Advance Data Sheet
January 1993

AT&T
Microelectronics

W2010
1 GHz Quadrature Modulator

Features

- 0 dBm output into 50 Ω load (single ended)
- Direct modulation of RF over 1 GHz
- Accurate 90° phase shifter for local oscillator (LO)
- Double-balanced mixers minimize carrier feedthrough
- Digital enable control selects between active mode and low-current sleep mode

Applications

- GSM, Japan Digital Cellular, and North American Cellular Radio Mobile
- Central cellular radio stations
- Digital satellite communications
- Multisymbol signaling transmitters
- Wireless LANs

Description

The W2010 1 GHz Quadrature Modulator is a monolithic integrated circuit that provides direct single-sideband modulation of RF carriers by I and Q baseband inputs. The W2010 is particularly suited for use in mobile and hand-held cellular telephones designed to North American (IS54), European (GSM), Japanese, and other digital personal-communications standards.

The phase-shifter provides two LO signals with 90° phase separation and equal amplitude (see Figure 1). The LO signals are fed to the in-phase (I) and quadrature (Q) double-balanced mixers. The double-sideband, suppressed-carrier products of the two mixers are summed and amplified to provide 0 dBm at a 50 Ω single-ended output.

A CMOS/TTL compatible logic input allows the device to be put into a powerdown mode, in which less than 10 µA of supply current is consumed.

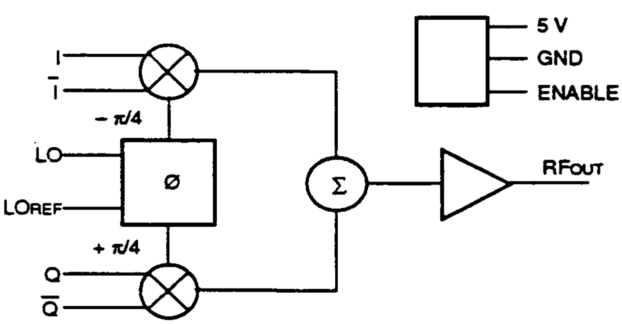

Figure 1. Block Diagram

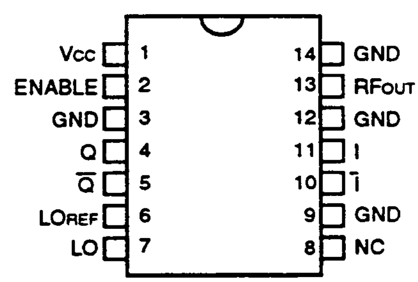

Figure 2. Pin Diagram

Absolute Maximum Ratings

Stresses in excess of the Absolute Maximum Ratings can cause permanent damage to the device. These are absolute stress ratings only. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of the data sheet. Exposure to Absolute Maximum Ratings for extended periods can adversely affect device reliability.

Parameter	Symbol	Min	Max	Unit
Ambient Operating Temperature	T_A	–30	85	°C
Storage Temperature	T_{stg}	–65	150	°C
Lead Temperature (soldering, 10 s)	T_L	—	300	°C
Positive Supply Voltage	V_{CC}	—	6.0	Vdc
Power Dissipation	P_D	—	750	mW
Output Current (continuous)	I_{OUT}	—	160	mA
ac Peak-to-Peak Input Voltage	—	—	V_{CC}	Vp-p
Enable Input Voltage	V_{ENB}	—	V_{CC}	Vdc

Electrical Characteristics

T_A = –30 °C to +85 °C; V_{CC} = 3.7 V to 5.5 V; RL = 50 Ω; P_{LO} = –13 dBm to –7 dBm.

Parameter	Min	Typ	Max	Unit
Supply Current:				
Active Mode:				
Vcc = 5.5 Vdc	—	—	47	mA
Vcc = 5.0 Vdc	—	40	—	mA
Sleep Mode	—	—	10	µA
I and Q Signal Path Bandwidth (I and Q dc coupled)	2	4	—	MHz
I and Q Baseband Input Impedance	150	300	—	kΩ
I and Q Input Bias Current	—	8	40	µA
I and Q Input Common Mode Range	1.75	—	3.25	V
I and Q Differential Input Signal for Maximum Output	—	2.5	—	Vpp
LO Input Impedance @ 900 MHz	—	14 – j120	—	Ω
LO VSWR (terminated)	—	—	2.0	
Output Impedance	—	50 + j2.5	—	Ω
LO Suppression (@ 2.5 Vpp (differential) baseband input level)	35	40	—	dB
Suppression of Spurious In-band Frequency Components	—	50	—	dB
LO Suppression (powerdown mode)	40	—	—	dB
LO Frequency	500	—	1100	MHz
Transmitted I and Q Amplitude Imbalance	–0.25	—	0.25	dB
Transmitted I and Q Phase Imbalance	–2	—	2	°
Unwanted Sideband Suppression	36	44	—	dB
Output VSWR (to 50 Ω)	—	—	1.5	
Output Power Variation vs. Supply Voltage	–2.8 @ 4.0	0 @ 4.8	1.2 @ 5.5	dB @ Vcc
Output Power Variation vs. Temperature	–1 @ 85	0 @ 25	1 @ –30	dB @ °C
Output Power Variation vs. Supply Voltage (±5%) and Temperature	–3	—	2	dB
Powerdown Mode:				
VIHMIN	2.8	—	—	V
VILMAX	—	—	0.7	V
IILMAX	—	—	10	µA
IIHMAX	—	—	750	µA
Powerup/down Time	—	10	—	µs

Using the W2010 Quadrature Modulator Evaluation Board (Issues 2 and 3)

Note: The following information is for revised versions (Issues 2 and 3) of the W2010 Modulator Evaluation Board with greatly improved board-level performance. Issue 3 corrects labeling errors for I and Q baseband inputs on Issue 2. These instructions do not apply to the original board, which is superseded by Issues 2 and 3.

Description

The W2010 is a 1 GHz quadrature modulator for digital and analog communication transmitters. The silicon, monolithic IC is available in a 14-pin, small-outline, narrow-body (SONB gull wing) package. The circuit produces a nominal 0 dBm peak output from a 5 Vdc supply with 40 mA typical consumption, reduced to less than 50 µA in powerdown mode. The output is controlled through a compatible logic input.

The evaluation board for the W2010 offers easy connection to the device for convenient characterization of ac performance at UHF with minimal degradation of performance by parasitics (see Figure 3). The following features are present on the evaluation board:

- Low-profile, surface-mount chip capacitors for coupling ac inputs and outputs and bypassing the power supply close to the IC.
- 50 Ω microstrip transmission line for RF inputs and output with SMA-type edge connectors for connecting coaxial cable from signal generators or measurement instruments.

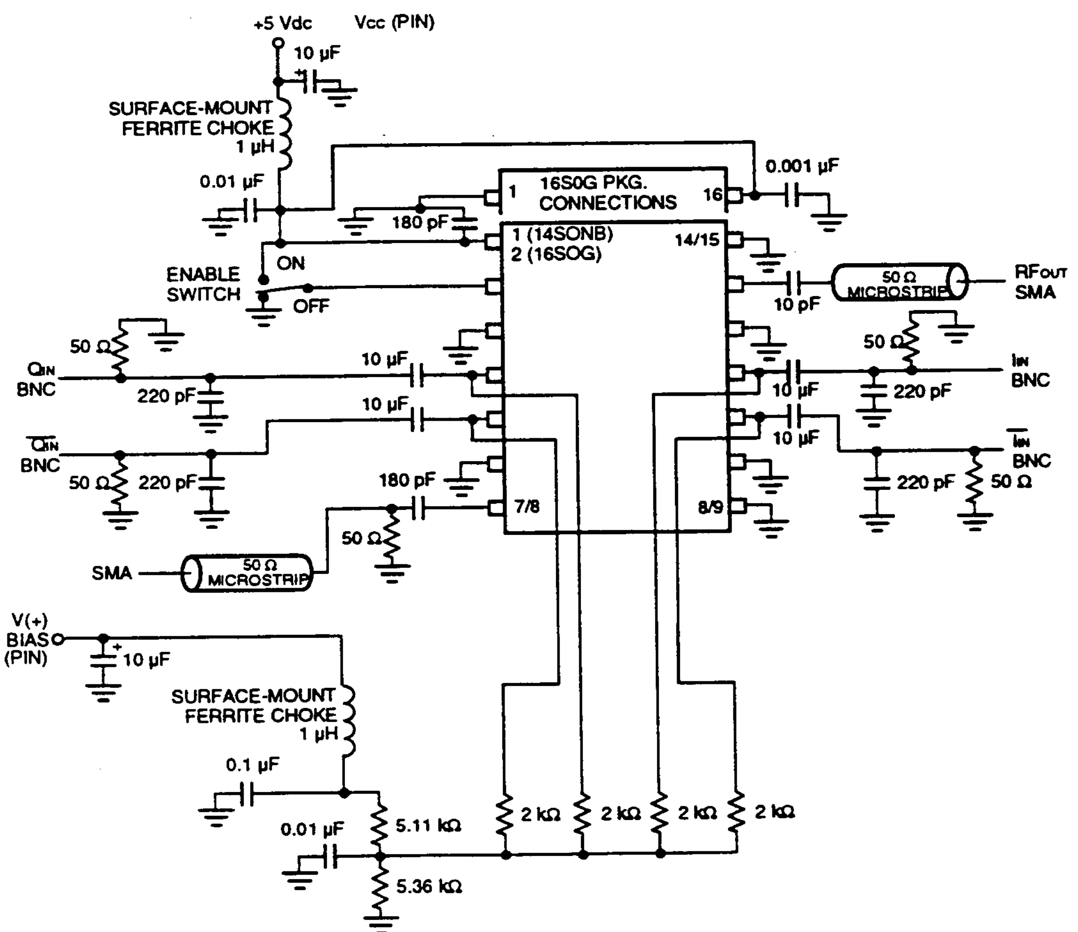

Figure 3. Evaluation Board Schematic

Using the W2010 Quadrature Modulator Evaluation Board (Issues 2 and 3)

(continued)

- 50 Ω termination resistors for all ac inputs and high-frequency, bypass capacitors at the baseband inputs to provide a return path for the on-chip, low-pass network in the event of single-ended, baseband feed.
- Dual BNC connectors for each baseband input (two for I, two for Q) to allow either single-ended or differential drive.
- Power supply filtering on board, with multiple-ground post-type pins for connecting test and power supply leads.
- An external bias network to provide bias current for the baseband inputs during measurements with modulating signals. The bias would not normally be used in a direct-coupled system, in which the baseband output of a codec IC would typically establish the dc bias.
- Post-type pins for connecting a power supply to the IC separate from the power supply to the external bias network.
- On-board rocker-type switches to enable/power-down the IC. The enable switch is in a dual-switch unit, in which the other switch is unused.
- A screw-down, plastic, clamp retainer to hold the surface-mount IC package (14SONB) securely in place on a contact pattern without soldering. This allows changing devices and placing network analyzer calibration terminations without soldering and unsoldering the IC.
- Extensive ground-plane on the top and bottom of the board with numerous vias to equalize ground potentials to the greatest extent possible.

Instructions for Demonstrating Basic Performance of the W2010 Modulator

1. Connect a 5 Vdc (±5%) power supply to both the board Vcc (IC supply) and V+ (bias network supply) post-pins. Ground the supply to any GND pin. To measure supply current to the IC, the same power supply may be used for both board supply connections: connect the supply directly to V+ and also, through an ammeter, to Vcc. However, make sure the voltmeter or power supply sense lead measuring the supply voltage is connected to the output side of the ammeter since there is a small supply-voltage drop across the ammeter and W2010 specifications are based on voltage applied to the IC. To vary the bias voltage (V+) independently, use two power supplies, one for the board bias network and one for the IC.
2. Connect an RF signal generator set to the frequency of interest (for example, 900 MHz) at about –10 dBm to the LO input SMA on the board.
3. Connect baseband signal sources to the I and Q inputs. Several notes are in order on this connection:

   A. The baseband input bias resistors are 2 kΩ. Approximate baseband input impedance is set by 50 Ω II 220 pF II (2.5 kΩ in series with 10 µF) on the board.

   B. The baseband inputs are connected to the IC through 10 µF ceramic coupling capacitors.

   C. The baseband inputs of the IC have high input impedance (input bias current < 5 µA, input resistance > 200 kΩ) and accordingly afford very low-frequency response with the 10 µF capacitors. However, the capacitors may be removed and the baseband direct-coupled if the source provides a dc reference level (normally the case with codecs designed to directly drive such an input).

   D. Full peak RF output is developed with 2.5 Vp-p differential or 1.25 Vp single-ended baseband input. This can be achieved by setting a function generator such as the Hewlett-Packard HP8904 to 2.5 V, which is the peak output, into a high-impedance load. Since the HP8904 is a 50 Ω source, the output is 1.25 V peak across a 50 Ω load.

Using the W2010 Quadrature Modulator Evaluation Board (Issues 2 and 3)

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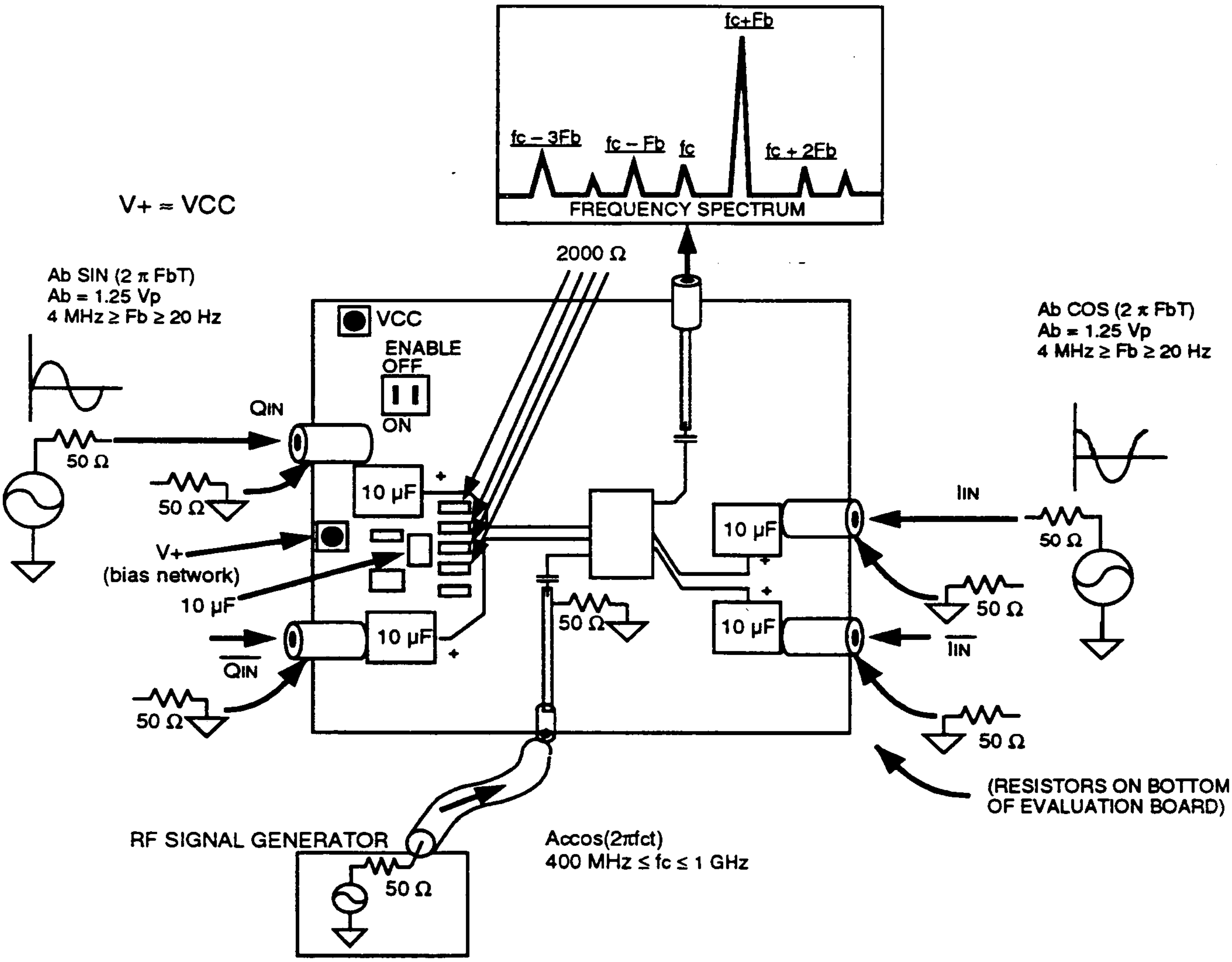


Figure 4. Using the W2010 Evaluation Board for Sine Wave Characterization of the Modulator

Using the W2010 Quadrature Modulator Evaluation Board (Issues 2 and 3)

(continued)

E. When using a high-impedance, baseband signal source, the 50 Ω terminating resistors on top of the board at the end of the baseband input microstrip lines may be removed. If the resistors are removed, the baseband voltage applied to the inputs should be measured to be sure it is not excessive since overdrive increases spurious distortion products at the output.

F. To use the W2010 for an application involving high data-rate/wideband baseband, one or more of the following may be done:

a. Recognize that the IC, as presently designed, has a 4 MHz low-pass network at the baseband inputs. Higher drive levels and/or appropriate pre-emphasis may be required to get acceptable modulation results.

b. Remove the 220 pF bypass capacitors on top of the board from the inputs to which signal sources are connected.

c. Replace the 220 pF bypass capacitors with smaller value ones appropriate for the baseband and RF frequencies being used.

d. If series inductance in the capacitor is a concern, replace the baseband 10 µF coupling capacitors with smaller values.

4. Connect a 50 Ω terminated test instrument such as a spectrum analyzer or vector modulation analyzer to the RF_{OUT} SMA.

5. Remove the hex nuts and plastic retainer clamp from the board and place an IC on the contact pattern with pins 7/8 (14SONB package) on the pinpads farthest from the board switches. Replace the plastic retainer clamp by gently sliding over the screw studs, and tighten the retainer nuts firmly—a good technique is to place the IC, slide down the plastic retainer clamp, turn on the power supply, turn on the enable switch, and tighten the hex nuts while watching an ac test display or a milliammeter monitoring current to Vcc (about 40 mA indicates proper contact). In case of difficulty, check the connections, IC position on the contact pattern, power supply, and enable switch setting. If the positioning of the IC under the plastic retainer is questionable, remove the retainer and apply pressure with the eraser end of a pencil directly on the center of the IC on the contact pattern.

   The device should now be ready for testing.

6. **Power Test.** With a spectrum analyzer on the RF_{OUT} SMA, apply equal amplitude, equal frequency (e.g. 80 kHz) sine-wave baseband signals from a waveform generator with accurate phase and amplitude control to the baseband inputs, such that the signal at I is offset 90° from that at Q. The baseband can be fed differentially (I input between I and $\overline{I}$, and Q input between Q and $\overline{Q}$) or single-ended (to I and Q or to $\overline{I}$ and $\overline{Q}$). Observe in the output spectrum that one sideband is near 0 dBm.

7. **On-Chip Phase Shifter Performance.** Connect the device to the evaluation board as in the preceding power test and note that the unwanted sideband is strongly reduced, respectively due to reinforcement and cancellation at the summing junction at the outputs of the two quadrature mixers. The exact phase and amplitude errors can either be determined by varying the phase of the baseband signal until maximum cancellation is obtained or estimated by calculation. When using the baseband cancellation technique, more accurate results may be obtained by measuring in advance the ac signal at the IC contact pattern baseband input pads without an IC present and adjusting the baseband input amplitude so the I and Q levels on the board are exactly equal. This compensates for tolerance-variations in the values of the resistors and capacitors on the board (1% and 10% respectively).

   Note also with respect to linearity of the mixers and output stage that spurious output peaks at the LO frequency and multiples of the baseband above and below the LO are strongly reduced.

8. **Enable/Powerdown.** With ac signals, power supplies, and bias applied, and a spectrum analyzer on the RF_{OUT} SMA, toggle the enable switch on and off. Notice that when the enable switch is off, the supply current reduces to a very low level and the output spectrum reduces to a low leakage level at the LO frequency. When turned on, the full mixing and output power performance appear within approximately 10 µs.

Using the W2010 Quadrature Modulator Evaluation Board (Issues 2 and 3)

(continued)

Modifying the W2010 Evaluation Board for Use with a Digital Baseband Source (Direct Coupled)

Figure 5 shows the evaluation board modified by shorting the baseband coupling capacitors, removing the 50 Ω baseband termination resistors, and removing the four 2 kΩ bias resistors. This allows a differential codec or other baseband source to be direct-coupled, thereby setting a low-offset bias level on the four I and Q inputs and supplying the 10 μA nominal input bias current at each pin.

If the digital baseband source is single-ended, it may still be direct coupled if baseband output bias voltage is available separately to connect as a reference voltage for the unused baseband input pins. This ensures low dc input offset at the W2010. Increased input offset voltage causes excessive carrier (LO) feedthrough. Also, the reference voltage should be filtered with a 4.7 μF capacitor and should be connected to the unused input pins through 1% tolerance resistors of about 2 kΩ to avoid cross talk between I and Q.

If a low-offset reference voltage cannot be provided to the unused input pins, the signal source should be capacitively coupled to the modulator and an external bias network connected to all four I and Q input pins. The evaluation board provides these, and in this case the only decision is whether or not the 50 Ω termination resistors should remain on the board as loads for the signal source.

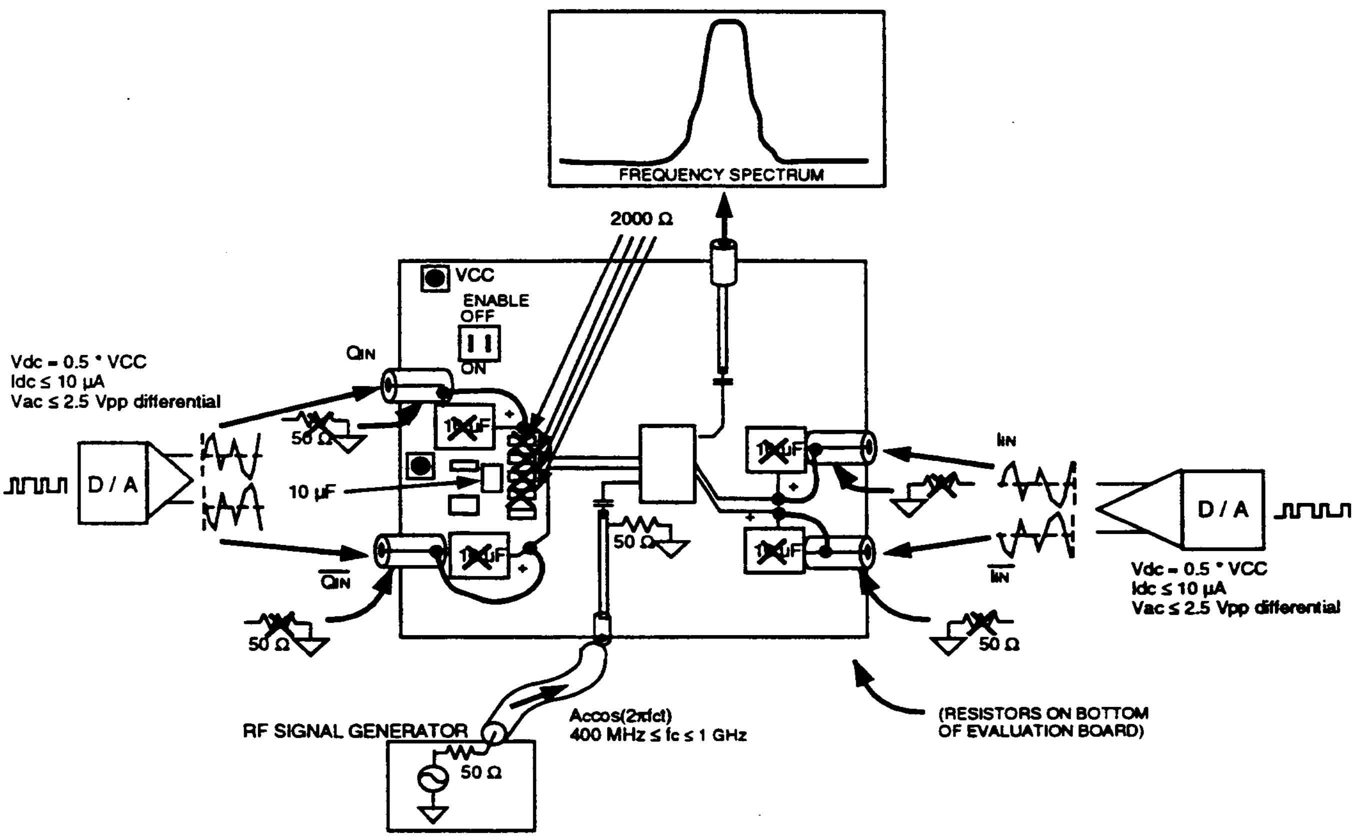
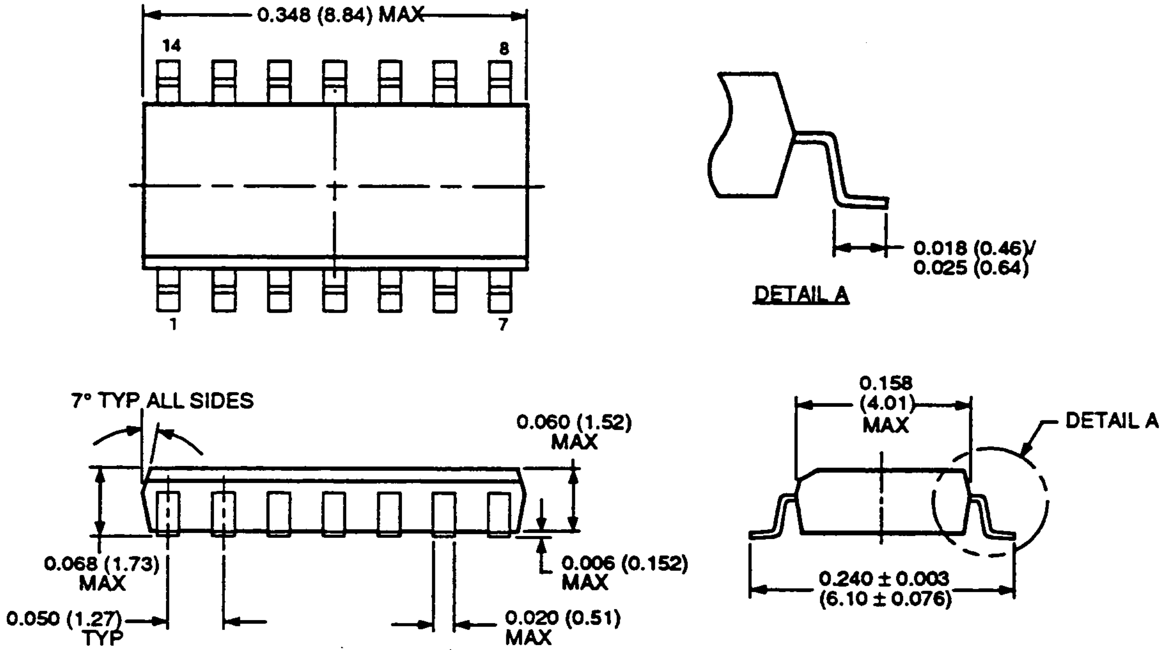


Figure 5. W2010 Evaluation Board Layout Modified for Use with a Digital Baseband Source (Direct Coupled)

Outline Diagram

Dimensions are in inches and (millimeters).



Ordering Information

Device Code	Description	Package	Comcode
W2010AAF	1 GHz Quadrature Modulator	14-pin SONB	106645088
EVB2010A	Evaluation Board	—	106891385

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