**30MHz, Voltage Output, Two Quadrant Analog Multiplier**

The HA-2546 is a monolithic, high speed, two quadrant, analog multiplier constructed in the Intersil Dielectrically Isolated High Frequency Process. The HA-2546 has a voltage output with a 30MHz signal bandwidth, 300V/μs slew rate and a 17MHz control bandwidth. High bandwidth and slew rate make this part an ideal component for use in video systems. The suitability for precision video applications is demonstrated further by the 0.1dB gain flatness to 5MHz, 1.6% multiplication error, -52dB feedthrough and differential inputs with 1.2μA bias currents. The HA-2546 also has low differential gain (0.1%) and phase (0.1 degree) errors.

The HA-2546 is well suited for AGC circuits as well as mixer applications for sonar, radar, and medical imaging equipment. The voltage output simplifies many designs by eliminating the current to voltage conversion stage required for current output multipliers. For MIL-STD-883 compliant product, consult the HA-2546/883 datasheet.

**Features**

- High Speed Voltage Output ..................... 300V/μs
- Low Multiplication error .......................... 1.6%
- Input Bias Currents .............................. 1.2μA
- Signal Input Feedthrough ....................... -52dB
- Wide Signal Bandwidth ......................... 30MHz
- Wide Control Bandwidth ......................... 17MHz
- Gain Flatness to 5MHz ......................... 0.10dB

**Applications**

- Military Avionics
- Missile Guidance Systems
- Medical Imaging Displays
- Video Mixers
- Sonar AGC Processors
- Radar Signal Conditioning
- Voltage Controlled Amplifier
- Vector Generator

**Pinout**

**Ordering Information**

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>TEMP. RANGE (ºC)</th>
<th>PACKAGE</th>
<th>PKG. DWG. #</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA9P2546-5</td>
<td>0 to 65</td>
<td>16 Ld SOIC</td>
<td>M16.3</td>
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</table>
Absolute Maximum Ratings

Voltage Between V+ and V- ........................................... 35V
Differential Input Voltage ........................................... 6V
Output Current ......................................................... ±60mA

Operating Conditions

Temperature Range

HA9P2546-5 .......................................................... 0°C to 65°C

CAUTION: Stresses above those listed in “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:
1. \( \theta_{JA} \) is measured with the component mounted on an evaluation PC board in free air.

Electrical Specifications

\( V_{SUPPLY} = \pm 15V, R_L = 1k\Omega, C_L = 50pF, \) Unless Otherwise Specified

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>TEMP (°C)</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MULTIPLIER PERFORMANCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplication Error (Note 2)</td>
<td></td>
<td>25</td>
<td>-</td>
<td>1.6</td>
<td>3</td>
<td>%</td>
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<tr>
<td></td>
<td></td>
<td>Full</td>
<td>-</td>
<td>3.0</td>
<td>7</td>
<td>%</td>
</tr>
<tr>
<td>Multiplication Error Drift</td>
<td></td>
<td>Full</td>
<td>-</td>
<td>0.003</td>
<td>-</td>
<td>%/°C</td>
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<td>Differential Gain (Notes 3, 9)</td>
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<td>25</td>
<td>-</td>
<td>0.1</td>
<td>0.2</td>
<td>%</td>
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<td>Differential Phase (Notes 3, 9)</td>
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<td>25</td>
<td>-</td>
<td>0.1</td>
<td>0.3</td>
<td>Degrees</td>
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<td>Gain Flatness (Note 9)</td>
<td>DC to 5MHz, ( V_X = 2V )</td>
<td>25</td>
<td>-</td>
<td>0.1</td>
<td>0.2</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>5 MHz to 8MHz, ( V_X = 2V )</td>
<td>25</td>
<td>-</td>
<td>0.18</td>
<td>0.3</td>
<td>dB</td>
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<td>-</td>
<td>0.7</td>
<td>5.0</td>
<td>%</td>
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<td>1% Amplitude Bandwidth Error</td>
<td></td>
<td>25</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>MHz</td>
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<tr>
<td>1% Vector Bandwidth Error</td>
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<td>25</td>
<td>-</td>
<td>260</td>
<td>-</td>
<td>kHz</td>
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<tr>
<td>THD + N (Note 4)</td>
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<td>25</td>
<td>-</td>
<td>0.03</td>
<td>-</td>
<td>%</td>
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<td>Voltage Noise</td>
<td>( f_O = 10Hz, V_X = V_Y = 0V )</td>
<td>25</td>
<td>-</td>
<td>400</td>
<td>-</td>
<td>nV/\sqrt{Hz}</td>
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<tr>
<td></td>
<td>( f_O = 100Hz, V_X = V_Y = 0V )</td>
<td>25</td>
<td>-</td>
<td>150</td>
<td>-</td>
<td>nV/\sqrt{Hz}</td>
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<tr>
<td></td>
<td>( f_O = 1kHz, V_X = V_Y = 0V )</td>
<td>25</td>
<td>-</td>
<td>75</td>
<td>-</td>
<td>nV/\sqrt{Hz}</td>
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<td>Common Mode Range</td>
<td></td>
<td>25</td>
<td>-</td>
<td>±9</td>
<td>-</td>
<td>V</td>
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<td>SIGNAL INPUT, ( V_Y )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td></td>
<td>25</td>
<td>-</td>
<td>3</td>
<td>10</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Full</td>
<td>-</td>
<td>8</td>
<td>20</td>
<td>mV</td>
</tr>
<tr>
<td>Average Offset Voltage Drift</td>
<td></td>
<td>Full</td>
<td>-</td>
<td>45</td>
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<td>µV/°C</td>
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<tr>
<td>Input Bias Current</td>
<td></td>
<td>25</td>
<td>-</td>
<td>7</td>
<td>15</td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Full</td>
<td>-</td>
<td>10</td>
<td>15</td>
<td>µA</td>
</tr>
</tbody>
</table>
### Electrical Specifications

**PARAMETER** | **TEST CONDITIONS** | **TEMP (°C)** | **MIN** | **TYP** | **MAX** | **UNITS**  
--- | --- | --- | --- | --- | --- | ---  
Input Offset Current |  | 25 | - | 0.7 | 2 | µA  
|  | Full | - | 1.0 | 3 | µA |  
Input Capacitance |  | 25 | - | 2.5 | - | pF  
Differential Input Resistance |  | 25 | - | 720 | - | kΩ  
Small Signal Bandwidth (-3dB) | $V_X = 2V$ | 25 | - | 30 | - | MHz  
Full Power Bandwidth (Note 5) | $V_X = 2V$ | 25 | - | 9.5 | - | MHz  
Feedthrough | Note 11 | 25 | - | -52 | - | dB  
CMRR | Note 6 | Full | 60 | 78 | - | dB  

**$V_Y$ TRANSIENT RESPONSE** (Note 10)  
Slew Rate | $V_{OUT} = ±5V, \ V_X = 2V$ | 25 | - | 300 | - | V/µs  
Rise Time | Note 7 | 25 | - | 11 | - | ns  
Overshoot | Note 7 | 25 | - | 17 | - | %  
Propagation Delay |  | 25 | - | 25 | - | ns  
Settling Time (To 0.1%) | $V_{OUT} = ±5V, \ V_X = 2V$ | 25 | - | 200 | - | ns  

**CONTROL INPUT, $V_X$**  
Input Offset Voltage |  | 25 | - | 0.3 | 2 | mV  
| Full | - | 3 | 20 | mV |  
Average Offset Voltage Drift | Full | - | 10 | - | µV/°C |  
Input Bias Current |  | 25 | - | 1.2 | 2 | µA  
| Full | - | 1.8 | 5 | µA |  
Input Offset Current |  | 25 | - | 0.3 | 2 | µA  
| Full | - | 0.4 | 3 | µA |  
Input Capacitance |  | 25 | - | 2.5 | - | pF  
Differential Input Resistance |  | 25 | - | 360 | - | kΩ |  
Small Signal Bandwidth (-3dB) | $V_Y = 5V, \ V_X = -1V$ | 25 | - | 17 | - | MHz  
Feedthrough | Note 12 | 25 | - | -40 | - | dB  
Common Mode Rejection Ratio | Note 13 | 25 | - | 80 | - | dB  

**HA-2546**

$V_{SUPPLY} = ±15V, R_L = 1kΩ, C_L = 50pF$, Unless Otherwise Specified (Continued)
### Electrical Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>TEMP (°C)</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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<td>Slew Rate</td>
<td>Note 13</td>
<td>25</td>
<td>-</td>
<td>95</td>
<td>-</td>
<td>V/µs</td>
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<tr>
<td>Rise Time</td>
<td>Note 14</td>
<td>25</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>ns</td>
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<td>Overshoot</td>
<td>Note 14</td>
<td>25</td>
<td>-</td>
<td>17</td>
<td>-</td>
<td>%</td>
</tr>
<tr>
<td>Propagation Delay</td>
<td></td>
<td>25</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>ns</td>
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<tr>
<td>Settling Time (To 0.1%)</td>
<td>Note 13</td>
<td>25</td>
<td>-</td>
<td>200</td>
<td>-</td>
<td>ns</td>
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<td><strong>V_Z CHARACTERISTICS</strong></td>
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<td></td>
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<td></td>
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<td>Input Offset Voltage</td>
<td>V_X = V_Y = 0V</td>
<td>25</td>
<td>-</td>
<td>4</td>
<td>15</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>Full</td>
<td></td>
<td></td>
<td>8</td>
<td>20</td>
<td>mV</td>
</tr>
<tr>
<td>Open Loop Gain</td>
<td></td>
<td>25</td>
<td>-</td>
<td>70</td>
<td>-</td>
<td>dB</td>
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<tr>
<td>Differential Input Resistance</td>
<td></td>
<td>25</td>
<td>-</td>
<td>900</td>
<td>-</td>
<td>kΩ</td>
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<tr>
<td><strong>OUTPUT CHARACTERISTICS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>V_X = 2.5V, V_Y = ±5V</td>
<td>Full</td>
<td>-</td>
<td>±6.25</td>
<td>-</td>
<td>V</td>
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<td>Output Current</td>
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<td>±20</td>
<td>±45</td>
<td>-</td>
<td>mA</td>
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<td>Output Resistance</td>
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<td>25</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>Ω</td>
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<td><strong>POWER SUPPLY</strong></td>
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<td></td>
<td></td>
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<tr>
<td>PSRR</td>
<td>Note 8</td>
<td>Full</td>
<td>58</td>
<td>63</td>
<td>-</td>
<td>dB</td>
</tr>
<tr>
<td>Supply Current</td>
<td>Full</td>
<td></td>
<td>-</td>
<td>23</td>
<td>29</td>
<td>mA</td>
</tr>
</tbody>
</table>

**NOTES:**

2. Error is percent of full scale, 1% = 50mV.
3. f_O = 3.58MHz/4.43MHz, V_Y = 300mVp-p, 0 to 1V_DC offset, V_X = 2V.
4. f_O = 10kHz, V_Y = 1V_RMS, V_X = 2V.
5. Full Power Bandwidth calculated by equation: FPBW = \( \frac{\text{Slew Rate}}{2\pi V_{\text{PEAK}}} \) V_{\text{PEAK}} = 5V.
6. V_Y = 0 to ±5V, V_X = 2V.
7. V_OUT = 0 to ±100mV, V_X = 2V.
8. V_S = ±12V to ±15V, V_Y = 5V, V_X = 2V.
9. Guaranteed by characterization and not 100% tested.
10. See Test Circuit.
11. f_O = 5MHz, V_X = 0, V_Y = 200mV_RMS.
12. f_O = 100kHz, V_Y = 0, V_X+ = 200mV_RMS, V_X- = -0.5V.
13. V_X = 0 to 2V, V_Y = 5V.
14. V_X = 0 to 200mV, V_Y = 5V.
Test Circuits and Waveforms

FIGURE 1. LARGE AND SMALL SIGNAL RESPONSE TEST CIRCUIT

VERTICAL SCALE: 5V/DIV HORIZONTAL SCALE: 50ns/DIV
V_Y LARGE SIGNAL RESPONSE

VERTICAL SCALE: 100mV/DIV HORIZONTAL SCALE: 50ns/DIV
V_Y SMALL SIGNAL RESPONSE

VERTICAL SCALE: 2V/DIV HORIZONTAL SCALE: 50ns/DIV
V_X LARGE SIGNAL RESPONSE

VERTICAL SCALE: 200mV/DIV HORIZONTAL SCALE: 50ns/DIV
V_X SMALL SIGNAL RESPONSE
Application Information

Theory Of Operation

The HA-2546 is a two quadrant multiplier with the following three differential inputs; the signal channel, \( V_{Y+} \) and \( V_{Y-} \), the control channel, \( V_{X+} \) and \( V_{X-} \), and the summed channel, \( V_{Z+} \) and \( V_{Z-} \), to complete the feedback of the output amplifier. The differential voltages of channel X and Y are converted to differential currents. These currents are then multiplied in a circuit similar to a Gilbert Cell multiplier, producing a differential current product. The differential voltage of the Z channel is converted into a differential current which then sums with the products currents. The differential “product/sum” currents are converted to a single-ended current and then converted to a voltage output by a transimpedance amplifier.

The open loop transfer equation for the HA-2546 is:

\[
V_{OUT} = A \left( \frac{(V_{X+} - V_{X-}) (V_{Y+} - V_{Y-})}{SF} - (V_{Z+} - V_{Z-}) \right)
\]

where:  
\( A = \) Output Amplifier Open Loop Gain  
\( SF = \) Scale Factor  
\( V_{X}, V_{Y}, V_{Z} = \) Differential Inputs

The scale factor is used to maintain the output of the multiplier within the normal operating range of ±5V. The scale factor can be defined by the user by way of an optional external resistor, \( R_{EXT} \), and the Gain Adjust pins, Gain Adjust A (GA A), Gain Adjust B (GA B), and Gain Adjust C (GA C). The scale factor is determined as follows:

- \( SF = 2 \), when GA B is shorted to GA C
- \( SF \approx 1.2 \cdot R_{EXT} \), when \( R_{EXT} \) is connected between GA A and GA C (\( R_{EXT} \) is in k\( \Omega \))
- \( SF \approx 1.2 \cdot (R_{EXT} + 1.667k\Omega) \), when \( R_{EXT} \) is connected to GA B and GA C (\( R_{EXT} \) is in k\( \Omega \))

The scale factor can be adjusted from 2 to 5. It should be noted that any adjustments to the scale factor will affect the AC performance of the control channel, \( V_{X} \). The normal input operating range of \( V_{X} \) is equal to the scale factor voltage.

The typical multiplier configuration is shown in Figure 2. The ideal transfer function for this configuration is:

\[
V_{OUT} = \begin{cases} 
\frac{(V_{X+} - V_{X-}) (V_{Y+} - V_{Y-})}{2} + V_{Z-}, & \text{when } V_{X} \geq 0V \\
0, & \text{when } V_{X} < 0V 
\end{cases}
\]

The \( V_{X} \) pin is usually connected to ground so that when \( V_{X+} \) is negative there is no signal at the output, i.e. two quadrant operation. If the \( V_{X} \) input is a negative going signal the \( V_{X+} \) pin maybe grounded and the \( V_{X} \) pin used as the control input.

Offset Adjustment

The signal channel offset voltage may be nulled by using a 20k\( \Omega \) potentiometer between \( V_{YIO} \) Adjust pins A and B and connecting the wiper to \( V_{-} \). Reducing the signal channel offset will reduce \( V_{X} \) AC feedthrough. Output offset voltage can also be nulled by connecting \( V_{Z-} \) to the wiper of a 20k\( \Omega \) potentiometer which is tied between \( V_{+} \) and \( V_{-} \).

Capacitive Drive Capability

When driving capacitive loads >20pF, a 50\( \Omega \) resistor is recommended between \( V_{OUT} \) and \( V_{Z+} \), using \( V_{Z+} \) as the output (see Figure 2). This will prevent the multiplier from going unstable.

Power Supply Decoupling

Power supply decoupling is essential for high frequency circuits. A 0.01\( \mu F \) high quality ceramic capacitor at each supply pin in parallel with a 1\( \mu F \) tantalum capacitor will provide excellent decoupling. Chip capacitors produce the best results due to the close spacing with which they may be placed to the supply pins minimizing lead inductance.

Adjusting Scale Factor

Adjusting the scale factor will tailor the control signal, \( V_{X+} \), input voltage range to match your needs. Referring to the simplified schematic on the front page and looking for the \( V_{X} \) input stage, you will notice the unusual design. The internal reference sets up a 1.2mA current sink for the \( V_{X} \) differential pair. The control signal applied to this input will be forced across the scale factor setting resistor and set the current flowing in the \( V_{X+} \) side of the differential pair. When the

\[
V_{OUT} = A \left( \frac{(V_{X+} - V_{X-}) (V_{Y+} - V_{Y-})}{SF} - (V_{Z+} - V_{Z-}) \right)
\]

where;  
\( A = \) Output Amplifier Open Loop Gain  
\( SF = \) Scale Factor  
\( V_{X}, V_{Y}, V_{Z} = \) Differential Inputs
current through this resistor reaches 1.2mA, all the current available is flowing in the one side and full scale has been reached. Normally the 1.67kΩ internal resistor sets the scale factor to 2V when the Gain Adjust pins B and C are connected together, but you may set this resistor to any convenient value using pins 16 (GA A) and 15 (GA C) (See Figure 3).

Typical Applications

Automatic Gain Control
In Figure 4 the HA-2546 is configured in a true Automatic Gain Control or AGC application. The HA-5127, low noise op amp, provides the gain control level to the X input. This level will set the peak output voltage of the multiplier to match the reference level. The feedback network around the HA-5127 provides stability and a response time adjustment for the gain control circuit.

This multiplier has the advantage over other AGC circuits, in that the signal bandwidth is not affected by the control signal gain adjustment.

Voltage Controlled Amplifier
A wide range of gain adjustment is available with the Voltage Controlled Amplifier configuration shown in Figure 5. Here the gain of the HFA0002 is swept from 20V/V at a control voltage of 0.902V to a gain of almost 1000V/V with a control voltage of 0.03V.

Video Fader
The Video Fader circuit provides a unique function. Here Ch B is applied to the minus Z input in addition to the minus Y input. In this way, the function in Figure 6 is generated. \( V_{\text{MIX}} \) will control the percentage of Ch A and Ch B that are mixed together to produce a resulting video image or other signal.

Many other applications are possible including division, squaring, square-root, percentage calculations, etc. Please refer to the HA-2556 four quadrant multiplier data sheet for additional applications.

FIGURE 3. SETTING THE SCALE FACTOR

FIGURE 4. AUTOMATIC GAIN CONTROL

MULTIPLIER, \( V_{\text{OUT}} = \frac{V_X V_Y}{2V} \)
SCALE FACTOR = 2V

MULTIPLIER, \( V_{\text{OUT}} = \frac{V_X V_Y}{5V} \)
SCALE FACTOR = 5V
FIGURE 5. VOLTAGE CONTROLLED AMPLIFIER

FIGURE 6. VIDEO FADER

\[ V_{OUT} = Ch\ B + (Ch\ A - Ch\ B) \frac{V_{MIX}}{Scale\ Factor} \]

Scale Factor = 2

\[ V_{OUT} = Ch\ B; \text{if } V_{MIX} = 0V \]
\[ V_{OUT} = All\ Ch\ B; \text{if } V_{MIX} = 2V \text{ (Full Scale)} \]
\[ V_{OUT} = Mix\ of\ Ch\ A\ and\ Ch\ B; \text{if } 0V < V_{MIX} < 2V \]
**Typical Performance Curves**  \( V_S = \pm 15V, T_A = 25^\circ C \), See Test Circuit For Multiplier Configuration

![Typical Performance Curves Diagrams](image)

- **FIGURE 7.** \( V_Y \text{ GAIN AND PHASE vs FREQUENCY} \)
- **FIGURE 8.** \( V_X \text{ GAIN AND PHASE vs FREQUENCY} \)
- **FIGURE 9.** \( V_Y \text{ FEEDTHROUGH vs FREQUENCY} \)
- **FIGURE 10.** \( V_X \text{ FEEDTHROUGH vs FREQUENCY} \)
- **FIGURE 11.** \( \text{VARIOUS } V_Y \text{ FREQUENCY RESPONSES} \)
- **FIGURE 12.** \( \text{VARIOUS } V_X \text{ FREQUENCY RESPONSES} \)
**Typical Performance Curves**  \( V_S = \pm 15V, T_A = 25^\circ C \), See Test Circuit For Multiplier Configuration  (Continued)
Typical Performance Curves \( V_S = \pm 15V, T_A = 25^\circ C, \) See Test Circuit For Multiplier Configuration  (Continued)
Typical Performance Curves \( V_S = \pm 15V, T_A = 25^\circ C \), See Test Circuit For Multiplier Configuration (Continued)
Typical Performance Curves \( V_S = \pm 15V, T_A = 25^oC, \) See Test Circuit For Multiplier Configuration (Continued)
**Die Characteristics**

**DIE DIMENSIONS:**
79.9 mils x 119.7 mils x 19 mils

**METALLIZATION:**
Type: Al, 1% Cul
Thickness: 16kÅ ± 2kÅ

**PASSIVATION:**
Type: Nitride (Si₃N₄) over Silox (SiO₂, 5% Phos)
Silox Thickness: 12kÅ ± 2kÅ
Nitride Thickness: 3.5kÅ ± 2kÅ

**TRANSISTOR COUNT:**
87

**Metallization Mask Layout**

![Metallization Mask Layout Diagram](Image)
Small Outline Plastic Packages (SOIC)

**NOTES:**

1. Symbols are defined in the “MO Series Symbol List” in Section 2.2 of Publication Number 95.
3. Dimension “D” does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension “E” does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. “L” is the length of terminal for soldering to a substrate.
7. “N” is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width “B”, as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch)
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

**M16.3 (JEDEC MS-013-AA ISSUE C)**
16 LEAD WIDE BODY SMALL OUTLINE PLASTIC PACKAGE

<table>
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