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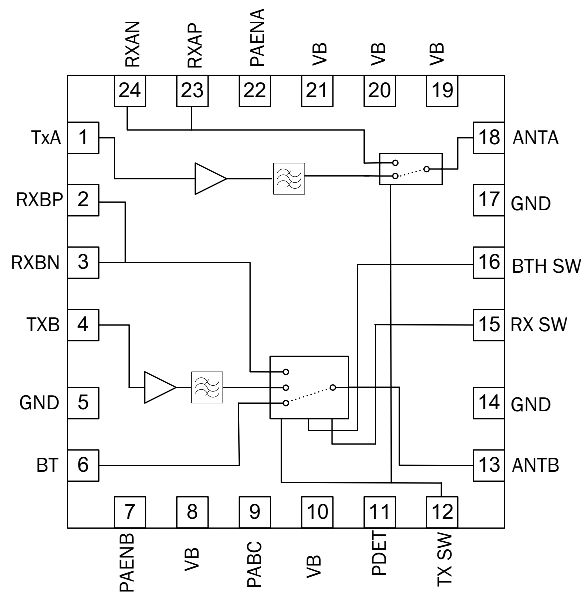
RF3688

2.4GHz TO 2.5GHz AND 4.9GHz TO 5.85GHz 802.11 b/g/a/n DUAL-BAND FEM

Package Style: QFN, 24-Pin, 4mm x 4mm x 0.45mm



Functional Block Diagram

Features

- Single-Module Radio Front End
- Single Supply Voltage 3.0V to 4.8V
- Integrated 2.4GHz to 2.5GHz and 4.9GHz to 5.85GHz PAs, Rx Baluns, Filters and Switches for Tx and Rx
- P_{OUT} = 17dBm, 11g, OFDM <2.4% EVM P_{OUT} = 16.5dBm, 11a, OFDM <2.4% EVM and P_{OUT} = 21.5dBm, Meeting 11b Mask
- Low Height Package, Suited for SiP and CoB Designs

Applications

- Cellular Handsets
- Mobile Devices
- Tablets
- Consumer Electronics
- Gaming
- Netbooks/Notebooks
- TV/Monitors/Video

Product Description

The RF3688 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 RF3688 addresses the need for aggressive size reduction for a typical 802.11a/b/g/n 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 RF3688 contains integrated PAs for 2.5GHz and 5GHz, Tx/Rx switch for each band, baluns for both low and high receive bands, some bypass capacitors, built-in power detector for both bands, and some filtering for transmit paths. The RF3688 is packaged in a 24-pin, 4mm x 4mm QFN package with backside ground. The RF3688 greatly minimizes next level board space and allows for simplified integration.

Ordering Information

RF3688	2.4GHz to 2.5GHz AND 4.9GHz to 5.85GHz 802.11 b/g/a/n Dual-Band FEM
RF3688PCBA-410	Fully Assembled Evaluation Board

Optimum Technology Matching® Applied

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

Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Voltage	-0.3 to +5.6	V_{DC}
Power Control Voltage (PAEN)	-0.5 to +2.0	V
Maximum Power Dissipation	3	W
Input RF Power	+10	dBm
Operating Case Temperature	-10 to +75	°C
Reduced Performance Temperatures	-40 to -10 +75 to +85	°C
Storage Temperature	-40 to +150	°C
Moisture Sensitivity	MSL1	

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.

RFMD Green: RoHS compliant per EU Directive 2002/95/EC, halogen free per IEC 61249-2-21, < 1000ppm each of antimony trioxide in polymeric materials and red phosphorus as a flame retardant, and <2% antimony in solder.

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Transmit					T = -10°C to +75°C, VB = 3.0V to 4.8V, PAEN B = 1.8V, 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, .205, .209
Frequency	2.4		2.5	GHz	
Output Power					
	15.5	17		dBm	11g (54-OFDM)
	14.5	16		dBm	11n (MCS7), see appendix A
	19			dBm	11g (6-OFDM)
	20.5	21.5		dBm	11b (11CCK)
Current 11g, 54Mbps	140	160	180	mA	P_{OUT} = 15.5dBm (54-OFDM)
Current 11b, 11Mbps	200	220	240	mA	P_{OUT} = 20.5dBm (11b)
11g EVM*		2.4	3.5	%	P_{OUT} = 15.5dBm minimum (54-OFDM)
11n EVM*		2.2	2.8	%	P_{OUT} = 14.5dBm minimum (MCS7)
Adjacent Channel Power					
ACP1		-36	-33	dBc	11Mbps, CCK P_{OUT} = 20.5dBM (11b)
ACP2		-56	-53	dBc	11Mbps, CCK P_{OUT} = 20.5dBM (11b)
Gain	28	33	38	dB	
Gain Variation	-2.0		+2.0	dB	
Frequency Variation	-1.0		+1.0	dB	2.4GHz to 2.5GHz
Power Detect					
Voltage Range	50	400		mV	P_{OUT} = 16dBm (11g)
Input Resistance		10		kΩ	
Input Capacitance		5		pF	
Bandwidth		1		MHz	
Sensitivity					
0dBm to +7dBm	2			mV/dB	
+8dBm to +15dBm	10			mV/dB	
>15dBm	20			mV/dB	
I_{PAENB}			450	µA	
Leakage			40	µA	PAEN B <0.2 V

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Transmit (continued)					T = -10°C to +75°C, VB = 3.0V to 4.8V, PAEN B = 1.8V, Pulsed at 1% to 100% Duty Cycle, Freq = 2.4GHz to 2.5GHz unless otherwise noted.
PAEN Voltage					
ON	1.6	1.8	2.0	V	
OFF		0	0.2	V	
PABC Voltage	0		0.9	V	Used to drive the PABC current
PABC Current	0		1.8	mA	
Input/Output Impedance		50		Ω	
Output Load VSWR Stability (Spurious Emissions)			-43	dBm	VSWR = 4:1; all phase angles (V_{RAMP} set for P_{OUT} ≤22dBm into 50Ω load; load switched to VSWR = 4:1; RBW = 3MHz)
Output Load VSWR Ruggedness	No damage or permanent degradation to device				VSWR = 10:1; all phase angles (V_{RAMP} set for P_{OUT} ≤22dBm into 50Ω load; load switched to VSWR = 10:1)
Frequency Response, S21					
			25	dBr	DC 894MHz
			25	dBr	925MHz to 980MHz
			20	dBr	1805MHz to 1990MHz
			20	dBr	2110MHz to 2170MHz
			15	dBr	3300MHz to 3800MHz
Thermal Resistance		42.7		°C/W	V_{CC} = 4.8, PAEN+1.8V, C_TX = 1.8V, C_RX = C_BT = GND, P_{OUT} = 15.5dBm, Modulation = 802.11g, Freq = 2.45GHz, DC = 100%, T = 85°C
Harmonic Rejection					P_{OUT} = 20dBm (11b), 1Mbps, CCK Modulation, RBW = 1MHz
Second			-25	dBc	
Third			-46	dBc	
Turn-On/Off Time		0.5	1.0	µs	Output stable to within 90% of final gain

*The EVM specification is obtained with a signal generator that has an EVM level <0.7%.

Appendix A

1. There will be a 1.0dB degradation in 11n MCS7 linear output power for Temperatures >75°C to 85°C
2. There will be a 1.5dB degradation in 11n MCS7 linear output power for Temperatures < -10°C to -30°C
3. There will be a 2.0dB degradation in 11n MCS7 linear output power for Temperatures < -30°C to -40°C

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
5.0GHz Transmit					T = -10°C to +75°C, VB = 3.0V to 4.8V, PAEN A = 1.8V, Pulsed at 1% to 100% Duty Cycle, Freq = 4.9GHz to 5.85GHz
Compliance					IEEE802.11a, FCC CFR 15.247, .205, .209
Frequency	4900		5900	MHz	
DC Supply voltage	3.0		4.8	V	
Output Power					
	15.5	16.5		dBm	11a (54-OFDM)
	14.5	15.5		dBm	11n (MCS7), see appendix B
	18.5			dBm	11a (6-OFDM)
	17.5			dBm	11n (MCS0)
Current 11a, 54Mbps		170	185	mA	P_{OUT} = 15.5dBm (54-OFDM)
11a EVM*		2.4	3.5	%	P_{OUT} = 15.5dBm minimum (54-OFDM)
11n EVM*		2.2	2.8		P_{OUT} = 14.5dBm minimum (MCS7)
Gain	28	32	36	dB	
Gain Variation	-2.0		+2.0		
Frequency Variation	-1.0		+1.0	dB	4.9GHz to 5.85GHz
Input Resistance		10		kΩ	
Input Capacitance		5		pF	
Bandwidth		1		MHz	
Sensitivity					
0dBm to +5dBm	2			mV/dB	
+5dBm to +15dBm	10			mV/dB	
>15dBm	20			mV/dB	
$I_{PAEN\ A}$			450	µA	
Leakage			40	µA	PAEN A <0.2V
Power Supply	2.7	3.6	4.8	V	
PAEN 5.0 Voltage					
ON	1.6	1.8	2.0	V	
OFF		0	0.2	V	
PABC	0		1.8		PA efficiency control.
Input/Output Impedance		50		Ω	
Output Load VSWR Stability (Spurious Emissions)			-43	dBm	VSWR = 4:1; all phase angles (V_{RAMP} set for P_{OUT} ≤22dBm into 50Ω load; load switched to VSWR = 4:1; RBW = 3MHz)
Output Load VSWR Ruggedness	No damage or permanent degradation to device				VSWR = 10:1; all phase angles (V_{RAMP} set for P_{OUT} ≤22dBm into 50Ω load; load switched to VSWR = 10:1)

*The EVM specification is obtained with a signal generator that has an EVM level <0.7%.

Appendix B

1. There will be a 1.0dB degradation in 11n MCS7 linear output power for Temperatures >75°C to 85°C
2. There will be a 2.0dB degradation in 11n MCS7 linear output power for Temperatures < -10°C to -30°C
3. There will be a 2.5dB degradation in 11n MCS7 linear output power for Temperatures < -30°C to -40°C

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
5.0GHz Transmit (continued)					T = -10°C to +75°C, VB = 3.0V to 4.8V, PAEN A = 1.8V, Pulsed at 1% to 100% Duty Cycle, Freq = 4.9GHz to 5.85GHz
Frequency Response, S21					
			30	dBr	DC 960MHz
			30	dBr	1570MHz to 1580MHz
			30	dBr	1805MHz to 1990MHz
			30	dBr	2110MHz to 2170MHz
Harmonic Rejection					P_{OUT} = 19.5dBm (11a)
Second			-35	dBc	9.8GHz to 12.7GHz measured with CW
Third and above			-45	dBc	15.35GHz to 16.2GHz measured with CW
Turn-On/Off Time		0.5	1.0	µs	Output stable to within 90% of final gain
2.4GHz Receive					T = +25°C, RX SW = 1.8V, Freq = 2.45GHz unless otherwise specified.
Compliance					IEEE802.11b, IEEE802.11g, FCC CFR 15.247, 0.205, 0.209
Frequency	2.4		2.5	GHz	
Insertion Loss		2.0	2.4	dB	Switch + balun, see appendx C
Passband Ripple	-0.3		+0.3	dB	
Output Return Loss			-9	dB	
Output Impedance		100		Ω	No external differential matching
Balun					
Amplitude Balance			1	±dB	
Phase Balance		5	10	±°	Relative to 180°
Current Consumption			10	µA	
5.0GHz Receive					T = +25°C, BTH SW = 1.8V, Freq = 5.5GHz unless otherwise specified.
Compliance					IEEE802.11a, FCC CFR 15.247, 0.205, 0.209
Frequency	4.90		5.85	GHz	
Output Return Loss			-10	dB	
Output Impedance		100		Ω	No external differential matching
Balun					
Amplitude Balance			1	±dB	
Phase Balance		5	10	±°	Relative to 180°
Insertion Loss		2.4	3.1	dB	see appendix C
Input IP3	-10	-1		dBm	
Current Consumption			10	µA	

Appendix C
1. There will be a 0.2dB degradation in 2.4GHz Rx Insertion Loss for Temperatures >75°C to 85°C
2. There will be a 0.4dB degradation in 5.0GHz Rx Insertion Loss for Temperatures >75°C to 85°C

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Bluetooth					
Frequency	2.4		2.5	GHz	
Insertion Loss		1.0	1.4	dB	SP3T switch
Passband Ripple	-0.3		0.3	dB	
Input/Output Power			15	dBm	
Output Return Loss		-14	-12	dB	
Output Impedance		50		Ω	No external matching
Current Consumption			10	μA	Switch leakage current
Other Requirements					
Antenna Port Impedance					
Low Band		50		Ω	
High Band		50		Ω	
Isolation					
High Band Rx-Tx	20			dB	4.9GHz to 5.85GHz
High Band Rx-BT	30			dB	
High Band Tx-BT	20			dB	
Low Band Rx-Tx	20			dB	2.4GHz to 2.5GHz
Low Band Rx-BT	22			dB	
Low Band Tx-BT	22			dB	
WiFi Rx to *Bluetooth*	30			dB	
WiFi Tx to *Bluetooth*	20			dB	
Control Voltage					
Low	0		0.01	V	
High	1.6	1.8	2.0	V	
Switch Control Current			10	μA	Per control line
Switch Control Speed			100	ns	
ESD					
Human Body Model		500		V	EIA/JESD22-114A
Charge Device Model		750		V	EIA/JESD22-C101

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Pin Names and Descriptions

Pin	Name	Description
1	TXA	RF input for the 802.11a PA. Input is matched to 50Ω and DC block is provided.
2	RXBP	Receive port for the 802.11b/g/n band. Internally matched to 100Ω differential. DC block provided.
3	RXBN	Receive port for 802.11b/g/n band. Internally matched to 100Ω differential. DC block provided.
4	TXB	RF input for the 802.11 PA. Input is matched to 50Ω and DC block is provided.
5	GND	Ground.
6	BT	RF bidirectional port for Bluetooth. Input is matched to 50Ω and DC block is provided.
7	PA EN B	PA Enable pin for the 802.11b/g/n PA.
8	VB	Voltage supply pin for the 11b/g/n (2.4GHz) power amplifier.
9	PABC	Power control pin, can be used to control linearity and efficiency of the PA.
10	VB	Voltage supply pin for the 11b/g/n (2.4GHz) power amplifier.
11	PDET	Power detector voltage for 802.11a/b/g/n PA's combined. P_{DET} voltage varies with output power. External decoupling may be needed for the best performance. A resistive dividor may be needed to bring the voltage to a desired level.
12	TX SW	Transmit switch control pin.
13	ANTB	RF output for the low band. This pin is internally matched to 50Ω.
14	GND	Ground.
15	RX SW	Receive switch control pin.
16	BTH SW	Bluetooth switch control pin.
17	GND	Ground.
18	ANTA	RF output for the high band. This pin is internally matched to 50Ω.
19	VB	Voltage supply pin for the 11a/n (5GHz) power amplifier.
20	VB	Voltage supply pin for the 11a/n (5GHz) power amplifier.
21	VB	Voltage supply pin for the 11a/n (5GHz) power amplifier.
22	PA EN A	PA Enable pin for the 802.11a/n PA.
23	RXAP	Receive port for 802.11a/n band. Internally matched to 100Ω differential. DC block provided.
24	RXAN	Receive port for 802.11a/n band. Internally matched to 100Ω differential. DC block provided.
Pkg Base	GND	Ground connection. The back side of the package should be connected to ground plane through as short a connection as possible; PCB vias under the device are recommended.

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RF3688 Biasing Instructions:

- 802.11 a/b/g/n Transmit (VB compliance = 5.5V, 400mA, PA EN compliance = 2V, 450µA)
  - Connect the FEM to a signal generator at the input and a spectrum analyzer at the output.
  - Bias VB to 3.6V first with PA_EN = 0.0V
  - Refer to switch operational truth table to set the control lines at the proper levels for WiFi Tx.
  - Turn on PA_EN to 1.8V (typ.). Be extremely careful not to exceed 3.0V on the PA_EN pin, or the part may exceed device current limits.
  - Turn on PABC to 1.1mA(11b, 11g, 11n). For 11a/MCS7 turn PABC to 1.2mA and for 6-OFDM/MCSO use 1.6mA. This controls the current drawn by the 802.11b/g or 11a power amplifier.
- 802.11 a/b/g/n Receive
  - To Receive WiFi set the switch control lines per the truth table below.
- Bluetooth Receive
  - To Receive Bluetooth set the switch control lines per the truth table below.

Switch Truth Table

Mode	BTH SW	TX SW	RX SW	PAEN A	PAEN B
Bluetooth Tx/Rx	1	0	0	0	0
WiFi 802.11a Transmit	0	1	0	1	0
WiFi 802.11b/g Transmit	0	1	0	0	1
WiFi 802.11a Receive	1	0	0	0	0
WiFi 802.11b/g Receive	0	0	1	0	0
Calibration	1	0	1	1	0
	1	0	0	1	0
	1	0	0	1	0
	1	0	1	0	1
	1	0	0	0	1
	0	0	1	0	1

I_{BIAS} Table

WiFi PABC	Setting	Units
11b/g/MCS0/MCS7	1.1	mA
11a/MCS7	1.2	mA
11a/MCS1-MCS6	1.4	mA
11a 6-OFDM/MCS0	1.6	mA

11a Power Detector Voltage Table

Freq (MHz)	mV	dBm
4940	305	16
5060	305	16
5200	290	16
5280	290	16
5540	295	16
5640	300	16
5785	310	16

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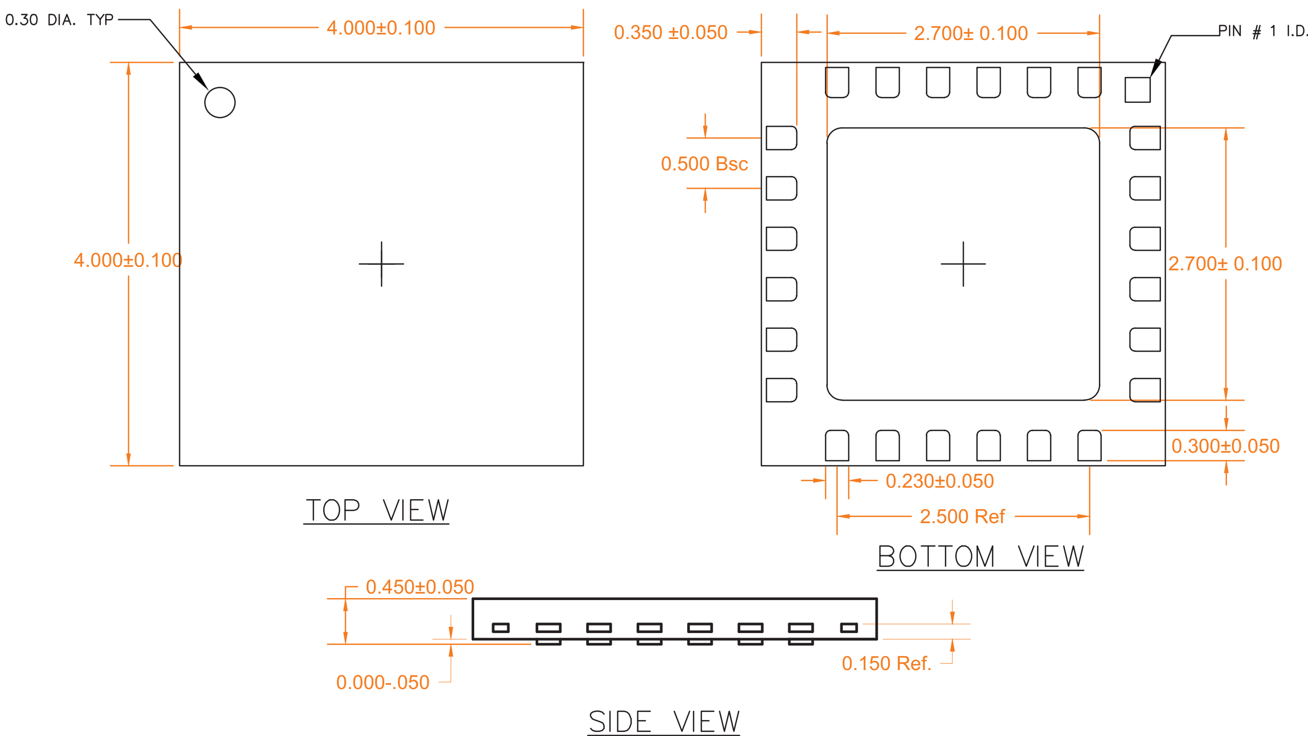
Package Drawing



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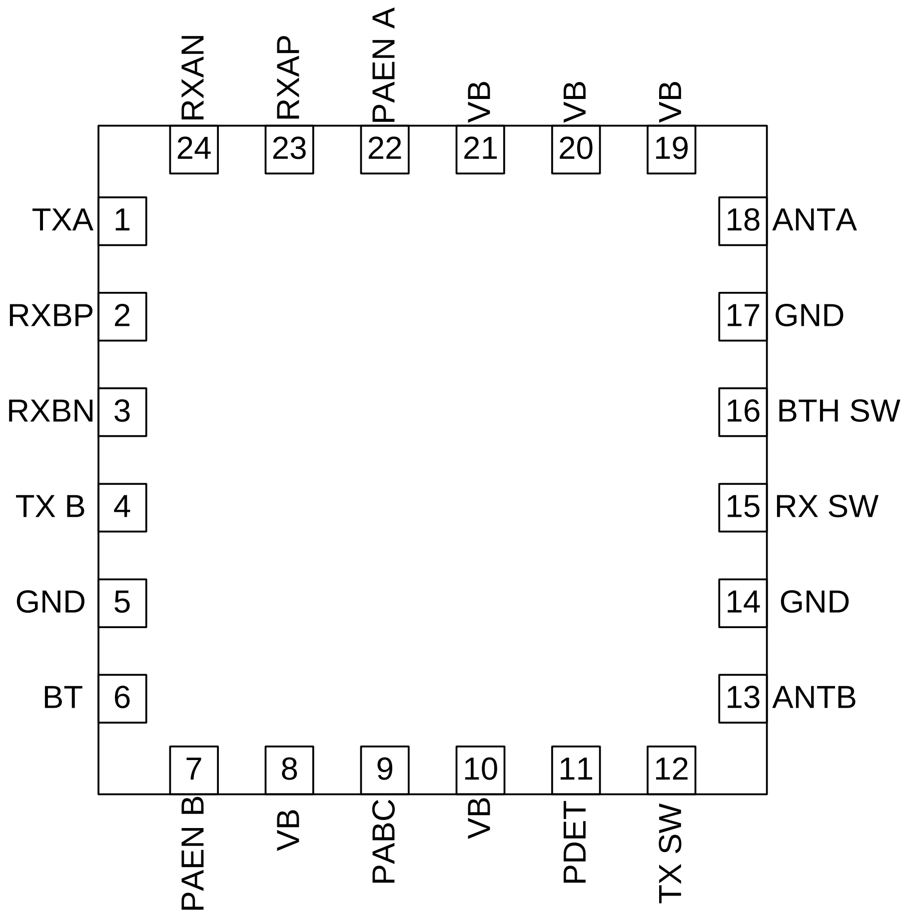
Pin Out



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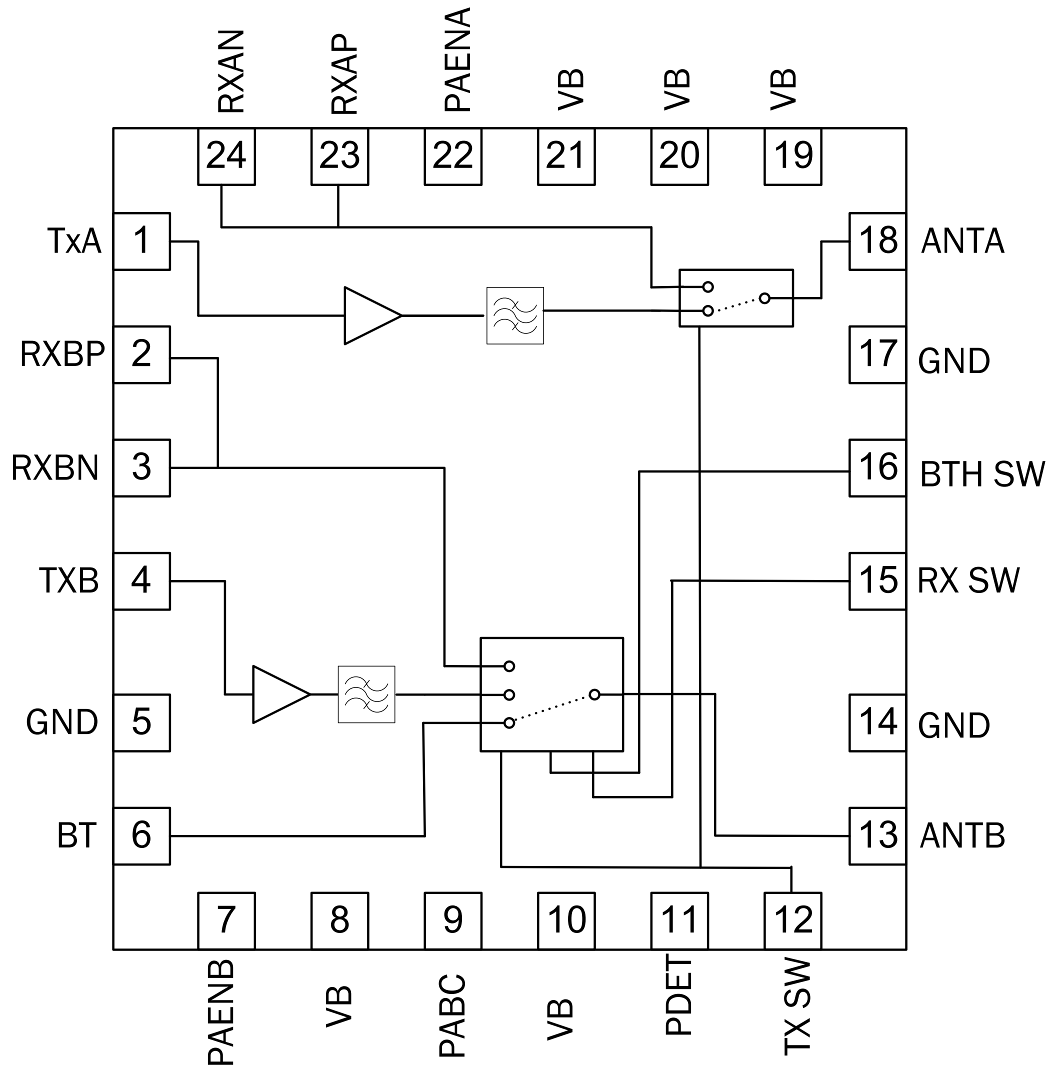
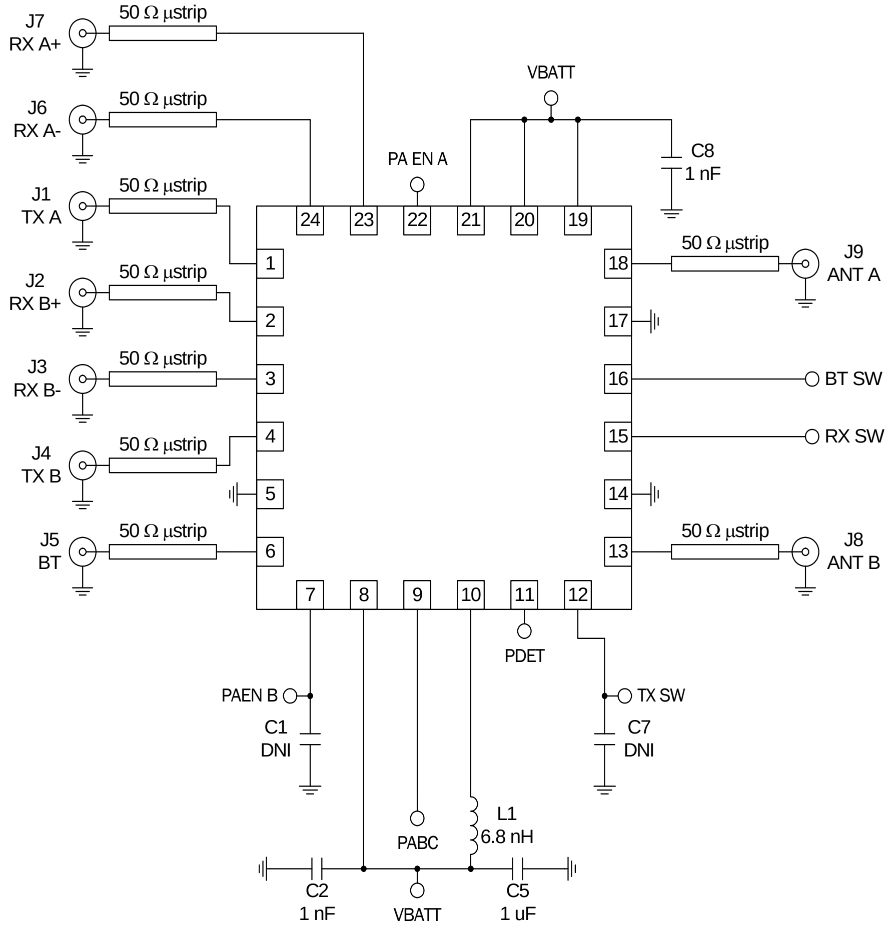
Detailed Functional Block Diagram



Application Schematic



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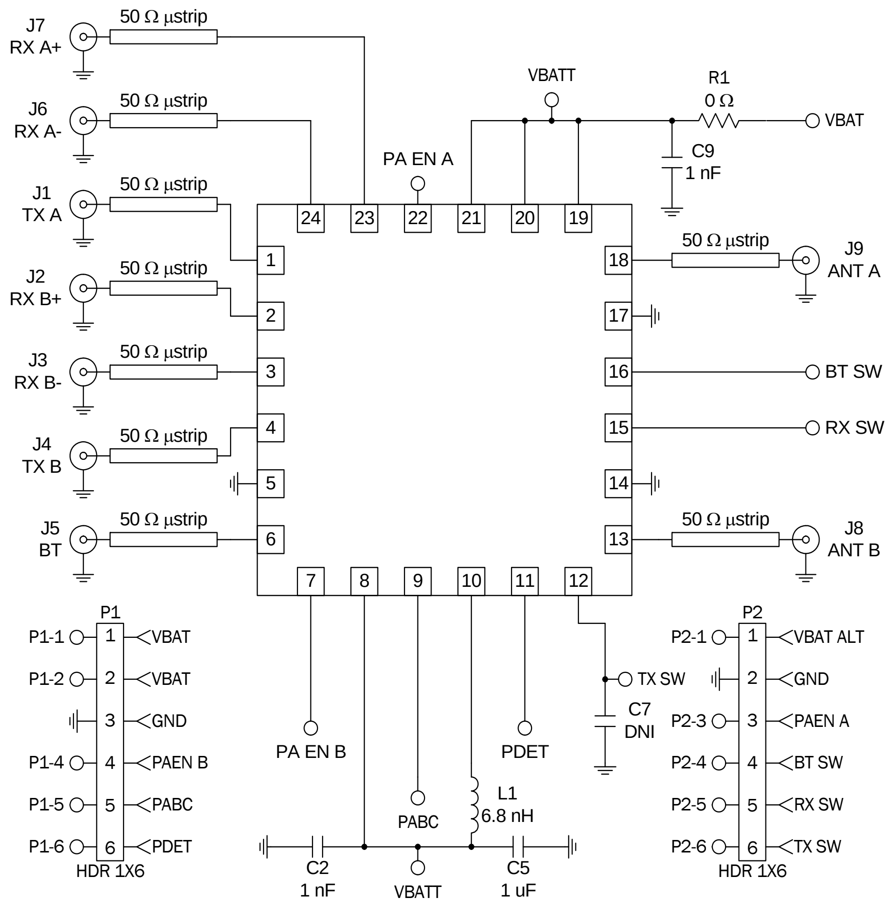
Evaluation Board Schematic



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PCB Design Requirements

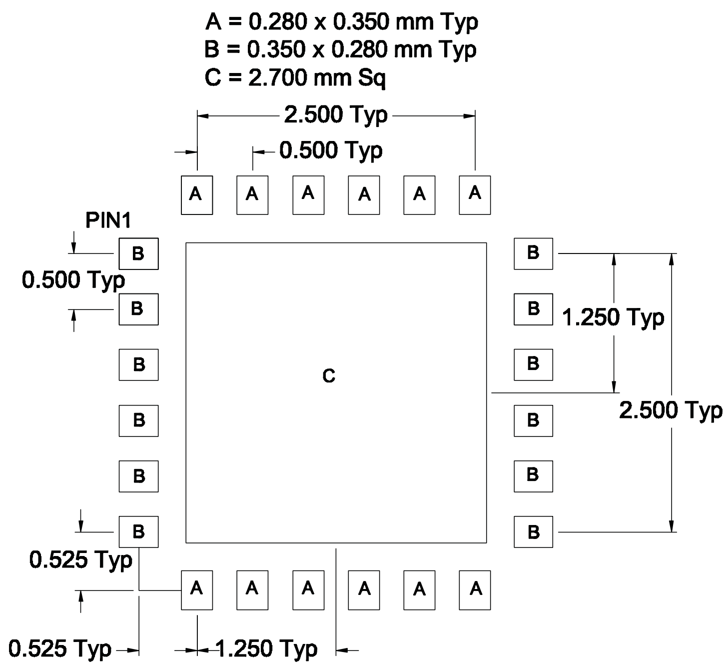
PCB Surface Finish

The PCB surface finish used for RFMD's qualification process is electroless nickel, immersion gold. Typical thickness is 3 inch to 8 inch gold over 180 inch nickel.

PCB Land Pattern Recommendation *

PCB land patterns for RFMD components are based on IPC-7351 standards and RFMD empirical data. The pad pattern shown has been developed and tested for optimized assembly at RFMD. The PCB land pattern has been developed to accommodate lead and package tolerances. Since surface mount processes vary from company-to-company, careful process development is recommended.

PCB Metal Land Pattern



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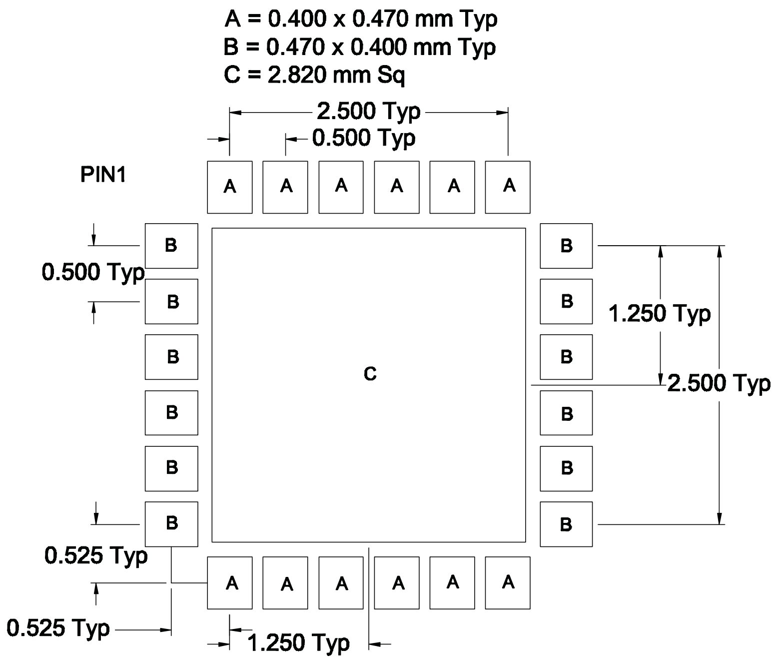
PCB Solder Mask Pattern

Liquid Photo-Imageable (LPI) solder mask is recommended. The solder mask footprint will match what is shown for the PCB metal land pattern with a 2 mil to 3 mil expansion to accommodate solder mask registration clearance around all pads. The center-grounding pad shall also have a solder mask clearance. Expansion of the pads to create solder mask clearance can be provided in the master data or requested from the PCB fabrication supplier.

PCB Solder Mask Pattern



SOLDER MASK PATTERN

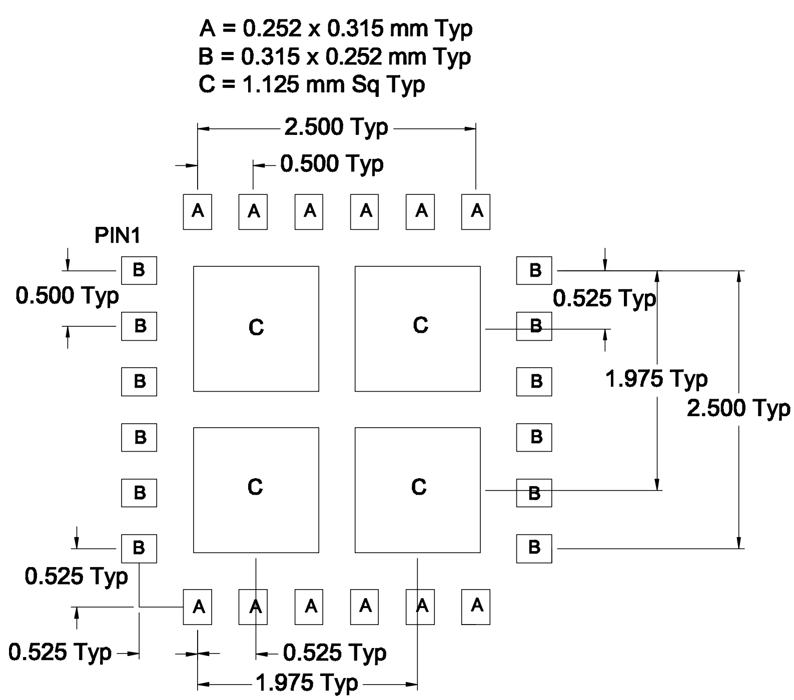
Thermal Pad and Via Design

The PCB land pattern has been designed with a thermal pad that matches the die paddle size on the bottom of the device.

Thermal vias are required in the PCB layout to effectively conduct heat away from the package. The via pattern has been designed to address thermal, power dissipation and electrical requirements of the device as well as accommodating routing strategies.

The via pattern used for the RFMD qualification is based on thru-hole vias with 0.203mm to 0.330mm finished hole size on a 0.5mm to 1.2mm grid pattern with 0.025mm plating on via walls. If micro vias are used in a design, it is suggested that the quantity of vias be increased by a 4:1 ratio to achieve similar results.

Stencil Pattern



STENCIL PATTERN

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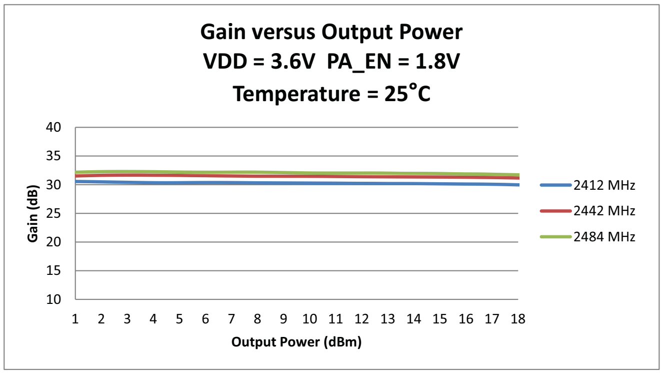
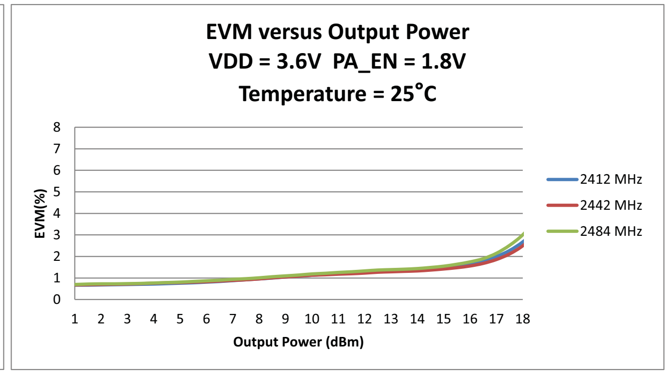
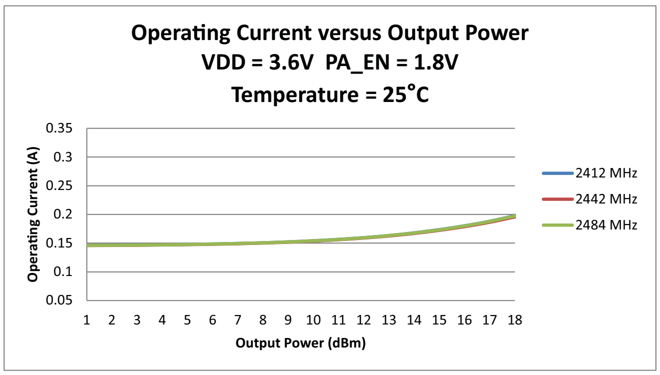
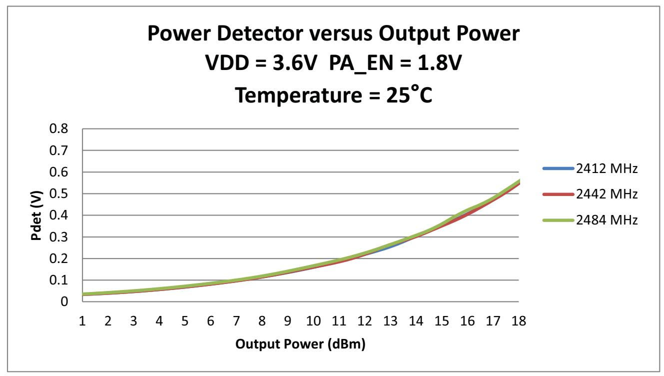
802.11g Performance Plots









802.11a Performance Plots