

# TL494C, TL494I, TL494M, TL494Y PULSE-WIDTH-MODULATION CONTROL CIRCUITS

SLVS074A – JANUARY 1983 – REVISED AUGUST 1995

- 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

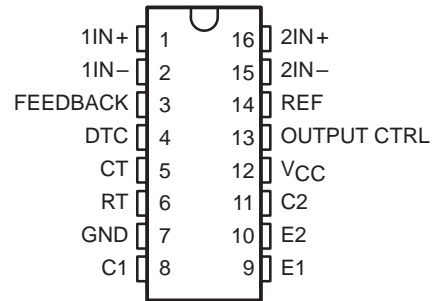
## description

The TL494 incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. 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.

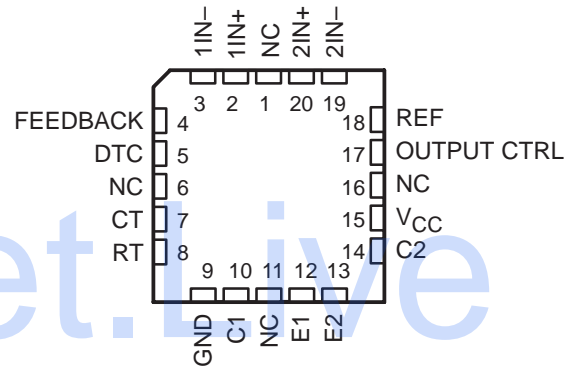
The TL494 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control (DTC) comparator, a pulse-steering control flip-flop, a 5-V, 5%-precision regulator, and output-control circuits.

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 may be bypassed by terminating RT to the reference output and providing a sawtooth input to CT, or it may drive the common circuits in synchronous multiple-rail power supplies.

TL494C, TL494I . . . D, N, OR PW PACKAGE  
TL494M . . . J PACKAGE  
(TOP VIEW)



TL494M . . . FK PACKAGE  
(TOP VIEW)



NC – No internal connection

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

## AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES					CHIP FORM (Y)
	SURFACE MOUNT (D) <sup>†</sup>	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)	SHRINK SMALL OUTLINE (PW) <sup>‡</sup>	
0°C to 70°C	TL494CD	—	—	TL494CN	TL494CPW	TL494Y
-40°C to 85°C	TL494ID	—	—	TL494IN	—	—
-55°C to 125°C	—	TL494MFK	TL494MJ	—	—	—

<sup>†</sup> The D package is available taped and reeled. Add R suffix to device type (e.g., TL494CDR).

<sup>‡</sup> The PW package is only available left-end taped and reeled.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS INSTRUMENTS

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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

# TL494C, TL494I, TL494M, TL494Y

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

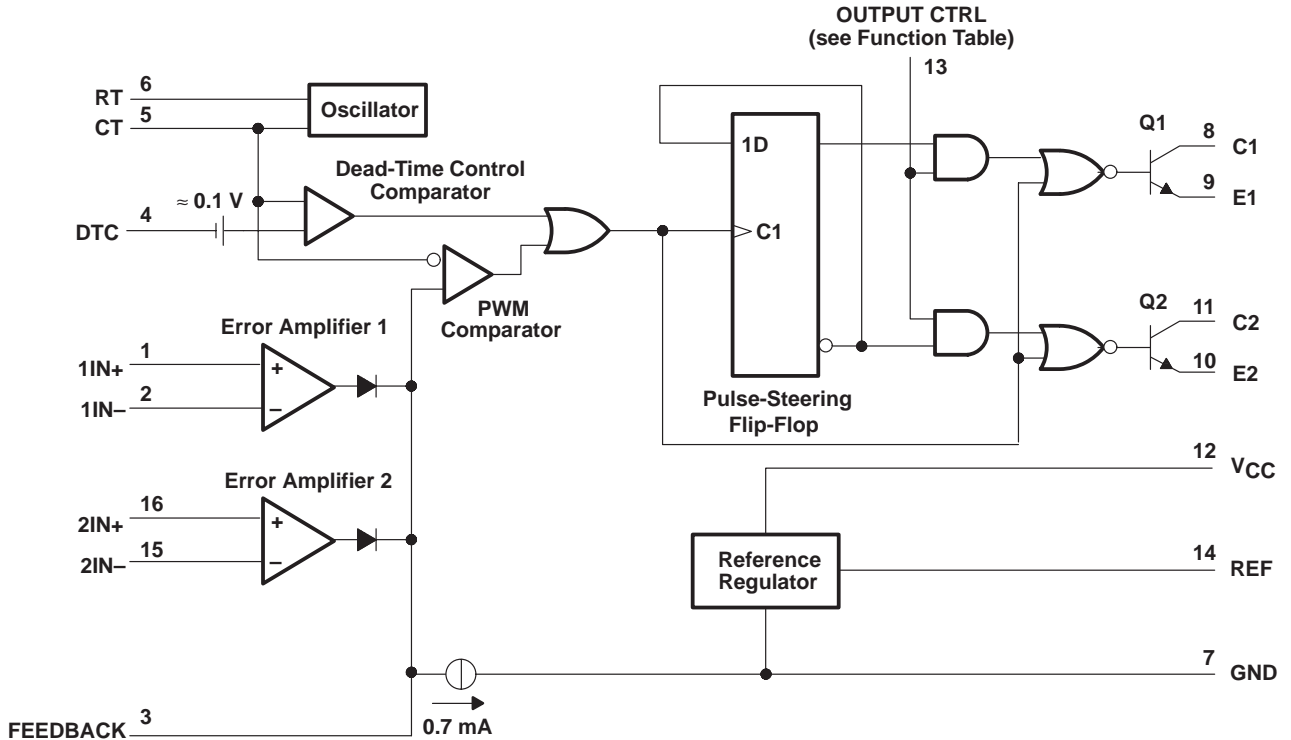
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### description (continued)

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 may 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°C to 70°C. The TL494I is characterized for operation from -40°C to 85°C. The TL494M is characterized for operation from -55°C to 125°C.

### functional block diagram



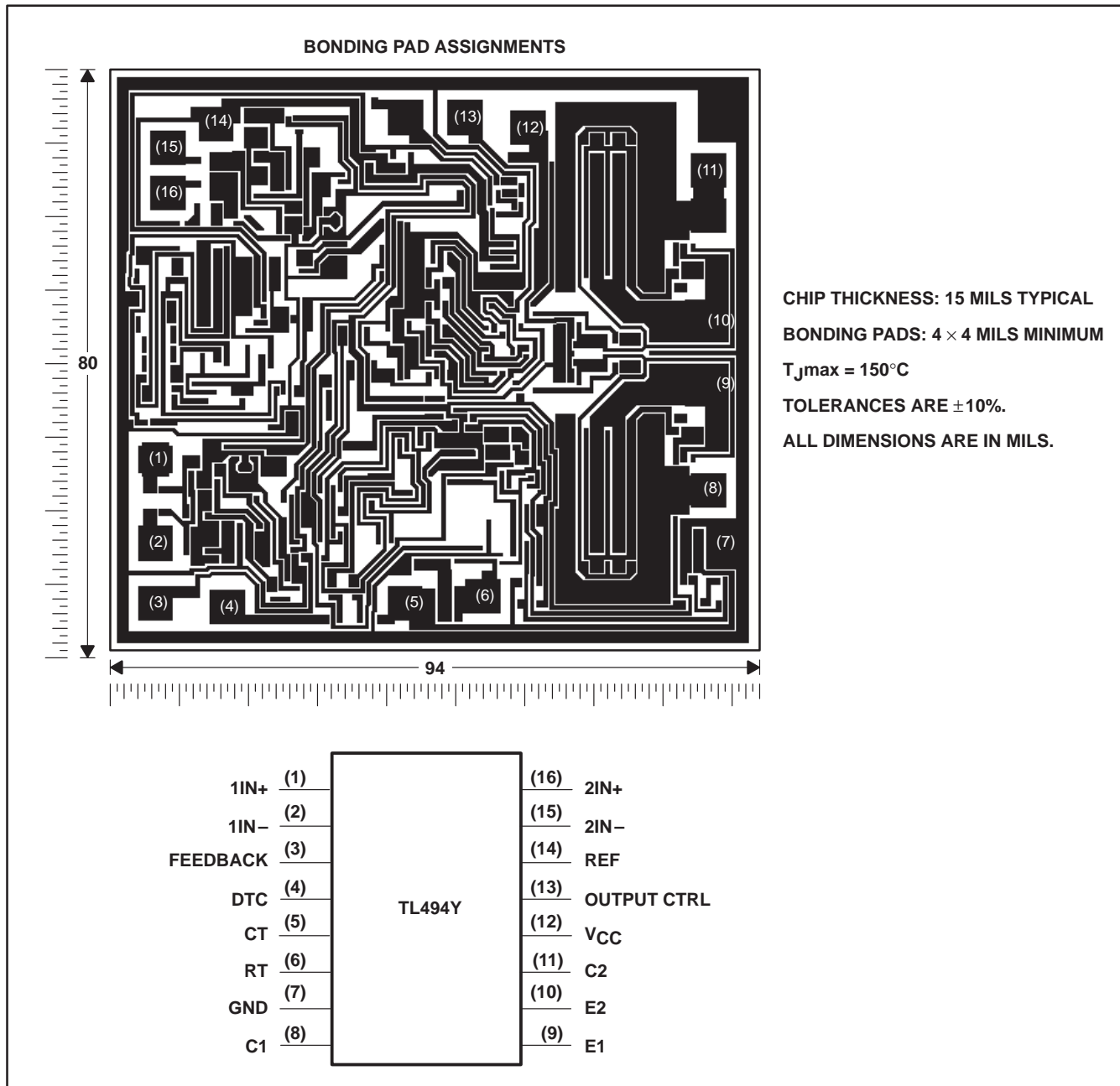
NOTE A. The terminal numbers indicated apply only to the D, J, N, and PW packages.

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## TL494Y chip information

This chip, when properly assembled, display characteristics similar to the TL494C. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. The chips may be mounted with conductive epoxy or a gold-silicon preform.



# TL494C, TL494I, TL494M, TL494Y

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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

	TL494C	TL494I	TL494M	UNIT
Supply voltage, $V_{CC}$ (see Note 1)	41	41	41	V
Amplifier input voltage, $V_I$	$V_{CC} + 0.3$	$V_{CC} + 0.3$	$V_{CC} + 0.3$	V
Collector output voltage, $V_O$	41	41	41	V
Collector output current, $I_O$	250	250	250	mA
Continuous total power dissipation	See Dissipation Rating Table			
Operating free-air temperature range, $T_A$	0 to 70	-40 to 85	-55 to 125	°C
Storage temperature range, $T_{stg}$	-65 to 150	-65 to 150	-65 to 150	°C
Case temperature for 60 seconds, $T_C$ : FK package	—	—	260	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or PW package	260	260	—	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J package	—	—	300	°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.

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR	DERATE ABOVE $T_A$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
D	900 mW	7.6 mW/°C	25°C	558 mW	444 mW	—
FK	1375 mW	11.0 mW/°C	25°C	880 mW	715 mW	275 mW
J	1375 mW	11.0 mW/°C	25°C	880 mW	715 mW	275 mW
N	1000 mW	9.2 mW/°C	41°C	733 mW	595 mW	—
PW	700 mW	5.6 mW/°C	25°C	448 mW	—	—

### recommended operating conditions

	TL494C		TL494I		TL494M		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, $V_{CC}$	7	40	7	40	7	40	V
Amplifier input voltage, $V_I$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	-0.3	$V_{CC} - 2$	V
Collector output voltage, $V_O$	40		40		40		V
Collector output current (each transistor)	200		200		200		mA
Current into feedback terminal	0.3		0.3		0.3		mA
Oscillator frequency, $f_{osc}$	1	300	1	300	1	300	kHz
Timing capacitor, $C_T$	0.47	10000	0.47	10000	0.47	10000	nF
Timing resistor, $R_T$	1.8	500	1.8	500	1.8	500	k $\Omega$
Operating free-air temperature, $T_A$	0	70	-40	85	-55	125	°C



# TL494C, TL494I, TL494M, TL494Y PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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**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†	TL494C, TL494I			TL494M			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Output voltage (REF)	$I_O = 1\text{ mA}$	4.75	5	5.25	4.75	5	5.25	V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$		2	25		2	25	mV
Output regulation	$I_O = 1\text{ mA to }10\text{ mA}$		1	15		1	15	mV
Output voltage change with temperature	$\Delta T_A = \text{MIN to MAX}$		2	10		2	30*	mV/V
Short-circuit output current§	REF = 0 V		25			-25		mA

\* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† 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  $T_A = 25^\circ\text{C}$ .

§ Duration of the short circuit should not exceed one second.

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

PARAMETER	TEST CONDITIONS†	TL494C, TL494I			TL494M			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Frequency			10			10		kHz
Standard deviation of frequency¶	All values of $V_{CC}$ , $C_T$ , $R_T$ , and $T_A$ constant		100			100		Hz/kHz
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$		1			1		Hz/kHz
Frequency change with temperature#	$\Delta T_A = \text{MIN to MAX}$			10			10*	Hz/kHz

\* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† 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  $T_A = 25^\circ\text{C}$ .

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

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

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

## error amplifier section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL494C, TL494I TL494M			UNIT
		MIN	TYP‡	MAX	
Input offset voltage	$V_O$ (FEEDBACK) = 2.5 V		2	10	mV
Input offset current	$V_O$ (FEEDBACK) = 2.5 V		25	250	nA
Input bias current	$V_O$ (FEEDBACK) = 2.5 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	$\Delta V_O = 3\text{ V}$ , $R_L = 2\ \text{k}\Omega$ , $V_O = 0.5\text{ V to }3.5\text{ V}$		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)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V$ (FEEDBACK) = 0.7 V		0.3	0.7	mA
Output source current (FEEDBACK)	$V_{ID} = 15\text{ mV to }5\text{ V}$ , $V$ (FEEDBACK) = 3.5 V		-2		mA

‡ All typical values except for parameter changes with temperature are at  $T_A = 25^\circ\text{C}$ .



# TL494C, TL494I, TL494M, TL494Y

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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electrical characteristics over recommended operating free-air temperature range,  $V_{CC} = 15\text{ V}$ ,  $f = 10\text{ kHz}$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

### reference section

PARAMETER	TEST CONDITIONS	TL494Y			UNIT
		MIN	TYP†	MAX	
Output voltage (REF)	$I_O = 1\text{ mA}$	5			V
Input regulation	$V_{CC} = 7\text{ V to }40\text{ V}$	2			mV
Output regulation	$I_O = 1\text{ mA to }10\text{ mA}$	1			mV
Short-circuit output current‡	REF = 0 V	25			mA

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

PARAMETER	TEST CONDITIONS	TL494Y			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	$V_{CC} = 7\text{ V to }40\text{ V}$ , $T_A = 25^\circ\text{C}$	1			Hz/kHz

### error amplifier section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL494Y			UNIT
		MIN	TYP†	MAX	
Input offset voltage	$V_O$ (FEEDBACK) = 2.5 V	2			mV
Input offset current	$V_O$ (FEEDBACK) = 2.5 V	25			nA
Input bias current	$V_O$ (FEEDBACK) = 2.5 V	0.2			$\mu\text{A}$
Open-loop voltage amplification	$\Delta V_O = 3\text{ V}$ , $R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V to }3.5\text{ V}$	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	$\Delta V_O = 40\text{ V}$ , $T_A = 25^\circ\text{C}$	80			dB
Output sink current (FEEDBACK)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V$ (FEEDBACK) = 0.7 V	0.7			mA

† All typical values except for parameter changes with temperature are at  $T_A = 25^\circ\text{C}$ .

‡ Duration of the short circuit should not exceed one second.

§ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

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

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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	TL494C, TL494I TL494M, TL494Y			UNIT
		MIN	TYP†	MAX	
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	$V_E = 0$ ,	$I_C = 200\text{ mA}$		V
	Emitter follower	$V_{O(C1\text{ or }C2)} = 15\text{ V}$ , $I_E = -200\text{ mA}$			
Output control input current	$V_I = V_{ref}$			3.5	mA

† 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	TL494C, TL494I TL494Y			TL494M		UNIT
		MIN	TYP†	MAX	MIN	TYP†	
Input bias current (DEAD-TIME CTRL)	$V_I = 0\text{ to }5.25\text{ V}$	-2	-10		-2	-10	$\mu\text{A}$
Maximum duty cycle, each output	$V_I$ (DEAD-TIME CTRL) = 0, $C_T = 0.1\ \mu\text{F}$ , $R_T = 12\ \text{k}\Omega$	45%			45%	50%*	
Input threshold voltage (DEAD-TIME CTRL)	Zero duty cycle	3	3.3		3	3.3	V
	Maximum duty cycle	0			0*		

\* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

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

## PWM comparator section (see Figure 1)

PARAMETER	TEST CONDITIONS	TL494C, TL494I TL494M, TL494Y			UNIT
		MIN	TYP†	MAX	
Input threshold voltage (FEEDBACK)	Zero duty cycle		4	4.5	V
Input sink current (FEEDBACK)	$V$ (FEEDBACK) = 0.7 V	0.3	0.7		mA

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

## total device

PARAMETER	TEST CONDITIONS	TL494C, TL494I TL494Y			TL494M		UNIT
		MIN	TYP†	MAX	MIN	TYP†	
Standby supply current	$R_T = V_{ref}$ , All other inputs and outputs open	$V_{CC} = 15\text{ V}$	6	10	6	21	mA
		$V_{CC} = 40\text{ V}$	9	15	9	26	
Average supply current	$V_I$ (DEAD-TIME CTRL) = 2 V, See Figure 1		7.5		7.5		mA

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



# TL494C, TL494I, TL494M, TL494Y

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

switching characteristics,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	TL494C, TL494I TL494Y			TL494M			UNIT
		MIN	TYP†	MAX	MIN	TYP†	MAX	
Rise time	Common-emitter configuration, See Figure 3	100	200		100	200*		ns
Fall time		25	100		25	100*		ns
Rise time	Emitter-follower configuration, See Figure 4	100	200		100	200*		ns
Fall time		40	100		40	100*		ns

\* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

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



PARAMETER MEASUREMENT INFORMATION

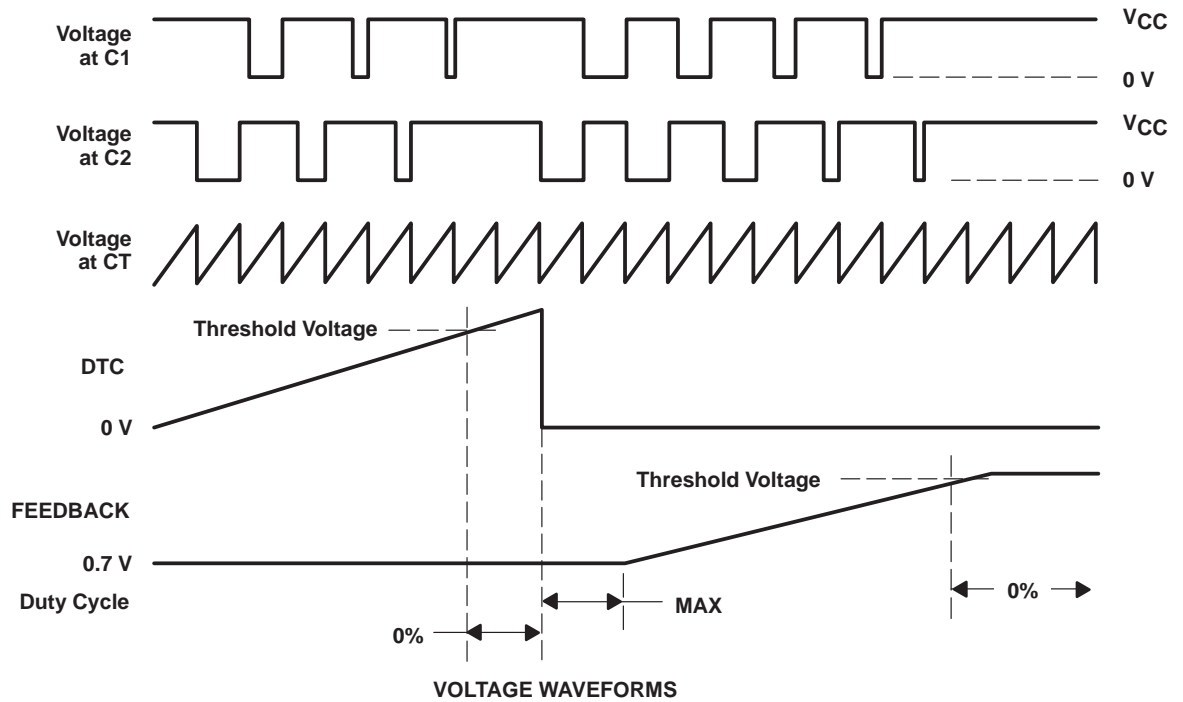
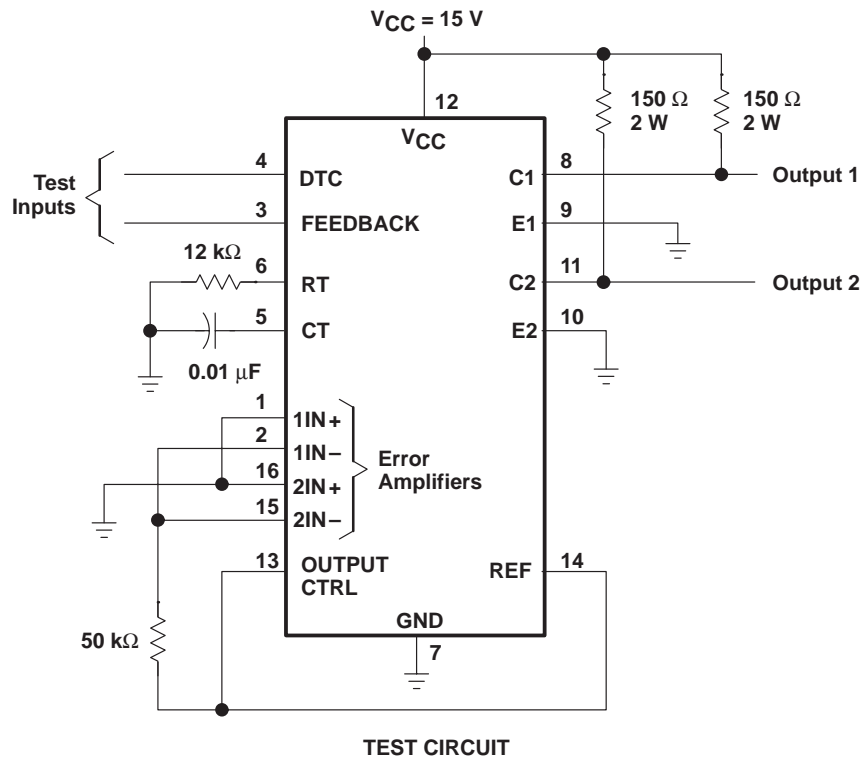


Figure 1. Operational Test Circuit and Waveforms

# TL494C, TL494I, TL494M, TL494Y PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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## PARAMETER MEASUREMENT INFORMATION

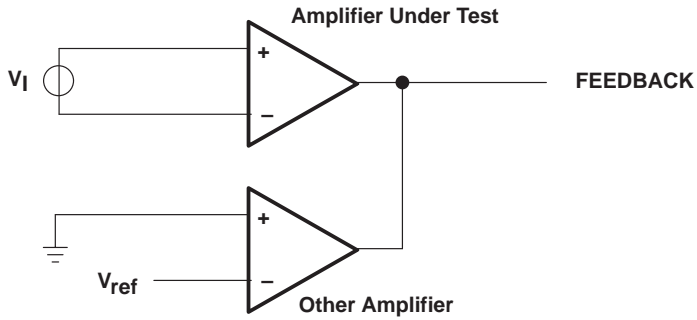
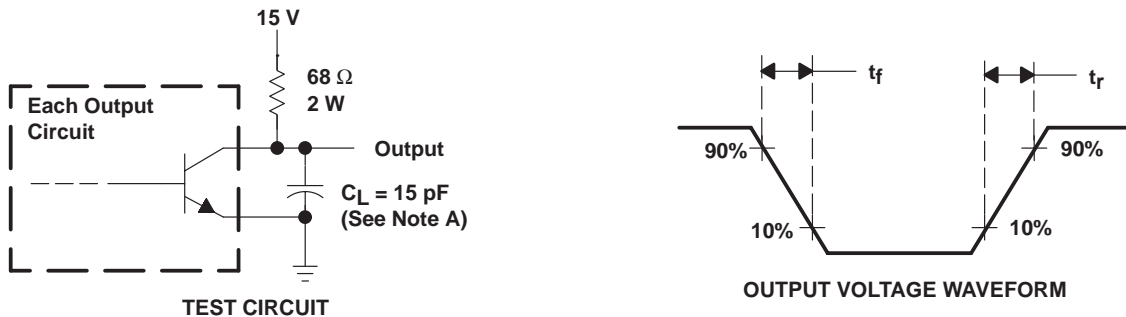
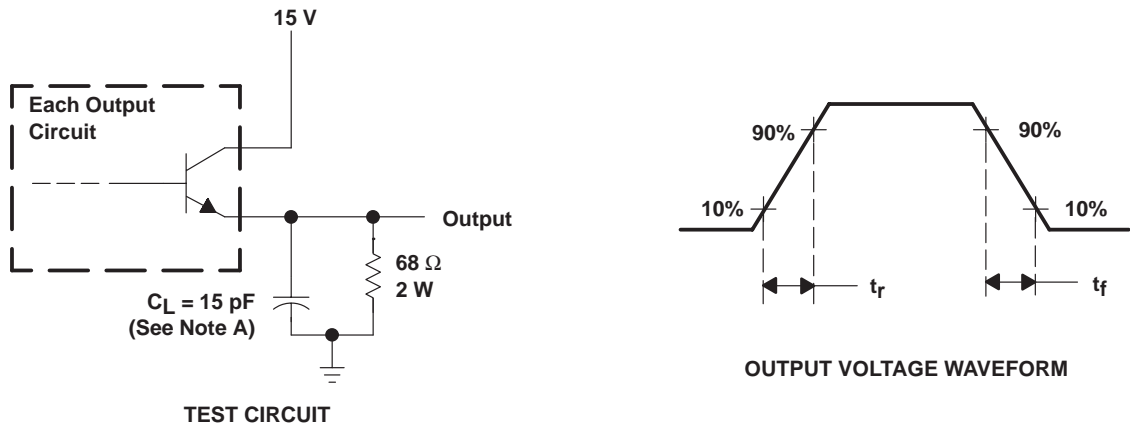


Figure 2. Amplifier Characteristics



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

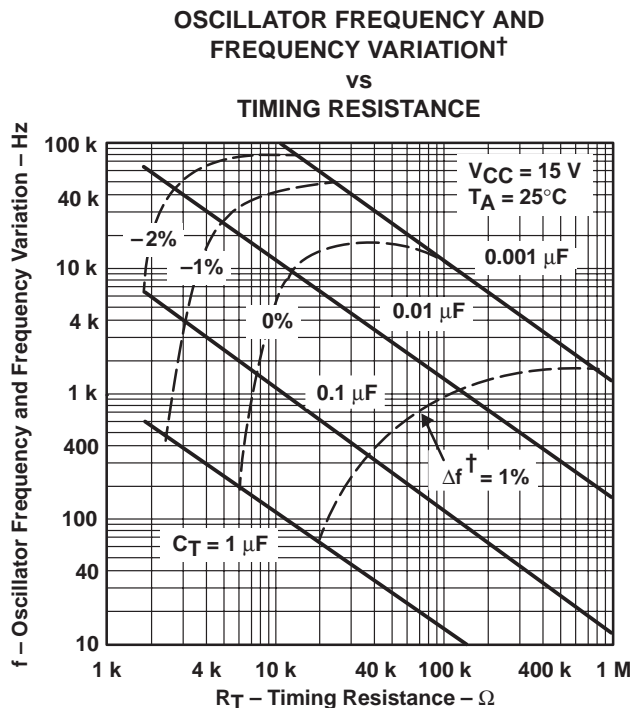


Figure 5

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

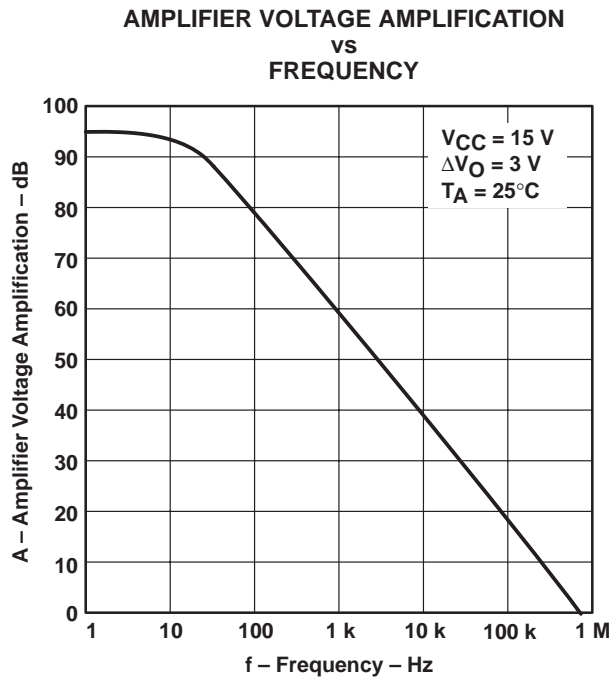


Figure 6



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