

## 2 GHz to 6 GHz, 46 dBm (40 W), GaN Power Amplifier

### FEATURES

- ▶ Internally matched and AC-coupled, 40 W, GaN power amplifier
- ▶ Integrated drain bias inductor
- ▶  $P_{OUT}$ : 46.5 dBm typical from 2.0 GHz to 5.7 GHz ( $P_{IN} = 21$  dBm)
- ▶ Small signal gain: 40.5 dB typical from 2.3 GHz to 5.7 GHz
- ▶ Power gain: 25.5 dB typical from 2.0 GHz to 5.7 GHz ( $P_{IN} = 21$  dBm)
- ▶ PAE: 39% typical from 2.3 GHz to 5.7 GHz
- ▶  $V_{DD} = 28$  V at  $I_{DQ} = 750$  mA
- ▶ 14-lead ceramic leaded chip carrier [LDCC] with a copper-molybdenum base

### APPLICATIONS

- ▶ Military jammers
- ▶ Commercial and military radars
- ▶ Test and measurement equipment

### GENERAL DESCRIPTION

The ADPA1113 is a gallium nitride (GaN), broadband power amplifier delivering 46.5 dBm (44.7 W) with 39.0% power added efficiency (PAE) from 2.3 GHz to 5.7 GHz. No external matching or AC-coupling are required to achieve full-band operation. Additionally, no external inductor is required to bias the amplifier.

The ADPA1113 is ideal for continuous wave applications, such as military jammers and radars.

### FUNCTIONAL BLOCK DIAGRAM

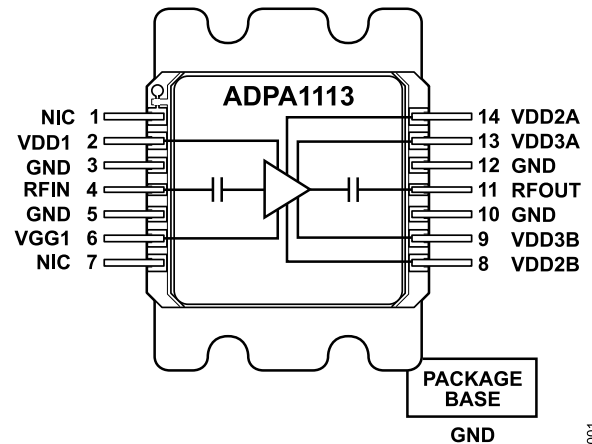


Figure 1. Functional Block Diagram

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REVISION HISTORY

1/2024—Revision 0: Initial Version

## SPECIFICATIONS

## ELECTRICAL SPECIFICATIONS

## 2.0 GHz to 2.3 GHz Frequency Range

$T_{CASE} = 25^{\circ}\text{C}$ , supply voltage ( $V_{DD}$ ) = 28 V, target quiescent current ( $I_{DQ}$ ) = 750 mA, and frequency range = 2.0 GHz to 2.3 GHz, unless otherwise noted.

Table 1. 2.0 GHz to 2.3 GHz Frequency Range

| Parameter                       | Min  | Typ       | Max | Unit                   | Test Conditions/Comments                                                                                      |
|---------------------------------|------|-----------|-----|------------------------|---------------------------------------------------------------------------------------------------------------|
| FREQUENCY RANGE                 | 2.0  |           | 2.3 | GHz                    |                                                                                                               |
| GAIN                            |      |           |     |                        |                                                                                                               |
| Small Signal Gain               | 36.5 | 39.0      |     | dB                     |                                                                                                               |
| Gain Variation over Temperature |      | 0.44      |     | dB/ $^{\circ}\text{C}$ |                                                                                                               |
| Gain Flatness                   |      | $\pm 1.2$ |     | dB                     |                                                                                                               |
| RETURN LOSS                     |      |           |     |                        |                                                                                                               |
| Input (S11)                     |      | 18        |     | dB                     |                                                                                                               |
| Output (S12)                    |      | 7         |     | dB                     |                                                                                                               |
| POWER                           |      |           |     |                        | Input power ( $P_{IN}$ ) = 21 dBm                                                                             |
| Output ( $P_{OUT}$ )            | 44.5 | 46.5      |     | dBm                    |                                                                                                               |
| Gain (S21)                      | 23.5 | 25.5      |     | dB                     |                                                                                                               |
| PAE                             |      | 47.0      |     | %                      |                                                                                                               |
| $I_{DQ}$                        |      | 750       |     | mA                     | Adjust the gate control voltage ( $V_{GG1}$ ) between -4 V and -1.9 V to achieve an $I_{DQ} = 750$ mA typical |

## 2.3 GHz to 5.7 GHz Frequency Range

$T_{CASE} = 25^{\circ}\text{C}$ ,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA, and frequency range = 2.3 GHz to 5.7 GHz, unless otherwise noted.

Table 2. 2.3 GHz to 5.7 GHz Frequency Range

| Parameter                       | Min  | Typ       | Max | Unit                   | Test Conditions/Comments                                                         |
|---------------------------------|------|-----------|-----|------------------------|----------------------------------------------------------------------------------|
| FREQUENCY RANGE                 | 2.3  |           | 5.7 | GHz                    |                                                                                  |
| GAIN                            |      |           |     |                        |                                                                                  |
| Small Signal Gain               | 38.0 | 40.5      |     | dB                     |                                                                                  |
| Gain Variation over Temperature |      | 0.05      |     | dB/ $^{\circ}\text{C}$ |                                                                                  |
| Gain Flatness                   |      | $\pm 0.8$ |     | dB                     |                                                                                  |
| RETURN LOSS                     |      |           |     |                        |                                                                                  |
| Input                           |      | 14        |     | dB                     |                                                                                  |
| Output                          |      | 10        |     | dB                     |                                                                                  |
| POWER                           |      |           |     |                        | $P_{IN} = 21$ dBm                                                                |
| $P_{OUT}$                       | 44.5 | 46.5      |     | dBm                    |                                                                                  |
| Gain                            | 23.5 | 25.5      |     | dB                     |                                                                                  |
| PAE                             |      | 39        |     | %                      |                                                                                  |
| $I_{DQ}$                        |      | 750       |     | mA                     | Adjust $V_{GG1}$ between -4 V and -1.9 V to achieve an $I_{DQ} = 750$ mA typical |

## SPECIFICATIONS

## 5.7 GHz to 6.0 GHz Frequency Range

$T_{CASE} = 25^{\circ}\text{C}$ ,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$ , and frequency range = 5.7 GHz to 6.0 GHz, unless otherwise noted.

Table 3. 5.7 GHz to 6.0 GHz Frequency Range

| Parameter                       | Min  | Typ       | Max | Unit                   | Test Conditions/Comments                                                                                  |
|---------------------------------|------|-----------|-----|------------------------|-----------------------------------------------------------------------------------------------------------|
| FREQUENCY RANGE                 | 5.7  |           | 6.0 | GHz                    |                                                                                                           |
| GAIN                            |      |           |     |                        |                                                                                                           |
| Small Signal Gain               | 36.5 | 39.0      |     | dB                     |                                                                                                           |
| Gain Variation over Temperature |      | 0.05      |     | dB/ $^{\circ}\text{C}$ |                                                                                                           |
| Gain Flatness                   |      | $\pm 0.4$ |     | dB                     |                                                                                                           |
| RETURN LOSS                     |      |           |     |                        |                                                                                                           |
| Input                           |      | 20.0      |     | dB                     |                                                                                                           |
| Output                          |      | 8.0       |     | dB                     |                                                                                                           |
| POWER                           |      |           |     |                        | $P_{IN} = 21\text{ dBm}$                                                                                  |
| $P_{OUT}$                       | 44.0 | 46.0      |     | dBm                    |                                                                                                           |
| Gain                            | 23.0 | 25.0      |     | dB                     |                                                                                                           |
| PAE                             |      | 32        |     | %                      |                                                                                                           |
| $I_{DQ}$                        |      | 750       |     | mA                     | Adjust $V_{GG1}$ between $-4\text{ V}$ and $-1.9\text{ V}$ to achieve an $I_{DQ} = 750\text{ mA}$ typical |

## ABSOLUTE MAXIMUM RATINGS

This device is not surface mountable and is not intended nor suitable to be used in a solder reflow process. This device must not be exposed to ambient temperatures above 150°C.

**Table 4. Absolute Maximum Ratings**

| Parameter                                                                                                  | Rating            |
|------------------------------------------------------------------------------------------------------------|-------------------|
| Bias Voltage                                                                                               |                   |
| Drain (VDD1, VDD2A, VDD2B, VDD3A, and VDD3B)                                                               | 35 V DC           |
| Gate (VGG1)                                                                                                | -8 V DC to 0 V DC |
| RFIN                                                                                                       | 26 dBm            |
| Continuous Power Dissipation ( $P_{DISS}$ ), $T_{CASE} = 85^{\circ}\text{C}$ , Derate 725 mW/°C Above 85°C | 101 W             |
| Temperature                                                                                                |                   |
| Maximum Channel                                                                                            | 225°C             |
| Nominal Peak Channel, $T_{CASE} = 85^{\circ}\text{C}$ , $P_{IN} = 21$ dBm, $P_{DISS} = 75$ W at 6 GHz      | 188.5°C           |
| Storage Range                                                                                              | -55°C to +150°C   |
| Operating Range                                                                                            | -40°C to +85°C    |

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

## THERMAL RESISTANCE

Thermal performance is directly linked to printed circuit board (PCB) design and operating environment. Careful attention to PCB thermal design is required.

**Table 5. Thermal Resistance**

| Package Type <sup>1, 2</sup> | $\theta_{JC}$ | Unit |
|------------------------------|---------------|------|
| EJ-14-1                      | 1.38          | °C/W |

<sup>1</sup>  $\theta_{JC}$  was determined by simulation under the following conditions: the heat transfer is due solely to the thermal conduction from the channel through the package flange to the heat sink. The package flange is held constant at the operating temperature of 85°C.

<sup>2</sup>  $\theta_{JC}$  is the channel to case thermal resistance where the case is the bottom of the package flange.

## ELECTROSTATIC DISCHARGE (ESD) RATINGS

The following ESD information is provided for handling of ESD sensitive devices in an ESD protected area only.

Human body model (HBM) per ANSI/ESDA/JEDEC JS-001.

## ESD Ratings for ADPA1113

**Table 6. ADPA1113, 14-Lead LDCC**

| ESD Model | Withstand Threshold (V) | Class |
|-----------|-------------------------|-------|
| HBM       | 500                     | 1B    |

## ESD CAUTION



**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

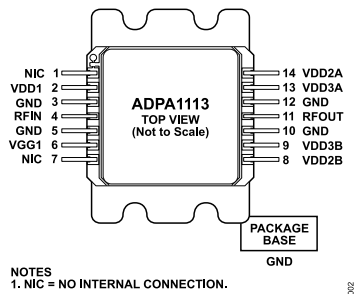


Figure 2. Pin Configuration

Table 7. Pin Function Descriptions

| Pin No.      | Mnemonic | Description                                                                                                                    |
|--------------|----------|--------------------------------------------------------------------------------------------------------------------------------|
| 1, 7         | NIC      | No Internal Connection. The NIC pins are not connected internally. For normal operation, connect to ground.                    |
| 2            | VDD1     | Drain Bias for First Stage of Amplifier. See Figure 3 for the VDD1 pin interface schematic.                                    |
| 3, 5, 10, 12 | GND      | Ground. The ground pins must be connected to the RF and the DC ground. See Figure 4 for the GND interface schematic.           |
| 4            | RFIN     | RF Input. The RFIN pin is AC-coupled and internally matched to 50 $\Omega$ . See Figure 3 for the RFIN interface schematic.    |
| 6            | VGG1     | Gate Control for All Three Stages of the Amplifier. See Figure 3 for the VGG1 interface schematic.                             |
| 8            | VDD2B    | Drain Bias for the Second Stage of the South Side of the Amplifier. See Figure 5 for the VDD2B interface schematic.            |
| 9            | VDD3B    | Drain Bias for the Third Stage of the South Side of the Amplifier. See Figure 6 for the VDD3B interface schematic.             |
| 11           | RFOUT    | RF Output. The RFOUT pin is AC-coupled and internally matched to 50 $\Omega$ . See Figure 6 for the RFOUT interface schematic. |
| 13           | VDD3A    | Drain Bias for the Third Stage of the North Side of the Amplifier. See Figure 6 for the VDD3A interface schematic.             |
| 14           | VDD2A    | Drain Bias for the Second Stage of the North Side of the Amplifier. See Figure 5 for the VDD2A interface schematic.            |
| Package Base | GND      | The package base must be connected to the RF and the DC ground. See Figure 4 for the GND Interface schematic.                  |

## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

## INTERFACE SCHEMATICS

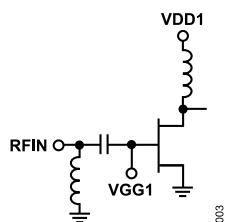


Figure 3. VDD1, RFIN, and VGG1 Interface Schematic



Figure 4. GND Interface Schematic

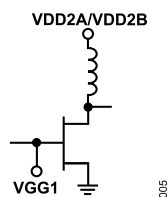


Figure 5. VDD2A and VDD2B Interface Schematic

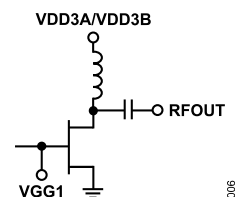


Figure 6. VDD3A, VDD3B, and RFOUT Interface Schematic

## TYPICAL PERFORMANCE CHARACTERISTICS

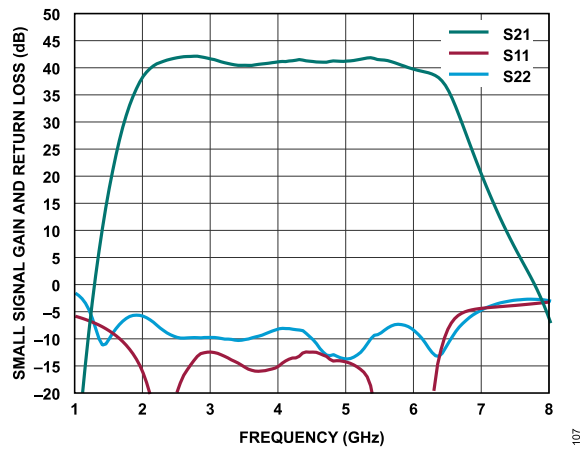
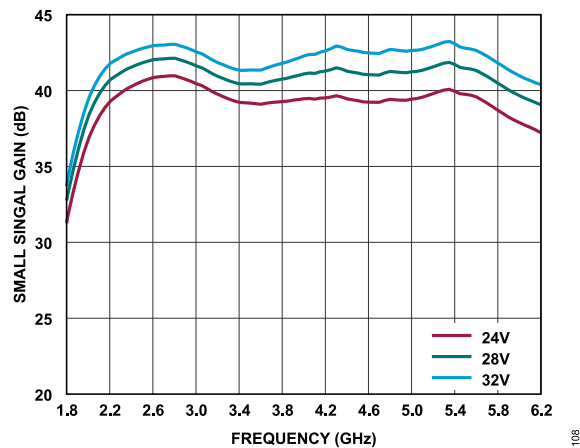
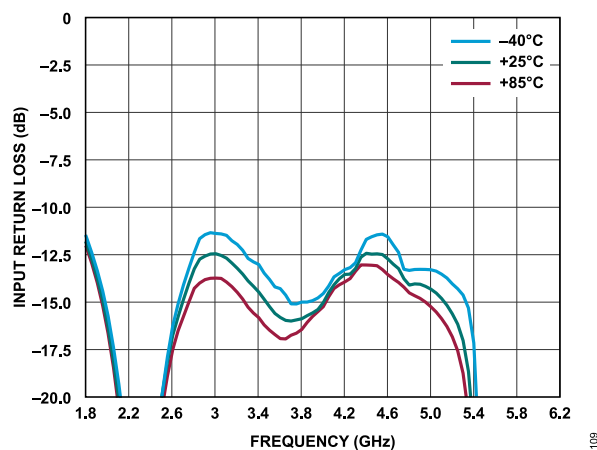
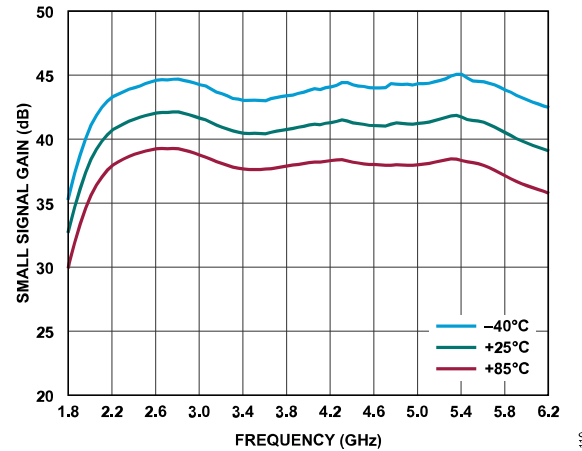
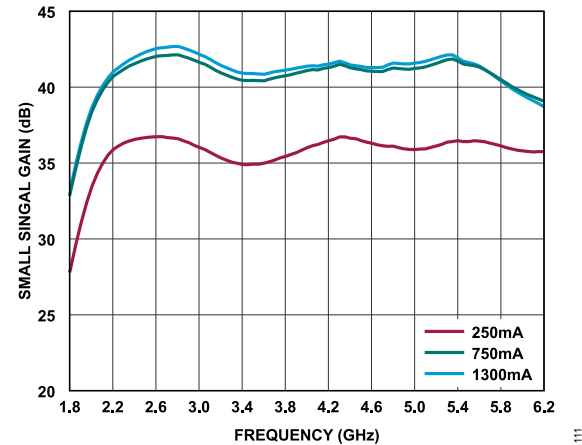
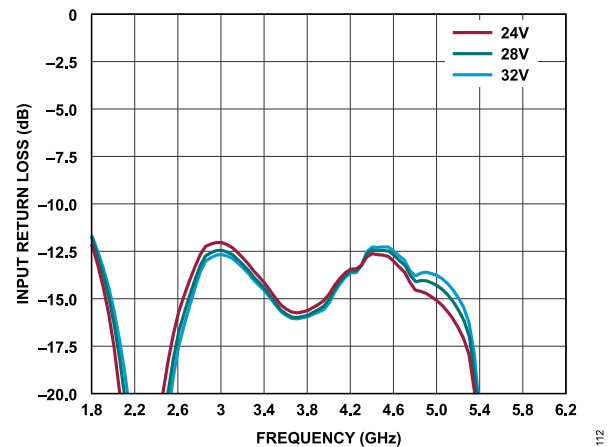


Figure 7. Small Signal Gain and Return Loss vs. Frequency

Figure 8. Small Signal Gain vs. Frequency for Various Supply Voltages,  $I_{DQ} = 750$  mAFigure 9. Input Return Loss vs. Frequency for Various Temperatures,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mAFigure 10. Small Signal Gain vs. Frequency for Various Temperatures,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mAFigure 11. Small Signal Gain vs. Frequency for Various  $I_{DQ}$  Supply Currents,  $V_{DD} = 28$  VFigure 12. Input Return Loss vs. Frequency for Various Supply Voltages,  $I_{DQ} = 750$  mA



## TYPICAL PERFORMANCE CHARACTERISTICS

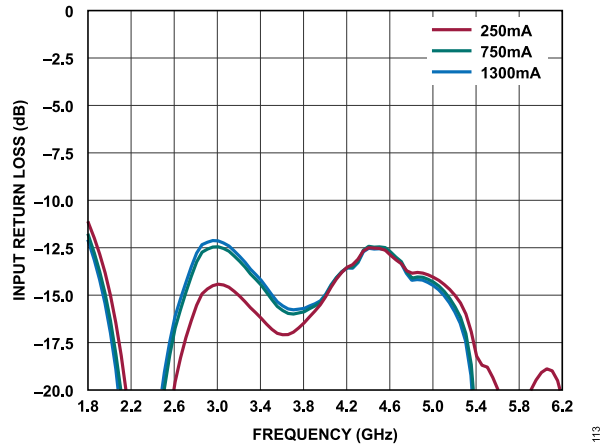


Figure 13. Input Return Loss vs. Frequency for Various  $I_{DQ}$  Supply Currents,  $V_{DD} = 28\text{ V}$

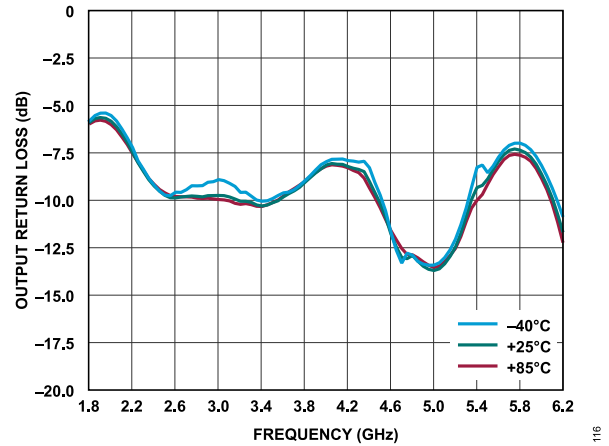


Figure 16. Output Return Loss vs. Frequency for Various Temperatures,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

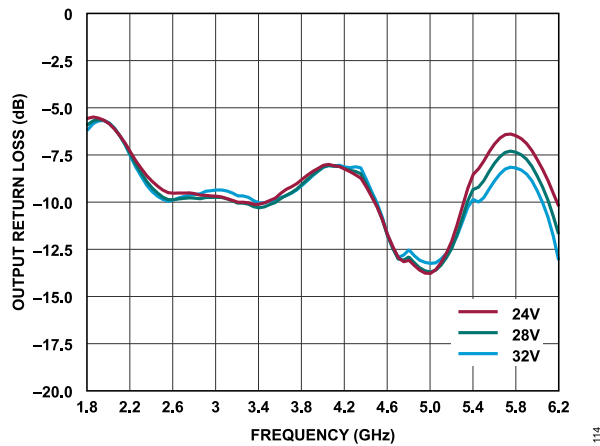


Figure 14. Output Return Loss vs. Frequency for Various Supply Voltages,  $I_{DQ} = 750\text{ mA}$

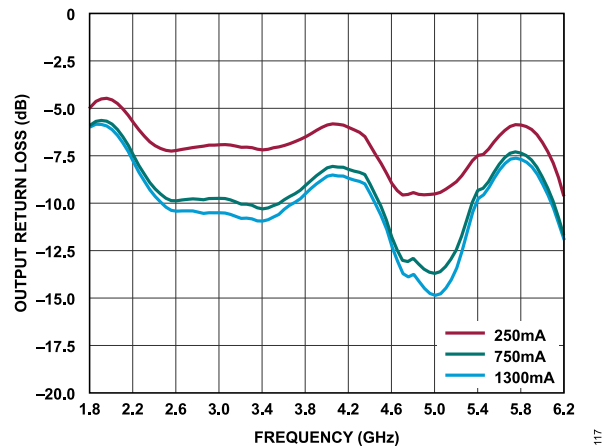


Figure 17. Output Return Loss vs. Frequency for Various  $I_{DQ}$  Supply Currents,  $V_{DD} = 28\text{ V}$

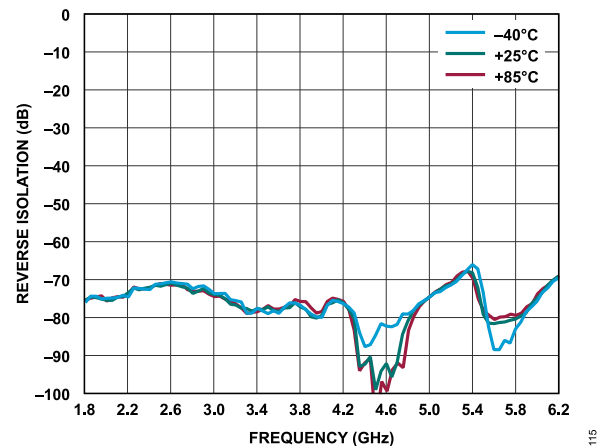


Figure 15. Reverse Isolation vs. Frequency for Various Temperatures,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

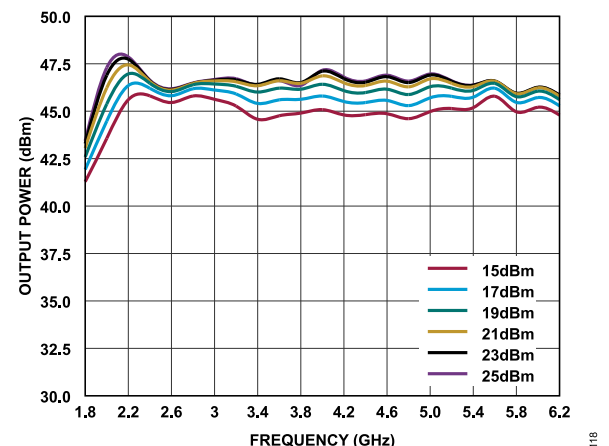


Figure 18. Output Power vs. Frequency for Various  $P_{IN}$  Levels,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

## TYPICAL PERFORMANCE CHARACTERISTICS

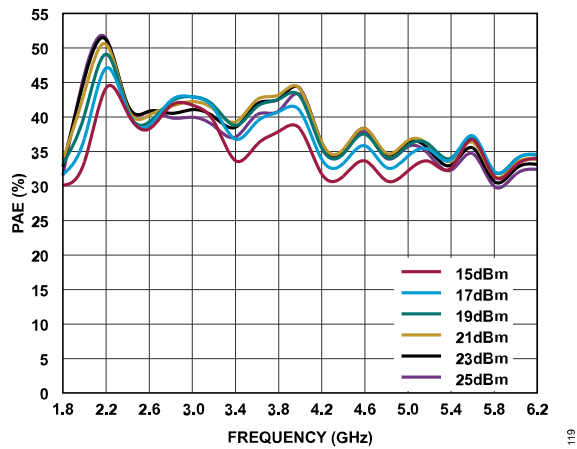


Figure 19. PAE vs. Frequency for Various  $P_{IN}$  Levels,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

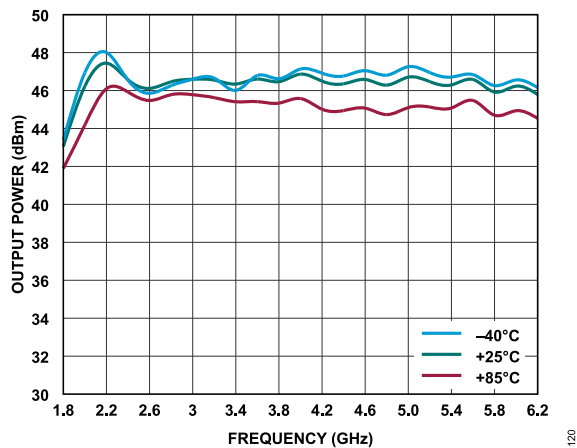


Figure 20. Output Power vs. Frequency at Various Temperatures for  $P_{IN} = 21$  dBm,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

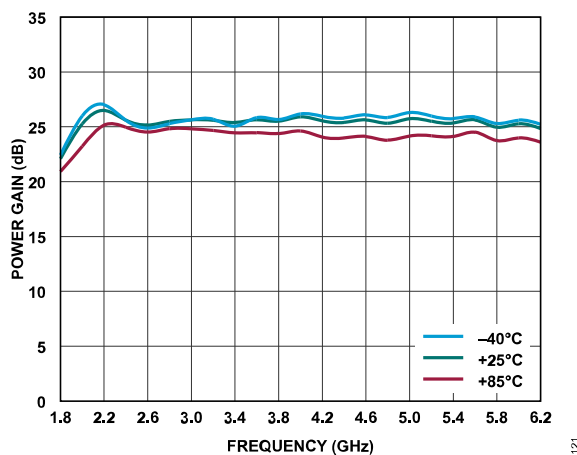


Figure 21. Power Gain vs. Frequency at Various Temperatures for  $P_{IN} = 21$  dBm,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

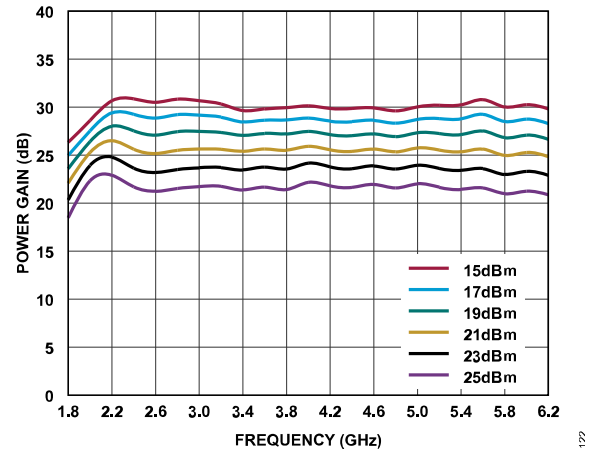


Figure 22. Power Gain vs. Frequency for Various  $P_{IN}$  Levels,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

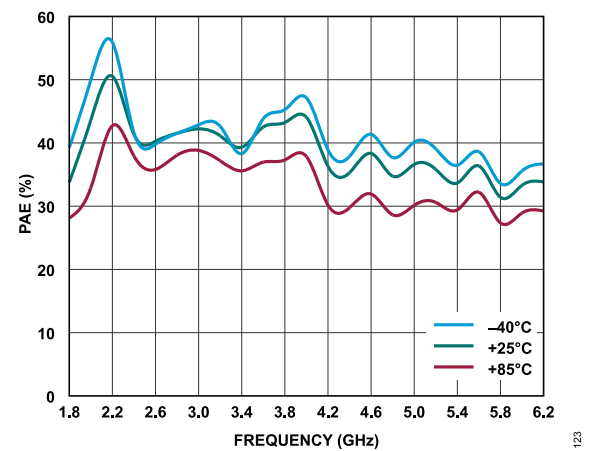


Figure 23. PAE vs. Frequency at Various Temperatures for  $P_{IN} = 21$  dBm,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

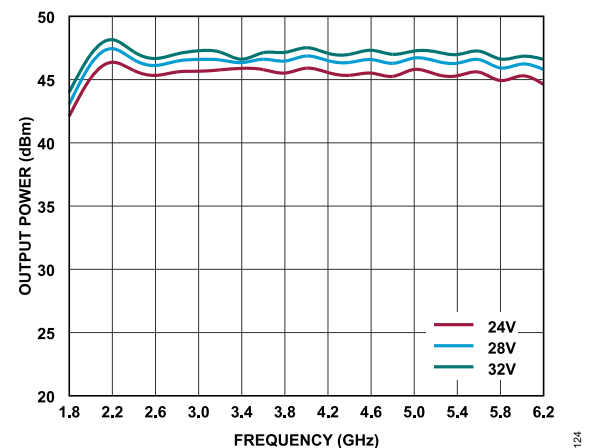


Figure 24. Output Power at  $P_{IN} = 21$  dBm vs. Frequency for Various Supply Voltages at  $I_{DQ} = 750$  mA

## TYPICAL PERFORMANCE CHARACTERISTICS

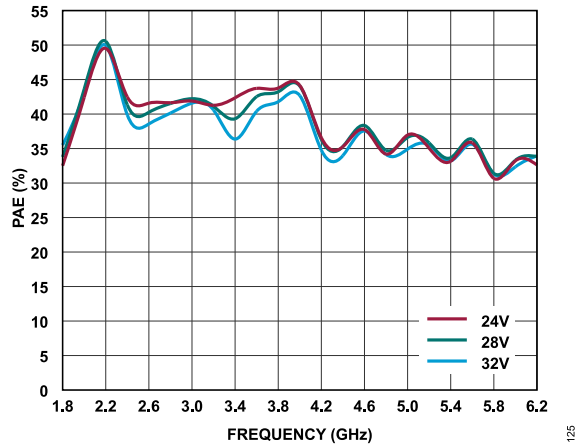


Figure 25. PAE at  $P_{IN} = 21$  dBm vs. Frequency for Various Supply Voltages at  $I_{DQ} = 750$  mA

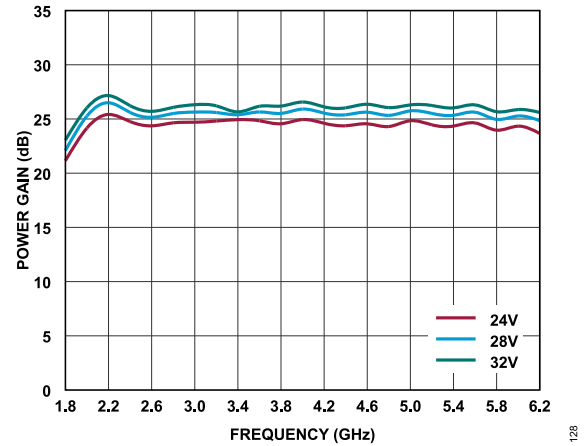


Figure 28. Power Gain at  $P_{IN} = 21$  dBm vs. Frequency for Various Supply Voltages at  $I_{DQ} = 750$  mA

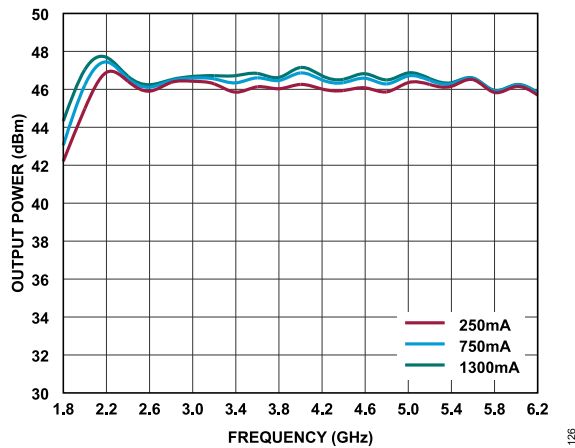


Figure 26. Output Power at  $P_{IN} = 21$  dBm vs. Frequency for Various  $I_{DQ}$  Supply Currents at  $V_{DD} = 28$  V

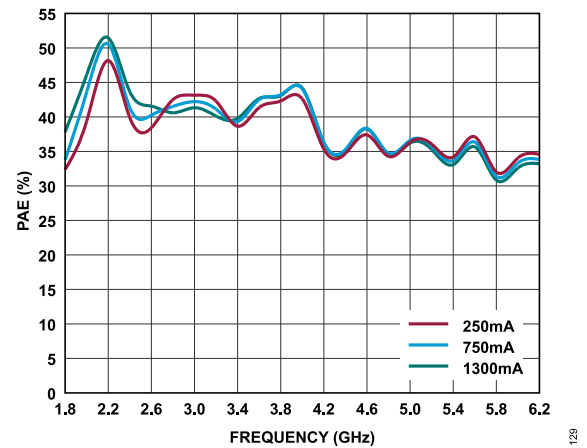


Figure 29. PAE at  $P_{IN} = 21$  dBm vs. Frequency for Various  $I_{DQ}$  Supply Currents at  $V_{DD} = 28$  V

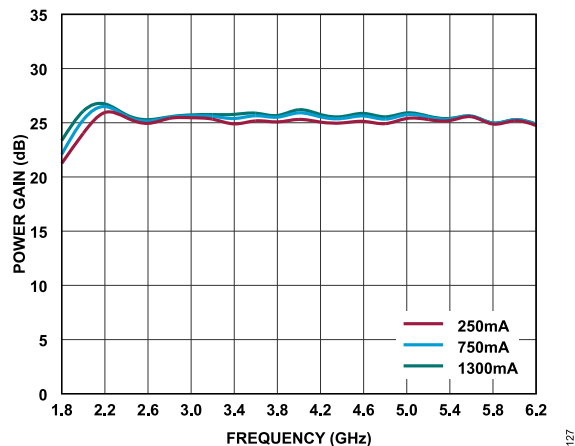


Figure 27. Power Gain at  $P_{IN} = 21$  dBm vs. Frequency for Various  $I_{DQ}$  Supply Currents at  $V_{DD} = 28$  V

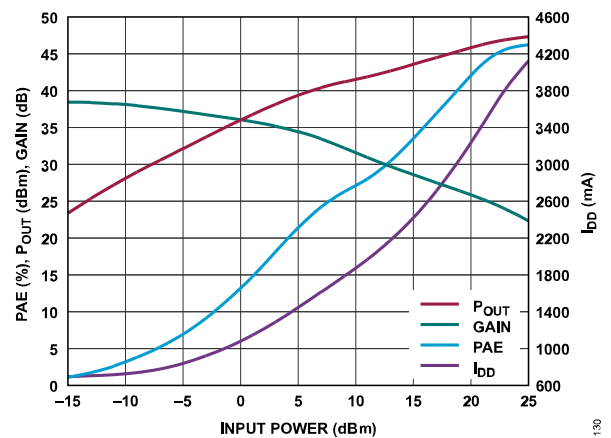


Figure 30. PAE,  $P_{OUT}$ , Gain, and Supply Current ( $I_{DD}$ ) vs. Input Power at 2.0 GHz,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

## TYPICAL PERFORMANCE CHARACTERISTICS

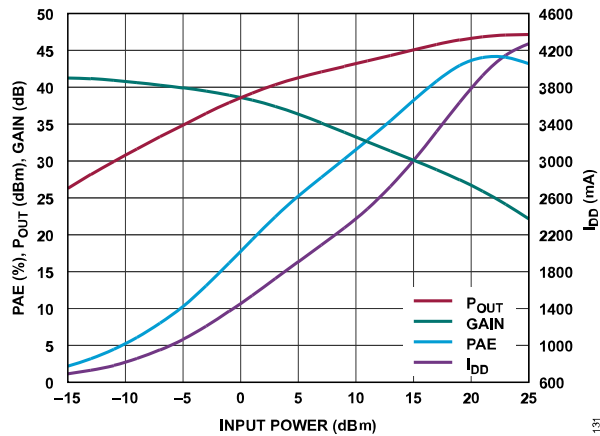


Figure 31. PAE,  $P_{OUT}$ , Gain, and  $I_{DD}$  vs. Input Power at 4.0 GHz,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

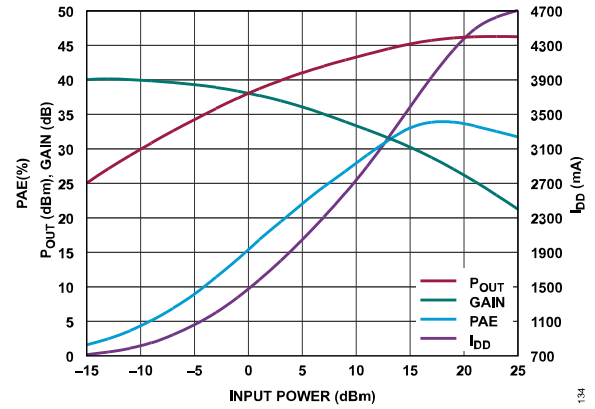


Figure 34. PAE,  $P_{OUT}$ , Gain, and  $I_{DD}$  vs. Input Power at 6.0 GHz,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

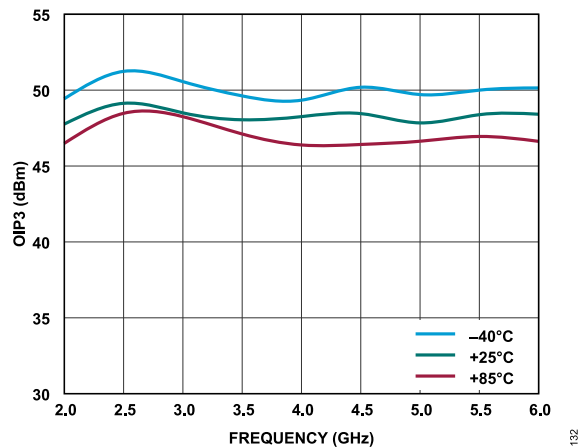


Figure 32. Output Third-Order Intercept (OIP3) vs. Frequency with  $P_{OUT}$  per Tone = 36 dBm for Various Temperatures,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

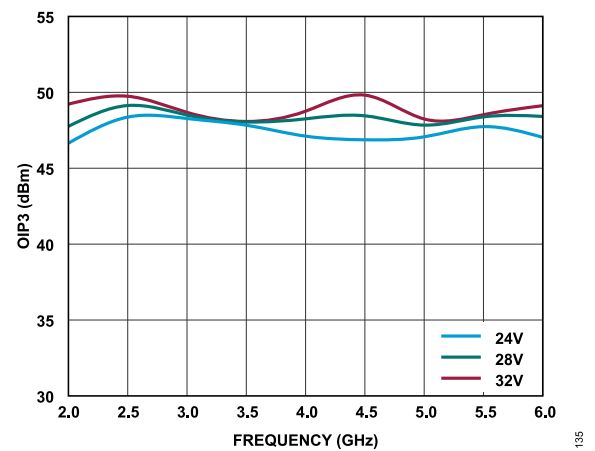


Figure 35. OIP3 vs. Frequency with  $P_{OUT}$  per Tone = 36 dBm for Various  $V_{DD}$ ,  $I_{DQ} = 750$  mA

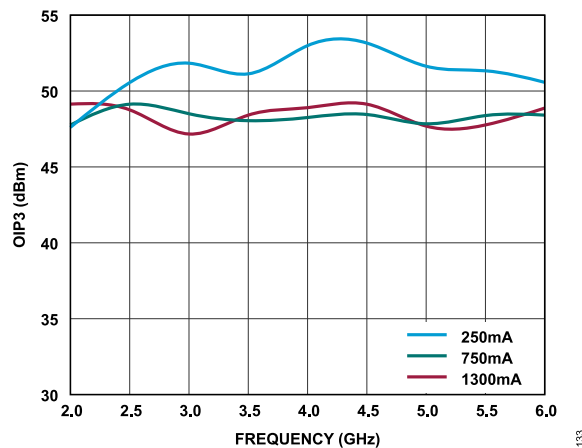


Figure 33. OIP3 vs. Frequency with  $P_{OUT}$  per Tone = 36 dBm for Various  $I_{DQ}$ ,  $V_{DD} = 28$  V

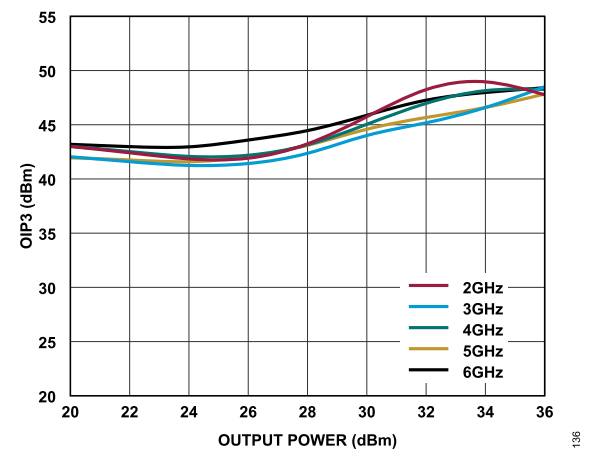


Figure 36. OIP3 vs. Output Power per Tone for Various Frequencies,  $V_{DD} = 28$  V,  $I_{DQ} = 750$  mA

## TYPICAL PERFORMANCE CHARACTERISTICS

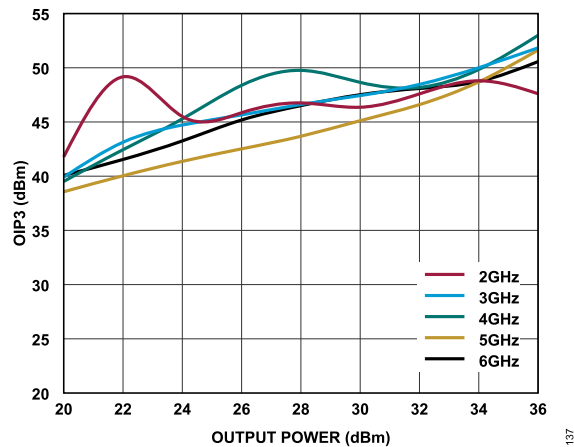


Figure 37. OIP3 vs.  $P_{OUT}$  per Tone for Various Frequencies,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 250\text{ mA}$

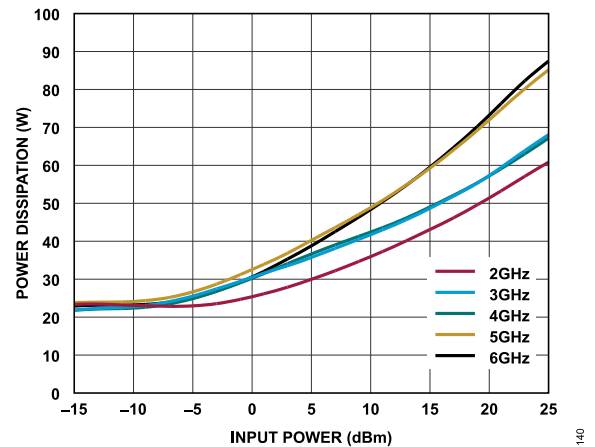


Figure 40. Power Dissipation vs. Input Power for Various Frequencies,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$ ,  $T_{CASE} = 85^\circ\text{C}$

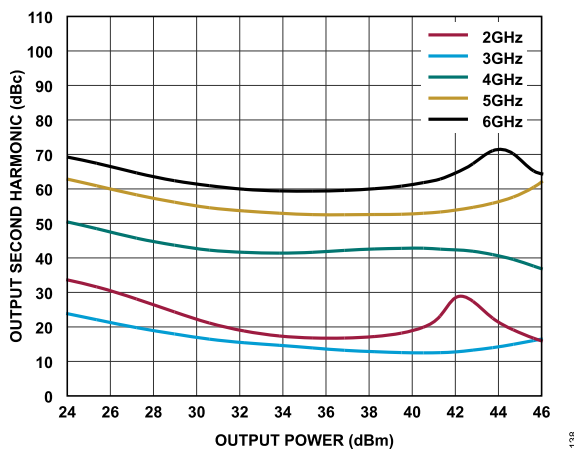


Figure 38. Output Second Harmonic vs. Output Power for Various Frequencies,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

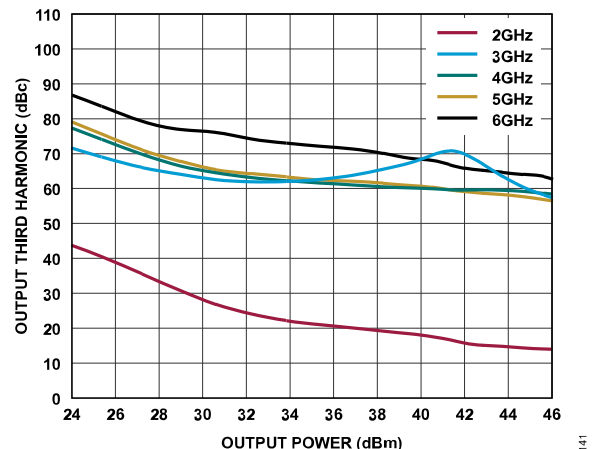


Figure 41. Output Third Harmonic vs. Output Power for Various Frequencies,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

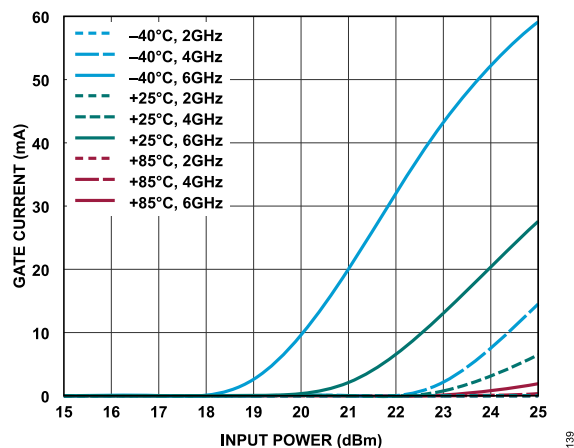


Figure 39. Gate Current vs. Input Power for Various Temperatures and Frequencies,  $V_{DD} = 28\text{ V}$ ,  $I_{DQ} = 750\text{ mA}$

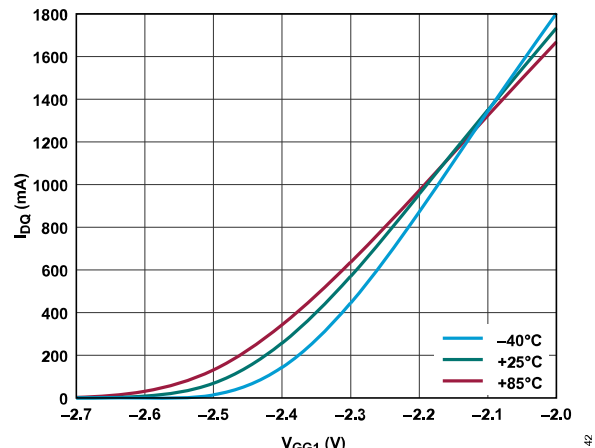


Figure 42.  $I_{DQ}$  vs.  $V_{GG1}$ ,  $V_{DD} = 28\text{ V}$

TYPICAL PERFORMANCE CHARACTERISTICS

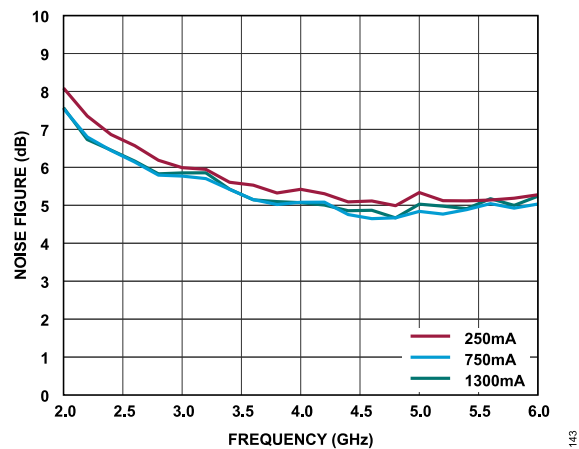


Figure 43. Noise Figure vs. Frequency for Various  $I_{DQ}$  Values,  $V_{DD} = 28\text{ V}$

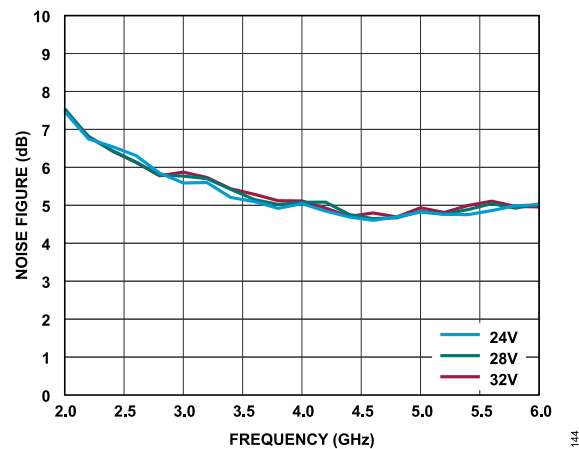
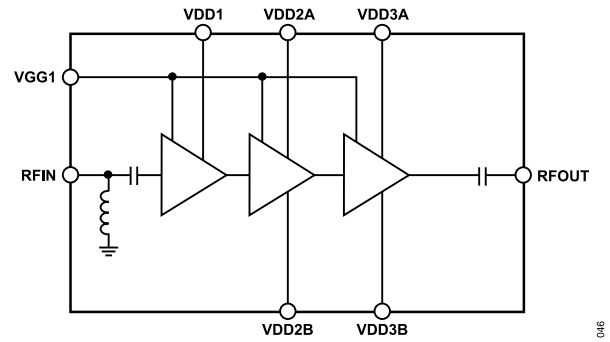


Figure 44. Noise Figure vs. Frequency for Various  $V_{DD}$  Values,  $I_{DQ} = 750\text{ mA}$

## THEORY OF OPERATION

The ADPA1113 is a GaN power amplifier with cascaded gain stages that is biased by a positive drain supply and an externally applied negative gate voltage applied to the VGG1 pin. A nominal 28 V is applied to the first, second, and third stages, and a negative voltage is applied to VGG1 to set the total  $I_{DQ}$  to 750 mA nominal.

When biased as described, the device operates in Class AB, resulting in the maximum PAE at saturation. The ADPA1113 features integrated RF chokes for each drain plus on-chip DC blocking of the RFIN and RFOUT ports. While the RFIN and RFOUT ports are internally DC blocked, there is a DC path to ground on the RFIN pin. As a result, if the DC bias level of the signal driving RFIN is not equal to zero, then the DC bias level must be externally AC-coupled.



**Figure 45. Basic Block Diagram**

## APPLICATIONS INFORMATION

## APPLICATIONS CIRCUIT

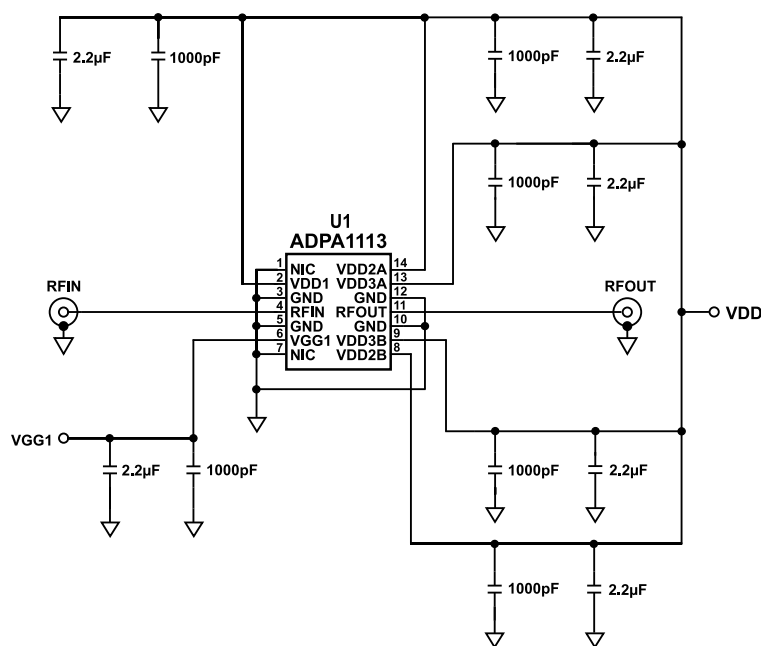


Figure 46. Typical Application Circuit

## BASIC CONNECTIONS

The basic connections to operate the ADPA1113 are shown in Figure 46. The same drain supply voltage, 28 V nominal, must be applied to all of the five VDD pins (VDD1, VDD2A, VDD2B, VDD3A, and VDD3B). The VDD pins are capacitively decoupled as shown in Figure 46. The gate voltage for all three stages (–1.9 V to –4.0 V for biased operation and –8 V for pinch-off voltage) is applied to the VGG1 pin that is decoupled as shown in Figure 46. Pin 1 and Pin 7 are designated as no internal connection (NIC) pins. Although these NIC pins are not internally connected, the NIC pins were all connected to ground during the characterization of the device.

To turn on the device, apply –4 V to VGG1 which places it in pinch-off voltage. Then, apply 28 V to VDD1, VDD2A, VDD2B, VDD3A, and VDD3B. Increase the gate voltage (more positive) until the drain current is 750 mA, VGG1 is approximately –2 V, and apply the RF signal. If the desired gate voltage is known in advance, VGG1 can be set to that voltage directly without going through the pinch-off step.

To turn off the device, turn off the RF signal and set the VDD voltages to 0 V before increasing VGG1 to 0 V.

The configuration shown in Figure 46, which is also the default configuration of the customer evaluation board, was used to char-

acterize the ADPA1113. It can be possible to reduce the number of power supply decoupling capacitors shown, but this reduction varies by system. When reducing capacitors, the recommendation is to first remove or combine the largest capacitors that are farthest from the device.

## Soldering and Assembly Considerations

The ADPA1113 is a nonhermetic air cavity device. The body of the package normally sits within a cutout in the PCB that allows direct access to a heatsink beneath the PCB. To facilitate good thermal and electrical conduction to the heatsink, a shim of electrically and thermally conductive material such as Heat-Spring indium from Indium Corporation can be used. (Alternatively, electrically and thermally conductive paste or grease can be used). The shim is placed between the heatsink and the bottom of the package flange. Then, the package can be attached to the heatsink using 0-80 thread size, 3/16 inches long stainless steel socket head screws (typically). Once attached with the screw hardware, the pins are flush with the PCB which allows the leads to be soldered to the PCB pads.



OUTLINE DIMENSIONS

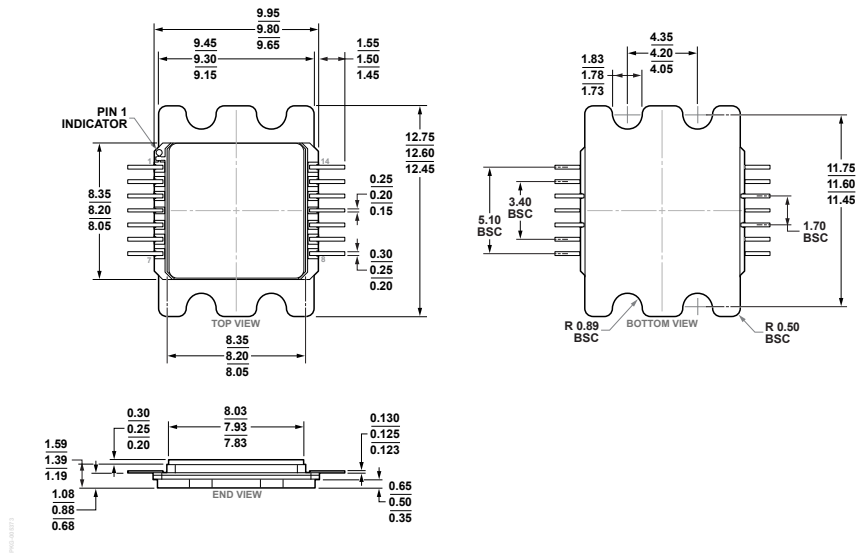


Figure 47. 14-Lead Ceramic Leaded Chip Carrier [LDCC]  
(EJ-14-1)  
Dimensions shown in millimeters

ORDERING GUIDE

| Model <sup>1</sup> | Temperature Range | Package Description              | Package Option |
|--------------------|-------------------|----------------------------------|----------------|
| ADPA1113AEJZ       | -40°C to +85°C    | 14-Lead LDCC (9.80 mm × 8.20 mm) | EJ-14-1        |

<sup>1</sup> Z = RoHS-Compliant Part.

EVALUATION BOARDS

| Models <sup>1</sup> | Description      |
|---------------------|------------------|
| ADPA1113-EVALZ      | Evaluation Board |

<sup>1</sup> Z = RoHS-Compliant Part.