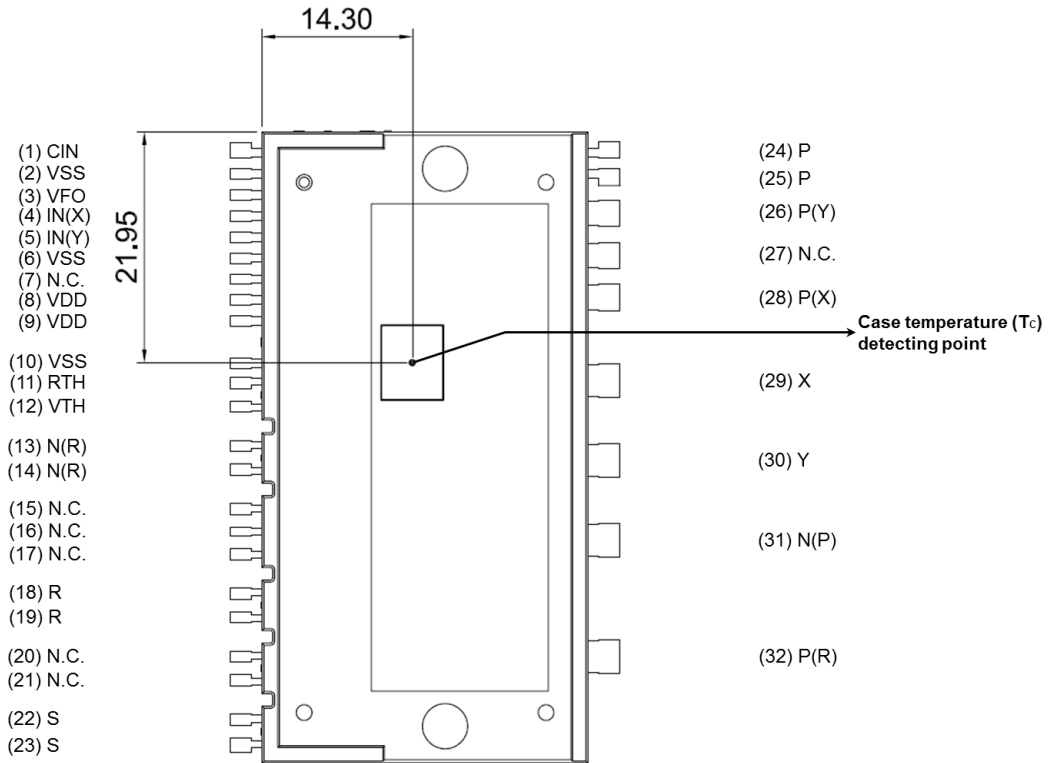


Figure 1. Pin Configuration – Top View

## INTERNAL EQUIVALENT CIRCUIT AND INPUT/OUTPUT PINS

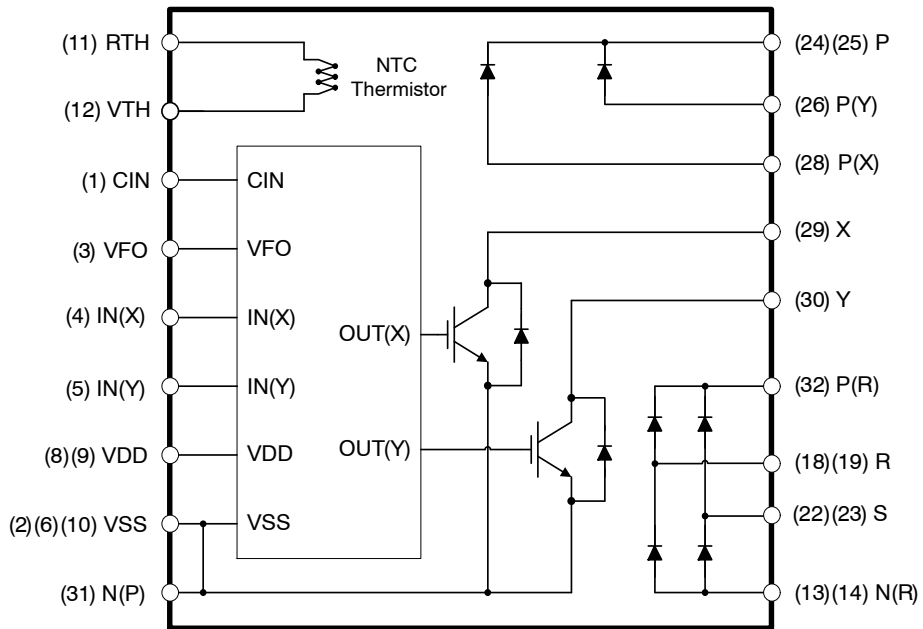


Figure 2. Internal Block Diagram

## NFL25065L4BT

**Table 1. PIN DESCRIPTION**

| Pin Number | Pin Name | Pin Description                            |
|------------|----------|--|
| 1          | CIN      | Signal Input for Over-Current Detection    |
| 2, 6, 10   | VSS      | Common Supply Ground                       |
| 3          | VFO      | Fault Output                               |
| 4          | IN(X)    | PWM Input for X IGBT Drive                 |
| 5          | IN(Y)    | PWM Input for Y IGBT Drive                 |
| 7          | N.C.     | No Connection                              |
| 8, 9       | VDD      | Supply Bias Voltage of IC for IGBT Driving |
| 11         | RTH      | Series Resistor for The Use of Thermistor  |
| 12         | VTH      | Thermistor Bias Voltage                    |
| 13, 14     | N(R)     | Negative DC-Link of Rectifier Diode        |
| 15, 16, 17 | N.C.     | No Connection                              |
| 18, 19     | R        | AC Input for R-Phase                       |
| 20, 21     | N.C.     | No Connection                              |
| 22, 23     | S        | AC Input for S-Phase                       |
| 24, 25     | P        | Output of Boost Diode                      |
| 26         | P(Y)     | Input of Boost Diode                       |
| 27         | N.C.     | No Connection                              |
| 28         | P(X)     | Input of Boost Diode                       |
| 29         | X        | Output of X Phase IGBT                     |
| 30         | Y        | Output of Y Phase IGBT                     |
| 31         | N(P)     | Negative DC-Link of IGBT                   |
| 32         | P(R)     | Positive DC-Link of Rectifier Diode        |

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**Table 2. ABSOLUTE MAXIMUM RATINGS** ( $T_J = 25^\circ\text{C}$  unless otherwise noted)

| Symbol                | Parameter                                      | Conditions  | Rating    | Unit             |
|-----------------------|--|---|-----------|------------------|
| <b>CONVERTER PART</b> |  |   |           |                  |
| $V_i$                 | Input Supply Voltage                           | Applied between R – S   | 264       | Vrms             |
| VPN                   | Output Voltage                                 | Applied between X – N(P), Y – N(P), P – P(X), P – P(Y)                                    | 450       | V                |
| VPN(Surge)            | Supply Voltage (Surge)                         | Applied between X – N(P), Y – N(P), P – P(X), P – P(Y)                                    | 500       | V                |
| VCES                  | Collector - Emitter Voltage                    | Breakdown Voltage between X – N(P), Y – N(P)  | 650       | V                |
| VRRM                  | Repetitive Peak Reverse Voltage of Boost Diode | Breakdown Voltage between P – P(X), P – P(Y)  | 650       | V                |
| VRRMR                 | Repetitive Peak Reverse Voltage of Rectifier   | Breakdown Voltage between P(R) – R, P(R) – S, R – N(R), S – N(R)                          | 900       | V                |
| IF                    | Boost Diode Forward Current                    | $T_c = 25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$ (Note 1)                          | 50        | A                |
| IFSM                  | Peak Surge Current of Boost Diode              | Non-Repetitive, 60 Hz Single Half-Sine Wave (Note 1)                                      | 150       | A                |
| IFR                   | Rectified Forward Current                      | $T_c = 25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$ (Note 1)                          | 50        | A                |
| IFSMR                 | Peak Surge Current of Rectifier                | Non-Repetitive, 60 Hz Single Half-Sine Wave (Note 1)                                      | 500       | A                |
| $\pm I_c$             | Each IGBT Collector Current                    | $T_c = 25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$ (Note 1)                          | 50        | A                |
| $\pm I_{cp}$          | Each IGBT Collector Current (Peak)             | $T_c = 25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$ , Under 1 ms Pulse Width (Note 1) | 100       | A                |
| Pc                    | Collector Dissipation                          | $T_c = 25^\circ\text{C}$ per IGBT (Note 1)  | 125       | W                |
| $T_j$                 | Operating Junction Temperature                 |   | -40 ~ 150 | $^\circ\text{C}$ |

## CONTROL PART

|       |                                |                                    |                  |                  |
|-------|--------------------------------|------------------------------------|------------------|------------------|
| VDD   | Control Supply Voltage         | Applied between VDD – VSS          | 20               | V                |
| VIN   | Input Signal Voltage           | Applied between IN(X), IN(Y) – VSS | -0.3 ~ VDD + 0.3 | V                |
| VFO   | Fault Output Supply Voltage    | Applied between VFO – VSS          | -0.3 ~ VDD + 0.3 | V                |
| IFO   | Fault Output Current           | Sink Current at VFO pin            | 1                | mA               |
| VCIN  | Current Sensing Input Voltage  | Applied between CIN – VSS          | -0.3 ~ VDD + 0.3 | V                |
| $T_j$ | Operating Junction Temperature |                                    | -40 ~ 150        | $^\circ\text{C}$ |

## TOTAL SYSTEM

|       |                                   |  |           |                  |
|-------|-----------------------------------|--|-----------|------------------|
| $T_c$ | Module Case Operation Temperature | See Figure 1   | -40 ~ 125 | $^\circ\text{C}$ |
| Tstg  | Storage Temperature               |  | -40 ~ 125 | $^\circ\text{C}$ |
| Viso  | Isolation Voltage                 | 60 Hz, Sinusoidal, AC 1 Minute, Connection Pins to Heat Sink Plate | 2500      | Vrms             |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. These values had been made an acquisition by the calculation considered to design factor.

**Table 3. THERMAL RESISTANCE**

| Symbol         | Parameter                                    | Conditions                                 | Min | Typ | Max  | Unit                      |
|----------------|--|--|-----|-----|------|---------------------------|
| $R_{th(j-c)Q}$ | Junction-to-Case Thermal Resistance (Note 2) | Each IGBT under Operating Condition        | -   | -   | 1.00 | $^\circ\text{C}/\text{W}$ |
| $R_{th(j-c)D}$ |  | Each Boost Diode under Operating Condition | -   | -   | 1.60 | $^\circ\text{C}/\text{W}$ |
| $R_{th(j-c)R}$ |  | Each Rectifier under Operating Condition   | -   | -   | 0.74 | $^\circ\text{C}/\text{W}$ |

2. For the measurement point of case temperature ( $T_c$ ), please refer to Figure 1. DBC discoloration and Picker Circle Printing allowed, please refer to application note AN-9190 (Impact of DBC Oxidation on SPM<sup>®</sup> Module Performance).

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**Table 4. ELECTRICAL CHARACTERISTICS** ( $T_J = 25^\circ\text{C}$  unless otherwise specified.)

| Symbol                | Parameter                               | Conditions  | Min                      | Typ  | Max  | Unit |    |
|-----------------------|---|---|--------------------------|------|------|------|----|
| <b>CONVERTER PART</b> |   |   |                          |      |      |      |    |
| VCE(sat)              | Collector – Emitter Saturation Voltage  | VDD = 15 V, VIN = 5 V, Ic = 50 A, Tj = 25°C   | –                        | 1.55 | 2.05 | V    |    |
| VFWD                  | FWDi Forward Voltage                    | Ifwd = 15 A, Tj = 25°C  | –                        | 1.95 | 2.45 | V    |    |
| VF                    | Boost Diode Forward Voltage             | If = 50 A, Tj = 25°C  | –                        | 1.80 | 2.30 | V    |    |
| VFR                   | Rectifier Forward Voltage               | Ifr = 50 A, Tj = 25°C   | –                        | 1.13 | 1.35 | V    |    |
| ton                   | Switching Times                         | VPN = 400 V, VDD = 15 V, Ic = 25 A<br>Tj = 25°C<br>VIN = 0 V ↔ 5 V, Inductive Load<br>See Figure 3<br>(Note 3)            | –                        | 650  | –    | ns   |    |
| tc(on)                |   |   | –                        | 75   | –    | ns   |    |
| toff                  |   |   | –                        | 900  | –    | ns   |    |
| tc(off)               |   |   | –                        | 100  | –    | ns   |    |
| trr                   |   |   | –                        | 50   | –    | ns   |    |
| Irr                   |   |   | –                        | 15   | –    | A    |    |
| ICES                  | Collector – Emitter Leakage Current     | VCE = VCES  | –                        | –    | 1    | mA   |    |
| IR                    | Boost Diode Revers Leakage Current      | VR = VRRM   | –                        | –    | 1    | mA   |    |
| <b>CONTROL PART</b>   |   |   |                          |      |      |      |    |
| IQDD                  | Quiescent VDD Supply Current            | VDD = 15 V, IN(X), IN(Y) – VSS = 0 V,<br>Supply Current between VDD and VSS   | –                        | –    | 2.65 | mA   |    |
| IPDD                  | Operating VDD Supply Current            | VDD = 15 V, FPWM = 20 kHz, Duty = 50%,<br>Applied to one PWM Signal Input per IGBT,<br>Supply Current between VDD and VSS | –                        | –    | 7.00 | mA   |    |
| VFOH                  | Fault Output Voltage                    | VDD = 15 V, VFO Circuit: 10 kΩ<br>to 5 V Pull-up  | VCIN = 0 V               | 4.50 | –    | –    | V  |
| VFOL                  |   | VDD = 15 V, IFO = 1mA   | VCIN = 1 V               | –    | –    | 0.50 | V  |
| VCIN(ref)             | Short Circuit Trip Level                | VDD = 15 V  | CIN – VSS                | 0.45 | 0.50 | 0.55 | V  |
| UVDDD                 | Supply Circuit Under-Voltage Protection | Detection Level   |                          | 10.5 | –    | 13.0 | V  |
| UVDDR                 |   | Reset Level   |                          | 11.0 | –    | 13.5 | V  |
| VIN(ON)               | ON Threshold Voltage                    | Applied between IN(X), IN(Y) – VSS  |                          | –    | –    | 2.6  | V  |
| VIN(OFF)              | OFF Threshold Voltage                   |   |                          | 0.8  | –    | –    | V  |
| tFOD                  | Fault-Out Pulse Width                   |   |                          | 30   | –    | –    | μs |
| RTH                   | Resistance of Thermistor                | at TTH = 25°C   | See Figure 4<br>(Note 4) | –    | 47   | –    | kΩ |
|                       |   | at TTH = 100°C  |                          | –    | 2.9  | –    |    |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

3. ton and toff include the propagation delay of the internal drive IC. tc(on) and tc(off) are the switching times of IGBT under the given gate-driving condition internally. For the detailed information, please see Figure 3.

4. TTH is the temperature of thermistor itself. To know case temperature (Tc), conduct experiments considering the application.

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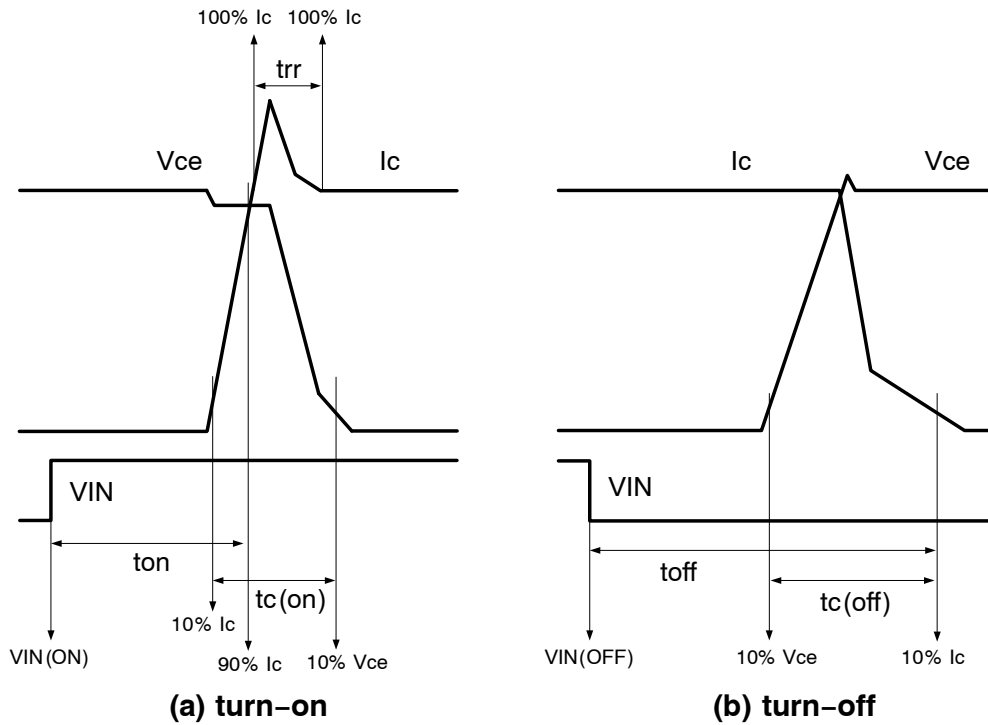


Figure 3. Switching Time Definition

## R-T Curve

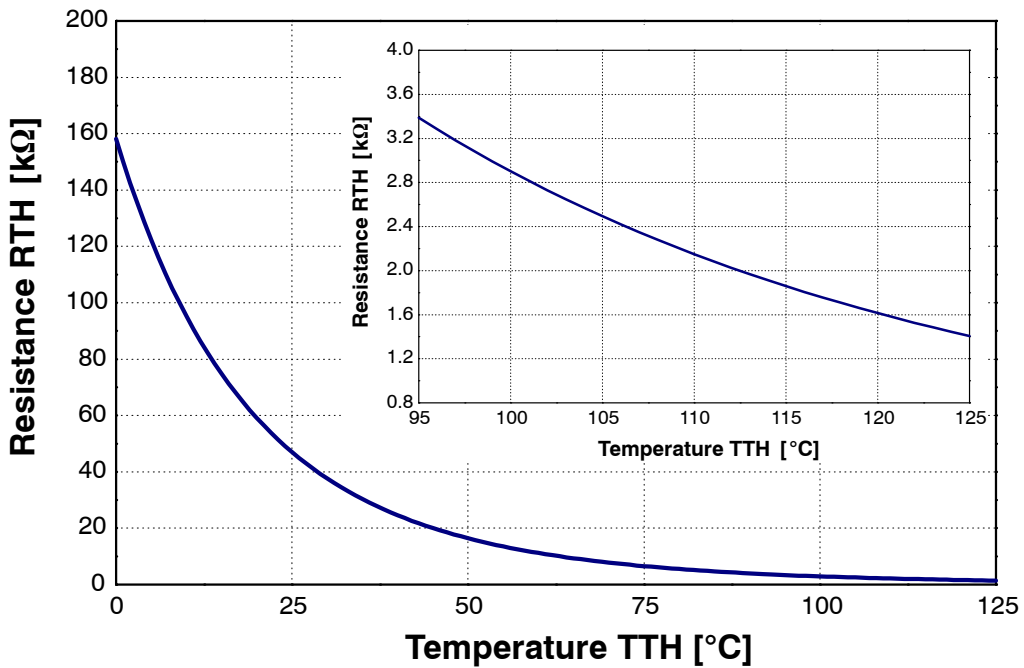


Figure 4. R-T Curve of Built-in Thermistor

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**Table 5. RECOMMENDED OPERATING CONDITIONS**

| Symbol    | Parameter                | Conditions  | Value |      |      | Unit              |
|-----------|--------------------------|---|-------|------|------|-------------------|
|           |                          |   | Min   | Typ  | Max  |                   |
| $V_i$     | Input Supply Voltage     | Applied between R – S   | 187   | –    | 253  | Vrms              |
| $I_i$     | Input Current            | $T_c \leq 100^\circ\text{C}$ , $V_i = 220\text{ V}$ , $V_o = 360\text{ V}$ ,<br>FPWM = 20 kHz per IGBT    | –     | –    | 35   | Arms              |
| VPN       | Supply Voltage           | Applied between X – NP, Y – NP, P – PX, P – PY  | –     | –    | 400  | V                 |
| VDD       | Control Supply Voltage   | Applied between VDD – VSS   | 13.5  | 15.0 | 16.5 | V                 |
| dVDD / dt | Control Supply Variation |   | –1    | –    | +1   | V / $\mu\text{s}$ |
| FPWM      | PWM Input Signal         | $-40^\circ\text{C} \leq T_c \leq 125^\circ\text{C}$ , $-40^\circ\text{C} \leq T_j \leq 150^\circ\text{C}$ | –     | 20   | –    | kHz               |
| $T_j$     | Junction Temperature     |   | –40   | –    | 150  | $^\circ\text{C}$  |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

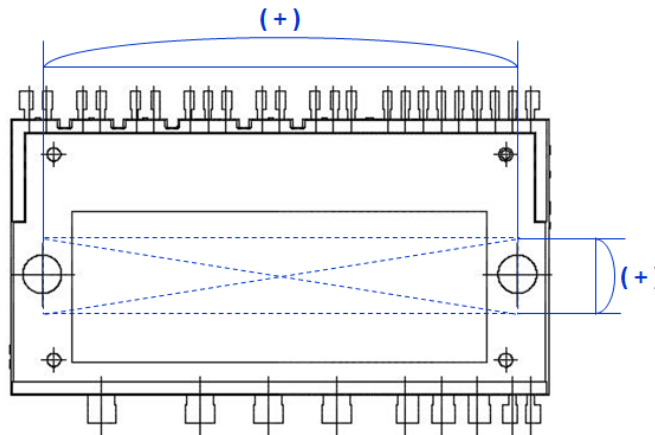
## PACKAGE MARKING AND ORDERING INFORMATION

| Device       | Device Marking | Package   | Shipping       |
|--------------|----------------|-----------|----------------|
| NFL25065L4BT | NFL25065L4BT   | S32EA-032 | 8 Units / Tube |

## MECHANICAL CHARACTERISTICS AND RATINGS

| Parameter       | Conditions                        | Value                  |      |      | Unit          |         |
|-----------------|-----------------------------------|------------------------|------|------|---------------|---------|
|                 |                                   | Min                    | Typ  | Max  |               |         |
| Device Flatness | See Figure 5                      | 0                      | –    | 150  | $\mu\text{m}$ |         |
| Mounting Torque | Mounting Screw: M4<br>(Note 5, 6) | Recommended 0.98 N • m | 0.78 | 0.98 | 1.17          | N • m   |
|                 |                                   | Recommended 10 kg • cm | 8    | 10   | 12            | kg • cm |
| Weight          |                                   | –                      | 32   | –    | g             |         |

- Do not over torque when mounting screws. Too much mounting torque may cause DBC cracks, as well as bolts and Al heat-sink destruction.
- Avoid one-sided tightening stress. Uneven mounting can cause the DBC substrate of package to be damaged. The pre-screwing torque is set to 20 ~ 30% of maximum torque rating.



**Figure 5. Flatness Measurement Position**

TIME CHARTS OF SPMs PROTECTIVE FUNCTION

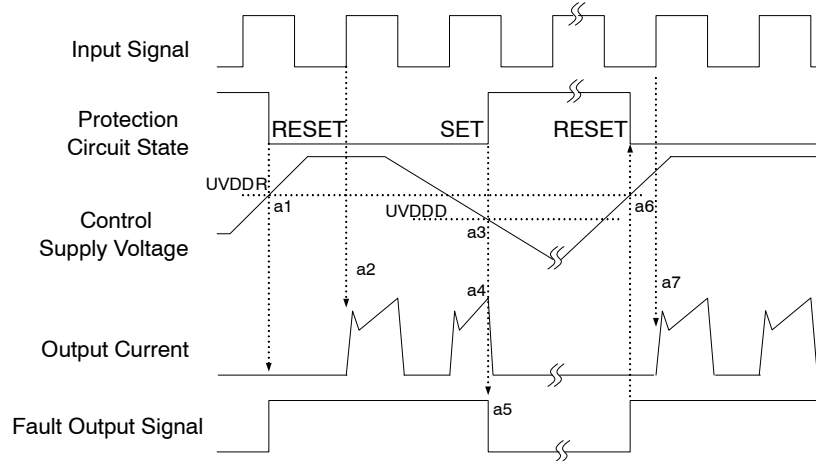


Figure 6. Under-Voltage Protection

- a1: Control supply voltage rises: after the voltage rises UVDDR, the circuits start to operate when the next input is applied.
- a2: Normal operation: IGBT ON and carrying current.
- a3: Under-voltage detection (UVDDD).
- a4: IGBT OFF in spite of control input condition.
- a5: Fault output operation starts.
- a6: Under-voltage reset (UVDDR).
- a7: Normal operation: IGBT ON and carrying current by triggering next signal from LOW to HIGH.

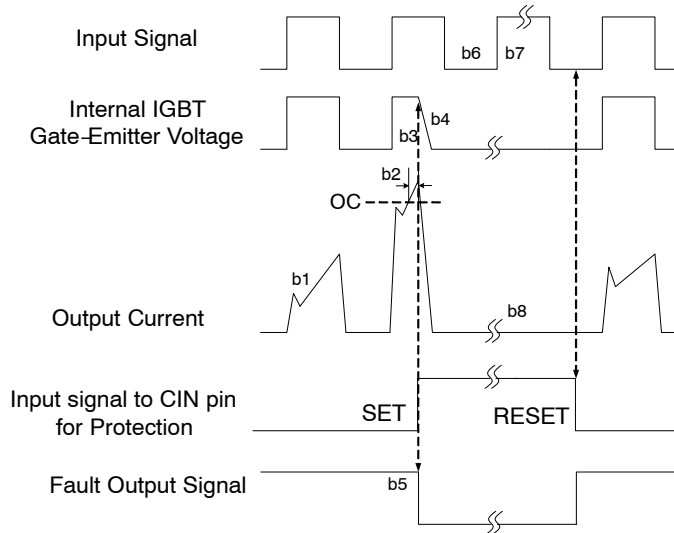
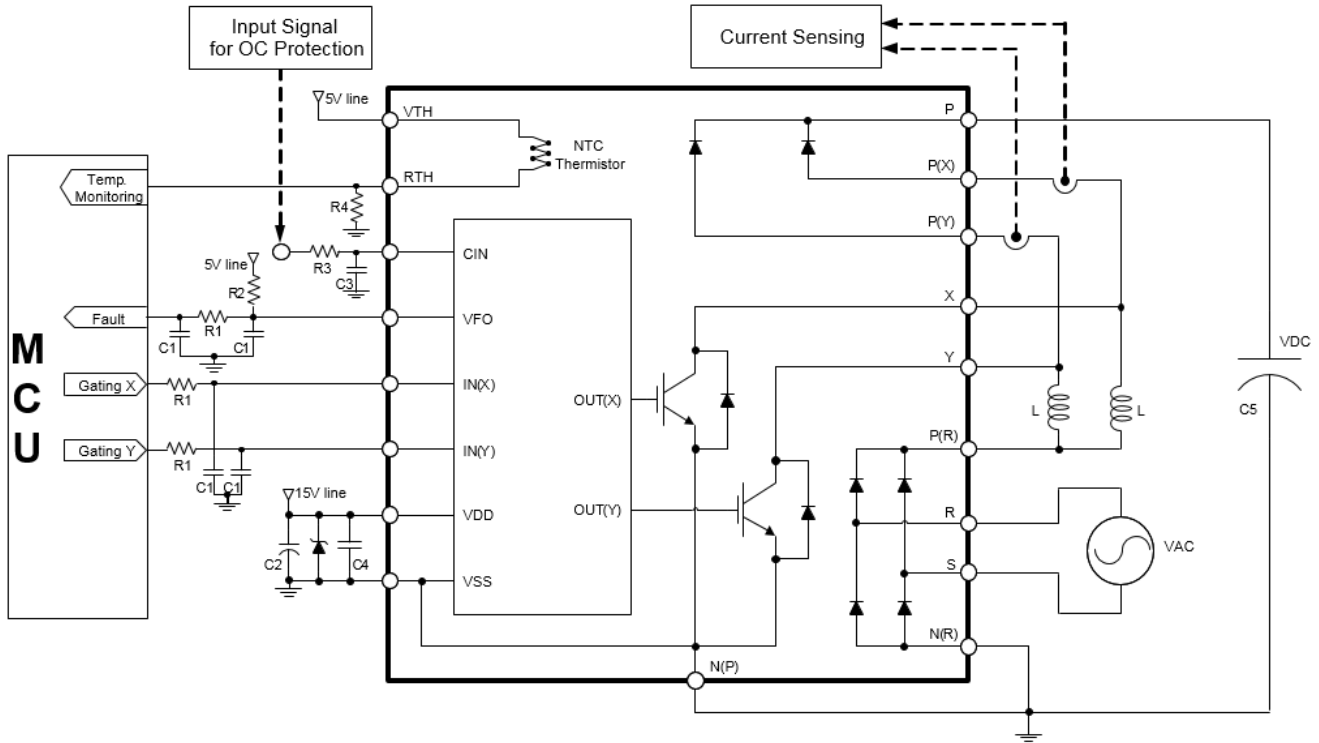


Figure 7. Over-Current Protection

- (With the external over current detection circuit)
- b1: Normal operation: IGBT ON and carrying current.
  - b2: Over-current detection (OC trigger).
  - b3: All IGBTs gate are hard interrupted.
  - b4: All IGBTs turn OFF.
  - b5: Fault output operation starts.
  - b6: Input LOW – IGBT OFF state.
  - b7: Input HIGH – IGBT ON state, but during the active period of fault output, the IGBT doesn't turn ON.
  - b8: IGBT OFF state.



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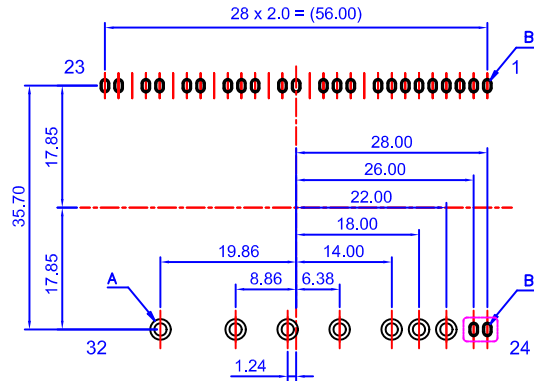
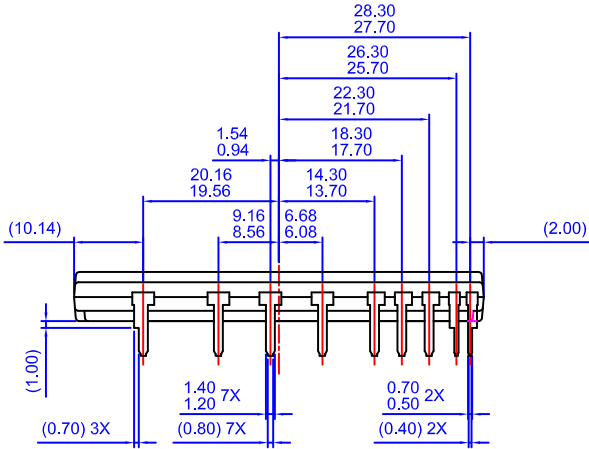
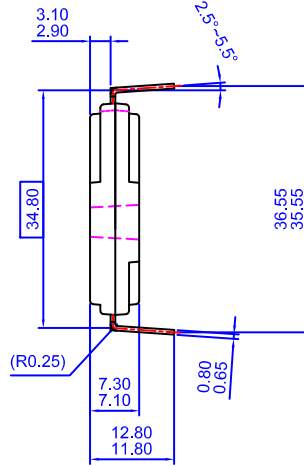
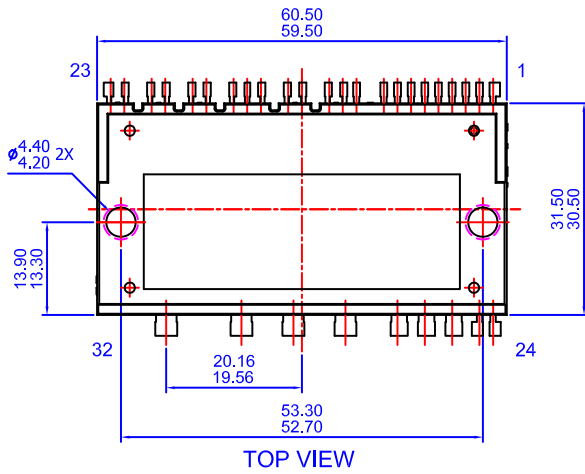
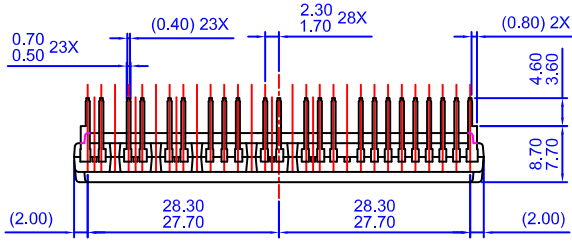
**Figure 8. Typical Application Circuit**

7. To avoid malfunction, the wiring of each input should be as short as possible (Less than 2 – 3 cm).
8. VFO output is an open-drain type. This signal line should be pulled up to the positive side of the MCU or control power supply with a resistor that makes IFO up to 1 mA.
9. Input signal is active-HIGH type. There is a 5 kΩ resistor inside the IC to pull-down each input signal line to GND. RC coupling circuits should be adopted for the prevention of input signal oscillation. RC coupling at each input might change depending on the PWM control scheme used in the application and the wiring impedance of the application's printed circuit board. R1C1 time constant should be selected in the range 50 ~ 150 ns (Recommended R1 = 100 Ω, C1 = 1 nF).
10. To prevent error of the protection function, the wiring related with R3 and C3 should be as short as possible.
11. In the over-current protection circuit, select the R3C3 time constant in the range 1.5 ~ 2.0 μs. Do enough evaluation on the real system because over-current protection time may vary wiring pattern layout and value of the R3C3 time constant.
12. Each capacitor should be mounted as close to the pins of the Motion SPM 2 product as possible.
13. Relays are used in most systems of electrical equipment in industrial application. In these cases, there should be sufficient distance between the MCU and the relays.
14. The zener diode or transient voltage suppressor should be adapted for the protection of ICs from the surge destruction between each pair of control supply terminals (Recommended zener diode is 22 V / 1 W, which has the lower zener impedance characteristic than about 15 Ω).
15. Please choose the electrolytic capacitor with good temperature characteristic in C2. Choose 0.1 ~ 0.2 μF R-category ceramic capacitors with good temperature and frequency characteristics in C4.

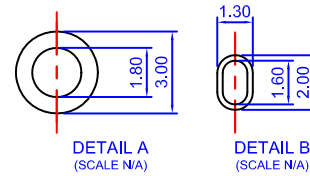
# NFL25065L4BT

## PACKAGE DIMENSIONS

S32CA-032 / 32LD, PDD STD, DBC, DIP TYPE (DBC AIN)  
CASE MODEB  
ISSUE O




- NOTES: UNLESS OTHERWISE SPECIFIED  
A) THIS PACKAGE DOES NOT COMPLY TO ANY CURRENT PACKAGING STANDARD  
B) ALL DIMENSIONS ARE IN MILLIMETERS  
C) DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS  
D) ( ) IS REFERENCE



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