

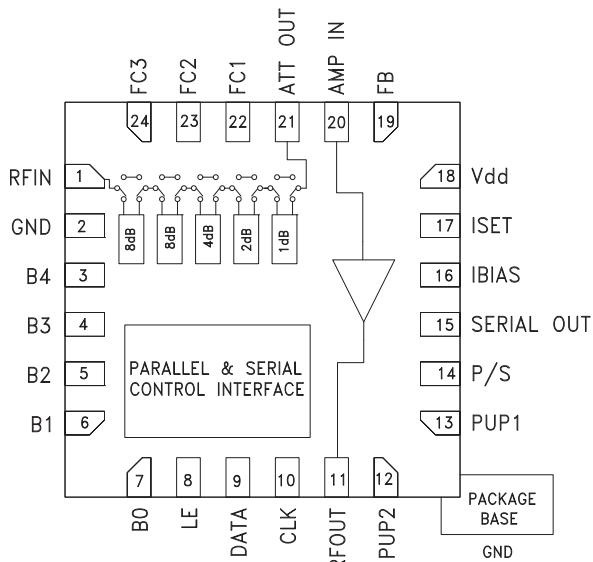

**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**

Typical Applications

The HMC628LP4(E) is ideal for:

- Cellular/3G Infrastructure
- WiBro / WiMAX / 4G
- Microwave Radio & VSAT
- Test Equipment and Sensors
- IF & RF Applications

Functional Diagram



Electrical Specifications, $T_A = +25^\circ C$, 50 Ohm System, $Vdd = +5V$

| Parameter | 50 - 250 | | | 250 - 500 | | | 500 - 800 | | | MHz |
|--|--|-------------------|------|--|-------------------|------|--|-------------------|------|------------|
| | Min. | Typ. | Max. | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Gain (Maximum Gain State) | 13 | 15 | | 12.8 | 14 | | 10.5 | 13 | | dB |
| Gain Control Range | | 23 | | | 23 | | | 23 | | dB |
| Input Return Loss | | 12 | | | 10 | | | 10 | | dB |
| Output Return Loss | | 10 | | | 12.5 | | | 9 | | dB |
| Gain Accuracy: (Referenced to Maximum Gain State) | $\pm (0.1 + 1\% \text{ of Gain Setting}) \text{Max}$ | | | $\pm (0.4 + 2\% \text{ of Gain Setting}) \text{Max}$ | | | $\pm (0.4 + 4\% \text{ of Gain Setting}) \text{Max}$ | | | dB |
| Output Power for 1dB Compression | 19 | 19.5 | | 16 | 18 | | 14 | 18 | | dBm |
| Output Third Order Intercept Point | | 35 ^[1] | | | 33 ^[2] | | | 32 ^[3] | | dBm |
| Output Second Order Intercept Point | | 46 ^[1] | | | 54 ^[2] | | | 55 ^[3] | | dBm |
| Harmonics | 2nd 3rd | 46 69 | | | 55 75 | | | 62 83 | | dBc dBc |
| Switching Characteristics | t _{RISE} , t _{FALL} (10 / 90% RF) | | | 11 | | | ns | | | ns |
| t _{ON} , t _{OFF} (Latch Enable to 10 / 90% RF) | | | | | 18 | | | | | ns |
| Noise Figure | | 5 | | | 6 | | | 6.5 | | dB |
| Supply Current (I _{dd}) | | 65 | 85 | | 65 | 85 | | 65 | 85 | mA |

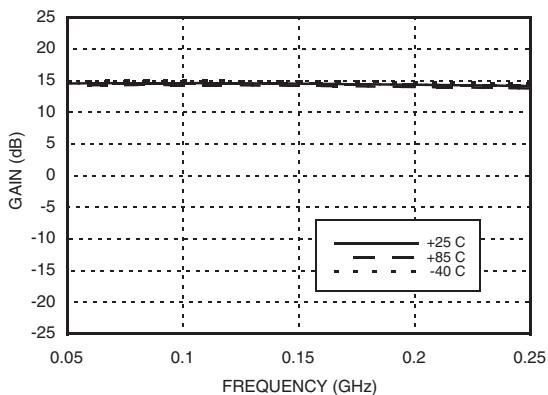
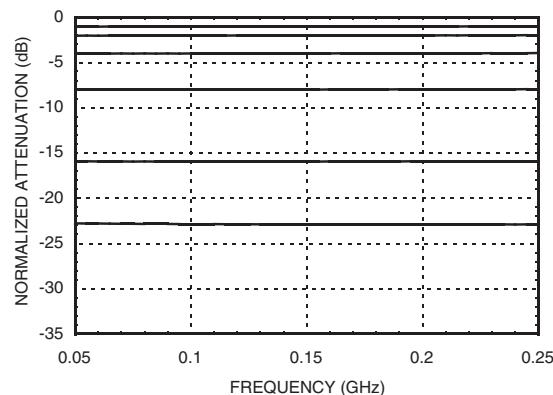
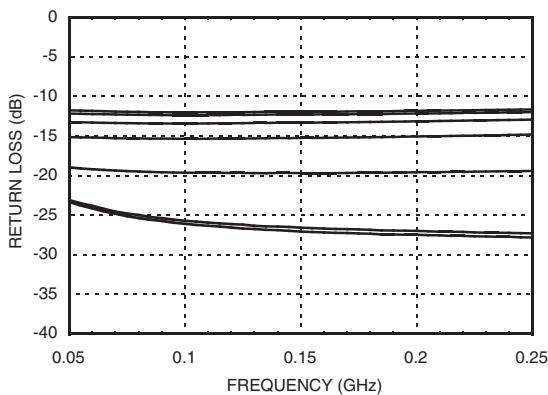
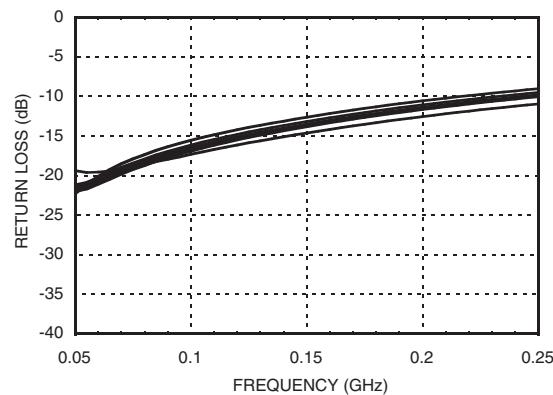
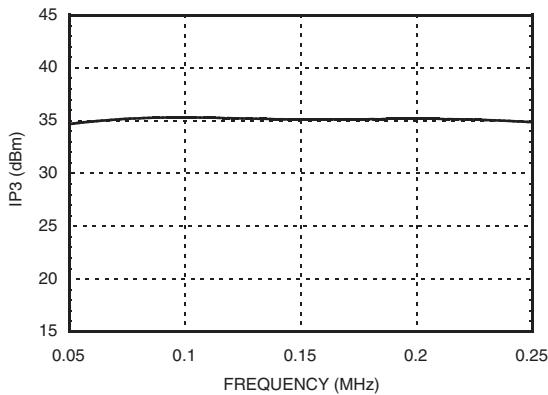
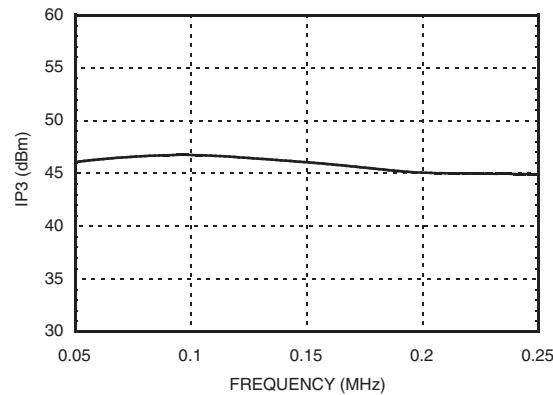
[1] Two-Tone Output Power @ 5 dBm

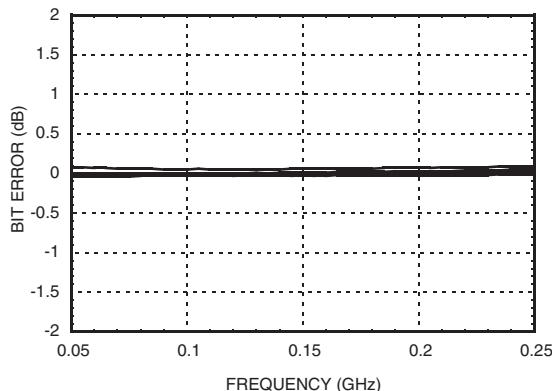
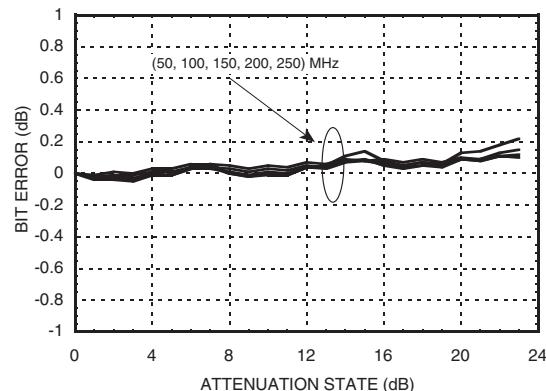
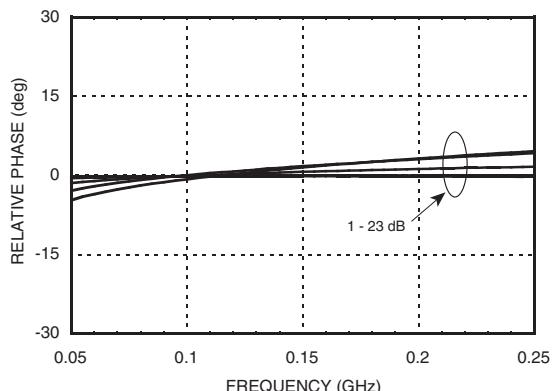
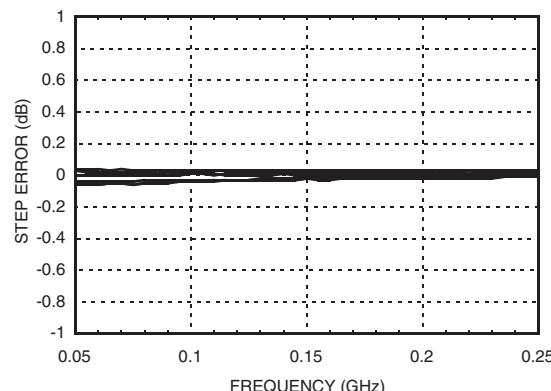
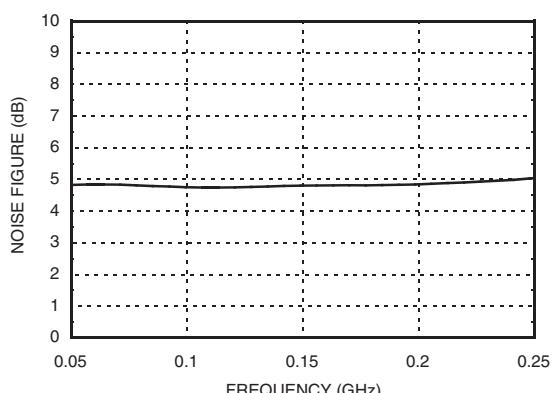
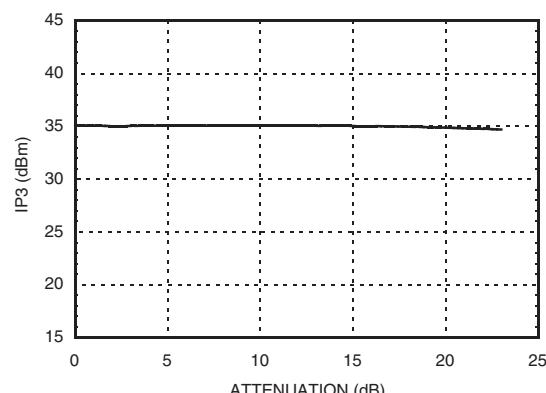
[2] Two-Tone Output Power @ 2 dBm

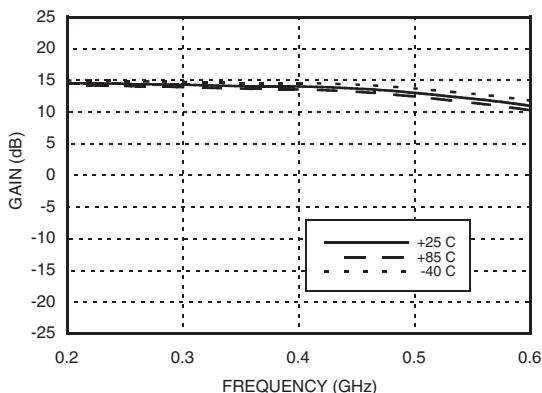
[3] Two-Tone Output Power @ 0 dBm

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices. Trademarks and registered trademarks are the property of their respective owners.

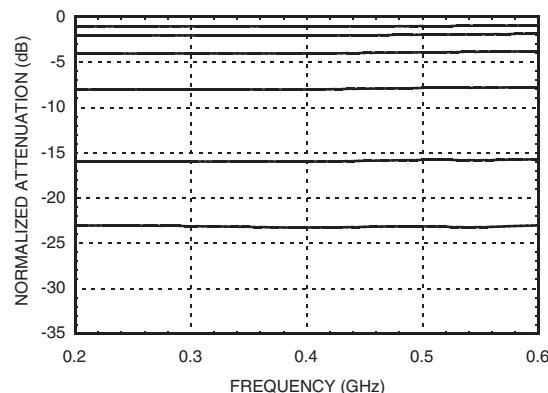
For price, delivery, and to place orders: Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106
Phone: 781-329-4700 • Order online at www.analog.com
Application Support: Phone: 1-800-ANALOG-D


**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
50 to 250 MHz Tuning
Maximum Gain vs. Frequency

Normalized Attenuation
(Only Major States are Shown)

Input Return Loss
(Only Major States are Shown)

Output Return Loss
(Only Major States are Shown)

Output IP3 vs. Frequency

Output IP2 vs. Frequency


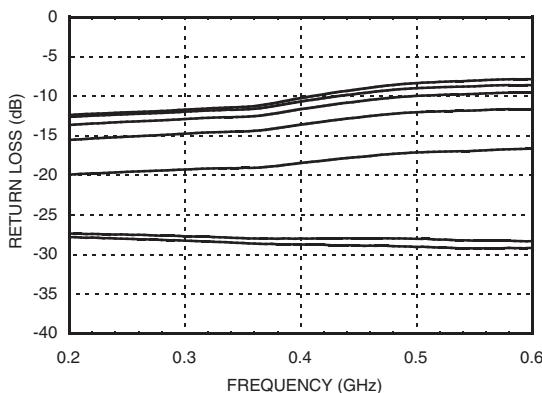

**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
50 to 250 MHz Tuning
Bit Error vs. Frequency
(Only Major States are Shown)

Bit Error vs. Attenuation State

Normal Relative Phase vs. Frequency
(Only Major States are Shown)

Step Error vs. Frequency
(Only Major States are Shown)

Noise Figure vs. Frequency

Output IP3 vs. Attenuation @ 150 MHz



**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
250 to 500 MHz Tuning
Maximum Gain vs. Frequency

Normalized Attenuation

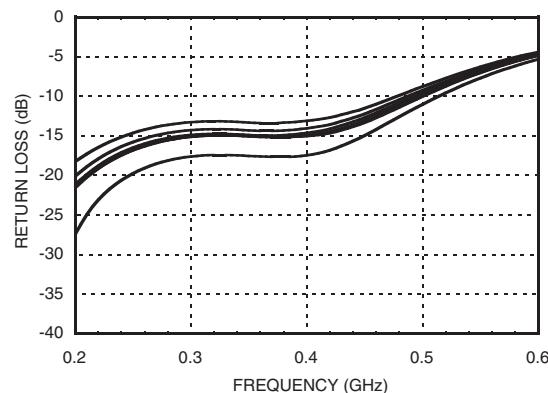
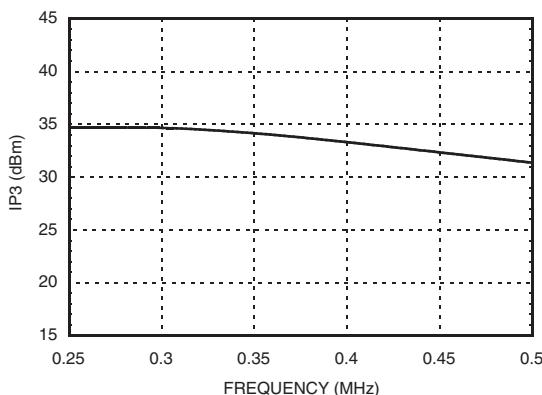
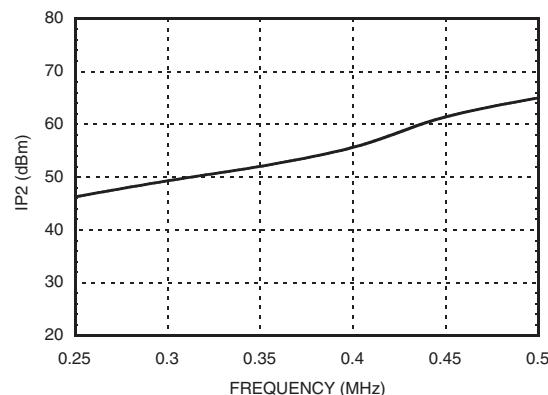
(Only Major States are Shown)

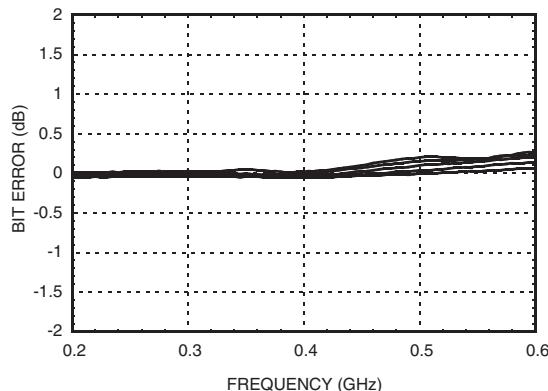
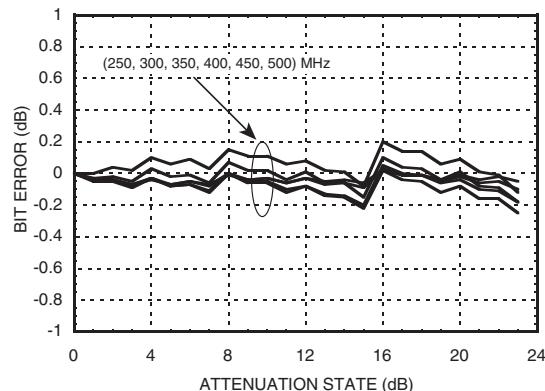
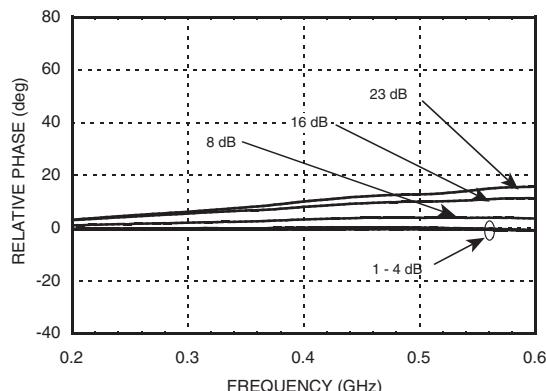
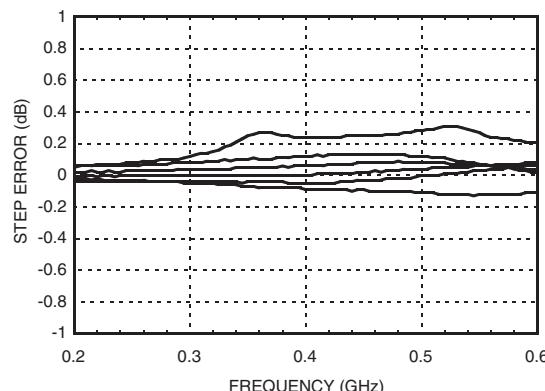
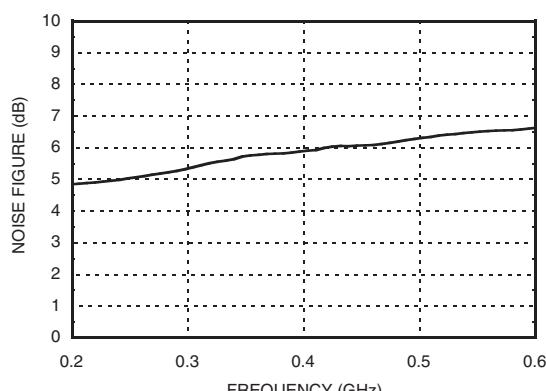
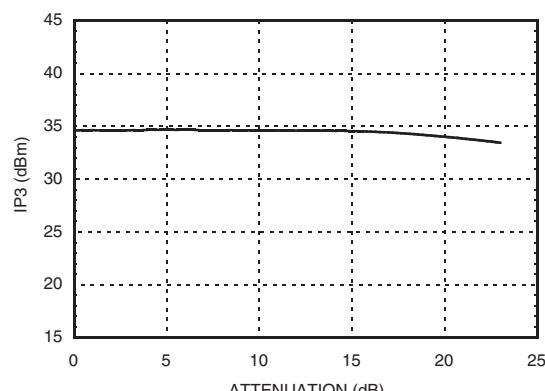

Input Return Loss

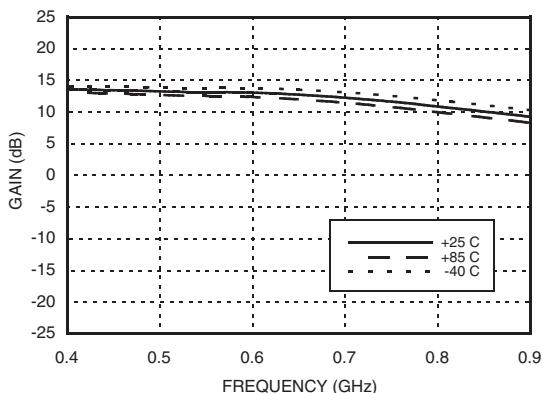
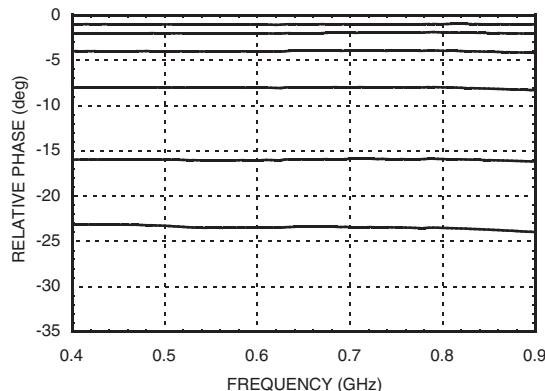
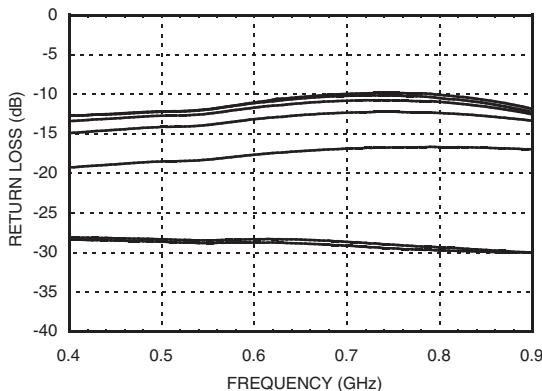
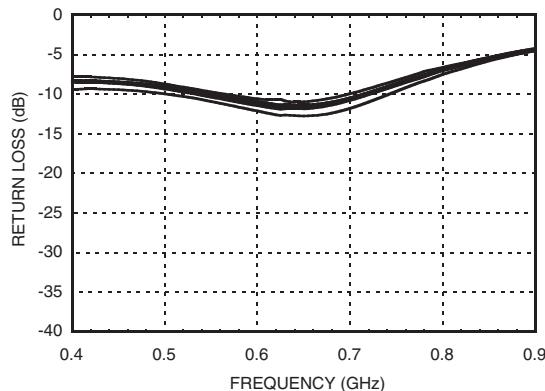
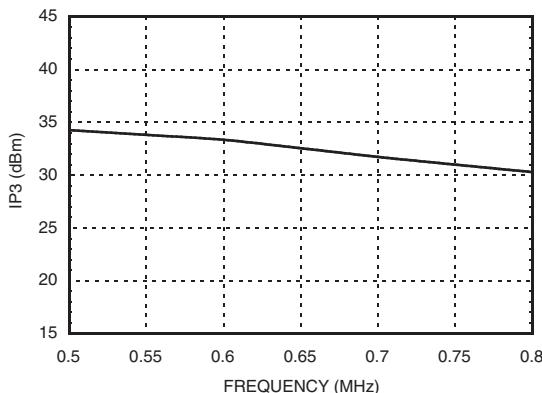
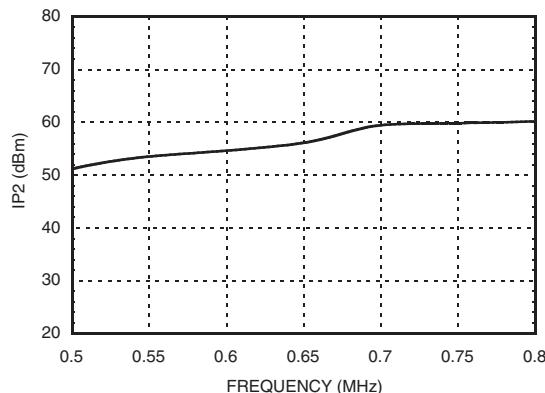
(Only Major States are Shown)

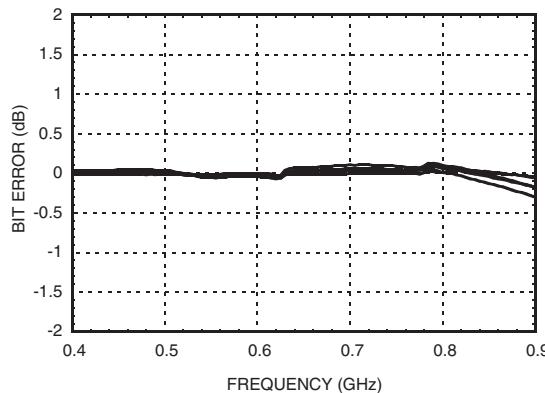
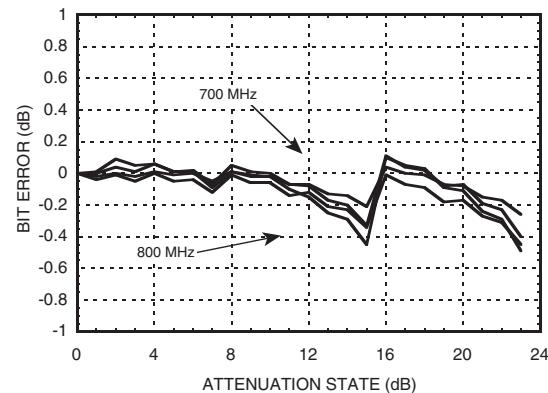
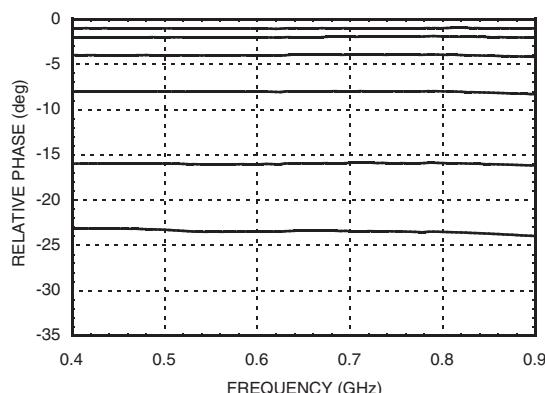
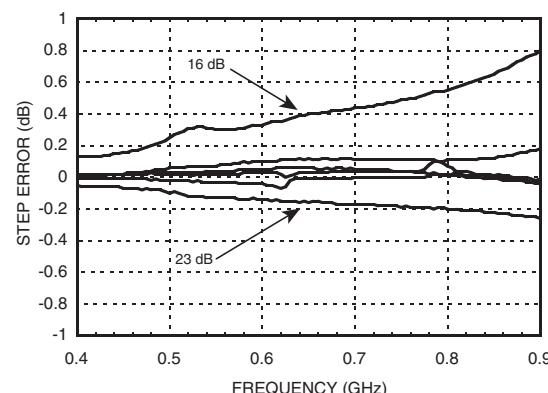
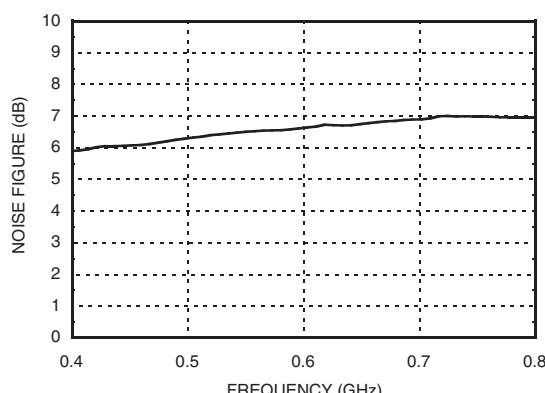
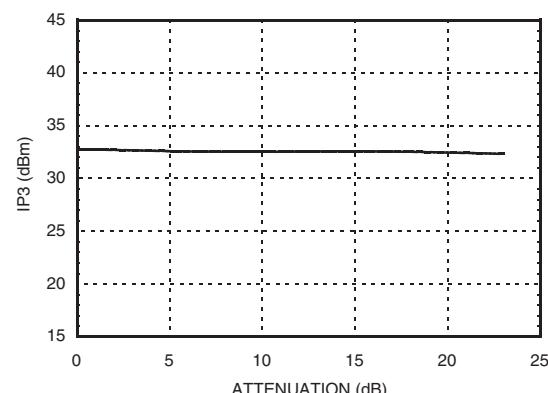

Output Return Loss

(Only Major States are Shown)


Output IP3 vs. Frequency

Output IP2 vs. Frequency



**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
250 to 500 MHz Tuning
Bit Error vs. Frequency
(Only Major States are Shown)

Bit Error vs. Attenuation State

Normal Relative Phase vs. Frequency
(Only Major States are Shown)

Step Error vs. Frequency
(Only Major States are Shown)

Noise Figure vs. Frequency

Output IP3 vs. Attenuation @ 350 MHz



500 to 800 MHz Tuning
Maximum Gain vs. Frequency

Normalized Attenuation
(Only Major States are Shown)

Input Return Loss
(Only Major States are Shown)

Output Return Loss
(Only Major States are Shown)

Output IP3 vs. Frequency

Output IP2 vs. Frequency



**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
500 to 800 MHz Tuning
Bit Error vs. Frequency
(Only Major States are Shown)

Bit Error vs. Attenuation State

Normal Relative Phase vs. Frequency
(Only Major States are Shown)

Step Error vs. Frequency
(Only Major States are Shown)

Noise Figure vs. Frequency

Output IP3 vs. Attenuation @ 650 MHz


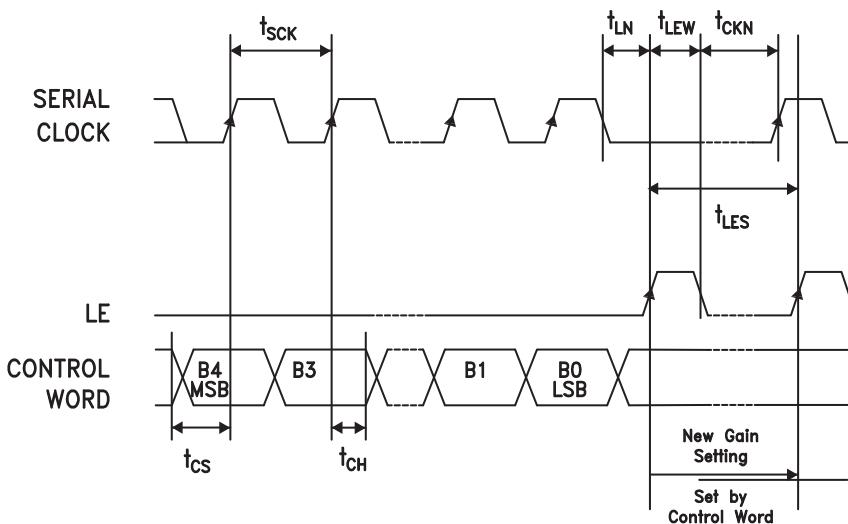

**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**

Serial Control Interface

The HMC628LP4(E) contains a 3-wire SPI compatible digital interface (DATA, CLK, LE). It is activated when P/S is kept high. The 5-bit serial word must be loaded MSB first. The positive-edge sensitive CLK and LE requires clean transitions. Standard logic families work well. If mechanical switches were used, sufficient debouncing should be provided. When LE is high, 5-bit data in the serial input register is transferred to the attenuator. When LE is high CLK is masked to prevent data transition during output loading.

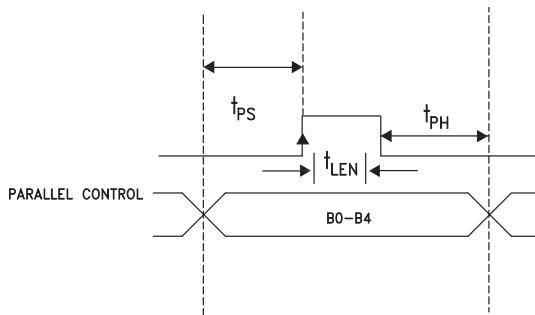
When P/S is low, 3-wire SPI interface inputs (DATA, CLK, LE) are disabled and serial input register is loaded asynchronously with parallel digital inputs (B0-B4). When LE is high, 5-bit parallel data is transferred to the attenuator.

For all modes of operations, attenuation state will stay constant while LE is kept low.



| Parameter | Typ. |
|---|--------|
| Min. serial period, t_{SCK} | 100 ns |
| Control set-up time, t_{CS} | 20 ns |
| Control hold-time, t_{CH} | 20 ns |
| LE Set up-time, t_{LN} | 10 ns |
| Min. LE pulse width, t_{LEW} | 10 ns |
| Min LE pulse spacing, t_{LES} | 530 ns |
| Serial clock hold-time from LE, t_{CKN} | 10 ns |
| Hold Time, t_{PH} | 0 ns |
| Latch Enable Minimum Width, t_{LEN} | 10 ns |
| Setup Time, t_{PS} | 2 ns |

Timing Diagram (Latched Parallel Mode)



Parallel Mode

(Direct Parallel Mode & Latched Parallel Mode)

Note: The parallel mode is enabled when P/S is set to low.

Direct Parallel Mode - The attenuation state is changed by the Control Voltage Inputs directly. The LE (Latch Enable) must be at a logic high to control the attenuator in this manner.

Latched Parallel Mode - The attenuation state is selected using the Control Voltage Inputs and set while the LE is in the Low state. The attenuator will not change state while LE is Low. Once all Control Voltage Inputs are at the desired states the LE is pulsed. See timing diagram above for reference.


**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**

Power-Up States

If LE is set to logic LOW at power-up, the logic state of PUP1 and PUP2 determines the power-up state of the part per PUP truth table. If the LE is set to logic HIGH at power-up, the logic state of B4-B0 determines the power-up state of the part per truth table. The DVGA latches in the desired power-up state approximately 200 ms after power-up.

Power-On Sequence

The ideal power-up sequence is: GND, Vdd, digital inputs, RF inputs. The relative order of the digital inputs are not important as long as they are powered after Vdd / GND

Absolute Maximum Ratings

| | |
|--|--------------------|
| RF Input Power | 20 dBm |
| RF Output Power | 22 dBm |
| Digital Inputs (B0-B4, Shift Clock, Latch Enable & Data Input) | -0.5V to Vdd +0.5V |
| Bias Voltage (Vdd) | 5.6 V |
| Junction Temperature | 125 °C |
| Continuous Pdiss (T = 85 °C) (derate 13.5 mW/°C above 85 °C) ^[1] | 0.54 W |
| Thermal Resistance (Junction to ground paddle) | 74.3 °C/W |
| Storage Temperature | -65 to +150 °C |
| Operating Temperature | -40 to +85 °C |

Bias Voltage

| Vdd (V) | Idd (Typ.) (mA) |
|---------|-----------------|
| 5V | 65 |

Control Voltage Table

| State | Vdd = +3V | Vdd = +5V |
|-------|-------------------|-------------------|
| Low | 0 to 0.5V @ <1 μA | 0 to 0.8V @ <1 μA |
| High | 2 to 3V @ <1 μA | 2 to 5V @ <1 μA |

PUP Truth Table

| LE | PUP1 | PUP2 | Gain Relative to Maximum Gain |
|----|------|------|-------------------------------|
| 0 | 0 | 0 | Insertion Loss |
| 0 | 1 | 0 | -8 |
| 0 | 0 | 1 | -16 |
| 0 | 1 | 1 | -23 |
| 1 | X | X | 0 to -23 dB |

Note: Power-Up with LE= 1 provides direct parallel operation with B4-B0.

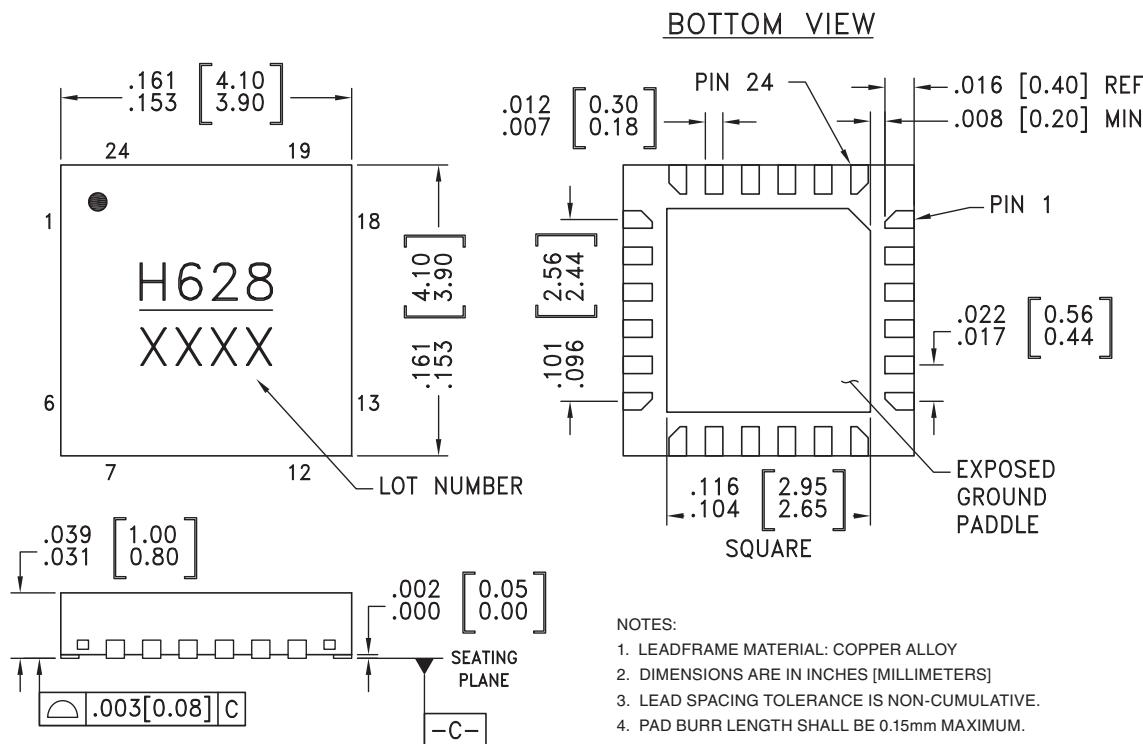
Truth Table

| ATTENUATION (dB) | B4 ^[1] | B3 ^[1] | B2 | B1 | B0 |
|------------------|-------------------|-------------------|----|----|----|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 |
| 2 | 0 | 0 | 0 | 1 | 0 |
| 3 | 0 | 0 | 0 | 1 | 1 |
| 4 | 0 | 0 | 1 | 0 | 0 |
| 5 | 0 | 0 | 1 | 0 | 1 |
| 6 | 0 | 0 | 1 | 1 | 0 |
| 7 | 0 | 0 | 1 | 1 | 1 |
| 8 | 0 | 1 | 0 | 0 | 0 |
| 9 | 0 | 1 | 0 | 0 | 1 |
| 10 | 0 | 1 | 0 | 1 | 0 |
| 11 | 0 | 1 | 0 | 1 | 1 |
| 12 | 0 | 1 | 1 | 0 | 0 |
| 13 | 0 | 1 | 1 | 0 | 1 |
| 14 | 0 | 1 | 1 | 1 | 0 |
| 15 | 0 | 1 | 1 | 1 | 1 |
| 16 | 1 | X | 0 | 0 | 0 |
| 17 | 1 | X | 0 | 0 | 1 |
| 18 | 1 | X | 0 | 1 | 0 |
| 19 | 1 | X | 0 | 1 | 1 |
| 20 | 1 | X | 1 | 0 | 0 |
| 21 | 1 | X | 1 | 0 | 1 |
| 22 | 1 | X | 1 | 1 | 0 |
| 23 | 1 | X | 1 | 1 | 1 |

[1] Enabling B4 disables B3, the minimum attenuation is 16 dB



ELECTROSTATIC SENSITIVE DEVICE
OBSERVE HANDLING PRECAUTIONS


**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
Outline Drawing

Package Information

| Part Number | Package Body Material | Lead Finish | MSL Rating | Package Marking ^[3] |
|-------------|--|---------------|---------------------|--------------------------------|
| HMC628LP4 | Low Stress Injection Molded Plastic | Sn/Pb Solder | MSL1 ^[1] | H628 XXXX |
| HMC628LP4E | RoHS-compliant Low Stress Injection Molded Plastic | 100% matte Sn | MSL1 ^[2] | H628 XXXX |

[1] Max peak reflow temperature of 235 °C

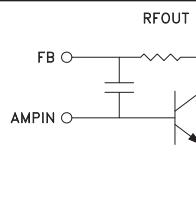
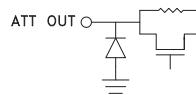
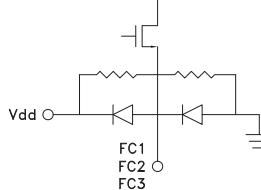
[2] Max peak reflow temperature of 260 °C

[3] 4-Digit lot number XXXX


**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**
Pin Descriptions

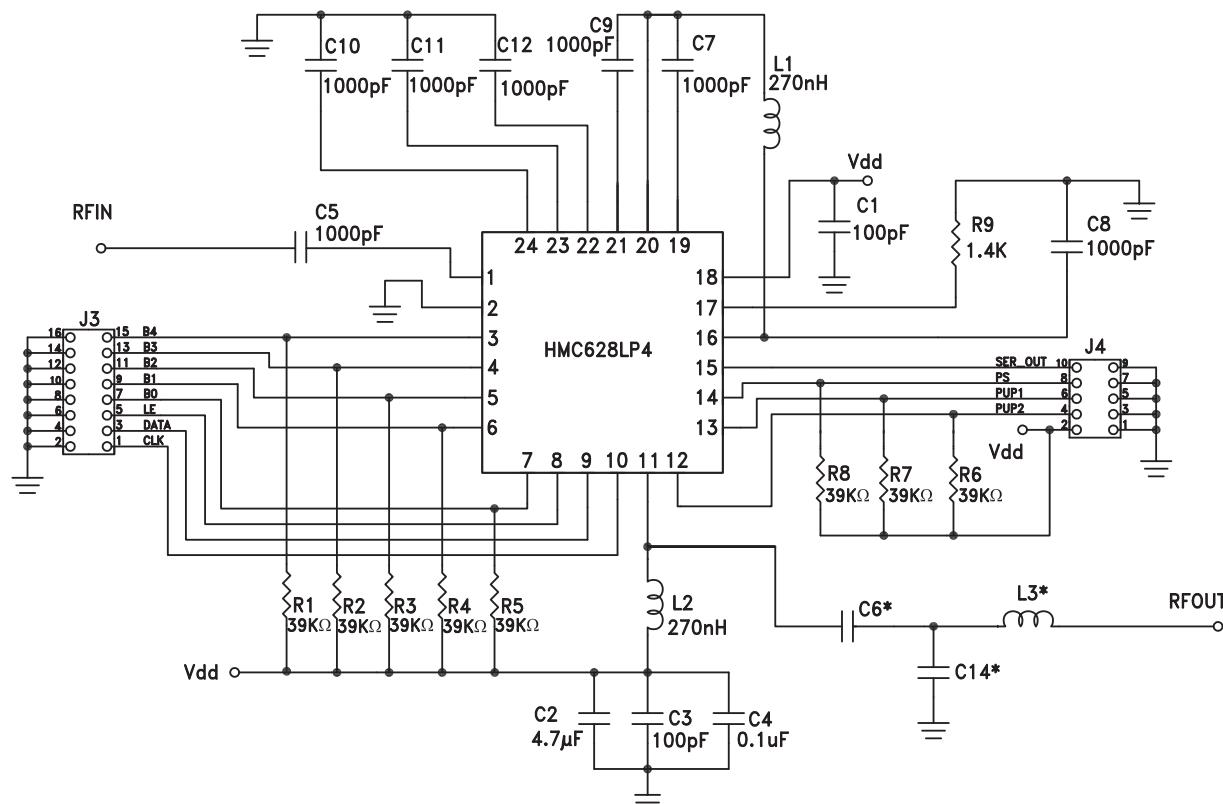
| Pin Number | Function | Description | Interface Schematic |
|------------|-----------------------|--|---------------------|
| 1 | RFIN | This pin is DC coupled and matched to 50 Ohms. A blocking capacitor is needed. | |
| 2 | GND | These pins and package bottom must be connected to RF/DC ground. | |
| 3 - 7 | B4, B3, B2, B1, B0 | | |
| 8 | LE | | |
| 9 | DATA | | |
| 10 | CLK | | |
| 12 | PUP2 | | |
| 13 | PUP1 | | |
| 14 | P/S | | |
| 15 | SERIAL OUT | Serial input data delayed by 5 clock cycles. | |
| 16 | IBIAS | Bias current to amplifier. External inductor is needed. | |
| 17 | ISET | External bias resistor to adjust the current of the amplifier. | |
| 18 | Vdd | Supply Voltage. | |
| 19 | FB | Feedback capacitance for the amplifier. | |


**BiCMOS MMIC 5-Bit DIGITAL
VARIABLE GAIN AMPLIFIER, 50 - 800 MHz**

| Pin Number | Function | Description | Interface Schematic |
|------------|---------------|--|--|
| 11, 20 | RFOUT, AMP IN | Amplifier input. External blocking capacitor required. |  |
| 21 | ATT OUT | Attenuator output. |  |
| 22 - 24 | FC1, FC2, FC3 | External capacitors to ground are required. Place these capacitors close to the package. |  |



Application Circuit



* Refer to Table X for values

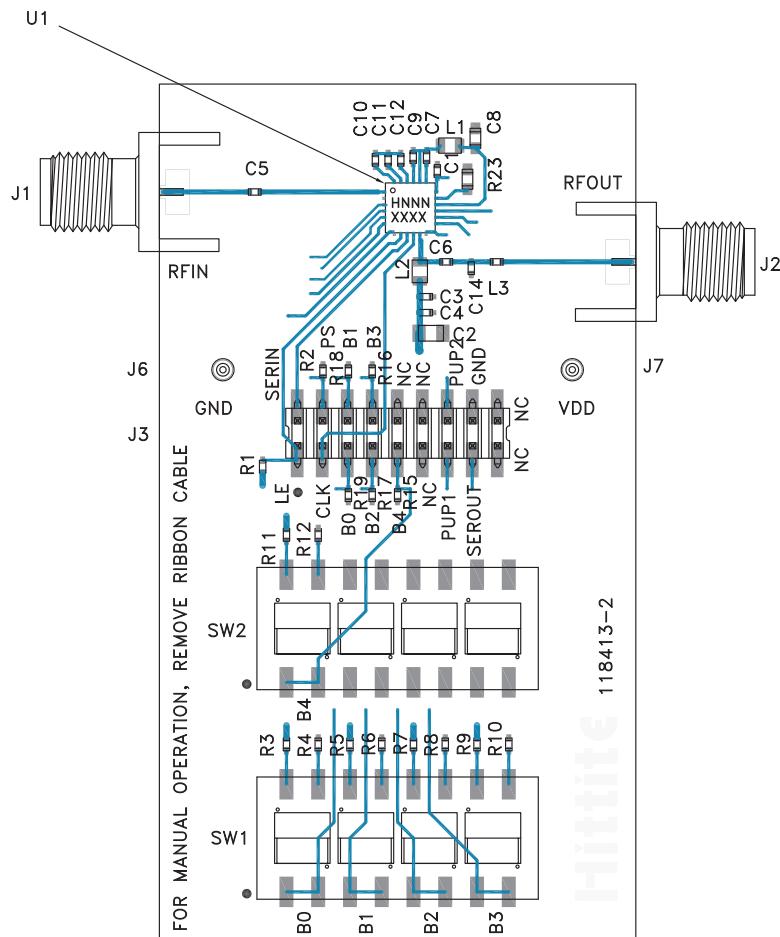
Components For Selected Frequencies

| Tuned Frequency | 50 - 250 MHz | 250 - 500 MHz | 500 - 800 MHz |
|----------------------|--------------|---------------|---------------|
| Evaluation Board P/N | 118415 | 120101 | 120102 |
| C6 | 1 nF | 33 pF | 33 pF |
| L3 | 0 Ohms | 15 nH | 12 nH |
| C14 | N/A | 4.7 pF | 1.5 pF |



BiCMOS MMIC 5-Bit DIGITAL VARIABLE GAIN AMPLIFIER, 50 - 800 MHz

Evaluation PCB



12

List of Materials for Evaluation PCB See Table^[1]

| Item | Description |
|-------------------|-----------------------------------|
| J1, J2 | PCB Mount SMA Connector |
| J3 | 18 Pin DC Connector |
| J6, J7 | DC Pin |
| C1, C3 | 100 pF Capacitor, 0402 Pkg. |
| C2 | 4.7 μ F Capacitor, 0805 Pkg. |
| C4 | 0.1 μ F Capacitor, 0402 Pkg. |
| C6, C14 | 0402 Pkg. ^[1] |
| C5 - C7, C9 - C12 | 1000 pF Capacitor, 0402 Pkg. |
| C8 | 10 k μ F Capacitor, 0805 Pkg. |
| R1 - R12 | 100 kOhm Resistor, 0402 Pkg. |
| R15 - R19 | 39 kOhm Resistor, 0402 Pkg. |
| R23 | 1.4 kOhm Resistor, 0603 Pkg. |
| L1, L2 | 270 nH Inductor, 0603 Pkg. |
| L3 | 0402 Pkg. ^[1] |

| Item | Description |
|----------|--------------------------------------|
| SW1, SW2 | SPDT 4 Position Dip Switch |
| U1 | HMC628LP4(E) Variable Gain Amplifier |
| PCB [2] | 118413 Evaluation PCB |

[1] When requesting an evaluation board, please reference the appropriate PCB number listed in the table “Components for Selected Frequencies.”

[2] Circuit Board Material: Arlon 25FR / FR4

The circuit board used in the application should use RF circuit design techniques. Signal lines should have 50 Ohm impedance while the package ground leads and exposed paddle should be connected directly to the ground plane similar to that shown. A sufficient number of via holes should be used to connect the top and bottom ground planes. The evaluation circuit board shown is available from Hittite upon request.

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices. Trademarks and registered trademarks are the property of their respective owners.

*For price, delivery, and to place orders: Analog Devices, Inc.,
One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106
Phone: 781-329-4700 • Order online at www.analog.com
Application Support: Phone: 1-800-ANALOG-D*