

4454/4455 4456/4457

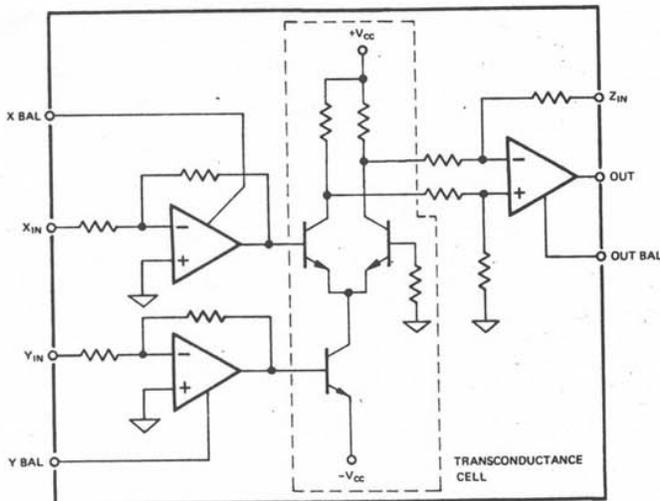
ACCURATE, FAST MULTIPLY-DIVIDE-SQUARE, SQUARE ROOT OPERATORS

Philbrick Models 4454, 4455, 4456, and 4457 variable transconductance multiplier/dividers achieve high performance without external amplifiers or trimming networks. Models 4454 and 4455 are high accuracy units featuring a maximum full scale error (untrimmed) of 0.5% and 0.25% respectively. Models 4456 and 4457 are high speed units providing 5 MHz (minimum) bandwidth with a maximum untrimmed full scale error of 1% and 0.5% respectively. For all models the maximum error is specified for all four quadrants in the multiplication mode.

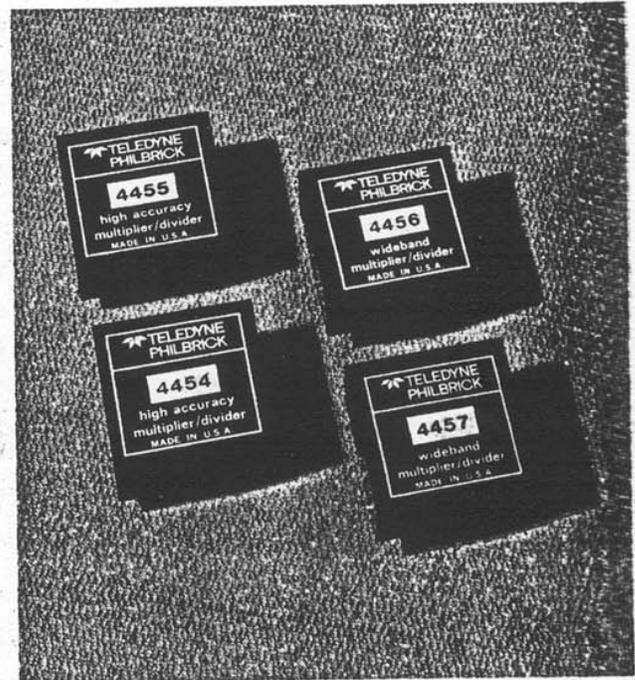
In combination with their high initial accuracy, these multipliers exhibit exceptionally low temperature drift to keep a low total error budget. For the most demanding applications these units can be externally trimmed for feedthrough and offset.

THEORY OF OPERATION

The variable transconductance multiplier is based on the principle that the gain of a differential amplifier can be controlled by varying its emitter currents. Transconductance is defined as the change in I_C (between the two transistors) as a function of ΔV_{BE} . Since transconductance is linearly proportional to collector current, and hence emitter current (assuming constant β), varying the emitter currents (by a voltage controlled current source) directly controls the gain of the differential stage. Therefore, if we let the X input of the multiplier vary the ΔV_{BE} and the Y input vary the collector current, the output of the differential amplifier will be proportional to $I_C \cdot \Delta E_{in}$, or $X \cdot Y$.



Equivalent Circuit for Models 4454, 4455, 4456, and 4457



FEATURES

- 0.25% Accuracy Maximum (4455)
- 5 MHz Min. Bandwidth (4456, 4457)
- 10 mA Output Current (4456, 4457)
- 4 Quadrant Multiplication
- 2 Quadrant Division
- No Trimming Required

APPLICATIONS

- Automatic Gain Control
- Measurement of Power
- Modulators
- Demodulators
- Phase Measurement
- Voltage Controlled Oscillators
- DC to Synchro Conversion
- Voltage Controlled Filters

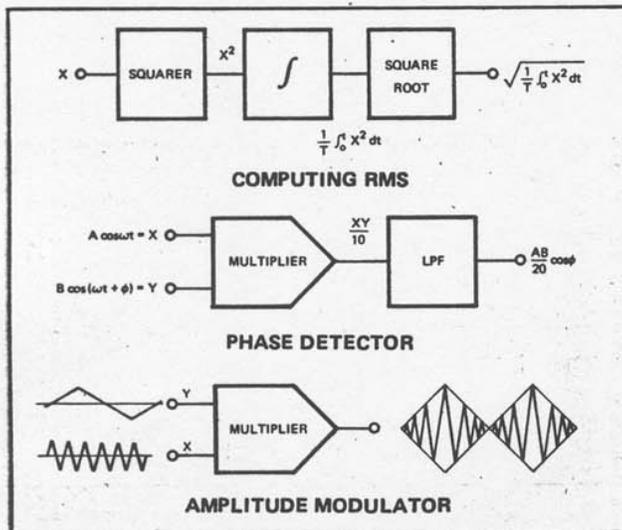
APPLICATIONS

In addition to their use in solving both implicit and explicit equations, multipliers are commonly used in signal averaging circuits. Shown below is a circuit for computing rms. In general, the critical design decisions are the integrator time-constant, and the bandwidth and dynamic limitation of the squarer circuit. The square-root of the sum of the squares

$\sqrt{X^2 + Y^2}$ can easily be computed with two squarer circuits, an op amp, and a square-root circuit.

Instantaneous power can be measured as the voltage across the load times a voltage proportional to the current through the load. This can then be converted to rms power with the above described rms circuit. If reactance power is being measured, the double-frequency component can be filtered out with a low pass filter after the multiplier. This technique is also used in phase detection.

A multiplier is commonly used as an Amplitude Modulator. In general, the higher of the two frequencies (carrier) is connected to the X input with the modulating signal connected to the Y input.



MULTIPLIER AND SQUARER MODE

Operation in these two modes is essentially the same and straightforward. A major consideration, however, should be the error caused by increased feedthrough and phase shift at higher frequencies. This is given as the 1% feedthrough and 1% vector error, respectively, which are listed under the specifications. Gain (or amplitude error) is also specified at the 1% error frequency. Therefore, it is important to realize that multipliers deviate from their rated accuracy prior to the (-3 dB) frequency, depending upon which parameter is the most critical in the application. It is also important to note that a multiplier, connected as a squarer, needs to accommodate twice the highest frequency component of the input signal.

DIVIDE MODE

When used as a divider, transconductance multipliers operate in two quadrants only. The voltage applied to the X terminal is the denominator and must be of negative polarity. As the denominator approaches 0V, the bandwidth decreases, i.e.

$$(-3 \text{ dB B.W.})_{\text{divider}} = \frac{X}{10} (-3 \text{ dB B.W.})_{\text{multiplier}}$$

Also, for small input signals the output error will rapidly increase. However, with external trimming a typical error of 1% is obtainable with an input as low as -1V. Therefore, in choosing operating ranges avoid, in-so-far-as possible, low values of denominator; always scale the problem so that the full scale voltage actually needed in the denominator is at least -7 volts.

SQUARE-ROOT MODE

External trimming is highly recommended for this mode, and a diode should be placed in series with the output to prevent latch-up. Without this diode, any small negative voltage applied to the Z input can cause a positive feedback condition which will saturate the output until power is removed. It is also important to realize that the AC small signal bandwidth is presented as:

$$(-3 \text{ dB B.W.})_{\text{square-root}} = \sqrt{\frac{Z}{10}} (-3 \text{ dB B.W.})_{\text{multiplier}}$$

OPTIONAL GAIN TRIM PROCEDURE

The gain through the three channels X, Y, and Z will be decreased by adding resistance in series. The approximate values in ohms which will produce a 0.1% change are:

	X	Y	Z
4454/4455	25	25	50
4456/4457	10	10	15

Small "cermet" element trim pots or equivalent are adequate. Rarely will it be necessary to trim more than two of the channels, and one channel will usually satisfy a critical application.

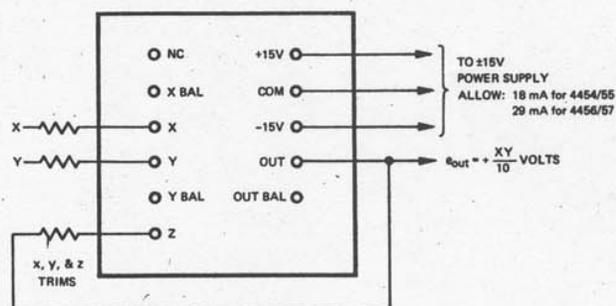
It is important to understand that any channel connected to the output is being used in the feedback loop of the operational amplifier. Therefore, decreasing this channel gain will increase the overall gain.

By applying the input voltages of the four combinations, i.e.

- 1) X = +10 V Y = +10 V } $e_{\text{out}} = +10 \text{ V}$
- 2) X = -10 V Y = -10 V } $e_{\text{out}} = +10 \text{ V}$
- 3) X = -10 V Y = +10 V } $e_{\text{out}} = -10 \text{ V}$
- 4) X = +10 V Y = -10 V } $e_{\text{out}} = -10 \text{ V}$

adjust the series resistance for the best compromise to 10V out for the conditions 1 and 2 and to -10V out for conditions 3 and 4, when used as a multiplier.

A reduction in nonlinear errors (often better than a factor of 2) can generally be obtained by setting full scale at 7 to 8 volts, or so, and trimming for these resulting voltages instead of for 10 volts.



Optional Gain Trim Circuit