intech ADVANCED ANALOG

MODEL 550 MULTIPLIER

DESCRIPTION

The Model 550 is an accurate analog multiplier that can be used for multiplying, dividing, or square-rooting. *Total error* over all four quadrants with any combination of X and Y inputs between ±10V is less than ±0.50%. The total error is less than ±50mV without external trimming! This multiplier uses a new error-nulling technique for transconductance multipliers to significantly improve accuracy.

APPLICATIONS

The Model 550 Multiplier computes the product of two input voltages. But by varying external connections, the 550 can also be used for dividing and square-rooting. Pin connections for these other modes of operation are shown on page 4.

Some key uses for multipliers in instrumentation are . . .

- Measuring Power
- Measuring RMS Levels
- Linearizing Signals
- Controlling System Gain

Multipliers are also used extensively in sophisticated communications and display systems for. . .

- Phase-Angle Detection
- Frequency Doubling
- Modulating
- Demodulating
- Voltage-Tuning of Active Filters and Oscillators
- Linearizing CRT Displays
- Coordinate Rotation

FILTERING OF NOISE

Accuracy of the Model 550 Multiplier is so good that semiconductor noise becomes a limiting factor on accuracy. With the 550, you can easily add a low-pass filter to trade off bandwidth for reduced noise. Simply add a capacitor C_O between the pins "SJ" and "OUT." This will provide a 6dB/octave roll-off with a time constant of 140kΩ x C_O seconds. Pin "SJ" is the summing junction of the output amplifier, so this low-pass filter acts only on the output stage. See Figure 1 for a simplified diagram.

FEATURES

- Accuracy of ± 0.50% without external trimming!
- Low Drift ±0.04%/°C max
- Low Nonlinearity ±0.2% max

Time Constant: $R_O C_O$, where $R_O \sim 140k\Omega$

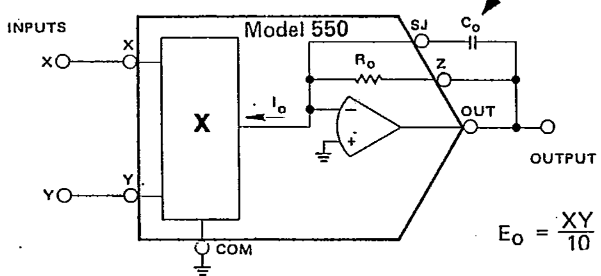


Figure 1. Low-Pass Filtering of the 550 Multiplier Output

ELECTRICAL SPECIFICATIONS—MULTIPLY MODE

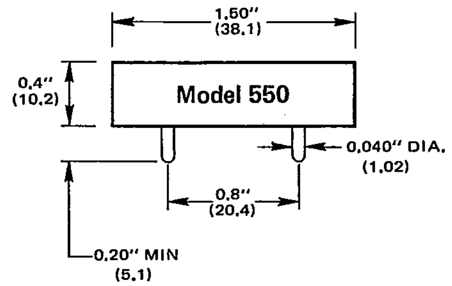
(Typical at 25°C and ±15Vdc unless otherwise specified.)

MODEL	**550**
ACCURACY	
Total Error (1)	±0.50% max
Avg. Error vs. Temperature (2)	±0.04%/°C max
Avg. Error vs. Supply	±0.1%/%
Output Noise up to 10kHz	1.5mVrms
Nonlinear Component of Error	±0.2% max
Warm—Up Time	1 minute
INPUTS (Both X and Y)	
Input Voltage Range	
for Rated Accuracy	±10V
for Safe Operation	±16V
Input Impedance	50kΩ
Input Bias Current	100nA max
OUTPUT	
Output—Voltage	±10V
—Current	±5mA
Output Impedance	1Ω
FREQUENCY RESPONSE	
-3dB Small Signal	150kHz
Small-Signal Amplitude Error	±1% at 5kHz min
Small-Signal Vector Error	±1% at 1kHz
Full-Power Response	8kHz
Slew Rate	0.5V/μsec
Settling-Time for 20V Step	60μsec to 0.1%
TEMPERATURE RANGE	
Rated Specifications	-25°C to +85°C
Storage	-55°C to +100°C
POWER SUPPLY	±14Vdc to ±16Vdc
Supply Drain at Quiescent	±18mA
PRICE, 1-9	$55

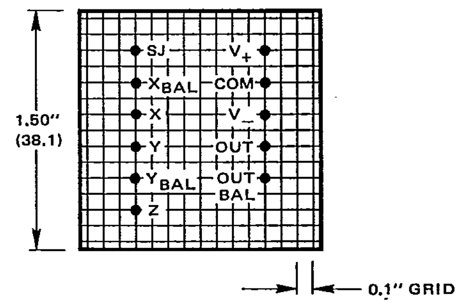
(1) Percent of full-scale, so the maximum error is ±50mV. Includes all error terms (offsets, gain, and nonlinearity) for any combination of X and Y. The output offset (X=0, Y=0) component of error is less than ±15mV at 25°C, and is typically ±5mV.

(2) This drift spec includes all error components (offsets, gain, and nonlinearity) for any combination of inputs X and Y. It is given as a percent of full-scale, so the maximum drift is 4mV/°C. Of this, the output offset drift (X=0, Y=0 condition) is guaranteed to be less than 1mV/°C.

OUTLINE DIMENSIONS

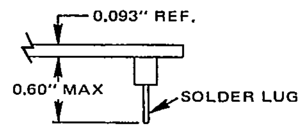


Dimensions in millimeters are shown in parentheses.



Case: Black Epoxy
Pins: Gold-flashed over silver plated, ½ hard brass
Weight: 1.5 oz.
Mating Socket: MS10.

MS10 is made of glass-epoxy board with swaged-in terminals. It has 11 terminals that mate with the pins of the 550 multiplier.



PIN CONNECTIONS

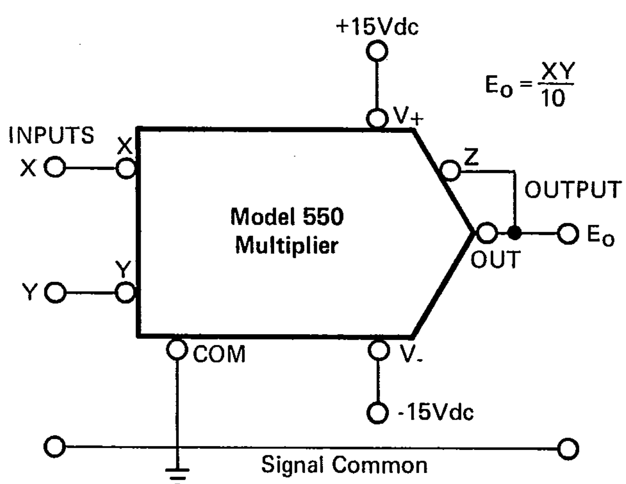


Figure 2. Pin Connections in Multiply-Mode

PERFORMANCE

Accuracy

An ideal multiplier would have an output of XY/10 volts, where X and Y are two input voltages ranging between ±10Vdc. Since the Model 550 has a full-scale output of ±10Vdc and a specified accuracy at 25°C of ±0.50%, the output must be within ±50mV of the ideal XY/10 volt output for any combination of X and Y. This total error limit of ±50mV includes output offset, input offsets, gain, and nonlinearity. For critical applications, the output offset, input offsets, and gain can be externally trimmed. The nonlinearity is a maximum of ±0.2% with X of ±10V and sweeping Y through ±10V, or with Y of ±10V and sweeping X through its range of ±10V. Also, the nonlinearity with X=0 or Y=0 is less than ±0.2% of full-scale. Since the linear error terms may be trimmed externally, the ±0.2% nonlinearity is the final limit on accuracy. The initial, untrimmed output offset will be less than ±15mV. The total error is given by:

$$\text{Error} = \underbrace{E_{OS}}_{\text{OUTPUT OFFSET}} + \underbrace{\epsilon_X Y + \epsilon_Y X}_{\text{INPUT OFFSET}} + \underbrace{K\frac{XY}{10}}_{\text{GAIN ERROR}} + \underbrace{f(X,Y)}_{\text{NON-LINEARITY}}$$

With the 550 multiplier, trimming E_{OS}, ϵ_X, and ϵ_Y to zero will generally reduce the error to less than ±0.2%.

Drift

Each of the error components (output offset, input offsets, and nonlinearity) change with temperature. Total error drift for the 550 is a maximum of ±0.04%/°C (or ±4mV/°C) from -25°C to +85°C. Output offset drift is less than ±1mV/°C from -25°C to +85°C. In conventional transconductance multipliers, the nonlinearity drift is usually very large. A new circuit technique was developed by FMI to compensate for drift in nonlinearity. The result is a remarkably low total drift that is typically better than ±0.02%/°C, and is guaranteed to be less than ±0.04%/°C.

Frequency Response

The accuracy is better than ±0.5% at low frequency but degrades with increasing signal frequency. The "small-signal frequency response" is measured with DC on either the X or Y input and with a small AC signal on the other input. The -3dB small-signal response is 3dB—down in amplitude from its ideal value. Small-signal amplitude error is a more meaningful spec—this is the frequency at which the amplitude error exceeds ±1%. A typical curve of amplitude error-versus-frequency is shown in Figure 3 for a full-scale sine wave. Vector error is found by directly subtracting the output from the input, so it is very dependent on phase-shift from input to output.

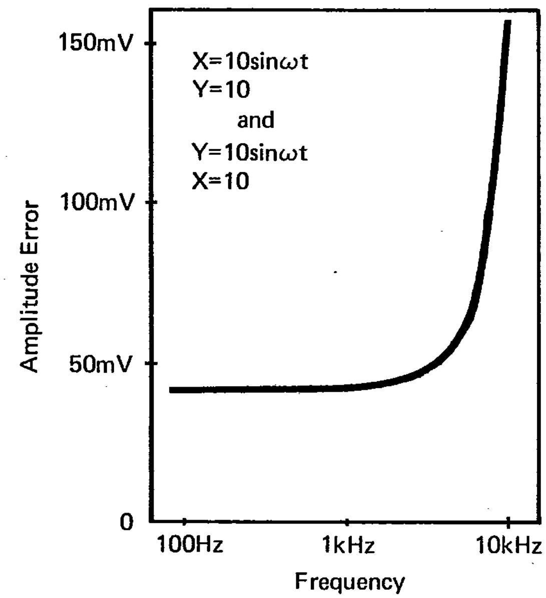


Figure 3. Amplitude Error vs. Frequency

AC null suppression is a critical factor in modulator applications. This is also referred to as "feedthrough." It is measured with zero on one input and a full-scale AC signal of 20V peak-to-peak on the other input. The output should be zero, but a small amount of the AC input will show up at the output. AC feedthrough depends on the input offsets, the nonlinearity around zero, and input-signal frequency. The input offset may be externally trimmed to minimize AC feedthrough, but at low frequencies it will always be less than 40mV peak-to-peak for the Model 550. Typical curves of AC feedthrough are shown below.

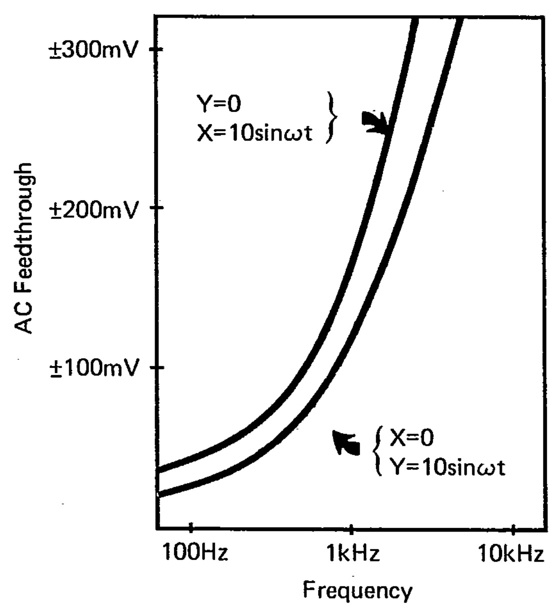


Figure 4. AC Feedthrough vs. Frequency

OPERATION

Multiply Mode

For multiplication, connect pin Z to OUT, as shown on page 2, and apply the inputs to pins X and Y. External trimming is usually not needed, but the unit has provisions for trimming all linear components of error if desired.

Output Offset: To adjust the output offset, make both X and Y zero. Then connect a 50kΩ potentiometer between ±15V, connect the wiper to pin OUT_{BAL}, and adjust for zero at pin OUT. Adjustment range is ±40mV.

Input Offset: To minimize AC feed-through with X=0 and Y=10sinωt, connect a 50kΩ potentiometer between ±15V; connect the wiper to pin X_{BAL}, and adjust for minimum output at pin OUT. Reverse the input connections to adjust Y_{BAL}. Range of adjustment is about ±30mV.

Gain Adjustment: First add a 2MΩ resistor between pins SJ and Z to lower the gain, then add a 20kΩ potentiometer between pins Z and OUT as shown below:

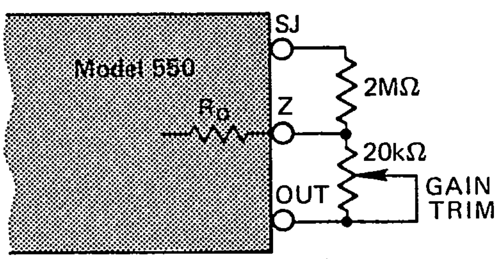


Figure 5. Optional Gain Trimming

This provides a ±6% range of adjustment.

Divide-Mode

For use as a divider, the 550 is connected as shown in Figure 6. The internal op amp will make Z/R_O equal to $XE_O/10R_O$, so the output E_O will be 10Z/X. There are two restrictions. . .

- The ratio of Z/X must be less than unity.
- The denominator X must be a negative voltage. Therefore, the output will be negative when the numerator Z is positive.

Error in divide-mode becomes greater as the denominator becomes smaller. With a multiplier error of ϵ_m, the output in divide-mode will be:

$$E_O = \frac{10Z}{X} - \boxed{\frac{10}{X}\epsilon_m \quad \text{Error in Divide-Mode}}$$

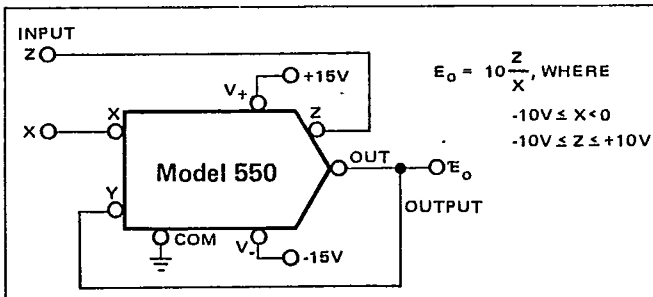


Figure 6. Connections for Divide-Mode

So the error in divide-mode is ±0.50% of full-scale (±50mV) when the denominator is at -10V, but becomes larger as X becomes smaller. Also, the bandwidth is reduced as the denominator becomes smaller. The -3dB bandwidth is approximately 100kHz with X of -10V, and 40kHz with X of -5V.

To externally trim error, first connect the unit in multiply-mode and trim the unit as a multiplier, then connect to divide. If gain is trimmed, the 20kΩ gain trim pot should be in series with the Z-input.

Square-Root Mode

Square-rooting is accomplished by putting the multiplier into a feedback loop as shown in Figure 7.

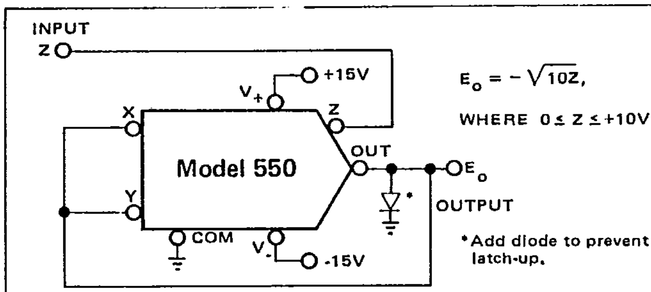


Figure 7. Connections for Square-Root Mode

The input signal must be positive, and as a practical matter must be limited in dynamic range. The error in square-root mode becomes greater as the input signal becomes smaller. With a multiplier error of ϵ_m, the output will be:

$$E_O = \sqrt{10Z - \boxed{10\epsilon_m \text{ Error Term}}}$$

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