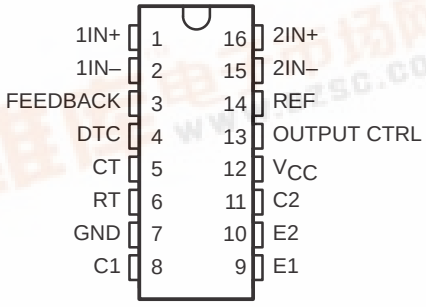
TL594
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

SLVS052C – APRIL 1988 – REVISED JULY 1999

- **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 OR N PACKAGE
(TOP VIEW)



description

The TL594 incorporates all the functions required in the construction of a pulse-width-modulation control circuit on a single chip. Designed primarily for power-supply control, these devices offer 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 exhibit a common-mode voltage range from –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.

FUNCTION TABLE

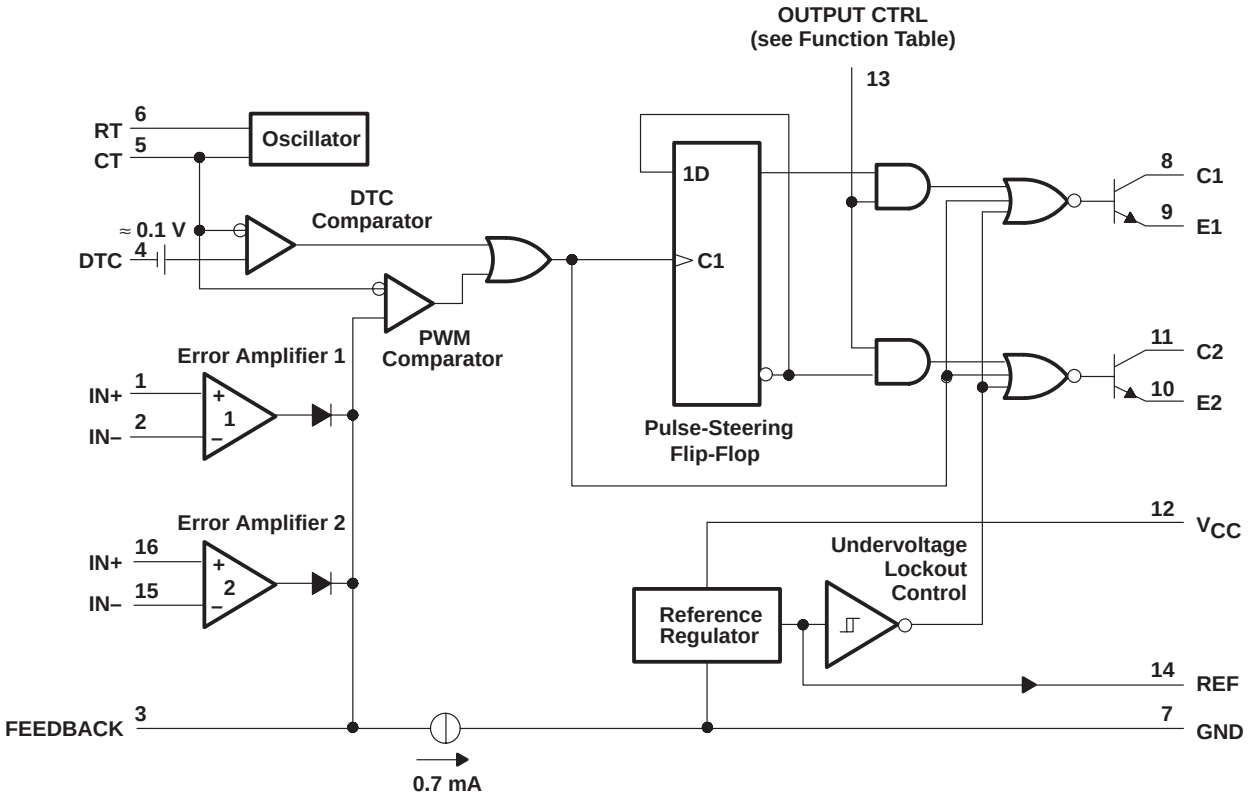
INPUT	OUTPUT FUNCTION
OUTPUT CTRL	
V_I = –0	Single-ended or parallel output
$V_I = V_{ref}$	Normal push-pull operation

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES		CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC DIP (N)	
0°C to 70°C	TL594CD	TL594CN	TL594Y
–40°C to 85°C	TL594ID	TL594IN	

The D package is available taped and reeled. Add “R” suffix to device type (e.g., TL594CDR). Chip forms are tested at 25°C.

functional block diagram



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

		TL594X	UNIT
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
	N package	88	
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260	°C
Storage temperature range, T_{stg}		–65 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 impact reliability.
3. The package thermal impedance is calculated in accordance with JESD 51, except for through-hole packages, which use a trace length of zero.

recommended operating conditions

		MIN	MAX	UNIT
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
Timing capacitor, C_T		0.47	10000	nF
Timing resistor, R_T		1.8	500	kΩ
Oscillator frequency, f_{osc}		1	300	kHz
Operating free-air temperature, T_A	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 not taken into account.

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

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.

electrical characteristics over recommended operating conditions, V_{CC} = 15 V, T_A = 25°C (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS	TL594Y			UNIT
		MIN	TYP	MAX	
Output voltage (REF)	I_O = 1 mA		5		V
Input regulation	V_{CC} = 7 V to 40 V		2		mV
Output regulation	I_O = 1 to 10 mA		14		mV
Short-circuit output current‡	V_{ref} = 0		35		mA

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

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

PARAMETER	TEST CONDITIONS	TL594Y			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		1		Hz/kHz

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

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

amplifier section (see Figure 1)

PARAMETER	TEST CONDITIONS			TL594Y			UNIT
				MIN	TYP	MAX	
Input offset voltage, error amplifier	FEEDBACK = 2.5 V				2		mV
Input offset current	FEEDBACK = 2.5 V				25		nA
Input bias current	FEEDBACK = 2.5 V				0.2		μA
Open-loop voltage amplification, error amplifier	ΔV_O = 3 V,	R_L = 2 kΩ,	V_O = 0.5 V to 3.5 V		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			80		dB
Output sink current, FEEDBACK	V_{ID} = –15 mV to –5 V,	FEEDBACK = 0.5 V			0.7		mA

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, T_A = 25°C (unless otherwise noted)

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594Y			UNIT
		MIN	TYP	MAX	
Input bias current	V_I = 0 to 5.25 V		–2		μA
Input threshold voltage	Zero duty cycle		3		V

output section

PARAMETER		TEST CONDITIONS	TL594Y			UNIT
			MIN	TYP†	MAX	
Collector off-state current		V_C = 40 V, V_E = 0 V, V_{CC} = 40 V		2		μA
		DTC and OUTPUT CTRL = 0 V, V_C = 15 V, V_E = 0 V, V_{CC} = 1 to 3 V		4		
Emitter off-state current		V_{CC} = V_C = 40 V, V_E = 0				μA
Collector-emitter saturation voltage	Common emitter	V_E = 0, I_C = 200 mA		1.1		V
	Emitter follower	V_C = 15 V, I_E = –200 mA		1.5		

pwm comparator section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594Y			UNIT
		MIN	TYP	MAX	
Input threshold voltage, FEEDBACK	Zero duty cycle		4		V
Input sink current, FEEDBACK	FEEDBACK = 0.5 V		0.7		mA

total device (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594Y			UNIT
		MIN	TYP	MAX	
Standby supply current	All other inputs and outputs open, R_T at V_{ref}		9		mA
Average supply current	DTC = 2 V, See Figure 2		12.4		mA

switching characteristics, T_A = 25°C

PARAMETER	TEST CONDITIONS	TL594Y			UNIT
		MIN	TYP	MAX	
Output-voltage rise time	Common-emitter configuration (see Figure 3)		100		ns
Output-voltage fall time			30		ns
Output-voltage rise time	Emitter-follower configuration (see Figure 4)		200		ns
Output-voltage fall time			45		ns

PARAMETER MEASUREMENT INFORMATION

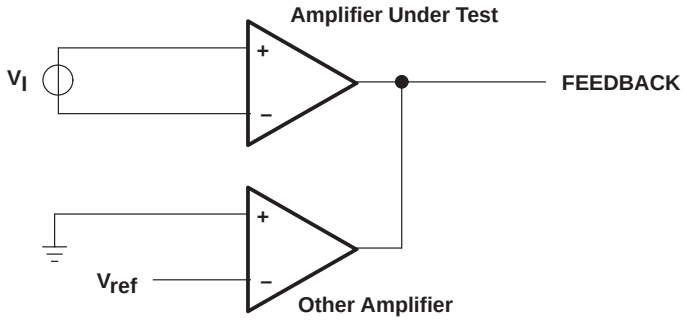
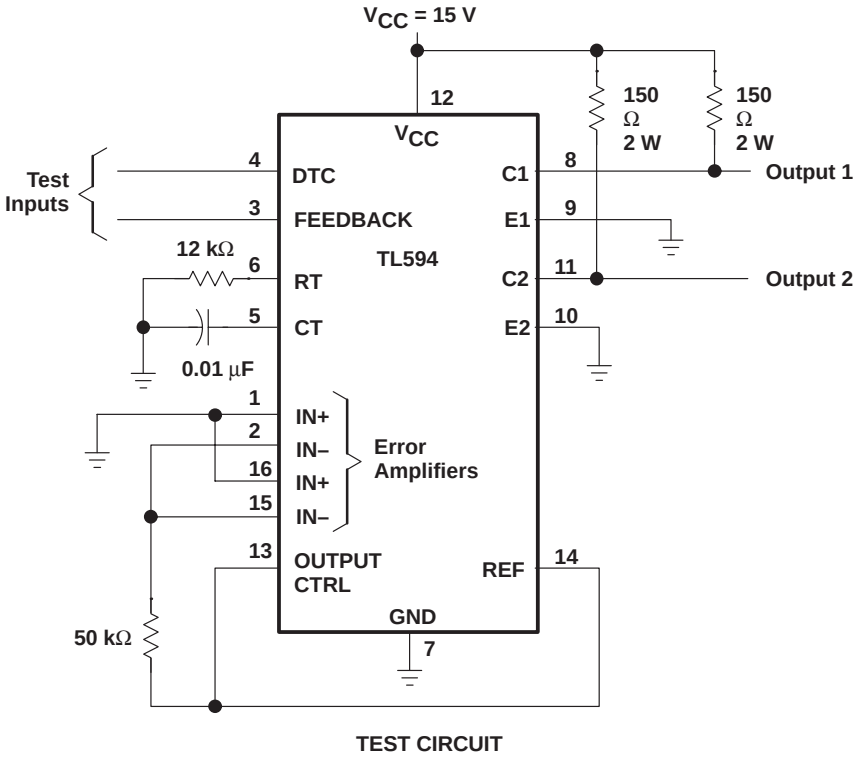
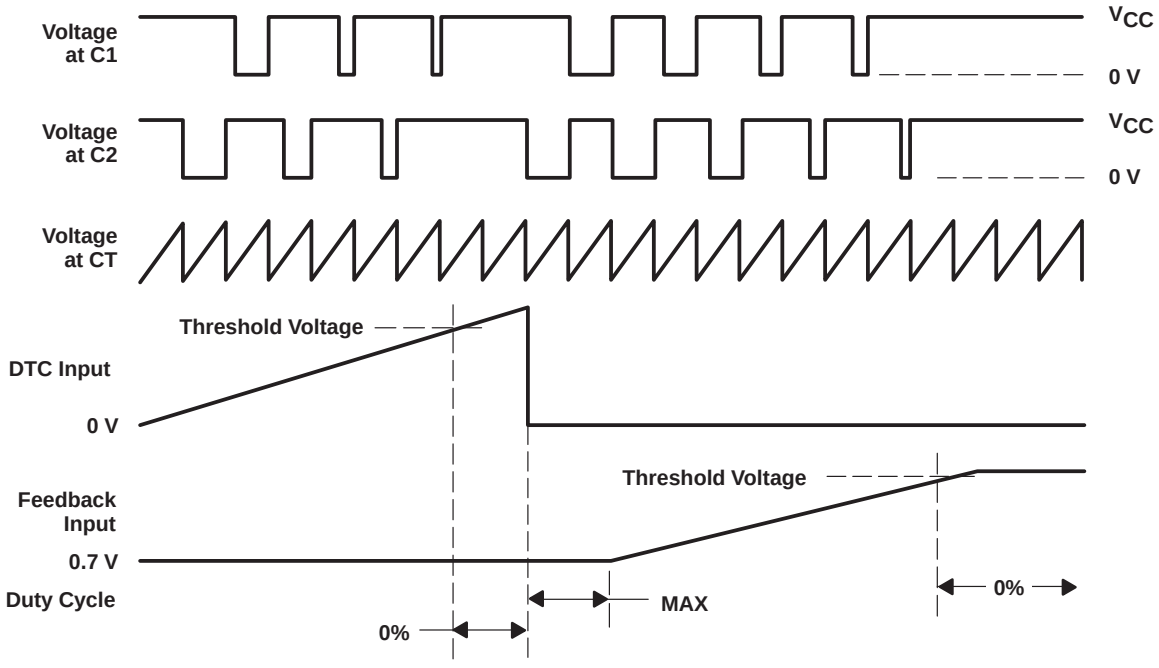


Figure 1. Amplifier-Characteristics Test Circuit

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

Figure 2. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

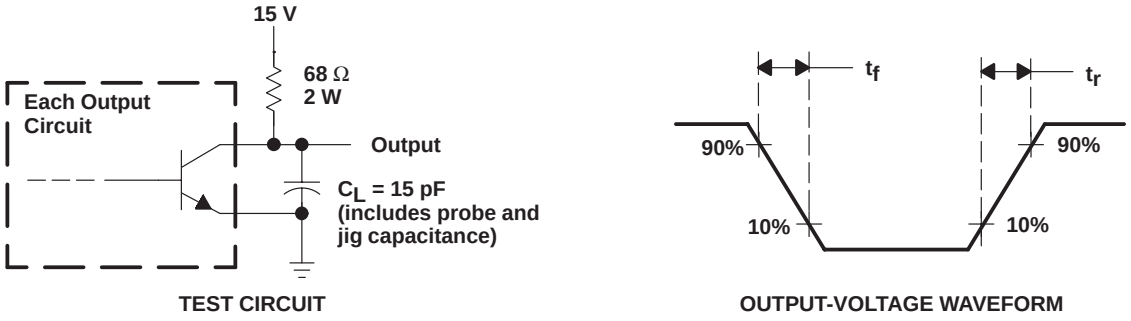


Figure 3. Common-Emitter Configuration

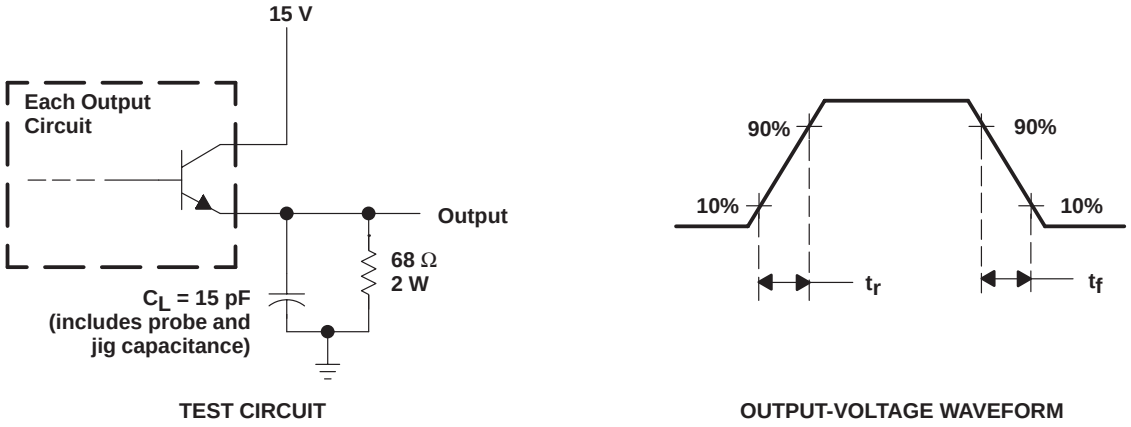
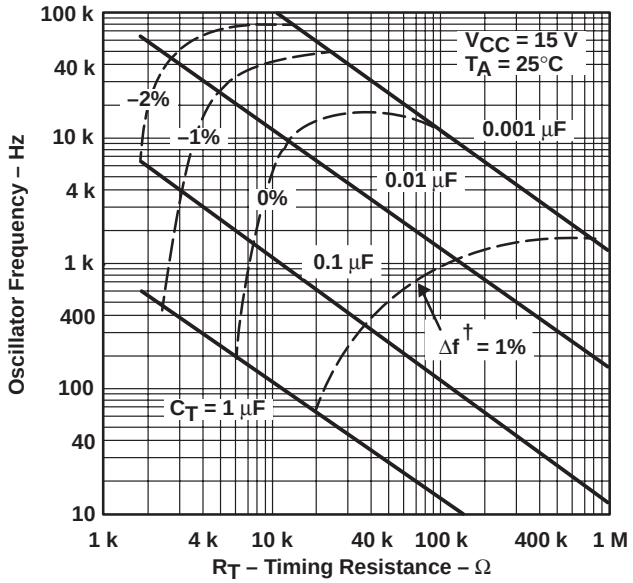


Figure 4. Emitter-Follower Configuration

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

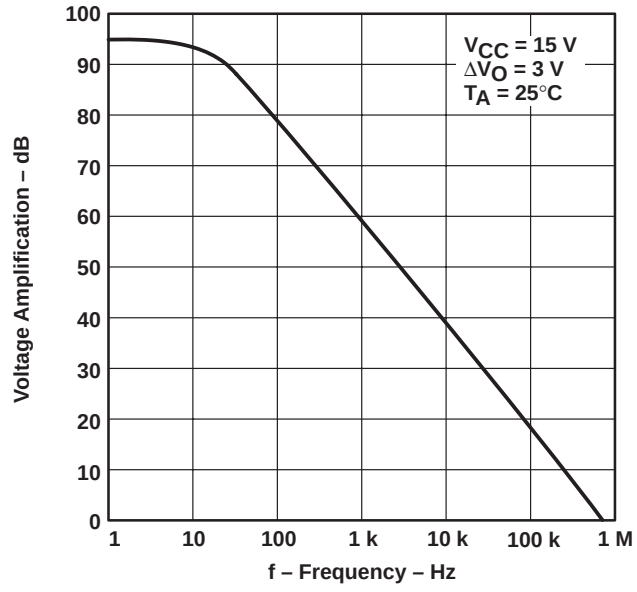


Figure 6

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