



**MPY600**

## Wide Bandwidth SIGNAL MULTIPLIER

### FEATURES

- **WIDE BANDWIDTH:**  
75MHz — Current Output  
30MHz — Voltage Output
- **LOW NOISE**
- **LOW FEEDTHROUGH: -60dB (5MHz)**
- **GROUND-REFERRED OUTPUT**
- **LOW OFFSET VOLTAGE**

### APPLICATIONS

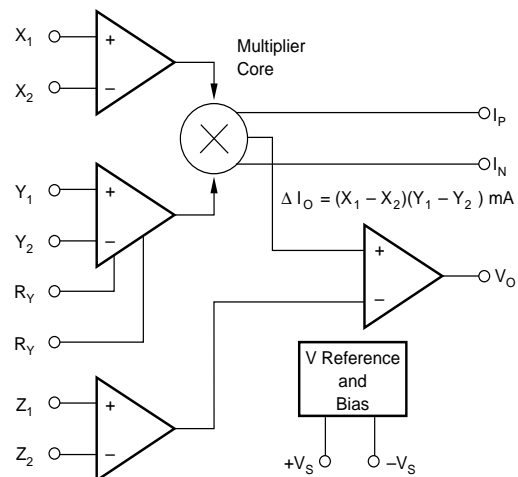
- **MODULATOR/DEMODULATOR**
- **VIDEO SIGNAL PROCESSING**
- **CRT GEOMETRY CORRECTION**
- **CRT FOCUS CORRECTION**
- **VOLTAGE-CONTROLLED CIRCUITS**

### DESCRIPTION

The MPY600 is a wide-bandwidth four-quadrant signal multiplier. Its output voltage is equal to the algebraic product of the X and Y input voltages. For signals up to 30MHz, the on-board output op amp provides the complete multiplication function with a low-impedance voltage output. Differential current outputs extend multiplier bandwidth to 75MHz.

The MPY600 offers improved performance compared to common semiconductor modulator or multiplier circuits. It can be used for both two-quadrant (voltage-controlled amplifier) and four-quadrant (double-balanced) applications. While previous devices required cumbersome circuitry for trimming, balance and level-shifting, the MPY600 requires no external components. A single external resistor can be used to program the conversion gain for optimum spurious-free dynamic range. When used as a modulator, carrier feedthrough measures -60dB at 5MHz.

Differential X, Y and Z inputs can be connected in a variety of useful configurations, including squarer, divider, and square-rooter circuits. The MPY600 is available in 16-pin plastic DIP, specified for the industrial temperature range.



$$V_O = A \left[ \frac{(X_1 - X_2)(Y_1 - Y_2)}{2V} + Z_2 - Z_1 \right]$$

International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706  
Tel: (520) 746-1111 • Twx: 910-952-1111 • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

# SPECIFICATIONS

At  $V_S = \pm 5V$ ,  $T_A = +25^\circ C$  unless otherwise noted.

SPECIFICATION	CONDITIONS	MPY600AP			UNITS
		MIN	TYP	MAX	
<b>INPUTS (X, Y, Z)</b> Full-Scale Differential Input $X_1-X_2$ $Y_1-Y_2$ $Z_1-Z_2$ Input Voltage Range Differential Input Range Input Impedance Input Offset Voltage Drift CMRR PSRR Input Bias Current (X, Y) Z Input	$V_{CM} = \pm 2V$	$\pm 1$			V
		$\pm 2$			V
		$\pm 2$			V
			$\pm 2.2$		V
			$\pm 2.5$		V
			100    1.5		k $\Omega$    pF
			$\pm 0.5$	$\pm 5$	mV
			25		$\mu V/^\circ C$
			70		dB
			70		dB
			+15		$\mu A$
			-15		$\mu A$
<b>VOLTAGE OUTPUT</b>  Transfer Function  Total Multiplier Error <sup>(1)</sup>  Gain Error Gain Temperature Drift Power Supply Rejection Noise Output Voltage Swing Output Current Short-Circuit Limit Bandwidth Slew Rate Settling Time to 0.1% Differential Gain Error Differential Phase Error Capacitive Load, Max Feedthrough, X  Feedthrough, Y  Distortion, X  Distortion, Y	$-1V \leq X \leq 1V, -2V \leq Y \leq 2V$ $-2V \leq X \leq 2V, -2V \leq Y \leq 2V$  $V_S = \pm 4$ to $\pm 6V$ $f = 1kHz$ to $30MHz$ $R_L = 100\Omega$  Small Signal  $4V$ Step $3.58MHz, 0$ to $0.7V$ $3.58MHz, 0$ to $0.7V$ Stable Operation $X = 0dBm, f = 500kHz; Y$ Nulled $X = 0dBm, f = 5MHz; Y$ Nulled $Y = 0dBm, f = 500kHz; X$ Nulled $Y = 0dBm, f = 5MHz; X$ Nulled $X = 0dBm, f = 500kHz, Y = 2V$ $X = 0dBm, f = 5MHz, Y = 2V$ $Y = 0dBm, f = 500kHz, X = 2V$ $Y = 0dBm, f = 5MHz, X = 2V$		$V_O = \frac{(X_1 - X_2)(Y_1 - Y_2)}{2} + Z_2$		V
			$\pm 15$	$\pm 25$	mV
			$\pm 25$		mV
			$\pm 1$		%
			$\pm 200$		ppm/ $^\circ C$
			70		dB
			120		nV/ $\sqrt{Hz}$
		$\pm 2.2$	$\pm 3$		V
		$\pm 22$	$\pm 30$		mA
			50		mA
			30		MHz
			150		V/ $\mu s$
			150		ns
			0.2		%
			0.2		Degrees
			100		pF
			-65		dB
			-60		dB
			-70		dB
			-50		dB
			-60		dB
			-55		dB
			-65		dB
			-55		dB
<b>CURRENT OUTPUT</b>  Transfer Function Total Multiplier Error <sup>(1)</sup>  Gain Error Gain Temperature Drift Power Supply Rejection Noise, Output Voltage Compliance Range Peak Output Current Noise, Input-Referred Bandwidth, Small-Signal Settling Time to 0.1% Feedthrough, X  Feedthrough, Y  Distortion, X  Distortion, Y	$-1V \leq X \leq 1V, -2V \leq Y \leq 2V$ $-2V \leq X \leq 2V, -2V \leq Y \leq 2V$  $V_S = \pm 4$ to $\pm 6V$  $f = 1kHz$ to $75MHz$  $4mA$ Step $X = 0dBm, f = 1MHz; Y$ Nulled $X = 0dBm, f = 10MHz; Y$ Nulled $Y = 0dBm, f = 1MHz; X$ Nulled $Y = 0dBm, f = 10MHz; X$ Nulled $X = 0dBm, f = 1MHz, Y = 2V$ $X = 0dBm, f = 10MHz, Y = 2V$ $Y = 0dBm, f = 1MHz, X = 2V$ $Y = 0dBm, f = 10MHz, X = 2V$		$\Delta I_O = (X_1 - X_2)(Y_1 - Y_2)/1000$		A
			$\pm 20$	$\pm 80$	$\mu A$
			$\pm 80$		$\mu A$
			$\pm 1$		%
			$\pm 200$		ppm/ $^\circ C$
			50		dB
			100		pA/ $\sqrt{Hz}$
			$\pm 2.5$		V
			5		mA
			50		nV/ $\sqrt{Hz}$
			75		MHz
			150		ns
			-65		dB
			-45		dB
			-75		dB
			-55		dB
			-55		dB
			-50		dB
			-65		dB
			-50		dB
<b>POWER SUPPLY</b>  Rated Performance Operating Current			$\pm 5$		V
			$\pm 4.75$	$\pm 8$	V
			$\pm 30$	$\pm 35$	mA
<b>TEMPERATURE RANGE</b>  Specified Temperature Range Storage Temperature Range Thermal Resistance, $\theta_{JA}$			-25	+85	$^\circ C$
			-40	+125	$^\circ C$
			50		$^\circ C/W$

NOTE: (1) Deviation from ideal transfer function referred to full scale output. Includes gain, nonlinearity and offset errors.



MPY600

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage .....	$\pm 18V$
Input Voltage Range .....	$\pm V_S$
Op Amp Output Current .....	100mA
Operating Temperature .....	+125°C
Storage Temperature .....	+150°C
Junction Temperature .....	+150°C
Lead Temperature (soldering, 10s) .....	+300°C

## ORDERING INFORMATION

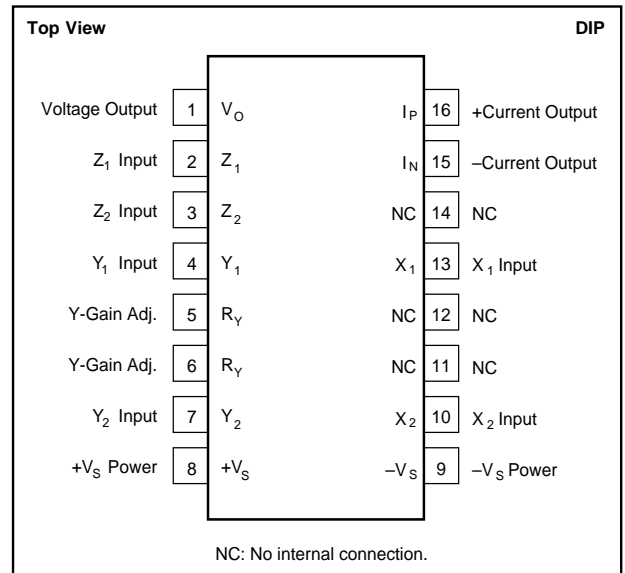
MODEL	PACKAGE	SPECIFIED TEMPERATURE RANGE
MPY600AP	16-Pin Plastic DIP	-25°C to +85°C

## PACKAGE INFORMATION

MODEL	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
MPY600AP	16-Pin Plastic DIP	180

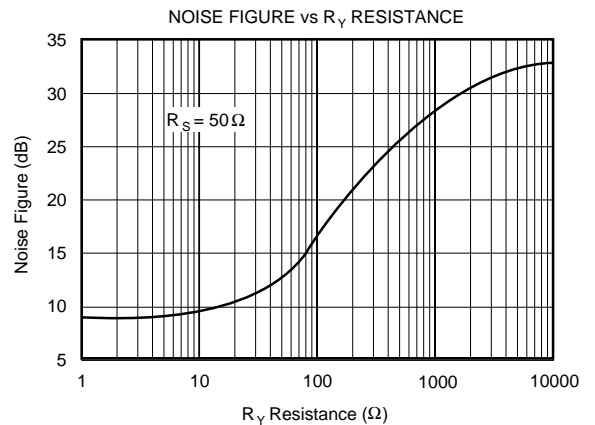
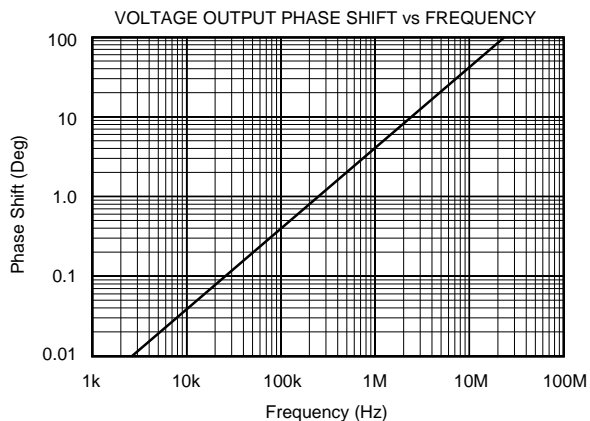
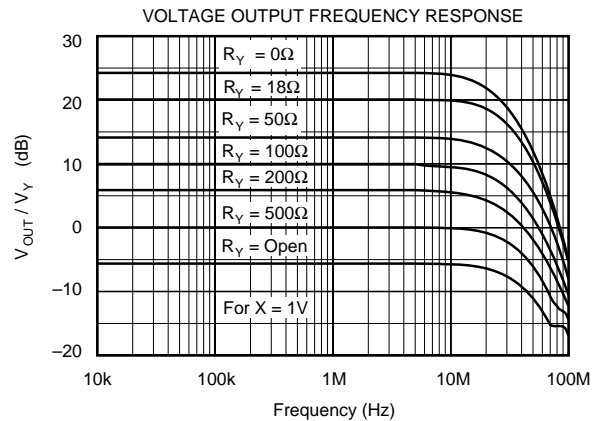
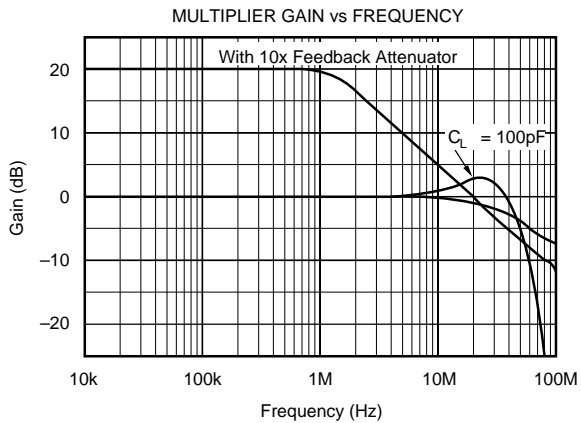
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

## PIN CONFIGURATION



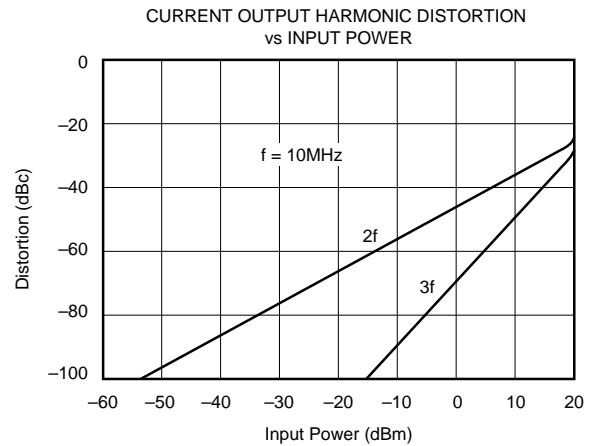
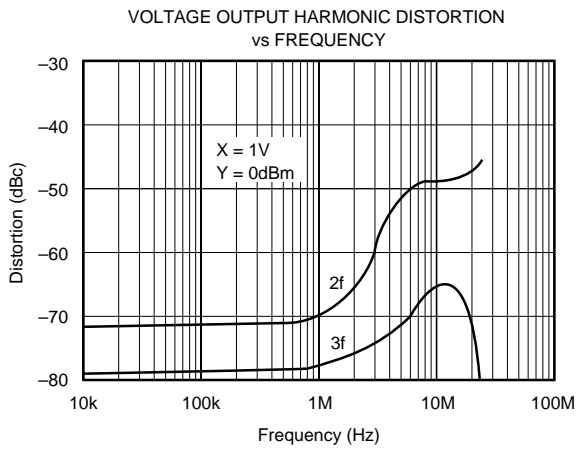
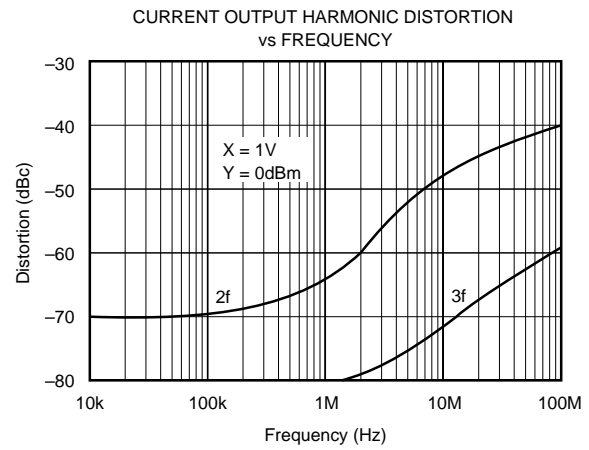
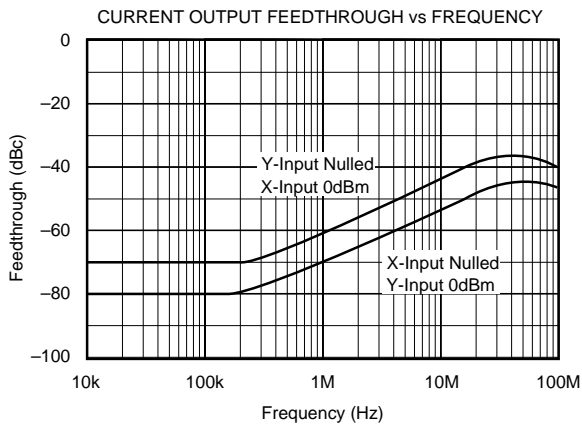
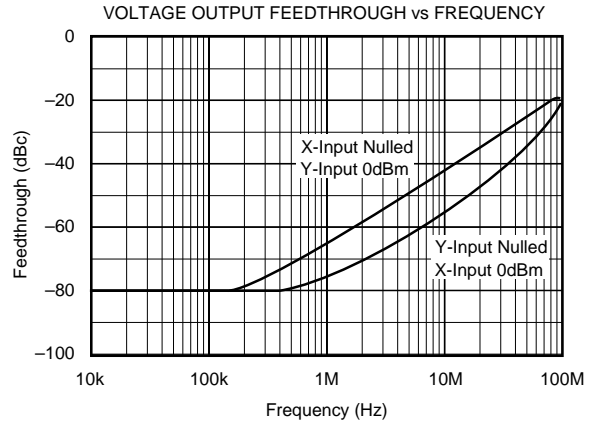
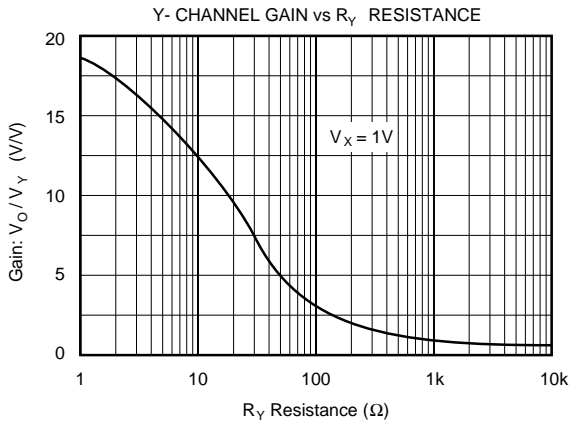
## TYPICAL PERFORMANCE CURVES

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5V$  unless otherwise noted.



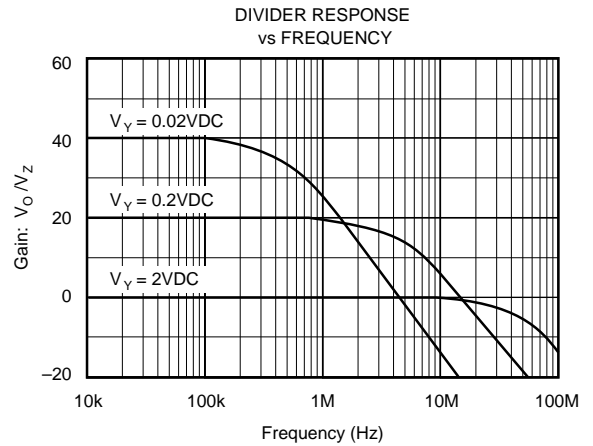
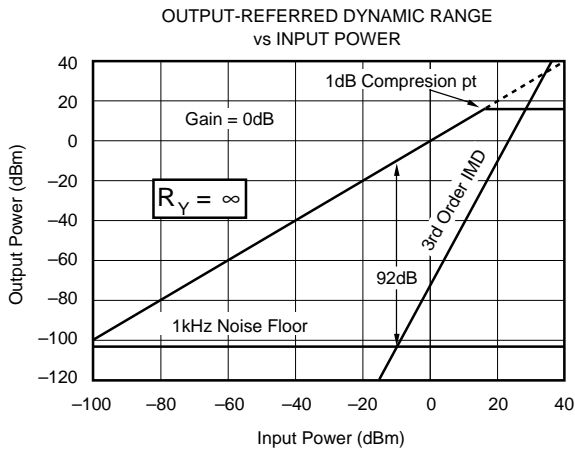
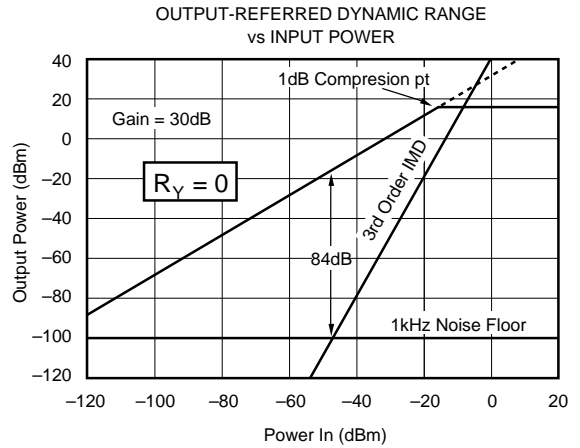
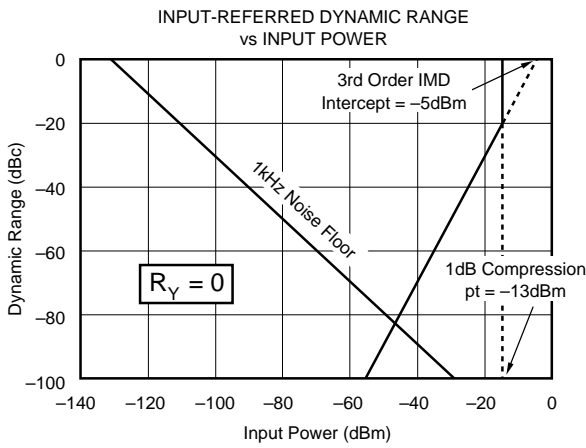
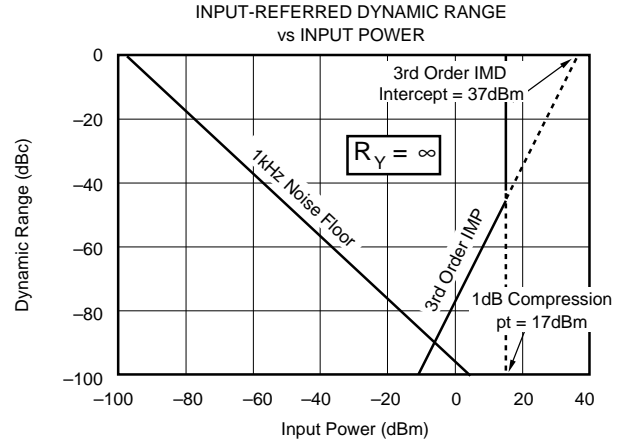
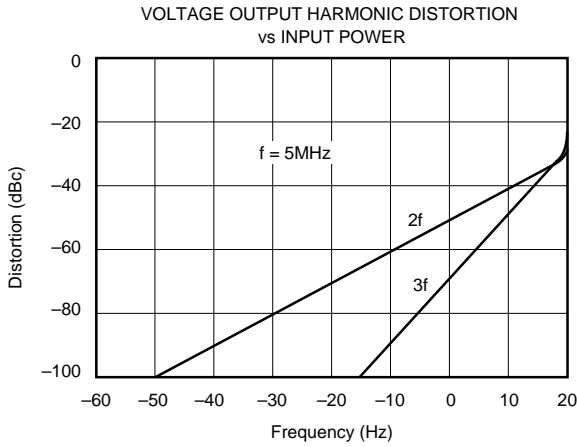
# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$  unless otherwise noted.



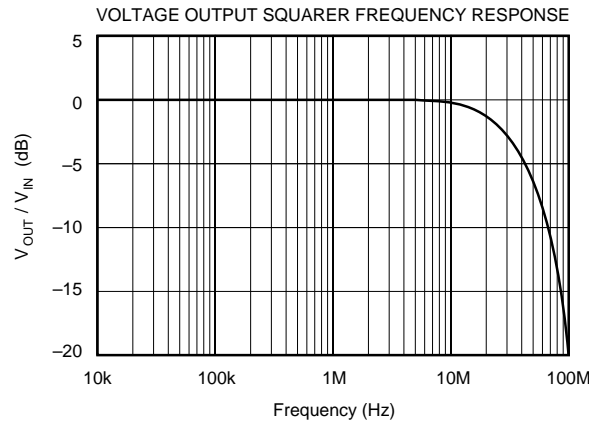
# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$  unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$  unless otherwise noted.



## APPLICATION INFORMATION

### POWER SUPPLIES

The MPY600 may be operated from power supplies from  $\pm 4.75\text{V}$  to  $\pm 8\text{V}$ . Operation from  $\pm 5\text{V}$  supplies is recommended. Since input and output levels are  $\pm 2\text{V}$ , larger supply voltage is not required for full output voltage swing. Furthermore, power dissipation can be minimized by using lower power supply voltage. Power supplies should be bypassed with good high-frequency capacitors such as ceramic or solid tantalum.

### TRANSFER FUNCTION

The open-loop transfer function of the MPY600 is:

$$V_O = A \left[ \frac{(X_1 - X_2) \cdot (Y_1 - Y_2)}{2V} - (Z_1 - Z_2) \right]$$

where  $A$  = open-loop gain of the output amplifier (typically 70dB).

$X$ ,  $Y$ ,  $Z$  are differential input voltages— $\pm 2\text{V}$  max.

An intuitive understanding of the transfer function can be gained by analogy to an op amp. Assuming that the open-loop gain is infinite, any output voltage can be created by an infinitesimally small quantity with the brackets. An applications circuit can be analyzed by assigning circuit voltages to the  $X$ ,  $Y$  and  $Z$  inputs and setting the bracketed quantity equal to zero.

For example, in the basic multiplier connection (Figure 1),  $Z_1 = V_O$  and  $Z_2 = 0$ . Setting this equal to zero:

$$\left[ \frac{(X_1 - X_2) \cdot (Y_1 - Y_2)}{2V} - V_O \right] = 0$$

Solving for  $V_O$  yields the transfer function of the circuit.

The  $X$  input is specified for  $\pm 1\text{V}$  full-scale differential input.  $X$  inputs up to  $\pm 2\text{V}$  provide useful operation with somewhat reduced accuracy and distortion performance. The  $Y$  input is rated for  $\pm 2\text{V}$  full-scale input. The  $Y$  input gain (and therefore its full-scale range) can be varied with an external resistor connected to the  $R_Y$  terminals—see “Modulator/Demodulator.” Full-scale inputs ( $X = \pm 1\text{V}$ ,  $Y = \pm 2\text{V}$ ) produce a  $\pm 1\text{V}$  output.

The differential inputs,  $X_1$ ,  $X_2$ , and  $Y_1$ ,  $Y_2$ , make it easy to trim offset voltage. The trim voltage is applied to the  $X_2$  or  $Y_2$  input, which is otherwise grounded (see  $X_2$  input, Figure 5). Polarity of the input signals can be reversed by interchanging the inputs (reversing the connections  $X_1$  and  $X_2$ , for instance). The unused current outputs (pins 15 and 16) must be grounded (or loaded—see discussion on current outputs).

The output amplifier is operated in unity gain. The output voltage can be increased (for small input signals) by placing the internal output op amp in higher gain (Figure 2). This reduces bandwidth and increases output offset voltage errors.

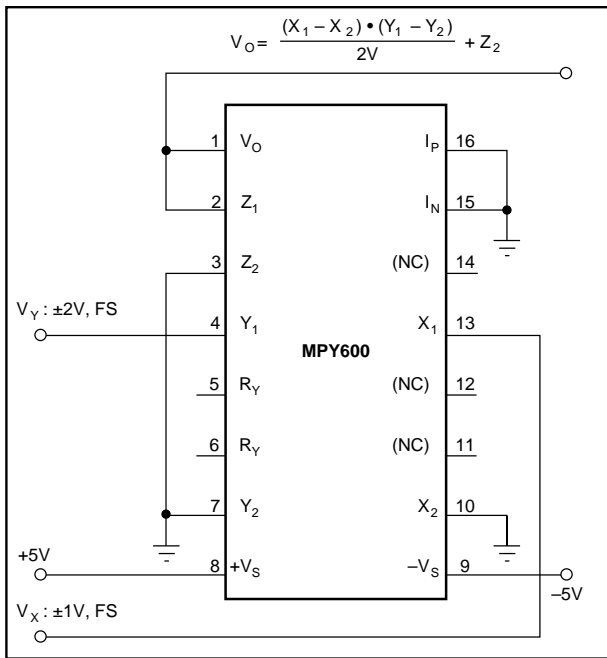


FIGURE 1. Basic Multiplier Connection.

### CURRENT OUTPUT

The current output connections of the MPY600 can achieve wider bandwidth multiplier operation (Figure 3). The current output is determined by the X and Y inputs only, so applications which use the Z input to modify the transfer function (e.g., divider and square-root modes) cannot be used. A full-scale input of  $\pm 1V$  on the X and  $\pm 2V$  on the Y inputs produces a 2mA differential current at the current outputs. This consists of approximately 2.5mA quiescent current  $\pm 1mA$  signal current on each output. The current outputs may be used to drive any load impedance which maintains the voltage on the current outputs within their compliance range. This compliance limit is approximately 2.5V from the power supply voltages. The current outputs and voltage output may be used simultaneously, if desired.

Output capacitance and stray capacitance at the current output terminals will limit the multiplier bandwidth. This makes large output resistors (greater than approximately 1k $\Omega$ ) impractical. The current outputs can be used to drive 50 $\Omega$  or 75 $\Omega$  loads directly.

The circuit shown in Figure 4 uses the current outputs to drive an external OPA621 op amp configured as a current-difference amplifier. It operates in a noise gain of 3.5. The OPA621 is stable in a noise gain of two or greater and has a 500MHz gain-bandwidth product. It achieves the full bandwidth performance of the MPY600.  $R_1$  determines the transfer function gain.  $R_3$  provides a proper load to optimize high-frequency effects.  $R_4$  is made equal to the parallel combination of  $R_1$  and  $R_3$ .

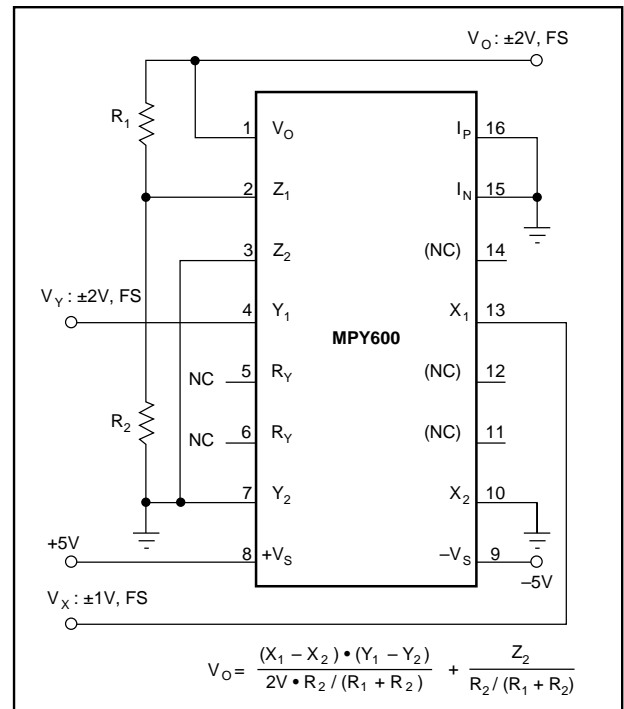


FIGURE 2. Adjusting the Scale Factor with Feedback.

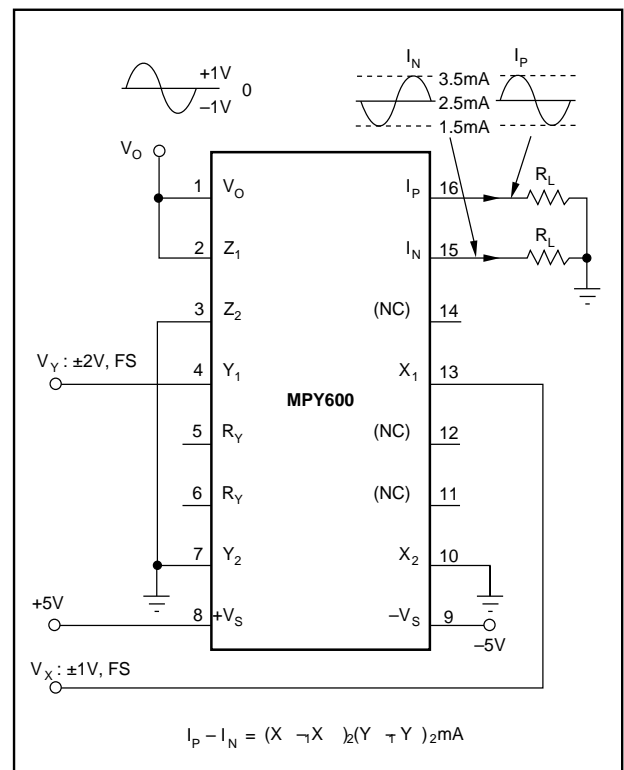


FIGURE 3. Current Output Connection.

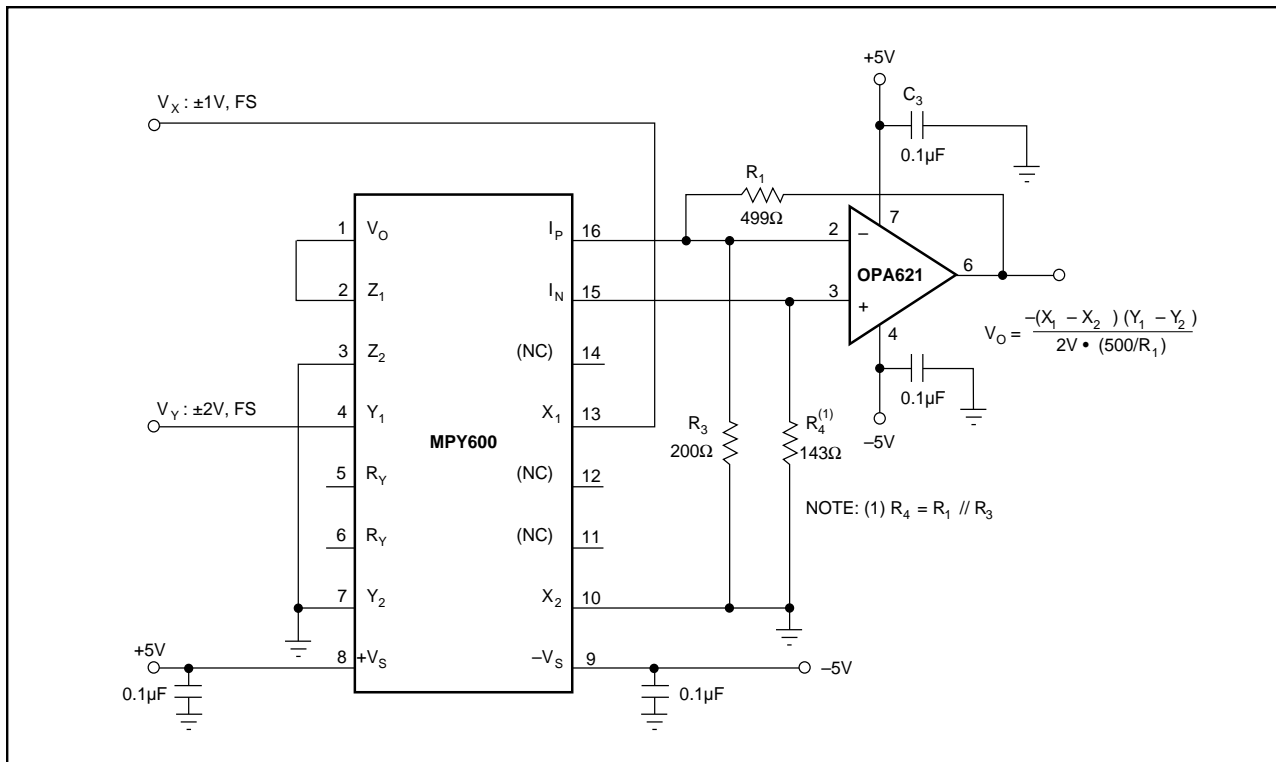


FIGURE 4. 75MHz DC-Coupled Multiplier.

### MODULATOR/DEMODULATOR

The balanced modulator or demodulator shown in Figure 5 uses the basic multiplier configuration. It shows the offset of the X input trimmed to null carrier feedthrough. It also illustrates the use of  $R_Y$  to change the gain of the Y input. This can be used to optimize the spurious-free dynamic range for a given input level. The Y input is optimized for  $\pm 2V$  inputs. For lower input signals, the Y input can be programmed for higher gain by connecting an external resistor to the  $R_Y$  terminals. The conceptual diagram in Figure 6 reveals why varying the Y-channel gain can yield improved dynamic range. The  $R_Y$  selection curve in Figure 5 shows the optimum value of  $R_Y$  for a given Y-input signal level.

### DIVIDER OPERATION

The MPY600 can be configured as a divider as shown in Figure 7. Numerator voltage is applied to the Z inputs; denominator voltage is applied to the  $Y_1$  input. Since the

feedback connection is made to a multiplying input, the effective gain of the output amplifier varies as a function of the denominator input. This causes the bandwidth to vary with denominator (see Typical Performance Curves for divider bandwidth performance). Accuracy in divider operation is approximately 3% for a 10:1 denominator range. Errors grow large and will eventually saturate the output as the denominator voltage approaches 0V.

### SQUARE-ROOT CIRCUIT

The circuit in Figure 8 provides an output voltage proportional to the square-root of the input (for positive input voltages). Diode  $D_1$  prevents latch-up if the input should go negative. The circuit can be configured for negative input and positive output by reversing the polarity of both the X and Y differential inputs. The output polarity can be inverted by reversing the X input polarity and the diode. Accuracy can be improved by trimming the offset at the Z input.



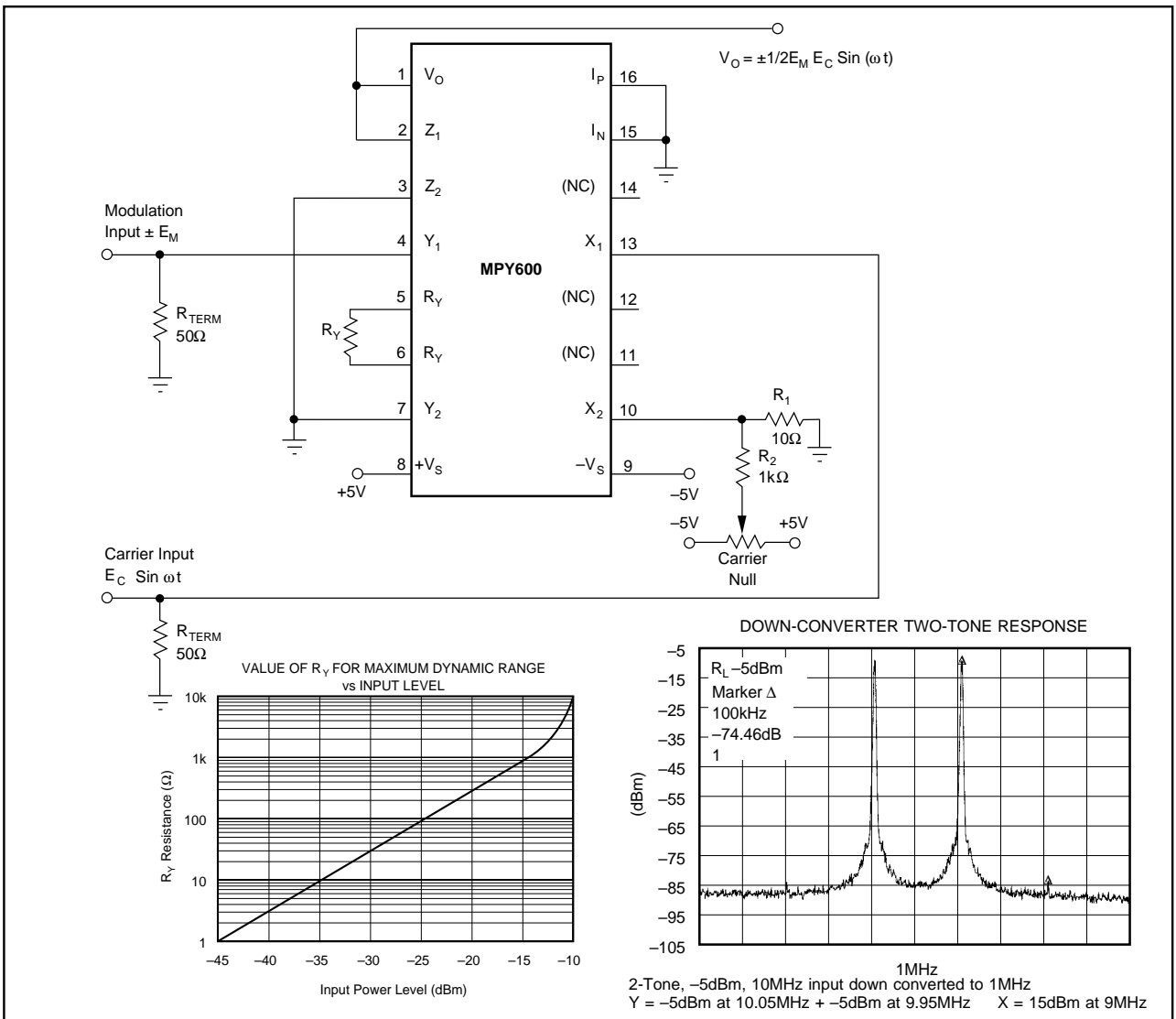


FIGURE 5. Balanced Modulator.

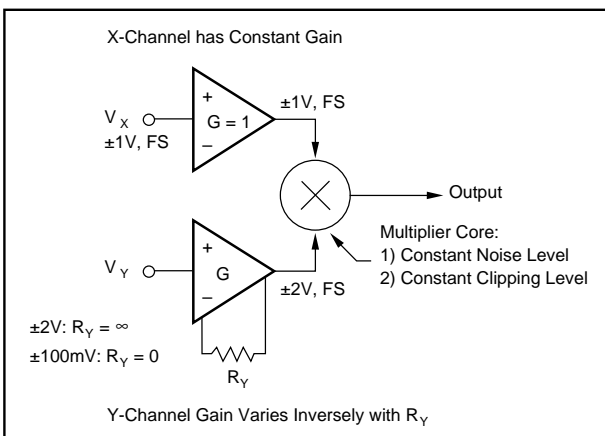


FIGURE 6. Variable Y-Channel Gain—Conceptual Model.

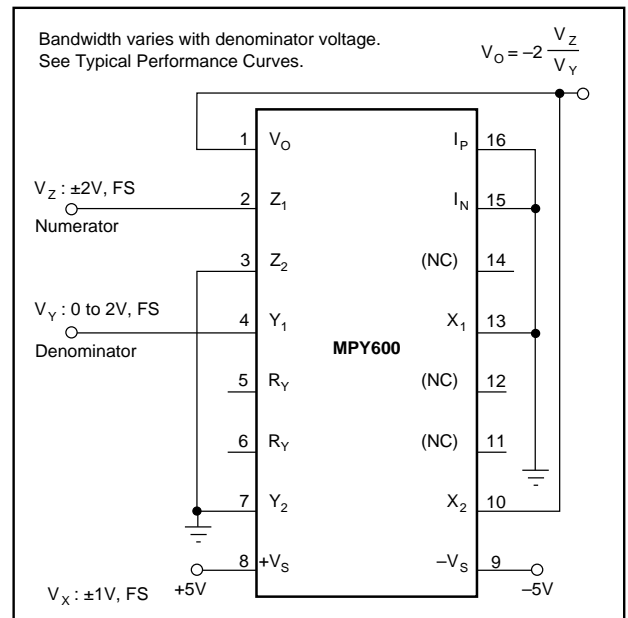


FIGURE 7. Divider Circuit.

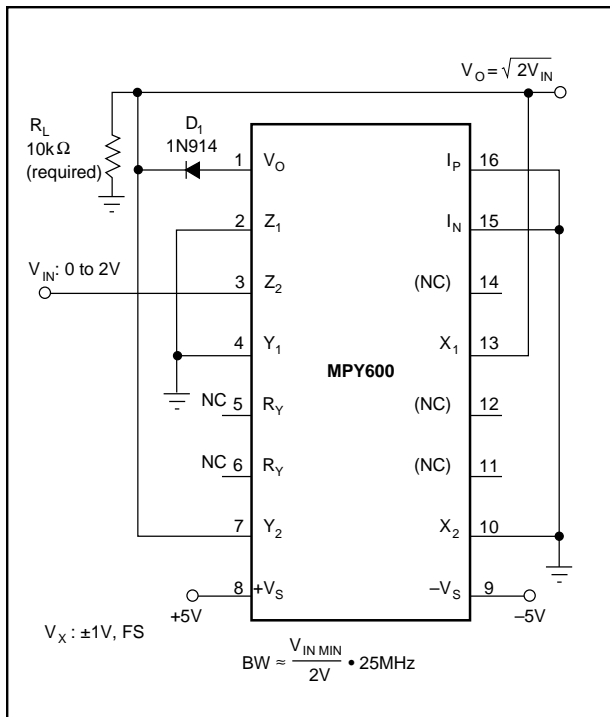


FIGURE 8. Square-Root Circuit.

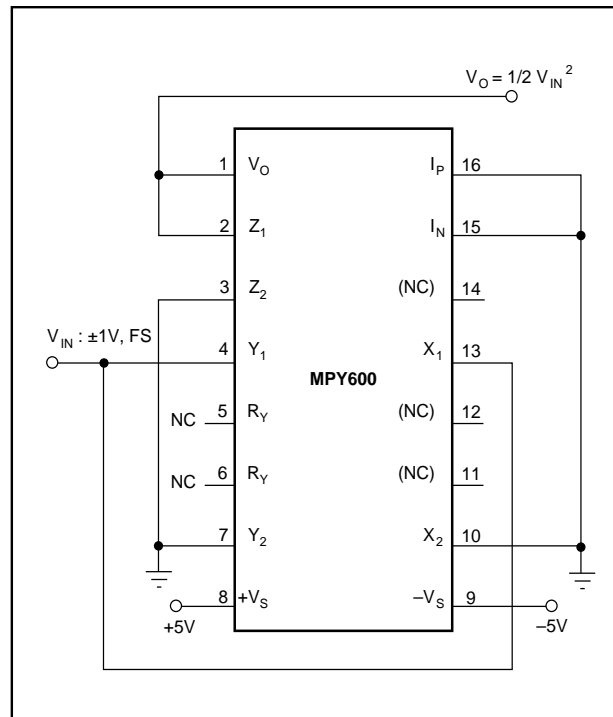


FIGURE 9. Squaring Circuit.

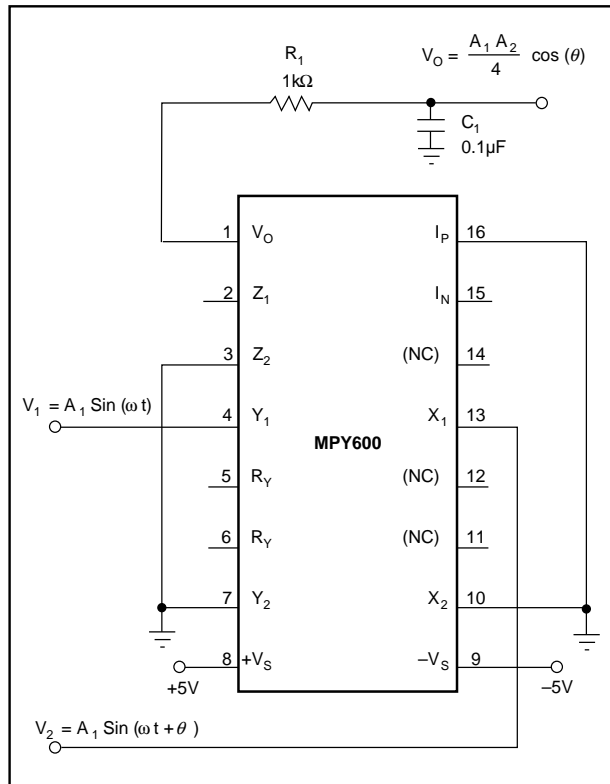


FIGURE 10. Phase Detector.

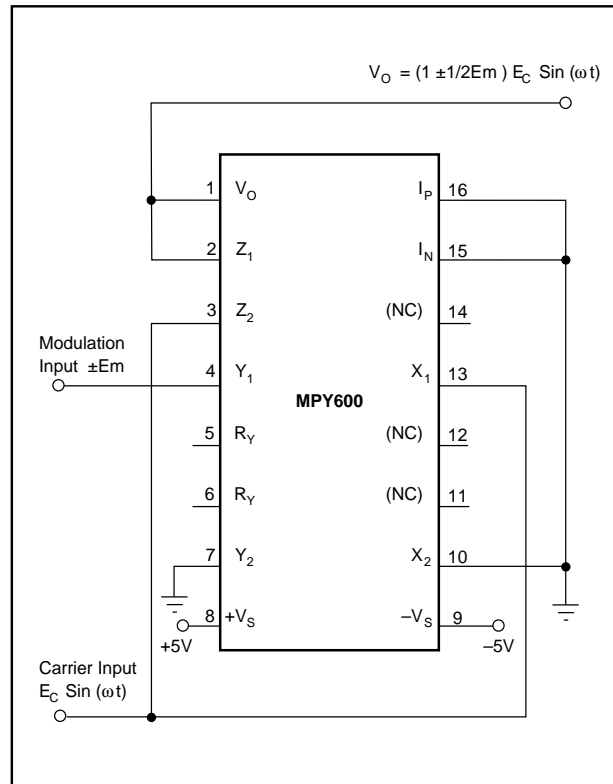


FIGURE 11. Linear AM Modulator.

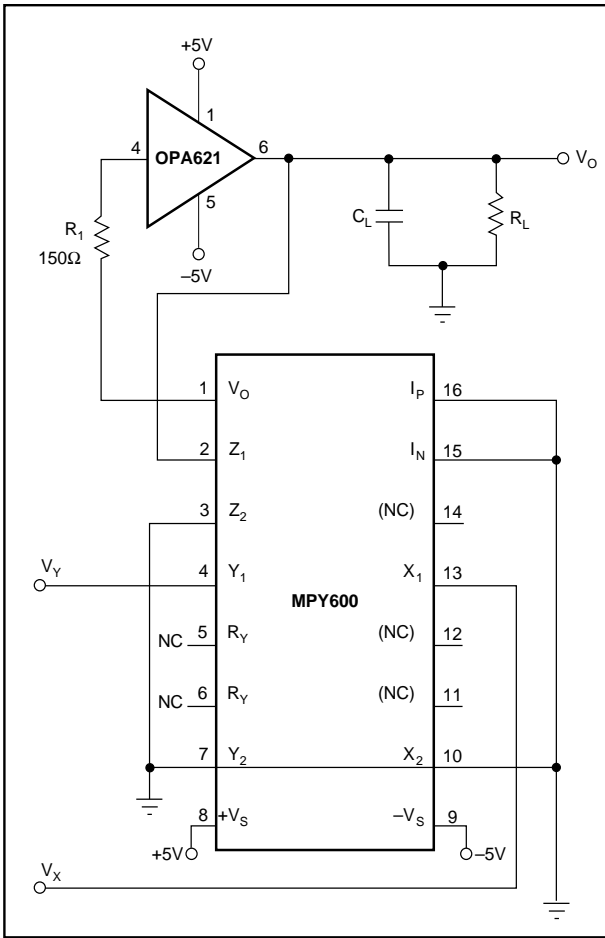


FIGURE 12. 25MHz Multiplier with Improved Load Driving Capability.

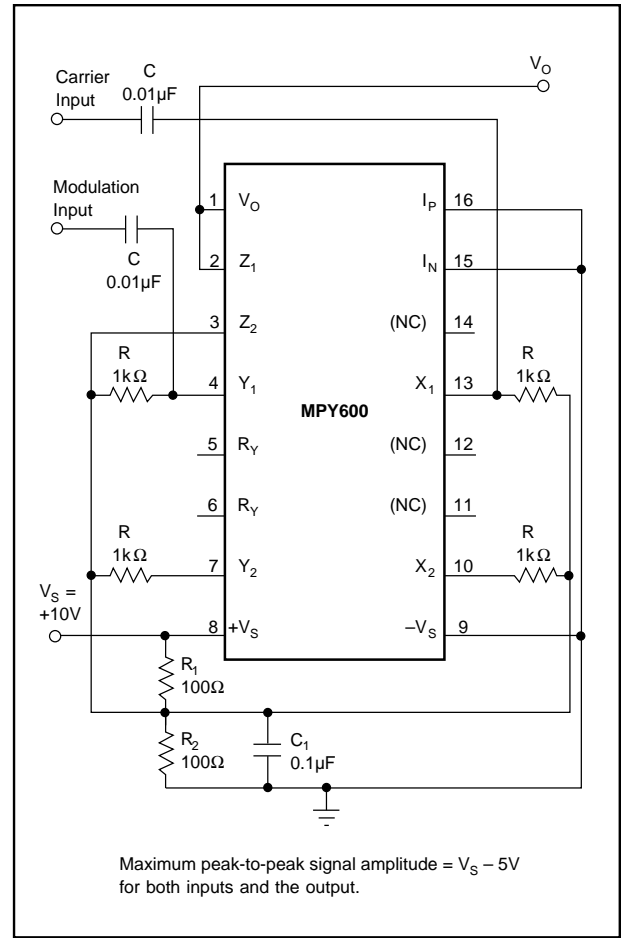


FIGURE 13. Single-Supply Balanced Modulator.

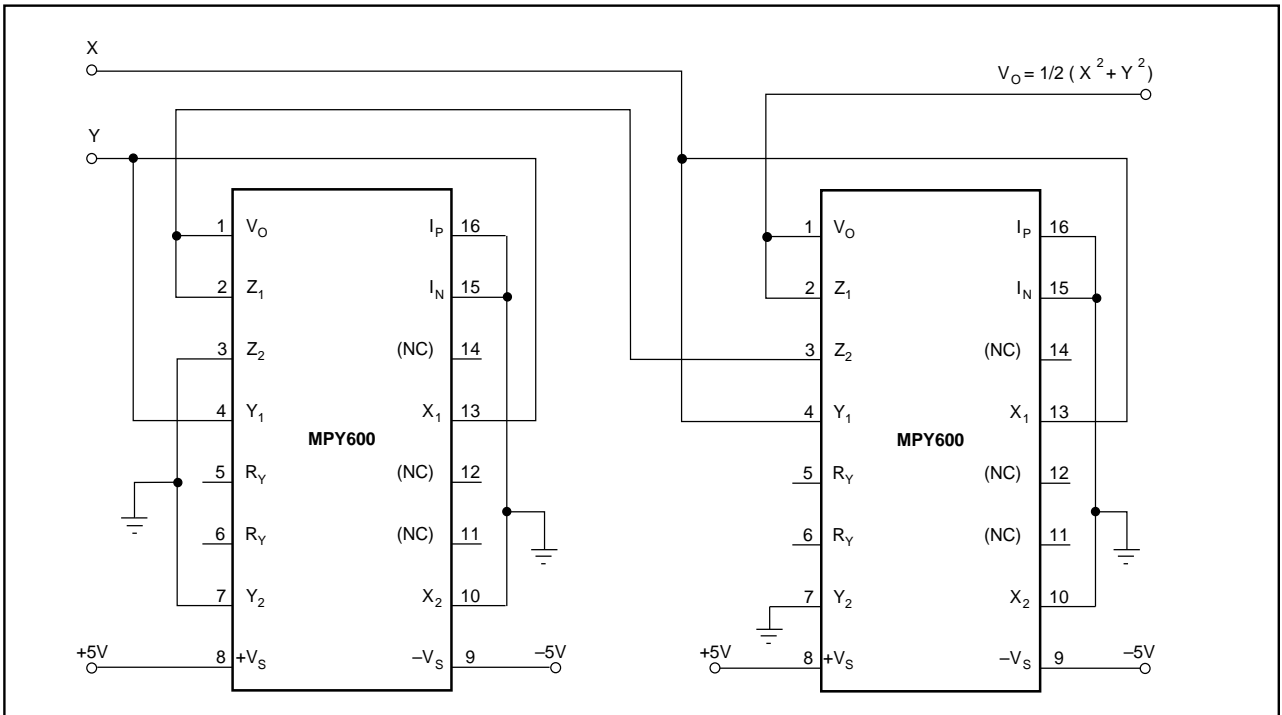


FIGURE 14. CRT Focus Correction.

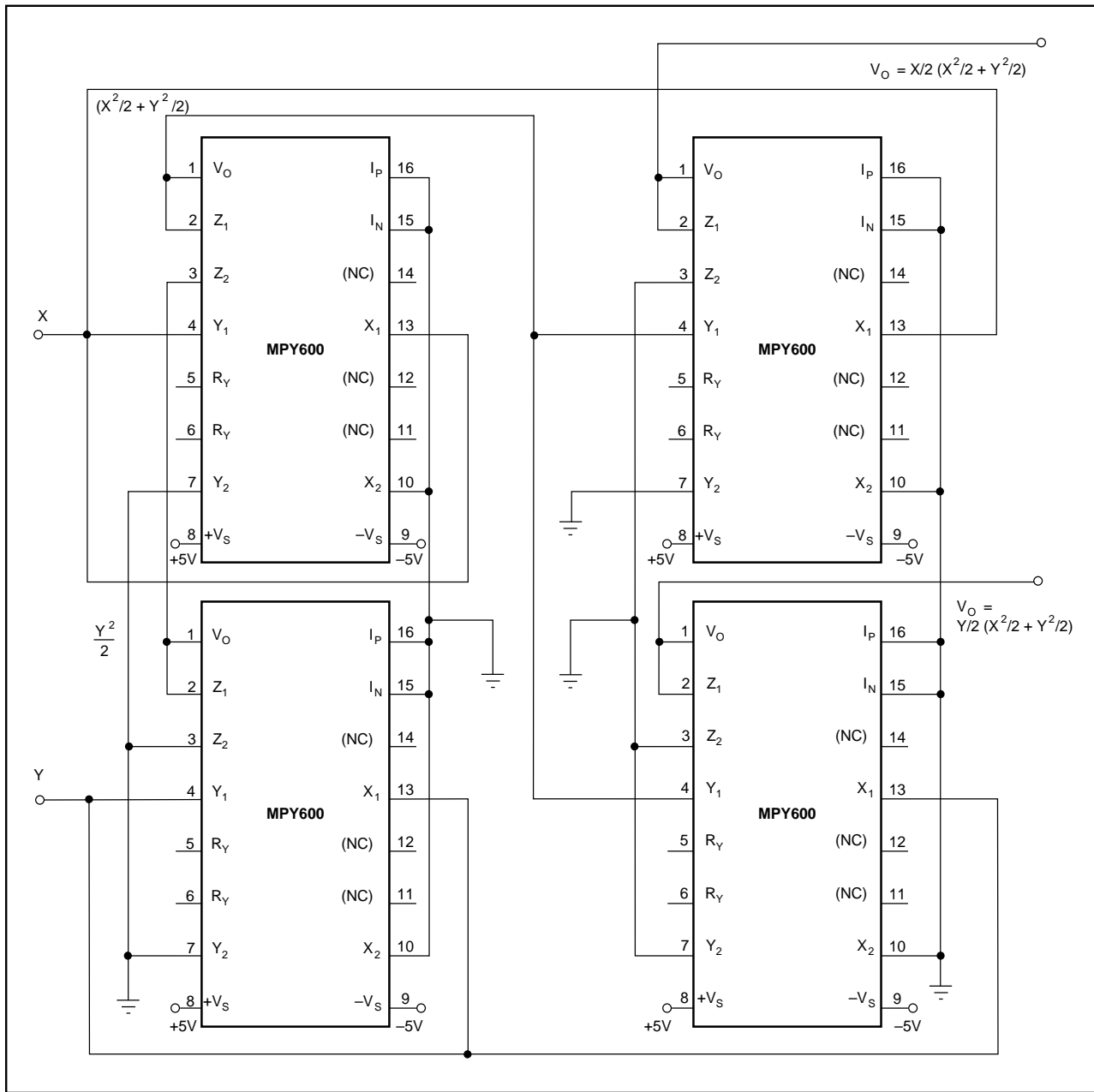


FIGURE 15. CRT Geometry Correction.

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