



# TF2106M

## High-Side and Low-Side Gate Driver

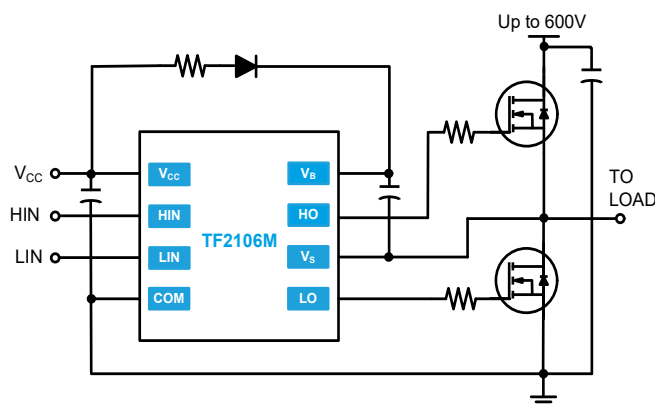
### Features

- Floating high-side driver in bootstrap operation to 600V
- Drives two N-channel MOSFETs or IGBTs in high-side/low-side configuration
- Outputs tolerant to negative transients
- Wide low-side gate driver and logic supply: 10V to 20V
- Logic inputs CMOS and TTL compatible (down to 3.3V)
- Schmitt triggered logic inputs with internal pull down
- Undervoltage lockout for high-side and low-side drivers
- Space-saving SOIC-8 package available
- Extended temperature range: -40°C to +125°C

### Applications

- DC-DC Converters
- AC-DC Inverters
- Motor Controls
- Class D Power Amplifiers

### Typical Application



### Description

The TF2106M is a high voltage, high speed gate driver capable of driving N-channel MOSFETs and IGBTs in a high-side/low-side configuration. TF Semiconductor's high voltage process enables the TF2106M's high-side to switch to 600V in a bootstrap operation. The 50ns (max) propagation delay matching between the high and the low side drivers allows high frequency switching.

The TF2106M logic inputs are compatible with standard TTL and CMOS levels (down to 3.3V) for easy interfacing with controlling devices. The driver outputs feature high pulse current buffers designed for minimum driver cross conduction. The low-side gate driver and logic share a common ground

The TF2106M is available in a space-saving 8-pin SOIC package and a 8-pin PDIP: the operating temperature extends from -40°C to +125°C .



SOIC-8(N)

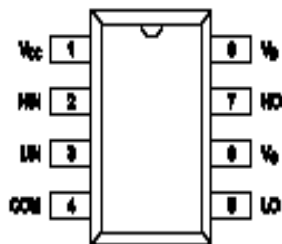


PDIP-8

### Ordering Information

Year Year Week Week

PART NUMBER	PACKAGE	PACK / Qty	MARK
TF2106M-TAU	SOIC-8(N)	Tube / 100	YYWW TF2106M Lot ID
TF2106M-TAH	SOIC-8(N)	T & R/ 2500	YYWW TF2106M Lot ID
TF2106M-3AS	PDIP-8	Tube / 50	YYWW TF2106M Lot ID



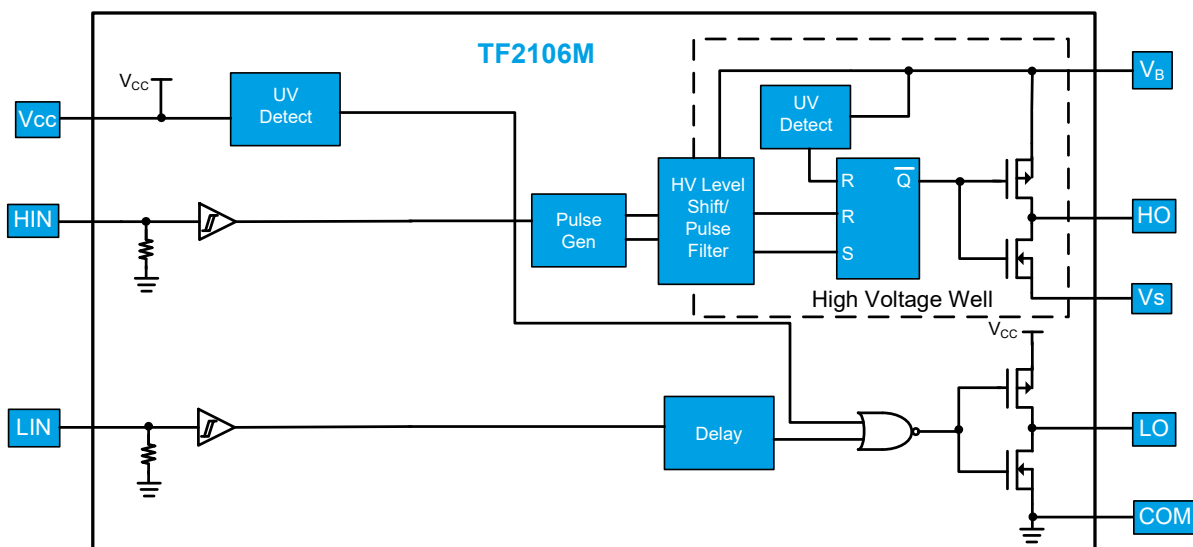
Top View: PDIP-8, SOIC-8

TF2106M

## Pin Descriptions

PIN NAME	PIN DESCRIPTION
HIN	Logic input for high-side gate driver output (HO), in phase
LIN	Logic input for low-side gate driver output (LO), in phase
V <sub>B</sub>	High-side floating supply
HO	High-side gate drive output
V <sub>S</sub>	High-side floating supply return
V <sub>CC</sub>	Low-side and logic fixed supply
LO	Low-side gate drive output
COM	Low-side return
NC	"No connect" pin

## Functional Block Diagram



## Absolute Maximum Ratings (NOTE1)

$V_B$  - High side floating supply voltage.....-0.3V to +624V  
 $V_S$  - High side floating supply offset voltage.... $V_B$ -24V to  $V_B$ +0.3V  
 $V_{HO}$  - High side floating output voltage..... $V_S$ -0.3V to  $V_B$ +0.3V  
 $dV_S/dt$  - Offset supply voltage transient.....50 V/ns

$V_{CC}$  - Low side and logic fixed supply voltage.....-0.3V to +24V  
 $V_{LO}$  - Low side output voltage.....-0.3V to  $V_{CC}$ +0.3V  
 $V_{IN}$  - Logic input voltage (HIN and LIN)... -0.3V to  $V_{CC}$ +0.3V

**NOTE1** 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.

$P_D$  - Package power dissipation at  $T_A \leq 25^\circ\text{C}$   
 SOIC-8.....0.625W  
 PDIP-8.....1.0W

### SOIC-8 Thermal Resistance (NOTE2)

$\theta_{JC}$ .....45  $^\circ\text{C/W}$   
 $\theta_{JA}$ .....200  $^\circ\text{C/W}$

### PDIP-8 Thermal Resistance (NOTE2)

$\theta_{JC}$ .....35  $^\circ\text{C/W}$   
 $\theta_{JA}$ .....125  $^\circ\text{C/W}$

$T_J$  - Junction operating temperature .....+150  $^\circ\text{C}$   
 $T_L$  - Lead temperature (soldering, 10s) ..... +300  $^\circ\text{C}$   
 $T_{stg}$  - Storage temperature range .....-55  $^\circ\text{C}$  to +150  $^\circ\text{C}$

**NOTE2** When mounted on a standard JEDEC 2-layer FR-4 board.

## Recommended Operating Conditions

Symbol	Parameter	MIN	TYP	MAX	Unit
$V_B$	High side floating supply absolute voltage	$V_S + 10$		$V_S + 20$	V
$V_S$	High side floating supply offset voltage	<b>NOTE3</b>		600	V
$V_{HO}$	High side floating output voltage	$V_S$		$V_B$	V
$V_{CC}$	Low side and logic fixed supply voltage	10		20	V
$V_{LO}$	Low side output voltage	0		$V_{CC}$	V
$V_{IN}$	Logic input voltage (HIN and LIN)	0		5	V
$T_A$	Ambient temperature	-40		125	$^\circ\text{C}$

**NOTE3** Logic operational for  $V_S = -5$  to +600V.

## DC Electrical Characteristics (NOTE4)

$V_{BIAS} (V_{CC}, V_{BS}) = 15V, T_A = 25^\circ C$ , unless otherwise specified.

Symbol	Parameter	Conditions	MIN	TYP	MAX	Unit
$V_{IH}$	Logic "1" input voltage	$V_{CC} = 10V \text{ to } 20V$ <b>(NOTE5)</b>	2.5			V
$V_{IL}$	Logic "0" input voltage				0.6	V
$V_{OH}$	High level output voltage, $V_{BIAS} - V_O$	$I_O = 2mA$		0.05	0.2	V
$V_{OL}$	Low level output voltage, $V_O$	$I_O = 2mA$		0.02	0.1	V
$I_{LK}$	Offset supply leakage current	$V_B = V_S = 600V$			50	$\mu A$
$I_{BSQ}$	Quiescent $V_{BS}$ supply current	$V_{IN} = 0V \text{ or } 5V$	20	75	130	$\mu A$
$I_{CCQ}$	Quiescent $V_{CC}$ supply current	$V_{IN} = 0V \text{ or } 5V$	60	120	180	$\mu A$
$I_{IN+}$	Logic "1" input bias current	$V_{IN} = 5V$		5	20	$\mu A$
$I_{IN-}$	Logic "0" input bias current	$V_{IN} = 0V$			2	$\mu A$
$V_{CCUV+}$	$V_{CC}$ supply under-voltage positive going threshold		7	8.4	9.8	V
$V_{CCUV-}$	$V_{CC}$ supply under-voltage negative going threshold		6.4	7.8	9	V
$V_{BSUV+}$	$V_{BS}$ supply under-voltage positive going threshold		7.0	8.4	9.8	V
$V_{BSUV-}$	$V_{CC}$ supply under-voltage negative going threshold		6.4	7.8	9	V
$V_{UVLOH}$	Undervoltage lockout hysteresis		0.3	0.7		V
$I_{O+}$	Output high short circuit pulsed current	$V_O = 0V, V_{IN} = \text{Logic "1"},$ $PW \leq 10 \mu s$	130	290		mA
$I_{O-}$	Output low short circuit pulsed current	$V_O = 15V, V_{IN} = \text{Logic "0"},$ $PW \leq 10 \mu s$	270	600		mA

## AC Electrical Characteristics

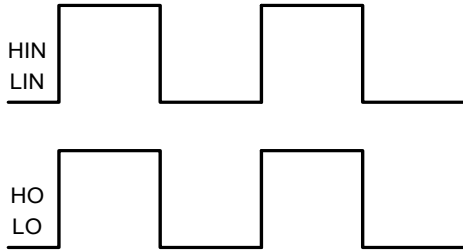
$V_{BIAS} (V_{CC}, V_{BS}) = 15V, T_A = 25^\circ C$ , and  $C_L = 1000pF$ , unless otherwise specified.

Symbol	Parameter	Conditions	MIN	TYP	MAX	Unit
$t_{ON}$	Turn-on propagation delay	$V_S = 0V$		220	300	ns
$t_{OFF}$	Turn-off propagation delay	$V_S = 0V \text{ or } 600V$		200	280	ns
$t_r$	Turn-on rise time			100	220	ns
$t_f$	Turn-off fall time	$V_S = 0V$		35	80	ns
$t_{DM}$	Delay matching				30	ns

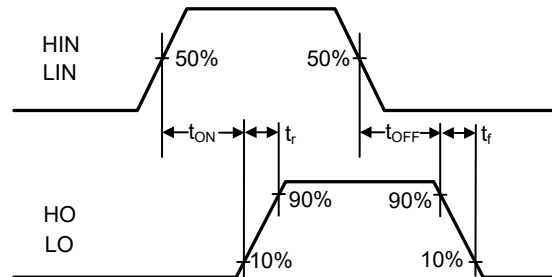
**NOTE4** The  $V_{IH}$ ,  $V_{IL}$ , and  $I_{IN}$  parameters are referenced to COM. The  $V_O$  and  $I_O$  parameters are referenced to COM and are applicable to the respective output pins: HO and LO.

**NOTE5** For optimal operation, it is recommended that the input pulse (to HIN and LIN) should have an amplitude of 2.5V minimum with a pulse width of 440ns minimum.

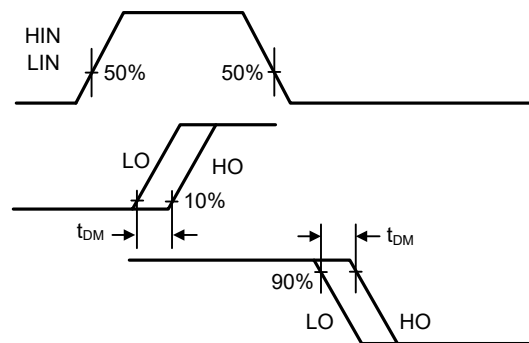
## Timing Waveforms



**Figure 1.** Input / Output Timing Diagram

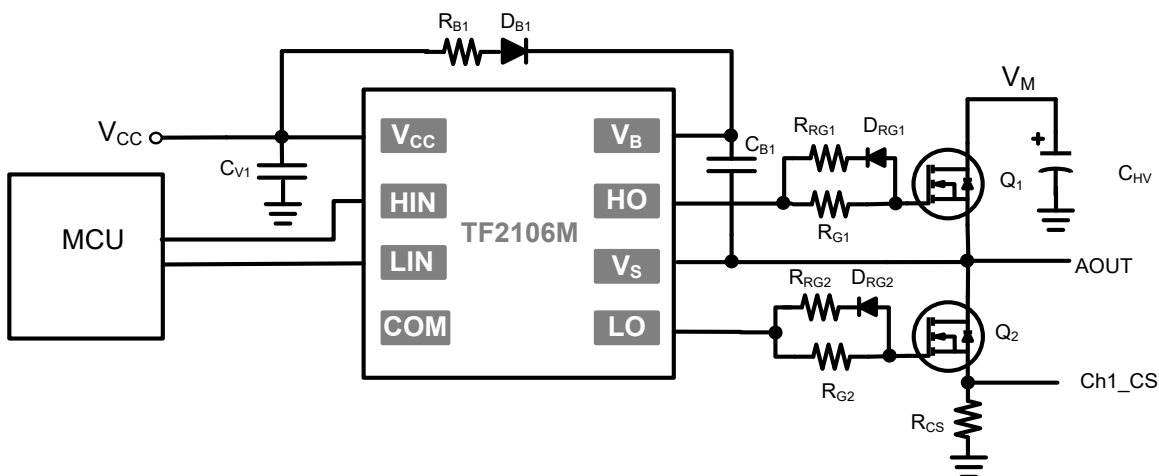


**Figure 2.** Switching Time Waveform Definitions



**Figure 3.** Delay Matching Waveform Definitions

## Application Information



**Figure 4.** Single phase (of four) for Stepper motor driver application using the TF2106M

- RRG1 and RRG2 values are typically between  $0\Omega$  and  $10\Omega$ , exact value decided by MOSFET junction capacitance and drive current of gate driver;  $10\Omega$  is used in this example.
- RG1 and RG2 values are typically between  $10\Omega$  and  $100\Omega$ , exact value decided by MOSFET junction capacitance and drive current of gate driver;  $50\Omega$  is used in this example.
- RB1 value is typically between  $3\Omega$  and  $20\Omega$ , exact value depending on bootstrap capacitor value and amount of current limiting required for bootstrap capacitor charging;  $10\Omega$  is used in this example. Also DB should be an ultra fast diode of 1A rating minimum and voltage rating greater than system operating voltage.
- It is recommended that the input pulse (to HIN and LIN) should have an amplitude of 2.5V minimum (for VDD=15V) with a minimum pulse width of 440ns.

## Typical Characteristics

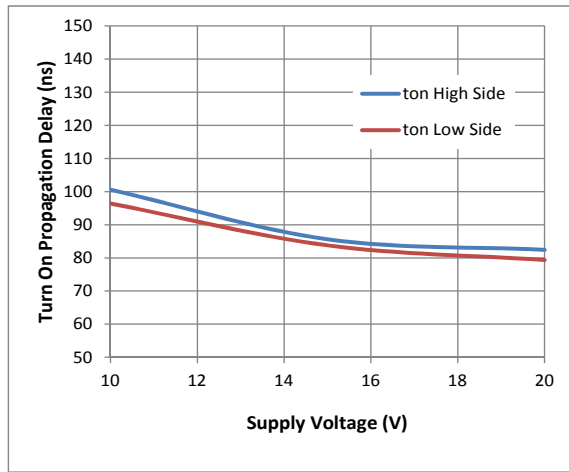


Figure 5. Turn-on Propagation Delay vs. Supply Voltage

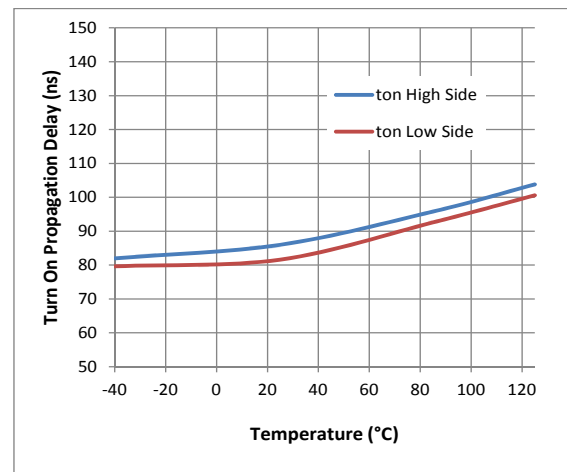


Figure 6. Turn-on Propagation Delay vs. Temperature

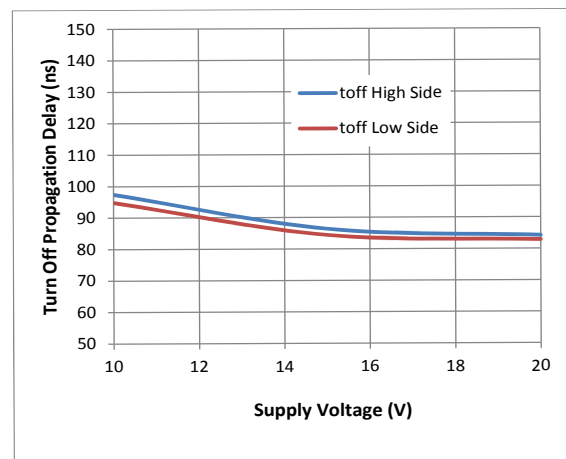


Figure 7. Turn-off Propagation Delay vs. Supply Voltage

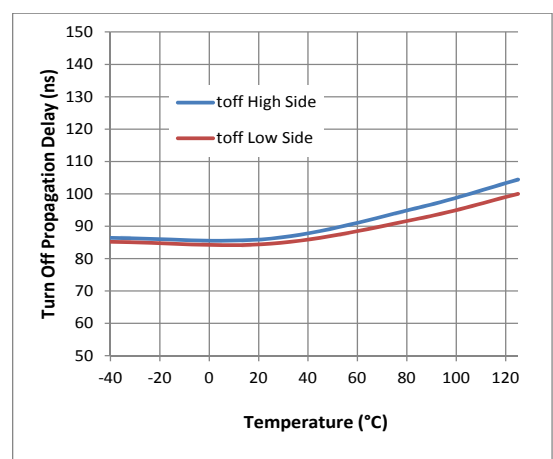


Figure 8. Turn-off Propagation Delay vs. Temperature

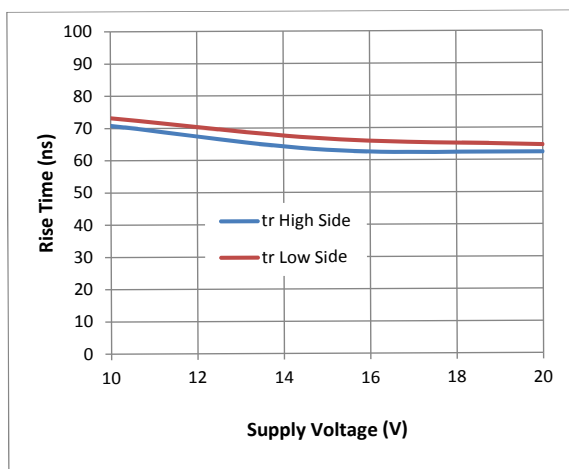


Figure 9. Rise Time vs. Supply Voltage

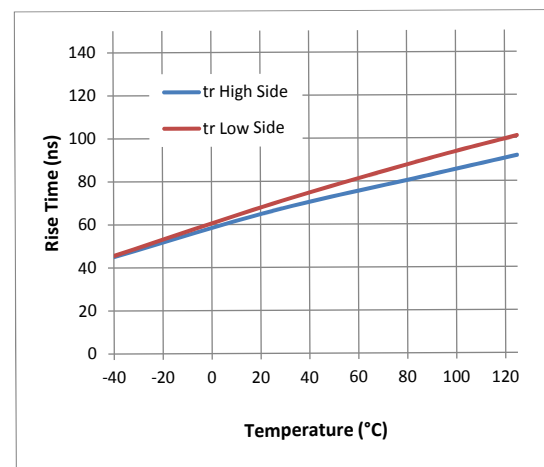


Figure 10. Rise Time vs. Temperature

## Typical Characteristics, cont'd

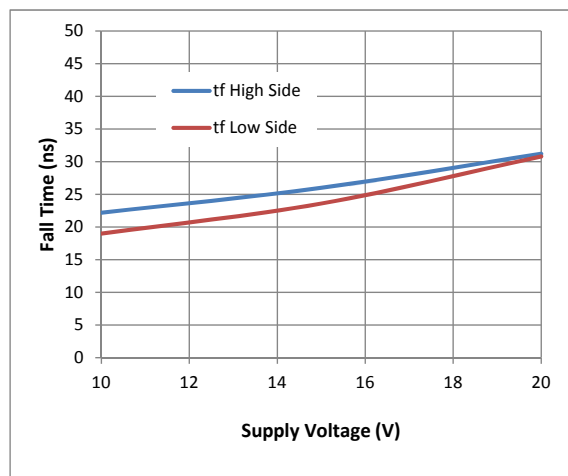


Figure 11. Fall Time vs. Supply Voltage

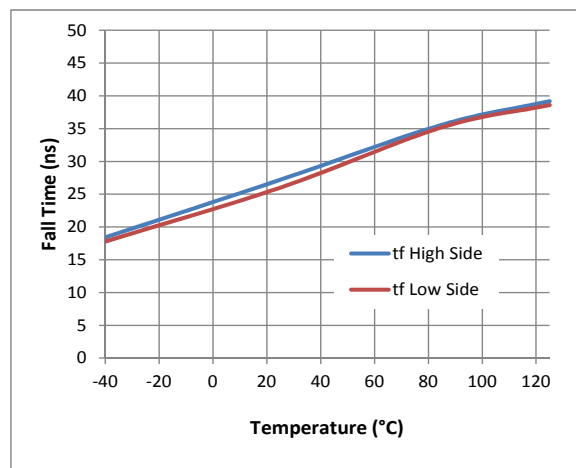


Figure 12. Fall Time vs. Temperature

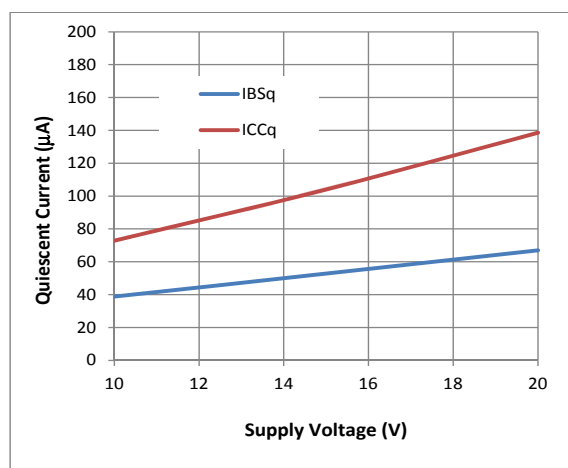


Figure 13. Quiescent Current vs. Supply Voltage

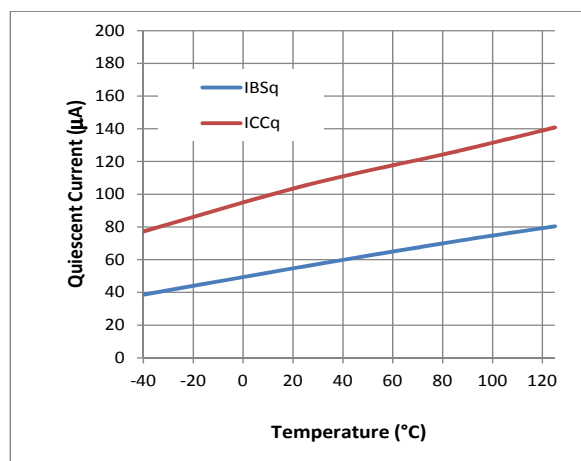


Figure 14. Quiescent Current vs. Temperature

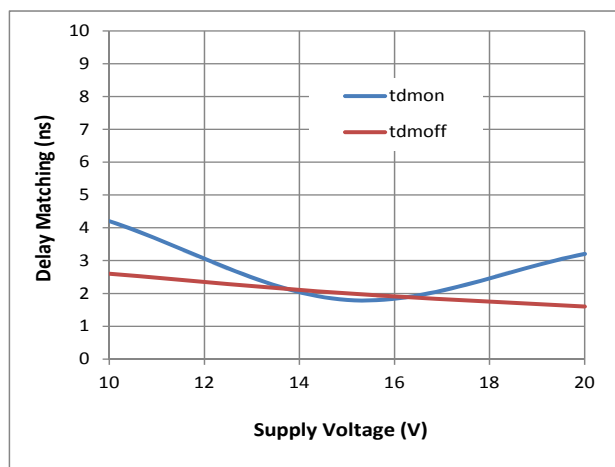


Figure 15. Delay Matching vs. Supply Voltage

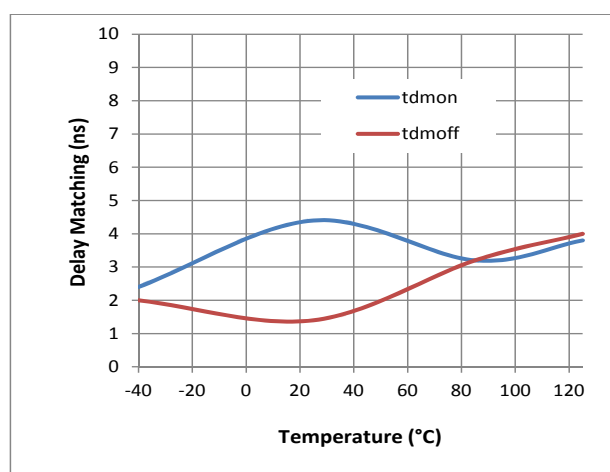


Figure 16. Delay Matching vs. Temperature



## Typical Characteristics, cont'd

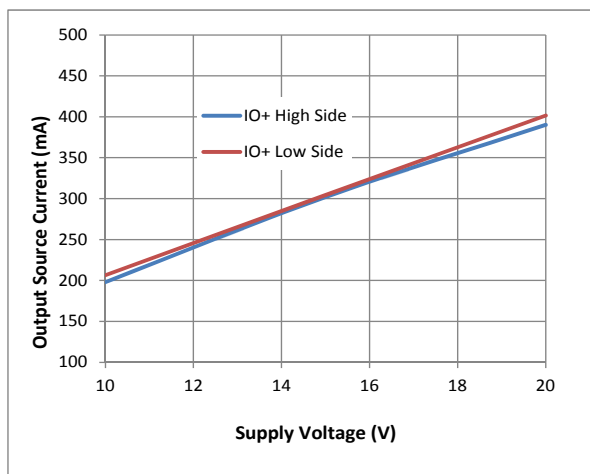


Figure 17. Output Source Current vs. Supply Voltage

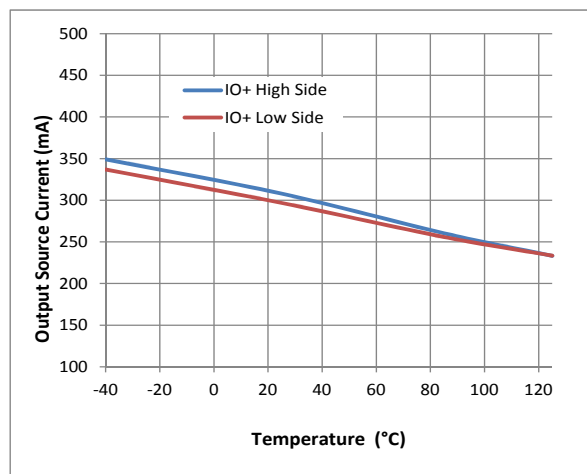


Figure 18. Output Source Current vs. Temperature

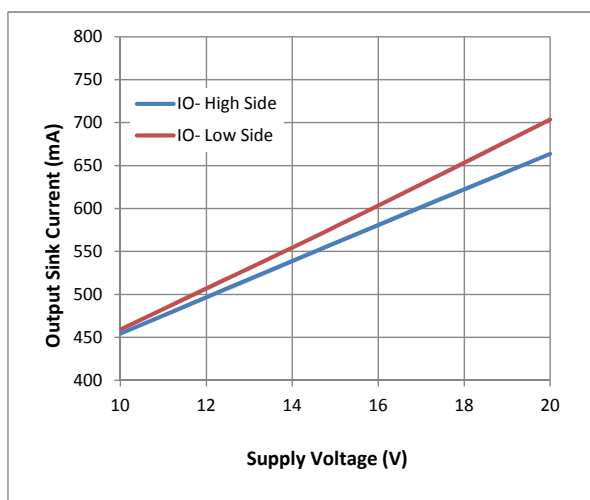


Figure 19. Output Sink Current vs. Supply Voltage

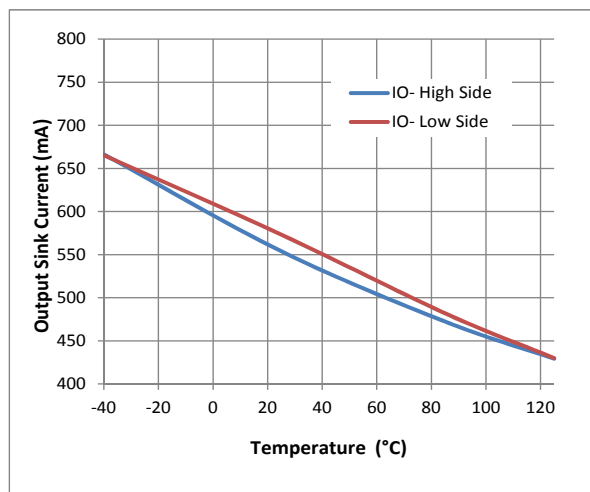


Figure 20. Output Sink Current vs. Temperature

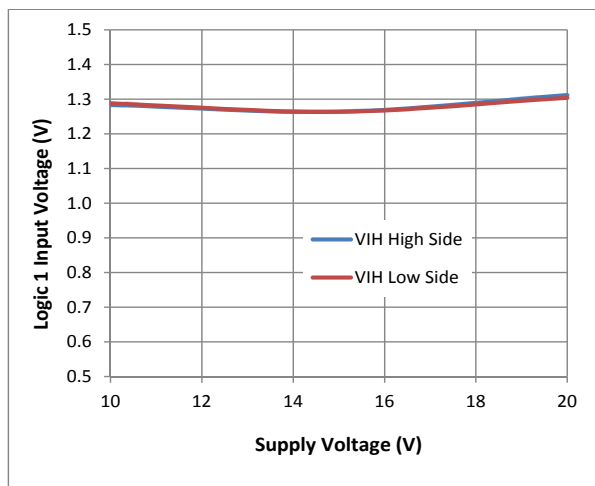


Figure 21. Logic 1 Input Voltage vs. Supply Voltage

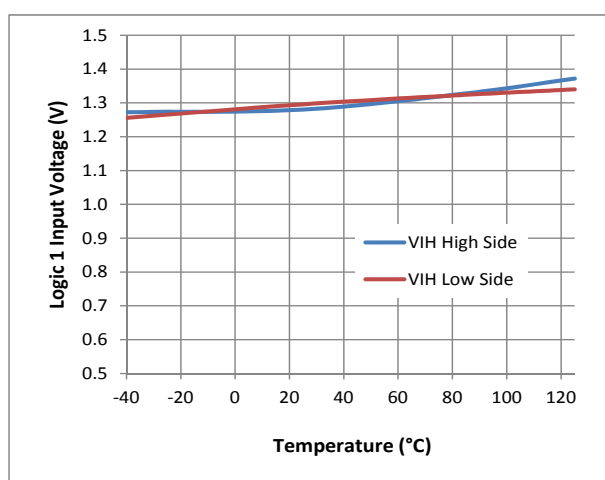


Figure 22. Logic 1 Input Voltage vs. Temperature

## Typical Characteristics, cont'd

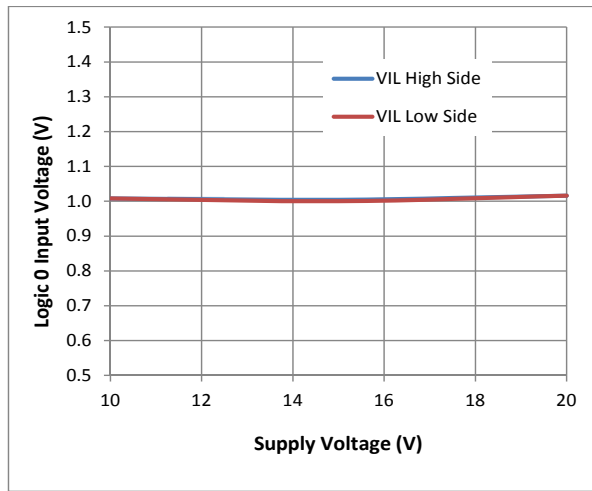


Figure 23. Logic 0 Input Voltage vs. Supply Voltage

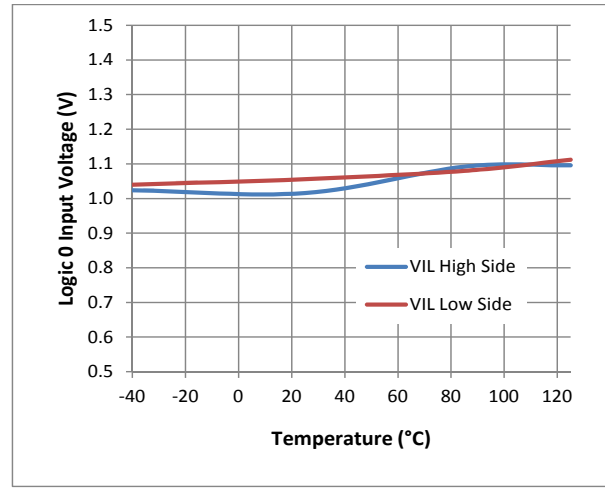


Figure 24. Logic 0 Input Voltage vs. Temperature

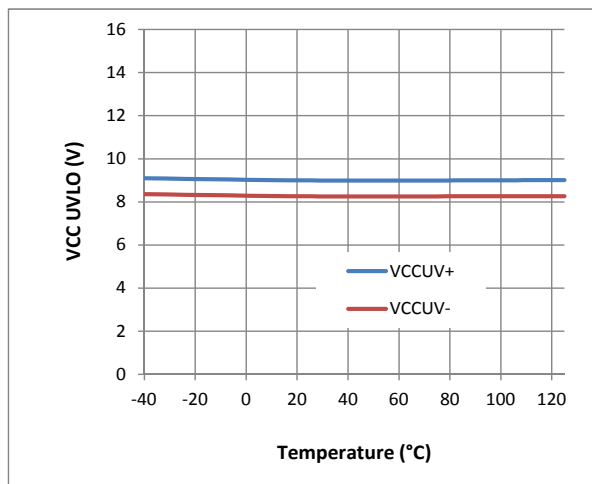


Figure 25.  $V_{CC}$  UVLO vs. Temperature

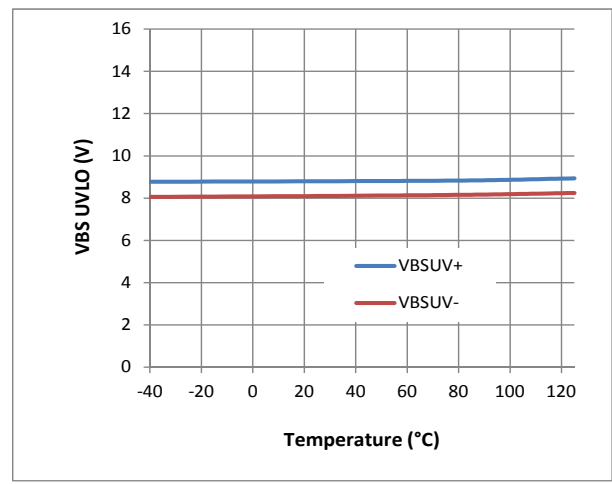


Figure 26.  $V_{BS}$  UVLO vs. Temperature

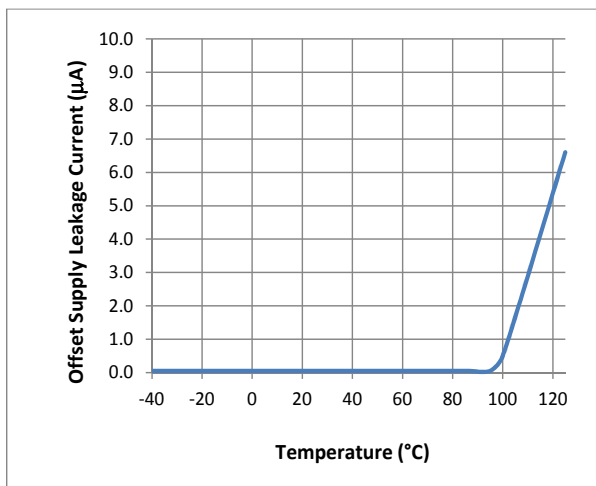


Figure 27. Offset Supply Leakage Current Temperature

### Halfbridge Configuration

A common configuration used for the TF2106M is a half-bridge (see fig. 28). In a half-bridge configuration the source of the high-side MOSFET ( $Q_H$ ) and the drain of the low-side MOSFET ( $Q_L$ ) are connected. That line ( $V_S$ ) is both the return for the high side in the gate driver IC as well as the output of the half-bridge. When  $Q_H$  is on and  $Q_L$  is off,  $V_S$  swings to high voltage, and when  $Q_H$  is off and  $Q_L$  is on,  $V_S$  swings to GND. Hence the output switches from GND to high voltage at the frequency of HIN and LIN, this line drives a transformer for a power supply, or a coil on a motor.

In this half-bridge configuration, high voltage DC is input to the MOSFETs, and converted to a high voltage switching signal to output to load (fig 28). The MOSFETs operate in saturation mode and an important function of the gate driver is to turn on the MOSFET quickly to minimize switching losses from the linear region of the MOSFET (turn on and turn off); the TF2106M has a typical rise/fall time of 100ns/35ns into a 1nF load.

Another important function of the gate driver IC in the half-bridge configuration is to convert the logic signals of control (TF2106M operates at logic 3.3V), to a voltage level and current capacity to drive the gate of the MOSFET and IGBT; this requires driving large currents initially to turn on/turn off the MOSFET quickly. Also the floating well of the high-side allows high voltage operation in the bootstrap operation.

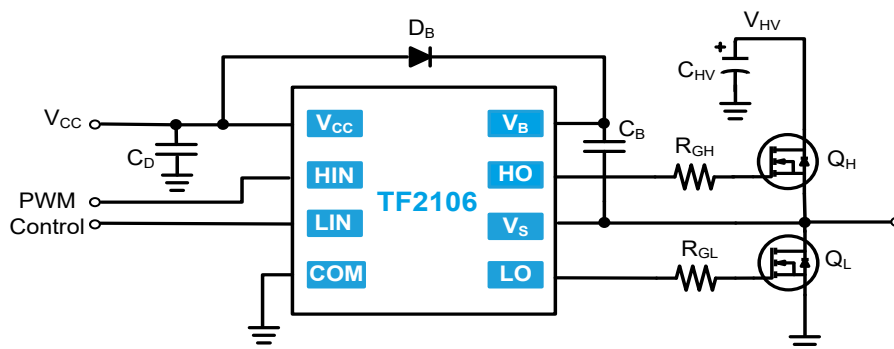


Figure 28. TF2106M in a half-bridge configuration

### Bootstrap Operation

The supply for the TF2106M High Side is provided by the bootstrap capacitor  $C_B$  (see fig 29). In the half-bridge configuration,  $V_S$  swings from 0V to  $V_{HV}$  depending on the PWM input of the IC. When  $V_S$  is 0V,  $V_{BS}$  will go below  $V_{CC}$  and  $V_{CC}$  will charge  $C_B$ . When HO goes high,  $V_S$  swings to  $V_{HV}$ , and  $V_{BS}$  remains at  $V_{CC}$  minus a diode drop ( $D_B$ ) due to the voltage on  $C_B$ . This is the supply for the high side gate driver and allows the gate driver to function with the floating well ( $V_S$ ) at the high voltage.

When considering the **value of the bootstrap capacitor  $C_B$** , it is important that it is sized to provide enough energy to quickly drive the gate of  $Q_H$ . Values of 1 $\mu$ F to 10 $\mu$ F are recommended, exact value depending on gate capacitance, and the noise in application. It is key to use a low ESR capacitor that is close to the device. This will best quickly supply charge to the gate of the MOSFET.

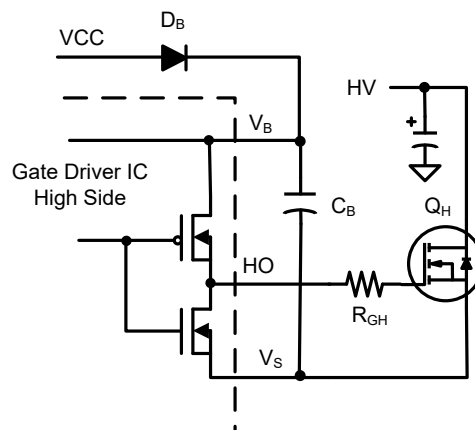


Figure 29. TF2106M high side in bootstrap operation

For a more detailed description on Gate Resistor Selection and Bootstrap Capacitor Selection, see the TF Semiconductor's Gate Driver Application Note (AN1347).

## Gate Drive Control

The most crucial time in the gate drive is the turn on and turn off of the MOSFET, and performing this function quickly, but with minimal noise and ringing is key. Too fast a rise/fall time can cause unnecessary ringing, and too slow a rise/fall time will increase switching losses in the MOSFET.

An example of just the high side gate driver is shown in figure 30 (any selection of gate driver components should be the same for high side and low side drive); two extra components are seen,  $R_{DH}$  and  $D_H$ . With the careful selection of  $R_{GH}$  and  $R_{DH}$ , it is possible to selectively control the rise time and fall time of the gate drive. For turn on, all current will go from the IC through  $R_{GH}$  and charge the MOSFET gate capacitor, hence increasing or decreasing  $R_{GH}$  will increase or decrease rise time in the application. With the addition of  $D_H$ , the fall time can be separately controlled as the turn off current flows from the MOSFET gate capacitor, through  $D_H$  and  $R_{DH}$  to the driver in the IC to  $V_S$ . So increasing or decreasing  $R_{DH}$  will increase or decrease the fall time.

Increasing turn on and turn off has the effect of limiting ringing and noise due to parasitic inductances, hence with a noisy environment, it may be necessary to increase the gate resistors. For **gate resistor value selection** the exact value depends on the type of application and desired level of noise and ringing expected. Generally, power supplies switch at a fast speed, and want to squeeze out efficiency of the MOSFETs, so lower values are recommended, for example  $R_{GH} = 5\Omega - 20\Omega$ . For motors, the switching speed is generally slower, and the application has more inherent noise, so higher values are recommended, for example  $R_{GH} = 10\Omega - 100\Omega$ .

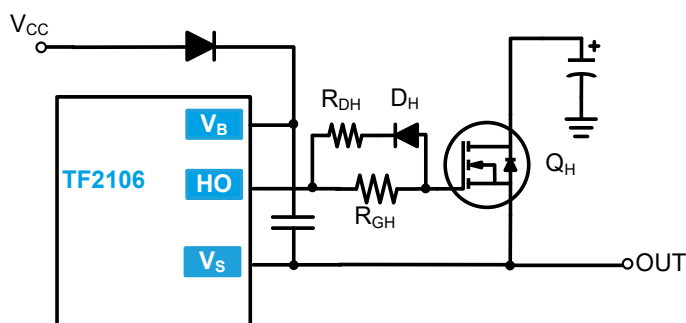
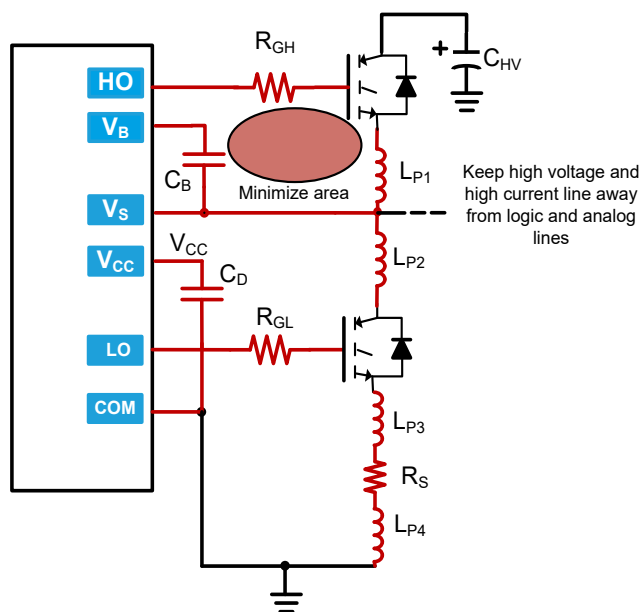


Figure 30. Gate Drive Control

## Application Information

### Layout Considerations

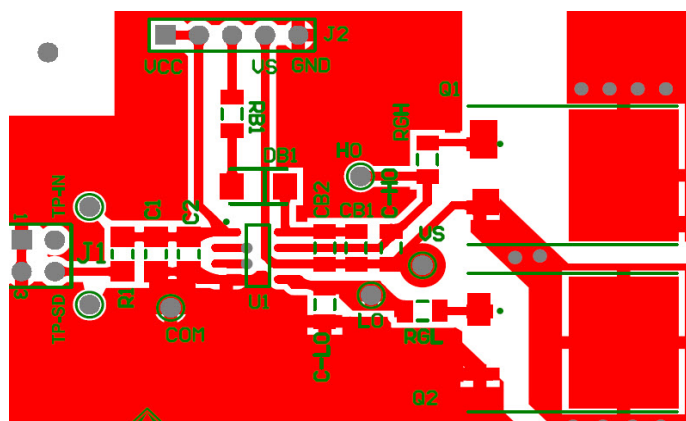
Layout plays a considerable role in noise and ringing in a circuit; unwanted noise coupling, unpredicted glitches and abnormal operation could arise due to poor layout of the associated components. Figure 31 shows a halfbridge schematic with parasitic inductances in the high current path ( $L_{P1}$ ,  $L_{P2}$ ,  $L_{P3}$ ,  $L_{P4}$ ) which would be caused by inductance in the metal of the trace. Considering fig. 31, the length of the tracks in red should be minimized, and the bootstrap capacitor ( $C_B$ ) and the decoupling capacitor ( $C_D$ ) should be placed as close to the IC as possible. Low ESR ceramic capacitors should be used to minimize inductance. And finally the gate resistors ( $R_{GH}$  and  $R_{GL}$ ) and the sense resistor ( $R_S$ ) should be surface mount devices. These suggestions will reduce the parasitics due to the PCB traces.



**Figure 31.** Layout Suggestions for TF2106M in a halfbridge

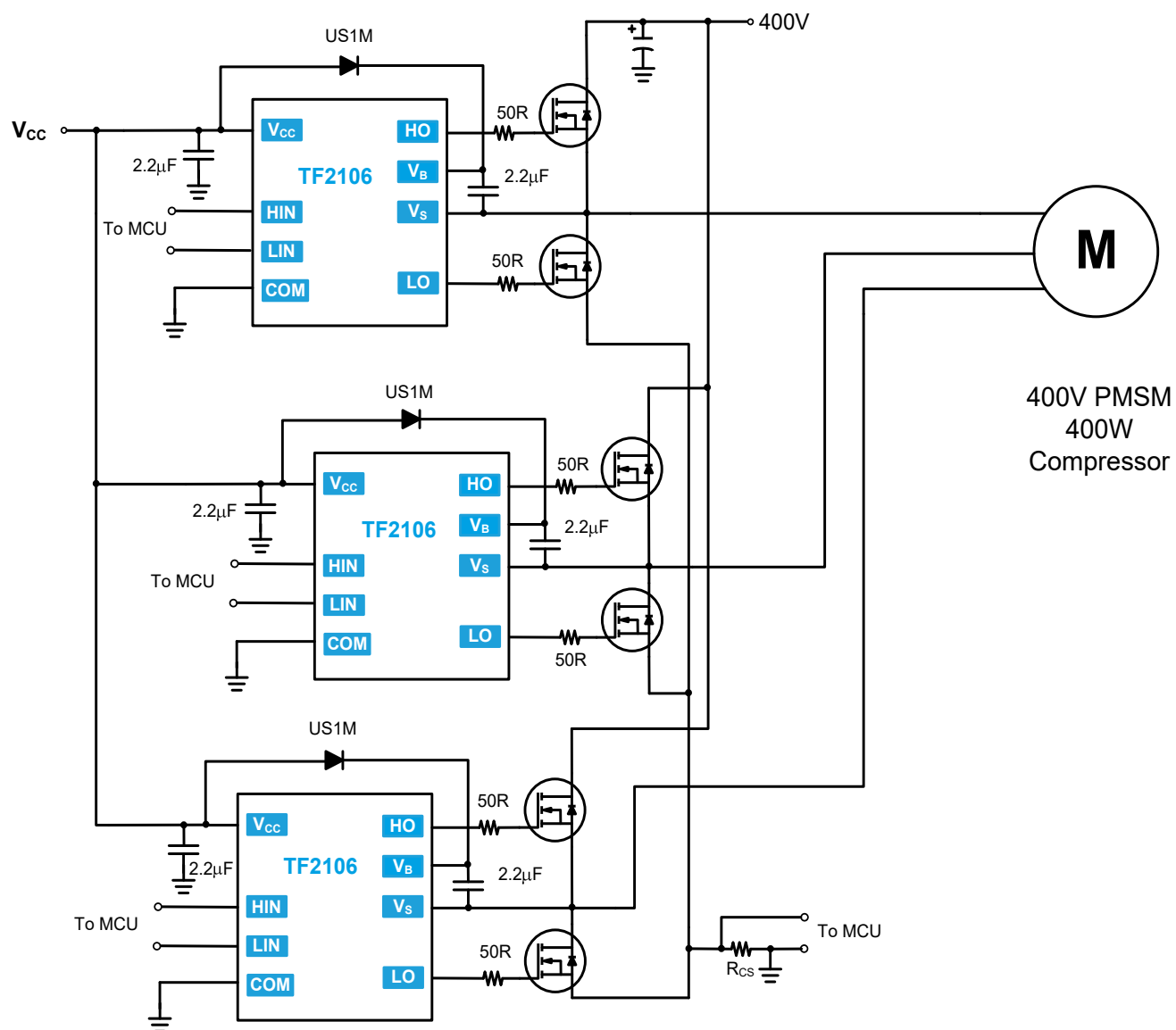
A layout example is seen in figure 32. Here there are two bootstrap capacitors (CB1 and CB2) and two decoupling capacitors (C1 and C2), and the caps are placed as close as possible to the HVIC. But even if only using one bootstrap cap and one decoupling capacitor, it needs to be as close as possible to minimize inductance between the cap and the driver.

Generally, for the **decoupling capacitor** on VCC, at least one low ESR capacitor is recommended with it close to the device as shown in figure 32. Recommended values are  $1\mu\text{F}$  to  $10\mu\text{F}$ . A second smaller decoupling capacitor is sometimes added to provide better high frequency response (for example  $0.1\mu\text{F}$ ).



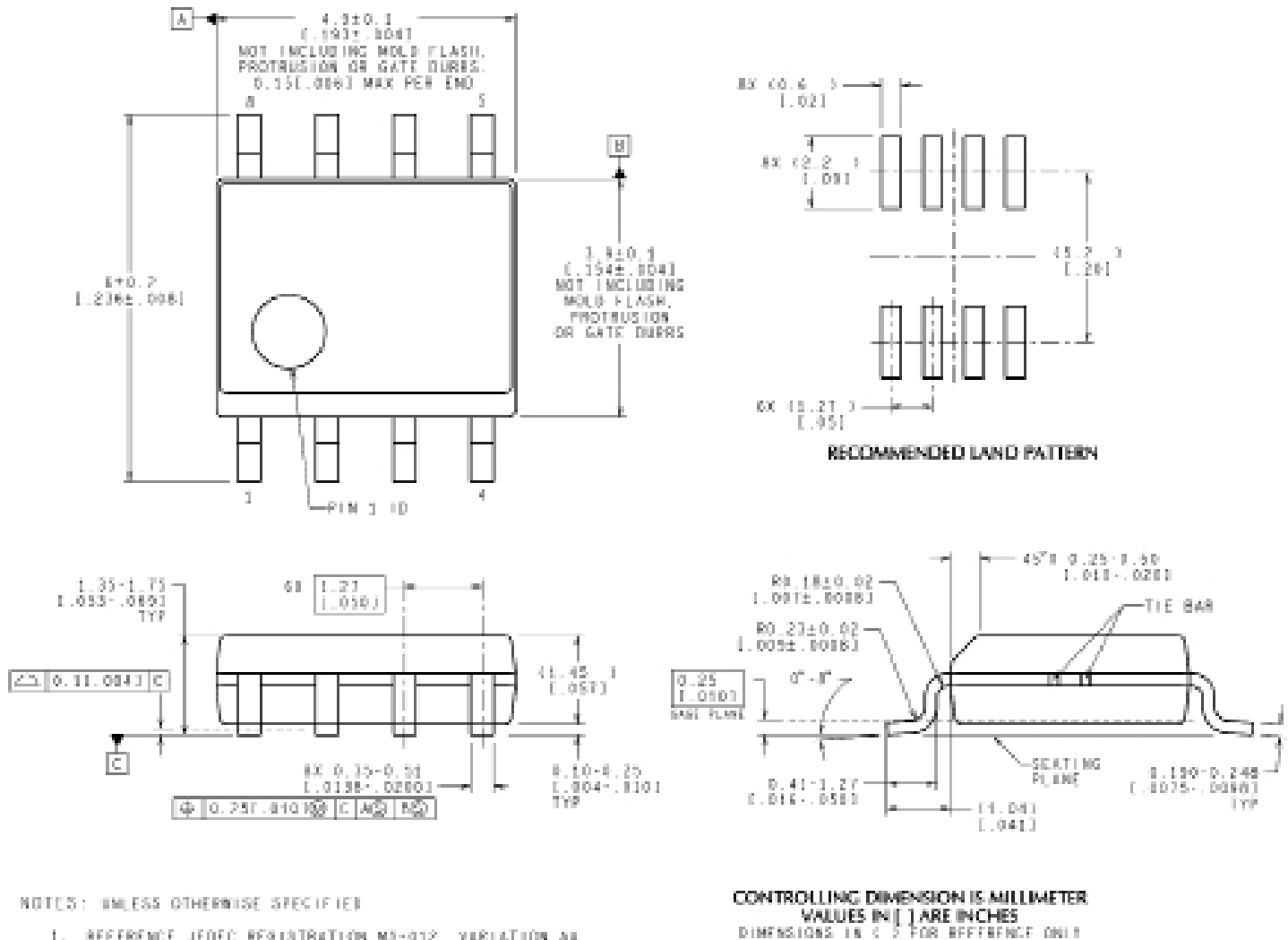
**Figure 32.** Layout example for TF2106M (U1) in a halfbridge, notice the bootstrap caps (CB1, CB2), VCC caps (C1 and C2), and bootstrap diode (DB1) adjacent to the IC.

## Application Example

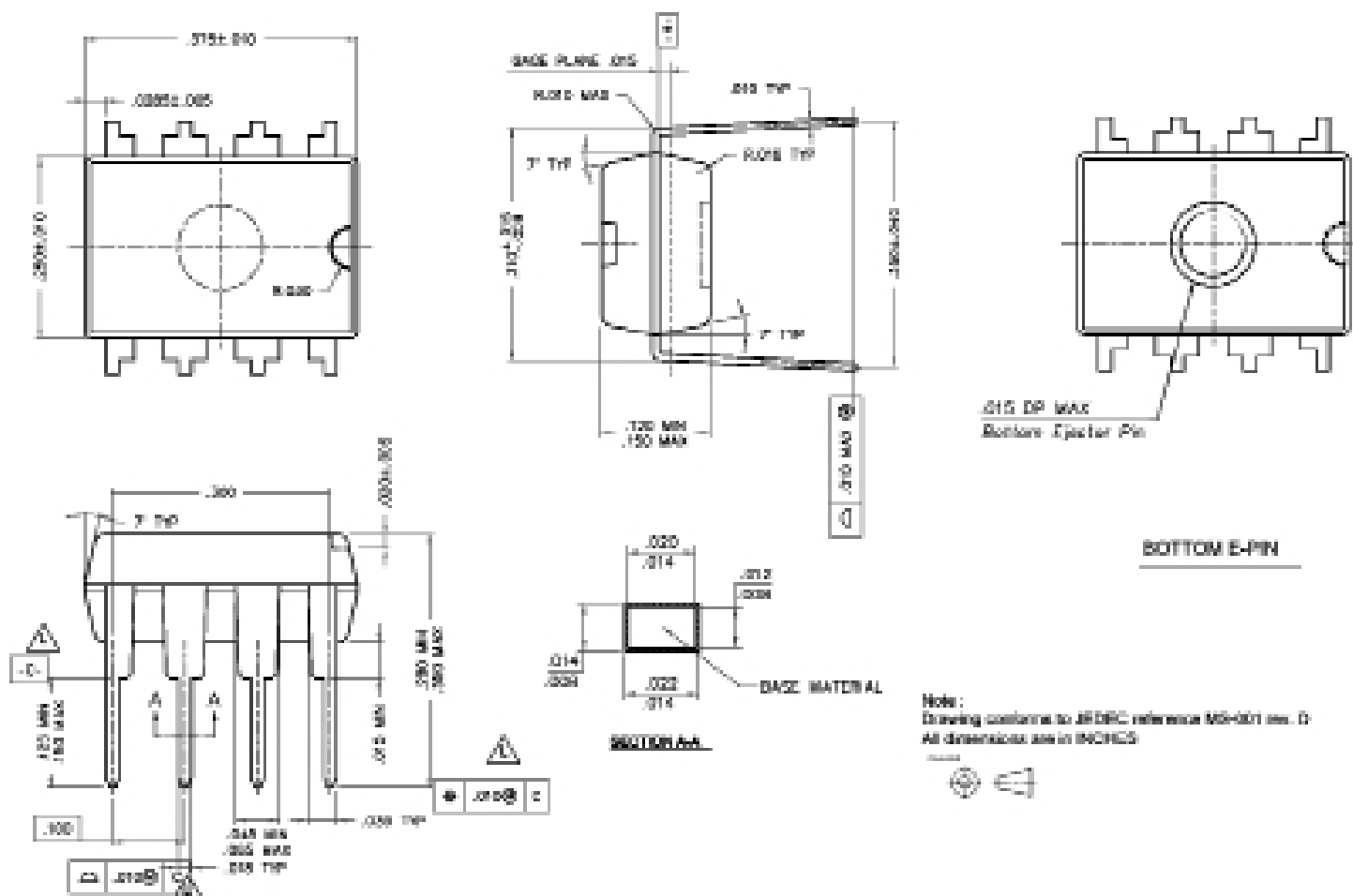


## Package Dimensions (SOIC-8 N)

Please contact support@tfsemi.com for package availability.



## Package Dimensions (PDIP-8)





## Revision History

Rev.	Change	Owner	Date
1.0	First release, final datasheet	Keith Spaulding	3/22/16
1.1	Text edit	Keith Spaulding	9/10/17
1.2	Add note 5	Duke Walton	9/15/19
1.3	Edit UVLO specifications	Keith Spaulding	6/3/2020
1.4	Add Applications Information page	Keith Spaulding	10/1/2020
1.5	Application notes update	Raj Selvaraj	6/28/2021
1.6	Update text in Features on pg. 1	Keith Spaulding	8/25/2022

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