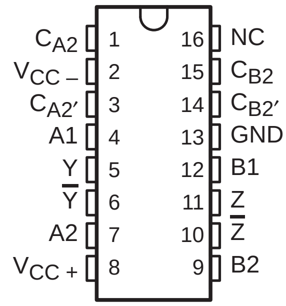
TL441 LOGARITHMIC AMPLIFIER

- **Excellent Dynamic Range**
- **Wide Bandwidth**
- **Built-In Temperature Compensation**
- **Log Linearity (30-dB Sections) . . . 1 dB Typ**
- **Wide Input Voltage Range**

N PACKAGE
(TOP VIEW)



NC — No internal connection

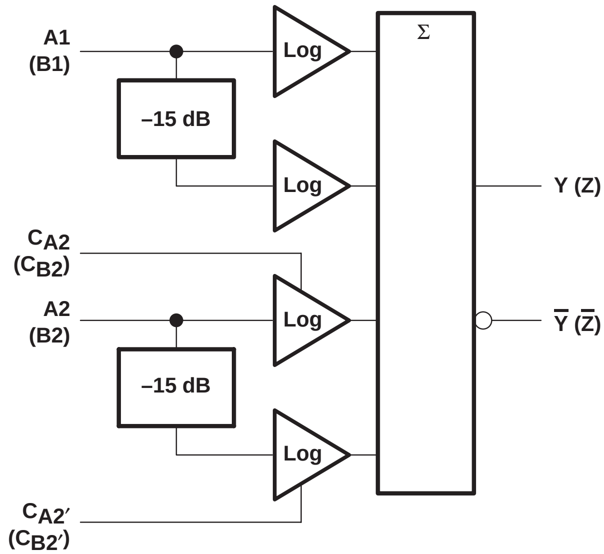
description

This amplifier circuit contains four 30-dB logarithmic stages. Gain in each stage is such that the output of each stage is proportional to the logarithm of the input voltage over the 30-dB input voltage range. Each half of the circuit contains two of these 30-dB stages summed together in one differential output that is proportional to the sum of the logarithms of the input voltages of the two stages. The four stages may be interconnected to obtain a theoretical input voltage range of 120-dB. In practice, this permits the input voltage range typically to be greater than 80-dB with log linearity of ± 0.5-dB (see application data). Bandwidth is from dc to 40 MHz.

This circuit is useful in data compression and analog compensation. This logarithmic amplifier is used in log IF circuitry as well as video and log amplifiers.

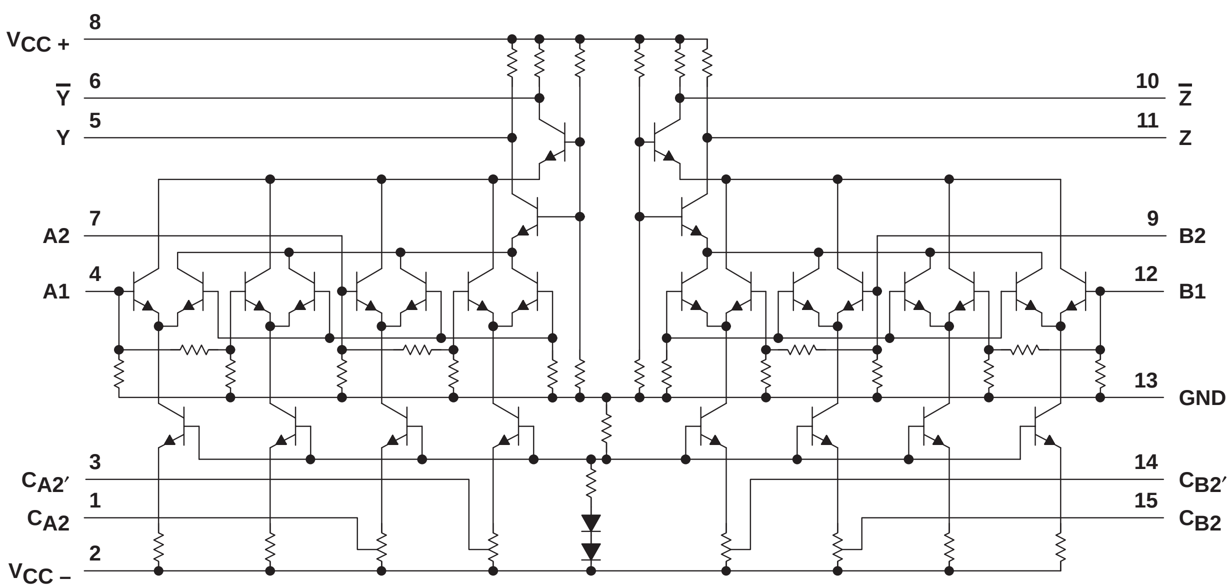
The TL441 is characterized for operation over 0°C to 70°C.

functional logic diagram (one half)



Y ∝ log A1 + log A2; Z ∝ log B1 + log B2 where: A1, A2, B1, and B2 are in dBV, 0 dBV = 1 V.
C_{A2}, $C_{A2'}$, C_{B2}, and $C_{B2'}$ are detector compensation inputs.

schematic



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

Supply voltages (see Note 1): V_{CC+} . . . . 8 V
V_{CC-} . . . . –8 V
Input voltage (see Note 1) . . . . 6 V
Output sink current (any one output) . . . . 30 mA
Package thermal impedance, θ_{JA} (see Notes 2 and 3) . . . . 67°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 voltages, except differential out voltages, are with respect to 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 affect reliability.
3. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

	MIN	MAX	UNIT
Peak-to-peak input voltage for each 30-dB stage	0.01	1	V
Operating free-air temperature, T_A	0	70	°C

electrical characteristics, $V_{CC\pm} = \pm 6$ V, T_A = 25°C

PARAMETER	TEST FIGURE	MIN	TYP	MAX	UNIT
Differential output offset voltage	1		±40		mV
Quiescent output voltage	2	5.45	5.6	5.85	V
DC scale factor (differential output), each 3-dB stage, – 35 dBV to – 5 dBV	3	6	8	12	mV/dB
AC scale factor (differential output)			8		mV/dB
DC error at – 20 dBV (midpoint of – 35 dBV to – 5 dBV range)	3		1		dB
Input impedance			500		Ω
Output impedance			200		Ω
Rise time, 10% to 90% points, C_L = 24 pF	4		20	30	ns
Supply current from V_{CC+}	2	14.5	18.5	23	mA
Supply current from V_{CC-}	2	– 6	– 8.5	– 10.5	mA
Power dissipation	2	123	162	201	mW

PARAMETER MEASUREMENT INFORMATION

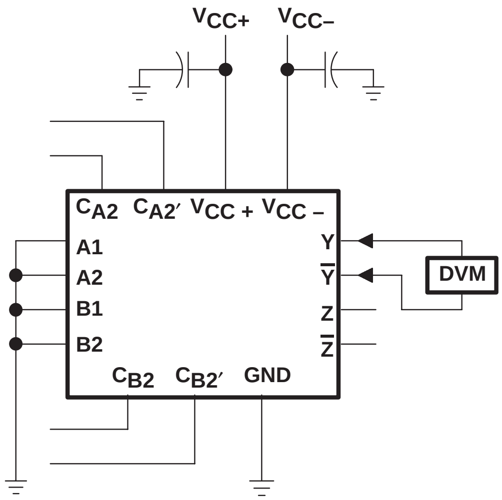


Figure 1

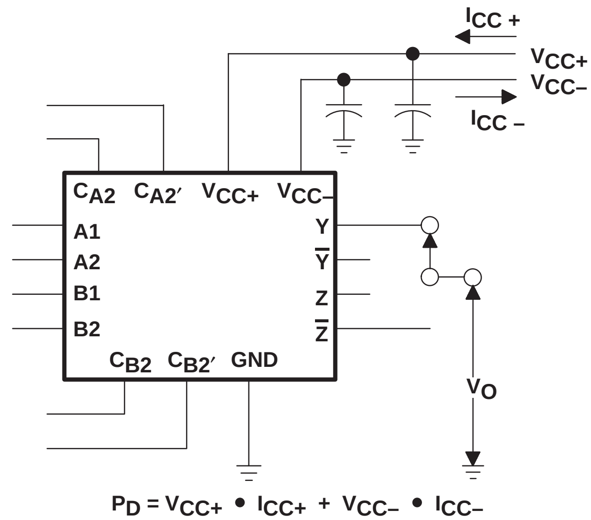


Figure 2

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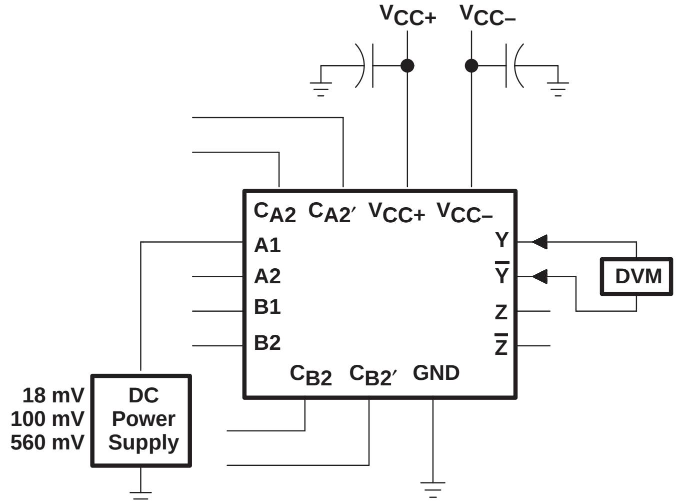
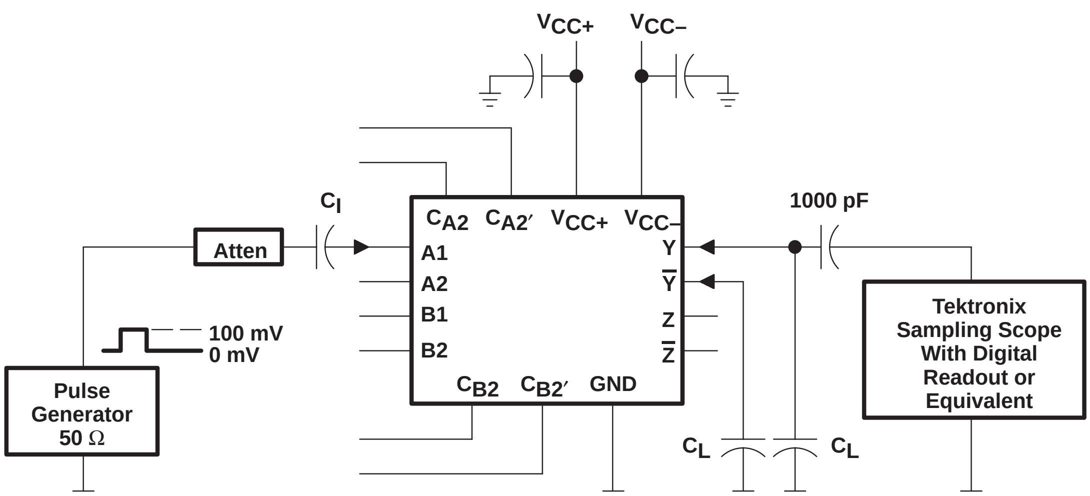
PARAMETER MEASUREMENT INFORMATION



$$\text{Scale Factor} = \frac{\left[V_{out(560\ mV)} - V_{out(18mV)}\right]\ \text{mV}}{30\ \text{dBV}}$$

$$\text{Error} = \frac{\left[Vout(100\ mV) - 0.5\ V_{out(560\ mV)} - 0.5\ V_{out(18\ mV)}\right]}{\text{Scale Factor}}$$

Figure 3



NOTES: A. The input pulse has the following characteristics: t_W = 200 ns, $t_r \le 2$ ns, $t_f \le 2$ ns, PRR ≤ 10 MHz.
B. Capacitor C_I consists of three capacitors in parallel: 1 µF, 0.1 µF, and 0.01 µF.
C. C_L includes probe and jig capacitance.

Figure 4

TYPICAL CHARACTERISTICS†

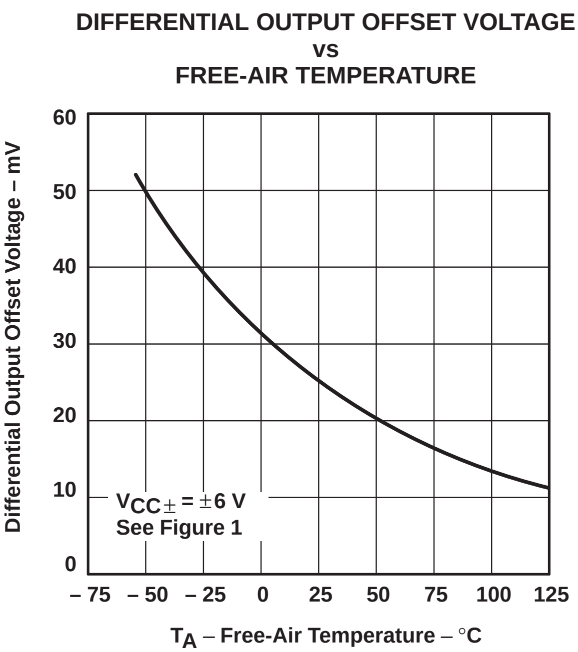


Figure 5

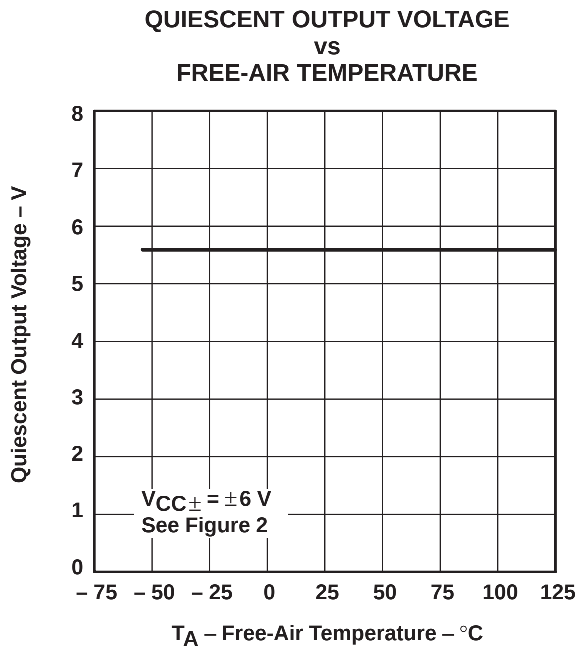


Figure 6

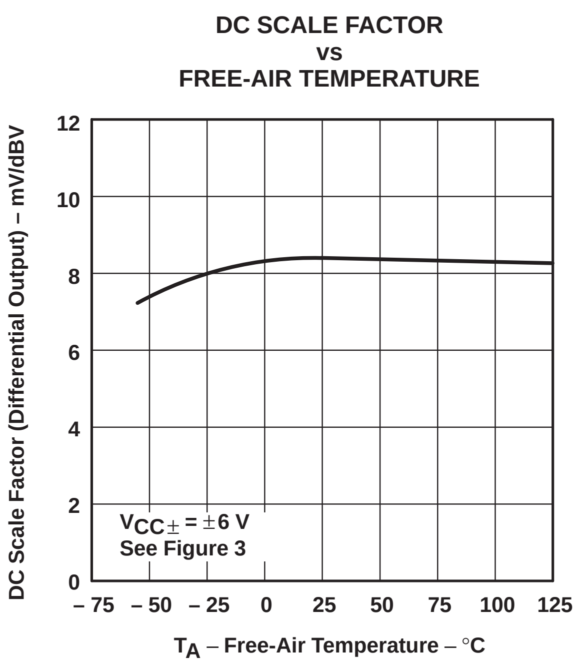


Figure 7

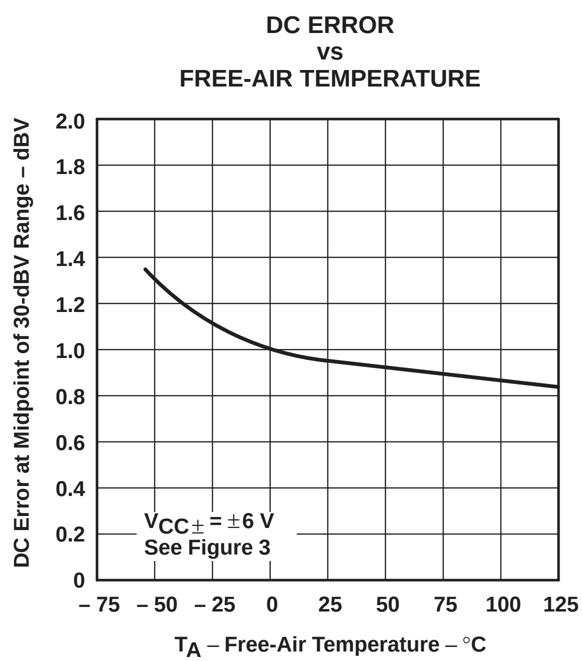


Figure 8

† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

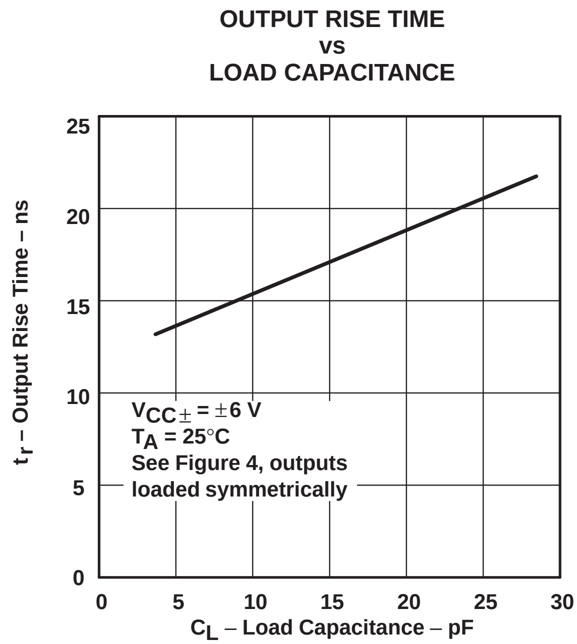


Figure 9

APPLICATION INFORMATION

Although designed for high-performance applications such as infrared detection, this device has a wide range of applications in data compression and analog computation.

basic logarithmic function

The basic logarithmic response is derived from the exponential current-voltage relationship of collector current and base-emitter voltage. This relationship is given in the equation:

$$m \bullet V_{BE} = \ln [(I_C + I_{CES})/I_{CES}]$$

where:

I_C = collector current

I_{CES} = collector current at $V_{BE} = 0$

m = q/kT (in V^{-1})

V_{BE} = base-emitter voltage

The differential input amplifier allows dual-polarity inputs, is self-compensating for temperature variations, and is relatively insensitive to common-mode noise.

functional block diagram

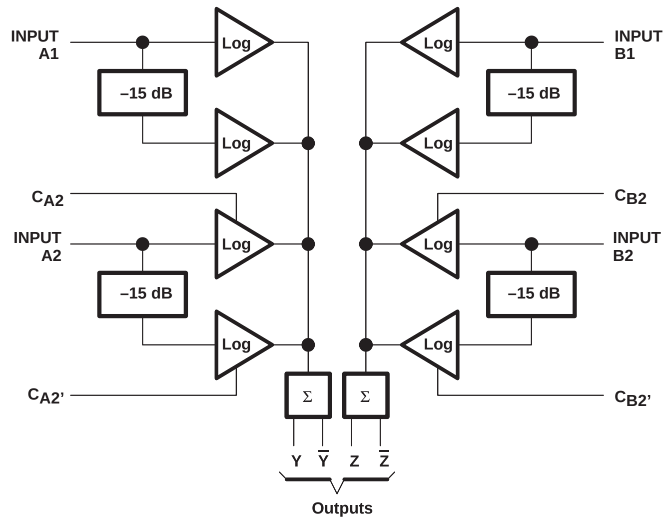


Figure 10

logarithmic sections

As can be seen from the schematic, there are eight differential pairs. Each pair is a 15-dB log subsection, and each input feeds two pairs, for a range of 30-dB per stage.

Four compensation points are available to allow slight variations in the gain (slope) of the two individual 15-dB stages of input A2 and B2. By slightly changing the voltage on any of the compensation pins from their quiescent values, the gain of that particular 15-dB stage can be adjusted to match the other 15-dB stage in the pair. The compensation pins also can be used to match the transfer characteristics of input A2 to A1 or B2 to B1.

The log stages in each half of the circuit are summed by directly connecting their collectors together and summing through a common-base output stage. The two sets of output collectors are used to give two log outputs, Y and $\overline{Y}$ (or Z and $\overline{Z}$), which are equal in amplitude, but opposite in polarity. This increases the versatility of the device.

By proper choice of external connections, linear amplification, and linear attenuation, and many different applications requiring logarithmic signal processing are possible

input levels

The recommended input voltage range of any one stage is given as 0.01 V to 1 V. Input levels in excess of 1 V may result in a distorted output. When several log sections are summed together, the distorted area of one section overlaps with the next section and the resulting distortion is insignificant. However, there is a limit to the amount of overdrive that can be applied. As the input drive reaches ±3.5 V, saturation occurs, clamping the collector-summing line and severely distorting the output. Therefore, the signal to any input must be limited to approximately ±3 V to ensure a clean output.

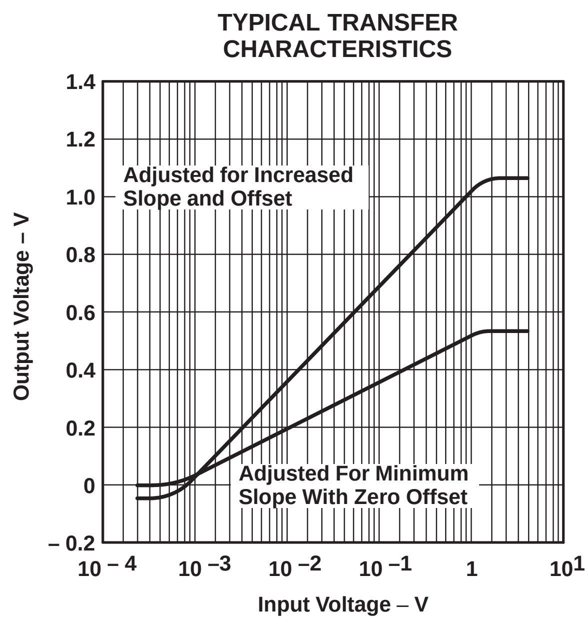
APPLICATION INFORMATION

output levels

Differential-output-voltage levels are low, generally less than 0.6 V. As demonstrated in Figure 12, the output swing and the slope of the output response can be adjusted by varying the gain by means of the slope control. The coordinate origin also can be adjusted by positioning the offset of the output buffer.

circuits

Figures 12 through 19 show typical circuits using this logarithmic amplifier. Operational amplifiers not otherwise designated are TLC271. For operation at higher frequencies, the TL592 is recommended instead of the TLC271.



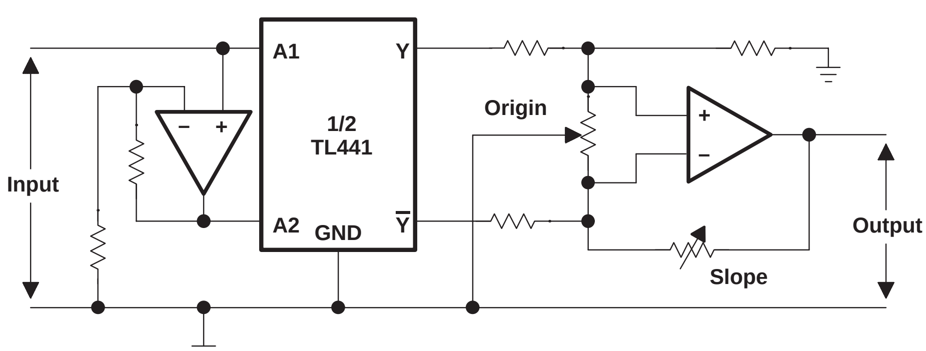
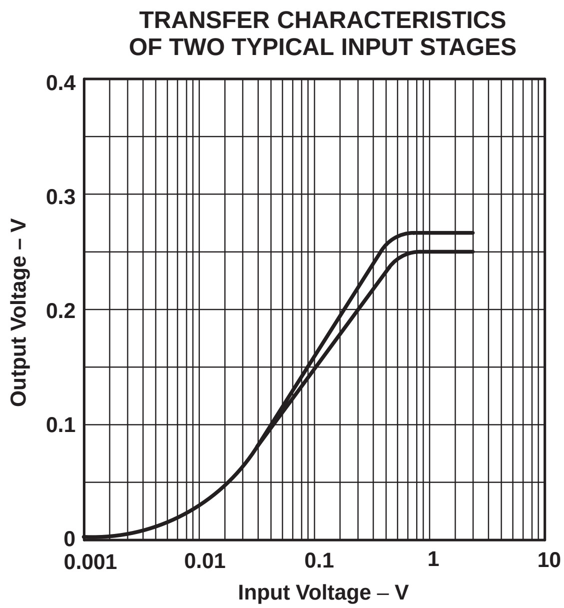


Figure 12. Output Slope and Origin Adjustment

APPLICATION INFORMATION



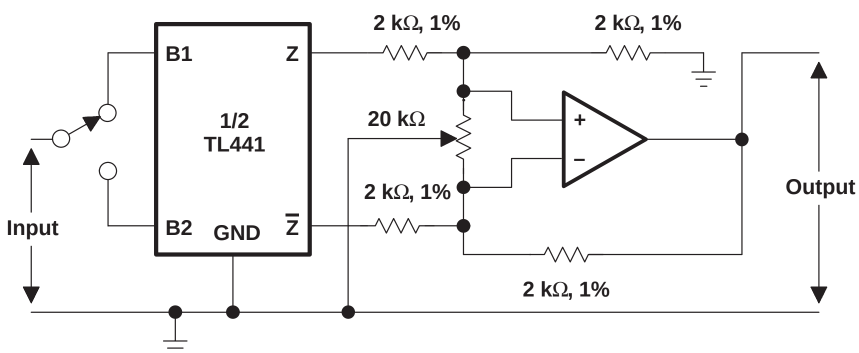
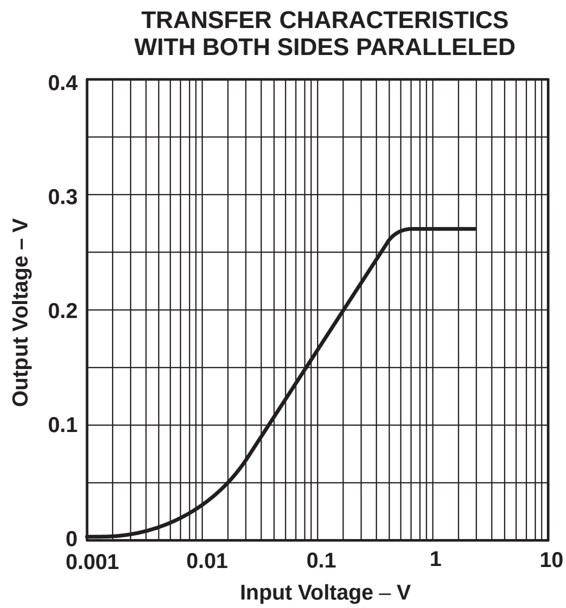


Figure 13. Utilization of Separate Stages

APPLICATION INFORMATION



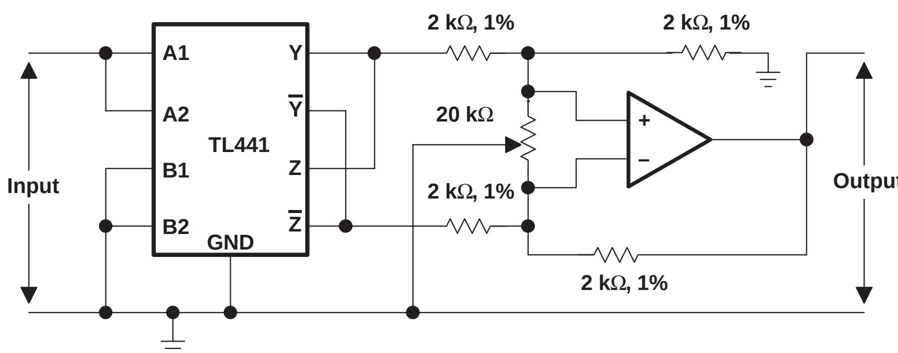
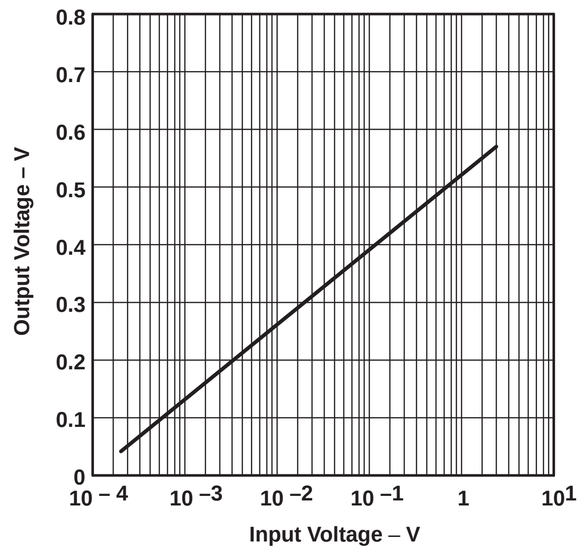
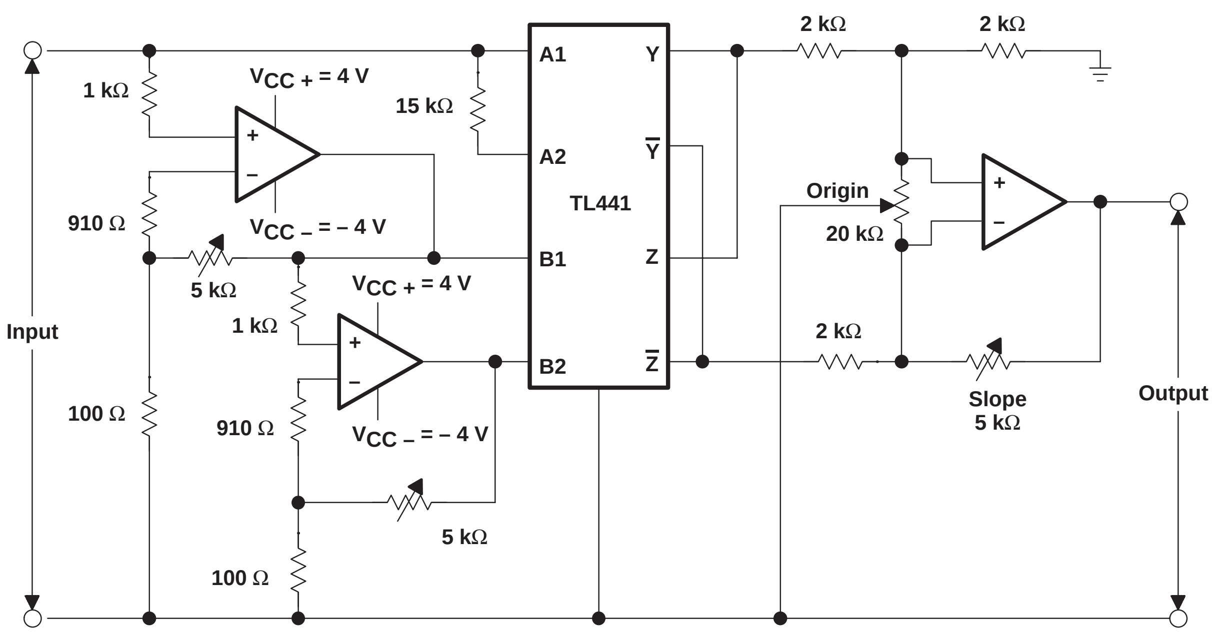


Figure 14. Utilization of Paralleled Inputs

APPLICATION INFORMATION

TRANSFER CHARACTERISTICS

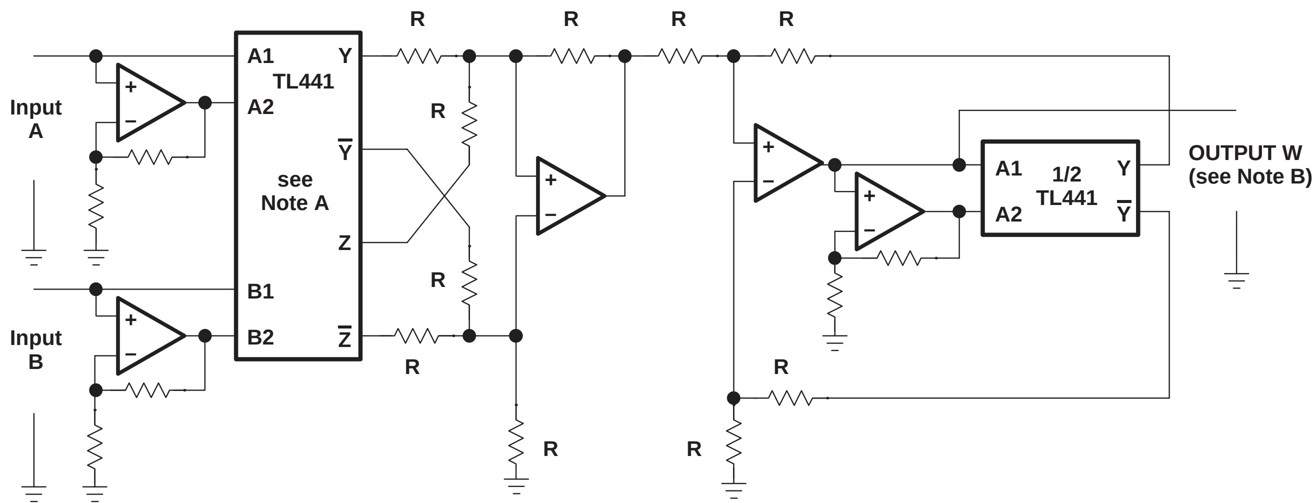




NOTES: A. Inputs are limited by reducing the supply voltages for the input amplifiers to ±4 V.
B. The gains of the input amplifiers are adjusted to achieve smooth transitions.

Figure 15. Logarithmic Amplifier With Input Voltage Range Greater Than 80 dB

APPLICATION INFORMATION

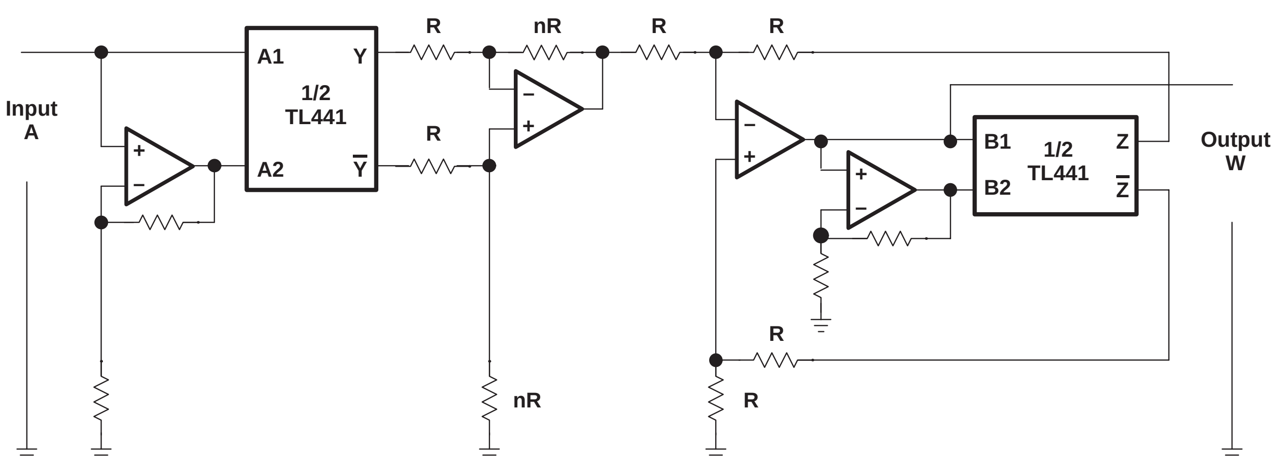


NOTES: A. Connections shown are for multiplication. For division, Z and $\overline{Z}$ connections are reversed.
B. Output W may need to be amplified to give actual product or quotient of A and B.
C. R designates resistors of equal value, typically 2 kΩ to 10 kΩ.

Multiplication: $W = A \bullet B \Rightarrow \log W = \log A + \log B$, or $W = a^{(\log_a A + \log_a B)}$

Division: $W = A/B \Rightarrow \log W = \log A - \log B$, or $W = a^{(\log_a A + \log_a B)}$

Figure 16. Multiplication or Division

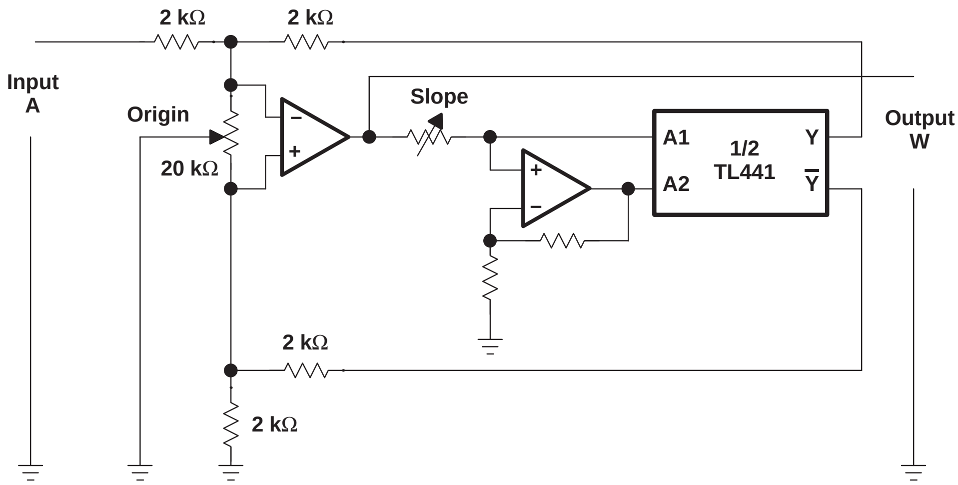


NOTE: R designates resistors of equal value, typically 2 kΩ to 10 kΩ. The power to which the input variable is raised is fixed by setting nR. Output W may need to be amplified to give the correct value.

Exponential: $W = A^n \Rightarrow \log W = n \log A$, or $W = a^{(n \log_a A)}$

Figure 17. Raising a Variable to a Fixed Power

APPLICATION INFORMATION



NOTE: Adjust the slope to correspond to the base “a”.
Exponential to any base: W = a.

Figure 18. Raising a Fixed Number to a Variable Power

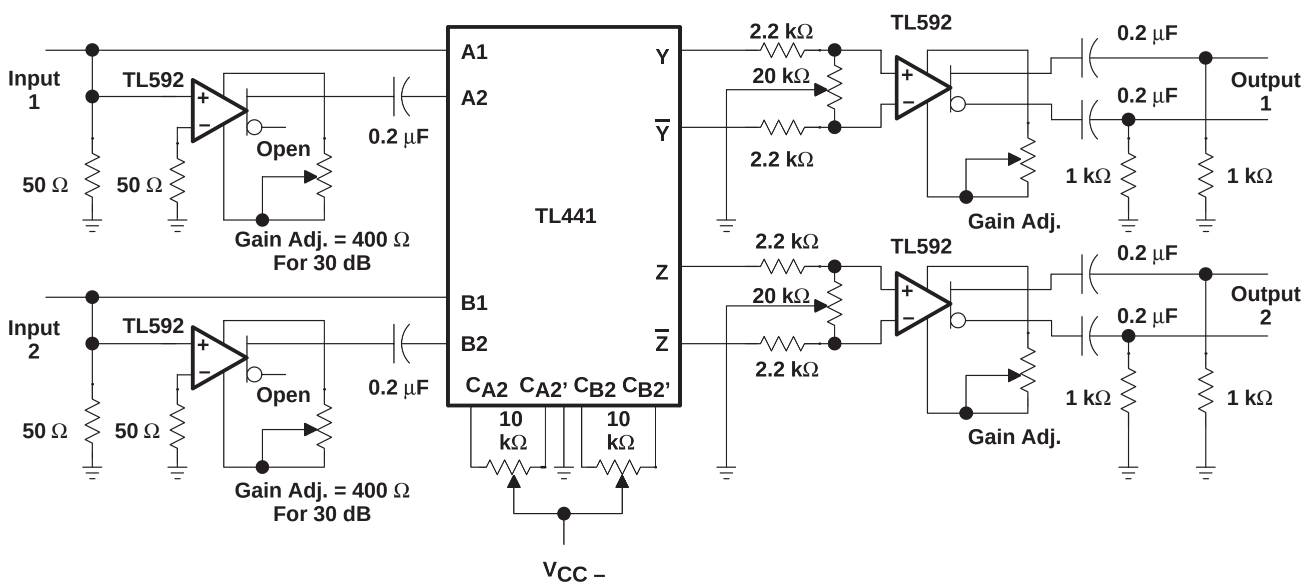


Figure 19. Dual-Channel RF Logarithmic Amplifier With 50-dB Input Range Per Channel at 10 MHz

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