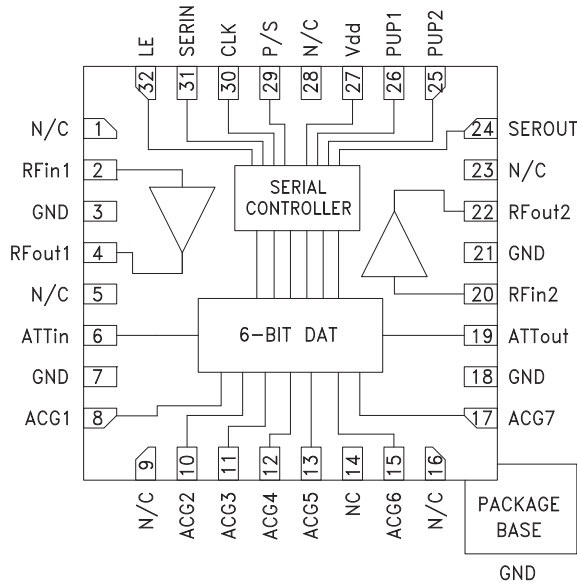


### Typical Applications

The HMC681LP5(E) 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 5x5mm SMT Package: 25mm<sup>2</sup>

### General Description

The HMC681LP5(E) 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 HMC681LP5(E) 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 HMC681LP5(E) 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 HMC626LP5(E).

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

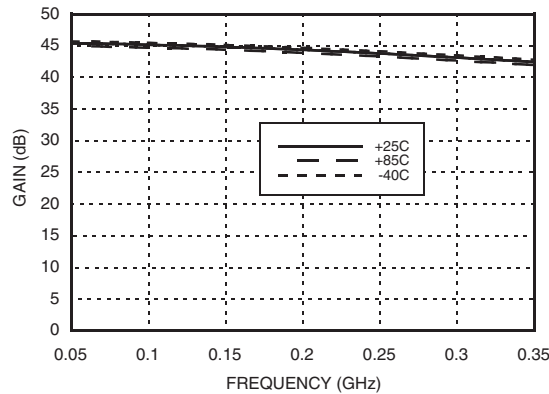
| Parameter                                                                                 | Min.                                        | Typ.      | Max. | Min.                                        | Typ.      | Max. | Units    |
|-------------------------------------------------------------------------------------------|---------------------------------------------|-----------|------|---------------------------------------------|-----------|------|----------|
|                                                                                           | 50 - 350                                    |           |      | 350 - 1000                                  |           |      | MHz      |
| 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:<br>(Referenced to Maximum Gain State)<br>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<br>(Two-Tone Output Power= 5 dBm Each Tone)            |                                             | 38        |      |                                             | 36        |      | dBm      |
| Noise Figure                                                                              |                                             | 2.7       |      |                                             | 2.8       |      | dB       |
| Switching Characteristics<br>tRISE, tFALL (10/90% RF)<br>tON, tOFF (50% CTL to 10/90% RF) |                                             | 60<br>120 |      |                                             | 60<br>120 |      | ns<br>ns |
| Total Supply Current                                                                      |                                             | 176       | 225  |                                             | 176       | 225  | mA       |

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

50 to 350 MHz Tuning

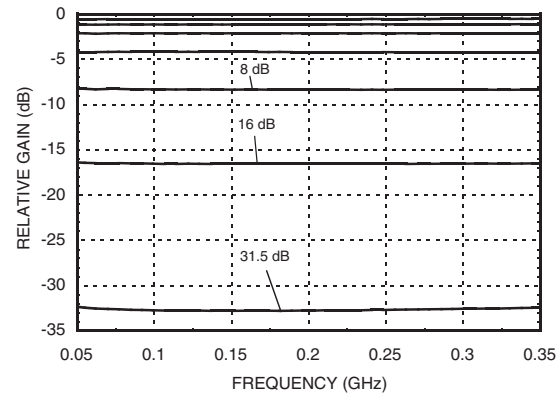
www.datasheet4u.com

### Gain vs. Frequency



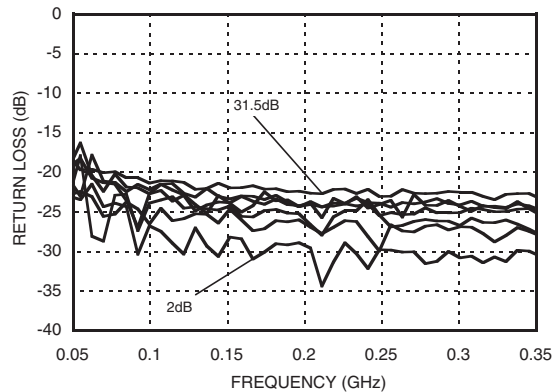
### Relative Gain Setting

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



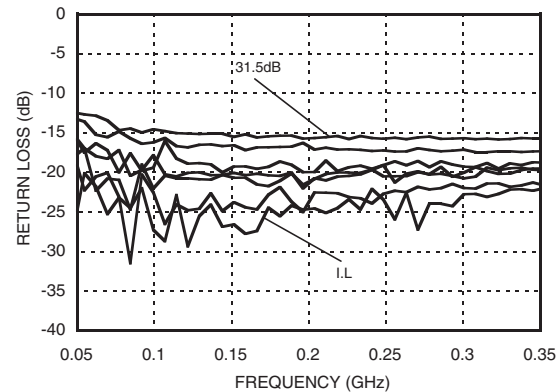
### Input Return Loss

(Only Major States are Shown)



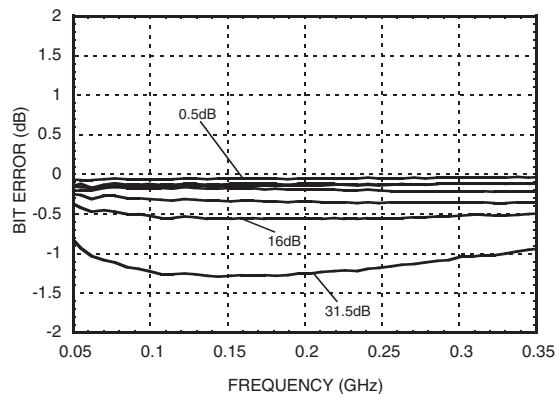
### Output Return Loss

(Only Major States are Shown)

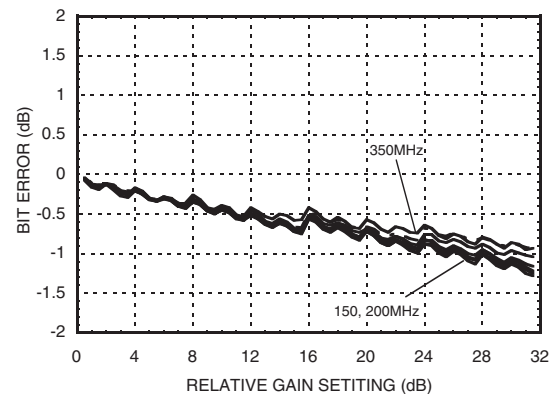


### Bit Error vs. Frequency

(Only Major States are Shown)



### Bit Error vs. Relative Gain Setting

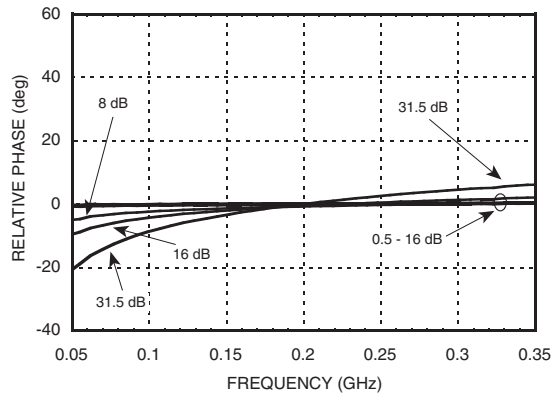


## 0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz

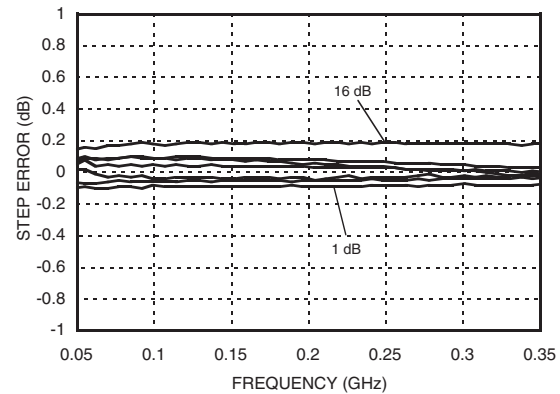
50 to 350 MHz Tuning

www.datasheet4u.com

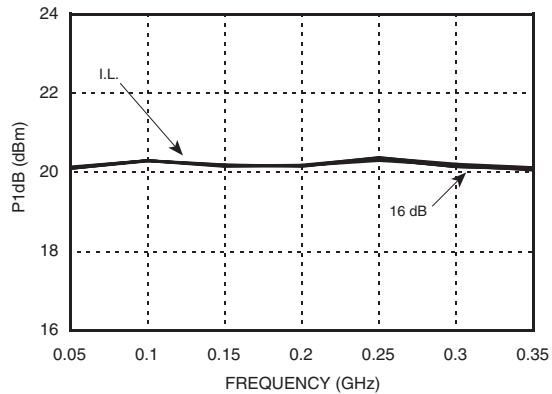
**Relative Phase vs. Frequency**  
(Only Major States are Shown)



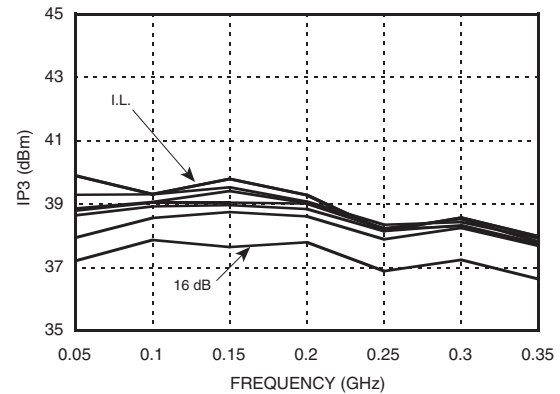
**Step Error vs. Frequency**  
(Only Major States are Shown)



**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)

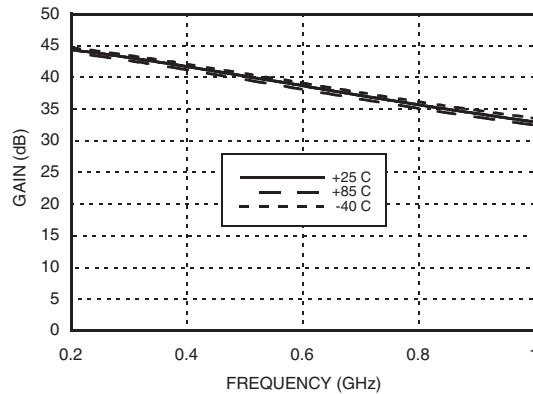


## 0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz

350 to 1000 MHz Tuning

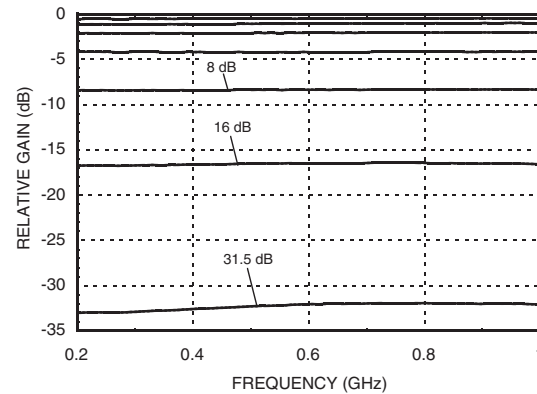
www.datasheet4u.com

### Gain vs. Frequency



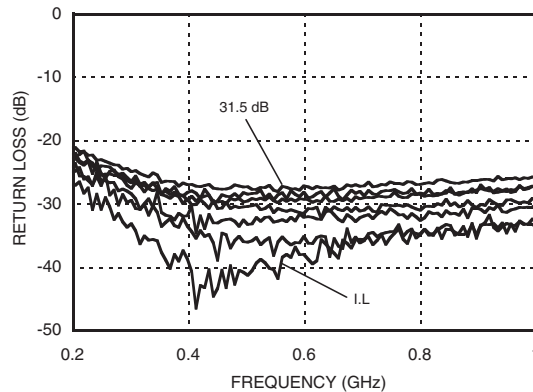
### Relative Gain Setting

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



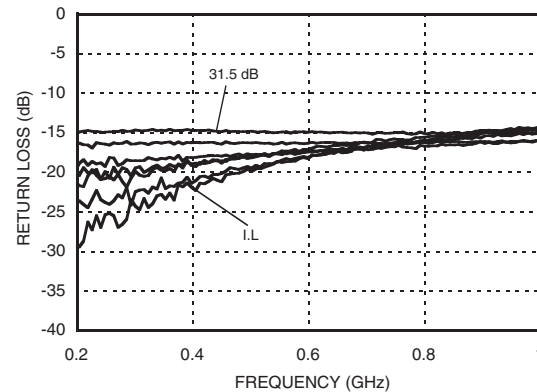
### Input Return Loss

(Only Major States are Shown)



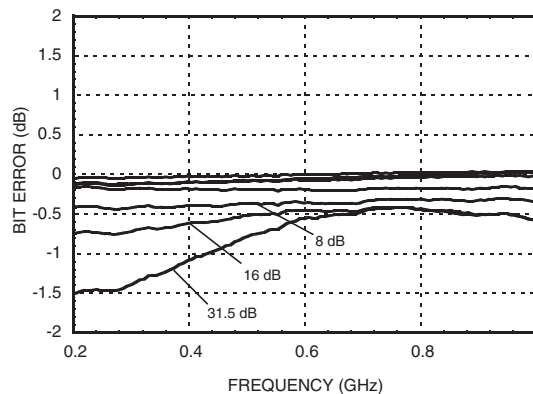
### Output Return Loss

(Only Major States are Shown)

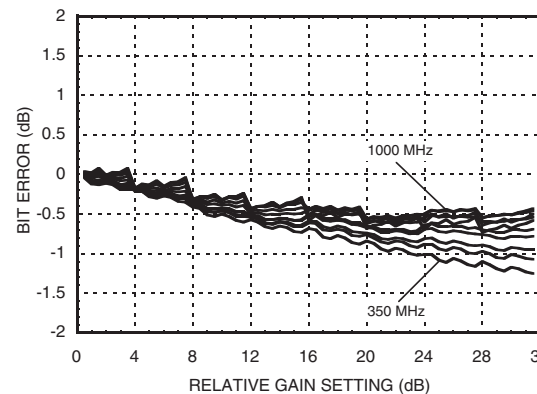


### Bit Error vs. Frequency

(Only Major States are Shown)



### Bit Error vs. Relative Gain Setting

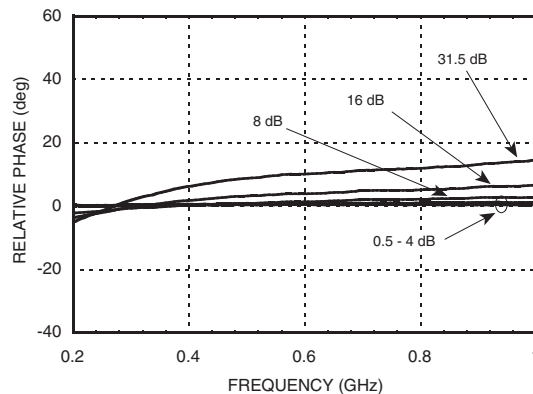


## 0.5 dB LSB GaAs MMIC 6-BIT DIGITAL VARIABLE GAIN AMPLIFIER w/ SERIAL CONTROL, DC - 1 GHz

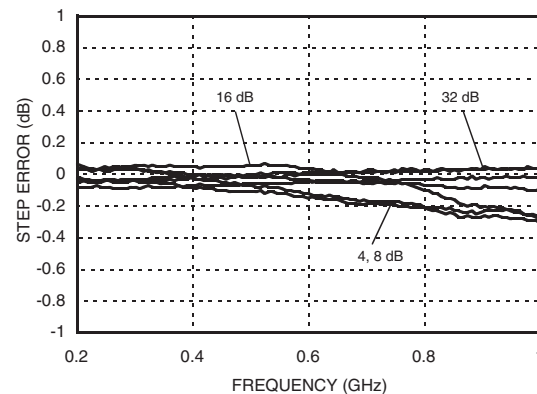
350 to 1000 MHz Tuning

www.datasheet4u.com

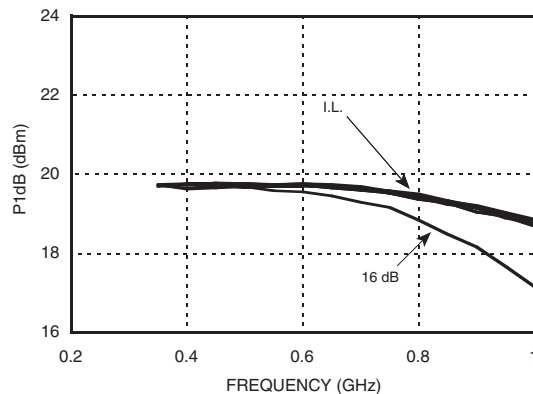
**Relative Phase vs. Frequency**  
(Only Major States are Shown)



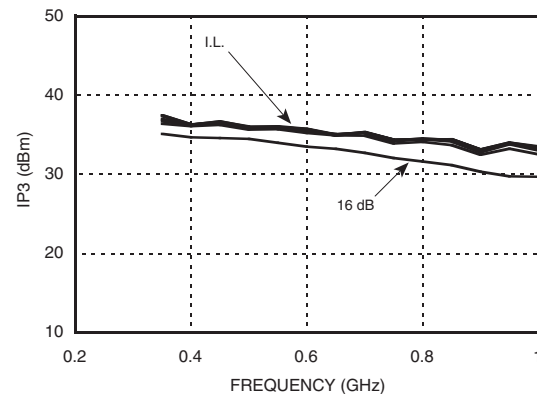
**Step Error vs. Frequency**  
(Only Major States are Shown)



**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

The Power-up (PUP) state is active at power-up provided that LE is held low. The PUP state is locked out after the first LE pulse or until Vdd drops below 4.5V.

### Power-Up 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

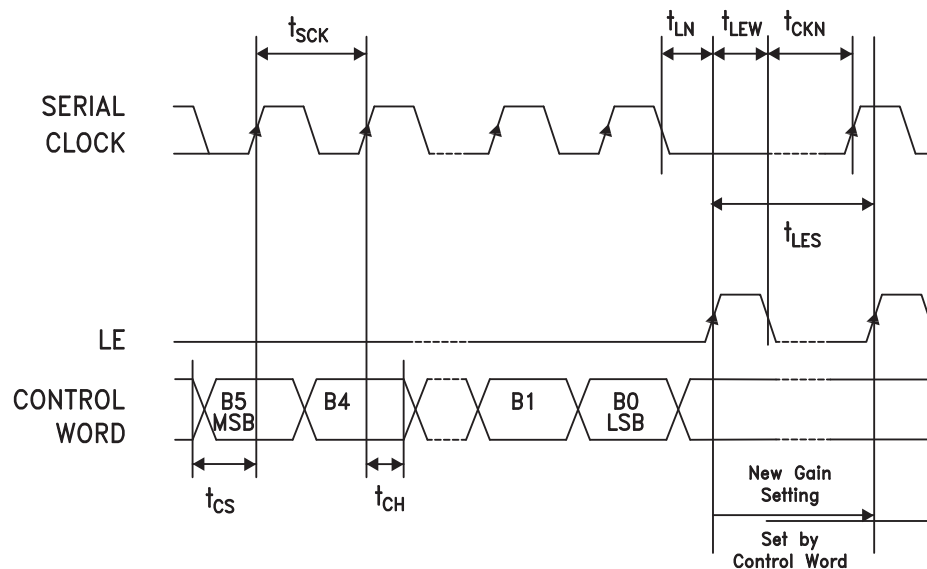
| LE | PUP1 | PUP2 | Relative Gain Setting |
|----|------|------|-----------------------|
| 0  | 0    | 0    | -31.5                 |
| 0  | 1    | 0    | -24                   |
| 0  | 0    | 1    | -16                   |
| 0  | 1    | 1    | Insertion Loss        |

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

### Serial Control Interface

The HMC681LP5(E) 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  |

| Serial Word |            |            |            |            |              | Relative Gain Setting |
|-------------|------------|------------|------------|------------|--------------|-----------------------|
| B5<br>16 dB | B4<br>8 dB | B3<br>4 dB | B2<br>2 dB | B1<br>1 dB | B0<br>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 <sup>[1]</sup> (At Max Gain Setting)                            | -10.5 dBm (T = +85 °C) |
| Bias Voltage (Vdd)                                                             | +5.5 Vdc               |
| Collector Bias Voltage (Vcc)                                                   | 5.5 Vdc                |
| Channel/Junction Temperature                                                   | 150 °C                 |
| Continuous Pdiss (T = 85 °C)<br>(derate 19.8 mW/°C above 85 °C) <sup>[1]</sup> | 1.29 W                 |
| Thermal Resistance                                                             | 50.8 °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.

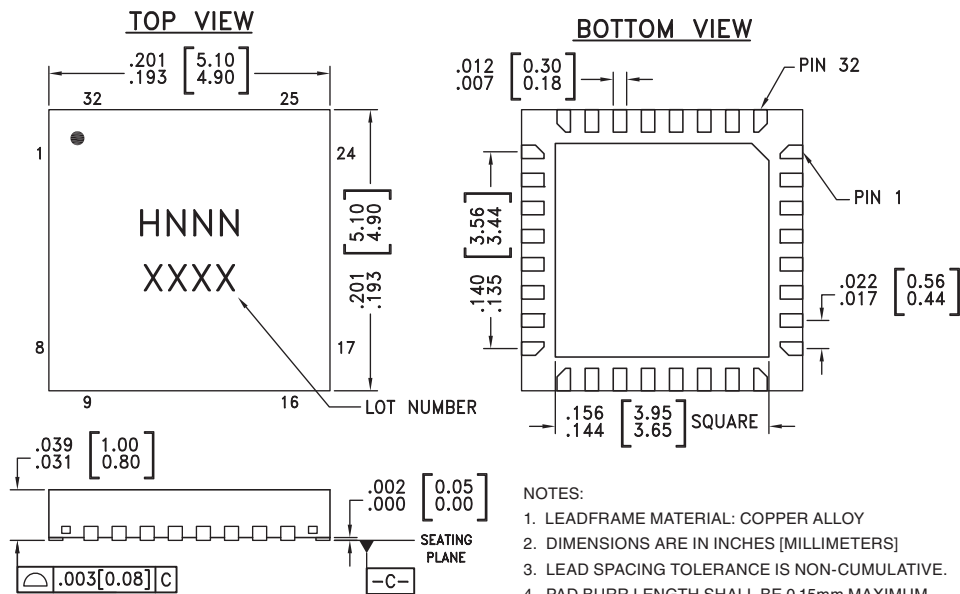
### Bias Voltage

| Vdd (V) | Idd (Typ.) (mA)      |                      |
|---------|----------------------|----------------------|
| +5.0    | 5                    |                      |
| Vs (V)  | Is <sub>1</sub> (mA) | Is <sub>2</sub> (mA) |
| +5.0    | 88                   | 88                   |



**ELECTROSTATIC SENSITIVE DEVICE  
OBSERVE HANDLING PRECAUTIONS**

### Outline Drawing



### Package Information

| Part Number | Package Body Material                              | Lead Finish   | MSL Rating          | Package Marking <sup>[3]</sup> |
|-------------|----------------------------------------------------|---------------|---------------------|--------------------------------|
| HMC681LP5   | Low Stress Injection Molded Plastic                | Sn/Pb Solder  | MSL1 <sup>[1]</sup> | H681<br>XXXX                   |
| HMC681LP5E  | RoHS-compliant Low Stress Injection Molded Plastic | 100% matte Sn | MSL1 <sup>[2]</sup> | H681<br>XXXX                   |

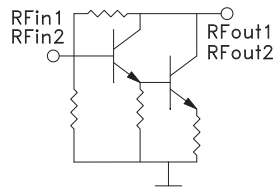
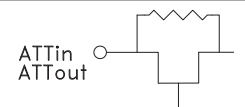
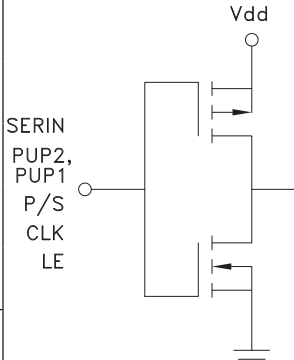
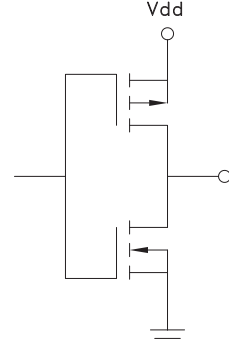
[1] Max peak reflow temperature of 235 °C

[2] Max peak reflow temperature of 260 °C

[3] 4-Digit lot number XXXX

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

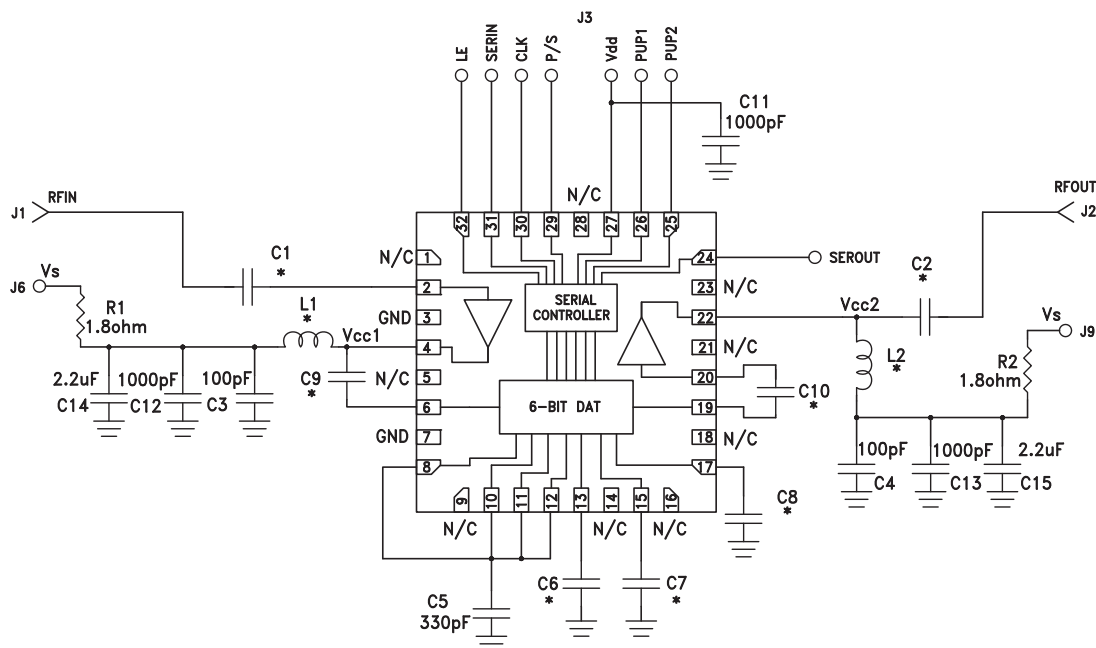
### Pin Descriptions

| Pin Number                         | Function                                       | Description                                                                                                                                        | Interface Schematic                                                                   |
|------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1, 5, 9, 14,<br>16, 23, 28         | N/C                                            | These pins may be connected to RF/DC ground.<br>Performance will not be affected.                                                                  |                                                                                       |
| 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,<br>11, 12,<br>13, 15,<br>17 | ACG1, ACG2,<br>ACG3, ACG4,<br>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.<br><br>Refer to truth tables and serial control interface diagram.                                    |  |
| 25, 26                             | PUP2, PUP1                                     |                                                                                                                                                    |                                                                                       |
| 30                                 | CLK                                            |                                                                                                                                                    |                                                                                       |
| 31                                 | SERIN                                          |                                                                                                                                                    |                                                                                       |
| 32                                 | LE                                             |                                                                                                                                                    |                                                                                       |
| 29                                 | P/S                                            | Apply +5V for normal operation.                                                                                                                    |                                                                                       |
| 27                                 | Vdd                                            | Supply voltage                                                                                                                                     |  |



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

### Application Circuit



### Components for Selected Frequencies

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

