

### FEATURES

DC to >500 MHz Operation  
 Differential  $\pm 1$  V Full-Scale Inputs  
 Differential  $\pm 4$  mA Full-Scale Output Current  
 Low Distortion ( $\leq 0.05\%$  for 0 dBm Input)  
 Supply Voltages from  $\pm 4$  V to  $\pm 9$  V  
 Low Power (280 mW typical at  $V_S = \pm 5$  V)

### APPLICATIONS

High Speed Real Time Computation  
 Wideband Modulation and Gain Control  
 Signal Correlation and RF Power Measurement  
 Voltage Controlled Filters and Oscillators  
 Linear Keyers for High Resolution Television  
 Wideband True RMS

### PRODUCT DESCRIPTION

The AD834 is a monolithic laser-trimmed four-quadrant analog multiplier intended for use in high frequency applications, having a transconductance bandwidth ( $R_L = 50 \Omega$ ) in excess of 500 MHz from either of the differential voltage inputs. In multiplier modes, the typical total full-scale error is 0.5%, dependent on the application mode and the external circuitry. Performance is relatively insensitive to temperature and supply variations, due to the use of stable biasing based on a bandgap reference generator and other design features.

To preserve the full bandwidth potential of the high speed bipolar process used to fabricate the AD834, the outputs appear as a differential pair of currents at open collectors. To provide a single ended ground referenced voltage output, some form of external current to voltage conversion is needed. This may take the form of a wideband transformer, balun, or active circuitry such as an op amp. In some applications (such as power measurement) the subsequent signal processing may not need to have high bandwidth.

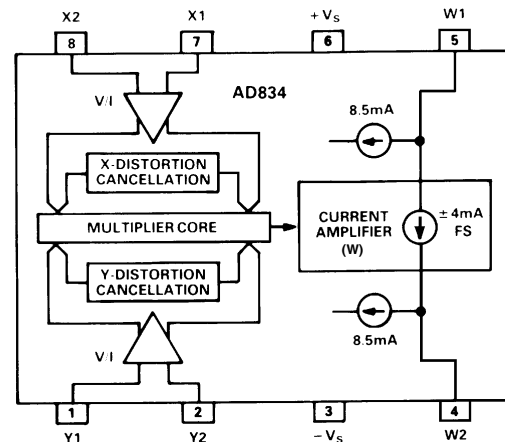
The transfer function is accurately trimmed such that when  $X = Y = \pm 1$  V, the differential output is  $\pm 4$  mA. This absolute calibration allows the outputs of two or more AD834s to be summed with precisely equal weighting, independent of the accuracy of the load circuit.

The AD834J is specified for use over the commercial temperature range of  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  and is available in an 8-lead DIP package and an 8-lead plastic SOIC package. AD834A is available in cerdip and 8-lead plastic SOIC packages for operation over the industrial temperature range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ . The AD834S/883B is specified for operation over the military temperature range of  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$  and is available in the 8-lead cerdip package. S-Grade chips are also available.

### REV. C

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### FUNCTIONAL BLOCK DIAGRAM



Two application notes featuring the AD834 (AN-212 and AN-216) can now be obtained by calling 1-800-ANALOG-D. For additional applications circuits consult the AD811 data sheet.

### PRODUCT HIGHLIGHTS

1. The AD834 combines high static accuracy (low input and output offsets and accurate scale factor) with very high bandwidth. As a four-quadrant multiplier or squarer, the response extends from dc to an upper frequency limited mainly by packaging and external board layout considerations. A large signal bandwidth of over 500 MHz is attainable under optimum conditions.
2. The AD834 can be used in many high speed nonlinear operations, such as square rooting, analog division, vector addition and rms-to-dc conversion. In these modes, the bandwidth is limited by the external active components.
3. Special design techniques result in low distortion levels (better than  $-60$  dB on either input) at high frequencies and low signal feedthrough (typically  $-65$  dB up to 20 MHz).
4. The AD834 exhibits low differential phase error over the input range—typically  $0.08^\circ$  at 5 MHz and  $0.8^\circ$  at 50 MHz. The large signal transient response is free from overshoot, and has an intrinsic rise time of 500 ps, typically settling to within 1% in under 5 ns.
5. The nonloading, high impedance, differential inputs simplify the application of the AD834.

# AD834—SPECIFICATIONS (T<sub>A</sub> = +25°C and ±V<sub>S</sub> = ±5 V, unless otherwise noted; dBm assumes 50 Ω load.)

Model	Conditions	AD834J			AD834A, S			Units
		Min	Typ	Max	Min	Typ	Max	
<b>MULTIPLIER PERFORMANCE</b>								
Transfer Function			$W = \frac{XY}{(1V)^2} \times 4 mA$			$W = \frac{XY}{(1V)^2} \times 4 mA$		
Total Error <sup>1</sup> (Figure 6) vs. Temperature	-1 V ≤ X, Y < +1 V T <sub>MIN</sub> to T <sub>MAX</sub>		±0.5	±2		±0.5	±2	% FS
vs. Supplies <sup>2</sup>	±4 V to ±6 V		0.1	0.3		0.1	0.3	% FS/V
Linearity <sup>3</sup>			±0.5	±1		±0.5	±1	% FS
Bandwidth <sup>4</sup>	See Figure 5	500			500			MHz
Feedthrough, X	X = ±1 V, Y = Nulled		0.2	0.3		0.2	0.3	% FS
Feedthrough, Y	X = Nulled, Y = ±1 V		0.1	0.2		0.1	0.2	% FS
AC Feedthrough, X <sup>5</sup>	X = 0 dBm, Y = Nulled f = 10 MHz			-65			-65	dB
	f = 100 MHz			-50			-50	dB
AC Feedthrough, Y <sup>5</sup>	X = Nulled, Y = 0 dBm f = 10 MHz			-70			-70	dB
	f = 100 MHz			-50			-50	dB
<b>INPUTS (X1, X2, Y1, Y2)</b>								
Full-Scale Range	Differential		±1			±1		V
Clipping Level	Differential	±1.1	±1.3		±1.1	±1.3		V
Input Resistance	Differential		25			25		kΩ
Offset Voltage			0.5	3		0.5	3	mV
vs. Temperature	T <sub>MIN</sub> to T <sub>MAX</sub>		10			10		μV/°C
vs. Supplies <sup>2</sup>	±4 V to ±6 V		100	300		100	300	mV
Bias Current			45			45		μA
Common-Mode Rejection	f ≤ 100 kHz; 1 V p-p		70			70		dB
Nonlinearity, X	Y = 1 V; X = ±1 V		0.2	0.5		0.2	0.5	% FS
Nonlinearity, Y	X = 1 V; Y = ±1 V		0.1	0.3		0.1	0.3	% FS
Distortion, X	X = 0 dBm, Y = 1 V f = 10 MHz			-60			-60	dB
	f = 100 MHz			-44			-44	dB
Distortion, Y	X = 1 V, Y = 0 dBm f = 10 MHz			-65			-65	dB
	f = 100 MHz			-50			-50	dB
<b>OUTPUTS (W1, W2)</b>								
Zero Signal Current	Each Output		8.5			8.5		mA
Differential Offset	X = 0, Y = 0		±20	±60		±20	±60	μA
vs. Temperature	T <sub>MIN</sub> to T <sub>MAX</sub>		40			40		nA/°C
Scaling Current	Differential	3.96	4	4.04	3.96	4	4.04	μA
Output Compliance		4.75		9	4.75		9	mA
Noise Spectral Density	f = 10 Hz to 1 MHz Outputs into 50 Ω Load		16			16		nV/√Hz
<b>POWER SUPPLIES</b>								
Operating Range		±4		±9	±4		±9	V
Quiescent Current <sup>6</sup>	T <sub>MIN</sub> to T <sub>MAX</sub>							
+V <sub>S</sub>			11	14		11	14	mA
-V <sub>S</sub>			28	35		28	35	mA
<b>TEMPERATURE RANGE</b>								
Operating, Rated Performance			AD834J			AD834S		
Commercial (0°C to +70°C)						AD834A		
Military (-55°C to +125°C)								
Industrial (-40°C to +85°C)								
<b>PACKAGE OPTIONS</b>								
8-Pin SOIC (R)			AD834JR, REEL, REEL7			AD834AR		
8-Pin Cerdip (Q)						AD834AQ, SQ/883B		
8-Pin Plastic DIP (N)			AD834JN					

## NOTES

<sup>1</sup>Error is defined as the maximum deviation from the ideal output, and expressed as a percentage of the full-scale output.

<sup>2</sup>Both supplies taken simultaneously; sinusoidal input at f ≤ 10 kHz.

<sup>3</sup>Linearity is defined as residual error after compensating for input offset voltage, output offset current and scaling current errors.

<sup>4</sup>Bandwidth is guaranteed when configured in squarer mode. See Figure 5.

<sup>5</sup>Sine input; relative to full-scale output; zero input port nulled; represents feedthrough of the fundamental.

<sup>6</sup>Negative supply current is equal to the sum of positive supply current, the signal currents into each output, W1 and W2, and the input bias currents.

Specifications in **boldface** are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels.

Specifications subject to change without notice.

### ABSOLUTE MAXIMUM RATINGS\*

Supply Voltage (+V <sub>S</sub> to -V <sub>S</sub> )	18 V
Internal Power Dissipation	500 mW
Input Voltages (X1, X2, Y1, Y2)	+V <sub>S</sub>
Operating Temperature Range	
AD834J	0°C to +70°C
AD834A	-40°C to +85°C
AD834S/883B	-55°C to +125°C
Storage Temperature Range (Q)	-65°C to +150°C
Storage Temperature Range (R, N)	-65°C to +125°C
Lead Temperature (Soldering 60 sec)	+300°C
ESD Rating	500 V

\*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the devices. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### THERMAL CHARACTERISTICS

	$\theta_{JC}$	$\theta_{JA}$
8-Pin Cerdip Package (Q)	30°C/W	110°C/W
8-Pin Plastic SOIC (R)	45°C/W	165°C/W
8-Pin Plastic Mini-DIP (N)	50°C/W	99°C/W

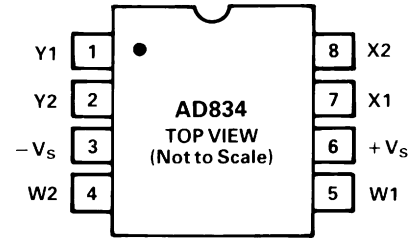
### ORDERING GUIDE

Model	Temperature Range	Package Option*
AD834JN	0°C to +70°C	N-8
AD834JR	0°C to +70°C	SO-8
AD834JR-REEL	0°C to +70°C	SO-8
AD834JR-REEL7	0°C to +70°C	SO-8
AD834AR	-40°C to +85°C	SO-8
AD834AQ	-40°C to +85°C	Q-8
AD834SQ/883B	-55°C to +125°C	Q-8
AD834S CHIPS	-55°C to +125°C	DIE

\*N = Plastic DIP; Q = Cerdip; SO = Small Outline IC (SOIC) Package.

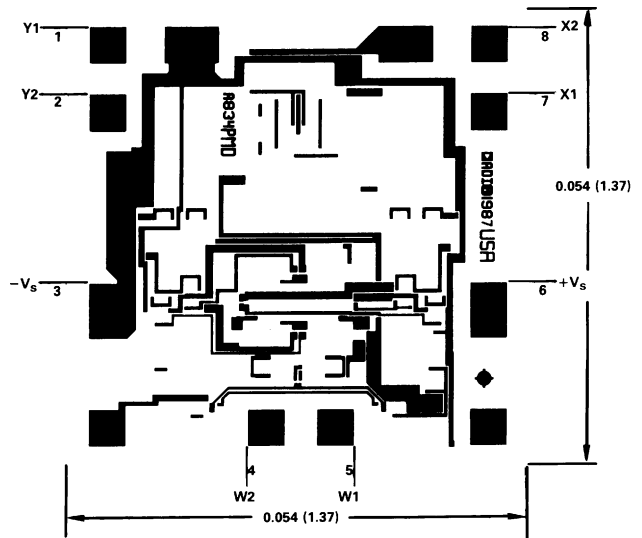
### CONNECTION DIAGRAM

Small Outline (R) Package  
Plastic DIP (N) Package  
Cerdip (Q) Package



### METALIZATION PHOTOGRAPH CHIP DIMENSIONS AND BONDING DIAGRAM

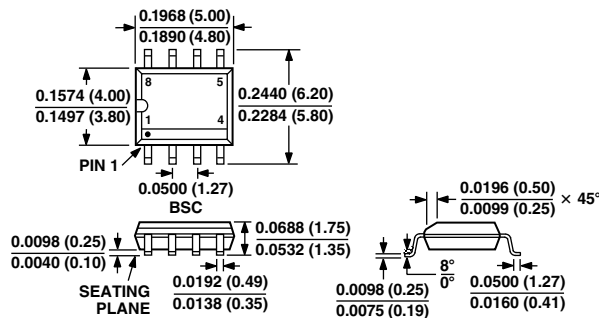
Dimensions shown in inches and (mm).  
Contact factory for latest dimensions.



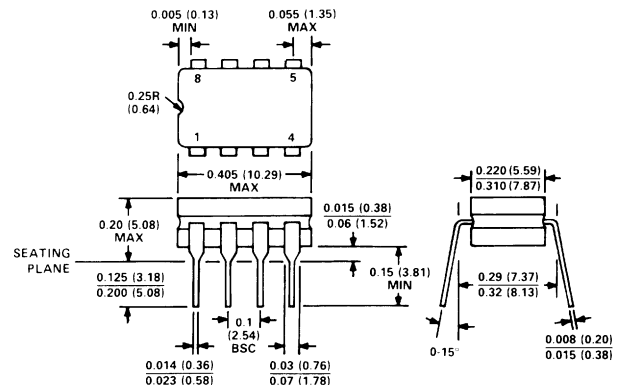
### OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

#### Small Outline (SO-8) Package



#### Cerdip (Q) Package



# AD834—Typical Characteristics

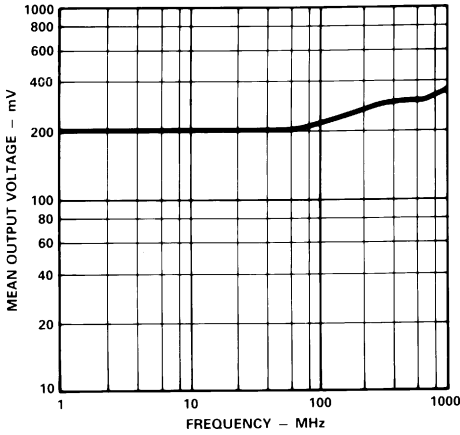


Figure 1. Mean-Square Output vs. Frequency

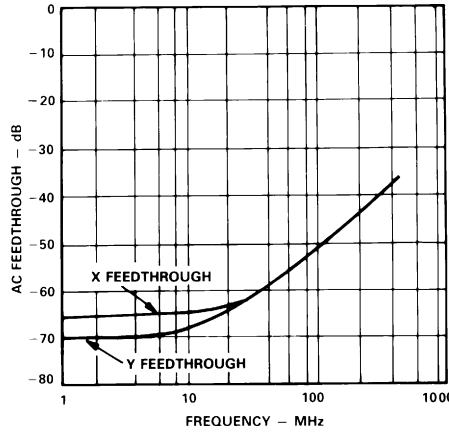


Figure 2. AC Feedthrough vs. Frequency

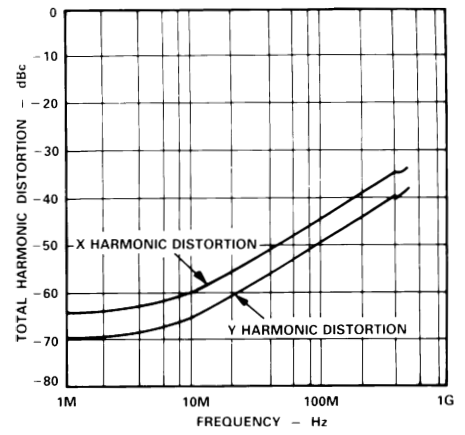


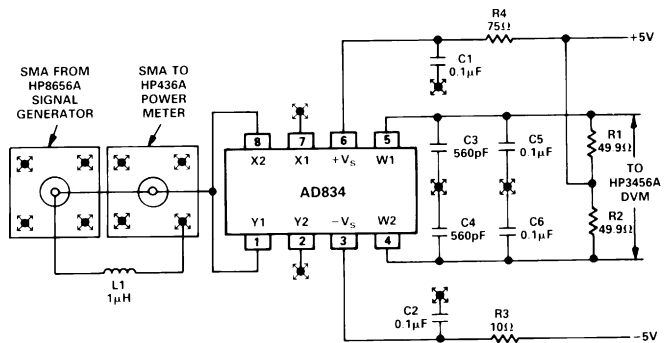
Figure 3. Total Harmonic Distortion vs. Frequency

**Figure 1.** Figure 1 is a plot of the mean-square output versus frequency for the test circuit of Figure 5. Note that the rising response is due to package resonances.

**Figure 2.** For frequencies above 1 MHz, ac feedthrough is dominated by static nonlinearities in the transfer function and the finite offset voltages. The offset voltages cause a small fraction of the fundamental to appear at the output, and can be nulled out.

**Figure 3.** THD data represented in Figure 3 is dominated by the second harmonic, and is generated with 0 dBm input on the ac input and +1 V on the dc input. For a given amplitude on the ac input, THD is relatively insensitive to changes in the dc input amplitude. Varying the ac input amplitude while maintaining a constant dc input amplitude will affect THD performance.

By placing capacitors C3/C5 and C4/C6 across load resistors R1 and R2, a simple low-pass filter is formed, and the mean-square value is extracted. The mean-square response can be measured using a DVM connected across R1 and R2.



⊗ DENOTES A SHORT DIRECT CONNECTION TO THE GROUND PLANE

Figure 5. Bandwidth Test Circuit

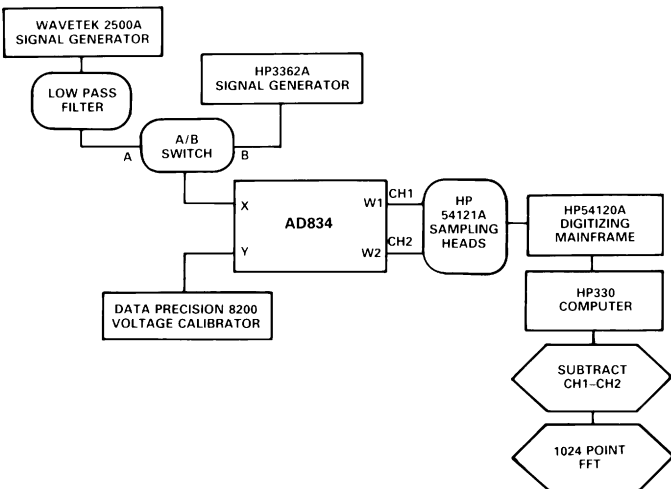
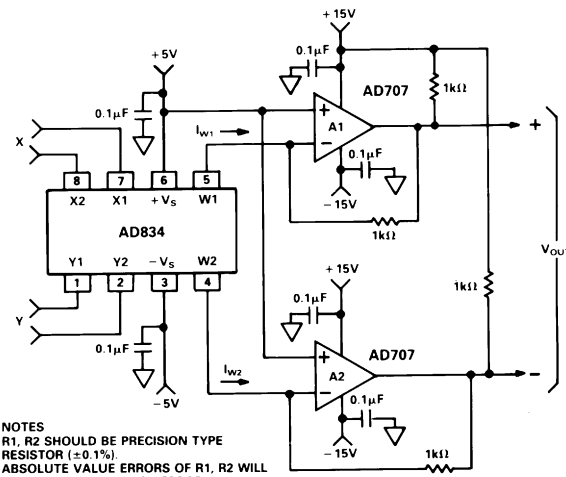


Figure 4. Test Configuration for Measuring AC Feedthrough and Total Harmonic Distortion

**Figure 5.** The squarer configuration shown in Figure 5 is used to determine wideband performance because it eliminates the need for (and the response uncertainties of) a wideband measurement device at the output. The wideband output of a squarer configuration is a fluctuating current at twice the input frequency with a mean value proportional to the square of the input amplitude.



NOTES  
R1, R2 SHOULD BE PRECISION TYPE RESISTOR ( $\pm 0.1\%$ )  
ABSOLUTE VALUE ERRORS OF R1, R2 WILL CAUSE A SCALE FACTOR ERROR.  
R1, R2 MISMATCHES WILL BE EXPRESSED AS LINEARITY ERRORS.  
 $V_{OUT} = I_{W1} R1 - I_{W2} R2$   
(IF  $R1 = R2$ ,  $V_{OUT} = \Delta I_{W1} R1$ .)

Figure 6. Low Frequency Test Circuit

## BASIC OPERATION

Figure 7 is a functional equivalent of the AD834. There are three differential signal interfaces: the voltage inputs  $X = X1-X2$  and  $Y = Y1-Y2$ , and the current output,  $W$  (see Figure 7) which flows in the direction shown when  $X$  and  $Y$  are positive. The outputs  $W1$  and  $W2$  each have a standing current of typically 8.5 mA.

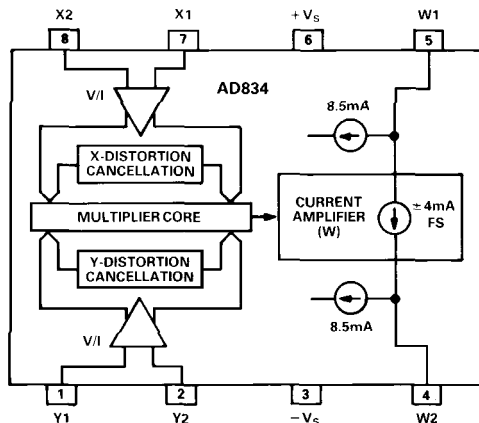


Figure 7. AD834 Functional Block Diagram

The input voltages are first converted to differential currents which drive the translinear core. The equivalent resistance of the voltage-to-current (V-I) converters is about 285  $\Omega$ . This low value results in low input related noise and drift. However, the low full-scale input voltage results in relatively high nonlinearity in the V-I converters. This is significantly reduced by the use of distortion cancellation circuits which operate by Kelvin sensing the voltages generated in the core—an important feature of the AD834.

The current mode output of the core is amplified by a special cascode stage which provides a current gain of nominally  $\times 1.6$ , trimmed during manufacture to set up the full-scale output current of  $\pm 4$  mA. **This output appears at a pair of open collectors which must be supplied with a voltage slightly above the voltage on Pin 6.** As shown in Figure 8, this can be arranged by inserting a resistor in series with the supply to this pin and taking the load resistors to the full supply. With  $R3 = 60 \Omega$ , the voltage drop across it is about 600 mV. Using two 50  $\Omega$  load resistors, the full-scale differential output voltage is  $\pm 400$  mV.

The full bandwidth potential of the AD834 can only be realized when very careful attention is paid to grounding and decoupling. The device must be mounted close to a high quality ground plane and all lead lengths must be extremely short, in keeping with UHF circuit layout practice. In fact, the AD834 shows useful response to well beyond 1 GHz, and the actual upper frequency in a typical application will usually be determined by the care with which the layout is effected. Note that  $R4$  (in series with the  $-V_S$  supply) carries about 30 mA and thus introduces a voltage drop of about 150 mV. It is made large enough to reduce the Q of the resonant circuit formed by the supply lead and the decoupling capacitor. Slightly larger values can be used, particularly when using higher supply voltages. Alternatively, lossy RF chokes or ferrite beads on the supply leads may be used.

Figure 8 shows the use of optional termination resistors at the inputs. Note that although the resistive component of the input

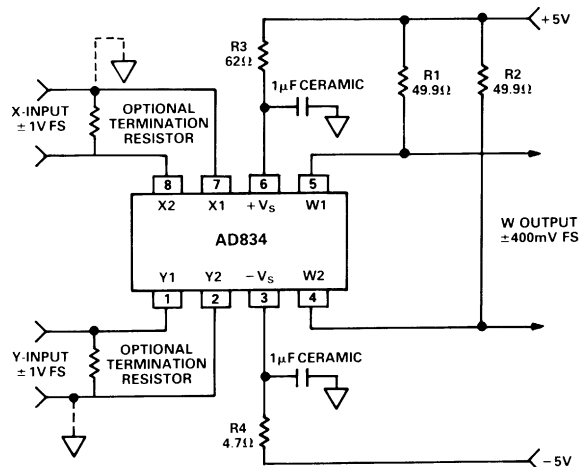


Figure 8. Basic Connections for Wideband Operation

impedance is quite high (about 25 k $\Omega$ ), the input bias current of typically 45  $\mu$ A can generate significant offset voltages if not compensated. For example, with a source and termination resistance of 50  $\Omega$  (net source of 25  $\Omega$ ) the offset would be  $25 \Omega \times 45 \mu\text{A} = 1.125$  mV. This can be almost fully cancelled by including (in this example) another 25  $\Omega$  resistor in series with the “unused” input (in Figure 8, either  $X1$  or  $Y2$ ). In order to minimize crosstalk the input pins closest to the output ( $X1$  and  $Y2$ ) should be grounded; the effect is merely to reverse the phase of the  $X$  input and thus alter the polarity of the output.

## TRANSFER FUNCTION

The output current  $W$  is the linear product of input voltages  $X$  and  $Y$  divided by  $(1 \text{ V})^2$  and multiplied by the “scaling current” of 4 mA:

$$W = \frac{XY}{(1V)^2} 4 \text{ mA}$$

Provided that it is understood that the inputs are specified in volts, a simplified expression can be used:

$$W = (XY) 4 \text{ mA}$$

Alternatively, the full transfer function can be written:

$$W = \frac{XY}{1V} \times \frac{1}{250 \Omega}$$

When both inputs are driven to their clipping level of about 1.3 V, the peak output current is roughly doubled, to  $\pm 8$  mA, but distortion levels will then be very high.

## TRANSFORMER COUPLING

In many high frequency applications where baseband operation is not required at either inputs or output, transformer coupling can be used. Figure 9 shows the use of a center-tapped output transformer, which provides the necessary dc load condition at the outputs  $W1$  and  $W2$ , and is designed to match into the desired load impedance by appropriate choice of turns ratio. The specific choice of the transformer design will depend entirely on the application. Transformers may also be used at the inputs. Center-tapped transformers can reduce high frequency distortion and lower HF feedthrough by driving the inputs with balanced signals.

# AD834

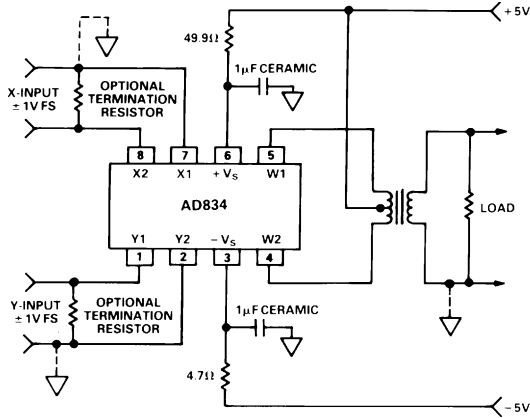


Figure 9. Transformer-Coupled Output

A particularly effective type of transformer is the balun<sup>1</sup> which is a short length of transmission line wound on to a toroidal ferrite core. Figure 10 shows this arrangement used to convert the bal(anced) output to an un(balanced) one (hence the use of the term). Although the symbol used is identical to that for a transformer, the mode of operation is quite different. In the first place, the load should now be equal to the characteristic impedance of the line (although this will usually not be critical for short line lengths). The collector load resistors  $R_C$  may also be chosen to reverse terminate the line, but again this will only be necessary when an electrically long line is used. In most cases,  $R_C$  will be made as large as the dc conditions allow, to minimize power loss to the load. The line may be a miniature coaxial cable or a twisted pair.

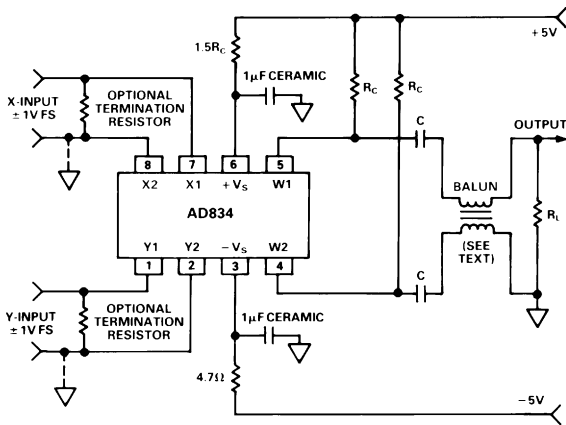


Figure 10. Using a Balun at the Output

It is important to note that the upper bandwidth limit of the balun is determined only by the quality of the transmission line; hence, it will usually exceed that of the multiplier. This is unlike a conventional transformer where the signal is conveyed as a flux in a magnetic core and is limited by core losses and leakage inductance. The lower limit on bandwidth is determined by the series inductance of the line, taken as a whole, and the load resistance (if the blocking capacitors  $C$  are sufficiently large). In practice, a balun can provide excellent differential-to-single-sided conversion over much wider bandwidths than a transformer.

<sup>1</sup>For a good treatment of baluns, see "Transmission Line Transformers" by Jerry Sevick; American Radio Relay League publication.

## WIDEBAND MULTIPLIER CONNECTIONS

Where operation down to dc and a ground based output are necessary, the configuration shown in Figure 11 can be used. The element values were chosen in this example to result in a full-scale output of  $\pm 1$  V at the load, so the overall multiplier transfer function is

$$W = (X1 - X2) (Y1 - Y2)$$

where it is understood that the *inputs and output are in volts*. The polarity of the output can be reversed simply by reversing either the X or Y input.

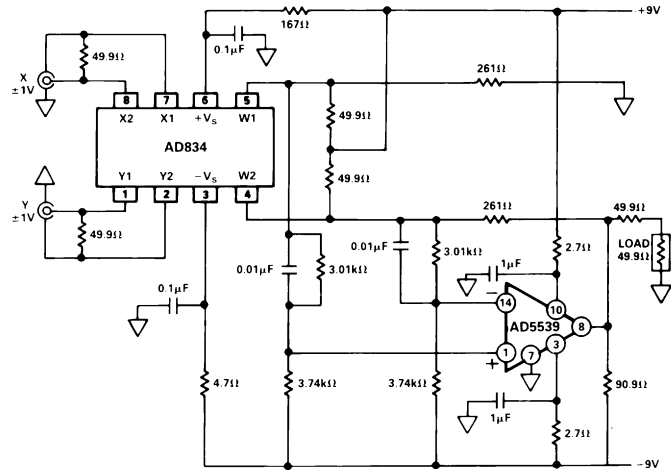


Figure 11. Sideband DC-Coupled Multiplier

The op amp should be chosen to support the desired output bandwidth. The AD5539 is shown here, providing an overall system bandwidth of 100 MHz. Many other choices are possible where lower post multiplication bandwidths are acceptable. The level shifting network places the input nodes of the op amp to within a few hundred millivolts of ground using the recommended balanced supplies. The output offset may be nulled by including a 100  $\Omega$  trim pot between each of the lower pair of resistors (3.74 k $\Omega$ ) and the negative supply.

The pulse response for this circuit shown in Figure 12; the X input was a pulse of 0 V to +1 V and the Y input was +1 V dc. The transition times at the output are about 4 ns.

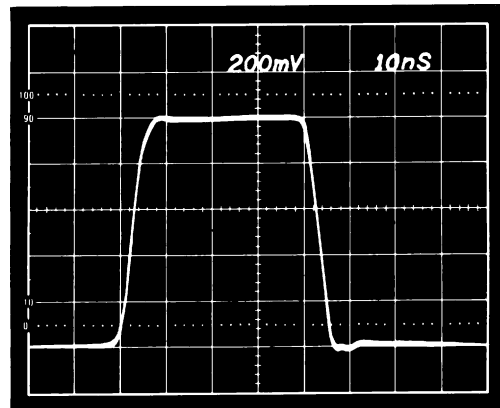


Figure 12. Pulse Response for the Circuit of Figure 11



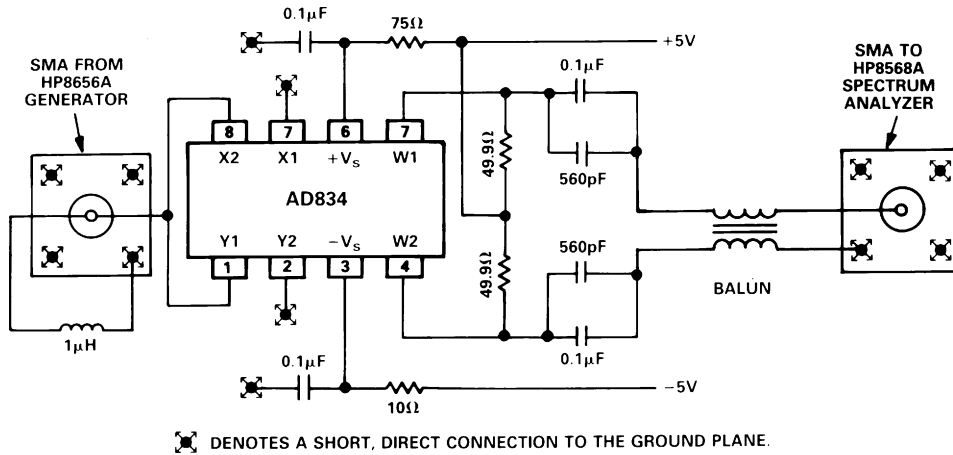


Figure 14. Frequency Doubler Connections

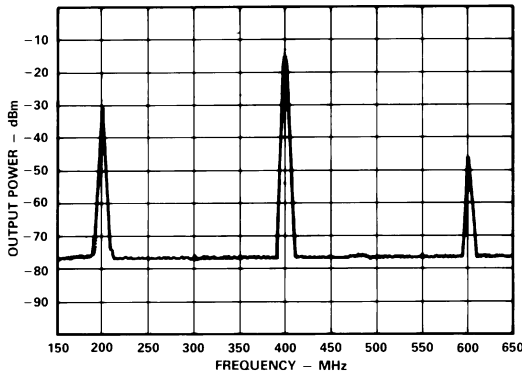


Figure 15. Output Spectrum for Configuration of Figure 14

### WIDEBAND THREE SIGNAL MULTIPLIER/DIVIDER

Two AD834s and a wideband op amp can be connected to make a versatile multiplier/divider having the transfer function

$$W = \frac{(X1 - X2)(Y1 - Y2)}{(U1 - U2)} + Z$$

with a denominator range of about 100:1. The denominator input  $U = U1 - U2$  must be positive and in the range 100 mV to 10 V; X, Y and Z inputs may have either polarity. Figure 16 shows a general configuration which may be simplified to suit a particular application. This circuit accepts full-scale input voltages of 10 V, and delivers a full-scale output voltage of 10 V. The optional offset trim at the output of the AD834 improves the accuracy for small denominator values. It is adjusted by nulling the output voltage when the X and Y inputs are zero and  $U = +100$  mV.

The AD840 is internally compensated to be stable without the use of any additional HF compensation. As the input U is reduced, the bandwidth falls because the feedback around the op amp is proportional to the input U.

This circuit may be modified in several ways. For example, if the differential input feature is not needed, the unused input

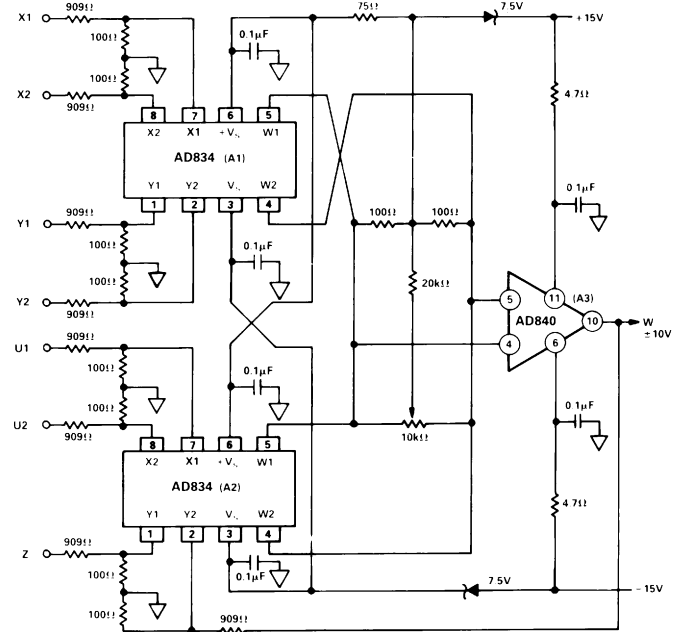


Figure 16. Wideband Three Signal Multiplier/Divider

can be connected to ground through a single resistor, equal to the parallel sum of the resistors in the attenuator section. The full-scale input levels on X, Y and U can be adapted to any full-scale voltage down to  $\pm 1$  V by altering the attenuator ratios. Note, however, that precautions must be taken if the attenuator ratio from the output of A3 back to the second AD834 (A2) is lowered. First, the HF compensation limit of the AD840 may be exceeded if the negative feedback factor is too high. Second, if the attenuated output at the AD834 exceeds its clipping level of  $\pm 1.3$  V, feedback control will be lost and the output will suddenly jump to the supply rails. However, with these limitations understood, it will be possible to adapt the circuit to smaller full-scale inputs and/or outputs, and for use with lower supply voltages.



Компания «Океан Электроники» предлагает заключение долгосрочных отношений при поставках импортных электронных компонентов на взаимовыгодных условиях!

Наши преимущества:

- Поставка оригинальных импортных электронных компонентов напрямую с производств Америки, Европы и Азии, а так же с крупнейших складов мира;
- Широкая линейка поставок активных и пассивных импортных электронных компонентов (более 30 млн. наименований);
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Компания «Океан Электроники» является официальным дистрибьютором и эксклюзивным представителем в России одного из крупнейших производителей разъемов военного и аэрокосмического назначения «JONHON», а так же официальным дистрибьютором и эксклюзивным представителем в России производителя высокотехнологичных и надежных решений для передачи СВЧ сигналов «FORSTAR».



## JONHON

«JONHON» (основан в 1970 г.)

Разъемы специального, военного и аэрокосмического назначения:

(Применяются в военной, авиационной, аэрокосмической, морской, железнодорожной, горно- и нефтедобывающей отраслях промышленности)

«FORSTAR» (основан в 1998 г.)

ВЧ соединители, коаксиальные кабели,  
кабельные сборки и микроволновые компоненты:

(Применяются в телекоммуникациях гражданского и специального назначения, в средствах связи, РЛС, а так же военной, авиационной и аэрокосмической отраслях промышленности).



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