FEATURES

- WIDE BANDWIDTH: 10MHz typ
- ±0.5% MAX FOUR-QUADRANT ACCURACY
- INTERNAL WIDE-BANDWIDTH OP AMP
- EASY TO USE
- LOW COST

APPLICATIONS

- PRECISION ANALOG SIGNAL PROCESSING
- MODULATION AND DEMODULATION
- VOLTAGE-CONTROLLED AMPLIFIERS
- VIDEO SIGNAL PROCESSING
- VOLTAGE-CONTROLLED FILTERS AND OSCILLATORS

DESCRIPTION

The MPY634 is a wide bandwidth, high accuracy, four-quadrant analog multiplier. Its accurately laser-trimmed multiplier characteristics make it easy to use in a wide variety of applications with a minimum of external parts, often eliminating all external trimming. 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 signal processing at IF, RF, and video frequencies. The internal output amplifier of the MPY634 reduces design complexity compared to other high frequency multipliers and balanced modulator circuits. It is capable of performing frequency mixing, balanced modulation, and demodulation with excellent carrier rejection.

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.

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

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### SPECIFICATIONS

#### ELECTRICAL

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

#### MULTIPLIER PERFORMANCE

<table>
<thead>
<tr>
<th>MODEL</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>OBSOLETE</th>
<th>OBSOLETE</th>
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<tbody>
<tr>
<td><strong>PERFORMANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer Function</td>
<td>$(X_i - X_o) (Y_i - Y_o) + Z_2$</td>
<td>$(X_i - X_o) (Y_i - Y_o) + Z_2$</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Error $^1$</td>
<td>$10V$</td>
<td>$10V$</td>
<td>$+2.0$</td>
<td>$+1.0$</td>
<td>$+0.5$</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>$(-10V \leq X, Y \leq +10V)$</td>
<td>$T_A = \text{min to max}$</td>
<td>$\pm2.5$</td>
<td>$\pm1.5$</td>
<td>$\pm1.0$</td>
<td>$\pm2.0$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Total Error vs Temperature</td>
<td>$\pm0.03$</td>
<td>$\pm0.022$</td>
<td>$\pm0.015$</td>
<td>$\pm0.02$</td>
<td>%/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale Factor Error</td>
<td>$\text{SF} = 10.000\text{V Nominal}^2$</td>
<td>$\pm0.25$</td>
<td>$\pm0.1$</td>
<td>*</td>
<td>*</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Temperature Coefficient of Scaling Voltage</td>
<td>$\pm0.01$</td>
<td>$\pm0.01$</td>
<td>*</td>
<td>$\pm0.1$</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>$X (X = 20\text{Vp-p}, Y = 10V)$</td>
<td>$\pm0.4$</td>
<td>$\pm0.4$</td>
<td>$0.2$</td>
<td>$\pm0.3$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>$Y (Y = 20\text{Vp-p}, X = 10V)$</td>
<td>$\pm0.01$</td>
<td>$\pm0.01$</td>
<td>*</td>
<td>$\pm0.1$</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedthrough $^3$</td>
<td>$X (Y \text{Nulled}, X = 20\text{Vp-p}, 50Hz)$</td>
<td>$\pm0.01$</td>
<td>$\pm0.01$</td>
<td>*</td>
<td>$\pm0.1$</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>$Y (X \text{Nulled}, Y = 20\text{Vp-p}, 50Hz)$</td>
<td>Both Inputs (500kHz, 1Vrms)</td>
<td>Unnulled</td>
<td>$40 \quad 50$</td>
<td>$45 \quad 55$</td>
<td>*</td>
<td>$60$</td>
<td>*</td>
</tr>
<tr>
<td>Nulled</td>
<td>$55 \quad 60$</td>
<td>$55 \quad 65$</td>
<td>$60 \quad 70$</td>
<td>*</td>
<td>*</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Output Offset Voltage</td>
<td>$\pm50 \quad \pm100$</td>
<td>$\pm15 \quad \pm30$</td>
<td>*</td>
<td>$\pm1$</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Offset Voltage Drift</td>
<td>$\pm50 \quad \pm100$</td>
<td>$\pm15 \quad \pm30$</td>
<td>*</td>
<td>$\pm15 \quad \pm500$</td>
<td>μV/°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### DYNAMICS

| **SMALL SIGNAL BW,** $(V_{\text{OUT}} = 0.1\text{Vrms})$ | 6 | 10 | 8 | 10 | * | * | 6 | * | MHz |
| **1% Amplitude Error** | $\text{CLOAD} = 1000\text{pF}$ | $\pm0.1$ | $\pm0.1$ | $\pm0.1$ | $\pm0.1$ | kHz |
| **Slew Rate** $(V_{\text{OUT}} = 20\text{Vp-p})$ | $\pm200$ | $\pm200$ | $\pm200$ | $\pm200$ | V/μs |
| **Settling Time** (to 1%, $\Delta V_{\text{OUT}} = 20V$) | $\pm0.2$ | $\pm0.2$ | $\pm0.2$ | $\pm0.2$ | μs |

#### NOISE

| **Noise Spectral Density:** | SF = 10V | $\pm0.8$ | $\pm0.8$ | * | * | * | μV/√Hz |
| **Wideband Noise:** | $f = 10\text{Hz}$ to $5\text{MHz}$ | $1\quad 1$ | * | * | mVrms |
| $f = 10\text{Hz}$ to $10\text{kHz}$ | $90\quad 90$ | * | * | mVrms |

#### OUTPUT

| **Output Voltage Swing** | $\pm11$ | $\pm11$ | * | * | * | * | V |
| **Output Impedance ($f \leq 1\text{kHz}$) | $0.1 \quad 0.1$ | * | * | mΩ |
| **Output Short Circuit Current** | $R_L = 0$, $T_A = \text{min to max}$ | $30 \quad 30$ | * | * | mA |
| **Amplifier Open Loop Gain** | $f = 50\text{Hz}$ | $85 \quad 85$ | * | * | dB |

#### INPUT AMPLIFIERS (X, Y and Z)

| **Input Voltage Range** | $\pm12$ | $\pm12$ | * | * | * | * | V |
| **Differential $V_{\text{IN}}$ ($V_{\text{CM}} = 0$)** | $\pm10$ | $\pm10$ | * | * | V |
| **Common-Mode $V_{\text{IN}}$ ($V_{\text{DIFF}} = 0$)** | (see Typical Performance Curves) | (see Typical Performance Curves) | * | * | * | mV |
| **Offset Voltage X, Y** | $\pm25 \quad \pm100$ | $\pm5 \quad \pm20$ | $\pm2 \quad \pm10$ | * | * | mV |
| **Offset Voltage Drift X, Y** | $200 \quad 100$ | $50 \quad 50$ | * | * | μV/°C |
| **Offset Voltage Z** | $\pm25 \quad \pm100$ | $\pm5 \quad \pm30$ | $\pm2 \quad \pm15$ | * | * | mV |
| **Offset Voltage Drift Z** | $200 \quad 200$ | $100 \quad 100$ | $50 \quad 50$ | * | * | μV/°C |
| **CMRR** | $60 \quad 80$ | $60 \quad 80$ | $70 \quad 90$ | * | * | dB |
| **Bias Current** | $0.8 \quad 2.0$ | $0.8 \quad 2.0$ | * | $\pm0.8 \quad \pm2.0$ | μA |
| **Offset Current** | $0.1 \quad 0.1$ | * | * | * | μA |
| **Differential Resistance** | $10 \quad 10$ | * | * | $\pm0.1 \quad \pm0.1$ | MΩ |

#### DIVIDER PERFORMANCE

| **Transfer Function** $(X_i > X_o)$ | $(Z_i - Z_o) (X_i - X_o) + Y_i$ | $(Z_i - Z_o) (X_i - X_o) + Y_i$ | * | * | * | * | |
| **Total Error** $^1$ untrimmed | $10V$ | $10V$ | $\pm0.75$ | $\pm0.36$ | $\pm0.75$ | % |
| $(X = 10V, -10V \leq X \leq +10V)$ | $X = 1V, -1V \leq Z \leq +1V$ | $4.0 \quad \pm2.0$ | $\pm1.0$ | * | % |
| $(0.1V < X < 10V, -10V \leq Z \leq +10V)$ | $5.0 \quad \pm2.5$ | $\pm1.0$ | * | % |

#### SQUARE PERFORMANCE

| **Transfer Function** $(X - X_o)^2, Z_2$ | $(X - X_o)^2, Z_2$ | * | * | * | % |
| **Total Error** $(-10V \leq X \leq +10V)$ | $10V$ | $10V$ | $\pm1.2$ | $\pm0.6$ | $\pm0.3$ | * | % |
### SPECIFICATIONS (CONT)

#### ELECTRICAL

At $T_A = +25^\circ C$ and $V_S = \pm 15$VDC, unless otherwise noted.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
<td>MIN</td>
<td>TYP</td>
</tr>
<tr>
<td>SQUARE-ROOTER PERFORMANCE</td>
<td>$\sqrt{10V (Z_2 - Z_1)} + X_2$</td>
<td>$\sqrt{10V (Z_2 - Z_1)} + X_2$</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer Function ($Z_1 \leq Z_2$)</td>
<td>$\pm 2.0$</td>
<td>$\pm 1.0$</td>
<td>$\pm 0.5$</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Total Error</td>
<td>$\pm 15$</td>
<td>$\pm 15$</td>
<td>$\pm 15$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td>$\pm 8 \rightarrow +15$</td>
<td>$\pm 8 \rightarrow +15$</td>
<td>$\pm 8 \rightarrow +15$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Voltage: Rated Performance</td>
<td>$4 \rightarrow 6$</td>
<td>$4 \rightarrow 6$</td>
<td>$4 \rightarrow 6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Supply Current, Quiescent</td>
<td>$\pm 8 \rightarrow +15$</td>
<td>$\pm 8 \rightarrow +15$</td>
<td>$\pm 8 \rightarrow +15$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TEMPERATURE RANGE</td>
<td>$-40 \rightarrow +85$</td>
<td>$-40 \rightarrow +85$</td>
<td>$-40 \rightarrow +85$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>$-25 \rightarrow +85$</td>
<td>$-25 \rightarrow +85$</td>
<td>$-25 \rightarrow +85$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>$-65 \rightarrow +150$</td>
<td>$-65 \rightarrow +150$</td>
<td>$-65 \rightarrow +150$</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

* Specification same as for MPY634AM.

Gray indicates obsolete parts.

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

### PIN CONFIGURATIONS

**TO-100:** MPY634AM/BM/SM  **DIP:** MPY634KP  **SOIC:** MPY634KU

### ABSOLUTE MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
<th>MPY634AM/BM</th>
<th>OBSOLETE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>$\pm 15$</td>
<td>$\pm 15$</td>
<td>$\pm 15$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>$500$mW</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Short-Circuit to Ground</td>
<td>Indefinite</td>
<td>Indefinite</td>
<td>Indefinite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage (all X, Y and Z)</td>
<td>$\pm V_S$</td>
<td>$\pm V_S$</td>
<td>$\pm V_S$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Range: Operating</td>
<td>$-25^\circ C$/$+85^\circ C$</td>
<td>$-25^\circ C$/$+85^\circ C$</td>
<td>$-25^\circ C$/$+85^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>$-65^\circ C$/$+150^\circ C$</td>
<td>$-65^\circ C$/$+150^\circ C$</td>
<td>$-65^\circ C$/$+150^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Temperature (soldering, 10s)</td>
<td>$+300^\circ C$</td>
<td>$+300^\circ C$</td>
<td>$+300^\circ C$</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SOIC ‘KU’ Package</td>
<td>$+260^\circ C$</td>
<td>$+260^\circ C$</td>
<td>$+260^\circ C$</td>
<td></td>
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</table>

* Specification same as for MPY634AM/BM.

**NOTE:** Gray indicates obsolete parts.

### ORDERING INFORMATION

<table>
<thead>
<tr>
<th>MPY634</th>
<th>( )</th>
<th>( )</th>
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</thead>
<tbody>
<tr>
<td>Basic Model Number</td>
<td>MPY634</td>
<td></td>
</tr>
<tr>
<td>Performance Grade (1)</td>
<td>MPY634</td>
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</tr>
<tr>
<td>K: $-40^\circ C$ to $+85^\circ C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U: $-8^\circ C$ to $+18^\circ C$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Package Code</td>
<td>P: Plastic 14-pin DIP</td>
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</tr>
<tr>
<td>U: 16-pin SOIC</td>
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</tbody>
</table>

**NOTE:** (1) Performance grade identifier may not be marked on the SOIC package; a blank denotes “K” grade.

### PACKAGE INFORMATION (1)

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PACKAGE</th>
<th>PACKAGE DRAWING NUMBER</th>
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</thead>
<tbody>
<tr>
<td>MPY634KP</td>
<td>14-Pin PDIP</td>
<td>010</td>
</tr>
<tr>
<td>MPY634KU</td>
<td>16-Pin SOIC</td>
<td>211</td>
</tr>
</tbody>
</table>

**NOTE:** (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.
TYPICAL PERFORMANCE CURVES

At $T_A = +25^\circ C$, $V_X = \pm 15$VDC, unless otherwise noted.

**FEEDTHROUGH vs FREQUENCY**

- Feedthrough Attenuation (dB)
- Frequency (Hz)

**FREQUENCY RESPONSE AS A MULTIPLIER**

- Output Response (dB)
- Frequency (Hz)

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

- CMRR (dB)
- Frequency (Hz)

**FEEDTHROUGH vs TEMPERATURE**

- Feedthrough Attenuation (dB)
- Temperature ($^\circ C$)

**NOISE SPECTRAL DENSITY vs FREQUENCY**

- Noise Spectral Density ($\mu$V/$\sqrt{Hz}$)
- Frequency (Hz)

**FREQUENCY RESPONSE AS A DIVIDER**

- Output, $V_0/V_2$ (dB)
- Frequency (Hz)
TYPICAL PERFORMANCE CURVES (CONT)

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

THEORY OF OPERATION

The transfer function for the MPY634 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 resistors.
- $X$, $Y$, $Z$ are input voltages. Full-scale input voltage is equal to the selected SF. (Max input voltage = $\pm 1.25$ SF).

An intuitive understanding of transfer function can be gained by analogy to the op amp. By assuming that the open-loop gain, $A$, of the output operational 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 $V_{OUT}$ to provide the closed-loop transfer function.

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, noise, 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.

The MPY634 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 1).

As with any wide bandwidth circuit, the power supplies should be bypassed with high frequency ceramic capacitors. These capacitors should be located as near as practical to the power supply connections of the MPY634. Improper bypassing can lead to instability, overshoot, and ringing in the output.

FIGURE 2. Basic Multiplier Connection.

FIGURE 3. Conversion of Output to Current.

FIGURE 4. Division Operation.

**BASIC MULTIPLIER CONNECTION**

Figure 2 shows the basic connection as a multiplier. Accuracy is fully specified without any additional user-trimming circuitry. Some applications can benefit from trimming of 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 ground reference and should be connected to the ground of the driven system for maximum accuracy.

A method of changing (lowering) SF by connecting to the SF pin was discussed previously. Figure 1 shows an alternative method of changing the effective SF of the overall circuit by 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.

**SQUARER CIRCUIT (FREQUENCY DOUBLER)**

Squarer, or frequency doubler, 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 reducing the scale factor, SF.

**DIVIDER OPERATION**

The MPY634 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).

**FIGURE 4. Basic Divider Connection.**

Accuracy of the divider mode typically ranges from 1.0% to 2.5% 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 $\pm 3.5$ mV applied to the “low side” X input ($X_2$ for positive input voltages on $X_1$) can produce similar accuracies over 100 to 1 denominator range. To trim, apply a signal which varies from 100 mV to 10 V at a low frequency (less than 500 Hz). An offset sine wave or ramp is suitable. Since the ratio of the quantities should be constant, the ideal output would be a constant 10 V. Using AC coupling on an oscilloscope, adjust the offset control for minimum output voltage variation.

**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 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 10 kΩ must be provided. Trimming for improved accuracy would be accomplished at the Z input.

**FIGURE 5. Square-Rooter Connection.**

**APPLICATIONS**

**FIGURE 6. Phase Detector.**

Multiplier connection followed by a low-pass filter forms phase detector useful in phase-locked-loop circuitry. $R_x$ is often used in PLL circuitry to provide desired loop-damping characteristics.

**FIGURE 7. Voltage-Controlled Amplifier.**

Minor gain adjustments are accomplished with the 1 kΩ variable resistor connected to the scale factor adjustment pin, SF. Bandwidth of this circuit is limited by $A_1$, which is operated at relatively high gain.
With a linearly changing 0-10V input, this circuit's output follows 0° to 90° of a sine function with a 10V peak output amplitude.

FIGURE 8. Sine-Function Generator.

FIGURE 9. Linear AM Modulator.

By injecting the input carrier signal into the output through connection to the Z2 input, conventional amplitude modulation is achieved. Amplification can be achieved by use of the SF pin, or Z attenuator (at the expense of bandwidth).

FIGURE 10. Frequency Doubler.

Squaring a sinusoidal input creates an output frequency of twice that of the input. The DC output component is removed by AC-coupling the output.

FIGURE 11. Balanced Modulator.

The basic multiplier connection performs balanced modulation. Carrier rejection can be improved by trimming the offset voltage of the modulation input. Better carrier rejection above 2MHz is typically achieved by interchanging the X and Y inputs (carrier applied to the X input).

Carrier: f_c = 2MHz, Amplitude = 1Vrms
Signal: f_s = 120kHz, Amplitude = 10V peak
PACKAGING INFORMATION

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<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish (6)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
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(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
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OBsolete: TI has discontinued the production of the device.

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TBD: The Pb-Free/Green conversion plan has not been defined.
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(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.
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### TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

**TAPE DIMENSIONS**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

*All dimensions are nominal.*

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TAPE AND REEL BOX DIMENSIONS

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*All dimensions are nominal*
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.
NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.
5. Reference JEDEC registration MS-013.
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

9. Board assembly site may have different recommendations for stencil design.
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.
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