High-Current, Half-Bridge, Gate-Driver IC

FAN73912

ON Semiconductor®

www.onsemi.com

SOIC−16W
CASE 751BH

Description

The FAN73912 is a monolithic half bridge gate−drive IC designed for high−voltage and high−speed driving for MOSFETs and IGBTs that operate up to +1200 V.

The advanced input filter of HIN provides protection against short−pulsed input signals caused by noise.

An advanced level−shift circuit offers high−side gate driver operation up to VS = −9.8 V (typical) for VBS = 15 V. The UVLO circuit prevents malfunction when VCC and VBS are lower than the specified threshold voltage.

Output drivers typically source and sink 2 A and 3 A, respectively.

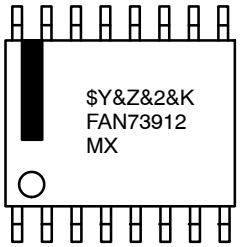
Features

- Floating Channel for Bootstrap Operation to +1200 V
- Typically 2 A/ 3 A Sourcing/Sinking Current Driving Capability for Both Channels
- Gate Driver Supply (VCC) Range from 12 V to 20 V
- Separate Logic Supply (VDD) Range from 3 V to 20 V
- Extended Allowable Negative VS Swing to −9.8 V for Signal Propagation at VCC = VBS = 15 V
- Built−in Cycle−by−Cycle Edge−Triggered Shutdown Logic
- Built−in Shoot−Through Protection Logic
- Common−Mode dv/dt Noise Canceling Circuit
- UVLO Functions for Both Channels
- Built−in Advanced Input Filter
- Matched Propagation Delay Below 50 ns
- Outputs in−Phase with Input Signal
- Logic and Power Ground +/− 10 V Offset
- This Device is Pb−Free and Halogen Free

Typical Application

- Electrical Contactor
- UPS
- Solar Inverter
- Ballast
- General−Purpose Half−Bridge Topology

MARKING DIAGRAM



$Y	= ON Semiconductor Logo
&Z	= Assembly Plant Code
&2	= 2−Digit Date Code
&K	= Lot Code
FAN73912MX	= Specific Device Code

ORDERING INFORMATION

Device	Package	Shipping†
FAN73912MX (Note 1)	Wide−16 SOIC	1,000/ Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

1. This device passed wave−soldering test by JESD22A−111

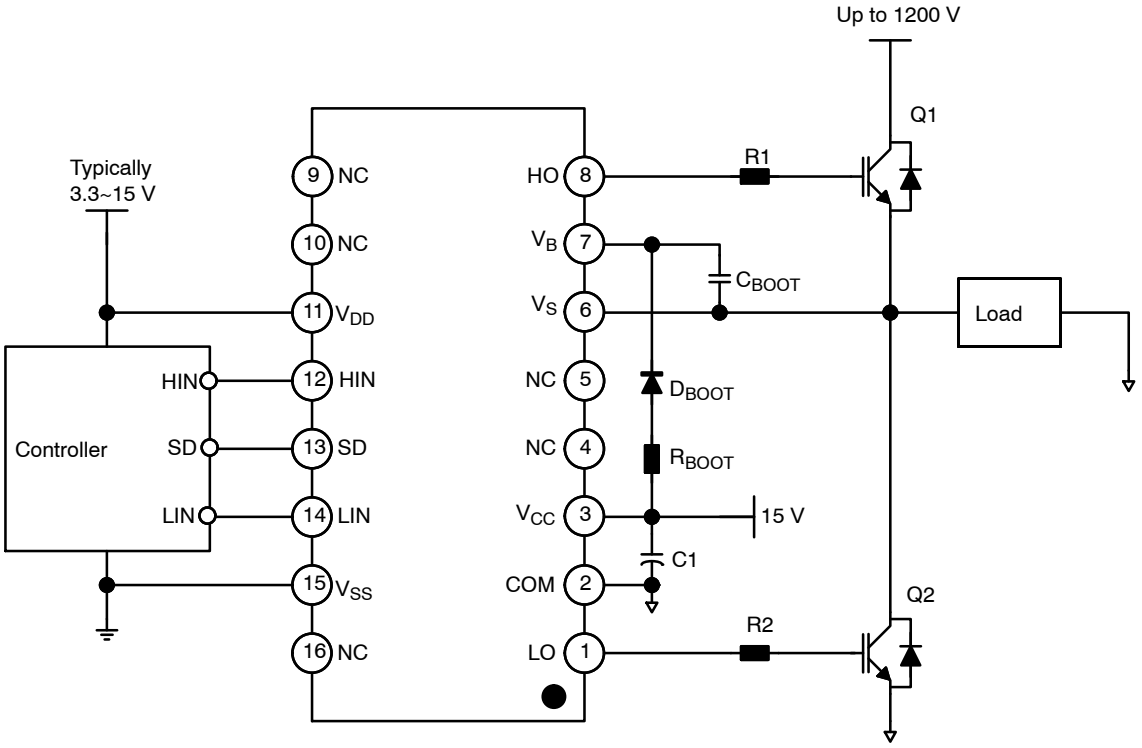


Figure 1. Application Schematic – Adjustable Option

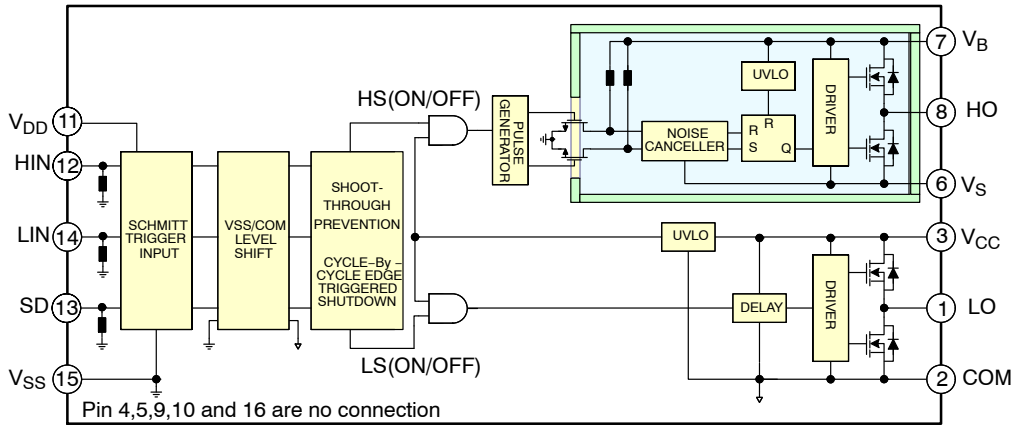


Figure 2. Simplified Block Diagram

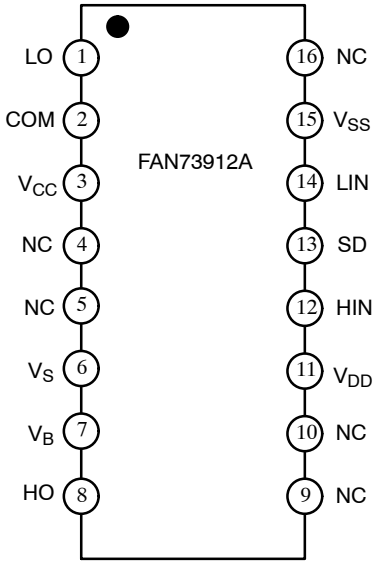


Figure 3. Pin Connections – Wide 16–SOIC (Top View)

Table 1. PIN FUNCTION DESCRIPTION

Pin No.	Symbol	Description
1	LO	Low–Side Driver Output
2	COM	Low–Side Driver Return
3	VCC	Low–Side Supply Voltage
4	NC	No Connection
5	NC	No Connection
6	V_S	High–Voltage Floating Supply Return
7	V_B	High–Side Floating Supply
8	HO	High–Side Driver Output
9	NC	No Connection
10	NC	No Connection
11	V_{DD}	Logic Supply Voltage
12	HIN	Logic Input for High–Side Gate Driver Output
13	SD	Logic Input for Shutdown
14	LIN	Logic Input for Low–Side Gate Driver Output
15	V_{SS}	Logic Ground
16	NC	No Connection

Table 2. MAXIMUM RATINGS (T_J = 25°C, unless otherwise specified. All voltage parameters are referenced to COM unless otherwise stated in the table.)

Symbol	Parameter	Min	Max	Unit
V_B	High−Side Floating Supply Voltage	−0.3	1225.0	V
V_S	High−Side Floating Offset Voltage	V_B −25	V_B +0.3	V
V_{HO}	High−Side Floating Output Voltage	V_S −0.3	V_B +0.3	V
V_{CC}	Low−Side Supply Voltage	−0.3	25	V
V_{LO}	Low−Side Floating Output Voltage	−0.3	V_{CC} +.0.3	V
V_{DD}	Logic Supply Voltage	V_{SS} −0.3 −0.3	V_{SS} +25 25	V
V_{SS}	Logic GND	V_{DD} −25	V_{DD} +0.3	V
V_{IN}	Logic Input Voltage (HIN, LIN and SD)	V_{SS} + V_{DD} −25.3 −0.3	V_{DD} +0.3 25	V
dV_S/dt	Allowable Offset Voltage Slew Rate	−	±50	V/ns
P_D (Note 2, 3, 4)	Power Dissipation	−	1.3	W
θ_{JA}	Thermal Resistance	−	95	°C/W
T_J	Junction Temperature	−	150	°C
T_{STG}	Storage Temperature	−55	150	°C

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.

2. Mounted on 76.2 x 114.3 x 1.6 mm PCB (FR−4 glass epoxy material).
3. Refer to the following standards:
   JESD51−2: Integral circuit's thermal test method environmental conditions, natural convection;
   JESD51−3: Low effective thermal conductivity test board for leaded surface−mount packages.
4. Do not exceed maximum power dissipation (P_D) under any circumstances.

Table 3. RECOMMENDED OPERATING CONDITIONS (All voltage parameters are referenced to COM unless otherwise stated in the table)

Symbol	Parameter	Min	Max	Unit
V_B	High−Side Floating Supply Voltage	V_S + 12	V_S + 20	V
V_S	High−Side Floating Supply Offset Voltage (Note 6)	8 − V_{CC}	1200	V
V_{HO}	High−Side (HO) Output Voltage	V_S	V_B	V
V_{CC}	Low−Side Supply Voltage	12	20	V
V_{LO}	Low−Side (LO) Output Voltage	0	V_{CC}	V
V_{DD}	Logic Supply Voltage	V_{SS} + 3 0	V_{SS} + 20 20	V
V_{SS}	Logic Ground (Note 5)	−10	10	V
V_{IN}	Logic Input Voltage (HIN, LIN, SD)	V_{SS} + V_{DD} − 20 0	V_{DD} 20	V
T_J	Junction Temperature	−40	+125	°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.

5. When V_{DD} < 10 V, the minimum V_{SS} offset is limited to −V_{DD}.
6. Referenced to T_J = 25°C.

Table 4. STATIC ELECTRICAL CHARACTERISTICS (V_{BIAS} (V_{CC}, V_{BS}, V_{DD}) = 15.0 V, T_J = 25°C, unless otherwise specified. The V_{IH}, V_{IL} and I_{IN} parameters are referenced to V_{SS} and are applicable to respective input leads: HIN, LIN and SD. The V_O and I_O parameters are referenced to V_S and COM and are applicable to the respective output leads: HO and LO. The V_{DDUV} parameters are referenced to COM. The V_{BSUV} parameters are referenced to $V_{S1, 2, 3}$.)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LOW−SIDE POWER SUPPLY SECTION						
I_{QCC}	Quiescent V_{CC} Supply Current	V_{IN} = 0 V or V_{DD}	–	170	300	μA
I_{QDD}	Quiescent V_{DD} Supply Current	V_{IN} = 0 V or V_{DD}	–	–	10	μA
I_{PCC}	Operating V_{CC} Supply Current	f_{IN} = 20 kHz, rms V_{IN} = 15 V_{PP}	–	650	950	μA
I_{PDD}	Operating V_{DD} Supply Current	f_{IN} = 20 kHz, rms V_{IN} = 15 V_{PP}	–	2	–	
I_{SD}	Shutdown Supply Current	S_D = V_{DD}	–	30	50	μA
V_{CCUV+}	V_{CC} Supply Under−Voltage Positive−Going Threshold Voltage	V_{CC} = Sweep	9.7	11.0	12	V
$V_{CCUV−}$	V_{CC} Supply Under−Voltage Negative−Going Threshold Voltage	V_{CC} = Sweep	9.2	10.5	11.4	V
V_{CCUVH}	V_{CC} Supply Under−Voltage Lockout Hysteresis Voltage	V_{CC} = Sweep	–	0.5	–	V
BOOTSTRAPPED SUPPLY SECTION						
I_{QBS}	Quiescent V_{BS} Supply Current	V_{IN} = 0 V or V_{DD}	–	50	100	μA
I_{PBS}	Operating V_{BS} Supply Current	f_{IN} = 20 kHz, rms value	–	550	850	μA
V_{BSUV+}	V_{BS} Supply Under−Voltage Positive−Going Threshold Voltage	V_{BS} = Sweep	9.7	11.0	12.0	V
$V_{BSUV−}$	V_{BS} Supply Under−Voltage Negative−Going Threshold Voltage	V_{BS} = Sweep	9.2	10.5	11.4	V
V_{BSUVH}	V_{BS} Supply Under−Voltage Lockout Hysteresis Voltage	V_{BS} = Sweep	–	0.5	–	V
I_{LK}	Offset Supply Leakage Current	V_B = V_S = 1200 V (T_J = 25°C)	–	–	50	μA
		V_B = V_S = 1200 V (T_J = 125°C) (Note 7)	–	–	100	
		V_B = V_S = 1100 V (T_J = −40°C) (Note 7)	–	–	100	
INPUT LOGIC SECTION (HIN.LIN AND AD)						
V_{IH}	Logic “1” Input Voltage	V_{DD} = 3 V	2.4	–	–	V
		V_{DD} = 15 V	9.5	–	–	
V_{IL}	Logic “0” Input Voltage	V_{DD} = 3 V	–	–	0.8	V
		V_{DD} = 15 V	–	–	6.0	
I_{IN+}	Logic “1” Input bias Current	V_{IN} = 15 V	–	30	50	μA
$I_{IN−}$	Logic “0” Input bias Current	V_{IN} = 0 V	–	–	1	μA
R_{IN}	Logic Input Pull−down Resistance		–	500	–	kΩ
GATE DRIVER OUTPUT SECTION						
V_{OH}	High−Level Output Voltage, V_{BIAS}−V_O	I_O = 0 A	–	–	1.2	V
V_{OL}	Low−Level Output Voltage, V_O	I_O = 0 A	–	–	0.1	V
I_{O+}	Output HIGH Short−Circuit Pulse Current	V_O = 0 V, V_{IN} = 5 V with PW ≤ 10 μs	–	2.0	–	A
$I_{O−}$	Output LOW Short−Circuit Pulsed Current	V_O = 15 V, V_{IN} = 0 V with PW ≤ 10 μs	–	3.0	–	A
V_S	Allowable Negative V_S Pin Voltage for HIN Signal Propagation to HO		–	−9.8	−7.0	V

7. These parameters are guaranteed by design.

Table 5. DYNAMIC ELECTRICAL CHARACTERISTICS (V_{BIAS}(V_{CC}, V_{BS}, V_{DD}) = 15.0 V, V_S = V_{SS} = COM, C_L = 1000 pF and T_J = 25°C, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LOW−SIDE POWER SUPPLY SECTION						
t_{ON}	Turn−On Propagation Delay	V_S = 0 V	−	500	−	ns
t_{OFF}	Turn−Off Propagation Delay	V_S = 0 V	−	550	−	ns
t_{FLTIN}	Input Filtering Time (HIN, LIN) (Note 8)		80	150	220	ns
t_{FLTSD}	Input Filtering Time (SD)		−	30	−	ns
t_{SD}	Shutdown Propagation Delay Time		260	330	400	ns
t_R	Turn−On Rise Time		−	25	−	ns
t_F	Turn−Off Fall Time		−	15	−	
DT	Dead Time					
MDT	Dead Time Matching (Note 9)					
MT	Delay Matching , HO & LO Turn−On/OFF (Note 10)		−	−	50	ns
PM	Output Pulse−Width Matching (Note 11)	PW_{IN} > 1 μs	−	50	100	ns

8. The minimum width of the input pulse should exceed 500 ns to ensure the filtering time of the input filter is exceeded.
9. MDT is defined as | DT_{HO-LO}−DT_{LO-HO} | referenced to Figure 40.
10. MT is defined as an absolute value of matching delay time between High−side and Low−Side.
11. PM is defined as an absolute value of matching pulse−width between Input and Output.

TYPICAL CHARACTERISTICS

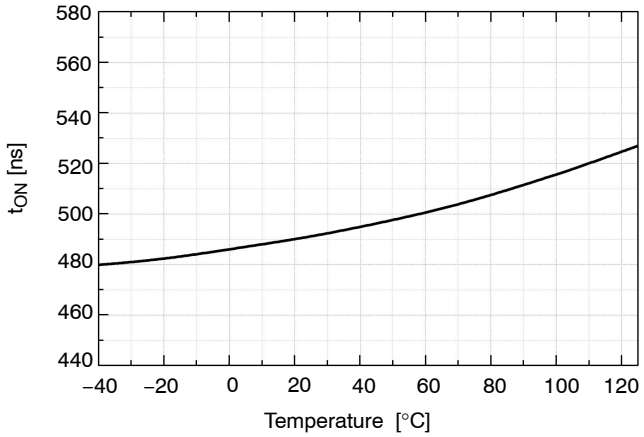


Figure 4. Turn−On Propagation Delay vs. Temperature

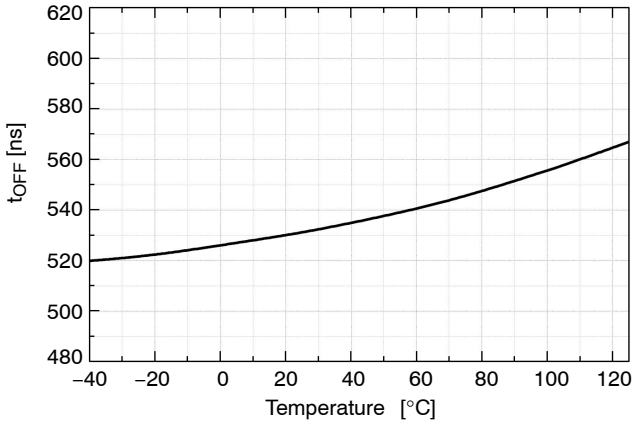


Figure 5. Turn−Off Propagation Delay vs. Temperature

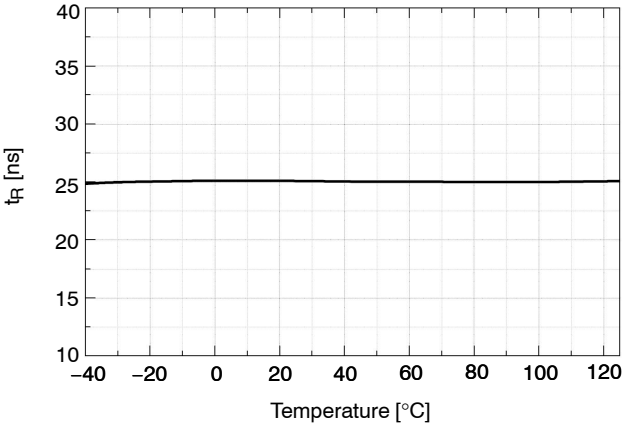


Figure 6. Turn−On Rise Time vs Temperature

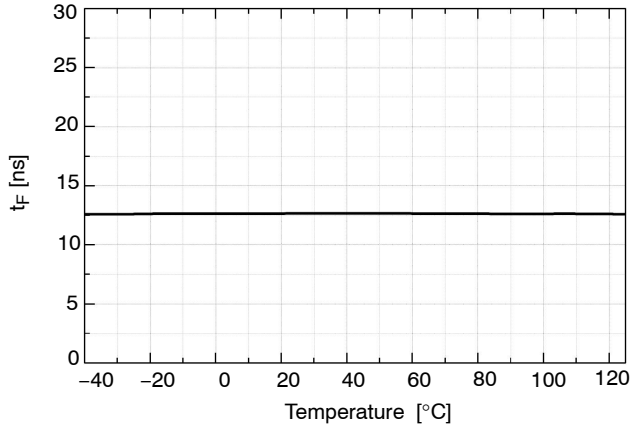


Figure 7. Turn−Off Fall Time vs. Temperature

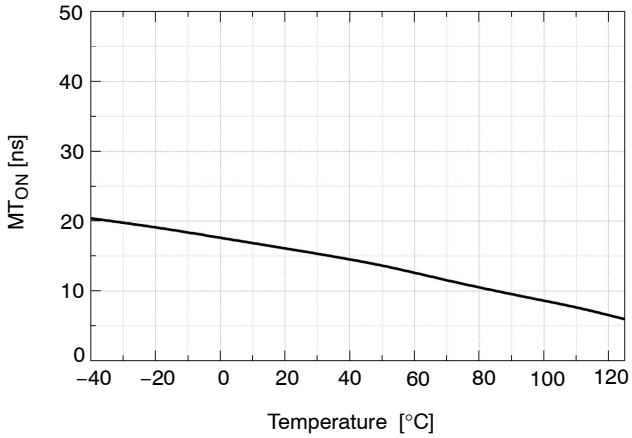


Figure 8. Turn−On Delay Matching vs. Temperature

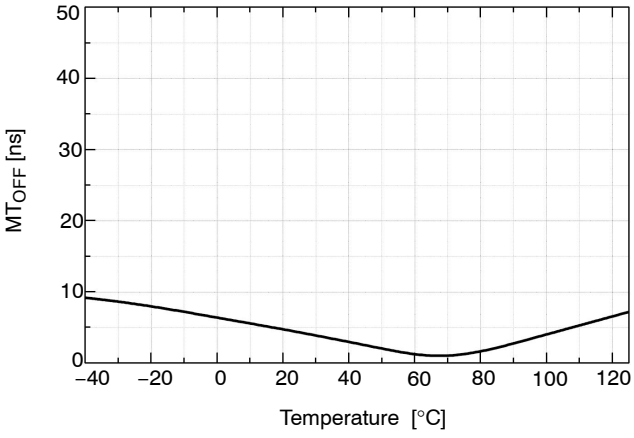


Figure 9. Turn−Off Delay Matching vs. Temperature

TYPICAL CHARACTERISTICS (continued)

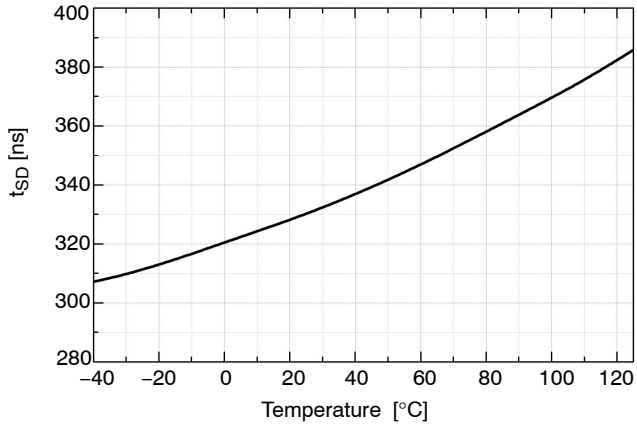


Figure 10. Shutdown Propagation Delay vs. Temperature

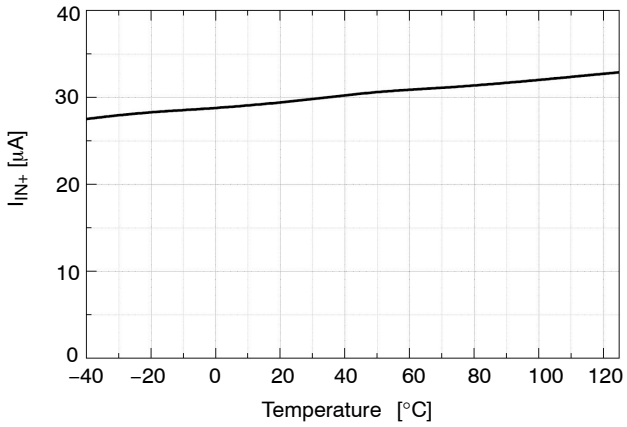


Figure 11. Logic Input High Bias Current vs. Temperature

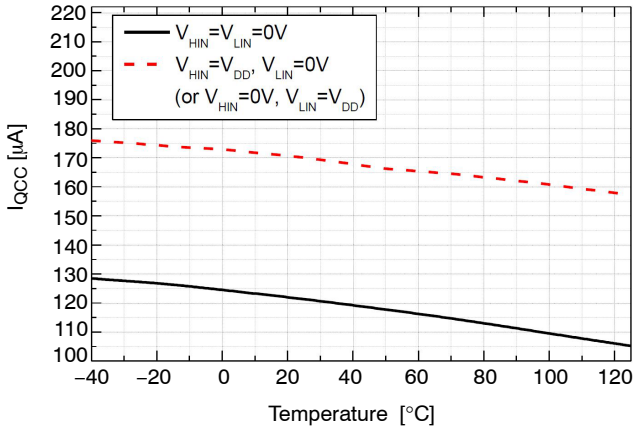


Figure 12. Quiescent V_{CC} Supply Current vs. Temperature

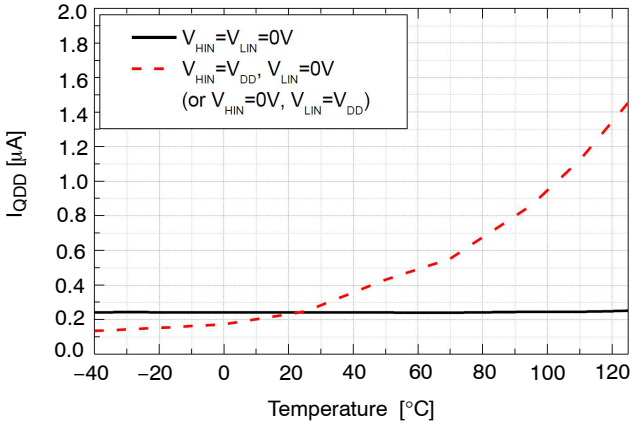


Figure 13. Quiescent V_{DD} Supply Current vs. Temperature

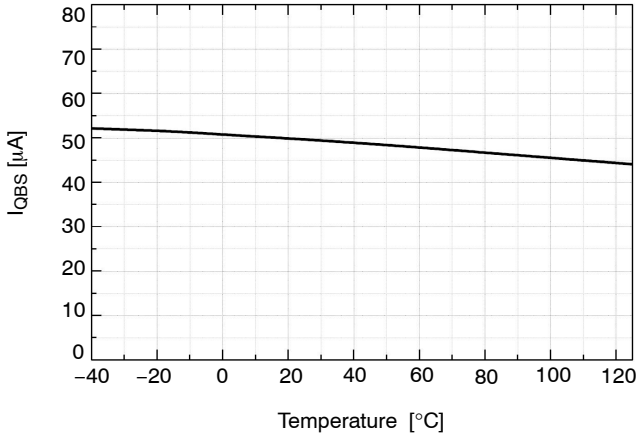


Figure 14. Quiescent V_{BS} Supply Current vs. Temperature

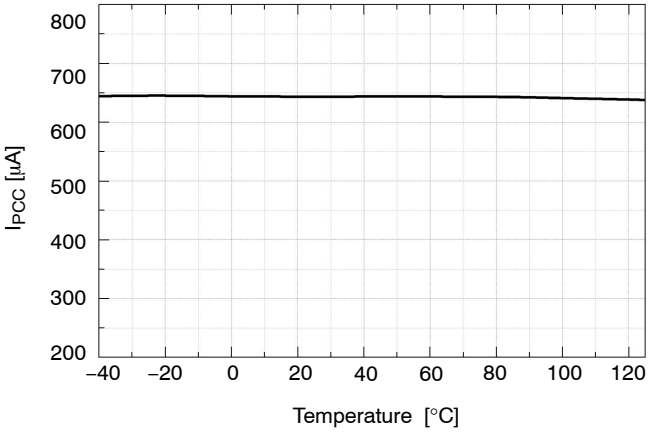


Figure 15. Operating V_{CC} Supply Current vs. Temperature

TYPICAL CHARACTERISTICS (continued)

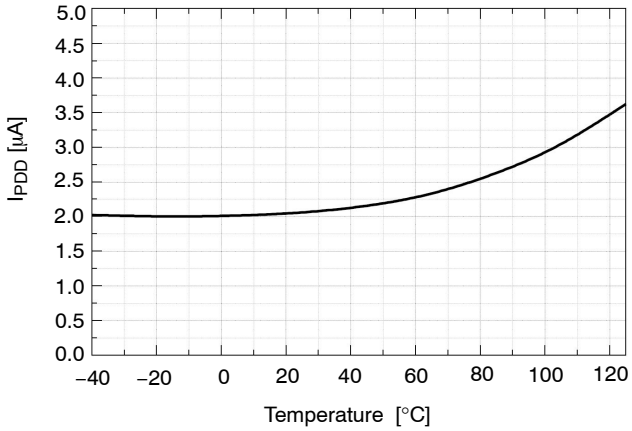


Figure 16. Operating V_{DD} Supply Current vs. Temperature

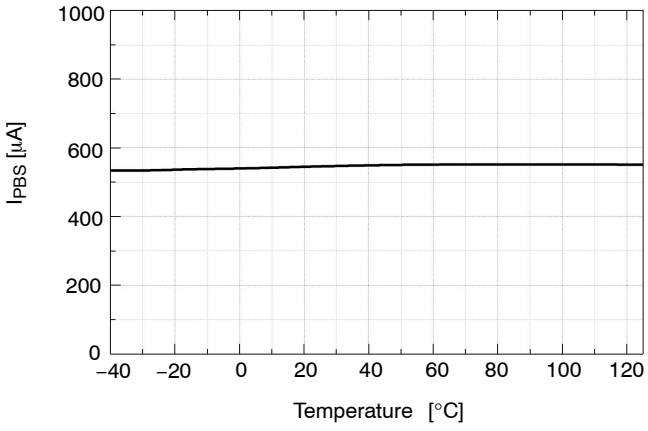


Figure 17. Operating V_{BS} Supply Current vs. Temperature

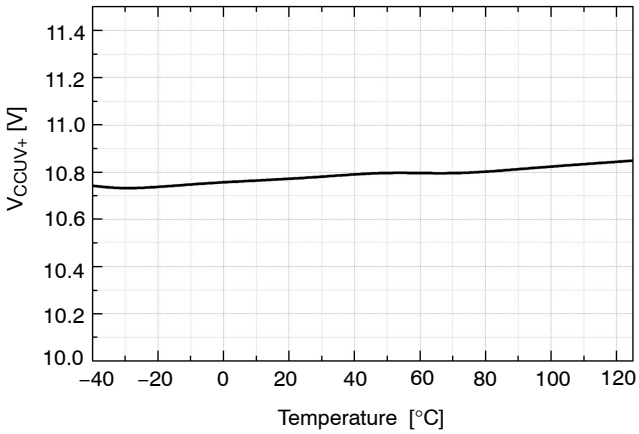


Figure 18. V_{CC} UVLO+ vs. Temperature

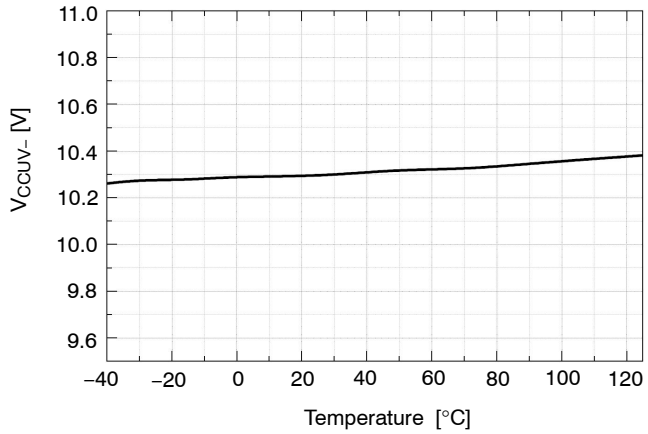


Figure 19. V_{CC} UVLO− vs. Temperature

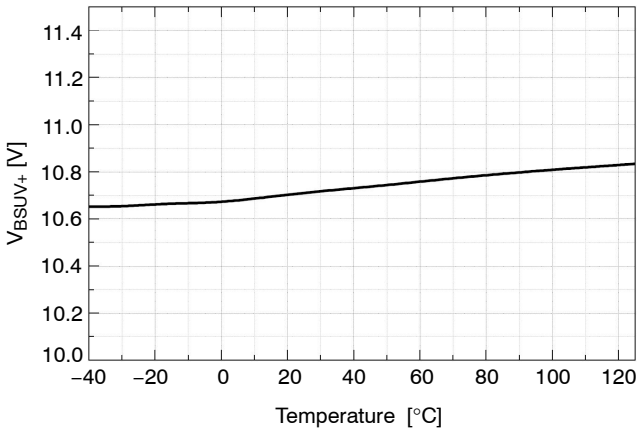


Figure 20. V_{BS} UVLO+ vs. Temperature

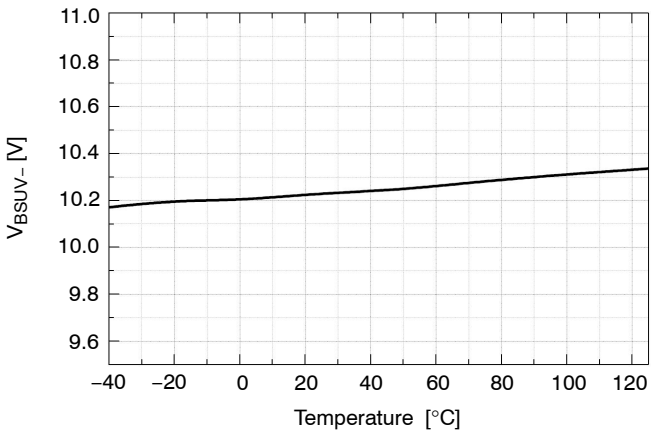


Figure 21. V_{BS} UVLO− vs. Temperature

TYPICAL CHARACTERISTICS (continued)

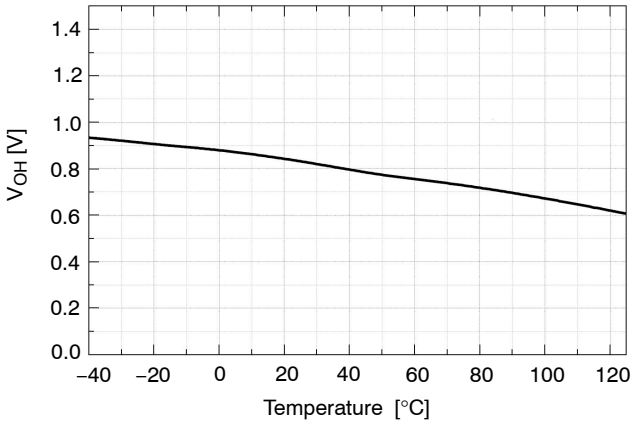


Figure 22. High−Level Output Voltage vs. Temperature

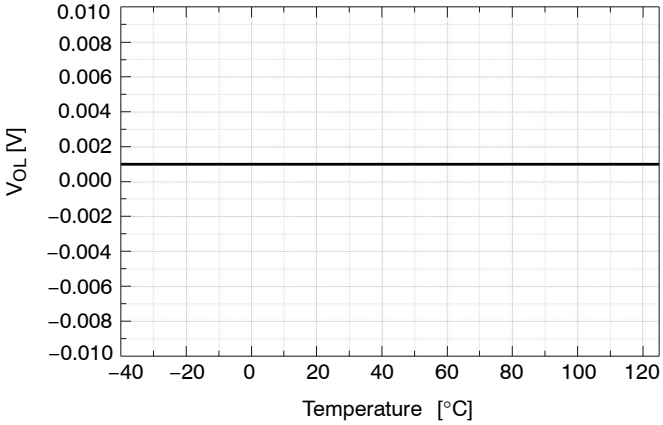


Figure 23. Low−Level Output Voltage vs. Temperature

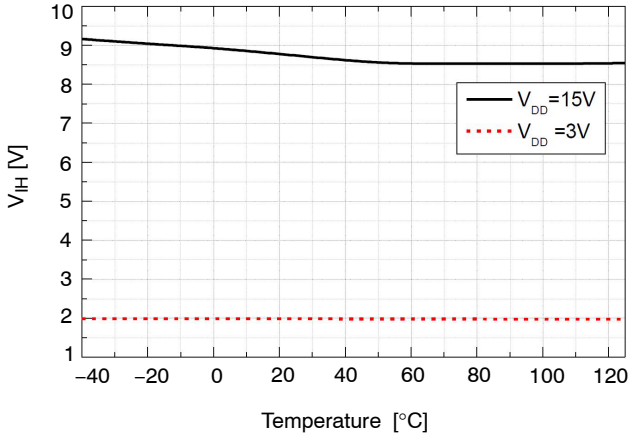


Figure 24. Logic High Input Voltage vs. Temperature

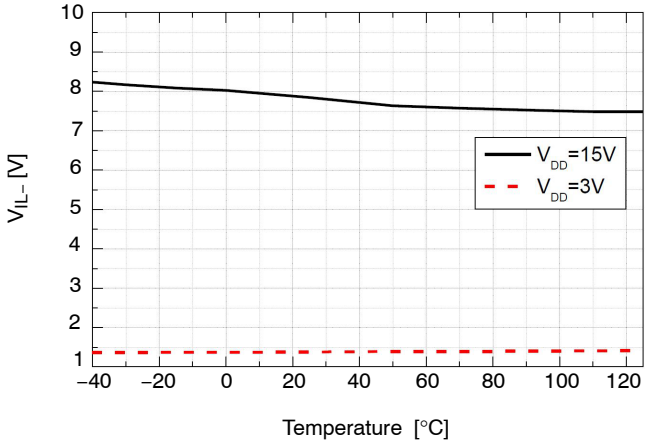


Figure 25. Logic Low Input Voltage vs. Temperature

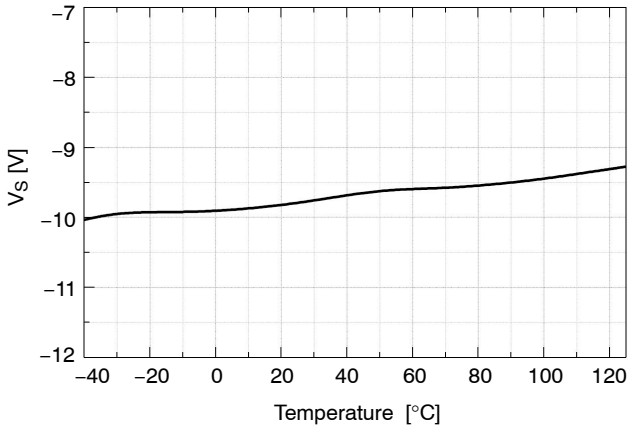


Figure 26. Allowable Negative V_S vs. Temperature

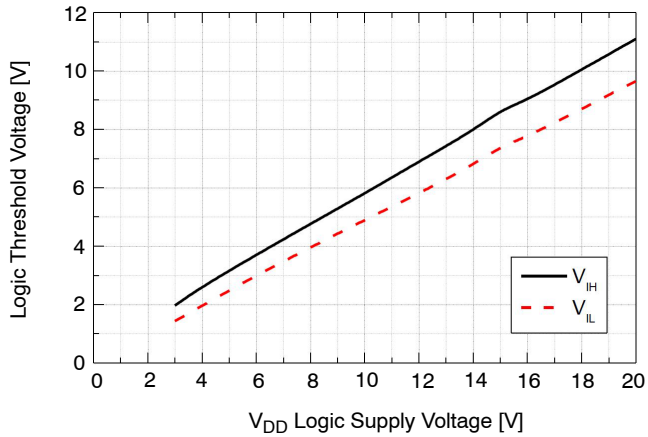


Figure 27. Input Logic (HIN&LIN) Threshold Voltage vs. V_{DD} Supply Voltage

TYPICAL CHARACTERISTICS (continued)

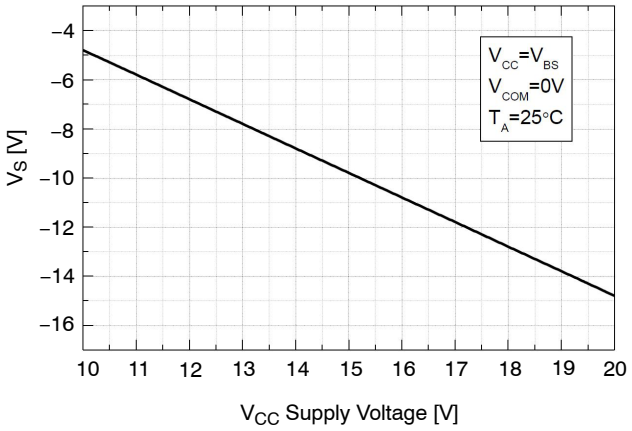


Figure 28. Allowable Negative V_S Voltage for HIN Signal Propagation to High Side vs. V_{CC} Supply Voltage

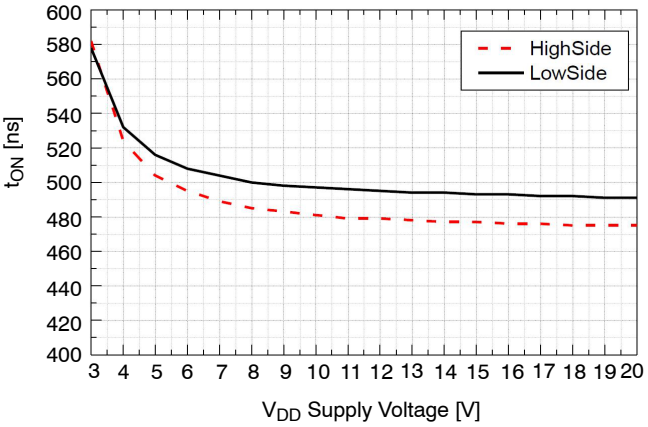


Figure 29. Turn−On Propagation Delay vs. V_{DD} Supply Voltage

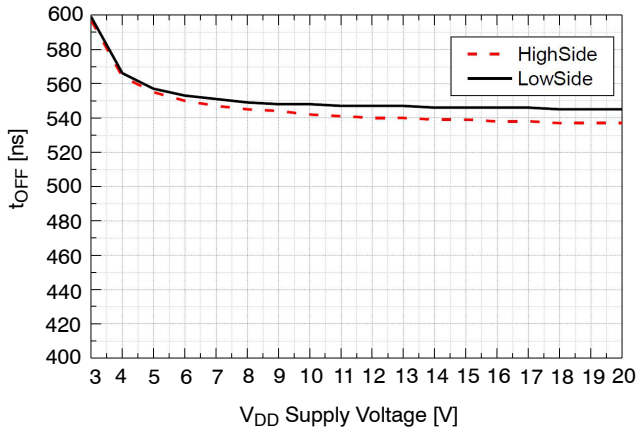


Figure 30. Turn−Off Propagation Delay vs. V_{DD} Supply Voltage

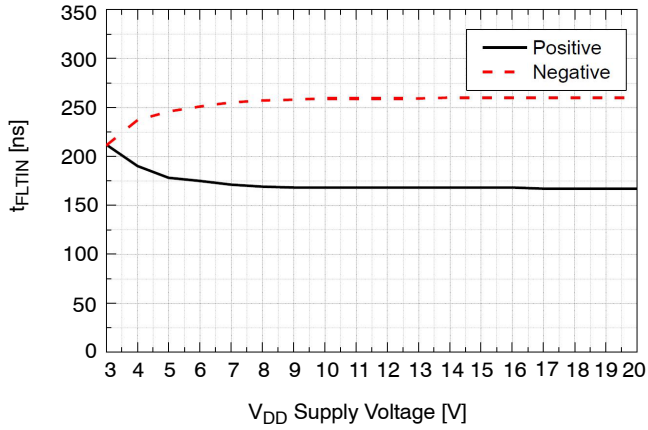


Figure 31. Logic Input Filtering Time vs. V_{DD} Supply Voltage

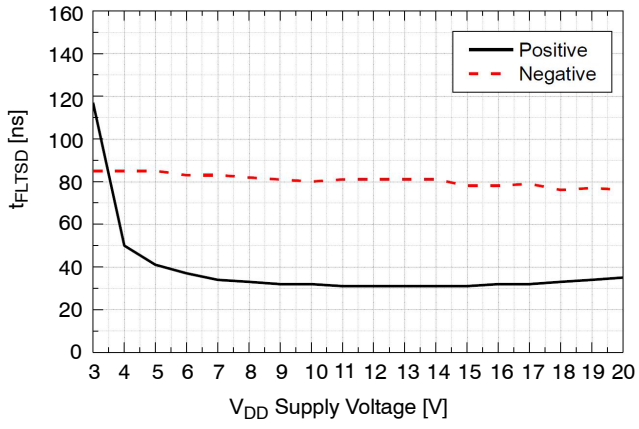


Figure 32. Shutdown Input Filtering Time vs. V_{DD} Supply Voltage

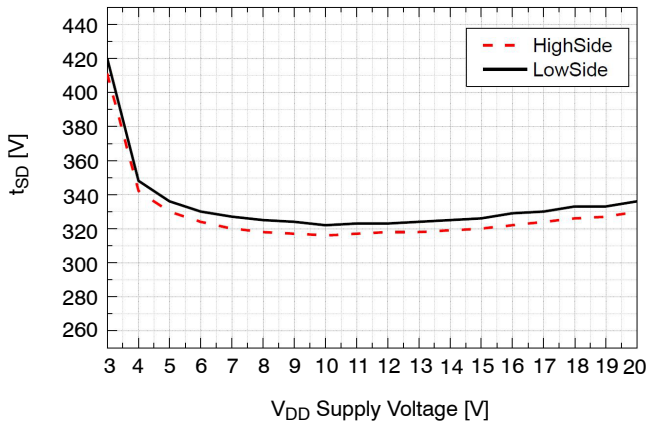


Figure 33. Shutdown Propagation Delay vs. V_{DD} Supply Voltage

TYPICAL CHARACTERISTICS (continued)

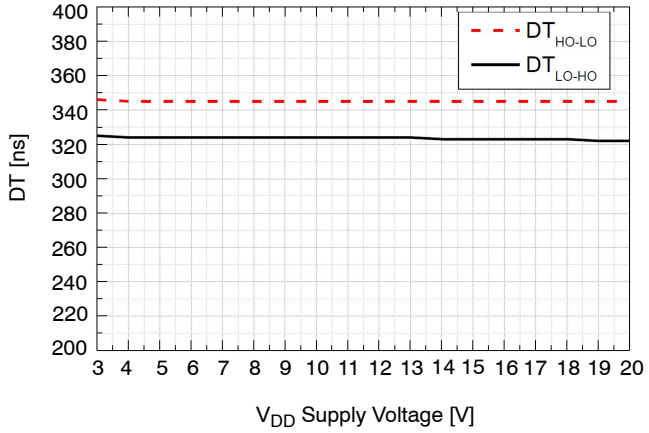


Figure 34. Dead Time vs. V_{DD} Supply Voltage

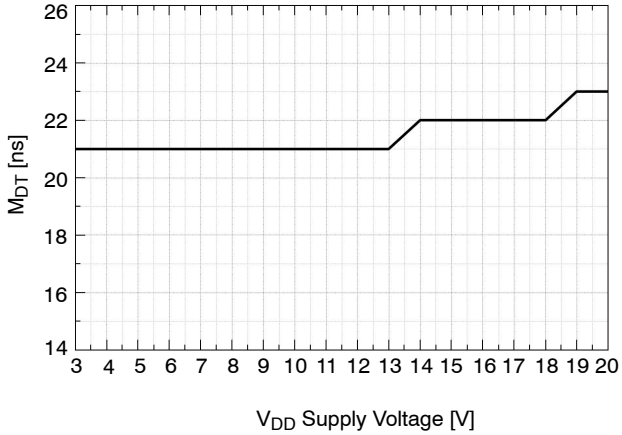


Figure 35. Dead−Time Matching vs. V_{DD} Supply Voltage

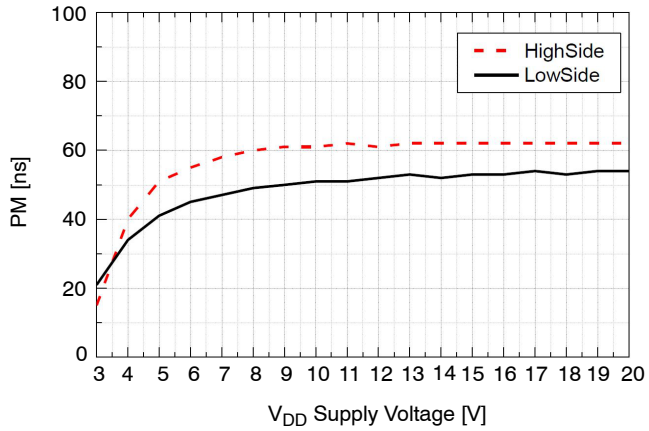


Figure 36. Output Pulse−Width Matching vs. V_{DD} Supply Voltage

SWITCHING TIME DEFINITIONS

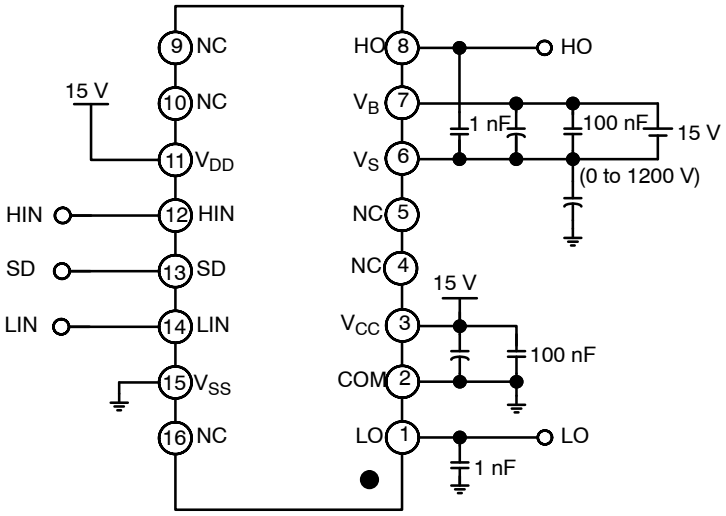


Figure 37. Switching Time Test Circuit

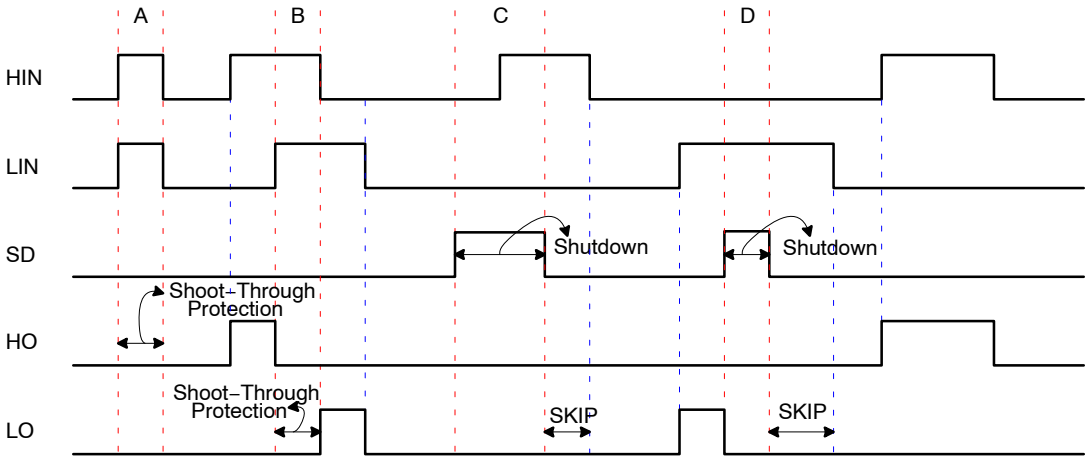


Figure 38. Input/Output Timing Diagram

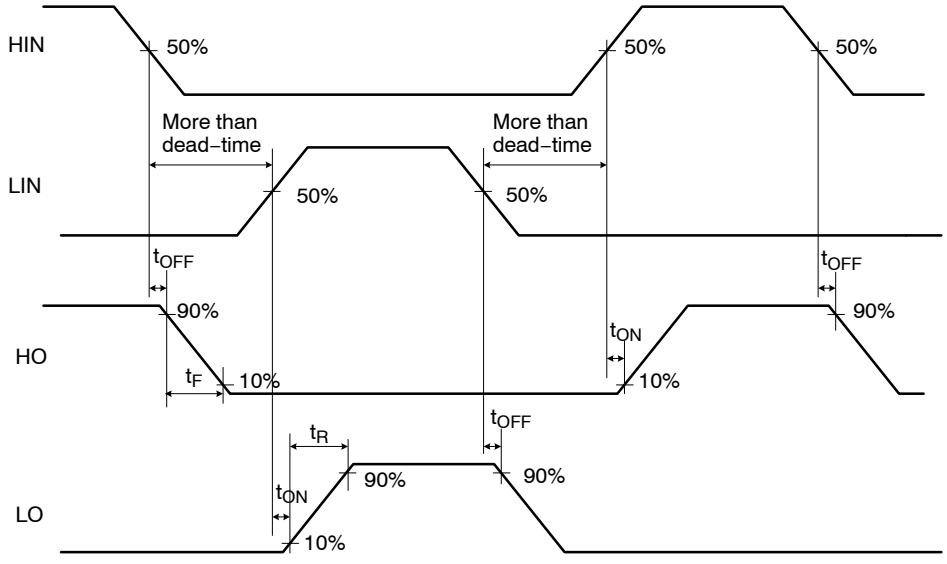


Figure 39. Switching Time Definition

SWITCHING TIME DEFINITIONS (continued)

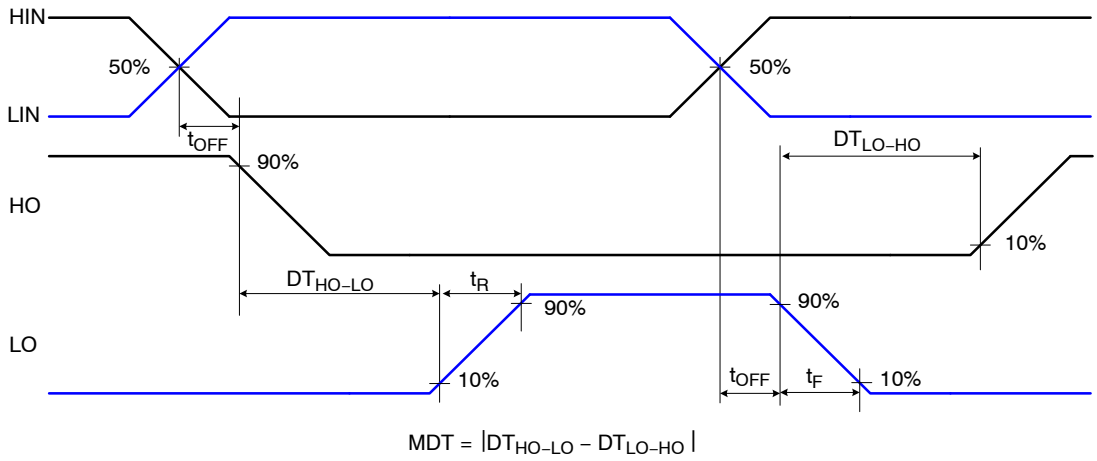


Figure 40. Internal Dead Time Definition

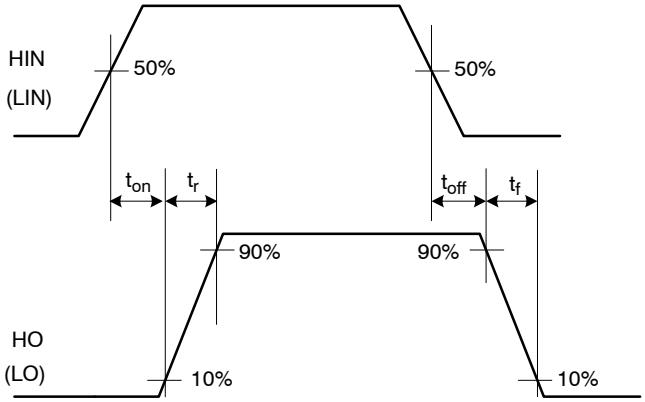


Figure 41. Switching Time Waveform Definitions

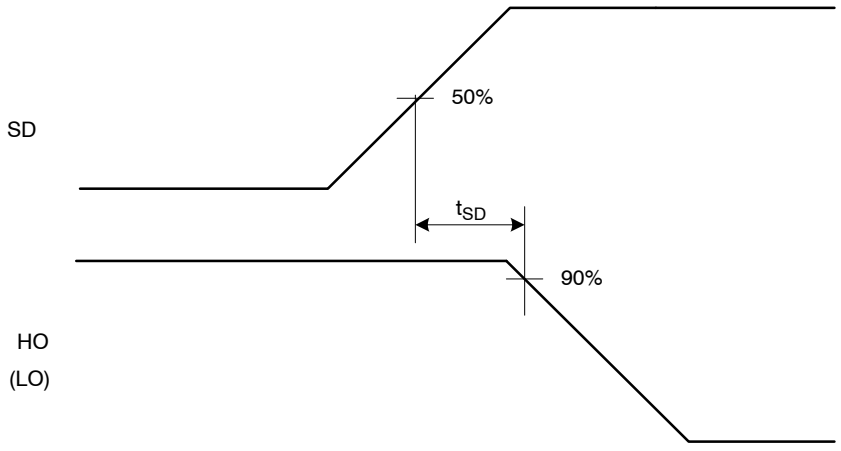


Figure 42. Switching Time Definitions

APPLICATIONS INFORMATION

Dead Time

Dead time is automatically inserted whenever the dead time of the external two input signals (between HIN and LIN signals) is shorter than internal fixed dead times (DT1 and DT2). Otherwise, external dead times larger than internal dead times are not modified by the gate driver and internal dead−time waveform definition is shown in Figure 43.

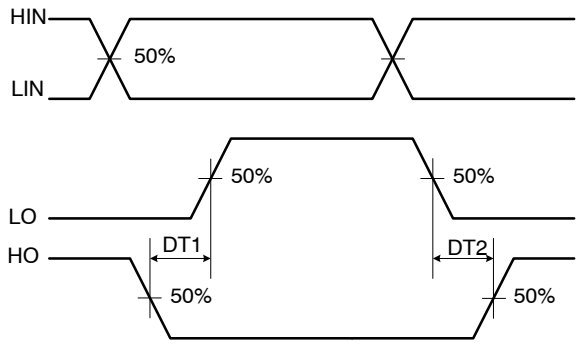


Figure 43. Internal Dead−Time Definitions

Protection Function

Shoot−Through Protection

The shoot−through protection circuitry prevents both high− and low−side switches from conducting at the same time, as shown in Figure 44.

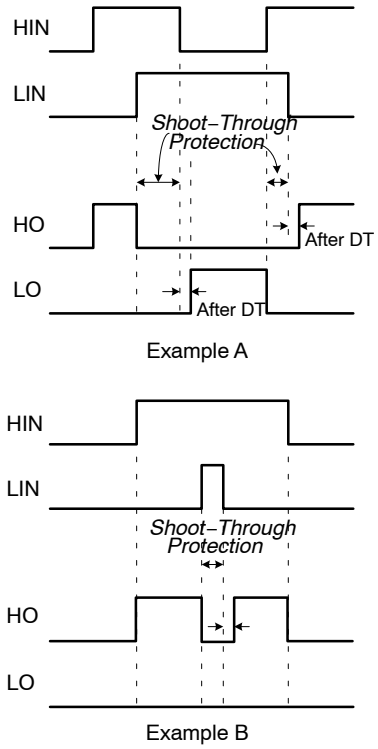


Figure 44. Shoot−Through Protection

Shutdown Input

When the SD pin is in LOW state, the gate driver operates normally. When a condition occurs that should shut down the gate driver, the SD pin should be HIGH. The Shutdown circuitry has an input filter; the minimum input duration is specified by t_{FLTIN} (typically 250 ns).

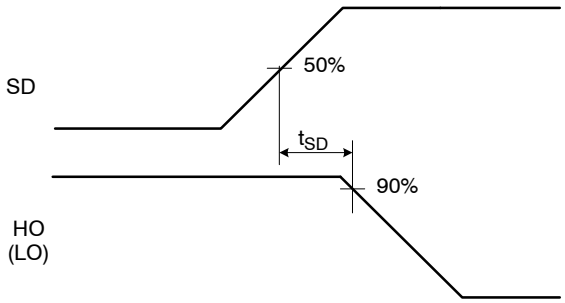


Figure 45. Output Shutdown Timing Waveform

Noise Filter

Input Noise Filter

Figure 46 shows the input noise filter method, which has symmetry duration between the input signal (t_{INPUT}) and the output signal (t_{OUTPUT}) and helps to reject noise spikes and short pulses. This input filter is applied to the HIN, LIN, and EN inputs. The upper pair of waveforms (Example A) shows an input signal duration (t_{INPUT}) much longer than input filter time (t_{FLTIN}); it is approximately the same duration between the input signal time (t_{INPUT}) and the output signal time (t_{OUTPUT}). The lower pair of waveforms (Example B) shows an input signal time (t_{INPUT}) slightly longer than input filter time (t_{FLTIN}); it is approximately the same duration between input signal time (t_{INPUT}) and the output signal time (t_{OUTPUT}).

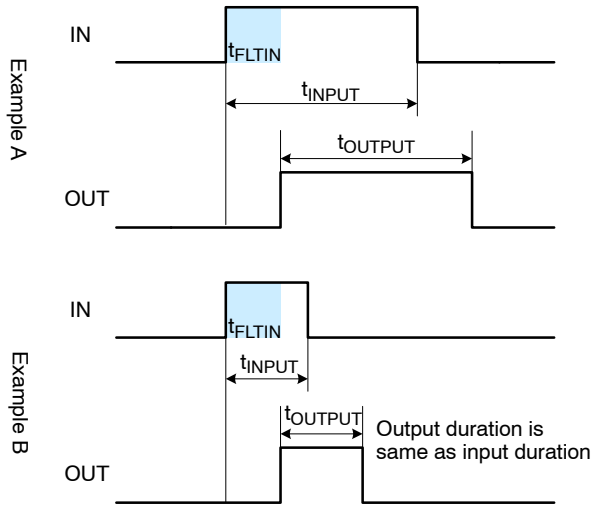


Figure 46. Input Noise Filter Definition

Short−Pulsed Input Noise Rejection Method

The input filter circuitry provides protection against short−pulsed input signals (HIN, LIN, and SD) on the input signal lines by applied noise signal. If the input signal duration is less than input filter time (t_{FLTIN}), the output does not change states. Example A and B of the Figure 47 show the input and output waveforms with short−pulsed noise spikes with a duration less than input filter time; the output does not change states.

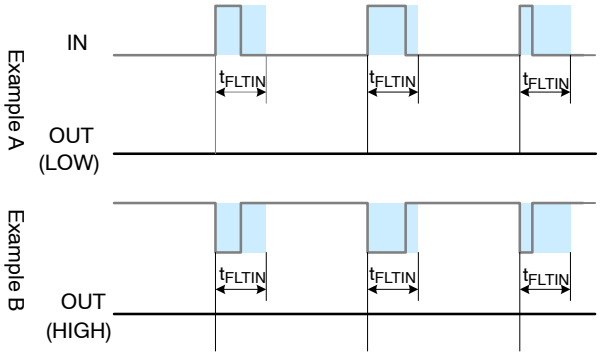


Figure 47. Noise Rejecting Input Filter Definition

Negative VS Transient

The bootstrap circuit has the advantage of being simple and low cost, but has some limitations. The biggest difficulty with this circuit is the negative voltage present at the emitter of the high−side switching device when high−side switch is turned−off in half−bridge application. If the high−side switch, Q1, turns−off while the load current is flowing to an inductive load, a current commutation occurs from high−side switch, Q1, to the diode, D2, in parallel with the low−side switch of the same inverter leg. Then the negative voltage present at the emitter of the high−side switching device, just before the freewheeling diode, D2, starts clamping, causes load current to suddenly flow to the low−side freewheeling diode, D2, as shown in Figure 48.

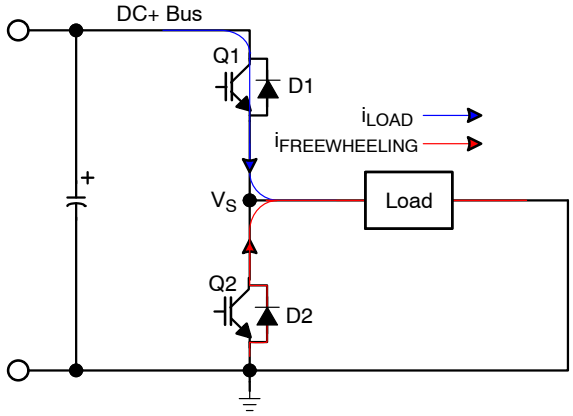


Figure 48. Half−Bridge Application Circuits

This negative voltage can be trouble for the gate driver's output stage, there is the possibility to develop an overvoltage condition of the bootstrap capacitor, input signal missing and latch−up problems because it directly affects the source VS pin of the gate driver, shown in Figure 49. This undershoot voltage is called "negative VS transient".

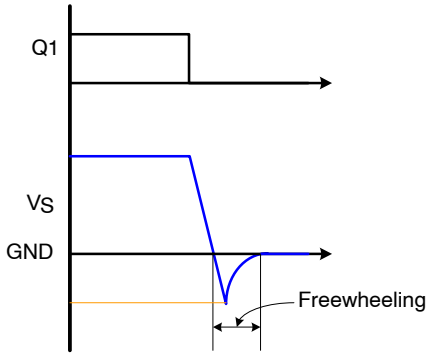


Figure 49. V_S Waveforms during Q1 Turn−Off

Figure 50 and Figure 51 show the commutation of the load current between high−side switch, Q1, and low−side freewheeling diode, D3, in same inverter leg. The parasitic inductances in the inverter circuit from the die wire bonding to the PCB tracks are jumped together in L_C and L_E for each IGBT. When the high−side switch, Q1, and low−side switch, Q4, are turned on, the V_{S1} node is below DC+ voltage by the voltage drops associated with the power switch and the parasitic inductances of the circuit due to load current is flows from Q1 and Q4, as shown in Figure 50. When the high−side switch, Q1, is turned off and Q4, remained turned on, the load current to flows the low−side freewheeling diode, D3, due to the inductive load connected to VS1 as shown in Figure 51. Q1 Turn−Off and D3 Conducting. The current flows from ground (which is connected to the COM pin of the gate driver) to the load and the negative voltage present at the emitter of the high−side switching device. In this case, the COM pin of the gate driver is at a higher potential than the V_S pin due to the voltage drops associated with freewheeling diode, D3, and parasitic elements, L_{C3} and L_{E3}.

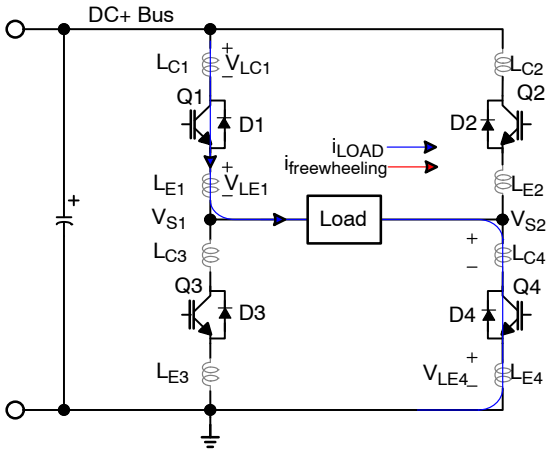


Figure 50. Q1 and Q4 Turn−On

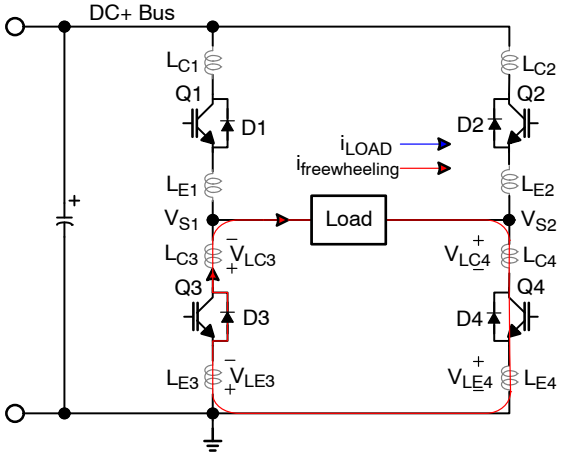


Figure 51. Q1 Turn−Off and D3 Conducting

The FAN73912 has a typical negative VS transient characteristics, as shown in Figure 52.

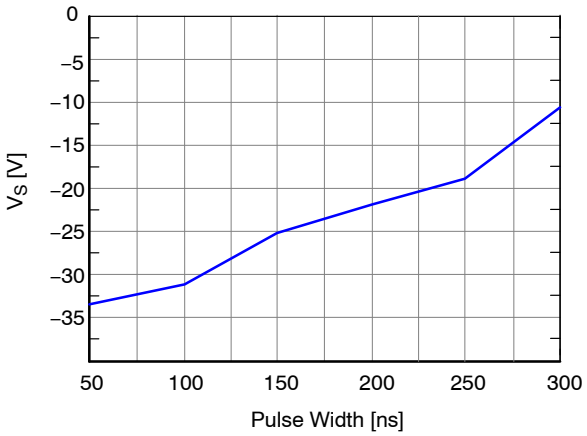


Figure 52. Negative V_S Transient Characteristic

Even though the FAN73912 has been shown able to handle these negative V_S transient conditions, it is strongly recommended that the circuit designer limit the negative VS transient as much as possible by careful PCB layout to minimize the value of parasitic elements and component use. The amplitude of negative V_S voltage is proportional to the parasitic inductances and the turn−off speed, di/dt, of the switching device.

General Guidelines

Printed Circuit Board Layout

The layout recommended for minimized parasitic elements is as follows:

- Direct tracks between switches with no loops or deviation.
- Avoid interconnect links. These can add significant inductance.
- Reduce the effect of lead−inductance by lowering package height above the PCB.
- Consider co−locating both power switches to reduce track length.
- To minimize noise coupling, the ground plane should not be placed under or near the high−voltage floating side.
- To reduce the EM coupling and improve the power switch turn−on/off performance, the gate drive loops must be reduced as much as possible.

Placement of Components

The recommended placement and selection of component as follows:

- Place a bypass capacitor between the V_{CC} and V_{SS} pins. A ceramic 1 μF capacitor is suitable for most applications. This component should be placed as close as possible to the pins to reduce parasitic elements.

- The bypass capacitor from V_{CC} to V_{SS} supports both the low−side driver and bootstrap capacitor recharge. A value at least ten times higher than the bootstrap capacitor is recommended.
- The bootstrap resistor, R_{BOOT}, must be considered in sizing the bootstrap resistance and the current developed during initial bootstrap charge. If the resistor is needed in series with the bootstrap diode, verify that V_B does not fall below COM (ground). Recommended use is typically 5 ~ 10 Ω that increase the V_{BS} time constant. If the voltage drop of bootstrap resistor and diode is too high or the circuit topology does not allow a sufficient charging time, a fast recovery or ultra−fast recovery diode can be used.
- The bootstrap capacitor, C_{BOOT}, uses a low−ESR capacitor, such as ceramic capacitor. It is strongly recommended that the placement of components is as follows:
- Place components tied to the floating voltage pins (V_B and V_S) near the respective high−voltage portions of the device and the FAN73912. Not Connected (NC) pins in this package maximize the distance between the high−voltage and low−voltage pins (see Figure 3).
- Place and route for bypass capacitors and gate resistors as close as possible to gate drive IC.
- Locate the bootstrap diode, D_{BOOT}, as close as possible to bootstrap capacitor, C_{BOOT}.
- The bootstrap diode must use a lower forward voltage drop and minimal switching time as soon as possible for fast recovery or ultra−fast diode.

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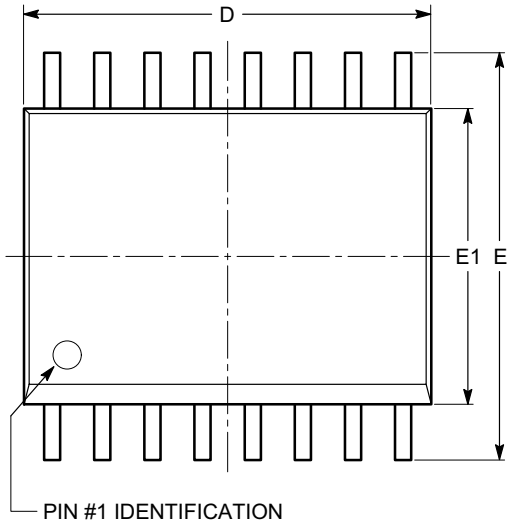
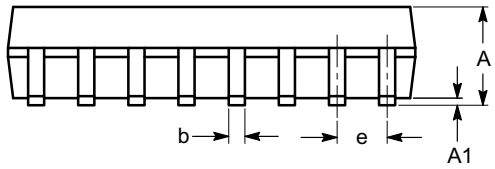
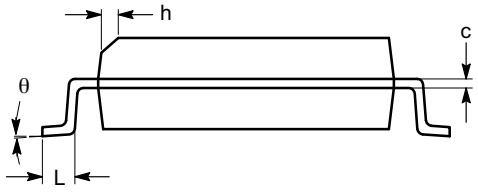


TOP VIEW

SYMBOL	MIN	NOM	MAX
A	2.36	2.49	2.64
A1	0.10		0.30
b	0.33	0.41	0.51
c	0.18	0.23	0.28
D	10.08	10.31	10.49
E	10.01	10.31	10.64
E1	7.39	7.49	7.59
e	1.27 BSC		
h	0.25		0.75
L	0.38	0.81	1.27
θ	0°		8°



SIDE VIEW



END VIEW

Notes:
(1) All dimensions are in millimeters. Angles in degrees.
(2) Complies with JEDEC MS-013.

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