

# LF2388B

## 3-Phase Half Bridge Gate Driver

### Features

- Three floating high-side drivers in bootstrap operation to 600V
- 420mA source / 750mA sink output current capability
- Logic input 3.3V capability
- Internal deadtime of 315ns to protect MOSFETs
- Matched propagation delay time of 50ns maximum
- Outputs in phase with inputs
- Schmitt triggered logic inputs
- Cross conduction prevention logic
- Under Voltage Lockout (UVLO) for all channels
- Extended temperature range: -40°C to +125°C
- Space saving SOIC-20 package

### Applications

- 3-Phase Motor Inverter Driver
- White Goods - Air Conditioner, Washing Machine, Refrigerator
- Industrial Motor Inverter - Power Tools, Robotics
- General Purpose 3-Phase Inverter



SOIC-20

### Description

The LF2388B is a three-phase gate driver IC designed for high voltage three-phase applications, driving N-channel MOSFETs and IGBTs in a half-bridge configuration. The high voltage technology enables LF2388B high sides to switch to 600V in a bootstrap operation.

LF2388B logic inputs are compatible with standard TTL and CMOS levels (down to 3.3V) to interface easily with controlling devices. The driver outputs feature high pulse current buffers designed for minimum driver cross conduction.

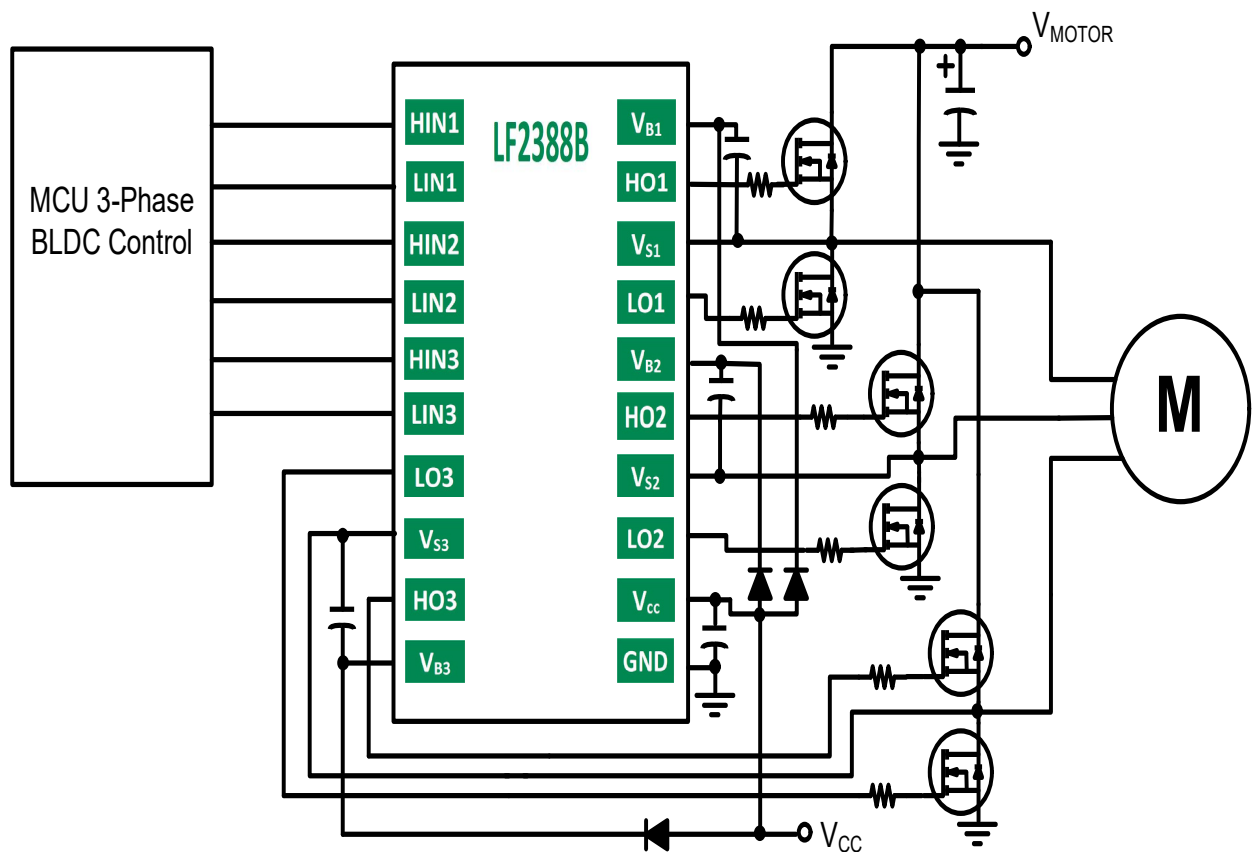
LF2388B offers numerous protection functions. A shoot-through protection logic prevents both outputs being high with both inputs high (fault state), an undervoltage lockout for  $V_{CC}$  shuts down all drivers through an internal fault control, and a UVLO for  $V_{BS}$  shuts down the respective high side output. LF2388B is offered in SOIC 20 package and operates over the extended temperature range of -40 °C to +125 °C .

### Ordering Information

| YearYear WeekWeek |         |            |                           |
|-------------------|---------|------------|---------------------------|
| Part#             | Package | Pack / Qty | Mark                      |
| LF2388BTR         | SOIC-20 | T&R / 1500 | YYWW<br>LF2388B<br>LOT ID |

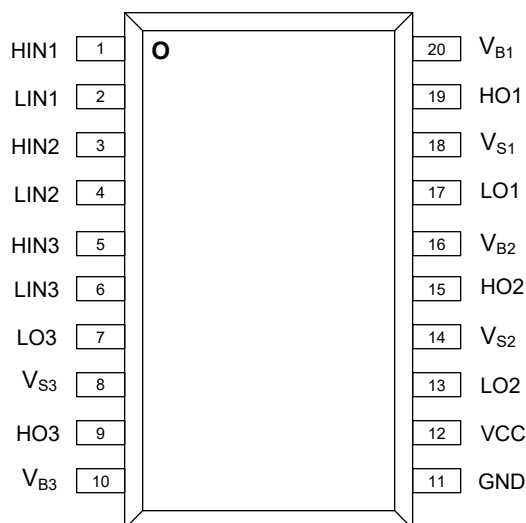


### Typical Application



## 1 Specifications

### 1.1 Pin Diagrams



**Top View: SOIC-20**

### 1.2 Pin Descriptions

| Pin#       | Pin Name                                            | Pin Type | Pin Description                                                 |
|------------|-----------------------------------------------------|----------|-----------------------------------------------------------------|
| 1, 3, 5    | HIN1, HIN2, HIN3                                    | Input    | Logic input for high-side gate driver output, in phase with HO. |
| 2, 4, 6    | LIN1, LIN2, LIN3                                    | Input    | Logic input for low-side gate driver output, in phase with LO.  |
| 7, 13, 17  | LO3, LO2, LO1                                       | Output   | Low-side gate driver output                                     |
| 8, 14, 18  | V <sub>S3</sub> , V <sub>S2</sub> , V <sub>S1</sub> | Power    | High-side floating supply return                                |
| 9, 15, 19  | HO3, HO2, HO1                                       | Output   | High-side gate driver output                                    |
| 10, 16, 20 | V <sub>B3</sub> , V <sub>B2</sub> , V <sub>B1</sub> | Power    | High-side floating supply                                       |
| 11         | GND                                                 | Power    | Low-side driver and logic return                                |
| 12         | V <sub>CC</sub>                                     | Power    | Low-side and logic fixed supply                                 |

### 1.3 Absolute Maximum Ratings

| Parameter                                | Symbol    | Min         | Max            | Unit |
|------------------------------------------|-----------|-------------|----------------|------|
| High side floating supply voltage        | $V_B$     | -0.3        | +624           | V    |
| High side floating supply offset voltage | $V_S$     | $V_B - 24$  | $V_B + 0.3$    | V    |
| High side floating output voltage        | $V_{HO}$  | $V_S - 0.3$ | $V_B + 0.3$    | V    |
| Low side output voltage                  | $V_{LO}$  | -0.3        | $V_{CC} + 0.3$ | V    |
| Offset supply voltage transient          | $dV_S/dt$ | --          | 50             | V/ns |
| Low side fixed supply voltage            | $V_{CC}$  | -0.3        | +24            | V    |
| Logic input voltage (HINx and LINx)      | $V_{IN}$  | -0.3        | 5.5            | V    |
| Package power dissipation                | $P_D$     | --          | 1.47           | W    |
| Junction Operating Temperature           | $T_J$     | --          | +150           | °C   |
| Storage Temperature                      | $T_{STG}$ | -55         | +150           | °C   |

Unless otherwise specified all voltages are referenced to GND. All electrical ratings are at  $T_A = 25^\circ\text{C}$

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### 1.4 Thermal Characteristics

| Parameter           | Symbol        | Rating | Unit |
|---------------------|---------------|--------|------|
| Junction to ambient | $\theta_{JA}$ | 85     | °C/W |

When mounted on a standard JEDEC 2-layer FR-4 board - JESD51-3

### 1.5 Recommended Operating Conditions

| Parameter                                  | Symbol   | Min          | Max        | Unit |
|--------------------------------------------|----------|--------------|------------|------|
| High side floating supply absolute voltage | $V_B$    | $V_S + 10$   | $V_S + 20$ | V    |
| High side floating supply offset voltage   | $V_S$    | <b>NOTE1</b> | 600        | V    |
| High side floating output voltage          | $V_{HO}$ | $V_S$        | $V_B$      | V    |
| Low side fixed supply voltage              | $V_{CC}$ | 10           | 20         | V    |
| Low side output voltage                    | $V_{LO}$ | 0            | $V_{CC}$   | V    |
| Logic input voltage (HINx and LINx)        | $V_{IN}$ | 0            | 5          | V    |
| Ambient temperature                        | $T_A$    | -40          | 125        | °C   |

Unless otherwise specified all voltages are referenced to GND

**NOTE1** High-side driver remains operational for  $V_S$  transients down to -5V

### 1.6 DC Electrical Characteristics

$V_{CC}=V_{BS}=15V$ ,  $T_A = 25\text{ }^{\circ}\text{C}$  and  $V_{GND} = 0V$ , unless otherwise specified.

The  $V_{IN}$  and  $I_{IN}$  parameters are referenced to GND and are applicable to all six channels (HIN1,2,3 and LIN1,2,3). The  $V_O$  and  $I_O$  parameters are applicable to the outputs (HO1,2,3 and LO1,2,3 and are referenced to GND).

| Parameter                                              | Symbol        | Conditions                          | Min | Typ  | Max | Unit      |
|--------------------------------------------------------|---------------|-------------------------------------|-----|------|-----|-----------|
| Logic "1" input voltage                                | $V_{IH}$      | <b>NOTE2</b>                        | 2.4 | --   | --  | V         |
| Logic "0" input voltage                                | $V_{IL}$      |                                     | --  | --   | 0.8 |           |
| Logic input voltage hysteresis                         | $V_{IN(HYS)}$ | --                                  | --  | 0.9  | --  |           |
| High level output voltage, $V_{BIAS} - V_O$            | $V_{OH}$      | $I_O = 2mA$                         | --  | 0.2  | 0.5 |           |
| Low level output voltage, $V_O$                        | $V_{OL}$      | $I_O = 2mA$                         | --  | 0.07 | 0.2 |           |
| Offset supply leakage current                          | $I_{LK}$      | $V_B = V_S = 600V$                  | --  | --   | 10  | $\mu A$   |
| Quiescent $V_{BS}$ supply current                      | $I_{BSQ}$     | $V_{IN} = 0V$ or $5V$               | --  | 50   | 80  |           |
| Operating $V_{BS}$ supply current                      | $I_{BSO}$     | $f_s = 20kHz$                       | --  | 400  | --  |           |
| Quiescent $V_{CC}$ supply current                      | $I_{CCQ}$     | $V_{IN} = 0V$ or $5V$               | --  | 230  | 330 |           |
| Operating $V_{CC}$ supply current                      | $I_{CCO}$     | $f_s = 20kHz$                       | --  | 500  | --  |           |
| Logic "1" input bias current                           | $I_{IN+}$     | $V_{IN} = 5V$                       | --  | 25   | 80  |           |
| Logic "0" input bias current                           | $I_{IN-}$     | $V_{IN} = 0V$                       | --  | --   | 2   | $k\Omega$ |
| Input pull-down resistance                             | $R_{IN}$      | --                                  | --  | 200  | --  |           |
| $V_{CC}, V_{BS}$ UVLO off, positive going threshold    | $V_{UV+}$     | --                                  | 7.1 | 8.5  | 9.9 | V         |
| $V_{CC}, V_{BS}$ UVLO enable, negative going threshold | $V_{UV-}$     | --                                  | 6.7 | 8.1  | 9.5 |           |
| UVLO hysteresis                                        | $V_{UV(HYS)}$ | --                                  | --  | 0.4  | --  |           |
| Output high, short circuit pulsed current              | $I_{O+}$      | $V_O = 0V, t \leq 10\text{ }\mu s$  | 270 | 420  | --  | mA        |
| Output low, short circuit pulsed current               | $I_{O-}$      | $V_O = 15V, t \leq 10\text{ }\mu s$ | 600 | 750  | --  |           |

**NOTE2** For optimal operation, it is recommended the input pulse (to HINx and LINx) MUST have a minimum amplitude of 2.4V with a minimum pulse width of 600ns.

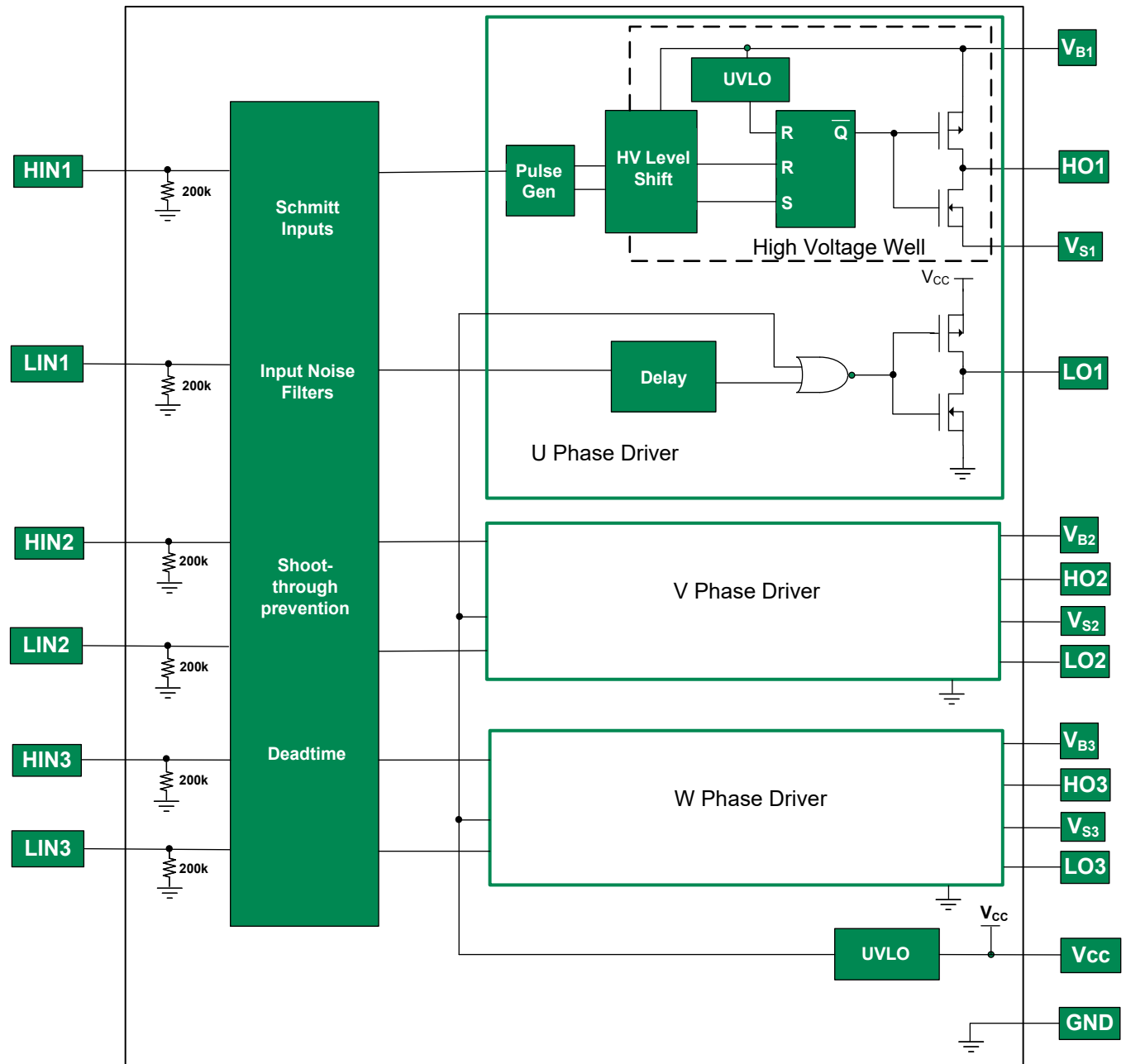
### 1.7 AC Electrical Characteristics

$V_{CC}=V_{BS} = 15V$ ,  $C_L = 1000pF$ , and  $T_A = 25\text{ }^{\circ}C$ , unless otherwise specified.

| Parameter                  | Symbol    | Conditions | Min | Typ | Max | Unit |
|----------------------------|-----------|------------|-----|-----|-----|------|
| Turn-on propagation delay  | $t_{on}$  | $V_s = 0V$ | 70  | 120 | 170 | ns   |
| Turn-off propagation delay | $t_{off}$ | $V_s = 0V$ | 70  | 120 | 170 |      |
| Turn-on rise time          | $t_r$     | $V_s = 0V$ | --  | 45  | 75  |      |
| Turn-off fall time         | $t_f$     |            | --  | 25  | 40  |      |
| Propagation delay matching | $t_{DM}$  | --         | --  | --  | 50  |      |
| Deadtime                   | $t_{DT}$  | --         | 200 | 315 | 430 |      |
| Deadtime matching          | $t_{DTM}$ | --         | --  | --  | 50  |      |

## 2 Functional Description

### 2.1 Functional Block Diagram

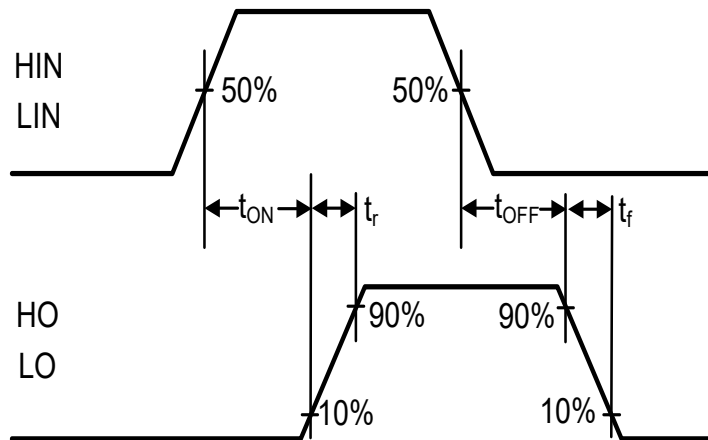


## 2.2 Timing Waveforms

# LF2388B

## 3-Phase Half Bridge Gate Driver

**Figure 1. Input-to-Output Delay Timing**

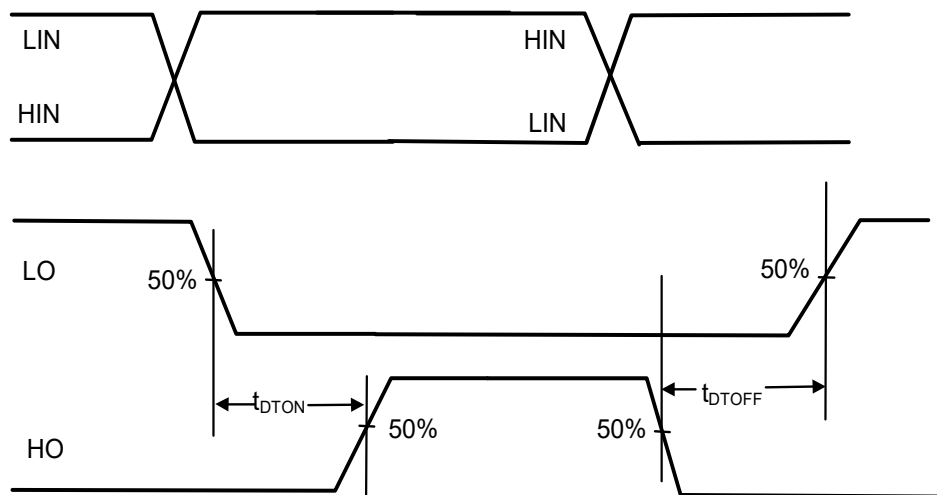


Delay Matching :

$$t_{DM\ OFF} = |t_{OFF\ LO} - t_{OFF\ HO}|$$

$$t_{DM\ ON} = |t_{ON\ LO} - t_{ON\ HO}|$$

**Figure 2. Deadtime Waveform Diagram**



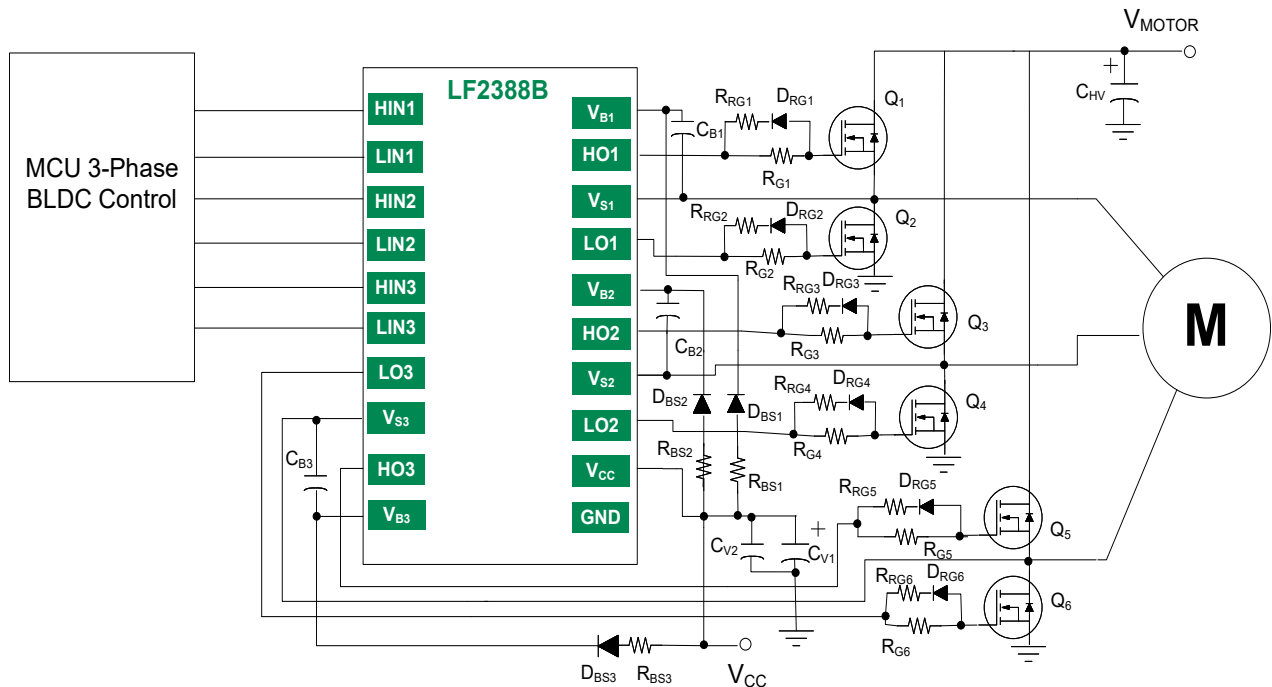
Deadtime :

$$t_{DT\ LO-HO} = t_{ON\ HO} - t_{OFF\ LO}$$

$$t_{DT\ HO-LO} = t_{ON\ LO} - t_{OFF\ HO}$$

$$\text{Deadtime Matching : } t_{DT\ MT} = |t_{DT\ LO-HO} - t_{DT\ HO-LO}|$$

### 2.3 Application Information



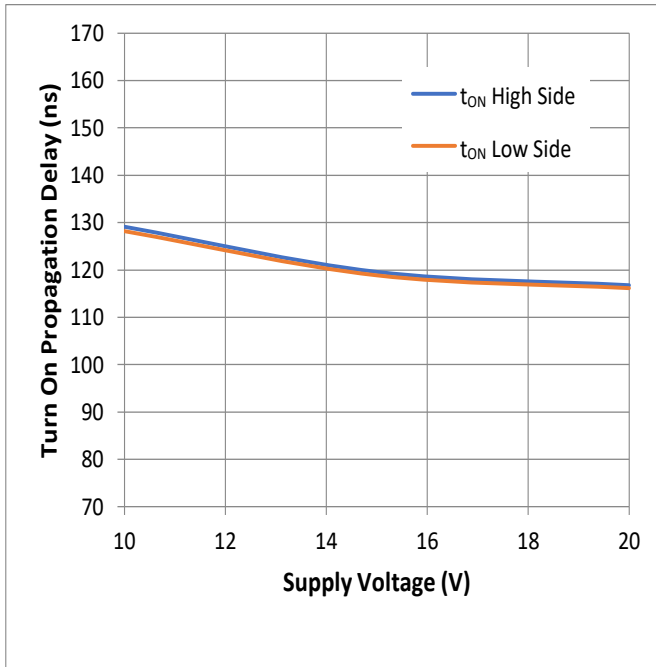
**Figure 3.** LF2388B in a 3 phase motor drive application.

- RRG1 - RRG6 values are typically between 0Ω and 10Ω, exact value decided by MOSFET junction capacitance and drive current of gate driver; 10Ω is used in this example.
- It is **highly recommended** that the input pulse (to HINx and LINx) should have a minimum amplitude of 2.4V and a minimum pulse width of 600ns.
- RG1 - RG6 values are typically between 20Ω and 100Ω, exact value decided by MOSFET junction capacitance and drive current of gate driver; 50Ω is used in this example.
- RBS1 - RBS3 values are typically between 3Ω and 20Ω, exact value depending on bootstrap capacitor value and amount of current limiting required for bootstrap capacitor charging; 10Ω is used in this example. Also DBS1 - DBS3 should be an ultra fast diode of 1A rating minimum and voltage rating greater than system operating voltage.

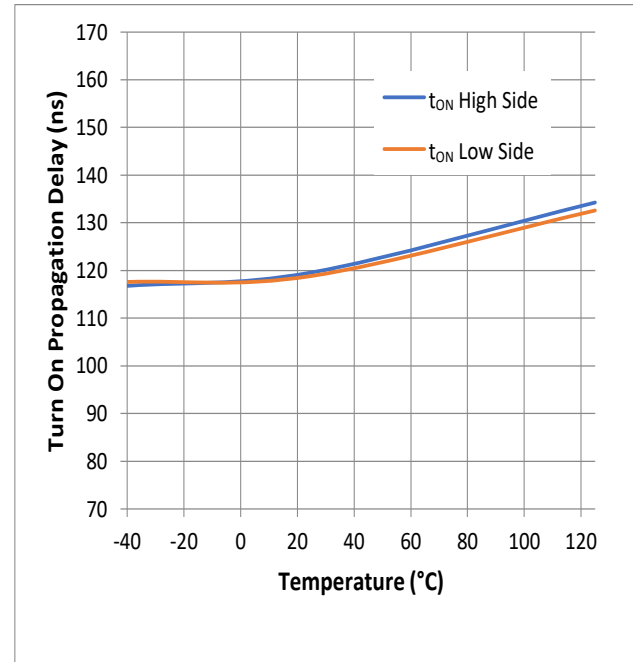
### 3 Performance Data

Unless otherwise noted  $V_{CC} = V_{BS} = 15V$ ,  $T_A = 25^\circ C$ ,  $V_{GND} = 0V$  and values are typical.

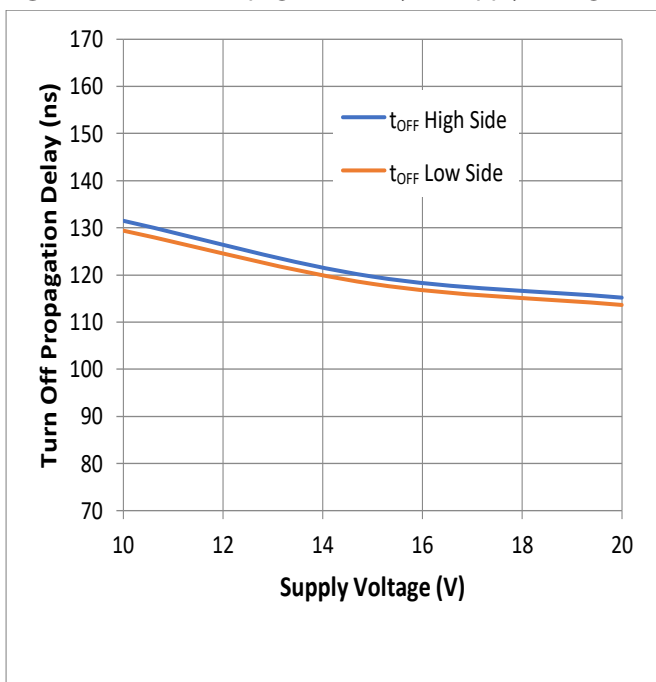
**Figure 4.** Turn On Propagation delay vs Supply Voltage



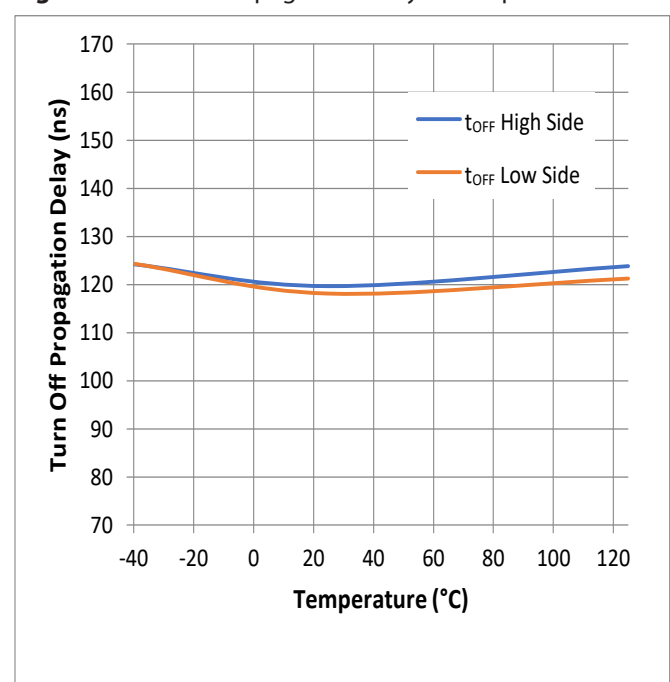
**Figure 5.** Turn On Propagation delay vs Temperature



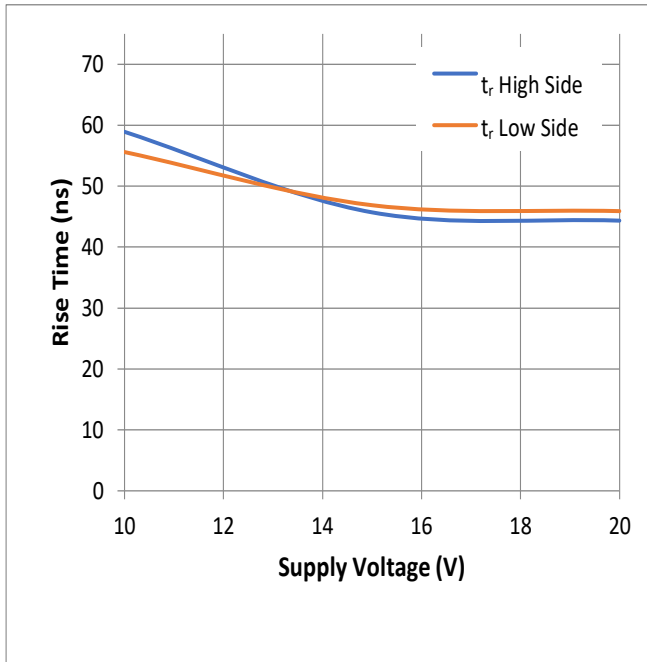
**Figure 6.** Turn Off Propagation delay vs Supply Voltage



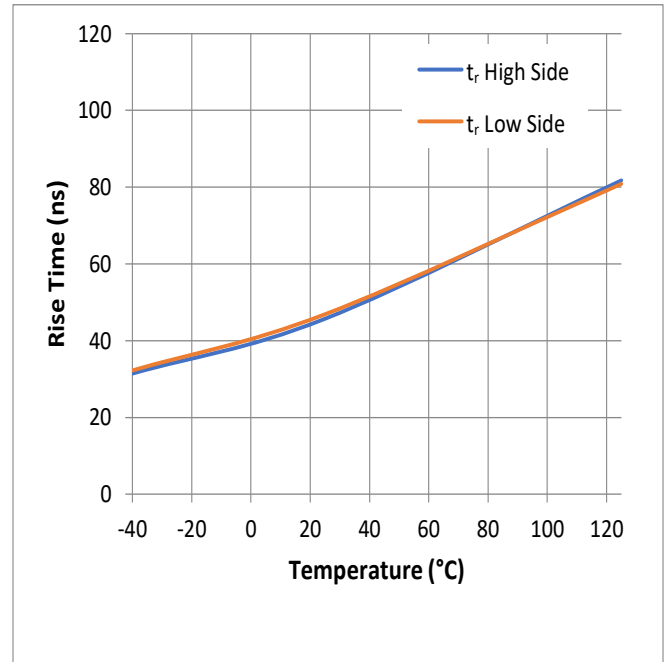
**Figure 7.** Turn Off Propagation delay vs Temperature



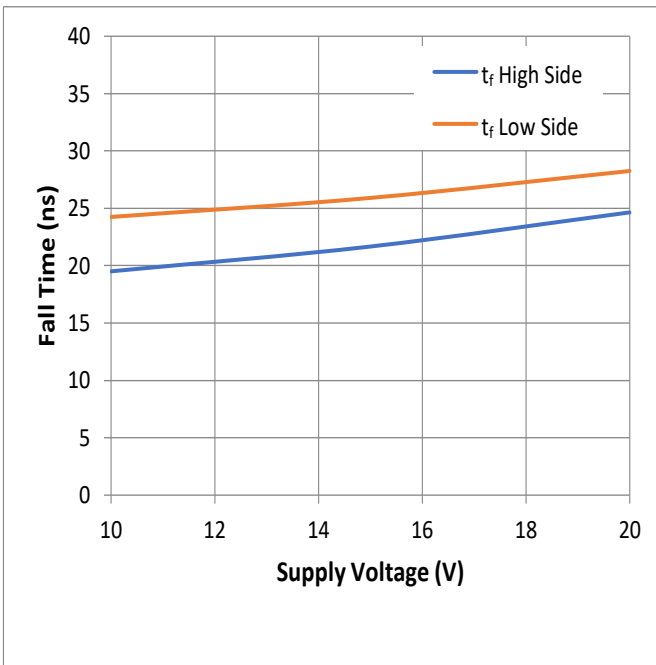
**Figure 8.** Rise time vs Supply voltage



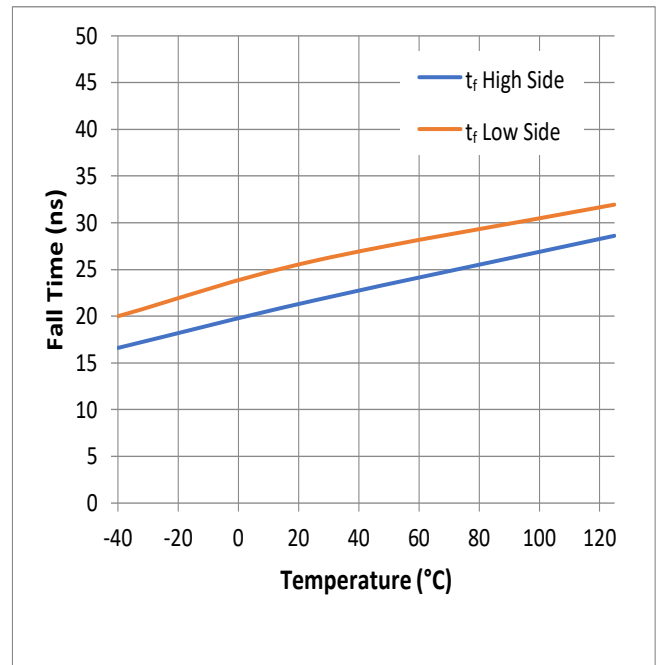
**Figure 9.** Rise time vs Temperature



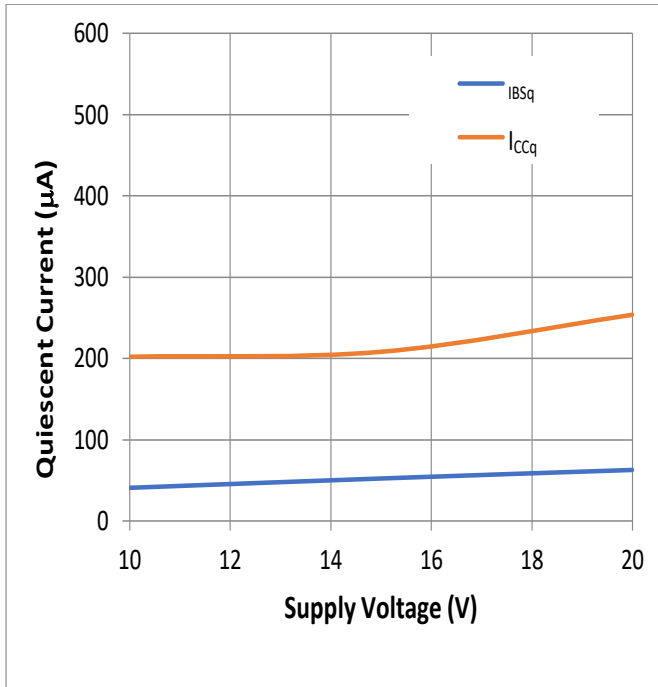
**Figure 10.** Fall time vs Supply voltage



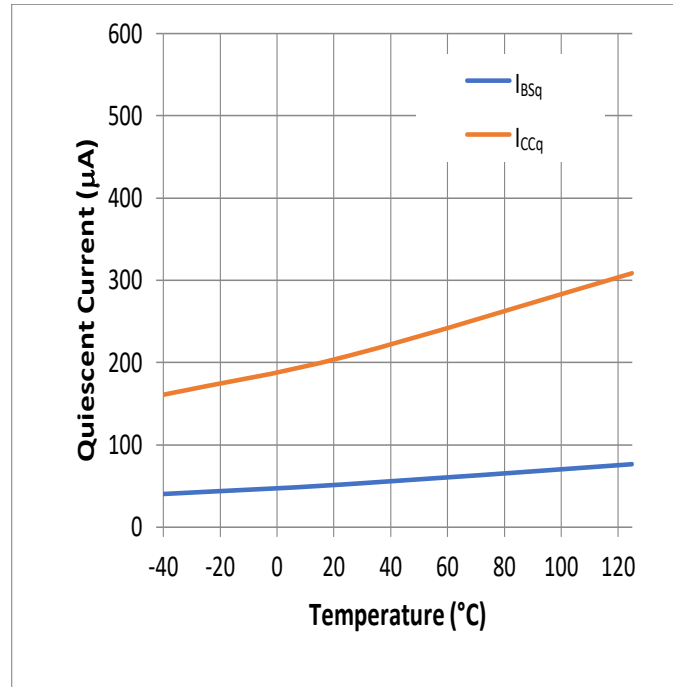
**Figure 11.** Fall time vs Temperature



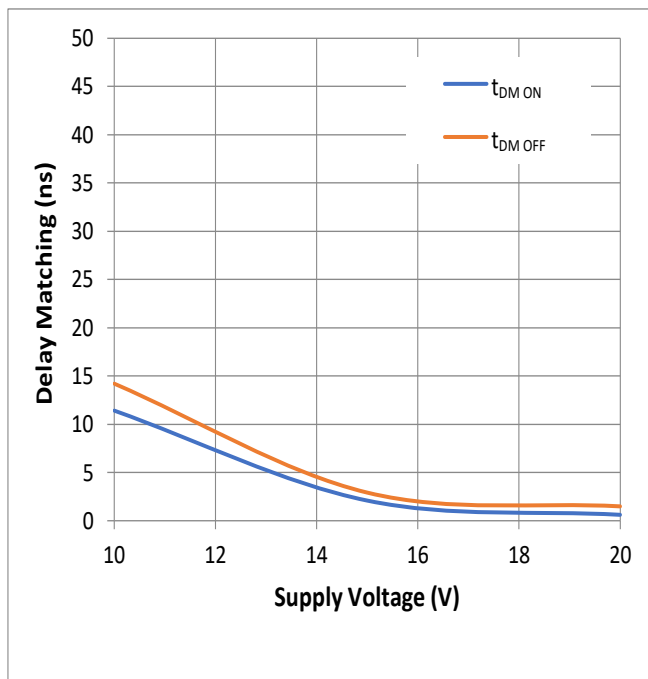
**Figure 12.** Quiescent current vs Supply voltage



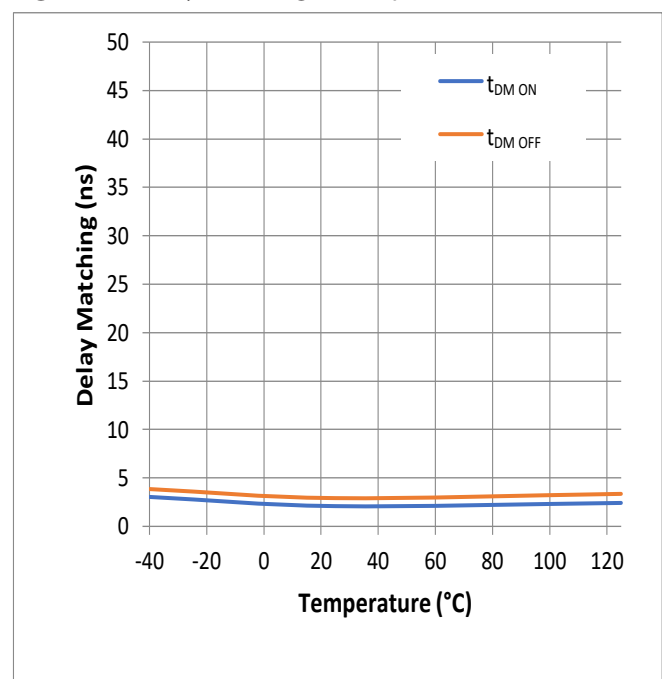
**Figure 13.** Quiescent current vs Temperature



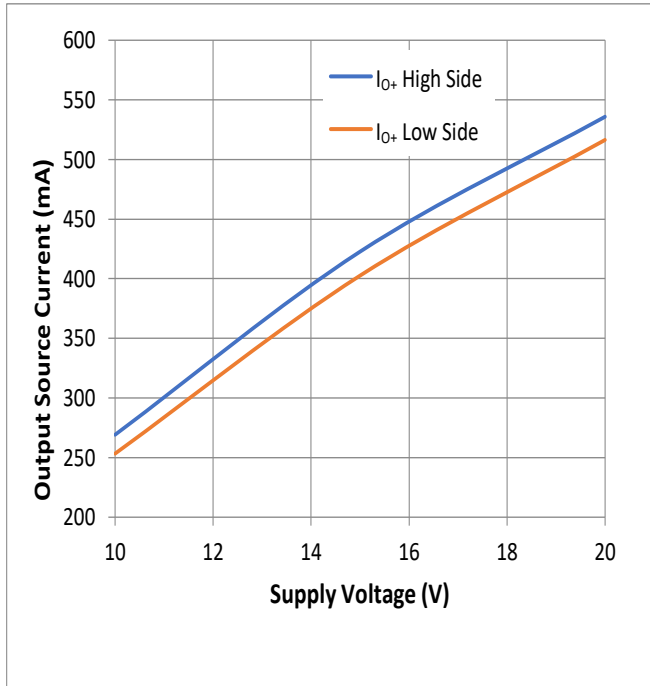
**Figure 14.** Delay Matching vs Supply voltage



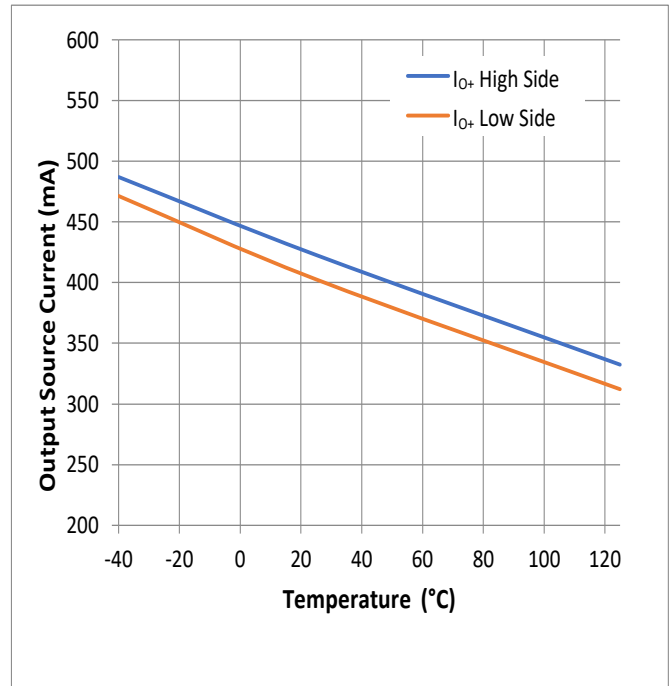
**Figure 15.** Delay Matching vs Temperature



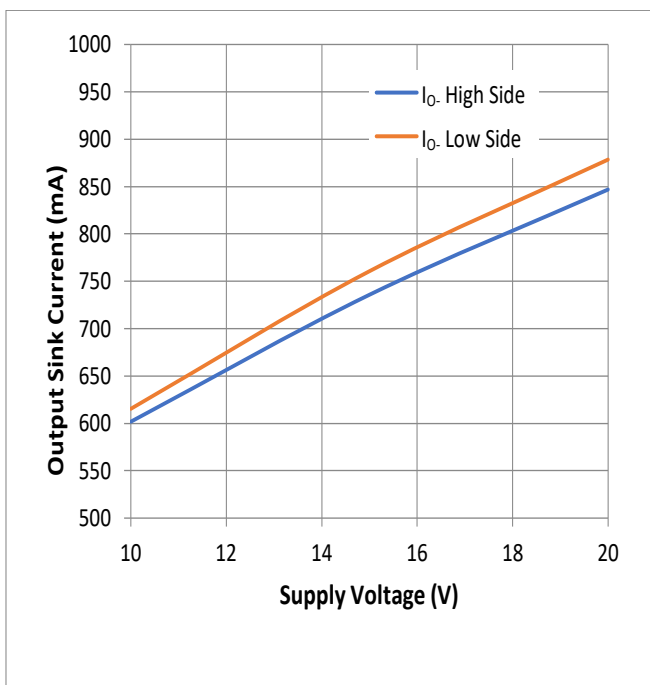
**Figure 16.**Source Current vs Supply voltage



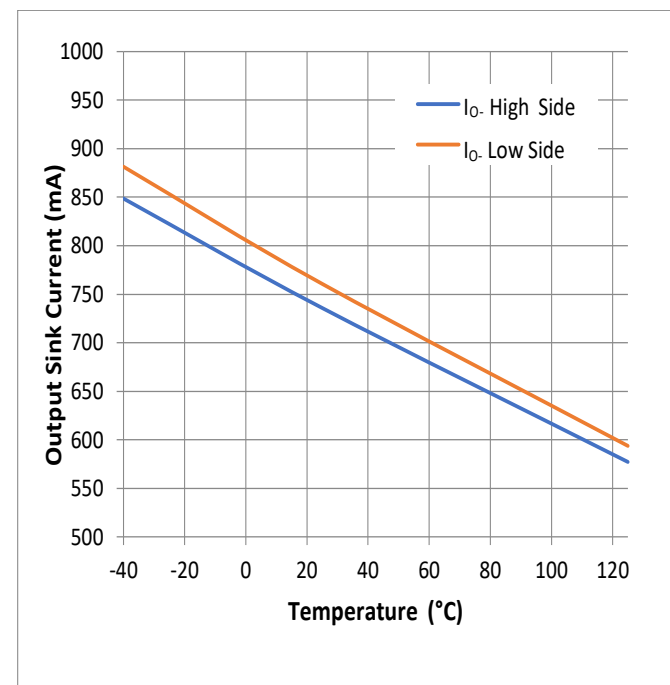
**Figure 17.**Source Current vs Temperature



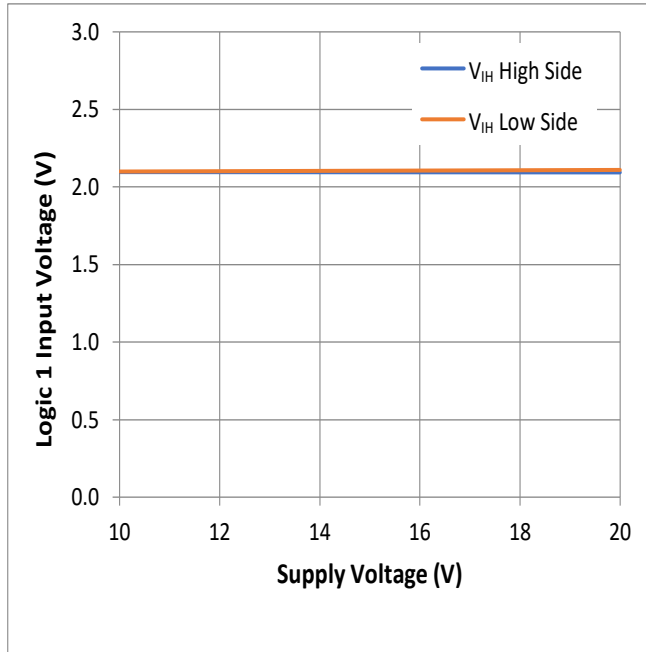
**Figure 18.**Sink Current vs Supply voltage



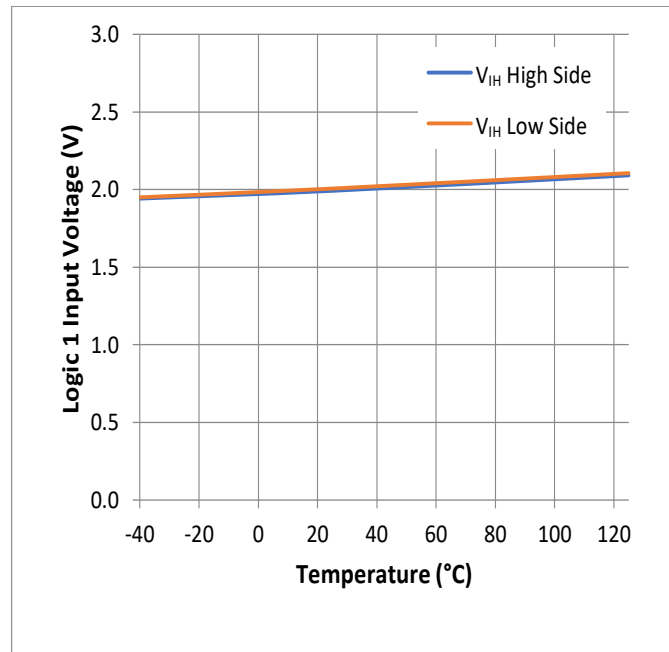
**Figure 19.**Sink Current vs Temperature



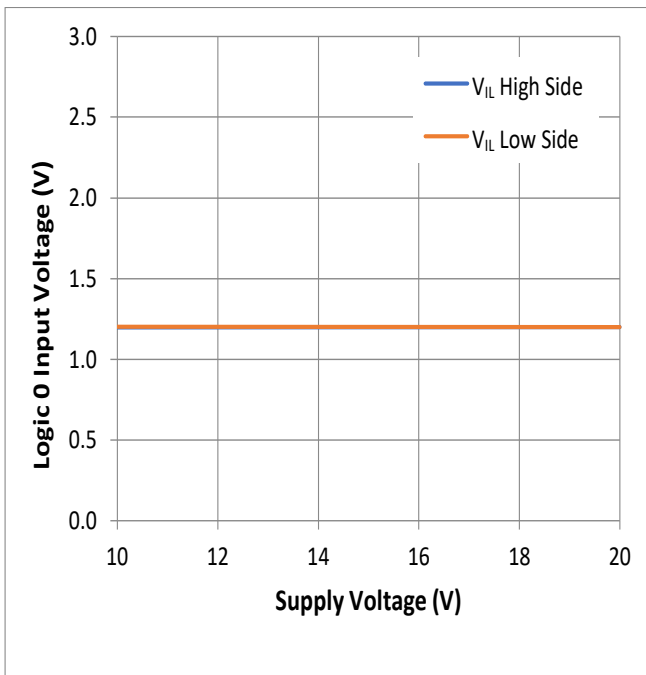
**Figure 20** Logic 1 Input Voltage vs Supply voltage



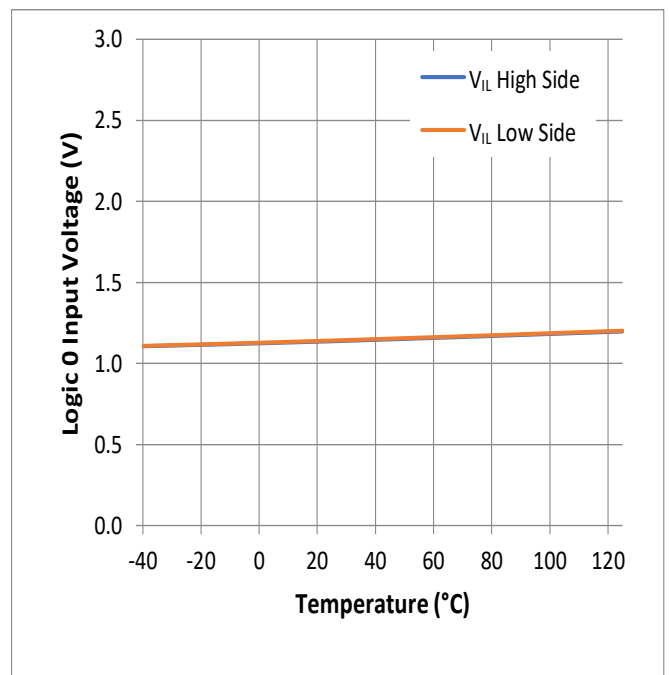
**Figure 21.** Logic 1 Input Voltage vs Temperature



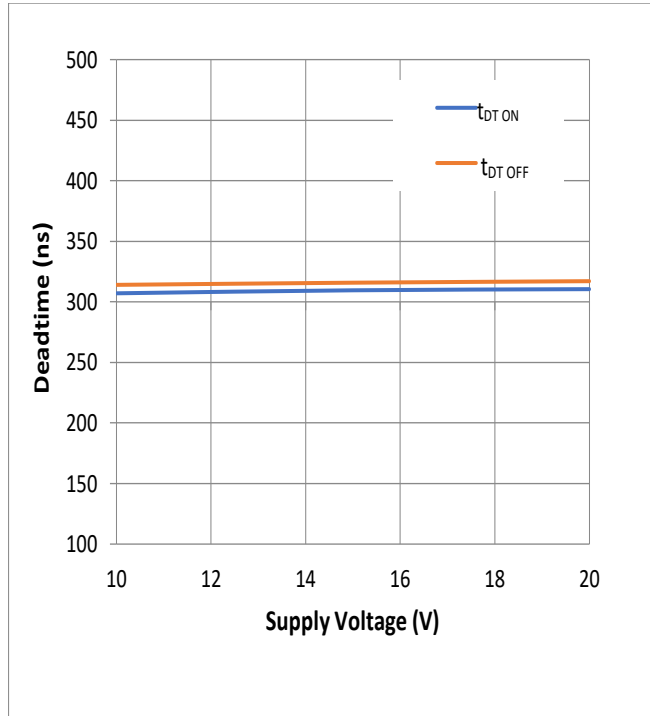
**Figure 22.** Logic 0 Input Voltage vs Supply voltage



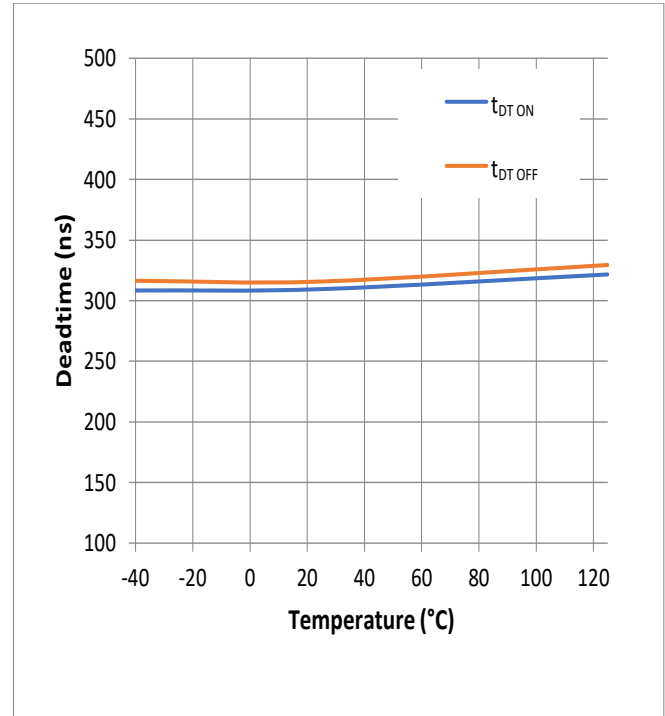
**Figure 23.** Logic 0 Input Voltage vs Supply voltage



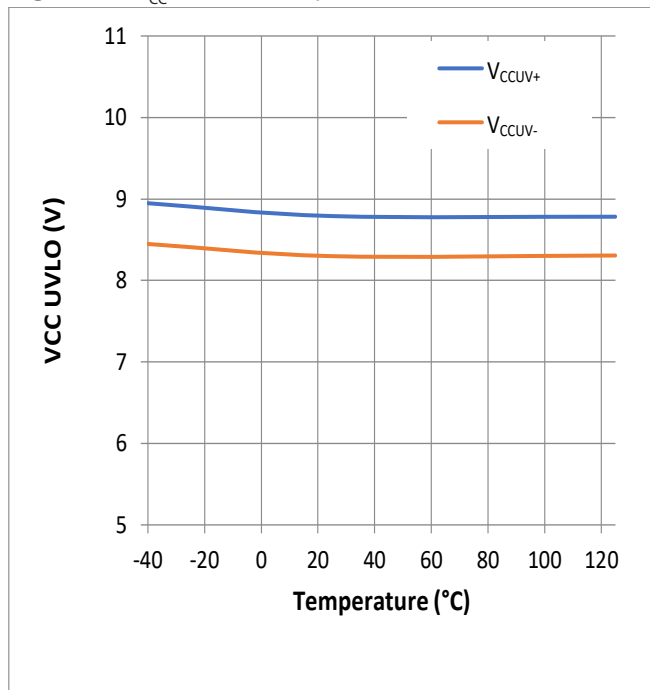
**Figure 24.** Deadtime vs Supply voltage



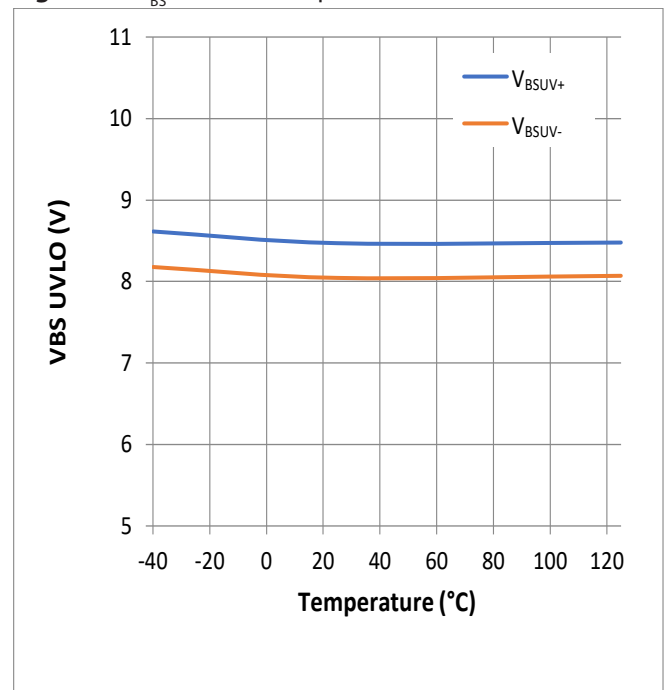
**Figure 25.** Deadtime vs Temperature



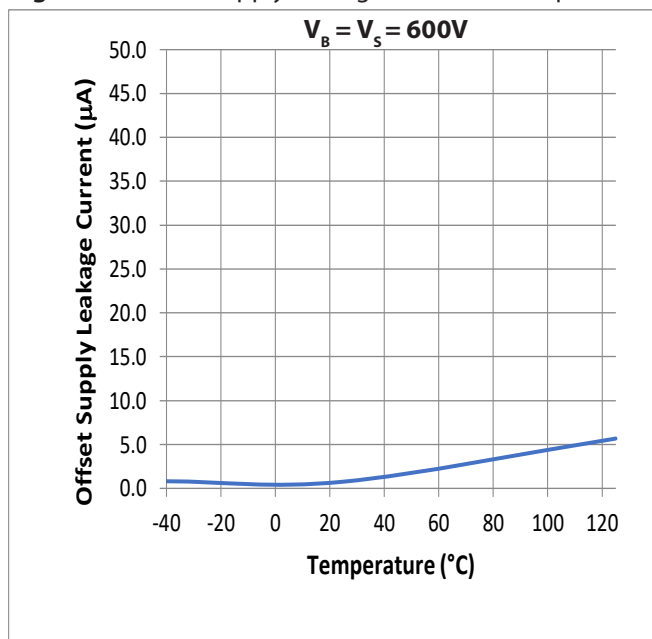
**Figure 26.**  $V_{CC}$  UVLO vs Temperature



**Figure 27.**  $V_{BS}$  UVLO vs Temperature



**Figure 28.** Offset Supply Leakage Current vs Temperature



### 4 Manufacturing Information

#### 4.1 Moisture Sensitivity



All plastic encapsulated semiconductor packages are susceptible to moisture ingress. Littelfuse Integrated Circuits Division classified all of its plastic encapsulated devices for moisture sensitivity according to the latest version of the joint industry standard, **IPC/JEDEC J-STD-020**, in force at the time of product evaluation. We test all of our products to the maximum conditions set forth in the standard, and guarantee proper operation of our devices when handled according to the limitations and information in that standard as well as to any limitations set forth in the information or standards referenced below.

Failure to adhere to the warnings or limitations as established by the listed specifications could result in reduced product performance, reduction of operable life, and/or reduction of overall reliability.

This product carries a **Moisture Sensitivity Level (MSL)** rating as shown below, and should be handled according to the requirements of the latest version of the joint industry standard **IPC/JEDEC J-STD-033**.

| Device  | Moisture Sensitivity Level (MSL) Classification |
|---------|-------------------------------------------------|
| LF2388B | MSL3                                            |

#### 4.2 ESD Sensitivity



This product is **ESD Sensitive**, and should be handled according to the industry standard **JESD-625**.

#### 4.3 Reflow Profile

Provided in the table below is the IPC/JEDEC J-STD-020 Classification Temperature ( $T_c$ ) and the maximum dwell time the body temperature of these surface mount devices may be ( $T_c - 5$ )°C or greater. The Classification Temperature sets the Maximum Body Temperature allowed for these devices during reflow soldering processes.

| Device  | Classification Temperature( $T_c$ ) | Dwell Time ( $t_p$ ) | Max Reflow Cycles |
|---------|-------------------------------------|----------------------|-------------------|
| LF2388B | 260°C                               | 30 seconds           | 3                 |

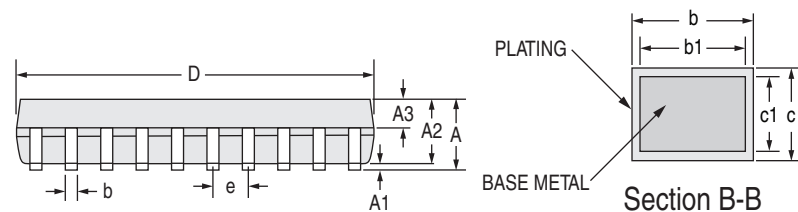
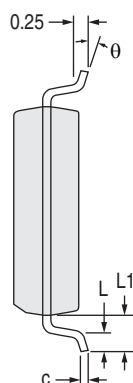
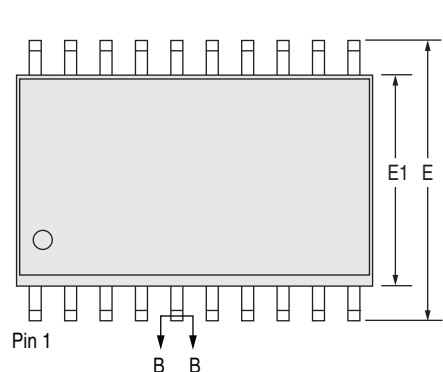


## 4.4 Board Wash

Littelfuse recommends the use of no-clean flux formulations. Board washing to reduce or remove flux residue following the solder reflow process is acceptable provided proper precautions are taken to prevent damage to the device. These precautions include but are not limited to: using a low pressure wash and providing a follow up bake cycle sufficient to remove any moisture trapped within the device due to the washing process. Due to the variability of the wash parameters used to clean the board, determination of the bake temperature and duration necessary to remove the moisture trapped within the package is the responsibility of the user (assembler). Cleaning or drying methods that employ ultrasonic energy may damage the device and should not be used. Additionally, the device must not be exposed to halide flux or solvents.

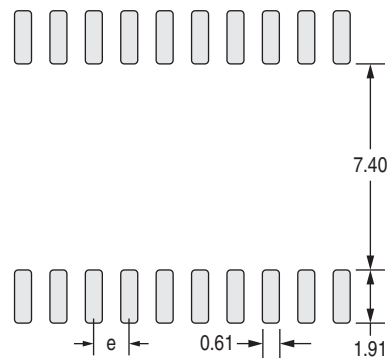


### 5 Package Dimensions: SOIC-20



| SYMBOL   | MILLIMETER |       |       |
|----------|------------|-------|-------|
|          | MIN        | NOM   | MAX   |
| A        | -          | -     | 2.65  |
| A1       | 0.10       | -     | 0.30  |
| A2       | 2.25       | 2.30  | 2.35  |
| A3       | 0.97       | 1.02  | 1.07  |
| b        | 0.35       | -     | 0.43  |
| b1       | 0.34       | 0.37  | 0.40  |
| c        | 0.25       | -     | 0.29  |
| c1       | 0.24       | 0.25  | 0.26  |
| D        | 12.70      | 12.80 | 12.90 |
| E        | 10.10      | 10.30 | 10.50 |
| E1       | 7.40       | 7.50  | 7.60  |
| e        | 1.27 BSC   |       |       |
| L        | 0.70       | -     | 1.00  |
| L1       | 1.40 REF   |       |       |
| $\theta$ | 0°         | -     | 8°    |

#### PCB Land Pattern



### Important Notice

Disclaimer Notice - Information furnished is believed to be accurate and reliable. However, users should independently evaluate the suitability of and test each product selected for their own applications. Littelfuse products are not designed for, and may not be used in, all applications. Read complete Disclaimer Notice at <https://www.littelfuse.com/disclaimer-electronics>.

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