1300MHz to 2700MHz Variable-Gain Amplifier with Analog Gain Control

ABSOLUTE MAXIMUM RATINGS

V_{CC} to GND ....-0.3V to +5.5V
V_{CNTL} to GND (with V_{CC} applied) ....0V to 4.75V
Current into V_{CNTL} pin (V_{CC} grounded) 40mA
All Other Pins to GND....................-0.3V to (V_{CC} + 0.3V)
RF Input Power (IN, IN_A, ATTN_OUT, OUT_A) ....+20dBm
RF Input Power (AMP_IN)....................+12dBm
θ_{JA} (natural convection)....................35°C/W
θ_{JA} (1m/s airflow) ....31°C/W
θ_{JA} (2.5m/s airflow) ....29°C/W
θ_{JC} (junction to exposed pad) ....10°C/W
Operating Temperature Range ....-40°C to +85°C
Storage Temperature Range ....-65°C to +150°C
Junction Temperature....................+150°C
Lead Temperature (soldering, 10s) ....+300°C
Soldering Temperature (reflow) ....+260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

(V_{CC} = +4.75V to +5.25V, no RF signals applied, all input and output ports terminated with 50Ω, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{CC} = +5.0V, T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage		4.75	5	5.25	V
Supply Current	R1 = 1.2kΩ, R2 = 2kΩ (Note 1)		180	230	mA
R_{SET1} Current	R1 = 1.2kΩ (Note 1)		1		mA
R_{SET2} Current	R1 = 2kΩ (Note 1)		0.6		mA
Gain-Control Voltage Range	(Note 2)	1.0		4.5	V
Gain-Control Pin Input Resistance	V_{CNTL} = 1V to 4.5V	50			kΩ

RECOMMENDED AC OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency Range	(Note 3)	1300		2700	MHz

AC ELECTRICAL CHARACTERISTICS

(Typical Operating Circuit with one attenuator connected, V_{CC} = +4.75V to +5.25V, T_A = -40°C to +85°C, f_{IN} = 1700MHz to 2500MHz, unless otherwise noted. Typical values are at V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, P_{OUT} = +5dBm, f_{IN} = 2100MHz, V_{CNTL} = 1V, 50Ω system impedance, second attenuator is not connected, T_A = +25°C, unless otherwise noted.) (Note 4)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Gain	T_A = +25°C, V_{CC} = 5.0V, f_{IN} = 2100MHz		13.5	15.5	17.5	dB
	T_A = +25°C, V_{CC} = 5.0V, f_{IN} = 1560MHz		11.5	14.5	16.5	
	T_A = +25°C, V_{CC} = 5.0V, f_{IN} = 1500MHz		11.5	14.3	16.5	
	T_A = +25°C, V_{CC} = 5.0V, f_{IN} = 1450MHz		11.5	14	16.5	
Maximum Gain Variation	T_A = +25°C to -40°C	V_{CNTL} = 1V		+0.9		dB
		V_{CNTL} = 1.8V		+0.41		
		V_{CNTL} = 2.6V		+0.09		
		V_{CNTL} = 3.5V		-0.16		
	T_A = +25°C to +85°C	V_{CNTL} = 1V		-1		
		V_{CNTL} = 1.8V		-0.56		
		V_{CNTL} = 2.6V		-0.32		
		V_{CNTL} = 3.5V		+0.1		

AC ELECTRICAL CHARACTERISTICS (continued)

(Typical Operating Circuit with one attenuator connected, V_{CC} = +4.75V to +5.25V, T_A = -40°C to +85°C, f_{IN} = 1700MHz to 2500MHz, unless otherwise noted. Typical values are at V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, P_{OUT} = +5dBm, f_{IN} = 2100MHz, V_{CNTL} = 1V, 50Ω system impedance, second attenuator is not connected, T_A = +25°C, unless otherwise noted.) (Note 3)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Reverse Isolation				37		dB
Noise Figure	(Note 5)			6		dB
Output 1dB Compression Point				+23.8		dBm
Output 2nd-Order Intercept Point	From maximum gain to 15dB attenuation, measured at $f_1 + f_2$ (Note 6)			+64		dBm
Output 3rd-Order Intercept Point	From maximum gain to 15dB attenuation (Note 5)			+37		dBm
Output 3rd-Order Intercept Point Variation Over Temperature	T_A = +25°C to +85°C			-0.83		dB
	T_A = +25°C to -40°C			-0.6		
2nd Harmonic	From maximum gain to 15dB attenuation, P_{OUT} = +5dBm			-65		dBc
3rd Harmonic	From maximum gain to 15dB attenuation, P_{OUT} = +5dBm			-83		dBc
RF Gain-Control Range	f_{IN} = 1700MHz to 2200MHz, V_{CNTL} = 1V to 4V	One attenuator	17	20.7		dB
		Two attenuators	34	42.4		
	f_{IN} = 1450MHz to 1560MHz, V_{CNTL} = 1V to 4V	One attenuator	17	22		
		Two attenuators	34	44		
RF Gain-Control Slope	V_{CNTL} = 1.8V to 3.5V			-10		dB/V
Maximum RF Gain-Control Slope	Maximum slope vs. gain-control voltage			-15.2		dB/V
Gain Flatness Over 100MHz Bandwidth	Peak-to-peak for all settings			0.5		dB
Attenuator Switching Time	15dB attenuation change (Note 7)			500		ns
Attenuator Insertion Loss	Second attenuator (IN_A, OUT_A)			2.2		dB
Input Return Loss	Entire band, all gain settings			18		dB
Output Return Loss	Entire band, all gain settings			15		dB
Group Delay	Input/output 50Ω lines de-embedded			300		ps
Group Delay Flatness Over 100MHz Bandwidth	Peak to peak			20		ps
Group Delay Change vs. Gain Control	V_{CNTL} = 1V to 4V			-70		ps
Insertion Phase Change vs. Gain Control	V_{CNTL} = 1V to 4V			50		degrees

Note 1: Total supply current reduces as R_1 and R_2 are increased.
Note 2: Operating outside this range for extended periods may affect device reliability. Limit pin input current to 40mA when V_{CC} is not present.
Note 3: Operation outside this range is possible, but with degraded performance of some parameters.
Note 4: All limits include external component losses, unless otherwise noted.
Note 5: Noise figure increases by approximately 1dB for every 1dB of gain reduction.
Note 6: f_1 = 2100MHz, f_2 = 2101MHz, +5dBm/tone at OUT.
Note 7: Switching time is measured from 50% of the control signal to when the RF output settles to ±1dB.

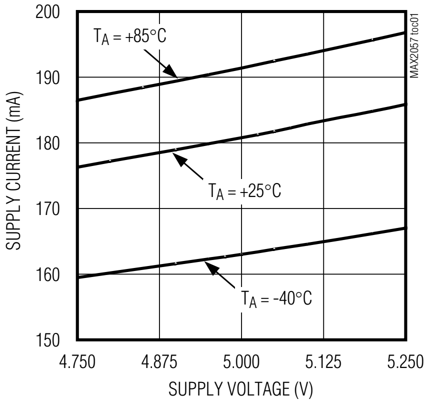
1300MHz to 2700MHz Variable-Gain Amplifier with Analog Gain Control

Typical Operating Characteristics

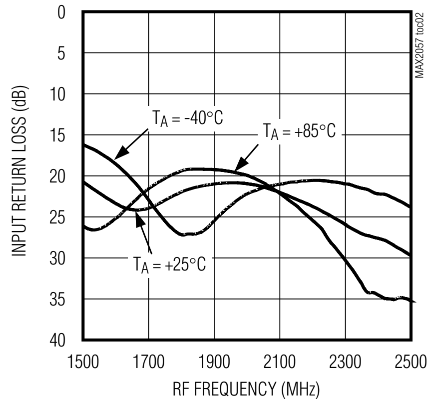
One Attenuator Configuration

(Typical Application Circuit with **one attenuator** connected, V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, f_{IN} = 2100MHz, maximum gain setting, P_{OUT} = +5dBm, linearity measured at P_{OUT} = +5dBm/tone, T_A = +25°C, unless otherwise noted.)

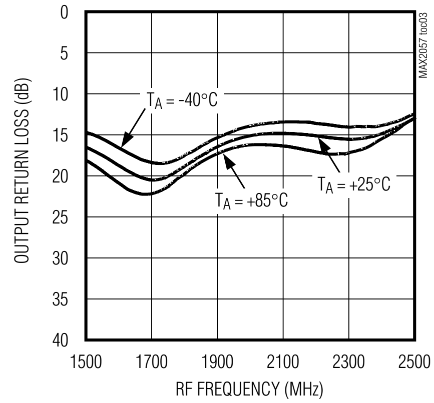
SUPPLY CURRENT vs. SUPPLY VOLTAGE



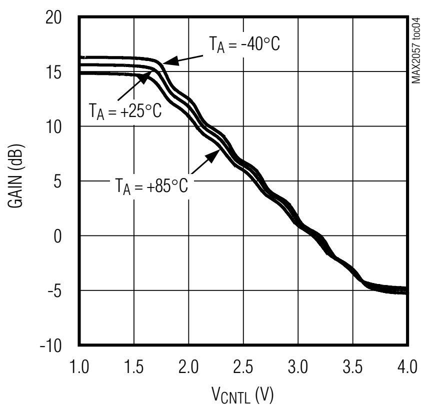
INPUT RETURN LOSS vs. RF FREQUENCY



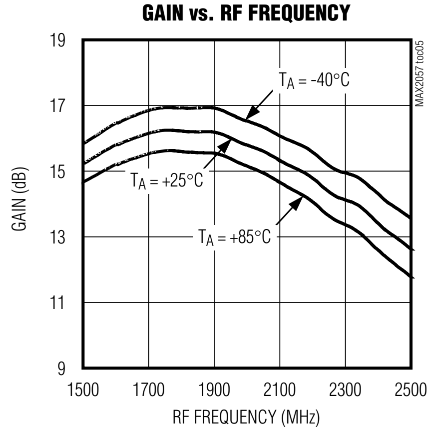
OUTPUT RETURN LOSS vs. RF FREQUENCY



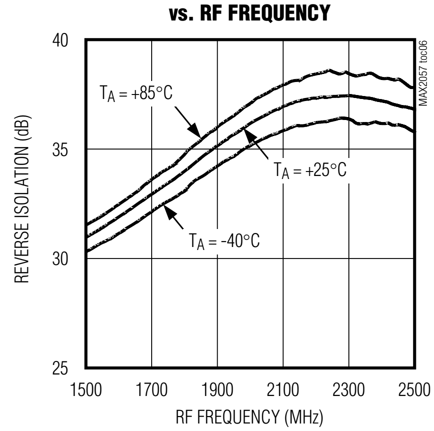
GAIN vs. GAIN-CONTROL VOLTAGE



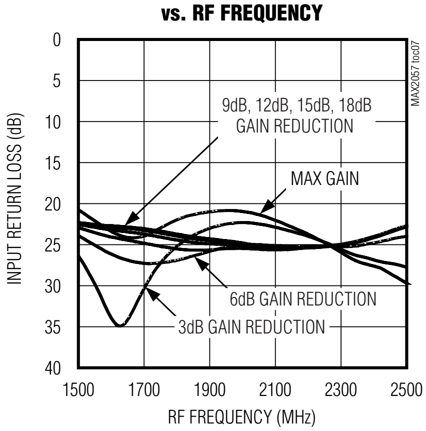
GAIN vs. RF FREQUENCY



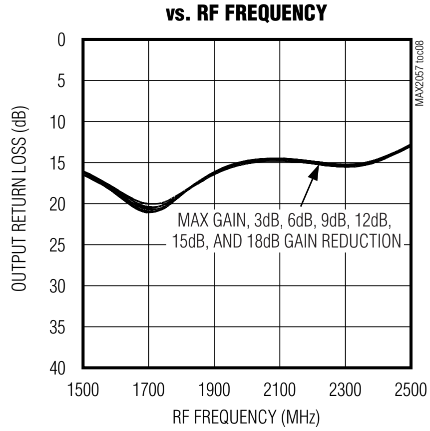
REVERSE ISOLATION vs. RF FREQUENCY



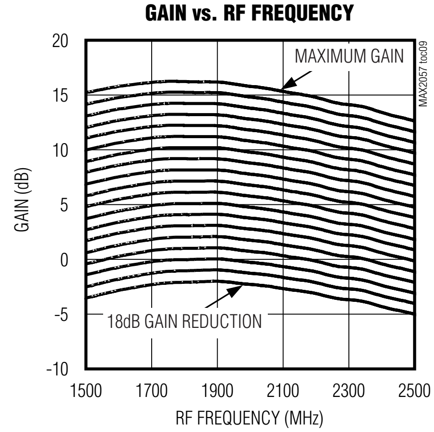
INPUT RETURN LOSS vs. RF FREQUENCY



OUTPUT RETURN LOSS vs. RF FREQUENCY



GAIN vs. RF FREQUENCY



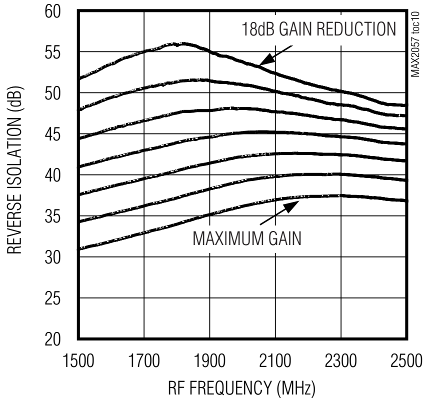
1300MHz to 2700MHz Variable-Gain Amplifier with Analog Gain Control

Typical Operating Characteristics (continued)

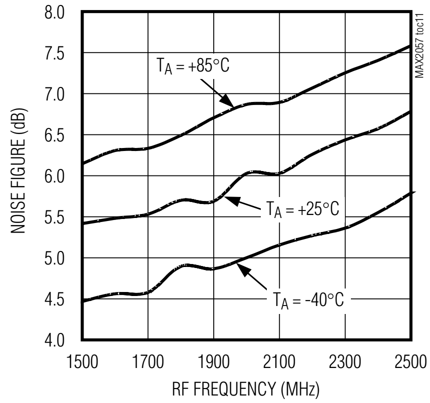
One Attenuator Configuration

(Typical Application Circuit with **one attenuator** connected, V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, f_{IN} = 2100MHz, maximum gain setting, P_{OUT} = +5dBm, linearity measured at P_{OUT} = +5dBm/tone, T_A = +25°C, unless otherwise noted.)

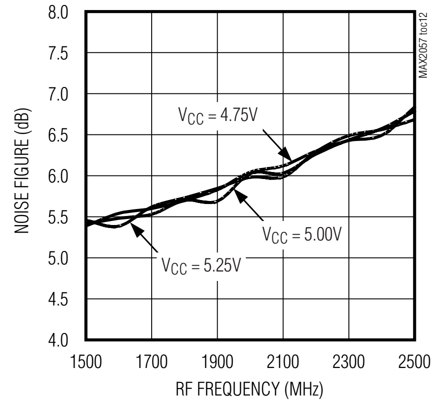
REVERSE ISOLATION vs. RF FREQUENCY



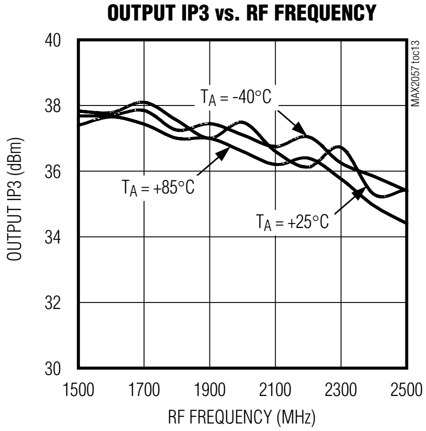
NOISE FIGURE vs. RF FREQUENCY



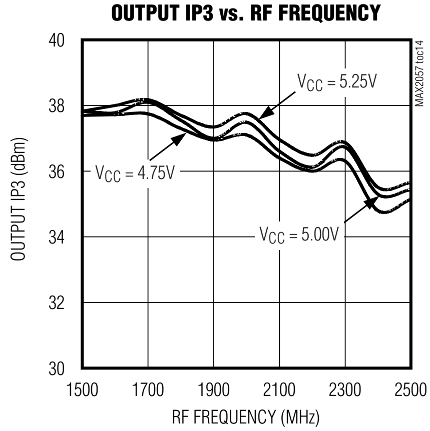
NOISE FIGURE vs. RF FREQUENCY



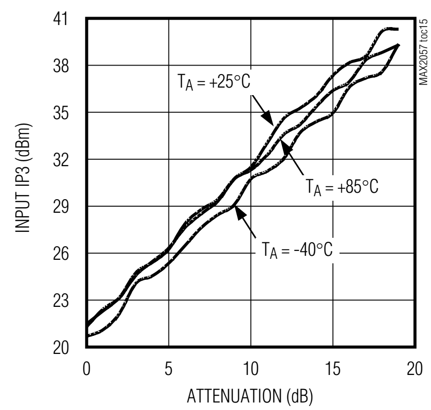
OUTPUT IP3 vs. RF FREQUENCY



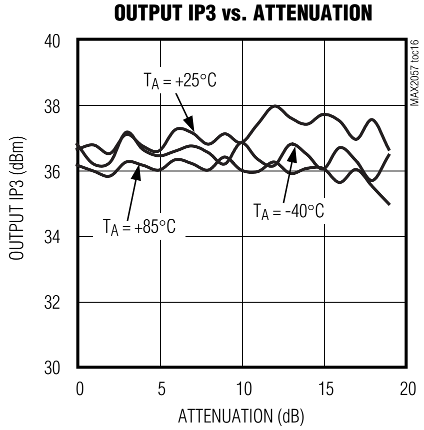
OUTPUT IP3 vs. RF FREQUENCY



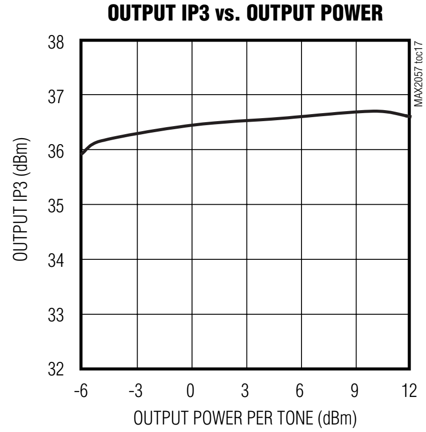
INPUT IP3 vs. ATTENUATION



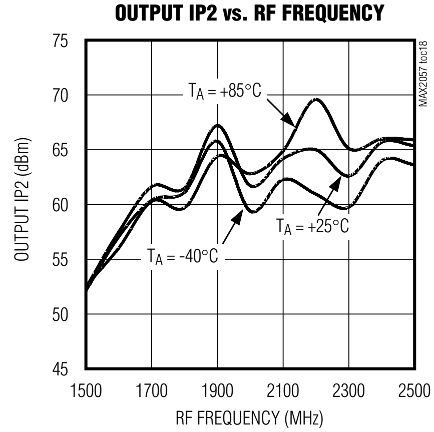
OUTPUT IP3 vs. ATTENUATION



OUTPUT IP3 vs. OUTPUT POWER



OUTPUT IP2 vs. RF FREQUENCY



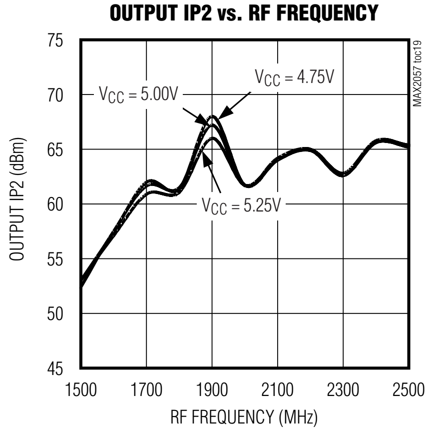
1300MHz to 2700MHz Variable-Gain Amplifier with Analog Gain Control

Typical Operating Characteristics (continued)

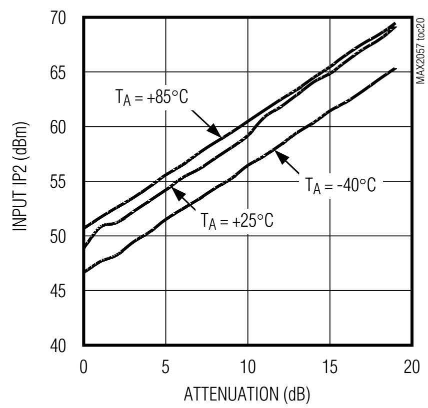
One Attenuator Configuration

(Typical Application Circuit with **one attenuator** connected, V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, f_{IN} = 2100MHz, maximum gain setting, P_{OUT} = +5dBm, linearity measured at P_{OUT} = +5dBm/tone, T_A = +25°C, unless otherwise noted.)

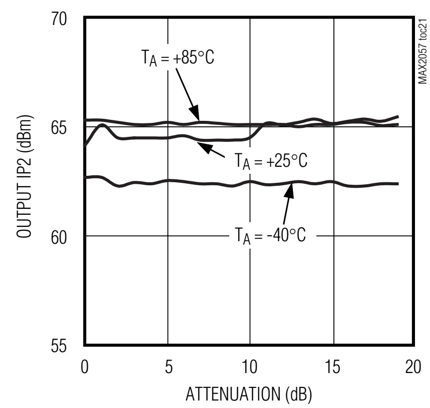
OUTPUT IP2 vs. RF FREQUENCY



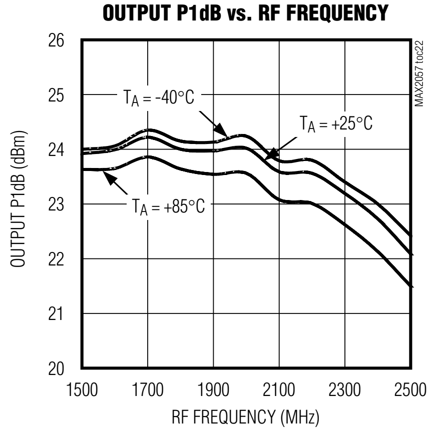
INPUT IP2 vs. ATTENUATION



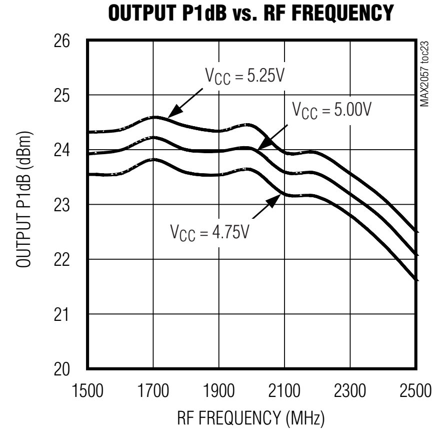
OUTPUT IP2 vs. ATTENUATION



OUTPUT P1dB vs. RF FREQUENCY



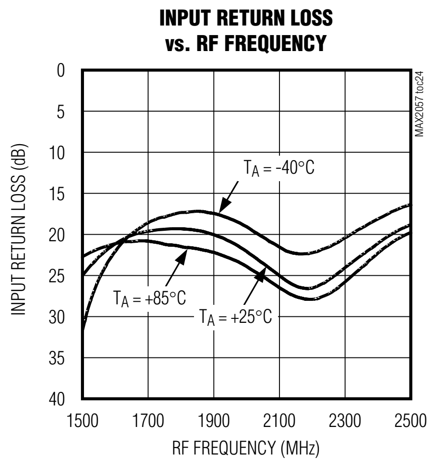
OUTPUT P1dB vs. RF FREQUENCY

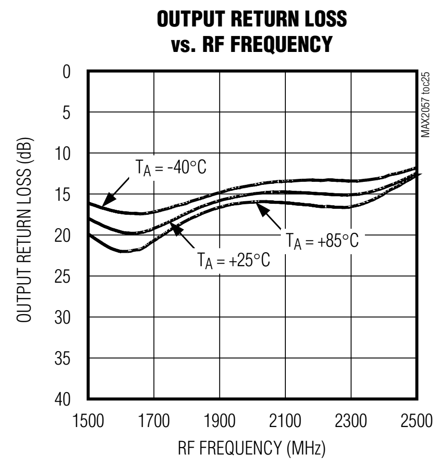


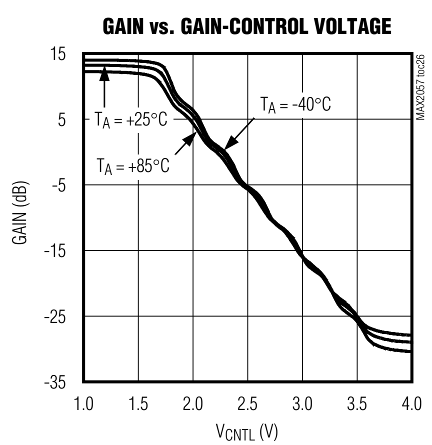
Typical Operating Characteristics

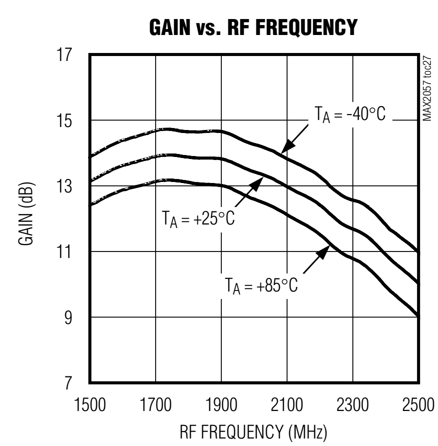
Two Attenuator Configuration

(Typical Application Circuit with **two attenuators** connected, V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, f_{IN} = 2100MHz, maximum gain setting, P_{OUT} = +5dBm, linearity measured at P_{OUT} = +5dBm/tone, T_A = +25°C, unless otherwise noted.)









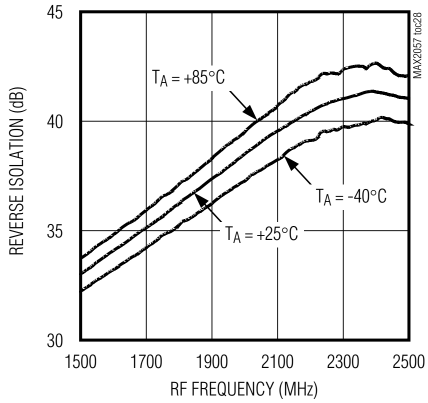
1300MHz to 2700MHz Variable-Gain Amplifier with Analog Gain Control

Typical Operating Characteristics (continued)

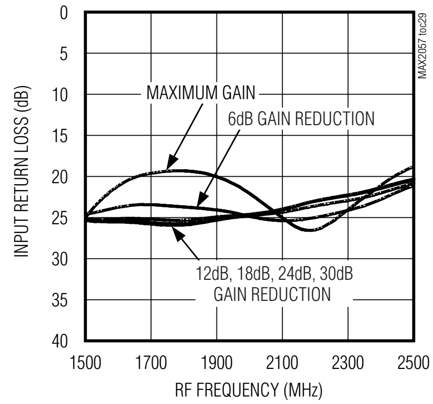
Two Attenuator Configuration

(Typical Application Circuit with **two attenuators** connected, V_{CC} = +5.0V, R1 = 1.2kΩ, R2 = 2kΩ, f_{IN} = 2100MHz, maximum gain setting, P_{OUT} = +5dBm, linearity measured at P_{OUT} = +5dBm/tone, T_A = +25°C, unless otherwise noted.)

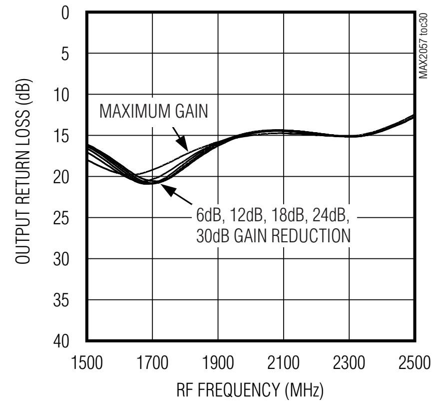
REVERSE ISOLATION vs. RF FREQUENCY



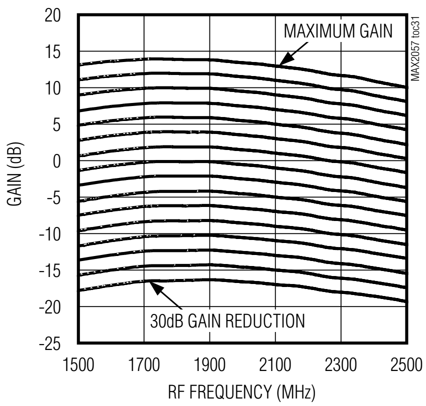
INPUT RETURN LOSS vs. RF FREQUENCY



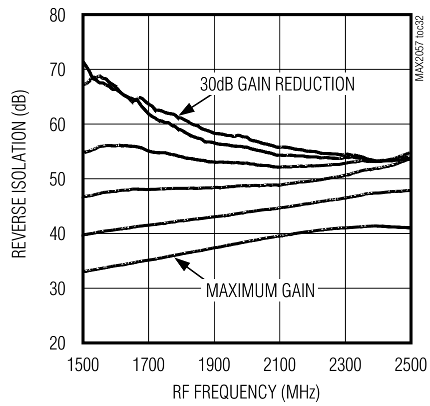
OUTPUT RETURN LOSS vs. RF FREQUENCY



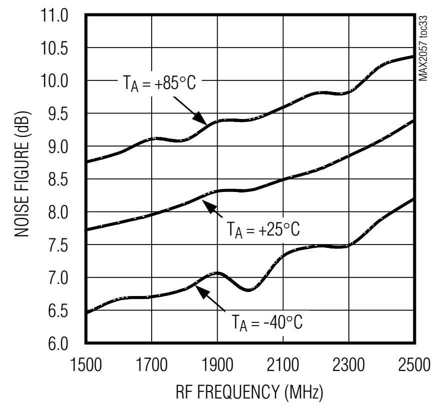
GAIN vs. RF FREQUENCY



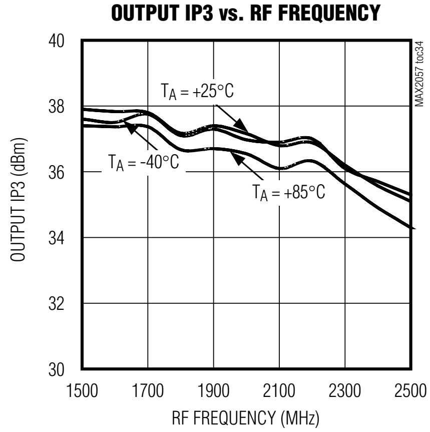
REVERSE ISOLATION vs. RF FREQUENCY



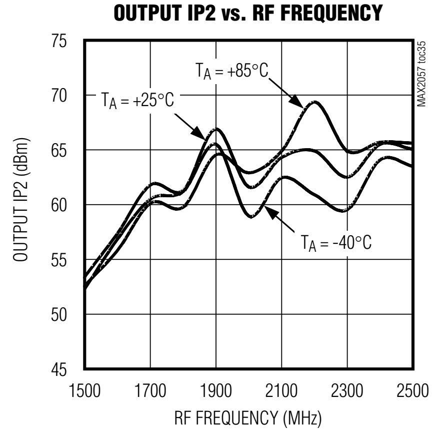
NOISE FIGURE vs. RF FREQUENCY



OUTPUT IP3 vs. RF FREQUENCY



OUTPUT IP2 vs. RF FREQUENCY



Pin Description

PIN	NAME	FUNCTION
1, 3, 4, 6, 7, 9, 10, 12, 14, 18, 19, 21–24, 27, 28, 30, 31, 33, 34, 36	GND	Ground. Connect to the board's ground plane using low-inductance layout techniques.
2	OUT_A	Second-Attenuator Output. Internally matched to 50Ω over the operating frequency band. Connect to IN through a DC-blocking capacitor if greater than 21dB of gain-control range is required. No connection is required if the second attenuator is not used.
5, 13, 16, 25, 32	V_{CC}	Power Supply. Bypass each pin to GND with capacitors as shown in the *Typical Application Circuit.* Place capacitors as close to the pin as possible.
8	IN_A	Second-Attenuator Input. Internally matched to 50Ω over the operating frequency band. Connect to a 50Ω RF source through a DC-blocking capacitor if greater than 21dB of gain-control range is required. No connection is required if the second attenuator is not used.
11	V_{CNTL}	Analog Gain-Control Input. **Limit voltages applied to this pin to a 1V to 4.5V range when V_{CC} is present to ensure device reliability.**
15	R_{SET1}	First-Stage Amplifier Bias-Current Setting. Connect to GND through a 1.2kΩ resistor.
17	R_{SET2}	Second-Stage Amplifier Bias-Current Setting. Connect to GND through a 2kΩ resistor.
20	OUT	RF Output. Internally matched to 50Ω over the operating frequency band. Requires a DC-blocking capacitor and a shunt-matching capacitor.
26	AMP_IN	Amplifier Input. Internally matched to 50Ω over the operating frequency band. Connect to ATTN_OUT through a DC-blocking capacitor.
29	ATTN_OUT	Attenuator Output. Internally matched to 50Ω over the operating frequency band. Connect to AMP_IN through a DC-blocking capacitor.
35	IN	RF Input. Internally matched to 50Ω over the operating frequency band. Connect to a 50Ω RF source through a DC-blocking capacitor if the second attenuator is not used.
—	EP	Exposed Pad. This pad affects RF performance and provides heat dissipation. This pad **MUST** be soldered evenly to the board's ground plane for proper operation.

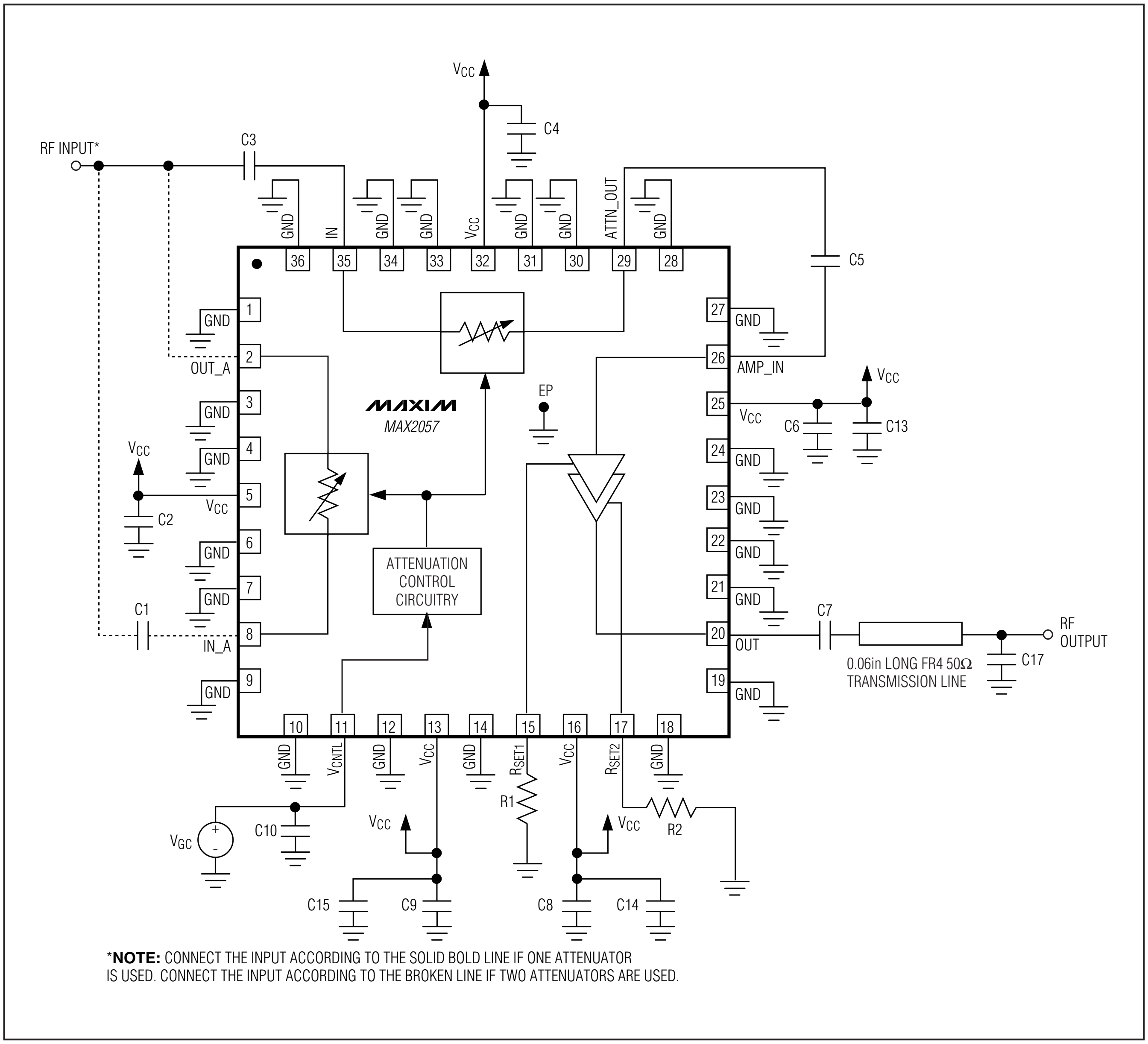


Figure 1. Typical Application Circuit

Detailed Description

The MAX2057 general-purpose, high-performance VGA with analog gain control is designed to interface with 50Ω systems operating in the 1300MHz to 2700MHz frequency range.

The MAX2057 integrates two attenuators to provide 21dB or 42dB of precision analog gain control, as well as a two-stage amplifier that has been optimized to provide high gain, high IP3, low noise figure, and low power consumption. The bias current of each amplifier stage can be adjusted by individual external resistors to further reduce power consumption for applications that do not require high linearity.

Table 1. Typical Application Circuit Component Values

DESIGNATION	VALUE	TYPE
C1, C3, C5, C7, C10	22pF	Microwave capacitors (0402)
C2, C4, C6, C8, C9	1000pF	Microwave capacitors (0402)
C13, C14, C15	0.1µF	Microwave capacitors (0603)
C17	0.75pF	Microwave capacitor (0402)
R1	1.2kΩ	±1% resistor (0402)
R2	2kΩ	±1% resistor (0402)

Applications Information

Analog Attenuation Control

A single input voltage at the V_{CNTL} pin adjusts the gain of the MAX2057. Up to 21dB of gain-control range is provided through a single attenuator. At the maximum gain setting, each attenuator's insertion loss is approximately 2.2dB. With the single attenuator at the maximum gain setting, the device provides a nominal 15.5dB of cascaded gain and 6dB of cascaded noise figure.

If a larger gain-control range is desired, a second on-chip attenuator can be connected in the signal path to provide an additional 21dB of gain-control range. With the second attenuator connected at the maximum gain setting, the device typically exhibits 13.3dB of cascaded gain. Note that the V_{CNTL} pin simultaneously adjusts both on-chip attenuators.

The V_{CNTL} input voltage drives a high-impedance load (> 50kΩ). It is suggested that a current-limiting resistor be included in series with this connection to limit the input current to less than 40mA should the control voltage be applied when V_{CC} is not present. A series resistor of greater than 200Ω will provide complete protection for 5V control voltage ranges. **Limit V_{CNTL} input voltages to a 1.0V to 4.5V range when V_{CC} is present to ensure the reliability of the device.**

Amplifier Bias Current

The MAX2057 integrates a two-stage amplifier to simultaneously provide high gain and high IP3. Optimal performance is obtained when R1 and R2 are equal to 1.2kΩ and 2kΩ, respectively. The typical supply current is 180mA and the typical output IP3 is 37dBm under these conditions.

Increasing R_1 and R_2 from the nominal values of 1.2kΩ and 2kΩ reduces the bias current of each amplifier stage, which reduces the total power consumption and IP3 of the device. This feature can be utilized to further decrease power consumption for applications that do not require high IP3.

Layout Considerations

A properly designed PC board is an essential part of any RF/microwave circuit. Keep RF signal lines as short as possible to reduce losses, radiation, and inductance. For best performance, route the ground-pin traces directly to the exposed pad underneath the package. This pad **MUST** be connected to the ground plane of the board by using multiple vias under the device to provide the best RF and thermal conduction path. Solder the exposed pad on the bottom of the device package to a PC board exposed pad.

Power-Supply Bypassing

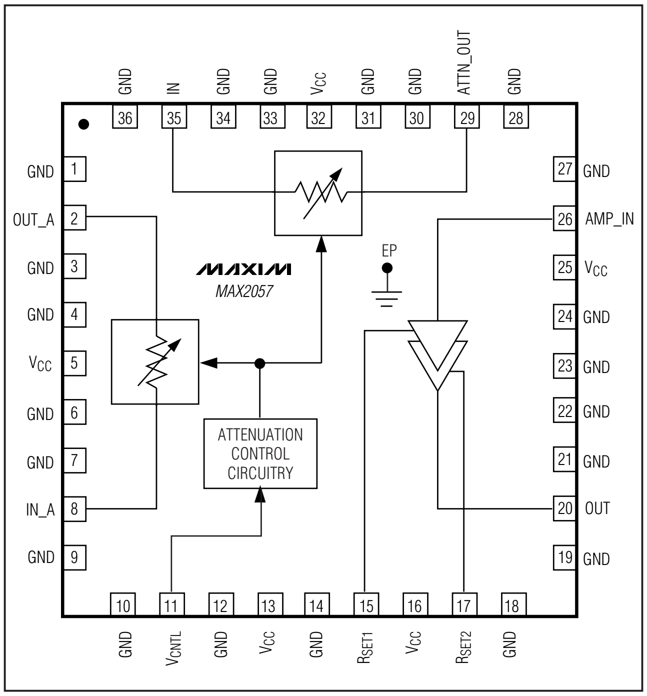
Proper voltage-supply bypassing is essential for high-frequency circuit stability. Bypass each V_{CC} pin with capacitors placed as close to the device as possible. Place the smallest capacitor closest to the device. Refer to the MAX2057 evaluation kit data sheet for more details.

Exposed Pad RF and Thermal Considerations

The EP of the MAX2057's 36-pin thin QFN-EP package provides a low-thermal-resistance path to the die. It is important that the PC board on which the IC is mounted be designed to conduct heat from this contact. In addition, the EP provides a low-inductance RF ground path for the device.

The EP **MUST** be soldered to a ground plane on the PC board either directly or through an array of plated via holes. Soldering the pad to ground is also critical for efficient heat transfer. Use a solid ground plane wherever possible.

Pin Configuration/ Functional Diagram



Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
36 TQFN-EP	T3666+2	**21-0141**	**90-0049**

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	1/05	Initial release	—
1	12/10	Updated *General Description, Features, Applications, Ordering Information, DC Electrical Characteristics*, *AC Electrical Characteristics, Detailed Description,* and *Analog Attenuation Control* sections, and added *Recommended AC Operating Conditions* section	1, 2, 3, 10, 11