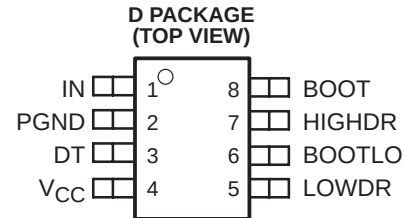


TPS2832, TPS2833 FAST SYNCHRONOUS-BUCK MOSFET DRIVERS WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

- Floating Bootstrap or Ground-Reference High-Side Driver
- Adaptive Dead-Time Control
- 50-ns Max Rise/Fall Times and 100-ns Max Propagation Delay – 3.3-nF Load
- Ideal for High-Current Single or Multiphase Power Supplies
- 2.4-A Typical Peak Output Current
- 4.5-V to 15-V Supply Voltage Range
- Internal Schottky Bootstrap Diode
- Low Supply Current...3-mA Typical
- –40°C to 125°C Operating Virtual Junction Temperature
- Available in SOIC Package



description

The TPS2832 and TPS2833 are MOSFET drivers for synchronous-buck power stages. These devices are ideal for designing a high-performance power supply using switching controllers that do not have MOSFET drivers. The drivers are designed to deliver 2.4-A peak currents into large capacitive loads. The high-side driver can be configured as a ground-reference driver or as a floating bootstrap driver. An adaptive dead-time control circuit eliminates shoot-through currents through the main power FETs during switching transitions and provides high efficiency for the buck regulator.

The TPS2832 has a noninverting input. The TPS2833 has an inverting input. The TPS2832/33 drivers, available in 8-terminal SOIC packages, operate over a junction temperature range of –40°C to 125°C.

AVAILABLE OPTIONS

T _J	PACKAGED DEVICES
	SOIC (D)
–40°C to 125°C	TPS2832D TPS2833D

The D package is available taped and reeled. Add R suffix to device type (e.g., TPS2832DR)

Related Synchronous MOSFET Drivers

DEVICE NAME	ADDITIONAL FEATURES	INPUTS	
TPS2830	ENABLE, SYNC and CROWBAR	CMOS	Noninverted
TPS2831			Inverted
TPS2834	ENABLE, SYNC and CROWBAR	TTL	Noninverted
TPS2835			Inverted
TPS2836	W/O ENABLE, SYNC and CROWBAR	TTL	Noninverted
TPS2837			Inverted



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 2001, Texas Instruments Incorporated

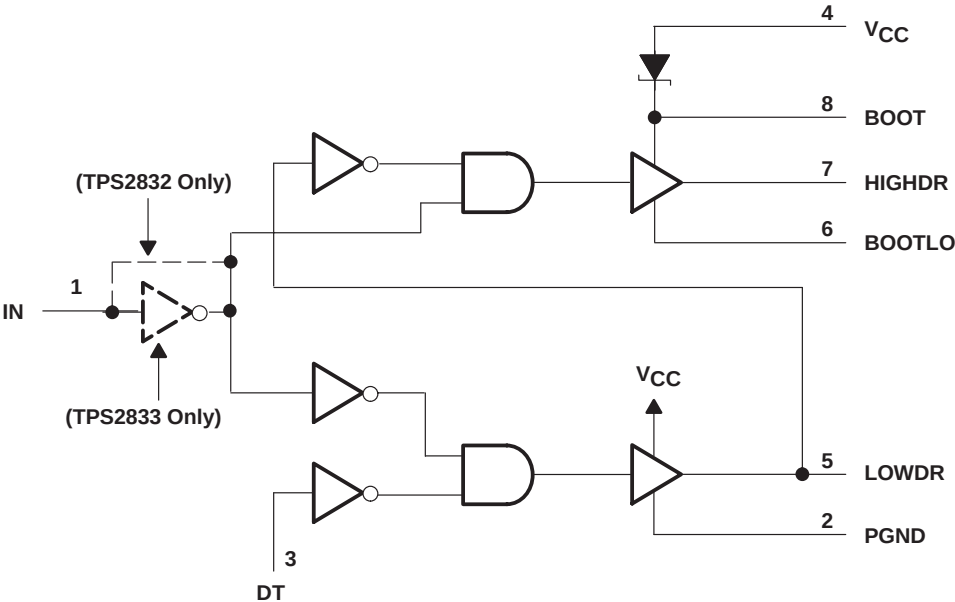
TPS2832, TPS2833

FAST SYNCHRONOUS-BUCK MOSFET DRIVERS

WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

functional block diagram



TERMINAL		I/O	DESCRIPTION
NAME	NO.		
BOOT	8	I	Bootstrap terminal. A ceramic capacitor is connected between BOOT and BOOTLO terminals to develop the floating bootstrap voltage for the high-side MOSFET. The capacitor value is typically between 0.1 μ F and 1 μ F. A 1-M Ω resistor should be connected across the bootstrap capacitor to provide a discharge path when the driver has been powered down.
BOOTLO	6	O	This terminal connects to the junction of the high-side and low-side MOSFETs.
DT	3	I	Dead-time control terminal. Connect DT to the junction of the high-side and low-side MOSFETs
HIGHDR	7	O	Output drive for the high-side power MOSFET
IN	1	I	Input signal to the MOSFET drivers (noninverting input for the TPS2832; inverting input for the TPS2833).
LOWDR	5	O	Output drive for the low-side power MOSFET
PGND	2		Power ground. Connect to the FET power ground.
VCC	4	I	Input supply. Recommended that a 1 μ F capacitor be connected from VCC to PGND.

detailed description

low-side driver

The low-side driver is designed to drive low $R_{ds(on)}$ N-channel MOSFETs. The current rating of the driver is 2 A, source and sink.

high-side driver

The high-side driver is designed to drive low $R_{ds(on)}$ N-channel MOSFETs. The current rating of the driver is 2 A, source and sink. The high-side driver can be configured as a ground-reference driver or a floating bootstrap driver. The internal bootstrap diode, is a Schottky for improved drive efficiency. The maximum voltage that can be applied between the BOOT terminal and ground is 30 V.

dead-time (DT) control[†]

Dead-time control prevents shoot through current from flowing through the main power FETs during switching transitions by controlling the turn-on times of the MOSFET drivers. The high-side driver is not allowed to turn on until the gate drive voltage to the low-side FET is low, and the low-side driver is not allowed to turn on until the voltage at the junction of the power FETs (V_{drain}) is low; the DT terminal connects to the junction of the power FETs.

IN[†]

The IN terminal is a digital terminal that is the input control signal for the drivers. The TPS2832 has a noninverting input; the TPS2833 has an inverting input.

[†]High-level input voltages on IN and DT must be greater than or equal to $0.7V_{CC}$.

TPS2832, TPS2833

FAST SYNCHRONOUS-BUCK MOSFET DRIVERS

WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

absolute maximum ratings over operating free-air temperature (unless otherwise noted)[†]

Supply voltage range, V_{CC} (see Note 1)	–0.3 V to 16 V
Input voltage range: BOOT to PGND (high-side driver ON)	–0.3 V to 30 V
BOOTLO to PGND	–0.3 V to 16 V
BOOT to BOOTLO	–0.3 V to 16 V
IN (see Note 2)	–0.3 V to 16 V
DT (see Note 2)	–0.3 V to 30 V
Continuous total power dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, T_J	–40°C to 125°C
Storage temperature range, T_{stg}	–65°C to 150°C
Lead temperature soldering 1,6 mm (1/16 inch) from case for 10 seconds	260°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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. Unless otherwise specified, all voltages are with respect to PGND.
2. High-level input voltages on the IN and DT terminals must be less than or equal to V_{CC} .

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
D	600 mW	6.0 mW/°C	330 mW	240 mW

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}	4.5		15	V
Input voltage	4.5		28	V

electrical characteristics over recommended operating virtual junction temperature range, $V_{CC} = 6.5$ V, $C_L = 3.3$ nF (unless otherwise noted)

supply current

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply voltage range		4.5		15	V
V_{CC}	Quiescent current	$V_{CC} = 15$ V		100	μA
		$V_{CC} = 12$ V, $f_{SWX} = 200$ kHz, $C_{HIGHDR} = 50$ pF,	BOOTLO grounded, $C_{LOWDR} = 50$ pF, See Note 3	3	mA

NOTE 3: Ensured by design, not production tested.

TPS2832, TPS2833
FAST SYNCHRONOUS-BUCK MOSFET DRIVERS
WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

electrical characteristics over recommended operating virtual junction temperature range,
 $V_{CC} = 6.5\text{ V}$, $C_L = 3.3\text{ nF}$ (unless otherwise noted) (continued)

output drivers

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
Peak output-current	High-side sink (see Note 4)	Duty cycle < 2%, $t_{pw} < 100\text{ }\mu\text{s}$ (see Note 3)	$V_{BOOT} - V_{BOOTLO} = 4.5\text{ V}$, $V_{HIGHDR} = 4\text{ V}$	0.7	1.1		A
			$V_{BOOT} - V_{BOOTLO} = 6.5\text{ V}$, $V_{HIGHDR} = 5\text{ V}$	1.1	1.5		
			$V_{BOOT} - V_{BOOTLO} = 12\text{ V}$, $V_{HIGHDR} = 10.5\text{ V}$	2	2.4		
	High-side source (see Note 4)	Duty cycle < 2%, $t_{pw} < 100\text{ }\mu\text{s}$ (see Note 3)	$V_{BOOT} - V_{BOOTLO} = 4.5\text{ V}$, $V_{HIGHDR} = 0.5\text{ V}$	1.2	1.4		A
			$V_{BOOT} - V_{BOOTLO} = 6.5\text{ V}$, $V_{HIGHDR} = 1.5\text{ V}$	1.3	1.6		
			$V_{BOOT} - V_{BOOTLO} = 12\text{ V}$, $V_{HIGHDR} = 1.5\text{ V}$	2.3	2.7		
	Low-side sink (see Note 4)	Duty cycle < 2%, $t_{pw} < 100\text{ }\mu\text{s}$ (see Note 3)	$V_{CC} = 4.5\text{ V}$, $V_{LOWDR} = 4\text{ V}$	1.3	1.8		A
			$V_{CC} = 6.5\text{ V}$, $V_{LOWDR} = 5\text{ V}$	2	2.5		
			$V_{CC} = 12\text{ V}$, $V_{LOWDR} = 10.5\text{ V}$	3	3.5		
	Low-side source (see Note 4)	Duty cycle < 2%, $t_{pw} < 100\text{ }\mu\text{s}$ (see Note 3)	$V_{CC} = 4.5\text{ V}$, $V_{LOWDR} = 0.5\text{ V}$	1.4	1.7		A
			$V_{CC} = 6.5\text{ V}$, $V_{LOWDR} = 1.5\text{ V}$	2	2.4		
			$V_{CC} = 12\text{ V}$, $V_{LOWDR} = 1.5\text{ V}$	2.5	3		
Output resistance	High-side sink (see Note 4)		$V_{BOOT} - V_{BOOTLO} = 4.5\text{ V}$, $V_{HIGHDR} = 0.5\text{ V}$			5	Ω
			$V_{BOOT} - V_{BOOTLO} = 6.5\text{ V}$, $V_{HIGHDR} = 0.5\text{ V}$			5	
			$V_{BOOT} - V_{BOOTLO} = 12\text{ V}$, $V_{HIGHDR} = 0.5\text{ V}$			5	
	High-side source (see Note 4)		$V_{BOOT} - V_{BOOTLO} = 4.5\text{ V}$, $V_{HIGHDR} = 4\text{ V}$			75	Ω
			$V_{BOOT} - V_{BOOTLO} = 6.5\text{ V}$, $V_{HIGHDR} = 6\text{ V}$			75	
			$V_{BOOT} - V_{BOOTLO} = 12\text{ V}$, $V_{HIGHDR} = 11.5\text{ V}$			75	
	Low-side sink (see Note 4)		$V_{DRV} = 4.5\text{ V}$, $V_{LOWDR} = 0.5\text{ V}$			9	Ω
			$V_{DRV} = 6.5\text{ V}$, $V_{LOWDR} = 0.5\text{ V}$			7.5	
			$V_{DRV} = 12\text{ V}$, $V_{LOWDR} = 0.5\text{ V}$			6	
	Low-side source (see Note 4)		$V_{DRV} = 4.5\text{ V}$, $V_{LOWDR} = 4\text{ V}$			75	Ω
			$V_{DRV} = 6.5\text{ V}$, $V_{LOWDR} = 6\text{ V}$			75	
			$V_{DRV} = 12\text{ V}$, $V_{LOWDR} = 11.5\text{ V}$			75	

NOTES: 3. Ensured by design, not production tested.

4. The pull-up/pull-down circuits of the drivers are bipolar and MOSFET transistors in parallel. The peak output current rating is the combined current from the bipolar and MOSFET transistors. The output resistance is the $R_{ds(on)}$ of the MOSFET transistor when the voltage on the driver output is less than the saturation voltage of the bipolar transistor.

dead time

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IH}	High-level input voltage	LOWDR	$0.7V_{CC}$		1	V
V_{IL}	Low-level input voltage					
V_{IH}	High-level input voltage	DT	$0.7V_{CC}$		1	V
V_{IL}	Low-level input voltage					

NOTE 3: Ensured by design, not production tested.

digital control terminals

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IH}	High-level input voltage	Over the V_{CC} range	$0.7V_{CC}$		1	V
V_{IL}	Low-level input voltage					



TPS2832, TPS2833

FAST SYNCHRONOUS-BUCK MOSFET DRIVERS

WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

switching characteristics over recommended operating virtual junction temperature range,
 $C_L = 3.3 \text{ nF}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Rise time	HIGHDR output (see Note 3)	$V_{BOOT} = 4.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			60	ns
		$V_{BOOT} = 6.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			50	
		$V_{BOOT} = 12 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			50	
	LOWDR output (see Note 3)	$V_{CC} = 4.5 \text{ V}$			40	ns
		$V_{CC} = 6.5 \text{ V}$			30	
		$V_{CC} = 12 \text{ V}$			30	
Fall time	HIGHDR output (see Note 3)	$V_{BOOT} = 4.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			60	ns
		$V_{BOOT} = 6.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			50	
		$V_{BOOT} = 12 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			50	
	LOWDR output (see Note 3)	$V_{CC} = 4.5 \text{ V}$			40	ns
		$V_{CC} = 6.5 \text{ V}$			30	
		$V_{CC} = 12 \text{ V}$			30	
Propagation delay time	HIGHDR going low (excluding dead time) (see Note 3)	$V_{BOOT} = 4.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			130	ns
		$V_{BOOT} = 6.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			100	
		$V_{BOOT} = 12 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			75	
	LOWDR going high (excluding dead time) (see Note 3)	$V_{BOOT} = 4.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			80	ns
		$V_{BOOT} = 6.5 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			70	
		$V_{BOOT} = 12 \text{ V}, V_{BOOTLO} = 0 \text{ V}$			60	
Propagation delay time	LOWDR going low (excluding dead time) (see Note 3)	$V_{CC} = 4.5 \text{ V}$			80	ns
		$V_{CC} = 6.5 \text{ V}$			70	
		$V_{CC} = 12 \text{ V}$			60	
Driver nonoverlap time	DT to LOWDR and LOWDR to HIGHDR (see Note 3)	$V_{CC} = 4.5 \text{ V}$	40		170	ns
		$V_{CC} = 6.5 \text{ V}$	25		135	
		$V_{CC} = 12 \text{ V}$	15		85	

NOTE 3: Ensured by design, not production tested.

TPS2832, TPS2833 FAST SYNCHRONOUS-BUCK MOSFET DRIVERS WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

TYPICAL CHARACTERISTICS

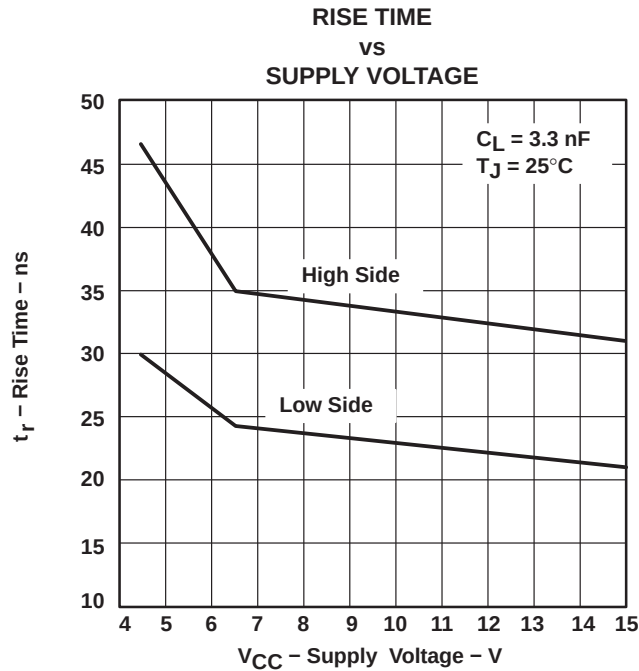


Figure 1

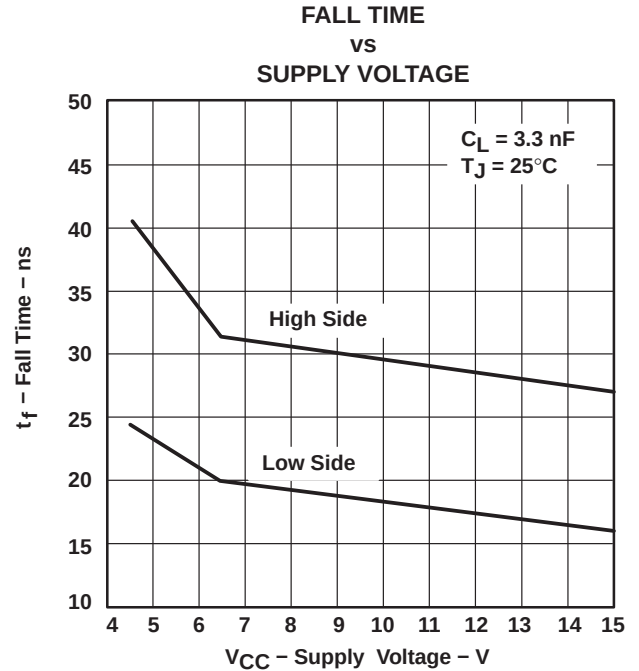


Figure 2

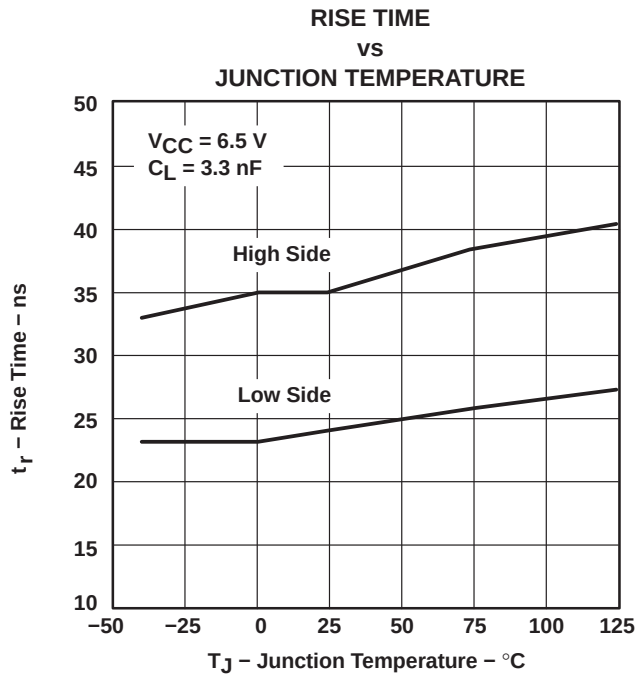


Figure 3

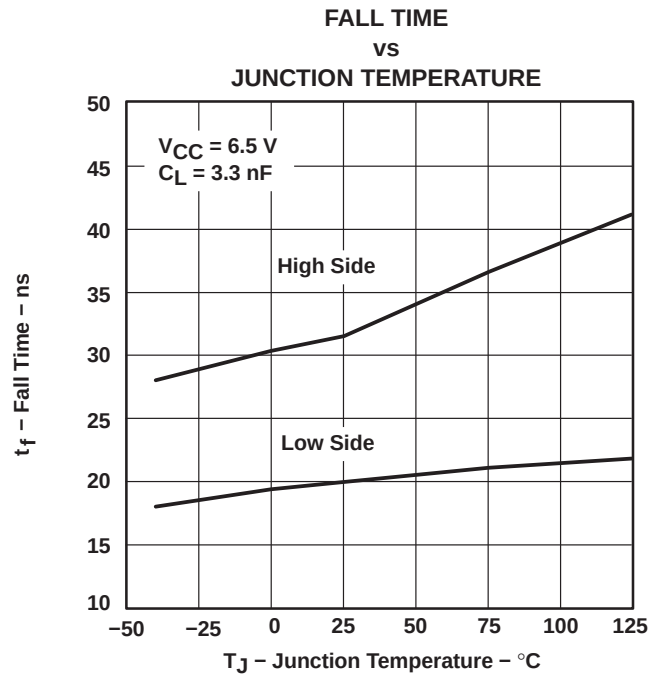


Figure 4

TPS2832, TPS2833

FAST SYNCHRONOUS-BUCK MOSFET DRIVERS

WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

TYPICAL CHARACTERISTICS

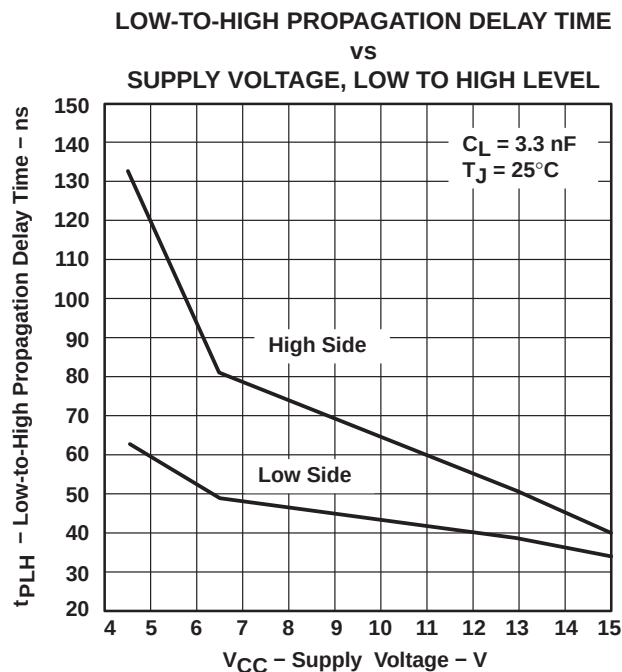


Figure 5

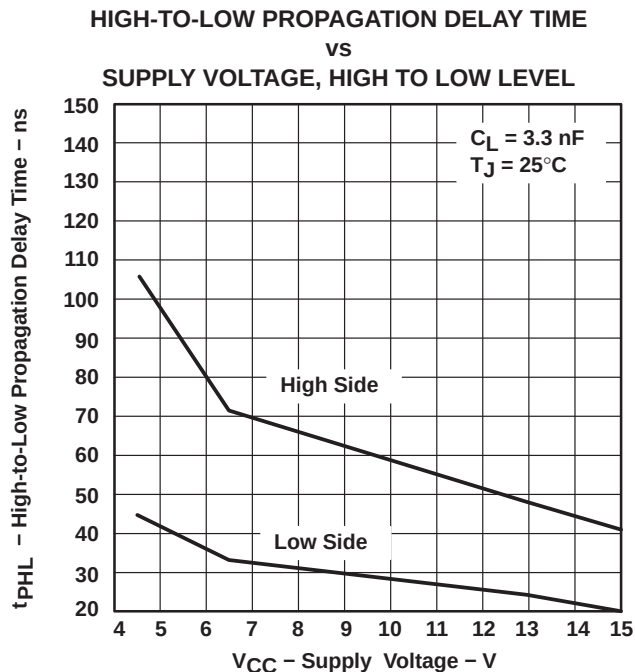


Figure 6

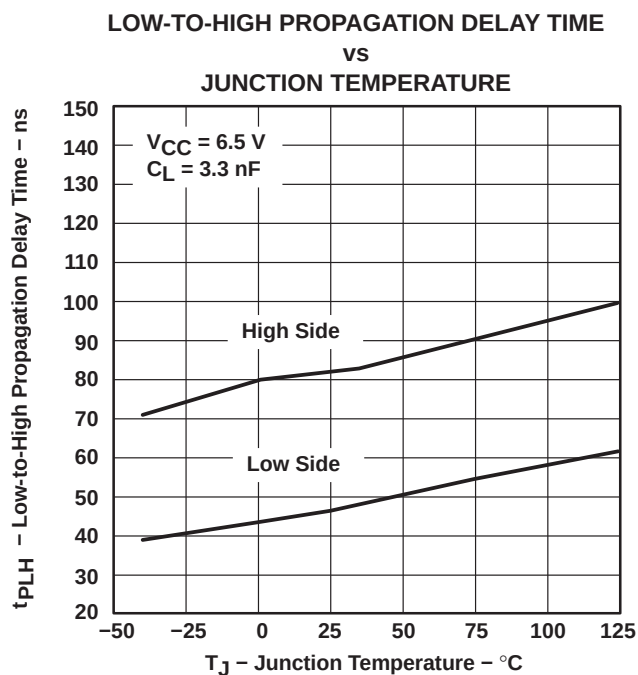


Figure 7

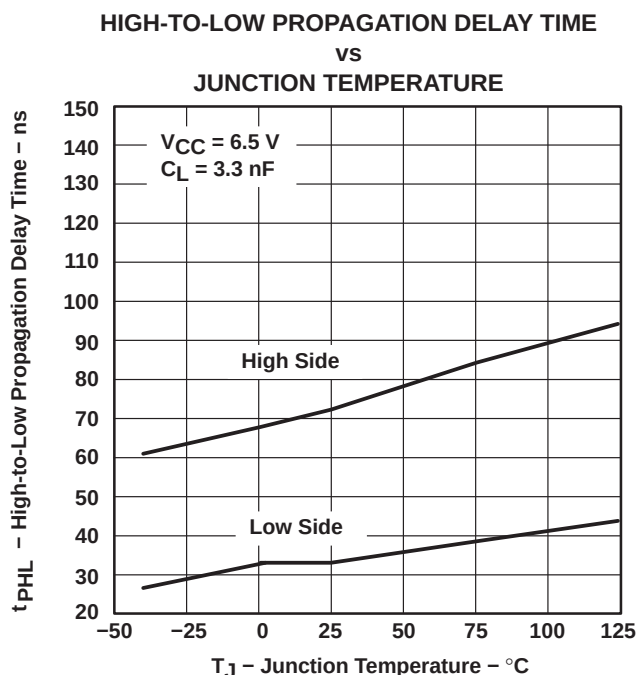
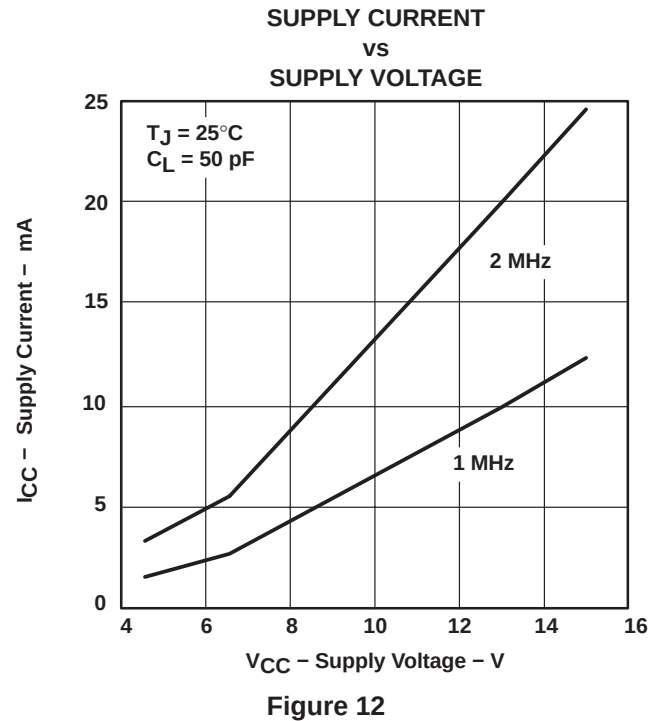
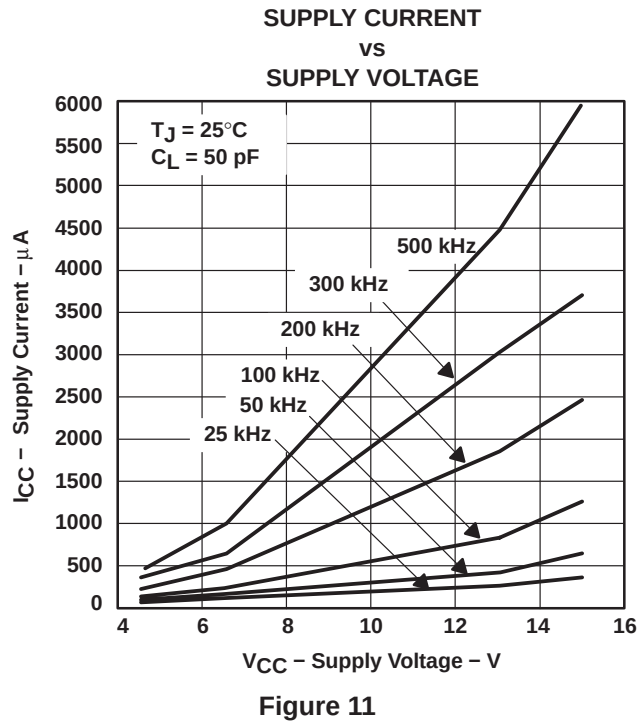
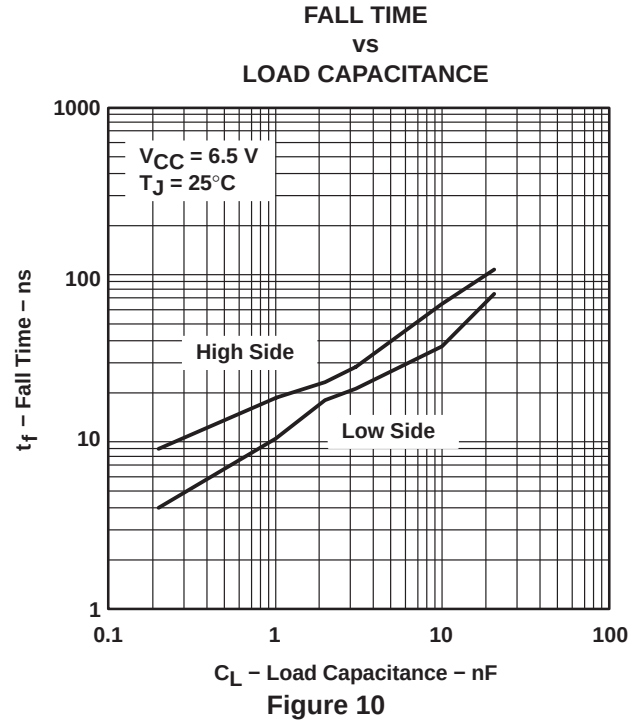
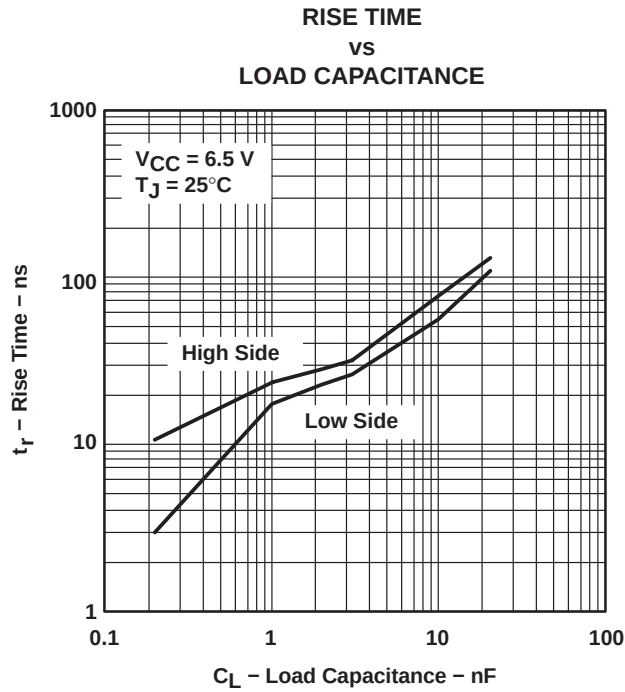


Figure 8

TPS2832, TPS2833 FAST SYNCHRONOUS-BUCK MOSFET DRIVERS WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

TYPICAL CHARACTERISTICS



TPS2832, TPS2833 FAST SYNCHRONOUS-BUCK MOSFET DRIVERS WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

TYPICAL CHARACTERISTICS

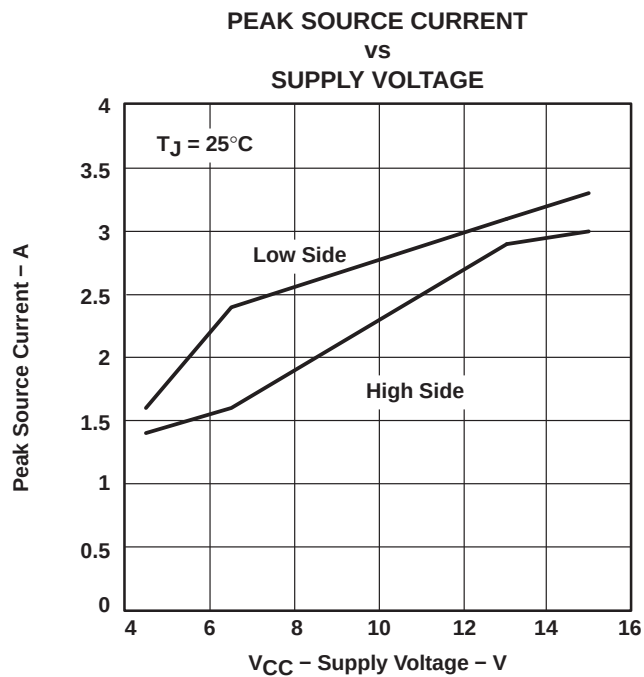


Figure 13

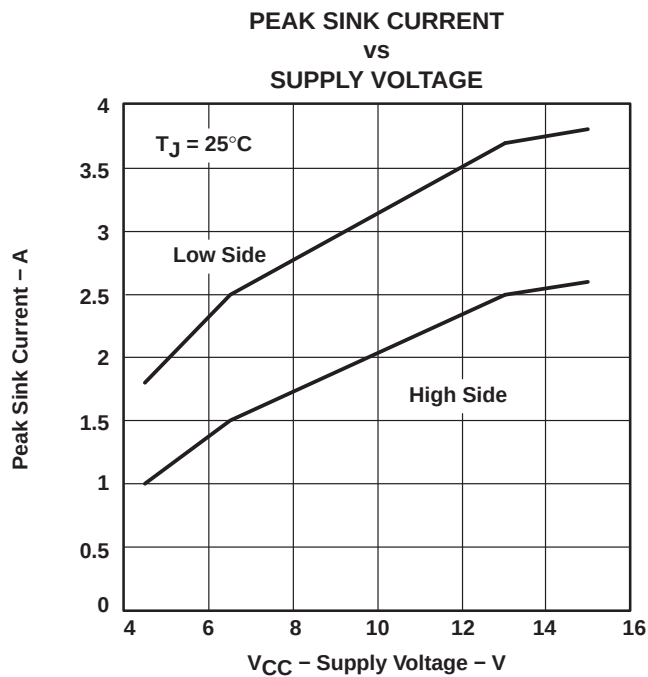


Figure 14

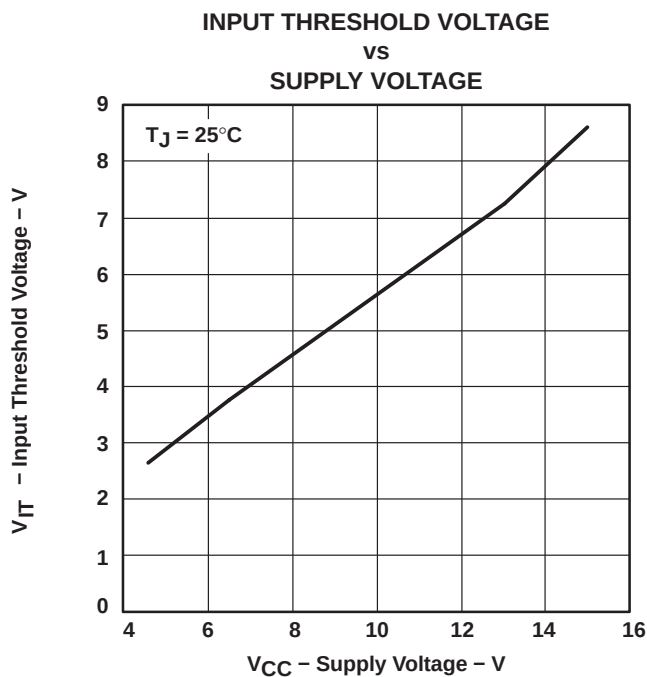


Figure 15

TPS2832, TPS2833 FAST SYNCHRONOUS-BUCK MOSFET DRIVERS WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

APPLICATION INFORMATION

Figure 16 shows the circuit schematic of a 100-kHz synchronous-buck converter implemented with a TL5001A pulse-width-modulation (PWM) controller and a TPS2833 driver. The converter operates over an input range from 4.5 V to 12 V and has a 3.3 V output. The circuit can supply 3 A continuous load and the transient load is 5 A. The converter achieves an efficiency of 94% for $V_{IN} = 5$ V, $I_{load} = 1$ A, and 93% for $V_{IN} = 5$ V, $I_{load} = 3$ A.

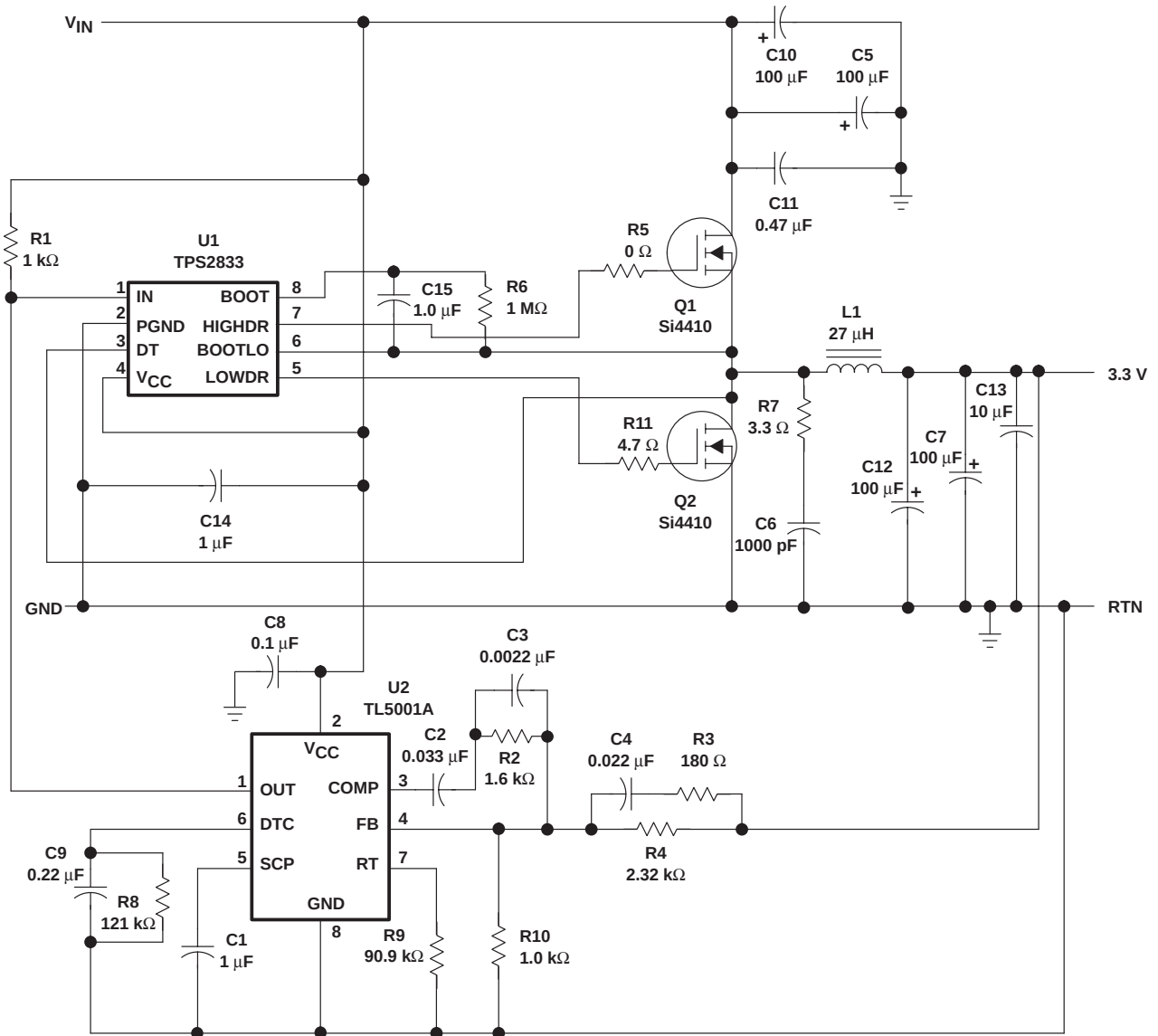


Figure 16. 3.3 V 3 A Synchronous-Buck Converter Circuit

TPS2832, TPS2833

FAST SYNCHRONOUS-BUCK MOSFET DRIVERS

WITH DEAD-TIME CONTROL

SLVS195C – FEBRUARY 1999 – REVISED JANUARY 2001

APPLICATION INFORMATION

Great care should be taken when laying out the pc board. The power-processing section is the most critical and will generate large amounts of EMI if not properly configured. The junction of Q1, Q2, and L1 should be very tight. The connection from Q1 drain to the positive sides of C5, C10, and C11 and the connection from Q2 source to the negative sides of C5, C10, and C11 should be as short as possible. The negative terminals of C7 and C12 should also be connected to Q2 source.

Next, the traces from the MOSFET driver to the power switches should be considered. The BOOTLO signal from the junction of Q1 and Q2 carries the large gate drive current pulses and should be as heavy as the gate drive traces. The bypass capacitor (C14) should be tied directly across V_{CC} and PGND.

The next most sensitive node is the FB node on the controller (terminal 4 on the TL5001A) This node is very sensitive to noise pickup and should be isolated from the high-current power stage and be as short as possible. The ground around the controller and low-level circuitry should be tied to the power ground as the output. If these three areas are properly laid out, the rest of the circuit should not have any other EMI problems and the power supply will be relatively free of noise.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS2832D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2832	Samples
TPS2832DG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2832	Samples
TPS2832DR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2832	Samples
TPS2832DRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2832	Samples
TPS2833D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2833	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBsolete: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

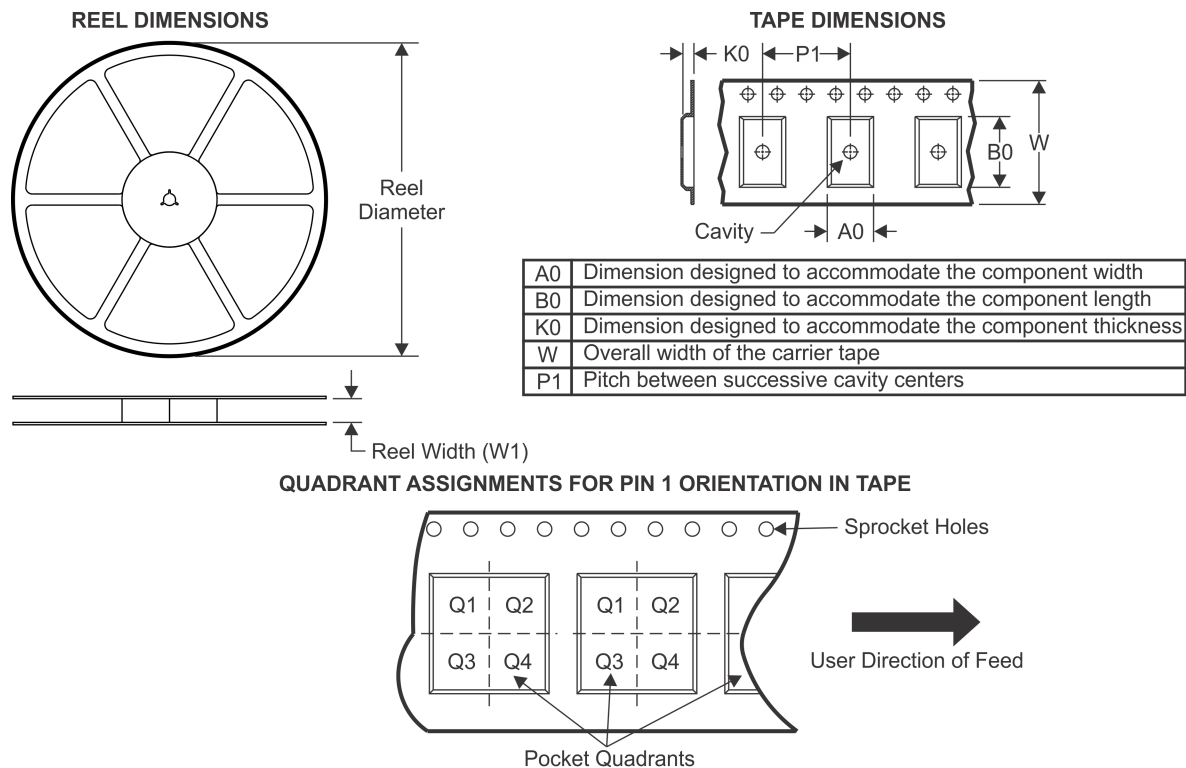
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

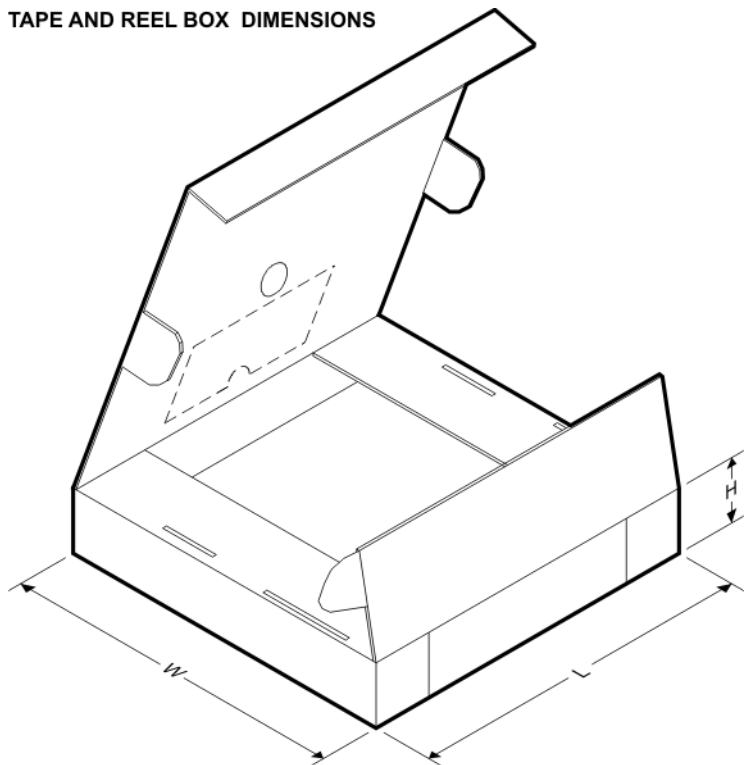
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS2832DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TPS2832DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS2832DR	SOIC	D	8	2500	340.5	338.1	20.6
TPS2832DR	SOIC	D	8	2500	367.0	367.0	38.0

IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.