Commercial Space Product

GaAs, pHEMT, MMIC, Low Noise Amplifier, 0.01 GHz to 9 GHz

FEATURES

- Low noise figure: 1.9 dB typical at 0.01 GHz to 7 GHz
- Single positive supply (self biased)
- High gain: 19.5 dB typical at 0.01 GHz to 7 GHz
- High OIP3: 35 dBm typical at 0.01 GHz to 7 GHz
- RoHS-compliant, 2 mm × 2 mm, 6-lead LFCSP

COMMERCIAL SPACE FEATURES

- Support aerospace applications
- Wafer diffusion lot traceability
- Radiation benchmark
  - Total ionizing dose (TID): 30 krads
  - No single event latchup (SEL) occurs at ≤ 62.4 MeV-cm^2/mg linear energy transfer

APPLICATIONS

- Low Earth orbit (LEO) space payloads
- Satellite communication

GENERAL DESCRIPTION

The HMC8413-CSL is a gallium arsenide (GaAs), monolithic microwave integrated circuit (MMIC), pseudomorphic high electron mobility transistor (pHEMT), low noise wideband amplifier that operates from 0.01 GHz to 9 GHz.

The HMC8413-CSL provides a typical gain of 19.5 dB, a 1.9 dB typical noise figure, and a typical output third-order intercept (OIP3) of 35 dBm at 0.01 GHz to 7 GHz, requiring only 95 mA from a 5 V supply voltage. The saturated output power (P_{SAT}) of 22 dBm typical at 0.01 GHz to 7 GHz enables the low noise amplifier to function as a local oscillator (LO) driver for many of Analog Devices, Inc., balanced, in-phase/quadrature (I/Q) or image rejection mixers.

The HMC8413-CSL also features inputs and outputs that are internally matched to 50 Ω, making the device ideal for surface-mounted technology (SMT)-based, high capacity microwave radio applications.

The HMC8413-CSL is housed in an RoHS-compliant, 2 mm × 2 mm, 6-lead LFCSP.

Throughout this data sheet, multifunction pins, such as RF_{OUT}/V_{DD}, are referred to either by the entire pin name or by a single function of the pin, for example RF_{OUT}, when only that function is relevant.

Additional application and technical information can be found in the Commercial Space Products Program brochure and the HMC8413 data sheet.

FUNCTIONAL BLOCK DIAGRAM

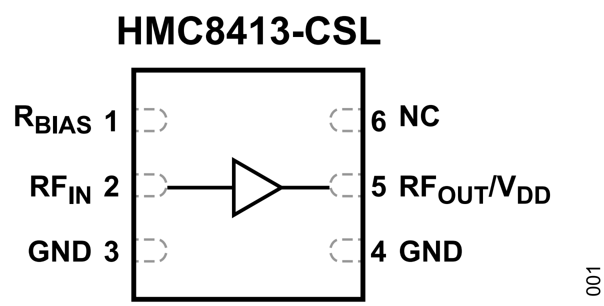

Figure 1.

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REVISION HISTORY

3/2023—Revision 0: Initial Version

SPECIFICATIONS

0.01 GHZ TO 7 GHZ FREQUENCY RANGE

Supply voltage (V_{DD}) = 5 V, supply current (I_{DQ}) = 95 mA, bias resistance (R_{BIAS}) = 787 Ω, and T_A = 25°C, unless otherwise noted.

Table 1.

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
FREQUENCY RANGE	0.01		7	GHz	
GAIN	17.5	19.5		dB	
Gain Variation over Temperature		0.013		dB/°C	
NOISE FIGURE		1.9		dB	
RETURN LOSS					
Input		15		dB	
Output		18		dB	
OUTPUT					
Output Power for 1 dB Compression (OP1dB)	19	21.5		dBm	
P_{SAT}		22		dBm	
OIP3		35		dBm	Measurement taken at output power (P_{OUT}) per tone = 5 dBm
Output Second-Order Intercept (OIP2)		39		dBm	Measurement taken at P_{OUT} per tone = 5 dBm
POWER ADDED EFFICIENCY (PAE)		37		%	Measured at P_{SAT}
SUPPLY					
I_{DQ}		95		mA	
V_{DD}	2	5	6	V	

7 GHZ TO 9 GHZ FREQUENCY RANGE

V_{DD} = 5 V, I_{DQ} = 95 mA, R_{BIAS} = 787 Ω, and T_A = 25°C, unless otherwise noted.

Table 2.

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
FREQUENCY RANGE	7		9	GHz	
GAIN	17	19		dB	
Gain Variation over Temperature		0.02		dB/°C	
NOISE FIGURE		2.8		dB	
RETURN LOSS					
Input		12		dB	
Output		15		dB	
OUTPUT					
OP1dB	16.5	19		dBm	
P_{SAT}		21		dBm	
OIP3		33		dBm	Measurement taken at P_{OUT} per tone = 5 dBm
OIP2		45		dBm	Measurement taken at P_{OUT} per tone = 5 dBm
PAE		22		%	Measured at P_{SAT}
SUPPLY					
I_{DQ}		95		mA	
V_{DD}	2	5	6	V	

SPECIFICATIONS

RADIATION TEST AND LIMIT SPECIFICATIONS

Electrical characteristics at V_{DD} = 5 V, I_{DQ} = 95 mA, R_{BIAS} = 787 Ω, and T_A = 25°C, unless otherwise noted. Total ionizing dose (TID) testing characterized to 30 krads, no SEL occurs at ≤ 62.4 MeV-cm^2/mg linear energy transfer.

Table 3.

Parameter	Min	Typ	Max	Unit
FREQUENCY RANGE	7		9	GHz
GAIN	17	19		dB
OUTPUT				
OP1dB	16.5	19		dBm
SUPPLY CURRENT (I_{DQ})		95		mA
SUPPLY VOLTAGE				
V_{DD}	2	5	6	V

ABSOLUTE MAXIMUM RATINGS

Table 4.

Parameter	Rating
V_{DD}	7 V
RF_{IN} Power	25 dBm
Continuous Power Dissipation (P_{DISS}), T_A = 105°C (Derate 13.9 mW/°C Above 85°C)	0.973 W
Temperature	
Storage Range	−65°C to +150°C
Operating Range	−55°C to +105°C
Nominal Junction (T_A = 105°C, V_{DD} = 5 V, I_{DQ} = 95 mA)	139.2°C
Maximum Junction	175°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. Close attention to PCB thermal design is required.

θ_{JC} is the junction to case thermal resistance.

Table 5. Thermal Resistance

Package Type	θ_{JC}	Unit
CP-6-12	72	°C/W

OUTGAS TESTING

The criteria used for the acceptance and rejection of materials must be determined by the user and based upon specific component and system requirements. Historically, a total mass loss (TML) of 1.00% and collected volatile condensable material (CVCM) of 0.10% have been used as screening levels for rejection of spacecraft materials.

Table 6. Outgas Testing

Specification (Tested per ASTM E595 -15)	Value	Unit
Total Mass Lost	0.08	%
Collected Volatile Condensable Material	<0.01	%
Water Vapor Recovered	0.04	%

RADIATION TESTING

Table 7. Radiation Testing

Specifications	Value	Unit
Maximum Total Dose Available (dose rate = 50 to 300 rads (Si)/sec)[1]	30	krads (Si)
No Single Event Latch-Up (SEL) Occurs at Effective Linear Energy Transfer (LET)[2]	≤62.4	MeV-cm^2/mg

[1] Guaranteed by device and process characterization. Contact Analog Devices for data available up to 30 krads.

[2] Limits are characterized at initial qualification and after any design or process changes that may affect the SEL characteristics, but are not production lot tested unless specified by the customer through the purchase order or contract. For more information on single event effect (SEE) test results, contact Analog Devices for further data beyond published report on the Analog Devices website.

ELECTROSTATIC DISCHARGE (ESD) RATINGS

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

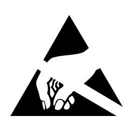
Human body model (HBM) per ANSI/ESDA/JEDEC JS-001.

ESD Ratings for HMC8413-CSL

Table 8. HMC8413-CSL, 6-Lead LFCSP

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

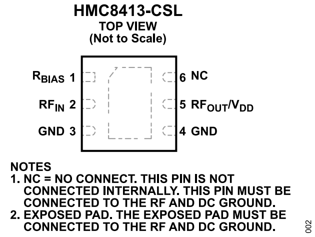


Figure 2. Pin Configuration

Table 9. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	R_{BIAS}	Current Mirror Bias Resistor. Use the R_{BIAS} pin via the external resistor (R2, see Figure 1) to set the current to the internal resistor.
2	RF_{IN}	RF Input. The RF_{IN} pin is DC-coupled and matched to 50 Ω.
3, 4	GND	Ground. This pin must be connected to the RF and DC ground.
5	RF_{OUT}/V_{DD}	RF Output/Drain Bias for the Amplifier. The RF_{OUT}/V_{DD} pin is DC-coupled and matched to 50 Ω.
6	NC	No Connect. This pin is not connected internally. This pin must be connected to the RF and DC ground.
	EPAD	Exposed Pad. The exposed pad must be connected to the RF and DC ground.

TYPICAL PERFORMANCE CHARACTERISTICS

I_{DQ} is the collector current without RF signal applied, and I_{DD} is the collector current with RF signal applied.

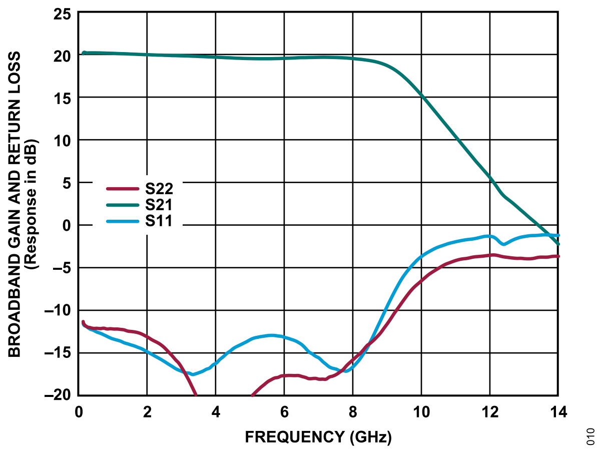


Figure 3. Broadband Gain and Return Loss vs. Frequency, 200 MHz to 14 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA (S22 Is the Output Return Loss, S21 Is the Gain, and S11 Is the Input Return Loss)

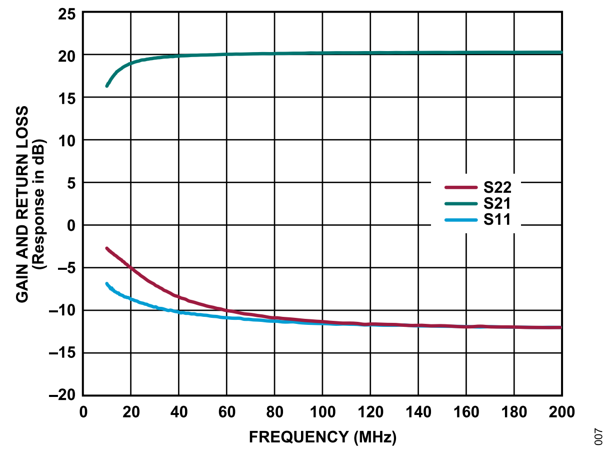


Figure 6. Gain and Return Loss vs. Frequency, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

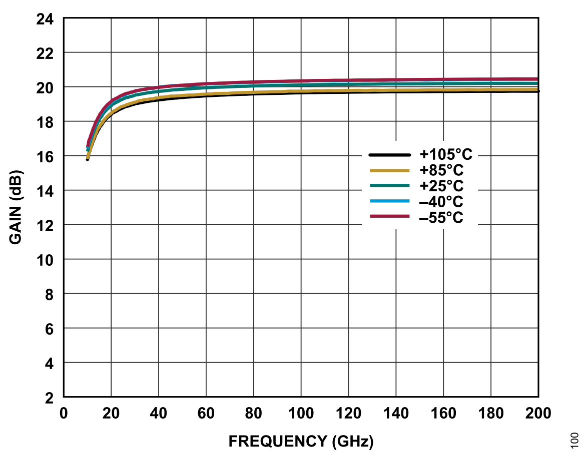


Figure 4. Gain vs. Frequency for Various Temperatures, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

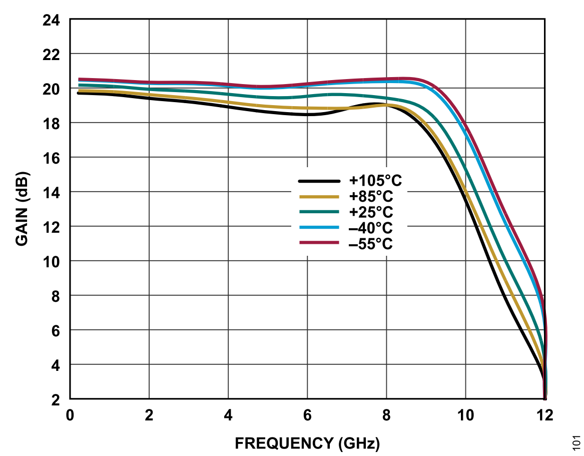


Figure 7. Gain vs. Frequency for Various Temperatures, 200 MHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

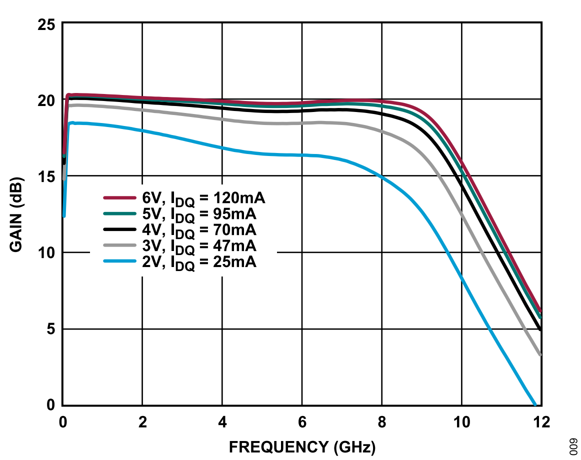


Figure 5. Gain vs. Frequency for Various Supply Voltages and I_{DQ}, R_{BIAS} = 787 Ω

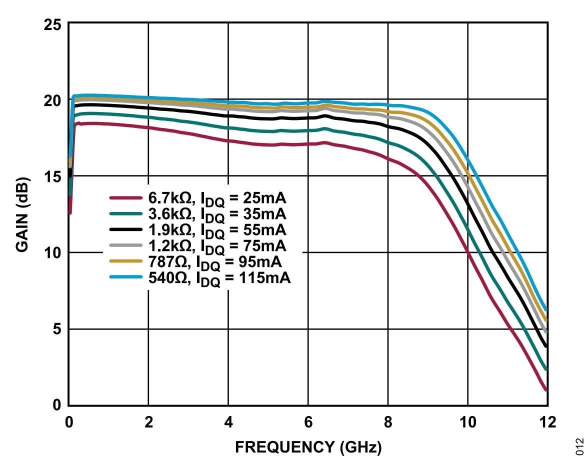


Figure 8. Gain vs. Frequency for Various Bias Resistor Values and I_{DQ}, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

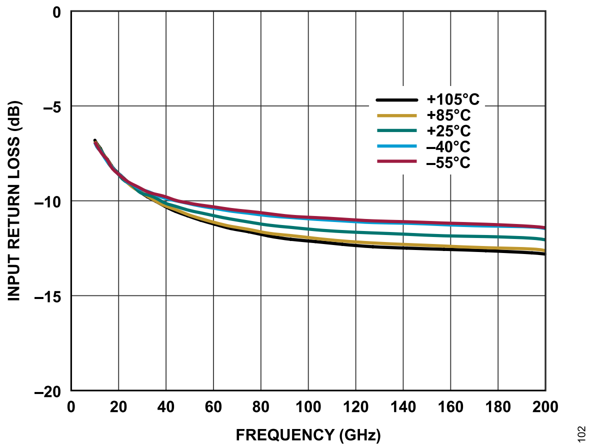


Figure 9. Input Return Loss vs. Frequency for Various Temperatures, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

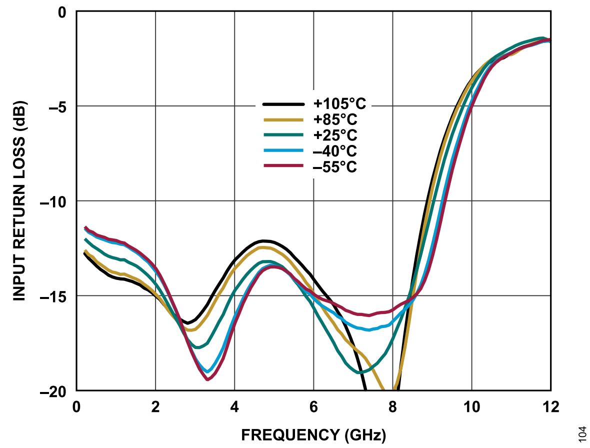


Figure 12. Input Return Loss vs. Frequency for Various Temperatures, 200 MHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

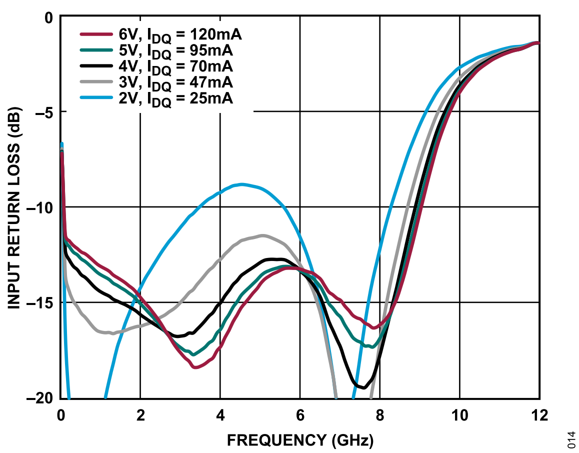


Figure 10. Input Return Loss vs. Frequency for Various Supply Voltages and I_{DQ}, R_{BIAS} = 787 Ω

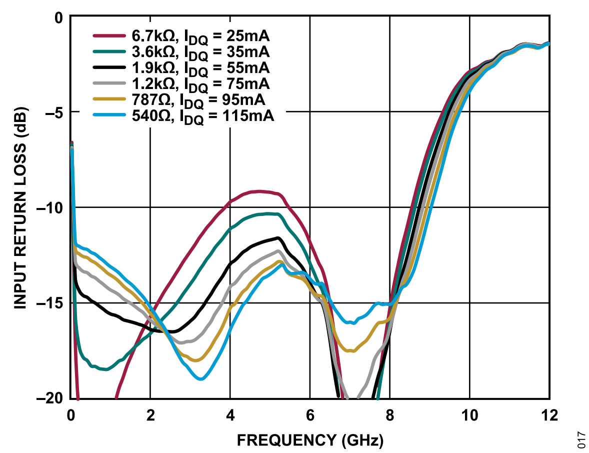


Figure 13. Input Return Loss vs. Frequency for Various Bias Resistor Values and I_{DQ}, V_{DD} = 5 V

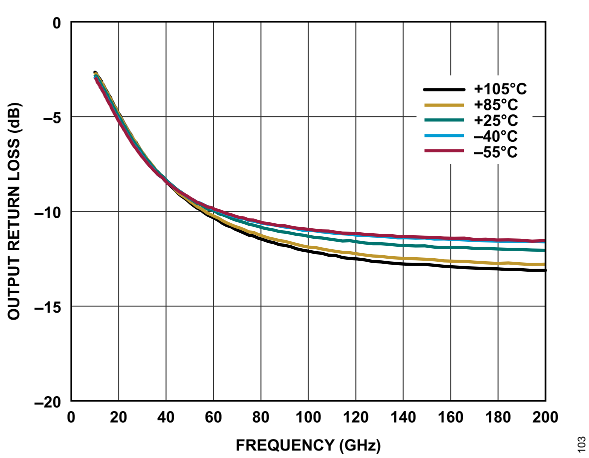


Figure 11. Output Return Loss vs. Frequency for Various Temperatures, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

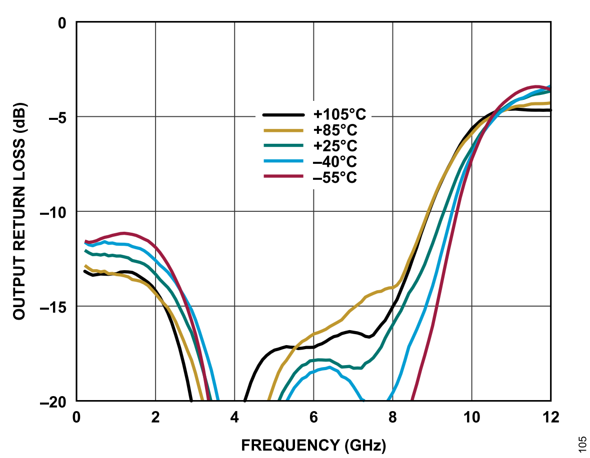


Figure 14. Output Return Loss vs. Frequency for Various Temperatures, 200 MHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

TYPICAL PERFORMANCE CHARACTERISTICS

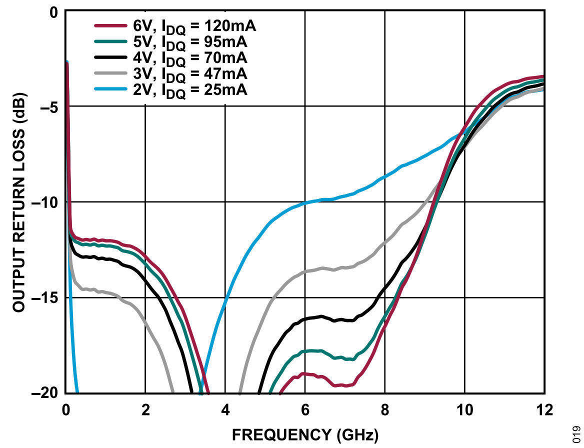


Figure 15. Output Return Loss vs. Frequency for Various Supply Voltages and I_{DQ}, R_{BIAS} = 787 Ω

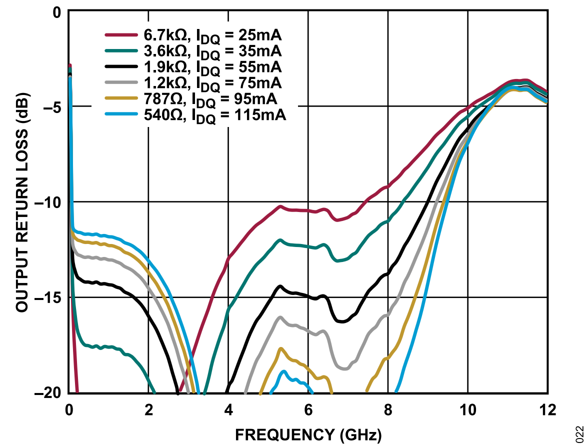


Figure 18. Output Return Loss vs. Frequency for Various Bias Resistor Values and I_{DQ}, V_{DD} = 5 V

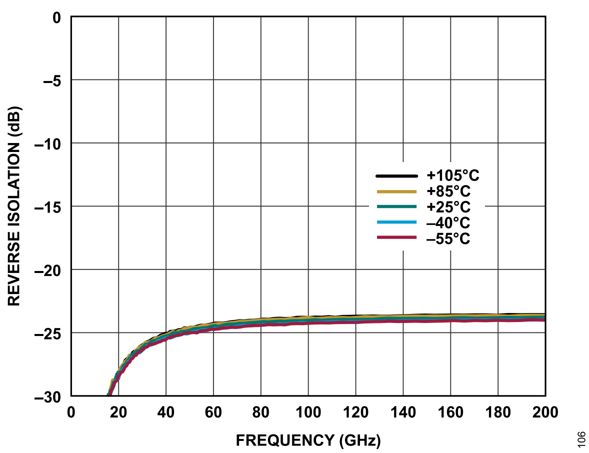


Figure 16. Reverse Isolation vs. Frequency for Various Temperatures, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

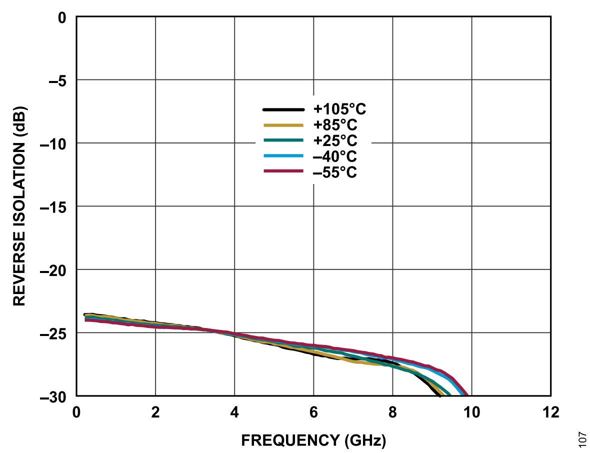


Figure 19. Reverse Isolation vs. Frequency for Various Temperatures, 200 MHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

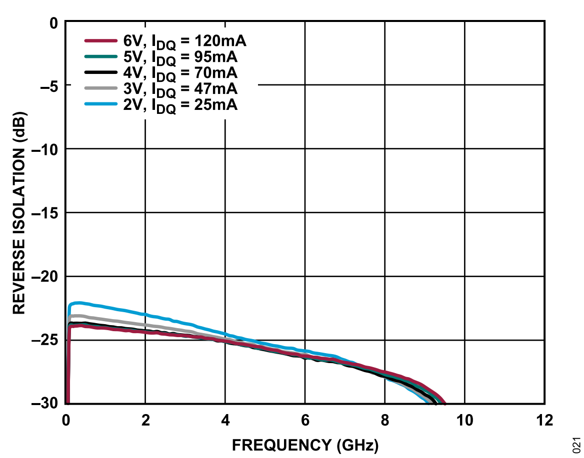


Figure 17. Reverse Isolation vs. Frequency for Various Supply Voltages and I_{DQ}, R_{BIAS} = 787 Ω

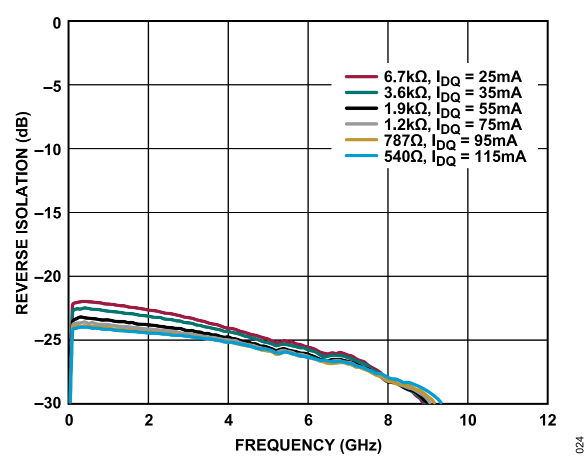


Figure 20. Reverse Isolation vs. Frequency for Various Bias Resistor Values and I_{DQ}, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

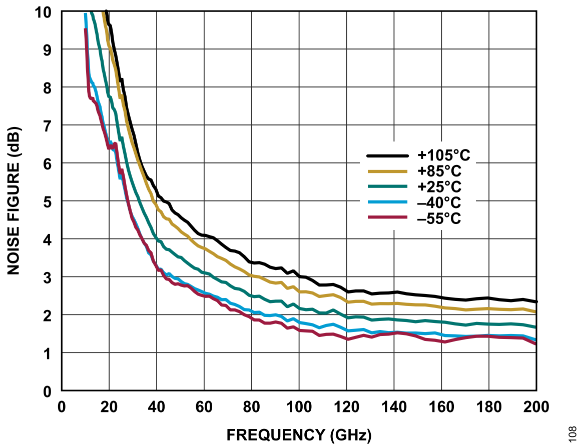


Figure 21. Noise Figure vs. Frequency for Various Temperatures, 10 MHz to 200 MHz, V_{DD} = 5 V, I_{DQ} = 95 mA

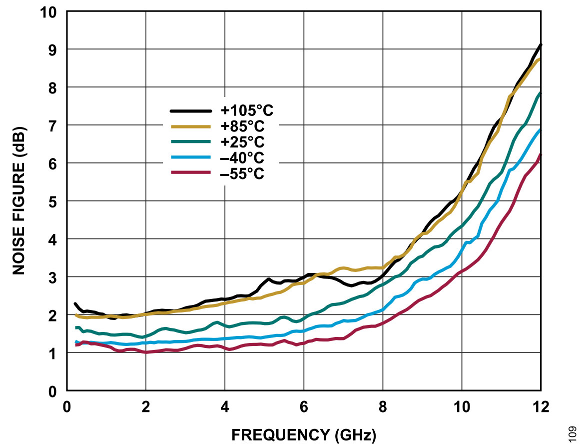


Figure 24. Noise Figure vs. Frequency for Various Temperatures, 200 MHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

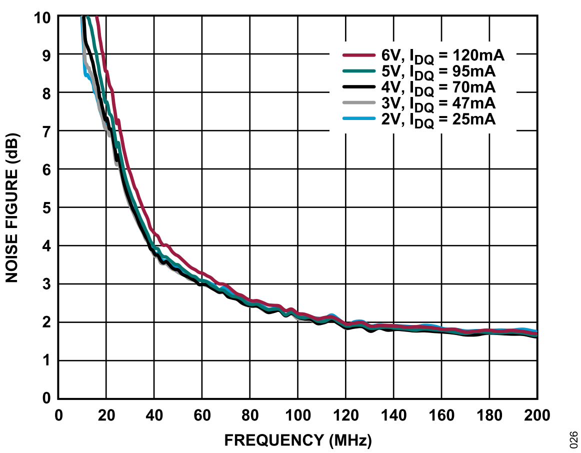


Figure 22. Noise Figure vs. Frequency for Various Supply Voltages and I_{DQ}, 10 MHz to 200 MHz, R_{BIAS} = 787 Ω

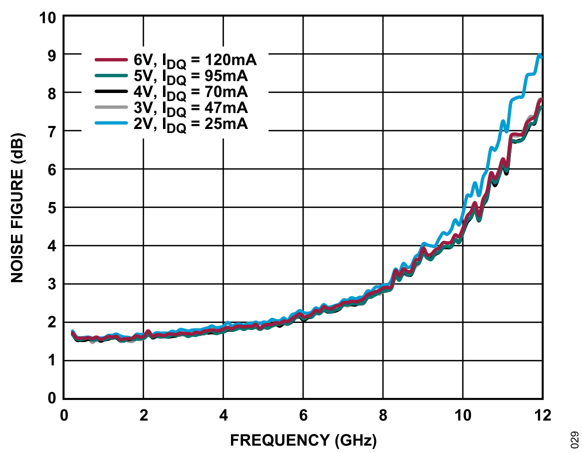


Figure 25. Noise Figure vs. Frequency for Various Supply Voltages and I_{DQ}, 200 MHz to 12 GHz, R_{BIAS} = 787 Ω

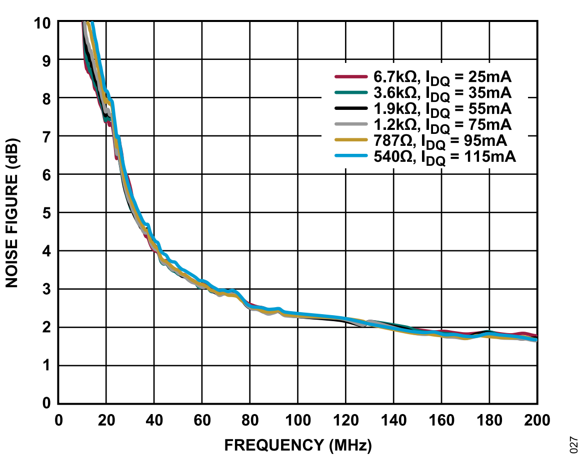


Figure 23. Noise Figure vs. Frequency for Various Bias Resistor Values and I_{DQ}, 10 MHz to 200 MHz, V_{DD} = 5 V

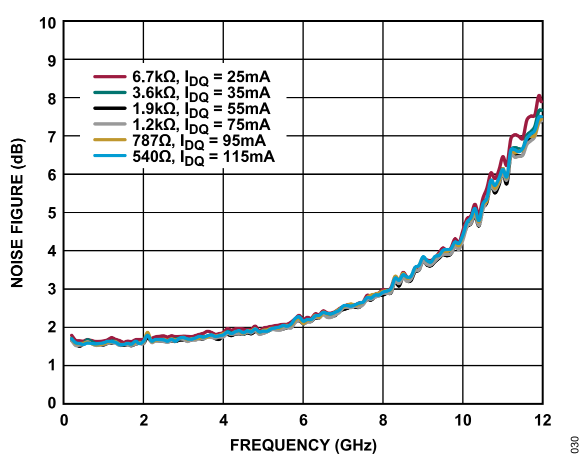


Figure 26. Noise Figure vs. Frequency for Various Bias Resistor Values and I_{DQ}, 200 MHz to 12 GHz, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

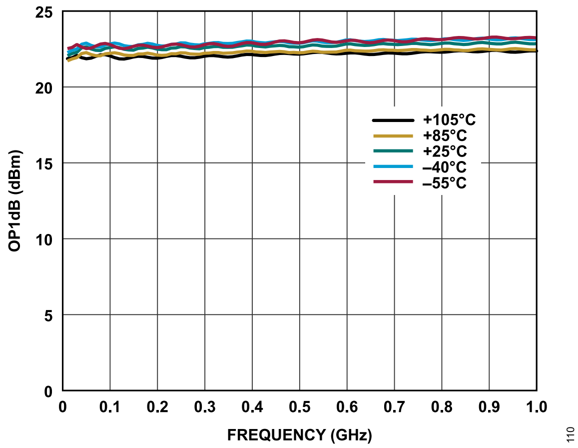


Figure 27. OP1dB vs. Frequency for Various Temperatures, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

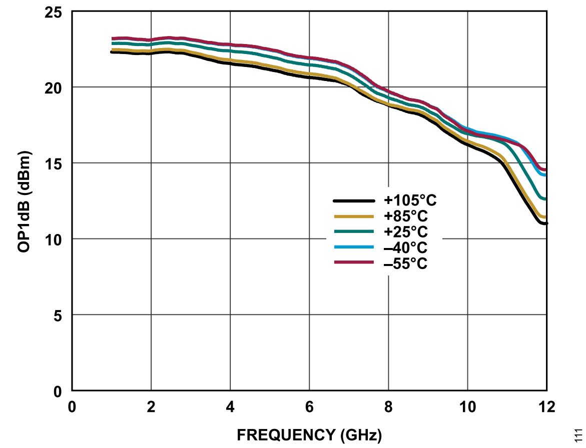


Figure 30. OP1dB vs. Frequency for Various Temperatures, 1 GHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

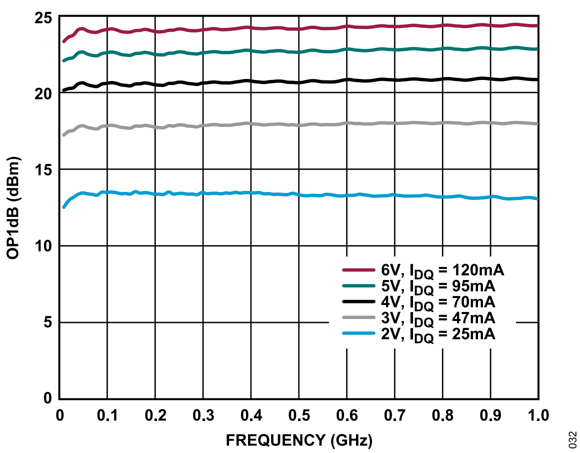


Figure 28. OP1dB vs. Frequency for Various Supply Voltages and I_{DQ}, 0.01 GHz to 1.0 GHz, R_{BIAS} = 787 Ω

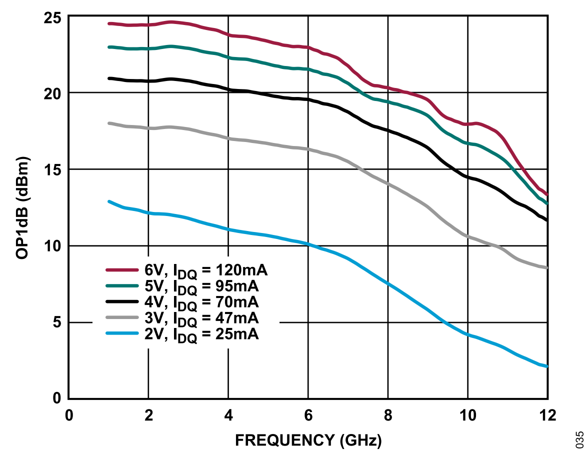


Figure 31. OP1dB vs. Frequency for Various Supply Voltages and I_{DQ}, 1 GHz to 12 GHz, R_{BIAS} = 787 Ω

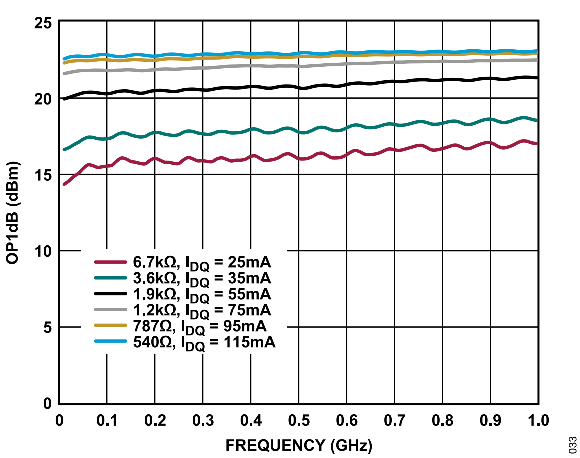


Figure 29. OP1dB vs. Frequency for Various Bias Resistor Values and I_{DQ}, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V

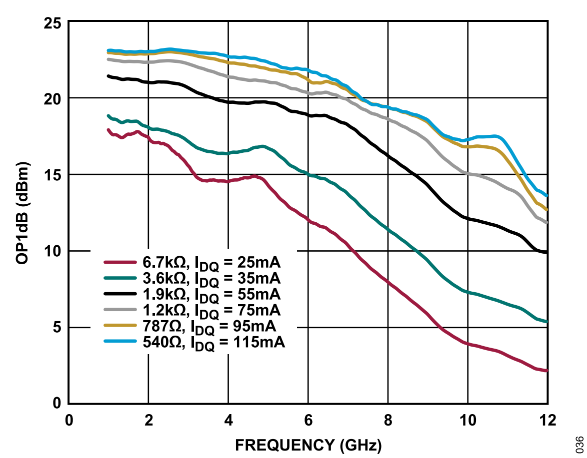


Figure 32. OP1dB vs. Frequency for Various Bias Resistor Values and I_{DQ}, 1 GHz to 12 GHz, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

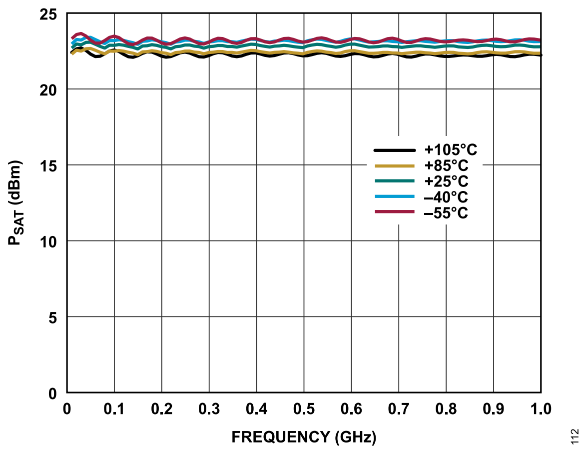


Figure 33. P_{SAT} vs. Frequency for Various Temperatures, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

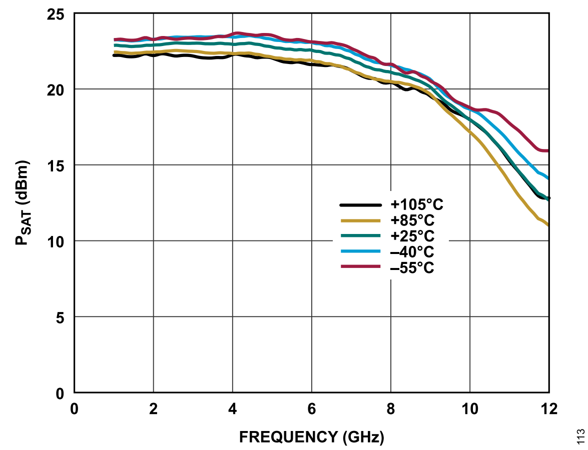


Figure 36. P_{SAT} vs. Frequency for Various Temperatures, 1 GHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

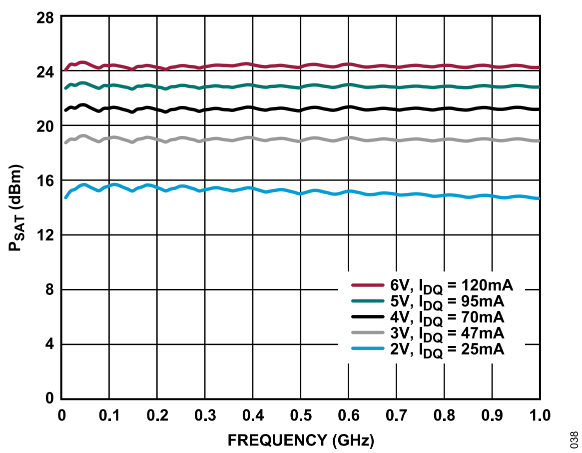


Figure 34. P_{SAT} vs. Frequency for Various Supply Voltages and I_{DQ}, 0.01 GHz to 1.0 GHz, R_{BIAS} = 787 Ω

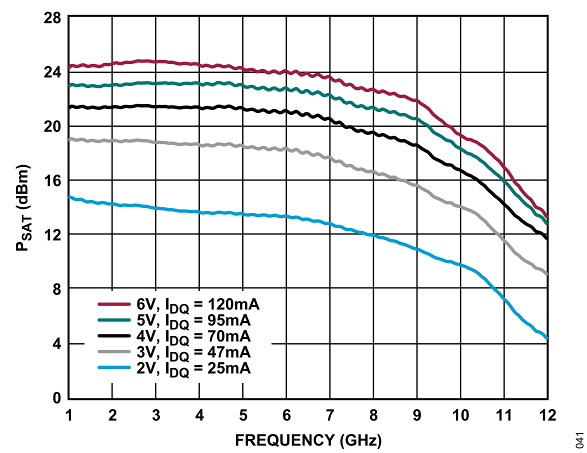


Figure 37. P_{SAT} vs. Frequency for Various Supply Voltages and I_{DQ}, 1 GHz to 12 GHz, R_{BIAS} = 787 Ω

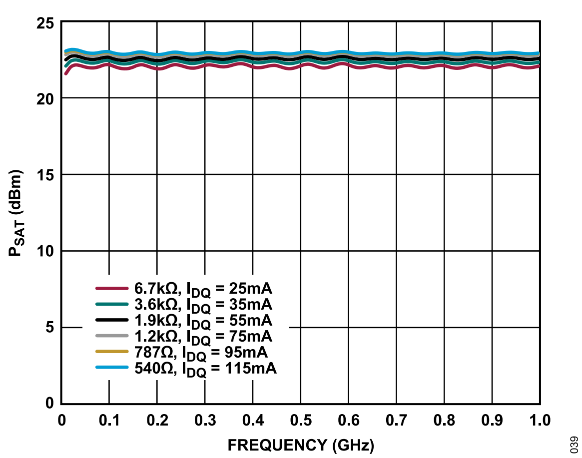


Figure 35. P_{SAT} vs. Frequency for Various Bias Resistor Values and I_{DQ}, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V

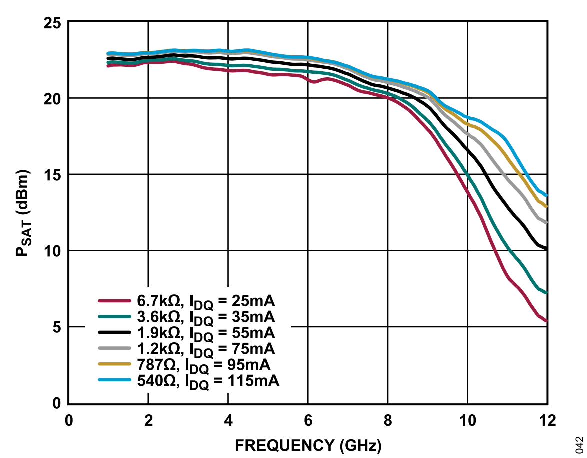


Figure 38. P_{SAT} vs. Frequency for Various Bias Resistor Values and I_{DQ}, 1 GHz to 12 GHz, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

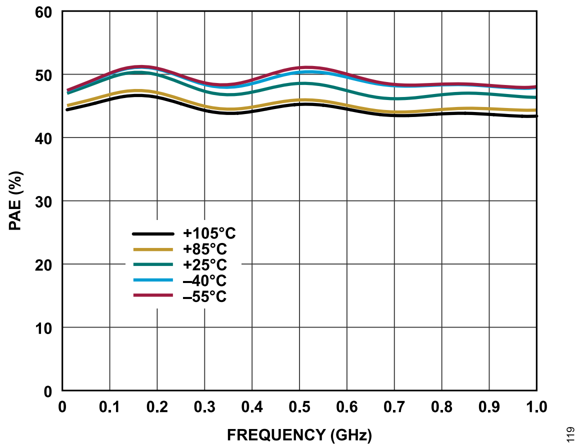


Figure 39. PAE vs. Frequency for Various Temperatures, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

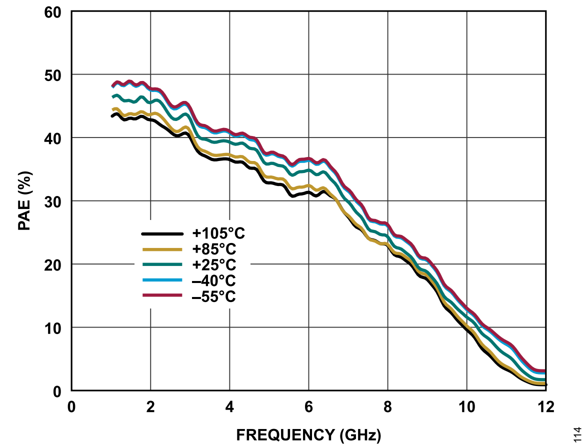


Figure 42. PAE vs. Frequency for Various Temperatures, 1 GHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

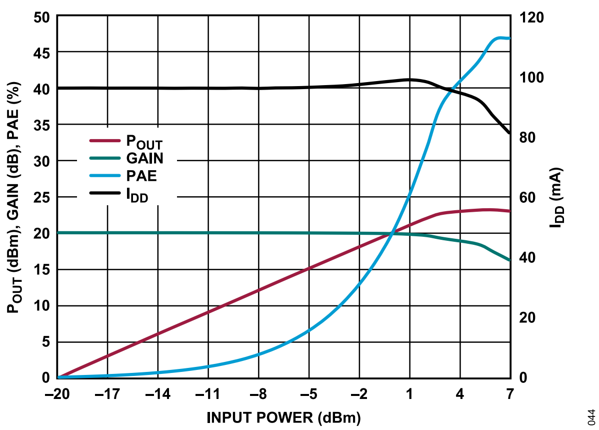


Figure 40. P_{OUT}, Gain, PAE, and I_{DD} vs. Input Power, Power Compression at 1 GHz, V_{DD} = 5 V, R_{BIAS} = 787 Ω

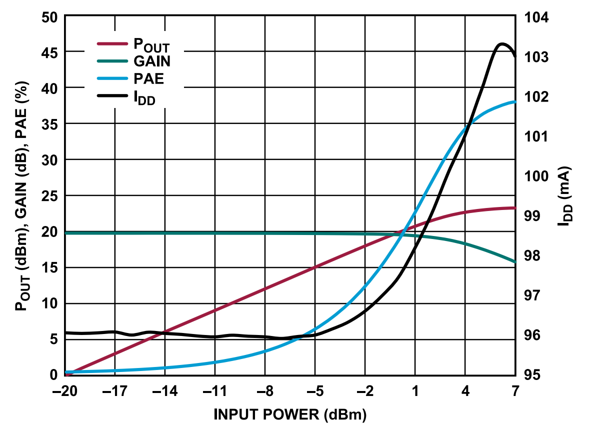


Figure 43. P_{OUT}, Gain, PAE, and I_{DD} vs. Input Power, Power Compression at 5 GHz, V_{DD} = 5 V, R_{BIAS} = 787 Ω

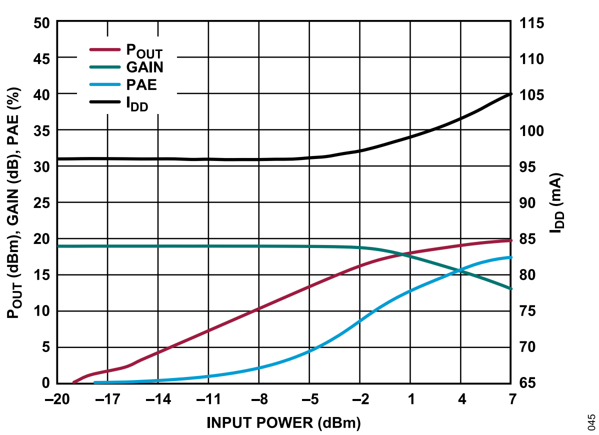


Figure 41. P_{OUT}, Gain, PAE, and I_{DD} vs. Input Power, Power Compression at 9 GHz, V_{DD} = 5 V, R_{BIAS} = 787 Ω

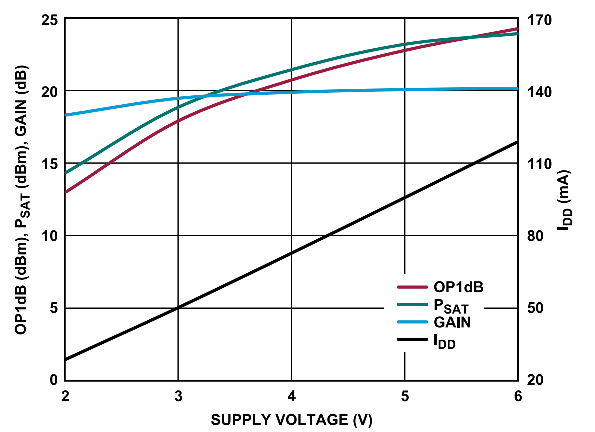


Figure 44. OP1dB, P_{SAT}, Gain, and I_{DD} vs. Supply Voltage, Power Compression at 1 GHz, R_{BIAS} = 787 Ω

TYPICAL PERFORMANCE CHARACTERISTICS

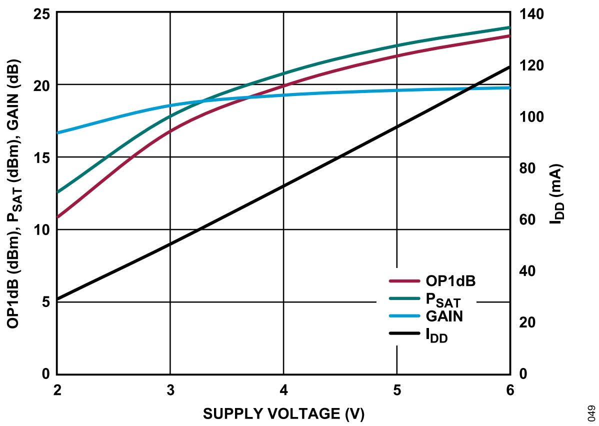


Figure 45. OP1dB, P_{SAT}, Gain, and I_{DD} vs. Supply Voltage, Power Compression at 5 GHz, R_{BIAS} = 787 Ω

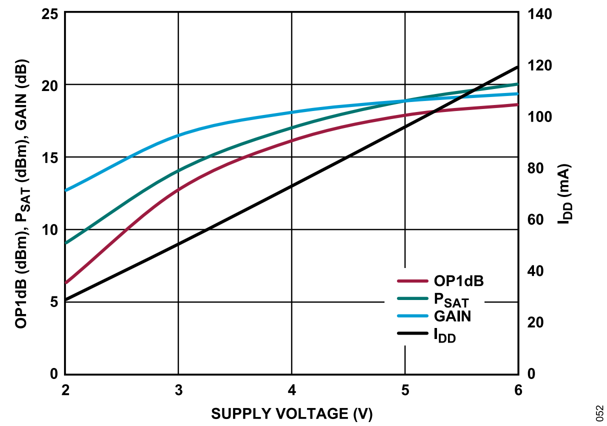


Figure 48. OP1dB, P_{SAT}, Gain, and I_{DD} vs. Supply Voltage, Power Compression at 9 GHz, R_{BIAS} = 787 Ω

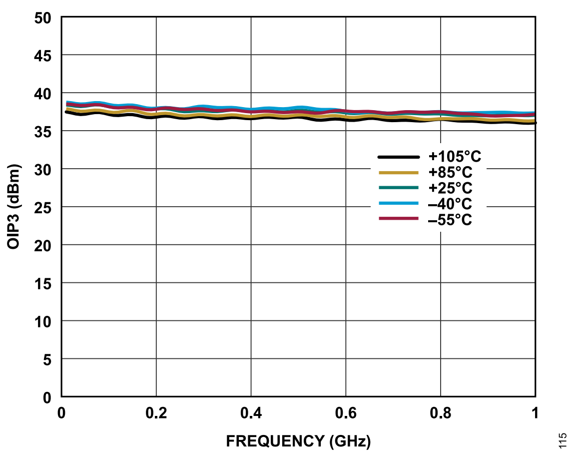


Figure 46. OIP3 vs. Frequency for Various Temperatures, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

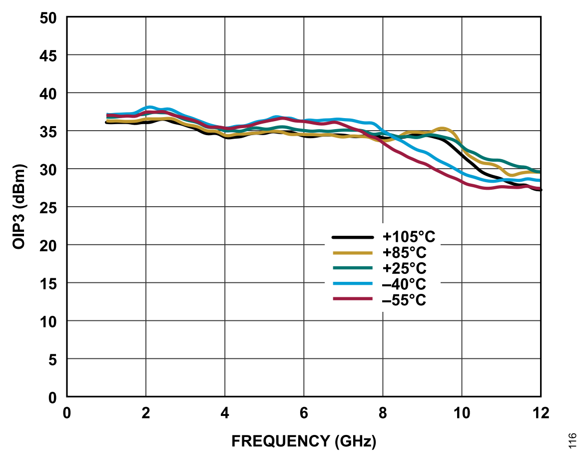


Figure 49. OIP3 vs. Frequency for Various Temperatures, 1 GHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

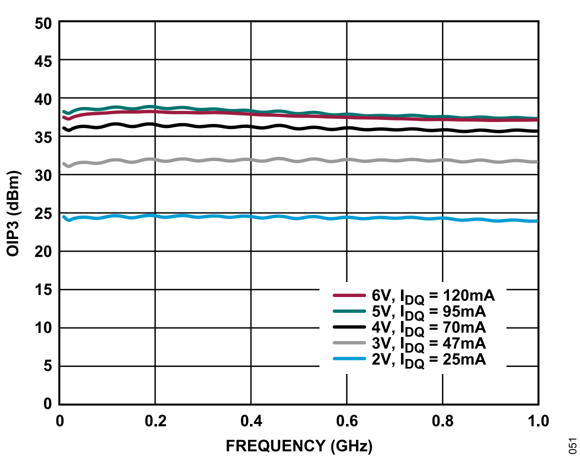


Figure 47. OIP3 vs. Frequency for Various Supply Voltages and I_{DQ}, 0.01 GHz to 1.0 GHz, R_{BIAS} = 787 Ω

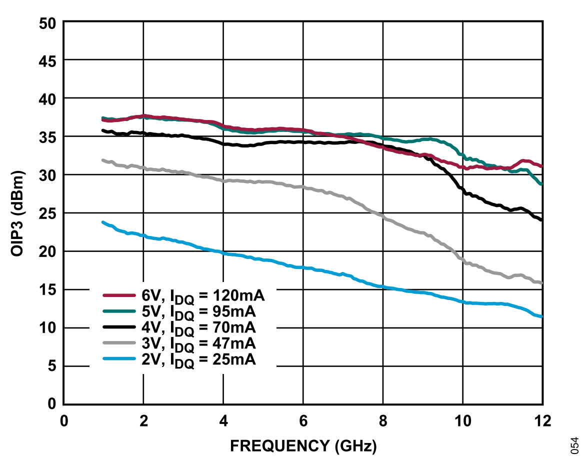


Figure 50. OIP3 vs. Frequency for Various Supply Voltages and I_{DQ}, 1 GHz to 12 GHz, R_{BIAS} = 787 Ω

TYPICAL PERFORMANCE CHARACTERISTICS

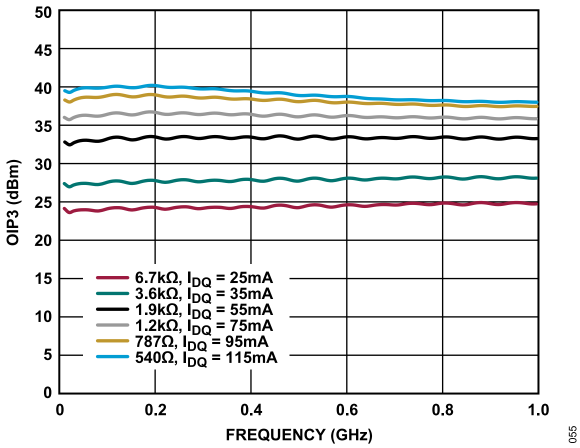


Figure 51. OIP3 vs. Frequency for Various Bias Resistor Values and I_{DQ}, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V

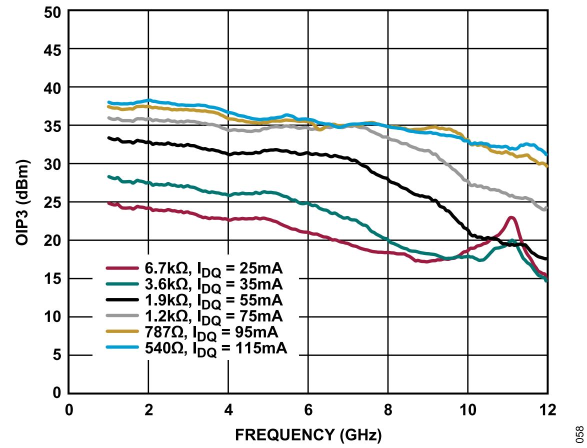


Figure 54. OIP3 vs. Frequency for Various Bias Resistor Values and I_{DQ}, 1 GHz to 12 GHz, V_{DD} = 5 V

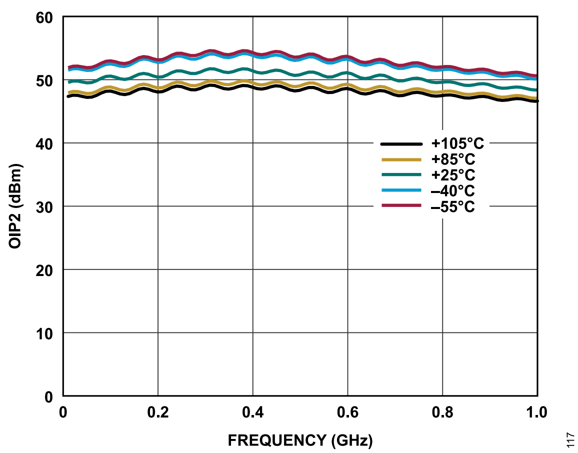


Figure 52. OIP2 vs. Frequency for Various Temperatures, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

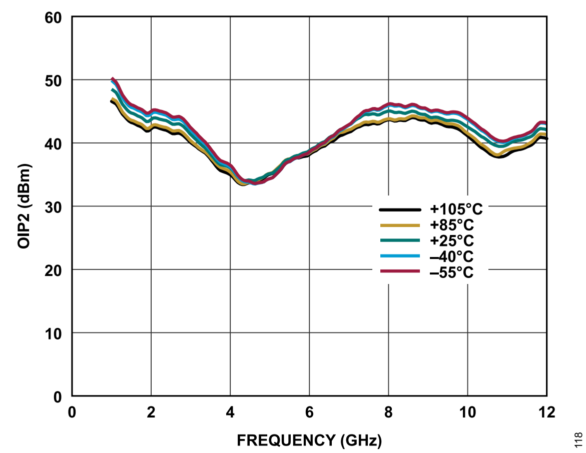


Figure 55. OIP2 vs. Frequency for Various Temperatures, 1 GHz to 12 GHz, V_{DD} = 5 V, I_{DQ} = 95 mA

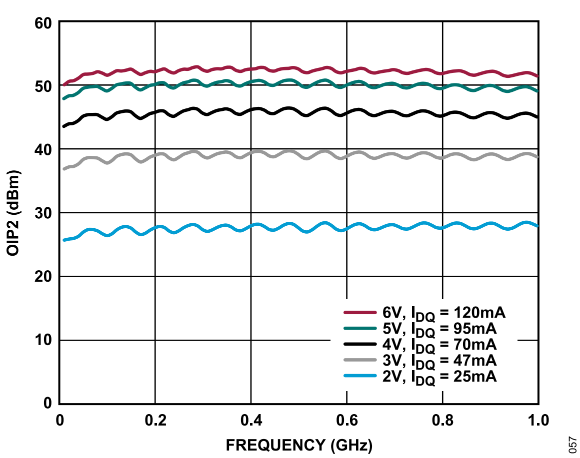


Figure 53. OIP2 vs. Frequency for Various Supply Voltages and I_{DQ}, 0.01 GHz to 1.0 GHz, R_{BIAS} = 787 Ω

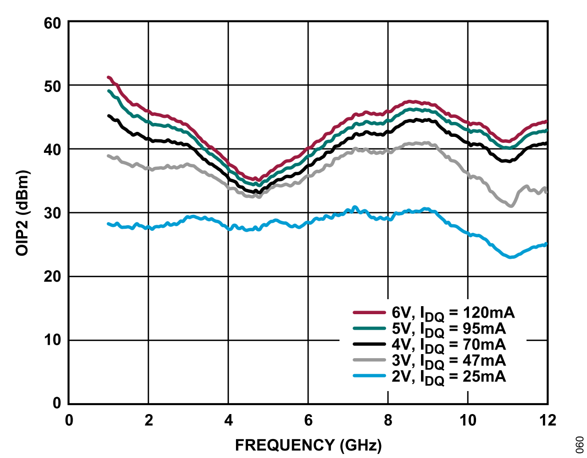


Figure 56. OIP2 vs. Frequency for Various Supply Voltages and I_{DQ}, 1 GHz to 12 GHz, R_{BIAS} = 787 Ω

TYPICAL PERFORMANCE CHARACTERISTICS

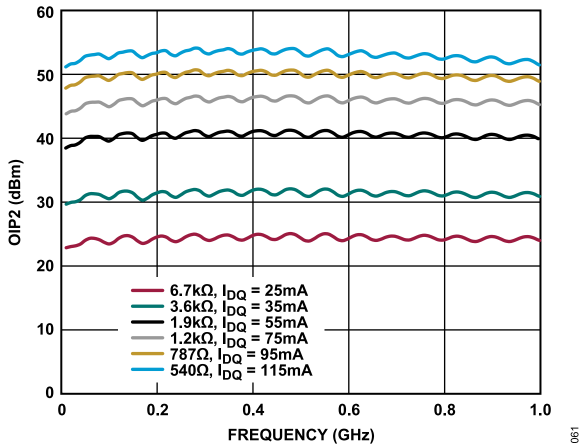


Figure 57. OIP2 vs. Frequency for Various Bias Resistor Values and I_{DQ}, 0.01 GHz to 1.0 GHz, V_{DD} = 5 V

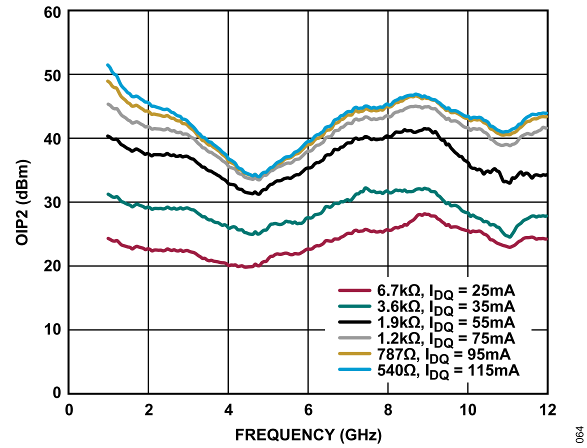


Figure 60. OIP2 vs. Frequency for Various Bias Resistor Values and I_{DQ}, 1 GHz to 12 GHz, V_{DD} = 5 V

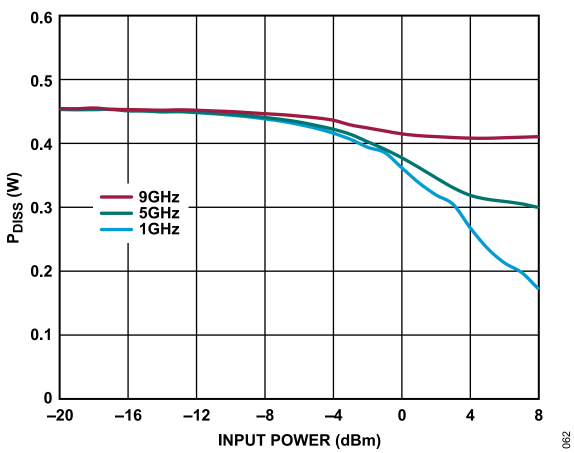


Figure 58. P_{DISS} vs. Input Power at T_A = 85°C, V_{DD} = 5 V, I_{DQ} = 95 mA

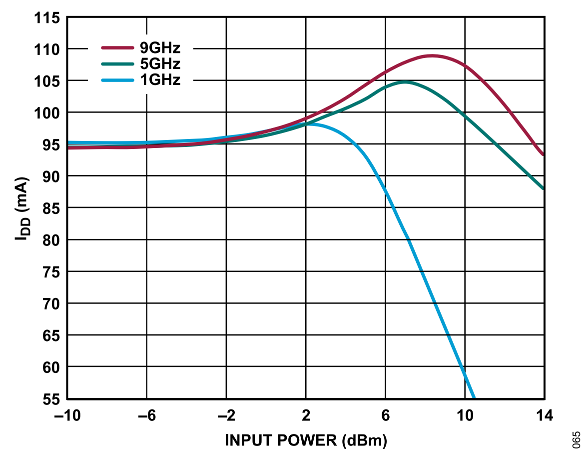


Figure 61. I_{DD} vs. Input Power for Various Frequencies, V_{DD} = 5 V

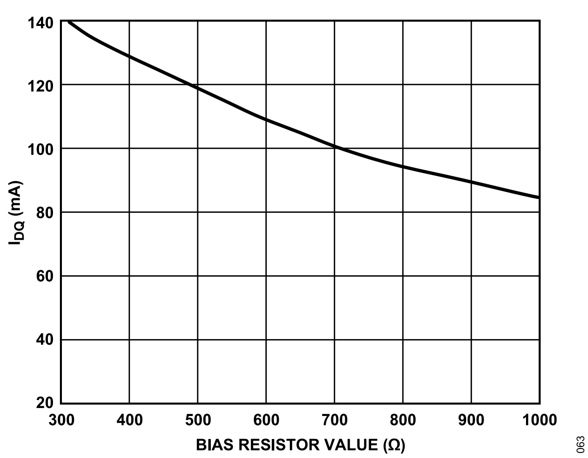


Figure 59. I_{DQ} vs. Bias Resistor Value, 300 Ω to 1 kΩ, V_{DD} = 5 V

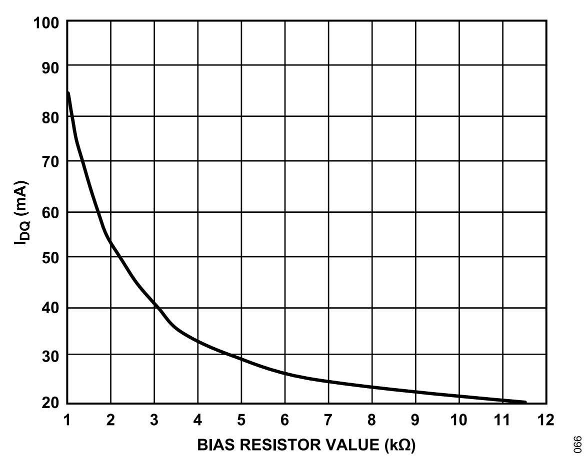


Figure 62. I_{DQ} vs. Bias Resistor Value, 1 kΩ to 12 kΩ, V_{DD} = 5 V

TYPICAL PERFORMANCE CHARACTERISTICS

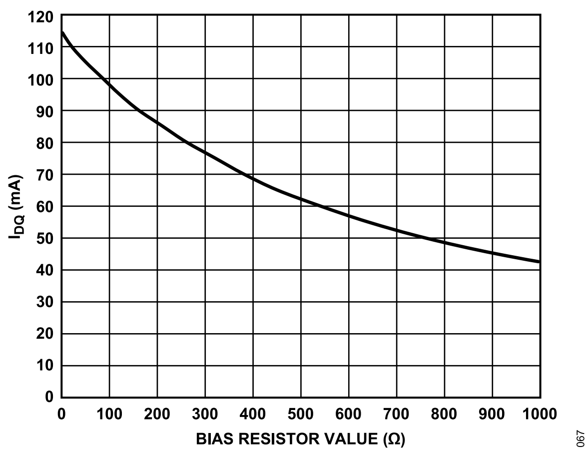


Figure 63. I_{DQ} vs. Bias Resistor Value, 1 Ω to 1 kΩ, V_{DD} = 3 V

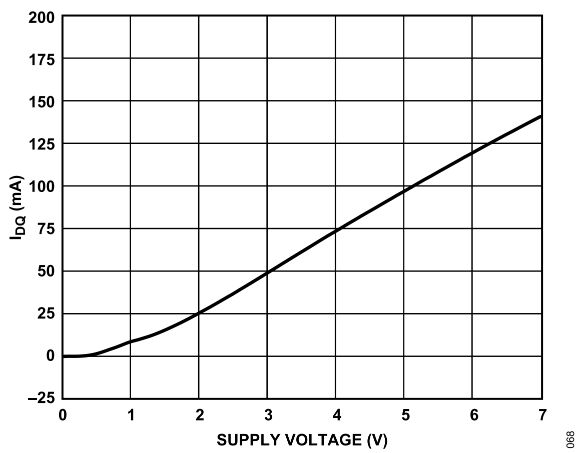


Figure 64. I_{DQ} vs. Supply Voltage, R_{BIAS} = 787 Ω

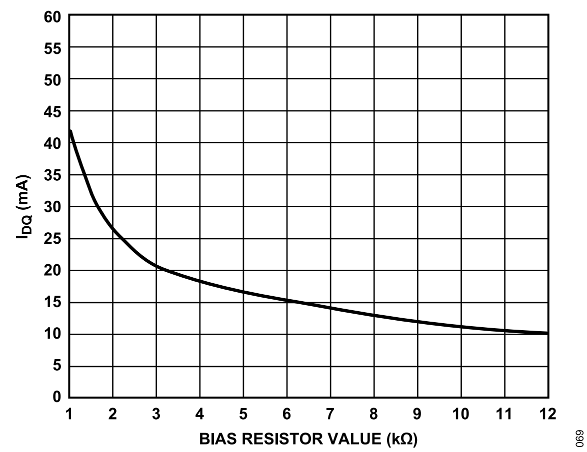


Figure 65. I_{DQ} vs. Bias Resistor Value, 1 kΩ to 12 kΩ, V_{DD} = 3 V

OUTLINE DIMENSIONS

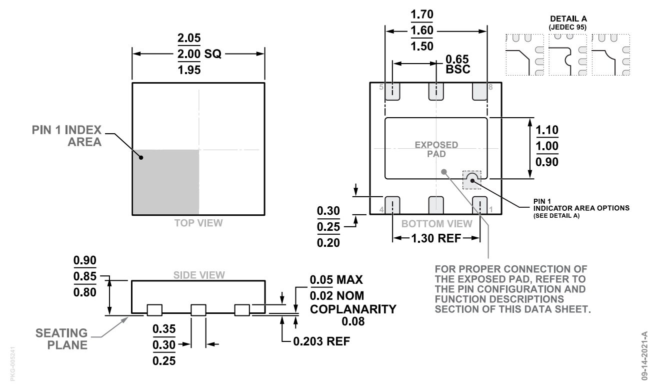


Figure 66. 6-Lead Lead Frame Chip Scale Package [LFCSP] 2 mm × 2 mm Body and 0.85 mm Package Height (CP-6-12) Dimensions shown in millimeters

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Package Option
HMC8413LP2FE-CSL	−55°C to +105°C	6-Lead Lead Frame Chip Scale Package [LFCSP]	CP-6-12
HMC8413LP2FETR-CSL	−55°C to +105°C	6-Lead Lead Frame Chip Scale Package [LFCSP]	CP-6-12

1 The HMC8413LP2FE-CSL and HMC8413LP2FETR-CSL are RoHS compliant parts.