ADVANCED REGULATING PULSE WIDTH MODULATORS

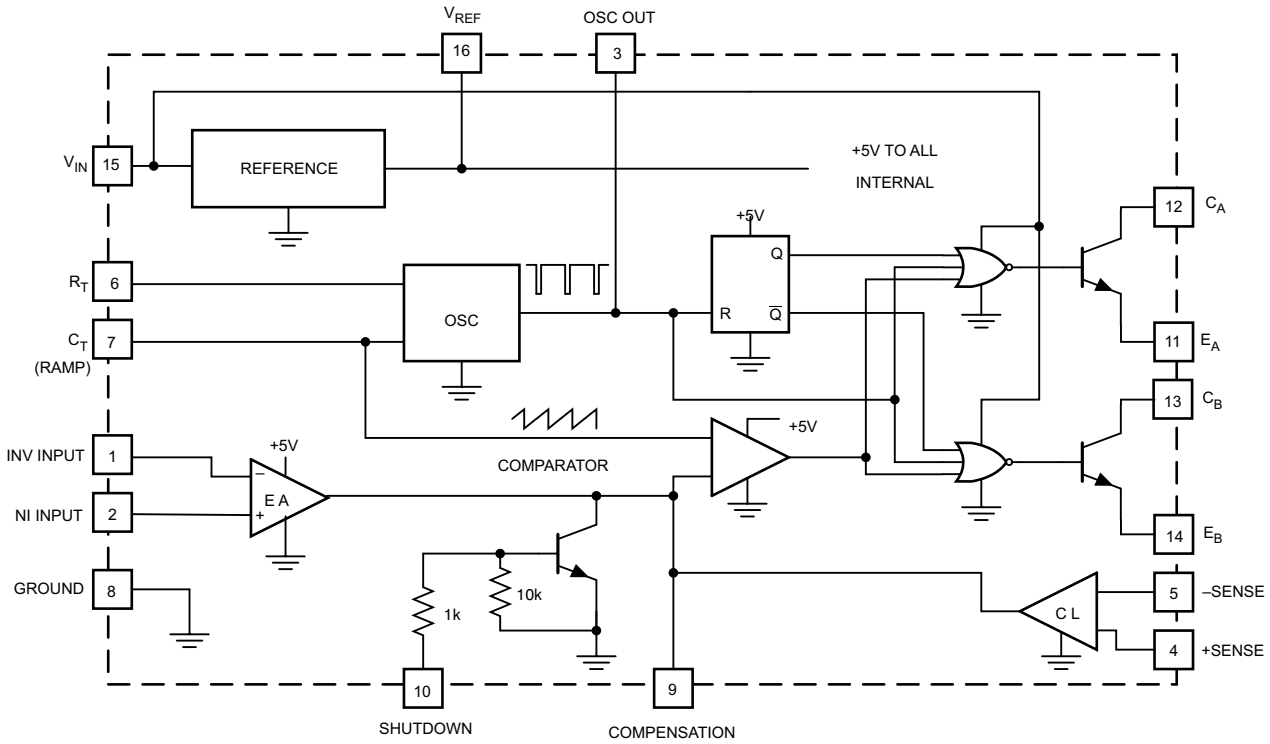
FEATURES

- **Complete PWM Power Control Circuitry**
- **Uncommitted Outputs for Single-Ended or Push-Pull Applications**
- **Low Standby Current . . . 8 mA Typical**
- **Interchangeable With SG1524, SG2524 and SG3524, Respectively**

DESCRIPTION

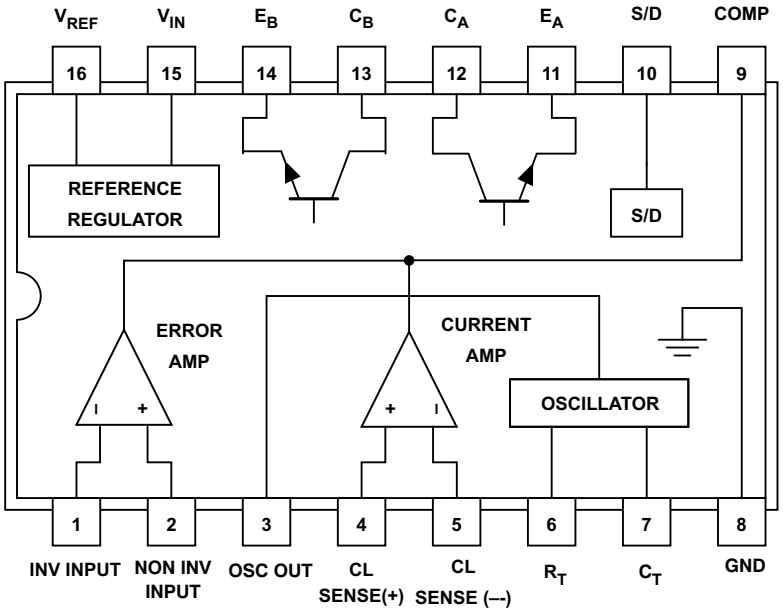
The UC1524, UC2524 and UC3524 incorporate on a single monolithic chip all the functions required for the construction of regulating power supplies, inverters or switching regulators. They can also be used as the control element for high-power-output applications. The UC1524 family was designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers and polarity converter applications employing fixed-frequency, pulse-width modulation techniques. The dual alternating outputs allow either single-ended or push-pull applications. Each device includes an on-chip reference, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted output transistors, a high-gain comparator, and current-limiting and shut-down circuitry. The UC1524 is characterized for operation over the full military temperature range of –55°C to 125°C. The UC2524 and UC3524 are designed for operation from –25°C to 85°C and 0°C to 70°C, respectively.

BLOCK DIAGRAM



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.

CONNECTION DIAGRAM



ABSOLUTE MAXIMUM RATINGS

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

			UNIT
V_{CC}	Supply voltage(1)(2)		40 V
	Collector output current		100 mA
	Reference output current		50 mA
	Current through C_T terminalg		–50 mA
	Power dissipation	T_A = 25°C(3)	1000 mW
		T_C = 25°C(3)	2000 mW
	Operating junction temperature range		–55°C to 150°C
	Storage temperature range		–65°C to +150°C

(1) All voltage values are with respect to the ground terminal, pin 8.
(2) The reference regulator may be bypassed for operation from a fixed 5 V supply by connecting the V_{CC} and reference output pins both to the supply voltage. In this configuration the maximum supply voltage is 6 V.
(3) Consult packaging section of data book for thermal limitations and considerations of package.

RECOMMENDED OPERATING CONDITIONS

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

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage		8		40	V
	Reference output current		0		20	mA
	Current through C_T terminal		–0.03		–2	mA
R_T	Timing resistor		1.8		100	kΩ
C_T	Timing capacitor		0.001		0.1	µF
	Operating ambient temperature range	UC1524	–55		125	°C
		UC2524	–25		85	
		UC3524	0		70	

ELECTRICAL CHARACTERISTICS

these specifications apply for T_A = –55°C to 125°C for the UC1524, –25°C to 85°C for the UC2524, and 0°C to 70°C for the UC3524, V_{IN} = 20 V, and f = 20 kHz, $T_A = T_J$, over operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	UC1524/UC2524			UC3524			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
REFERENCE SECTION								
Output voltage		4.8	5.0	5.2	4.6	5.0	5.4	V
Line regulation	V_{IN} = 8 V to 40 V		10	20		10	30	mV
Load regulation	I_L = 0 mA to 20 mA		20	50		20	50	mV
Ripple rejection	f = 120 Hz, T_J = 25°C		66			66		dB
Short circuit current limit	V_{REF} = 0, T_J = 25°C		100			100		mA
Temperature stability	Over operating temperature range		0.3%	1%		0.3%	1%	
Long term stability	T_J = 125°C, t = 1000 Hrs		20			20		mV
OSCILLATOR SECTION								
Maximum frequency	C_T = 1 nF, R_T = 2 kΩ		300			300		kHz
Initial accuracy	R_T and C_T constant		5%			5%		
Voltage stability	V_{IN} = 8 V to 40 V, T_J = 25°C			1%			1%	
Temperature stability	Over operating temperature range			5%			5%	
Output amplitude	Pin 3, T_J = 25°C		3.5			3.5		V
Output pulse width	C_T = 0.01 mfd, T_J = 25°C		0.5			0.5		µs
ERROR AMPLIFIER SECTION								
Input offset voltage	V_{CM} = 2.5 V		0.5	5		2	10	mV
Input bias current	V_{CM} = 2.5 V		2	10		2	10	µA
Open loop voltage gain		72	80		60	80		dB
Common mode voltage	T_J = 25°C	1.8		3.4	1.8		3.4	V
Common mode rejection ratio	T_J = 25°C		70			70		dB
Small signal bandwidth	A_V = 0 dB, T_J = 25°C		3			3		MHz
Output voltage	T_J = 25°C	0.5		3.8	0.5		3.8	V
COMPARATOR SECTION								
Duty-cycle	% Each output on	0%		45%	0%		45%	
Input threshold	Zero duty-cycle		1			1		V
	Maximum duty-cycle		3.5			3.5		
Input bias current			1			1		µA
CURRENT LIMITING SECTION								
Sense voltage	Pin 9 = 2 V with error amplifier set for maximum out, T_J = 25°C	190	200	210	180	200	220	mV
Sense voltage T.C.			0.2			0.2		mV/°C
Common mode voltage	T_J = –55°C to 85°C for the –1 V to 1 V limit	–1		1	–1		1	V
	T_J = 25°C	–0.3		1				
OUTPUT SECTION (EACH OUTPUT)								
Collector-emitter voltage		40			40			V
Collector leakage current	V_{CE} = 40 V		0.1	50		0.1	50	µ A
Saturation voltage	I_C = 50 mA		1	2		1	2	V
Emitter output voltage	V_{IN} = 20 V	17	18		17	18		V
Rise Time	R_C = 2 kΩ, T_J = 25°C		0.2			0.2		µs
Fall Time	R_C = 2 kΩ, T_J = 25°C		0.1			0.1		µs
Total standby current (Note)	V_{IN} = 40 V		8	10		8	10	mA

PRINCIPLES OF OPERATION

The UC1524 is a fixed-frequency pulse-width-modulation voltage regulator control circuit. The regulator operates at a 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 width by the error amplifier. The UC1524 contains an on-board 5 V regulator that serves as a reference as well as powering the UC1524's internal control circuitry and is also useful in supplying external support functions. This reference voltage is lowered externally by a resistor divider to provide a reference within the common-mode range of the error amplifier or an external reference may be used. The power supply output is sensed by a second resistor divider network to generate a feedback signal to the error amplifier. The amplifier output voltage is then compared to the linear voltage ramp at C_T. The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q_1 or Q_2) 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 assure both outputs are never on simultaneously during the transition times. The width of the blanking pulse is controlled by the valve of C_T. The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator Note that for buck regulator topologies, the two outputs can be wire-ORed for an effective 0-90% duty cycle range. With this connection, the output frequency is the same as the oscillator frequency. The output of the error amplifier shares a common input to the comparator with the current limiting and shutdown circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, or to compensate, the error amplifier or to provide additional control to the regulator.

TYPICAL CHARACTERISTICS

OPEN-LOOP VOLTRAGE AMPLIFICATION OF ERROR AMPLIFIER vs FREQUENCY

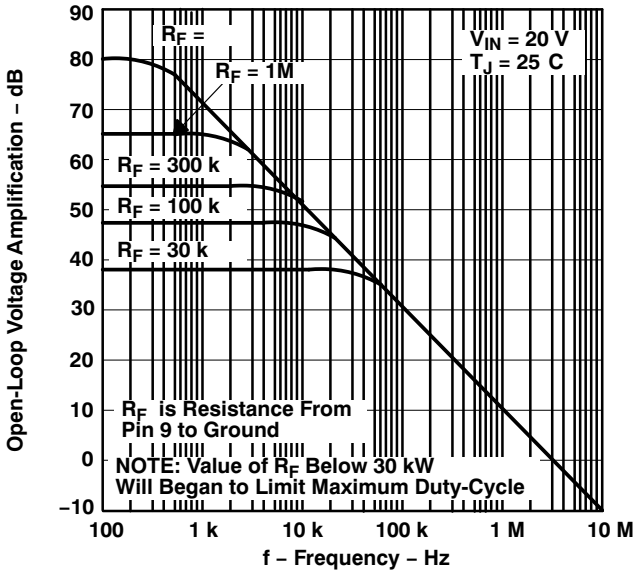


Figure 1.

OSCILLATOR FREQUENCY vs TIMING COMPONENTS

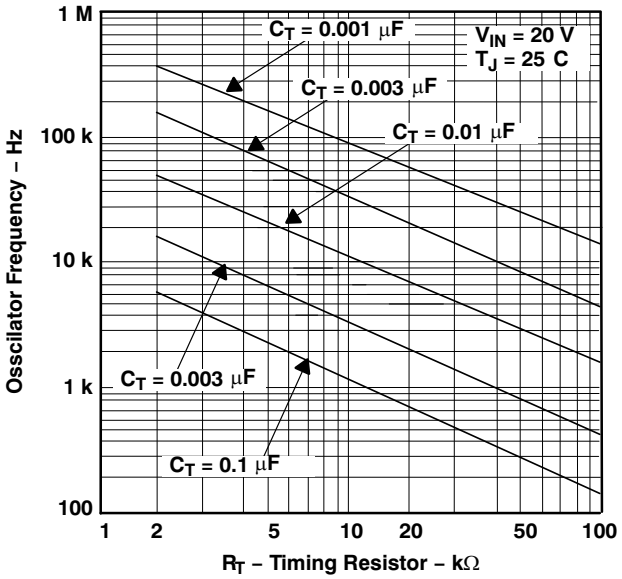


Figure 2.

OUTPUT DEAD TIME vs TIMING CAPACITANCE VALUE

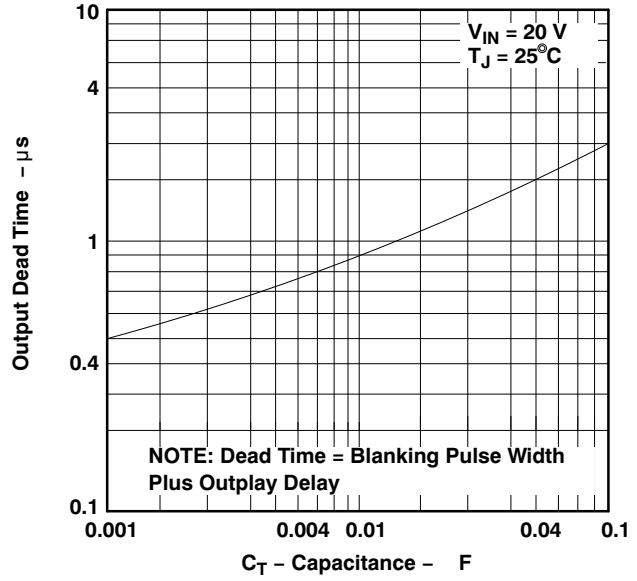


Figure 3.

OUTPUT SATURATION VOLTAGE vs LOAD CURRENT

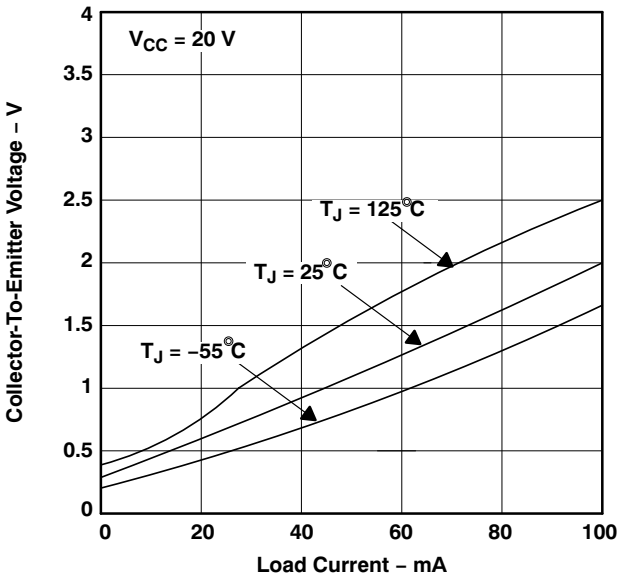


Figure 4.

APPLICATION INFORMATION

OSCILLATOR

The oscillator controls the frequency of the UC1524 and is programmed by R_T and C_T according to the approximate formula:

$$f \quad \frac{1.18}{R_T C_T} \qquad (1)$$

where

R_T is in kΩ
C_T is in μF
f is in kHz

Practical values of C_T fall between 1 nF and 100 nF. Practical values of R_T fall between 1.8 kΩ and 100 kΩ. This results in a frequency range typically from 120 Hz to 500 kHz.

BLANKING

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse width is controlled by the value of C_T. If small values of C_T are required for frequency control, the oscillator output pulse width may still be increased by applying a shunt capacitance of up to 100 pF from pin 3 to ground. If still greater dead-time is required, it should be accomplished by limiting the maximum duty cycle by clamping the output of the error amplifier. This can easily be done with the circuit in Figure 5.

SYNCHRONOUS OPERATIONS

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 kΩ. 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 UC1524 regulators are to operated synchronously, all oscillator output terminals should be tied together, all C_T terminals connected to single timing capacitor, and the timing resistor connected to a single R_T, terminal.

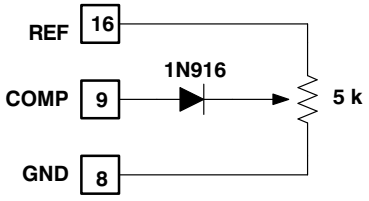


Figure 5. Error Amplifier Clamp

The other R_T terminals can be left open or shorted to V_{REF}. Minimum lead lengths should be used between the C_T terminals.

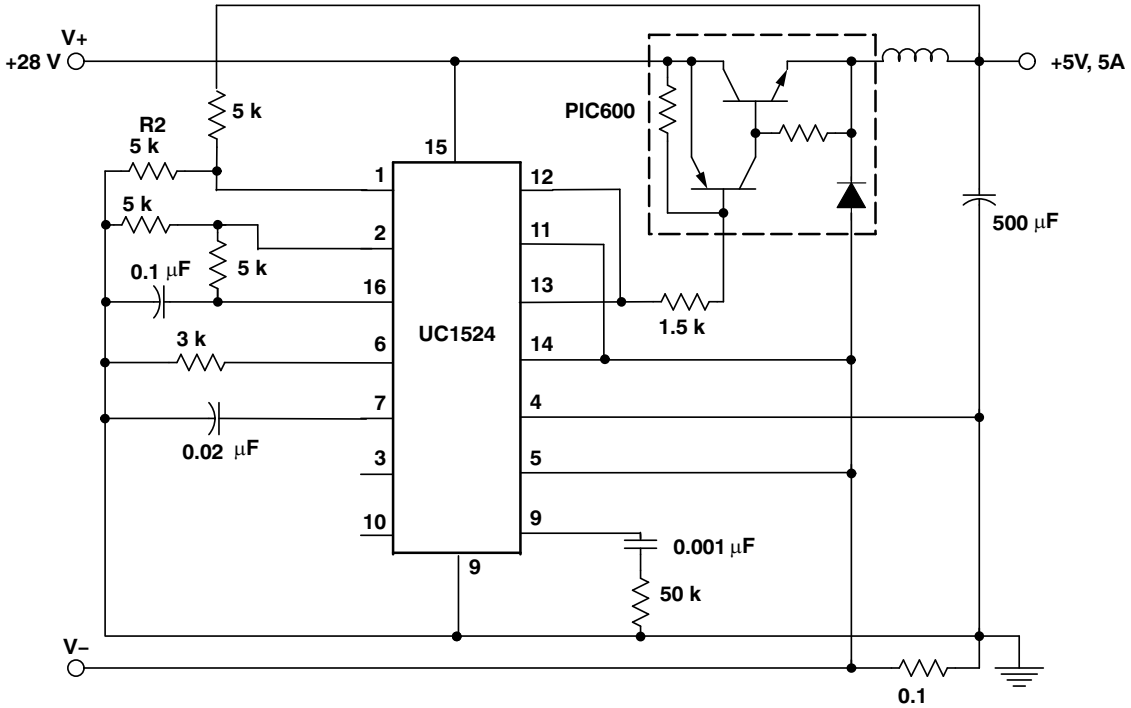


Figure 6. Single-Ended LC Switching Regulator Circuit

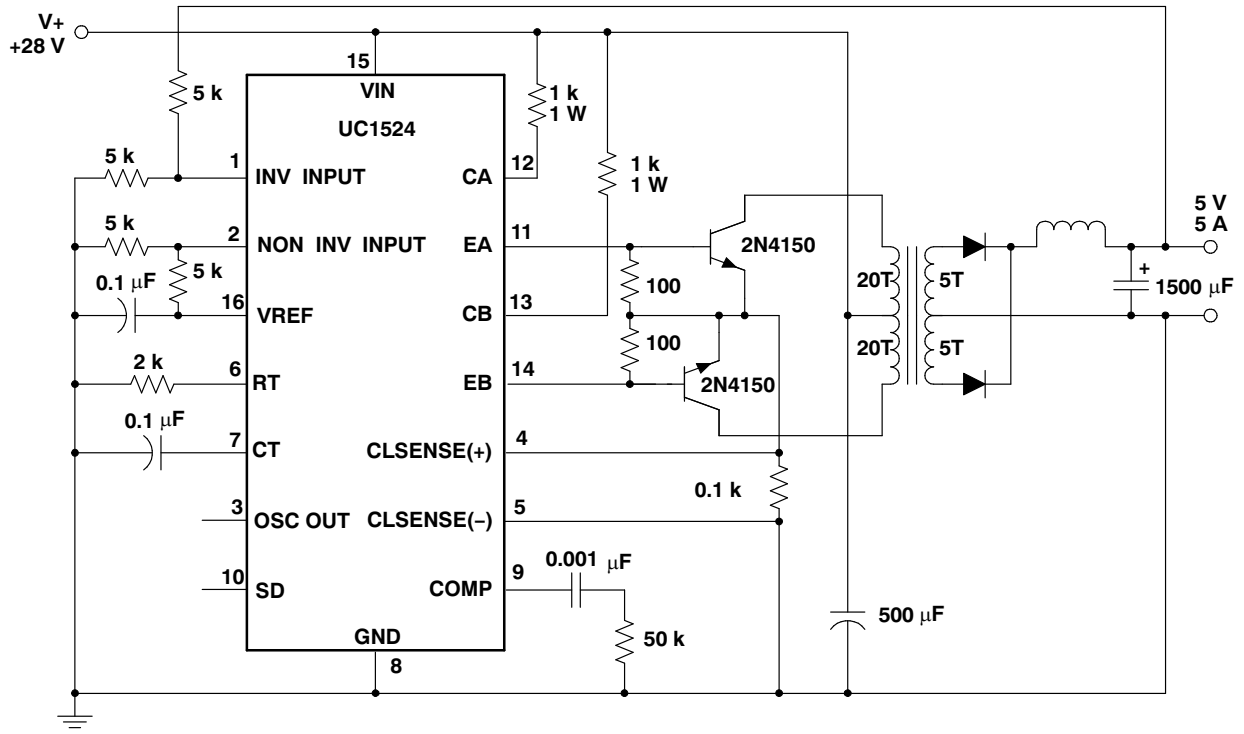


Figure 7. Push-Pull Transformer Coupled Circuit

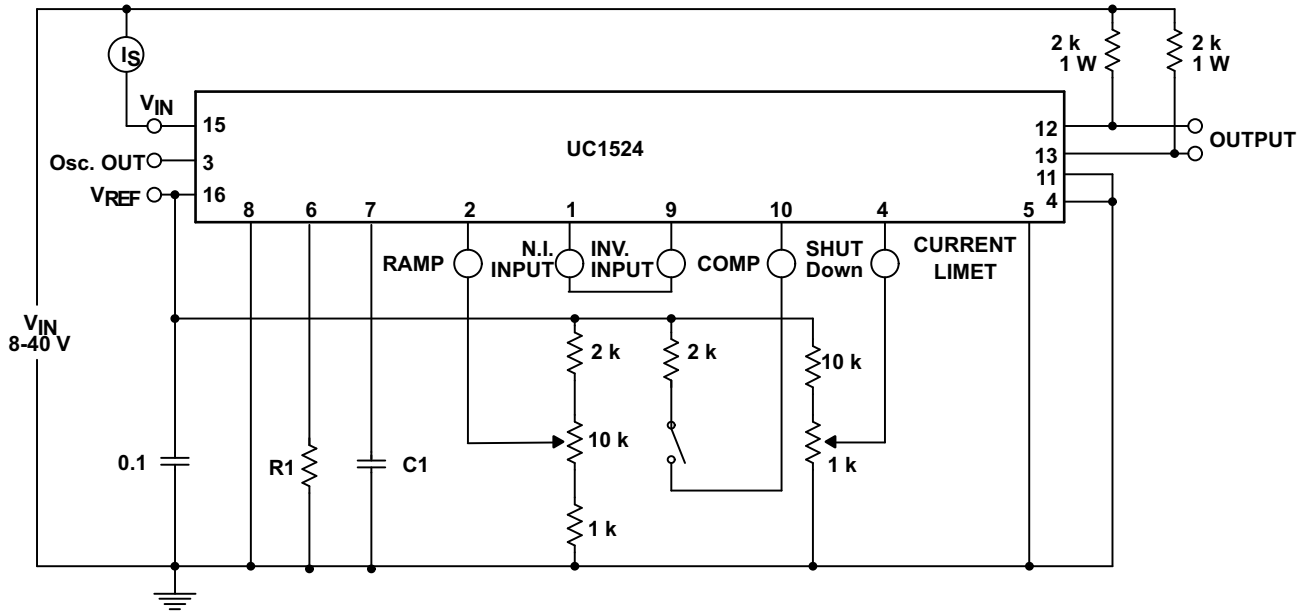


Figure 8. Open Loop Test Circuit

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
UC2524DW	ACTIVE	SOIC	DW	16	40	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2524DW	Samples
UC3524D	ACTIVE	SOIC	D	16	40	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3524D	Samples
UC3524DW	ACTIVE	SOIC	DW	16	40	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3524DW	Samples
UC3524DWTR	ACTIVE	SOIC	DW	16	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3524DW	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 finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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.
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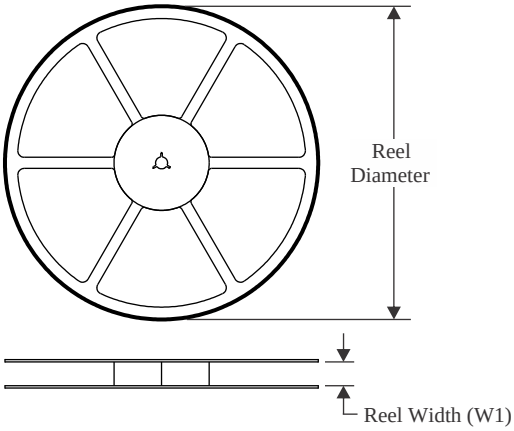
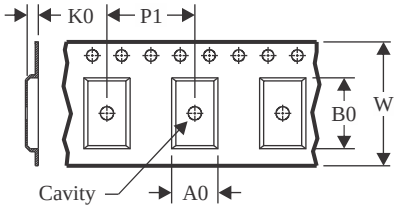
TAPE AND REEL INFORMATION

REEL DIMENSIONS

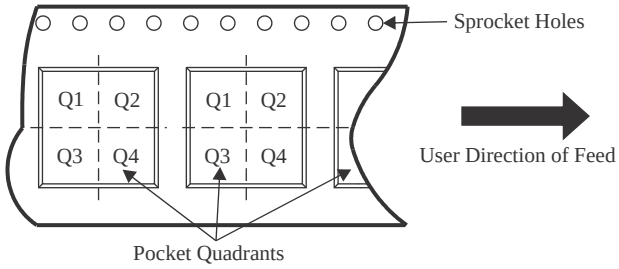


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

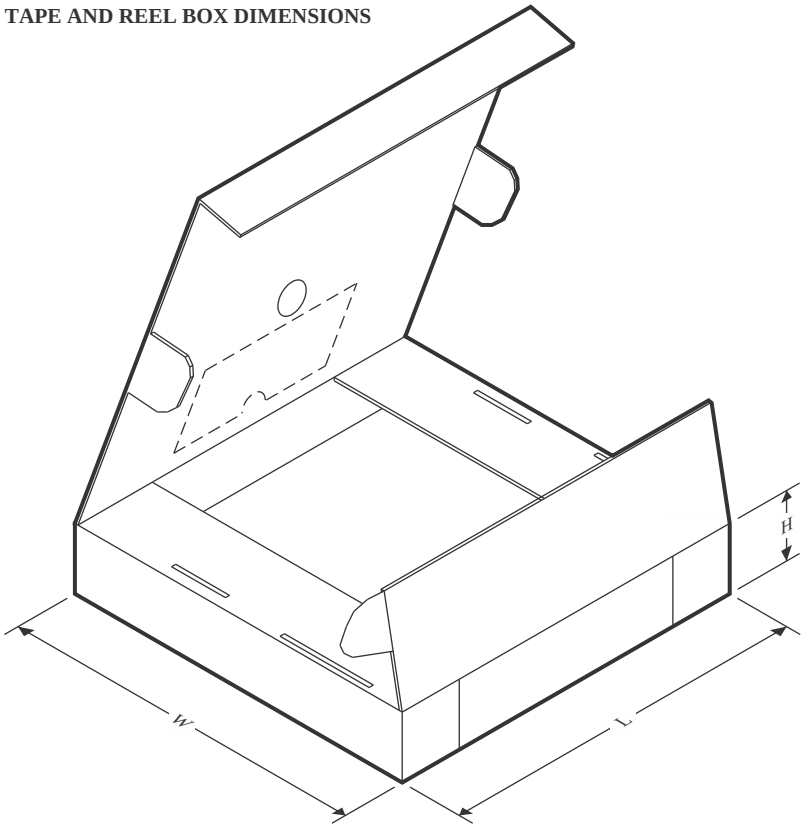
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
UC3524DWTR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1

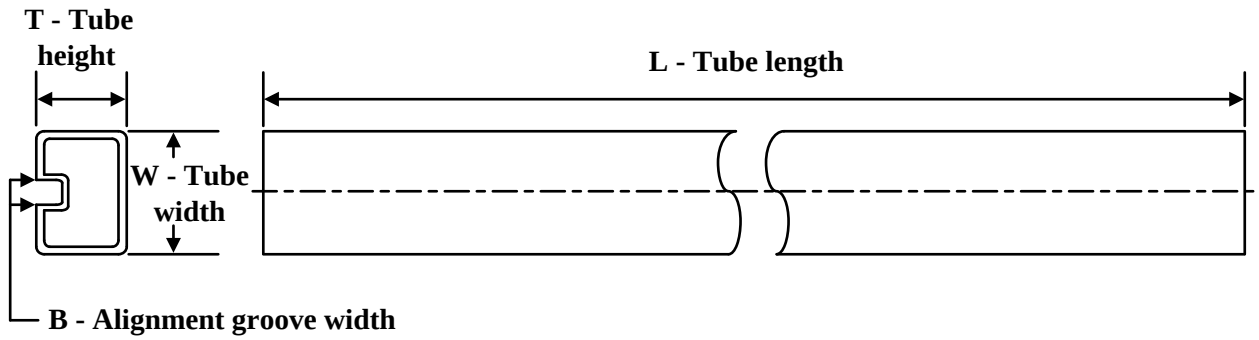
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
UC3524DWTR	SOIC	DW	16	2000	356.0	356.0	35.0

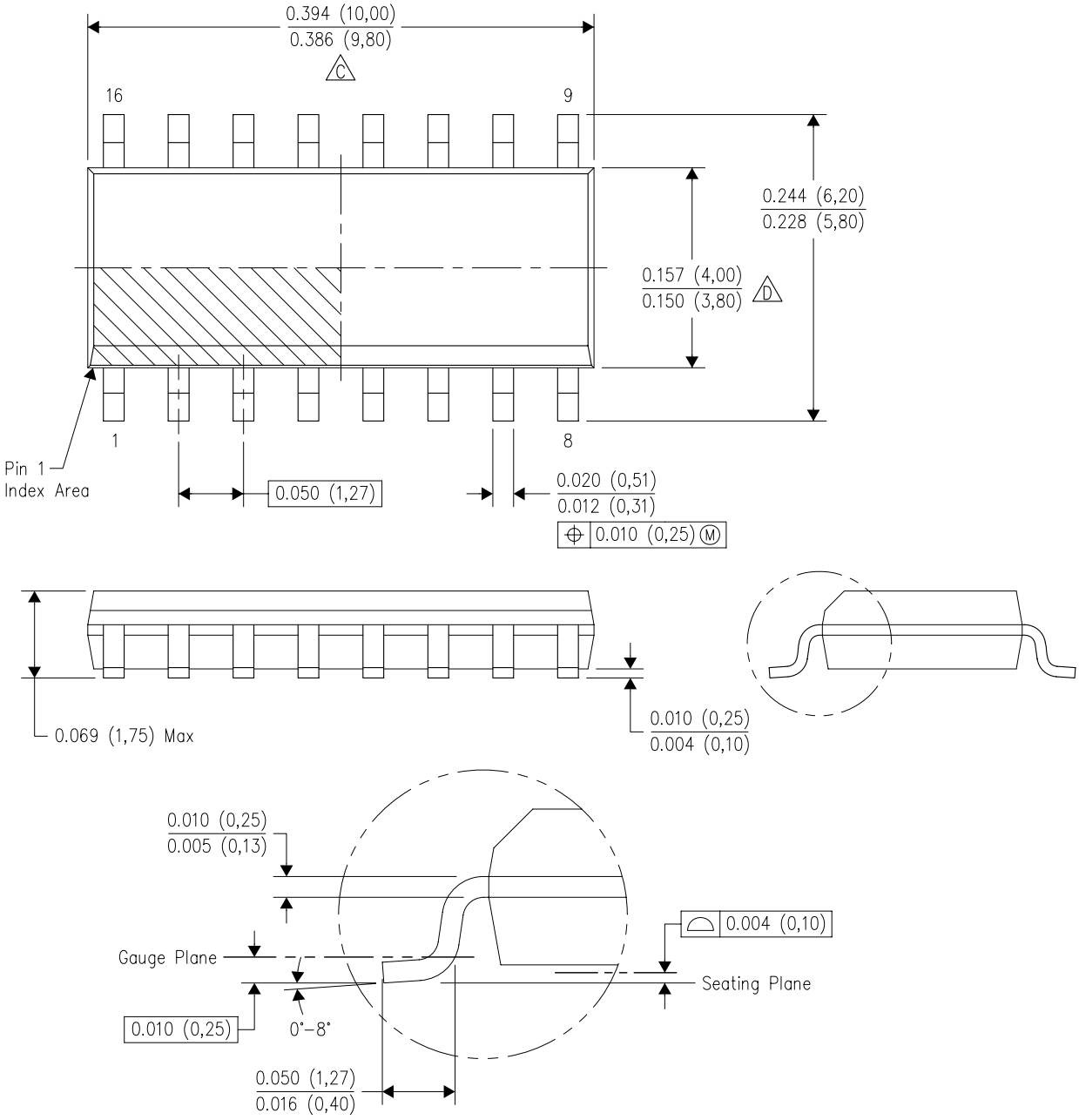
TUBE



*All dimensions are nominal

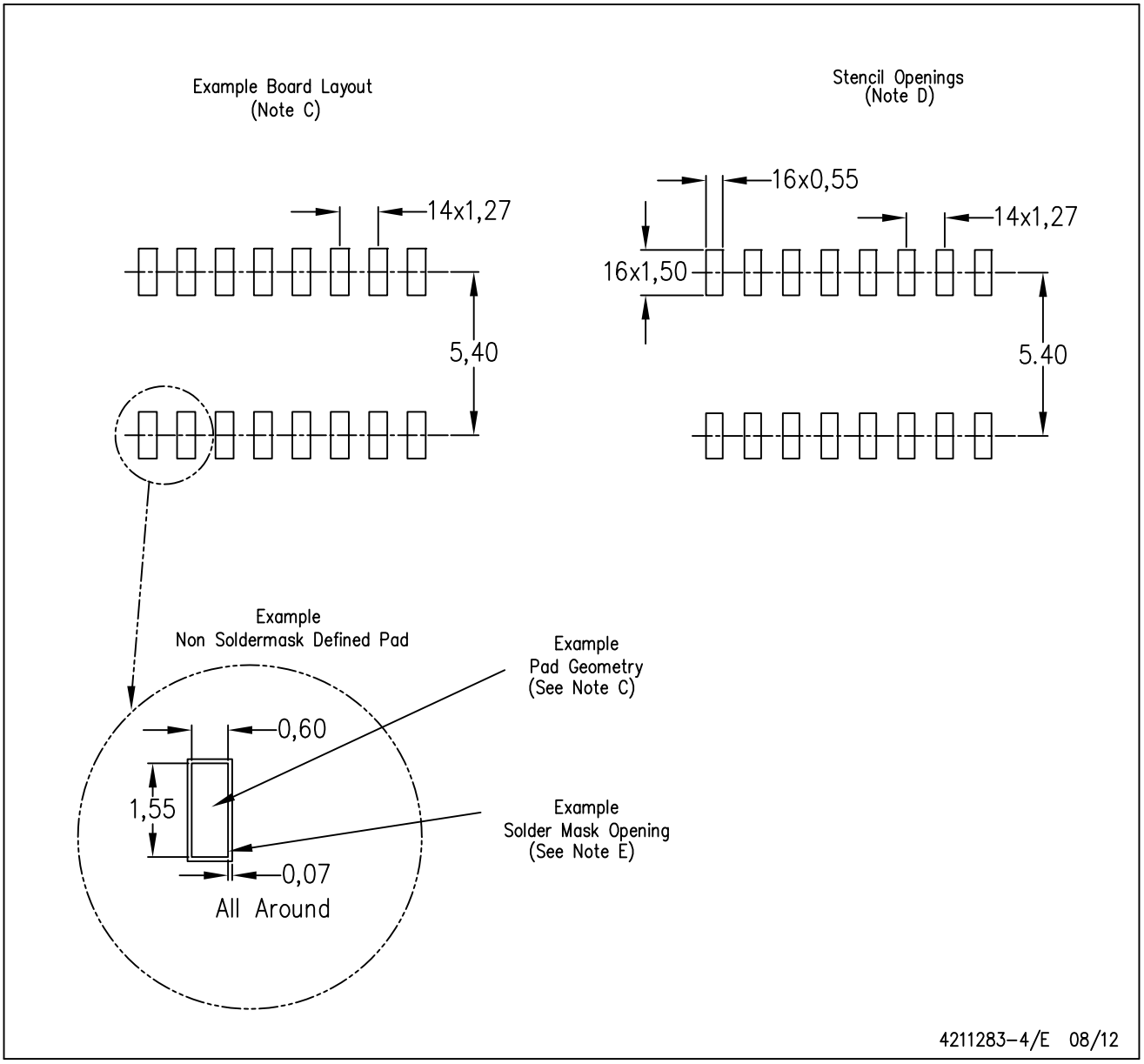
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
UC2524DW	DW	SOIC	16	40	507	12.83	5080	6.6
UC3524D	D	SOIC	16	40	506.6	8	3940	4.32
UC3524DW	DW	SOIC	16	40	507	12.83	5080	6.6

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:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. 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.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

GENERIC PACKAGE VIEW

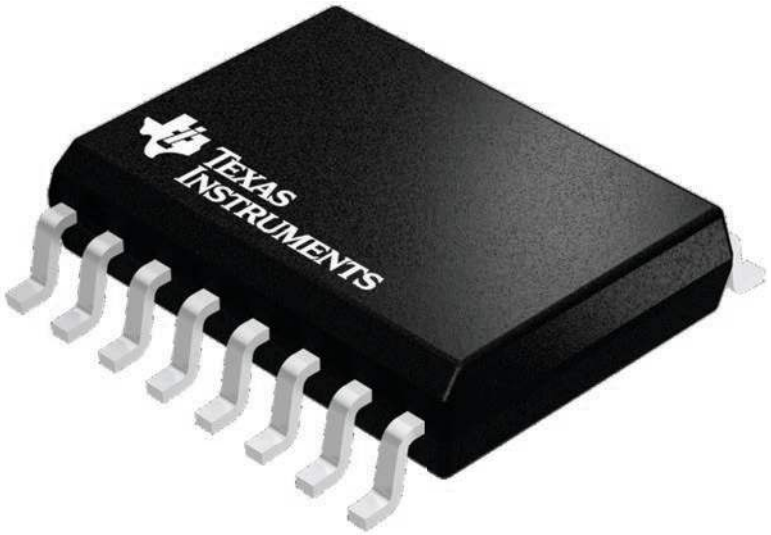
DW 16

SOIC - 2.65 mm max height

7.5 x 10.3, 1.27 mm pitch

SMALL OUTLINE INTEGRATED CIRCUIT

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



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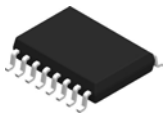
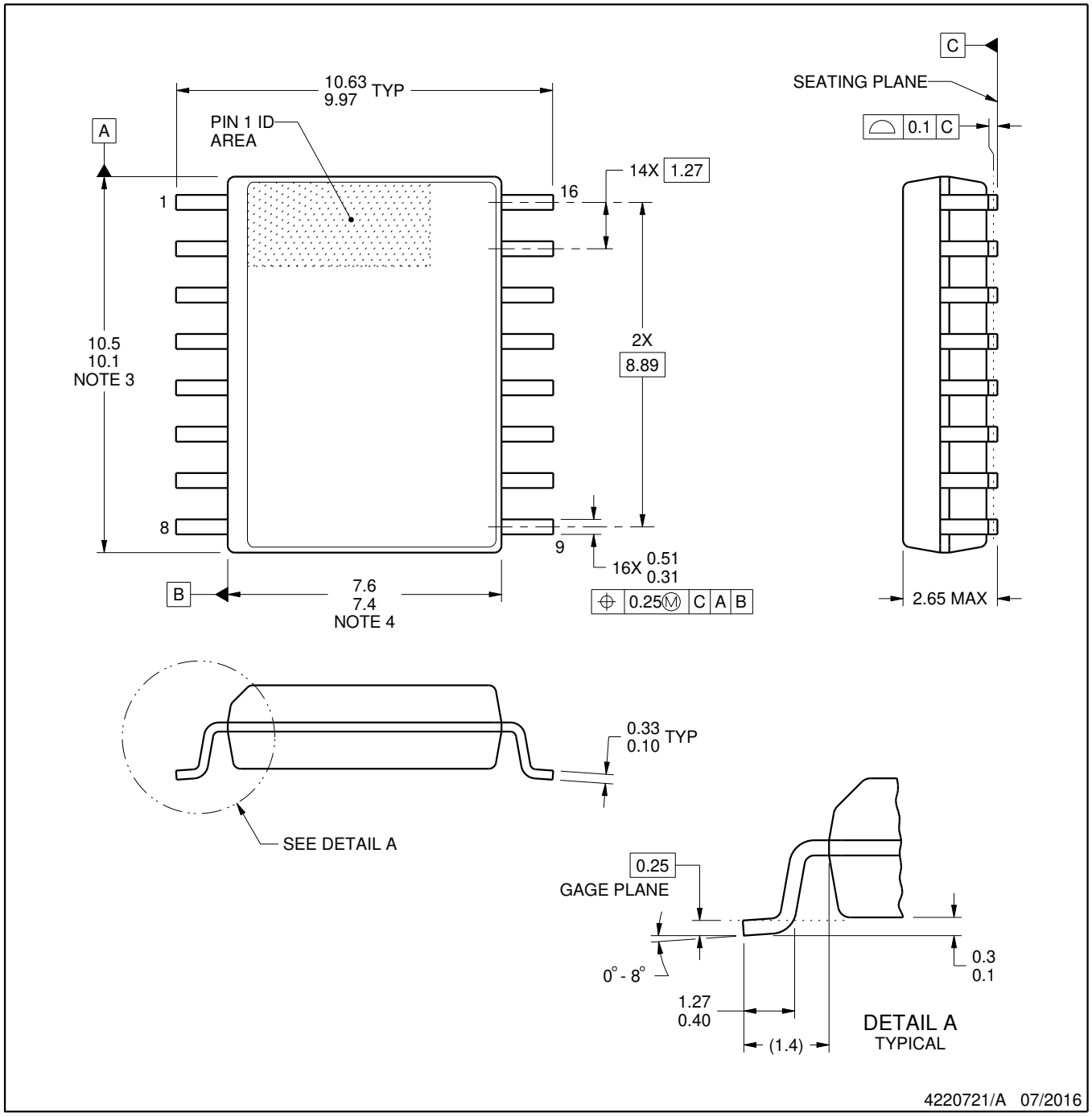


PACKAGE OUTLINE

DW0016A

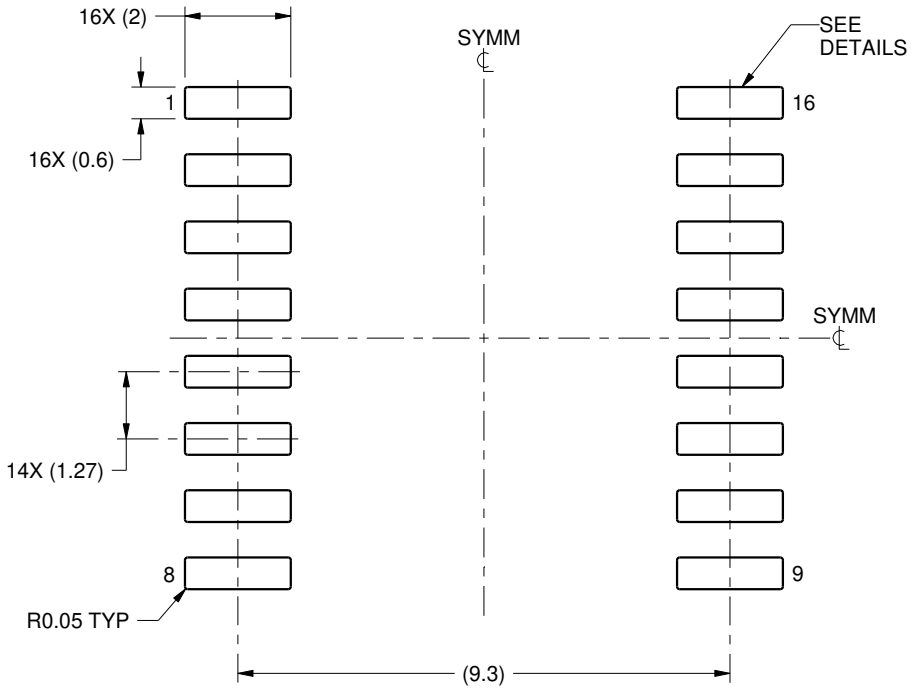
SOIC - 2.65 mm max height

SOIC

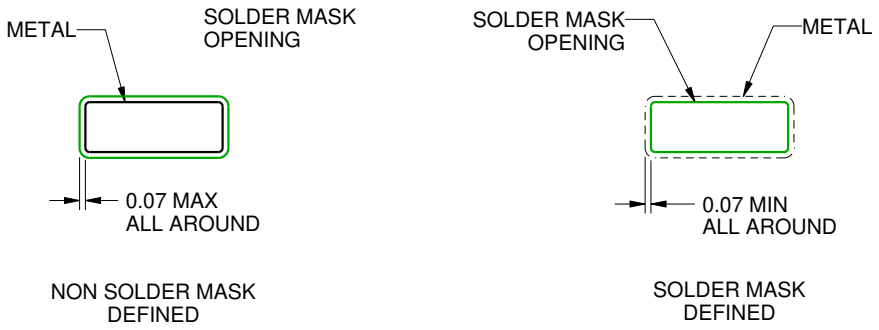


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.
5. Reference JEDEC registration MS-013.



LAND PATTERN EXAMPLE
SCALE:7X

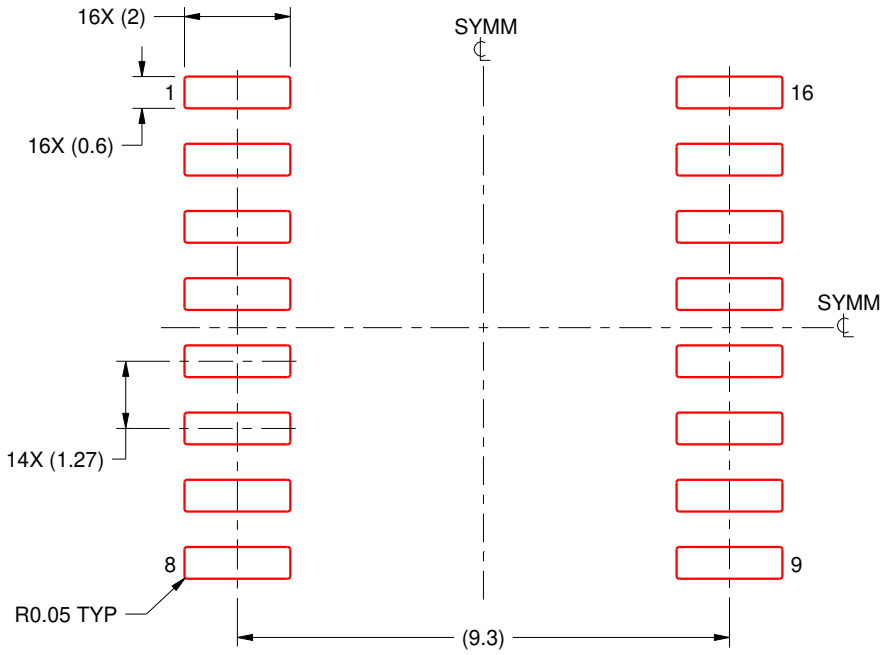


SOLDER MASK DETAILS

4220721/A 07/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:7X

4220721/A 07/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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