IAM-8 Series Active Mixers

Application Note S013

Introduction

Hewlett-Packard's IAM-8 products are Gilbert cell based double balanced active mixers capable of accepting RF inputs up to 5 GHz and producing IF outputs up to 2 GHz. They feature conversion gain, insensitivity to mismatch, and superior isolation in a very compact format. These devices are part of HP's product line of silicon bipolar Microwave Monolithic Integrated Circuits (MMICs) built with the ISOlated Self Aligned Transistor (ISOSAT™) process.

This Application Note follows the sequence "What the IAM-8 mixers are," "How their structure affects performance", "What they can be used for", and "How to build circuits with them". This progression allows the reader who is unfamiliar with Gilbert cell mixers to build up to proper circuit design with these MMICs. Each section is sufficiently self-contained, however, that it may be read independently by those already familiar with Gilbert cell mixers.

Product Family

The IAM-8 series mixers have part numbers that give information about the product. The prefix IAM-8 is used to designate a product that is a standard (catalog) ISOSAT based Active Mixer. The first two digits following the hyphen designate die type. The third digit is reserved for performance selections or assembly options. The last two digits designate package type.

The present IAM-8 geometries are:

IAM-81: low power consumption design
5 volt, 12 mA bias
8.5 dB conversion gain
–6 dBm output power at 1 dB compression
RF from .05 GHz to 5 GHz
IF from DC to 1 GHz

IAM-82: higher intercept point design
10 volt, 50 mA bias
15 dB conversion gain
+8 dBm output power at 1 dB compression
IF from DC to 2 GHz

Available package options include:

08 - S08 (.158" x .192") 8-lead plastic surface mount package.

28 -180 mil 8-lead glass-metal hermetic surface mount package.

Note: Some die-package combinations may not be offered; consult your local HP representative for available combinations.

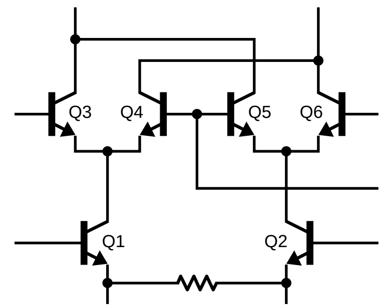

Figure 1. The Basic Gilbert Cell

Product Design and Performance Features

Gilbert cell mixers are very different in structure from conventional passive diode mixers. The differences in design topology lead to a number of special “features” in how the IAM-8 MMICs perform.

Circuit Topology

Devices in the IAM-8 product family are based on a circuit known as the Gilbert cell. This structure consists of an emitter-coupled transistor pair Q1 – Q2, and four collector-cross-coupled transistors Q3 – Q6 (Figure 1). An LO signal is used to switch the conduction path between the outer and inner transistors of the cross-coupled quad, creating the mixing action.

To complete the mixer, the RF and LO ports are resistively matched, and an emitter follower is added to the Gilbert cell output to buffer the IF port. On-chip voltage and current sources provide the DC biasing. The resulting structure is a double-balanced active mixer with conversion gain, port insensitivity, and good isolation. A representational schematic is shown in Figure 2.

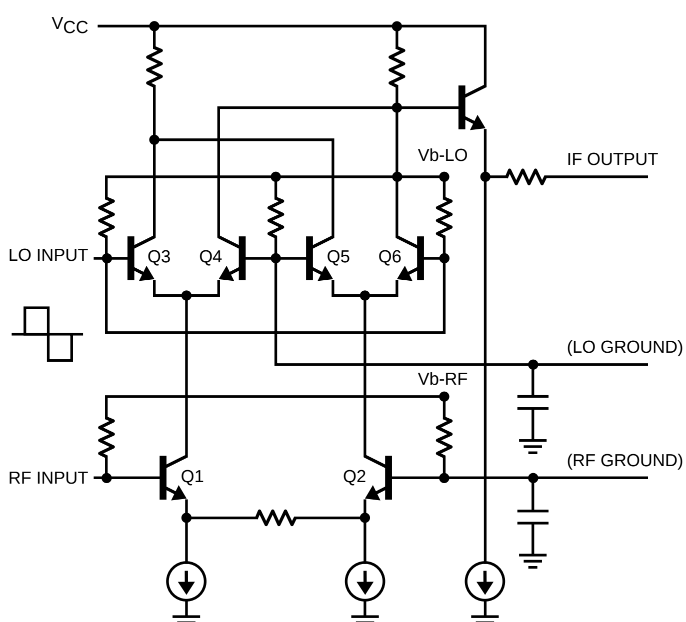

Figure 2. The IAM-8 Mixer Topology

Consequent Performance Features

The IAM-8 series of Gilbert cell mixers perform the same basic frequency conversion functions as do conventional passive diode-based double-balanced mixers. The structure of IAM-8 MMICs leads to many significant variations in the details of how they perform these functions.

Bias

The IAM-8 series active mixers require a DC bias. Whereas conventional passive mixers use AC signals to create device conduction, active Gilbert cell mixers require a DC power supply. DC bias is applied to IAM-8 MMICs in the form of a voltage V_{cc}. Enough voltage must be applied to cause the transistors in the Gilbert cell to conduct, otherwise the desired switching action will not occur. This level sets the minimum voltage at which the mixer will operate. As V_{cc} is increased, the simple on-chip bias scheme allows the transistors to turn on harder. The gain of the mixer increases, as does the compression point. Individual product data sheets contain graphs of these changes in performance. Since changes in bias effect linearity, such changes alter the levels of the harmonic and spurious signals produced by the MMIC. Biasing changes also effect the f_t of the transistors in the MMIC and, hence, the frequency range over which the mixer operates. Eventually, the current handling capabilities of the transistors will be reached. This level, plus the power dissipation capability of the MMIC chip, will determine the maximum allowable bias level.

An IAM-8 series mixer can be operated from either a voltage source or a current source with nearly identical performance over temperature. In either case, the V_{cc} terminal of the IAM-8 MMIC must be at AC ground for proper operation. Typical gain and $P_{1\ dB}$ variation over temperature are shown on the individual data sheets; gain decreases with temperature, whereas $P_{1\ dB}$ increases.

Gain

IAM-8 active mixers have conversion gain, so in conventional use the output (IF) signal will be at a higher power level than the input (RF) signal. This is in contrast to passive mixers, which have a typical insertion loss of 7 dB. The advantage of gain is obvious. With between 8 and 15 dB of signal increase rather than 7 dB of signal attenuation, one or more IF stages can be eliminated from the IF post-amplifier, yielding a simpler and more economical system design. The majority of the gain in the IAM-8 MMICs is provided by the emitter-coupled amplifier in the Gilbert cell. The amount of gain achieved will vary with die geometry, frequency, temperature of operation, oscillator signal, and bias level. Specific information is listed on the individual data sheets.

The upper frequency limit for the IF output on an IAM-8 mixer data sheet is the highest frequency at which the MMIC has conversion gain. IAM-8 mixers can be used at higher IF output frequencies if the designer is willing to tolerate conversion loss through the mixer.

Output Spectral Purity

The output spectral purity of the IAM-8 series active mixers is at least as good as that of conventional passive double-balanced mixers. This is not immediately apparent when comparing port-to-port isolation specifications. Isolation specifications compare the level of an unwanted signal at an output port to its level at an input port. What is usually more significant is the degree of suppression of the unwanted signals at the output port when compared to the output level of the desired signals. Since an active mixer increases the level of the desired output signal, whereas a passive mixer decreases it, active mixers are cast in an unrealistically unfavorable light when characterized solely in terms of isolation. The advantage of lower oscillator power requirements is also hidden when isolation numbers are used. For this reason output spectral purity of IAM-8 series mixers is characterized in terms of RF feedthrough and LO leakage.

Oscillator Signals

IAM-8 active mixers require low oscillator drive levels. In a Gilbert cell based mixer, the primary function of the LO signal is to switch the conduction path between the outer and inner transistors of the cross-coupled quad. This requires relatively little power, an advantage over passive mixers where a strong LO signal is needed to supply bias to the diodes.

In general, the spurious response of a Gilbert cell mixer will improve at lower oscillator drive levels. This is in contrast to diode mixers, where increasing the LO drive level will turn the diodes on harder, improving linearity. Increasing the LO power to an IAM-8 series mixer will saturate (actually “quasi-saturate”) the transistors of the quad and emitter-coupled pair, and can decrease linearity. This phenomenon is more pronounced in the 5 volt IAM-81 family than in the 10 volt IAM-8-82 family as the lower operating voltage allows the output AC voltage swing to clip at lower signal levels.

The conversion gain of IAM-8 series mixers varies with the power of the LO signal. As the LO drive level is decreased from the nominal (data sheet) characterization value, there is a 5 to 10 dB range over which conversion gain is not significantly affected. When the LO drive level is reduced still further, conversion gain will “roll off”. It is possible to adjust the mixer gain by as much as 10 dB by adjusting the LO drive level. Non-sinusoidal LO signals may have frequency components at many (harmonically related) frequencies. The gain of an IAM-8 series mixer is primarily dependent on the strength of the fundamental component of the LO signal. Thus, attenuating a square wave LO signal by 10 dB will cause the same gain decrease as attenuating a sinusoidal LO signal by 10 dB. Measurements show that there is typically no significant difference in conversion gain for high-side versus low-side LO operation.

Operating Frequency Range

IAM-8 series mixers operate over a very wide frequency range. The IAM-8 mixers function by using the LO signal to switch the conduction path of the RF signal through the Gilbert cell quad. The quad will pass and react to signals as high in frequency as 5 GHz. This performance sets the upper frequency limit of the active mixer input (RF and LO) signals. The design of the MMIC chip does not limit the lower frequency at which the RF and LO ports will work. This limit is set instead by the AC grounding provided to these ports external to the chip. MOS capacitors are used in packaged IAM-8 mixers to provide these grounds; package dimensions limit the values of these capacitors to 50 to 200 pF, which sets a lower frequency of operation for the RF and LO ports of approximately 50 MHz. The frequency response of the IF port is set by the gain-bandwidth product of the emitter follower and the emitter-coupled pair. For the technology used, the active mixer exhibits no conversion gain above approximately 2 GHz. The low frequency of operation for the IF is set solely by the value of the DC blocking capacitor used at this port.

The lower frequency of operation for the RF and LO inputs can be extended by using an external capacitor at the appropriate port or ports. The locations to use are labeled “optional RF ground” and “optional LO ground” on the device data sheets. Capacitors only need to be added to ports requiring signal response below 50 MHz. Otherwise, the “optional ground” ports should be left unterminated. If, for example, the RF signal will be from 10 MHz to 100 MHz but the LO signal will be fixed at 1 GHz, only the “optional RF ground” capacitor would be required. The value of the optional grounding capacitor is selected to provide a low impedance path at the lowest desired frequency of operation. Values are commonly in the 1000 pF range for operation in the low MHz range, and on the order of μF for operation in the kHz range. The optional grounding capacitor should be “de-Qd” by connecting a low valued (1-10 Ω) resistor in series with it. This prevents resonances with the internal grounding capacitor, and reduces “dropouts” in the operational frequency band. Typical circuitry is shown schematically in Figure 3. Since the RF and LO ports have non-zero voltage potentials appearing across them, the mixer will not function if either of these ports is DC grounded.

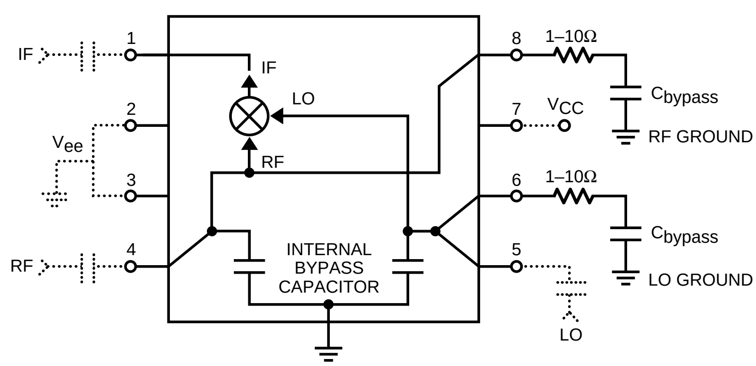

Figure 3. Using an External Capacitor to Extend Low Frequency Performance

DC and Differential Use

Although IAM-8 series mixers were not designed for differential use or for operation at DC, under certain limited circumstances such operation is possible.

A true DC output signal can be achieved if the IF port blocking capacitor is omitted. In this configuration, the output voltage is typically 3.4 volts for IAM-81 geometry mixers and 5.8 volts for IAM-82 geometry mixers. Of course any external DC loading must be avoided, as it will alter the bias point of the mixer and inhibit proper operation. It is possible to obtain a 0 volt DC output if both positive and negative voltages are used to bias the mixer and shift the output level appropriately. A circuit arrangement is shown in Figure 4. Such a scheme is typically only stable over a relatively narrow temperature range, however.

IAM-8 series mixers can be used in differential mode at the RF input when operated at frequencies below 50 MHz. This follows from the fact that it is the internal AC grounding capacitors that reference the input port, and that these capacitors do not provide an adequate ground reference below 50 MHz. No external RF-port AC grounding capacitor would be used for low frequency differential operation, and circuitry would be as described for the MMIC chip, above.

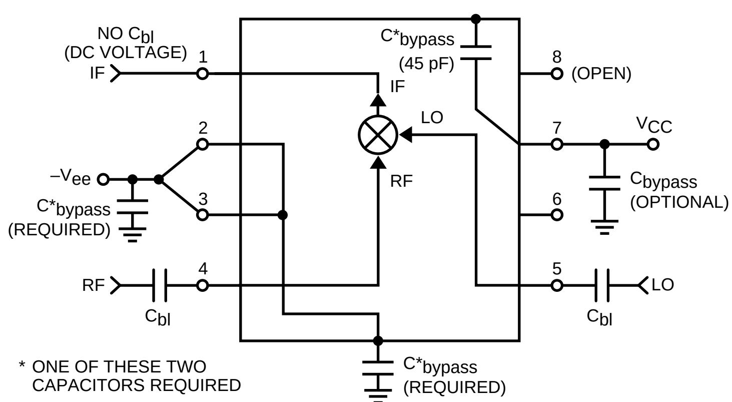

Figure 4. “Floating” an IAM-8 Mixer to Achieve a DC Output

Insensitivity To Mismatch

Designed-in terminations and buffers make the performance of IAM-8 series mixers insensitive to mismatches at any port. The IAM-8 MMIC circuit employs 100 Ω resistors in parallel with both the RF and LO ports. Since these ports are always well terminated, little frequency pulling results when the mixer is driven from a mismatched signal source. Oscillations or spurious signals resulting from high reflections when the RF or LO ports are driven from poorly-matched sources also become extremely unlikely with this kind of internal port termination. The IF port is similarly insensitive to loading, as it is buffered by a series resistor on the output of an emitter follower.

Noise Figure

The Gilbert cell structure is not a low noise structure. The mixer noise figure comes primarily from the shot noise of the four collector-cross-coupled transistors, the noise of both transistors in the emitter-coupled pair, and the thermal noise of the feedback resistor used with the emitter-coupled pair. Noise is generated in both the RF and the image bands. The resistors used as port terminations also contribute thermal noise. None of these noise sources can be easily reduced without severely affecting the performance of the mixer. Typical single sideband noise figure is on the order of 15 dB.

The noise figure of the mixer can be masked if a low noise amplifier having 20 dB or more of gain is used to drive the RF port. The INA family of low noise amplifiers works well for this application. The gain provided by such a preamplifier/active mixer combination is comparable to that of a passive mixer/IF amplifier combination.

The switching action of the LO can affect the mixer noise figure when very low oscillator frequencies are employed. When a low-frequency sinusoidal LO signal is used, there is a substantial portion of each cycle where neither side of the mixer quad is conducting. During this time the noise figure of the mixer increases significantly. This effect can be minimized if the LO port is driven with a square wave instead of a sinusoid. The fast edges of the square wave will minimize the time that both sides of the quad are simultaneously “off”, keeping the noise figure at its nominal level.

Dynamic Range

The Gilbert cell structure does not yield a high dynamic range mixer. This can be seen from the equations for linear dynamic range DR and spurious free dynamic range DR:

$$DR = P_{1\ dB} – [NF + G + 3\ dB - 114\ dBm + 10\ \log_{10}(BW)] \quad (1)$$

$$DR_f = 2/3\ [IP_3 – G – NF – 10\ \log_{10}(BW) + 114\ dBm] \quad (2)$$

where

$P_{1\ dB}$ = the output power of the mixer at 1 dB gain compression (in dBm)
NF = the noise figure of the mixer (in dB)
G = the conversion gain of the mixer (in dB)
BW = the bandwidth of the mixer (in MHz)
IP_3 = the output third order intercept point (in dBm)

These equations show that dynamic range is a function of noise figure, output compression point/intercept point, and gain. Since active mixers have higher noise figures (15 dB versus 7 dB), lower compression points (+8 dBm versus up to +20 dBm), and more gain (+10 dB versus –7 dB) than do passive diode mixers, it follows that they will have lower dynamic ranges.

Applications

Since IAM-8 series MMICs are mixers, their primary use is for frequency conversion. Conventionally this will take the form of down-conversion or up-conversion, but multiplication and division are also possible. IAM-8 MMICs may also be used for some specialty applications, including phase detectors and switches.

Downconverter

The most common use of an IAM-8 series mixer is as a frequency downconverter, where the output (IF) frequency is lower than the input (RF) frequency. For this application, the signal to be converted is injected into the RF port of the mixer. An appropriate oscillator is connected to the LO port, and the $f_{RF} – f_{LO}$ mixing product is taken from the IF port as the output (downconverted) signal (Figure 5). IAM-8 MMICs will accept RF and LO signals from arbitrarily low frequencies up through 5 GHz. The IF (output) signal must be below 1 GHz for the IAM-81 mixers and below 2 GHz for the IAM-82 mixers if the MMIC is to exhibit conversion gain. IAM-8 MMICs can be operated at higher IF frequencies in applications where conversion loss is acceptable.

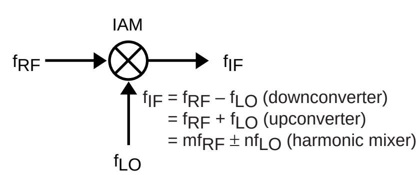

Figure 5. IAM-8 Mixer Use as a Downconverter, Upconverter, or Harmonic Mixer

Upconverter

The IAM-8 series mixers can also be used to up-convert frequencies. In this use the output (IF) signal of the mixer is at a higher frequency than the input (RF) signal. Port use does not change from that described above for downconverter applications, and the $f_{RF} + f_{LO}$ mixing product is taken as the output signal. The limitation of having the output (IF) signal at a frequency below 1 GHz for IAM-81 geometry or below

2 GHz for IAM-82 geometry still applies if the mixer is to have conversion gain. Output signals at higher frequencies can be obtained when the mixer is operated with conversion loss; typically outputs beyond 4 GHz are impractical.

Harmonic Mixer

Although the mixing product selected as the IF product is most commonly either the difference (downconverter) or the sum (upconverter) of the RF and LO frequencies, it is possible to use other mixing products as the IF output. This might be desirable because a particular LO frequency is more readily available, or because the mixer is required to generate harmonically related signals in more than one IF band. Harmonic mixers can be either upconverters or downconverters, depending on which mixing product is selected as the output (IF) signal. The relative strengths of the various components of the output spectrum are sensitive to the RF drive level, the LO drive level, and the type of LO signal applied. Square wave LO signals, for example, produce output spectra with stronger components at even harmonics than do sinusoidal LO signals. Mixers operating at or near saturation tend to have output spectra with many strong mixing products, and so often work well for harmonic mixer applications.

As an example, consider a case where a designer has a 275 MHz oscillator available, and wants to generate a 75 MHz IF signal from a 900 MHz RF signal. By injecting a –20 dBm signal into an IAM-81028 at 900 MHz, and driving the LO port at –5 dBm from the 275 MHz oscillator, the mixing product $f_{RF} - 3f_{LO}$ provides a –22 dBm signal at 75 MHz. The available oscillator can be used; moreover the 2 dB of conversion loss achieved provides a 5 dB stronger signal than would even the normal $f_{RF} - f_{LO}$ mixing product of a conventional diode mixer.

Regenerative Divider

If the signal from the IF port of a mixer is fed back into the LO port, a regenerative divider may be created (Figure 6). Noise at half the RF frequency mixes with the injected RF signal, and the difference product reinforces the 1/2 f signal at the output port. The performance of such a divider is significantly influenced by the phase length of the feedback loop. Best performance occurs with a minimal-length feedback path; an electrically “long” loop from IF to LO can cause erratic performance, extreme sensitivity to drive levels, or even undesired oscillations. Since the performance of IAM-8 series mixers (including conversion gain) is influenced by the power level of the LO signal, an amplifier may be required in the feedback loop to provide adequate LO drive, especially when working with low level RF signals.

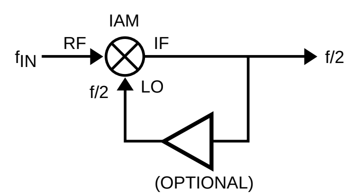

Figure 6. IAM-8 Mixer Use as a Regenerative Divider

Frequency Multiplier

If the LO and RF ports of the mixer are driven from the same source, a frequency multiplier is created, and a strong output signal is created at twice the input frequency (Figure 7). The 2f component comes both from the summing of the LO and RF signals and from the feedthrough of the LO signal harmonics. When operated as this kind of multiplier, IAM-8 series mixers typically have conversion gain.

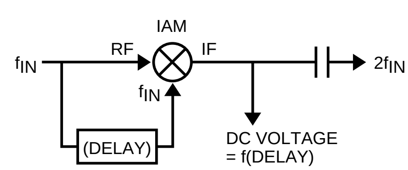

Figure 7. IAM-8 Mixer Use as a Frequency Multiplier, or Phase Detector

It is actually possible to use IAM-8 series mixers as multipliers simply by injecting a reasonably strong signal into the LO port, terminating the RF port in 50 Ω. and using the desired oscillator harmonic appearing at the IF port as the output. This approach yields a 2f output signal 10 to 20 dB lower than what is achievable if both RF and LO ports are driven, however.

Phase Detector

If a signal is split and fed into both the RF port and the LO port, the mixer will operate as a phase detector (Figure 7). The output will consist of an AC signal at twice the frequency of the input signal, plus a DC component that will vary in magnitude depending on the phase difference between the signals at the RF and LO ports. For the IAM-81 geometry mixers, at a 90° phase difference the DC component will typically be at 3.4 volts, but can vary between 2.9 to 3.9 volts. For IAM-82 geometry mixers, the DC offset at 90° phase difference will typically be 5.8 volts, but can vary between 3 and 8 volts. The DC component of the output signal can be re-centered at 0 volts by using plus and minus supplies to bias the mixer. The output signal may only remain centered over a limited temperature range, however.

Switch

An interesting feature of the Gilbert cell mixer is the very large drop in IF signal level that occurs when the mixer is turned off. The power at the IF frequency can be attenuated by more than 60 dB when DC bias is removed from the mixer. This suggests a possible use of the mixer as an RF switch. Care should be taken that the frequency being switched is not harmonically related to either the LO or RF signals, however, as there may be significant signal feedthrough at these frequencies.

Circuit Design

The differences in mixer functioning between Gilbert cell active mixers and passive diode mixers leads to some special circuit considerations for the IAM-8 series MMICs.

Pin-By-Pin Circuitry

The support circuitry needed by the IAM-8 series mixers is minimal, making these very easy devices to use. Pin-by-pin, the requirements are as follows.

IF Output

This pin in conjunction with the terminal designated “V_{ee}, AC ground” forms the output port of the mixer. In normal systems use, this terminal connects to an IF amplifier, either directly or through a filter.

The IF output port of an IAM-8 mixer is matched on chip to 50 Ω, eliminating the need for any external matching circuitry. Typical output reflection coefficient data is given in Table 1 for both the IAM-81028 and the IAM-82028. This data shows that no significant improvement in mixer conversion gain would result from the use of additional external impedance matching. To prevent unnecessary reflections, the output connection should be made using 50 Ω transmission line.

Since a DC voltage appears on the IF output pin, a series blocking capacitor is needed at this port.

Table 1. Typical Reflection Coefficients for IAM-8 Mixers (Opposing Ports Terminated in 50 Ω)

IAM-82028 5 V 14 mA

Freq.	Refl. Coeff-in RF		Refl. Coeff-in LO		Refl. Coeff-in IF	
MHz	Mag	Ang	Mag	Ang	Mag	Ang
100	.07	–1.4	.08	–11.0	.18	–177.2
200	.09	8.2	.08	–.4	.24	149.4
300	.10	8.4	.09	–2.0	.24	128.1
400	.11	4.1	.11	–5.7	.24	110.6
500	.12	–2.4	.12	–9.4	.25	94.3
600	.13	–6.7	.13	–12.3	.25	81.3
700	.13	–10.8	.13	–12.4	.25	69.5
800	.14	–16.5	.15	–26.7	.25	58.6
900	.14	–21.5	.15	–29.0	.26	49.6
1000	.14	–27.6	.14	–32.7	.25	41.6
1100	.14	–27.3	.14	–32.5	.26	35.7
1200	.15	–30.7	.14	–34.1	.26	30.8
1300	.15	–31.8	.14	–34.0	.27	27.7
1400	.14	–34.1	.13	–35.4	.27	25.2
1500	.14	–34.1	.12	–35.5	.28	23.8
1600	.12	–33.3	.11	–34.1	.29	22.1
1700	.12	–32.3	.10	–28.4	.30	22.6
1800	.11	–27.6	.08	–25.3	.32	20.4
1900	.10	–22.2	.07	–12.5	.33	19.9
2000	.10	–16.1	.05	7.1	.34	17.8
2500	.10	29.8	.08	67.9	.37	14.5
3000	.15	43.0	.17	88.3	.34	7.2
3500	.22	40.3	.28	79.7	.31	.9
4000	.29	33.3	.31	66.5	.27	–2.5
4500	.31	23.0	.35	54.6	.24	–5.1
5000	.32	1.4	.37	30.3	.24	–11.5

IAM-81028 10 V 51 mA

Freq. MHz	Refl. Coeff-in RF Mag	Ang	Refl. Coeff-in LO Mag	Ang	Refl. Coeff-in IF Mag	Ang
100	.10	4.9	.09	–5.5	.30	–168.4
200	.12	7.2	.10	–10.1	.38	175.2
300	.14	2.9	.12	–20.8	.38	167.8
400	.16	–3.6	.13	–31.3	.38	161.0
500	.16	–9.7	.14	–40.8	.37	154.0
600	.17	–16.0	.14	–50.1	.37	148.3
700	.17	–21.9	.14	–58.6	.36	142.6
800	.17	26.5	.17	–65.9	.36	137.0
900	.17	–32.0	.16	–74.9	.36	130.3
1000	.18	–37.0	.16	–82.6	.36	125.0
1100	.17	–38.0	.15	–89.7	.37	118.3
1200	.17	–39.8	.14	–96.6	.39	111.7
1300	.17	–41.9	.14	–105.8	.40	104.5
1400	.17	–42.2	.13	–115.2	.41	97.5
1500	.16	43.1	.12	–126.5	.43	90.0
1600	.16	–45.2	.12	–143.5	.44	82.7
1700	.16	–43.3	.12	–162.3	.45	75.6
1800	.15	–43.1	.13	–179.1	.46	68.4
1900	.14	–43.4	.15	164.9	.46	62.2
2000	.14	–42.8	.17	148.2	.46	56.5
2500	.09	–22.2	.27	123.1	.44	47.0
3000	.08	12.0	.39	99.0	.42	37.9
3500	.12	31.0	.48	79.5	.41	30.4
4000	.18	26.5	.50	62.3	.42	22.0
4500	.20	9.5	.50	44.8	.41	12.4
5000	.22	–32.3	.48	16.2	.43	–2.3

V_{ee}, AC Ground

The V_{ee} connection is the AC ground reference terminal of the mixer. At least one V_{ee} terminal must be solidly at AC ground if full RF performance is to be achieved. A lossy or inductive path from the V_{ee} terminal to ground will result in lower mixer conversion gain and reduced operating bandwidth.

Most commonly, IAM-8 mixers are biased from a single positive power supply. In this configuration, the V_{ee} terminals (including the bottom of the 18 package) should be connected directly to system ground.

When two power supplies are used to bias the mixer, or when the mixer is biased from a single negative supply, the V_{ee} terminals are connected to the most negative voltage supply used. A bypass capacitor must then be used at the V_{ee} terminals to provide AC ground to the IAM-8 mixer.

For the IAM-8 MMICs in the “28” package, the bottom of the package provides a lower inductance path to system ground than do pins (2) and (3). If the bottom of the 18 package is well grounded pins (2) and (3) need not be connected as they are internally shorted to the bottom of the case. Poor grounding of the bottom of the case will often result in high frequency (> 2 GHz) gain ripple and VSWR “drop-outs”.

RF Input
This pin, in conjunction with the terminal designated “V_{ee}, AC ground”, forms the input port of the mixer. In normal use, this terminal connects to a low noise preamplifier, either directly or through a bandpass filter.

The RF input port of an IAM-8 mixer is matched on chip to 50 Ω, eliminating the need for any external matching circuitry. Typical input reflection coefficient data is given in Table 1 for both the IAM-81018 and the IAM-82018. This data shows that no significant improvement in mixer conversion gain would result from the use of additional external impedance matching. To prevent unnecessary reflections, the connection to the LNA (or bandpass filter) should be made using 50 Ω characteristic impedance transmission line.

Since a DC voltage appears on the RF input pin, a series blocking capacitor is needed at this port.

LO Input
This pin, in conjunction with the terminal designated “V_{ee}, AC ground”, forms the LO port of the mixer, and is usually connected to the output of the local oscillator. The low sensitivity of the IAM-8 MMICs to mismatches on any port typically removes the need for any buffer amplifier between the oscillator and the mixer.

The LO input port of an IAM-8 mixer is matched on chip to 50 Ω, eliminating the need for any external matching circuitry. No significant improvement in mixer performance can be achieved by the use of additional external matching. To prevent unnecessary reflections, the connection to the local oscillator should be made using 50 Ω characteristic impedance transmission line.

Since a DC voltage appears on the LO input pin, a series blocking capacitor is needed at this port.

LO Ground, Optional
This terminal connects to the optional low frequency LO ground. If the LO signal operates at frequencies above 50 MHz this pin should be left unterminated. As it carries a DC potential, it should not be connected to DC ground.

When an oscillator operating at a frequency below 50 MHz is used, this pin must provide the necessary low frequency AC path to ground, i.e. it needs to be terminated with a large-valued capacitor that provides a low impedance path (< 10 Ω,) to ground at the lowest oscillator frequency used. Hewlett-Packard suggests that a small valued (1 to 10 Ω,) resistor be connected in series with this external low frequency bypass capacitor. This resistor lowers the Q of the resonant tank circuit created by the parallel combination of the external and internal AC grounding capacitors, and thus reduces drop-outs in mixer gain vs. frequency performance.

V_{cc}
The V_{cc} terminal is used to apply DC bias to the MMIC. It should be connected to the highest DC potential used to bias the mixer. For proper operation, this pin must be at AC ground.

This pin is AC shorted to the bottom of the case (V_{ee}) through an internal 45 pF capacitor. Thus when the MMIC case is well grounded, no external high frequency bypass capacitor is required at pin (7). An external low frequency bypass capacitor (≥ 1000 pF) may be necessary depending on the termination presented by the power supply line, and is a commonly employed option.

RF Ground, Optional
This terminal connects to the optional low frequency RF ground. If the RF signal operates at frequencies above 50 MHz this pin should be left unterminated. As it carries a DC potential, it should not be connected to DC ground.

When an input signal operating at a frequency below 50 MHz is used, this pin must provide the necessary low frequency AC path to ground, i.e. it needs to be terminated with a large valued capacitor that provides a low impedance path (< 10 Ω,) to ground at the lowest drive frequency used. To prevent drop-outs in performance resulting from the resonant tank circuit created by the parallel combination of the external and internal AC grounding capacitors, a small valued (1 to 10 Ω,) resistor should be connected in series with the external low frequency bypass capacitor.

The DC voltage appearing across the “RF ground, optional” pin and the RF input pin must be maintained even when the mixer is operated differentially. Usually this is accomplished by placing blocking capacitors between the mixer and an input balun (1:1 unbalanced to balanced transformer).

Unlabeled Pins

Any unlabeled pins are not used, and should be left unconnected (floating). They should not be grounded, as they may carry a DC voltage. Such pins may be probe points used for evaluating the die during the fabrication and assembly process, or unused connections resulting from the use of standard packages or die layout formats.

Blocks, Bypasses, and Chokes

Since IAM-8 MMICs are active devices requiring DC bias, circuits using these MMICs typically contain blocking capacitors, bypass capacitors, and RF chokes.

Blocking Capacitors

MMICs in the IAM-8 family are designed to be used with DC blocking capacitors on the RF, LO, and IF ports. These capacitors prevent the loads presented to the MMIC from shifting the DC operating point set by the internal bias network. Blocking capacitors should provide a low series impedance (usually less than 10 Ω,) throughout the frequency band that the IAM-8 MMIC is to be used. Remember that at microwave frequencies, the reactive impedance of the blocking capacitor is the sum of the impedance provided by its capacitance ($-1/(2\pi fC)$), plus the impedance from its associated parasitic inductance ($2\pi fL$). Dissipative loss in the capacitor will also contribute a resistive component to its impedance; capacitors with unduly high dissipative losses will cause the apparent gain of the MMIC to decrease.

Blocking capacitors may be used either above or below resonance, so long as their net series impedance is low. For narrow-band applications, capacitors at resonance can be used, as this provides minimal insertion impedance ($2\pi fL - 1/(2\pi fC) \equiv 0$ at resonance). Typical values for blocking capacitors are on the order of 1000 pF, with associated parasitic inductances of 0.5 nH.

The value of blocking capacitor selected will generally determine the lower frequency of operation of the circuit output (IF). As can be seen from the section on circuit topology, there is no internal low frequency limit inherent in the MMIC design.

Bypass Capacitors

IAM-8 series mixers require the use of bypass capacitors on several terminals. These capacitors connect from the pin in question to system ground, and are used to apply an AC ground to terminals that must carry a non-zero DC potential. To minimize parasitic inductance, these capacitors should be located as near to the MMIC as possible.

IAM-8 series mixers use internal bypass capacitors with values on the order of 45 pF. This value is set by the physical dimensions of the package cavity; higher valued capacitors are physically too large to fit. A 45 pF capacitor provides an adequate ground path to frequencies as low as 50 MHz. External bypass capacitors can be used on pins (6) and (8) of packaged mixers to extend the low frequency of operation of the LO and the RF ports respectively.

Choke Networks
Choke networks are not generally required when biasing IAM-8 MMICs. The internal circuitry provides adequate isolation between the power supply and the RF circuitry. The bias voltage is most often connected to the power supply via a pc trace of convenient length.

IAM-8 MMICs contain an internal high-frequency bypass of 45 pF on the V_{CC} terminal.

Demonstration Circuit Board
A demonstration board for IAM-8 series mixers in the “28” package has been laid out on .032 inch thick epoxy glass ($\varepsilon = 4.8$). This material was selected for economy; PTFE-fiberglass substrates ($\varepsilon = 2.5$) will generally provide superior high-frequency performance but at a higher cost. A scale drawing of the board artwork is shown in Figure 6.
This circuit board can be used to evaluate the mixer for many of the above applications.

A circuit was assembled using the pc board shown in Figure 8 and an IAM-8-82028. An assembly drawing for this circuit (including component values) is shown in Figure 9. The circuit was biased from a +10 volt power supply; the mixer drew 56 mA of current. A 2 GHz signal of –20 dBm was used to drive the RF port and a 1.75 GHz signal of 0 dBm was used to drive the LO port. The resulting output spectrum is shown in Figure 10. The conversion gain shown for an IF of 250 MHz was 15.5 dB, in good agreement with the IAM-82028 data sheet.

The conversion gain and input (RF port) VSWR versus frequency of this circuit were also measured for the condition of a 100 MHz IF. The resulting data is presented in Figure 11. The frequency range tested was 100 MHz to 5 GHz.

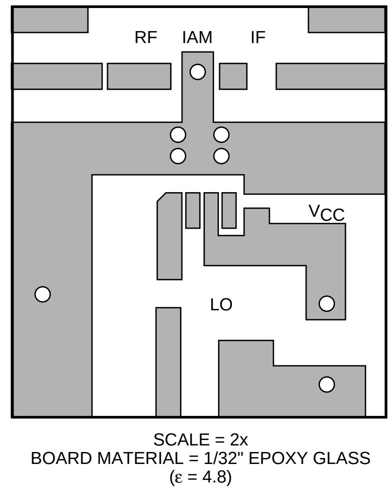

Figure 8. IAM-8 Mixer Demonstration Circuit PC Board Layout

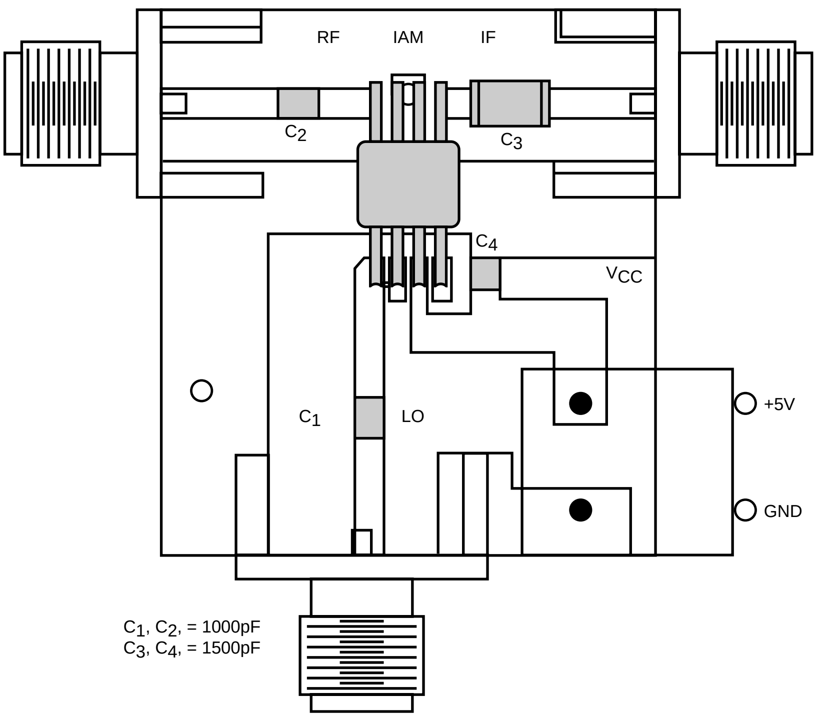

Figure 9. IAM-8 Mixer Demonstration Circuit Showing Component Placement

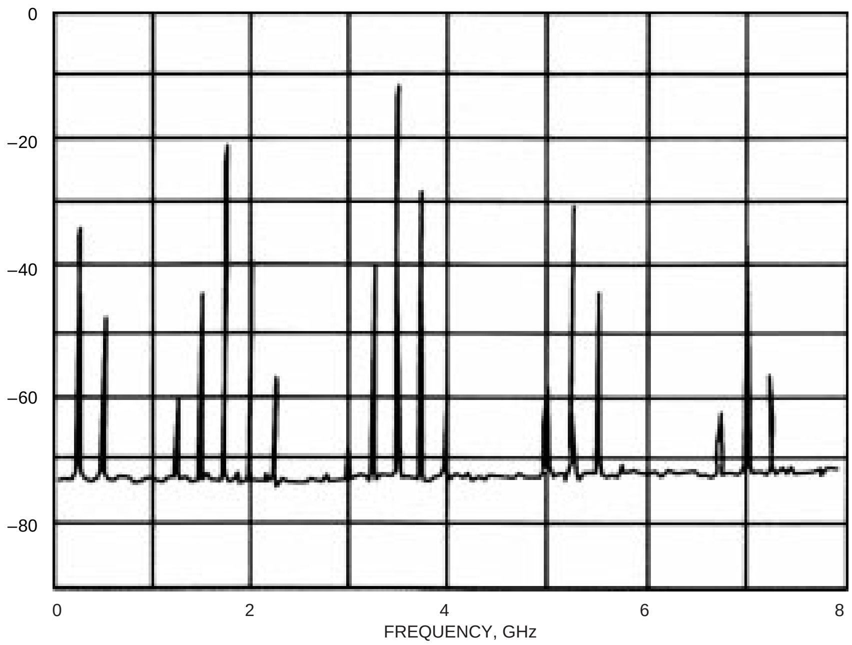

Figure 10. Output Spectrum, IAM-82028, LO = 0 dBm @ 1.75 GHz, RF = –20 dBm @ 2.0 GHz

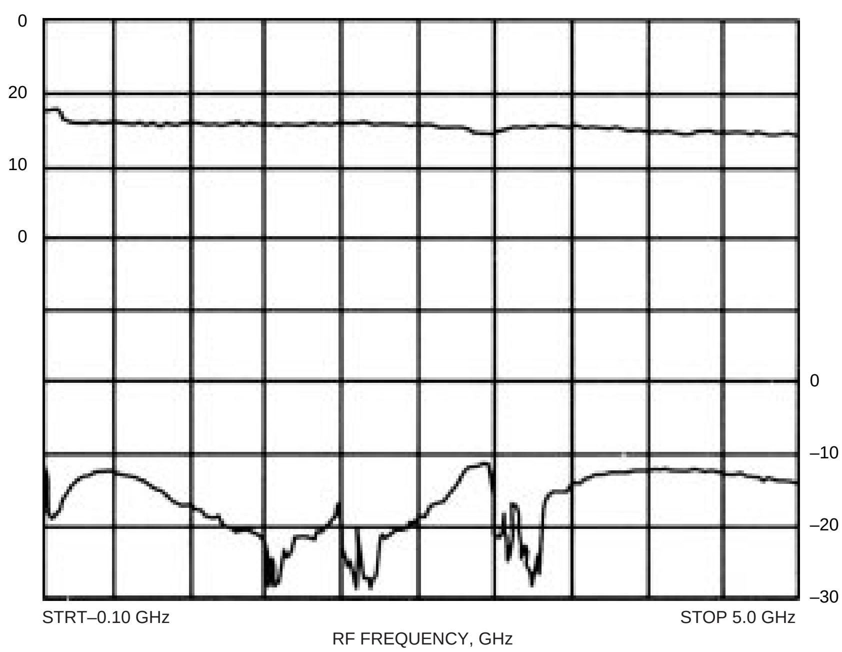

Figure 11. Conversion Gain and Input Return Loss vs. Frequency, IAM-82028, I_d = 56 mA, F_{IF} = 100 MHz

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