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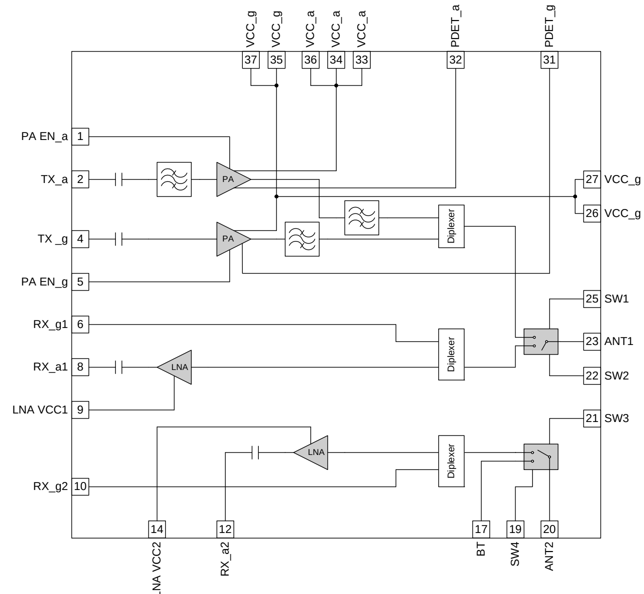
RF5389

3.3V, DUAL-BAND FRONT-END MODULE

Package Style: QFN, 40-Pin, 6mmx6mmx0.95mm



Functional Block Diagram

Features

- Single 1x2 11n MIMO FEM
- Single Supply Voltage 3.0V to 3.6V
- Integrated 2.5GHz & 5GHZ PA's, Diplexers, Filters & Switches for TX & RX
- P_{OUT}=18dBm, 11g, OFDM@<4% EVM
  P_{OUT}=16dBm, 11a, OFDM 4% Typ EVM

Applications

- IEEE802.11a/b/g/n Applications
- Single-Chip RF Front-End Module
- 2.5GHz and 5GHz ISM Bands Applications
- WiFi Systems
- Portable Battery-Powered Equipment
- Supports 1x2 11n MIMO Applications

Product Description

The RF5389 is a single-chip dual-band integrated front-end module (FEM) for high-performance WiFi applications in the 2.5GHz and 5GHz ISM bands. The RF5389 addresses the need for aggressive size reduction for typical 802.11a/b/g and 1x2 11n MIMO RF front-end design and greatly reduces the number of components outside of the core chipset thus minimizing the footprint and assembly cost of the overall 802.11a/b/g and 11n solution. The RF5389 contains integrated PA's for 2.5GHz and 5GHz, diplexers, TX/RX switch, dual LNA's for high receive bands, matching components, some bypass capacitors, built-in power detector for both bands, and filtering for transmit and receive paths. The RF5389 is packaged in a 40-pin, 6mmx6mmx0.95mm QFN package with backside ground which greatly minimizes next level board space and allows for simplified integration.

Ordering Information

RF5389	Standard 25 piece bag
RF5389SR	Standard 100 piece reel
RF5389TR7	Standard 2500 piece reel
RF5389PCK-410	Fully assembled evaluation board and 5 piece loose samples

Optimum Technology Matching® Applied

☐ GaAs HBT	☐ SiGe BiCMOS	☑ GaAs pHEMT	☐ GaN HEMT
☐ GaAs MESFET	☐ Si BiCMOS	☐ Si CMOS	
☑ InGaP HBT	☐ SiGe HBT	☐ Si BJT	

Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Voltage	-0.3 to +4.0	V_{DC}
Power Control Voltage (PA EN)	-0.5 to +3.5	V
DC Supply Current	400	mA
Input RF Power	+10	dBm
Operating Ambient Temperature	-10 to +70	°C
Reduced Performance Temp	-30 to -10	°C
	+70 to +85	°C
Storage Temperature	-40 to +85	°C
Moisture Sensitivity	JEDEC Level MSL3	

Caution! ESD sensitive device.

Exceeding any one or a combination of the Absolute Maximum Rating conditions may cause permanent damage to the device. Extended application of Absolute Maximum Rating conditions to the device may reduce device reliability. Specified typical performance or functional operation of the device under Absolute Maximum Rating conditions is not implied.

RoHS status based on EUDirective2002/95/EC (at time of this document revision).

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Transmit					T=+25°C, V_{CC}(b/g)=3.3V, PAEN_g=2.85V, Pulsed at 1% to 100% duty cycle, Freq=2.4GHz to 2.5GHz, unless otherwise noted.
Compliance					IEEE802.11b, IEEE802.11g FCC CFR 15.247, 0.205, 0.209
Frequency	2.4		2.5	GHz	
Output Power		14		dBm	With a standard IEEE802.11g waveform @ 54Mbps, 64 QAM
EVM*		2		%	At 14dBm, 11g output power, rated 11g P_{OUT}, RMS, Mean with a standard IEEE802.11g waveform, OFDM, 54Mbps, 64 QAM
Output Power		18		dBm	With a standard IEEE802.11g waveform @ 54Mbps, 64 QAM
EVM*		4		%	At rated 11g P_{OUT}, RMS, Mean with a standard IEEE802.11g waveform, OFDM, 54Mbps, 64 QAM
Output Power		20		dBm	With a standard IEEE802.11b waveform @ 11Mbps, CCK
Gain	24	26		dB	
Gain Variance		±2.0		dB	Over Temperature and Frequency
Power Detect					
P_{DET} Voltage Range	0.1	1.8	TBD	V	P_{OUT}=0dBm to 20dBm in 11b mode with 11Mbps
P_{DET} Output Resistance		10		kΩ	
P_{DET} Output Capacitance		5		pF	
P_{DET} Bandwidth		8		MHz	
P_{DET} Sensitivity					
>10dBm	25			mV/dB	
$0<P_{OUT}<10$dBm	8			mV/dB	
Current Operating		140		mA	RF P_{OUT}=18dBm with a standard IEEE802.11g waveform, OFDM, 54Mbits/s, 64 QAM
		180		mA	RF P_{OUT}=20dBm with a standard IEEE802.11b waveform, CCK, 11Mbits/s

*The EVM specification includes a 0.5% to 0.7% source EVM floor.

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Transmit, cont.					
Idle Current		100		mA	
PAEN_g Current		3		mA	V_{CC}=ON, PAEN_g=ON, and RF=ON
Shutdown		5		uA	V_{CC}=ON, PAEN_g=OFF, and RF=OFF
V_{CC} (Power Supply)	3.0	3.3	3.6	V	
PA EN_g Voltage	2.8	2.85	2.9	V	PAEN_g is in the high state (ON)
	-0.2		+0.2	V	PAEN_g is in the off state (OFF)
Switch Voltages	3.0		3.6	V	Switch voltage in the high state.
	0		0.2	V	Switch voltage in the low state.
Input Impedance		50		Ω	
Output Impedance		50		Ω	
Stability Output VSWR	4:1				Stable, max spurious -47dBm
Ruggedness Output VSWR	10:1				No damage, conditions: max operating voltage, max input power
Second Harmonic			-43	dBm	Freq=2400MHz to 2500MHz@18dBm P_{OUT}, RBW=1MHz, average detector tested with 1Mbps
Turn-On Time		0.5	1.0	µsec	Output stable to within 90% of final gain
Turn-Off Time		0.5	1.0	µsec	Output stable to within 90% of final gain
5.0GHz Transmit					T=+25°C, V_{CC}(a)=3.3V, PAEN_a=2.85V, Pulsed at 1% to 100% duty cycle, Freq=4.9GHz to 5.85GHz, unless otherwise noted.
Compliance					IEEE802.11a IEEE802.11j FCC CFR 15.247, 0.205, 0.209
Frequency	4.9		5.85	GHz	
Output Power		16		dBm	With a standard IEEE802.11a waveform, OFDM, 54Mbits/s, 64 QAM
EVM*		4	6	%	RMS, mean with a standard IEEE802.11a waveform, OFDM, 54Mbits/s, 64 QAM at 16dBm output power
Output Power		13		dBm	With a standard IEEE802.11a waveform, OFDM, 54Mbits/s, 64 QAM
EVM*		2		%	RMS, mean with a standard IEEE802.11a waveform, OFDM, 54Mbits/s, 64 QAM at 13dBm output power
Gain	23	25		dB	
Gain Variance		±2.0		dB	
Power Detect					
P_{DET} Voltage Range	0.7	1.5	TBD	V	P_{OUT}=0dBm to 16dBm in 11a mode with 54Mbps
P_{DET} Output Resistance		10		kΩ	
P_{DET} Output Capacitance		5		pF	
P_{DET} Bandwidth		8		MHz	

*The EVM specification includes a 0.5% to 0.7% source EVM floor.

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
5.0GHz Transmit, cont.					
P_{DET} Sensitivity					
>10dBm	25			mV/dB	
$0<P_{OUT}<10$dBm	8			mV/dB	
Current Operating		150		mA	RF P_{OUT}=+16dBm, RMS, mean with a standard IEEE802.11g waveform, OFDM, 54Mbits/s, 64 QAM at rated output power
Idle Current		100		mA	
PAEN_a Current		8		mA	V_{CC}=ON, PAEN_a=ON, and RF=ON
Shutdown		5		μA	V_{CC}=ON, PAEN_a=OFF, and RF=OFF
V_{CC} (Power Supply)	3.0	3.3	3.6	V	
PA EN_a Voltage	2.8	2.85	2.9	V	PAEN_a is in the high state (ON)
	-0.2		+0.2	V	PAEN_a is in the off state (OFF)
Switch Voltages	3.0		3.6	V	Switch voltage in the high state.
	0		0.2	V	Switch voltage in the low state.
Input Impedance		50		Ω	
Output Impedance		50		Ω	
Stability Output VSWR	3:1				Stable, max spurious -47dBm Conditions: max operating voltage, max input power
Ruggedness Output VSWR	10:1				No damage, conditions: max operating voltage, max input power
Second Harmonic			-30	dBm	Fundamental frequency is between 4900MHz and 5299MHz at P_{OUT}=+16dBm measured with 6Mbps
			-43	dBm	Fundamental frequency is between 5300MHz and 5825MHz at P_{OUT}=+16dBm measured with 6Mbps
IEEE802.11a Spectral Mask per FCC Part 15.205			-43	dBm	Amplifier set up for best IEEE802.11a performance; F_C=5180MHz; RF P_{OUT}=+16dBm; T=+25°C, Measured @ 5150MHz
IEEE802.11a Spectral Mask per FCC Part 15.205			-43	dBm	Amplifier set up for best IEEE802.11a performance; F_C=5320MHz; RF P_{OUT}=+16dBm; T=+25°C, Measured @ 5350MHz
Turn-On Time		0.5	1.0	μsec	Output stable to within 90% of final gain
Turn-Off Time		0.5	1.0	μsec	Output stable to within 90% of final gain
Antenna Port Impedance					
Input		50		Ω	
Output		50		Ω	

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Receive, RX_g1 and RX_g2					
Compliance					IEEE802.11b IEEE802.11g IEEE802.11n FCC CFR 15.247, 0.205, 0.209
Frequency	2.4		2.5	GHz	
Insertion Loss		2.3		dB	SPDT switch+diplexer, 2.4GHz to 2.5GHz
Noise Figure		2.3		dB	SPDT switch+diplexer, 2.4GHz to 2.5GHz
Passband Ripple	-0.3		+0.3	dB	
Output Return Loss		-10		dB	
Current Consumption		15		μA	
Switch Voltages	3.0	3.3	3.6	V	Switch voltage in the high state.
	0		0.2	V	Switch voltage in the low state.
Switch Leakage			30	μA	
5.0GHz Receive, RX_a1 and RX_a2					
Compliance					IEEE802.11a IEEE802.11j FCC CFR 15.247, 0.205, 0.209
Frequency	4.9		5.9	GHz	
Insertion Gain		8		dB	
Noise Figure		4.9		dB	SPDT switch+diplexer+LNA
Input P1dB		-5		dBm	
Input IP3		+5		dBm	
Passband Ripple		±1		dB	
Output Return Loss		-10		dB	
Current Consumption		15		mA	
Switch Leakage Current			30	uA	
LNA V_{CC}	3.0	3.3	3.6	V	LNA V_{CC} is in the high state
	-0.2		+0.2	V	LNA V_{CC} is in the low state
5.0GHz Receive, RX_a1 and RX_a2, cont.					
Switch Voltages	3.0		3.6	V	Switch voltage in the high state.
	0		0.2	V	Switch voltage in the low state.
Bluetooth					
Frequency	2.4		2.5	GHz	
Insertion Loss			1.0	dB	SPDT switch
Passband Ripple	-0.2		+0.2	dB	
Input/Output Power			8	dBm	
Output Return Loss		-10		dB	
Output Impedance		50		Ω	No external matching
Current Consumption		15		μA	
Switch Voltages	3.0		3.6	V	Switch voltage in the high state.
	0		0.2	V	Switch voltage in the low state.

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Pin	Function	Description
1	PA EN_a	Bias voltage for the 802.11a PA. Internally decoupled port with approximately 100pF.
2	TX_a	TX RF input for the 802.11a PA. Input is matched to 50Ω and DC block is provided internally.
3	NC	Not connected.
4	TX_g	RF input for the 802.11b/g PA. Input is matched to 50Ω and DC block is provided.
5	PA ENg	Bias voltage for the 802.11b/g PA. Internally decoupled port with approximately 100pF.
6	RX_g1	Receive port for 802.11b/g band. Internally matched to 50Ω.
7	GND	Ground connection.
8	RX_a1	Receive port for 802.11a band. Internally matched to 50Ω and DC block is provided internally.
9	LNA VCC1	Voltage supply for the LNA.
10	RX_g2	Receive port for 802.11b/g band. Internally matched to 50Ω.
11	GND	Ground connection.
12	RX_a2	Receive port for 802.11a band. Internally matched to 50Ω and DC block is provided internally.
13	NC	Not connected.
14	LNA VCC2	Voltage supply for the LNA.
15	NC	Not connected.
16	GND	Ground connection.
17	BT	Bluetooth receive port.
18	GND	Ground connection.
19	SW4	Switch control port.
20	ANT2	RF output. This port is matched to 50Ω and DC block is provided internally.
21	SW3	Switch control port.
22	SW2	Switch control port.
23	ANT1	RF output. This port is matched to 50Ω and DC block is provided internally.
24	GND	Ground connection.
25	SW1	Switch control port. (See Switch Truth table for operation.)
26	VCC_g	Supply voltage for the IEEE802.11b/g PA. Requires external decoupling capacitors for best performance.
27	VCC_g	Supply voltage for the IEEE802.11b/g PA. Requires external decoupling capacitors for best performance.
28	GND	Ground connection.
29	GND	Ground connection.
30	GND	Ground connection.
31	PDET_g	Power detector voltage for the 802.11b/g PA. PDET voltage varies with output power. May need external decoupling capacitor for module stability. May need resistive voltage divider to bring output voltage to desired level.
32	PDET_a	Power detector voltage for the 802.11a PA. PDET voltage varies with output power. May need external decoupling capacitor for module stability. May need resistive voltage divider to bring output voltage to desired level.
33	VCC_a	Supply voltage for the IEEE802.11a PA. Requires external decoupling capacitors for best performance.
34	VCC_a	Supply voltage for the IEEE802.11a PA. Requires external decoupling capacitors for best performance.
35	VCC_g	Supply voltage for the IEEE802.11b/g PA. Requires external decoupling capacitors for best performance.
36	VCC_a	Supply voltage for the IEEE802.11a PA. Requires external decoupling capacitors for best performance.
37	VCC_g	Supply voltage for the bias reference circuit. Requires external decoupling capacitors for best performance.

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Pin	Function	Description
38	GND	Ground connection.
39	GND	Ground connection.
40	GND	Ground connection.
Pkg Base	GND	Ground connection. The back side of the package should be connected to ground plane through as short a connection as possible (e.g., PCB vias under the device are recommended).

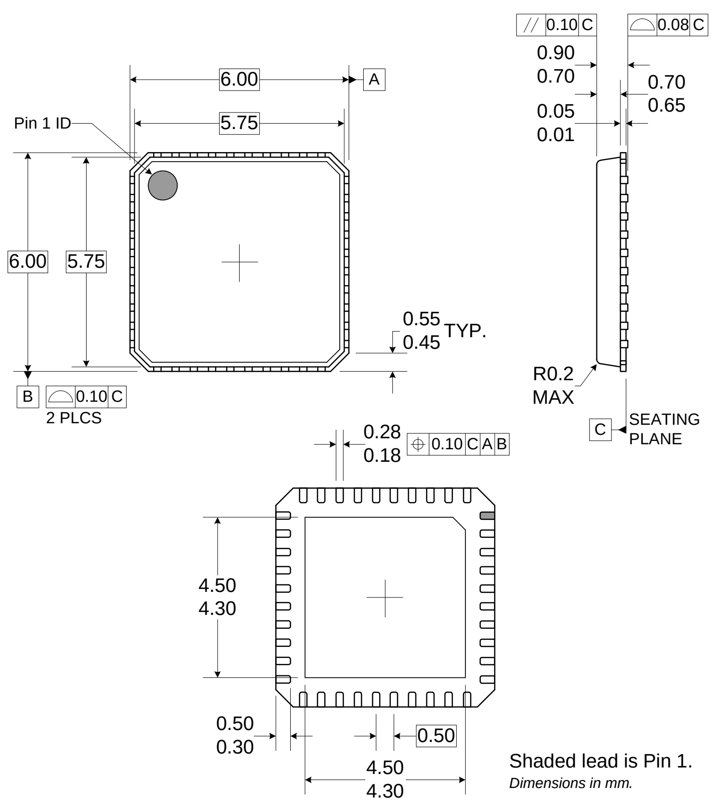
Switch Truth Table for Transmit and Receive Path 1 (ANT1)

Mode #	Description	SW1	SW2	PA EN_a	PA EN_g	LNA VCC1
1	Transmit, 2.4GHz	L	H	L	H	L
2	Receive, 2.4GHz	H	L	L	L	L
3	Transmit, 5.0GHz	L	H	H	L	L
4	Receive, 5.0GHz	H	L	L	L	H

Switch Truth Table for Receive Path 2 (ANT2)

Mode #	Description	SW3	SW4	LNA VCC2
1	Receive, 2.4GHz	H	L	L
2	Receive, 5.0GHz	H	L	H
3	Receive, BT	L	H	L

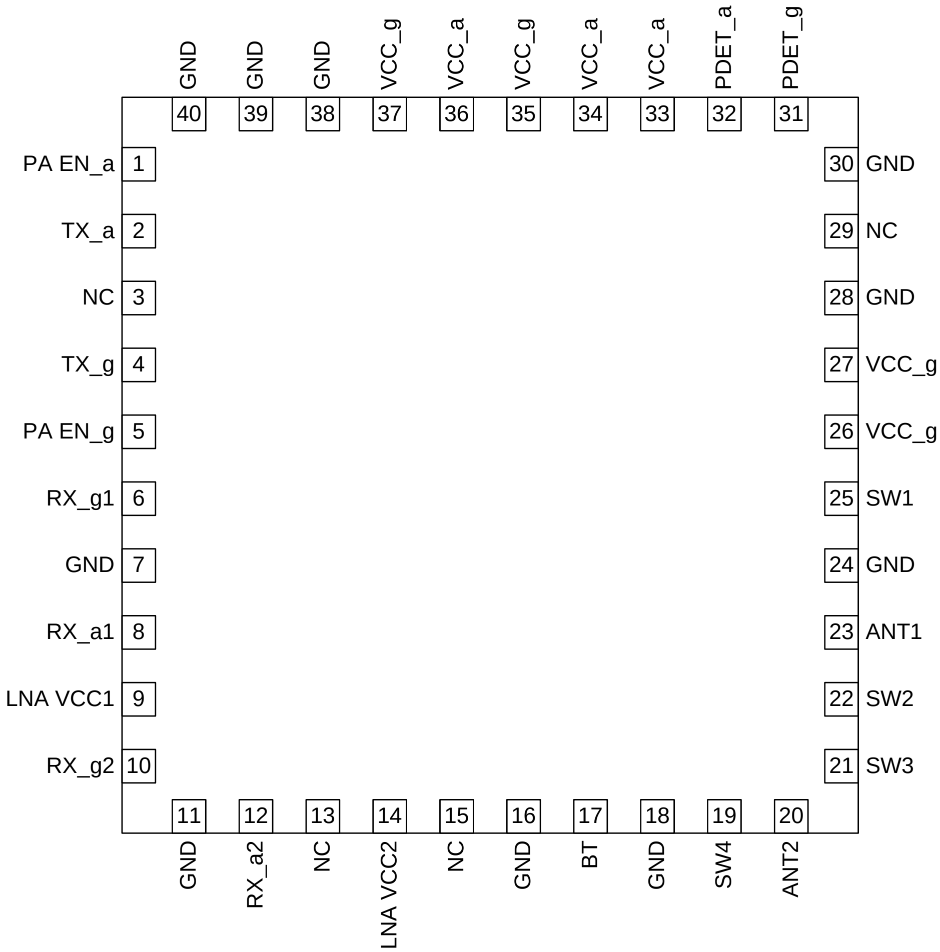
Package Drawing



Shaded lead is Pin 1.
Dimensions in mm.

Pin Out

(Top View)



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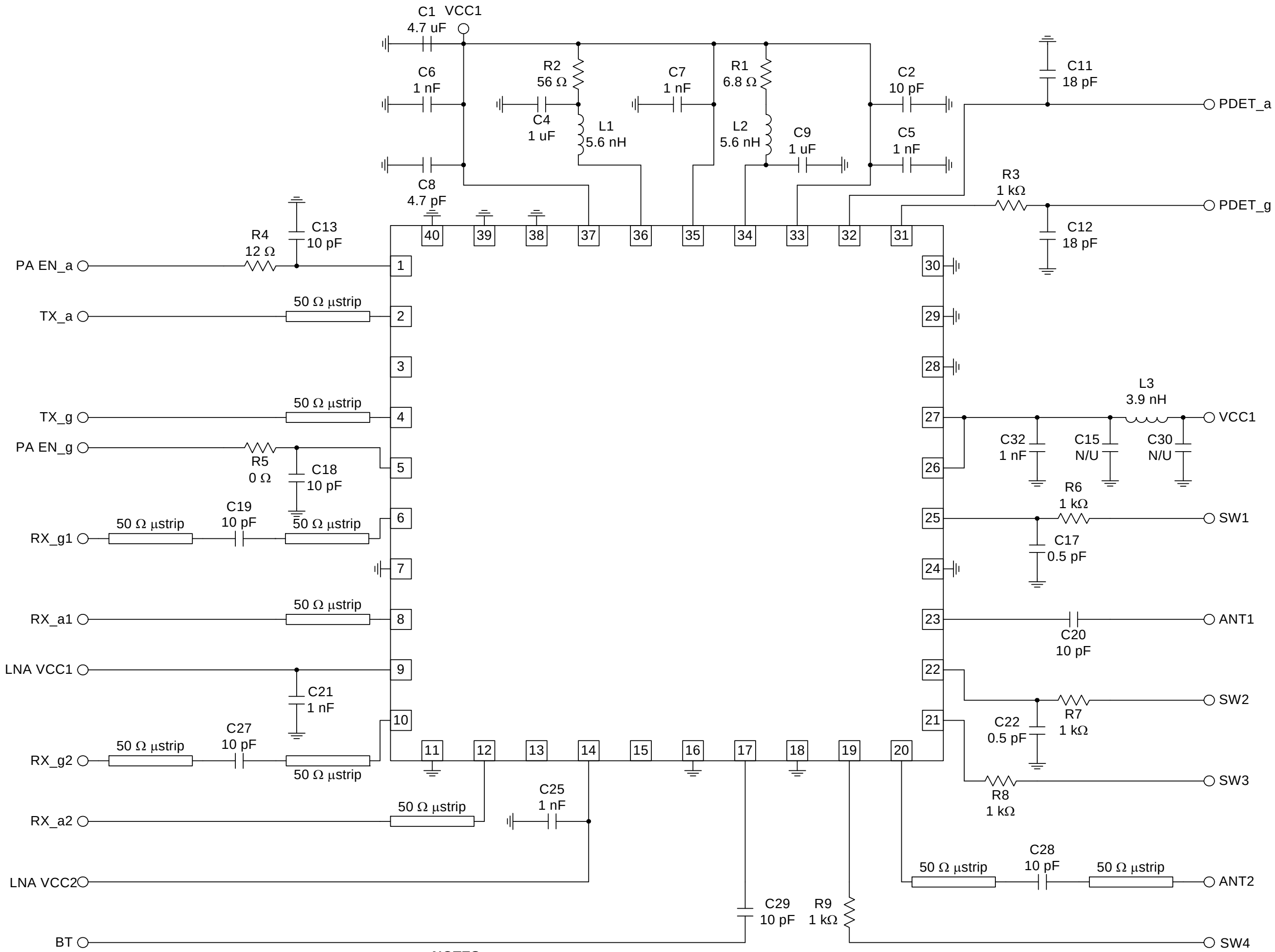
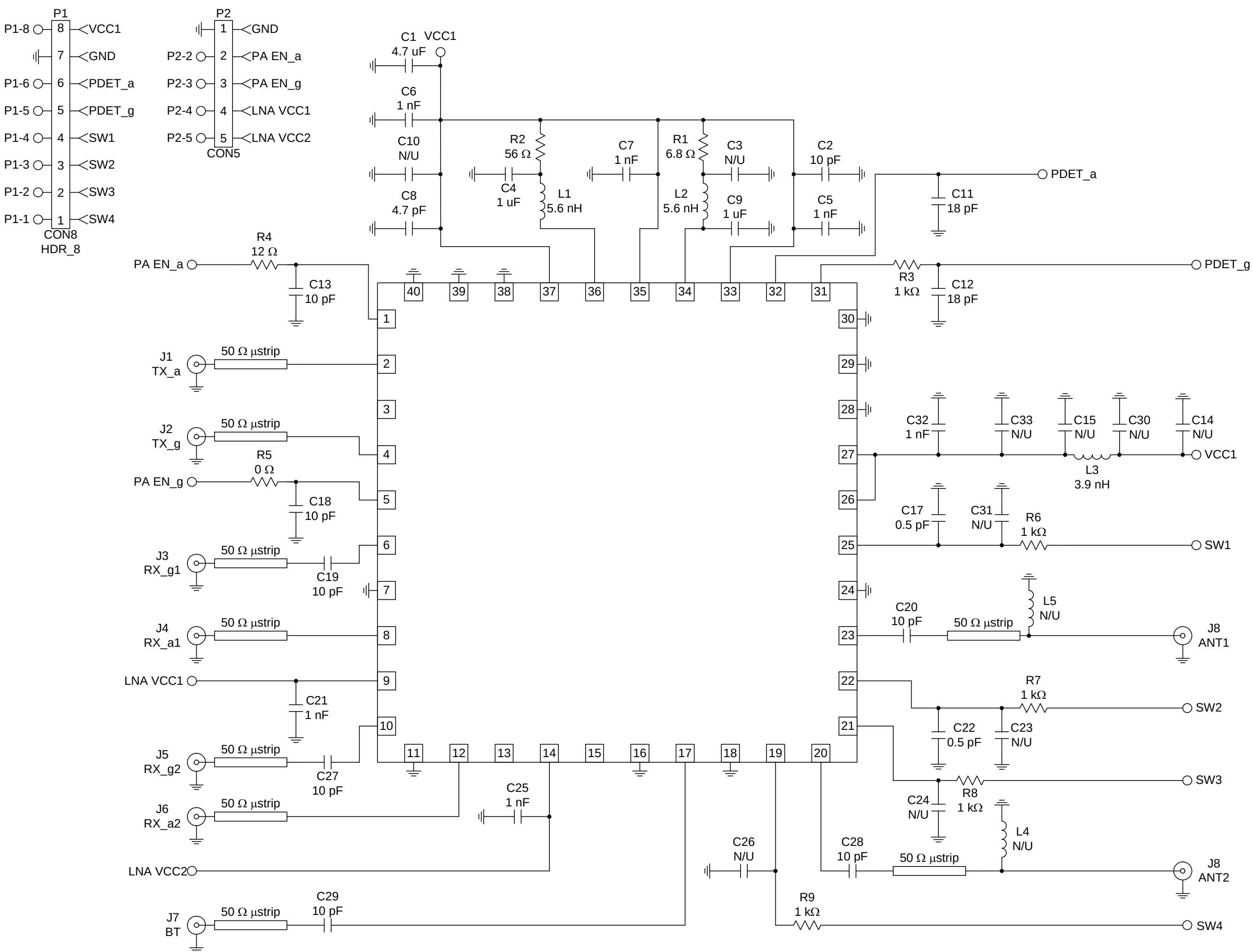
Application Schematic



NOTES:
1. It is recommended that C32 is placed close to pins 26 and 27.
2. It is recommended that C9 is placed close to pin 34.
3. It is recommended that C8 is placed close to pin 37.
4. It is recommended that C17 is placed close to pin 25, and C22 placed close to pin 22.
5. Depending on the layout, C30, C2, C6, C18, C25, C21, and C12 can be eliminated. It is recommended to first keep them on the layout until the design is proven to meet specifications without these components.

Evaluation Board Schematic



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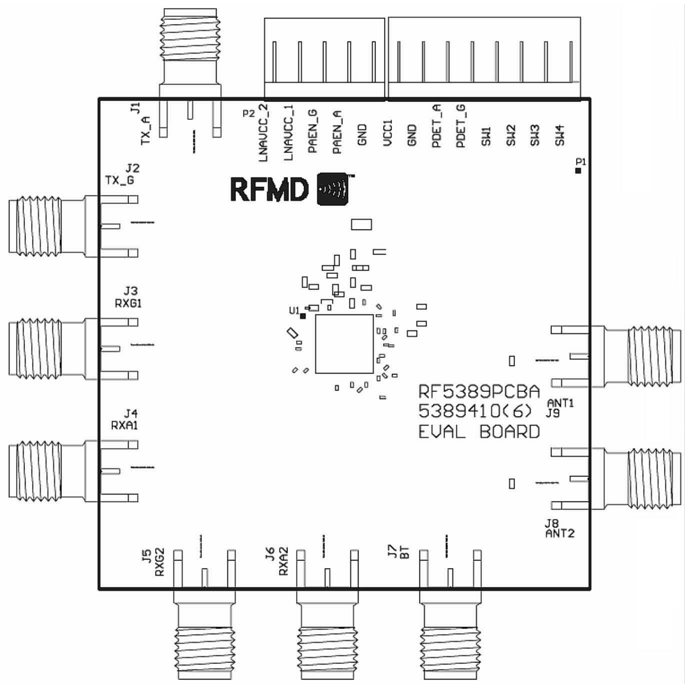
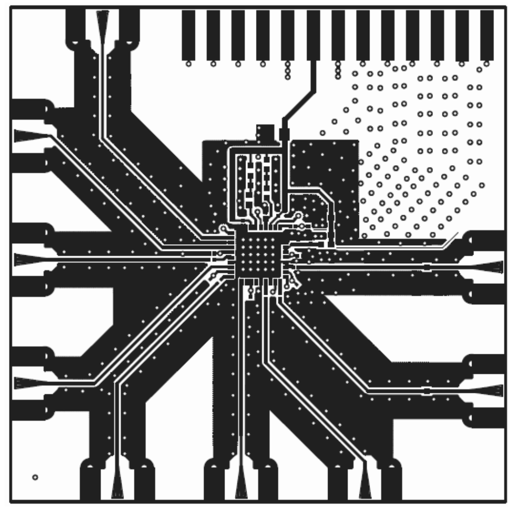
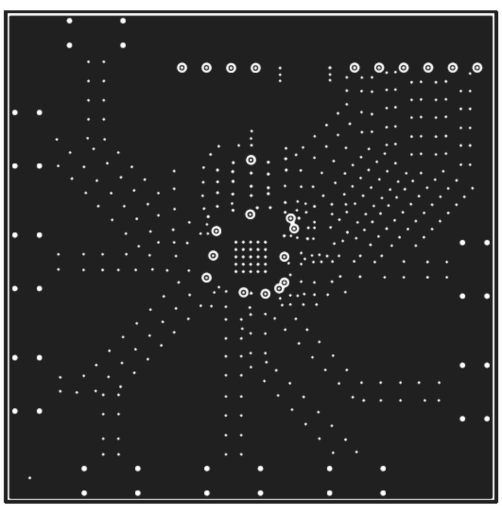
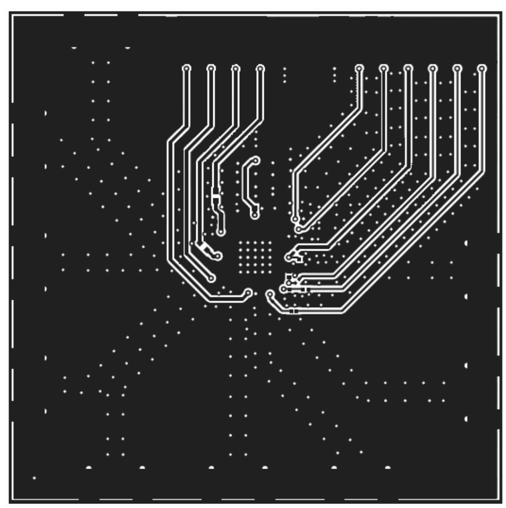
Evaluation Board Layouts
Board Size 2.0" x 2.0"
Board Thickness 0.032", Board Material FR-4, Multi-Layer









Theory of Operation

The RF5389 is a single-chip dual-band integrated front-end module (FEM) for high performance WiFi applications in the 2.5GHz and 5GHz ISM bands. The RF5389 addresses the need for aggressive size reduction for a typical 802.11a/b/g RF front-end design and greatly reduces the number of components outside of the core chipset thus minimizing the footprint and assembly cost of the overall 802.11a/b/g/n solution. The RF5389 contains integrated PA's for 2.5GHz and 5GHz, diplexers, TX/RX switch, LNA for the 5.0GHz receive band, matching components, some bypass capacitors, built-in power detector for both bands, and filters for transmit and receive paths. The RF5389 is packaged in a 40-pin, 6mmx6mmx0.9mm QFN package with backside ground which greatly minimizes next level board space and allows for simplified integration.

The RF5389 is designed primarily for IEEE802.11 b/g/a/n WiFi applications where the available supply voltage and current are limited. The RF5389 has one transmit path and two receive paths for a/b/g operation but it has two power amplifiers, one for the low band (b/g) and one for the high band (11a). The RF5389 requires a single positive supply voltage (V_{CC}), positive current control bias (PAEN) supply for each band, and a positive supply for switch control to simplify bias requirements. The RF5389 FEM also has built in power detectors for both 11b/g PA and 11a PA. All inputs and outputs are internally matched to 50Ω.

802.11b/g Transmit Path

The RF5389 low band power amplifier operates at frequencies between 2.4GHz to 2.5GHz and has a typical gain of 26dB and delivers 18dBm typical output power under 54Mbps OFDM modulation meeting the specified Error Vector Magnitude (EVM) and >20dBm under 11Mbps CCK modulation meeting the spectral mask. The RF5389 requires a single positive supply of 3.0V to 3.6V to operate at full specifications. Current control optimization for the 802.11b/g band is provided through one bias control input pin (PAEN_g). The PAEN_g pin requires a regulated supply to maintain nominal bias current. In general, higher PAEN_g voltage produce higher linear output power, higher operating current and higher gain but this voltage should be set in the range that it is specified. Second and third harmonic filtering is provided on the die so that the second and third harmonics level are well below -41.3dBm and passes the FCC restricted band requirements.

For best performance of the low band transmit path care has to be taken with the placement and values of some of the components around the FEM. We recommend that the layout of the evaluation board should be copied as close as possible to prevent any performance degradation. From one layout to another, the space and parts placement can change therefore, these are important recommendations one has to keep in mind (Please refer to the evaluation board schematic):

- For best linearity C32 and C08 should be placed as close to the FEM as possible.
- For best harmonic rejection, the combination of C32, C33, C15, L3, and C30 placement and values are important. It is recommended to follow the evaluation board layout for best performance. Also the value and placement of C17, C31, C22, and C23 are important for harmonic rejection so care has to be taken on the placement and values of these parts.
- All RF transmission lines should be as close as possible to 50Ω no matter what the stack is and what board material is used.
- We recommend that you contact RFMD application support to review your schematics and layout to provide recommendations.

802.11a Transmit Path

The RF5389 high band power amplifier operates at frequencies between 4.9GHz to 5.85GHz and has a typical gain of 26dB and delivers 16dBm typical output power under 54Mbps OFDM modulation meeting the specified EVM. The RF5389 requires a single positive supply of 3.0V to 3.6V to operate at full specifications. Current control optimization for the 802.11a band is provided through one bias control input pin (PAEN_a). The PAEN_a pin requires a regulated supply to maintain nominal bias current. In general, higher PAEN_a voltage produce higher linear output power, higher operating current and higher gain but this voltage should be set in the range that it is specified as per the data sheet. Second and third harmonic filtering is provided on the die so that the second and third harmonics level are well below -30dBm for the bands that are not restricted by the FCC and <-41.3dBm for bands that are restricted by the FCC.

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For best performance of the high band transmit path care has to be taken with the placement and values of some of the components around the FEM. We recommend that the layout of the evaluation board should be copied as close as possible to prevent any performance degradation. From one layout to another, the space and parts placement can change therefore, these are important recommendations one has to keep in mind (Please refer to the evaluation board schematic):

- For best linearity, the combination of components on Pins 33, 34, 36, and 37 should be copied as per the evaluation board. The placement of these components should be as close to the FEM as possible.
- All RF transmission lines should be as close as possible to 50 ohm.
- We recommend that you contact RFMD application support to review your layout and to provide recommendations.

802.11b/g Receive Paths (RX_g1 and RX_g2):
The 802.11b/g receive paths have 50Ω impedance with a nominal insertion loss and noise figure of 2.3dB. Both RX port return loss is -10dB typical. Depending on the application, if filtering is required beyond what the RF5389 can achieve then additional external filters will need to be added outside of the RF5389.

802.11a Receive Paths (RX_a1 and RX_a2)
The 802.11a receive paths have 50Ω impedance with a nominal gain of 9dB and 4.5dB typical noise figure pin to pin. Both RX port return loss is -10dB typical. Depending on the application, if filtering is required beyond what the RF5389 can achieve then additional external filters will need to be added outside of the RF5389.

Biasing instruction for TX Measurements:
- Connect (TX_a or TX_g) to RFIN from the signal Generator and ANT to RFOUT to the signal analyzer.
- Terminate all unused ports to 50Ω.
- Connect GND first and then the bias pins (V_{CC}) which is common between $V_{CC\text{-}a}$ and $V_{CC\text{-}g}$ but make sure the V_{CC} is off at this point.
- Connect Switch Control pins (SW1 and SW2) with all set to 0V.
- Set compliance on PAEN_a / PAEN_g to <10mA.
- Set compliance on V_{CC} to <300mA.
- Set SW2=High or equal to V_{CC} and turn on.
- Connect SW1 to GND for both 11a and 11g TX operation.
- Set V_{CC}=3.30V and turn on.
- Set PAEN_a/PAEN _g=2.85V and turn on. With no RF drive the part should draw ~ 100mA to 130mA quiescent current for either 11a or 11g bands.
- Turn RF signal on from the signal Generator.
- Perform measurements
- Follow reverse procedure to turn part off.
- Max RFIN power allowed is +5dBm.

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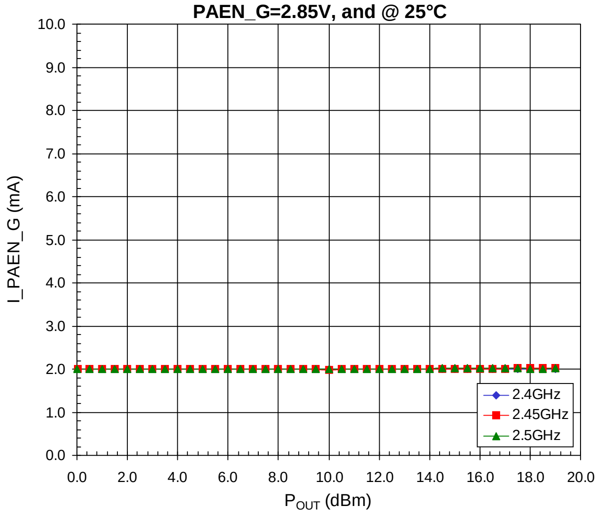
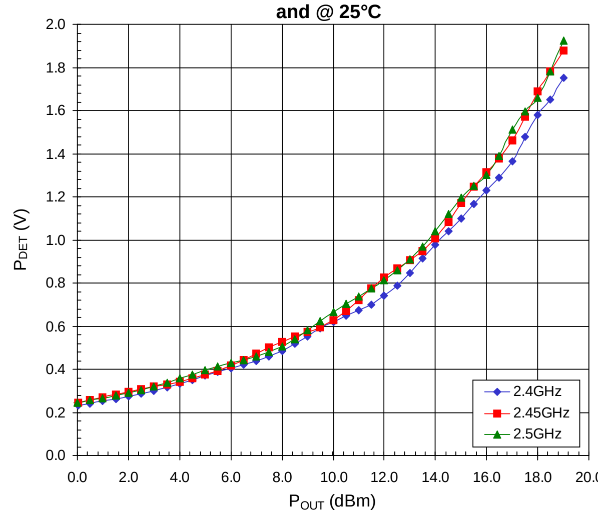
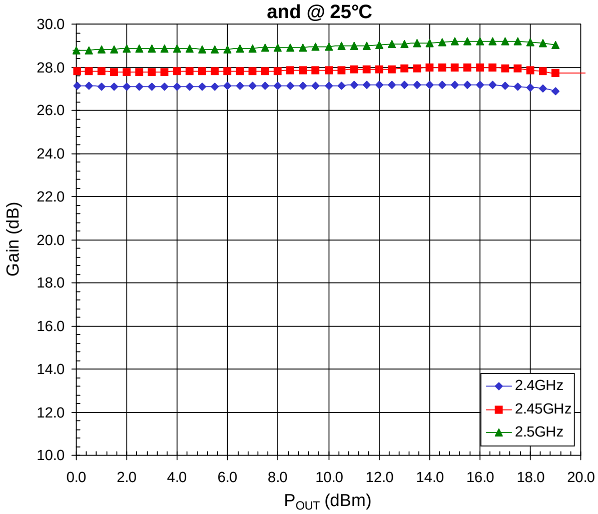
Typical I_PAEN_G versus P_{OUT} @ V_{CC}=3.3V, PAEN_G=2.85V, and @ 25°C



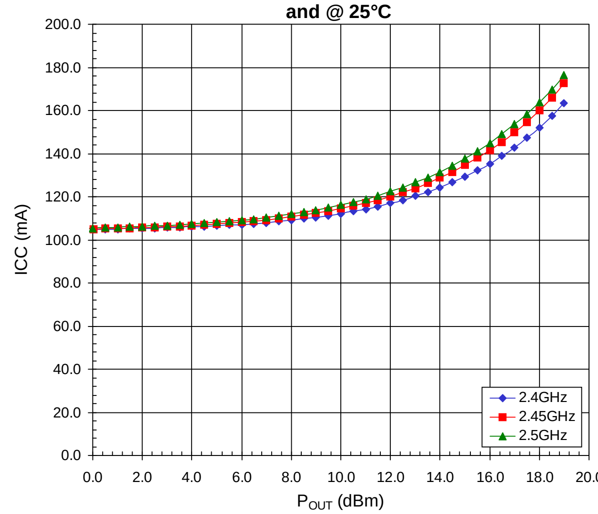
Typical P_{DET} versus P_{OUT} @ V_{CC}=3.3V, PAEN_G=2.85V, and @ 25°C



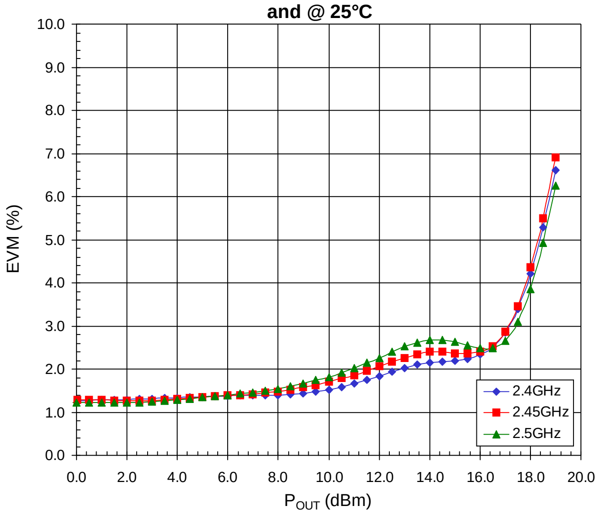
Typical Gain versus P_{OUT} @ V_{CC}=3.3V PAEN_G=2.85V, and @ 25°C



Typical ICC versus P_{OUT} @ V_{CC}=3.3V, PAEN_G=2.85V, and @ 25°C



Typical EVM versus P_{OUT} @ V_{CC}=3.3V, PAEN_G=2.85V, and @ 25°C



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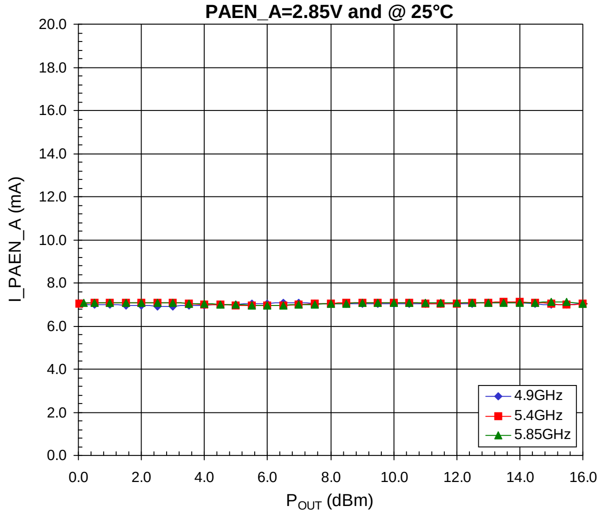
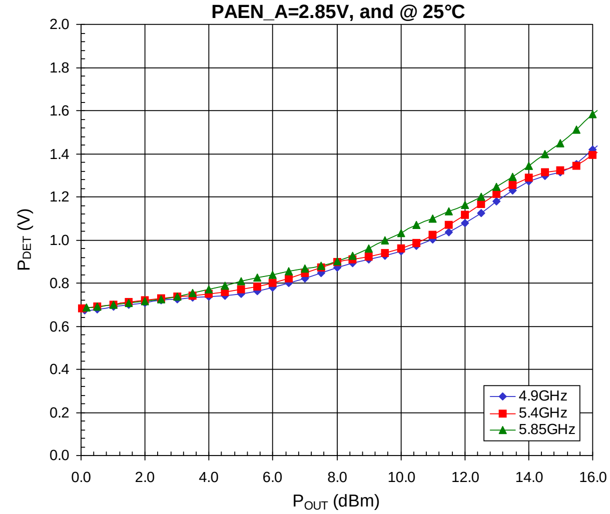
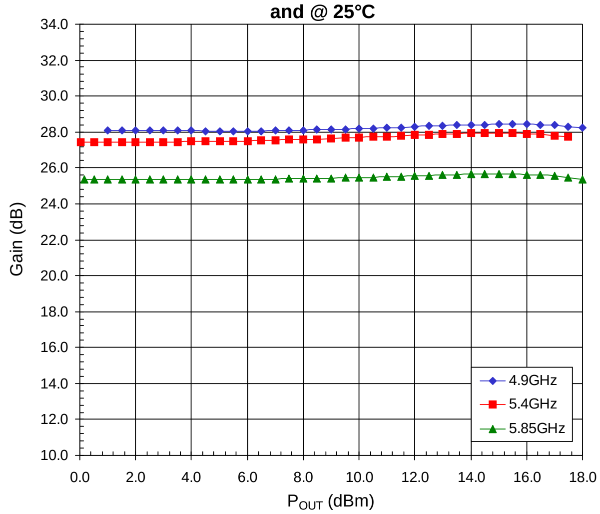
Typical I_PAEN_A versus P_{OUT} @ V_{CC}=3.3V, PAEN_A=2.85V and @ 25°C



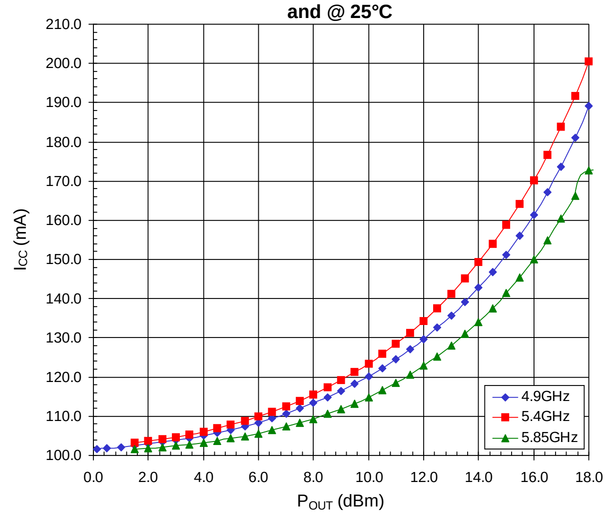
Typical P_{DET} Voltage versus P_{OUT} @ V_{CC}=3.3V, PAEN_A=2.85V, and @ 25°C



Typical Gain versus P_{OUT} @ V_{CC}=3.3V, PAEN_A=2.85V, and @ 25°C



Typical I_{CC} versus P_{OUT} @ V_{CC}=3.3V, PAEN_A=2.85V, and @ 25°C



Typical EVM versus P_{OUT} @ V_{CC}=3.3V, PAEN_A=2.85V, and 25°C