- **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, N, OR PW PACKAGE
(TOP VIEW)

1IN+	1	16	2IN+
1IN–	2	15	2IN–
FEEDBACK	3	14	REF
DTC	4	13	OUTPUT CTRL
CT	5	12	V_{CC}
RT	6	11	C2
GND	7	10	E2
C1	8	9	E1
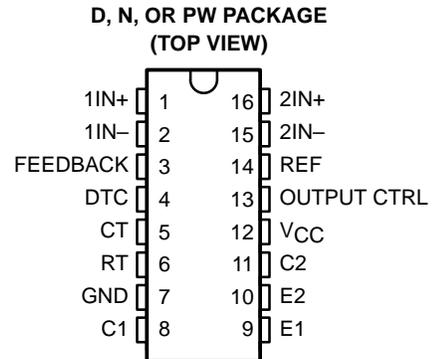
description

The TL594 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 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

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.

TEXAS INSTRUMENTS

TL594
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES		
	SMALL OUTLINE (D)	PLASTIC DIP (N)	PLASTIC THIN SHRINK SMALL OUTLINE (PW)
0°C to 70°C	TL594CD	TL594CN	TL594CPW
−40°C to 85°C	TL594ID	TL594IN	TL594IPW

The D and PW packages are also available taped and reeled. Add the suffix R to device type (e.g., TL594CDR).

functional block diagram

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

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 Note 2): D package . . . . 73°C/W
N package . . . . 67°C/W
PW package . . . . 108°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C
Storage temperature range, T_{stg} . . . . −65°C 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. The package thermal impedance is calculated in accordance with JESD 51-7.

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

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TL594
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

SLVS052E – APRIL 1988 – REVISED AUGUST 2001

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 is not taken into account.

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

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	TL594C, TL594I MIN	TYP†	MAX	UNIT
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 MIN	TYP†	MAX	UNIT
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 MIN	TYP†	MAX	UNIT
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 MIN	MAX	UNIT
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 MIN	TYP†	MAX	UNIT
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.

TL594
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

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.

PARAMETER MEASUREMENT INFORMATION

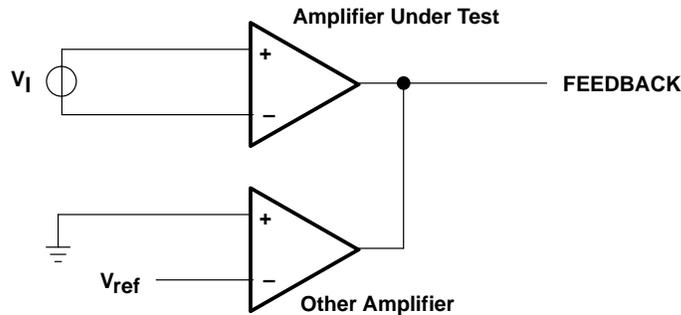**Figure 1. Amplifier-Characteristics Test Circuit**

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PARAMETER MEASUREMENT INFORMATION

TEST CIRCUIT

VOLTAGE WAVEFORMS
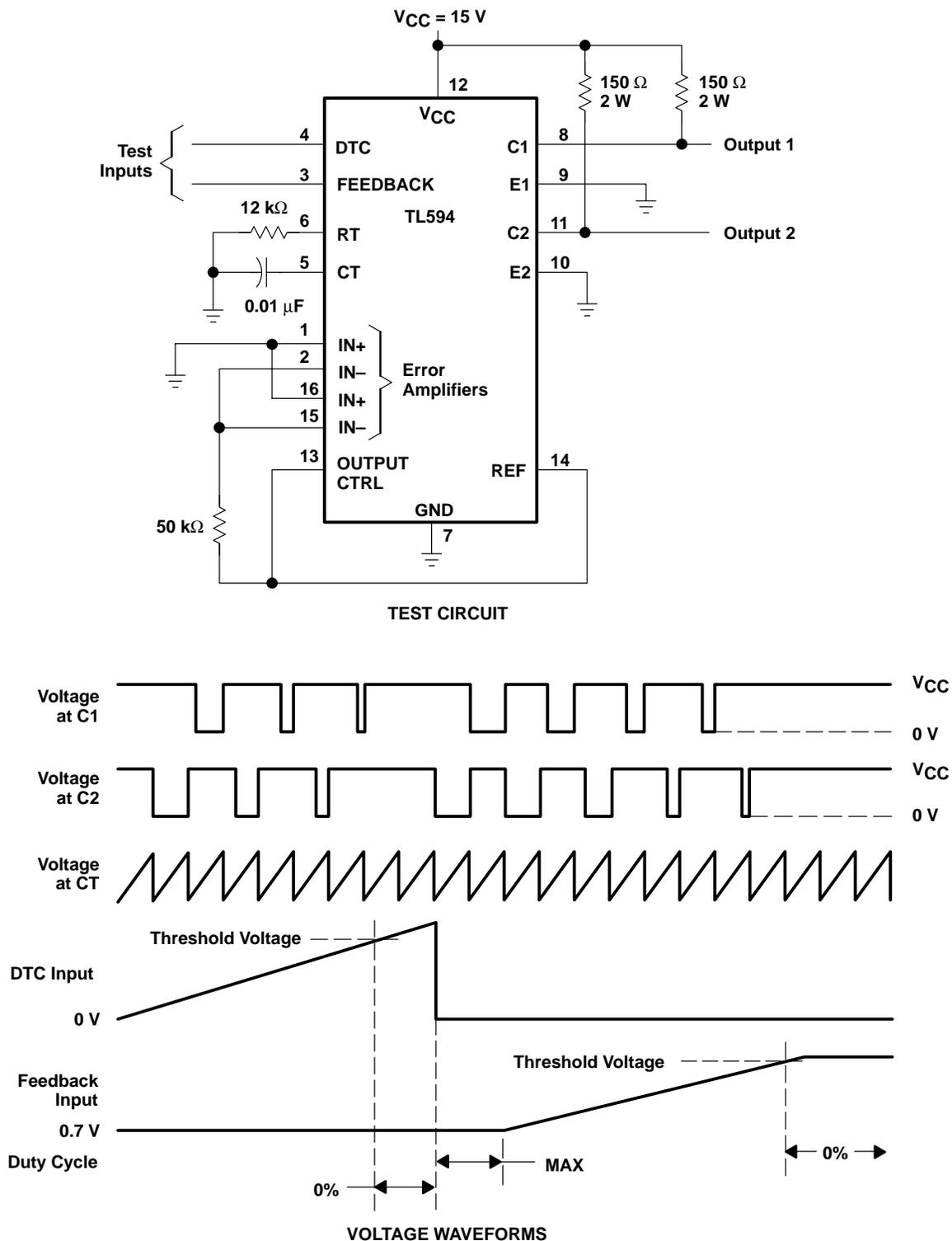
Figure 2. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

15 V

Each Output Circuit

68 Ω 2 W

Output

$C_L = 15$ pF (includes probe and jig capacitance)

TEST CIRCUIT

t_f t_r

90%   90%

10%   10%

OUTPUT-VOLTAGE WAVEFORM
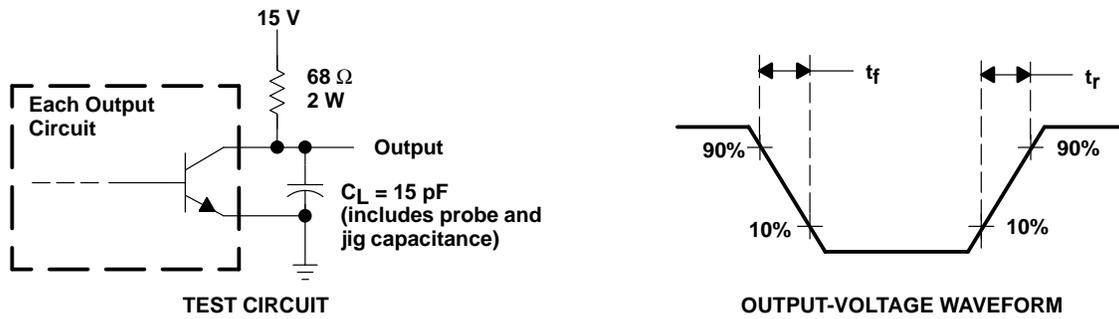
Figure 3. Common-Emitter Configuration

15 V

Each Output Circuit

Output

68 Ω 2 W

$C_L = 15$ pF (includes probe and jig capacitance)

TEST CIRCUIT

90%   90%

10%   10%

t_r t_f

OUTPUT-VOLTAGE WAVEFORM
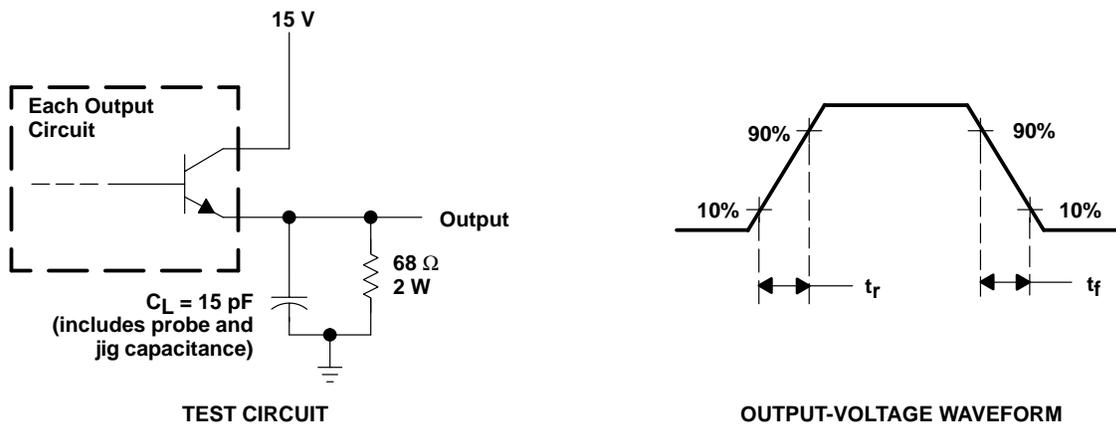
Figure 4. Emitter-Follower Configuration

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TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION†
vs
TIMING RESISTANCE
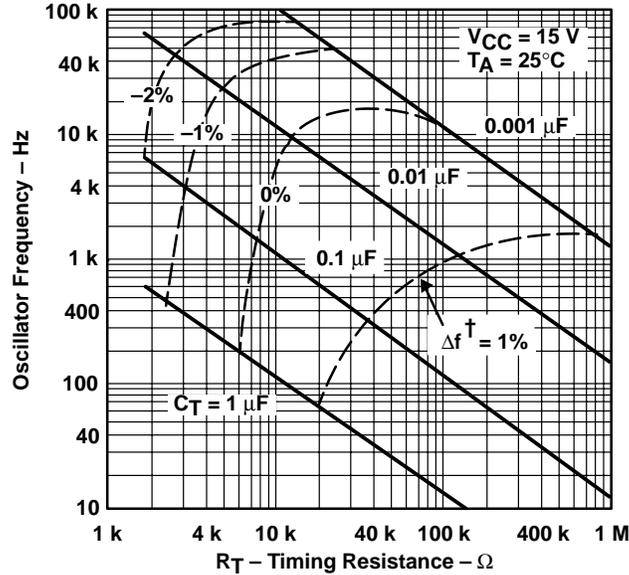
† Frequency variation (∆f) is the change in oscillator frequency that occurs over the full temperature range.

Figure 5

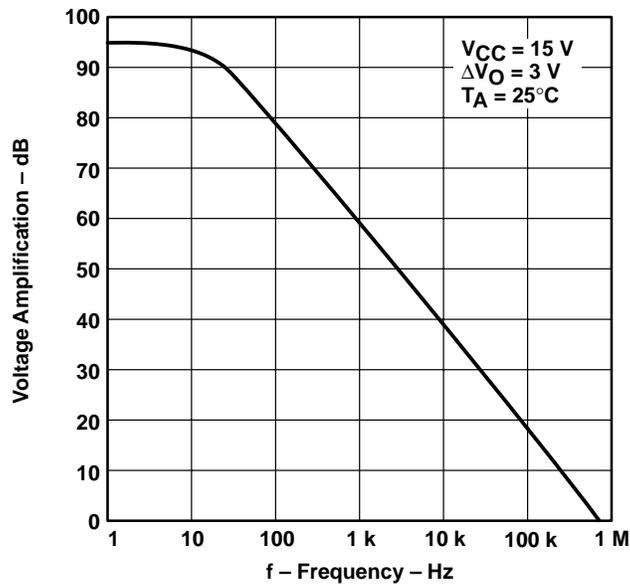**AMPLIFIER VOLTAGE AMPLIFICATION**
vs
FREQUENCY

Figure 6

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