

**OBSOLETE PRODUCT  
RECOMMENDED REPLACEMENT  
HA-2556**

# HA-2557

**130MHz, Four Quadrant,  
Current Output Analog Multiplier**

September 1998

## Features

- Low Multiplication Error ..... 1.5%
- Input Bias Currents ..... 8 $\mu$ A
- Y Input Feedthrough at 5MHz ..... -50dB
- Wide Y Channel Bandwidth ..... 130MHz
- Wide X Channel Bandwidth ..... 75MHz

## Applications

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

## Part Number Information

PART NUMBER	TEMP. RANGE (°C)	PACKAGE	PKG. NO.
HA3-2557-9	-40 to 85	16 Ld PDIP	E16.3
HA9P2557-9	-40 to 85	16 Ld SOIC	M16.3

## Description

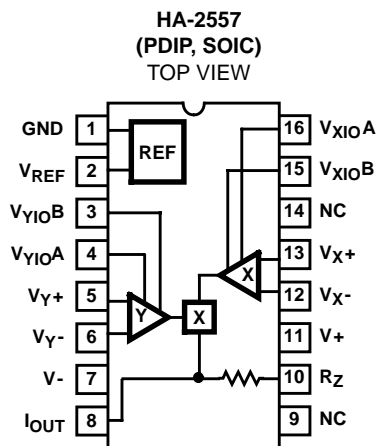
The HA-2557 is a monolithic, high speed, four quadrant, analog multiplier constructed in Harris' Dielectrically Isolated High Frequency Process. The single-ended current output of the HA-2557 has a 130MHz signal bandwidth ( $R_L = 50\Omega$ ). High bandwidth and low distortion make this part an ideal component in video systems.

The suitability for precision video applications is demonstrated further by low multiplication error (1.5%), low feedthrough (-50dB), and differential inputs with low bias currents (8 $\mu$ A). The HA-2557 is also well suited for mixer circuits as well as AGC applications for sonar, radar, and medical imaging equipment.

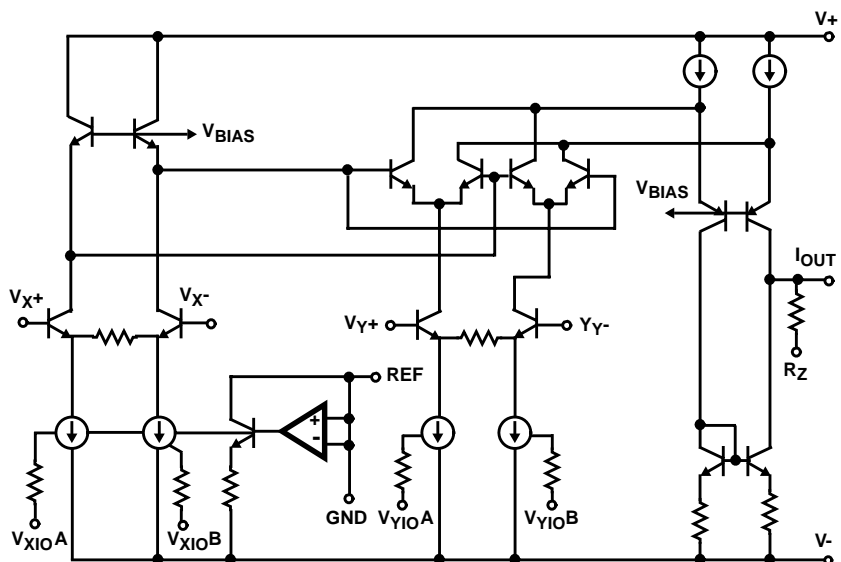
The current output of the HA-2557 allows it to achieve higher bandwidths than voltage output multipliers. Full scale output current is trimmed to 1.6mA. An internal 2500 $\Omega$  feedback resistor is also provided to accurately convert the current, if desired, to a full scale output voltage of  $\pm 4V$ . The HA-2557 is not limited to multiplication applications only; frequency doubling and power detection are also possible.

For MIL-STD-883 compliant product consult the HA-2557/883 datasheet.

## Pinout



## Schematic



# HA-2557

## Absolute Maximum Ratings

Voltage Between V+ and V- Terminals . . . . .	35V
Differential Input Voltage . . . . .	6V
Output Current . . . . .	3mA

## Thermal Information

Thermal Resistance (Typical, Note 1)	$\theta_{JA}$ (°C/W)
PDIP Package . . . . .	77
SOIC Package . . . . .	90
Maximum Junction Temperature (Die) . . . . .	175°C
Maximum Junction Temperature (Plastic Package) . . . . .	150°C
Maximum Storage Temperature Range . . . . .	-65°C to 150°C
Maximum Lead Temperature (Soldering 10s) . . . . .	300°C (SOIC - Lead Tips Only)

## Operating Conditions

Temperature Range . . . . .	-40°C to 85°C
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*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:**

- $\theta_{JA}$  is measured with the component mounted on an evaluation PC board in free air.

## Electrical Specifications $V_{SUPPLY} = \pm 15V$ , Unless Otherwise Specified

PARAMETER	TEST CONDITIONS	TEMP. (°C)	HA-2557-9			UNITS
			MIN	TYP	MAX	
<b>MULTIPLIER PERFORMANCE</b>						
Transfer Function			$I_{OUT} = \frac{(V_{X+} - V_{X-}) \times (V_{Y+} - V_{Y-})}{10kV\Omega}$			
Multiplication Error (Note 2)		25	-	1.5	3	%FS
		Full	-	3.0	6	%FS
Multiplication Error Drift		Full	-	0.003	-	%/°C
Scale Factor		25	-	10	-	kVΩ
Linearity Error	$V_X, V_Y = \pm 4V$ , Full Scale = 4V	25	-	0.1	0.25	%
	$V_X, V_Y = \pm 3V$ , Full Scale = 3V	25	-	0.05	-	%
<b>AC CHARACTERISTICS</b>						
Small Signal Bandwidth (-3dB) ( $R_L = 50\Omega$ )	$V_Y = 200mV_{P-P}$ , $V_X = 4V$	25	-	130	-	MHz
	$V_X = 200mV_{P-P}$ , $V_Y = 4V$	25	-	75	-	MHz
Rise Time	$V_{OUT} = -80mV$ to $+80mV$ , $R_L = 50\Omega$	25	-	7	-	ns
Propagation Delay	$R_L = 50\Omega$	25	-	3	-	ns
Feedthrough (Note 4)	$f = 5MHz$	25	-	-50	-	dB
THD+N	$f = 10kHz$ , $V_Y = 1V_{RMS}$ , $V_X = 4V$	25	-	0.03	-	%
<b>SIGNAL INPUT <math>V_X, V_Y</math></b>						
Input Offset Voltage		25	-	4	15	mV
		Full	-	8	25	mV
Average Offset Voltage Drift		Full	-	35	-	$\mu V/°C$
Input Bias Current		25	-	8	15	$\mu A$
		Full	-	12	25	$\mu A$
Input Offset Current		25	-	0.5	2	$\mu A$
		Full	-	1.0	3	$\mu A$
Differential Input Resistance		25	-	1	-	MΩ
Differential Input Range		25	$\pm 4$	-	-	V
CMRR	Note 3	Full	65	78	-	dB
Voltage Noise (Pin 10 = GND) ( $V_X = V_Y = GND$ )	$f = 1kHz$	25	-	150	-	$nV/\sqrt{Hz}$
	$f = 100kHz$	25	-	40	-	$nV/\sqrt{Hz}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Offset Current		25	-	2.4	10	$\mu A$
		Full	-	5.6	15	$\mu A$
Full Scale Output Compliance Voltage		Full	$\pm 4$	-	-	V
Full Scale Output Current		25	-	$\pm 1.6$	-	mA

**Electrical Specifications**  $V_{SUPPLY} = \pm 15V$ , Unless Otherwise Specified (Continued)

PARAMETER	TEST CONDITIONS	TEMP. (°C)	HA-2557-9			UNITS
			MIN	TYP	MAX	
Output Resistance	$\pm 10V$	25	1.0	1.5	-	M $\Omega$
Output Capacitance		25	-	6.5	-	pF
Internal Resistor ( $R_Z$ )		25	2425	2500	2575	$\Omega$
		Full	2375	2500	2625	$\Omega$
<b>POWER SUPPLY</b>						
+PSRR	$V_S = \pm 12V$ to $\pm 17V$	Full	65	80	-	dB
-PSRR	$V_S = \pm 12V$ to $\pm 17V$	Full	45	55	-	dB
Supply Current		Full	-	13	17	mA

NOTES:

2. Error is percent of full scale, 1% = 16 $\mu$ A.
3.  $V_{XCM} = \pm 10V$ ,  $V_{YCM} = +9V, -10V$ .
4. Relative to full scale output.

**Test Circuit and Waveform**

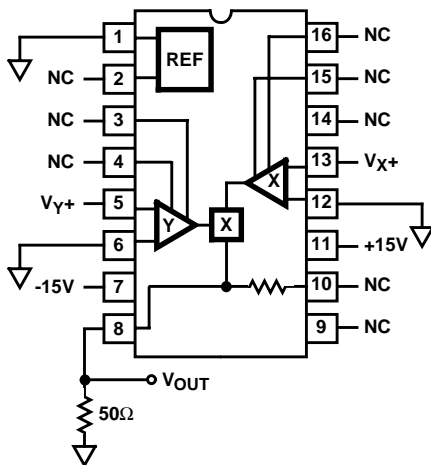
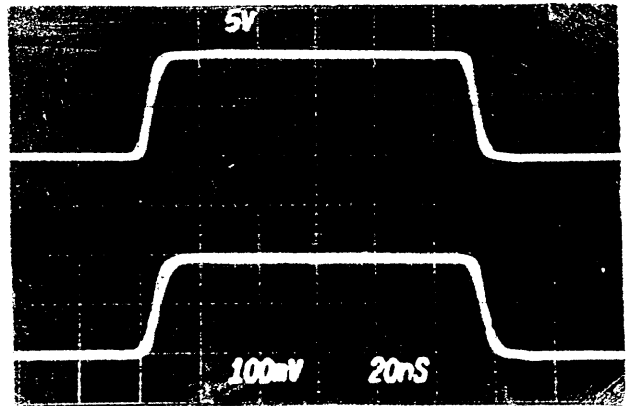


FIGURE 1. AC AND TRANSIENT RESPONSE TEST CIRCUIT



Vertical Scale: Top 5V/Div. Bottom: 100mV/Div.  
Horizontal Scale: 20ns/Div.

$V_Y$  TRANSIENT RESPONSE

**Application Information**

**Operation at Reduced Supply Voltages**

The HA-2557 will operate over a range of supply voltages,  $\pm 5V$  to  $\pm 15V$ . Use of supply voltages below  $\pm 12V$  will reduce input and output voltage ranges. See "Typical Performance Curves" for more information. The  $\pm 5V$  range is particularly useful in video applications. At  $\pm 5V$  the input voltage range is reduced to  $\pm 1.4V$  limiting the fullscale output current. Another current output option is the HA-2556 voltage output multiplier configured for current output with an output sensing resistor (Refer to the HA-2556 data sheet).

**Offset Adjustment**

The channel offset voltage may be nulled by using a 20K potentiometer between the  $V_{YIO}$  or  $V_{XIO}$  adjust pin A and B and connecting the wiper to  $V_-$ . Reducing the channel offset voltage will reduce AC feedthrough and improve the multiplication error.

**Theory of Operation**

The HA-2557 creates an output current that is the product of the X and Y input voltages divided by a constant scale factor of

10kV $\Omega$ . The resulting output has the correct polarity in each of the four quadrants defined by the combinations of positive and negative X and Y inputs. This results in the following equation, where X and Y are high impedance differential inputs:

$$I_{OUT} = \frac{X \times Y}{10kV\Omega}$$

To accomplish this the differential input voltages are first converted into differential currents by the X and Y input transconductance stages. The currents are then scaled by a constant reference and combined in the multiplier core. The multiplier core is a basic Gilbert Cell that produces a differential output current proportional to the product of X and Y input signal currents. This current is converted into the output for the HA-2557.

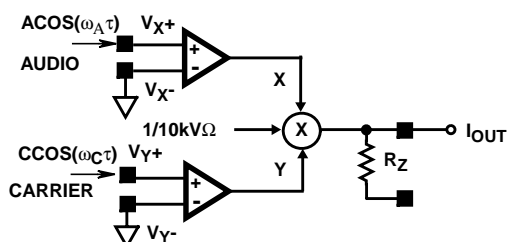
The purpose of the reference circuit is to provide a stable current, used in setting the scale factor. This is achieved with a bandgap reference circuit to produce a temperature stable voltage of 1.2V which is forced across a NiCr resistor. Slight adjustments to scale factor may be possible by overriding the internal reference with the  $V_{REF}$  pin. The scale factor is used

to maintain the output of the multiplier within the normal operating range of  $\pm 1.6\text{mA}$  when full scale inputs are applied.

### Typical Applications

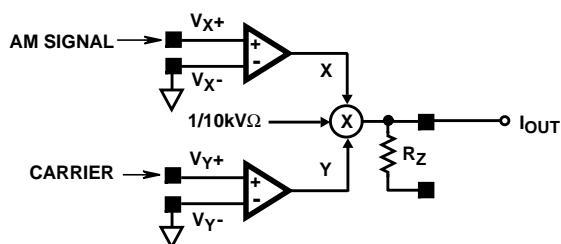
#### Communication Applications

The multiplier function of the HA-2557 has applications in AM Signal Generation, Synchronous AM Detection and Phase Detection. These circuit configurations are shown in Figure 2, Figure 3 and Figure 4. By feeding a signal into both X and Y inputs a Square function results that is useful as a Frequency Doubler as shown in Figure 5. The HA-2557 is particularly useful in applications that require the interaction of high speed signals. Both inputs X and Y have similar wide bandwidth and input characteristics. This is unlike earlier products where one input was dedicated to a slow moving control function as is required for Automatic Gain Control. The HA-2557 is versatile enough for both.



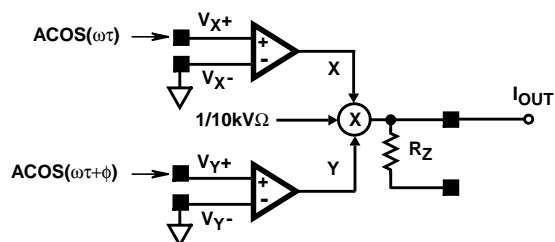
$$I_{OUT} = \frac{AC}{20kV\Omega} (\cos(\omega_C - \omega_A)\tau + \cos(\omega_C + \omega_A)\tau)$$

FIGURE 2. AM SIGNAL GENERATION



LIKE THE FREQUENCY DOUBLER YOU GET AUDIO CENTERED AT DC AND  $2F_C$ .

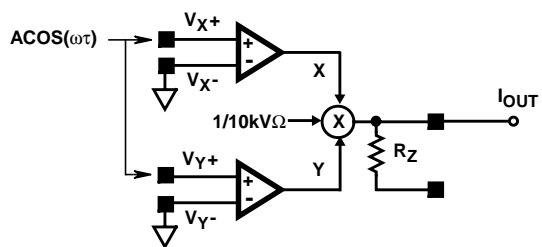
FIGURE 3. SYNCHRONOUS AM DETECTION



$$I_{OUT} = \frac{A^2}{20kV\Omega} (\cos(\phi) + \cos(2\omega\tau + \phi))$$

DC COMPONENT IS PROPORTIONAL TO  $\cos(\phi)$

FIGURE 4. PHASE DETECTION



$$(AC\cos(\omega\tau) \times AC\cos(\omega\tau)) = 10kV\Omega(I_{OUT})$$

WHICH EVALUATES TO:

$$I_{OUT} = \frac{A^2}{20K}(1 + \cos(2\omega\tau))$$

FIGURE 5. FREQUENCY DOUBLER

Although the X and Y inputs have similar AC characteristics, they are not the same. The designer should consider input parameters such as small signal bandwidth and AC feedthrough to get the most performance from the HA-2557. The Y channel is the faster of the two inputs with a small signal bandwidth of typically 130MHz versus 75MHz for the X channel. Therefore in AM Signal Generation, the best performance will be obtained with the Carrier applied to the Y channel and the modulation signal (lower frequency) applied to the X channel.

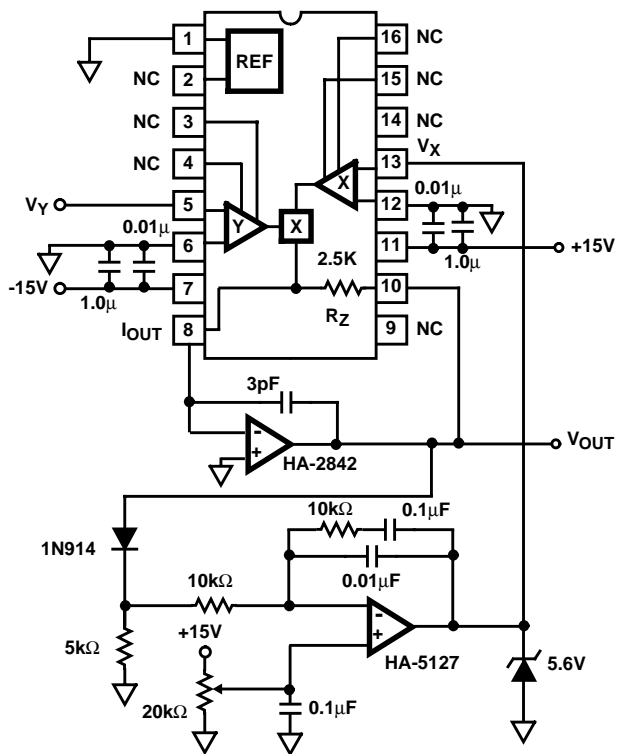


FIGURE 6. AUTOMATIC GAIN CONTROL

#### Automatic Gain Control

Figure 6 shows the HA-2557 configured in an Automatic Gain Control or AGC application. The HA-2842 serves as an output I to V converter using  $R_Z$  which is trimmed to provide an accurate 4V Fullscale conversion. Refer to **Voltage Output**

**Conversion** for more details about this function. The HA-5127 low noise amplifier provides the gain control signal to the X input. This control signal sets the peak output voltage of the multiplier to match the preset reference level. The feedback network around the HA-5127 provides a response time adjustment. High frequency changes in the peak are rejected as noise or the desired signal to be transmitted. These signals do not indicate a change in the average peak value and therefore no gain adjustment is needed. Lower frequency changes in the peak value are given a gain of -1 for feedback to the control input. At DC the circuit is an integrator automatically compensating for offset and other constant error terms.

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

**Voltage Output Conversion**

The HA-2842 is an excellent choice to perform the output current to voltage conversion as shown in Figure 7. The combination of 400V/ $\mu$ s slew rate and 80MHz Gain Bandwidth product will maintain signal dynamics while providing a full scale  $\pm 4V$  output. The HA-2842 also provides a hefty output drive capability of 100mA.

This voltage feedback amplifier takes advantage of the internal  $R_Z$  resistor, trimmed to provide an accurate 4V fullscale conversion. The parasitic capacitance at the negative input of the HA-2842 must be compensated with a 3pF capacitor from pin 2 to pin 6. This compensation will also insure that the amp will see a noise gain of 2 at its crossover frequency, the minimum required for stability with this device. The full power bandwidth curve and large signal pulse response for this circuit are shown in Figure 11 and Figure 12 respectively. The fast slew rate of the HA-2842 results in a minimal reduction of bandwidth for large signals.

Another choice for an I to V converter that takes better advantage of the wide bandwidth of the HA-2557, is to use the HA5023 Dual 100MHz current feedback amp. The optimum bandwidth of a current feedback amp is obtained with a fixed feedback resistor. Therefore scaling the I to V conversion to a convenient value requires two stages. Fortunately the HA5023 provides two wideband amplifiers in a single 8 pin Mini-DIP or SOIC package, while their current feedback architecture provides signal gain with minimal reduction in bandwidth. This circuit configuration is shown in Figure 8.

The optimum bandwidth is achieved in stage 1 with a 909 $\Omega$  feedback resistor. This voltage is then gained up by the second stage to provide a  $\pm 4V$  Fullscale Voltage output with a bandwidth in excess of 90MHz. The 10pF capacitor and the additional 220 $\Omega$  resistor improve gain flatness and reduce gain peaking. The HA5023 also provides excellent Full Power Bandwidth (-3dB at 80MHz for a 3.5V<sub>p-p</sub> signal). Typical curves for this application circuit are shown in Figures 13, 14, 15 and 16.

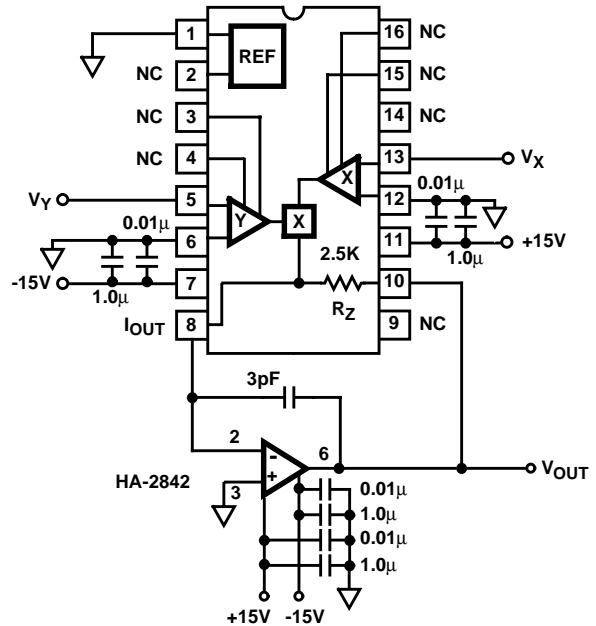


FIGURE 7. VOLTAGE OUTPUT CONVERSION

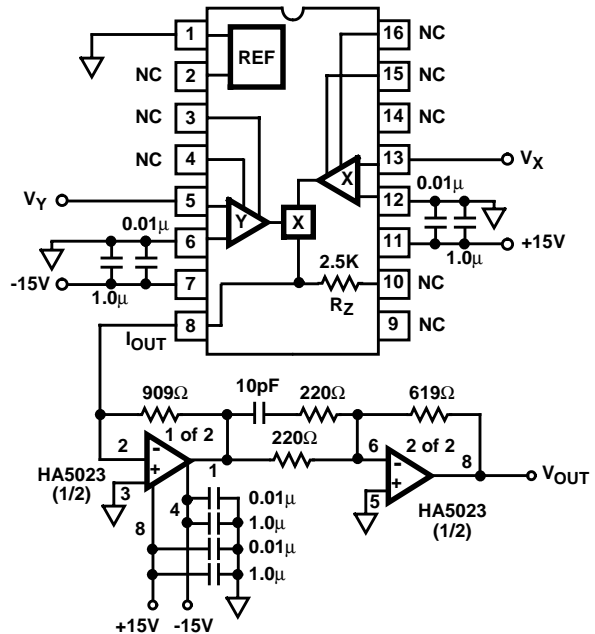


FIGURE 8. VOLTAGE OUTPUT CONVERSION

Typical Performance Curves

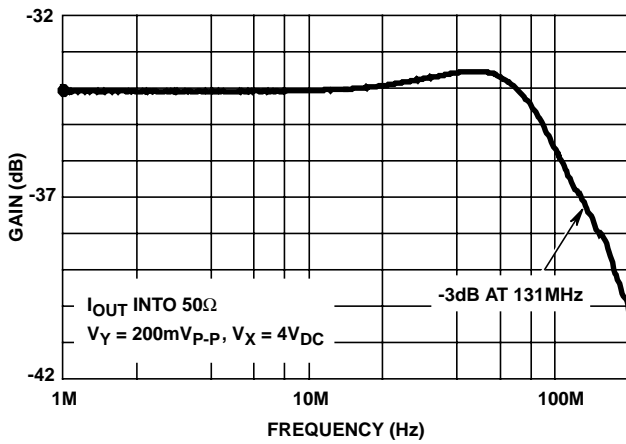


FIGURE 9. FIGURE 9.  $V_Y$  BANDWIDTH

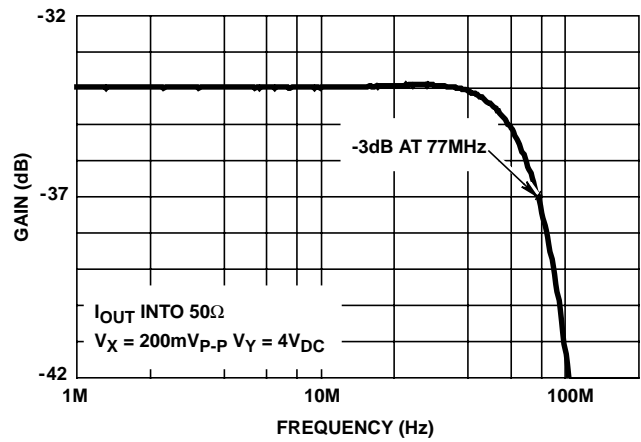


FIGURE 10. FIGURE 10.  $V_X$  BANDWIDTH

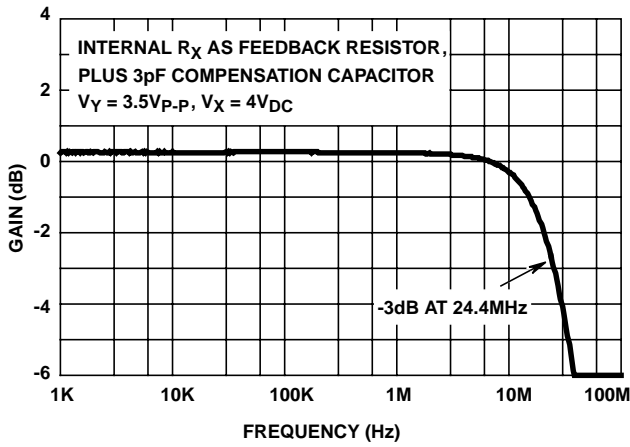
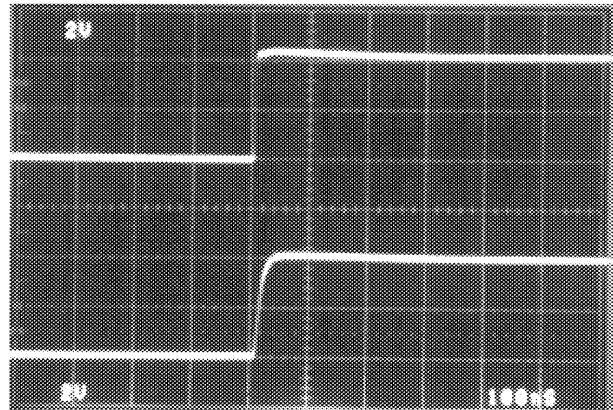


FIGURE 11. HA-2557 INTO HA-2842 AS I TO V CONVERTER  $V_Y$  FULLPOWER BANDWIDTH



Top:  $V_Y$  Input 0 to 4V Step  
Bottom: HA-2842 0 to 4V Response

FIGURE 12.  $V_Y$  TRANSIENT RESPONSE OF HA-2842 AS I TO V CONVERTER

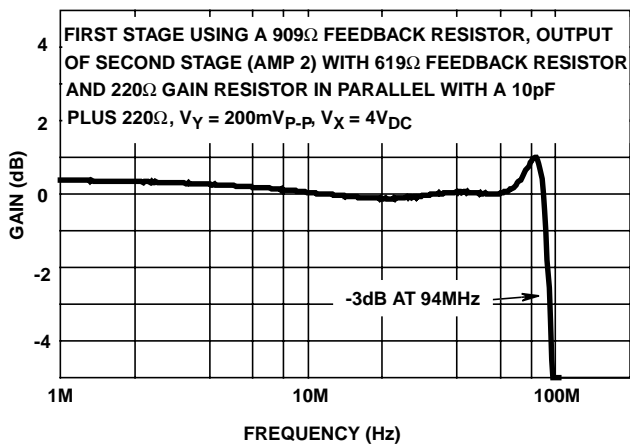
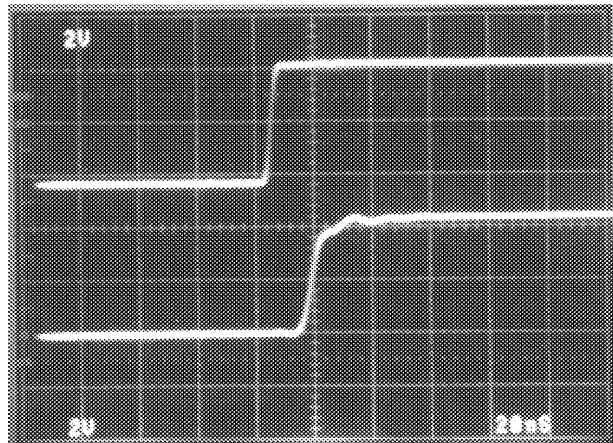


FIGURE 13. DRIVING HA5023 AS I TO V CONVERTER  $V_Y$  BANDWIDTH



Top:  $V_Y$  Input 0 to 4V Step  
Bottom: HA5023 0 to 4V Response

FIGURE 14.  $V_Y$  TRANSIENT RESPONSE OF HA5023 AS I TO V CONVERTER

Typical Performance Curves (Continued)

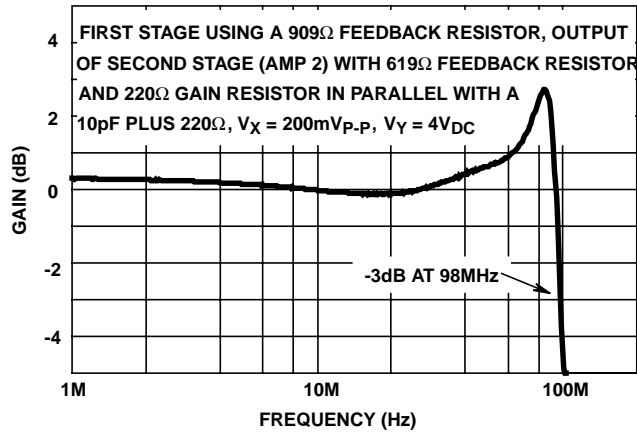


FIGURE 15. DRIVING HA5023 AS I TO V CONVERTER  $V_X$  BANDWIDTH

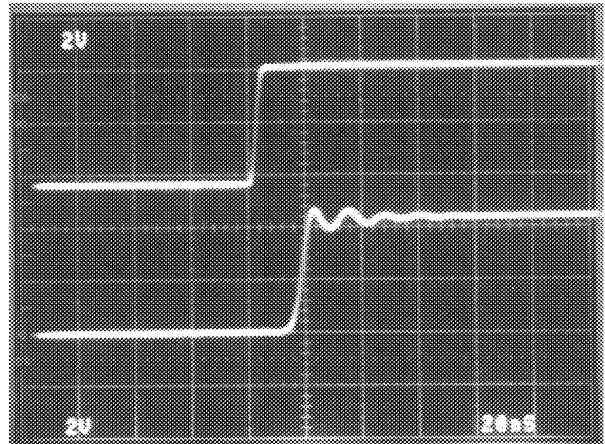


FIGURE 16.  $V_Y$  TRANSIENT RESPONSE OF HA5023 AS I TO V CONVERTER

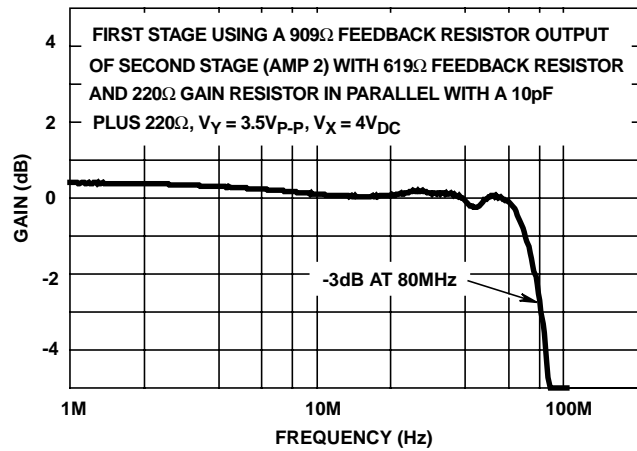


FIGURE 17. DRIVING HA5023 AS I TO V CONVERTER  $V_Y$  FULLPOWER BANDWIDTH

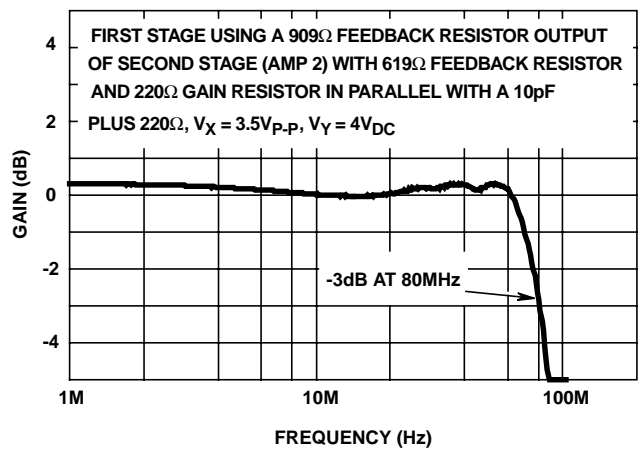


FIGURE 18. DRIVING HA5023 AS I TO V CONVERTER  $V_X$  FULLPOWER BANDWIDTH

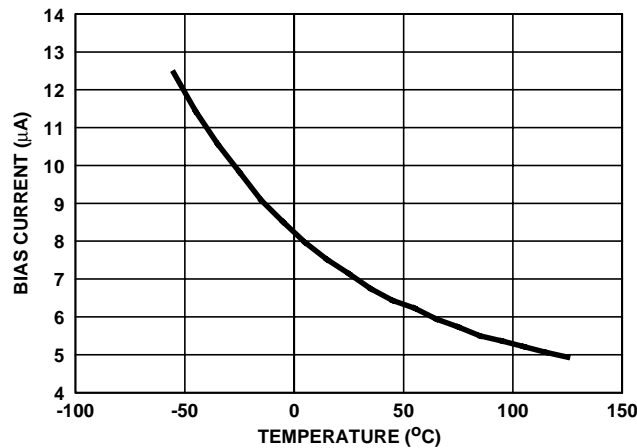


FIGURE 19. INPUT BIAS CURRENT vs TEMPERATURE

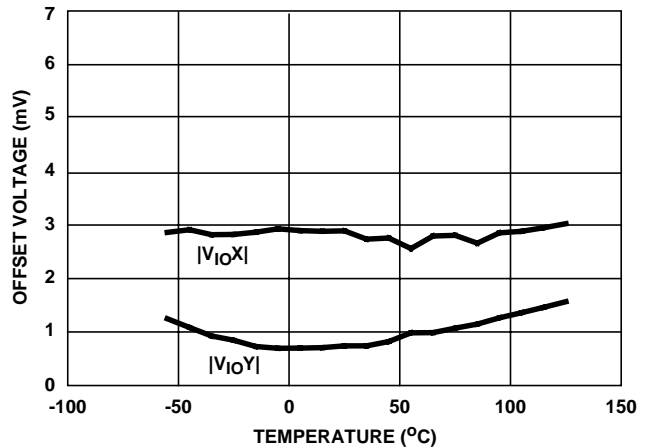


FIGURE 20. OFFSET VOLTAGE vs TEMPERATURE

Typical Performance Curves (Continued)

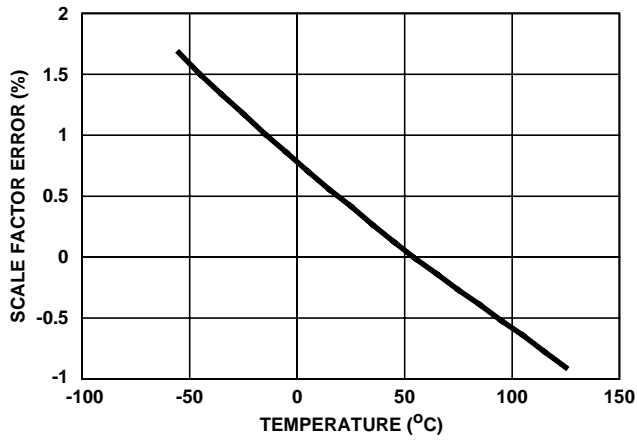


FIGURE 21. SCALE FACTOR ERROR vs TEMPERATURE

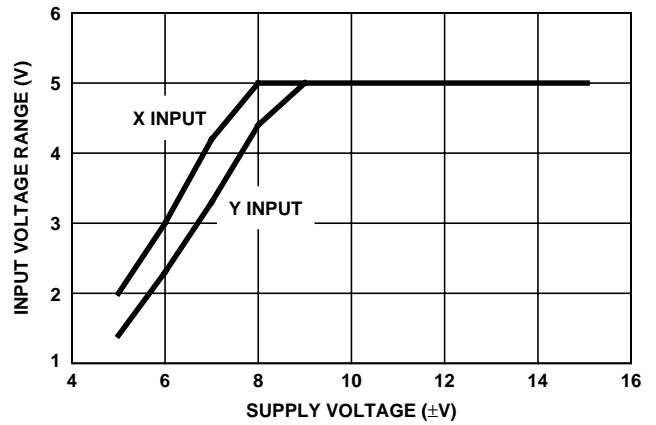


FIGURE 22. INPUT VOLTAGE RANGE vs SUPPLY VOLTAGE

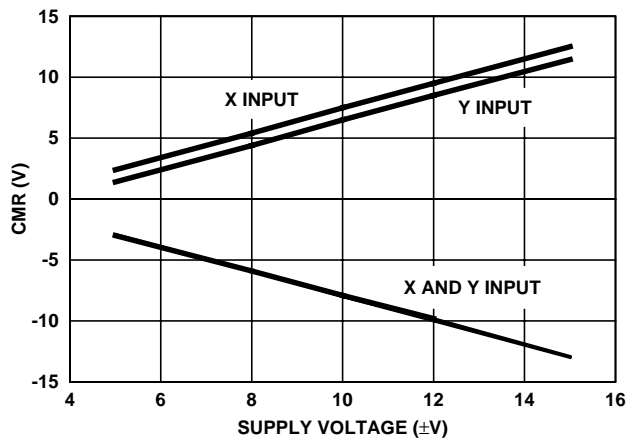


FIGURE 23. INPUT COMMON MODE RANGE vs SUPPLY VOLTAGE



# HA-2557

## Die Characteristics

### DIE DIMENSIONS:

71 mils x 100 mils x 19 mils

### METALLIZATION:

Type: Aluminum, 1% Copper  
Thickness:  $16\text{k}\text{\AA} \pm 2\text{k}\text{\AA}$

### SUBSTRATE POTENTIAL

V-

### PASSIVATION:

Type: Nitride ( $\text{Si}_3\text{N}_4$ ) over Silox ( $\text{SiO}_2$ , 5% Phos)  
Nitride Thickness:  $3.5\text{k}\text{\AA} \pm 2\text{k}\text{\AA}$   
Silox Thickness:  $12\text{k}\text{\AA} \pm 2\text{k}\text{\AA}$

### TRANSISTOR COUNT:

72

### PROCESS:

Bipolar Dielectric Isolation

## Metallization Mask Layout

