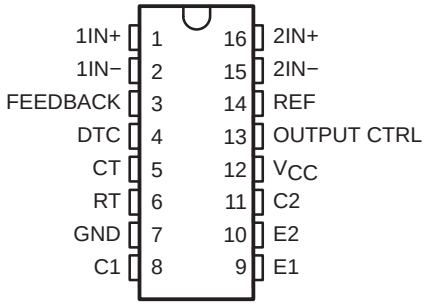
TL594
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

SLVS052F − APRIL 1988 − REVISED NOVEMBER 2003

- **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 Trimmed to 1%**
- **Circuit Architecture Allows Easy Synchronization**
- **Undervoltage Lockout for Low-V_{CC} Conditions**

D, N, NS, OR PW PACKAGE
(TOP VIEW)



description/ordering information

The TL594 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 systems engineer the flexibility to tailor the power-supply control circuitry to a specific application.

The TL594 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control (DTC) comparator, a pulse-steering control flip-flop, a 5-V regulator with a precision of 1%, an undervoltage lockout control circuit, and output control circuitry.

The error amplifiers have a common-mode voltage range of −0.3 V to V_{CC} − 2 V. The DTC 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 be used to drive the common circuitry in synchronous multiple-rail power supplies.

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation, with selection by means of the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation. The undervoltage lockout control circuit locks the outputs off until the internal circuitry is operational.

The TL594C is characterized for operation from 0°C to 70°C. The TL594I is characterized for operation from −40°C to 85°C.

description/ordering information (continued)

ORDERING INFORMATION

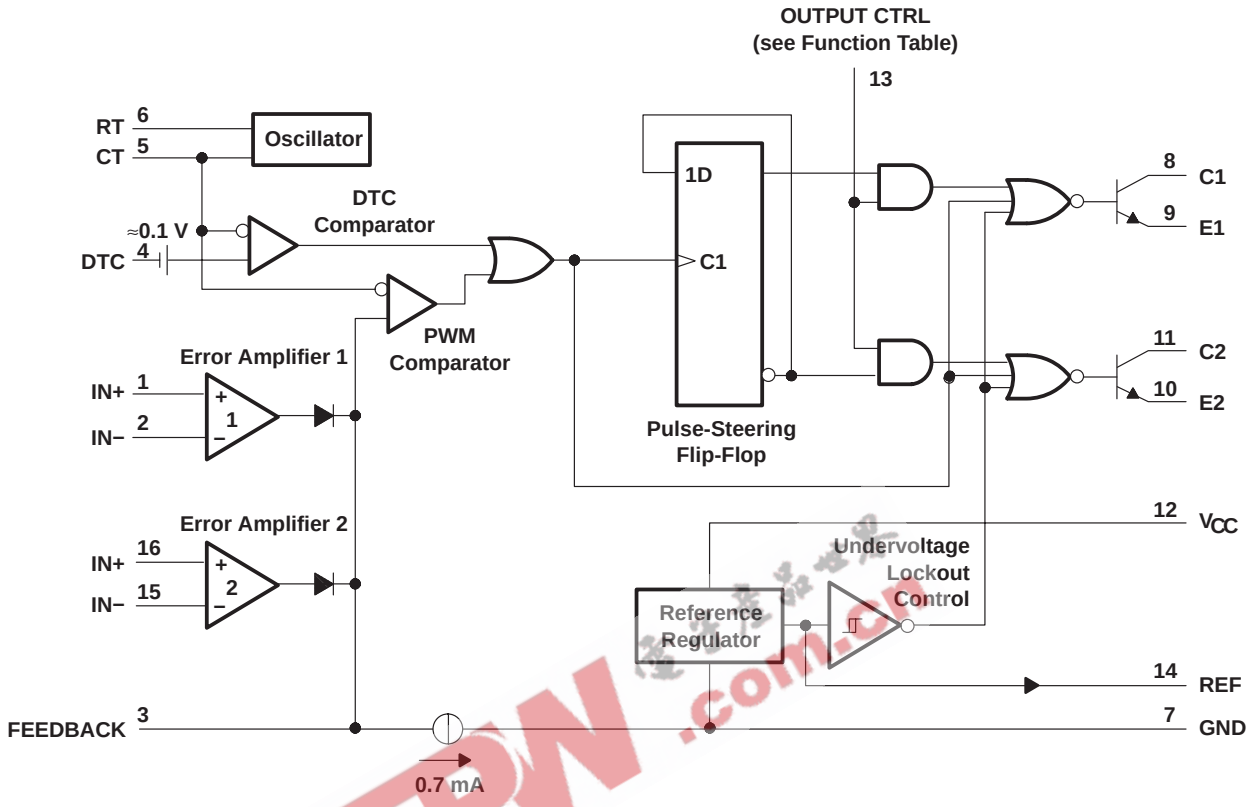
T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	PDIP (N)	Tube of 25	TL594CN	TL594CN
	SOIC (D)	Tube of 40	TL594CD	TL594C
		Reel of 2500	TL594CDR	
	SOP (NS)	Reel of 2000	TL594CNSR	TL594
	TSSOP (PW)	Tube of 90	TL594CPW	T594
		Reel of 2000	TL594CPWR	
−40°C to 85°C	PDIP (N)	Tube of 25	TL594IN	TL594IN
	SOIC (D)	Tube of 40	TL594ID	TL594I
		Reel of 2500	TL594IDR	
	SOP (NS)	Reel of 2000	TL594INSR	TL594I
	TSSOP (PW)	Tube of 90	TL594IPW	Z594
		Reel of 2000	TL594IPWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

FUNCTION TABLE

INPUT OUTPUT CTRL	OUTPUT FUNCTION
V_I = 0	Single-ended or parallel output
$V_I = V_{ref}$	Normal push-pull operation

functional block diagram



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

Supply voltage, V_{CC} (see Note 1)	41 V
Amplifier input voltage	V_{CC} + 0.3 V
Collector output voltage	41 V
Collector output current	250 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package	73°C/W
N package	67°C/W
NS package	64°C/W
PW package	108°C/W
Operating virtual junction temperature, T_J	150°C
Storage temperature range, T_{stg}	−65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
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 $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
3. The package thermal impedance is calculated in accordance with JESD 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
C_T	Timing capacitor		0.47	10000	nF
R_T	Timing resistor		1.8	500	kΩ
f_{osc}	Oscillator frequency		1	300	kHz
T_A	Operating free-air temperature	TL594C	0	70	°C
		TL594I	−40	85	°C

electrical characteristics over recommended operating conditions, V_{CC} = 15 V, (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS†		TL594C, TL594I			UNIT
			MIN	TYP‡	MAX	
Output voltage (REF)	I_O = 1 mA,	T_A = 25°C	4.95	5	5.05	V
Input regulation	V_{CC} = 7 V to 40 V,	T_A = 25°C		2	25	mV
Output regulation	I_O = 1 to 10 mA,	T_A = 25°C		14	35	mV
Output-voltage change with temperature	ΔT_A = MIN to MAX			2	10	mV/V
Short-circuit output current§	V_{ref} = 0		10	35	50	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values, except for parameter changes with temperature, are at T_A = 25°C.
§ Duration of the short circuit should not exceed one second.

amplifier section (see Figure 1)

PARAMETER	TEST CONDITIONS			TL594C, TL594I			UNIT
				MIN	TYP‡	MAX	
Input offset voltage, error amplifier	FEEDBACK = 2.5 V				2	10	mV
Input offset current	FEEDBACK = 2.5 V				25	250	nA
Input bias current	FEEDBACK = 2.5 V				0.2	1	μA
Common-mode input voltage range, error amplifier	V_{CC} = 7 V to 40 V			0.3 to V_{CC}−2			V
Open-loop voltage amplification, error amplifier	ΔV_O = 3 V,	R_L = 2 kΩ,	V_O = 0.5 V to 3.5 V	70	95		dB
Unity-gain bandwidth	V_O = 0.5 V to 3.5 V,	R_L = 2 kΩ			800		kHz
Common-mode rejection ratio, error amplifier	V_{CC} = 40 V,	T_A = 25°C		65	80		dB
Output sink current, FEEDBACK	V_{ID} = −15 mV to −5 V,	FEEDBACK = 0.5 V		0.3	0.7		mA
Output source current, FEEDBACK	V_{ID} = 15 mV to 5 V,	FEEDBACK = 3.5 V		−2			mA

‡ All typical values, except for parameter changes with temperature, are at T_A = 25°C.

oscillator section, C_T = 0.01 μF, R_T = 12 kΩ (see Figure 2)

PARAMETER	TEST CONDITIONS†		TL594C, TL594I			UNIT
			MIN	TYP‡	MAX	
Frequency				10		kHz
Standard deviation of frequency¶	All values of V_{CC}, C_T, R_T, and T_A constant			100		Hz/kHz
Frequency change with voltage	V_{CC} = 7 V to 40 V,	T_A = 25°C		1		Hz/kHz
Frequency change with temperature#	ΔT_A = MIN to MAX				50	Hz/kHz

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values, except for parameter changes with temperature, are at T_A = 25°C.
¶ Standard deviation is a measure of the statistical distribution about the mean, as derived from the formula:

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

Temperature coefficient of timing capacitor and timing resistor is not taken into account.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, (unless otherwise noted) (continued)

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594C, TL594I			UNIT
		MIN	TYP†	MAX	
Input bias current	V_I = 0 to 5.25 V		−2	−10	µA
Maximum duty cycle, each output	DTC = 0 V	0.45			
Input threshold voltage	Zero duty cycle		3	3.3	V
	Maximum duty cycle	0			

† All typical values, except for parameter changes with temperature, are at T_A = 25°C.

output section

PARAMETER		TEST CONDITIONS	TL594C, TL594I			UNIT
			MIN	TYP†	MAX	
Collector off-state current		V_C = 40 V, V_E = 0 V, V_{CC} = 40 V		2	100	µA
		DTC and OUTPUT CTRL = 0 V, V_C = 15 V, V_E = 0 V, V_{CC} = 1 to 3 V		4	200	
Emitter off-state current		V_{CC} = V_C = 40 V, V_E = 0			−100	µA
Collector-emitter saturation voltage	Common emitter	V_E = 0, I_C = 200 mA		1.1	1.3	V
	Emitter follower	V_C = 15 V, I_E = −200 mA		1.5	2.5	
Output control input current		V_I = V_{ref}			3.5	mA

† All typical values, except for parameter changes with temperature, are at T_A = 25°C.

pwm comparator section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594C, TL594I			UNIT
		MIN	TYP†	MAX	
Input threshold voltage, FEEDBACK	Zero duty cycle		4	4.5	V
Input sink current, FEEDBACK	FEEDBACK = 0.5 V	0.3	0.7		mA

† All typical values, except for parameter changes with temperature, are at T_A = 25°C.

undervoltage lockout section (see Figure 2)

PARAMETER	TEST CONDITIONS‡	TL594C, TL594I		UNIT
		MIN	MAX	
Threshold voltage	T_A = 25°C		6	V
	ΔT_A = MIN to MAX	3.5	6.9	
Hysteresis§		100		mV

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
§ Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

PARAMETER	TEST CONDITIONS		TL594C, TL594I			UNIT
			MIN	TYP†	MAX	
Standby supply current	RT at V_{ref}, All other inputs and outputs open	V_{CC} = 15 V		9	15	mA
		V_{CC} = 40 V		11	18	
Average supply current	DTC = 2 V,	See Figure 2		12.4		mA

† All typical values, except for parameter changes with temperature, are at T_A = 25°C.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, (unless otherwise noted) (continued)

switching characteristics, T_A = 25°C

PARAMETER	TEST CONDITIONS	TL594C, TL594I			UNIT
		MIN	TYP†	MAX	
Output-voltage rise time	Common-emitter configuration (see Figure 3)		100	200	ns
Output-voltage fall time			30	100	ns
Output-voltage rise time	Emitter-follower configuration (see Figure 4)		200	400	ns
Output-voltage fall time			45	100	ns

† All typical values, except for parameter changes with temperature, are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION

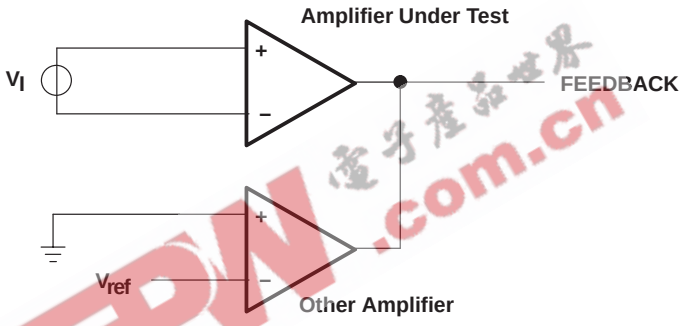


Figure 1. Amplifier-Characteristics Test Circuit

PARAMETER MEASUREMENT INFORMATION

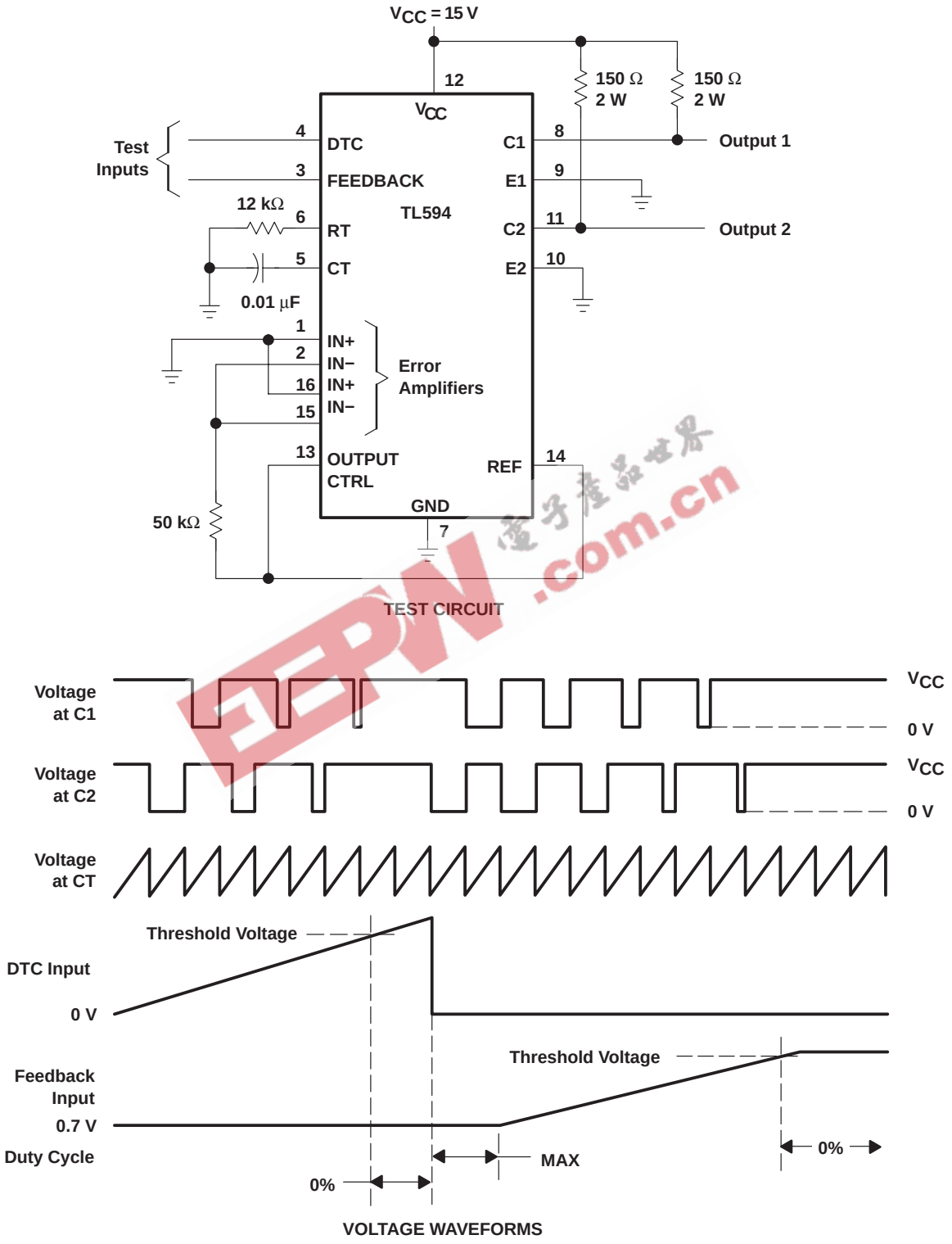


Figure 2. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

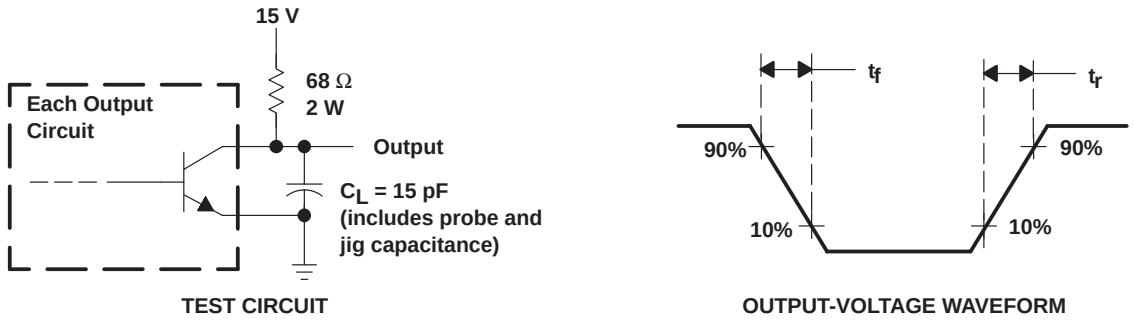


Figure 3. Common-Emitter Configuration

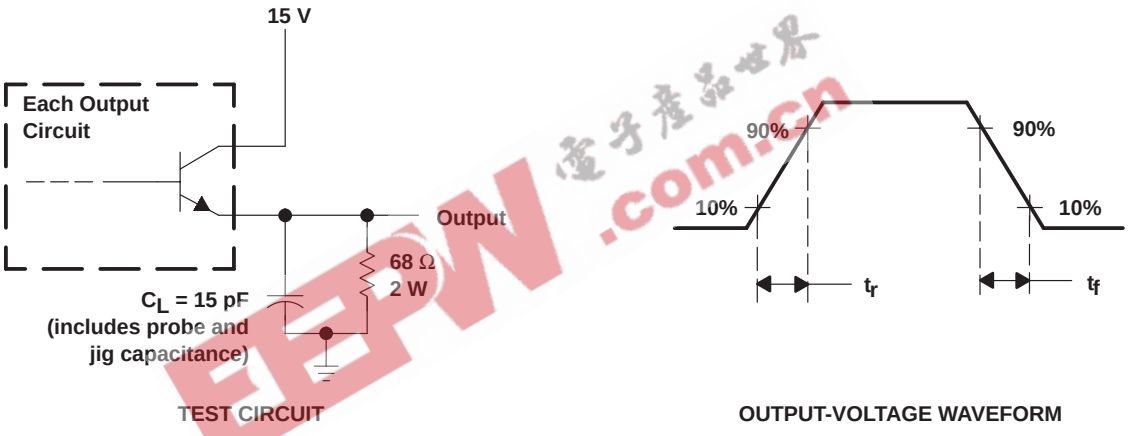
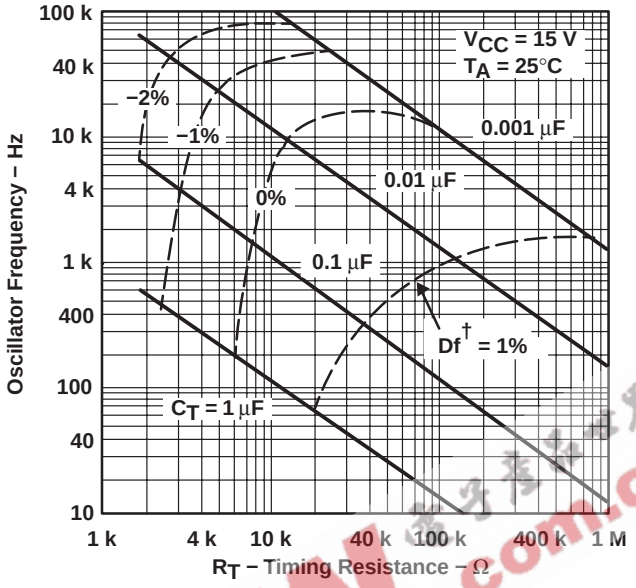


Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND FREQUENCY VARIATION† VS TIMING RESISTANCE



† Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

Figure 5

AMPLIFIER VOLTAGE AMPLIFICATION VS FREQUENCY

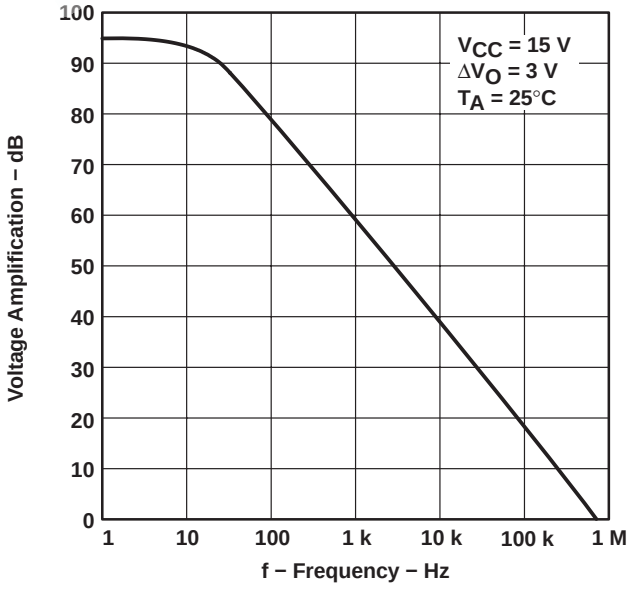


Figure 6

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TL594CD	ACTIVE	SOIC	D	16	40	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR
TL594CDR	ACTIVE	SOIC	D	16	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR
TL594CN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TL594CNSR	ACTIVE	SO	NS	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL594CPW	ACTIVE	TSSOP	PW	16	90	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM
TL594CPWR	ACTIVE	TSSOP	PW	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM
TL594ID	ACTIVE	SOIC	D	16	40	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR
TL594IDR	ACTIVE	SOIC	D	16	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR
TL594IN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	Level-NC-NC-NC
TL594INSR	ACTIVE	SO	NS	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-2-260C-1 YEAR/ Level-1-235C-UNLIM
TL594IPW	ACTIVE	TSSOP	PW	16	90	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM
TL594IPWR	ACTIVE	TSSOP	PW	16	2000	Pb-Free (RoHS)	CU NIPDAU	Level-1-250C-UNLIM

(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.

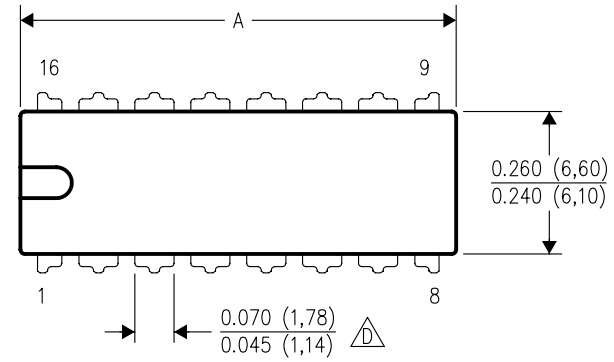
(2) Eco Plan - May not be currently available - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
None: Not yet available Lead (Pb-Free).
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are 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.

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

N (R–PDIP–T**)

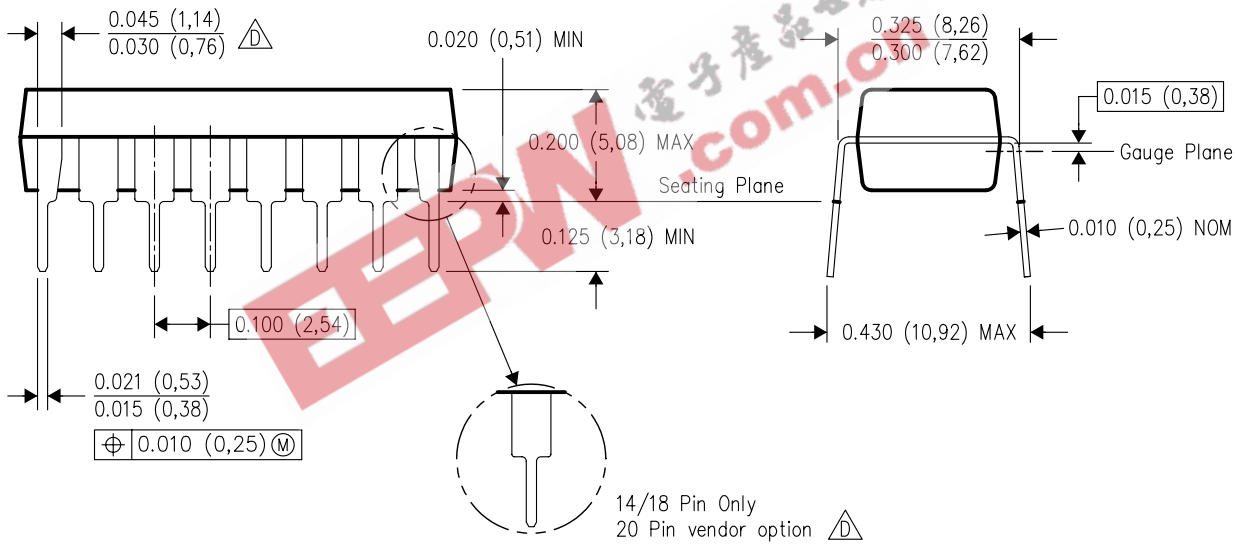
PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS–001 VARIATION	AA	BB	AC	AD

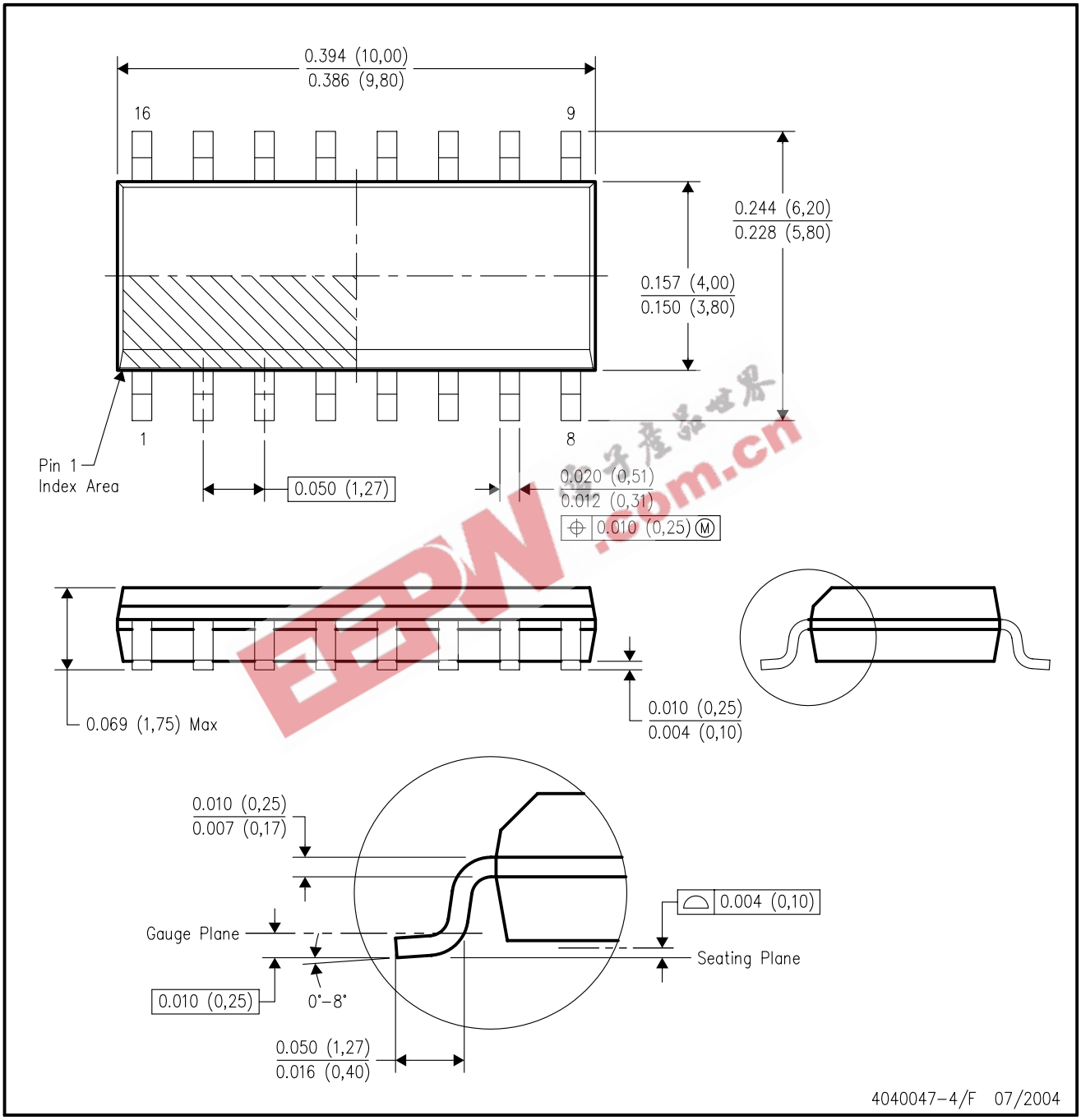
C



4040049/E 12/2002

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

D (R–PDSO–G16) PLASTIC SMALL–OUTLINE PACKAGE

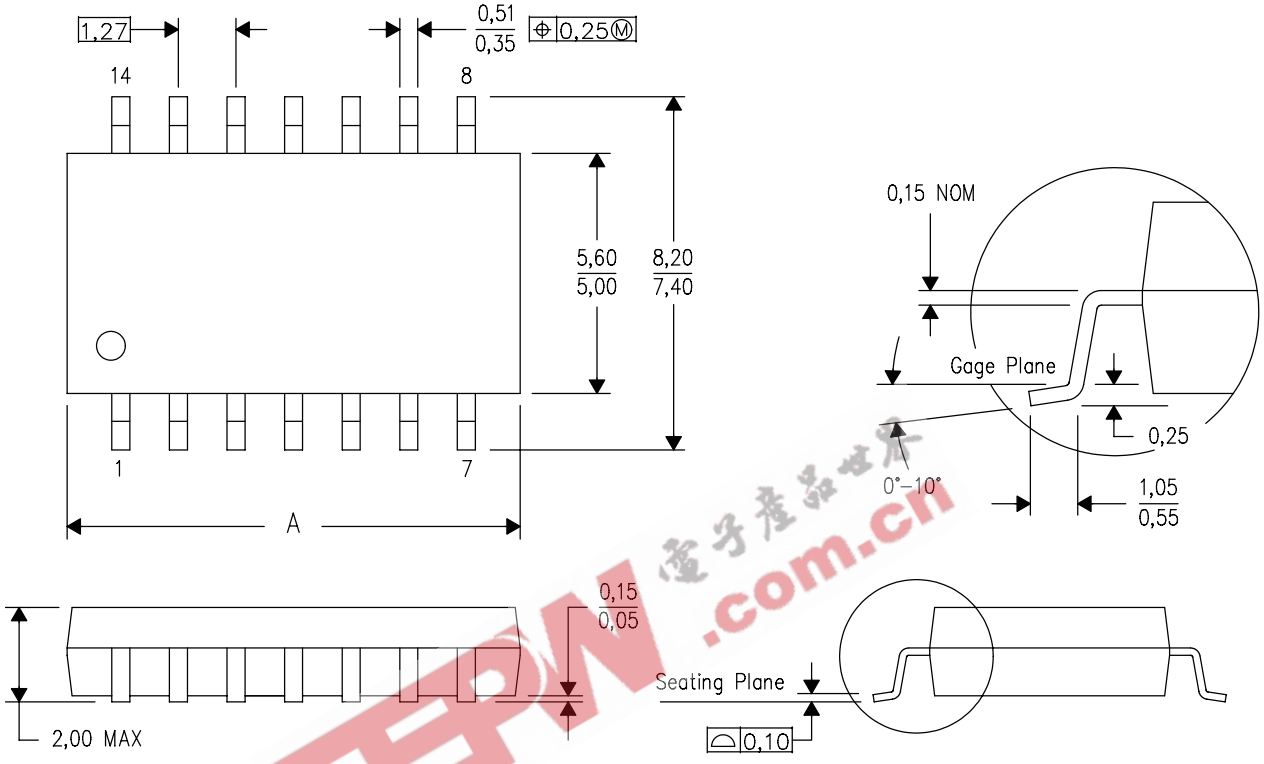


NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
D. Falls within JEDEC MS–012 variation AC.

MECHANICAL DATA

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



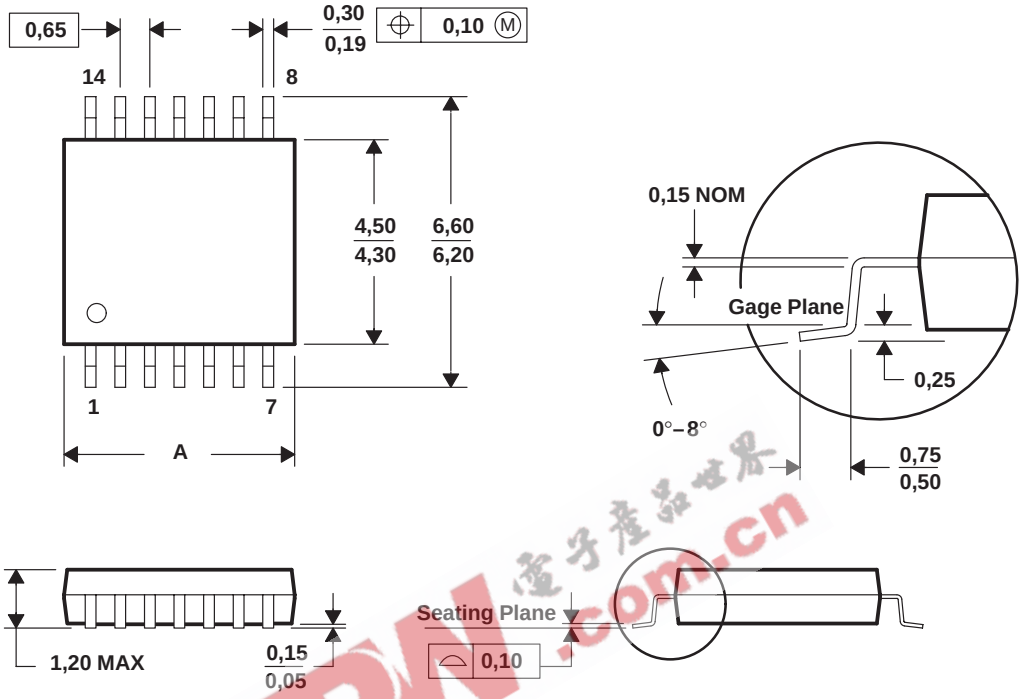
DIM \ PINS **	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/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.

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

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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