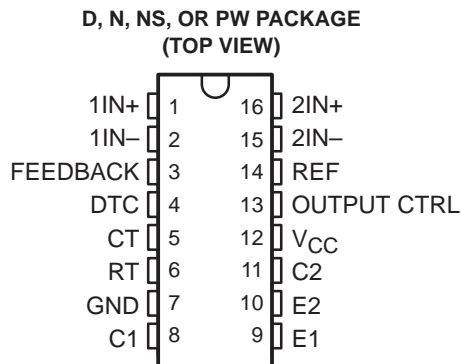


- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides 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  $85^{\circ}\text{C}$ .

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



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

# TL494

## PULSE-WIDTH-MODULATION CONTROL CIRCUITS

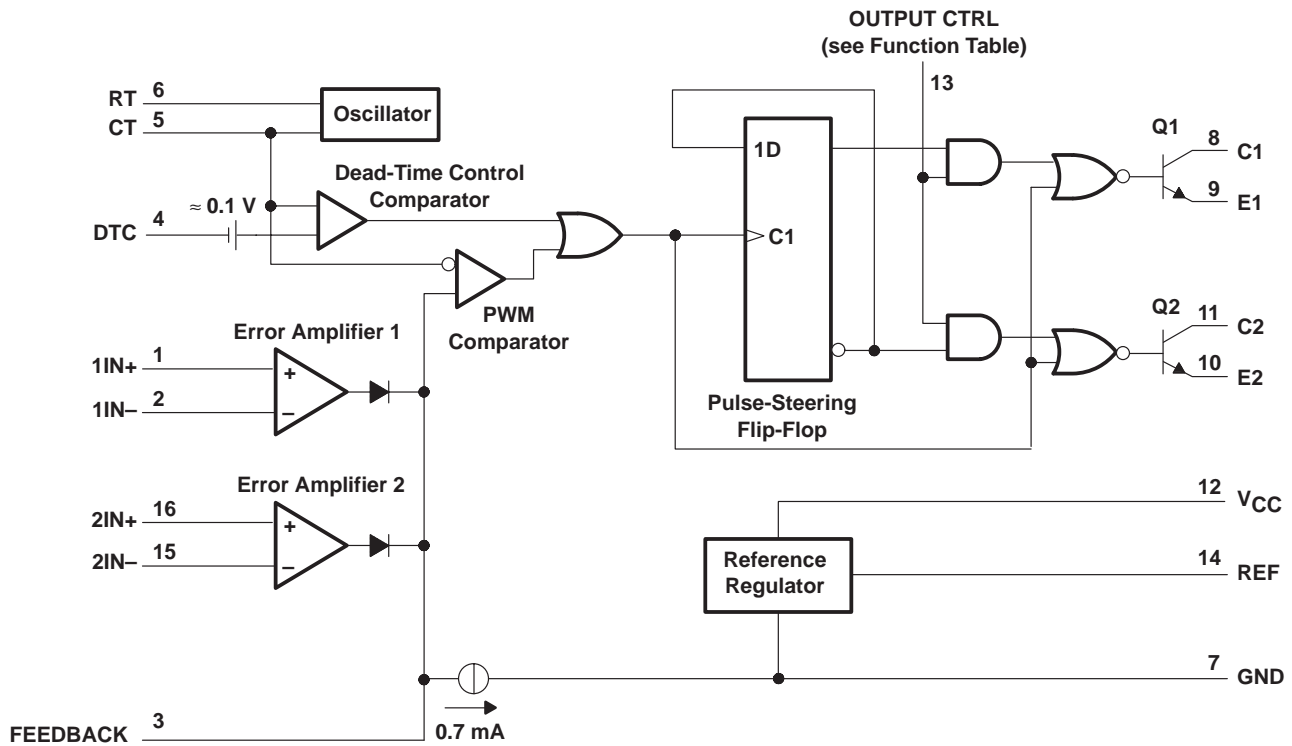
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### AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES				CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC DIP (N)	SMALL OUTLINE (NS)	SHRINK SMALL OUTLINE (PW)	
0°C to 70°C	TL494CD	TL494CN	TL494CNS	TL494CPW	TL494Y
-40°C to 85°C	TL494ID	TL494IN	—	—	—

The D, NS, and PW packages are available taped and reeled. Add the suffix R to device type (e.g., TL494CDR). Chip forms are tested at 25°C.

### functional block diagram



# TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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

		TL494	UNIT	
Supply voltage, $V_{CC}$ (see Note 1)		41	V	
Amplifier input voltage, $V_I$		$V_{CC}+0.3$	V	
Collector output voltage, $V_O$		41	V	
Collector output current, $I_O$		250	mA	
Package thermal impedance, $\theta_{JA}$ (see Notes 2 and 3)	D package	73	°C	
	N package	88		
	NS package	64		
	PW package	108		
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		D, N, or PW package	260	°C
Storage temperature range, $T_{stg}$			-65 to 150	°C

<sup>†</sup> 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  $T_J(\max)$ ,  $\theta_{JA}$ , 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 impact reliability.
  3. The package thermal impedance is calculated in accordance with JEDEC 51, except for through-hole packages, which use a trace length of zero.

## recommended operating conditions

		TL494		UNIT
		MIN	MAX	
Supply voltage, $V_{CC}$		7	40	V
Amplifier input voltage, $V_I$		-0.3	$V_{CC}-2$	V
Collector output voltage, $V_O$			40	V
Collector output current (each transistor)			200	mA
Current into feedback terminal			0.3	mA
Oscillator frequency, $f_{osc}$		1	300	kHz
Timing capacitor, $C_T$		0.47	10000	nF
Timing resistor, $R_T$		1.8	500	k $\Omega$
Operating free-air temperature, $T_A$	TL494C	0	70	°C
	TL494I	-40	85	

# TL494

## 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			UNIT
		MIN	TYP‡	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§	REF = 0 V		25		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  $T_A = 25^\circ\text{C}$ .

§ 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†	TL494, TL494I			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
Frequency change with temperature#	$\Delta T_A = \text{MIN to MAX}$			10	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  $T_A = 25^\circ\text{C}$ .

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

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

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

### error-amplifier section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL494, TL494I			UNIT
		MIN	TYP‡	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	$\Delta V_O = 3\text{ V}$ , $R_L = 2\ \text{k}\Omega$ , $V_O = 0.5\text{ V to }3.5\text{ V}$	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)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V (\text{FEEDBACK}) = 0.7\text{ V}$	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

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



# TL494 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 CONDITION <sup>†</sup>	TL494Y			UNIT
		MIN	TYP <sup>†</sup>	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 <sup>‡</sup>	REF = 0 V		25		mA

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

<sup>‡</sup> 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 CONDITION <sup>†</sup>	TL494Y			UNIT
		MIN	TYP <sup>†</sup>	MAX	
Frequency			10		kHz
Standard deviation of frequency <sup>§</sup>	All values of $V_{CC}$ , $C_T$ , $R_T$ , and $T_A$ constant		100		Hz/kHz
Frequency change with voltage	$V_{CC} = 7\text{ V to }40\text{ V}$		1		Hz/kHz

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

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

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

## error-amplifier section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL494Y			UNIT
		MIN	TYP <sup>†</sup>	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	$\Delta V_O = 40\text{ V}$		80		dB
Output sink current (FEEDBACK)	$V_{ID} = -15\text{ mV to }-5\text{ V}$ , $V$ (FEEDBACK) = 0.7 V		0.7		mA

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

# TL494

## 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)

### output section

PARAMETER	TEST CONDITIONS	TL494, 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 $V_E = 0$ , $I_C = 200\text{ mA}$		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

† 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	TL494, TL494Y			UNIT
		MIN	TYP†	MAX	
Input bias current (DEAD-TIME CTRL)	$V_I = 0\text{ to }5.25\text{ V}$		-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%		
Input threshold voltage (DEAD-TIME CTRL)	Zero duty cycle		3	3.3	V
	Maximum duty cycle		0		

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

### PWM comparator section (see Figure 1)

PARAMETER	TEST CONDITIONS	TL494, 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	TL494, TL494Y			UNIT
		MIN	TYP†	MAX	
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 V, See Figure 1		7.5		mA

† 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	TL494, TL494Y			UNIT
		MIN	TYP†	MAX	
Rise time	Common-emitter configuration, See Figure 3		100	200	ns
Fall time			25	100	
Rise time	Emitter-follower configuration, See Figure 4		100	200	ns
Fall time			40	100	

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



PARAMETER MEASUREMENT INFORMATION

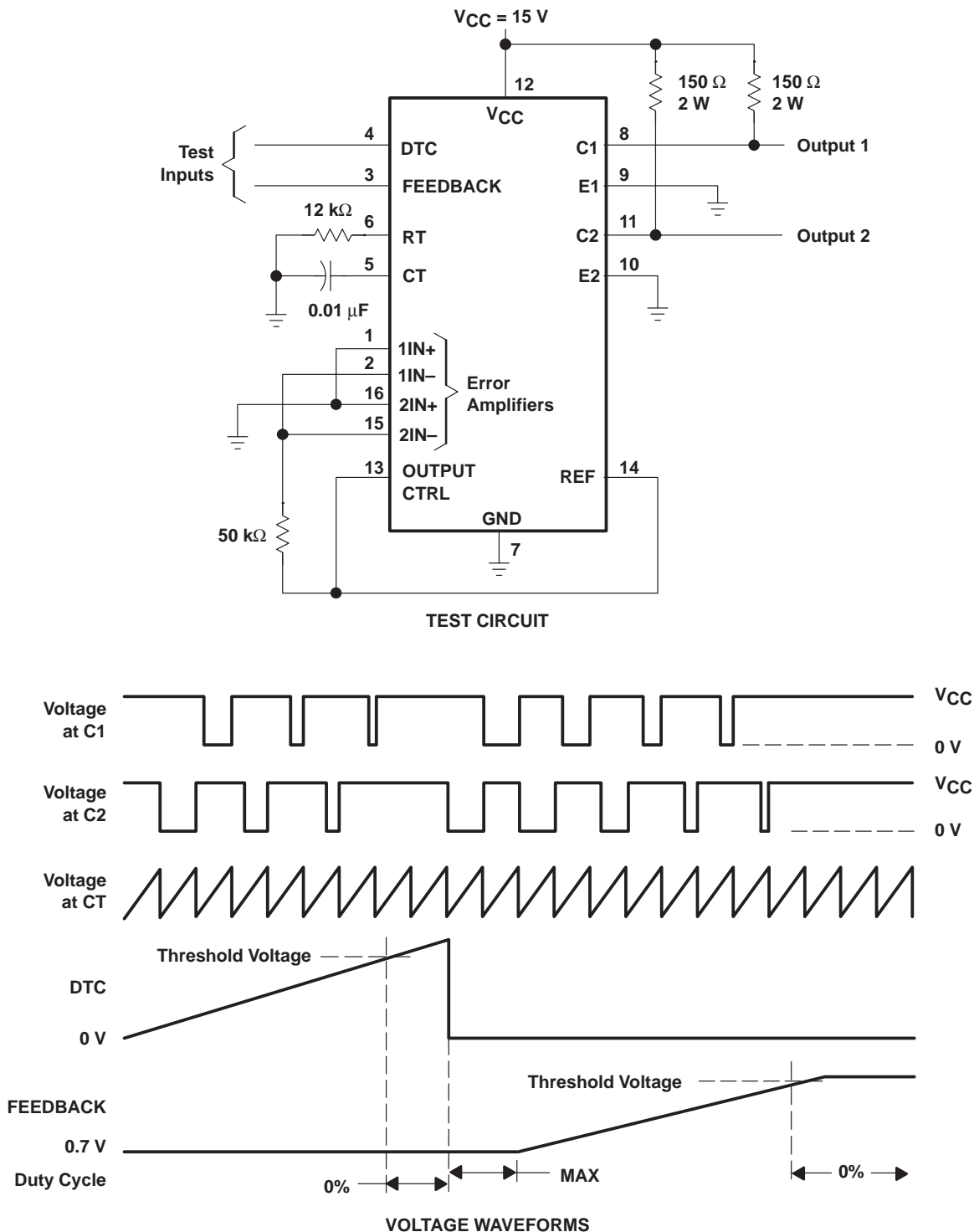


Figure 1. Operational Test Circuit and Waveforms

# TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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## PARAMETER MEASUREMENT INFORMATION

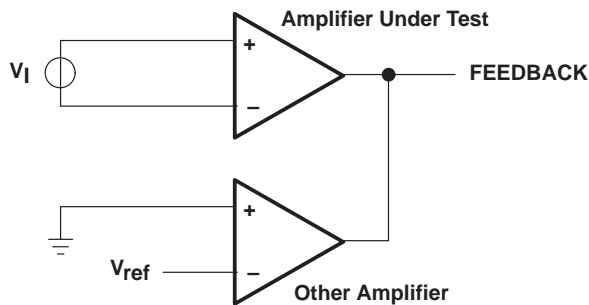
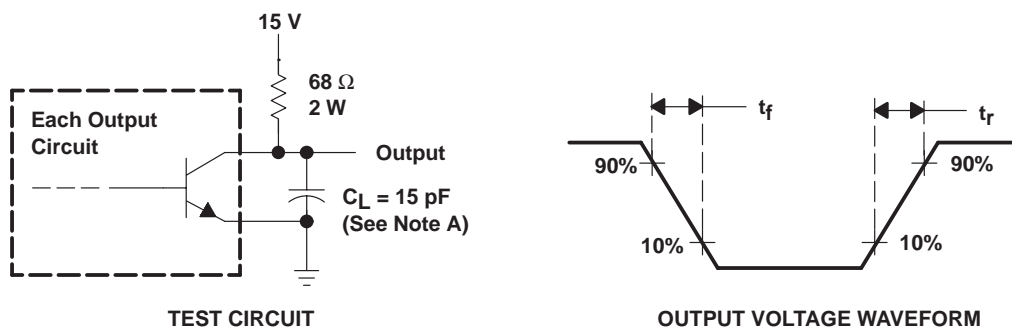
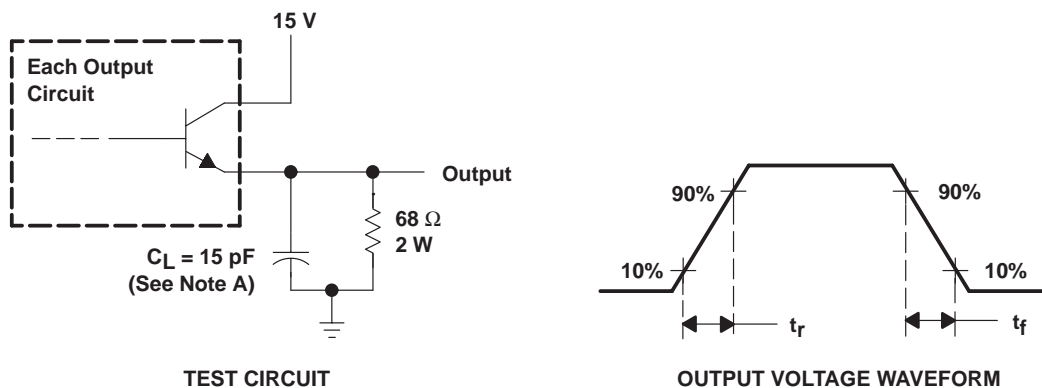


Figure 2. Amplifier Characteristics



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

Figure 3. Common-Emitter Configuration

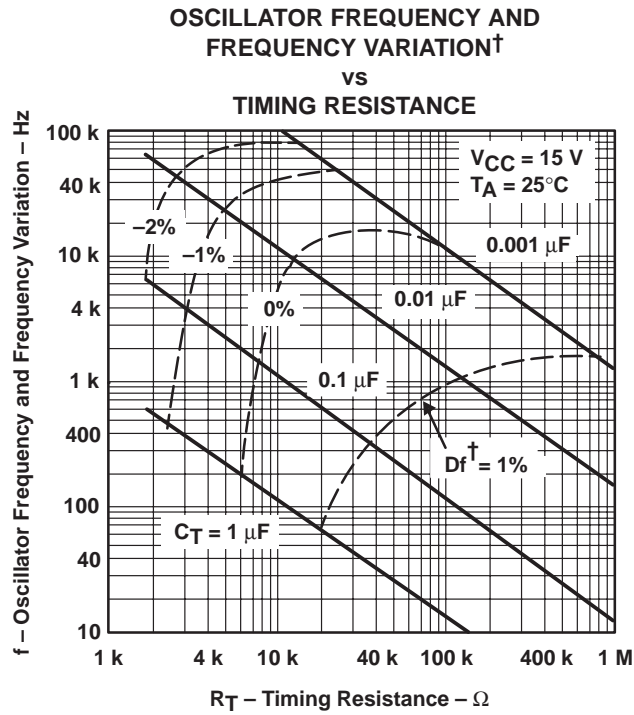


NOTE A:  $C_L$  includes probe and jig capacitance.

Figure 4. Emitter-Follower Configuration



TYPICAL CHARACTERISTICS



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

Figure 5

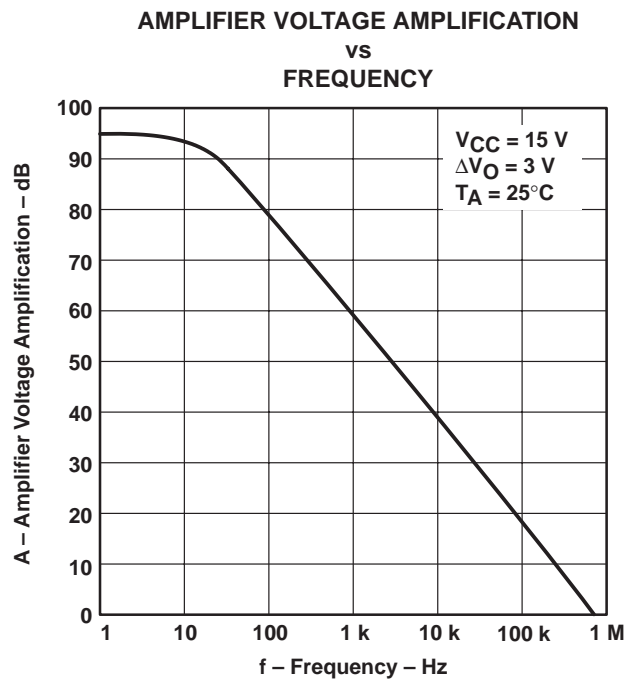


Figure 6

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