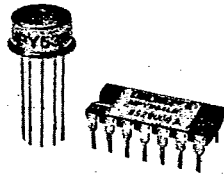


T-73-29



MPY534

MILITARY & DIE VERSIONS AVAILABLE

Precision ANALOG MULTIPLIER

FEATURES

- ±0.25% MAX 4-QUADRANT ERROR
- WIDE BANDWIDTH: 1MHz MIN, 3MHz TYP
- ADJUSTABLE SCALE FACTOR: GAINS TO 100
- STABLE AND RELIABLE MONOLITHIC CONSTRUCTION
- LOW COST

APPLICATIONS

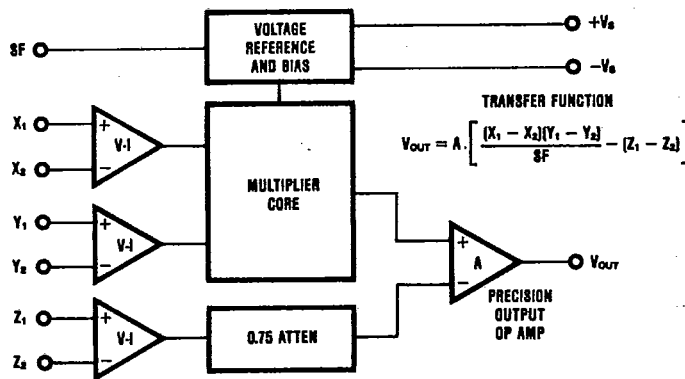
- PRECISION ANALOG SIGNAL PROCESSING
- VIDEO SIGNAL PROCESSING
- VOLTAGE CONTROLLED FILTERS AND OSCILLATORS
- MODULATION AND DEMODULATION
- RATIO AND PERCENTAGE COMPUTATION

DESCRIPTION

The MPY534 is a high accuracy, general purpose four-quadrant analog multiplier. Its accurately laser trimmed transfer characteristics make it easy to use in a wide variety of applications with a minimum of external parts and trimming circuitry. Its differential X, Y and Z inputs allow configuration as a multiplier, squarer, divider, square-rooter and other functions while maintaining high accuracy.

The wide bandwidth of this new design allows accurate signal processing at higher frequencies suitable for video signal processing. It is capable of performing IF and RF frequency mixing, modulation and demodulation with excellent carrier rejection and very simple feedthrough adjustment.

An accurate internal voltage reference provides precise setting of the scale factor. The differential Z input allows user selected scale factors from 0.1 to 10 using external feedback resistors.



International Airport Industrial Park - P.O. Box 11400 - Tucson, Arizona 85734 - Tel: (602) 746-1111 - Twx: 910-952-1111 - Cable: BBRCORP - Telex: 66-6491

PDS-614B

SPECIFICATIONS

ELECTRICAL

At $T_A = +25^\circ\text{C}$ and $V_S = \pm 15\text{VDC}$ unless otherwise specified.

| MODEL | MPY534J | | | MPY534K | | | MPY534L | | | MPY534S | | | MPY534T | | | UNITS |
|---|---------|-----|-----|--------------------------------|-----|-----|---|-----|-----|---------|-----|-----|---------|-----|-----|--------|
| | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| MULTIPLIER | | | | | | | | | | | | | | | | |
| PERFORMANCE | | | | | | | | | | | | | | | | |
| Transfer Function | | | | | | | | | | | | | | | | |
| | | | | $(X_1 - X_2)(Y_1 - Y_2) + Z_2$ | | | | | | | | | | | | |
| | | | | 10V | | | | | | | | | | | | |
| Total Error ⁽¹⁾ | | | | ±1.0 | | | ±0.5 | | | ±0.25 | | | ±1.0 | | | % |
| (-10V ≤ X, Y ≤ +10V) | | | | | | | | | | | | | ±2.0 | | | % |
| T _A = min to max | | | | ±1.5 | | | ±1.0 | | | ±0.5 | | | ±1.0 | | | % |
| Total Error vs Temperature | | | | ±0.022 | | | ±0.015 | | | ±0.008 | | | ±0.02 | | | %/°C |
| Scale Factor Error | | | | | | | | | | | | | | | | % |
| (SF = 10.000V Nominal) ⁽²⁾ | | | | ±0.25 | | | ±0.1 | | | . | | | ±0.25 | | | % |
| Temperature Coefficient of Scaling Voltage | | | | ±0.02 | | | ±0.01 | | | ±0.005 | | | ±0.02 | | | %/°C |
| Supply Rejection (±15V ±1V) | | | | | | | | | | | | | | | | % |
| Nonlinearity: | | | | | | | | | | | | | | | | % |
| X (X = 20V pk-pk, Y = 10V) | | | | ±0.4 | | | ±0.2 | | | ±0.10 | | | ±0.12 | | | % |
| Y (Y = 20V pk-pk, X = 10V) | | | | | | | ±0.01 | | | ±0.005 | | | | | | % |
| Feedthrough ⁽³⁾ | | | | | | | | | | | | | | | | % |
| X (Y Nulled, Y = 20V pk-pk, 50Hz) | | | | ±0.3 | | | ±0.15 | | | ±0.05 | | | ±0.12 | | | % |
| Y (X Nulled, Y = 20V pk-pk, 50Hz) | | | | | | | ±0.01 | | | ±0.003 | | | | | | % |
| Output Offset Voltage | | | | ±5 | | | ±2 | | | ±10 | | | ±5 | | | mV |
| Output Offset Voltage Drift | | | | 200 | | | 100 | | | | | | ±30 | | | μV/°C |
| | | | | | | | | | | 500 | | | 300 | | | |
| DYNAMICS | | | | | | | | | | | | | | | | |
| Small Signal BW, (V _{OUT} = 0.1V rms) | | | | | | | | | | | | | | | | |
| | | | | 1 | | | 3 | | | | | | | | | MHz |
| 1% Amplitude Error (C _{LOAD} = 1000pF) | | | | | | | | | | | | | | | | |
| | | | | | | | 50 | | | | | | | | | kHz |
| Slew Rate (V _{OUT} = 20V pk-pk) | | | | | | | | | | | | | | | | |
| | | | | | | | 20 | | | | | | | | | V/μs |
| Settling Time (to 1%, ΔV _{OUT} = 20V) | | | | | | | | | | | | | | | | |
| | | | | | | | 2 | | | | | | | | | μs |
| NOISE | | | | | | | | | | | | | | | | |
| Noise Spectral Density: SF = 10V | | | | | | | | | | | | | | | | |
| | | | | | | | 0.8 | | | | | | | | | μV/√Hz |
| Wideband Noise: f = 10Hz to 5MHz | | | | | | | | | | | | | | | | |
| | | | | | | | 1 | | | | | | | | | mVrms |
| f = 10Hz to 10kHz | | | | | | | | | | | | | | | | |
| | | | | | | | 90 | | | | | | | | | μVrms |
| OUTPUT | | | | | | | | | | | | | | | | |
| Output Voltage Swing | | | | | | | | | | | | | | | | |
| | | | | ±11 | | | | | | | | | | | | V |
| Output Impedance (f ≤ 1kHz) | | | | | | | | | | | | | | | | |
| | | | | 0.1 | | | | | | | | | | | | Ω |
| Output Short Circuit Current (R _L = 0, T _A = min to max) | | | | | | | | | | | | | | | | |
| | | | | 30 | | | | | | | | | | | | mA |
| Amplifier Open Loop Gain (f = 50Hz) | | | | | | | | | | | | | | | | |
| | | | | 70 | | | | | | | | | | | | dB |
| INPUT AMPLIFIERS (X, Y and Z) | | | | | | | | | | | | | | | | |
| Input Voltage Range Differential V _{IN} (V _{CM} = 0) | | | | | | | | | | | | | | | | |
| | | | | | | | ±12 | | | | | | | | | V |
| Common-Mode V _{IN} (V _{OFF} = 0) (see Typical Performance Curves) | | | | | | | | | | | | | | | | |
| | | | | | | | ±10 | | | | | | | | | V |
| Offset Voltage X, Y | | | | | | | | | | | | | | | | |
| | | | | ±5 | | | ±20 | | | | | | ±5 | | | mV |
| Offset Voltage Drift X, Y | | | | | | | | | | | | | | | | |
| | | | | 100 | | | 50 | | | | | | 100 | | | μV/°C |
| Offset Voltage Z | | | | | | | | | | | | | | | | |
| | | | | ±5 | | | ±30 | | | ±10 | | | ±30 | | | mV |
| Offset Voltage Drift Z | | | | | | | | | | | | | | | | |
| | | | | 200 | | | 100 | | | | | | 500 | | | μV/°C |
| CMRR | | | | | | | | | | | | | | | | |
| 60 | | | | 80 | | | 70 | | | 60 | | | 80 | | | dB |
| Bias Current | | | | | | | | | | | | | | | | |
| | | | | | | | 0.8 | | | 2.0 | | | | | | μA |
| Offset Current | | | | | | | | | | | | | | | | |
| | | | | | | | 0.1 | | | 0.05 | | | 2.0 | | | μA |
| Differential Resistance | | | | | | | | | | | | | | | | |
| | | | | | | | 10 | | | | | | | | | MΩ |
| DIVIDER PERFORMANCE | | | | | | | | | | | | | | | | |
| Transfer Function (X ₁ > X ₂) | | | | | | | | | | | | | | | | |
| | | | | | | | $10V \frac{(Z_2 - Z_1)}{(X_1 - X_2)} + Y_1$ | | | | | | | | | |
| Total Error ⁽¹⁾ (X = 10V, -10V ≤ Z ≤ +10V) | | | | | | | | | | | | | | | | |
| | | | | ±0.75 | | | ±0.35 | | | ±0.2 | | | ±0.75 | | | % |
| (X = 1V, -1V ≤ Z ≤ +1V) | | | | | | | | | | | | | | | | |
| | | | | ±2.0 | | | ±1.0 | | | ±0.8 | | | ±2.0 | | | % |
| (0.1V ≤ X ≤ 10V, -10V ≤ Z ≤ 10V) | | | | | | | | | | | | | | | | |
| | | | | ±2.5 | | | ±1.0 | | | ±0.8 | | | ±2.5 | | | % |

*Specifications same as for MPY534K.

MPY534

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ANALOG CIRCUIT FUNCTIONS

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ELECTRICAL (CONT)

At $T_A = +25^\circ\text{C}$ and $V_S = \pm 15\text{VDC}$ unless otherwise specified.

| MODEL | MPY534J | | | MPY534K | | | MPY534L | | | MPY534S | | | MPY534T | | | UNITS |
|---|---------|-----------|-----|-----------------------------------|----------|----------|---------|-----|------------|---------|-----|-----------|---------|-----------|----------|------------------|
| | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| SQUARE PERFORMANCE | | | | | | | | | | | | | | | | |
| Transfer Function | | * | | $\frac{(X_1 - X_0)^2}{10V} + Z_2$ | | | | | | | * | | | * | | |
| Total Error ($-10V \leq X \leq 10V$) | | 0.6 | | ± 0.3 | | | | | ± 0.2 | | | ± 0.6 | | * | | % |
| SQUARE-ROOTER PERFORMANCE | | | | | | | | | | | | | | | | |
| Transfer Function ($Z_1 \leq Z_2$) | | * | | $\sqrt{10V(Z_2 - Z_1)} + X_2$ | | | | | | | * | | | * | | |
| Total Error ⁽¹⁾ ($1V \leq Z \leq 10V$) | | ± 1.0 | | ± 0.5 | | | | | ± 0.25 | | | ± 1.0 | | ± 0.5 | | % |
| POWER SUPPLY | | | | | | | | | | | | | | | | |
| Supply Voltage: | | | | | | | | | | | | | | | | |
| Rated Performance | | * | * | | ± 15 | | | * | * | * | * | | * | * | | VDC |
| Operating | * | * | * | ± 8 | 4 | ± 18 | * | * | * | * | * | ± 20 | * | * | ± 20 | VDC |
| Supply Current, Quiescent | * | * | * | | 4 | 6 | * | * | * | * | * | | * | * | | mA |
| TEMPERATURE RANGE | | | | | | | | | | | | | | | | |
| Operating | * | * | * | 0 | | +70 | * | * | * | -55 | * | +125 | -55 | * | +125 | $^\circ\text{C}$ |
| Storage | * | * | * | -65 | | +150 | * | * | * | * | * | | * | * | | $^\circ\text{C}$ |

*Specification same as for MPY534K.

NOTES: (1) Figures given are percent of full scale, $\pm 10V$ (i.e., $0.01\% = 1mV$). (2) May be reduced to 3V using external resistor between $-V_S$ and SF. (3) Irreducible component due to nonlinearity; excludes effect of offsets.

ABSOLUTE MAXIMUM RATINGS

| Parameter | MPY534J, K, L | MPY534S, T |
|----------------------------------|---|---|
| Power Supply Voltage | ± 18 | ± 20 |
| Power Dissipation | 500mW | * |
| Output Short-Circuit to Ground | Indefinite | * |
| Input Voltage (all X, Y and Z) | $\pm V_S$ | * |
| Operating Temperature Range | 0°C to -70°C | -55°C to -125°C |
| Storage Temperature Range | -65°C to -150°C | * |
| Lead Temperature (10s soldering) | 300°C | * |

*Specification same as for MPY534K.

MECHANICAL

NOTE:
Leads in true position within $.010"$ ($.25\text{mm}$) R at MMT at seating plane.
Pin numbers shown for reference only. Numbers may not be marked on package.

| DIM | INCHES | | MILLIMETERS | |
|-----|------------|------------------|-------------|------------------|
| | MIN | MAX | MIN | MAX |
| A | .335 | .370 | 8.51 | 9.40 |
| B | .305 | .335 | 7.75 | 8.51 |
| C | .185 | .185 | 4.19 | 4.70 |
| D | .016 | .021 | 0.41 | 0.53 |
| E | .010 | .040 | 0.25 | 1.02 |
| F | .010 | .040 | 0.25 | 1.02 |
| G | .230 BASIC | | 5.84 BASIC | |
| H | .028 | .034 | 0.71 | 0.86 |
| J | .025 | .045 | 0.74 | 1.14 |
| K | .500 | --- | 12.70 | --- |
| L | .120 | .160 | 3.05 | 4.06 |
| M | --- | 36° BASIC | --- | 36° BASIC |
| N | .110 | .120 | 2.79 | 3.05 |

NOTE:
Leads in true position within $.010"$ ($.25\text{mm}$) R at MMT at seating plane.
Pin numbers shown for reference only. Numbers may not be marked on package.

| DIM | INCHES | | MILLIMETERS | |
|-----|------------|------------|-------------|------------|
| | MIN | MAX | MIN | MAX |
| A | .570 | .710 | 17.02 | 18.03 |
| C | .065 | .170 | 1.65 | 4.32 |
| D | .015 | .021 | 0.38 | 0.53 |
| F | .045 | .060 | 1.14 | 1.52 |
| G | .100 BASIC | | 2.54 BASIC | |
| H | .025 | .070 | 0.64 | 1.78 |
| J | .008 | .012 | 0.20 | 0.30 |
| K | .120 | .240 | 3.05 | 6.10 |
| L | .300 BASIC | | 7.62 BASIC | |
| M | --- | 10° | --- | 10° |
| N | .009 | .060 | 0.23 | 1.52 |

MPY534**

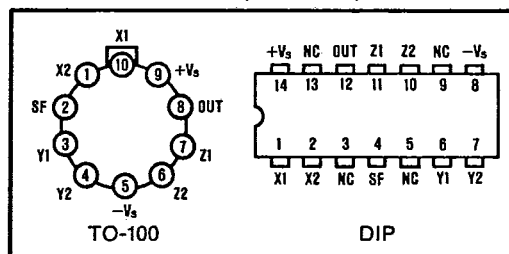
Grade Designation _____

J }
K } 0 to 70°C
L }
S }
T } -55 to 125°C

Package Designation _____

H = TO-100
D = DIP

PIN CONFIGURATION (TOP VIEW)

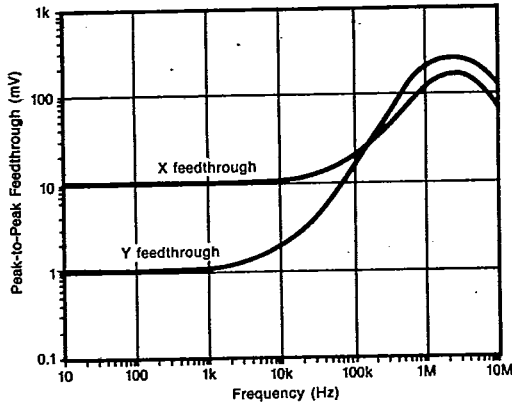


T-73-29

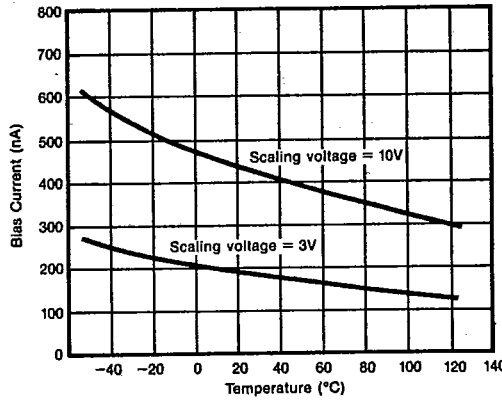
TYPICAL PERFORMANCE CURVES

$T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{VDC}$ unless otherwise noted.

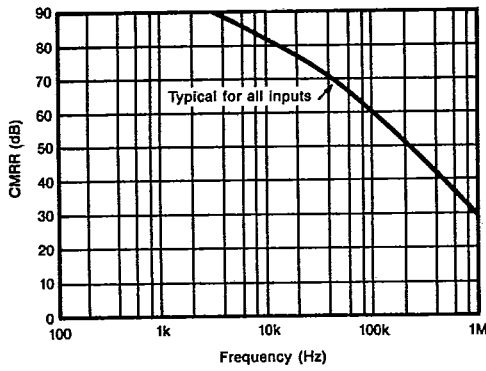
AC FEEDTHROUGH VS FREQUENCY



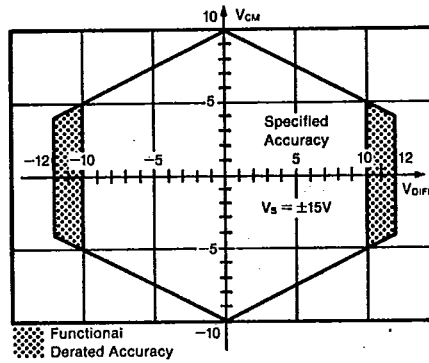
BIAS CURRENTS VS TEMPERATURE
(X, Y or Z inputs)



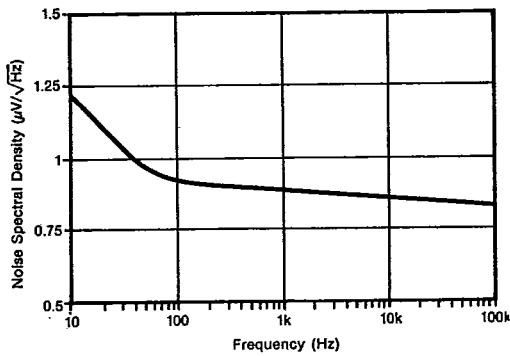
COMMON-MODE-REJECTION RATIO VS FREQUENCY



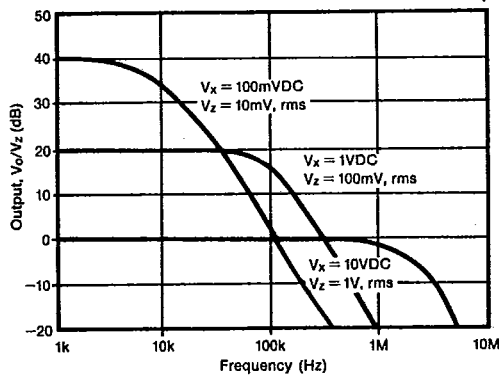
INPUT DIFFERENTIAL-MODE/COMMON-MODE VOLTAGE



NOISE SPECTRAL DENSITY VS FREQUENCY



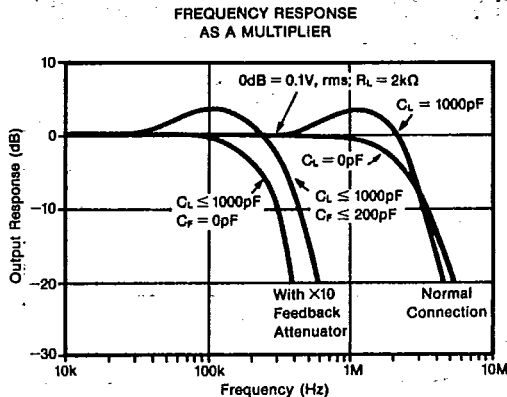
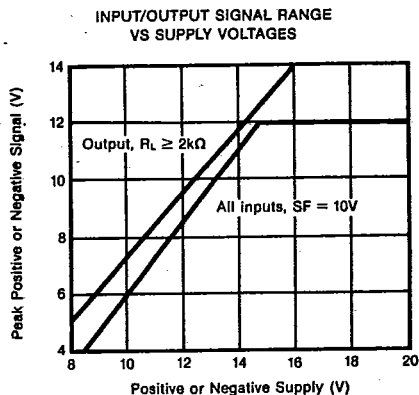
FREQUENCY RESPONSE VS DIVIDER DENOMINATOR INPUT VOLTAGE



MPY534

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ANALOG CIRCUIT FUNCTIONS



THEORY OF OPERATION

The transfer function for the MPY534 is:

$$V_{OUT} = A \left[\frac{(X_1 - X_2)(Y_1 - Y_2)}{SF} - (Z_1 - Z_2) \right]$$

where:

A = Open-loop gain of the output amplifier (Typically 85dB at DC).

SF = Scale Factor. Laser-trimmed to 10V but adjustable over a 3V to 10V range using external resistor.

X, Y, Z are input voltages. Full-scale input voltage is equal to the selected SF. (Max input voltage = ±1.25 SF.)

An intuitive understanding of transfer function can be gained by analogy to an op amp. By assuming that the open-loop gain, A, of the output amplifier is infinite, inspection of the transfer function reveals that any V_{OUT} can be created with an infinitesimally small quantity within the brackets. Then, an application circuit can be analyzed by assigning circuit voltages for all X, Y and Z inputs and setting the bracketed quantity equal to zero. For example, the basic multiplier connection in Figure 1, $Z_1 = V_{OUT}$ and $Z_2 = 0$. The quantity within the brackets then reduces to:

$$\frac{(X_1 - X_2)(Y_1 - Y_2)}{SF} - (V_{OUT} - 0) = 0$$

This approach leads to a simple relationship which can be solved for V_{OUT} .

The scale factor is accurately factory-adjusted to 10V and is typically accurate to within 0.1% or less. The scale factor may be adjusted by connecting a resistor or potentiometer between pin SF and the $-V_S$ power supply. The value of the external resistor can be approximated by:

$$R_{SF} = 5.4k\Omega \left[\frac{SF}{10 - SF} \right]$$

Internal device tolerances make this relationship accurate to within approximately 25%. Some applications can benefit from reduction of the SF by this technique. The reduced input bias current and drift achieved by

this technique can be likened to operating the input circuitry in a higher gain, thus reducing output contributions to these effects. Adjustment of the scale factor does not affect bandwidth.

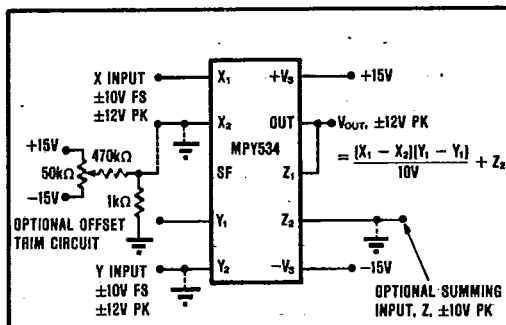


FIGURE 1. Basic Multiplier Connection.

The MPY534 is fully characterized at $V_S = \pm 15V$ but operation is possible down to $\pm 8V$ with an attendant reduction of input and output range capability. Operation at voltages greater than $\pm 15V$ allows greater output swing to be achieved by using an output feedback attenuator (Figure 2).

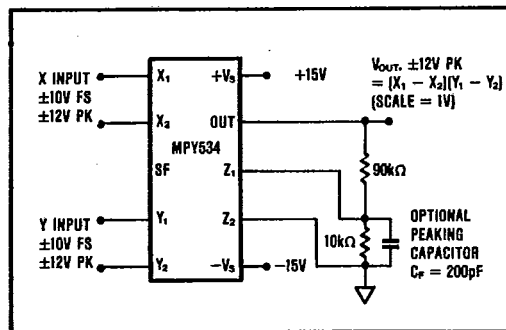


FIGURE 2. Connections for Scale-Factor of Unity.

BASIC MULTIPLIER CONNECTION

Figure 1 shows the basic connection as a multiplier. Accuracy is fully specified without any additional user trimming circuitry. Some applications can benefit from trimming one or more of the inputs. The fully differential inputs facilitate referencing the input quantities to the source voltage common terminal for maximum accuracy. They also allow use of simple offset voltage trimming circuitry as shown on the X input.

The differential Z input allows an offset to be summed in V_{OUT} . In basic multiplier operation the Z_2 input serves as the output voltage reference and should be connected to the ground reference of the driven system for maximum accuracy.

A method of changing (lowering) SF by connecting to the SF pin was discussed previously. Figure 2 shows another method of changing the effective SF of the overall circuit using an attenuator in the feedback connection to Z_1 . This method puts the output amplifier in a higher gain and is thus accompanied by a reduction in bandwidth and an increase in output offset voltage. The larger output offset may be reduced by applying a trimming voltage to the high impedance input, Z_2 .

The flexibility of the differential Z inputs allows direct conversion of the output quantity to a current. Figure 3 shows the output voltage differentially-sensed across a series resistor forcing an output-controlled current. Addition of a capacitor load then creates a time integration function useful in a variety of applications such as power computation.

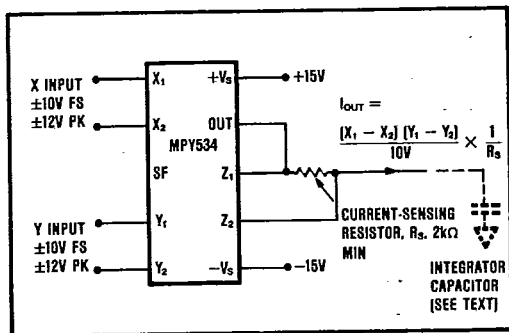


FIGURE 3. Conversion of Output to Current.

SQUARER CIRCUIT

Squarer operation is achieved by paralleling the X and Y inputs of the standard multiplier circuit. Inverted output can be achieved by reversing the differential input terminals of either the X or Y input. Accuracy in the squaring mode is typically a factor of two better than the specified multiplier mode with maximum error occurring with small (less than 1V) inputs. Better accuracy can be achieved for small input voltage levels by using a reduced SF value.

DIVIDER OPERATION

The MPY534 can be configured as a divider as shown in

Figure 4. High impedance differential inputs for the numerator and denominator are achieved at the Z and X inputs respectively. Feedback is applied to the Y_2 input, and Y_1 is normally referenced to output ground. Alternatively, as the transfer function implies, an input applied to Y_1 can be summed directly into V_{OUT} . Since the feedback connection is made to a multiplying input, the effective gain of the output op amp varies as a function of the denominator input voltage. Therefore the bandwidth of the divider function is proportional to the denominator voltage (see Typical Performance Curves).

Accuracy of the divider mode typically ranges from 0.75% to 2.0% for a 10 to 1 denominator range depending on device grade. Accuracy is primarily limited by input offset voltages and can be significantly improved by trimming the offset of the X input. A trim voltage of $\pm 3.5mV$ applied to the "low side" X input (X_2 for positive input voltages on X_1) can produce similar accuracies over a 100 to 1 denominator range. To trim, apply a signal which varies from 100mV to 10V at a low frequency (less than 500Hz) to both inputs. An offset sine wave or ramp is suitable. Since the ratio of the quantities should be constant, the ideal output would be a constant 10V. Using AC coupling on an oscilloscope, adjust the offset control for minimum output voltage variation.

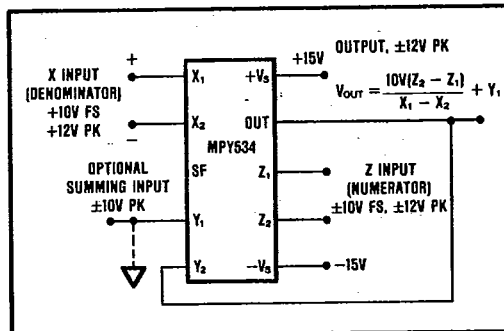


FIGURE 4. Basic Divider Connection.

SQUARE-ROOTER

A square-rooter connection is shown in Figure 5. Input voltage is limited to one polarity (positive for the connection shown). The diode prevents circuit latch-up

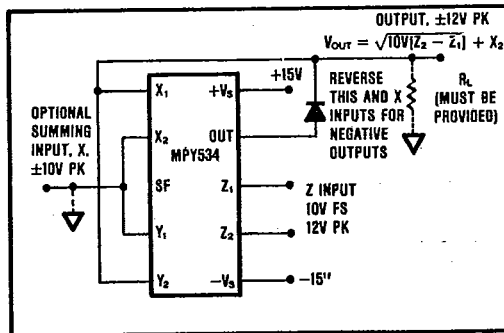


FIGURE 5. Square-Rooter Connection.

MPY534

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ANALOG CIRCUIT FUNCTIONS

should the input go negative. The circuit can be configured for negative input and positive output by reversing the polarity of both the X and Y inputs. The output polarity can be reversed by reversing the diode and X

input polarity. A load resistance of approximately 10kΩ must be provided. Trimming for improved accuracy would be accomplished at the Z input.

APPLICATIONS

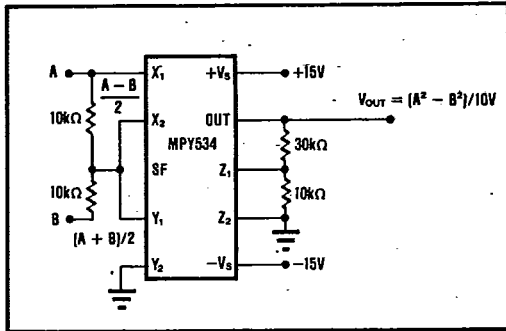


FIGURE 6. Difference-of-Squares.

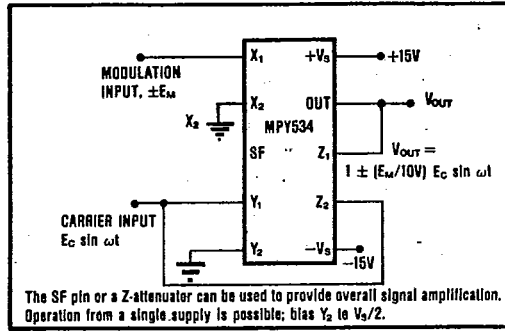


FIGURE 9. Linear AM Modulator.

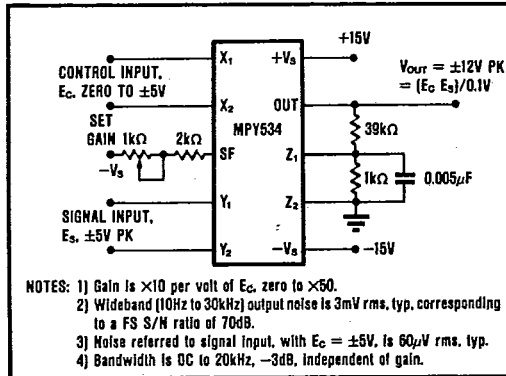


FIGURE 7. Voltage-Controlled Amplifier.

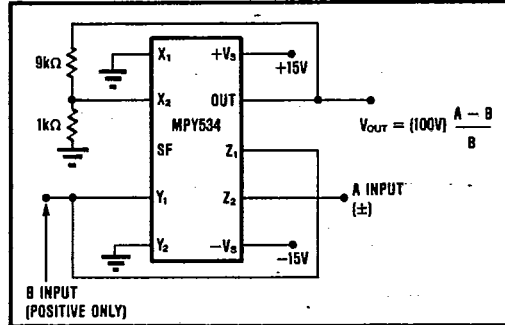


FIGURE 10. Percentage Computer.

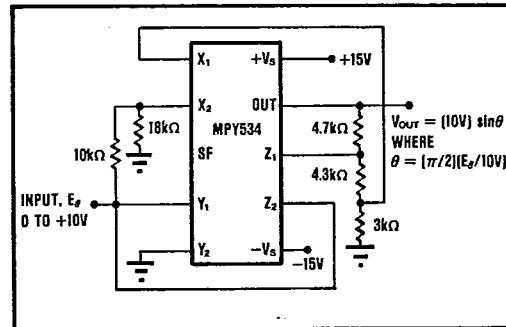


FIGURE 8. Sine-Function Generator.

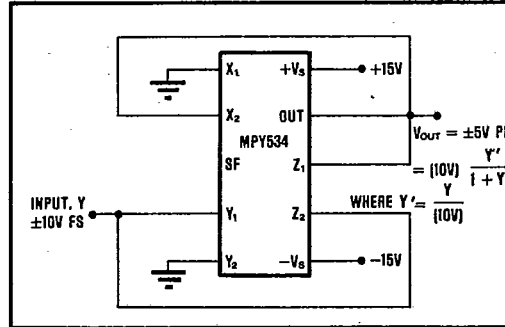


FIGURE 11. Bridge-Linearization Function.