

SGx524 Regulating Pulse-Width Modulators

1 Features

- Complete Pulse-Width Modulation (PWM) Power-Control Circuitry
- Uncommitted Outputs for Single-Ended or Push-Pull Applications
- 8 mA (TYP) Standby Current

2 Applications

- Transformer-coupled DC/DC convertors
- Switching-regulators of any polarity

3 Description

The SG2524 and SG3524 devices incorporate all the functions required in the construction of a regulating power supply, inverter, or switching regulator on a single chip. They also can be used as the control element for high-power-output applications. The SG2524 and SG3524 were designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers, and polarity-converter applications employing fixed-frequency, pulse-width modulation (PWM) techniques. The complementary output allows either single-ended or push-pull application. Each device includes an on-chip regulator, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted pass transistors, a high-gain comparator, and current-limiting and shutdown circuitry.

Device Information⁽¹⁾

PART NUMBER	PACKAGE (PIN)	BODY SIZE (NOM)
SGx524	SOIC (16)	9.90 mm × 3.91 mm
	PDIP (16)	9.90 mm × 6.35 mm
	NS (16)	10.30 mm × 5.30 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

4 Pinout Drawing

SG2524 . . . D OR N PACKAGE
SG3524 . . . D, N, OR NS PACKAGE
(TOP VIEW)

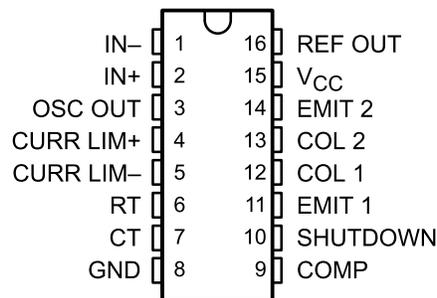


Table of Contents

1 Features	1	9.2 Functional Block Diagram	9
2 Applications	1	9.3 Feature Description	10
3 Description	1	9.4 Device Functional Modes	11
4 Pinout Drawing	1	10 Application and Implementation	12
5 Revision History	2	10.1 Application Information	12
6 Pin Configurations and Functions	3	10.2 Typical Application	14
7 Specifications	4	10.3 Examples of Other Output Stages	16
7.1 Absolute Maximum Ratings	4	11 Power Supply Recommendations	18
7.2 ESD Ratings	4	12 Layout	18
7.3 Recommended Operating Conditions	4	12.1 Layout Guidelines	18
7.4 Thermal Information	4	12.2 Layout Example	19
7.5 Electrical Characteristics	5	13 Device and Documentation Support	20
7.6 Electrical Characteristics — Continued, Both Parts ..	6	13.1 Related Links	20
7.7 Typical Characteristics	7	13.2 Trademarks	20
8 Parameter Measurement Information	8	13.3 Electrostatic Discharge Caution	20
9 Detailed Description	9	13.4 Glossary	20
9.1 Overview	9	14 Mechanical, Packaging, and Orderable Information	20

5 Revision History

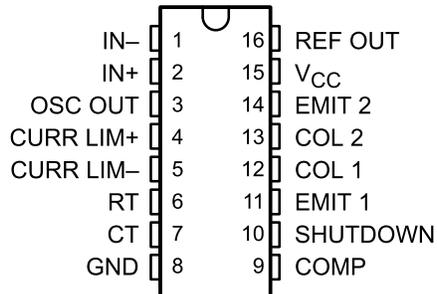
Changes from Revision I (February 2003) to Revision J

Page

• Added <i>Applications</i> , <i>Device Information</i> table, <i>Pin Functions</i> table, <i>ESD Ratings</i> table, <i>Thermal Information</i> table, <i>Typical Characteristics</i> , <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section.	1
• Deleted <i>Ordering Information</i> table.	1

6 Pin Configurations and Functions

SG2524 . . . D OR N PACKAGE
SG3524 . . . D, N, OR NS PACKAGE
(TOP VIEW)



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
COL 1	12	O	Collector terminal of BJT output 1
COL 2	13	O	Collector terminal of BJT output 2
COMP	9	I/O	Error amplifier compensation pin
CT	7	—	Capacitor terminal used to set oscillator frequency
CURR LIM+	4	I	Positive current limiting amplifier input
CURR LIM-	5	I	Negative current limiting amplifier input
EMIT 1	11	O	Emitter terminal of BJT output 1
EMIT 2	14	O	Emitter terminal of BJT output 2
GND	8	—	Ground
IN+	2	I	Positive error amplifier input
IN-	1	I	Positive error amplifier input
OSC OUT	3	O	Oscillator Output
REF OUT	16	O	Reference regulator output
RT	6	—	Resistor terminal used to set oscillator frequency
SHUTDOWN	10	I	Device shutdown
V _{CC}	15	—	Positive supply

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
V _{CC}	Supply voltage ⁽²⁾⁽³⁾		40	V
I _{CC}	Collector output current		100	mA
I _{O(ref)}	Reference output current		50	mA
	Current through CT terminal	–5		mA
T _J	Maximum junction temperature		150	°C
	Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260	°C
T _{stg}	Storage temperature range	–65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* table 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* table are not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground terminal.
- (3) The reference regulator may be bypassed for operation from a fixed 5-V supply by connecting the VCC and reference output (REF OUT) pin both to the supply voltage. In this configuration, the maximum supply voltage is 6 V.

7.2 ESD Ratings

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	1000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽²⁾	1000	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V _{CC}	Supply Voltage	8	40	V
	Reference output current	0	50	mA
	Current through CT terminal	–0.03	–2	mA
R _T	Timing resistor	1.8	100	kΩ
C _T	Timing capacitor	0.001	0.1	μF
T _A	Operating free-air temperature	SG2524	–25	85
		SG3524	0	70

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾	SGx524			UNIT	
	D	N	NS		
	16 PINS				
R _{θJA}	Junction-to-ambient thermal resistance ⁽²⁾⁽³⁾	73	67	64	°C/W

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) Maximum power dissipation is a function of T_{J(max)}, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is PD = (T_{J(max)} – T_A)/θ_{JA}. Operation at the absolute maximum T_J of 150°C can impact reliability.
- (3) The package thermal impedance is calculated in accordance with JESD 51-7.

7.5 Electrical Characteristics

over operating free-air temperature range, $V_{CC} = 20\text{ V}$, $f = 20\text{ kHz}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS ⁽¹⁾	SG2524			SG3524			UNIT	
		MIN	TYP ⁽¹⁾	MAX	MIN	TYP ⁽²⁾	MAX		
Reference section									
Output voltage		4.8	5	5.2	4.6	5	5.4	V	
Input Regulation	$V_{CC} = 8\text{ V to }40\text{ V}$		10	20		10	30	mV	
Ripple rejection	$f = 120\text{ Hz}$		66			66		dB	
Output regulation	$I_O = 0\text{ mA to }20\text{ mA}$		20	50		20	50	mV	
Output voltage change with temperature	$T_A = \text{MIN to MAX}$		0.3%	1%		0.3%	1%		
Short-circuit output current ⁽³⁾	$V_{ref} = 0$		100			100		mA	
Error Amplifier section									
V_{IO}	Input offset voltage	$V_{IC} = 2.5\text{ V}$	0.5	5		2	10	mV	
I_{IB}	Input bias current	$V_{IC} = 2.5\text{ V}$		2	10		2	10	μA
	Open-loop voltage amplification		72	80		60	80	dB	
V_{ICR}	Common-mode input voltage range	$T_A = 25^\circ\text{C}$	1.8 to 3.4			1.8 to 3.4		V	
CMMR	Common-mode rejection ratio			70			70	dB	
B_1	Unity-gain bandwidth			3			3	MHz	
	Output swing	$T_A = 25^\circ\text{C}$	0.5		3.8	0.5		3.8	V

- (1) For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
 (2) All typical values, except for temperature coefficients, are at $T_A = 25^\circ\text{C}$.
 (3) Standard deviation is a measure of the statistical distribution about the mean, as derived from the formula:

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{x})^2}{N - 1}}$$

7.6 Electrical Characteristics — Continued, Both Parts

 over operating free-air temperature range, $V_{CC} = 20\text{ V}$, $f = 20\text{ kHz}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS ⁽¹⁾	MIN	TYP ⁽²⁾	MAX	UNIT
Oscillator section						
f_{OSC}	Oscillator frequency	$C_T = 0.001\ \mu\text{F}$, $R_T = 2\ \text{k}\Omega$		450		kHz
	Standard deviation of frequency ⁽³⁾	All values of voltage, temperature, resistance, and capacitance constant		5		—
Δf_{OSC}	Frequency change with voltage	$V_{CC} = 8\ \text{V}$ to $40\ \text{V}$, $T_A = 25^\circ\text{C}$			1%	—
	Frequency change with temperature	$T_A = \text{MIN}$ to MAX			2%	—
	Output amplitude at OSC OUT	$T_A = 25^\circ\text{C}$		3.5		V
t_W	Output pulse duration (width) at OSC OUT	$C_T = 0.01\ \mu\text{F}$, $T_A = 25^\circ\text{C}$		0.5		μs
Output section						
$V_{(BR)CE}$	Collector-emitter breakdown voltage		40			V
	Collector off-state current	$V_{CE} = 40\ \text{V}$		0.01	50	μA
V_{sat}	Collector-emitter saturation voltage	$I_C = 50\ \text{mA}$		1	2	V
V_O	Emitter output voltage	$V_C = 20\ \text{V}$, $I_E = -250\ \mu\text{A}$	17	18		V
t_r	Turn-off voltage rise time	$R_C = 2\ \text{k}\Omega$		0.2		μs
t_f	Turn-on voltage fall time	$R_C = 2\ \text{k}\Omega$		0.1		μs
Comparator section						
	Maximum duty cycle, each output		45%			
V_{IT}	Input threshold voltage at COMP	Zero duty cycle		1		V
		Maximum duty cycle		3.5		
I_{IB}	Input bias current			-1		μA
Current limiting section						
V_I	Input voltage range		-1		1	V
$V_{(SENSE)}$	Sense voltage at $T_A = 25^\circ\text{C}$	$V_{(IN+)} - V_{(IN-)} \geq 50\ \text{mV}$, $V_{(COMP)} = 2\ \text{V}$	175	200	225	mV
	Temperature coefficient of sense voltage			0.2		$\text{mV}/^\circ\text{C}$
Total Device						
I_{st}	Standby current	$V_{CC} = 40\ \text{V}$, $IN-$, CURR LIM+, C_T , GND, COMP, EMIT 1, EMIT 2 grounded, $IN+$ at $2\ \text{V}$, All other inputs and outputs open		8	10	mA

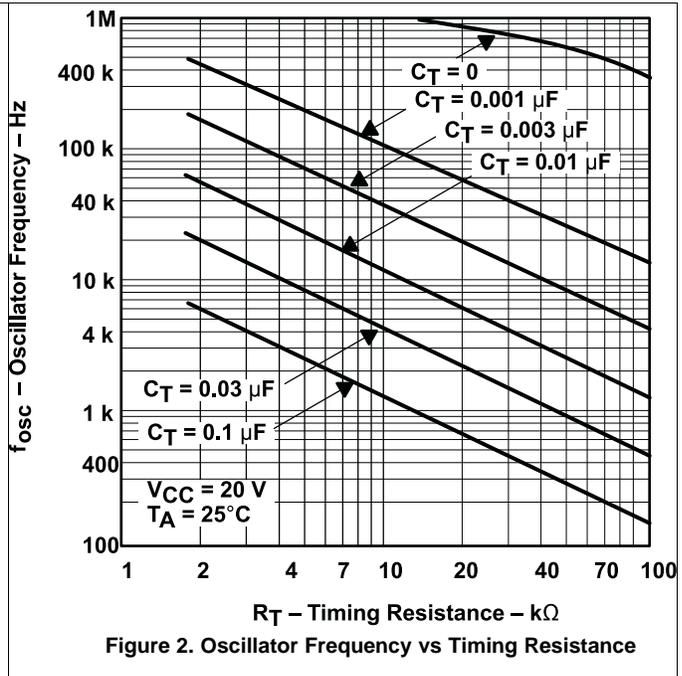
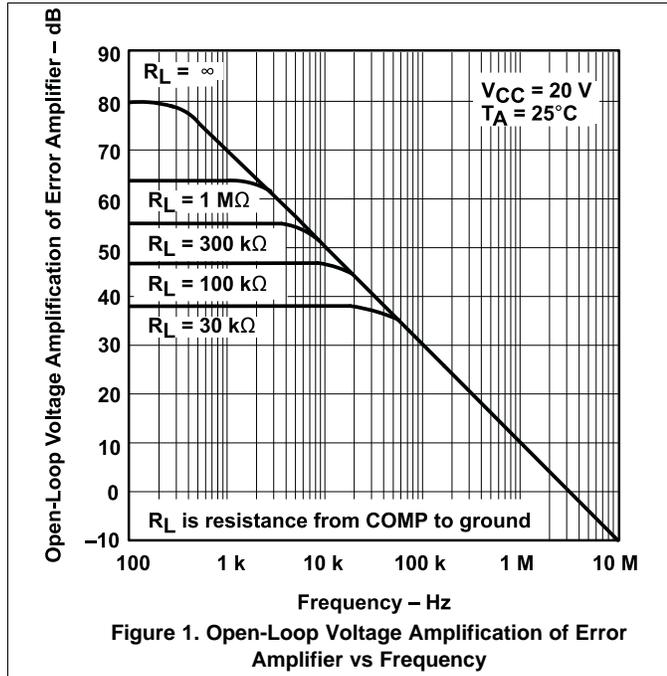
(1) For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

 (2) All typical values, except for temperature coefficients, are at $T_A = 25^\circ\text{C}$.

(3) Standard deviation is a measure of the statistical distribution about the mean, as derived from the formula:

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{x})^2}{N - 1}}$$

7.7 Typical Characteristics



8 Parameter Measurement Information

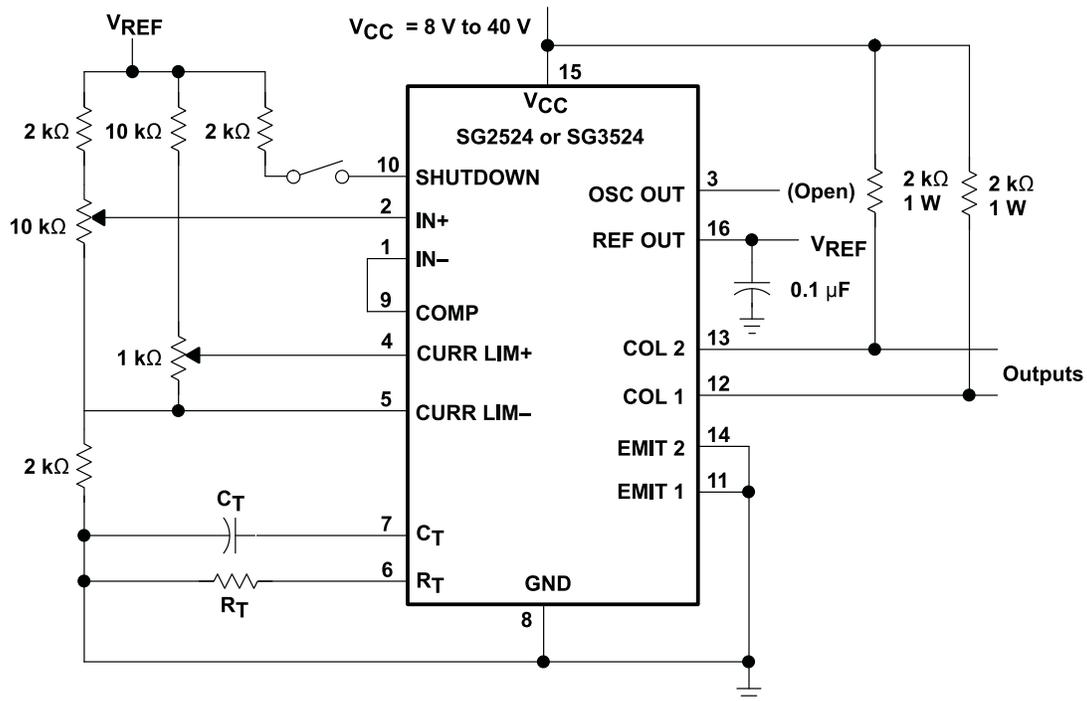


Figure 3. General Test Circuit

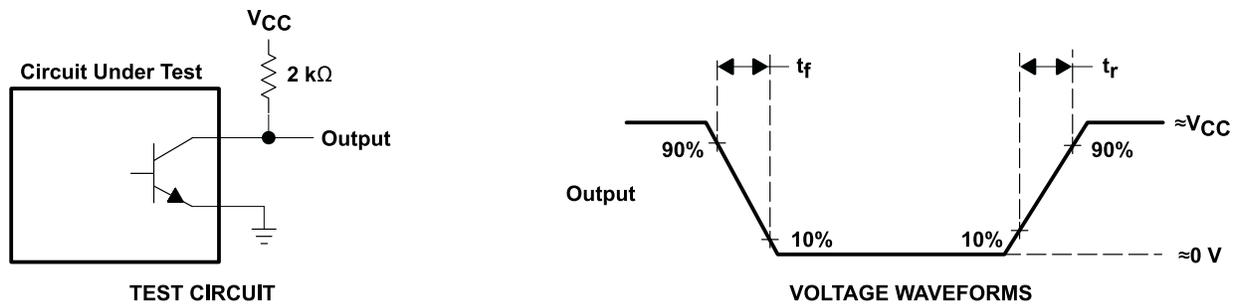


Figure 4. Switching Times

9 Detailed Description

9.1 Overview

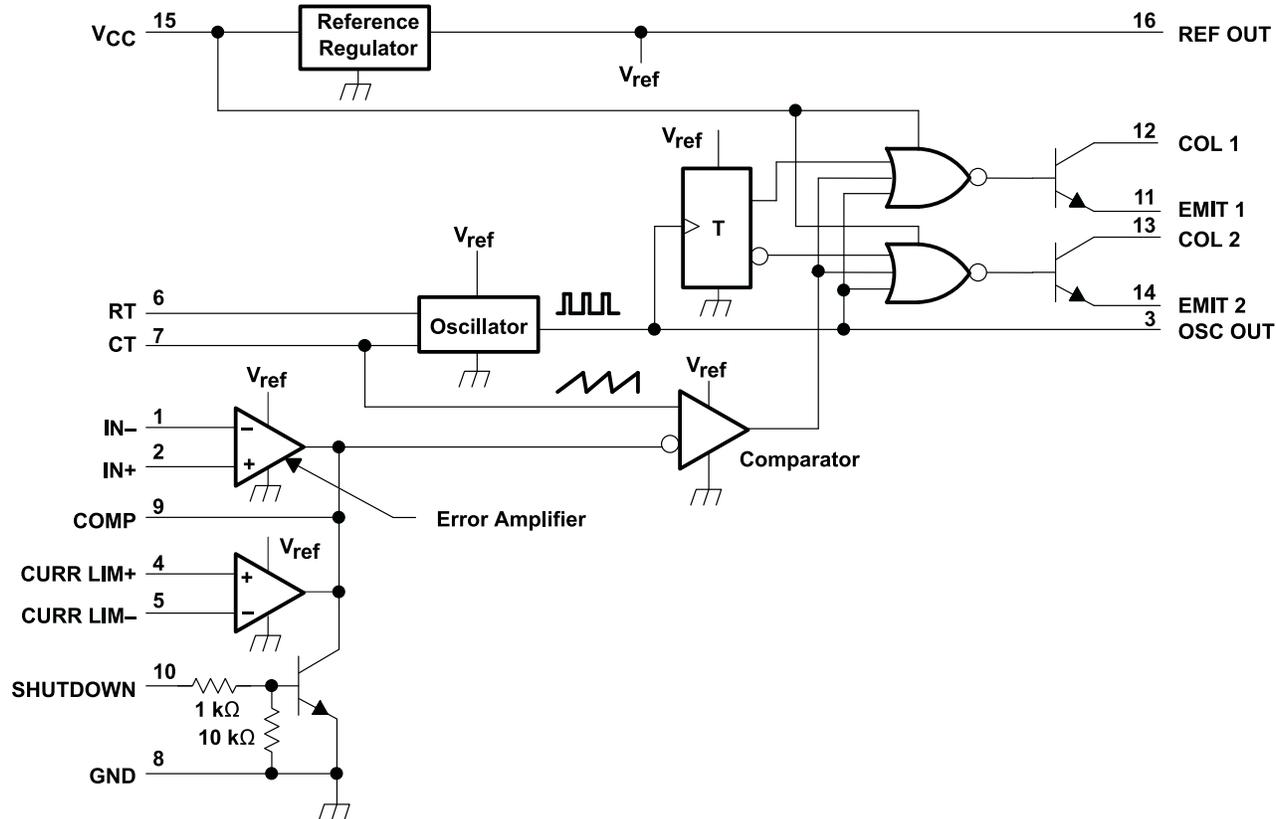
SGx524 is a fixed-frequency pulse-width-modulation (PWM) voltage-regulator control circuit. The regulator operates at a fixed frequency that is programmed by one timing resistor, R_T , and one timing capacitor, C_T . R_T establishes a constant charging current for C_T . This results in a linear voltage ramp at C_T , which is fed to the comparator, providing linear control of the output pulse duration (width) by the error amplifier.

The SGx524 contains an onboard 5-V regulator that serves as a reference, as well as supplying the SGx524 internal regulator control circuitry. The internal reference voltage is divided externally by a resistor ladder network to provide a reference within the common-mode range of the error amplifier as shown in Figure 11, or an external reference can be used.

The output is sensed by a second resistor divider network and the error signal is amplified. This voltage is then compared to the linear voltage ramp at C_T . The resulting modulated pulse out of the high-gain comparator then is steered to the appropriate output pass transistor (Q1 or Q2) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to ensure both outputs are never on simultaneously during the transition times. The duration of the blanking pulse is controlled by the value of C_T .

The outputs may be applied in a push-pull configuration in which their frequency is one-half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current-limiting and shut-down circuitry and can be overridden by signals from either of these inputs. This common point is pinned out externally via the COMP pin, which can be employed to either control the gain of the error amplifier or to compensate it. In addition, the COMP pin can be used to provide additional control to the regulator.

9.2 Functional Block Diagram



A. Resistor values shown are nominal.

9.3 Feature Description

9.3.1 Blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse duration is controlled by the value of C_T as shown in Figure 2. If small values of C_T are required, the oscillator output pulse duration can be maintained by applying a shunt capacitance from OSC OUT to ground.

9.3.2 Error Amplifier

The error amplifier is a differential-input transconductance amplifier. The output is available for DC gain control or AC phase compensation. The compensation node (COMP) is a high-impedance node ($R_L = 5\text{ M}\Omega$). The gain of the amplifier is $AV = (0.002\ \Omega^{-1})R_L$ and easily can be reduced from a nominal 10,000 by an external shunt resistance from COMP to ground. Refer to Figure 1 for data.

9.3.3 Compensation

COMP, as previously discussed, is made available for compensation. Since most output filters introduce one or more additional poles at frequencies below 200 Hz, which is the pole of the uncompensated amplifier, introduction of a zero to cancel one of the output filter poles is desirable. This can be accomplished best with a series RC circuit from COMP to ground in the range of 50 k Ω and 0.001 μF . Other frequencies can be canceled by use of the formula $f \approx 1/RC$.

9.3.4 Output Circuitry

SGx524 contains two identical npn transistors, the collectors and emitters of which are uncommitted. Each transistor has antisaturation circuitry that limits the current through that transistor to a maximum of 100 mA for fast response.

9.3.5 Current Limiting

A current-limiting sense amplifier is provided in the SGx524 device. The current-limiting sense amplifier exhibits a threshold of 200 mV \pm 25 mV and must be applied in the ground line since the voltage range of the inputs is limited to 1 V to -1 V . Caution should be taken to ensure the -1-V limit is not exceeded by either input, otherwise, damage to the device may result.

Foldback current limiting can be provided with the network shown in Figure 5. The current-limit schematic is shown in Figure 6.

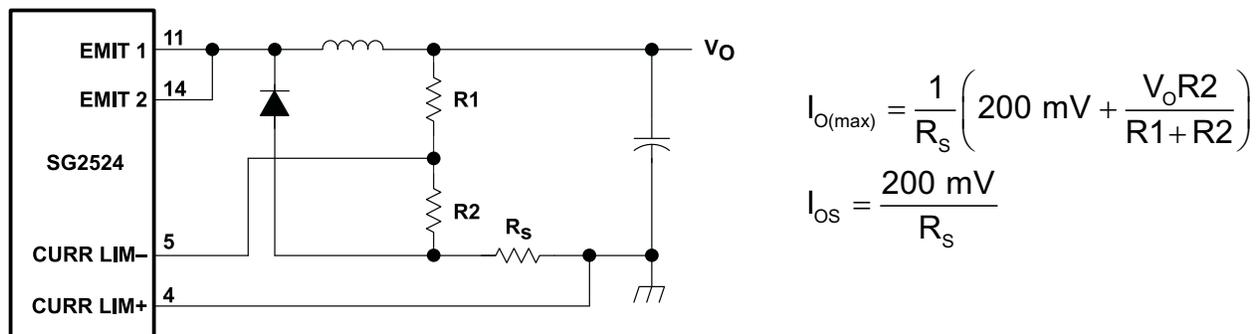


Figure 5. Foldback Current Limiting for Shorted Output Conditions

Feature Description (continued)

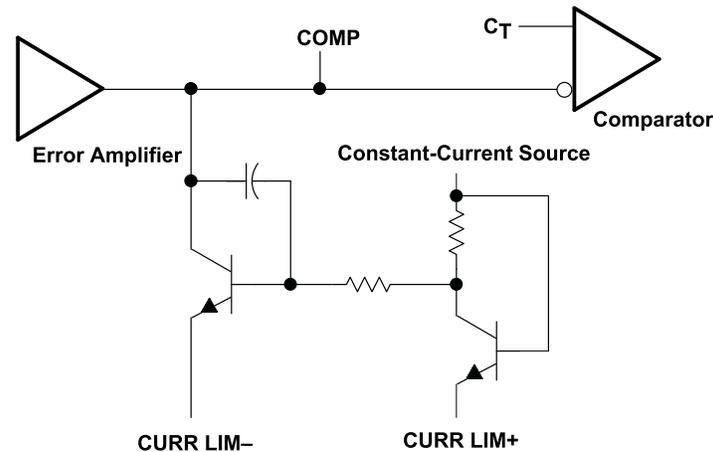


Figure 6. Current-Limit Schematic

9.4 Device Functional Modes

9.4.1 Synchronous Operation

When an external clock is desired, a clock pulse of approximately 3 V can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2 k Ω . In this configuration, $R_T C_T$ must be selected for a clock period slightly greater than that of the external clock.

If two or more SGx524 regulators are operated synchronously, all oscillator output terminals must be tied together. The oscillator programmed for the minimum clock period is the master from which all the other SGx524s operate. In this application, the $C_T R_T$ values of the slaved regulators must be set for a period approximately 10% longer than that of the master regulator. In addition, C_T (master) = 2 C_T (slave) to ensure that the master output pulse, which occurs first, has a longer pulse duration and, subsequently, resets the slave regulators.

9.4.2 Shutdown Circuitry

COMP also can be employed to introduce external control of the SGx524. Any circuit that can sink 200 μ A can pull the compensation terminal to ground and, thus, disable the SGx524.

In addition to constant-current limiting, CURR LIM+ and CURR LIM- also can be used in transformer-coupled circuits to sense primary current and shorten an output pulse should transformer saturation occur. CURR LIM- also can be grounded to convert CURR LIM+ into an additional shutdown terminal.

10 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

There are a wide variety of output configurations possible when considering the application of the SG2524 as a voltage-regulator control circuit. They can be segregated into three basic categories:

- Capacitor-diode-coupled voltage multipliers
- Inductor-capacitor-implemented single-ended circuits
- Transformer-coupled circuits

Examples of these categories are shown in [Figure 7](#), [Figure 8](#), and [Figure 9](#), respectively. *Typical Application* demonstrates how to set up the SG2524 for a capacitor-diode output design. The same techniques for setting up the internal circuitry of the IC may also be used for the other two output stage examples shown [Examples of Other Output Stages](#).

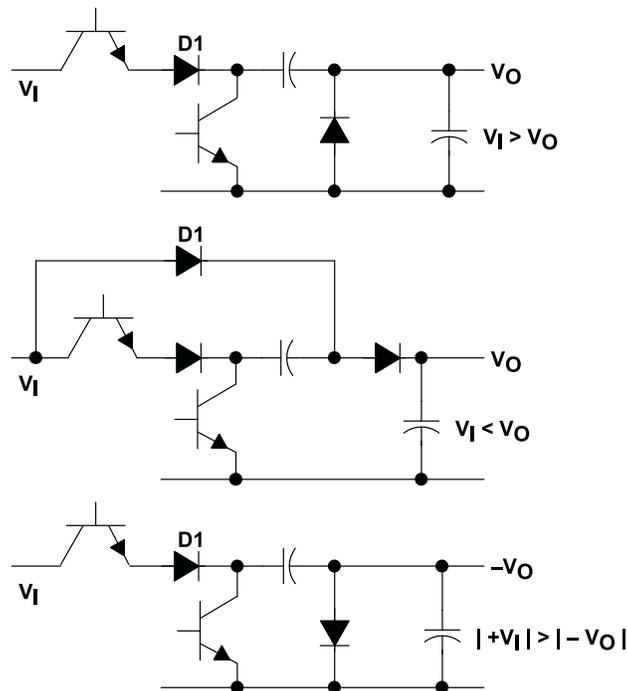


Figure 7. Capacitor-Diode-Coupled Voltage-Multiplier Output Stages

Application Information (continued)

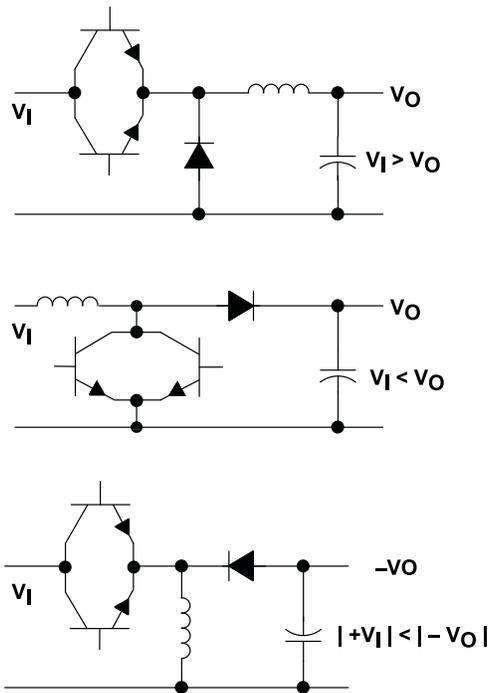


Figure 8. Single-Ended Inductor Circuit

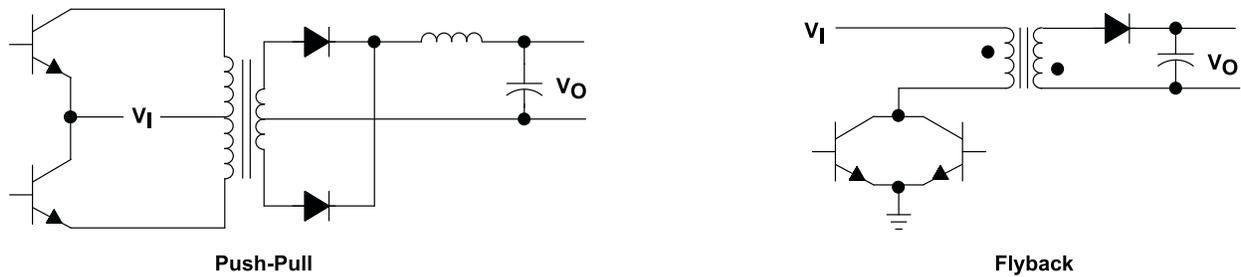


Figure 9. Transformer-Coupled Outputs

10.2 Typical Application

10.2.1 Capacitor-Diode Output

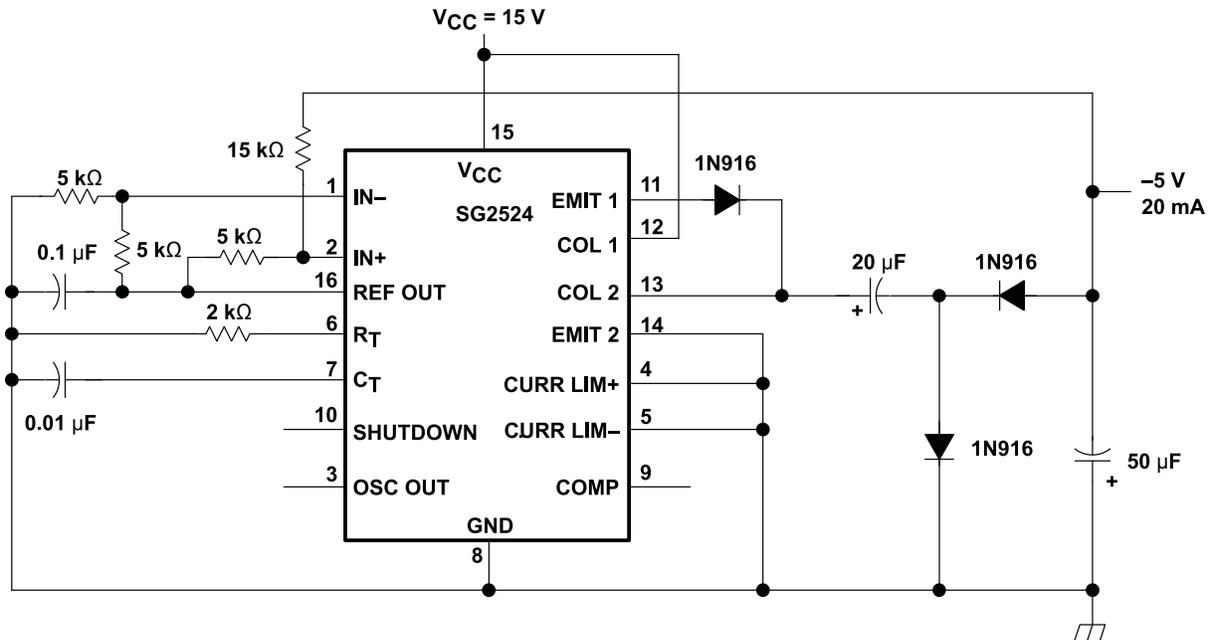


Figure 10. Capacitor-Diode Output Circuit Schematic

10.2.1.1 Design Requirements

- 15-V supply voltage
- –5-V output voltage

10.2.1.2 Detailed Design Procedure

10.2.1.2.1 Oscillator

The oscillator controls the frequency of the SG2524 and is programmed by R_T and C_T as shown in [Figure 12](#).

$$f \approx \frac{1.30}{R_T R_C}$$

where

- R_T is in $k\Omega$
- C_T is in μF
- f is in kHz

(1)

Practical values of C_T fall between $0.001 \mu F$ and $0.1 \mu F$. Practical values of R_T fall between $1.8 k\Omega$ and $100 k\Omega$. This results in a frequency range typically from 130 Hz to 722 kHz.

10.2.1.2.2 Voltage Reference

The 5-V internal reference can be employed by use of an external resistor divider network to establish a reference common-mode voltage range (1.8 V to 3.4 V) within the error amplifiers (see [Figure 11](#)), or an external reference can be applied directly to the error amplifier. For operation from a fixed 5-V supply, the internal reference can be bypassed by applying the input voltage to both the V_{CC} and V_{REF} terminals. In this configuration, however, the input voltage is limited to a maximum of 6 V.

Typical Application (continued)

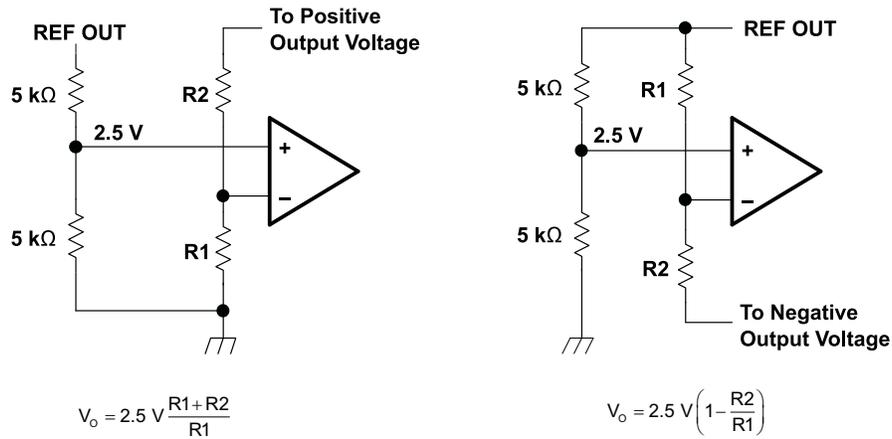


Figure 11. Error-Amplifier Bias Circuits

10.2.1.3 Application Curves

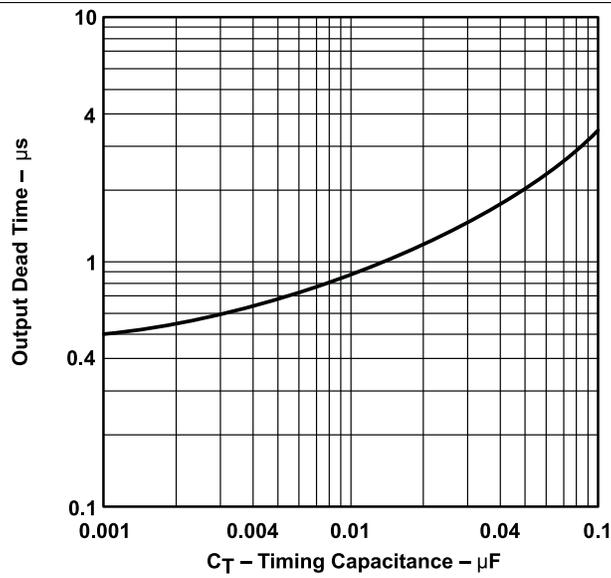


Figure 12. Output Dead Time vs Timing Capacitance

10.3 Examples of Other Output Stages

10.3.1 Flyback Converter

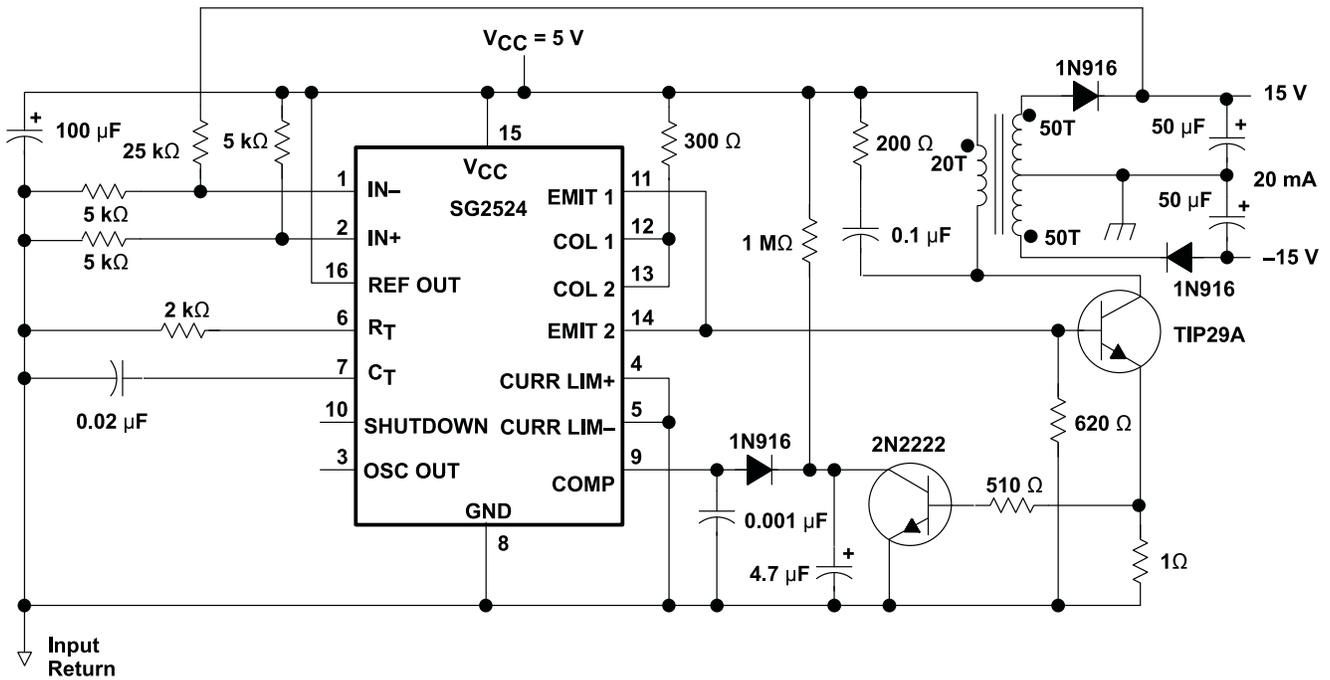


Figure 13. Flyback Converter Circuit Schematic

10.3.2 Single-Ended LC

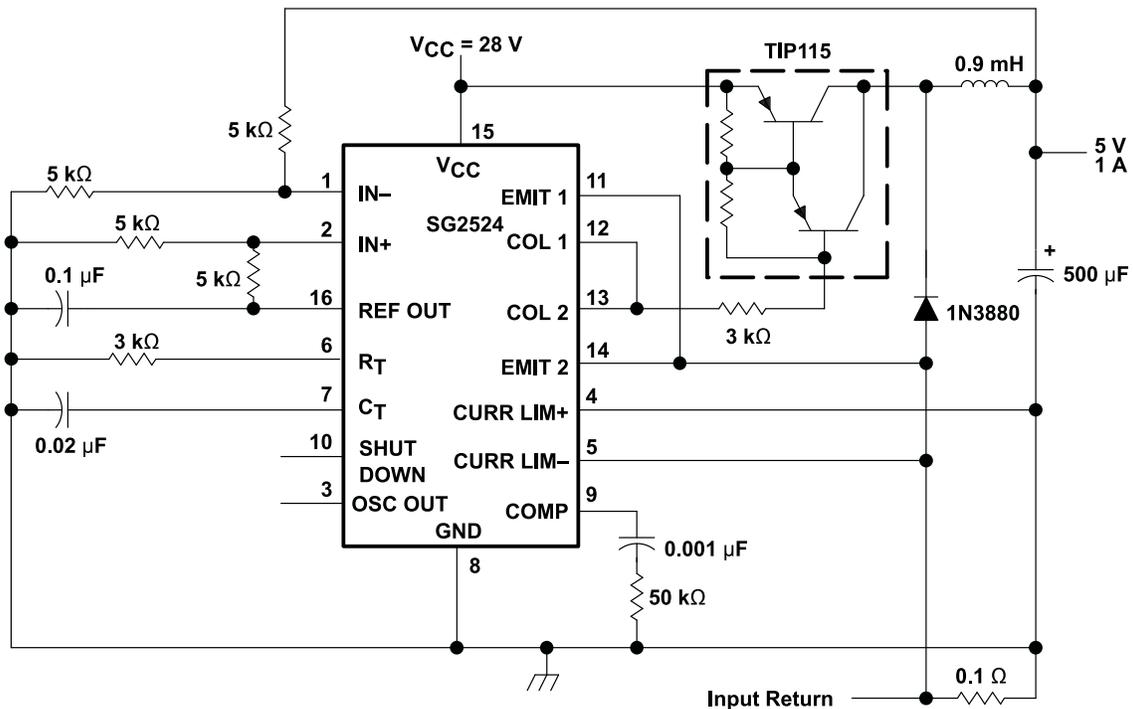


Figure 14. Single-Ended LC Circuit Schematic

Examples of Other Output Stages (continued)

10.3.3 Push-Pull Transformer-Coupled

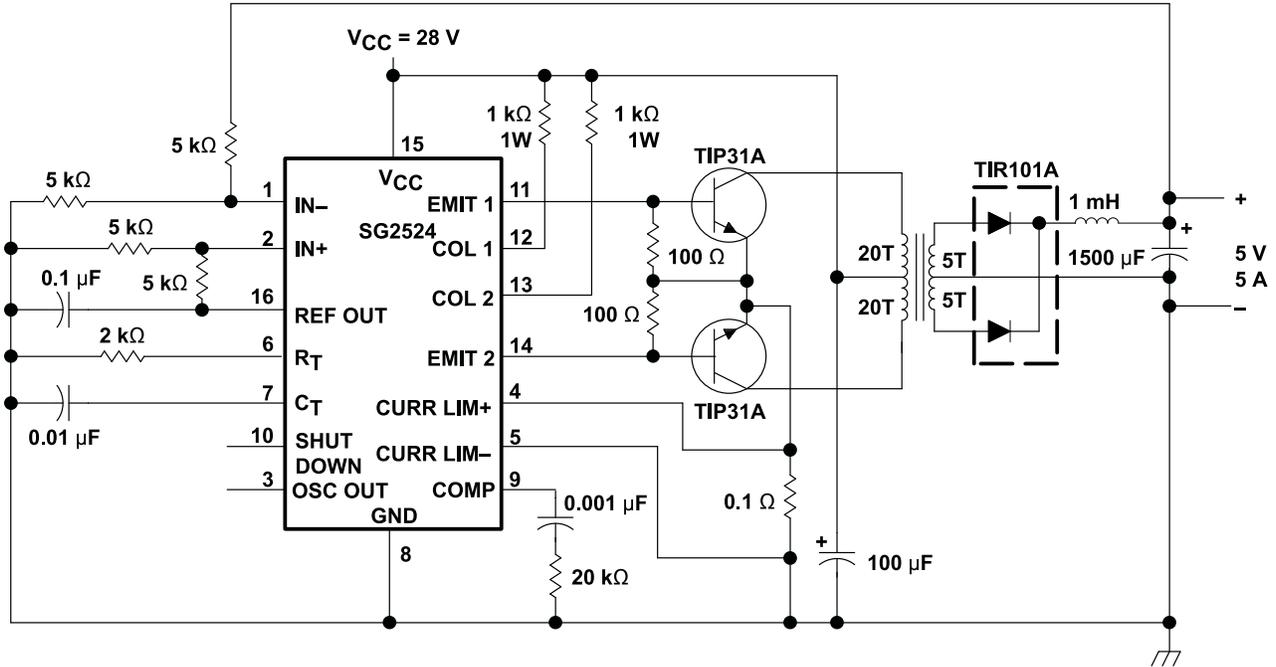


Figure 15. Push-Pull Transformer-Coupled Circuit Schematic

11 Power Supply Recommendations

SGx524 is designed to operate from an input voltage supply range between 8 V and 40 V. This input supply should be well regulated. If the input supply is located more than a few inches from the device, additional bulk capacitance may be required in addition to the ceramic bypass capacitors. A tantalum capacitor with a value of 47 μ F is a typical choice, however this may vary depending upon the output power being delivered.

12 Layout

12.1 Layout Guidelines

Always try to use a low EMI inductor with a ferrite type closed core. Some examples would be toroid and encased E core inductors. Open core can be used if they have low EMI characteristics and are located a bit more away from the low power traces and components. Make the poles perpendicular to the PCB as well if using an open core. Stick cores usually emit the most unwanted noise.

12.1.1 Feedback Traces

Try to run the feedback trace as far from the inductor and noisy power traces as possible. You would also like the feedback trace to be as direct as possible and somewhat thick. These two sometimes involve a trade-off, but keeping it away from inductor EMI and other noise sources is the more critical of the two. Run the feedback trace on the side of the PCB opposite of the inductor with a ground plane separating the two.

12.1.2 Input/Output Capacitors

When using a low value ceramic input filter capacitor, it should be located as close to the VIN pin of the IC as possible. This will eliminate as much trace inductance effects as possible and give the internal IC rail a cleaner voltage supply. Some designs require the use of a feed-forward capacitor connected from the output to the feedback pin as well, usually for stability reasons. In this case it should also be positioned as close to the IC as possible. Using surface mount capacitors also reduces lead length and lessens the chance of noise coupling into the effective antenna created by through-hole components.

12.1.3 Compensation Components

External compensation components for stability should also be placed close to the IC. Surface mount components are recommended here as well for the same reasons discussed for the filter capacitors. These should not be located very close to the inductor either.

12.1.4 Traces and Ground Planes

Make all of the power (high-current) traces as short, direct, and thick as possible. It is good practice on a standard PCB board to make the traces an absolute minimum of 15 mils (0.381 mm) per ampere. The inductor, output capacitors, and output diode should be as close to each other possible. This helps reduce the EMI radiated by the power traces due to the high switching currents through them. This will also reduce lead inductance and resistance as well, which in turn reduces noise spikes, ringing, and resistive losses that produce voltage errors.

The grounds of the IC, input capacitors, output capacitors, and output diode (if applicable) should be connected close together directly to a ground plane. It would also be a good idea to have a ground plane on both sides of the PCB. This will reduce noise as well by reducing ground loop errors as well as by absorbing more of the EMI radiated by the inductor. For multi-layer boards with more than two layers, a ground plane can be used to separate the power plane (where the power traces and components are) and the signal plane (where the feedback and compensation and components are) for improved performance. On multi-layer boards the use of vias will be required to connect traces and different planes. It is good practice to use one standard via per 200 mA of current if the trace will need to conduct a significant amount of current from one plane to the other.

Arrange the components so that the switching current loops curl in the same direction. Due to the way switching regulators operate, there are two power states. One state when the switch is on and one when the switch is off. During each state there will be a current loop made by the power components that are currently conducting. Place the power components so that during each of the two states the current loop is conducting in the same direction. This prevents magnetic field reversal caused by the traces between the two half-cycles and reduces radiated EMI.

12.2 Layout Example

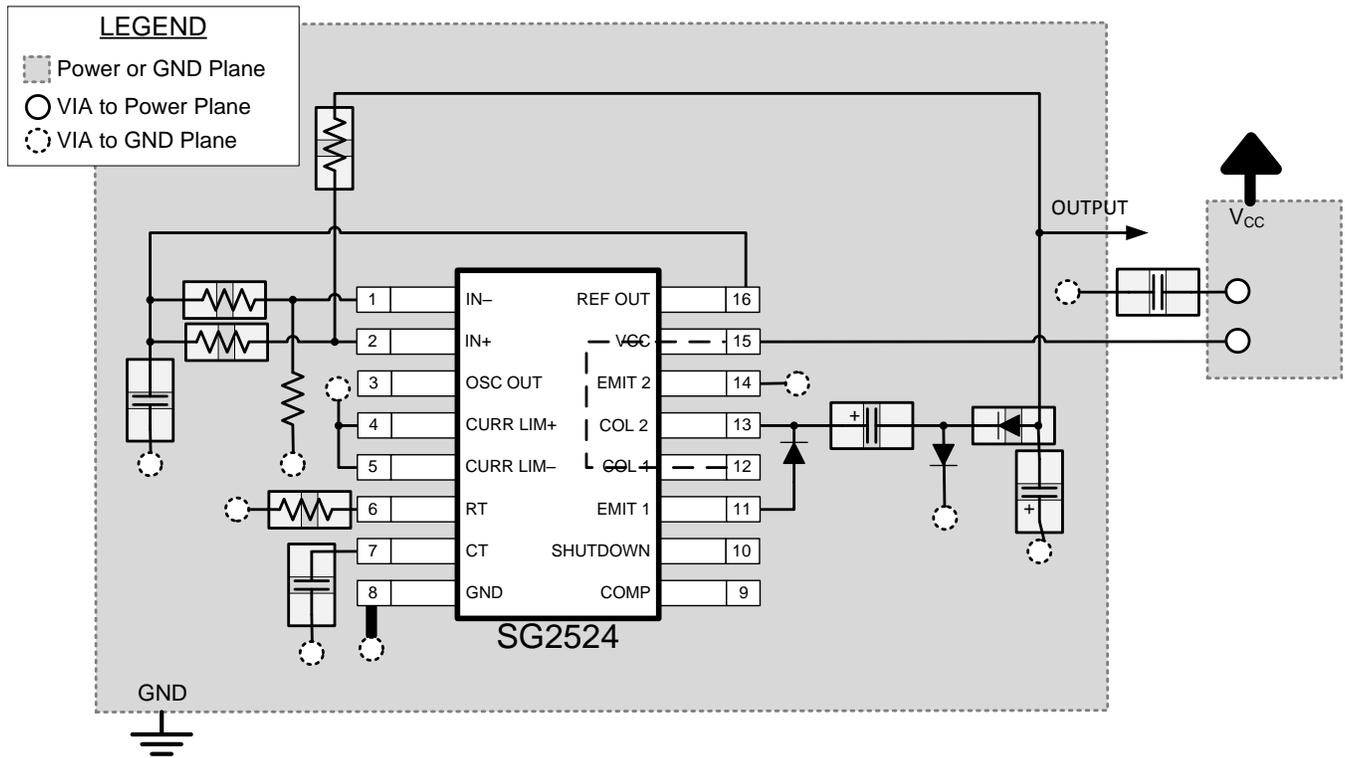


Figure 16. Layout Example for SG2524

13 Device and Documentation Support

13.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
SG2524	Click here				
SG3524	Click here				

13.2 Trademarks

All trademarks are the property of their respective owners.

13.3 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

13.4 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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
SG2524D	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-25 to 85	SG2524	Samples
SG2524DR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-25 to 85	SG2524	Samples
SG2524DRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-25 to 85	SG2524	Samples
SG2524DRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-25 to 85	SG2524	Samples
SG2524N	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	SG2524N	Samples
SG3524D	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	SG3524	Samples
SG3524DR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	SG3524	Samples
SG3524DRE4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	SG3524	Samples
SG3524N	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	SG3524N	Samples
SG3524NE4	ACTIVE	PDIP	N	16	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	SG3524N	Samples
SG3524NSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	SG3524	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.

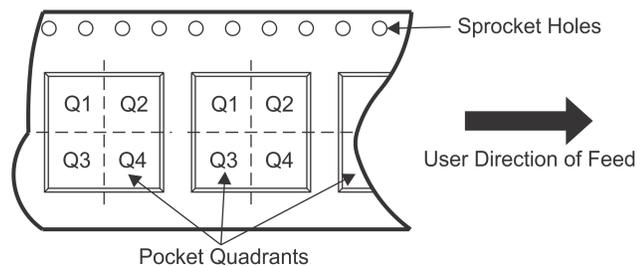
Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. 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



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
SG2524DR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
SG2524DRG4	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
SG3524DR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
SG3524NSR	SO	NS	16	2000	330.0	16.4	8.2	10.5	2.5	12.0	16.0	Q1

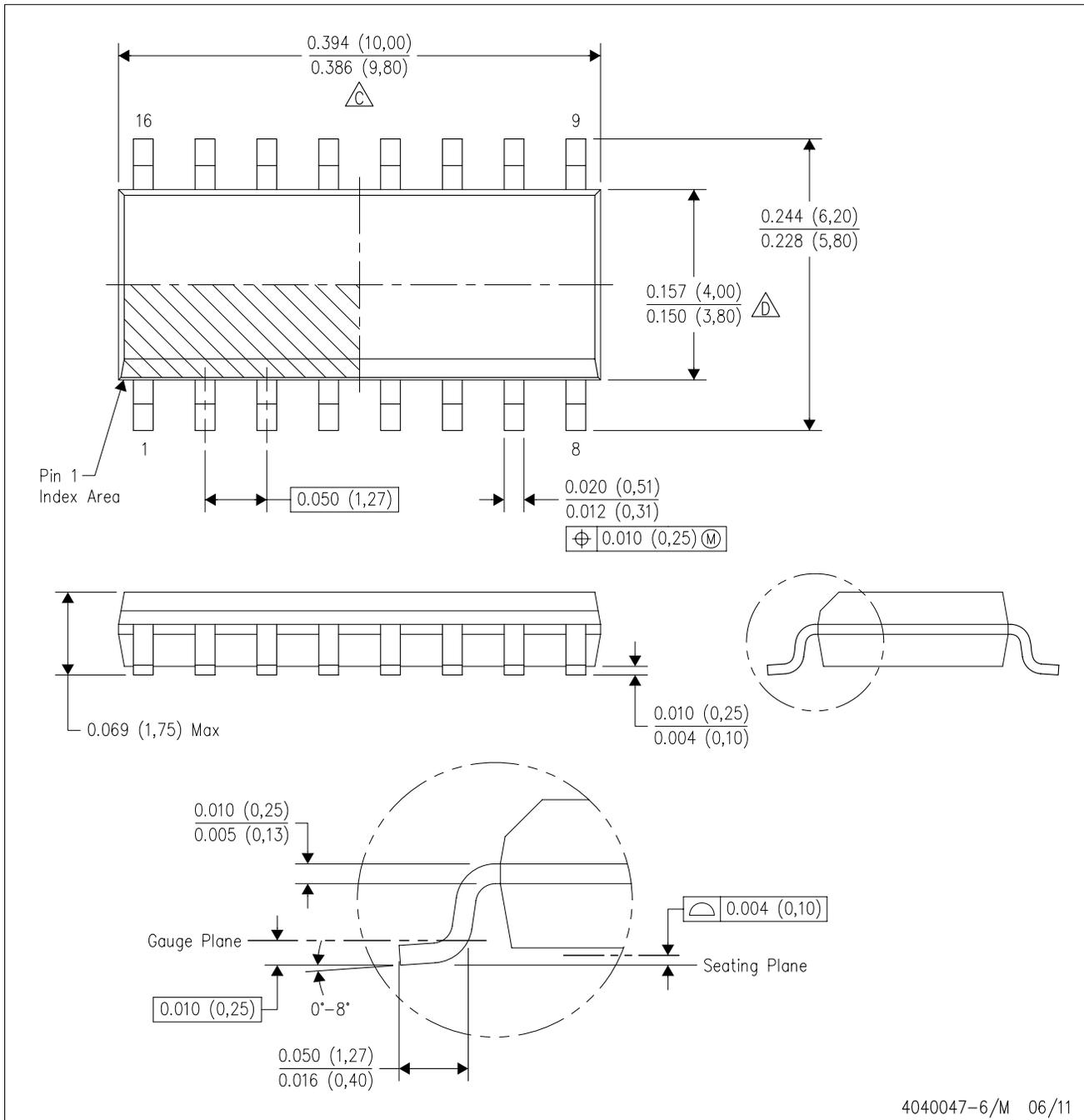
TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
SG2524DR	SOIC	D	16	2500	333.2	345.9	28.6
SG2524DRG4	SOIC	D	16	2500	333.2	345.9	28.6
SG3524DR	SOIC	D	16	2500	333.2	345.9	28.6
SG3524NSR	SO	NS	16	2000	367.0	367.0	38.0

D (R-PDSO-G16)

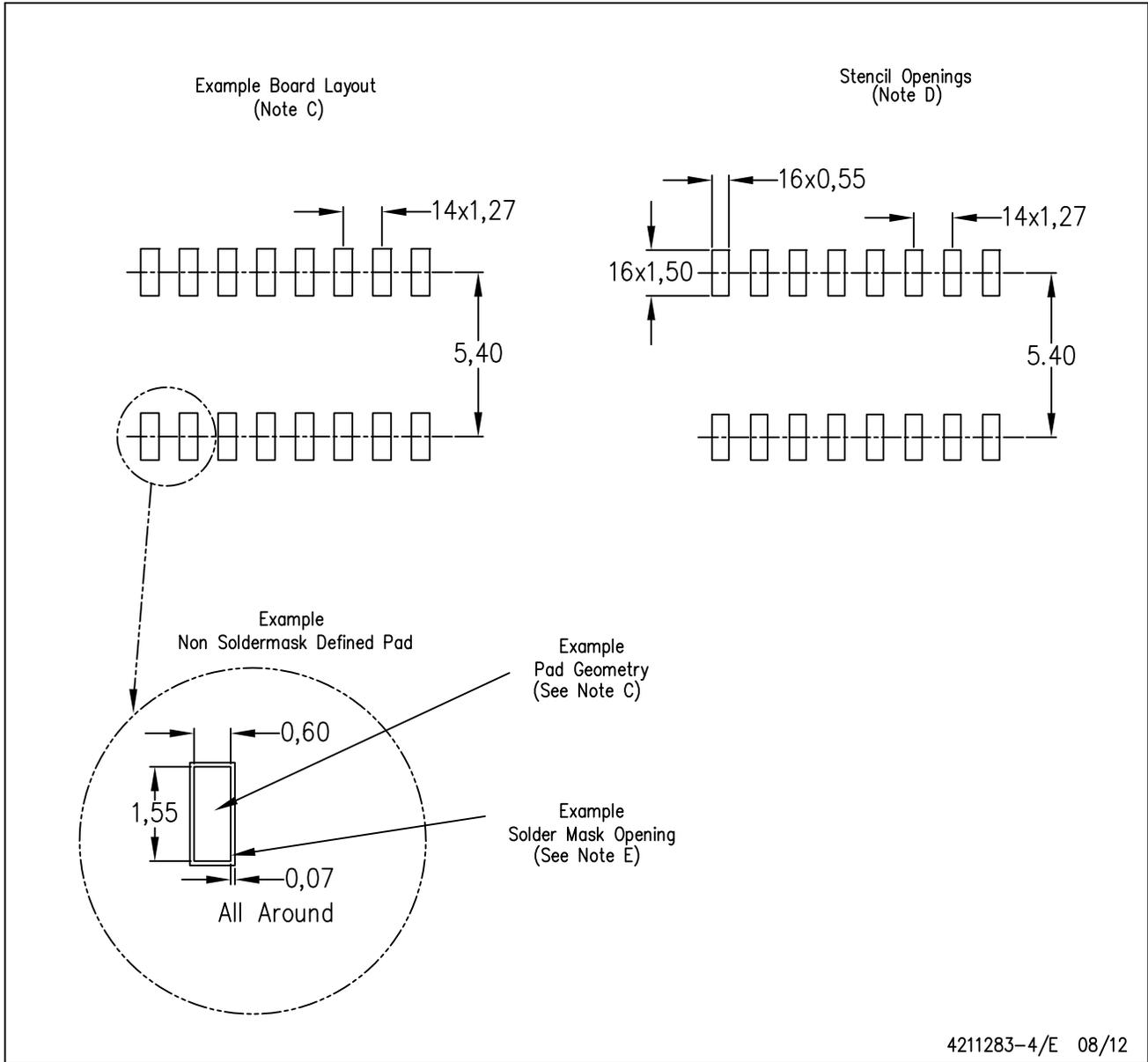
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
 - E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



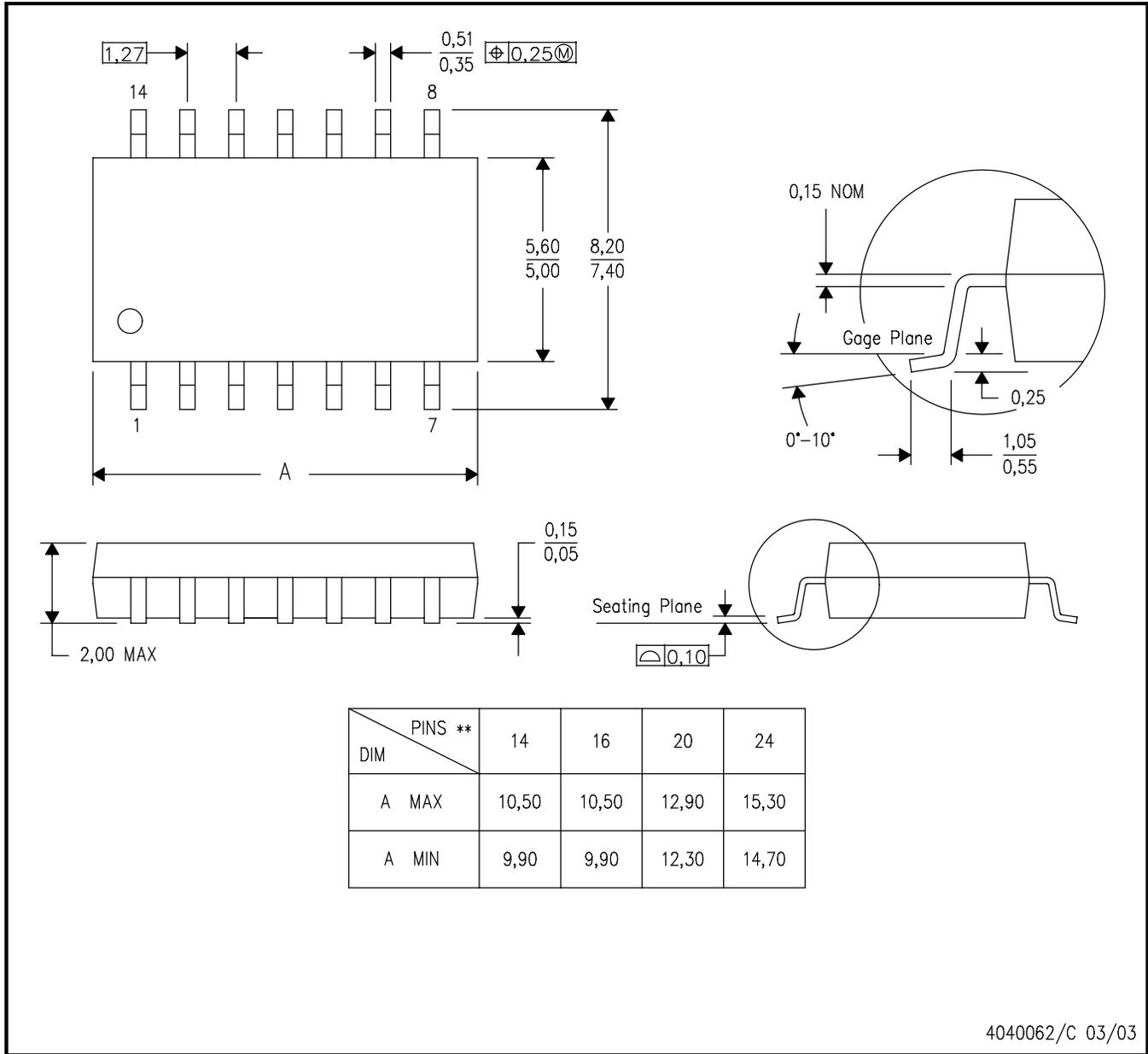
- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

MECHANICAL DATA

NS (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN

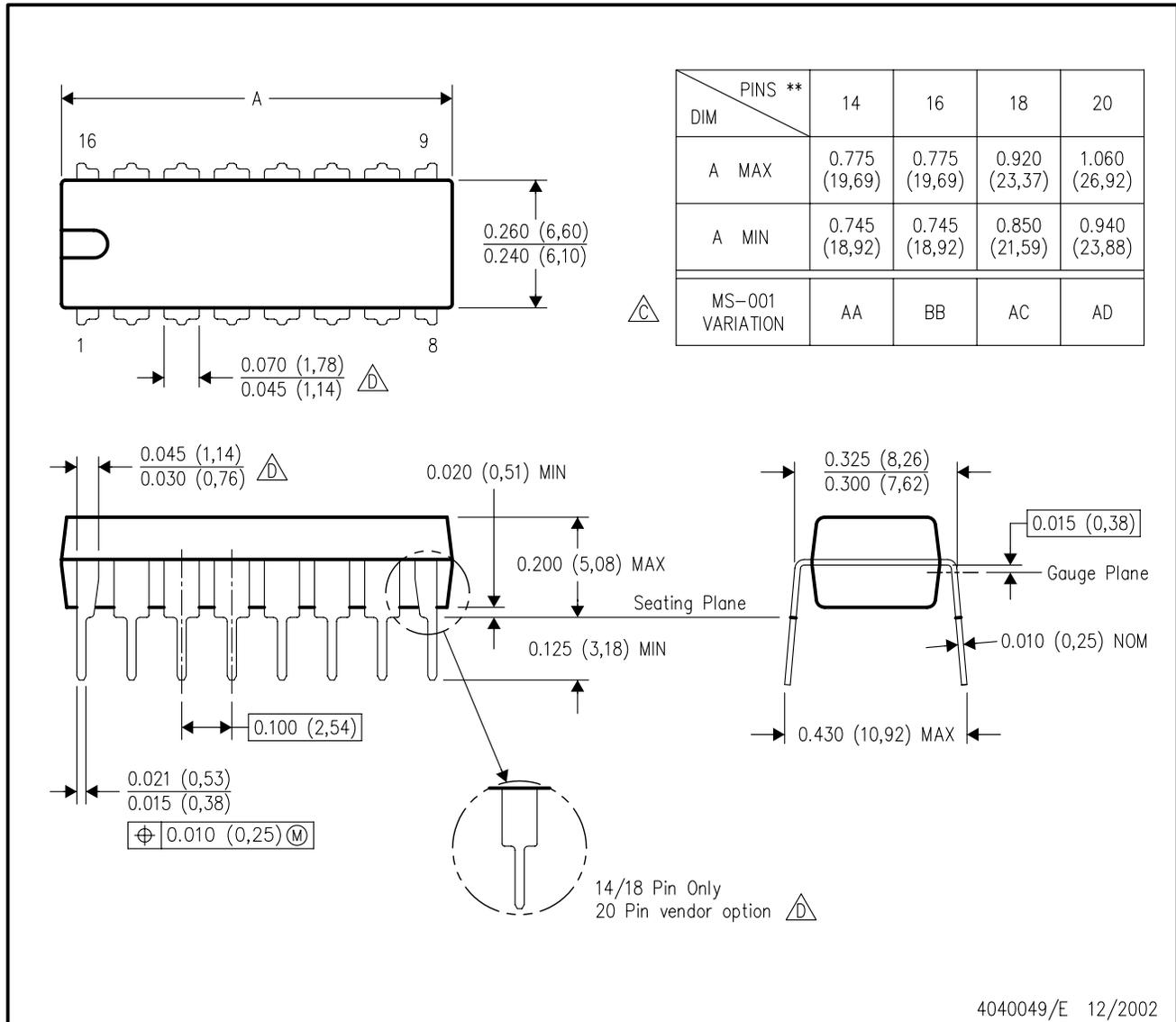


- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



4040049/E 12/2002

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - $\triangle C$ Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - $\triangle D$ The 20 pin end lead shoulder width is a vendor option, either half or full width.

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.