

TL441AM LOGARITHMIC AMPLIFIER

SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

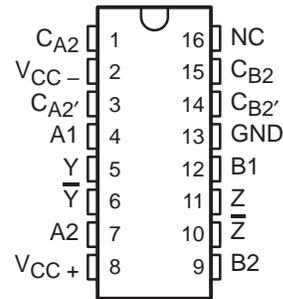
- Excellent Dynamic Range
- Wide Bandwidth
- Built-In Temperature Compensation
- Log Linearity (30 dB Sections) . . . 1 dB Typ
- Wide Input Voltage Range

description

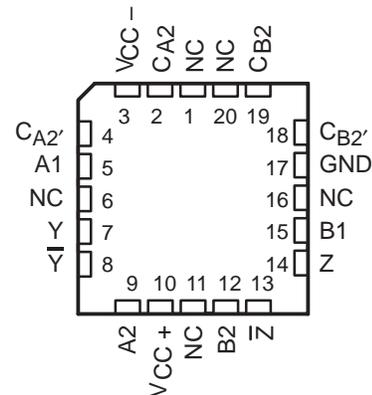
This monolithic amplifier circuit contains four 30-dB logarithmic stages. Gain in each stage is such that the output of each stage is proportional to the logarithm of the input voltage over the 30-dB input voltage range. Each half of the circuit contains two of these 30-dB stages summed together in one 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 to be typically 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 military weapons systems, broadband radar, and infrared reconnaissance systems. It serves for data compression and analog compensation. This logarithmic amplifier is used in log IF circuitry as well as video and log amplifiers. The TL441AM is characterized for operation over the full military temperature range of -55°C to 125°C .

J PACKAGE
(TOP VIEW)

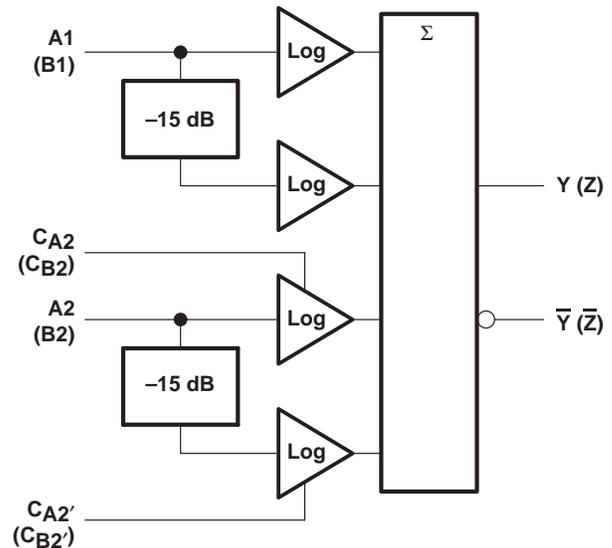


FK PACKAGE
(TOP VIEW)



NC — No internal connection

functional block diagram (one half)

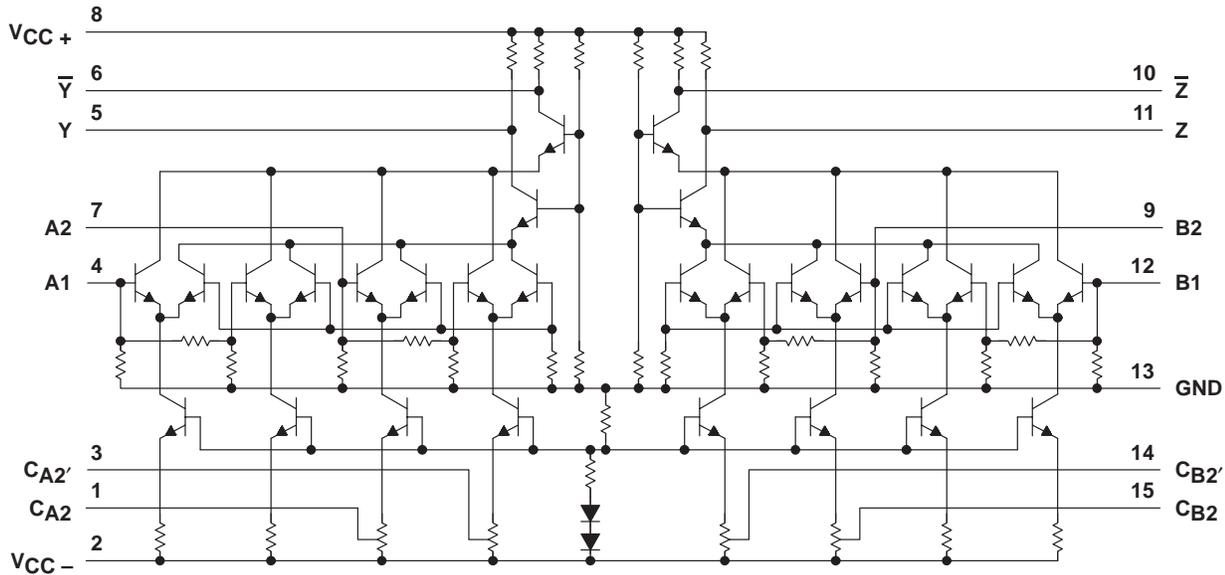


$Y \propto \log A1 + \log A2$; $Z \propto \log B1 + \log B2$
 where: A1, A2, B1, and B2 are in dBV, 0 dBV = 1 V.
 CA2, CA2', CB2, and CB2' are detector compensation inputs.

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SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

schematic



Pin numbers shown are for the J package.

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 |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

† Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at these or any other conditions beyond those indicated in the recommended operating conditions section of this specification is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltages, except differential output voltages, are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|---|
| FK | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |
| J | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |

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 | -55 | 125 | °C |



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

| 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, $C_L = 24\text{ pF}$ | 4 | | 20 | 35 | 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 |

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 | | ± 100 | 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 | 7 | 11 | mV/dB |
| DC error at -20 dBV (midpoint of -35 dBV to -5 dBV range) | 3 | | 4 | dB |
| | | $T_A = -55^\circ\text{C}$ | 3 | |
| Supply current from V_{CC+} | 2 | 10 | 31 | mA |
| Supply current from V_{CC-} | 2 | -4.5 | -15 | mA |
| Power dissipation | 2 | 87 | 276 | mW |

PARAMETER MEASUREMENT INFORMATION

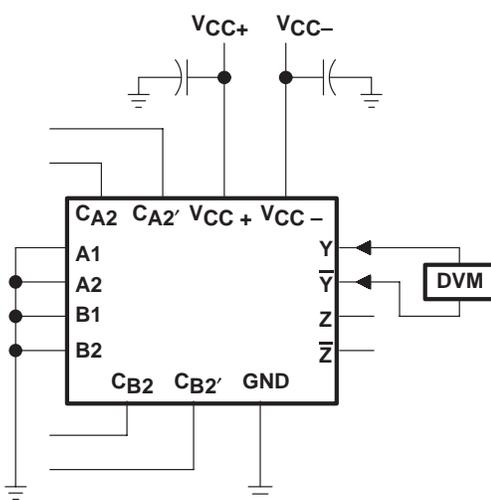


Figure 1

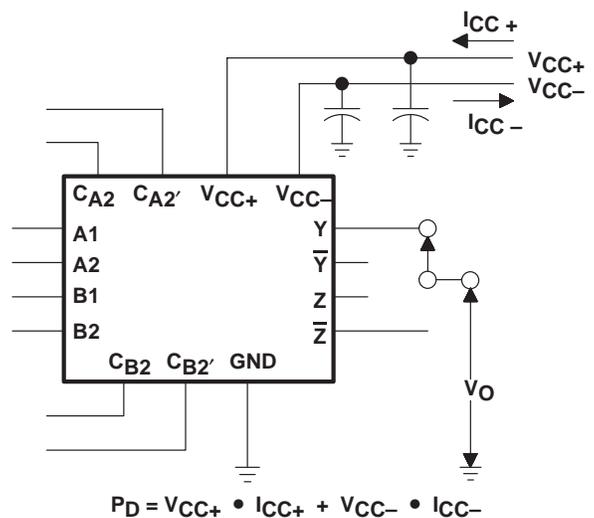


Figure 2

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SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

PARAMETER MEASUREMENT INFORMATION

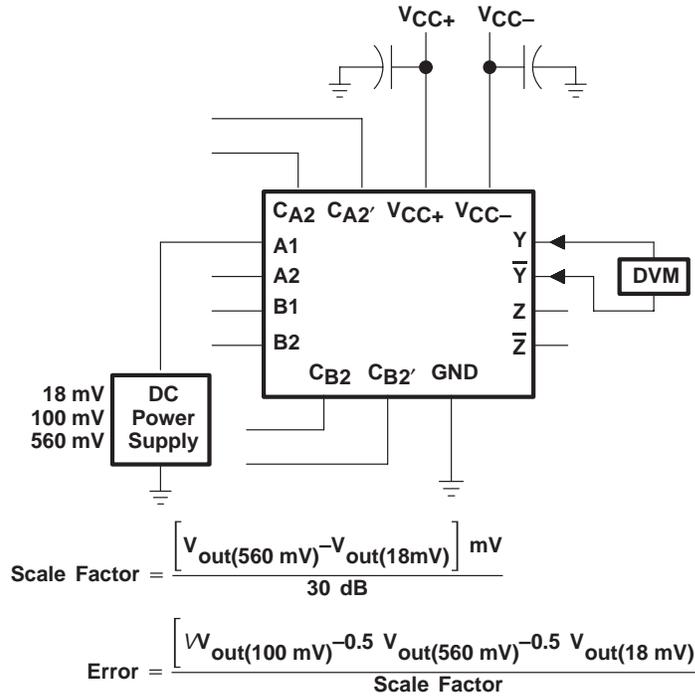
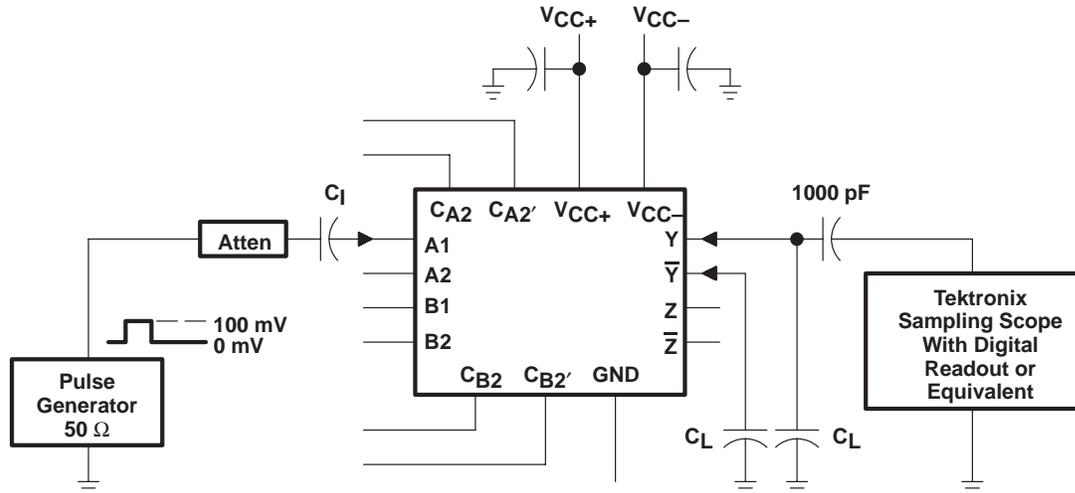


Figure 3



- 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

DIFFERENTIAL OUTPUT OFFSET VOLTAGE
vs
FREE-AIR TEMPERATURE

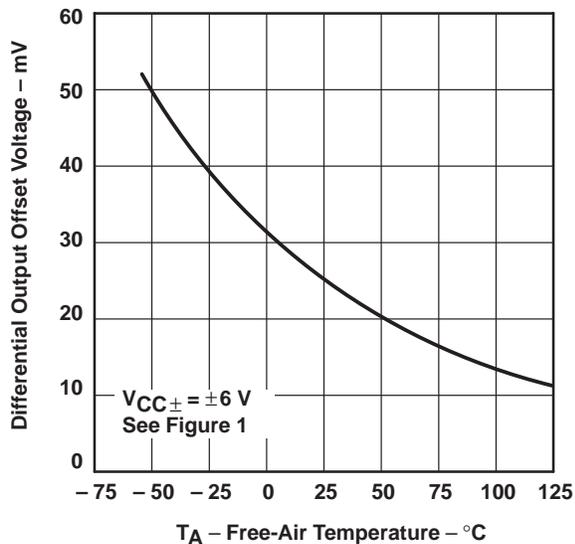


Figure 5

QUIESCENT OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

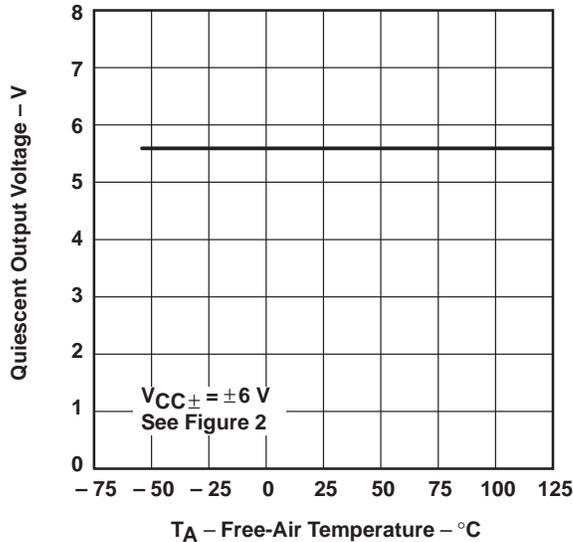


Figure 6

DC SCALE FACTOR
vs
FREE-AIR TEMPERATURE

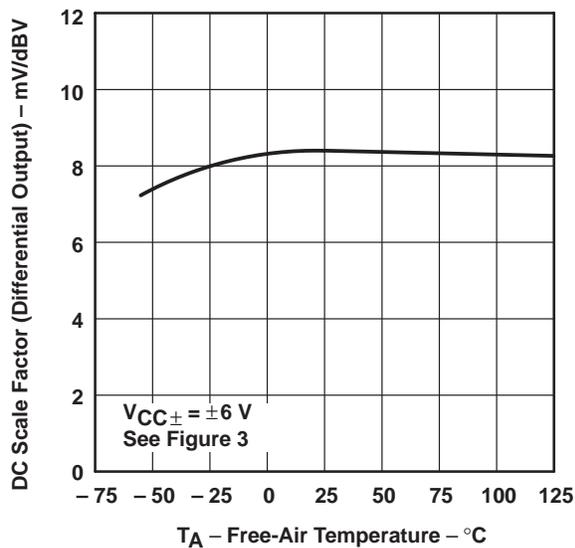


Figure 7

DC ERROR
vs
FREE-AIR TEMPERATURE

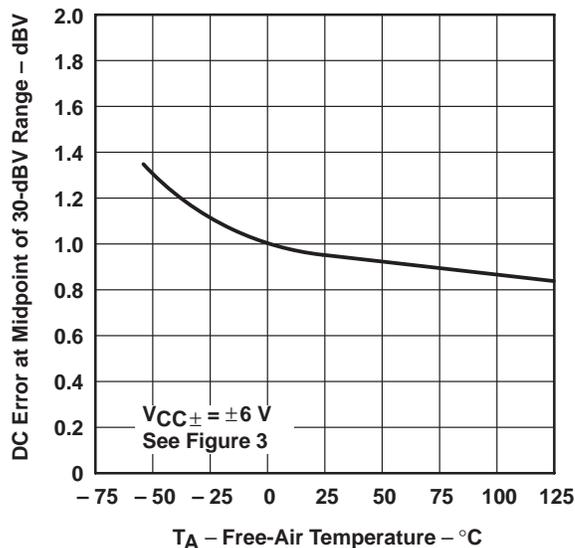


Figure 8

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SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

TYPICAL CHARACTERISTICS

OUTPUT RISE TIME VS LOAD CAPACITANCE

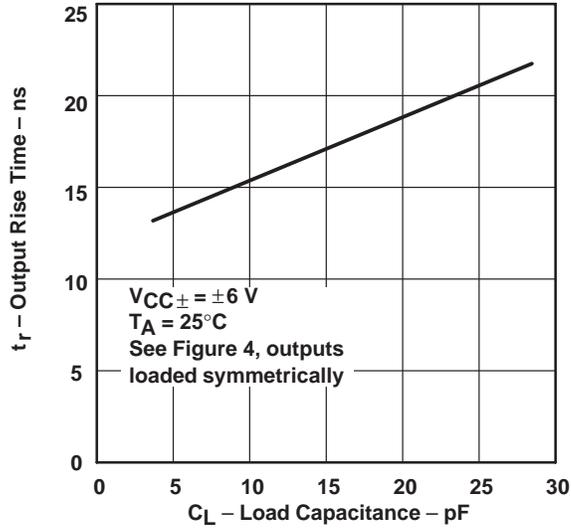


Figure 9

POWER DISSIPATION VS FREE-AIR TEMPERATURE

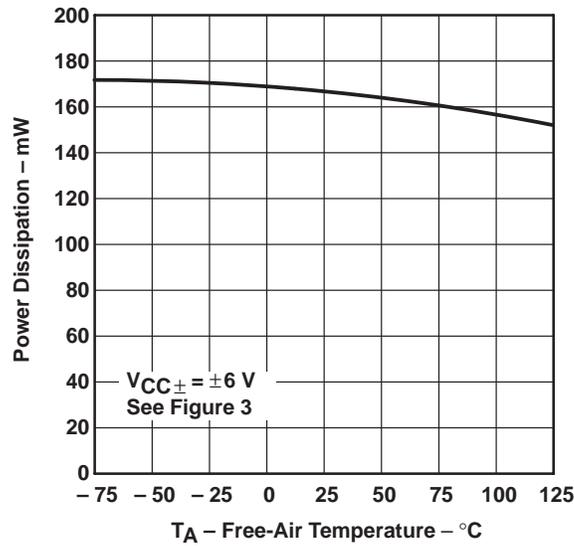


Figure 10

APPLICATION INFORMATION

Although designed for high-performance applications such as broadband radar, infrared detection and weapons systems, 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

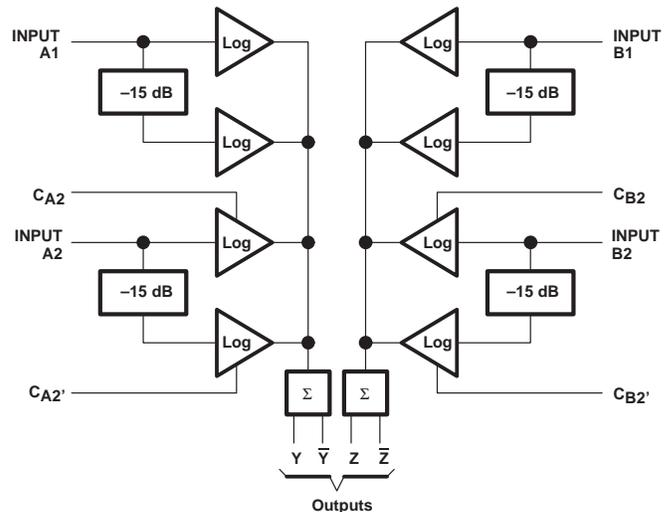


Figure 11

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 made 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 its quiescent value, the gain of that particular 15-dB stage can be adjusted to match the other 15-dB stage in the pair. The compensation pins may also 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, 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 may 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.

TL441AM LOGARITHMIC AMPLIFIER

SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

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 may also 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.

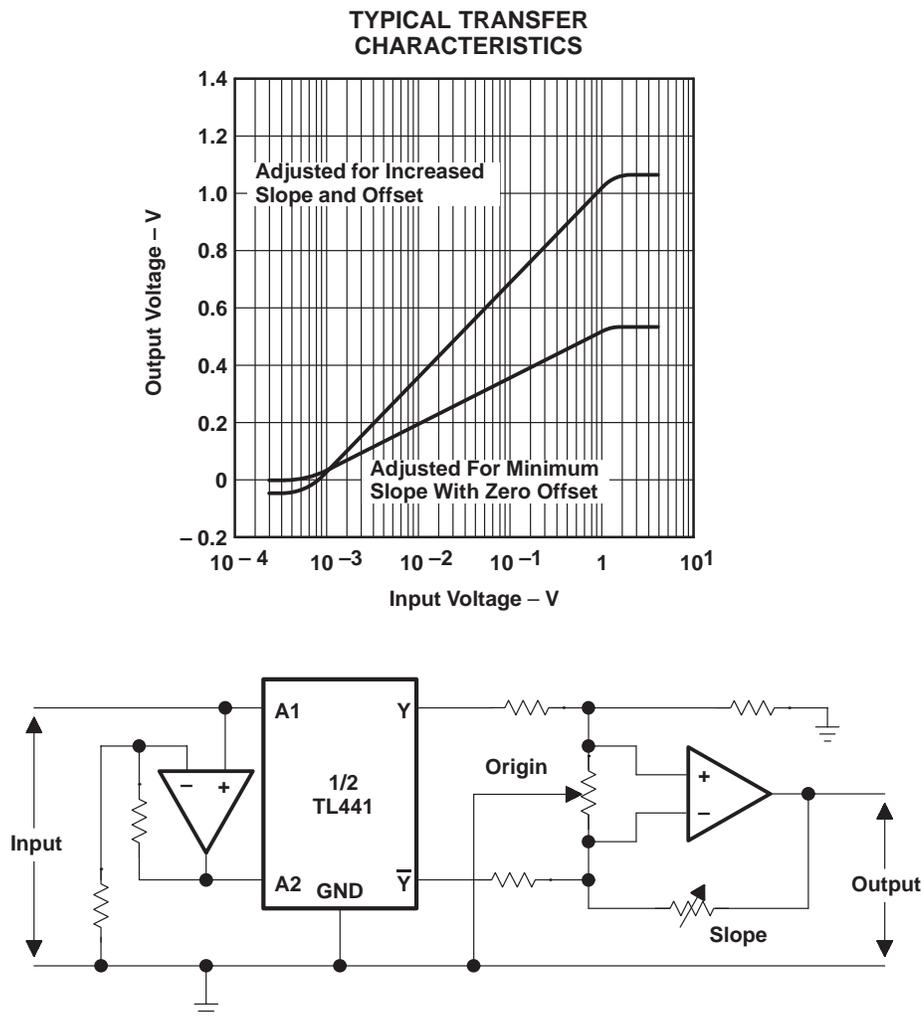


Figure 12. Output Slope and Origin Adjustment

APPLICATION INFORMATION

TRANSFER CHARACTERISTICS
OF TWO TYPICAL INPUT STAGES

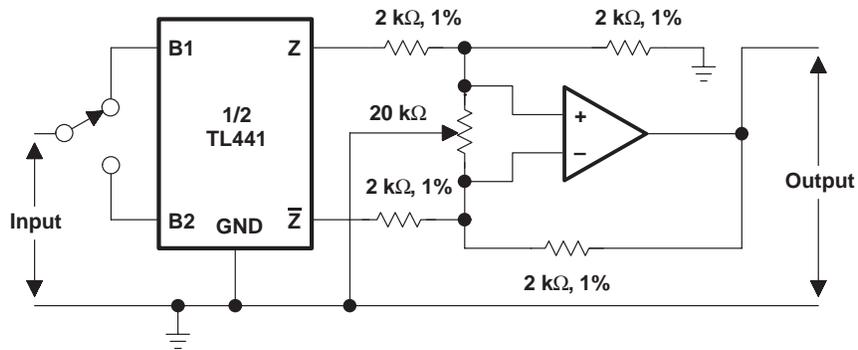
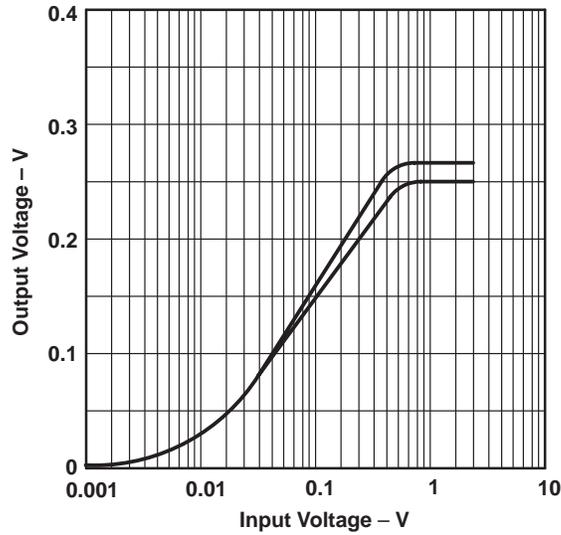


Figure 13. Utilization of Separate Stages

TL441AM LOGARITHMIC AMPLIFIER

SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

APPLICATION INFORMATION

TRANSFER CHARACTERISTICS WITH BOTH SIDES PARALLELED

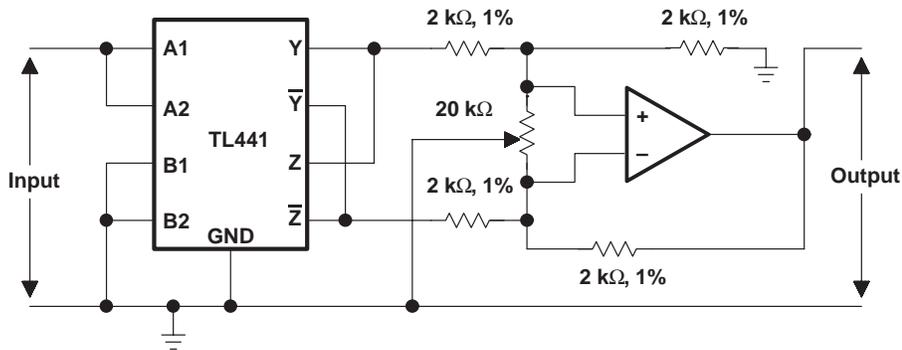
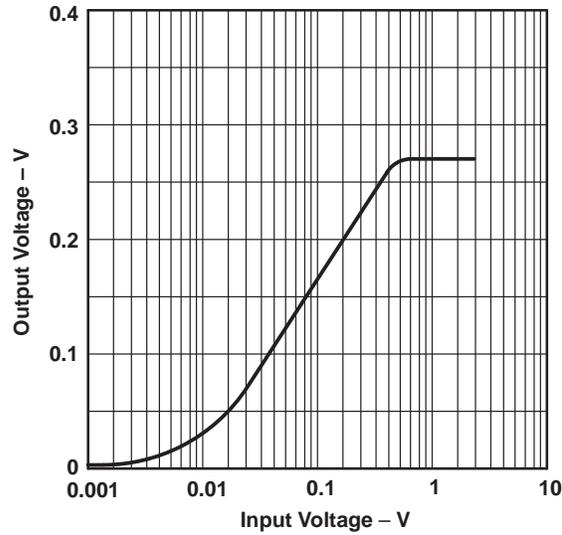
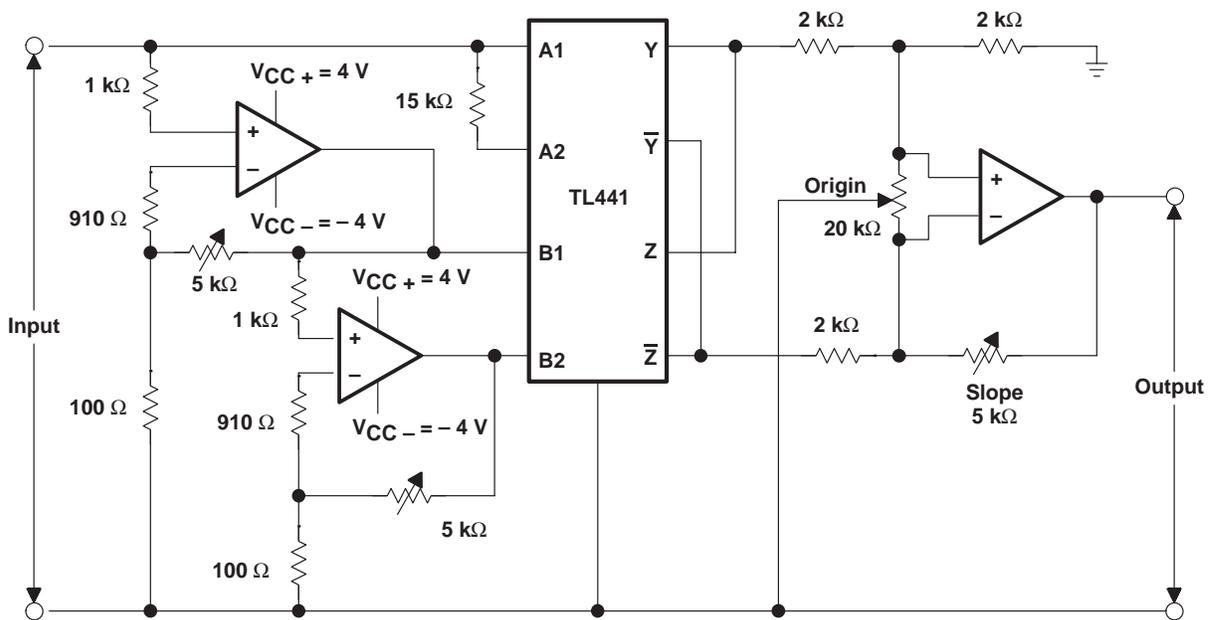
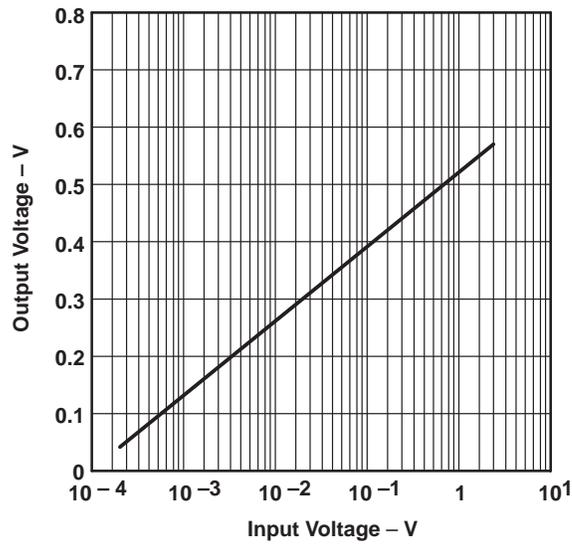


Figure 14. Utilization of Paralleled Inputs

APPLICATION INFORMATION

TRANSFER CHARACTERISTICS



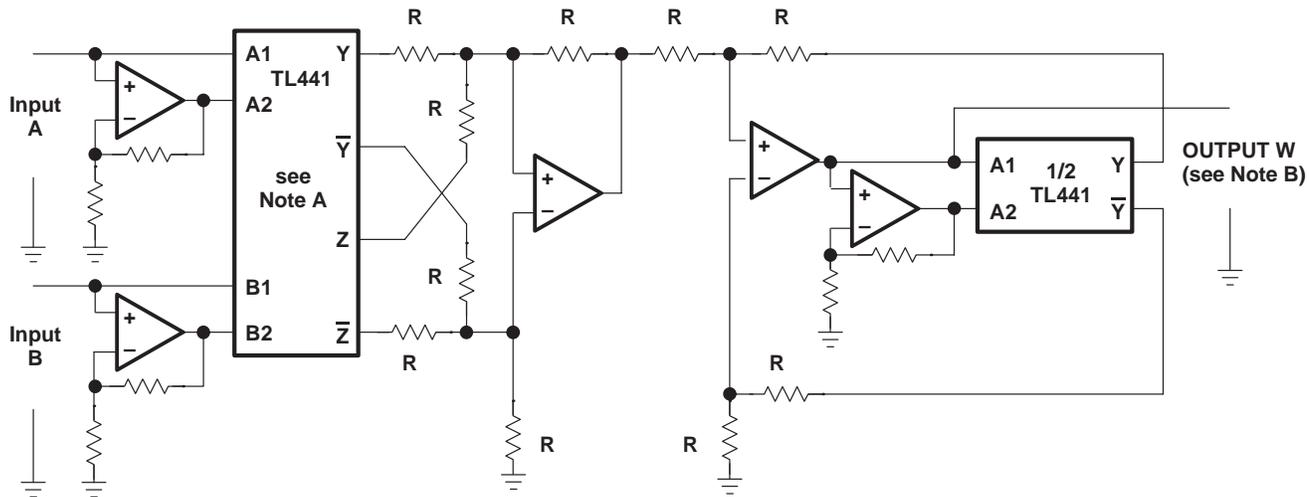
- NOTES: A. Inputs are limited by reducing the supply voltages for the input amplifiers to ± 4 V.
B. The gains of the input amplifiers are adjusted to achieve smooth transitions.

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

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SLFS038 – JUNE 1976 – REVISED FEBRUARY 1989

APPLICATION INFORMATION

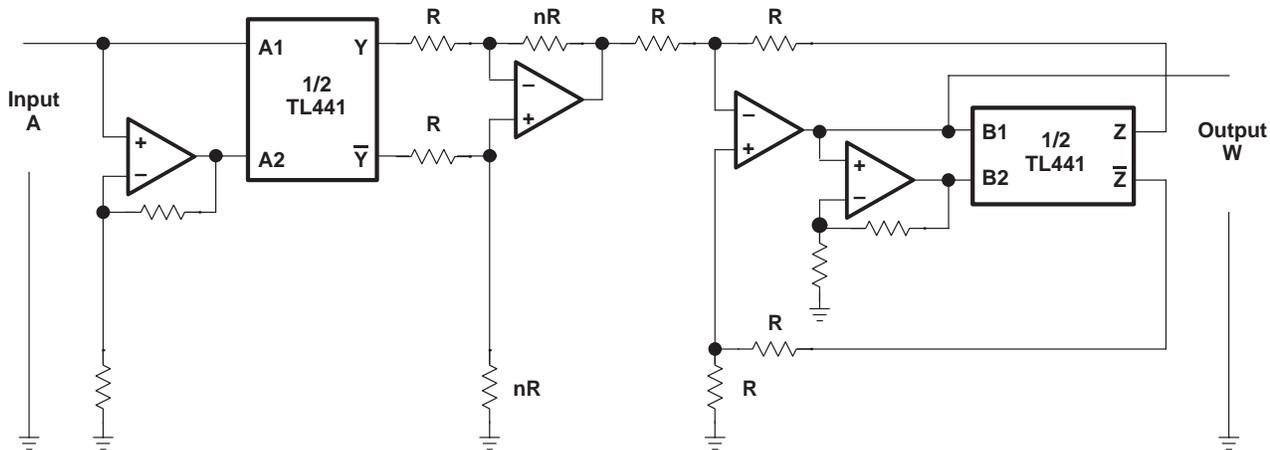


- NOTES: A. Connections shown are for multiplication. For division, Z and \bar{Z} connections are reversed.
 B. Output W may need to be amplified to give actual product or quotient of A and B.
 C. R designates resistors of equal value, typically 2 k Ω to 10 k Ω .

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 16. Multiplication or Division

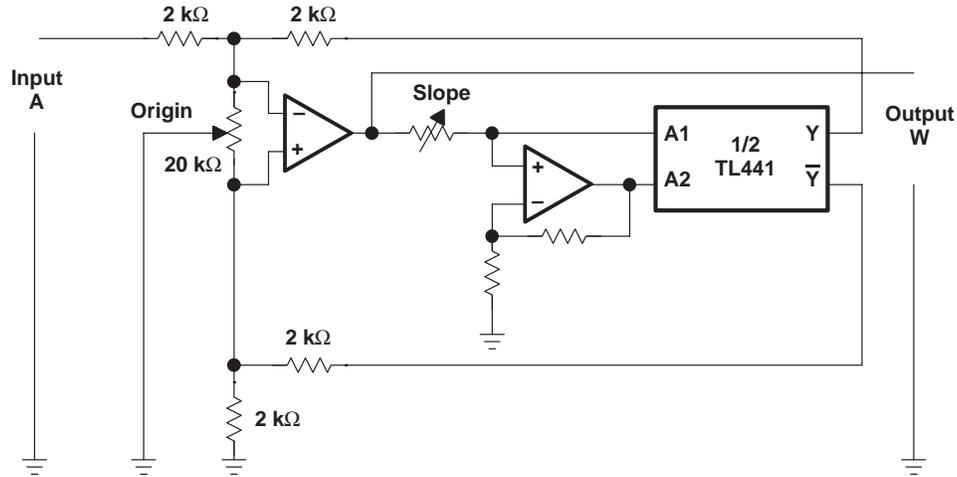


NOTE: R designates resistors of equal value, typically 2 k Ω to 10 k Ω . The power to which the input variable is raised is fixed by setting nR. Output W may need to be amplified to give the correct value.

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

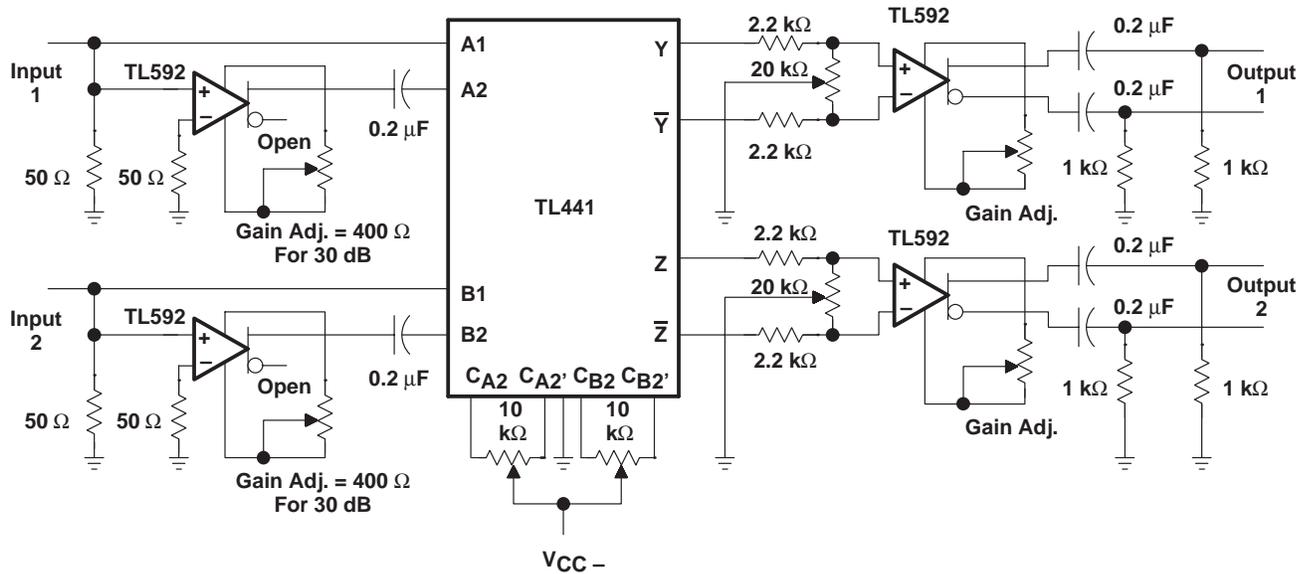


Figure 19. Dual-Channel RF Logarithmic Amplifier With 50-dB Input Range Per Channel at 10 MHz

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|---------------------|--------------------------------------|----------------------|--------------|----------------------------------|---|
| 5962-9176301QEA | ACTIVE | CDIP | J | 16 | 1 | Non-RoHS & Green | SNPB | N / A for Pkg Type | -55 to 125 | 5962-9176301QE A TL441AMJB |  |
| TL441AMJ | ACTIVE | CDIP | J | 16 | 1 | Non-RoHS & Green | SNPB | N / A for Pkg Type | | TL441AMJ |  |
| TL441AMJB | ACTIVE | CDIP | J | 16 | 1 | Non-RoHS & Green | SNPB | N / A for Pkg Type | | 5962-9176301QE A TL441AMJB |  |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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