Features
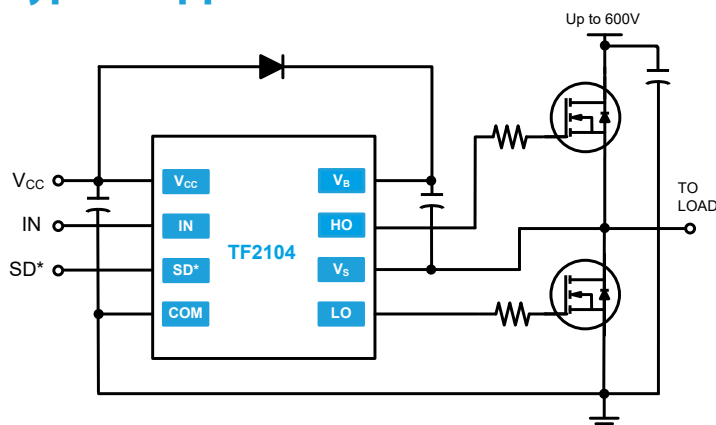
- **Floating high-side driver in bootstrap operation to 600V**
- **Drives two N-channel MOSFETs or IGBTs in a half bridge configuration**
- **290mA source/600mA sink output current capability**
- **Outputs tolerant to negative transients**
- **Internal dead time of 520ns to protect MOSFETs**
- **Wide low side gate driver supply voltage: 10V to 20V**
- **Logic input (IN and SD*) 3.3V capability**
- **Schmitt triggered logic inputs**
- **Undervoltage lockout for V_{cc} (logic and low side supply)**
- **Extended temperature range: -40°C to +125°C**

Description

The TF2104 is a high voltage, high speed gate driver capable of driving N-channel MOSFETs and IGBTs in a half bridge configuration. TF Semiconductor's high voltage process enables the TF2104's high side to switch to 600V in a bootstrap operation.

The TF2104 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. TF2104 has a fixed internal deadtime of 520ns (typical).

The TF2104 is offered in PDIP-8 and SOIC-8(N) packages and operate over an extended -40 °C to +125 °C temperature range.

SOIC-8(N)

PDIP-8

Applications

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

Ordering Information

Year Year Week Week

PART NUMBER	PACKAGE	PACK / Qty	MARK
TF2104-3AS	PDIP-8	Tube / 50	TF YYWW TF2104 Lot ID
TF2104-TAU	SOIC-8(N)	Tube / 100	TF YYWW TF2104 Lot ID
TF2104-TAH	SOIC-8(N)	T&R / 2500	

Typical Application

Pin Diagrams
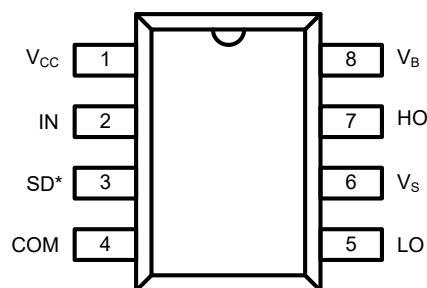
Top View: PDIP-8, SOIC-8

TF2104

Pin Descriptions

PIN NAME	PIN NUMBER	PIN DESCRIPTION
V_{CC}	1	Logic and low side supply
IN	2	Logic input for high-side and low-side gate driver outputs (HO and LO), in phase with HO
SD*	3	Logic input for shutdown, enabled low
COM	4	Low-side and logic return
LO	5	Low-side gate drive output
V_S	6	High-side floating supply return
HO	7	High-side gate drive output
V_B	8	High-side floating supply

Functional Block Diagram
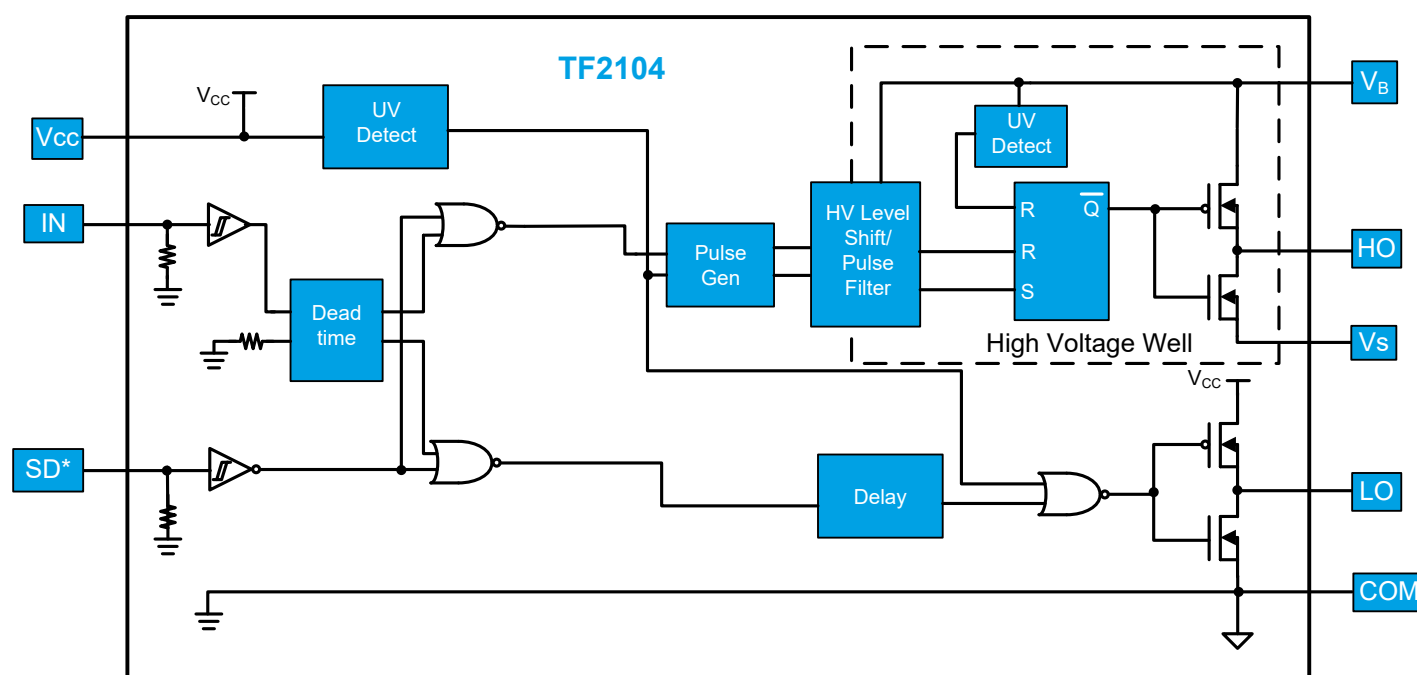
Absolute Maximum Ratings *(NOTE1)*

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 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 (IN and SD*)..................-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 °C
  SOIC-8...0.625W
  PDIP-8..1.0W

SOIC-8(N) Thermal Resistance *(NOTE2)*
  θ_{JA}...200 °C/W
PDIP-8 Thermal Resistance *(NOTE2)*
  θ_{JA}...125 °C/W

T_J - Junction operating temperature.......................................+150 °C
T_L - Lead Temperature (soldering, 10 seconds).......................+300 °C
T_{stg} - Storage temerature ....-55 to 150 °C

NOTE2 *Thermal resistance and power dissipation ratings are measured under board mounted and still air conditions.*

Recommended Operating Conditions

Symbol	Parameter	MIN	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	*NOTE3*	600	V
V_{HO}	High side floating output voltage	V_S	V_B	V
V_{CC}	Low side fixed supply voltage	10	20	V
V_{LO}	Low side output voltage	0	V_{CC}	V
V_{IN}	Logic input voltage (IN and SD*)	0	5	V
T_A	Ambient temperature	-40	125	°C

NOTE3 *Logic operational for V_S of -5V to +600V. Logic state held for V_S of -5V to -V_{BS}*

DC Electrical Characteristics (NOTE4)

V_{BIAS} (V_{CC}, V_{BS}) = 15V, T_A = 25 °C , unless otherwise specified.

Symbol	Parameter	Conditions	MIN	TYP	MAX	Unit
V_{IH}	Logic "1" (IN) & Logic "0" (SD*) input voltage	V_{CC} = 10V to 20V *Note 5*	2.5			V
V_{IL}	Logic "0" (IN) & Logic "1" (SD*) input voltage				0.8	
V_{OH}	High level output voltage, V_{BIAS} - V_O	I_O = 2mA		0.05	0.2	
V_{OL}	Low level output voltage, V_O	I_O = 2mA		0.02	0.1	
I_{LK}	Offset supply leakage current	VB = VS = 600V			50	µA
I_{BSQ}	Quiescent V_{BS} supply current	V_{IN} = 0V or 5V		60	100	
I_{CCQ}	Quiescent V_{CC} supply current	V_{IN} = 0V or 5V		350	500	
I_{IN+}	Logic "1" input bias current	V_{IN} = 5V, SD* = 0V		3	10	
I_{IN-}	Logic "0" input bias current	V_{IN} = 0V, SD* = 5V			5	
V_{CCUV+}	V_{CC} supply under-voltage positive going threshold		8.0	8.9	9.8	V
V_{CCUV-}	V_{CC} supply under-voltage negative going threshold		7.4	8.2	9.0	
I_{O+}	Output high short circuit pulsed current	V_O = 0V, PW ≤ 10 µs	130	290		mA
I_{O-}	Output low short circuit pulsed current	V_O = 15V, PW ≤ 10 µs	270	600		

NOTE4 *The V_{IN}, V_{TH}, and I_{IN} parameters are applicable to the two logic input pins: IN and SD*. The V_O and I_O parameters are applicable to the respective output pins: HO and LO*
NOTE5 *For optimal operation, it is recommended that the input pulse (to IN and SD*) should have an amplitude of 2.5V minimum with a pulse width of 1µs minimum.*

AC Electrical Characteristics

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

Symbol	Parameter	Conditions	MIN	TYP	MAX	Unit
t_{on}	Turn-on propagation delay	V_S = 0V		680	820	ns
t_{off}	Turn-off propagation delay	V_S = 600V		150	220	
t_{SD}	Shutdown propagation delay			160	220	
t_{DM}	Delay matching, HS & LS turn-on/turn-off				60	
t_r	Turn-on rise time	V_S = 0V		70	170	
t_f	Turn-off fall time			35	90	
t_{DT}	Deadtime: $t_{DT\,LO\text{-}HO}$ & $t_{DT\,HO\text{-}LO}$		400	520	650	

tfss **TF Semiconductor Solutions**
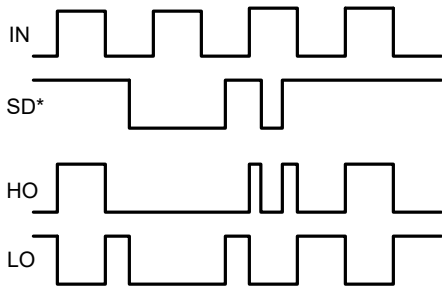
Timing Waveforms

Figure 1. Input / Output Timing Diagram
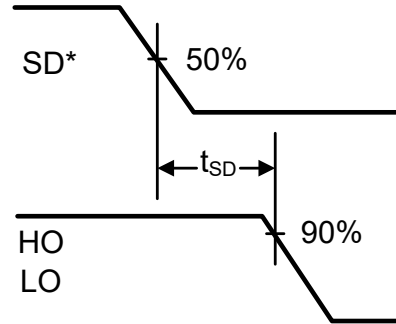
Figure 2. Shutdown Waveform Definition
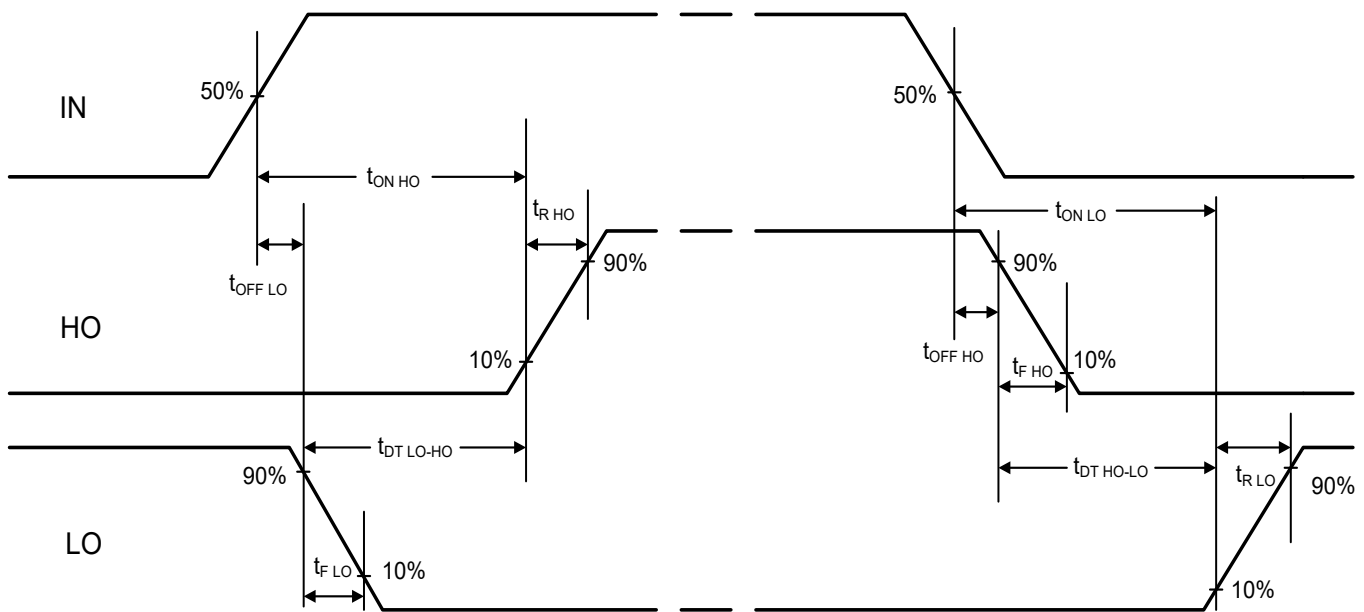
Deadtime $t_{DT\,LO\text{-}HO} = t_{ON\,HO} - t_{OFF\,LO}$
$t_{DT\,HO\text{-}LO} = t_{ON\,LO} - t_{OFF\,HO}$

Deadtime matching
$t_{MDT} = t_{DT\,LO\text{-}HO} - t_{DT\,HO\text{-}LO}$

Delay matching
$t_{DM\,OFF} = t_{OFF\,LO} - t_{OFF\,HO}$
$t_{DM\,ON} = t_{ON\,LO} - t_{ON\,HO}$

Figure 3. Switching Time Waveform Definitions
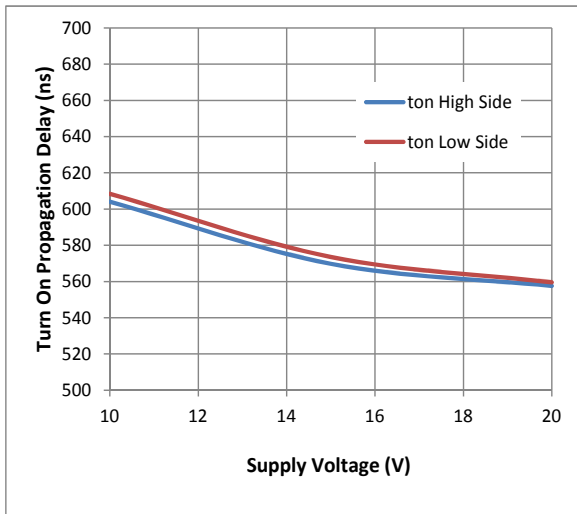
Figure 4. Turn-on Propagation Delay vs. Supply Voltage
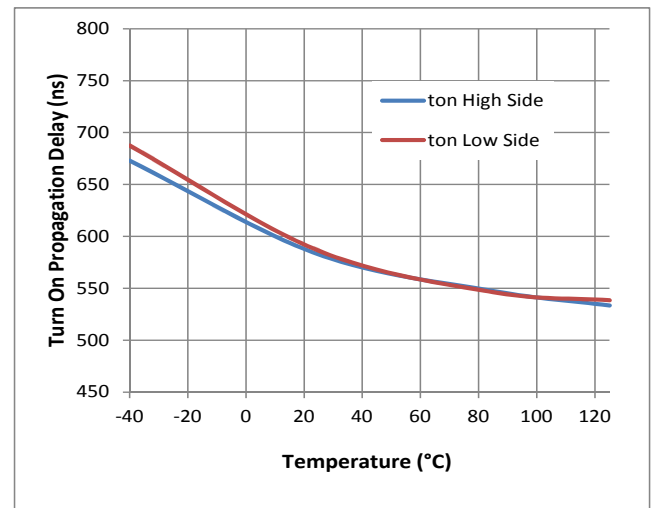
Figure 5. Turn-on Propagation Delay vs. Temperature
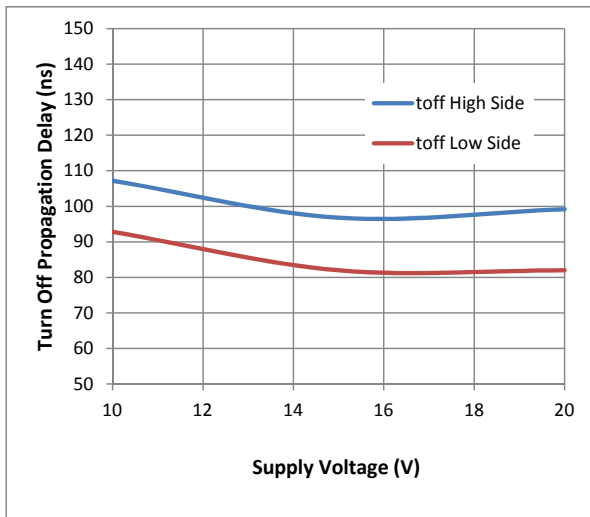
Figure 6. Turn-off Propagation Delay vs. Supply Voltage
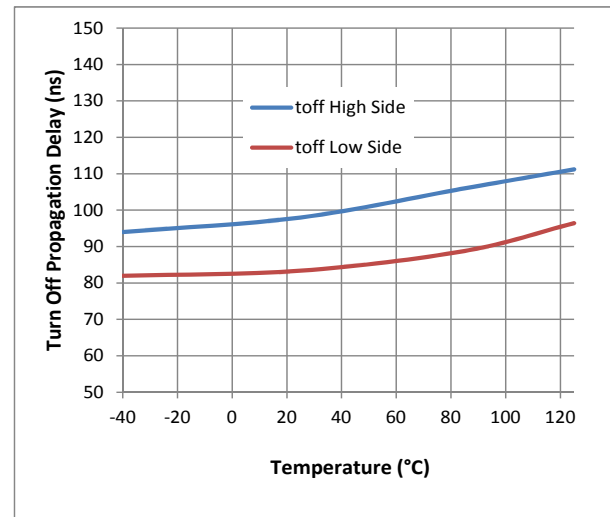
Figure 7. Turn-off Propagation Delay vs. Temperature
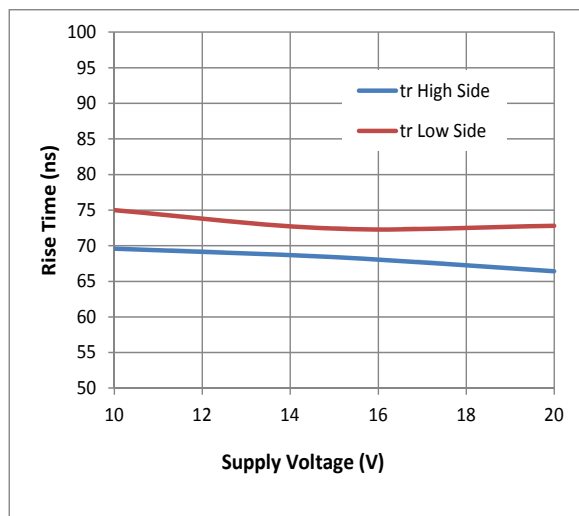
Figure 8. Rise Time vs. Supply Voltage
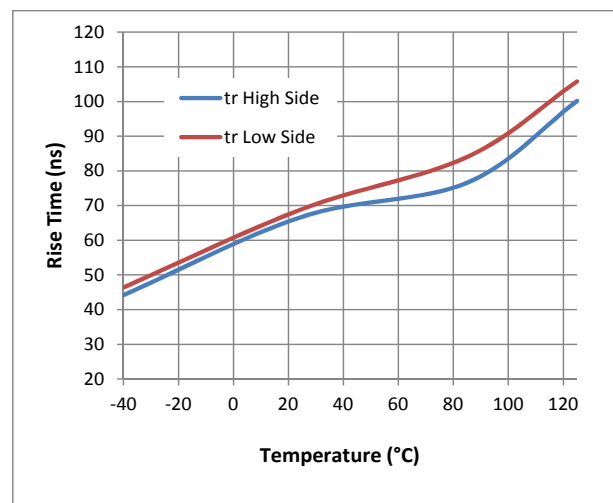
Figure 9. Rise Time vs. Temperature
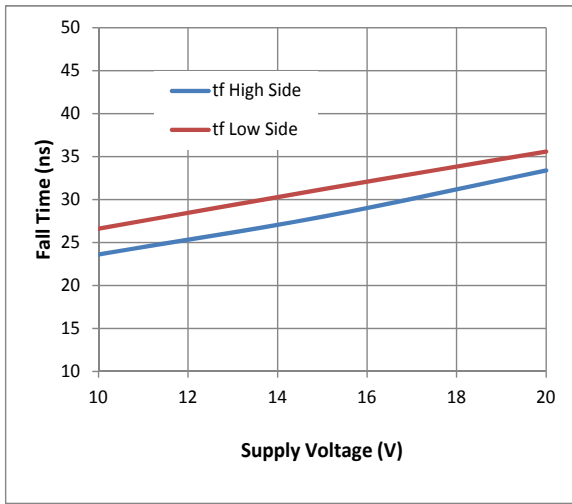
Figure 10. Fall Time vs. Supply Voltage
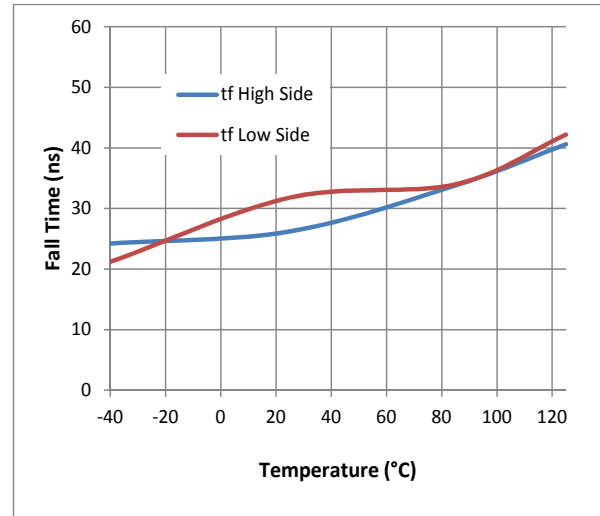
Figure 11. Fall Time vs. Temperature
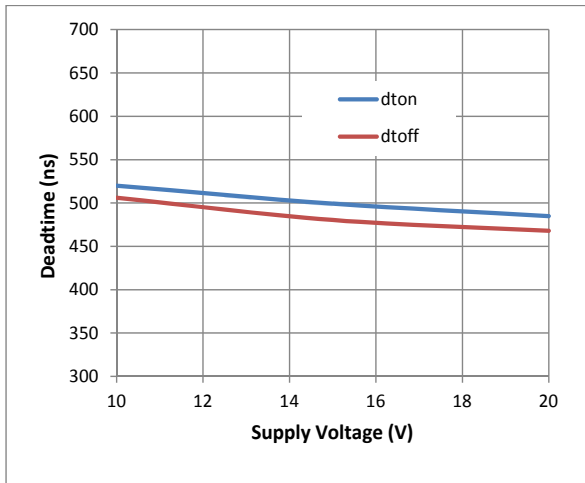
Figure 12. Deadtime vs. Supply Voltage
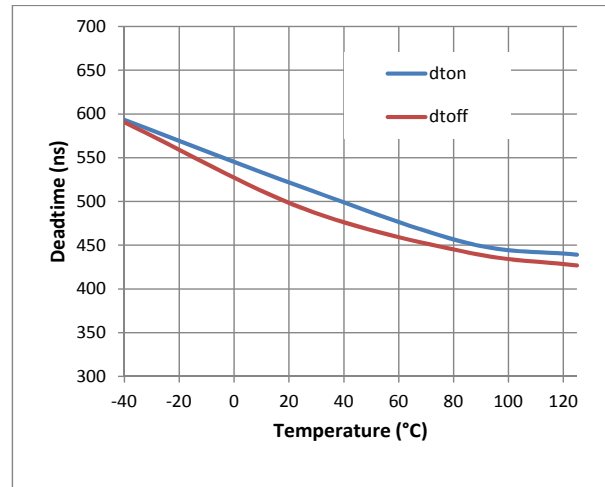
Figure 13. Deadtime vs. Temperature
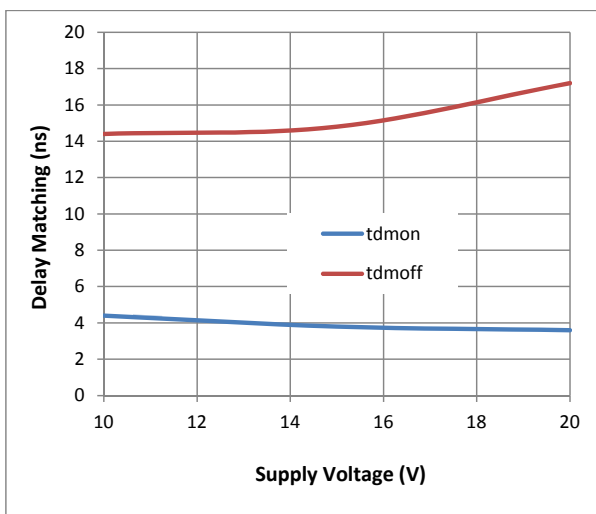
Figure 14. Delay Matching vs. Supply Voltage
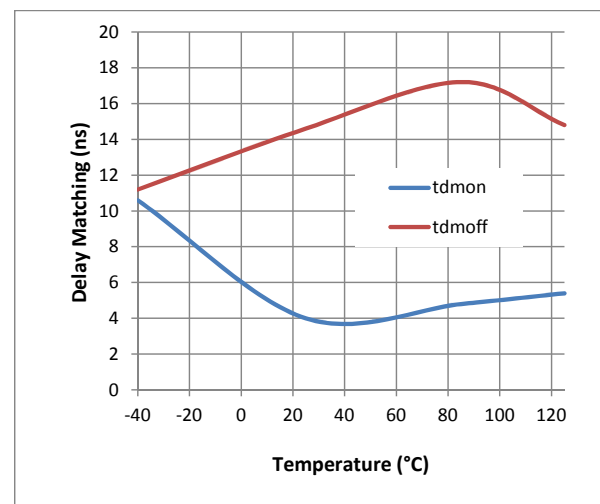
Figure 15. Delay Matching vs. Temperature

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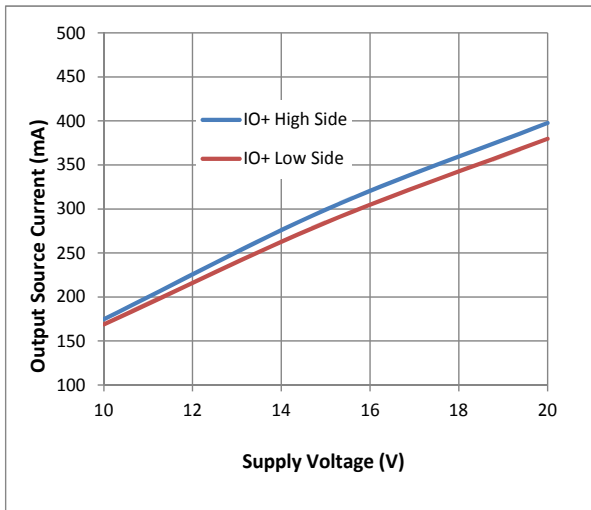
Figure 16. Output Source Current vs. Supply Voltage
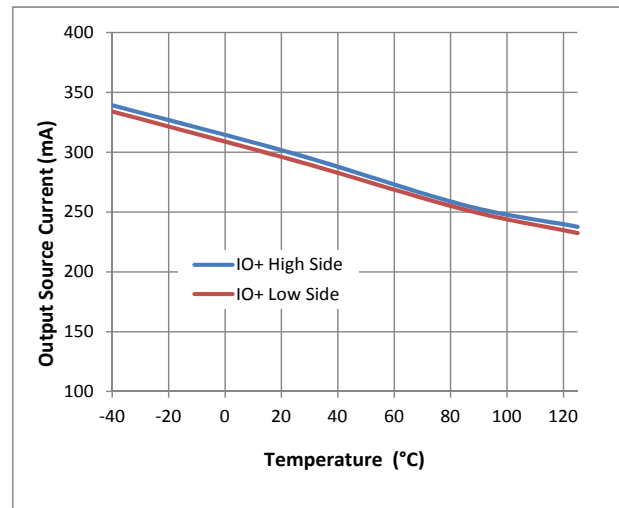
Figure 17. Output Source Current vs. Temperature
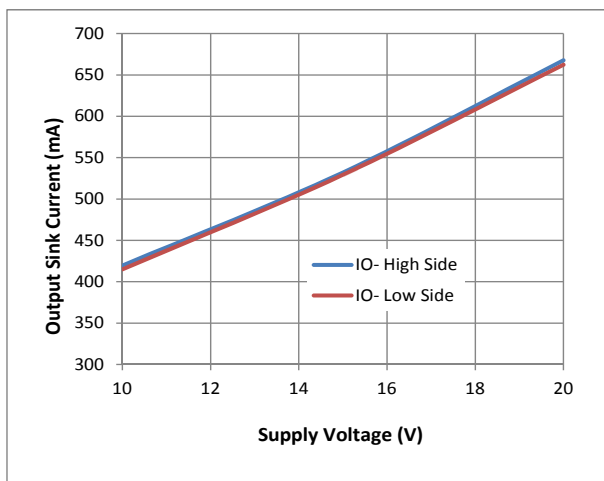
Figure 18. Output Sink Current vs. Supply Voltage
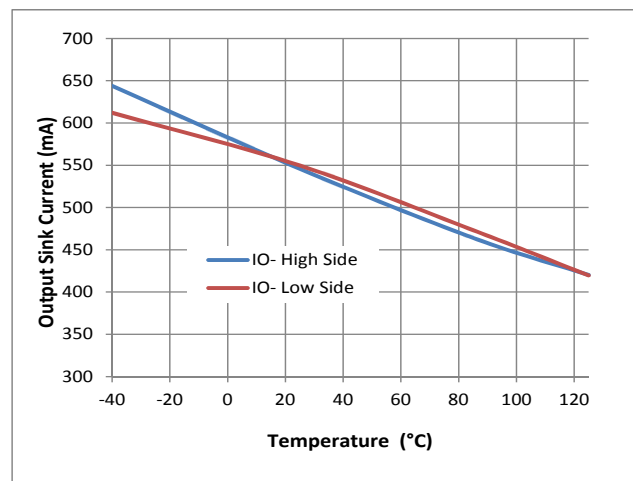
Figure 19. Output Sink Current vs. Temperature
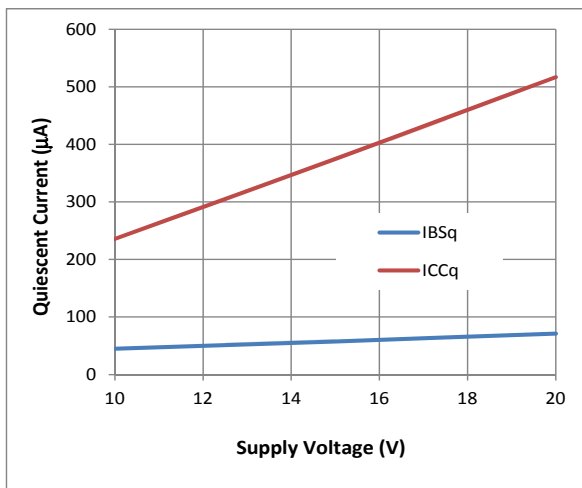
Figure 20. Quiescent Current vs. Supply Voltage
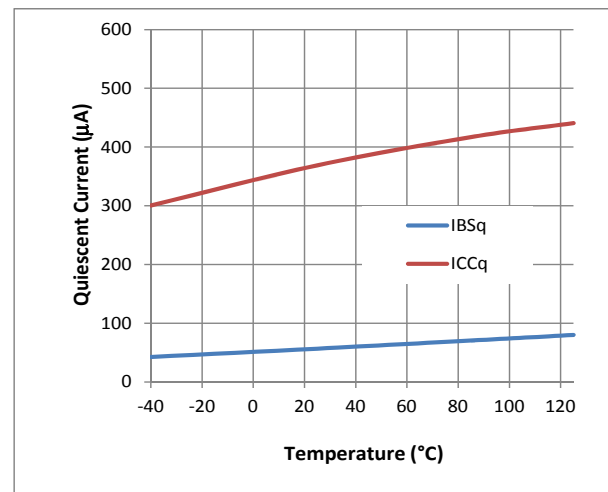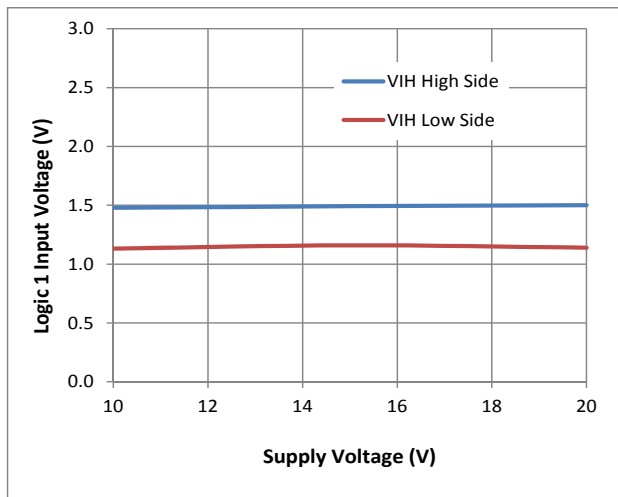
Figure 21. Quiescent Current vs. Temperature

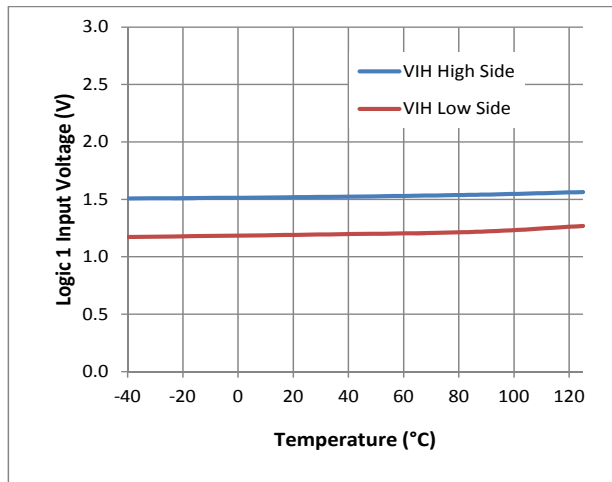**Figure 22.** Logic 1 Input Voltage vs. Supply Voltage
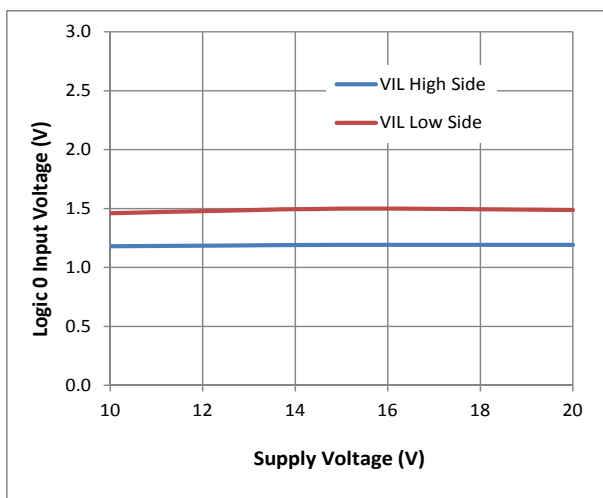

Figure 23. Logic 1 Input Voltage vs. Temperature

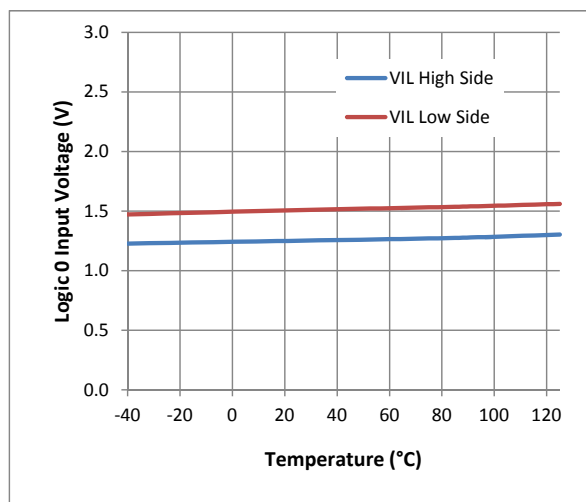

Figure 24. Logic 0 Input Voltage vs. Supply Voltage
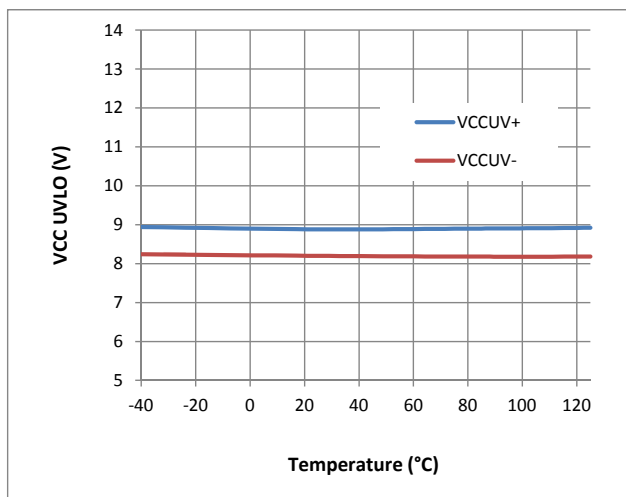

Figure 25. Logic 0 Input Voltage vs. Temperature

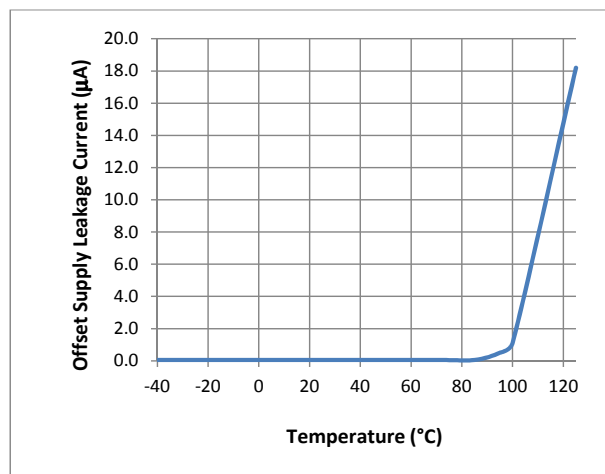**Figure 26.** V_{CC} UVLO vs. Temperature

Figure 27. Offset Supply Leakage Current Temperature, VB=VS= 600V

Operation

Halfbridge Configuration

A common configuration used for the TF2104 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 TF2104 has a typical rise/fall time of 70ns/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 (TF2104 operates at logic 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.
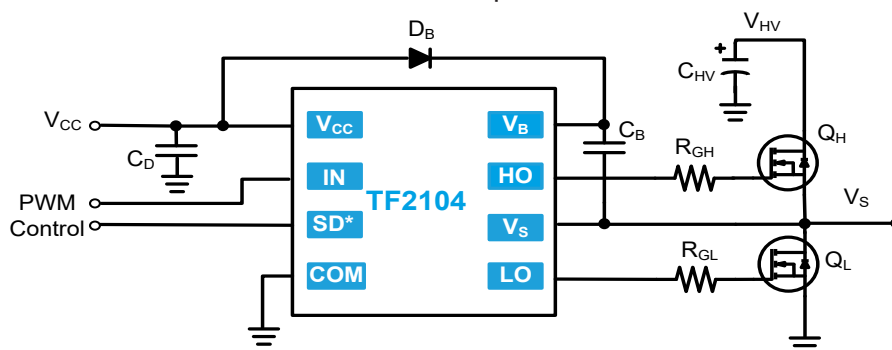

Figure 28. TF2104 in a half-bridge configuration

Bootstrap Operation

The supply for the TF2104 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 ot 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 1μF to 10μF 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.
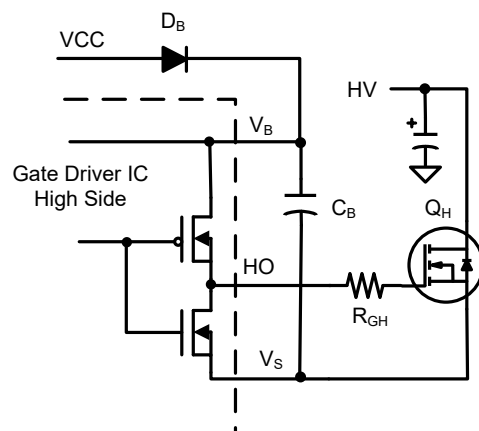

Figure 29. TF2104 high side in bootstrap operation

For a more detailed description on Gate Resistor Selection and Bootstrap Capacitor Selectrion, see the TF Semiconductor's High Voltage 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 VS. 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 RGH = 5Ω - 20Ω. For motors, the switching speed is generally slower, and the application has more inherent noise, so higher values are recommended, for example RGH = 20Ω - 100Ω.
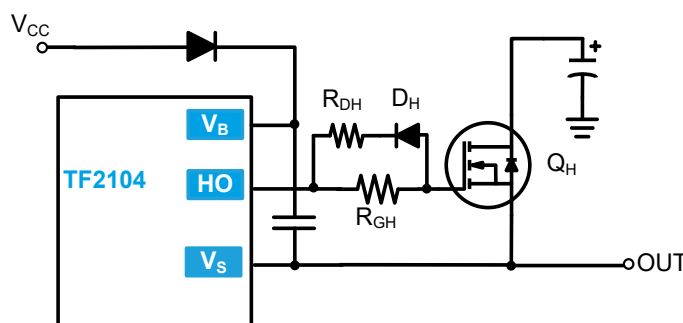

Figure 30. Gate Drive Control

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.

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 boostrap 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 1µF to 10µF. A second smaller decoupling capacitor is sometimes added to provide better high frequency response (for example 0.1µF).

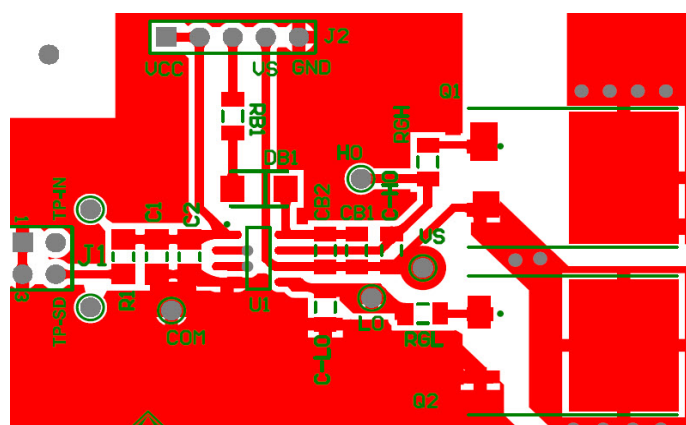**Figure 31.** Layout Suggestions for TF2104 in a halfbridge

Figure 32. Layout example for TF2104 (U1) in a halfbridge, notice the bootstrap caps (CB1, CB2), VCC caps (C1 and C2), and bootstrap diode (DB1) adjacent to the IC.
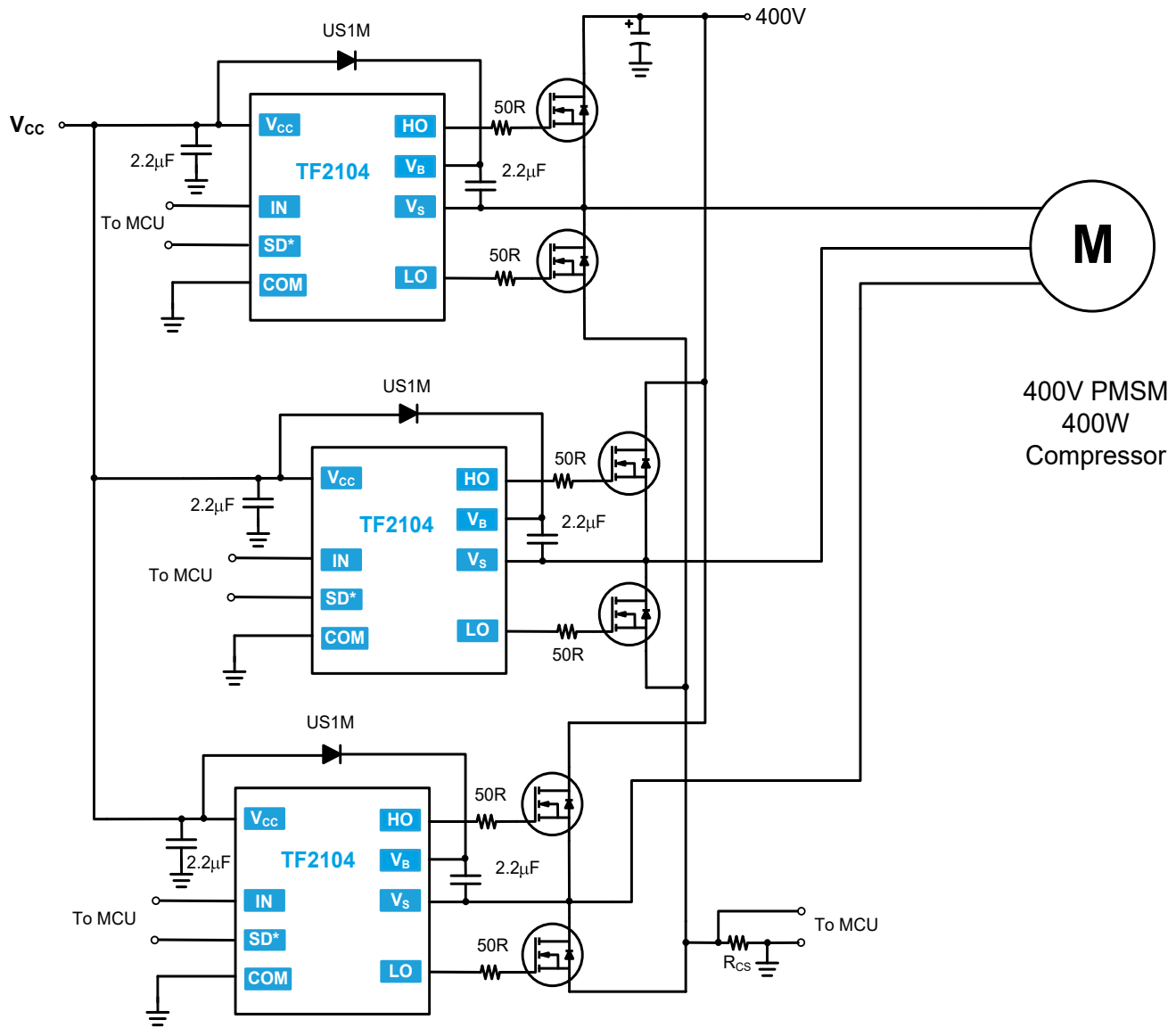
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Application Example
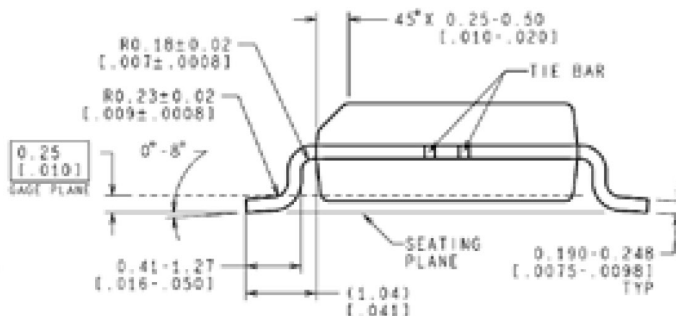

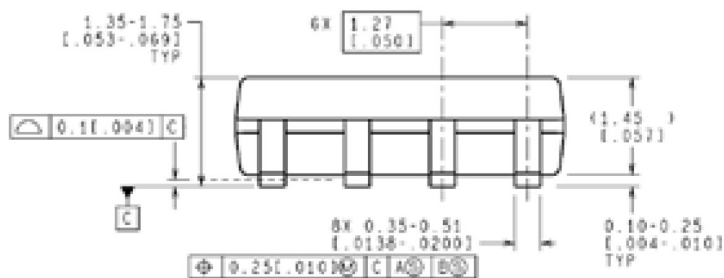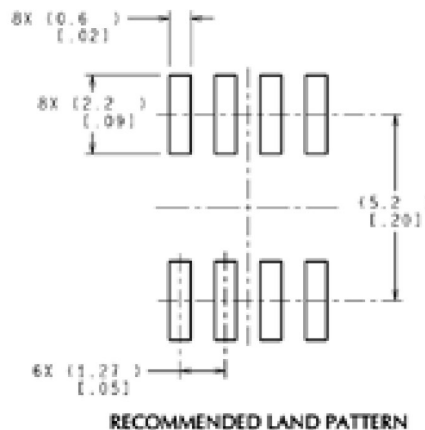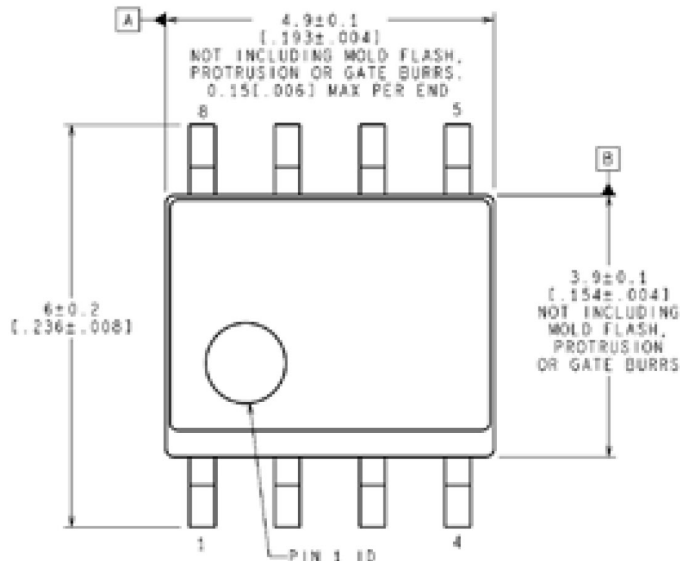**Figure 33.** Three Phase Motor Driver using the TF2104
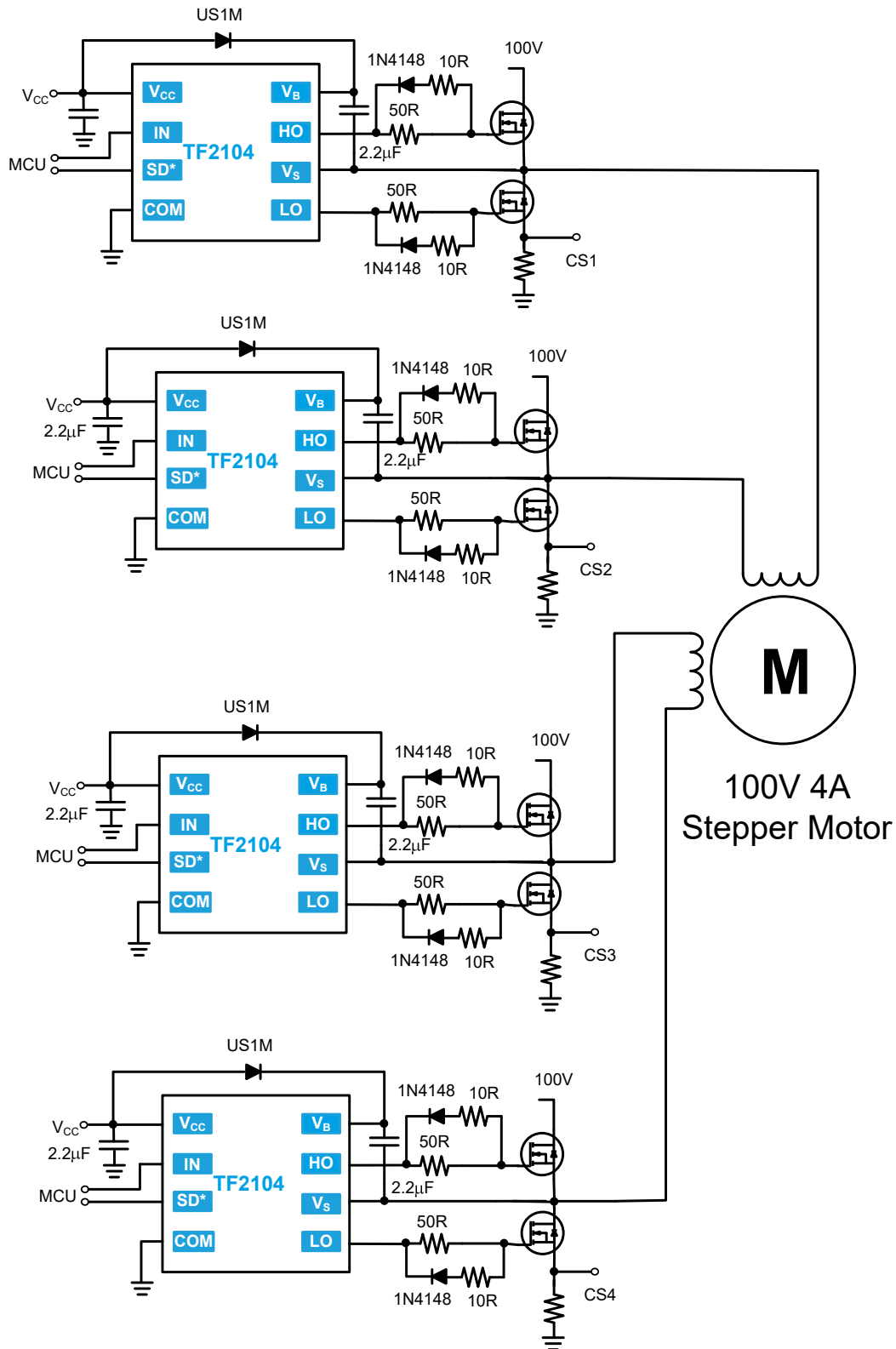
Figure 34. Motor Driver using the TF2104 for 100V, 4A Stepper Motor

Package Dimensions (SOIC-8 N)

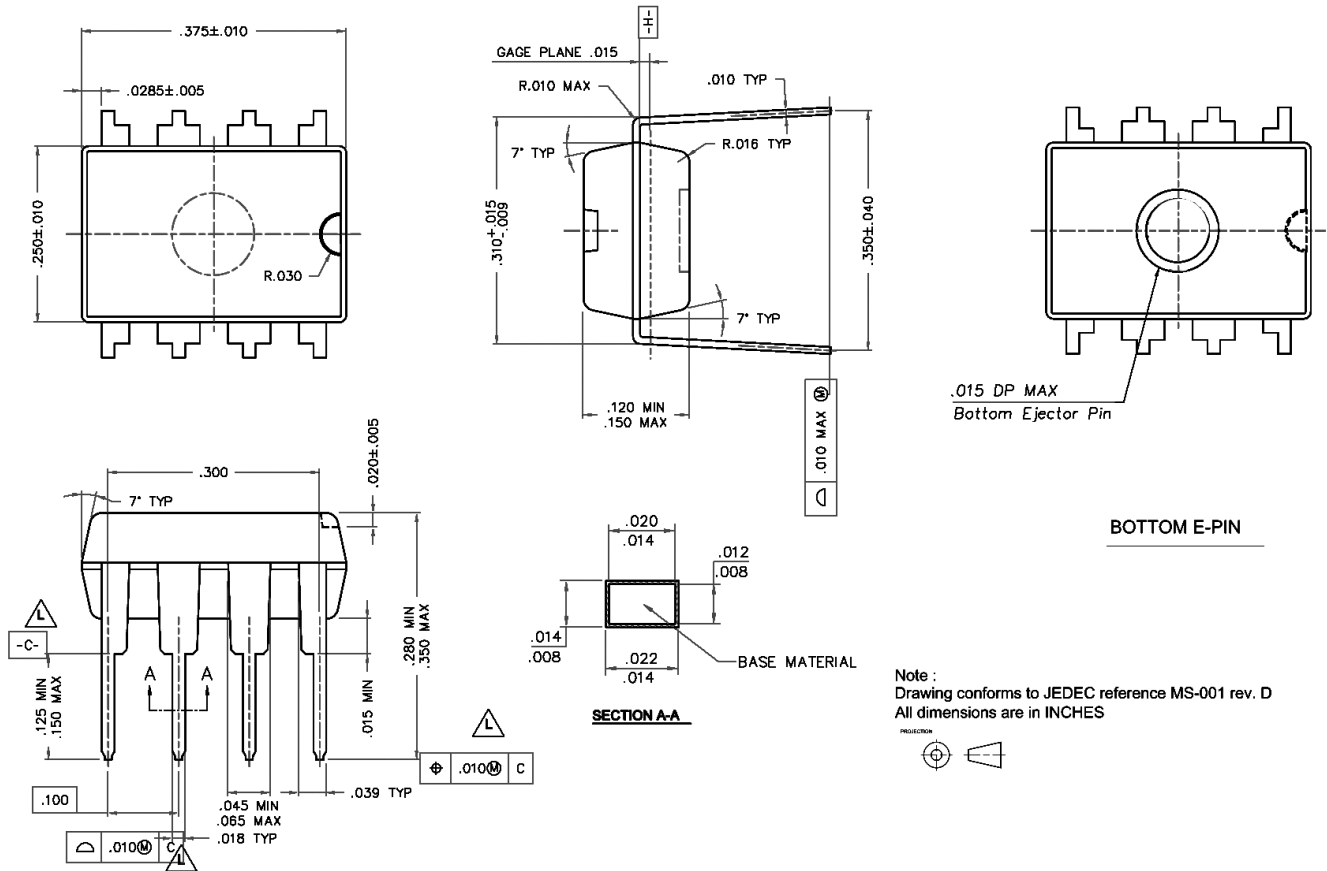Please contact support@tfsemi.com for package availability.

RECOMMENDED LAND PATTERN

NOTES: UNLESS OTHERWISE SPECIFIED

1. REFERENCE JEDEC REGISTRATION MS-012, VARIATION AA.

CONTROLLING DIMENSION IS MILLIMETER
VALUES IN [ ] ARE INCHES
DIMENSIONS IN [ ] FOR REFERENCE ONLY

Package Dimensions (PDIP-8)

Please contact support@tfsemi.com for package availability.

BOTTOM E-PIN

.015 DP MAX
Bottom Ejector Pin

SECTION A-A

BASE MATERIAL

Note :
Drawing conforms to JEDEC reference MS-001 rev. D
All dimensions are in INCHES

Revision History

Rev.	Change	Owner	Date
1.0	First release, final datasheet	Keith Spaulding	1/29/2016
1.1	Added deadtime graphs, fig. 12 and fig 13	Keith Spaulding	2/26/2016
1.2	Text edit	Keith Spaulding	7/17/2017
1.3	Add Note 5	Duke Walton	7/25/2019

Important Notice

For additional information please contact support@tfproducts.com or visit www.tfsemi.com