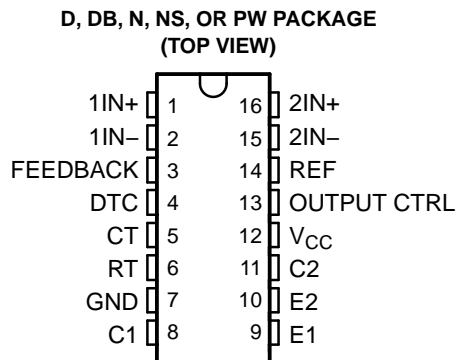


## FEATURES

- Complete PWM Power-Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply With 5% Tolerance
- Circuit Architecture Allows Easy Synchronization



## DESCRIPTION

The TL494 incorporates all the functions required in the construction of a pulse-width-modulation (PWM) control circuit on a single chip. Designed primarily for power-supply control, this device offers the flexibility to tailor the power-supply control circuitry to a specific application.

The TL494 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control (DTC) comparator, a pulse-steering control flip-flop, a 5-V, 5%-precision regulator, and output-control circuits.

The error amplifiers exhibit a common-mode voltage range from  $-0.3\text{ V}$  to  $V_{CC} - 2\text{ V}$ . The dead-time control comparator has a fixed offset that provides approximately 5% dead time. The on-chip oscillator can be bypassed by terminating RT to the reference output and providing a sawtooth input to CT, or it can drive the common circuits in synchronous multiple-rail power supplies.

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. The TL494 provides for push-pull or single-ended output operation, which can be selected through the output-control function. The architecture of this device prohibits the possibility of either output being pulsed twice during push-pull operation.

The TL494C is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The TL494I is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

## AVAILABLE OPTIONS

$T_A$	PACKAGED DEVICES <sup>(1)</sup>				
	SMALL OUTLINE (D)	PLASTIC DIP (N)	SMALL OUTLINE (NS)	SHRINK SMALL OUTLINE (DB)	THIN SHRINK SMALL OUTLINE (PW)
$0^{\circ}\text{C}$ to $70^{\circ}\text{C}$	TL494CD	TL494CN	TL494CNS	TL494CDB	TL494CPW
$-40^{\circ}\text{C}$ to $85^{\circ}\text{C}$	TL494ID	TL494IN	—	—	—

(1) The D, DB, NS, and PW packages are available taped and reeled. Add the suffix R to device type (e.g., TL494CDR).

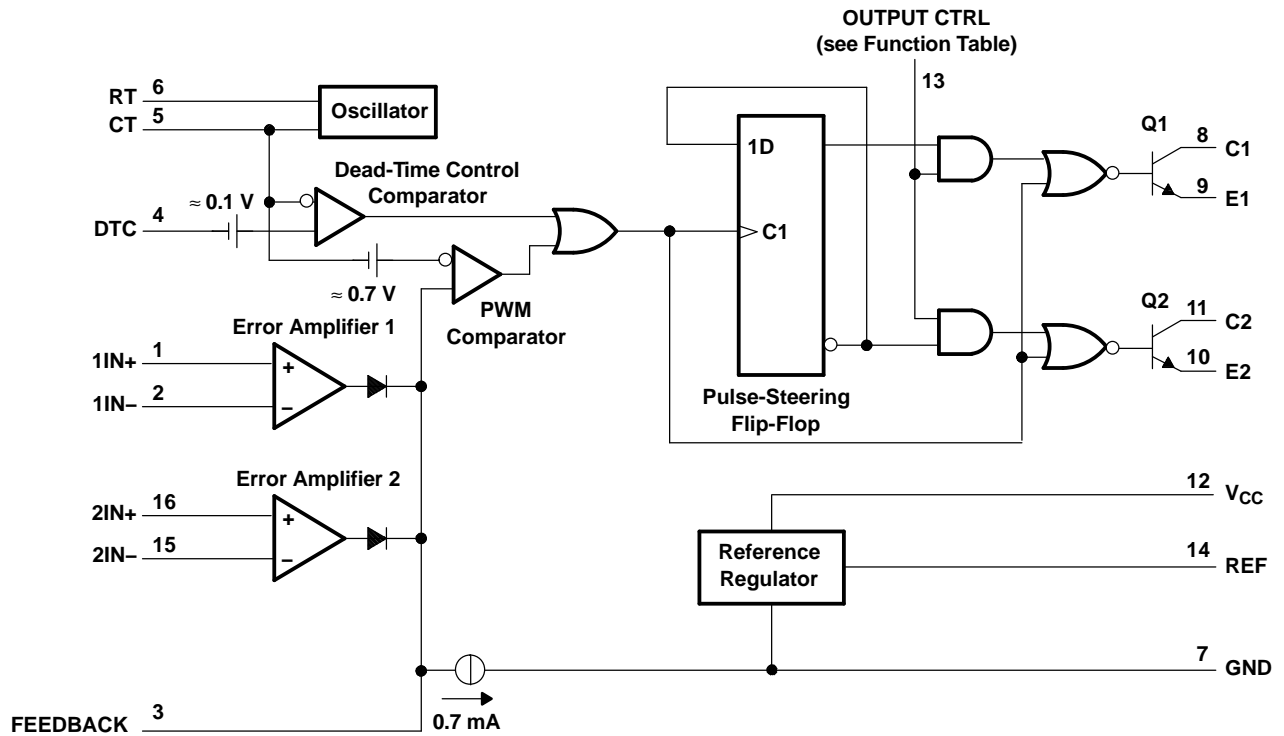


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**FUNCTION TABLE**

INPUT TO OUTPUT CTRL	OUTPUT FUNCTION
$V_I = \text{GND}$	Single-ended or parallel output
$V_I = V_{\text{ref}}$	Normal push-pull operation

**FUNCTIONAL BLOCK DIAGRAM**



### Absolute Maximum Ratings<sup>(1)</sup>

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

		MIN	MAX	UNIT
$V_{CC}$	Supply voltage <sup>(2)</sup>		41	V
$V_I$	Amplifier input voltage		$V_{CC} + 0.3$	V
$V_O$	Collector output voltage		41	V
$I_O$	Collector output current		250	mA
$\theta_{JA}$	Package thermal impedance <sup>(3)(4)</sup>	D package	73	°C/W
		DB package	82	
		N package	67	
		NS package	64	
		PW package	108	
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" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages are with respect to the network ground terminal.
- (3) Maximum power dissipation is a function of  $T_J(\text{max})$ ,  $\theta_{JA}$ , and  $T_A$ . The maximum allowable power dissipation at any allowable ambient temperature is  $P_D = (T_J(\text{max}) - T_A)/\theta_{JA}$ . Operating at the absolute maximum  $T_J$  of 150°C can affect reliability.
- (4) The package thermal impedance is calculated in accordance with JEDEC 51-7.

### Recommended Operating Conditions

		MIN	MAX	UNIT	
$V_{CC}$	Supply voltage	7	40	V	
$V_I$	Amplifier input voltage	–0.3	$V_{CC} - 2$	V	
$V_O$	Collector output voltage		40	V	
	Collector output current (each transistor)		200	mA	
	Current into feedback terminal		0.3	mA	
$f_{OSC}$	Oscillator frequency	1	300	kHz	
$C_T$	Timing capacitor	0.47	10000	nF	
$R_T$	Timing resistor	1.8	500	k $\Omega$	
$T_A$	Operating free-air temperature	TL494C	0	70	°C
		TL494I	–40	85	

## Electrical Characteristics

over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

## Reference Section

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	TL494C, TL494I			UNIT
		MIN	TYP <sup>(2)</sup>	MAX	
Output voltage (REF)	$I_O = 1\text{ mA}$	4.75	5	5.25	V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$		2	25	mV
Output regulation	$I_O = 1\text{ mA to }10\text{ mA}$		1	15	mV
Output voltage change with temperature	$\Delta T_A = \text{MIN to MAX}$		2	10	mV/V
Short-circuit output current <sup>(3)</sup>	REF = 0 V		25		mA

- (1) For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.  
(2) All typical values, except for parameter changes with temperature, are at  $T_A = 25^\circ\text{C}$ .  
(3) Duration of short circuit should not exceed one second.

## Oscillator Section

$C_T = 0.01\text{ }\mu\text{F}$ ,  $R_T = 12\text{ k}\Omega$  (see [Figure 1](#))

PARAMETER	TEST CONDITIONS <sup>(1)</sup>	TL494C, TL494I			UNIT
		MIN	TYP <sup>(2)</sup>	MAX	
Frequency			10		kHz
Standard deviation of frequency <sup>(3)</sup>	All values of $V_{CC}$ , $C_T$ , $R_T$ , and $T_A$ constant		100		Hz/kHz
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$		1		Hz/kHz
Frequency change with temperature <sup>(4)</sup>	$\Delta T_A = \text{MIN to MAX}$			10	Hz/kHz

- (1) For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.  
(2) All typical values, except for parameter changes with temperature, 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:

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

- (4) Temperature coefficient of timing capacitor and timing resistor are not taken into account.

## Error-Amplifier Section

See [Figure 2](#)

PARAMETER	TEST CONDITIONS	TL494C, TL494I			UNIT
		MIN	TYP <sup>(1)</sup>	MAX	
Input offset voltage	$V_O (\text{FEEDBACK}) = 2.5\text{ V}$		2	10	mV
Input offset current	$V_O (\text{FEEDBACK}) = 2.5\text{ V}$		25	250	nA
Input bias current	$V_O (\text{FEEDBACK}) = 2.5\text{ V}$		0.2	1	$\mu\text{A}$
Common-mode input voltage range	$V_{CC} = 7\text{ V to }40\text{ V}$		-0.3 to $V_{CC} - 2$		V
Open-loop voltage amplification	$\Delta V_O = 3\text{ V}$ , $V_O = 0.5\text{ V to }3.5\text{ V}$ , $R_L = 2\text{ k}\Omega$		70	95	dB
Unity-gain bandwidth	$V_O = 0.5\text{ V to }3.5\text{ V}$ , $R_L = 2\text{ k}\Omega$		800		kHz
Common-mode rejection ratio	$\Delta V_O = 40\text{ V}$ , $T_A = 25^\circ\text{C}$		65	80	dB
Output sink current (FEEDBACK)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V (\text{FEEDBACK}) = 0.7\text{ V}$		0.3	0.7	mA
Output source current (FEEDBACK)	$V_{ID} = 15\text{ mV to }5\text{ V}$ , $V (\text{FEEDBACK}) = 3.5\text{ V}$		-2		mA

- (1) All typical values, except for parameter changes with temperature, are at  $T_A = 25^\circ\text{C}$ .

## Electrical Characteristics

over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$  (unless otherwise noted)

### Output Section

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
Collector off-state current		$V_{CE} = 40\text{ V}$ , $V_{CC} = 40\text{ V}$		2	100	$\mu\text{A}$
Emitter off-state current		$V_{CC} = V_C = 40\text{ V}$ , $V_E = 0$			-100	$\mu\text{A}$
Collector-emitter saturation voltage	Common emitter	$V_E = 0$ , $I_C = 200\text{ mA}$		1.1	1.3	V
	Emitter follower	$V_{O(C1\text{ or }C2)} = 15\text{ V}$ , $I_E = -200\text{ mA}$		1.5	2.5	
Output control input current		$V_I = V_{ref}$			3.5	mA

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

### Dead-Time Control Section

See [Figure 1](#)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
Input bias current (DEAD-TIME CTRL)		$V_I = 0$ to $5.25\text{ V}$		-2	-10	$\mu\text{A}$
Maximum duty cycle, each output		$V_I$ (DEAD-TIME CTRL) = 0, $C_T = 0.01\ \mu\text{F}$ , $R_T = 12\text{ k}\Omega$		45		%
Input threshold voltage (DEAD-TIME CTRL)	Zero duty cycle			3	3.3	V
	Maximum duty cycle		0			

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

### PWM Comparator Section

See [Figure 1](#)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
Input threshold voltage (FEEDBACK)		Zero duty cycle		4	4.5	V
Input sink current (FEEDBACK)		$V$ (FEEDBACK) = $0.7\text{ V}$	0.3	0.7		mA

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

### Total Device

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
Standby supply current	$R_T = V_{ref}$ , All other inputs and outputs open	$V_{CC} = 15\text{ V}$		6	10	mA
		$V_{CC} = 40\text{ V}$		9	15	
Average supply current		$V_I$ (DEAD-TIME CTRL) = $2\text{ V}$ , See <a href="#">Figure 1</a>		7.5		mA

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

### Switching Characteristics

$T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
Rise time	Common-emitter configuration, See <a href="#">Figure 3</a>			100	200	ns
Fall time				25	100	ns
Rise time	Emitter-follower configuration, See <a href="#">Figure 4</a>			100	200	ns
Fall time				40	100	ns

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

PARAMETER MEASUREMENT INFORMATION

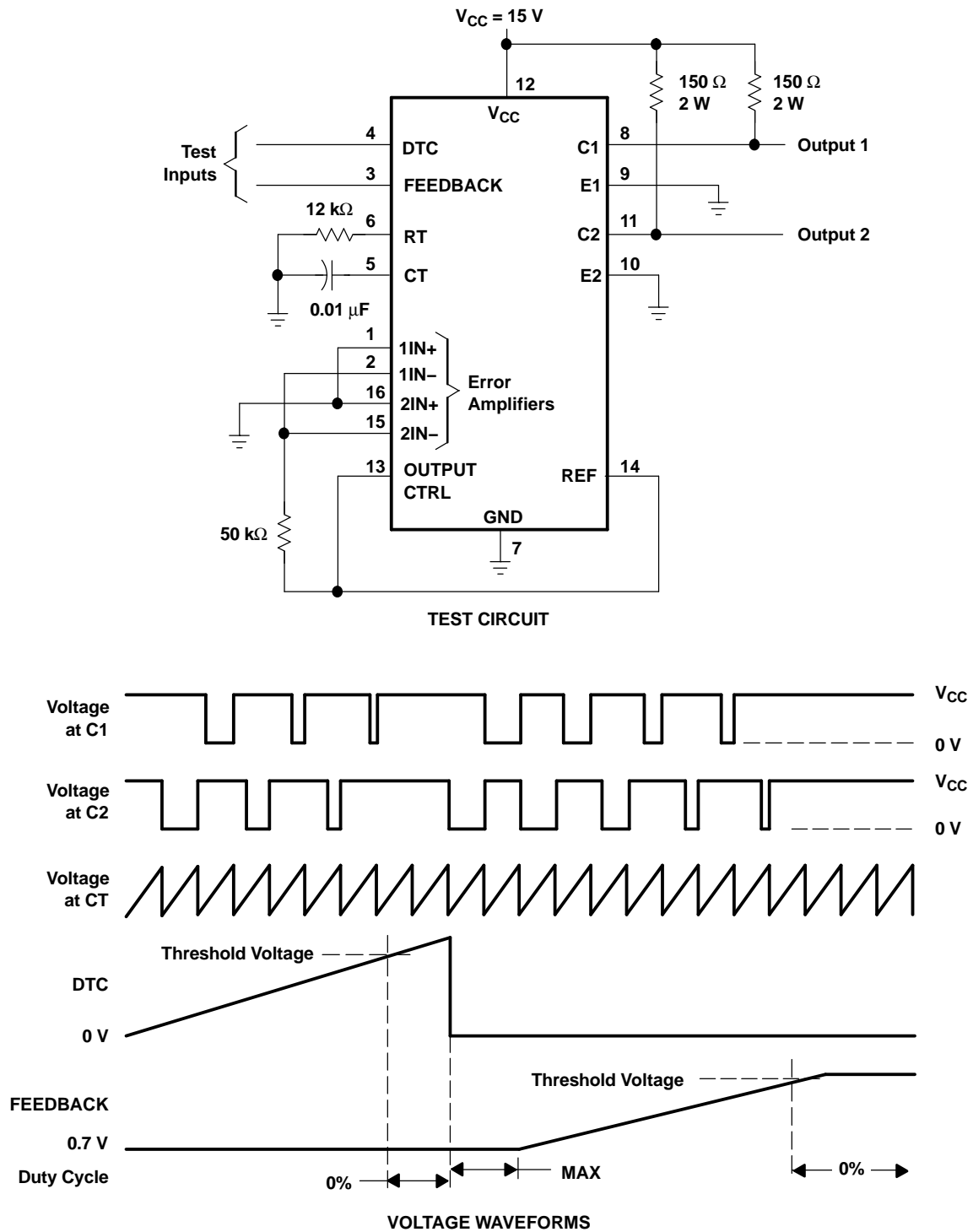
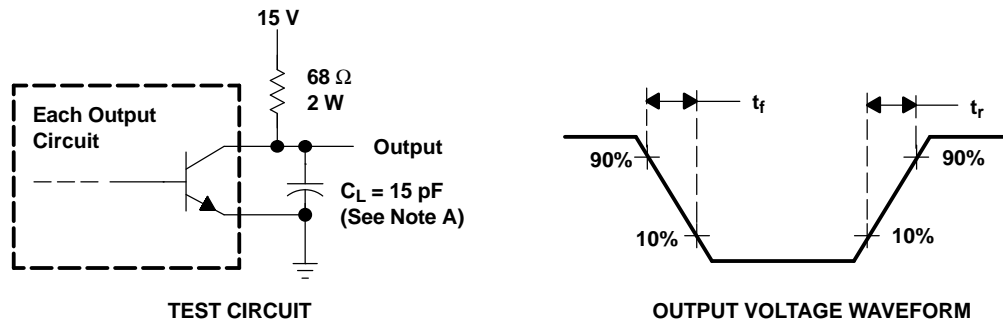


Figure 1. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION



Figure 2. Amplifier Characteristics



NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 3. Common-Emitter Configuration



NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS



† Frequency variation ( $\Delta f$ ) is the change in oscillator frequency that occurs over the full temperature range.

Figure 5.



Figure 6.



**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TL494CD	ACTIVE	SOIC	D	16	40	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494CDBR	ACTIVE	SSOP	DB	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494CDR	ACTIVE	SOIC	D	16	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494CJ	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
TL494CN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TL494CNSR	ACTIVE	SO	NS	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494CPW	ACTIVE	TSSOP	PW	16	90	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM
TL494CPWLE	OBSOLETE	TSSOP	PW	16		None	Call TI	Call TI
TL494CPWR	ACTIVE	TSSOP	PW	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM
TL494ID	ACTIVE	SOIC	D	16	40	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494IDR	ACTIVE	SOIC	D	16	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL494IN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TL494MJ	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
TL494MJB	OBSOLETE	CDIP	J	16		None	Call TI	Call TI

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

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N (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

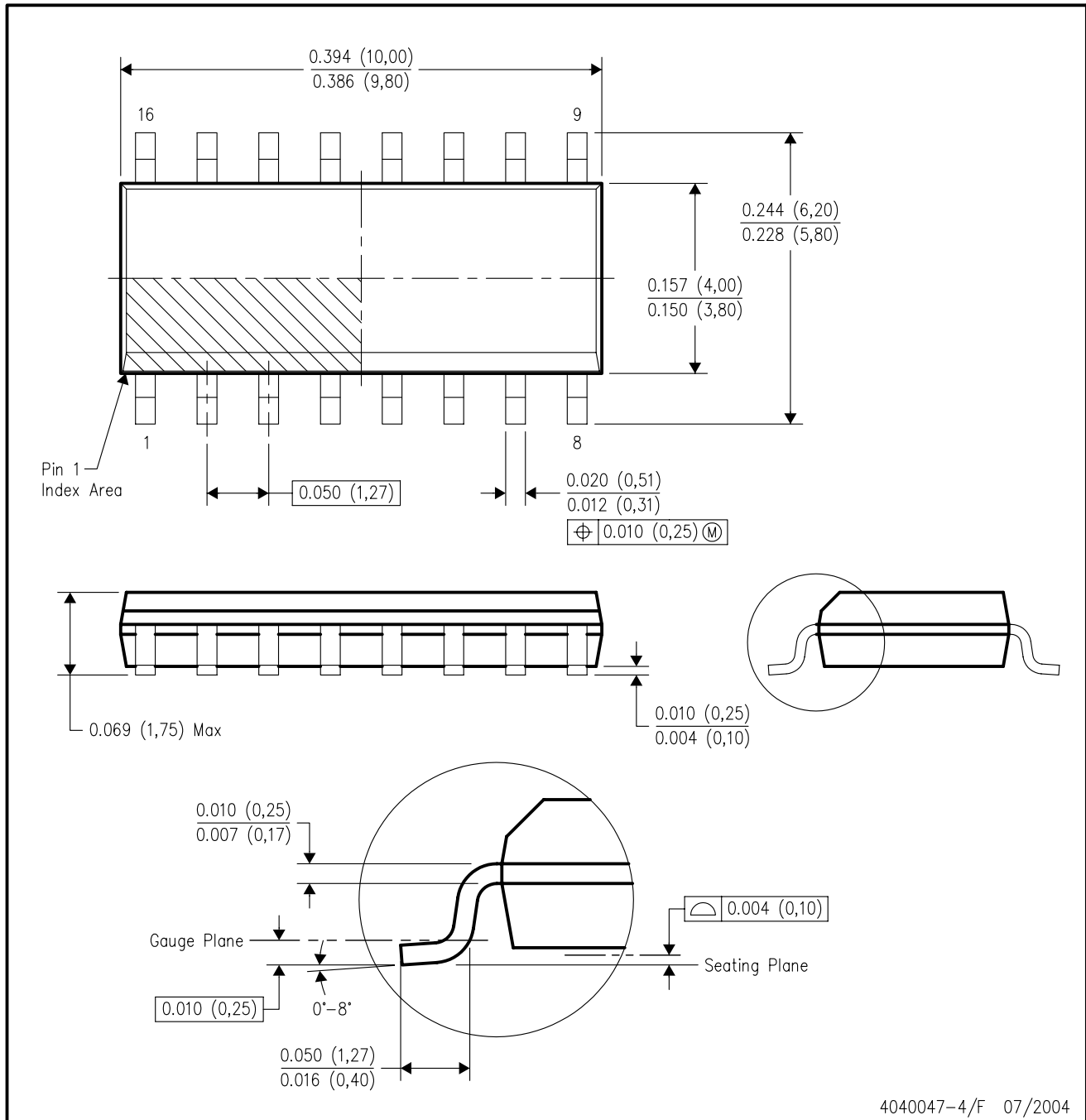
16 PINS SHOWN



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

D (R-PDSO-G16)

PLASTIC SMALL-OUTLINE PACKAGE



4040047-4/F 07/2004

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - D. Falls within JEDEC MS-012 variation AC.

# MECHANICAL DATA

NS (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN



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



PW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

- 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.  
 D. Falls within JEDEC MO-153

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Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>	Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
		Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
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