

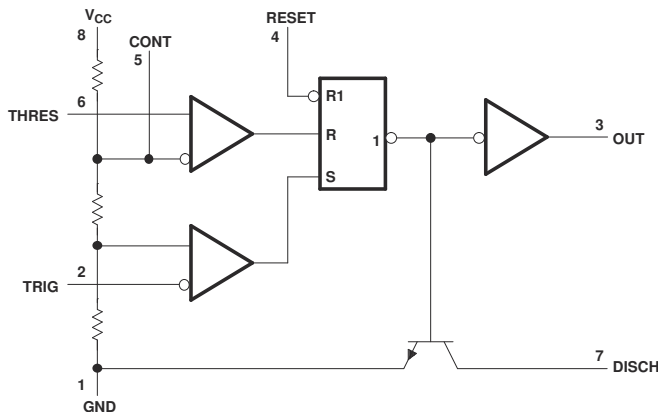
## xx555 Precision Timers

### 1 Features

- Timing from microseconds to hours
- Astable or monostable operation
- Adjustable duty cycle
- TTL-compatible output can sink or source up to 200mA
- On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

### 2 Applications

- Pulse-shaping circuits
- Missing-pulse detectors
- Pulse-width modulators
- Pulse-position modulators
- Sequential timers
- Pulse generators
- Frequency dividers
- Industrial controls



**Simplified Schematic**

### 3 Description

The Nx555 and Sx555 devices are precision timing circuits capable of producing accurate time delays or oscillation. In time-delay or monostable operating modes, the timed interval is controlled by a single external resistor and capacitor network. In the astable mode of operation, the frequency and duty cycle are controlled independently with two external resistors and a single external capacitor.

Each timer has a trigger level equal to approximately one-third of the supply voltage and a threshold level equal to approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage pin (CONT). When the trigger input (TRIG) is less than the trigger level, the flip-flop is set and the output goes high. If TRIG is greater than the trigger level and the threshold input (THRES) is greater than the threshold level, the flip-flop is reset and the output is low. The reset input (RESET) overrides all other inputs and is used to initiate a new timing cycle. If RESET is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge pin (DISCH) and the ground pin (GND). Tie all unused inputs to an appropriate logic level to prevent false triggering.

The output circuit is capable of sinking or sourcing current up to 200mA. Operation is specified for supplies of 5V to 15V. With a 5V supply, output levels are compatible with TTL inputs.

#### Device Information

PART NUMBER	OPERATING TEMPERATURE	PACKAGE <sup>(1)</sup>
NA555	$T_A = -40^{\circ}\text{C}$ to $+105^{\circ}\text{C}$	D (SOIC, 8)
		P (PDIP, 8)
NE555	$T_A = 0^{\circ}\text{C}$ to $70^{\circ}\text{C}$	D (SOIC, 8)
		P (PDIP, 8)
		PS (SO, 8)
SA555	$T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	PW (TSSOP, 8)
		D (SOIC, 8)
SE555	$T_A = -55^{\circ}\text{C}$ to $+125^{\circ}\text{C}$	P (PDIP, 8)
		D (SOIC, 8)
		FK (LCCC, 20)
		JG (CDIP, 8)

(1) For more information, see [Section 10](#).

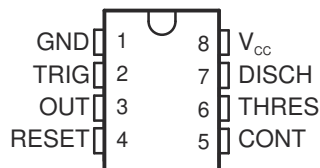


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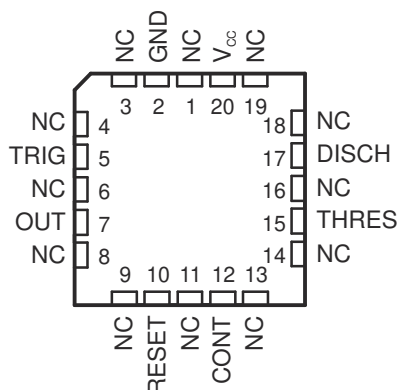
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## 4 Pin Configuration and Functions

NA555...D OR P PACKAGE  
NE555...D, P, PS, OR PW PACKAGE  
SA555...D OR P PACKAGE  
SE555...D, JG, OR P PACKAGE  
(TOP VIEW)



SE555...FK PACKAGE  
(TOP VIEW)



NC – No internal connection

**Table 4-1. Pin Functions**

NAME	PIN NO.		TYPE	DESCRIPTION
	D (SOIC), P (PDIP), PS (SO), PW (TSSOP), JG (CDIP)	FK (LCCC)		
CONT	5	12	Input/output	Controls comparator thresholds, Outputs $2/3 \times V_{CC}$ , allows bypass capacitor connection
DISCH	7	17	Output	Open collector output to discharge timing capacitor
GND	1	2	—	Ground
NC	—	1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	—	No internal connection
OUT	3	7	Output	High current timer output signal
RESET	4	10	Input	Active low reset input forces output and discharge low.
THRES	6	15	Input	End of timing input. THRES > CONT sets output low and discharge low
TRIG	2	5	Input	Start of timing input. TRIG < $1/2$ CONT sets output high and discharge open
V <sub>CC</sub>	8	20	—	Input supply voltage, 4.5V to 16V. SE555 maximum is 18V.

## 5 Specifications

### 5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

			MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage <sup>(2)</sup>			18	V
V <sub>I</sub>	Input voltage	CONT, RESET, THRES, TRIG		V <sub>CC</sub>	V
I <sub>O</sub>	Output current			±225	mA
T <sub>J</sub>	Operating virtual junction temperature			150	°C
	Case temperature for 60 seconds	FK package		260	°C
	Lead temperature 1.6mm (1/16 inch) from case	JG package, 60 seconds		300	°C
T <sub>stg</sub>	Storage temperature		–65	150	°C

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) All voltage values are with respect to GND.

### 5.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	±1500	

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

### 5.3 Recommended Operating Conditions

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

			MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage	NA555, NE555, SA555	4.5	16	V
		SE555	4.5	18	
I <sub>O</sub>	Output current			±200	mA
T <sub>A</sub>	Operating free-air temperature	NA555	–40	105	°C
		NE555	0	70	
		SA555	–40	85	
		SE555	–55	125	

## 5.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		NA556, NE556, SA555, SE555	SE555		NA555, NE555	NE555		UNIT
		D (SOIC)	FK (LCCC)	JG (CDIP)	P (PDIP)	PS (SO)	PW (TSSOP)	
		8 PINS	20 PINS	8 PINS	8 PINS	8 PINS	8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	125.4	92.2	125.0	98.5	124.5	164.2	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	64.9	67.6	73.3	77.8	61.2	70.5	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	73.2	66.7	114.9	61.0	79.3	104.8	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	14.3	61.6	44.4	43.9	16.5	8.2	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	72.1	66.5	106.6	60.3	77.8	103.1	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A	14.2	29.3	N/A	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC package thermal metrics](#) application report.

## 5.5 Electrical Characteristics

at V<sub>CC</sub> = 5V to 15V and T<sub>A</sub> = 25°C (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
THRES voltage level	V <sub>CC</sub> = 15V	NA555, NE555, SA555	8.8	10	11.2	V
		SE555	9.4	10	10.6	
	V <sub>CC</sub> = 5V	NA555, NE555, SA555	2.4	3.3	4.2	
		SE555	2.7	3.3	4	
THRES current <sup>(1)</sup>				30	250	nA
TRIG voltage level	V <sub>CC</sub> = 15V	NA555, NE555, SA555	4.5	5	5.6	V
		SE555	4.8	5	5.2	
	V <sub>CC</sub> = 15V, T <sub>A</sub> = –55°C to +125°C		3		6	
	V <sub>CC</sub> = 5V	NA555, NE555, SA555	1.1	1.67	2.2	
		SE555	1.45	1.67	1.9	
	V <sub>CC</sub> = 5V, T <sub>A</sub> = –55°C to +125°C				1.9	
TRIG current	TRIG at 0V	NA555, NE555, SA555		0.5	2	μA
		SE555		0.5	0.9	
RESET voltage level			0.3	0.7	1	V
	T <sub>A</sub> = –55°C to +125°C	SE555			1.1	
RESET current	RESET at V <sub>CC</sub>			0.1	0.4	mA
	RESET at 0V	NA555, NE555, SA555		–0.4	–1.5	
		SE555		–0.4	–1	
DISCH switch off-state current				20	100	nA
DISCH switch on-state voltage	V <sub>CC</sub> = 5V, I <sub>O</sub> = 8mA	NA555, NE555, SA555		0.15	0.4	V
CONT voltage (open circuit)	V <sub>CC</sub> = 15V	NA555, NE555, SA555	9	10	11	V
		SE555	9.6	10	10.4	
	V <sub>CC</sub> = 15V, T <sub>A</sub> = –55°C to +125°C		9.6		10.4	
	V <sub>CC</sub> = 5V	NA555, NE555, SA555	2.6	3.3	4	
		SE555	2.9	3.3	3.8	
	V <sub>CC</sub> = 5V, T <sub>A</sub> = –55°C to +125°C		2.9		3.8	

## 5.5 Electrical Characteristics (continued)

at  $V_{CC} = 5V$  to  $15V$  and  $T_A = 25^\circ C$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Low-level output voltage	$V_{CC} = 15V, I_{OL} = 10mA$	NA555, NE555, SA555	0.1	0.25	V
		SE555	0.1	0.15	
	$V_{CC} = 15V, I_{OL} = 10mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555		0.2	
	$V_{CC} = 15V, I_{OL} = 50mA$	NA555, NE555, SA555	0.4	0.75	
		SE555	0.4	0.5	
	$V_{CC} = 15V, I_{OL} = 50mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555		1	
	$V_{CC} = 15V, I_{OL} = 100mA$	NA555, NE555, SA555	2	2.5	
		SE555	2	2.2	
	$V_{CC} = 15V, I_{OL} = 100mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555		2.7	
	$V_{CC} = 15V, I_{OL} = 200mA$		2.5		
	$V_{CC} = 5V, I_{OL} = 3.5mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555		0.35	
	$V_{CC} = 5V, I_{OL} = 5mA$	NA555, NE555, SA555	0.1	0.35	
		SE555	0.1	0.2	
	$V_{CC} = 5V, I_{OL} = 5mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555		0.8	
	$V_{CC} = 5V, I_{OL} = 8mA$	NA555, NE555, SA555	0.15	0.4	
		SE555	0.15	0.25	
High-level output voltage	$V_{CC} = 15V, I_{OH} = -100mA$	NA555, NE555, SA555	12.75	13.3	V
		SE555	13	13.3	
	$V_{CC} = 15V, I_{OH} = -100mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555	12		
	$V_{CC} = 15V, I_{OH} = -200mA$		12.5		
	$V_{CC} = 5V, I_{OH} = -100mA$	NA555, NE555, SA555	2.75	3.3	
		SE555	3	3.3	
Supply current	$V_{CC} = 5V, I_{OH} = -100mA, T_A = -55^\circ C$ to $+125^\circ C$	SE555	2		mA
	Output low, no load, $V_{CC} = 15V$	NA555, NE555, SA555	10	15	
		SE555	10	12	
	Output low, no load, $V_{CC} = 5V$	NA555, NE555, SA555	3	6	
		SE555	3	5	
	Output high, no load, $V_{CC} = 15V$	NA555, NE555, SA555	9	13	
		SE555	9	10	
	Output high, no load, $V_{CC} = 5V$	NA555, NE555, SA555	2	5	
		SE555	2	4	

- (1) This parameter influences the maximum value of the timing resistors  $R_A$  and  $R_B$  in the circuit of [Figure 6-5](#). For example, when  $V_{CC} = 5V$ , the maximum value is  $R = R_A + R_B \cong 3.4M\Omega$ , and for  $V_{CC} = 15V$ , the maximum value is  $R_A + R_B \cong 10M\Omega$ .

## 5.6 Switching Characteristics

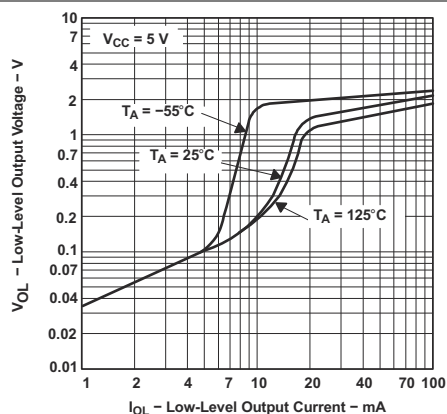
$V_{CC} = 5V$  to  $15V$  and  $T_A = 25^\circ C$  (unless otherwise noted); characteristic values are specified by design, characterization, or both, and are not production tested

PARAMETER		TEST CONDITIONS <sup>(1)</sup>		MIN	TYP	MAX	UNIT
	Temperature coefficient of timing interval	Each timer, monostable <sup>(2)</sup> , $T_A = \text{MIN to MAX}$	NA555, NE555, SA555		50		ppm/ $^\circ C$
			SE555		30	100	
		Each timer, astable <sup>(3)</sup> , $T_A = \text{MIN to MAX}$	NA555, NE555, SA555		150		
			SE555		90		
	Supply-voltage sensitivity of timing interval	Each timer, monostable <sup>(2)</sup>	NA555, NE555, SA555		0.1	0.5	%/ $V$
			SE555		0.05	0.2	
		Each timer, astable <sup>(3)</sup>	NA555, NE555, SA555		0.3		
			SE555		0.15		
$t_r$	Output-pulse rise time	$C_L = 15pF$ , $T_A = 25^\circ C$ , 20% to 80%	NA555, NE555, SA555		100	300	ns
			SE555		100	200	
$t_f$	Output-pulse fall time	$C_L = 15pF$ , $T_A = 25^\circ C$ , 80% to 20%	NA555, NE555, SA555		100	300	ns
			SE555		100	200	

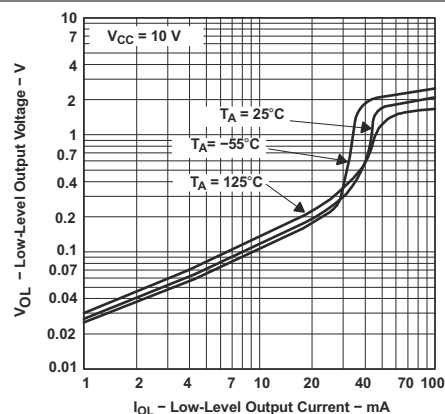
- (1) For conditions shown as MIN or MAX, use the appropriate value specified under *Recommended Operating Conditions*.
- (2) Values specified are for a device in a monostable circuit similar to [Figure 6-2](#), with the following component values:  $R_A = 2k\Omega$  to  $100k\Omega$ ,  $C = 0.1\mu F$ .
- (3) Values specified are for a device in an astable circuit similar to [Figure 6-5](#), with the following component values:  $R_A = 1k\Omega$  to  $100k\Omega$ ,  $C = 0.1\mu F$ .

## 5.7 Typical Characteristics

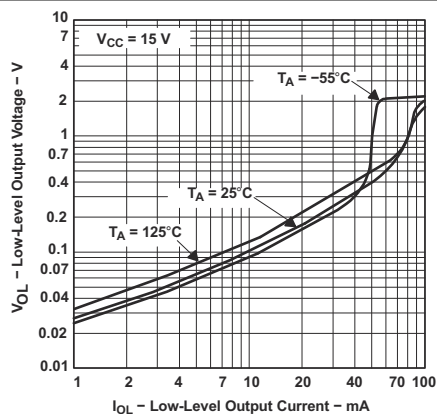
data for temperatures less than  $-40^{\circ}\text{C}$  and greater than  $105^{\circ}\text{C}$  are applicable for SE555 circuits only



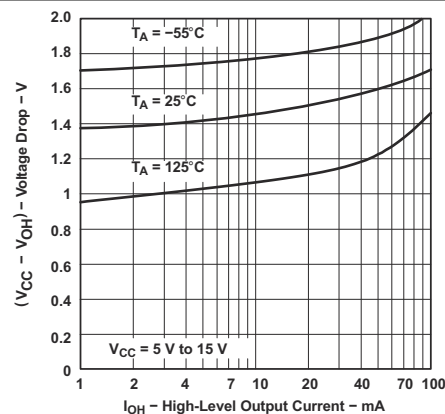
**Figure 5-1. Low-Level Output Voltage vs Low-Level Output Current**



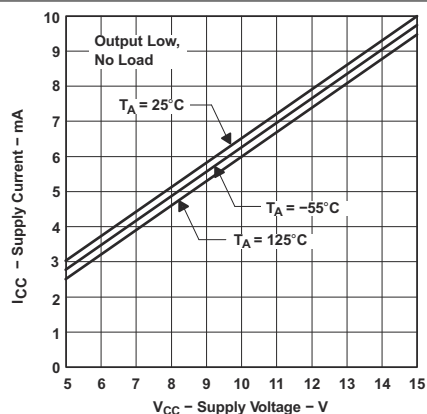
**Figure 5-2. Low-Level Output Voltage vs Low-Level Output Current**



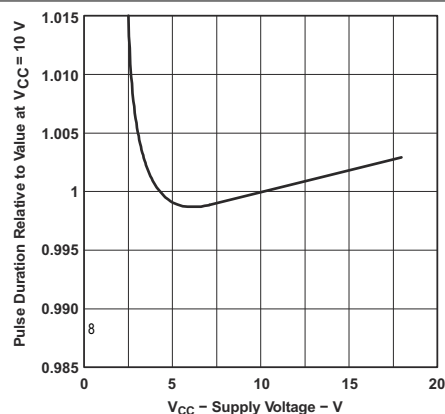
**Figure 5-3. Low-Level Output Voltage vs Low-Level Output Current**



**Figure 5-4. Drop Between Supply Voltage and Output vs High-Level Output Current**



**Figure 5-5. Supply Current vs Supply Voltage**

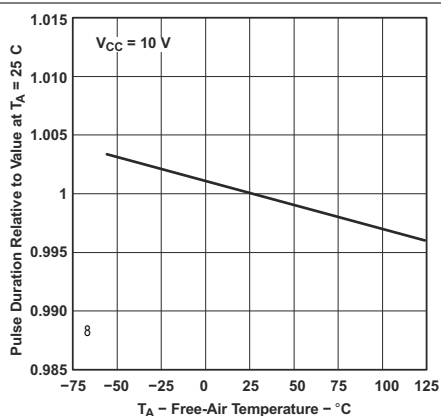


**Figure 5-6. Normalized Output Pulse Duration (Monostable Operation) vs Supply Voltage**

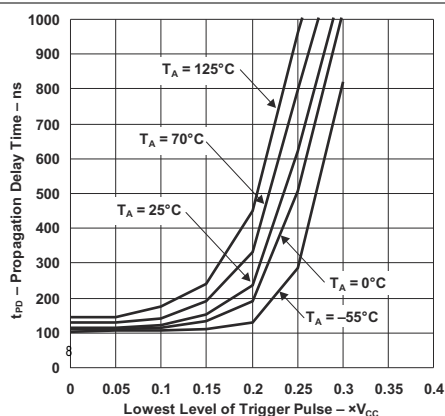


## 5.7 Typical Characteristics (continued)

data for temperatures less than  $-40^{\circ}\text{C}$  and greater than  $105^{\circ}\text{C}$  are applicable for SE555 circuits only



**Figure 5-7. Normalized Output Pulse Duration  
(Monostable Operation)  
vs  
Free-Air Temperature**

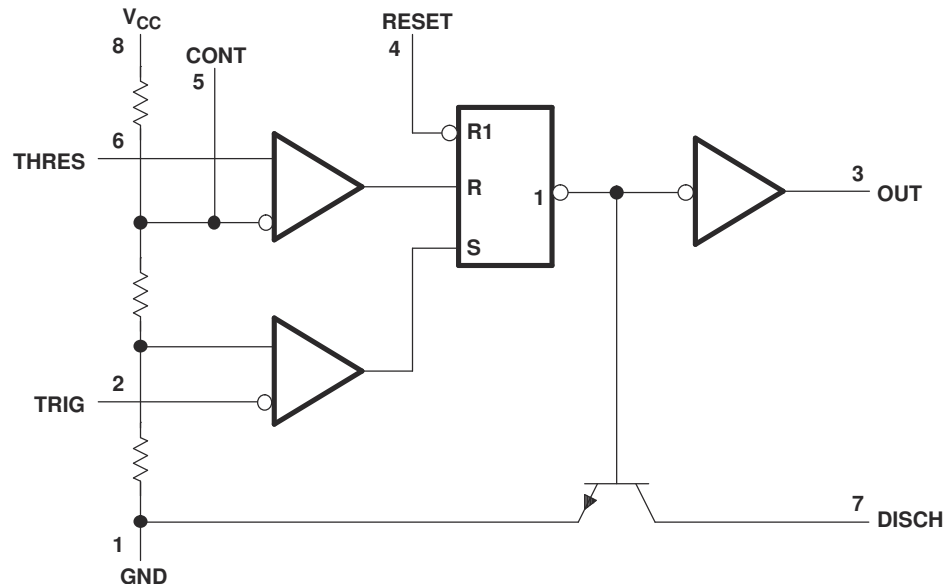


**Figure 5-8. Propagation Delay Time  
vs  
Lowest Voltage Level of Trigger Pulse**

## 6 Detailed Description

## 6.1 Overview

The Nx555 or Sx555 is a precision timing device for general-purpose timing applications from 10 $\mu$ s to hours or from < 1mHz to 100kHz. In the time-delay or monostable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the astable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor. Maximum output sink and discharge sink current are greater for higher V<sub>CC</sub> and less for lower V<sub>CC</sub>.

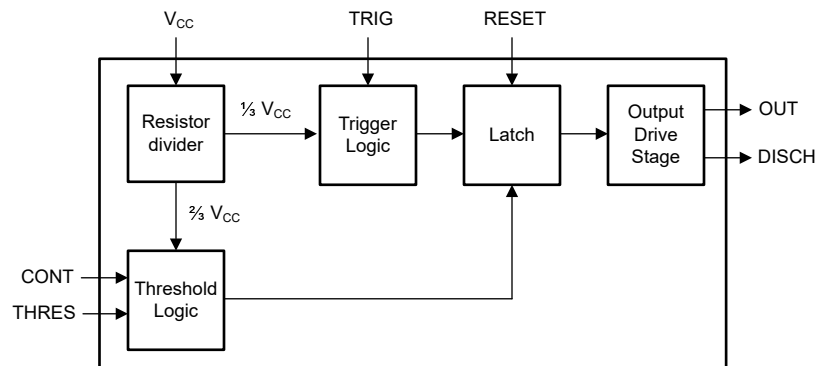


Note: Pin numbers shown are for the D, JG, P, PS, and PW packages.

Note: RESET can override TRIG, which can override THRES.

### Figure 6-1. Simplified Schematic

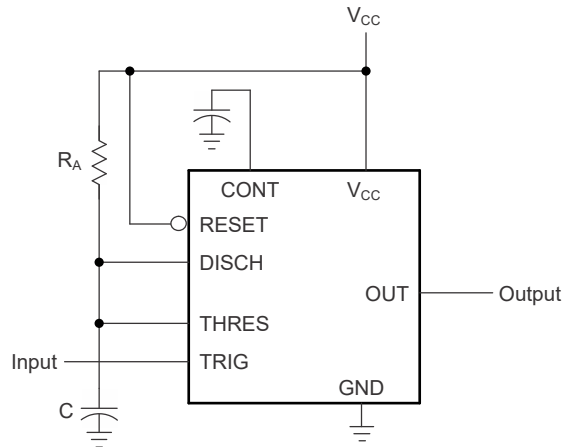
## 6.2 Functional Block Diagram



## 6.3 Feature Description

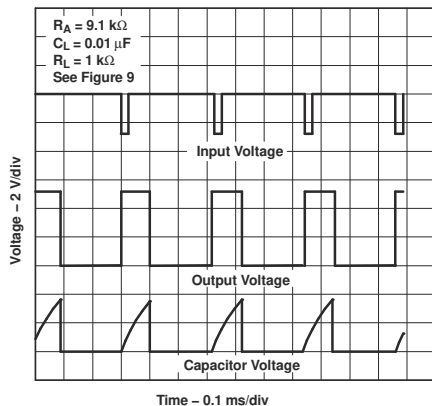
### 6.3.1 Monostable Operation

For monostable operation, [Figure 6-2](#) shows how to connect any of these timers. If the output is low, application of a negative-going pulse to the trigger (TRIG) sets the flip-flop ( $\overline{Q}$  goes low), drives the output high, and turns off Q1. Capacitor C is then charged through  $R_A$  until the voltage across the capacitor reaches the threshold voltage of the threshold (THRES) input. If TRIG has returned to a high level, the output of the threshold comparator resets the flip-flop ( $\overline{Q}$  goes high), drives the output low, and discharges C through Q1.

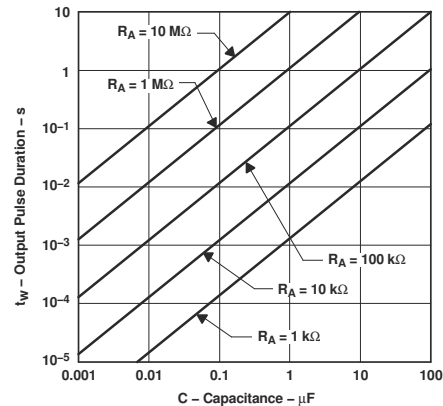


**Figure 6-2. Circuit for Monostable Operation**

Monostable operation is initiated when the TRIG voltage is less than the trigger threshold. After being initiated, the sequence ends only if TRIG is high for at least  $10\mu\text{s}$  before the end of the timing interval. When the trigger is grounded, the comparator storage time can be as long as  $10\mu\text{s}$ , which limits the minimum monostable pulse width to  $10\mu\text{s}$ . As a result of the threshold level and saturation voltage of Q1, the output pulse duration is approximately  $t_w = 1.1 \times R_A C$ . [Figure 6-4](#) is a plot of the time constant for various values of  $R_A$  and C. The threshold levels and charge rates both are directly proportional to the supply voltage,  $V_{CC}$ . The timing interval is, therefore, independent of the supply voltage, as long as the supply voltage is constant during the time interval.



**Figure 6-3. Typical Monostable Waveforms**

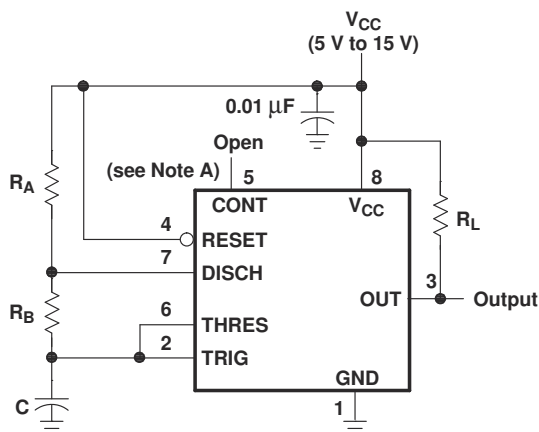


**Figure 6-4. Output Pulse Duration vs Capacitance**

Applying a negative-going trigger pulse simultaneously to RESET and TRIG during the timing interval discharges C and reinitiates the cycle, commencing on the positive edge of the reset pulse. The output is held low for as long as the reset pulse is low. To prevent false triggering, when RESET is not used, connect RESET to  $V_{CC}$ .

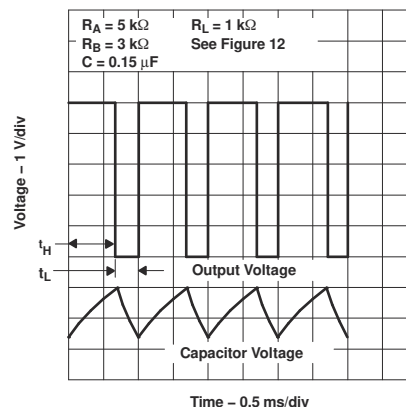
### 6.3.2 Astable Operation

Figure 6-5 shows that adding a second resistor,  $R_B$ , to the circuit of Figure 6-2 and connecting the trigger input to the threshold input causes the timer to self-trigger and run as a multivibrator. Capacitor  $C$  charges through  $R_A$  and  $R_B$  and then discharges through  $R_B$  only. Therefore, the duty cycle is controlled by the values of  $R_A$  and  $R_B$ .



Pin numbers shown are for the D, JG, P, PS, and PW packages.  
NOTE A: Decoupling CONT voltage to ground with a capacitor can improve operation. This should be evaluated for individual applications.

**Figure 6-5. Circuit for Astable Operation**



**Figure 6-6. Typical Astable Waveforms**

This astable connection results in capacitor  $C$  charging and discharging between the threshold-voltage level ( $\cong 0.67 \times V_{CC}$ ) and the trigger-voltage level ( $\cong 0.33 \times V_{CC}$ ). As in the mono-stable circuit, charge and discharge times (and, therefore, the frequency and duty cycle) are independent of the supply voltage. To reduce distortion, use at maximum frequency of 100kHz or below. If higher-frequency operation is required, consider using the [TLC555 LinCMOS™ Timer](#) instead.

Figure 6-6 shows typical waveforms generated during astable operation. The output high-level duration  $t_H$  and low-level duration  $t_L$  are calculated as follows:

$$t_H \cong 0.693 \times (R_A + R_B) \times C \quad (1)$$

$$t_L \cong 0.693 \times R_B \times C \quad (2)$$

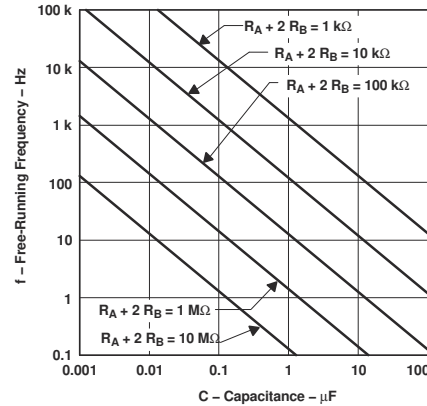
Other useful relationships for period, frequency, and driver-referred and waveform-referred duty cycle are calculated as follows:

$$T = t_H + t_L \cong 0.693 \times (R_A + 2R_B) \times C \quad (3)$$

$$f = \frac{1}{T} \cong \frac{1.44}{(R_A + 2R_B) \times C} \quad (4)$$

$$\text{Output driver duty cycle} = \frac{t_L}{T} \cong \frac{R_B}{R_A + 2R_B} \quad (5)$$

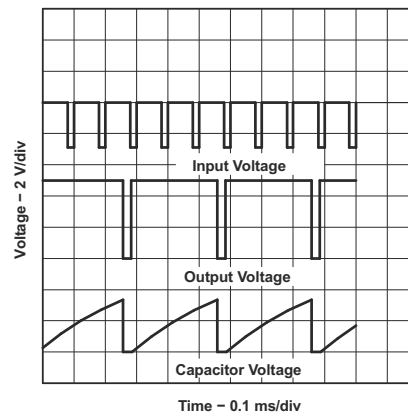
$$\text{Output waveform duty cycle} = \frac{t_H}{T} \cong 1 - \frac{R_B}{R_A + 2R_B} = \frac{R_A + R_B}{R_A + 2R_B} \quad (6)$$



**Figure 6-7. Free-Running Frequency**

### 6.3.3 Frequency Divider

By adjusting the length of the timing cycle, the basic circuit of [Figure 6-2](#) can be made to operate as a frequency divider. [Figure 6-8](#) shows a divide-by-three circuit that makes use of the fact that retriggering cannot occur during the timing cycle.



$V_{CC} = 5V$

$R_A = 1250\Omega$

$C = 0.2\mu F$

See [Figure 6-2](#)

**Figure 6-8. Divide-by-Three Circuit Waveforms**

## 6.4 Device Functional Modes

[Table 6-1](#) shows the device truth table. For a valid reset voltage condition, use an external pullup resistor to  $V_{CC}$  (if using the RESET functionality), or short the RESET pin directly to  $V_{CC}$  (if the RESET functionality is not used).

**Table 6-1. Function Table**

RESET VOLTAGE <sup>(1)</sup>	TRIGGER VOLTAGE <sup>(1)</sup>	THRESHOLD VOLTAGE <sup>(1)</sup>	OUTPUT	DISCHARGE SWITCH
LOW	Irrelevant	Irrelevant	Low	On
> MAX	$< 1/3 \times V_{CC}$	Irrelevant <sup>(2)</sup>	High	Off
> MAX	$> 1/3 \times V_{CC}$	$> 2/3 \times V_{CC}$	Low	On
> MAX	$> 1/3 \times V_{CC}$	$< 2/3 \times V_{CC}$	As previously established	

(1) Voltage levels shown are nominal.

(2) CONT pin open or  $2/3 \times V_{CC}$ .

## 7 Applications 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, as well as validating and testing their design implementation to confirm system functionality.

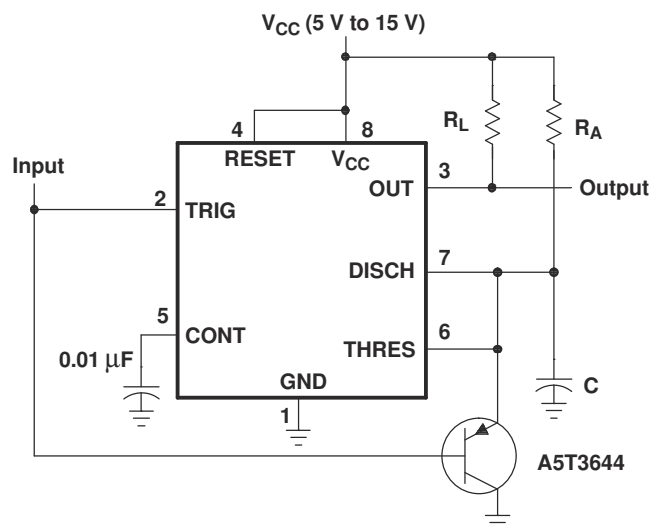
### 7.1 Application Information

The Nx555 and Sx555 precision timers use resistor and capacitor charging delay to provide a programmable time delay or operating frequency. This section presents a simplified discussion of the design process.

### 7.2 Typical Applications

#### 7.2.1 Missing-Pulse Detector

The circuit shown in [Figure 7-1](#) can be used to detect a missing pulse or abnormally long spacing between consecutive pulses in a train of pulses. The timing interval of the monostable circuit is re-triggered continuously by the input pulse train as long as the pulse spacing is less than the timing interval. A longer pulse spacing, missing pulse, or terminated pulse train permits the timing interval to be completed, thereby generating an output pulse as shown in [Figure 7-2](#).



Pin numbers shown are shown for the D, JG, P, PS, and PW packages.

**Figure 7-1. Circuit for Missing-Pulse Detector**

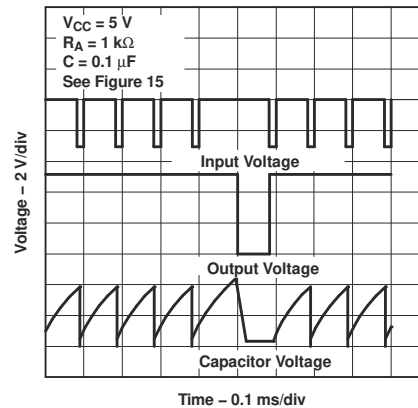
#### 7.2.1.1 Design Requirements

Input fault (missing pulses) must be input high. Input stuck low cannot be detected because the timing capacitor (C) remains discharged.

#### 7.2.1.2 Detailed Design Procedure

Choose  $R_A$  and C so that  $R_A \times C > [\text{maximum normal input high time}]$ .  $R_L$  improves  $V_{OH}$ , but is not required for TTL compatibility.

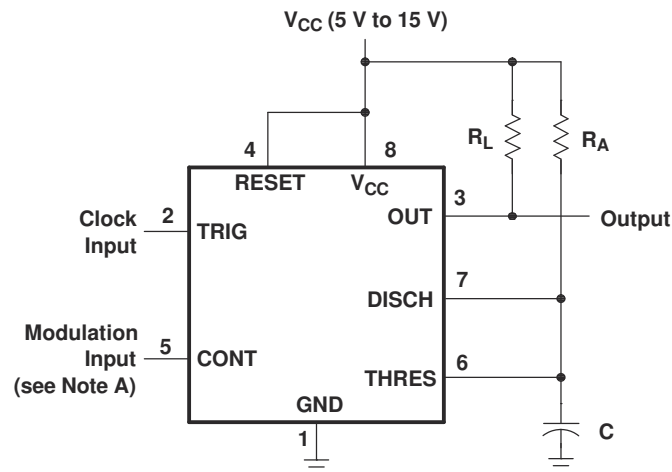
### 7.2.1.3 Application Curve



**Figure 7-2. Completed Timing Waveforms for Missing-Pulse Detector**

### 7.2.2 Pulse-Width Modulation

The operation of the timer can be modified by modulating the internal threshold and trigger voltages, which is accomplished by applying an external voltage (or current) to CONT. Figure 7-3 shows a circuit for pulse-width modulation. A continuous input pulse train triggers the monostable circuit, and a control signal modulates the threshold voltage. Figure 7-4 shows the resulting output pulse-width modulation. While a sine-wave modulation signal is shown, any wave shape can be used.



Pin numbers shown are for the D, JG, P, PS, and PW packages.

NOTE A: The modulating signal can be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

**Figure 7-3. Circuit for Pulse-Width Modulation**

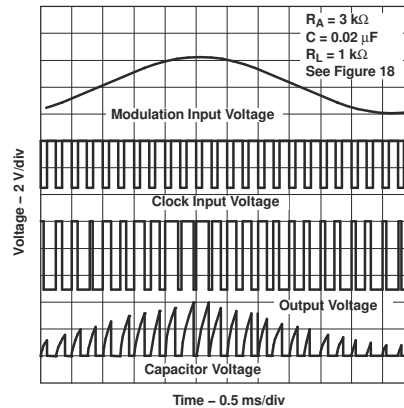
#### 7.2.2.1 Design Requirements

Clock input must have  $V_{OL}$  and  $V_{OH}$  levels that are less than and greater than  $1/3 \times V_{CC}$ . Modulation input can vary from ground to  $V_{CC}$ . The application must be tolerant of a nonlinear transfer function; the relationship between modulation input and pulse width is not linear because the capacitor charge is RC-based with an negative exponential curve.

### 7.2.2.2 Detailed Design Procedure

Choose  $R_A$  and  $C$  so that  $R_A \times C = 1/4$  [clock input period].  $R_L$  improves  $V_{OH}$ , but is not required for TTL compatibility.

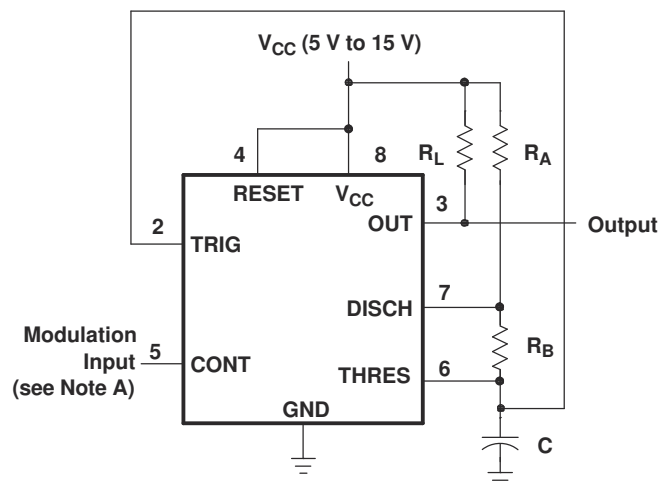
### 7.2.2.3 Application Curve



**Figure 7-4. Pulse-Width-Modulation Waveforms**

### 7.2.3 Pulse-Position Modulation

As shown in Figure 7-5, any of these timers can be used as a pulse-position modulator. This application modulates the threshold voltage and, thereby, the time delay, of a free-running oscillator. Figure 7-6 shows a triangular-wave modulation signal for such a circuit; however, any wave shape can be used.



Pin numbers shown are for the D, JG, P, PS, and PW packages.

NOTE A: The modulating signal can be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

**Figure 7-5. Circuit for Pulse-Position Modulation**

### 7.2.3.1 Design Requirements

Both dc- and ac-coupled modulation input changes the upper and lower voltage thresholds for the timing capacitor. Both frequency and duty cycle vary with the modulation voltage.

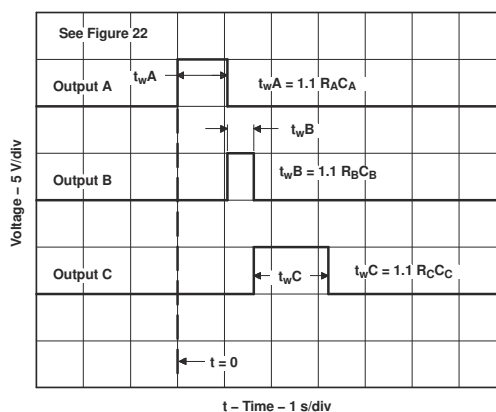




### 7.2.4.2 Detailed Design Procedure

The timing resistors and capacitors can be chosen using this formula.  $t_w = 1.1 \times R \times C$ .

### 7.2.4.3 Application Curve



**Figure 7-8. Sequential Timer Waveforms**

## 7.3 Power Supply Recommendations

The Nx555 and Sx555 precision timers are designed to operate from an input voltage supply range between 4.5V and 16V (18V for SE555). A bypass capacitor is highly recommended from  $V_{CC}$  to the ground pin; a ceramic 0.1 $\mu$ F capacitor is sufficient.

## 8 Device and Documentation Support

### 8.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 8.2 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 8.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 8.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 8.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision I (September 2014) to Revision J (February 2025)</b>	<b>Page</b>
• Updated list of end equipment in <i>Applications</i> .....	1
• Updated <i>Device Information</i> table.....	1
• Deleted package thermal impedance specifications from <i>Absolute Maximum Ratings</i> and added <i>Thermal Information</i> table with updated per-package thermal specifications.....	4
• Deleted <i>Handling Ratings</i> and moved storage temperature specification to <i>Absolute Maximum Ratings</i> .....	4
• Added <i>ESD Ratings</i> table.....	4
• Deleted redundant input voltage specification in <i>Recommended Operating Conditions</i> .....	4
• Changed <i>Operating Characteristics</i> title to <i>Switching Characteristics</i> , and clarified that values are specified by design or characterization and are not production tested.....	7
• Deleted initial error of timing interval specification in <i>Switching Characteristics</i> and clarified that output rise and fall times are 20% to 80% and 80% to 20%, respectively.....	7
• Changed functional block diagram to simplified schematic and moved to Overview.....	10
• Updated <i>Functional Block Diagram</i> .....	10
• Added CONT pin table note to Table 6-1, <i>Function Table</i> .....	13

<b>Changes from Revision H (June 2010) to Revision I (September 2014)</b>	<b>Page</b>
• Updated document to new TI enhanced data sheet format.....	1
• Deleted <i>Ordering Information</i> table.....	1
• Added Military Disclaimer to <i>Features</i> .....	1
• Added <i>Applications</i> .....	1

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• Added <i>Device Information</i> table.....	1
• Added DISCH switch on-state voltage parameter.....	5
• Added Mechanical, Packaging, and Orderable Information section.....	20

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## 10 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-side navigation.

## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">JM38510/10901BPA</a>	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	JM38510 /10901BPA
JM38510/10901BPA.A	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	JM38510 /10901BPA
<a href="#">NA555D</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	-40 to 105	NA555
<a href="#">NA555DR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	NA555
NA555DR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	NA555
<a href="#">NA555P</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU   SN	N/A for Pkg Type	-40 to 105	NA555P
NA555P.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 105	NA555P
<a href="#">NA555PE4</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 105	NA555P
NA555PE4.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 105	NA555P
<a href="#">NE555D</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	0 to 70	NE555
<a href="#">NE555DR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU   SN	Level-1-260C-UNLIM	0 to 70	NE555
NE555DR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555
<a href="#">NE555DR1G4</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555
NE555DR1G4.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	NE555
<a href="#">NE555DRG4</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	0 to 70	NE555
<a href="#">NE555P</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU   SN	N/A for Pkg Type	0 to 70	NE555P
NE555P.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	0 to 70	NE555P
<a href="#">NE555PE4</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	0 to 70	NE555P
NE555PE4.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	0 to 70	NE555P
<a href="#">NE555PS</a>	Active	Production	SO (PS)   8	80   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-	N555
NE555PS.A	Active	Production	SO (PS)   8	80   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
<a href="#">NE555PSR</a>	Active	Production	SO (PS)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
NE555PSR.A	Active	Production	SO (PS)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
<a href="#">NE555PW</a>	Obsolete	Production	TSSOP (PW)   8	-	-	Call TI	Call TI	0 to 70	N555
<a href="#">NE555PWR</a>	Active	Production	TSSOP (PW)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
NE555PWR.A	Active	Production	TSSOP (PW)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
NE555PWR.B	Active	Production	TSSOP (PW)   8	2000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	N555
<a href="#">SA555D</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	-40 to 85	SA555

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">SA555DR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU   SN	Level-1-260C-UNLIM	-40 to 85	SA555
SA555DR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	SA555
<a href="#">SA555DRG4</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	-40 to 85	SA555
<a href="#">SA555P</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	SA555P
SA555P.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	SA555P
<a href="#">SE555D</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	-55 to 125	SE555
<a href="#">SE555DG4</a>	Obsolete	Production	SOIC (D)   8	-	-	Call TI	Call TI	-55 to 125	SE555
<a href="#">SE555DR</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555
SE555DR.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555
<a href="#">SE555DRG4</a>	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555
SE555DRG4.A	Active	Production	SOIC (D)   8	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	SE555
<a href="#">SE555FKB</a>	Active	Production	LCCC (FK)   20	55   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555FKB
SE555FKB.A	Active	Production	LCCC (FK)   20	55   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555FKB
<a href="#">SE555JG</a>	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555JG
SE555JG.A	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555JG
<a href="#">SE555JGB</a>	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555JGB
SE555JGB.A	Active	Production	CDIP (JG)   8	50   TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	SE555JGB
<a href="#">SE555P</a>	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-55 to 125	SE555P
SE555P.A	Active	Production	PDIP (P)   8	50   TUBE	Yes	NIPDAU	N/A for Pkg Type	-55 to 125	SE555P

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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.

**OTHER QUALIFIED VERSIONS OF SE555, SE555M :**

- Catalog : [SE555](#)
- Military : [SE555M](#)
- Space : [SE555-SP](#), [SE555-SP](#)

**NOTE: Qualified Version Definitions:**

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

## TAPE AND REEL INFORMATION

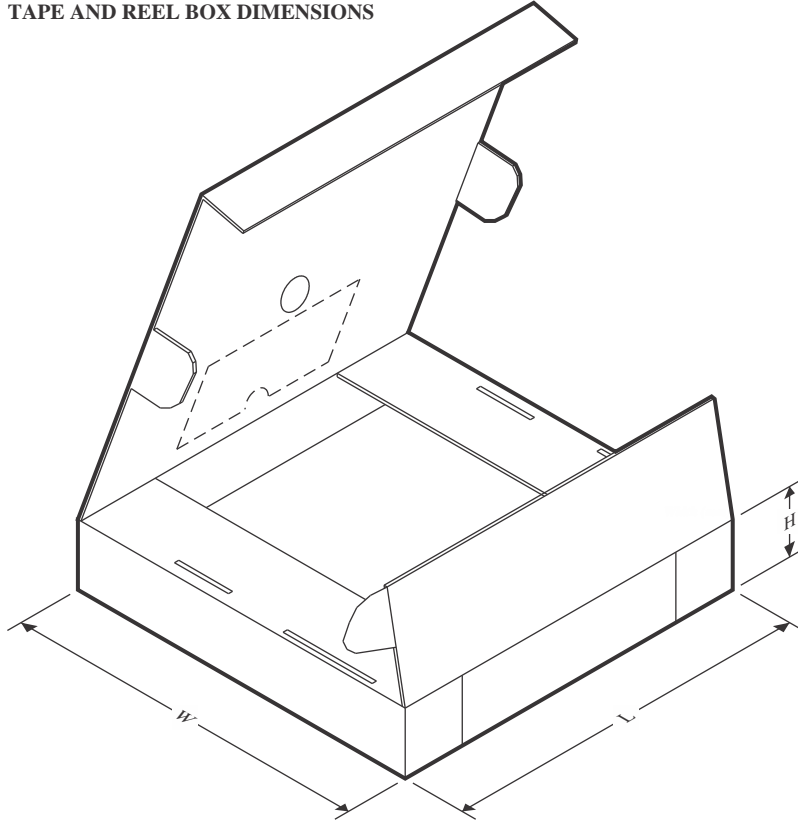


\*All dimensions are nominal

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
NA555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555DR1G4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
NE555PSR	SO	PS	8	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
NE555PWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
SA555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
SE555DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
SE555DRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1



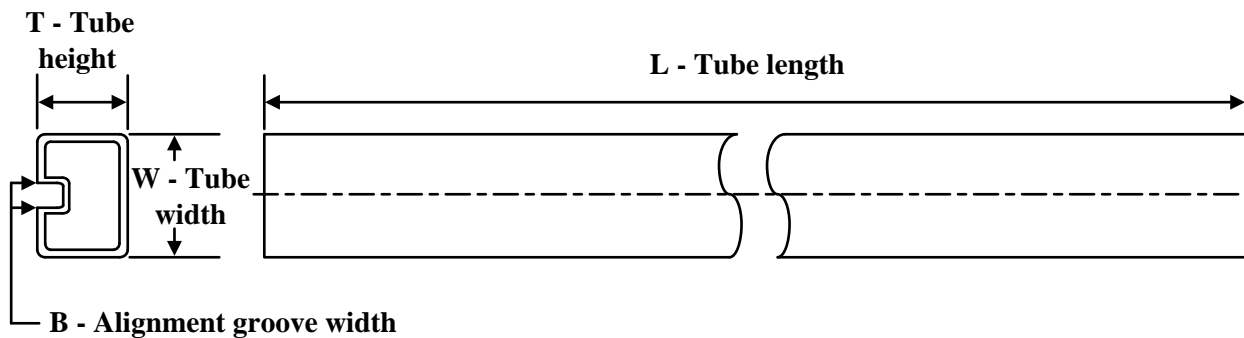
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
NA555DR	SOIC	D	8	2500	353.0	353.0	32.0
NE555DR	SOIC	D	8	2500	353.0	353.0	32.0
NE555DR1G4	SOIC	D	8	2500	353.0	353.0	32.0
NE555PSR	SO	PS	8	2000	353.0	353.0	32.0
NE555PWR	TSSOP	PW	8	2000	353.0	353.0	32.0
SA555DR	SOIC	D	8	2500	353.0	353.0	32.0
SE555DR	SOIC	D	8	2500	350.0	350.0	43.0
SE555DRG4	SOIC	D	8	2500	350.0	350.0	43.0

## TUBE



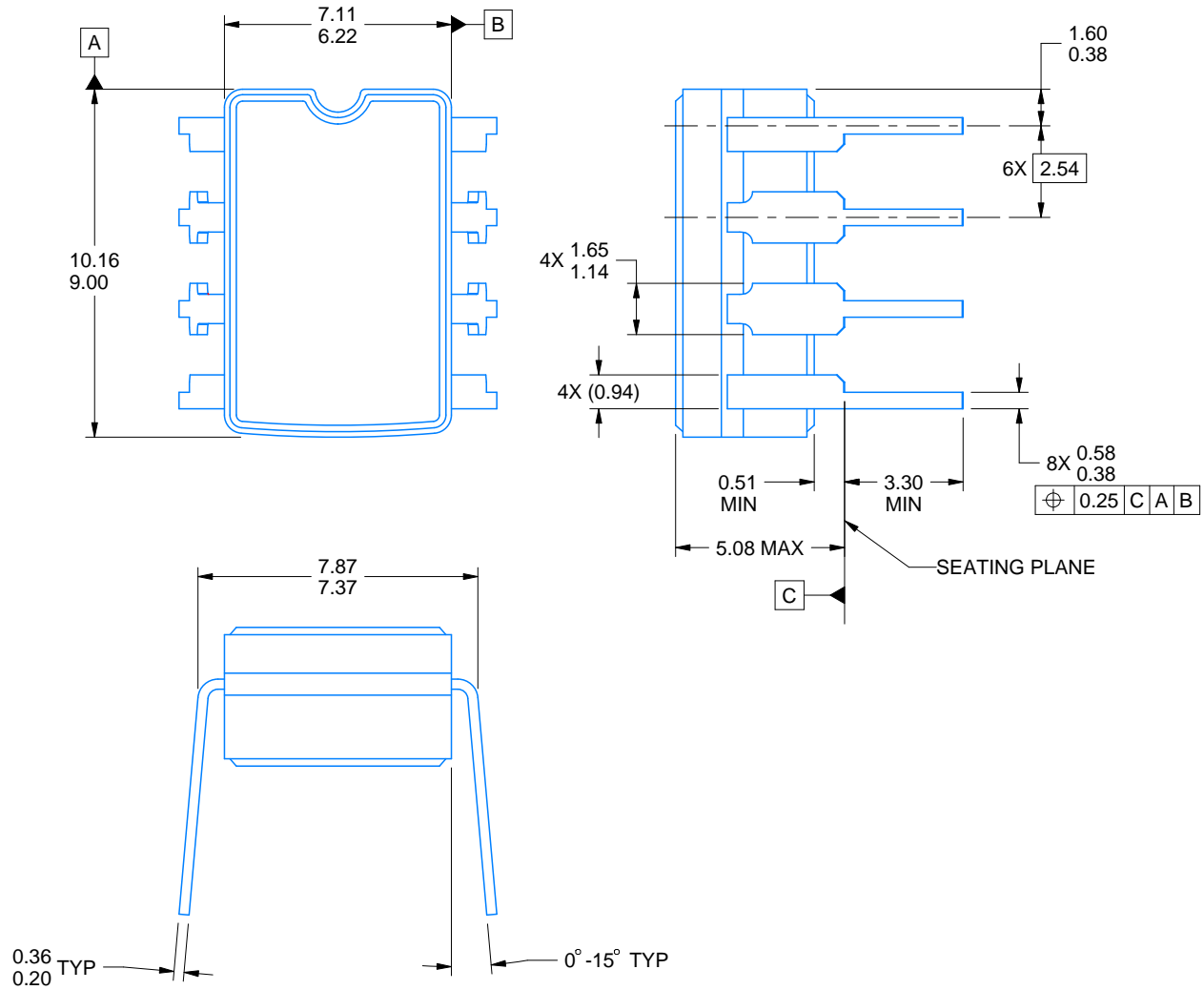
\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
NA555P	P	PDIP	8	50	506	13.97	11230	4.32
NA555P	P	PDIP	8	50	506.1	9	600	5.4
NA555P.A	P	PDIP	8	50	506.1	9	600	5.4
NA555P.A	P	PDIP	8	50	506	13.97	11230	4.32
NA555PE4	P	PDIP	8	50	506	13.97	11230	4.32
NA555PE4.A	P	PDIP	8	50	506	13.97	11230	4.32
NE555P	P	PDIP	8	50	506	13.97	11230	4.32
NE555P	P	PDIP	8	50	506.1	9	600	5.4
NE555P.A	P	PDIP	8	50	506.1	9	600	5.4
NE555P.A	P	PDIP	8	50	506	13.97	11230	4.32
NE555PE4	P	PDIP	8	50	506	13.97	11230	4.32
NE555PE4.A	P	PDIP	8	50	506	13.97	11230	4.32
NE555PS	PS	SOP	8	80	530	10.5	4000	4.1
NE555PS.A	PS	SOP	8	80	530	10.5	4000	4.1
SA555P	P	PDIP	8	50	506	13.97	11230	4.32
SA555P.A	P	PDIP	8	50	506	13.97	11230	4.32
SE555FKB	FK	LCCC	20	55	506.98	12.06	2030	NA
SE555FKB.A	FK	LCCC	20	55	506.98	12.06	2030	NA
SE555P	P	PDIP	8	50	506	13.97	11230	4.32
SE555P.A	P	PDIP	8	50	506	13.97	11230	4.32

**JG0008A**

**CDIP - 5.08 mm max height**

CERAMIC DUAL IN-LINE PACKAGE



4230036/A 09/2023

NOTES:

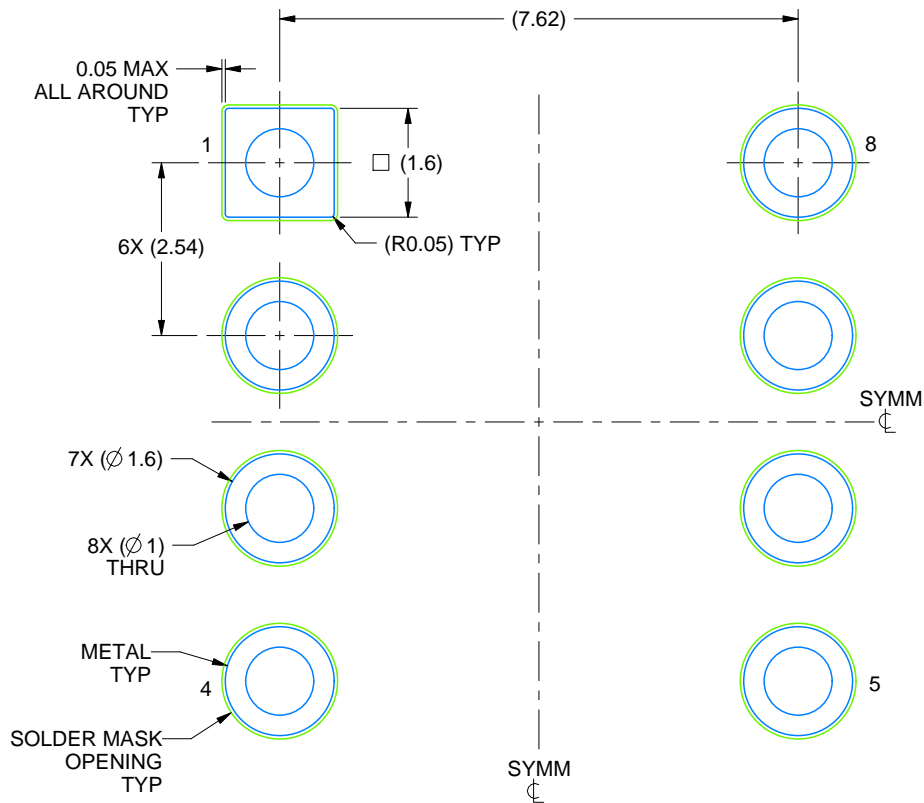
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package can be hermetically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification.
5. Falls within MIL STD 1835 GDIP1-T8

# EXAMPLE BOARD LAYOUT

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



LAND PATTERN EXAMPLE  
NON SOLDER MASK DEFINED  
SCALE: 9X

4230036/A 09/2023

## GENERIC PACKAGE VIEW

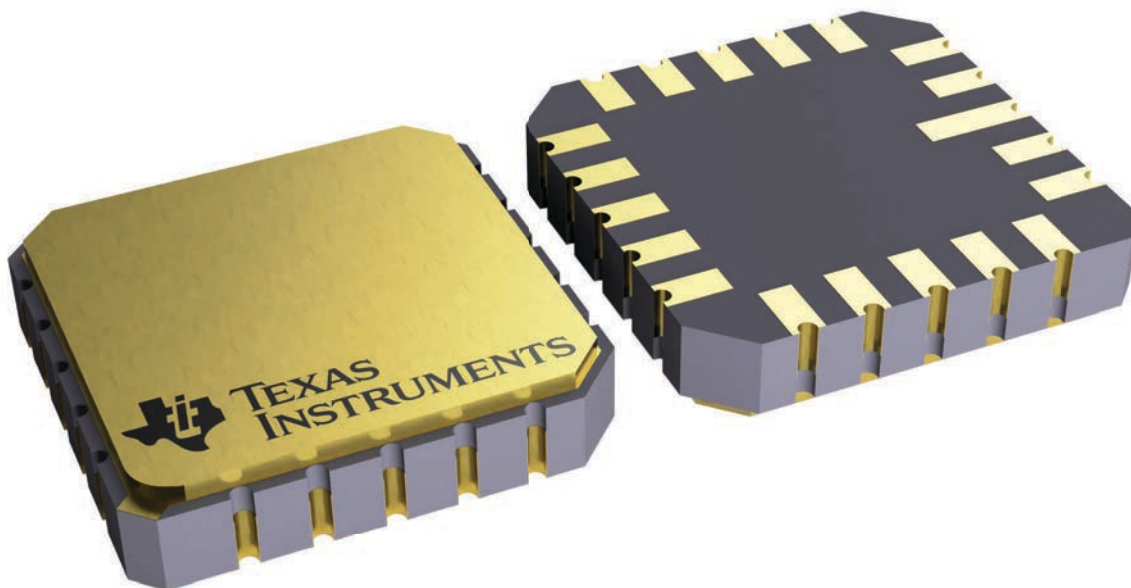
**FK 20**

**LCCC - 2.03 mm max height**

8.89 x 8.89, 1.27 mm pitch

LEADLESS CERAMIC CHIP CARRIER

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



4229370VA\

**D0008A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

**NOTES:**

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. 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 .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

**D0008A**

### SOIC - 1.75 mm max height

## SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



## SOLDER MASK DETAILS

4214825/C 02/2019

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.

## EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

4214825/C 02/2019

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.



# MECHANICAL DATA

PS (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



4040063/C 03/03

- 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.

## PS (R-PDSO-G8)

## 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.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.

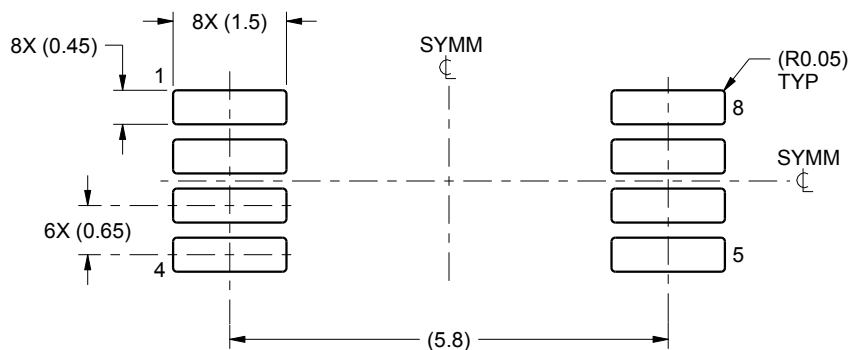


# EXAMPLE BOARD LAYOUT

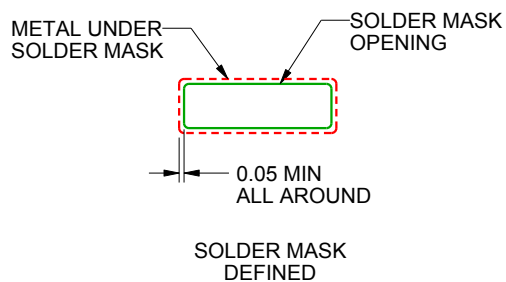
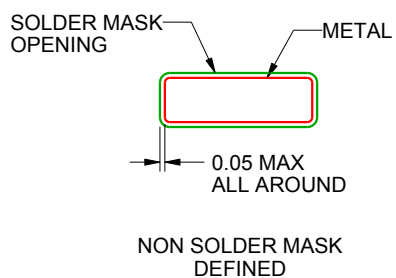
PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:10X



SOLDER MASK DETAILS  
NOT TO SCALE

4221848/A 02/2015

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.

## EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:10X

4221848/A 02/2015

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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