

Intelligent Power Module (IPM) 600 V, 10 A

NFAP1060L3TT

The NFAP1060L3TT is a fully-integrated inverter power stage consisting of a high-voltage driver, six IGBT's and a thermistor, suitable for driving permanent magnet synchronous (PMSM) motors, brushless-DC (BLDC) motors and AC asynchronous motors. The IGBT's are configured in a 3-phase bridge with separate emitter connections for the lower legs for maximum flexibility in the choice of control algorithm. The power stage has a full range of protection functions including cross-conduction protection, external shutdown and under-voltage lockout functions. An internal comparator and reference connected to the over-current protection circuit allows the designer to set the over-current protection level.

Features

- Three-phase 10 A/600 V IGBT Module with Integrated Drivers
- Compact 44 mm x 20.9 mm Single In-line Package
- Built-in Under Voltage Protection
- Cross-conduction Protection
- ITRIP Input to Shut Down All IGBTs
- Integrated Bootstrap Diodes and Resistors
- Thermistor for Substrate Temperature Measurement
- UL1557 Certification (File number: E339285)

Typical Applications

- Industrial Drives
- Industrial Pumps
- Industrial Fans
- Industrial Automation

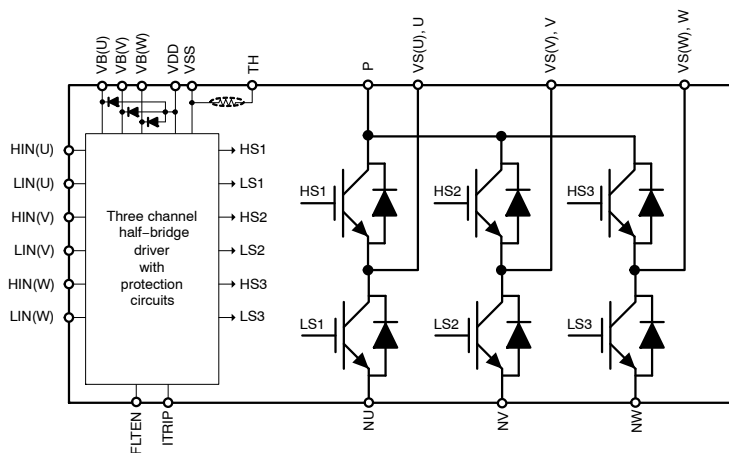
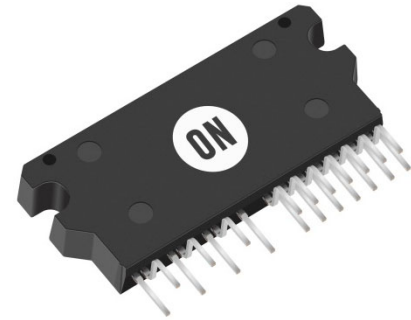
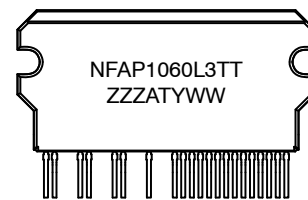


Figure 1. Functional Diagram



SIP29
CASE 127FB

MARKING DIAGRAM



NFAP1060L3TT = Specific Device Code
ZZZ = Assembly Lot Code
A = Assembly Location
T = Test Location
Y = Year
WW = Work Week

Device marking is on package top side

ORDERING INFORMATION

| Device | Package | Shipping |
|--------------|--------------------|-----------|
| NFAP1060L3TT | SIP29 (Pb-Free) | 120 / Box |

NFAP1060L3TT

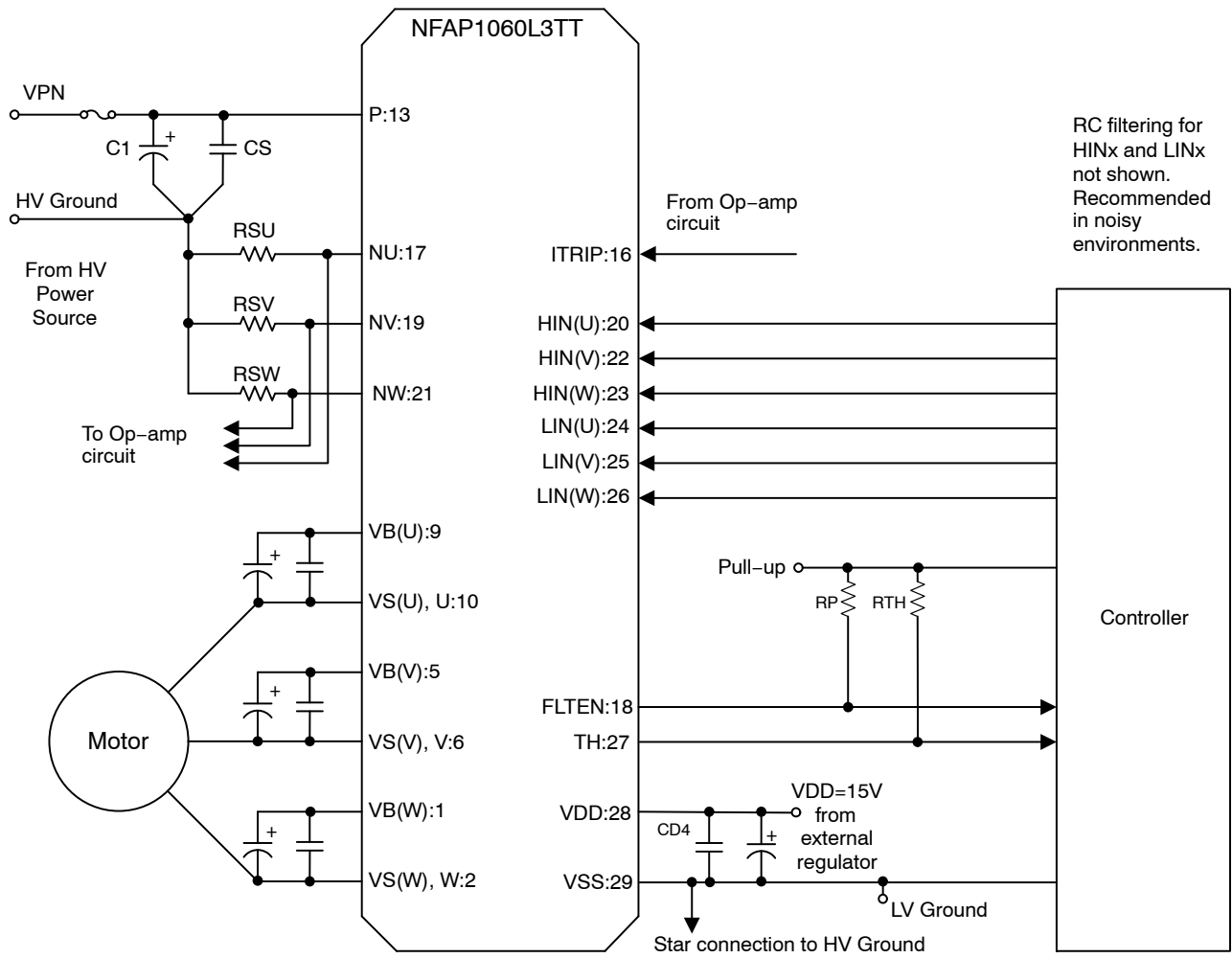


Figure 2. Application Schematic

NFAP1060L3TT

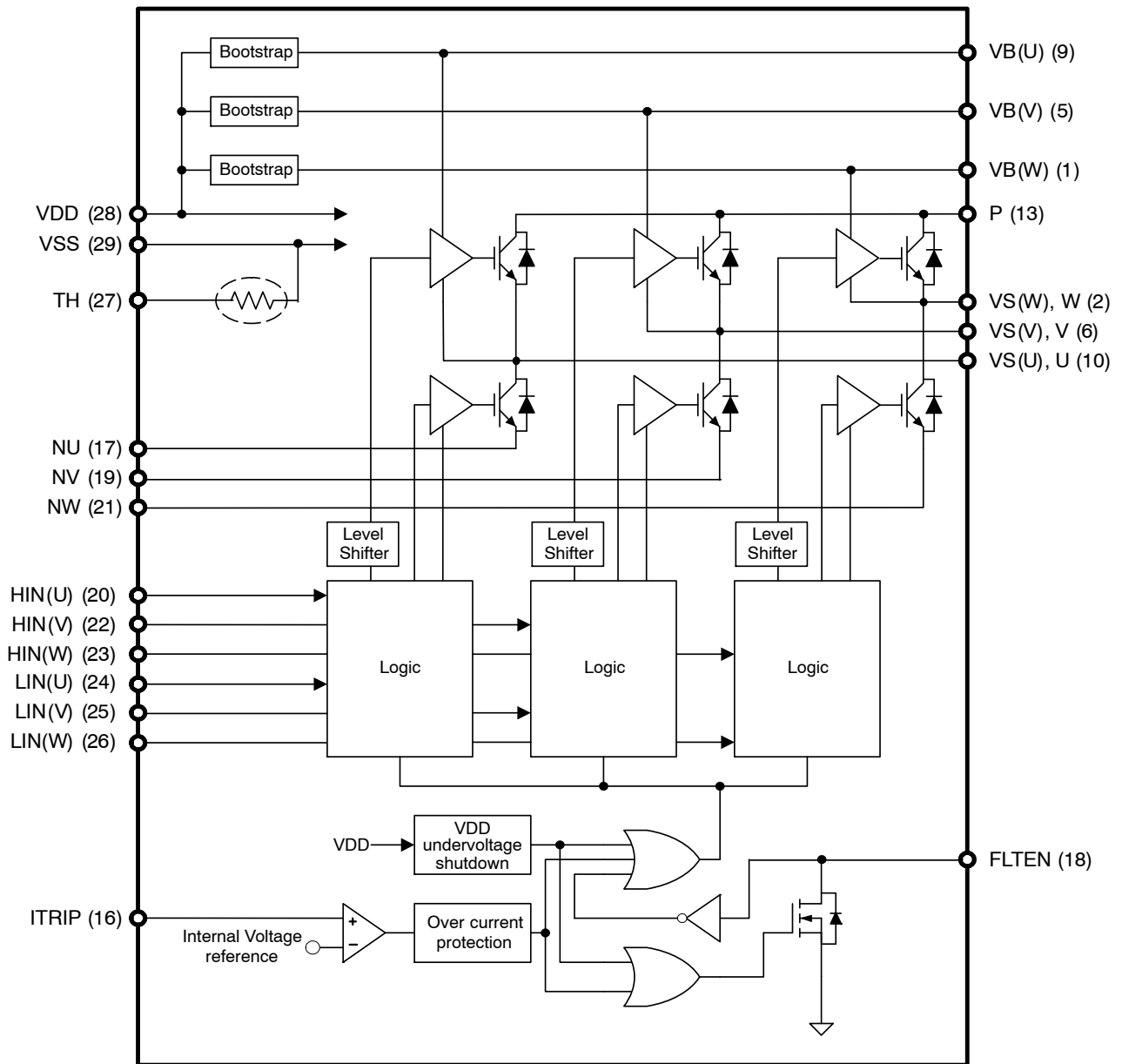


Figure 3. Simplified Block Diagram

NFAP1060L3TT

Table 1. PIN FUNCTION DESCRIPTION

| Pin | Name | Description |
|-----|----------|---|
| 1 | VB(W) | High-Side Bias Voltage for W phase IGBT Driving |
| 2 | VS(W), W | High-Side Bias Voltage GND for W phase IGBT Driving, Output for W Phase |
| 5 | VB(V) | High-Side Bias Voltage for V phase IGBT Driving |
| 6 | VS(V), V | High-Side Bias Voltage GND for V phase IGBT Driving, Output for V Phase |
| 9 | VB(U) | High-Side Bias Voltage for U phase IGBT Driving |
| 10 | VS(U), U | High-Side Bias Voltage GND for U phase IGBT Driving, Output for U Phase |
| 13 | P | Positive DC-Link Input |
| 16 | ITRIP | Input for Over Current Protection |
| 17 | NU | Negative DC-Link Input for U Phase |
| 18 | FLTEN | Fault Output, Enable Input |
| 19 | NV | Negative DC-Link Input for V Phase |
| 20 | HIN(U) | Signal Input for High-Side U Phase |
| 21 | NW | Negative DC-Link Input for W Phase |
| 22 | HIN(V) | Signal Input for High-Side V Phase |
| 23 | HIN(W) | Signal Input for High-Side W Phase |
| 24 | LIN(U) | Signal Input for Low-Side U Phase |
| 25 | LIN(V) | Signal Input for Low-Side V Phase |
| 26 | LIN(W) | Signal Input for Low-Side W Phase |
| 27 | TH | Series Resistor for Thermistor (Temperature Detection) |
| 28 | VDD | Low-Side Bias Voltage for IC and IGBTs Driving |
| 29 | VSS | Low-Side Common Supply Ground |

NOTE: Pins 3, 4, 7, 8, 11, 12, 14 and 15 are not present

Table 2. ABSOLUTE MAXIMUM RATINGS at Tc = 25°C (Note 1)

| Parameter | Symbol | Conditions | Rating | Unit |
|------------------------------------|--------|--|---------------|------|
| Supply Voltage | VPN | P-NU,NV,NW, VPN (surge) < 500 V (Note 2) | 450 | V |
| Collector - Emitter Voltage | Vces | P-U,V,W; U-NU; V-NV; W-NW | 600 | V |
| Each IGBT Collector Current | ±Ic | P,U,V,W,NU,NV,NW terminal current | ±10 | A |
| Each IGBT Collector Current (Peak) | ±Icp | Tc = 25°C, Under 1ms Pulse Width | 20 | A |
| Corrector Dissipation | Pc | Tc = 25°C, Per One Chip | 19 | W |
| High-Side Control Bias voltage | VBS | VB(U)-VS(U), VB(V)-VS(V), VB(W)-VS(W) (Note 3) | -0.3 to +20.0 | V |
| Control Supply Voltage | VDD | VDD-VSS | -0.3 to +20.0 | V |
| Input Signal Voltage | VIN | HIN(U), HIN(V), HIN(W), LIN(U), LIN(V), LIN(W)-VSS | -0.3 to VDD | V |
| FLTEN Terminal Voltage | VFLTEN | FLTEN-VSS | -0.3 to VDD | V |
| Current Sensing Input Voltage | VITRIP | ITRIP-VSS | -0.3 to +7.0 | V |
| Operating Junction Temperature | Tj | | 150 | °C |
| Storage Temperature | Tstg | | -40 to +125 | °C |
| Module Case Operation Temperature | Tc | | -40 to +125 | °C |
| Tightening Torque | MT | Case mounting screws | 0.9 | Nm |
| Isolation Voltage | Viso | 50 Hz sine wave AC 1 minute (Note 4) | 2000 | 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. Refer to ELECTRICAL CHARACTERISTICS, RECOMMENDED OPERATING RANGES and/or APPLICATION INFORMATION for Safe Operating parameters.
2. This surge voltage developed by the switching operation due to the wiring inductance between P and NU, NV, NW terminal.
3. VBS = VB(U)-VS(U), VB(V)-VS(V), VB(W)-VS(W)
4. Test conditions: AC2500V, 1 s

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Table 3. RECOMMENDED OPERATING RANGES

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|--------------------------------|----------|---|------|-----|------|------|
| Supply voltage | VPN | P–NU,NV,NW | 0 | 280 | 450 | V |
| High–Side Control Bias voltage | VBS | VB(U)–VS(U), VB(V)–VS(V), VB(W)–VS(W) | 13.0 | 15 | 17.5 | V |
| Control Supply Voltage | VDD | VDD–VSS | 14.0 | 15 | 16.5 | V |
| ON–state Input Voltage | VIN(ON) | HIN(U), HIN(V), HIN(W), LIN(U), LIN(V), LIN(W)–VSS | 3.0 | – | 5.0 | V |
| OFF–state Input Voltage | VIN(OFF) | | 0 | – | 0.3 | V |
| PWM Frequency | fPWM | | 1 | – | 20 | kHz |
| Dead Time | DT | Turn–off to Turn–on (external) | 0.5 | – | – | μs |
| Allowable Input Pulse Width | PWIN | ON and OFF | 1 | – | – | μs |
| Tightening Torque | | 'M3' type screw | 0.6 | – | 0.9 | Nm |

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.

Table 4. ELECTRICAL CHARACTERISTICS at T_c = 25°C, V_{BIAS} (VBS, VDD) = 15 V unless otherwise noted.

| Parameter | Test Conditions | Symbol | Min | Typ | Max | Unit |
|---|---|-----------------------|------|------|------|------|
| POWER OUTPUT SECTION | | | | | | |
| Collector–Emitter Leakage Current | V _{ce} = 600 V | I _{ces} | – | – | 1 | mA |
| Bootstrap Diode Reverse Current | VR(DB) = 600 V | IR(DB) | – | – | 1 | mA |
| Collector–Emitter Saturation Voltage | VDD = VBS = 15 V, I _N = 5 V, I _c = 10 A, T _j = 25°C | VCE(sat) | – | 2.1 | 2.7 | V |
| | VDD = VBS = 15 V, I _N = 5 V, I _c = 5 A, T _j = 100°C | | – | 1.8 | – | V |
| FWDi Forward Voltage | I _N = 0 V, I _c = –10 A, T _j = 25°C | VF | – | 2.2 | 2.8 | V |
| | I _N = 0 V, I _c = –5 A, T _j = 100°C | | – | 1.7 | – | V |
| Junction to Case Thermal Resistance | Inverter IGBT Part (per 1/6 Module) | R _{th(j–c)Q} | – | – | 6.3 | °C/W |
| | Inverter FRD Part (per 1/6 Module) | R _{th(j–c)F} | – | – | 11.6 | °C/W |
| DRIVER SECTION | | | | | | |
| Quiescent VBS Supply Current | VBS = 15 V, HIN = 0 V, per driver | IQBS | – | 0.07 | 0.4 | mA |
| Quiescent VDD Supply Current | VDD = 15 V, HIN = 0 V, VDD–VSS | IQDDL | – | 0.85 | 3.0 | mA |
| ON Threshold voltage | HIN(U), HIN(V), HIN(W), LIN(U), LIN(V), LIN(W)–VSS | VIN(ON) | – | – | 2.5 | V |
| OFF Threshold voltage | | VIN(OFF) | 0.8 | – | – | V |
| Logic 1 Input Current | VIN = +3.3 V | IIN+ | – | 660 | – | μA |
| Logic 0 Input Current | VIN = 0 V | IIN– | – | – | 2 | μA |
| FLTEN Terminal Sink Current | FAULT: ON / VFLTEN = 0.1 V | I _{oSD} | – | 2 | – | mA |
| Fault–Output Pulse Width | FLTEN–VSS | tFOD | 20 | – | – | μs |
| Enable Threshold | FLTEN–VSS | VEN+ | – | – | 2.5 | V |
| | | VEN– | 0.8 | – | – | V |
| Short Circuit Trip Level | ITRIP–VSS | VSC(ref) | 0.44 | 0.49 | 0.54 | V |
| High–Side Control Bias Voltage Under–Voltage Protection | Reset Level | UVBSR | 10.3 | 11.1 | 11.9 | V |
| | Detection Level | UVBSD | 10.1 | 10.9 | 11.7 | V |
| Supply Voltage Under–Voltage Protection | Reset Level | UVDDR | 10.3 | 11.1 | 11.7 | V |
| | Detection Level | UVDDD | 10.1 | 10.9 | 11.5 | V |

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.

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Table 5. ELECTRICAL CHARACTERISTICS

at $T_c = 25^\circ\text{C}$, V_{BIAS} (VBS, VDD) = 15 V, $V_{\text{CC}} = 300\text{ V}$, $L = 3.0\text{ mH}$ unless otherwise noted.

| Parameter | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------------------------------|--|------------------|-------------|-----|-----|---------------|
| SWITCHING CHARACTER | | | | | | |
| Switching Time | $I_C = 10\text{ A}$, $T_j = 25^\circ\text{C}$ | t_{ON} | - | 0.5 | 1.0 | μs |
| | | t_{OFF} | - | 0.5 | 1.0 | μs |
| Turn-on Switching Loss | $I_C = 5\text{ A}$, $T_j = 25^\circ\text{C}$ | E_{ON} | - | 114 | - | μJ |
| Turn-off Switching Loss | | E_{OFF} | - | 65 | - | μJ |
| Total Switching Loss | | E_{TOT} | - | 179 | - | μJ |
| Turn-on Switching Loss | $I_C = 5\text{ A}$, $T_j = 100^\circ\text{C}$ | E_{ON} | - | 136 | - | μJ |
| Turn-off Switching Loss | | E_{OFF} | - | 75 | - | μJ |
| Total Switching Loss | | E_{TOT} | - | 211 | - | μJ |
| Diode Reverse Recovery Energy | $I_C = 5\text{ A}$, $T_j = 100^\circ\text{C}$ | E_{REC} | - | 27 | - | μJ |
| Diode Reverse Recovery Time | | t_{RR} | - | 174 | - | ns |
| Reverse Bias Safe Operating Area | $I_C = 20\text{ A}$, $V_{\text{CE}} = 450\text{ V}$ | RBSOA | Full Square | | | |
| Short Circuit Safe Operating Area | $V_{\text{CE}} = 400\text{ V}$, $T_j = 100^\circ\text{C}$ | SCSOA | 5 | - | - | μs |

TYPICAL CHARACTERISTICS INV SECTION

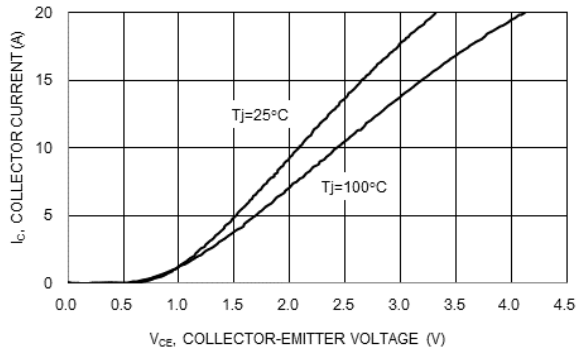


Figure 4. V_{CE} vs. I_C for Different Temperatures ($V_{\text{DD}} = 15\text{ V}$)

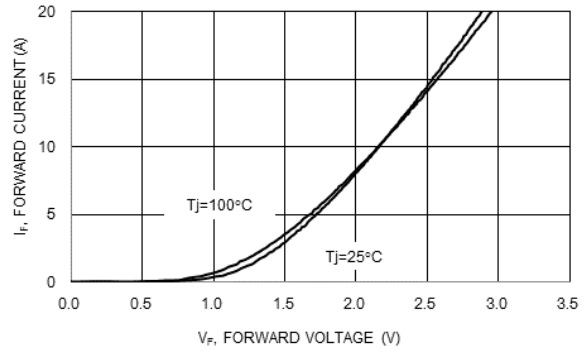


Figure 5. V_F vs. I_F for Different Temperatures

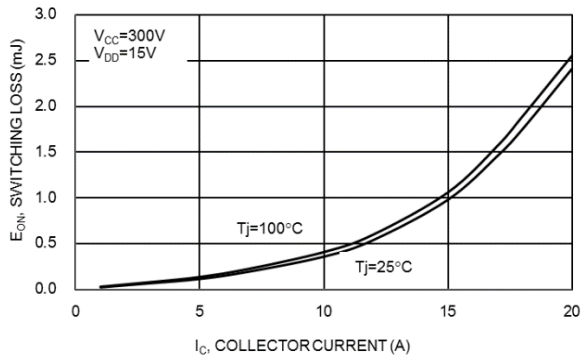


Figure 6. E_{ON} vs. I_C for Different Temperatures

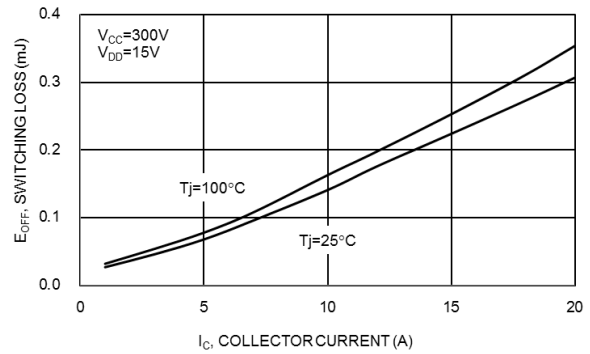


Figure 7. E_{OFF} vs. I_C for Different Temperatures

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TYPICAL CHARACTERISTICS INV SECTION

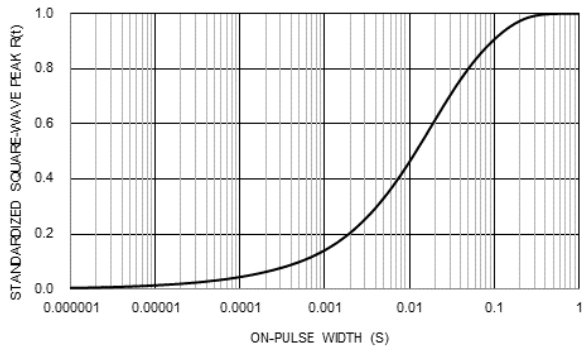


Figure 8. Thermal Impedance Plot

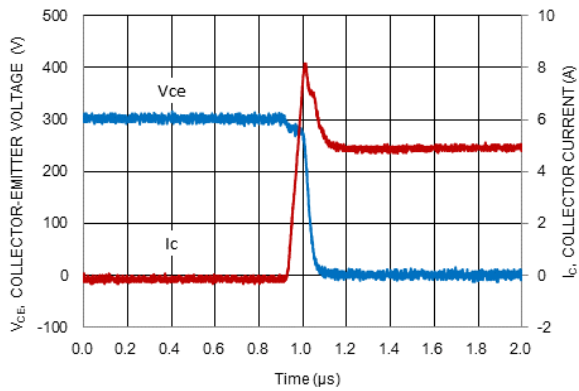


Figure 9. Turn-on Waveform
T_j = 100°C, V_{CC} = 300 V

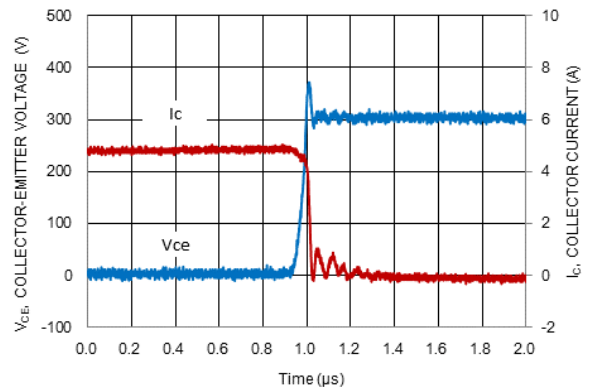


Figure 10. Turn-off Waveform
T_j = 100°C, V_{CC} = 300 V

APPLICATIONS INFORMATION

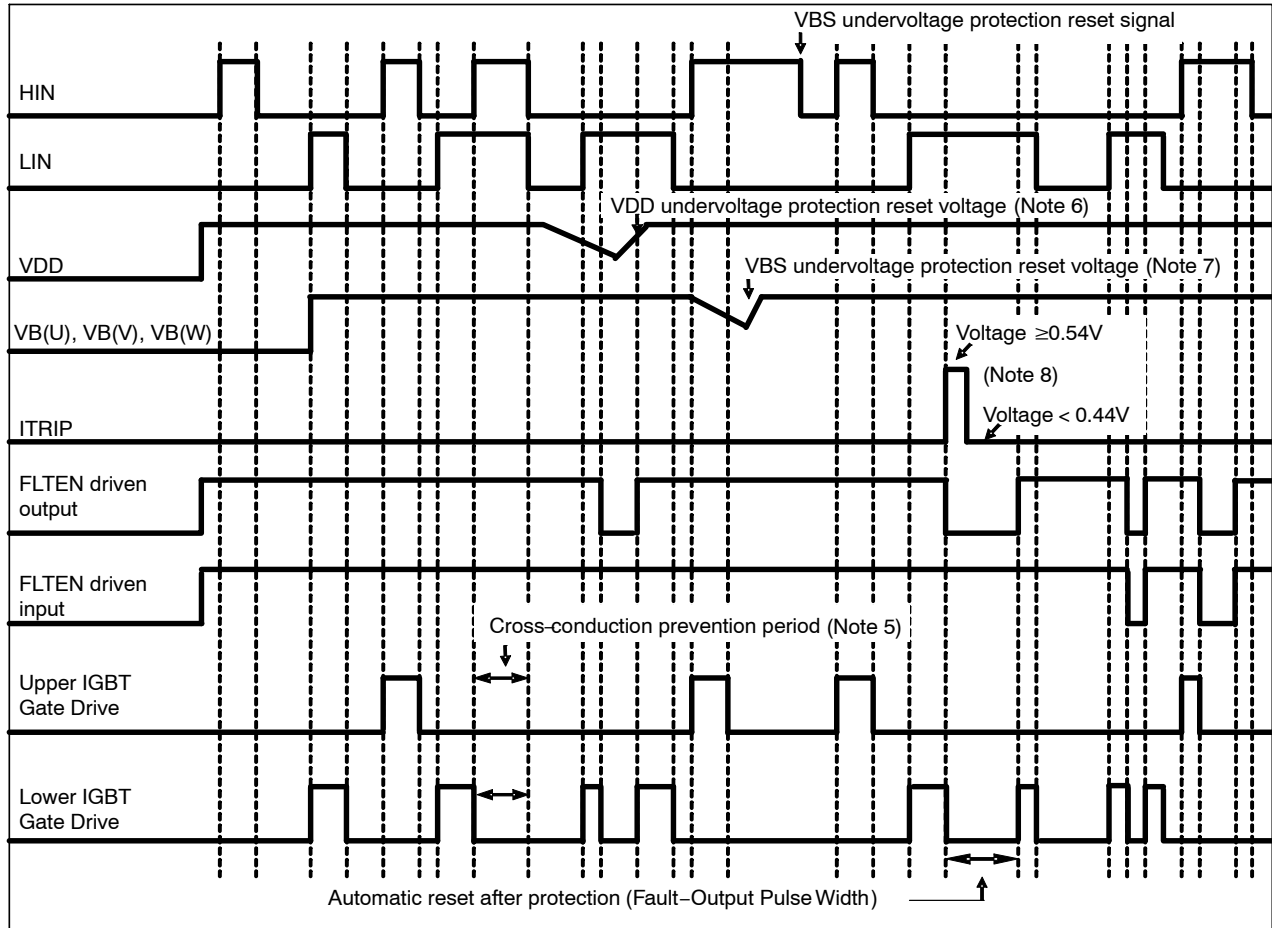


Figure 11. Input / Output Timing Chart

5. This section of the timing diagram shows the effect of cross-conduction prevention.
6. This section of the timing diagram shows that when the voltage on VDD decreases sufficiently all gate output signals will go low, switching off all six IGBTs. When the voltage on VDD rises sufficiently, normal operation will resume.
7. This section shows that when the bootstrap voltage on VB(U) (VB(V), VB(W)) drops, the corresponding high side output U (V, W) is switched off. When the voltage on VB(U) (VB(V), VB(W)) rises sufficiently, normal operation will resume.
8. This section shows that when the voltage on ITRIP exceeds the threshold, all IGBT's are turned off. Normal operation resumes later after the over-current condition is removed.

Table 6. INPUT / OUTPUT LOGIC TABLE

| INPUT | | | OUTPUT | | | |
|-------|-----|-------|----------------|---------------|----------------|-------|
| HIN | LIN | ITRIP | High side IGBT | Low side IGBT | U,V,W | FAULT |
| H | L | L | ON | OFF | P | OFF |
| L | H | L | OFF | ON | NU, NV, NW | OFF |
| L | L | L | OFF | OFF | High Impedance | OFF |
| H | H | L | OFF | OFF | High Impedance | OFF |
| X | X | H | OFF | OFF | High Impedance | ON |

Table 7. THERMISTOR CHARACTERISTICS

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|-------------------------|------------------|------------------------|-------|------|-------|------|
| Resistance | R ₂₅ | T _{th} =25°C | 45.59 | 47 | 48.41 | kΩ |
| | R ₁₂₅ | T _{th} =125°C | 1.34 | 1.45 | 1.59 | kΩ |
| B-Constant (25 to 50°C) | B | | 3953 | 4021 | 4033 | K |
| Temperature Range | | | -40 | | +125 | °C |

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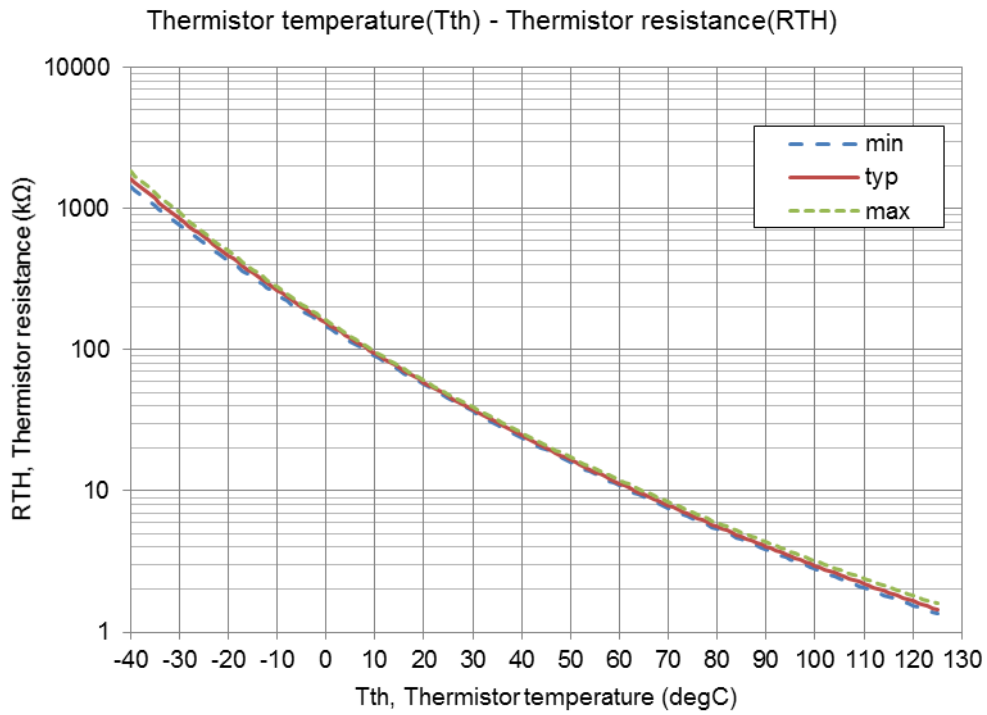


Figure 12. Thermistor Resistance vs. Thermistor Temperature

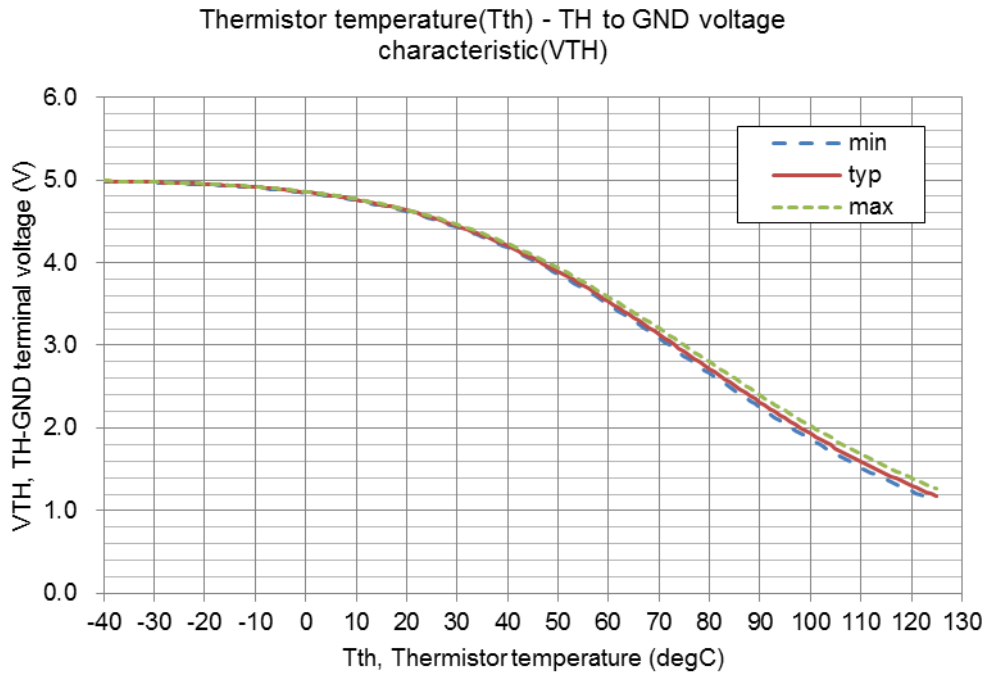


Figure 13. Thermistor Voltage vs. Thermistor Temperature
Conditions: RTH = 4.7 kΩ, pull-up voltage 5.0 V (see Figure 12)

FLTEN Pin

The FLTEN pin is connected to an open-drain FAULT output and an ENABLE input, it is required a pull-up resistor. If the pull-up voltage is 5 V, use a pull-up resistor with a value of 6.8 kΩ or higher. If the pull-up voltage is 15 V, use a pull-up resistor with a value of 20 kΩ or higher. The pulled up voltage in normal operation for the FLTEN pin should be above 2.5 V, noting that it is connected to an internal ENABLE input. The FAULT output is triggered if there is a VDD under-voltage or an overcurrent condition.

Driving the FLTEN terminal pin is used to enable or shut down the built-in driver. If the voltage on the FLTEN pin rises above the positive going ENABLE threshold, the output drivers are enabled. If the voltage on the FLTEN pin falls below the negative going ENABLE threshold, the drivers are disabled.

Under-voltage Protection

If VDD goes below the VDD supply under-voltage lockout falling threshold, the FAULT output is switched on. The FAULT output stays on until VDD rises above the VDD supply under-voltage lockout rising threshold. After VDD has risen above the threshold to enable normal operation, the driver waits to receive an input signal on the LIN input before enabling the driver for the HIN signal. The hysteresis is approximately 200 mV.

Overcurrent Protection

An over-current condition is detected if the voltage on the ITRIP pin is larger than the reference voltage. There is a blanking time of typically 350 ns to improve noise immunity. After a shutdown propagation delay of typically 0.9 μs, the FAULT output is switched on. The FAULT output is held on for 20 μs (minimum).

The over-current protection threshold should be set to be equal or lower to 2 times the module rated current (Io).

An additional fuse is recommended to protect against system level or abnormal over-current fault conditions.

Capacitors on High Voltage and VDD Supplies

Both the high voltage and VDD supplies require an electrolytic capacitor and an additional high frequency capacitor. The recommended value of the high frequency capacitor is between 100 nF and 10 μF.

Minimum Input Pulse Width

When input pulse width is less than 1 μs, an output may not react to the pulse. (Both ON signal and OFF signal)

Calculation of Bootstrap Capacitor Value

The bootstrap capacitor value CB is calculated using the following approach. The following parameters influence the choice of bootstrap capacitor:

- VBS: Bootstrap power supply.
15 V is recommended.
- QG: Total gate charge of IGBT at VBS = 15 V.
17 nC
- UVLO: Falling threshold for UVLO.
Specified as 12 V.
- IDMAX: High-side drive power dissipation.
Specified as 0.4 mA
- TONMAX: Maximum ON pulse width of high side IGBT.

Capacitance Calculation Formula:

$$CB = (QG + IDMAX * TONMAX) / (VBS - UVLO)$$

The relationship between TONMAX and CB becomes as follows. CB is recommended to be approximately 3 times the value calculated above. The recommended value of CB is in the range of 1 to 47 μF, however, the value needs to be verified prior to production. When not using the bootstrap circuit, each high side driver power supply requires an external independent power supply.

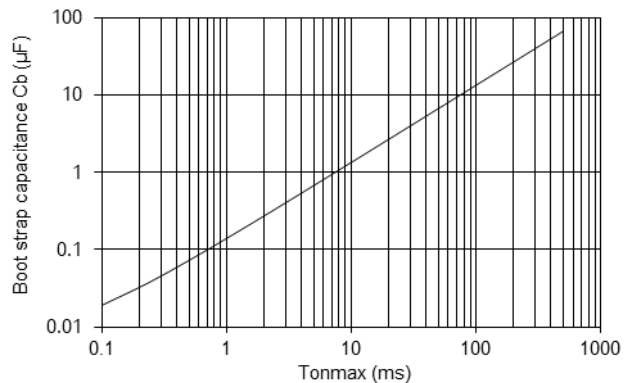


Figure 14. Bootstrap Capacitance vs. Tonmax

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TEST CIRCUITS

I_{ces}, I_R(DB)

| | U+ | V+ | W+ | U- | V- | W- |
|---|----|----|----|----|----|----|
| A | 13 | 13 | 13 | 10 | 6 | 2 |
| B | 10 | 6 | 2 | 17 | 19 | 21 |

U+,V+,W+ : High side phase

U-,V-,W- : Low side phase

| | U(DB) | V(DB) | W(DB) |
|---|-------|-------|-------|
| A | 9 | 5 | 1 |
| B | 29 | 29 | 29 |

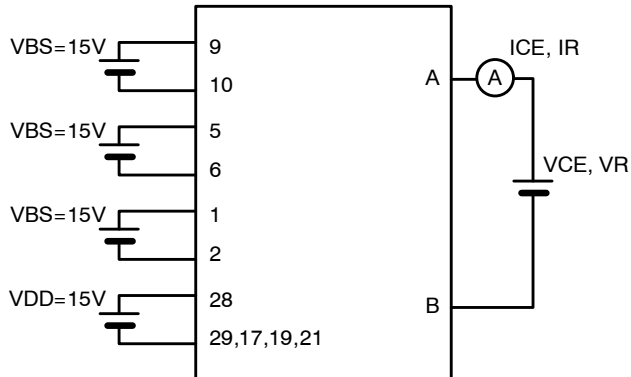


Figure 15. Test Circuit for I_{CE}

V_{CE}(sat) (Test by pulse)

| | U+ | V+ | W+ | U- | V- | W- |
|---|----|----|----|----|----|----|
| A | 13 | 13 | 13 | 10 | 6 | 2 |
| B | 10 | 6 | 2 | 17 | 19 | 21 |
| C | 20 | 22 | 23 | 24 | 25 | 26 |

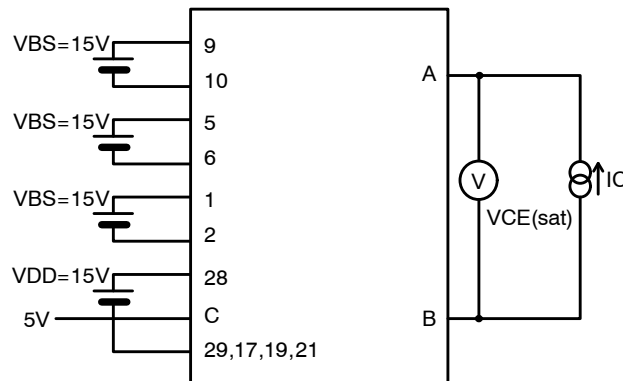


Figure 16. Test Circuit for V_{CE}(SAT)

V_F (Test by pulse)

| | U+ | V+ | W+ | U- | V- | W- |
|---|----|----|----|----|----|----|
| A | 13 | 13 | 13 | 10 | 6 | 2 |
| B | 10 | 6 | 2 | 17 | 19 | 21 |

| | U(DB) | V(DB) | W(DB) |
|---|-------|-------|-------|
| A | 9 | 5 | 1 |
| B | 28 | 28 | 28 |

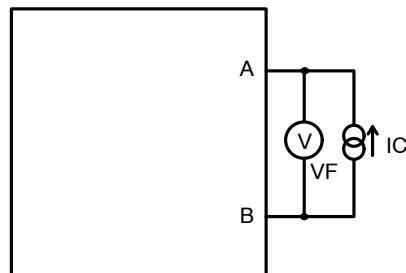


Figure 17. Test Circuit for V_F

I_{QBS}, I_{QDDL}

| | VBS U+ | VBS V+ | VBS W+ | V _{DD} |
|---|--------|--------|--------|-----------------|
| A | 9 | 5 | 1 | 28 |
| B | 10 | 6 | 2 | 29 |

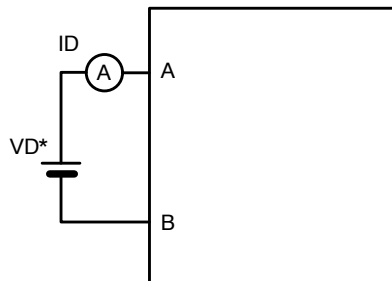


Figure 18. Test Circuit for I_D

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SWITCHING TIME (The circuit is a representative example of the lower side U phase.)

| | U+ | V+ | W+ | U- | V- | W- |
|---|----|----|----|----|----|----|
| A | 13 | 13 | 13 | 13 | 13 | 13 |
| B | 17 | 19 | 21 | 17 | 19 | 21 |
| C | 10 | 6 | 2 | 13 | 13 | 13 |
| D | 17 | 19 | 21 | 10 | 6 | 2 |
| E | 20 | 22 | 23 | 24 | 25 | 26 |

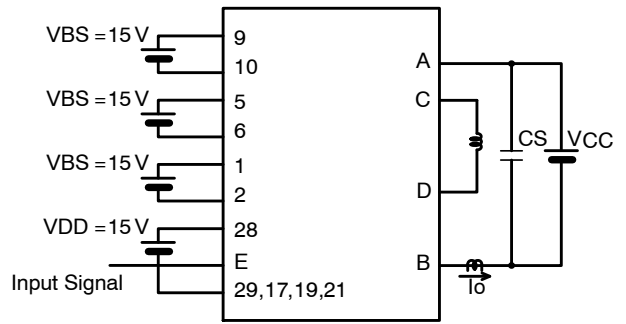
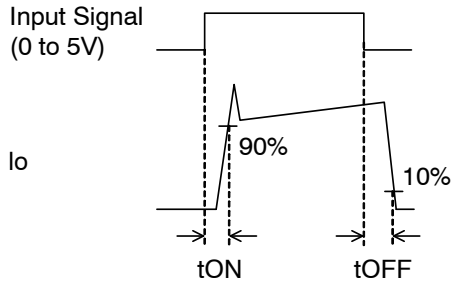
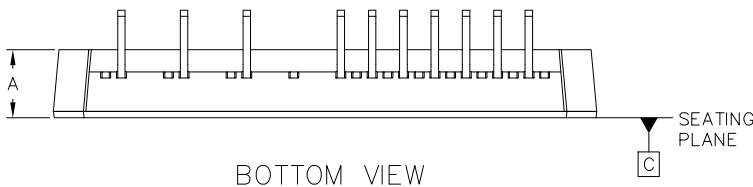
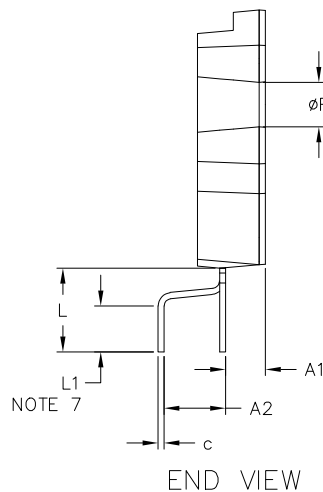
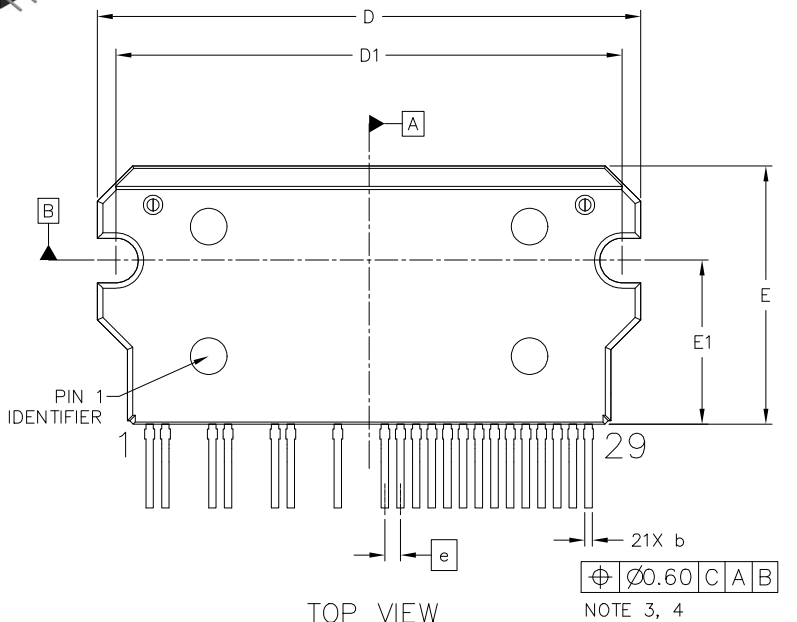
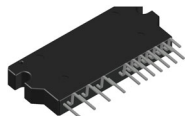


Figure 19. Test Circuit for Switching Time



SIP-29 44.00x20.90x5.50, 1.27P
CASE 127FB
ISSUE C

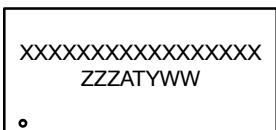
DATE 08 JUN 2026



- NOTES:
1. DIMENSIONING AND TOLERANCING AS PER SAME Y14.5M, 2018.
 2. CONTROLLING DIMENSIONS: MILLIMETERS.
 3. DIMENSION b AND c APPLY TO THE PLATED LEADS AND ARE MEASURED BETWEEN 1.00 AND 2.00 FROM THE LEAD TIP.
 4. POSITION OF THE LEAD IS DETERMINED AT THE ROOT OF THE LEAD WHERE IT EXITS THE PACKAGE BODY.
 5. PIN 1 IDENTIFICATION IS A MIRRORED SURFACE INDENT.
 6. MISSING PINS ARE 3, 4, 7, 8, 11, 12, 14 AND 15.
 7. L1 IS THE STRAIGHT PORTION OF THE LEAD AFTER THE BEND.
 8. FP-1

| MILLIMETERS | | | |
|-------------|----------|-------|-------|
| DIM | MIN | NOM | MAX |
| A | 5.30 | 5.50 | 5.70 |
| A1 | 3.00 | 3.20 | 3.40 |
| A2 | 4.50 | 5.00 | 5.50 |
| b | 0.55 | 0.60 | 0.80 |
| c | 0.45 | 0.50 | 0.70 |
| D | 43.50 | 44.00 | 44.50 |
| D1 | 40.50 | 41.00 | 41.50 |
| E | 20.40 | 20.90 | 21.40 |
| E1 | 12.75 | 13.25 | 13.75 |
| e | 1.27 BSC | | |
| F | 3.10 | 3.60 | 4.10 |
| L | 6.30 | 6.80 | 7.30 |
| L1 | 3.23 | 3.73 | 4.23 |

GENERIC MARKING DIAGRAM*



XXXX = Specific Device Code
 ZZZ = Assembly Lot Code
 AT = Assembly & Test Location
 Y = Year
 WW = Work Week

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "•", may or may not be present. Some products may not follow the Generic Marking.

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| DESCRIPTION: | SIP-29 44.00x20.90x5.50, 1.27P | PAGE 1 OF 1 |

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