

**FEATURES**

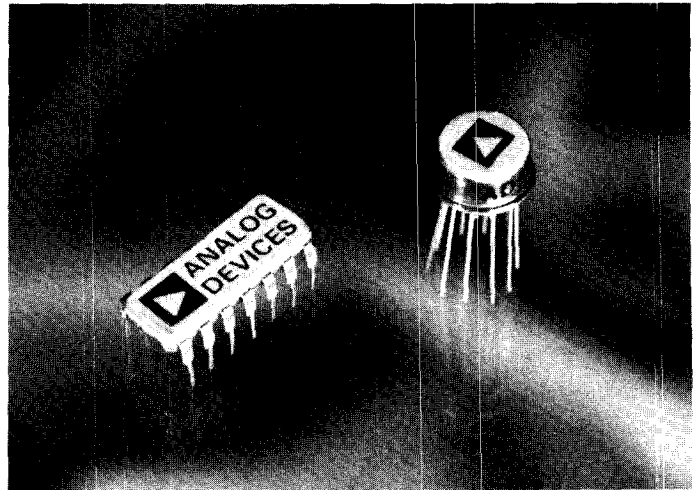
Low Cost

Simplicity of Operation: Only

Four External Adjustments

Max 4-Quadrant Error Below 0.5%  
(AD533L)Low Temperature Drift: 0.01%/°C  
(AD533L)

Multiplies, Divides, Squares, Square Roots

**PRODUCT DESCRIPTION**

The Analog Devices AD533 is a low cost integrated circuit multiplier comprised of a transconductance multiplying element, stable reference, and output amplifier on a monolithic silicon chip. Specified accuracy is easily achieved by the straight-forward adjustment of feedthrough, output zero, and gain trim pots. The AD533 multiplies in four quadrants with a transfer function of  $XY/10$ , divides in two quadrants with a  $10Z/X$  transfer function, and square roots in one quadrant with a transfer function of  $-\sqrt{10Z}$ . Several levels of accuracy are provided: the AD533J, AD533K, and AD533L, for 0 to +70°C operation, are specified for maximum multiplying errors of 2%, 1%, and 0.5% respectively at +25°C. The AD533S, for operation from -55°C to +125°C, is guaranteed for a maximum 1% multiplying error at +25°C. The maximum error specification is a true measure of overall accuracy since it includes the effects of offset voltage, feedthrough, scale factor, and nonlinearity in all four quadrants.

The low drift design of the AD533 insures that high accuracy is maintained with variations in temperature. The op amp output provides  $\pm 10$  volts at 5mA, and is fully protected against short circuits to ground or either supply voltage: all inputs are fully protected against over-voltage transients with internal series resistors. The devices provide excellent ac performance, with typical small signal bandwidth of 1.0MHz, full power bandwidth of 750kHz, and slew rate of 45V/ $\mu$ s.

The low cost and simplicity of operation of the AD533 make it especially well suited for use in such widespread applications as modulation and demodulation, automatic gain control and phase detection. Other applications include frequency discrimination, rms computation, peak detection, voltage controlled oscillators and filters, function generation, and power measurements.

All models are available in the hermetically-sealed TO-100 metal can and TO-116 ceramic DIL packages.

# SPECIFICATIONS (typical @ +25°C, externally trimmed and $V_S = \pm 15V$ dc unless otherwise specified)

PARAMETER	CONDITIONS	AD533J	AD533K	AD533L	AD533S
<b>ABSOLUTE MAX RATINGS</b>					
Internal Power Dissipation		500mW	*	*	*
Input Voltage (Note 1)		$\pm V_S$	*	*	*
$X_{in}, Y_{in}, Z_{in}, X_o, Y_o, Z_o$		$\pm V_S$	*	*	*
Rated Operating Temp Range		0 to +70°C	*	*	-55°C to +125°C
Storage Temp Range		-65°C to +150°C	*	*	*
Output Short Circuit	To Ground	Indefinite	*	*	*
<b>MULTIPLIER SPECIFICATIONS</b>					
Transfer Function		XY/10	*	*	*
	Untrimmed	XY/6 max [XY/10 min]	*	*	*
Total Error (of full scale)		$\pm 2.0\%$ max	$\pm 1.0\%$ max	$\pm 0.5\%$ max	$\pm 1.0\%$ max
	$T_A = \text{min to max}$	$\pm 3.0\%$	$\pm 2.0\%$	$\pm 1.0\%$	$\pm 1.5\%$
vs. Temperature	$T_A = \text{min to max}$	$\pm 0.04\%/^{\circ}\text{C}$	$\pm 0.03\%/^{\circ}\text{C}$	$\pm 0.01\%/^{\circ}\text{C}$	$\pm 0.01\%/^{\circ}\text{C}$
Nonlinearity					
X Input	$V_X = V_O = 20V(\text{p-p})$	$\pm 0.8\%$	$\pm 0.5\%$	**	**
Y Input	$V_Y = V_O = 20V(\text{p-p})$	$\pm 0.3\%$	$\pm 0.2\%$	**	**
Feedthrough					
X Input	$V_X = 20V(\text{p-p}), V_Y = 0,$ $f = 50\text{Hz}$	150mV(p-p) max	200mV(p-p) max	50mV(p-p) max	100mV (p-p) max
Y Input	$V_Y = 20V(\text{p-p}), V_X = 0,$ $f = 50\text{Hz}$	200mV(p-p) max	150mV(p-p) max	50mV(p-p) max	100mV (p-p) max
<b>DIVIDER SPECIFICATIONS</b>					
Transfer Function		10Z/X	*	*	*
	Untrimmed	10Z/X max [6Z/X min]	*	*	*
Total Error (of full scale)		$\pm 1.0\%$	$\pm 0.5\%$	$\pm 0.2\%$	$\pm 0.5\%$
	$V_X = -10V \text{ dc}, V_Z = \pm 10V \text{ dc}$	$\pm 3.0\%$	$\pm 2.0\%$	$\pm 1.5\%$	$\pm 2.0\%$
	$V_X = -1V \text{ dc}, V_Z = \pm 10V \text{ cc}$				
<b>SQUARER SPECIFICATIONS</b>					
Transfer Function		$X^2/10$	*	*	*
	Untrimmed	$X^2/6 \text{ max } [X^2/10 \text{ min}]$	*	*	*
Total Error (of full scale)		$\pm 0.8\%$	$\pm 0.4\%$	$\pm 0.2\%$	$\pm 0.4\%$
<b>SQUARE ROOTER SPECIFICATIONS</b>					
Transfer Function		$-\sqrt{10Z}$	*	*	*
	Untrimmed	$-\sqrt{10Z} \text{ max } [-\sqrt{6Z} \text{ min}]$	*	*	*
Total Error (of full scale)		$\pm 0.8\%$	$\pm 0.4\%$	$\pm 0.2\%$	$\pm 0.4\%$
<b>INPUT SPECIFICATIONS</b>					
Input Resistance					
X Input		10M $\Omega$	*	*	*
Y Input		6M $\Omega$	*	*	*
Z Input		36k $\Omega$	*	*	*
Input Bias Current					
X, Y Inputs		3 $\mu\text{A}$	7.5 $\mu\text{A}$ max	5 $\mu\text{A}$ max	7.5 $\mu\text{A}$ max
Z Input		$\pm 25\mu\text{A}$	*	*	*
X, Y Inputs	$T_A = \text{min to max}$	12 $\mu\text{A}$	10 $\mu\text{A}$	7 $\mu\text{A}$	7 $\mu\text{A}$
Z Input	$T_A = \text{min to max}$	$\pm 35\mu\text{A}$	*	*	*
Input Voltage	$T_A = \text{min to max}$				
$V_X, V_Y, V_Z$	For Rated Accuracy	$\pm 10V$	*	*	*
<b>DYNAMIC SPECIFICATIONS</b>					
Small Signal, Unity Gain		1.0MHz	*	*	*
Full Power Bandwidth		750kHz	*	*	*
Slew Rate		45V/ $\mu\text{s}$	*	*	*
Small Signal Amplitude Error		1% at 75kHz	*	*	*
Sm Sig 1% Vector Error	0.5° phase shift	5kHz	*	*	*
Settling Time	$\pm 10V$ step	1 $\mu\text{s}$ to 2%	*	*	*
Overload Recovery		2 $\mu\text{s}$ to 2%	*	*	*
<b>OUTPUT AMPLIFIER SPECIFICATIONS</b>					
Output Impedance		100 $\Omega$	*	*	*
Output Voltage Swing	$T_A = \text{min to max}$ $R_L \geq 2k\Omega, C_L \leq 100\text{pF}$	$\pm 10V$ min	*	*	*
Output Noise	$f = 5\text{Hz to } 10\text{kHz}$	0.6mV(rms)	*	*	*
	$f = 5\text{Hz to } 5\text{MHz}$	3.0mV(rms)	*	*	*
Output Offset Voltage		Trimable To Zero	*	*	*
vs. Temperature	$T_A = \text{min to max}$	0.7mV/ $^{\circ}\text{C}$	*	*	*
<b>POWER SUPPLY SPECIFICATIONS</b>					
Supply Voltage	Rated Performance	$\pm 15V$	*	*	*
	Operating	$\pm 15V$ to $\pm 18V$	$\pm 10V$ to $\pm 18V$	$\pm 10V$ to $\pm 18V$	$\pm 10V$ to $\pm 22V$
Supply Current	Quiescent	$\pm 6\text{mA}$ max	*	*	*
Power Supply Variation	Includes Effects of Recommended Null Pots				
Multiplier Accuracy		$\pm 0.5\%/%$	*	*	*
Output Offset		$\pm 10\text{mV}/%$	*	*	*
Scale Factor		$\pm 0.1\%/%$	*	*	*
Feedthrough		$\pm 10\text{mV}/%$	*	*	*

Note 1: Max input voltage is zero when supplies are turned off.

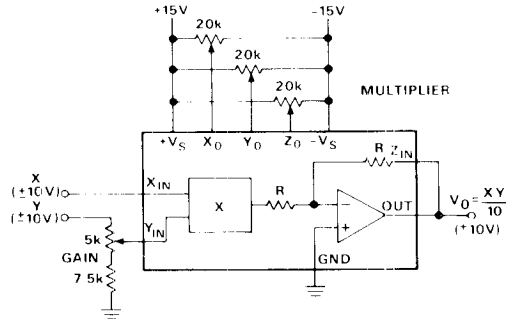
\*Specifications same as AD533J

\*\*Specifications same as AD533K

Specifications subject to change without notice.

## MULTIPLIER

Multiplier operation is accomplished by closing the loop around the internal op amp with the Z input connected to the output. The  $X_0$  null pot balances the X input channel to minimize Y feedthrough and similarly the  $Y_0$  pot minimizes the X feedthrough. The  $Z_0$  pot nulls the output op amp offset voltage and the gain pot sets the full scale output level.



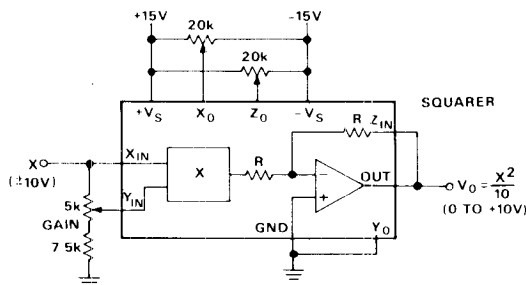
### TRIM PROCEDURES

1. With  $X = Y = 0$  volts, adjust  $Z_0$  for 0V dc output.
2. With  $Y = 20$  volts p-p (at  $f = 50$ Hz) and  $X = 0$ V, adjust  $X_0$  for minimum ac output.
3. With  $X = 20$  volts p-p (at  $f = 50$ Hz) and  $Y = 0$ V, adjust  $Y_0$  for minimum ac output.
4. Readjust  $Z_0$  for 0V dc output.
5. With  $X = +10$ V dc and  $Y = 20$  volts p-p (at  $f = 50$ Hz), adjust gain for output =  $Y_{in}$ .

NOTE: For best accuracy over limited voltage ranges (e.g.,  $\pm 5$ V), gain and feedthrough adjustments should be optimized with the inputs in the desired range, as linearity is considerably better over smaller ranges of input.

## SQUARER

Squarer operation is a special case of multiplier operation where the X and Y inputs are connected together and two quadrant operation results since the output is always positive. When the X and Y inputs are connected together, a composite offset results which is the algebraic sum of the individual offsets which can be nulled using the  $X_0$  pot alone.

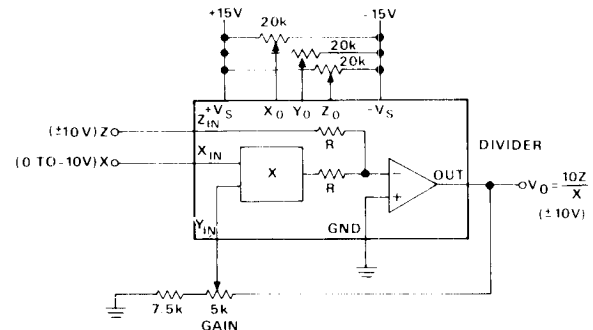


### TRIM PROCEDURES

1. With  $X = 0$  volts, adjust  $Z_0$  for 0V dc output.
2. With  $X = +10$ V dc, adjust gain for +10V dc output.
3. Reverse polarity of X input and adjust  $X_0$  to reduce the output error to  $\frac{1}{2}$  its original value, readjust the gain to take out the remaining error.
4. Check the output offset with input grounded. If nonzero, repeat the above procedure until no errors remain.

## DIVIDER

The divide mode utilizes the multiplier in a fed-back configuration where the Y input now controls the feedback factor. With  $X =$  full scale, the gain ( $V_0/Z$ ) becomes unity after trimming. Reducing the X input reduces the feedback around the op amp by a like amount, thereby increasing the gain. This reciprocal relationship forms the basis of the divide mode. Accuracy and bandwidth decrease as the denominator decreases.

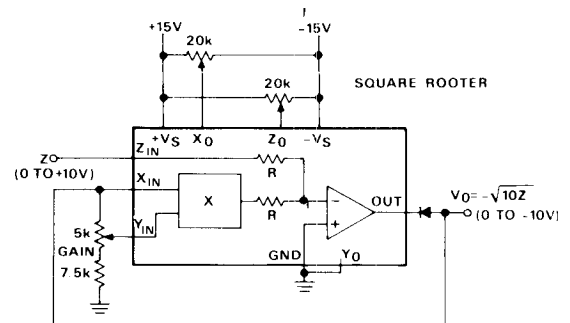


### TRIM PROCEDURES

1. Set all pots at mid-scale.
2. With  $Z = 0$ V, trim  $Z_0$  to hold the output constant, as X is varied from -10V dc through -1V dc.
3. With  $Z = 0$ V,  $X = -10$ V dc, trim  $Y_0$  for 0V dc.
4. With  $Z = X$  or  $-X$ , trim  $X_0$  for the minimum worst-case variations as X is varied from -10V dc to -1V dc.
5. Repeat steps 2 and 3 if step 4 required a large initial adjustment.
6. With  $Z = X$  or  $-X$ , trim the gain for the closest average approach to  $\pm 10$ V dc output as X is varied from -10V dc to -3V dc.

## SQUARE ROOTER

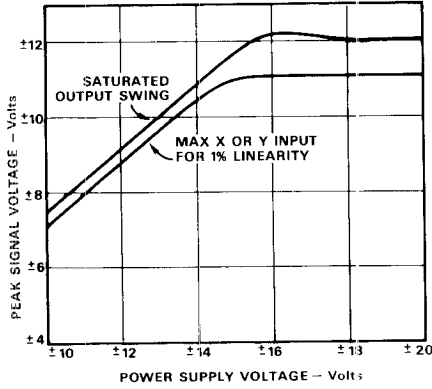
This mode is also a fed-back configuration with both the X and Y inputs tied to the op amp output through an external diode to prevent latchup. Accuracy, noise and frequency response are proportional to  $\sqrt{Z}$ , which implies a wider usable dynamic range than the divide mode.



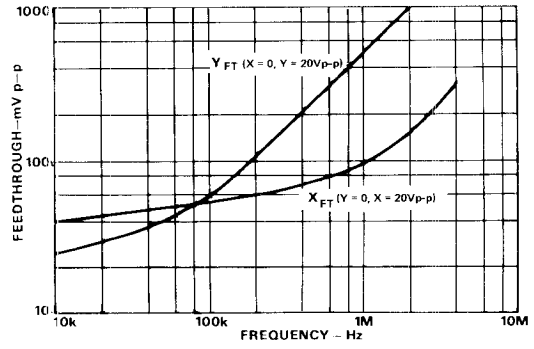
### TRIM PROCEDURES

1. With  $Z = +0.1$ V dc, adjust  $Z_0$  for Output = -1.0V dc.
2. With  $Z = +10.0$ V dc, adjust gain for Output = -10.0V dc.
3. With  $Z = +2.0$ V dc, adjust  $X_0$  for Output = -4.47  $\pm 0.1$ V dc.
4. Repeat steps 2 and 3, if necessary. Repeat step 1.

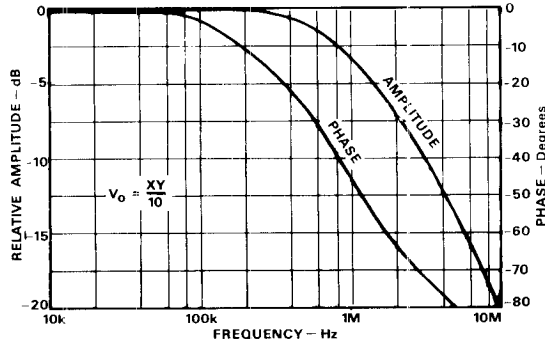
## TYPICAL PERFORMANCE CHARACTERISTICS



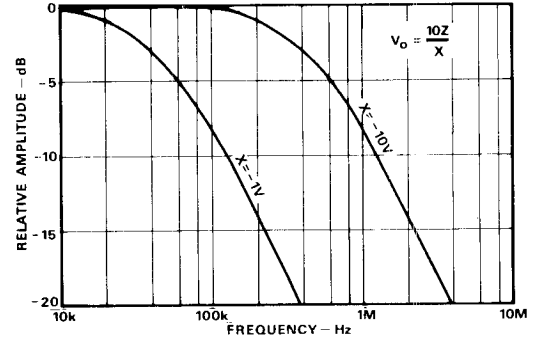
*Allowable Signal Swing vs. Supply Voltage*



*Feedthrough vs. Frequency*



*Closed Loop Frequency and Phase Response*

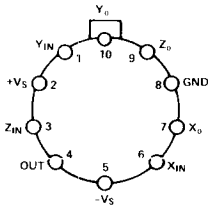


*Divide Mode Frequency Response*

## PIN CONFIGURATION & DIMENSIONS

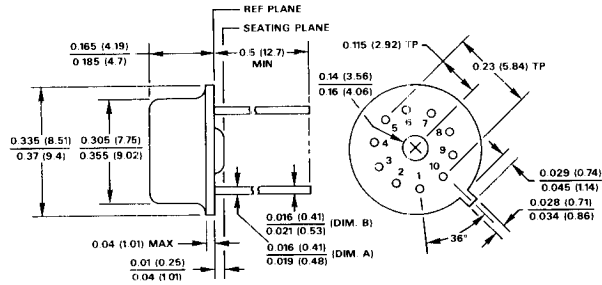
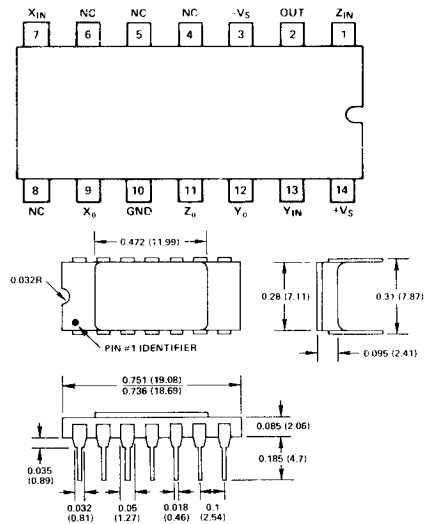
Dimensions shown in inches and (mm).

**AD533H**  
TO-100



TOP VIEW

**AD533D**  
TO-116



## ORDERING GUIDE

MODEL	MULT. ERROR (Max @ +25°C)	TEMP. RANGE	ORDER NUMBER
AD533J	±2.0%	0 to +70°C	AD533JH* AD533JD†
AD533K	±1.0%	0 to +70°C	AD533KH AD533KD
AD533L	±0.5%	0 to +70°C	AD533LH AD533LD
AD533S	±1.0%	-55°C to +125°C	AD533SH AD533SD

\*TO-100 metal can package

†TO-116 ceramic DIL package