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Vector Modulator ICs Make it Easy to Control Phase and Gain

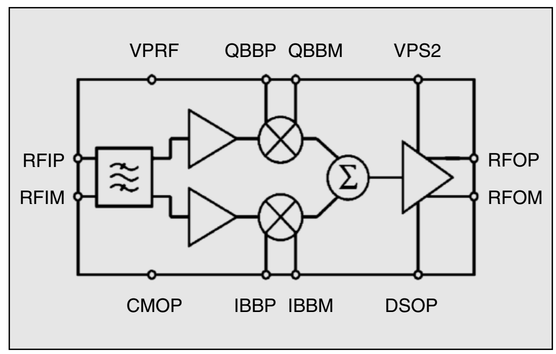
New vector modulators provide simultaneous control of gain and phase, simplifying the design of power amplifier linearization circuits, smart antennas and RF modulators.

Analog Devices' new AD8340 and AD8341 vector modulators are single-chip RFICs that enable manufacturers of high power amplifiers and radio transceivers for cellular base station equipment to adjust both amplitude and phase of their RF carriers. These devices perform arbitrary amplitude and phase modulation of the RF signal, while maintaining a linear signal path. The devices may be used as a general-purpose modulator or as a variable attenuator and phase shifter.

Power Amplifier Linearization Application

Cellular infrastructure base station deployments continue to migrate from SCPA (single-carrier power amplifiers) to MCPA (multi-carrier power amplifiers) to enhance capacity and reduce loss, power consumption and system cost. MCPA designers face the need to implement adaptable linearization within the MCPA to meet 2.5G and 3G standards, in particular for GSM EDGE, CDMA2000 and W-CDMA.

Unlike discrete designs, the AD8340 and AD8341 provide simultaneous control of both gain and phase within a single monolithic IC. The phase control range provides a continuous 360-degree adjustment, while the amplitude control provides an adjustment range of greater than 30 dB. The AD8340 and AD8341 provide significant cost and space savings over discrete, diode-based amplitude and phase shifters. Both products further simplify system implementation—compared to discrete solutions—through a simplified linear Cartesian interface with a 230-MHz modulation bandwidth.



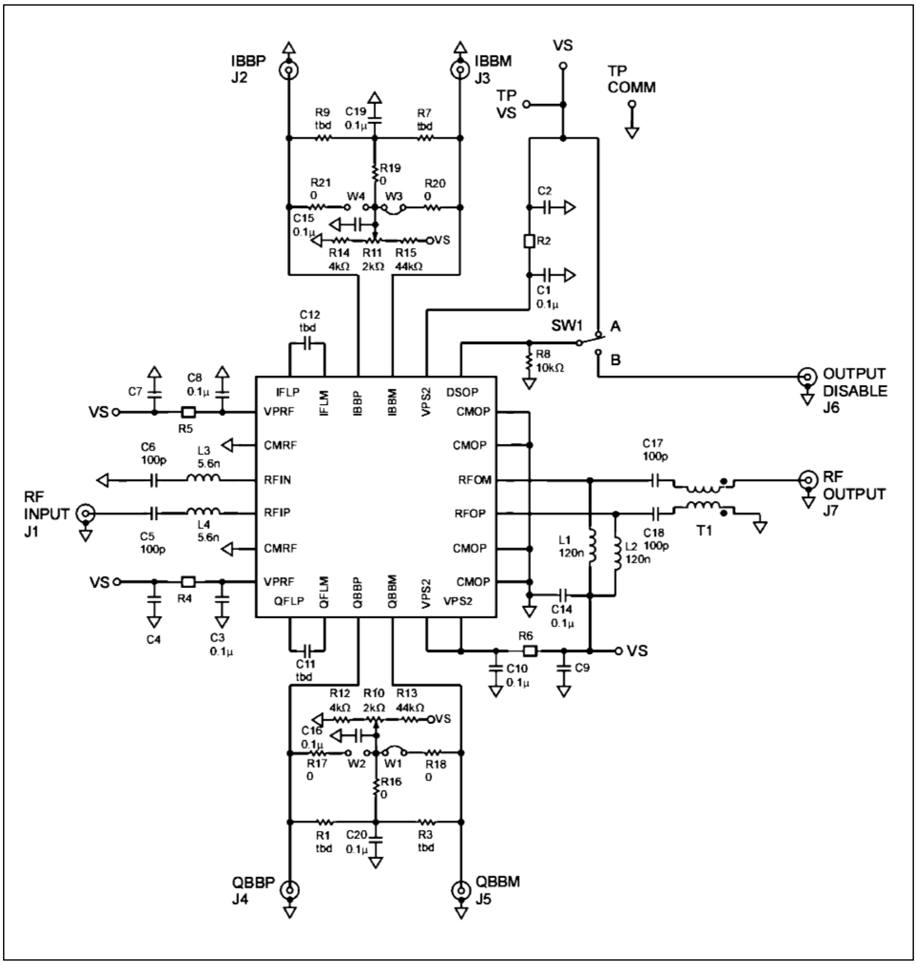
Functional block diagram of the AD8340 and AD8341 Vector Modulators.

The baseband inputs in Cartesian I and Q format control the amplitude and phase modulation imposed on the RF signal. Both I and Q inputs are DC-coupled with ±500 mV differential full-scale range. The 230 MHz bandwidth can be reduced by adding capacitors to limit noise bandwidth on the control lines.

Both RF inputs and outputs can be used differentially or single-ended, and must be AC-coupled. Input and output impedances are nominally 50 ohms over the specified operating frequency range. A disable pin allows near-instantaneous shutoff.

Coverage in Two Bands

The two models cover the two wireless frequency bands. AD8340 operates over a frequency range from 700 MHz to 1.0 GHz, while the AD8341 operates from 1.5 GHz to 2.4 GHz. Both parts are pin- and functionally compatible, allowing one standardized foot-



Evaluation board schematic diagram.

print to be used for any cellular band of interest. The AD8340 and AD8341 complement Analog Devices' AD8302 gain and phase detector, providing a complete measurement and control solution. The AD8340, AD8341 and AD8302 are suited for use in feed-forward linearization control loops and RF pre-distortion applications within cellular MCPA equipment. In addition to their benefits in cellular MCPA linearization, the AD8340 and AD8341 are equally applicable for use in smart antennas and as single-sideband RF modulators. Evaluation boards are available (see diagram).

The AD8340 and AD8341 RF vector modulators are fabricated on Analog Devices' proprietary, high-performance 25 GHz SOI (silicon on insulator) complementary bipolar IC process. Available in 24-lead CSP (chip scale package) packaging, the parts are priced at $7.50 per unit in 1,000-piece quantities.

Analog Devices, Inc.
Tel: 1-800-ANALOGD (262-5643)
www.analog.com/AD8340
www.analog.com/AD8341
HFeLink 301

Vector Modulation: Theory of Operation

The AD8340 is a linear RF vector modulator with Cartesian baseband controls. The RF input is first split into in-phase (I) and quadrature (Q) components using a multistage passive polyphase network tuned to the frequency range of each device. The linear variable attenuators dedicated to each branch scale their respective inputs. The attenuator outputs are then summed and buffered to the output. In the block diagram, the RF signal path generally propagates from the left to the right while baseband controls are placed above and below.

By controlling the relative amounts of I and Q signal components that are summed, arbitrary, continuous magnitude and phase control of the input signal is possible. The attenuation factor for the I and Q signal components can be represented on the x and y-axis, respectively of a polar plot, and their vector sum indicates the vector gain at a particular gain and phase set-point.

The correspondence between these set-points and the Cartesian inputs, VBBI and VBBQ is given by simple trigonometric identities:

$$Gain_{SP} = \text{sqrt}\ [(V_{BBI}/V_0)^2 + (V_{BBQ}/V_0)^2]$$

$$Phase_{SP} = \arctan\ (V_{BBQ}/V_{BBI}),$$

where V_0 is the baseband scaling constant (500 mV) and $Gain_{SP}$ and $Phase_{SP}$ are the desired gain and phase set-points. In general, both V_{BBI} and V_{BBQ} are needed in concert to modulate the gain and the phase.

Pure amplitude modulation is represented by radial movement of the gain vector tip at a fixed angle, while pure phase modulation is represented by rotation of the vector tip around the circle at a fixed radius. Unlike traditional I-Q modulators, the AD8340 is designed to have a linear RF signal path from input to output. Traditional I-Q modulators provide a limited LO carrier path through which any amplitude information is removed.