



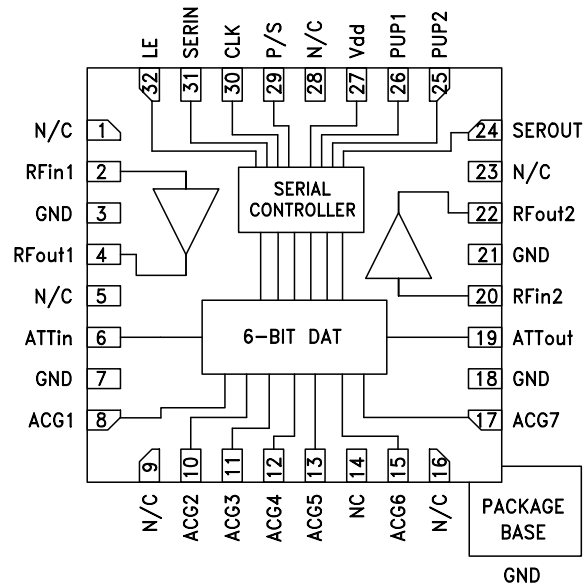
0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz

Typical Applications

The HMC681ALP5E is ideal for:

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

Functional Diagram



Features

- +13.5 dB to +45 dB Gain Control in 0.5 dB Steps
- High Output IP3: +36 dBm
- ±0.25 dB Typical Gain Step Error
- Single +5V Supply
- 32 Lead 5x5 mm SMT Package: 25 mm²

General Description

The HMC681ALP5E is a digitally controlled variable gain amplifier which operates from DC to 1 GHz, and can be programmed to provide anywhere from 13.5 dB, to 45 dB of gain, in 0.5 dB steps. The HMC681ALP5E delivers noise figure of 2.8 dB in its maximum gain state, with output IP3 of up to +36 dBm in any state. This serially controlled digital VGA incorporates off chip AC ground capacitors for near DC operation, making it suitable for a wide variety of RF and IF applications. The HMC681ALP5E is housed in a RoHS compliant 5x5 mm QFN leadless package, and provides the user with a highly integrated solution. This functionality is also available with parallel control as the HMC626ALP5E.

Electrical Specifications, $T_A = +25^\circ C$, $V_{dd} = V_s = P/S = +5V$

| Parameter | Min. | Typ. | Max. | Min. | Typ. | Max. | Units |
|---|---|-----------|------|---|-----------|------|----------|
| | 50 - 350 | | | 350 - 1000 | | | |
| Gain (Maximum Gain State) | 40 | 45 | | 30 | 40 | | dB |
| Gain Control Range | | 31.5 | | | 31.5 | | dB |
| Input Return Loss | | 25 | | | 30 | | dB |
| Output Return Loss | | 20 | | | 17 | | dB |
| Gain Setting Accuracy: (Referenced to Maximum Gain State) All Gain States | ± (0.15 + 3% of Relative Gain Setting) Max. | | | ± (0.15 + 3% of Relative Gain Setting) Max. | | | dB |
| Output Power for 1 dB Compression | | 20 | | | 19 | | dBm |
| Output Third Order Intercept Point (Two-Tone Output Power= 5 dBm Each Tone) | | 38 | | | 36 | | dBm |
| Noise Figure | | 2.7 | | | 2.8 | | dB |
| Switching Characteristics tRISE, tFALL (10/90% RF) tON, tOFF (50% CTL to 10/90% RF) | | 60 120 | | | 60 120 | | ns ns |
| Total Supply Current (I _{dd} + 2*I _s) | | 184.5 | 225 | | 184.5 | 225 | mA |

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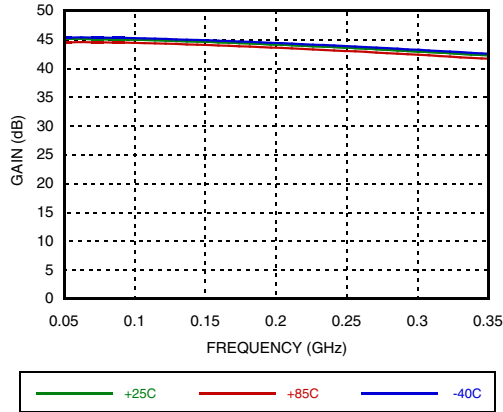
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AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz**

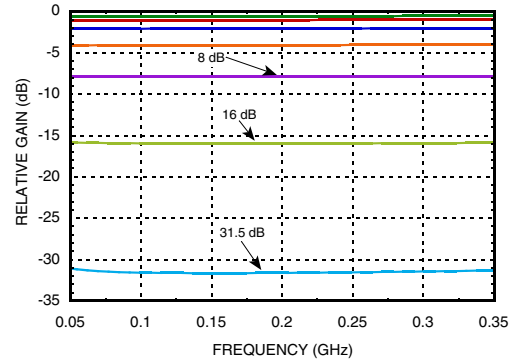
50 to 350 MHz Tuning

Gain vs. Frequency



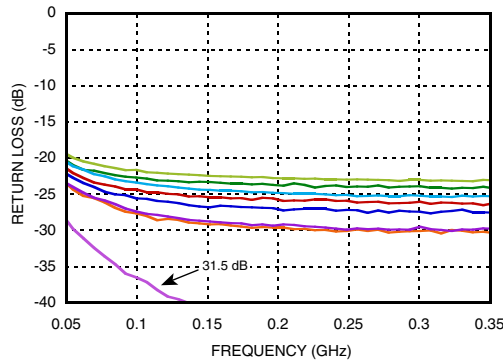
Relative Gain Setting

(Referenced to Maximum Gain State)
(Only Major States are Shown)



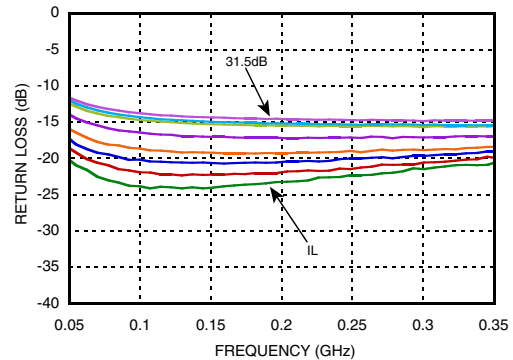
Input Return Loss

(Only Major States are Shown)



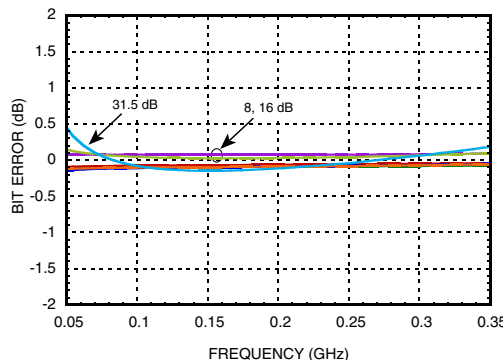
Output Return Loss

(Only Major States are Shown)

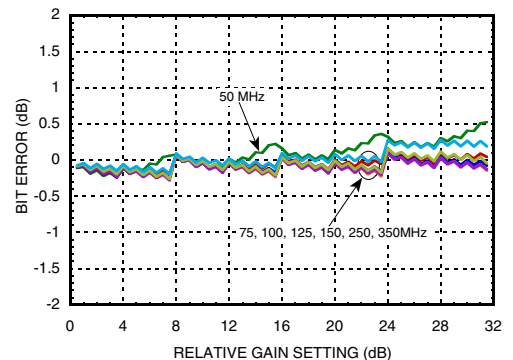


Bit Error vs. Frequency

(Only Major States are Shown)



Bit Error vs. Relative Gain Setting



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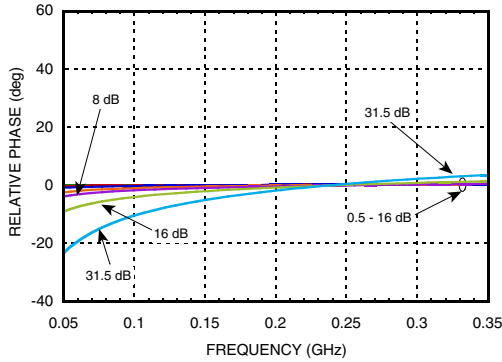
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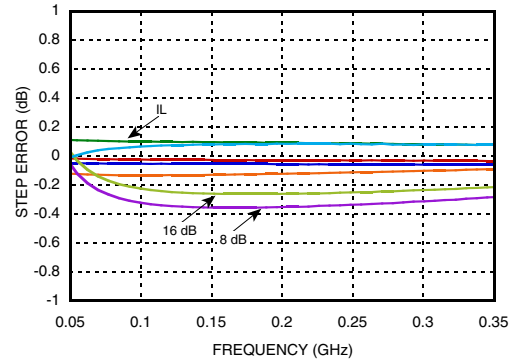
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50 to 350 MHz Tuning

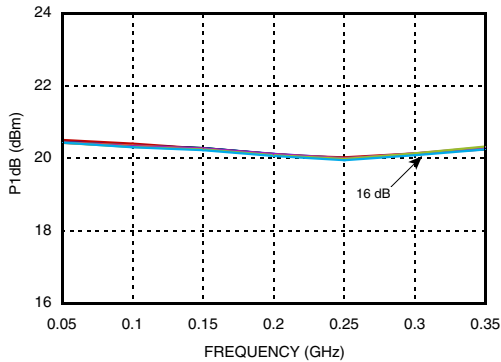
Relative Phase vs. Frequency
(Only Major States are Shown)



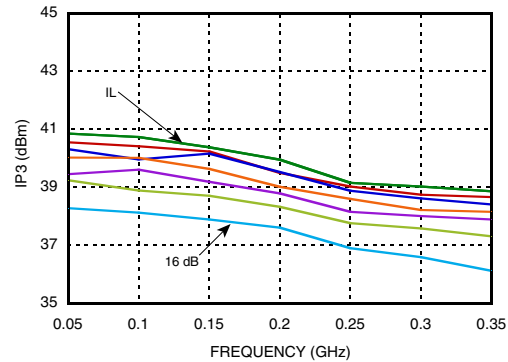
Step Error vs. Frequency
(Only Major States are Shown)



Output P1dB
(Major States shown are IL through 16 dB)



Output IP3 @ 5 dBm Output Power per Tone
(Major States shown are IL through 16 dB)



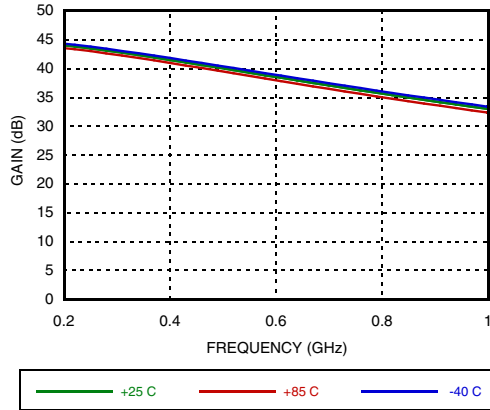
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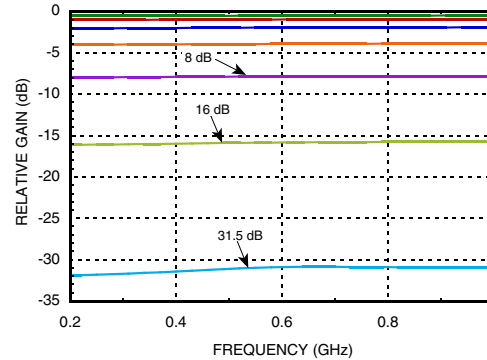
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AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz**
350 to 1000 MHz Tuning

Gain vs. Frequency



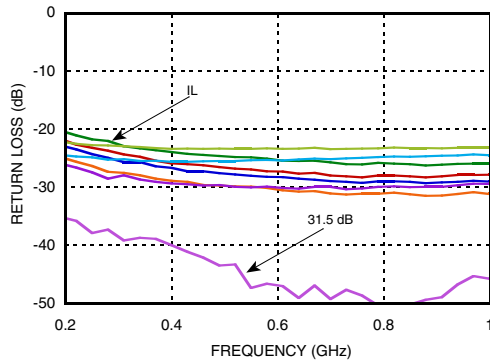
Relative Gain Setting

(Referenced to Maximum Gain State)
(Only Major States are Shown)



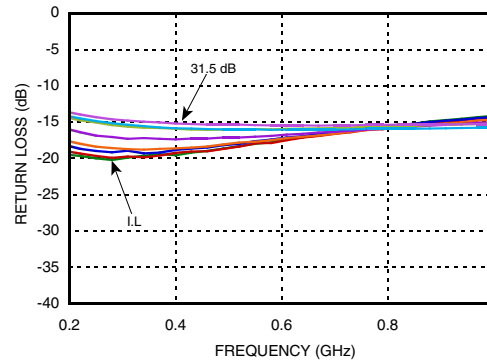
Input Return Loss

(Only Major States are Shown)



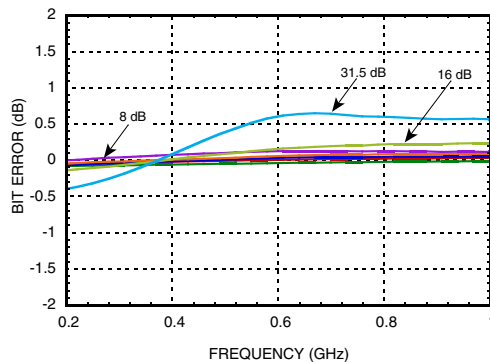
Output Return Loss

(Only Major States are Shown)

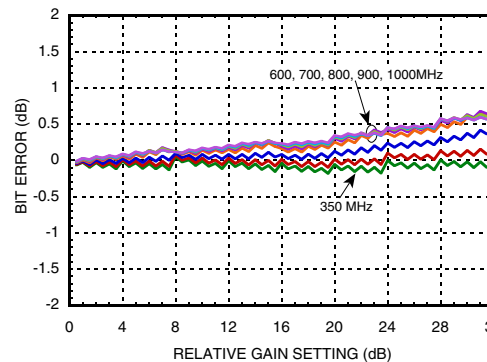


Bit Error vs. Frequency

(Only Major States are Shown)



Bit Error vs. Relative Gain Setting



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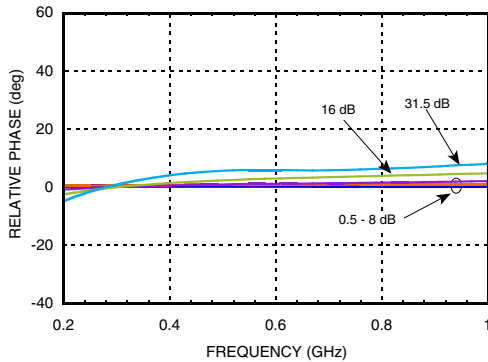
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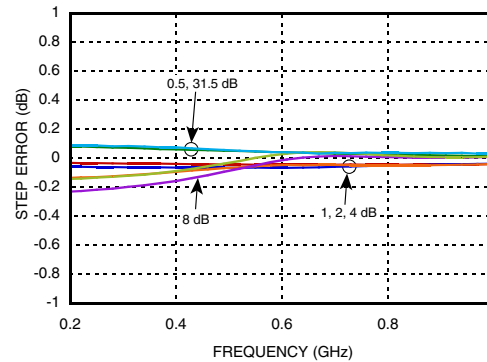
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350 to 1000 MHz Tuning

VARIABLE GAIN AMPLIFIERS - DIGITAL - SMT

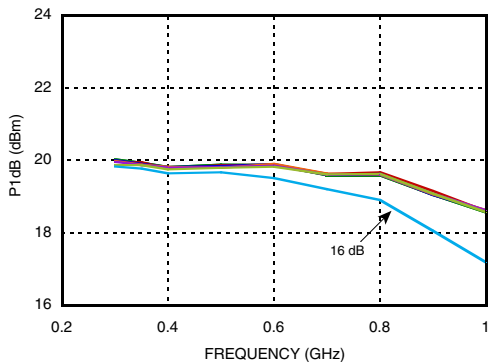
Relative Phase vs. Frequency
(Only Major States are Shown)



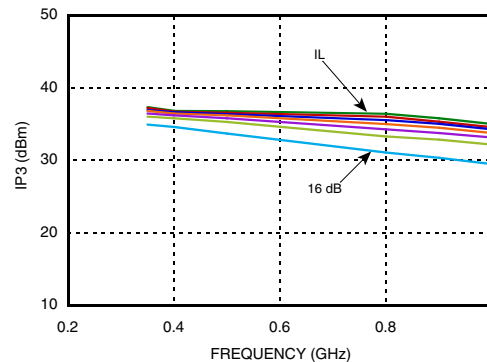
Step Error vs. Frequency
(Only Major States are Shown)



Output P1dB
(Major States shown are IL through 16 dB)



Output IP3 @ 5 dBm Output Power per Tone
(Major States shown are IL through 16 dB)



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. The attenuator 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

PUP Truth Table

| LE | PUP1 | PUP2 | Relative Gain Setting |
|----|------|------|-----------------------|
| 0 | 0 | 0 | -31.5 |
| 0 | 1 | 0 | -24 |
| 0 | 0 | 1 | -16 |
| 0 | 1 | 1 | Insertion Loss |

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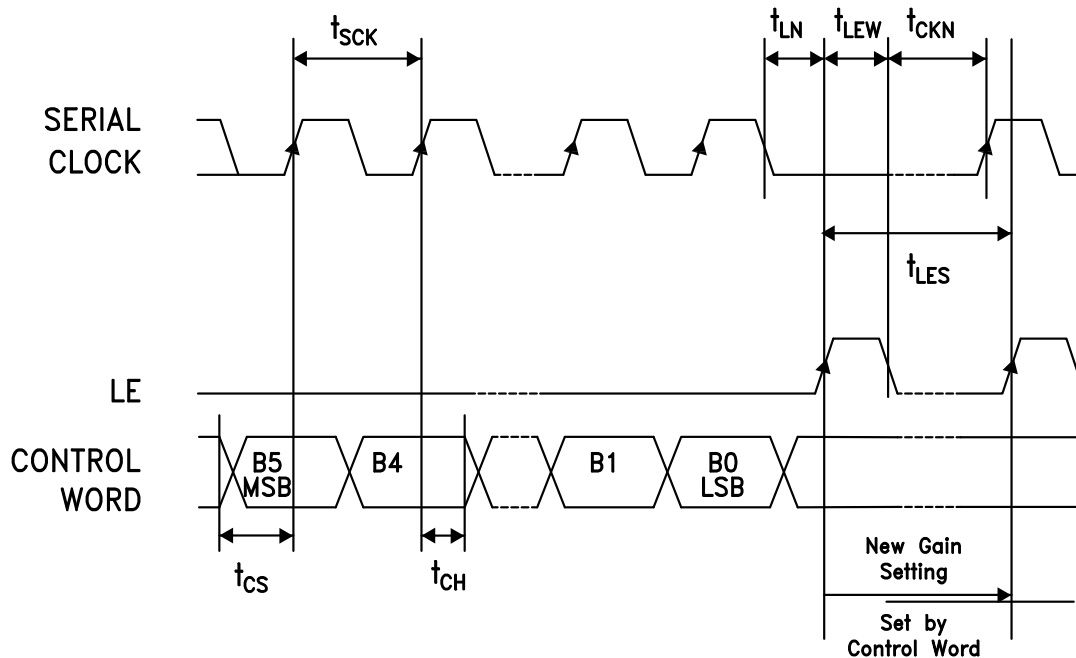
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Serial Control Interface

The HMC681ALP5E contains a 3-wire SPI compatible digital interface (SERIN, CLK, LE). It is activated when P/S is kept high. The 6-bit serial word must be loaded MSB first. The positive-edge sensitive CLK and LE requires clean transitions. If mechanical switches were used, sufficient debouncing should be provided. When LE is high, 6-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.

For all modes of operations, gain will remain constant while LE is kept low.



Truth Table

| 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 setup-time, t_{LN} | 10 ns |
| Min. LE pulse width, t_{LEW} | 10 ns |
| Min LE pulse spacing, t_{LES} | 630 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 |

| Serial Word | | | | | | Relative Gain Setting |
|-------------|-----------|------------|------------|------------|--------------|-----------------------|
| B5 16 dB | B4 8dB | B3 4 dB | B2 2 dB | B1 1 dB | B0 0.5 dB | |
| High | High | High | High | High | High | Reference 0 dB |
| High | High | High | High | High | Low | -0.5 dB |
| High | High | High | High | Low | High | -1 dB |
| High | High | High | Low | High | High | -2 dB |
| High | High | Low | High | High | High | -4 dB |
| High | Low | High | High | High | High | -8 dB |
| Low | High | High | High | High | High | -16 dB |
| Low | Low | Low | Low | Low | Low | -31.5 dB |

Any combination of the above states will provide a relative gain setting approximately equal to the sum of the bits selected.


**0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN
AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz**
Absolute Maximum Ratings

| | |
|---|------------------------|
| RF Input Power ^[1] (At Max Gain Setting) | -10.5 dBm (T = +85 °C) |
| Digital Inputs (Reset, Shift Clock, Latch Enable & Serial Input) | -0.5 to Vdd +0.5V |
| Bias Voltage (Vdd) | 5.5V |
| Collector Bias Voltage (Vcc) | 5.5V |
| Channel/Junction Temperature | 150 °C |
| Continuous Pdiss (T = 85 °C) (derate 18.2 mW/°C above 85 °C) ^[2] | 1.18 W |
| Thermal Resistance ^[3] | 55 °C/W |
| Storage Temperature | -65 to +150 °C |
| Operating Temperature | -40 to +85 °C |

[1] The Max RF Input Power Rating will increase by 0.5 dB for every 0.5 dB reduction in gain to a maximum RF Input Power of 10 dBm.

[2] This value is the total power dissipation in the amplifier.

[3] This is the thermal resistance for the amplifier.

Bias Voltage

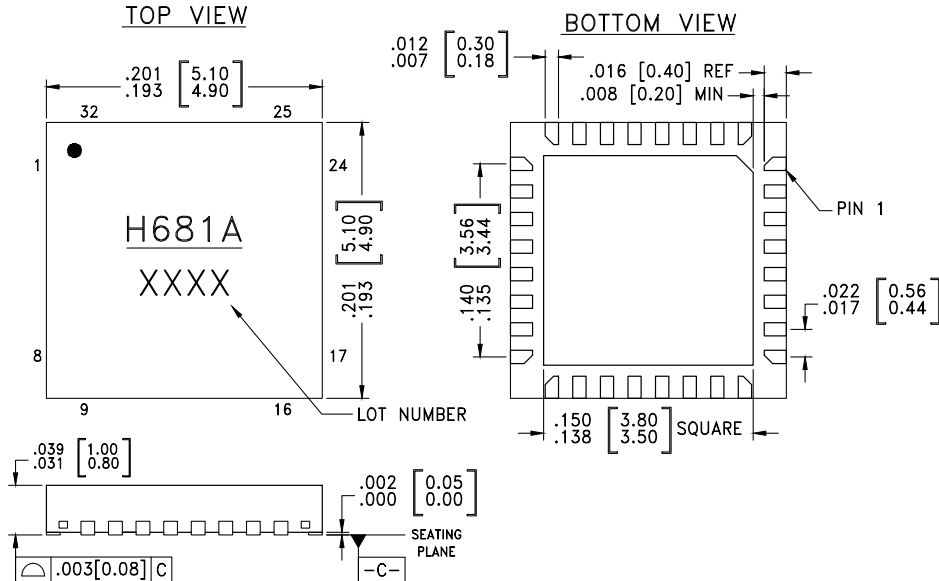
| | | |
|---------|----------------------|----------------------|
| Vdd (V) | Idd (Typ.) (mA) | |
| +5 | 2.5 | |
| Vs (V) | Is ₁ (mA) | Is ₂ (mA) |
| +5 | 91 | 91 |

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 |



**ELECTROSTATIC SENSITIVE DEVICE
OBSERVE HANDLING PRECAUTIONS**


**0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN
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Outline Drawing

NOTES:

- LEADFRAME MATERIAL: COPPER ALLOY
- DIMENSIONS ARE IN INCHES [MILLIMETERS]
- LEAD SPACING TOLERANCE IS NON-CUMULATIVE.
- PAD BURR LENGTH SHALL BE 0.15mm MAXIMUM.
PAD BURR HEIGHT SHALL BE 0.05mm MAXIMUM.
- PACKAGE WARP SHALL NOT EXCEED 0.05mm.
- ALL GROUND LEADS AND GROUND PADDLE MUST BE SOLDERED TO PCB RF GROUND.
- REFER TO HITTITE APPLICATION NOTE FOR SUGGESTED LAND PATTERN.

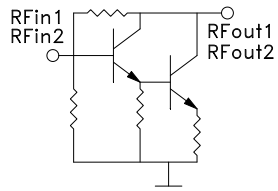
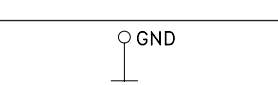
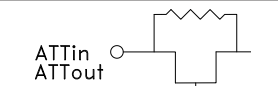
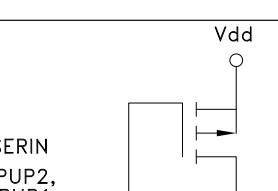
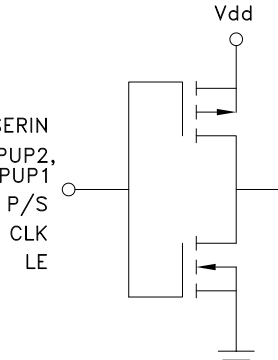
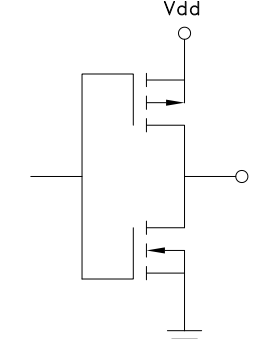
Package Information

| Part Number | Package Body Material | Lead Finish | MSL Rating | Package Marking ^[2] |
|-------------|--|---------------|---------------------|--------------------------------|
| HMC681ALP5E | RoHS-compliant Low Stress Injection Molded Plastic | 100% matte Sn | MSL1 ^[1] | H681A XXXX |

[1] Max peak reflow temperature of 260 °C

[2] 4-Digit lot number XXXX

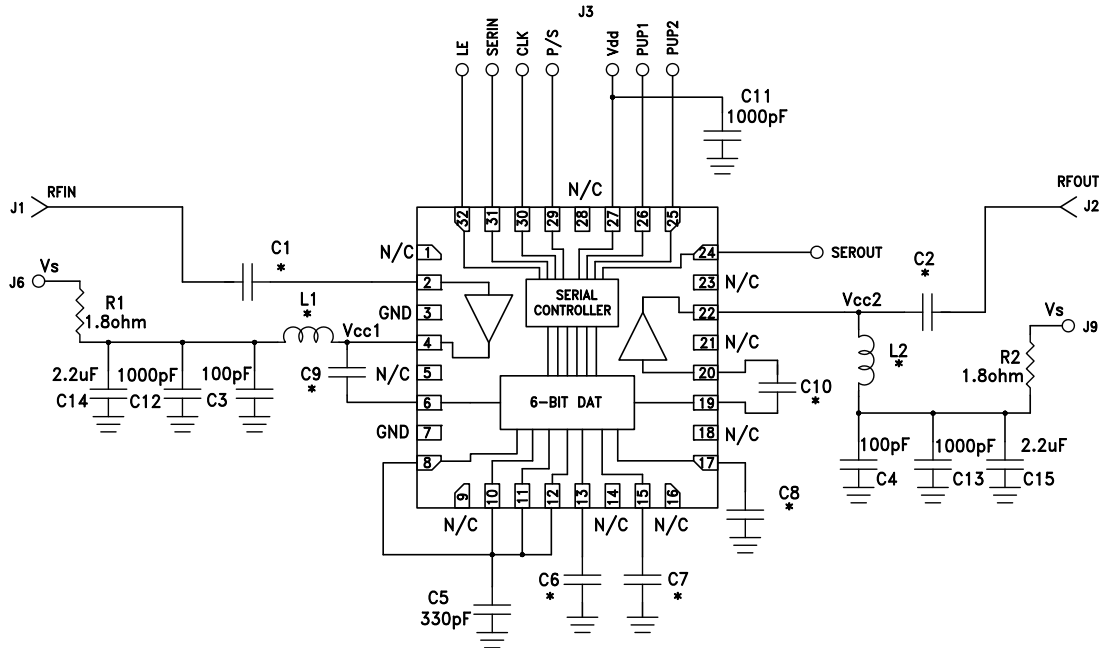

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Pin Descriptions

| Pin Number | Function | Description | Interface Schematic |
|------------------------------------|--|--|---|
| 1, 5, 9, 14, 16, 23, 28 | N/C | The pins are not connected internally; however, all data shown herein was measured with these pins connected to RF/DC ground externally. | |
| 2, 20 | RFin1,RFin2 | This pin is DC coupled. An off chip DC blocking capacitor is required. |  |
| 4, 22 | RFout1, RFout2 | RF output and DC bias (Vcc) for the output stage of the amplifiers. Amplifier bias provided via external bias tee as shown in application circuit. |  |
| 3, 7, 18, 21 | GND | These pins and package bottom must be connected to RF/DC ground. |  |
| 6, 19 | ATTin, ATTout | These pins are DC coupled and matched to 50 Ohms. Blocking capacitors are required. Select value based on lowest frequency of operation. |  |
| 8, 10, 11, 12, 13, 15, 17 | ACG1, ACG2, ACG3, ACG4, ACG5, ACG6, ACG7 | External capacitors to ground is required. Select value for lowest frequency of operation. Place capacitor as close to pins as possible. | |
| 24 | SEROUT | Serial input data delayed by 6 clock cycles. |  |
| 25, 26 | PUP2, PUP1 | Refer to truth tables and serial control interface diagram. | |
| 30 | CLK | | |
| 31 | SERIN | | |
| 32 | LE | | |
| 29 | P/S | | Apply +5V for normal operation. |
| 27 | Vdd | Supply voltage |  |



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Application Circuit



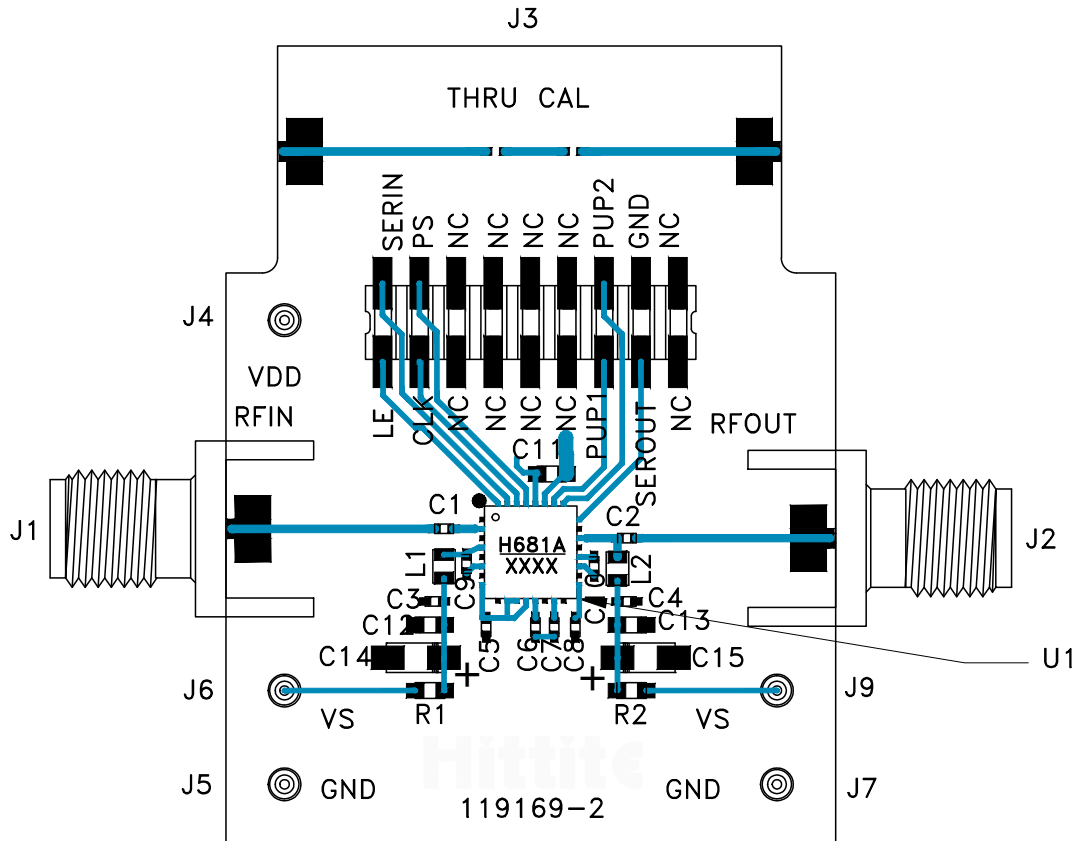
Components for Selected Frequencies

| Tuned Frequency | 50 - 350 MHz | 350 - 1000 MHz |
|-----------------|-------------------|-------------------|
| Evaluation PCB | 119171-HMC681ALP5 | 123115-HMC681ALP5 |
| C1, C2, C9, C10 | 3300 pF | 100 pF |
| C6 - C8 | 330 pF | 100 pF |
| L1, L2 | 560 nH | 270 nH |

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Evaluation PCB



List of Materials for Evaluation PCB [1]

| Item | Description |
|-----------------|-------------------------------------|
| J1 - J2 | PCB Mount SMA Connector |
| J3 | 18 Pin DC Connector |
| J4 - J7, J9 | DC Pin |
| C1, C2, C9, C10 | Capacitor, 0402 Pkg. [1] |
| C3 - C5 | 100 pF Capacitor, 0402 Pkg. |
| C6 - C8 | Capacitor, 0402 Pkg. [1] |
| C11 - C13 | 1000 pF Capacitor, 0402 Pkg. |
| C14, C15 | 2.2 μ F Capacitor, CASE A Pkg. |
| R1, R2 | 1.8 Ohm Resistor, 0603 Pkg. |
| L1, L2 | Inductor, 0603 Pkg. [1] |
| U1 | HMC681ALP5E Variable Gain Amplifier |
| PCB [2] | 119169 Evaluation PCB |

[1] Please reference "Components for Selected Frequencies" table.

[2] Circuit Board Material: Arlon 25FR

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. Refer to "Components for Selected Frequencies" table for part number.

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[HMC7441-SX](#) [HMC-ALH310](#) [XD1001-BD-000V](#) [A4011](#)