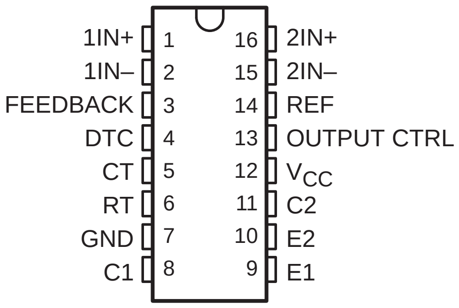
TL494
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

SLVS074B – JANUARY 1983 – 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 With 5% Tolerance**
- **Circuit Architecture Allows Easy Synchronization**

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



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 V to V_{CC} – 2 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°C to 70°C. The TL494I is characterized for operation from –40°C to 85°C.

FUNCTION TABLE

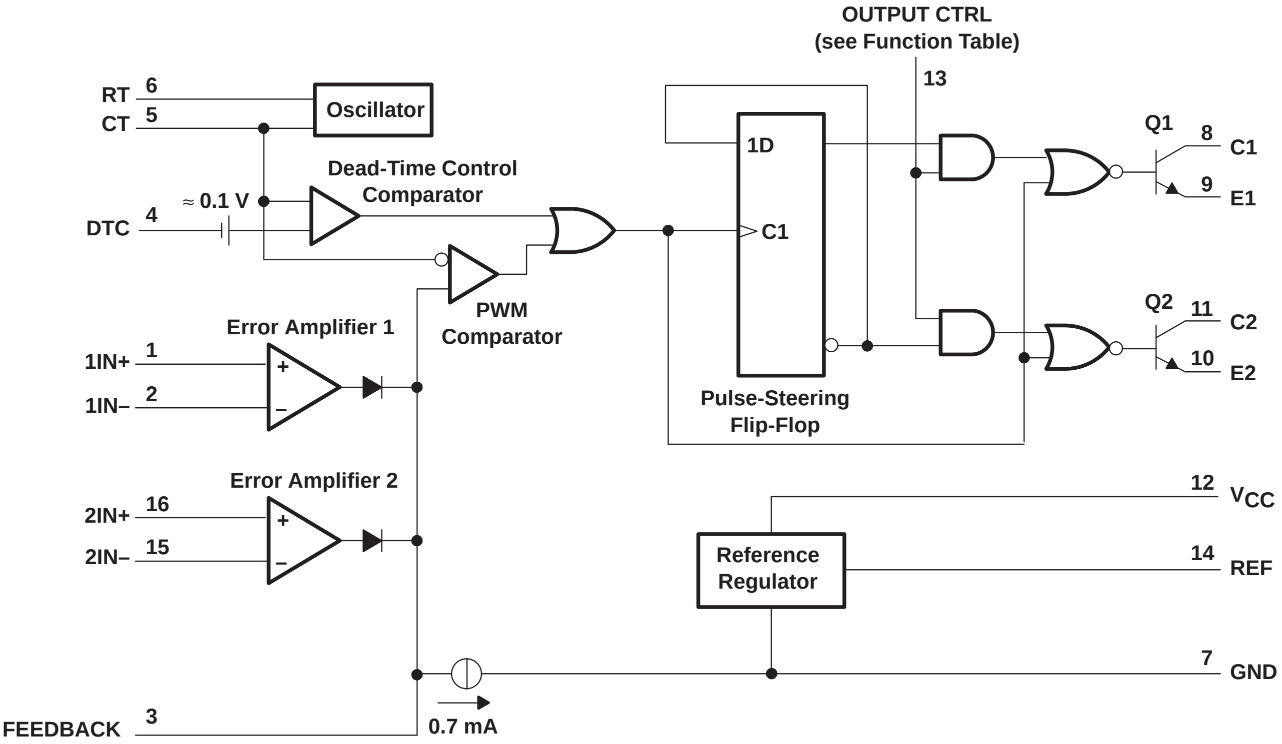
INPUT TO OUTPUT CTRL	OUTPUT FUNCTION
V_I = GND	Single-ended or parallel output
V_I = V_{ref}	Normal push-pull operation

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES				CHIP FORM (Y)
	SMALL OUTLINE (D)	PLASTIC DIP (N)	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



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

		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, θ_{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

[†] 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 $P_D = (T_J(\text{max}) - T_A)/\theta_{JA}$. 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

		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	kΩ
Operating free-air temperature, T_A	TL494C	0	70	°C
	TL494I	–40	85	

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

reference section

PARAMETER	TEST CONDITIONS[†]	TL494C, TL494I			UNIT
		MIN	TYP[‡]	MAX	
Output voltage (REF)	I_O = 1 mA	4.75	5	5.25	V
Input regulation	V_{CC} = 7 V to 40 V		2	25	mV
Output regulation	I_O = 1 mA to 10 mA		1	15	mV
Output voltage change with temperature	ΔT_A = 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°C.

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

oscillator section, C_T = 0.01 μF, R_T = 12 kΩ (see Figure 1)

PARAMETER	TEST CONDITIONS[†]	TL494, TL494I			UNIT
		MIN	TYP[‡]	MAX	
Frequency			10		kHz
Standard deviation of frequency[¶]	All values of V_{CC}, CT, RT, 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			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°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 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 (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	μA
Common-mode input voltage range	V_{CC} = 7 V to 40 V	–0.3 to V_{CC}–2			V
Open-loop voltage amplification	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	ΔV_O = 40 V, T_A = 25°C	65	80		dB
Output sink current (FEEDBACK)	V_{ID} = –15 mV to –5 V, V (FEEDBACK) = 0.7 V	0.3	0.7		mA
Output source current (FEEDBACK)	V_{ID} = 15 mV to 5 V, V (FEEDBACK) = 3.5 V	–2			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, f = 10 kHz, T_A = 25°C (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS[†]	TL494Y			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 mA to 10 mA		1		mV
Short-circuit output current[‡]	REF = 0 V		25		mA

[†] 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.

oscillator section, C_T = 0.01 μF, R_T = 12 kΩ (see Figure 1)

PARAMETER	TEST CONDITIONS[†]	TL494Y			UNIT
		MIN	TYP[†]	MAX	
Frequency			10		kHz
Standard deviation of frequency[§]	All values of V_{CC}, CT, RT, and T_A constant		100		Hz/kHz
Frequency change with voltage	V_{CC} = 7 V to 40 V		1		Hz/kHz

[†] 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:

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

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		μA
Open-loop voltage amplification	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	ΔV_O = 40 V		80		dB
Output sink current (FEEDBACK)	V_{ID} = –15 mV to –5 V, V (FEEDBACK) = 0.7 V		0.7		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, f = 10 kHz (unless otherwise noted)

output section

PARAMETER		TEST CONDITIONS		TL494, TL494Y			UNIT
				MIN	TYP[†]	MAX	
Collector off-state current		V_{CE} = 40 V,	V_{CC} = 40 V		2	100	µA
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	$V_{O(C1\ or\ C2)}$ = 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 temperature coefficient are at T_A = 25°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 to 5.25 V		–2	–10	µA
Maximum duty cycle, each output	V_I (DEAD-TIME CTRL) = 0, C_T = 0.1 µF, R_T = 12 kΩ		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°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°C.

total device

PARAMETER	TEST CONDITIONS			TL494, TL494Y			UNIT
				MIN	TYP[†]	MAX	
Standby supply current	RT = V_{ref},	All other inputs and outputs open	V_{CC} = 15 V		6	10	mA
			V_{CC} = 40 V		9	15	
Average supply current	V_I (DEAD-TIME CTRL) = 2 V,	See Figure 1			7.5		mA

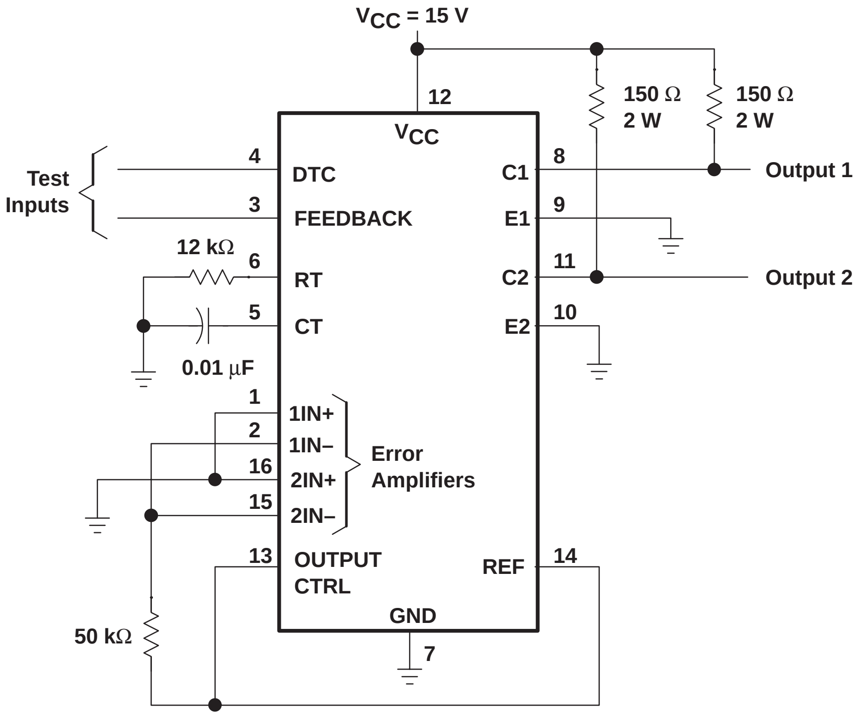
[†] All typical values except for temperature coefficient are at T_A = 25°C.

switching characteristics, T_A = 25°C

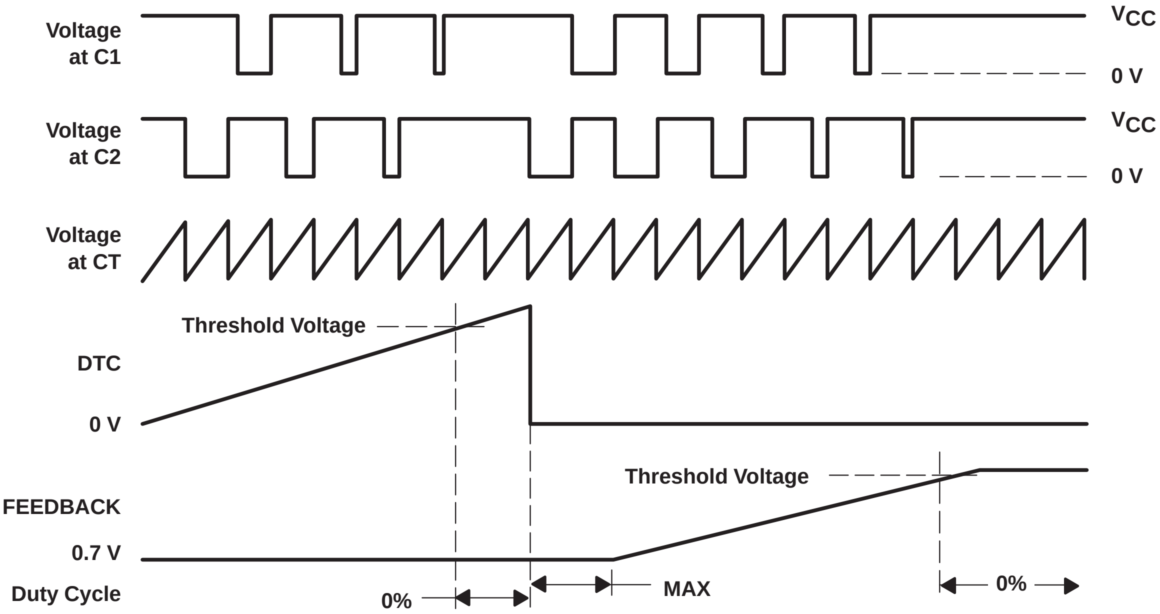
PARAMETER	TEST CONDITIONS		TL494, TL494Y			UNIT
			MIN	TYP[†]	MAX	
Rise time	Common-emitter configuration,	See Figure 3		100	200	ns
Fall time				25	100	ns
Rise time	Emitter-follower configuration,	See Figure 4		100	200	ns
Fall time				40	100	ns

[†] All typical values except for temperature coefficient are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

Figure 1. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

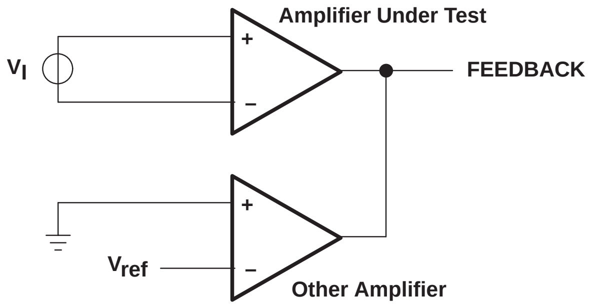
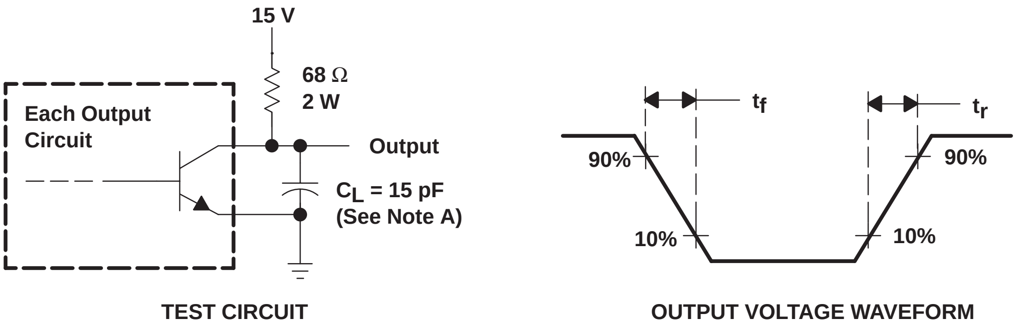
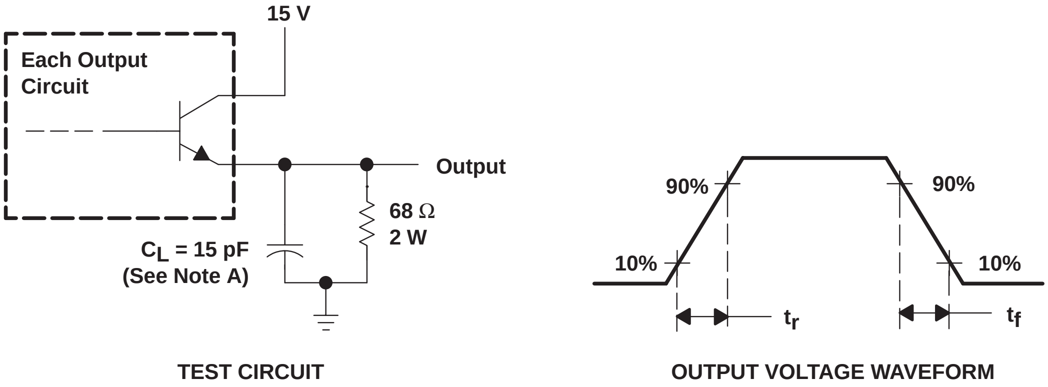


Figure 2. Amplifier Characteristics



NOTE A: C_L includes probe and jig capacitance.

Figure 3. Common-Emitter Configuration

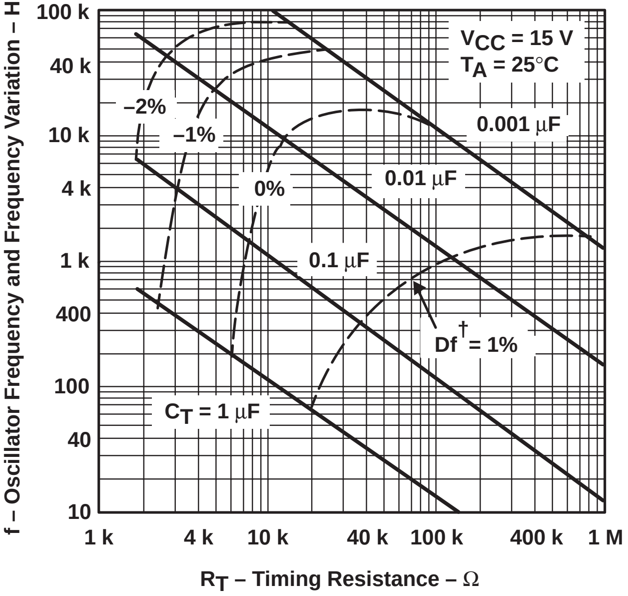


NOTE A: C_L includes probe and jig capacitance.

Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS

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

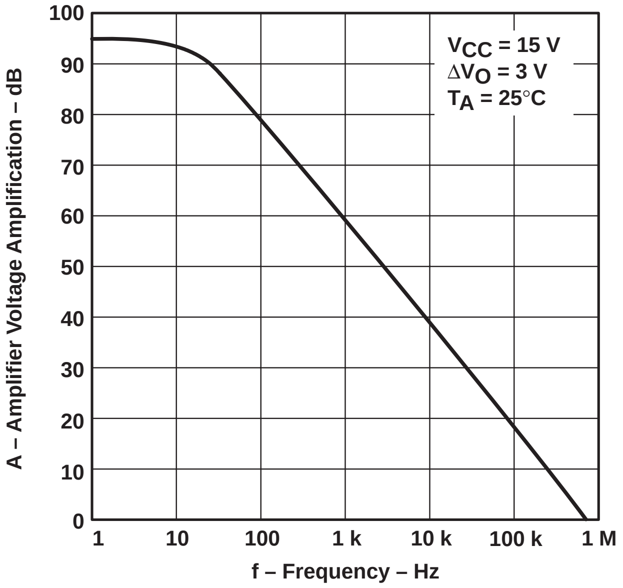


Figure 6

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