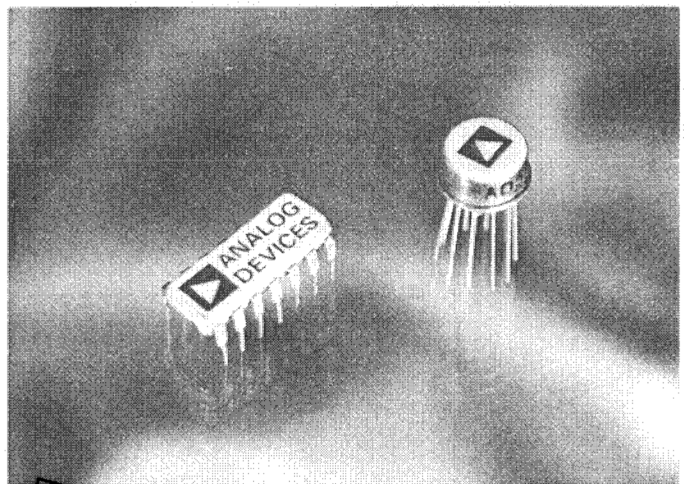
ANALOG DEVICES

Low Cost IC Multiplier, Divider, Squarer, Square Rooter

AD533

FEATURES
- 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/10V, divides in two quadrants with a 10VZ/X transfer function, and square roots in one quadrant with a transfer function of $-\sqrt{10VZ}$. 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 ±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/μs.

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 DIP packages.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 Fax: 617/326-8703 Twx: 710/394-6577
Telex: 924491 Cable: ANALOG NORWOODMASS

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

PARAMETER	CONDITIONS	AD533J	AD533K	AD533L	AD533S
ABSOLUTE MAX RATINGS					
Internal Power Dissipation		500mW	*	*	*
Input Voltage[1]					
$X_{in}, Y_{in}, Z_{in}, X_o, Y_o, Z_o$		$\pm V_S$	*	*	*
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	*	*	*
MULTIPLIER SPECIFICATIONS					
Transfer Function		XY/10V	*	*	*
	Untrimmed	XY/6V max [XY/10V min]	*	*	*
Total Error (of full scale)		±2.0% max	±1.0% max	±0.5% max	±1.0% max
	T_A = min to max	±3.0%	±2.0%	±1.0%	±1.5%
vs. Temperature	T_A = min to max	±0.04%/°C	±0.03%/°C	±0.01%/°C	±0.01%/°C
Nonlinearity					
X Input	$V_x = V_o$ = 20V(p-p)	±0.8%	±0.5%	**	**
Y Input	$V_y = V_o$ = 20V(p-p)	±0.3%	±0.2%	**	**
Feedthrough					
X Input	V_x = 20V(p-p), V_y = 0, f = 50Hz	200mV (p-p) max	150mV(p-p) max	50mV(p-p) max	100mV (p-p) max
Y Input	V_y = 20V(p-p), V_x = 0, f = 50Hz	200mV(p-p) max	150mV(p-p) max	50mV(p-p) max	100mV (p-p) max
DIVIDER SPECIFICATIONS					
Transfer Function		10VZ/X	*	*	*
	Untrimmed	10VZ/X max [6VZ/X min]	*	*	*
Total Error (of full scale)	V_x = −10V dc, V_z = ±10V dc	±1.0%	±0.5%	±0.2%	±0.5%
	V_x = −1V dc, V_z = ±10V dc	±3.0%	±2.0%	±1.5%	±2.0%
SQUARER SPECIFICATIONS					
Transfer Function		X^2/10V	*	*	*
	Untrimmed	X^2/6V max [X^2/10V min]	*	*	*
Total Error (of full scale)		±0.8%	±0.4%	±0.2%	±0.4%
SQUARE ROOTER SPECIFICATIONS					
Transfer Function		$-\sqrt{10VZ}$	*	*	*
	Untrimmed	$-\sqrt{10VZ}$ max [$-\sqrt{6VZ}$ min]	*	*	*
Total Error (of full scale)		±0.8%	±0.4%	±0.2%	±0.4%
INPUT SPECIFICATIONS					
Input Resistance					
X Input		10MΩ	*	*	*
Y Input		6MΩ	*	*	*
Z Input		36kΩ	*	*	*
Input Bias Current					
X, Y Inputs		3μA	7.5μA max	5μA max	7.5μA max
Z Input		±25μA	*	*	*
X, Y Inputs	T_A = min to max	12μA	10μA	7μA	7μA
Z Input	T_A = min to max	±35μA	*	*	*
Input Voltage	T_A = min to max				
V_x, V_y, V_z	For Rated Accuracy	±10V	*	*	*
DYNAMIC SPECIFICATIONS					
Small Signal, Unity Gain		1.0MHz	*	*	*
Full Power Bandwidth		750kHz	*	*	*
Slew Rate		45V/μs	*	*	*
Small Signal Amplitude Error		1% at 75kHz	*	*	*
Sm Sig 1% Vector Error	0.5° phase shift	5kHz	*	*	*
Settling Time	±10V step	1μs to 2%	*	*	*
Overload Recovery		2μs to 2%	*	*	*
OUTPUT AMPLIFIER SPECIFICATIONS					
Output Impedance		1Ω	*	*	*
Output Voltage Swing	T_A = min to max				
	$R_L \geqslant 2k\Omega$, $C_L \leqslant 1000pF$	±10V min	*	*	*
Output Noise	f = 5Hz to 10kHz	0.6mV(rms)	*	*	*
	f = 5Hz to 5MHz	3.0mV(rms)	*	*	*
Output Offset Voltage		Trimmable To Zero	*	*	*
vs. Temperature	T_A = min to max	0.7mV/°C	*	*	*
POWER SUPPLY SPECIFICATIONS					
Supply Voltage	Rated Performance	±15V	*	*	*
	Operating	±15V to ±18V	±10V to ±18V	±10V to ±18V	±10V to ±22V
Supply Current	Quiescent	±6mA max	*	*	*
Power Supply Variation	*Includes* Effects of Recommended Null Pots				
Multiplier Accuracy		±0.5%/%	*	*	*
Output Offset		±10mV/%	*	*	*
Scale Factor		±0.1%/%	*	*	*
Feedthrough		±10mV/%	*	*	*

NOTES

[1] Max input voltage is zero when supplies are turned off.

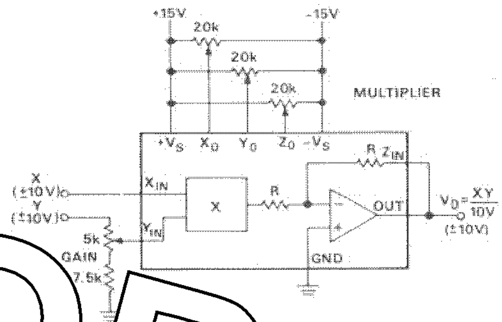
*Specifications same as AD533J.

**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_O null pot balances the X input channel to minimize Y feedthrough and similarly the Y_O pot minimizes the X feedthrough. The Z_O pot nulls the output op amp offset voltage and the gain pot sets the full scale output level.



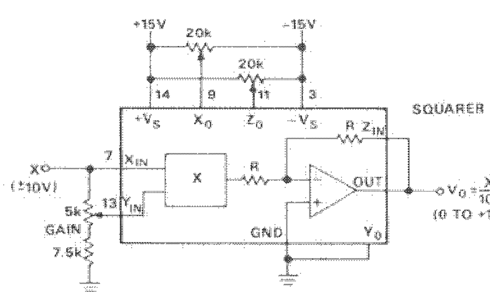
TRIM PROCEDURES

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

NOTE: For best accuracy over limited voltage ranges (e.g., ±5V), 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_O pot alone.

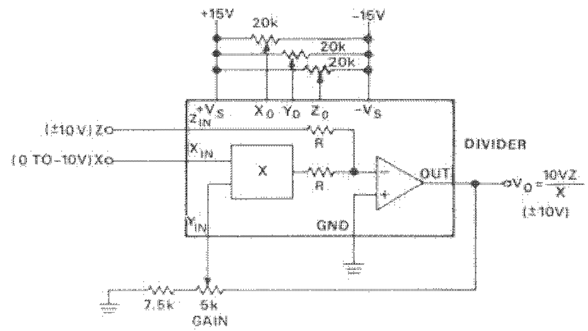


TRIM PROCEDURES

1. With X = 0 volts, adjust Z_O for 0V dc output.
2. With X = +10V dc, adjust gain for +10V dc output.
3. Reverse polarity of X input and adjust X_O to reduce the output error to ½ 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_O/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.

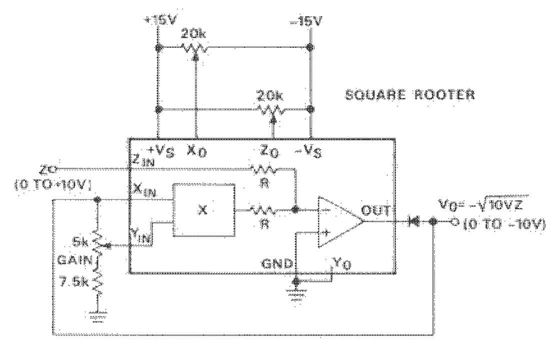


TRIM PROCEDURES

1. Set all pots at mid-scale.
2. With Z = 0V, trim Z_O to hold the output constant, as X is varied from −10V dc through −1V dc.
3. With Z = 0V, X = −10V dc, trim Y_O for 0V dc.
4. With Z = X or −X, trim X_O 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 ±10V dc output as X is varied from −10V dc to −3V dc.

SQUARE ROOTER

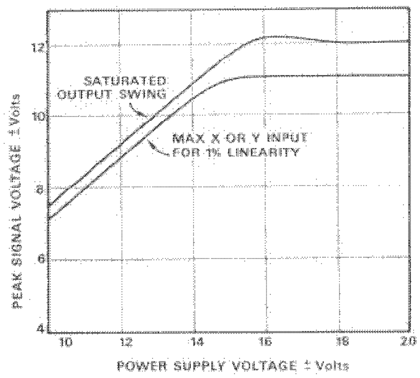
This mode is also a fed-back configuration with both the X and Y inputs tied to the op amp output through an external diode to prevent latchup. Accuracy, noise and frequency response are proportional to $\sqrt{Z}$, which implies a wider usable dynamic range than the divide mode.



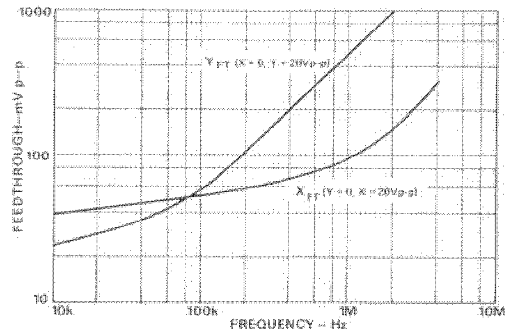
TRIM PROCEDURES

1. With Z = +0.1V dc, adjust Z_O for Output = −1.0V dc.
2. With Z = +10.0V dc, adjust gain for Output = −10.0V dc.
3. With Z = +2.0V dc, adjust X_O for Output = −4.47 ±0.1V dc.
4. Repeat steps 2 and 3, if necessary. Repeat step 1.

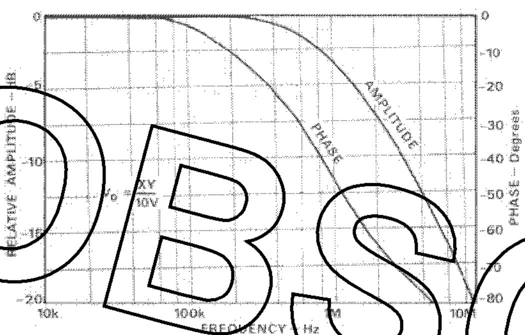
TYPICAL PERFORMANCE CHARACTERISTICS



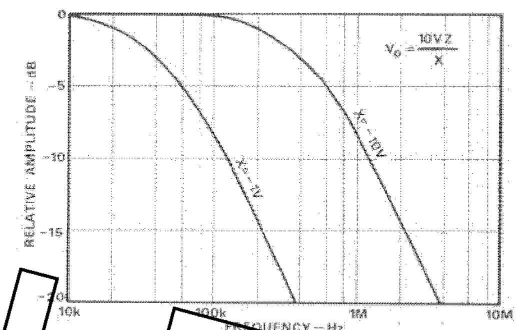
Allowable Signal Swing vs. Supply Voltage



Feedthrough vs. Frequency



Closed Loop Frequency and Phase Response



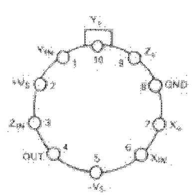
Divide Mode Frequency Response

PIN CONFIGURATION & DIMENSIONS

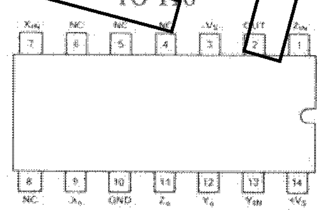
Dimensions shown in inches and (mm).

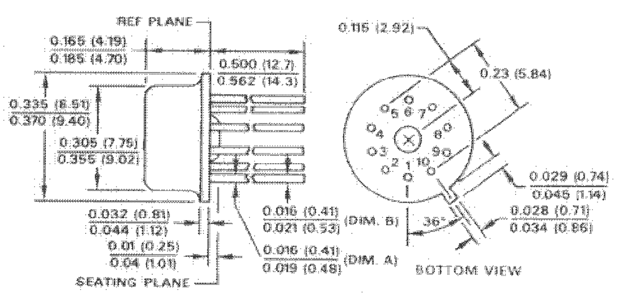
AD533H
TO-100

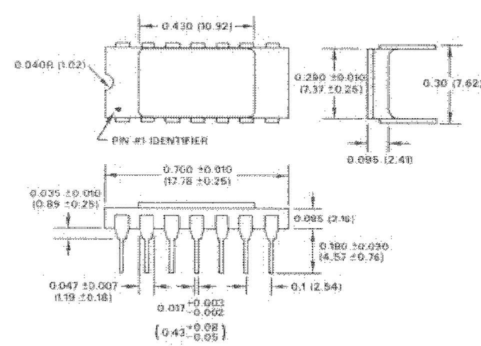
TOP VIEW



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 DIP package