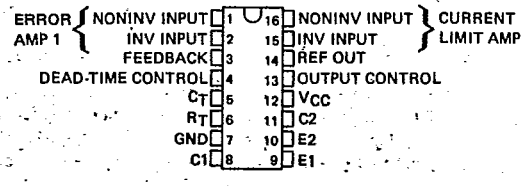
LINEAR INTEGRATED CIRCUITS

TYPES TL593, TL594, TL595 PULSE-WIDTH-MODULATION CONTROL CIRCUITS

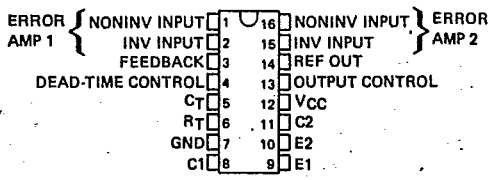
D2712, APRIL 1983—REVISED DECEMBER 1983

- **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**
- **Under-Voltage Lockout for Low V_{CC} Conditions**
- **TL593 has Output Current-Limit Sensing**
- **TL595 has On-Chip 39-V Zener and External Control of Output Steering**
- **Improved Direct Replacements for TL493, TL494, and TL495**

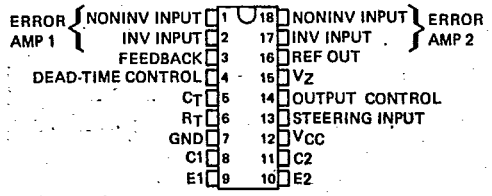
TL593M . . . J
TL593C . . . N
DUAL-IN-LINE PACKAGE (TOP VIEW)



TL594M . . . J
TL594I, TL594C . . . J OR N
DUAL-IN-LINE PACKAGE (TOP VIEW)



TL595C . . . N
DUAL-IN-LINE PACKAGE (TOP VIEW)



DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL593	TL594	TL595
TL59—M	J	J	*
TL59—I	*	J,N	*
TL59—C	N	J,N	N

*These combinations are not defined by this data sheet.

description

The TL593, TL594, and TL595 devices, each incorporate 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, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to his application. The TL593, TL594, and TL595 are improved direct replacements for the TL493, TL494, and TL495.

The TL593 contains an error amplifier, current-limiting amplifier, an on-chip adjustable oscillator, a dead-time control comparator, pulse-steering control flip-flop, 5-volt regulator with a precision of 1%, an under-voltage lockout control circuit, and output control circuitry.

The error amplifier exhibits a common-mode voltage range from −0.3 volts to V_{CC} −2 volts. The current-limit amplifier exhibits a common-mode voltage range from −0.3 volts to V_{CC} −6 volts with an offset voltage of approximately 80 millivolts in series with the inverting input to ease circuit design requirements. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T (pin 6) to the reference output and providing a sawtooth input to C_T (pin 5), or it may be used to drive the common circuitry in synchronous multiple-rail power supplies.

FUNCTION TABLE

INPUTS		OUTPUT FUNCTION
OUTPUT CONTROL	STEERING INPUT (TL595 only)	
V_I < 0.4 V	Open	Single ended or parallel output
V_I > 2.4 V	Open	Normal push-pull operation
V_I > 2.4 V	V_I < 0.4 V	PWM Output at Q1
V_I > 2.4 V	V_I > 2.4 V	PWM Output at Q2

TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

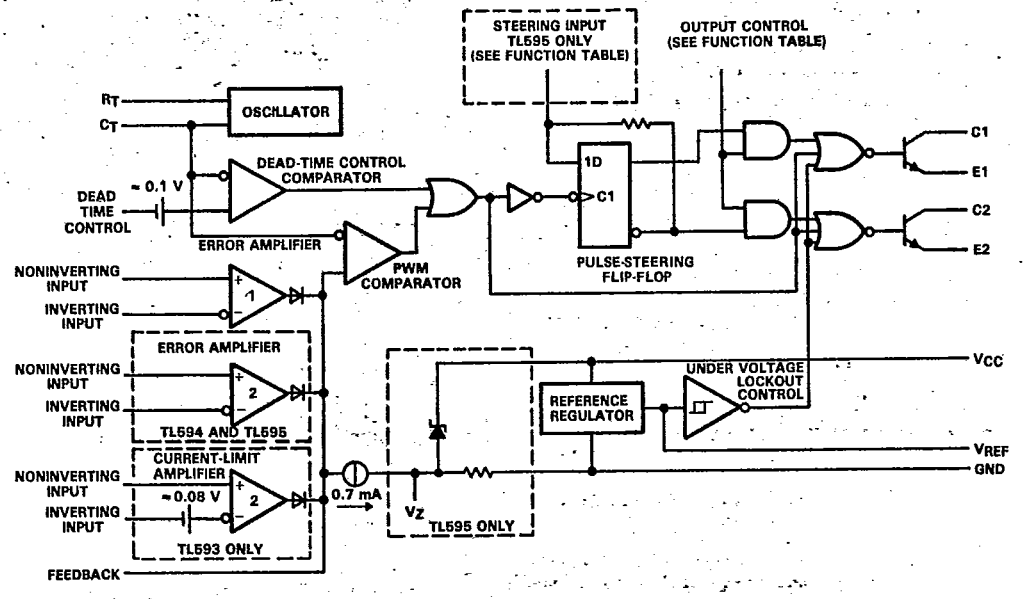
description (continued)

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 under-voltage lockout control circuit locks the outputs off until the internal circuitry is operational.

The TL593 and TL594 are similar except that an additional error amplifier is included in the TL594 instead of a current-limiting amplifier. The TL595 provides the identical functions found in the TL594. In addition, the TL595 also contains an on-chip 39-volt zener diode for high-voltage applications where V_{CC} is greater than 40 volts, and an output steering control that overrides the internal control of the pulse-steering flip-flop.

The TL593M and TL594M are characterized for operation over the full military temperature range from −55°C to 125°C. The TL594I is characterized for operation from −25°C to 85°C. The TL593C, TL594C, and TL595C are characterized for operation from 0°C to 70°C.

functional block diagram



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TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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

	TL593M TL594M	TL594I	TL593C TL594C TL595C	UNIT
Supply voltage, V_{CC} (see Note 1)	41	41	41	V
Amplifier input voltages	$V_{CC}+0.3$	$V_{CC}+0.3$	$V_{CC}+0.3$	V
Collector output voltage	41	41	41	V
Collector output current	250	250	250	mA
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2)	1000	1000	1000	mW
Operating free-air temperature range	−55 to 125	−25 to 85	0 to 70	°C
Storage temperature range	−65 to 150	−65 to 150	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package		260	260	°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. For operation above 25°C free-air temperature, refer to Dissipation Derating Table. In the J package, the TL593M and TL594M chips are alloy mounted; TL594I and TL594C chips are glass mounted.

DISSIPATION DERATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE T_A
J (Alloy-Mounted Chip)	1000 mW	11.0 mW/°C	59°C
J (Glass-Mounted Chip)	1000 mW	8.2 mW/°C	28°C
N	1000 mW	9.2 mW	41°C

recommended operating conditions

	TL593M TL594M		TL594I		TL593C TL594C TL595C		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, V_{CC}	7	40	7	40	7	40	V
Amplifier input voltages, 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
Timing capacitor, C_T	0.47	10 000	0.47	10 000	0.47	10 000	nF
Timing resistor, R_T	1.8	500	1.8	500	1.8	500	kΩ
Oscillator frequency	1	300	1	300	1	300	kHz
Operating free-air temperature, T_A	−55	125	−25	85	0	70	°C

TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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

reference section

PARAMETER	TEST CONDITIONS†	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Output voltage (V_{ref})	I_O = 1 mA, T_A = 25°C	4.95	5	5.05	4.95	5	5.05	V
Input regulation	V_{CC} = 7 V to 40 V, T_A = 25°C		2	25		2	25	mV
Output regulation	I_O = 1 to 10 mA, T_A = 25°C		14	35		14	35	mV
Output voltage change with temperature	ΔT_A = MIN to MAX		0.2	1		0.2	1	%
Short-circuit output current§	V_{ref} = 0	10	35	60	10	35	50	mA

oscillator section (see Figure 2)

PARAMETER	TEST CONDITIONS†	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Frequency			10			10		kHz
Standard deviation of frequency¶	All values of V_{CC}, C_T, R_T, T_A constant		10			10		%
Frequency change with voltage	V_{CC} = 7 V to 40 V, T_A = 25°C		0.1			0.1		%
Frequency change with temperature	ΔT_A = MIN to MAX			12			12	%

amplifier sections (see Figure 1)

PARAMETER		TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Input offset voltage	Error	Feedback pin at 2.5 V		2	10	mV
	current-limit (TL593 only)			80		
Input offset current		Feedback control at 2.5 V		25	250	nA
Input bias current		Feedback control at 2.5 V		0.2	1	μA
Common-mode input voltage range	Error	V_{CC} = 7 V to 40 V	−0.3 to V_{CC}−2			V
	Current-limit (TL593 only)		−0.3 to V_{CC}−6			
Open-loop voltage amplification	Error	ΔV_O = 3 V, V_O = 0.5 V to 3.5 V	70	95		dB
	Current-limit (TL593 only)			90		
Unity-gain bandwidth				800		kHz
Common-mode rejection ratio	Error	V_{CC} = 40 V, T_A = 25°C	65	80		dB
	Current-limit (TL593 only)			70		
Output sink current (pin 3)		V_{ID} = −15 mV to −5 V, Feedback control at 0.5 V	0.3	0.7		mA
Output source current (pin 3)		V_{ID} = 15 mV to 5 V, Feedback at 3.5 V	−2			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.
¶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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TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

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

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Input bias current (pin 4)	V_I = 0 to 5.25 V		−2	−10	μA
Maximum duty cycle, each output	Dead-time control at 0 V	45			%
Input threshold voltage (pin 4)	Zero duty cycle		3	3.3	V
	Maximum duty cycle	0			

output section

PARAMETER		TEST CONDITIONS	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Collector off-state current		V_{CE} = 40 V, V_{CC} = 40 V		2	100		2	100	μA
		V_C = 15 V, V_E = 0 V, V_{CC} = 1 to 3 V, Dead-time and output control pins at 0 V		4	200		4	200	
Emitter off-state current		V_{CC} = V_C = 40 V, V_E = 0			−150			−100	μA
Collector-emitter saturation voltage	Common-emitter	V_E = 0, I_C = 200 mA		1.1	1.5		1.1	1.3	V
	Emitter-follower	V_C = 15 V, I_E = −200 mA		1.5	2.5		1.5	2.5	
Output control input current		V_I = V_{ref}			3.5			3.5	mA

pwm comparator section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V_{(pin\ 3)}$ = 0.5 V	0.3	0.7		mA

under-voltage lockout section (see Figure 2)

PARAMETER	TEST CONDITIONS†	TL593M TL594M			TL593C TL594I, TL594C TL595C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Threshold voltage	T_A = 25°C			6			6	V
	ΔT_A = MIN to MAX	3		6.9	3.5		6.9	
Hysteresis‖		30			100			mV

total device (see Figure 2)

PARAMETER	TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Standby supply current	Pin 6 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	Dead-time Control at 2 V, See Figure 2			12.4		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.
‖Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

switching characteristics, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Output voltage rise time	Common-emitter configuration, See Figure 3		100	200	ns
Output voltage fall time			30	100	
Output voltage rise time	Emitter-follower configuration, See Figure 4		200	400	ns
Output voltage fall time			45	100	

‡All typical values are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION

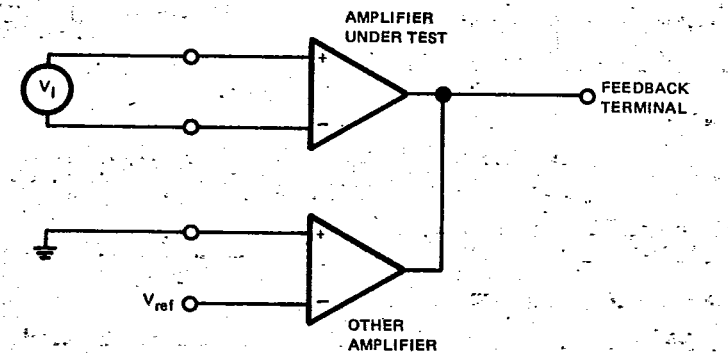

FIGURE 1 — AMPLIFIER CHARACTERISTICS

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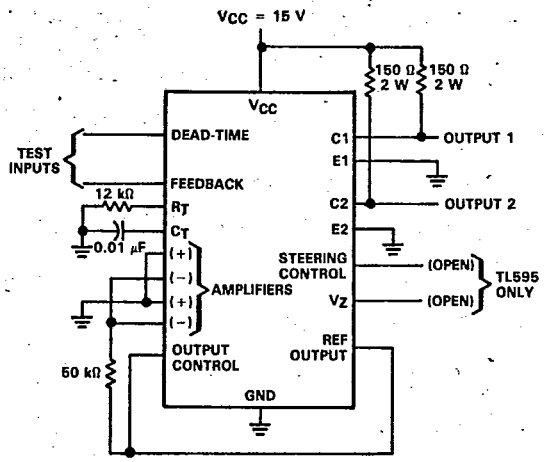
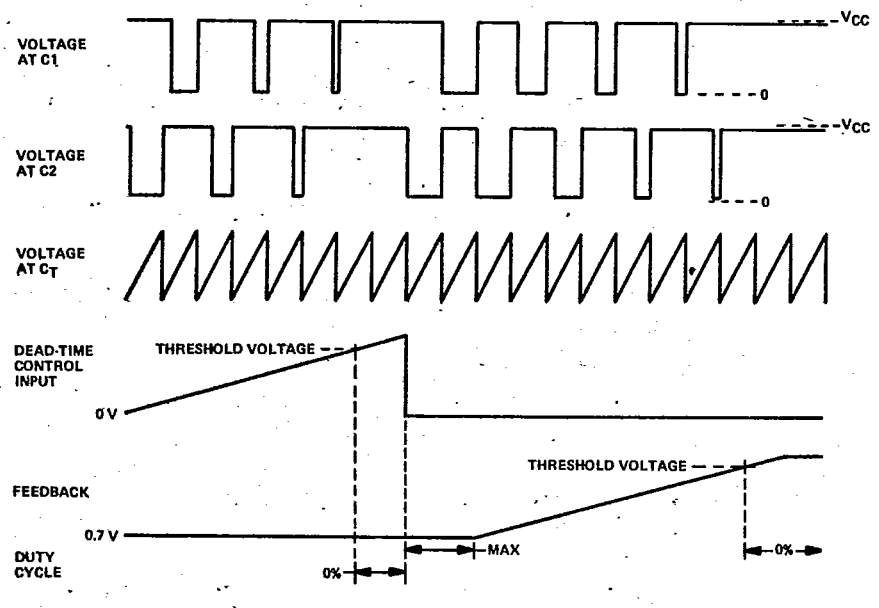
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

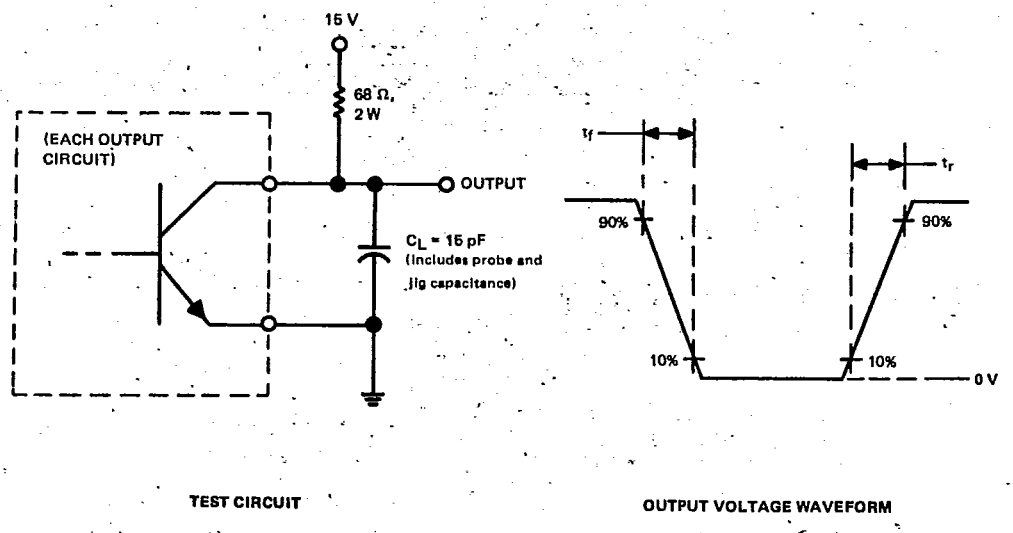


VOLTAGE WAVEFORMS

FIGURE 2–OPERATIONAL TEST CIRCUIT AND WAVEFORMS

TYPES TL593, TL594, TL595
PULSE-WIDTH-MODULATION CONTROL CIRCUITS

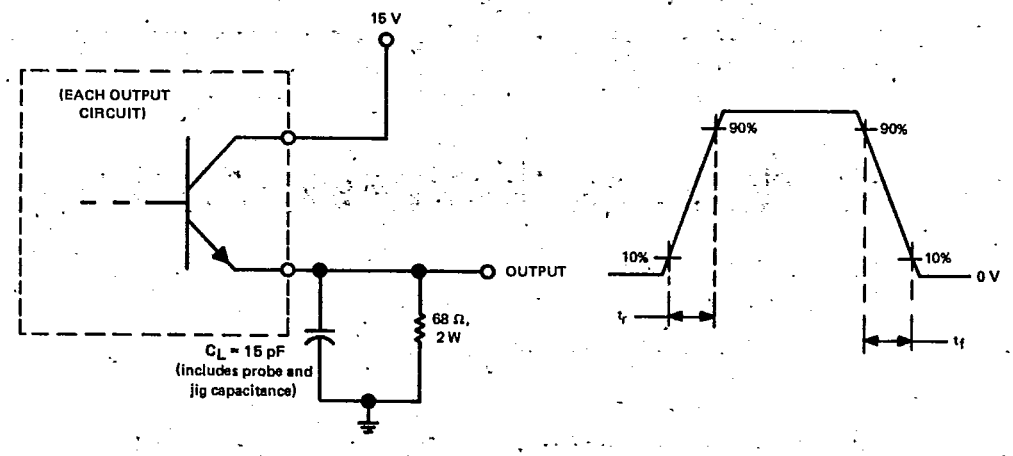
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 3—COMMON-EMITTER CONFIGURATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 4—EMITTER-FOLLOWER CONFIGURATION

Voltage Regulators

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TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY and
FREQUENCY VARIATION† vs
TIMING RESISTANCE

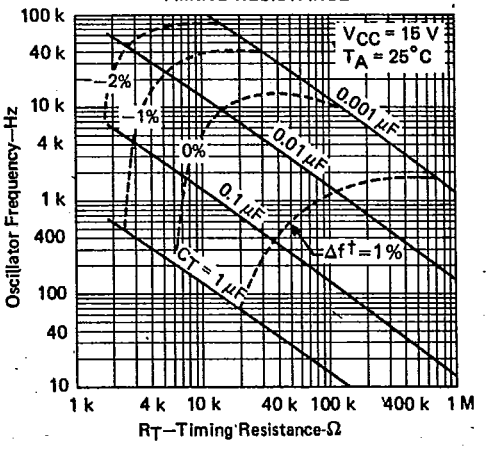

FIGURE 5

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

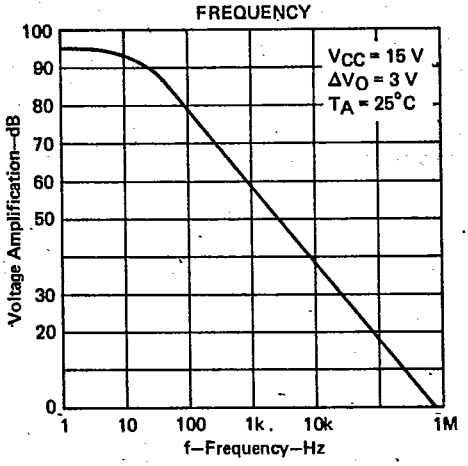

FIGURE 6

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