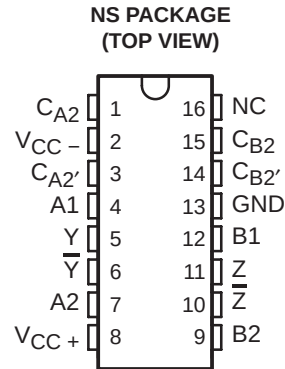


- **Controlled Baseline**
  - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of –55°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree<sup>†</sup>**
- **Excellent Dynamic Range**
- **Wide Bandwidth**
- **Built-In Temperature Compensation**
- **Log Linearity (30-dB Sections) . . . 1 dB Typ**
- **Wide Input Voltage Range**

<sup>†</sup> Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.



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  $\pm 0.5$ -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 TL441M is characterized for operation over the full military temperature range of –55°C to 125°C.

## ORDERING INFORMATION

| TA             | PACKAGE <sup>†</sup> |               | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|----------------------|---------------|-----------------------|------------------|
| –55°C to 125°C | SOP (NS)             | Tape and reel | TL441MNSREP           | TL441MEP         |

<sup>†</sup> Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



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.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS  
INSTRUMENTS**

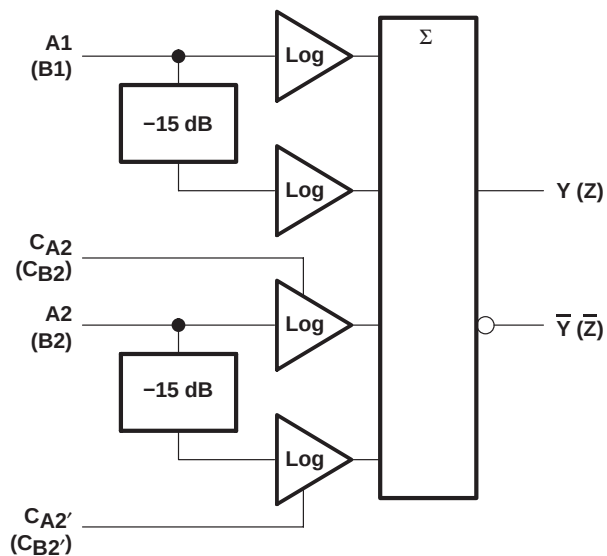
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# TL441-EP LOGARITHMIC AMPLIFIER

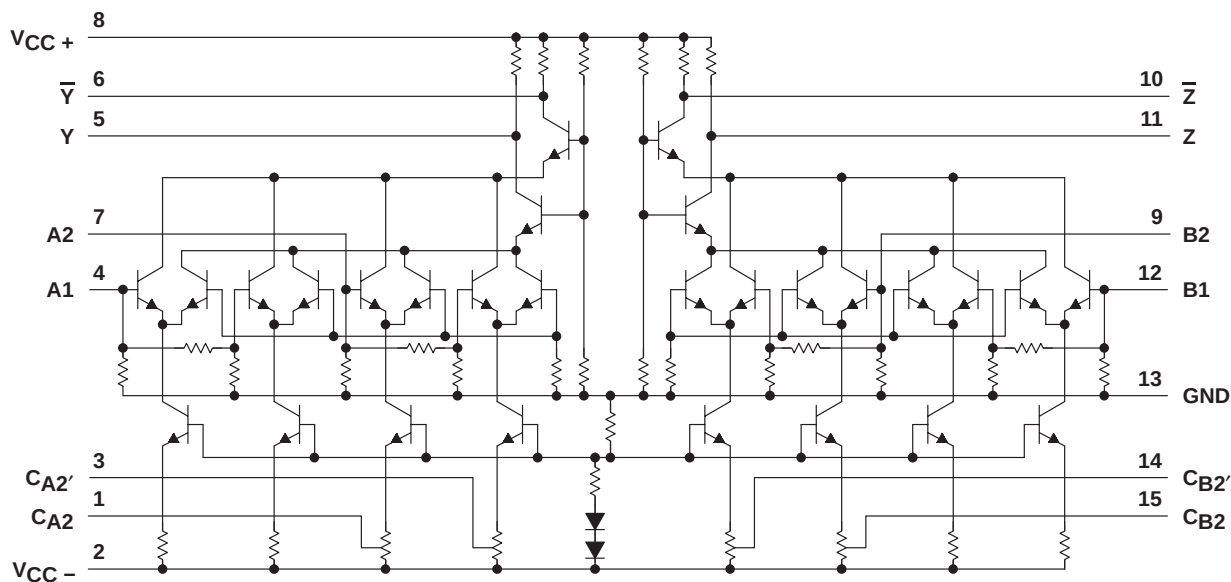
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## FUNCTIONAL LOGIC DIAGRAM (one half)



$Y \propto \log A1 + \log A2$ ;  $Z \propto \log B1 + \log B2$  where:  $A1$ ,  $A2$ ,  $B1$ , and  $B2$  are in dBV,  $0\text{ dBV} = 1\text{ V}$ .  
 $CA2$ ,  $CA2'$ ,  $CB2$ , and  $CB2'$  are detector compensation inputs.

## SCHEMATIC



**ABSOLUTE MAXIMUM RATINGS OVER OPERATING FREE-AIR TEMPERATURE RANGE (unless otherwise noted)<sup>†</sup>**

|                                                              |                                               | TL441-EP       |
|--------------------------------------------------------------|-----------------------------------------------|----------------|
| V <sub>CC+</sub>                                             | Supply voltages (see Note 1)                  | 8 V            |
| V <sub>CC-</sub>                                             |                                               | -8 V           |
| Input voltage (see Note 1)                                   |                                               | 6 V            |
| Output sink current (any one output)                         |                                               | 30 mA          |
| θ <sub>JA</sub>                                              | Package thermal impedance (see Notes 2 and 3) | 83°C/W         |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds |                                               | 260°C          |
| T <sub>stg</sub>                                             | Storage temperature range (see Note 4)        | -65°C to 150°C |

<sup>†</sup> 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<sub>J(max)</sub>, θ<sub>JA</sub>, and T<sub>A</sub>. The maximum allowable power dissipation at any allowable ambient temperature is P<sub>D</sub> = (T<sub>J(max)</sub> - T<sub>A</sub>)/θ<sub>JA</sub>. Operating at the absolute maximum T<sub>J</sub> of 150°C can affect reliability.
  3. The package thermal impedance is calculated in accordance with JESD 51-7.
  4. Long-term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See [http://www.ti.com/ep\\_quality](http://www.ti.com/ep_quality) for additional information on enhanced plastic packaging.

**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 <sub>A</sub>  | -55  | 125 | °C   |

**ELECTRICAL CHARACTERISTICS, V<sub>CC±</sub> = ±6 V, T<sub>A</sub> = 25°C**

| PARAMETER                                                                 | TEST FIGURE | MIN  | TYP  | MAX   | UNIT  |
|---------------------------------------------------------------------------|-------------|------|------|-------|-------|
| Differential output offset voltage                                        | 1           |      | ±25  | ±70   | 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           | 7    | 8    | 11    | 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    | 2.6   | dB    |
| Input impedance                                                           |             |      | 500  |       | Ω     |
| Output impedance                                                          |             |      | 200  |       | Ω     |
| Rise time, 10% to 90% points, C <sub>L</sub> = 24 pF                      | 4           |      | 20   | 35    | ns    |
| Supply current from V <sub>CC+</sub>                                      | 2           | 14.5 | 18.5 | 23    | mA    |
| Supply current from V <sub>CC-</sub>                                      | 2           | -6   | -8.5 | -10.5 | mA    |
| Power dissipation                                                         | 2           | 123  | 162  | 201   | mW    |

# TL441-EP

## LOGARITHMIC AMPLIFIER

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### ELECTRICAL CHARACTERISTICS OVER OPERATING FREE-AIR TEMPERATURE RANGE, $V_{CC\pm} = \pm 6\text{ V}$ (unless otherwise noted)

| PARAMETER                                                                 |                        | TEST FIGURE | MIN  | MAX  | UNIT  |
|---------------------------------------------------------------------------|------------------------|-------------|------|------|-------|
| Differential output offset voltage                                        |                        | 1           | ±125 |      | mV    |
| Quiescent output voltage                                                  |                        | 2           | 5.3  | 5.85 | V     |
| DC scale factor (differential output) each 30-dB stage, −35 dBV to −5 dBV |                        | 3           | 6    | 11   | mV/dB |
| DC error at −20 dBV (midpoint of −35 dBV to −5 dBV range)                 | T <sub>A</sub> = −55°C | 3           | 4    |      | dB    |
|                                                                           | T <sub>A</sub> = 125°C |             | 3    |      |       |
| Supply current from V <sub>CC</sub> +                                     |                        | 2           | 10   | 31   | mA    |
| Supply current from V <sub>CC</sub> −                                     |                        | 2           | −4.5 | −15  | mA    |
| Power dissipation                                                         |                        | 2           | 87   | 276  | mW    |

### PARAMETER MEASUREMENT INFORMATION

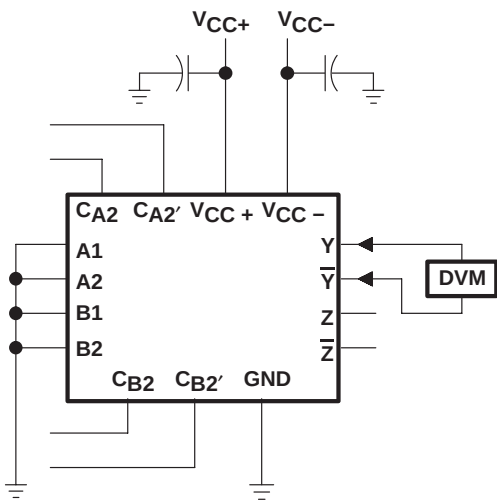


Figure 1

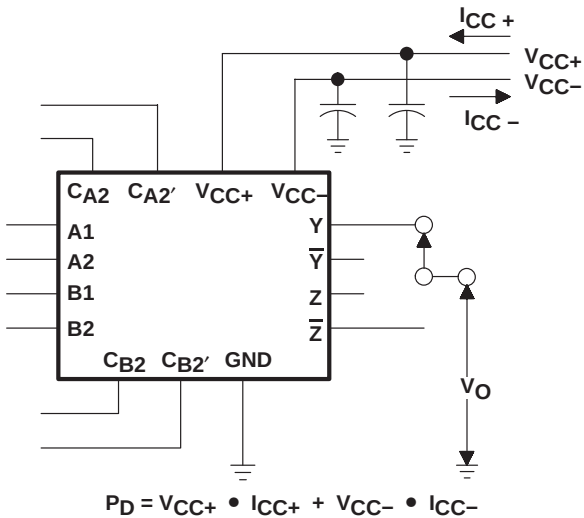


Figure 2

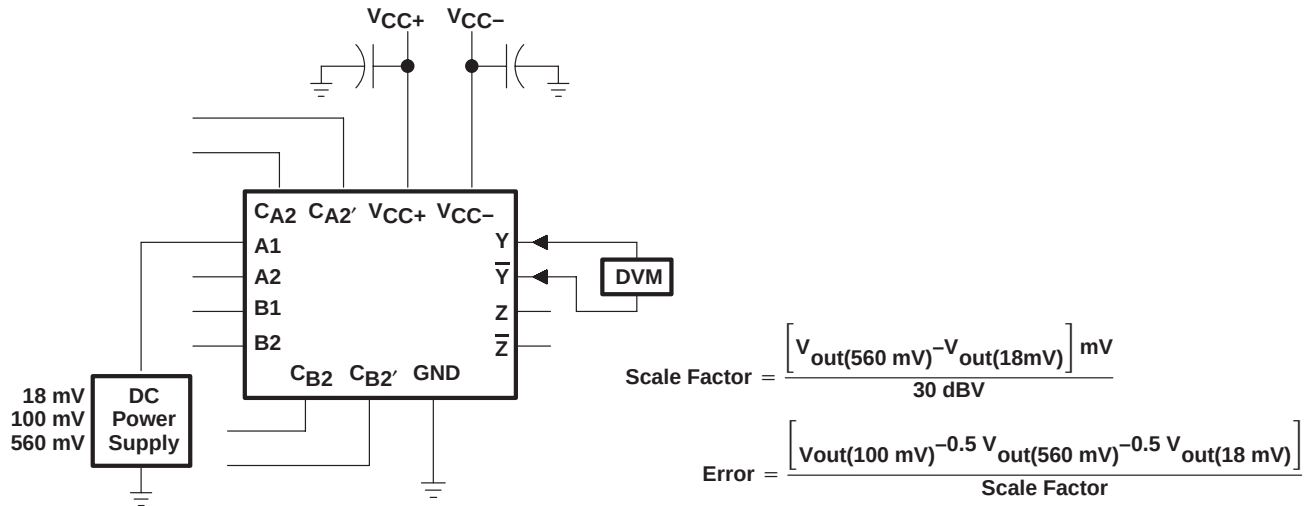
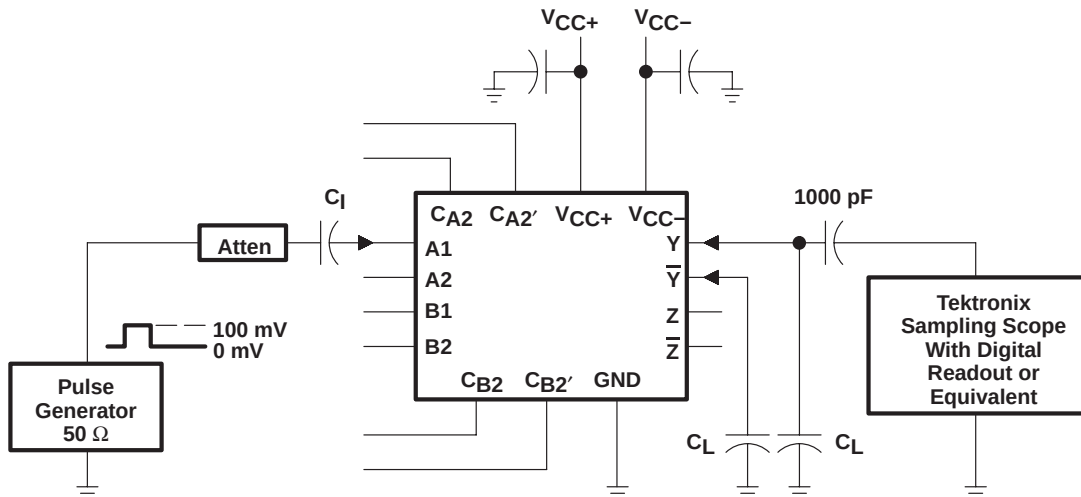


Figure 3



- NOTES: A. The input pulse has the following characteristics:  $t_W = 200 \text{ ns}$ ,  $t_r \leq 2 \text{ ns}$ ,  $t_f \leq 2 \text{ ns}$ ,  $\text{PRR} \leq 10 \text{ MHz}$ .  
 B. Capacitor  $C_1$  consists of three capacitors in parallel:  $1 \mu\text{F}$ ,  $0.1 \mu\text{F}$ , and  $0.01 \mu\text{F}$ .  
 C.  $C_L$  includes probe and jig capacitance.

Figure 4

TYPICAL CHARACTERISTICS

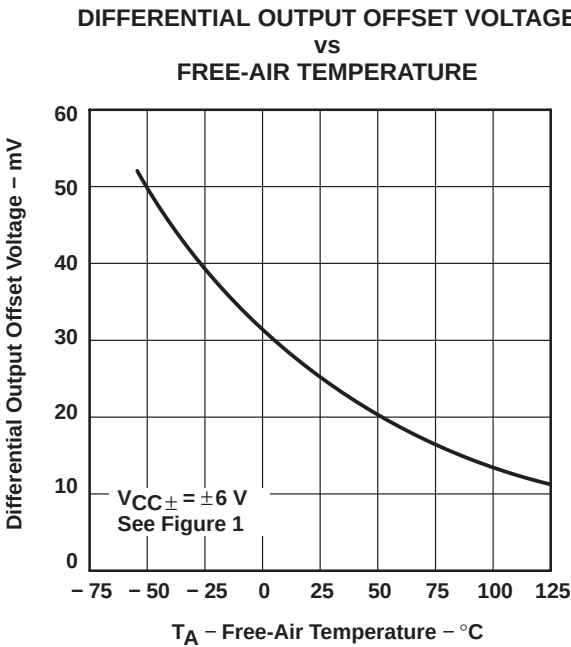


Figure 5

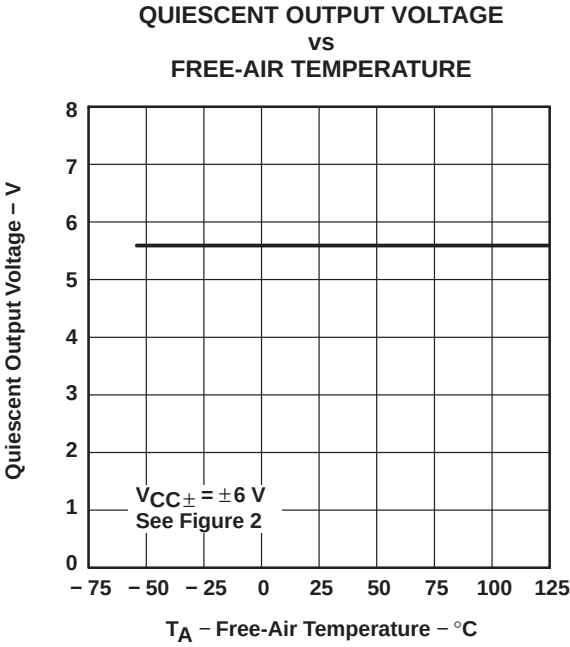


Figure 6

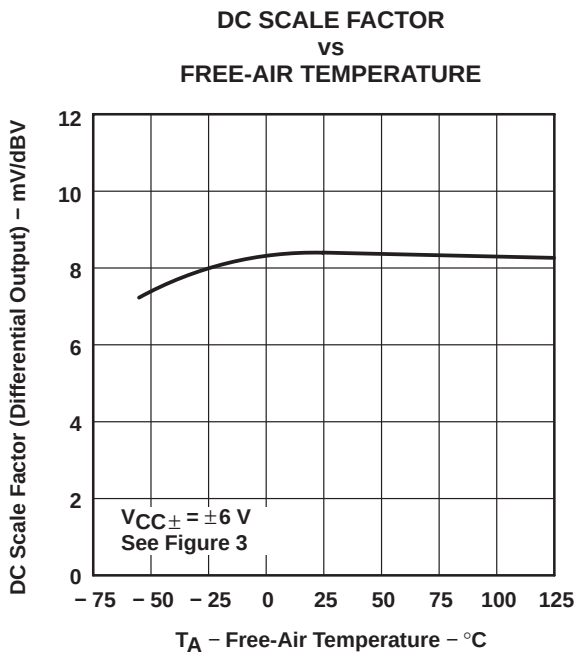


Figure 7

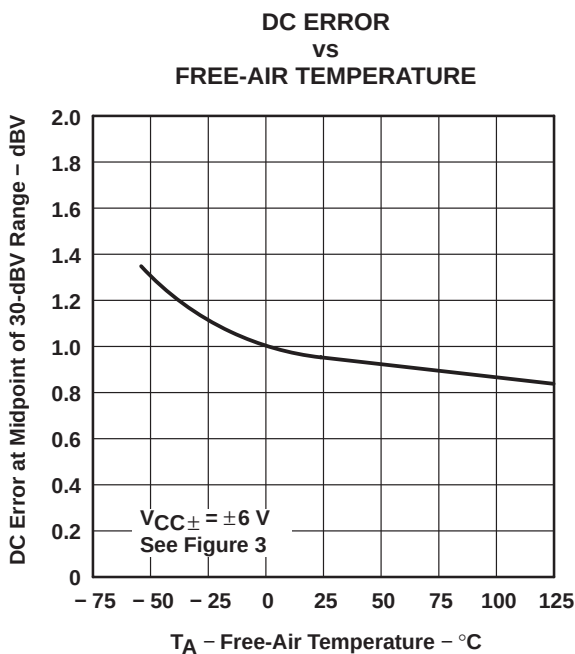


Figure 8

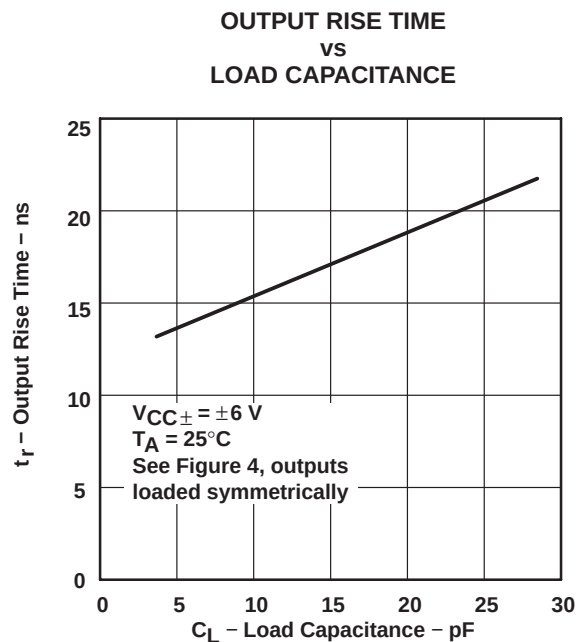


Figure 9

## 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:

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

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

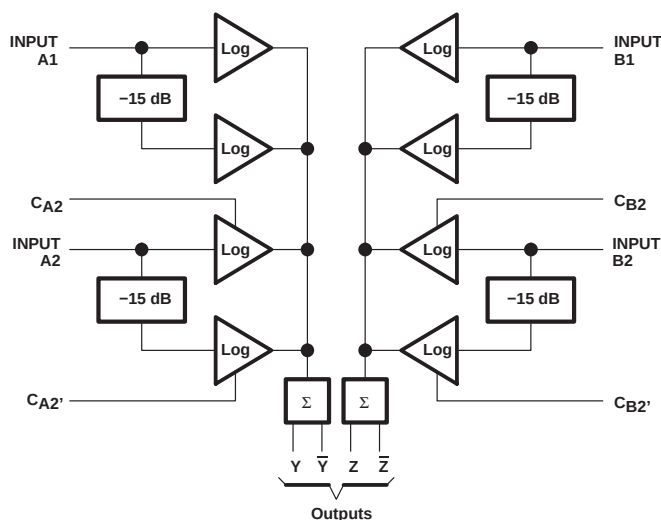


Figure 10

### 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  $\bar{Y}$  (or Z and  $\bar{Z}$ ), 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 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  $\pm 3.5$  V, saturation occurs, clamping the collector-summing line and severely distorting the output. Therefore, the signal to any input must be limited to approximately  $\pm 3$  V to ensure a clean output.

## Output Levels

Differential-output-voltage levels are low, generally less than 0.6 V. As demonstrated in Figure 11, 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

Figure 11 through Figure 18 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.

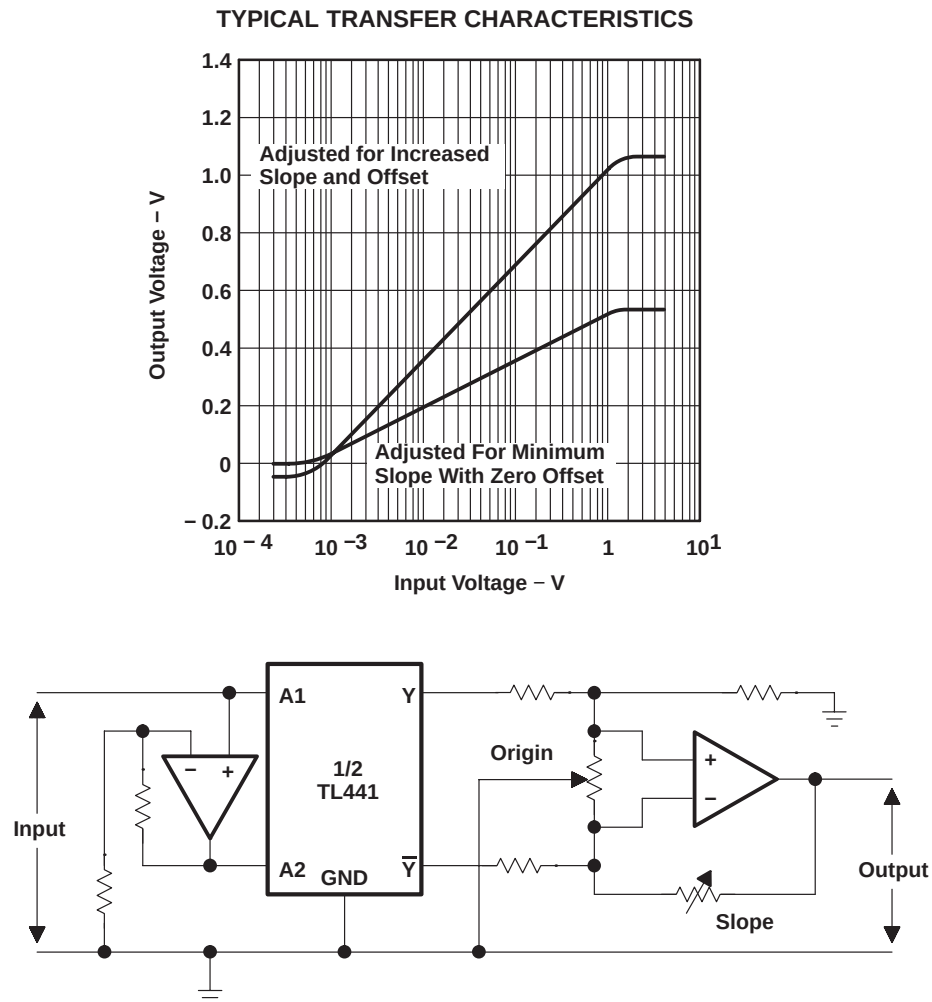


Figure 11. Output Slope and Origin Adjustment

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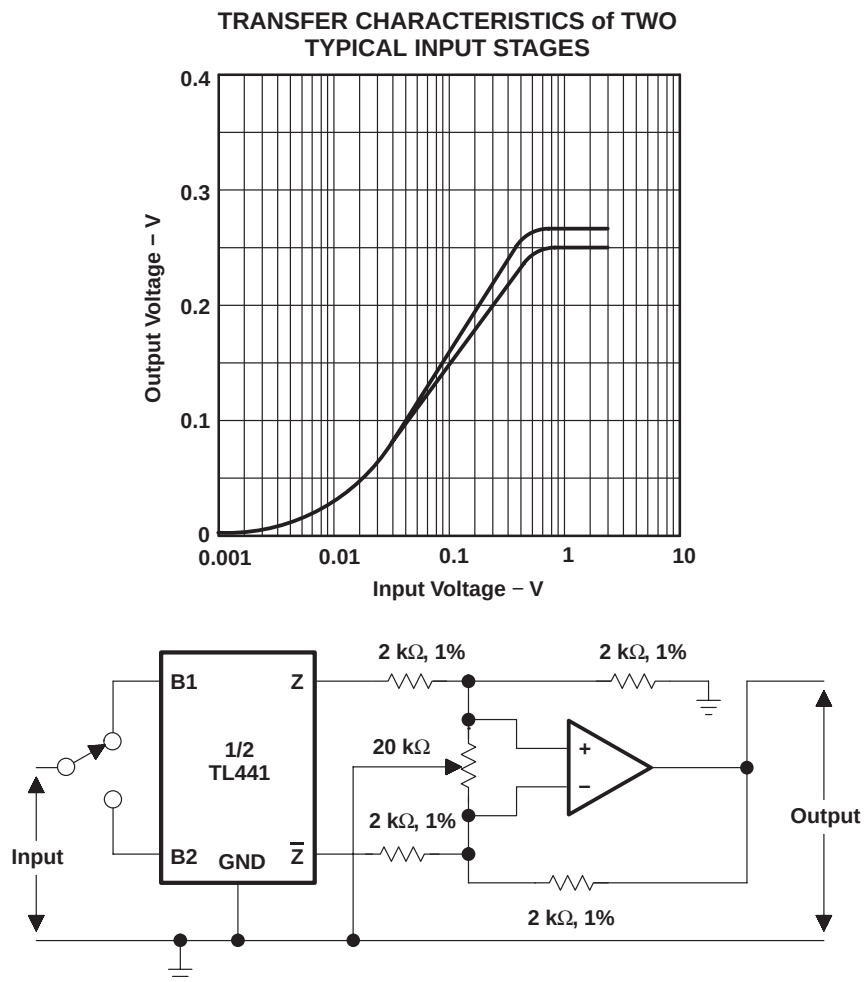
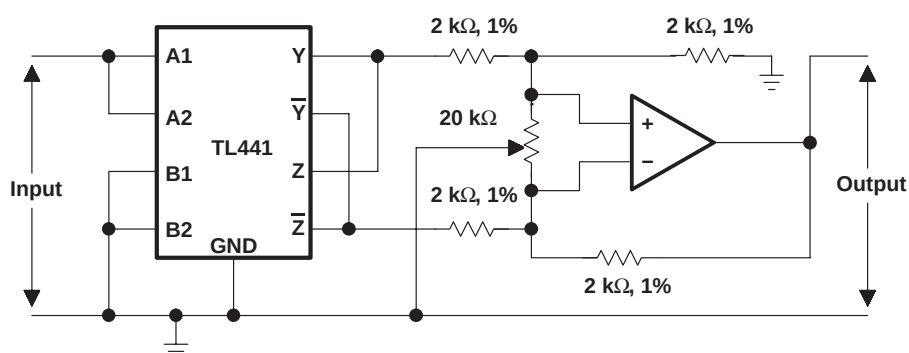
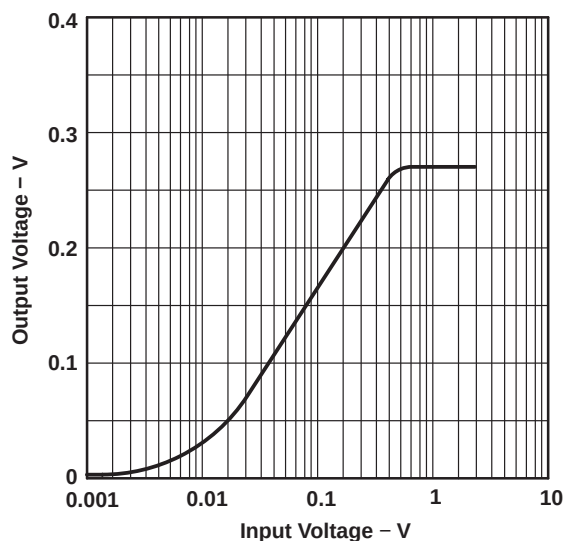


Figure 12. Utilization of Separate Stages

**TRANSFER CHARACTERISTICS  
WITH BOTH SIDES PARALLELED**

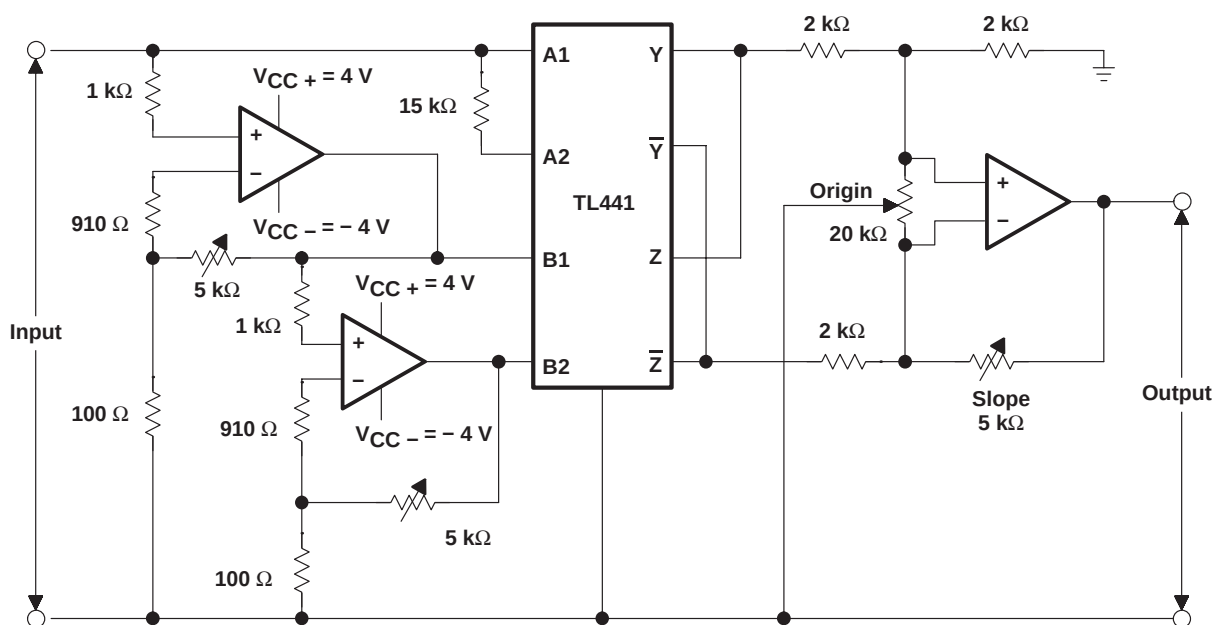
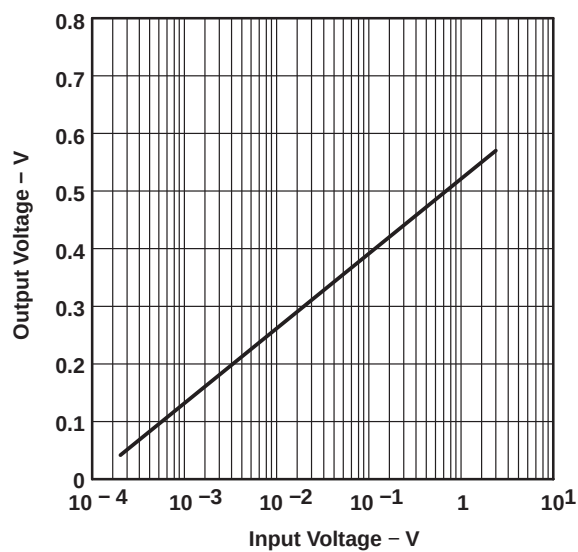


**Figure 13. Utilization of Paralleled Inputs**

# TL441-EP LOGARITHMIC AMPLIFIER

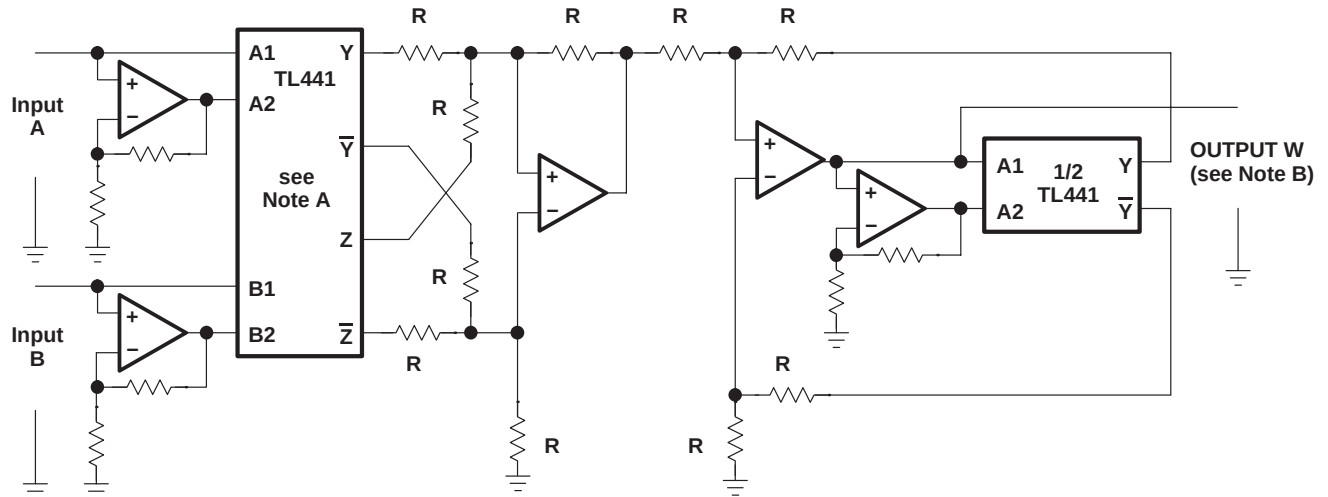
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TRANSFER CHARACTERISTICS



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

Figure 14. Logarithmic Amplifier With Input Voltage Range Greater Than 80 dB

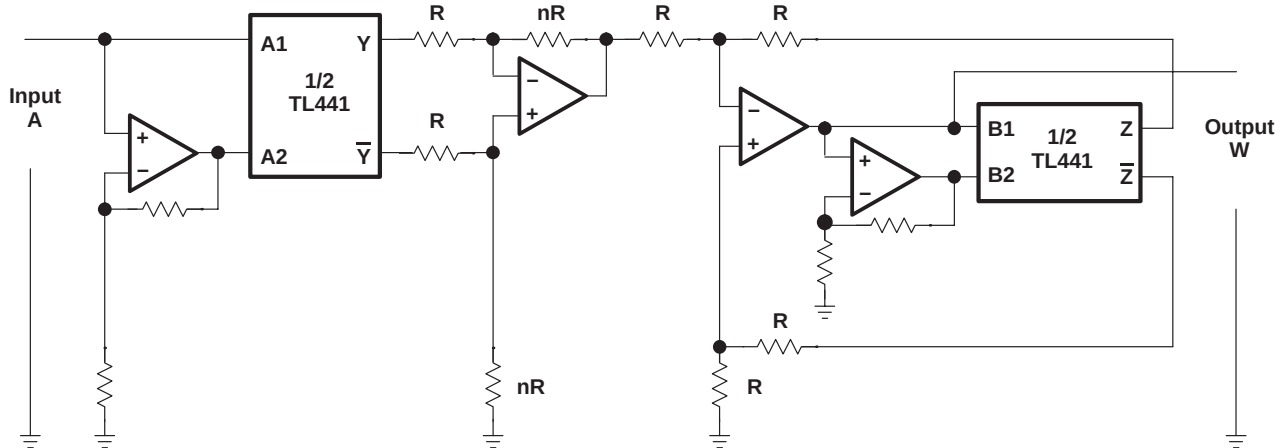


- NOTES: A. Connections shown are for multiplication. For division, Z and  $\bar{Z}$  connections are reversed.  
 B. Output W may need to be amplified to give actual product or quotient of A and B.  
 C. R designates resistors of equal value, typically 2 k $\Omega$  to 10 k $\Omega$ .

Multiplication:  $W = A \cdot B \Rightarrow \log W = \log A + \log B$ , 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 15. Multiplication or Division**



NOTE: R designates resistors of equal value, typically 2 k $\Omega$  to 10 k $\Omega$ . 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.

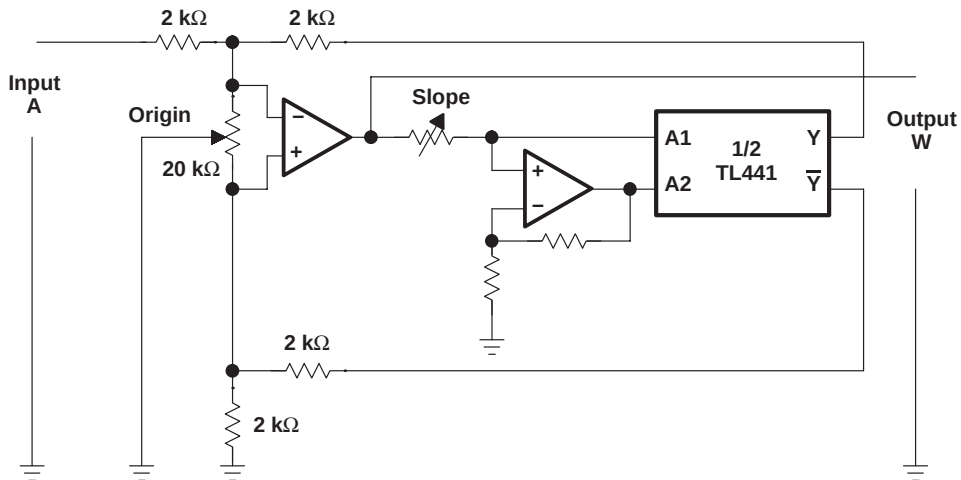
Exponential:  $W = A^n \Rightarrow \log W = n \log A$ , or  $W = a^{(n \log_a A)}$

**Figure 16. Raising a Variable to a Fixed Power**

# TL441-EP

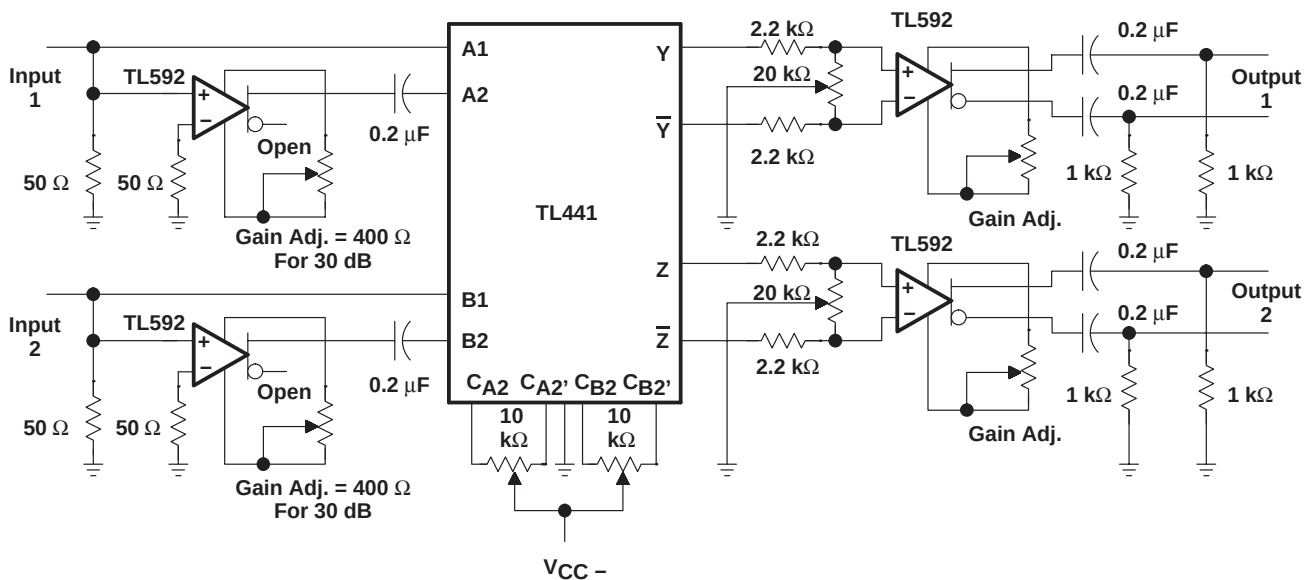
## LOGARITHMIC AMPLIFIER

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NOTE: Adjust the slope to correspond to the base "a". Exponential to any base:  $W = a$ .

### Figure 17. Raising a Fixed Number to a Variable Power



**Figure 18. Dual-Channel RF Logarithmic Amplifier With 50-dB Input Range Per Channel at 10 MHz**

## PACKAGING INFORMATION

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TL441MNSREP</a> | Active        | Production           | SOP (NS)   16  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -55 to 125   | TL441MEP            |
| TL441MNSREP.A               | Active        | Production           | SOP (NS)   16  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -55 to 125   | TL441MEP            |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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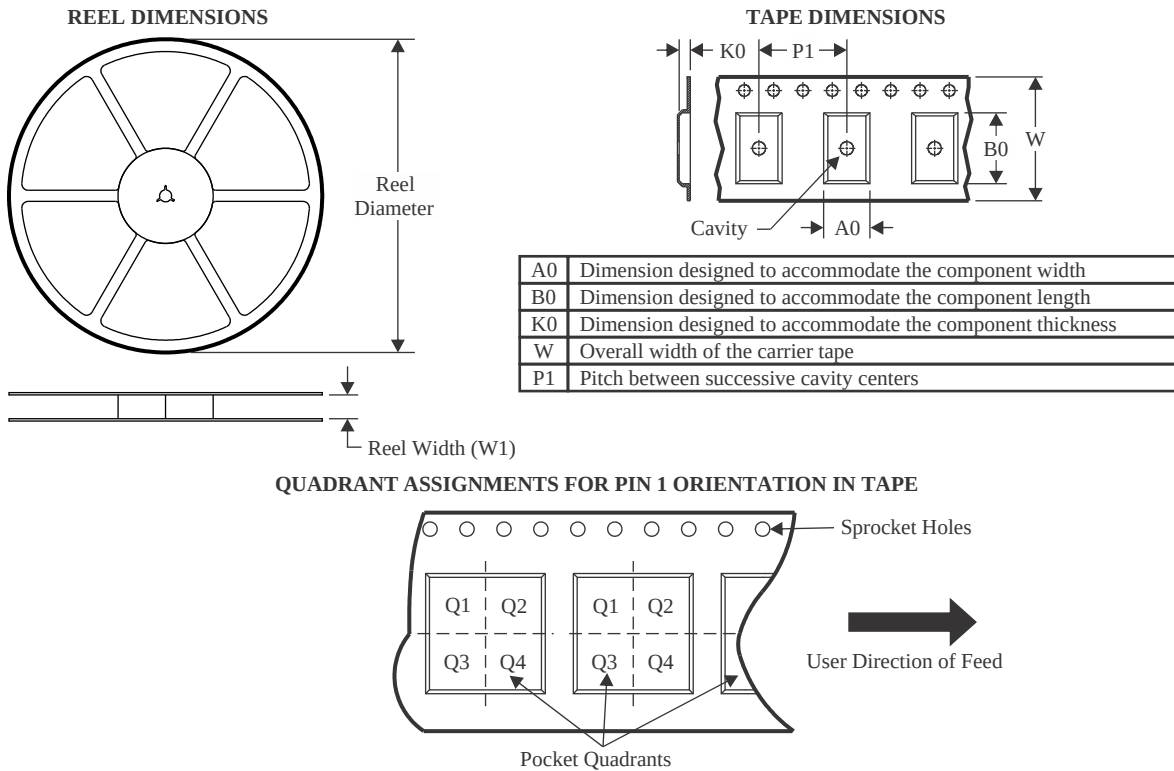
### OTHER QUALIFIED VERSIONS OF TL441-EP :

- Catalog : [TL441](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

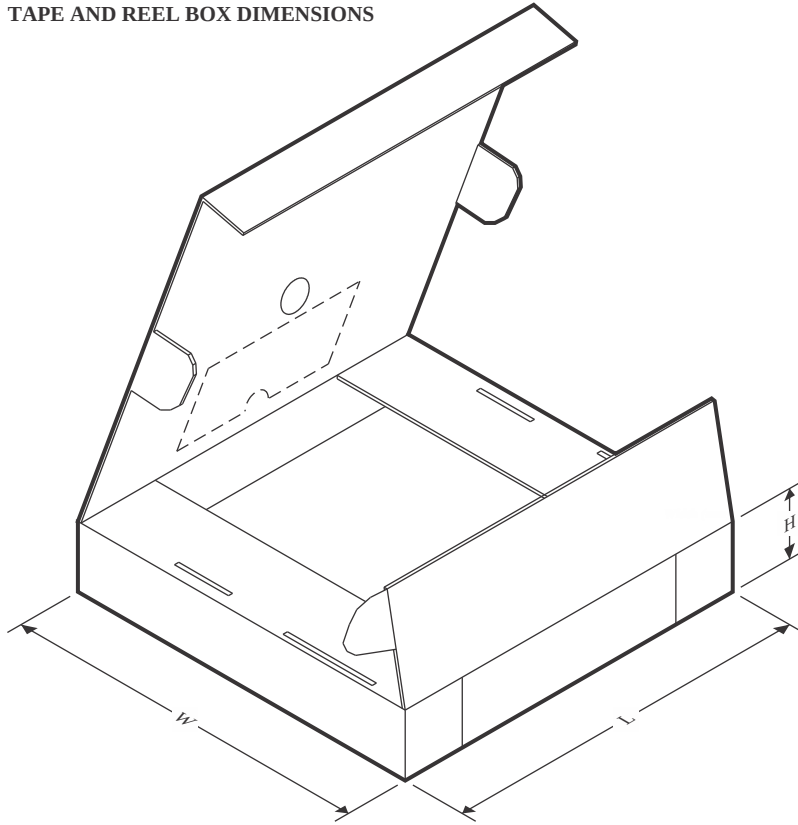
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TL441MNSREP | SOP          | NS              | 16   | 2000 | 330.0              | 16.4               | 8.2     | 10.5    | 2.5     | 12.0    | 16.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TL441MNSREP | SOP          | NS              | 16   | 2000 | 356.0       | 356.0      | 35.0        |

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