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# FAN7389

## 3-Phase Half-Bridge Gate-Drive IC

### Features

- Floating Channel for Bootstrap Operation to +600 V
- Typically 350 mA/650 mA Sourcing/Sinking Current Driving Capability for All Channels
- Extended Allowable Negative  $V_S$  Swing to -9.8 V for Signal Propagation at  $V_{DD}=V_{BS}=15$  V
- Output In-Phase with Input Signal
- Over-Current Shutdown Turns off All Six Drivers
- Matched Propagation Delay for All Channels
- 3.3 V and 5.0 V Input Logic Compatible
- Adjustable Fault-Clear Timing
- Built-in Advanced Input Filter
- Built-in Shoot-Through Prevention Logic
- Built-in Soft Turn-Off Function
- Common-Mode dv/dt Noise Canceling Circuit
- Built-in UVLO Functions for All Channels

### Applications

- 3-Phase Motor Inverter Driver
- Air Conditioners
- Washing Machines
- General-Purpose Three-Phase Inverters

### Description

The FAN7389 is a monolithic three-phase half-bridge gate-drive IC designed for high-voltage, high-speed driving MOSFETs and IGBTs operating up to +600 V.

Fairchild's high-voltage process and common-mode noise canceling technique provide stable operation of high-side drivers under high-dv/dt noise circumstances.

An advanced level-shift circuit allows high-side gate driver operation up to  $V_S = -9.8$  V (typical) for  $V_{BS} = 15$  V.

The protection functions include under-voltage lockout and inverter over-current trip with an automatic fault-clear function.

Over-current protection that terminates all six outputs can be derived from an external current-sense resistor. An open-drain fault signal is provided to indicate that an over-current or under-voltage shutdown has occurred.

The UVLO circuits prevent malfunction when  $V_{DD}$  and  $V_{BS}$  are lower than the specified threshold voltage.

Output drivers typically source and sink 350 mA and 650 mA, respectively; which is suitable for three-phase half-bridge applications in motor drive systems.

### 28-SOIC



### Ordering Information

Part Number	Package	Operating Temperature	Packing Method
FAN7389MX1 <sup>(1)</sup>	28-Lead, Small Outline Integrated Circuit Wide Body (SOIC)	-40 to +125°C	Tape & Reel

#### Note:

1. These devices passed wave soldering test by JESD22A-111.

## Typical Application Diagram

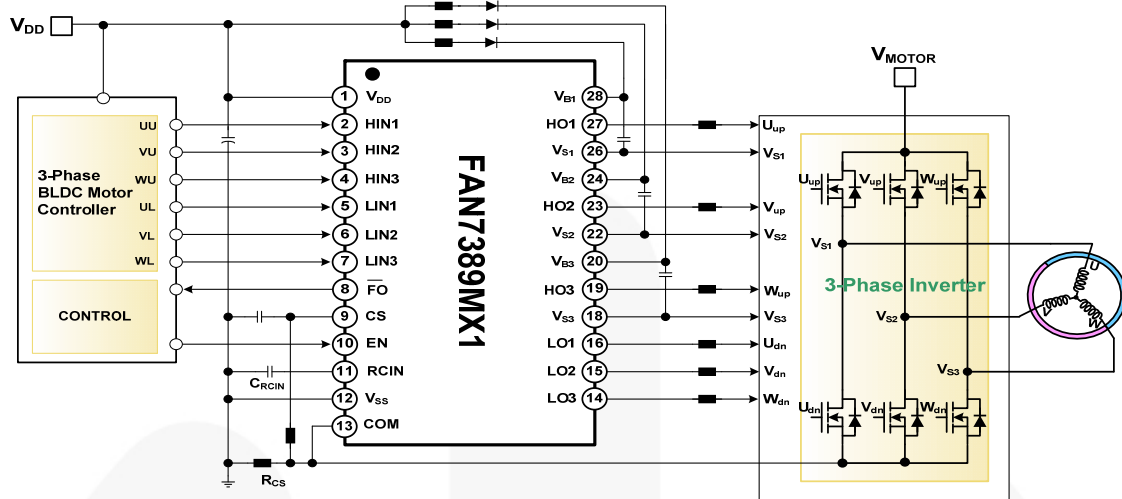


Figure 1. 3-Phase BLDC Motor Drive Application

## Internal Block Diagram

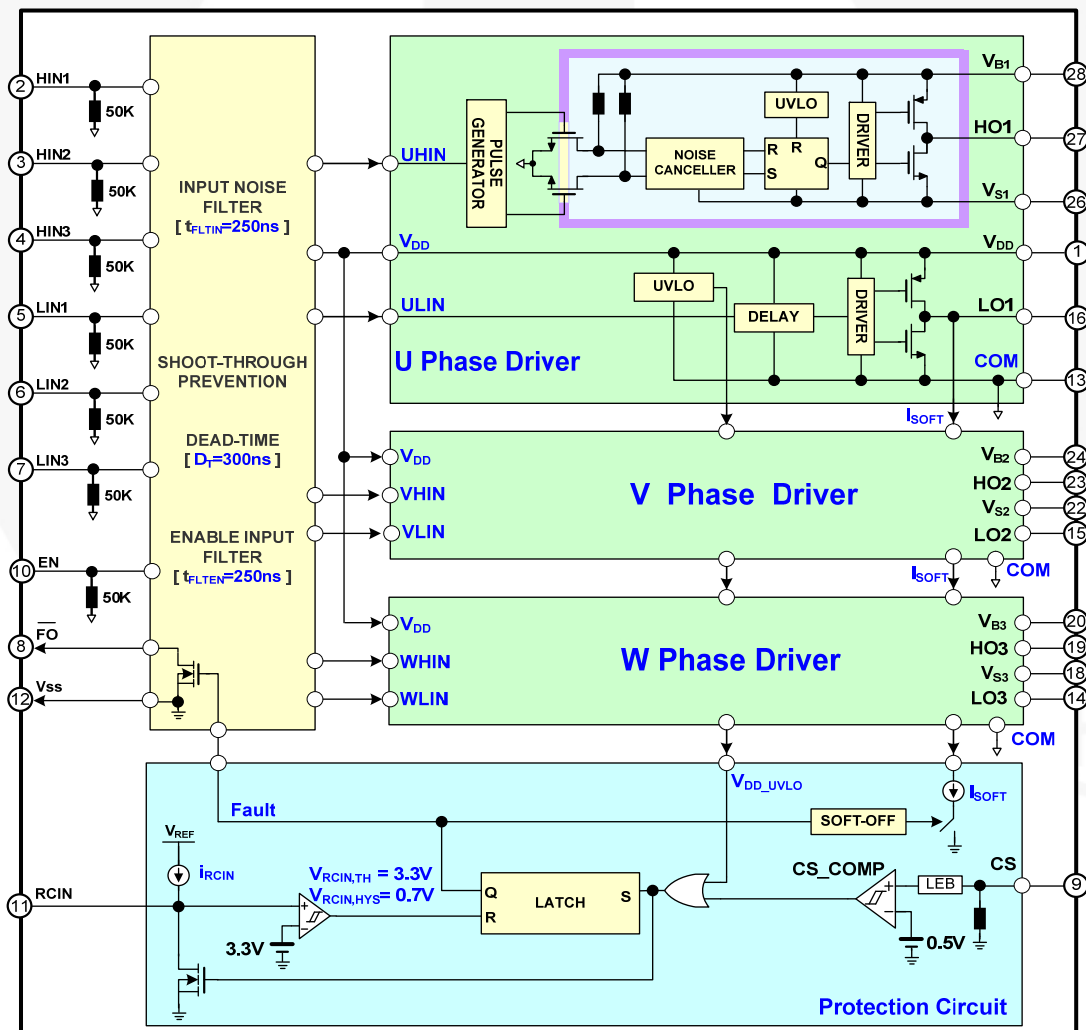


Figure 2. Functional Block Diagram

## Pin Configuration

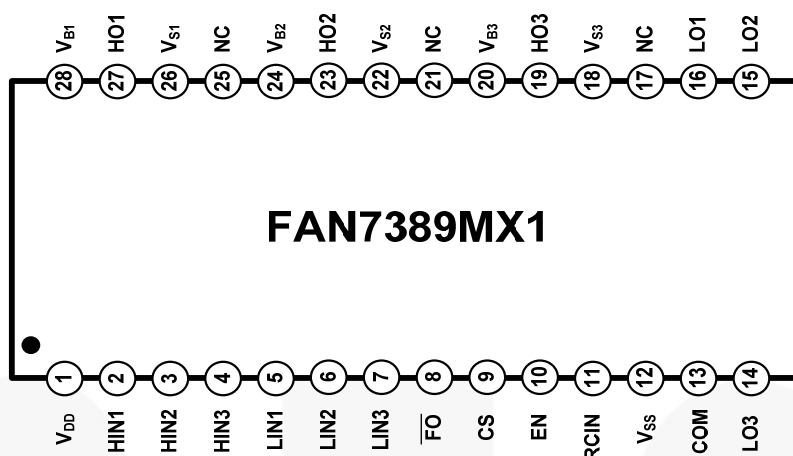


Figure 3. Pin Configuration

## Pin Definitions

Pin	Name	Description
1	V <sub>DD</sub>	Logic and low-side gate driver power supply voltage
2	HIN1	Logic Input 1 for high-side gate 1 driver
3	HIN2	Logic Input 2 for high-side gate 2 driver
4	HIN3	Logic Input 3 for high-side gate 3 driver
5	LIN1	Logic Input 1 for low-side gate 1 driver
6	LIN2	Logic Input 2 for low-side gate 2 driver
7	LIN3	Logic Input 3 for low-side gate 3 driver
8	FO	Fault output with open drain (indicates over-current and low-side under-voltage)
9	CS	Analog input for over-current shutdown
10	EN	Logic input for shutdown functionality
11	RCIN	An external RC network input used to define the fault-clear delay
12	V <sub>SS</sub>	Logic ground
13	COM	Low-side driver return
14	LO3	Low-side gate driver 3 output
15	LO2	Low-side gate driver 2 output
16	LO1	Low-side gate driver 1 output
17, 21, 25	NC	No connect
18	V <sub>S3</sub>	High-side driver 3 floating supply offset voltage
19	HO3	High-side driver 3 gate driver output
20	V <sub>B3</sub>	High-side driver 3 floating supply
22	V <sub>S2</sub>	High-side driver 2 floating supply offset voltage
23	HO2	High-side driver 2 gate driver output
24	V <sub>B2</sub>	High-side driver 2 floating supply
26	V <sub>S1</sub>	High-side driver 1 floating supply offset voltage
27	HO1	High-side driver 1 gate driver output
28	V <sub>B1</sub>	High-side driver 1 floating supply

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.  $T_A=25^{\circ}\text{C}$ , unless otherwise specified.

Symbol	Parameter	Min.	Max.	Unit
$V_S$	High-Side Floating Offset Voltage	$V_{B1,2,3}-25.0$	$V_{B1,2,3}+0.3$	V
$V_B$	High-Side Floating Supply Voltage	-0.3	625.0	V
$V_{DD}$	Low-Side and Logic-Fixed Supply Voltage	-0.3	25.0	V
$V_{HO}$	High-Side Floating Output Voltage $V_{HO1,2,3}$	$V_{S1,2,3}-0.3$	$V_{B1,2,3}+0.3$	V
$V_{LO}$	Low-Side Floating Output Voltage $V_{LO1,2,3}$	-0.3	$V_{DD}+0.3$	V
$V_{IN}$	Input Voltage (HINx, LINx, CS, and EN)	-0.3	5.5	V
$V_{FO}$	Fault Output Voltage ( $\overline{FO}$ )	-0.3	$V_{DD}+0.3$	V
$PW_{HIN}$	High-Side Input Pulse Width	500		ns
$dV_S/dt$	Allowable Offset Voltage Slew Rate		$\pm 50$	V/ns
$P_D$	Power Dissipation <sup>(2,3,4)</sup>		1.4	W
$\theta_{JA}$	Thermal Resistance		70	$^{\circ}\text{C/W}$
$T_J$	Junction Temperature		150	$^{\circ}\text{C}$
$T_{STG}$	Storage Temperature	-55	150	$^{\circ}\text{C}$

### Notes:

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

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter	Min.	Max.	Unit
$V_{B1,2,3}$	High-Side Floating Supply Voltage	$V_{S1,2,3}+10$	$V_{S1,2,3}+20$	V
$V_{S1,2,3}$	High-Side Floating Supply Offset Voltage	$6-V_{DD}$	600	V
$V_{DD}$	Low-Side and Logic Fixed Supply Voltage	10	20	V
$V_{HO1,2,3}$	High-Side Output Voltage	$V_{S1,2,3}$	$V_{B1,2,3}$	V
$V_{LO1,2,3}$	Low-Side Output Voltage	COM	$V_{DD}$	V
$V_{FO}$	Fault Output Voltage ( $\overline{FO}$ )	COM	$V_{DD}$	V
$V_{CS}$	Current-Sense Pin Input Voltage	COM	5	V
$V_{IN}$	Logic Input Voltage (HIN1,2,3 and LIN1,2,3)	COM	5	V
$V_{SS}$	Logic Ground	-5	5	V
$T_A$	Ambient Temperature	-40	+125	$^{\circ}\text{C}$

## Electrical Characteristics

$V_{BIAS}$  ( $V_{DD}$ ,  $V_{BS1,2,3}$ ) = 15.0 V and  $T_A$  = 25°C unless otherwise specified. The  $V_{IN}$  and  $I_{IN}$  parameters are referenced to COM and are applicable to all six channels. The  $V_O$  and  $I_O$  parameters are referenced to  $V_{S1,2,3}$  and COM and are applicable to the respective output leads: HO1,2,3 and LO1,2,3. 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.	Unit
<b>Low-Side Power Supply Section</b>						
$I_{QDD}$	Quiescent $V_{DD}$ Supply Current	$V_{LIN1,2,3}=0$ V or 5 V, $EN=0$ V		200		$\mu$ A
$I_{PDD}$	Operating $V_{DD}$ Supply Current	$f_{LIN1,2,3}=20$ kHz, rms Value		400		$\mu$ A
$V_{DDUV+}$	$V_{DD}$ Supply Under-Voltage Positive-Going Threshold	$V_{DD}=\text{Sweep}$	7.5	8.5	9.3	V
$V_{DDUV-}$	$V_{DD}$ Supply Under-Voltage Negative-Going Threshold	$V_{DD}=\text{Sweep}$	7.0	8.0	8.7	V
$V_{DDHYS}$	$V_{DD}$ Supply Under-Voltage Lockout Hysteresis	$V_{DD}=\text{Sweep}$		0.5		V
<b>Bootstrapped Power Supply Section</b>						
$V_{BSUV+}$	$V_{BS}$ Supply Under-Voltage Positive-Going Threshold	$V_{BS1,2,3}=\text{Sweep}$	7.5	8.5	9.3	V
$V_{BSUV-}$	$V_{BS}$ Supply Under-Voltage Negative-Going Threshold	$V_{BS1,2,3}=\text{Sweep}$	7.0	8.0	8.7	V
$V_{BSHYS}$	$V_{BS}$ Supply Under-Voltage Lockout Hysteresis	$V_{BS1,2,3}=\text{Sweep}$		0.5		V
$I_{LK}$	Offset Supply Leakage Current	$V_{B1,2,3}=V_{S1,2,3}=600$ V			10	$\mu$ A
$I_{QBS}$	Quiescent $V_{BS}$ Supply Current	$V_{HIN1,2,3}=0$ V or 5 V, $EN=0$ V	10	50	80	$\mu$ A
$I_{PBS}$	Operating $V_{BS}$ Supply Current	$f_{HIN1,2,3}=20$ kHz, rms Value	200	420	480	$\mu$ A
<b>Gate Driver Output Section</b>						
$V_{OH}$	High-Level Output voltage, $V_{BIAS}-V_O$	$I_O=0$ mA (No Load)			100	mV
$V_{OL}$	Low-Level Output voltage, $V_O$	$I_O=0$ mA (No Load)			100	mV
$I_{O+}$	Output HIGH Short-Circuit Pulse Current <sup>(5)</sup>	$V_O=0$ V, $V_{IN}=5$ V with $PW \leq 10$ $\mu$ s	250	350		mA
$I_{O-}$	Output LOW Short-Circuit Pulsed Current <sup>(5)</sup>	$V_O=15$ V, $V_{IN}=0$ V with $PW \leq 10$ $\mu$ s	500	650		mA
$V_S$	Allowable Negative $V_S$ Pin Voltage for HIN Signal Propagation to HO			-9.8	-7.0	V
<b>Logic Input Section</b>						
$V_{IH}$	Logic "1" Input Voltage $HIN1,2,3$ , $LIN1,2,3$		2.5			V
$V_{IL}$	Logic "0" Input Voltage $HIN1,2,3$ , $LIN1,2,3$				0.8	V
$I_{IN+}$	Logic Input Bias Current ( $HO=LO=HIGH$ )	$V_{IN}=5$ V		100		$\mu$ A
$I_{IN-}$	Logic Input Bias Current ( $HO=LO=LOW$ )	$V_{IN}=0$ V			2	$\mu$ A
$R_{IN}$	Logic Input Pull-Down Resistance			50		K $\Omega$
<b>Enable Control Section (EN)</b>						
$V_{EN+}$	Enable Positive-Going Threshold Voltage		2.5			V
$V_{EN-}$	Enable Negative-Going Threshold Voltage				0.8	V
$I_{EN+}$	Logic Enable "1" Input Bias Current	$V_{EN}=5$ V (Pull-Down=150K $\Omega$ )		33		$\mu$ A
$I_{EN-}$	Logic Enable "0" Input Bias Current	$V_{EN}=0$ V			2	$\mu$ A

Continued on the following page...

## Electrical Characteristics

$V_{BIAS}$  ( $V_{DD}$ ,  $V_{BS1,2,3}$ ) = 15.0 V and  $T_A$  = 25°C unless otherwise specified. The  $V_{IN}$  and  $I_{IN}$  parameters are referenced to COM and are applicable to all six channels. The  $V_O$  and  $I_O$  parameters are referenced to  $V_{S1,2,3}$  and COM and are applicable to the respective output leads: HO1,2,3 and LO1,2,3. 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.	Unit
<b>Over-Current Protection Section</b>						
$V_{CSTH+}$	Over-Current Detect Positive Threshold <sup>(5)</sup>		400	500	600	mV
$V_{CSTH-}$	Over-Current Detect Negative Threshold <sup>(5)</sup>			440		mV
$V_{CSHYS}$	Over-Current Detect Hysteresis <sup>(5)</sup>			60		mV
$I_{CSIN}$	Short-Circuit Input Current	$V_{CSIN}=1\text{ V}$	5	10	15	μA
$I_{SOFT}$	Soft Turn-Off Sink Current		25	40	55	mA
<b>Fault Output Section</b>						
$V_{RCINT+}$	RCIN Positive-Going Threshold Voltage			3.3		V
$V_{RCINT-}$	RCIN Negative-Going Threshold Voltage			2.6		V
$V_{RCINHYS}$	RCIN Hysteresis Voltage			0.7		V
$I_{RCIN}$	RCIN Internal Current Source	$C_{RCIN}=2\text{ nF}$	3	5	7	μA
$V_{FOL}$	Fault Output Low Level Voltage	$V_{CS}=1\text{ V}$ , $I_{FO}=1.5\text{ mA}$		0.2	0.5	V
$R_{DSRCIN}$	RCIN On Resistance	$I_{RCIN}=1.5\text{ mA}$	50	75	100	Ω
$R_{DSFO}$	Fault Output On Resistance	$I_{FO}=1.5\text{ mA}$	90	130	170	Ω

### Note:

5. These parameters are guaranteed by design.

## Dynamic Electrical Characteristics

$T_A=25^\circ\text{C}$ ,  $V_{BIAS}$  ( $V_{DD}$ ,  $V_{BS1,2,3}$ ) = 15.0 V,  $V_{S1,2,3}$  = COM,  $C_{RCIN}=2\text{ nF}$ , and  $C_{Load}$  = 1000 pF unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$t_{ON}$	Turn-On Propagation Delay	$V_{LIN1,2,3}=V_{HIN1,2,3}=0\text{ V}$ , $V_{S1,2,3}=0\text{ V}$	350	500	650	ns
$t_{OFF}$	Turn-Off Propagation Delay	$V_{LIN1,2,3}=V_{HIN1,2,3}=5\text{ V}$ , $V_{S1,2,3}=0\text{ V}$	350	500	650	ns
$t_R$	Turn-On Rise Time	$V_{LIN1,2,3}=V_{HIN1,2,3}=0\text{ V}$	20	50	100	ns
$t_F$	Turn-Off Fall Time	$V_{LIN1,2,3}=V_{HIN1,2,3}=5\text{ V}$	10	30	80	ns
$t_{EN}$	Enable LOW to Output Shutdown Delay		400	500	600	ns
$t_{CSBLT}$	CS Pin Leading-Edge Blanking Time <sup>(6)</sup>		200	300	400	ns
$t_{CSFO}$	Time from CS Triggering to $\overline{FO}$ <sup>(7)</sup>	From $V_{CSC}=1\text{ V}$ to $\overline{FO}$ Turn-Off		630		ns
$t_{CSOFF}$	Time from CS Triggering to All Gate Outputs Turn-Off <sup>(7)</sup>	From $V_{CSC}=1\text{ V}$ to Starting Gate Turn-Off		640		ns
$t_{FLTIN}$	Input Filtering Time <sup>(8)</sup> ( $HINx$ , $LINx$ , $EN$ )		200	250	300	ns
$t_{FLTCLR}$	Fault-Clear Time			1.3		ms
DT	Dead Time		250	300	350	ns
MDT	Dead-Time Matching (All Six Channels)				50	ns
MT	Delay Matching (All Six Channels)				50	ns
PM	Output Pulse-Width Matching <sup>(6,9)</sup>	$PW_{IN} > 1\mu\text{s}$		50	100	ns

### Notes:

- These parameters are guaranteed by design.
- These parameters are referenced to specified  $C_{RCIN}$  (=2 nF), and proportional to value of  $C_{RCIN}$  as shown in Figure 43. It is strongly recommended that the capacitor on  $R_{CIN}$  pin should be less than 5 nF.
- The minimum width of the input pulse should exceed 500 ns to ensure the filtering time of the input filter is exceeded.
- PM is defined as  $PW_{IN}-PW_{OUT}$ .

## Typical Characteristics

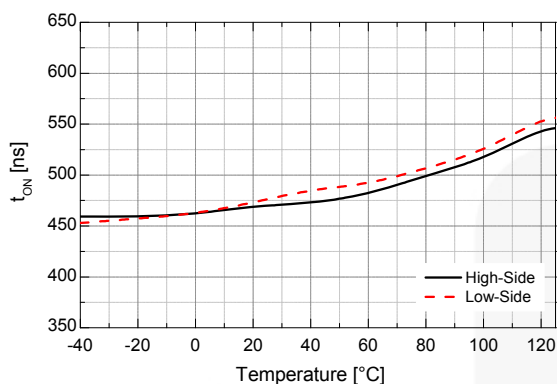


Figure 4. Turn-On Propagation Delay vs. Temperature

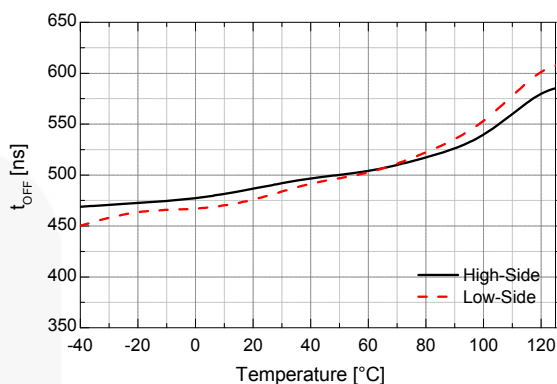


Figure 5. Turn-Off Propagation Delay vs. Temperature

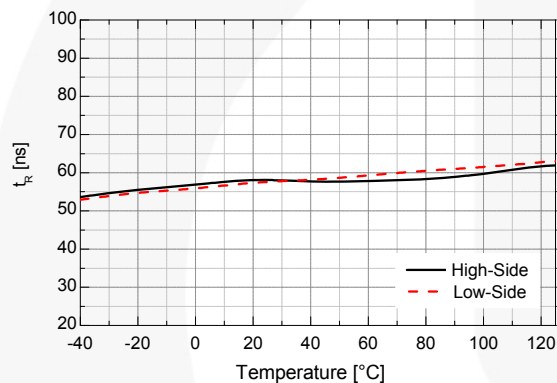


Figure 6. Turn-On Rise Time vs. Temperature

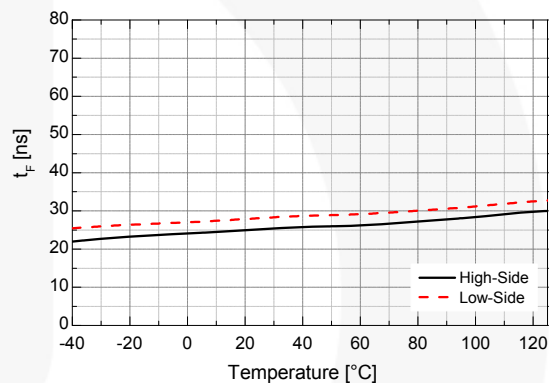


Figure 7. Turn-Off Fall Time vs. Temperature

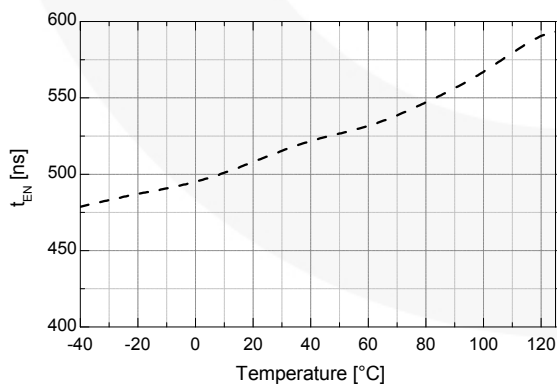


Figure 8. Enable LOW to Output Shutdown Delay vs. Temperature

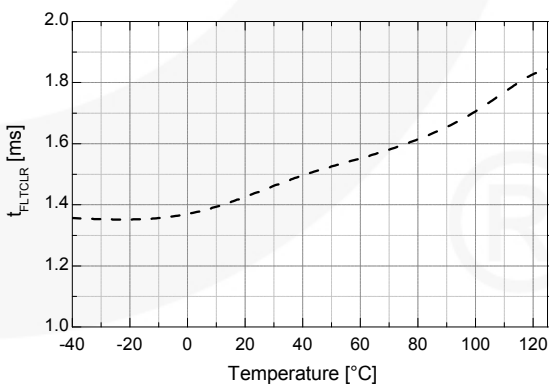


Figure 9. Fault-Clear Time vs. Temperature



## Typical Characteristics (Continued)

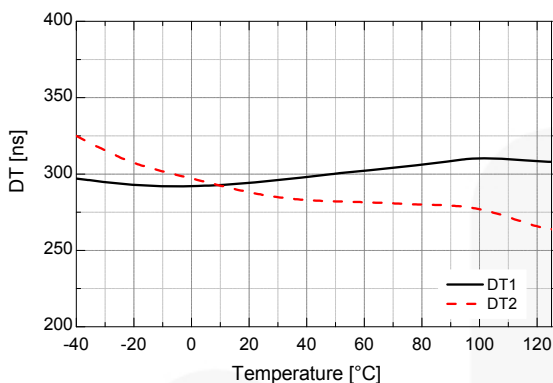


Figure 10. Dead Time vs. Temperature

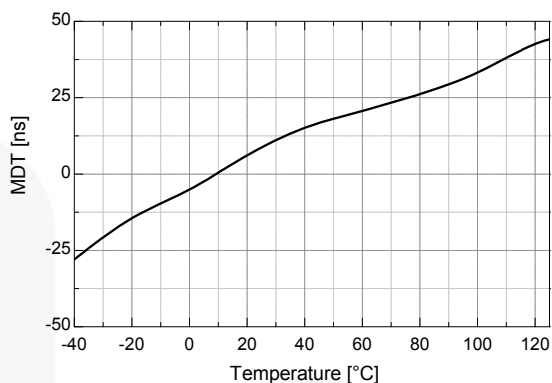


Figure 11. Dead-Time Matching vs. Temperature

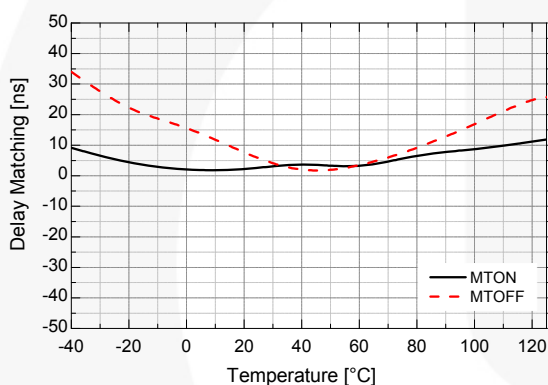


Figure 12. Delay Matching vs. Temperature

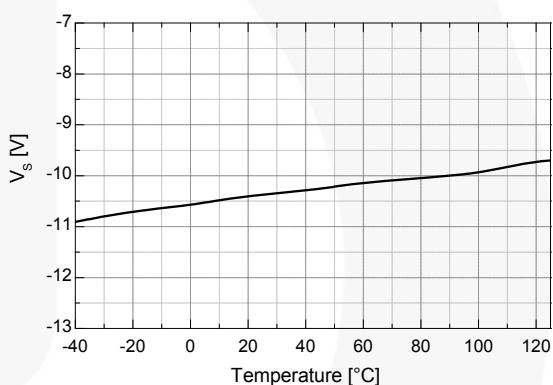


Figure 13. Allowable Negative  $V_S$  Voltage vs. Temperature

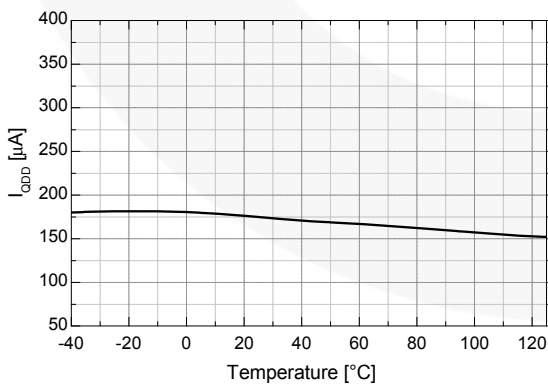


Figure 14. Quiescent  $V_{DD}$  Supply Current vs. Temperature

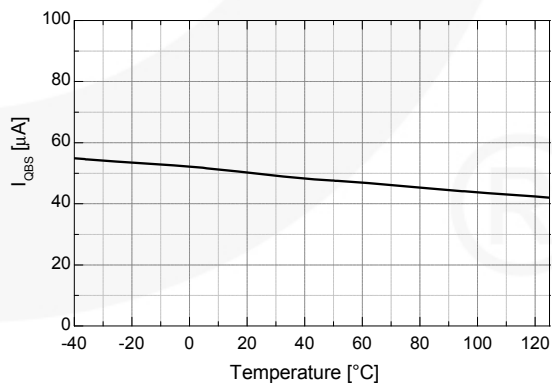
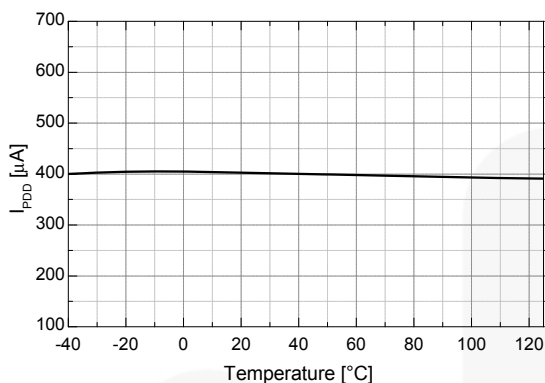
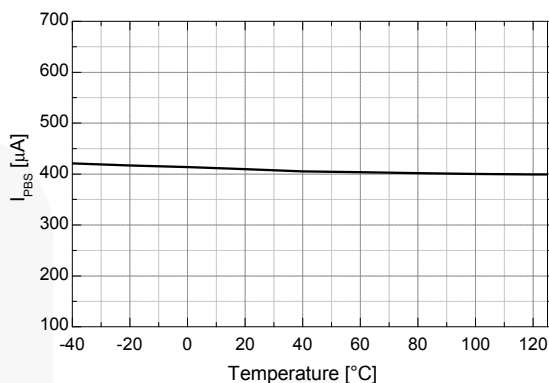


Figure 15. Quiescent  $V_{BS}$  Supply Current vs. Temperature

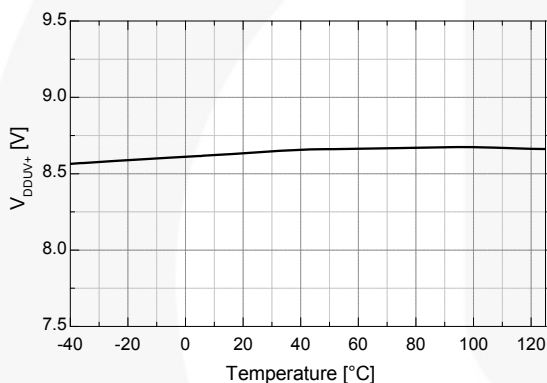
## Typical Characteristics (Continued)



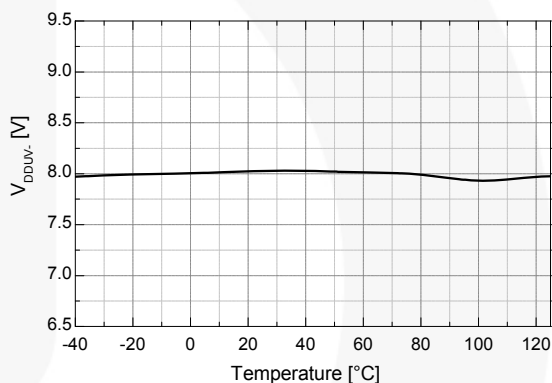
**Figure 16. Operating  $V_{DD}$  Supply Current vs. Temperature**



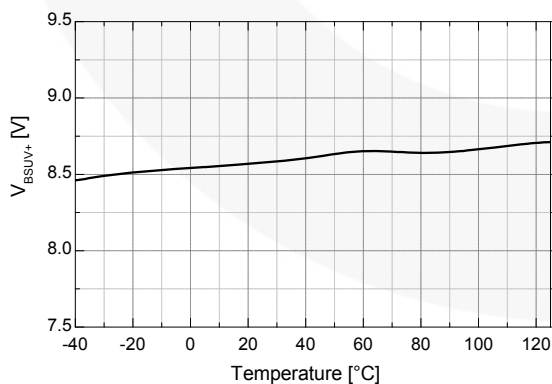
**Figure 17. Operating  $V_{BS}$  Supply Current vs. Temperature**



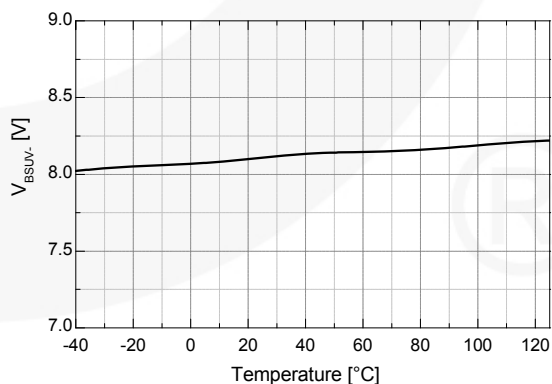
**Figure 18.  $V_{DD}$  UVLO+ vs. Temperature**



**Figure 19.  $V_{DD}$  UVLO- vs. Temperature**



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



**Figure 21.  $V_{BS}$  UVLO- vs. Temperature**

## Typical Characteristics (Continued)

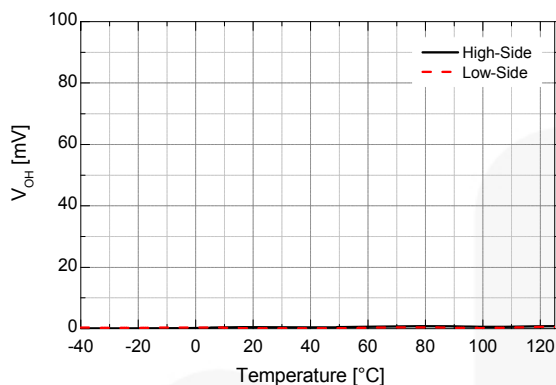


Figure 22. High-Level Output Voltage vs. Temperature

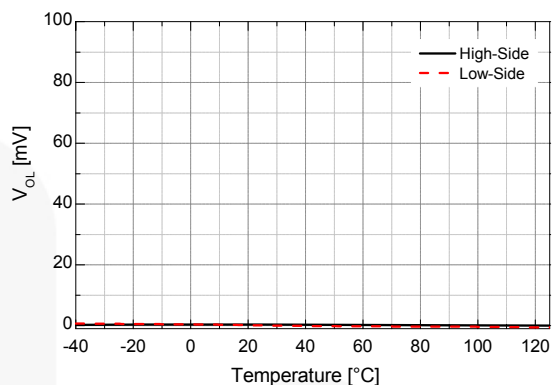


Figure 23. Low-Level Output Voltage vs. Temperature

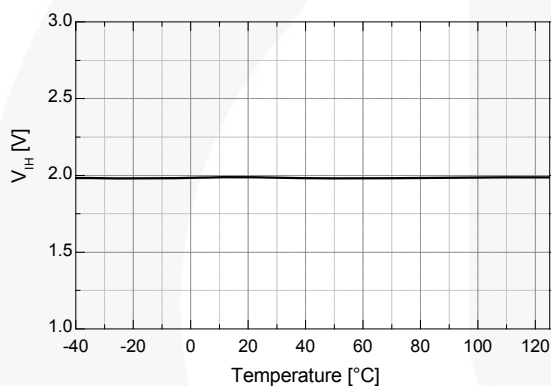


Figure 24. Logic HIGH Input Voltage vs. Temperature

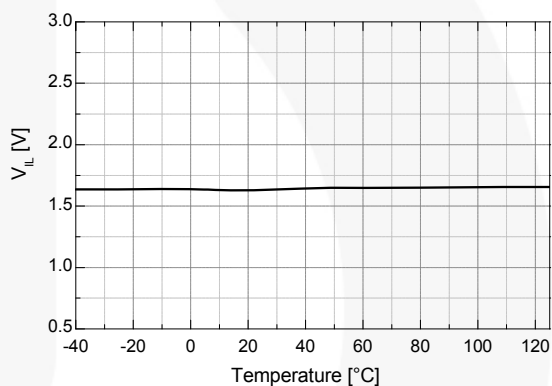


Figure 25. Logic LOW Input Voltage vs. Temperature

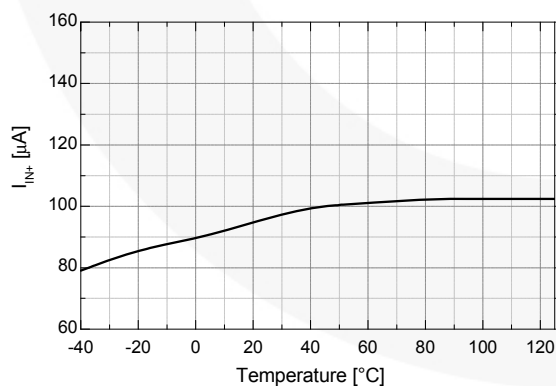


Figure 26. Logic Input HIGH Bias Current vs. Temperature

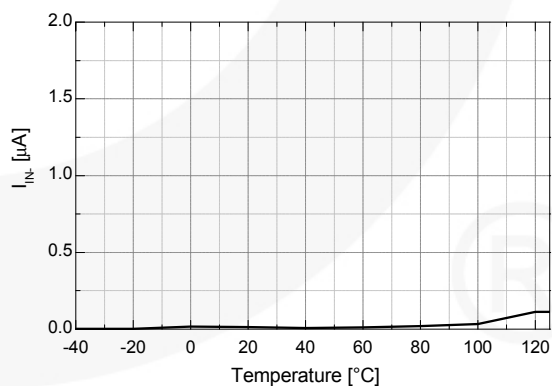
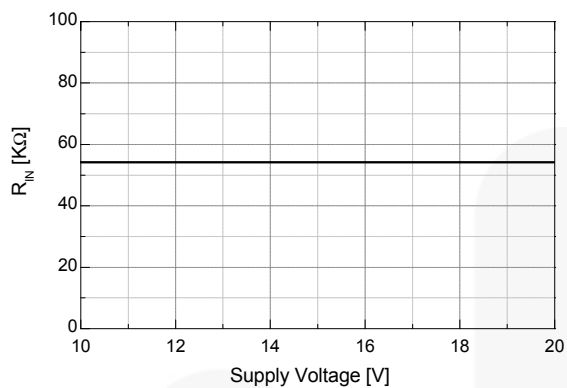
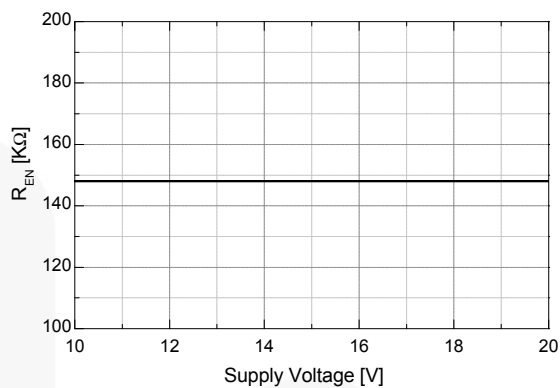


Figure 27. Logic Input LOW Bias Current vs. Temperature

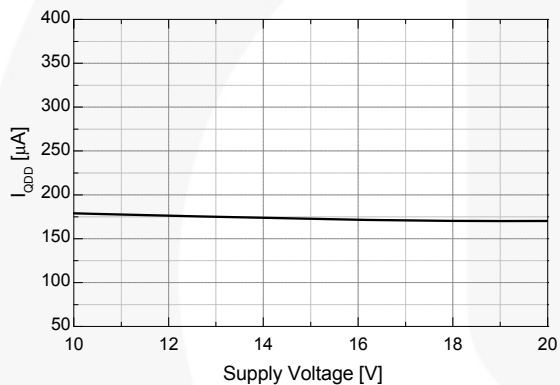
## Typical Characteristics (Continued)



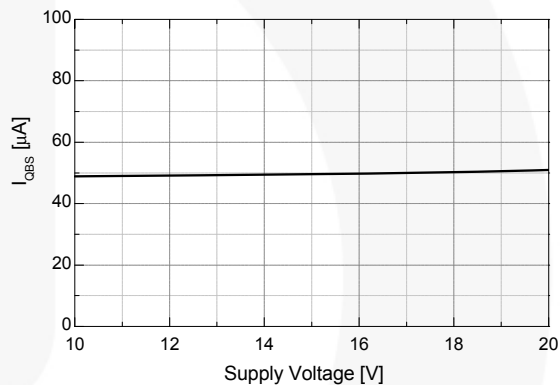
**Figure 28. Input Pull-Down Resistance vs. Supply Voltage**



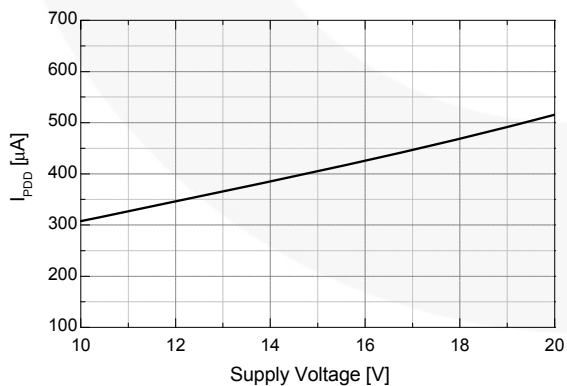
**Figure 29. Enable Pin Pull-Down Resistance vs. Supply Voltage**



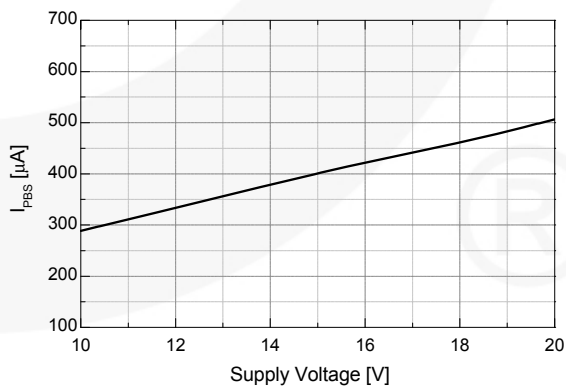
**Figure 30. Quiescent  $V_{DD}$  Supply Current vs. Supply Voltage**



**Figure 31. Quiescent  $V_{BS}$  Supply Current vs. Supply Voltage**



**Figure 32. Operating  $V_{DD}$  Supply Current vs. Supply Voltage**



**Figure 33. Operating  $V_{BS}$  Supply Current vs. Supply Voltage**

## Switching Time Definitions

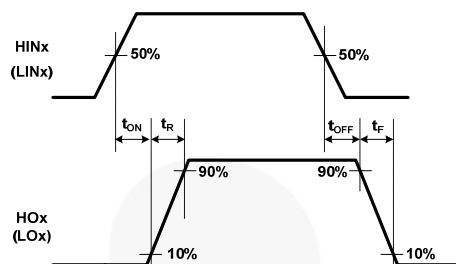


Figure 34. Switching Time Waveform Definitions

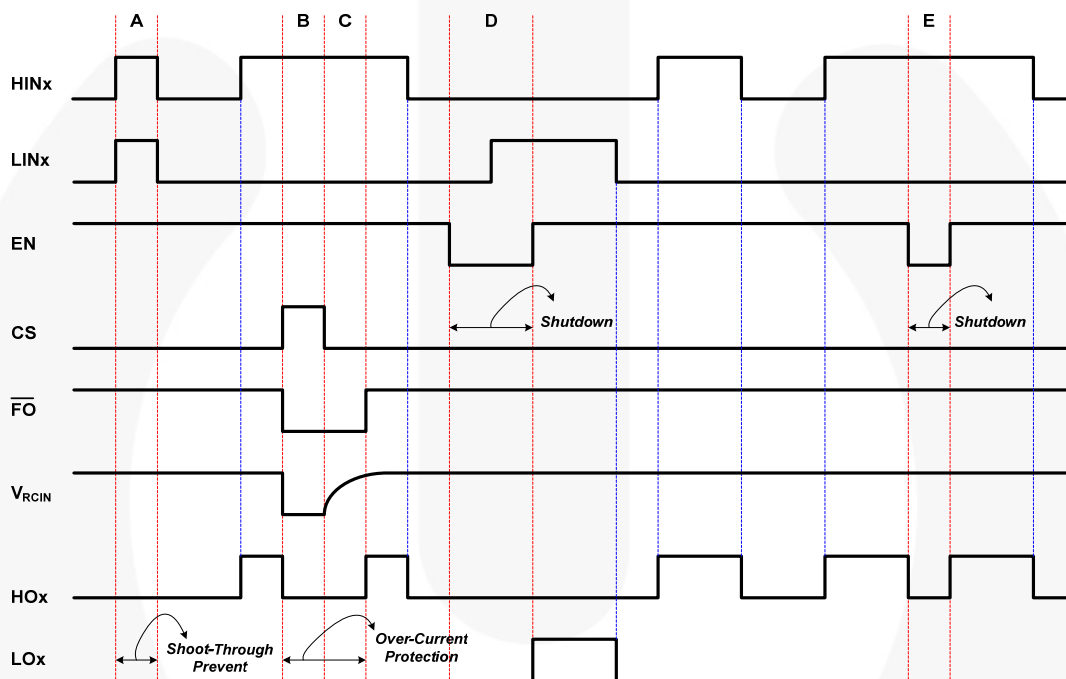


Figure 35. Input / Output Timing Diagram

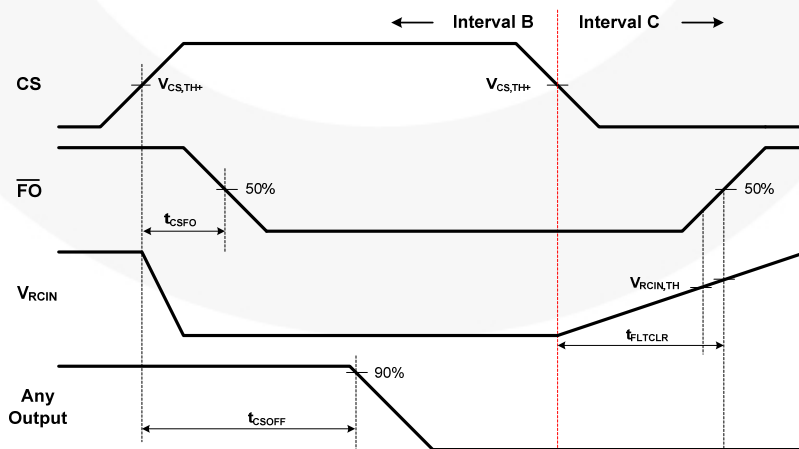


Figure 36. Detailed View of B and C Intervals During Over-Current Protection

## Applications Information

### 1. Dead Time

Dead time is automatically inserted whenever the dead time of the external two input signals (between HINx and LINx 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 37.

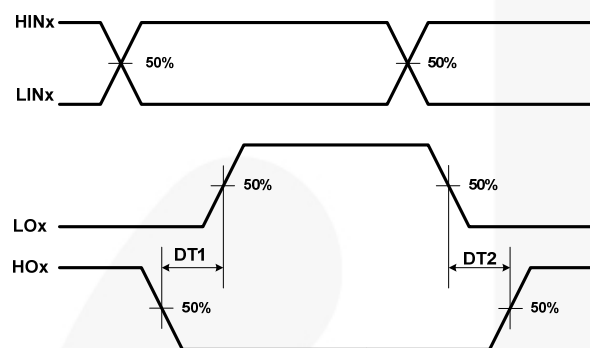


Figure 37. Internal Dead-Time Definitions

### 2. Protection Function

#### 2.1 Fault Out ( $\overline{FO}$ ) and Under-Voltage Lockout

The high- and low-side drivers include under-voltage lockout (UVLO) protection circuitry that monitors the supply voltage for  $V_{DD}$  and  $V_{BS}$  independently. It can be designed to prevent malfunction when  $V_{DD}$  and  $V_{BS}$  are lower than the specified threshold voltage. Also, the UVLO hysteresis prevents chattering during power-supply transitions. Moreover, the fault signal (FO) goes to LOW state to operate reliably during power-on events, when the power supply ( $V_{DD}$ ) is below the under-voltage lockout high threshold voltage for the circuit (during  $t_1 \sim t_2$ ). The UVLO circuit is not otherwise activated; shown Figure 38.

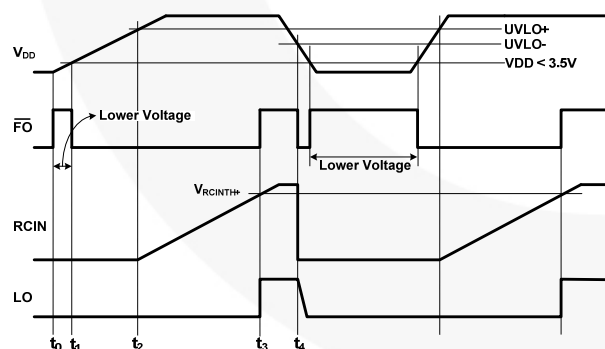
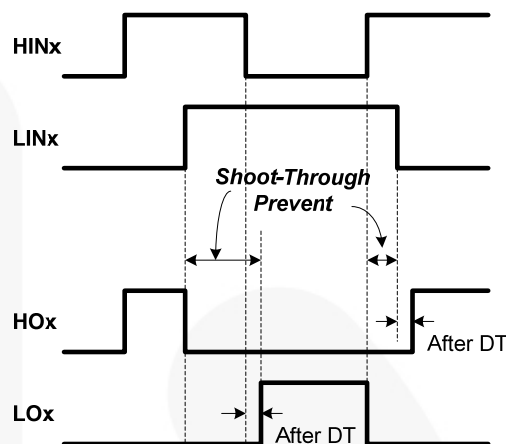


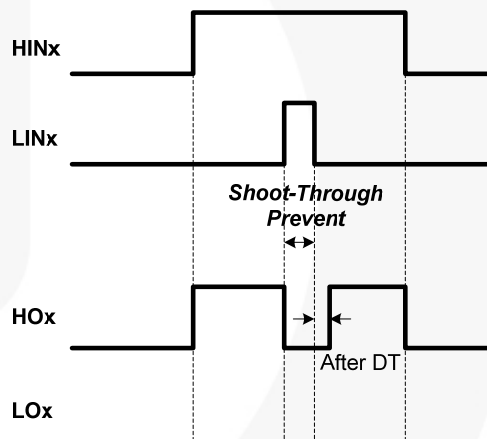
Figure 38. Waveforms for Under-Voltage Lockout

### 2.2 Shoot-Through Protection

The shoot-through protection circuitry prevents both high- and low-side switches from conducting at the same time, as shown Figure 39.



Example A



Example B

Figure 39. Shoot-Through Protection

### 2.3 Enable Input

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

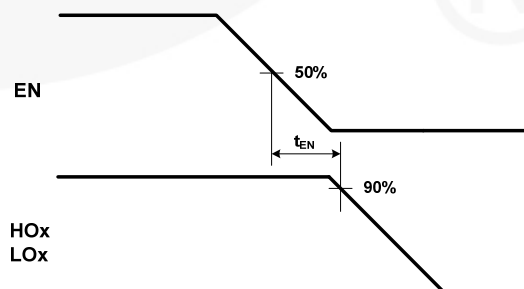


Figure 40. Output Enable Timing Waveform



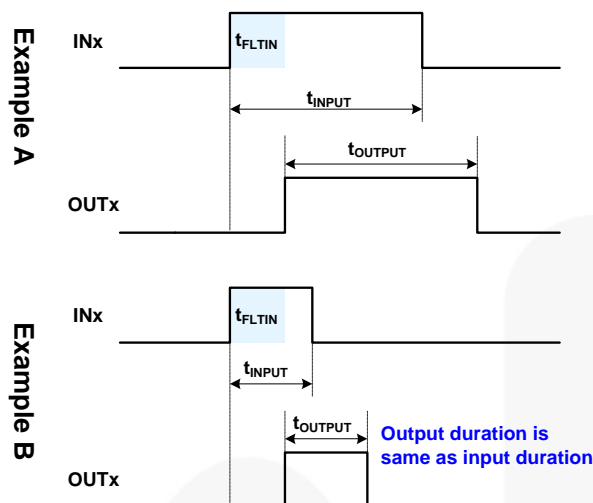


Figure 44. Input Noise Filter Definition

### 3.2. Short-Pulsed Input Noise Rejection Method

The input filter circuitry provides protection against short-pulsed input signals ( $H_{INx}$ ,  $L_{INx}$ , and  $EN$ ) 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 45 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.

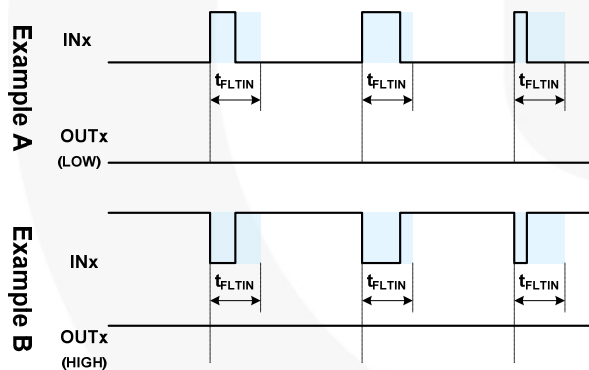


Figure 45. Noise Rejecting Input Filter Definition

Figure 46 shows the characteristics of the input filters while receiving narrow ON and OFF pulses. If input signal pulse duration,  $PW_{IN}$ , is less than input filter time,  $t_{FLTIN}$ ; the output pulse,  $PW_{OUT}$ , is zero. The input signal is rejected by input filter. Once the input signal pulse duration,  $PW_{IN}$ , exceeds input filter time,  $t_{FLTIN}$ , the output pulse durations,  $PW_{OUT}$ , matches the input pulse durations,  $PW_{IN}$ . FAN7389 input filter time,  $t_{FLTIN}$ , is about 250 ns for the high- and low-side outputs.

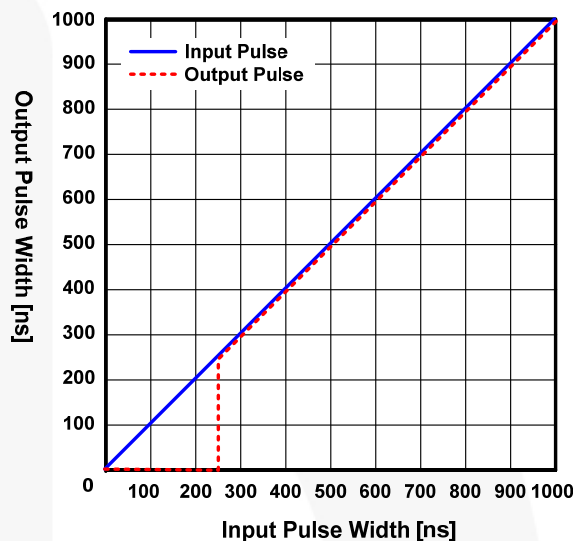


Figure 46. Input Filter Characteristic of Narrow ON







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