250 MHz, Voltage Output, 4-Quadrant Multiplier

Data Sheet

AD835

FEATURES

Simple: basic function is W = XY + Z
Complete: minimal external components required
Very fast: Settles to 0.1% of full scale (FS) in 20 ns
DC-coupled voltage output simplifies use
High differential input impedance X, Y, and Z inputs
Low multiplier noise: 50 nV/√Hz

APPLICATIONS

Very fast multiplication, division, squaring
Wideband modulation and demodulation
Phase detection and measurement
Sinusoidal frequency doubling
Video gain control and keying
Voltage-controlled amplifiers and filters

FUNCTIONAL BLOCK DIAGRAM

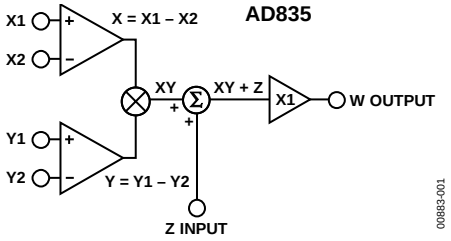


Figure 1.

GENERAL DESCRIPTION

The AD835 is a complete four-quadrant, voltage output analog multiplier, fabricated on an advanced dielectrically isolated complementary bipolar process. It generates the linear product of its X and Y voltage inputs with a −3 dB output bandwidth of 250 MHz (a small signal rise time of 1 ns). Full-scale (−1 V to +1 V) rise to fall times are 2.5 ns (with a standard R_L of 150 Ω), and the settling time to 0.1% under the same conditions is typically 20 ns.

Its differential multiplication inputs (X, Y) and its summing input (Z) are at high impedance. The low impedance output voltage (W) can provide up to ±2.5 V and drive loads as low as 25 Ω. Normal operation is from ±5 V supplies.

Though providing state-of-the-art speed, the AD835 is simple to use and versatile. For example, as well as permitting the addition of a signal at the output, the Z input provides the means to operate the AD835 with voltage gains up to about ×10. In this capacity, the very low product noise of this multiplier (50 nV/√Hz) makes it much more useful than earlier products.

The AD835 is available in an 8-lead PDIP package (N) and an 8-lead SOIC package (R) and is specified to operate over the −40°C to +85°C industrial temperature range.

PRODUCT HIGHLIGHTS

1. The AD835 is the first monolithic 250 MHz, four-quadrant voltage output multiplier.
2. Minimal external components are required to apply the AD835 to a variety of signal processing applications.
3. High input impedances (100 kΩ||2 pF) make signal source loading negligible.
4. High output current capability allows low impedance loads to be driven.
5. State-of-the-art noise levels achieved through careful device optimization and the use of a special low noise, band gap voltage reference.
6. Designed to be easy to use and cost effective in applications that require the use of hybrid or board-level solutions.

Rev. E Document Feedback

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700
Technical Support **www.analog.com**

TABLE OF CONTENTS

REVISION HISTORY

12/14—Rev. D to Rev. E

Changes to Figure 1 ... 1
Changes to Figure 20 ... 10
Changes to Wideband Voltage-Controlled Amplifier Section and Figure 21 ... 11
Changes to Ordering Guide ... 14

12/10—Rev. C to Rev. D

Changes to Figure 1 ... 1
Changes to Absolute Maximum Ratings and Table 2 ... 5
Added Figure 19, Renumbered Subsequent Tables ... 10
Added Figure 23 ... 11

10/09—Rev. B to Rev. C

Updated Format ... Universal
Changes to Figure 22 ... 11
Updated Outline Dimensions ... 13
Changes to Ordering Guide ... 14

6/03—Rev. A to Rev. B

Updated Format ... Universal
Updated Outline Dimensions ... 10

SPECIFICATIONS

T_A = 25°C, V_S = ±5 V, R_L = 150 Ω, C_L ≤ 5 pF, unless otherwise noted.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
TRANSFER FUNCTION			$W = \frac{(X1-X2)(Y1-Y2)}{U} + Z$		
INPUT CHARACTERISTICS (X, Y)					
Differential Voltage Range	V_{CM} = 0 V		±1		V
Differential Clipping Level		±1.2[1]	±1.4		V
Low Frequency Nonlinearity	X = ±1 V, Y = 1 V		0.3	0.5[1]	% FS
	Y = ±1 V, X = 1 V		0.1	0.3[1]	% FS
vs. Temperature	T_{MIN} to T_{MAX}[2]				
	X = ±1 V, Y = 1 V			0.7	% FS
	Y = ±1 V, X = 1 V			0.5	% FS
Common-Mode Voltage Range		−2.5		+3	V
Offset Voltage			±3	±20[1]	mV
vs. Temperature	T_{MIN} to T_{MAX}[2]			±25	mV
CMRR	f ≤ 100 kHz; ±1 V p-p	70[1]			dB
Bias Current			10	20[1]	µA
vs. Temperature	T_{MIN} to T_{MAX}[2]			27	µA
Offset Bias Current			2		µA
Differential Resistance			100		kΩ
Single-Sided Capacitance			2		pF
Feedthrough, X	X = ±1 V, Y = 0 V			−46[1]	dB
Feedthrough, Y	Y = ±1 V, X = 0 V			−60[1]	dB
DYNAMIC CHARACTERISTICS					
−3 dB Small Signal Bandwidth		150	250		MHz
−0.1 dB Gain Flatness Frequency			15		MHz
Slew Rate	W = −2.5 V to +2.5 V		1000		V/µs
Differential Gain Error, X	f = 3.58 MHz		0.3		%
Differential Phase Error, X	f = 3.58 MHz		0.2		Degrees
Differential Gain Error, Y	f = 3.58 MHz		0.1		%
Differential Phase Error, Y	f = 3.58 MHz		0.1		Degrees
Harmonic Distortion	X or Y = 10 dBm, second and third harmonic				
	Fund = 10 MHz		−70		dB
	Fund = 50 MHz		−40		dB
Settling Time, X or Y	To 0.1%, W = 2 V p-p		20		ns
SUMMING INPUT (Z)					
Gain	From Z to W, f ≤ 10 MHz	0.990	0.995		
−3 dB Small Signal Bandwidth			250		MHz
Differential Input Resistance			60		kΩ
Single-Sided Capacitance			2		pF
Maximum Gain	X, Y to W, Z shorted to W, f = 1 kHz		50		dB
Bias Current			50		µA

Parameter	Conditions	Min	Typ	Max	Unit
OUTPUT CHARACTERISTICS					
Voltage Swing		±2.2	±2.5		V
vs. Temperature	T_{MIN} to T_{MAX}[2]	±2.0			V
Voltage Noise Spectral Density	X = Y = 0 V, f < 10 MHz		50		nV/√Hz
Offset Voltage			±25	±75[1]	mV
vs. Temperature[3]	T_{MIN} to T_{MAX}[2]			±10	mV
Short-Circuit Current			75		mA
Scale Factor Error			±5	±8[1]	% FS
vs. Temperature	T_{MIN} to T_{MAX}[2]			±9	% FS
Linearity (Relative Error)[4]			±0.5	±1.0[1]	% FS
vs. Temperature	T_{MIN} to T_{MAX}[2]			±1.25	% FS
POWER SUPPLIES					
Supply Voltage					
For Specified Performance		±4.5	±5	±5.5	V
Quiescent Supply Current			16	25[1]	mA
vs. Temperature	T_{MIN} to T_{MAX}[2]			26	mA
PSRR at Output vs. VP	+4.5 V to +5.5 V			0.5[1]	%/V
PSRR at Output vs. VN	−4.5 V to −5.5 V			0.5	%/V

[1] All minimum and maximum specifications are guaranteed. These specifications are tested on all production units at final electrical test.
[2] T_{MIN} = −40°C, T_{MAX} = 85°C.
[3] Normalized to zero at 25°C.
[4] Linearity is defined as residual error after compensating for input offset, output voltage offset, and scale factor errors.

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Supply Voltage	±6 V
Internal Power Dissipation	300 mW
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature, Soldering 60 sec	300°C
ESD Rating	
HBM	1500 V
CDM	250 V

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

For more information, see the Analog Devices, Inc., Tutorial MT-092, *Electrostatic Discharge*.

THERMAL RESISTANCE

Table 3.

Package Type	θ_{JA}	θ_{JC}	Unit
8-Lead PDIP (N)	90	35	°C/W
8-Lead SOIC (R)	115	45	°C/W

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

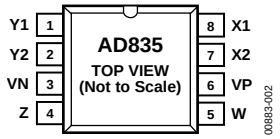


Figure 2. Pin Configuration

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	Y1	Noninverting Y Multiplicand Input
2	Y2	Inverting Y Multiplicand Input
3	VN	Negative Supply Voltage
4	Z	Summing Input
5	W	Product
6	VP	Positive Supply Voltage
7	X2	Inverting X Multiplicand Input
8	X1	Noninverting X Multiplicand Input

TYPICAL PERFORMANCE CHARACTERISTICS

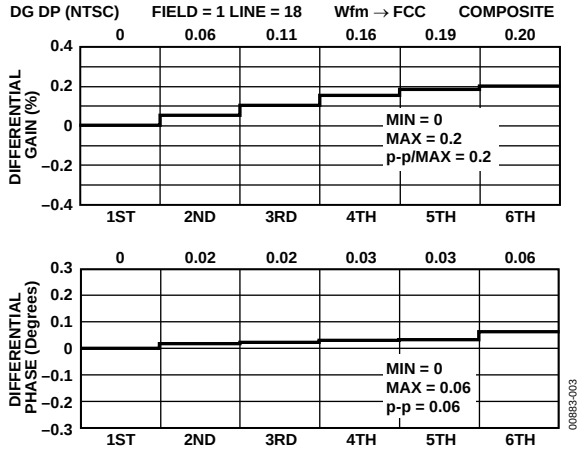


Figure 3. Typical Composite Output Differential Gain and Phase, NTSC for X Channel; f = 3.58 MHz, R_L = 150 Ω

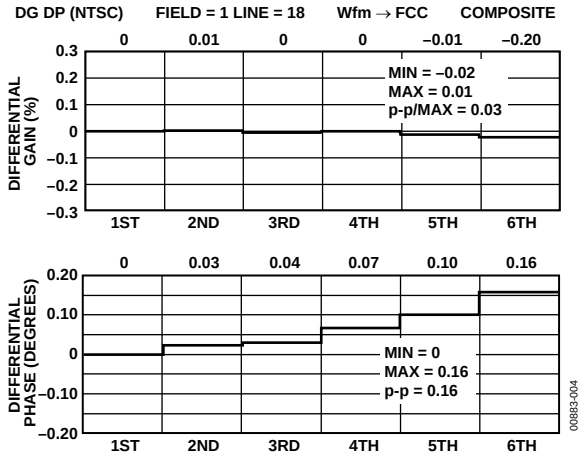


Figure 4. Typical Composite Output Differential Gain and Phase, NTSC for Y Channel; f = 3.58 MHz, R_L = 150 Ω

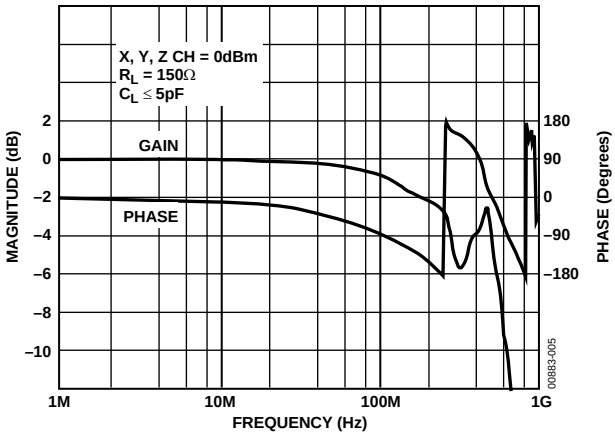


Figure 5. Gain and Phase vs. Frequency of X, Y, Z Inputs

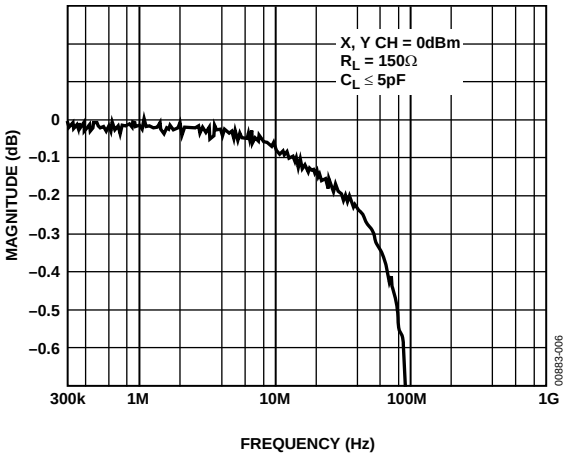


Figure 6. Gain Flatness to 0.1 dB

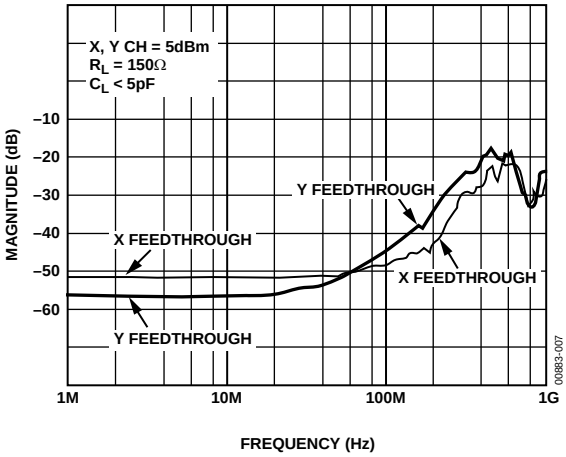


Figure 7. X and Y Feedthrough vs. Frequency

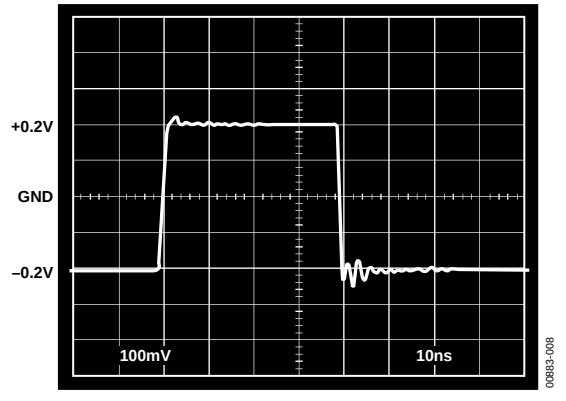


Figure 8. Small Signal Pulse Response at W Output, R_L = 150 Ω, C_L ≤ 5 pF, X Channel = ±0.2 V, Y Channel = ±1.0 V

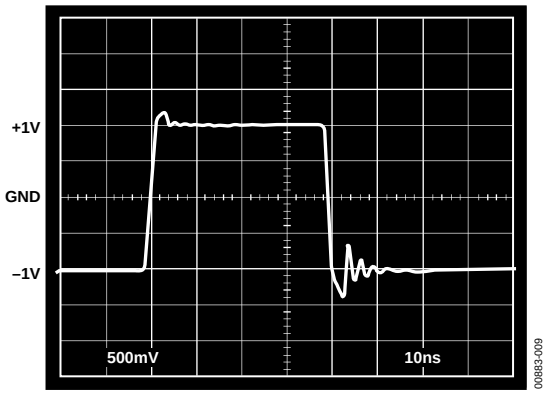


Figure 9. Large Signal Pulse Response at W Output, R_L = 150 Ω, C_L ≤ 5 pF, X Channel = ±1.0 V, Y Channel = ±1.0 V

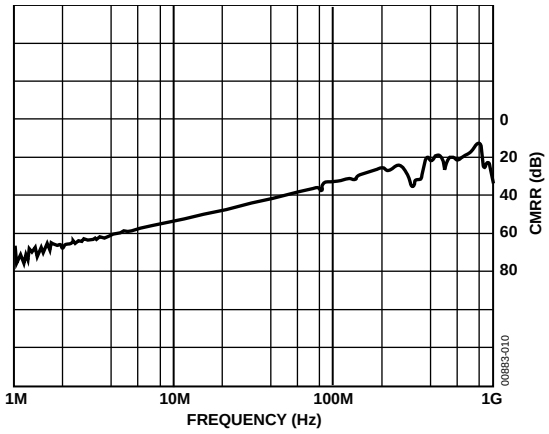


Figure 10. CMRR vs. Frequency for X or Y Channel, R_L = 150 Ω, C_L ≤ 5 pF

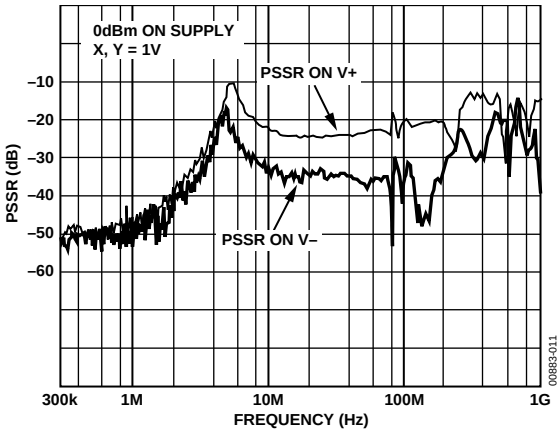


Figure 11. PSRR vs. Frequency for V+ and V– Supply

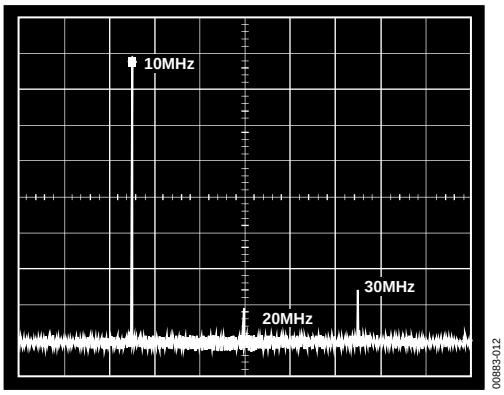


Figure 12. Harmonic Distortion at 10 MHz; 10 dBm Input to X or Y Channels, R_L = 150 Ω, C_L = ≤ 5 pF

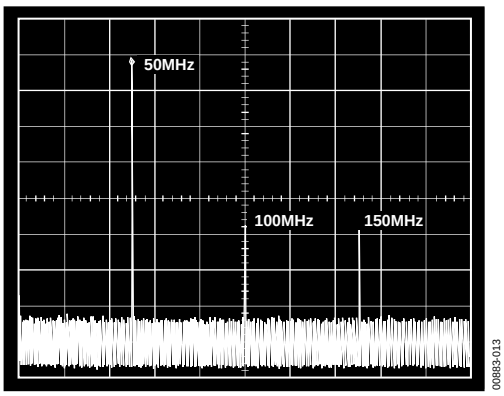


Figure 13. Harmonic Distortion at 50 MHz, 10 dBm Input to X or Y Channel, R_L = 150 Ω, C_L ≤ 5 pF

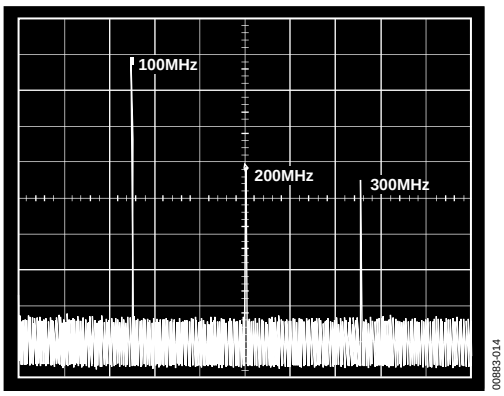


Figure 14. Harmonic Distortion at 100 MHz, 10 dBm Input to X or Y Channel, R_L = 150 Ω, C_L ≤ 5 pF

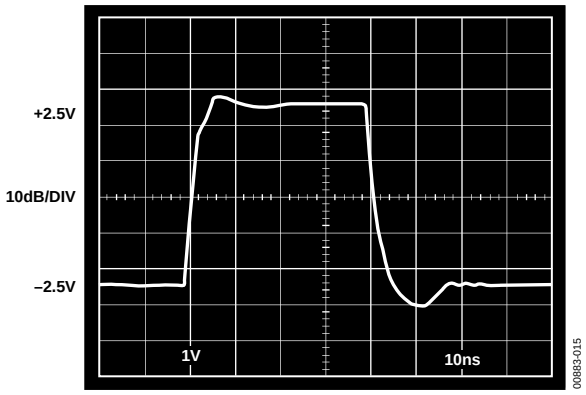


Figure 15. Maximum Output Voltage Swing, R_L = 50 Ω, C_L ≤ 5 pF

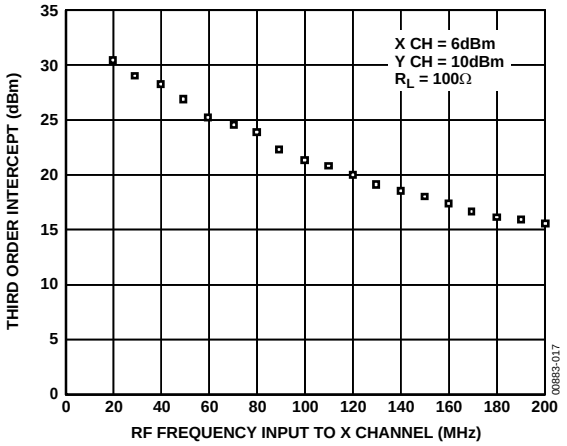


Figure 17. Fixed LO on Y Channel vs. RF Frequency Input to X Channel

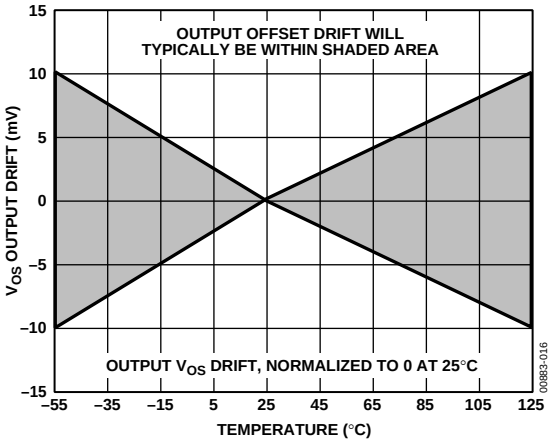


Figure 16. V_{OS} Output Drift vs. Temperature

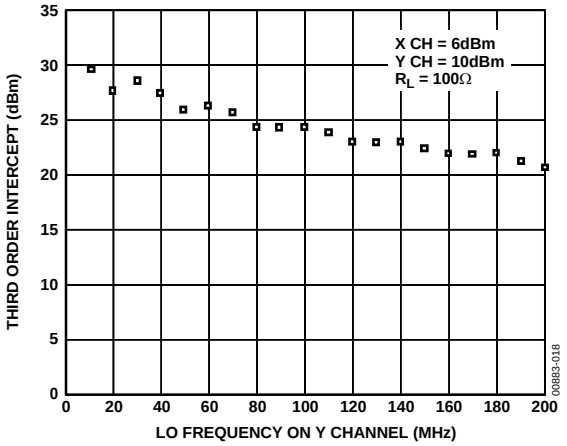


Figure 18. Fixed IF vs. LO Frequency on Y Channel

THEORY OF OPERATION

The AD835 is a four-quadrant, voltage output analog multiplier, fabricated on an advanced dielectrically isolated complementary bipolar process. In its basic mode, it provides the linear product of its X and Y voltage inputs. In this mode, the −3 dB output voltage bandwidth is 250 MHz (with small signal rise time of 1 ns). Full-scale (−1 V to +1 V) rise to fall times are 2.5 ns (with a standard R_L of 150 Ω), and the settling time to 0.1% under the same conditions is typically 20 ns.

As in earlier multipliers from Analog Devices a unique summing feature is provided at the Z input. As well as providing independent ground references for the input and the output and enhanced versatility, this feature allows the AD835 to operate with voltage gain. Its X-, Y-, and Z-input voltages are all nominally ±1 V FS, with an overrange of at least 20%. The inputs are fully differential at high impedance (100 kΩ||2 pF) and provide a 70 dB CMRR (f ≤ 1 MHz).

The low impedance output is capable of driving loads as small as 25 Ω. The peak output can be as large as ±2.2 V minimum for R_L = 150 Ω, or ±2.0 V minimum into R_L = 50 Ω. The AD835 has much lower noise than the AD534 or AD734, making it attractive in low level, signal processing applications, for example, as a wideband gain control element or modulator.

BASIC THEORY

The multiplier is based on a classic form, having a translinear core, supported by three (X, Y, and Z) linearized voltage-to-current converters, and the load driving output amplifier. The scaling voltage (the denominator U in the equations) is provided by a band gap reference of novel design, optimized for ultralow noise. Figure 19 shows the functional block diagram.

In general terms, the AD835 provides the function

$$W = \frac{(X1 - X2)(Y1 - Y2)}{U} + Z \quad (1)$$

where the variables *W*, *U*, *X*, *Y*, and *Z* are all voltages. Connected as a simple multiplier, with *X* = X1 − X2, *Y* = Y1 − Y2, and *Z* = 0 and with a scale factor adjustment (see Figure 19) that sets *U* = 1 V, the output can be expressed as

$$W = XY \quad (2)$$

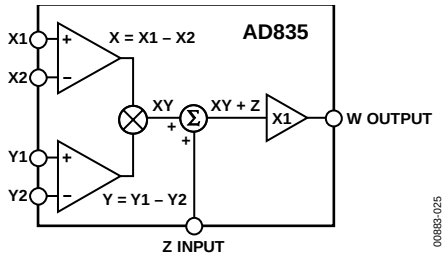


Figure 19. Functional Block Diagram

Simplified representations of this sort, where all signals are presumed expressed in V, are used throughout this data sheet to avoid the needless use of less intuitive subscripted variables (such as, V_{X1}). All variables as being normalized to 1 V.

For example, the input X can either be stated as being in the −1 V to +1 V range or simply −1 to +1. The latter representation is found to facilitate the development of new functions using the AD835. The explicit inclusion of the denominator, U, is also less helpful, as in the case of the AD835, if it is not an electrical input variable.

SCALING ADJUSTMENT

The basic value of U in Equation 1 is nominally 1.05 V. Figure 20, which shows the basic multiplier connections, also shows how the effective value of U can be adjusted to have any lower voltage (usually 1 V) through the use of a resistive divider between W (Pin 5) and Z (Pin 4). Using the general resistor values shown, Equation 1can be rewritten as

$$W = \frac{XY}{U} + \mathrm{kW} + (1 - k)Z' \quad (3)$$

where *Z'* is distinguished from the signal Z at Pin 4. It follows that

$$W = \frac{XY}{(1 - k)U} + Z' \quad (4)$$

In this way, the effective value of *U* can be modified to

$$U' = (1 - k)U \quad (5)$$

without altering the scaling of the Z' input, which is expected because the only ground reference for the output is through the Z' input.

Therefore, to set U' to 1 V, remembering that the basic value of U is 1.05 V, R1 must have a nominal value of 20 × R2. The values shown allow U to be adjusted through the nominal range of 0.95 V to 1.05 V. That is, R2 provides a 5% gain adjustment.

In many applications, the exact gain of the multiplier may not be very important; in which case, this network may be omitted entirely, or R2 fixed at 100 Ω.

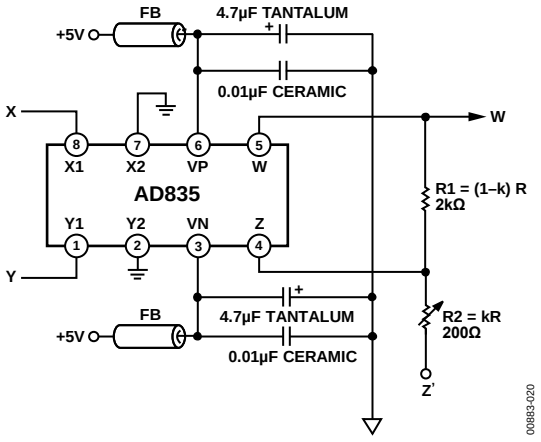


Figure 20. Multiplier Connections

APPLICATIONS INFORMATION

The AD835 is easy to use and versatile. The capability for adding another signal to the output at the Z input is frequently valuable. Three applications of this feature are presented here: a wideband voltage-controlled amplifier, an amplitude modulator, and a frequency doubler. Of course, the AD835 may also be used as a square law detector (with its X inputs and Y inputs connected in parallel). In this mode, it is useful at input frequencies to well over 250 MHz because that is the bandwidth limitation of the output amplifier only.

MULTIPLIER CONNECTIONS

Figure 20 shows the basic connections for multiplication. The inputs are often single sided, in which case the X2 and Y2 inputs are normally grounded. Note that by assigning Pin 7 (X2) and Pin 2 (Y2), respectively, to these (inverting) inputs, an extra measure of isolation between inputs and output is provided. The X and Y inputs may be reversed to achieve some desired overall sign with inputs of a particular polarity, or they may be driven fully differentially.

Power supply decoupling and careful board layout are always important in applying wideband circuits. The decoupling recommendations shown in Figure 20 should be followed closely. In Figure 21, Figure 23, and Figure 24, these power supply decoupling components are omitted for clarity but should be used wherever optimal performance with high speed inputs is required. However, if the full, high frequency capabilities of the AD835 are not being exploited, these components can be omitted.

WIDEBAND VOLTAGE-CONTROLLED AMPLIFIER

Figure 21 shows the AD835 configured to provide a gain of nominally 0 dB to 12 dB. (In fact, the control range extends from well under −12 dB to about +14 dB.) R1 and R2 set the gain to be nominally ×4. The attendant bandwidth reduction that comes with this increased gain is partially offset by the addition of the peaking capacitor C1. Although this circuit shows the use of dual supplies, the AD835 can operate from a single 9 V supply (such as a 9 V battery) with a slight revision. For G = 0 dB, omit R1 and R2, and connect Pin Z directly to ground. Pin Z must be connected to a reference; otherwise, the output W floats to a rail.

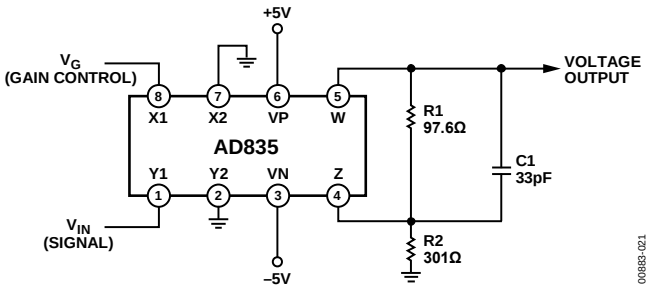


Figure 21. Voltage-Controlled 50 MHz Amplifier Using the AD835

The ac response of this amplifier for gains of 0 dB (V_G = 0.25 V), 6 dB (V_G = 0.5 V), and 12 dB (V_G = 1 V) is shown in Figure 22. In this application, the resistor values have been slightly adjusted to reflect the nominal value of U = 1.05 V. The overall sign of the gain may be controlled by the sign of V_G.

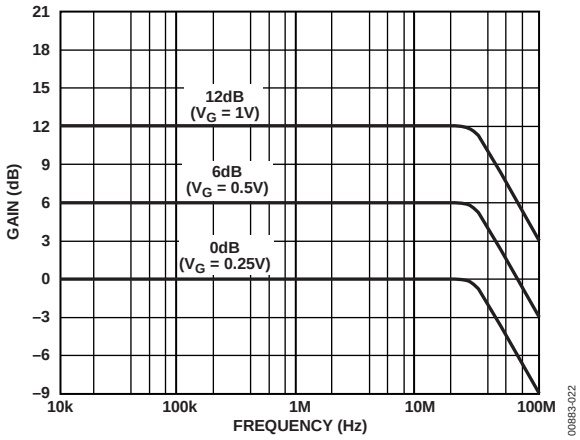


Figure 22. AC Response of VCA

AMPLITUDE MODULATOR

Figure 23 shows a simple modulator. The carrier is applied to the Y input and the Z input, while the modulating signal is applied to the X input. For zero modulation, there is no product term so the carrier input is simply replicated at unity gain by the voltage follower action from the Z input. At X = 1 V, the RF output is doubled, while for X = −1 V, it is fully suppressed. That is, an X input of approximately ±1 V (actually ±U or about 1.05 V) corresponds to a modulation index of 100%. Carrier and modulation frequencies can be up to 300 MHz, somewhat beyond the nominal −3 dB bandwidth.

Of course, a suppressed carrier modulator can be implemented by omitting the feedforward to the Z input, grounding that pin instead.

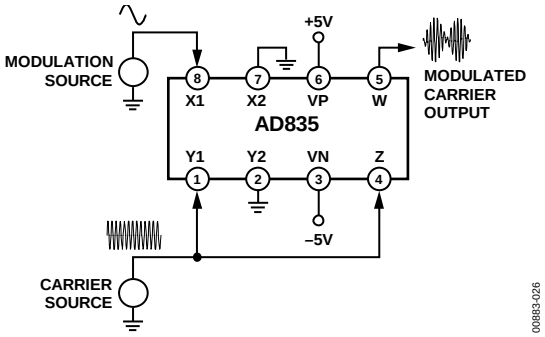


Figure 23. Simple Amplitude Modulator Using the AD835

SQUARING AND FREQUENCY DOUBLING

Amplitude domain squaring of an input signal, E, is achieved simply by connecting the X and Y inputs in parallel to produce an output of E^2/U. The input can have either polarity, but the output in this case is always positive. The output polarity can be reversed by interchanging either the X or Y inputs.

When the input is a sine wave E sin ωt, a signal squarer behaves as a frequency doubler because

$$\frac{(E\sin\omega t)^2}{U} = \frac{E^2}{2U}(1-\cos 2\omega t) \quad (6)$$

While useful, Equation 6 shows a dc term at the output, which varies strongly with the amplitude of the input, *E*.

Figure 24 shows a frequency doubler that overcomes this limitation and provides a relatively constant output over a moderately wide frequency range, determined by the time constant R1C1. The voltage applied to the X and Y inputs is exactly in quadrature at a frequency f = ½πC1R1, and their amplitudes are equal. At higher frequencies, the X input becomes smaller while the Y input increases in amplitude; the opposite happens at lower frequencies. The result is a double frequency output centered on ground whose amplitude of 1 V for a 1 V input varies by only 0.5% over a frequency range of ±10%. Because there is no squared dc component at the output, sudden changes in the input amplitude do not cause a bounce in the dc level.

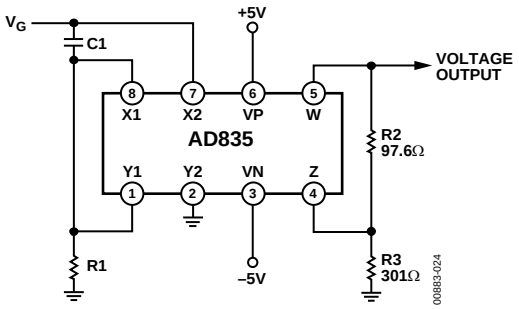


Figure 24. Broadband Zero-Bounce Frequency Doubler

This circuit is based on the identity

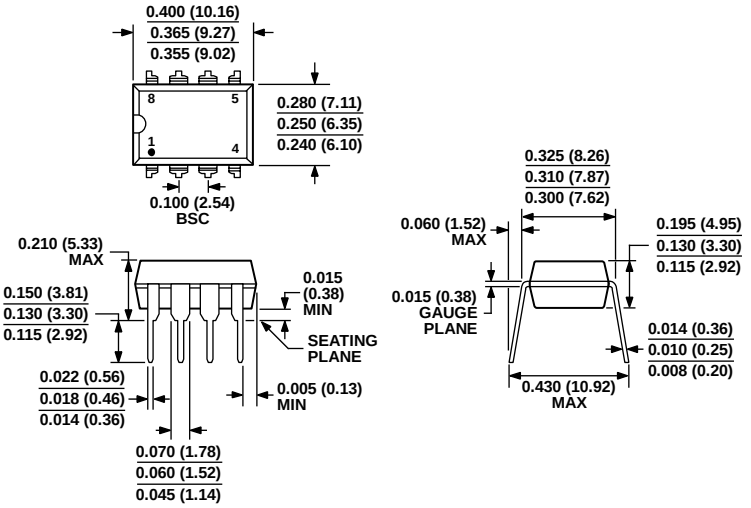
$$\cos\theta\sin\theta = \frac{1}{2}\sin 2\theta \quad (7)$$

At ω_O = 1/C1R1, the X input leads the input signal by 45° (and is attenuated by √2, while the Y input lags the input signal by 45° and is also attenuated by √2. Because the X and Y inputs are 90° out of phase, the response of the circuit is

$$W = \frac{1}{U}\frac{E}{\sqrt{2}}(\sin\omega t - 45°)\frac{E}{\sqrt{2}}(\sin\omega t + 45°) = \frac{E^2}{2U}(\sin 2\omega t) \quad (8)$$

which has no dc component, R2 and R3 are included to restore the output to 1 V for an input amplitude of 1 V (the same gain adjustment as previously mentioned). Because the voltage across the capacitor (C1) decreases with frequency, while that across the resistor (R1) increases, the amplitude of the output varies only slightly with frequency. In fact, it is only 0.5% below its full value (at its center frequency ω_O = 1/C1R1) at 90% and 110% of this frequency.

OUTLINE DIMENSIONS

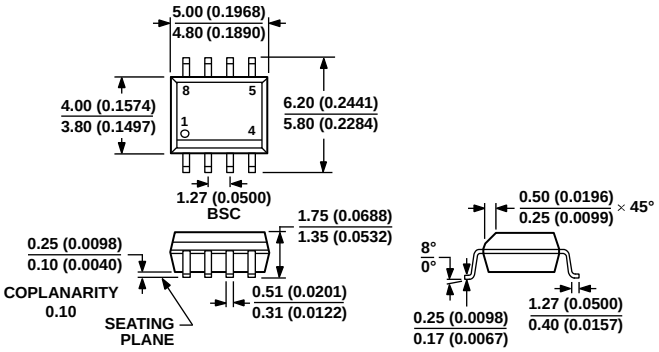


COMPLIANT TO JEDEC STANDARDS MS-001

CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN. CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

070606-A

Figure 25. 8-Lead Plastic Dual In-Line Package [PDIP]
Narrow Body
(N-8)
Dimensions shown in inches and (millimeters)



COMPLIANT TO JEDEC STANDARDS MS-012-AA

CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

012407-A

Figure 26. 8-Lead Standard Small Outline Package [SOIC_N]
Narrow Body
(R-8)
Dimensions shown in millimeters and (inches)

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Package Option
AD835ANZ	−40°C to +85°C	8-Lead Plastic Dual In-Line Package [PDIP]	N-8
AD835AR	−40°C to +85°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8
AD835AR-REEL7	−40°C to +85°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8
AD835ARZ	−40°C to +85°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8
AD835ARZ-REEL	−40°C to +85°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8
AD835ARZ-REEL7	−40°C to +85°C	8-Lead Standard Small Outline Package [SOIC_N]	R-8

[1] Z = RoHS Compliant Part.

D00883-0-12/14(E)

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Analog Devices Inc.:

AD835ARZ AD835AR AD835AR-REEL7 AD835ARZ-REEL7 AD835ANZ AD835ARZ-REEL