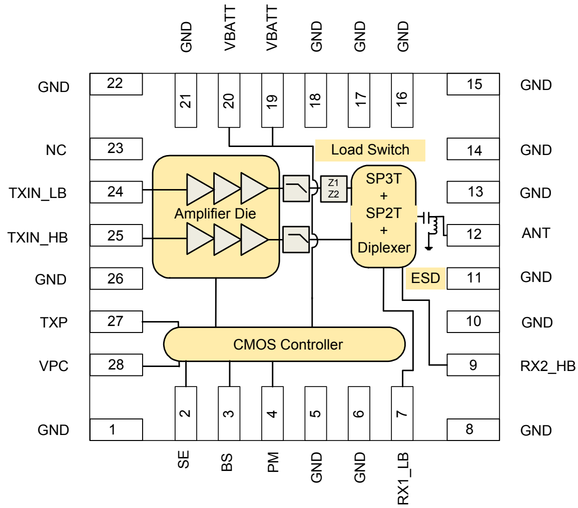
RF7188

DUAL-BAND GSM900/DCS1800 TRANSMIT MODULE

rfmd.com

Package Style: Module (6mmx5.93mmx1mm)



Functional Block Diagram

Features

- High Power and High Efficiency Transmit Module
- GSM900 PAE 34%
- DCS1800 PAE 38%
- GSM900 P_{OUT} 33.4dBm
- DCS1800 P_{OUT} 31.9dBm
- Less Current Consumption at Rated and ECTEL Power Levels
- Integrated Power Flattening Circuit for Lower Power Variation under Mismatch Conditions
- Integrated VBATT Tracking Circuit for Improved Switching Spectrum under Low VBATT Conditions
- Dedicated RX Ports
- Excellent ESD Protection at Antenna Port: 8kV

Applications

- GSM900/DCS1800 Products
- GPRS Class 12 Compatible
- 3V Dual-Band GSM/GPRS Handsets
- Portable Battery-Powered Equipment

Product Description

The RF7188 is a high-power, high-efficiency transmit module containing RFMD's PowerStar™ integrated power control, integrated pHEMT front end antenna switch, and harmonic filtering functionality. These features combine to provide for best-in-class harmonic emission control and RX and TX insertion loss. The device is self-contained with 50Ω input and output terminals with no matching components required. The integrated power control function based on RFMD's patented PowerStar™ control eliminates the need for directional couplers, detector diodes, power control ASICs, and other power control circuitry. This allows the module to be driven directly from the DAC output. The device is designed for use as the final portion of the transmit chain in dual-band applications utilizing GSM900/DCS1800 and eliminates the need for PA-to-antenna switch module matching. On-board power control provides over 70dB control range. The integrated antenna switch allows true dual-band TX and RX functionality.
The RF7188 features patented Load Switch functionality to provide less current consumption at rated and ECTEL power levels

Ordering Information

RF7188	Dual-Band GSM900/DCS1800 Transmit Module
RF7188SB	Transmit Module 5-Piece Sample Pack
RF7188PCBA-41X	Fully Assembled Evaluation Board

Optimum Technology Matching® Applied

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

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Absolute Maximum Ratings

Parameter	Rating	Unit
Supply Voltage	-0.3 to +6.0	V
Power Control Voltage (V_{RAMP})	-0.3 to +3.0	V
Input RF Power	+10	dBm
Max Duty Cycle	25	%
Output Load VSWR	20:1	
Operating Temperature	-30 to +85	°C
Storage Temperature	-55 to +150	°C

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).

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Recommended Operating Conditions					
Overall Power Control V_{RAMP}					
Power Control “ON”			2.15	V	Max. P_{OUT}, Voltage supplied to the input
Power Control “OFF”	0.2			V	Min. P_{OUT}, Voltage supplied to the input
V_{RAMP} Input Capacitance			10.0	pF	DC to 2MHz
V_{RAMP} Input Current			10.0	µA	$V_{RAMP}=V_{RAMP\ MAX}$
Turn On/Off Time			2.0	us	V_{RAMP}=0V to $V_{RAMP\ MAX}$
Power Control Range		50.0		dB	V_{RAMP}=0.2V to $V_{RAMP\ MAX}$
Overall Power Supply					
Power Supply Voltage	3.0	3.6	4.35	V	Nominal operating limits
Power Supply Current			20.0	µA	P_{IN}<-30dBm, TX Enable=Low, V_{RAMP}=0V, Temp=-30°C to +85°C
Overall Control Signals					
BS, PM, SE “Low”	0		0.5	V	
BS, PM, SE “High”	2.2		2.65	V	
BS, PM, SE “High Current”			10.0	uA	
TX Enable “Low”	0		0.5		
TX Enable “High”	2.2		2.65	V	
TX Enable “High Current”			10.0	uA	

Module Control and Antenna Switch Logic

Mode	TX Enable (TXP)	Band Select (BS)	Power Mode (PM)	Switch Enabled (SE)
Standby	0	0	0	0
LB RX	0	0	0	1
HB RX	0	1	0	1
LB Pre-TX (High Isolation)	1	0	x	0
LB TX Medium Power	1	0	0	1
LB TX High Power	1	0	1	1
HB Pre-TX (High Isolation)	1	1	X	0
HB TX High Power	1	1	1	1

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
GSM900 Mode					Nominal test conditions unless otherwise stated. All unused ports are terminated with 50Ω. Temp=+25°C, V_{BATT}=3.6V, V_{RAMP}=2.15V, P_{IN}=2dBm, TXP=High, Duty Cycle=25%, Pulse Width=1154µs. Refer to Refer to logic table for mode of operation
Operating Frequency Range	880		915	MHz	
Input Power	0	2	4.0	dBm	Full P_{OUT} guaranteed at minimum drive level.
Input VSWR			2:1		Over all power levels (5dBm to 33dBm)
Maximum Output Power	33.1			dBm	Full P_{OUT} guaranteed at minimum drive level
	31.3			dBm	Temp=+85°C, V_{BATT}=3.0V, P_{IN}=0dBm
PAE(Max P_{OUT})		40		%	P_{OUT}=33.1dBm
Output Noise Power					RBW=100kHz, Set P_{OUT}=33.1dBm
925MHz to 935MHz		-77		dBm	
935MHz to 960MHz		-88		dBm	
1805MHz to 1880MHz		-79		dBm	
Forward Isolation 1			-58	dBm	TX_EN=Low, P_{IN}=-50dBm, V_{RAMP}=0V
Harmonics up to 12.75GHz		-40		dBm	Over all power levels (5.3dBm to 33.1dBm)
Output Load VSWR Stability			-36	dBm	VSWR=15:1; all phase angles, set V_{RAMP} where P_{OUT}≤33.1dBm into 50Ω load
Output Load VSWR Ruggedness	No damage or permanent degradation.				VSWR=20:1; all phase angles, set V_{RAMP} where P_{OUT}≤33.1dBm into 50Ω load.
Delivered P_{OUT}	30.55		32.8		V_{BATT}=3.6V, PIN=2dBm, V_{RAMP} where P_{OUT}=32.8dBm@ Load impedance=50Ω Change Load VSWR=3:1 all phases Measure delivered P_{OUT}

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
DCS1800 Mode					Nominal test conditions unless otherwise stated. All unused ports are terminated with 50Ω. Temp=+25°C, V_{BATT}=3.6V, V_{RAMP}=2.15V, P_{IN}=2dBm, TXP=High, Duty Cycle=25%, Pulse Width=1154μs. Refer to logic table for mode of operation
Operating Frequency Range	1710		1785	MHz	
Input Power	0	2	4	dBm	Full P_{OUT} guaranteed at minimum drive level.
Input VSWR			2:1	dBm	Over all power levels (0dBm to 30dBm)
Maximum Output Power	31.4			dBm	Full P_{OUT} guaranteed at minimum drive level
	28.9			dBm	Temp=+85°C, V_{BATT}=3.0V, P_{IN}=0dBm
PAE(Max P_{OUT})		38		%	P_{OUT}=31.4dBm
Output Noise Power, 1805MHz to 1880MHz		-81		dBm	RBW=100kHz, Set P_{OUT}≤31.4dBm
Forward Isolation 1			-52	dBm	TX_EN=Low, P_{IN}=-50dBm, V_{RAMP}=0V
All Harmonics up to 12.75GHz		-40		dBm	Over all power levels (0.4dBm to 31.4dBm)
Output Load VSWR Stability			-36	dBm	VSWR=15:1; all phase angles, set V_{RAMP} where P_{OUT}≤31.4dBm into 50Ω load
Output Load VSWR Ruggedness	No damage or permanent degradation.				VSWR=20:1; all phase angles, set V_{RAMP} where P_{OUT}≤31.4dBm into 50Ω load.
Delivered P_{OUT}	28.65		30.9		VBATT=3.6V, PIN=2dBm V_{RAMP} where P_{OUT}=31.4dBm@ Load impedance=50Ω Change Load VSWR=3:1 all phases Measure delivered P_{OUT}

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Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
RX-Section					Nominal test conditions unless otherwise stated. All unused ports are terminated with 50Ω. Temp=+25°C, V_{BATT}=3.6V, TXP=Low. Refer to logic table for mode of operation
Insertion Loss, ANT-RX1:LB		1.0		dB	925MHz to 960MHz
Insertion Loss, ANT-RX2:HB		1.2		dB	1805MHz to 1880MHz
Ripple, ANT-RX1 LB			0.2	dB	925MHz to 960MHz
Ripple, ANT-RX2 HB			0.2	dB	1805MHz to 1880MHz
VSWR, ANT-RX1: LB			1.3:1		925MHz to 960MHz
VSWR, ANT-RX2: HB			1.3:1		1805MHz to 1880MHz
TX-Section					Temp=+25°C, V_{BATT}=3.5V, V_{RAMP}=2.1V, P_{IN}=0dBm, TX EN=High, Duty Cycle=25%, Pulse Width=1154µs
TX Leakage to RX Port					
GSM900 ANT-RX 1			0	dBm	GSM900 TX Mode:Frequency=880MHz to 915MHz, P_{OUT}=+5.3dBm to +33.1dBm
GSM900 ANT-RX 2			0	dBm	GSM900 TX Mode:Frequency=880MHz to 915MHz, P_{OUT}=+5.3dBm to +33.1dBm
DCS1800 ANT-RX 1			0	dBm	DCS1800 TX Mode:Frequency=1710MHz to 1785MHz, P_{OUT}=0.4dBm to +31.4dBm
DCS1800 ANT-RX 2			0	dBm	DCS1800 TX Mode:Frequency=1710MHz to 1785MHz, P_{OUT}=0.4dBm to +31.4dBm

Note: Isolation Calculation Example: Isolation=P_{OUT}@ANT-P_{OUT}@RXPort. Isolation LB(ANT-RX1)=33-10=23dB, Isolation HB(ANT-RX2)=30-8=22dB

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Pin	Function	Description
1	GND	Ground.
2	Switch Enable	Control Voltage to switch between RX and TX.
3	Band Select	Control Voltage to switch between LB and HB.
4	Power Mode	Control Voltage to switch between High Power Mode and Medium Power Mode
5	GND	Ground.
6	GND	Ground.
7	RX1_LB	Low band RX output. This output covers the frequency range of EGSM900 RX bands. No DC voltage from the module allowed on this pin.
8	GND	Ground
9	RX2_HB	High band RX output. This output covers the frequency range of DCS1800 RX bands. No DC voltage from the module allowed on this pin.
10	GND	Ground.
11	GND	Ground.
12	ANT	Antenna terminal. No DC voltage from the module allowed on this pin.
13	GND	Ground.
14	GND	Ground.
15	GND	Ground.
16	GND	Ground.
17	GND	Ground.
18	GND	Ground.
19	VBATT	Supply Voltage for Module.
20	VBATT	Supply Voltage for Module.
21	GND	Ground.
22	GND	Ground.
23	NC	No Connection.
24	TXIN_LB	TX RF input to PA for EGSM900 TX band.
25	TXIN_HB	TX RF input to PA for DCS1800 TX band.
26	GND	Ground.
27	TXP	TX enable signal, controls powering up power loop and bias circuit.
28	VPC	Power control voltage, ramps the output power up and down.
29	GND	Ground.

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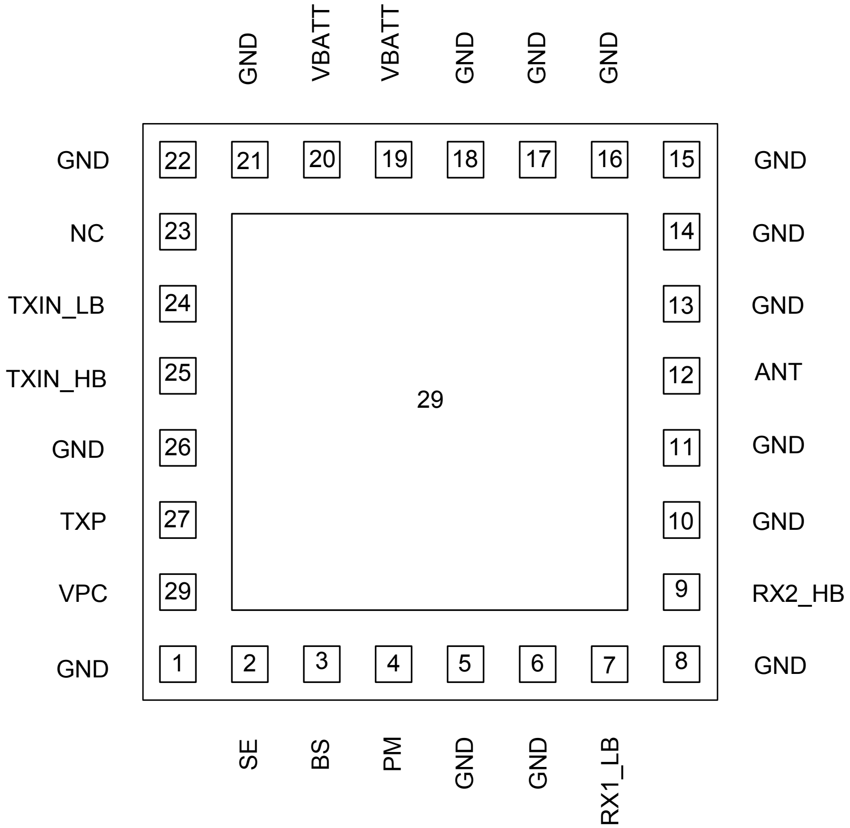
Pin Out

Top View



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Theory of Operation

Product Description

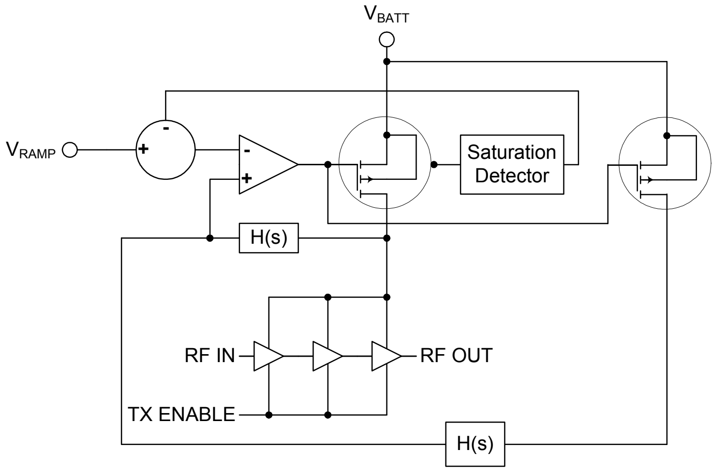
The RF7188 is a high-power, high-efficiency, transmit module (TXM) with fully-integrated power control functionality, harmonic filtering, band selectivity, and TX/RX switching. The TXM is self-contained, with 50Ω I/O terminals with two RX ports allowing true dual-band operation. The power control function eliminates all power control circuitry, including directional couplers, diode detectors, and power control ASIC's, etc. The power control capability provides 50dB continuous control range, and 70dB total control range, using a DAC-compatible, analog voltage input. Output power variations into varying load impedance are minimized by the power control circuitry in order to meet Total Radiated Power (TRP) requirements. The TX Enable feature provides for PA activation (TX mode) or RX mode/Stand-by. Internal switching provides a low-loss, low-distortion path from the Antenna port to the TX path (or RX port), while maintaining proper isolation. Integrated filtering provides ETSI compliant harmonic suppression at the antenna port even under high mismatch conditions, which is important as modern antennas today often present a load that significantly deviates from nominal impedance.

Overview

The RF7188 is a dual-band GSM900/DCS1800 power amplifier module with fully integrated power control and antenna switch module eliminating the need for the complicated control loop design, harmonic filters, TX/RX switch and possible matching components. The power control loop can be driven directly from the DAC output in the baseband circuit. The module has two RX ports for GSM900/DCS1800 bands of operation. To control the mode of operation, there are four logic control signals: TX Enable, TXP, BS, PM, SE.

Power Control Theory of Operation

Most power control systems in GSM sense either forward power or collector/drain current. The RF7188 uses RFMD's PowerStar™ collector voltage control instead of a power detector. A high-speed control loop is incorporated to regulate the collector voltage of the amplifier while the stages are held at a constant bias. The V_{RAMP} signal is multiplied by a factor of approximately 2.65, and the collector voltage for all three stages is regulated to the multiplied V_{RAMP} voltage. This circuit is what performs the V_{BATT} tracking so no external V_{RAMP} adjustment is necessary. By doing so, the power amplifier can operate over a wider range of V_{RAMP} values, and can meet transient spectrum requirements at lower V_{CC} values. In addition, a current mirror is added to sense the power amplifier current. This loop senses the current, and feeds a voltage back into the control loop, and the collector voltage is further compensated to limit power and current variation. This allows for more efficient operation under mismatch conditions. Under nominal conditions, this loop is not activated, and is seemingly transparent. The basic circuit is shown in the following diagram.



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By regulating the power, the stages are held in saturation across all power levels. As the required output power is decreased from full power down to -15dBm, the collector voltage is also decreased. This regulation of output power is demonstrated in Equation 1 where the relationship between collector voltage and output power is shown. Although load impedance affects output power, supply fluctuations are the dominate mode of power variations. With the RF7188 regulating, there are several key factors to consider in the implementation of a transmitter solution for a mobile phone. Some of them are:

$$P_{dBm} = 10 \cdot \log\left[\frac{(2 \cdot V_{CC} - V_{SAT})^2}{8 \cdot R_{LOAD} \cdot 10^{-3}}\right] \qquad \text{(Eq. 1)}$$

- Effective efficiency (η_{EFF})
- Current draw and system efficiency
- Power variation due to Supply Voltage
- Power variation due to frequency
- Power variation due to temperature
- Input impedance variation
- Noise power
- Loop stability
- Loop bandwidth variations across power levels
- Burst timing and transient spectrum trade offs
- Harmonics
- Post PA loss
- Insertion loss in receive ports
- TX power leakage into the RX ports
- Performance during VSWR
- Time needed to implement the solution
- Needed board area for the solution

Talk time and power management are key concerns in transmitter design since the power amplifier is the leading current consumer in a mobile terminal. Considering only the power amplifier's efficiency does not provide a true picture for the total system efficiency. It is important to consider effective efficiency which is represented by η_{EFF}. (η_{EFF} considers the loss between the PA and antenna and is a more accurate measurement to determine how much current will be drawn in the application). η_{EFF} is defined by the following relationship (Equation 2):

$$\eta_{EFF} = \frac{10^{\frac{P_{PA} + P_{LOSS}}{10}} - 10^{\frac{P_{IN}}{10}}}{V_{BAT} \cdot I_{BAT} \cdot 10} \qquad \text{(Eq. 2)}$$

Where P_{PA} is the output power from the PA, P_{LOSS} the insertion loss and P_{IN} the input power to the PA. The RF7188 improves the effective efficiency by minimizing the P_{LOSS} term in the equation. An ASM may have a typical loss of 1.2dB in LB and 1.4dB in high band. To be added to this is trace losses and mismatch losses. A post PA loss of 1.5dB in LB and 1.8dB in HB is common. With the integration of a low loss pHEMT switch and matching network in the same module, higher system efficiency can be achieved.

The components following the power amplifier often have insertion loss variation with respect to frequency. Usually, there is some length of microstrip that follows the power amplifier. There is also a frequency response found in directional couplers due to variation in the coupling factor over frequency, as well as the sensitivity of the detector diode. Since the RF7188 does not use a directional coupler with a diode detector, these variations do not occur. Also the TX/RX switch with low pass filters that usually follows the PA may contribute to frequency variation. The TX/RX switch incorporated in the RF7188 is very broadband and does not contribute to frequency roll off. Traditionally working with PA modules, some matching network is necessary between the PA output and the input of the TX/RX switch in order to get best possible performance. This work no longer has to be carried out, as this matching network is included in the RF7188.

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Noise power in PA's where output power is controlled by changing the bias voltage is often a problem when backing off of output power. The reason is that the gain is changed in all stages and according to the noise formula (Equation 3),

$$F_{TOT} = F1 + \frac{F2-1}{G1} + \frac{F3-1}{G1 \cdot G2} \qquad \text{(Eq. 3)}$$

The noise figure depends on noise factor and gain in all stages. The bias point of the RF7188 is kept constant, therefore the gain in the first stage is always high and the overall noise power is not increased when decreasing output power.

Power control loop stability often presents many challenges to transmitter design. Designing a proper power control loop involves trade-offs affecting stability, transient spectrum and burst timing.

The RF7188 loop bandwidth is determined by internal bandwidth and does not change with respect to power levels. This makes it easier to maintain loop stability with a high bandwidth loop since the bias voltage and collector voltage do not vary. An often overlooked problem in PA control loops is that a delay not only decreases loop stability it also affects the burst timing when, for instance the input power from the VCO decreases (or increases) with respect to temperature or supply voltage. The burst timing then appears to shift to the right especially at low power levels. The RF7188 is insensitive to a change in input power and the burst timing is constant and requires no software compensation. Switching transients occur when the up and down ramp of the burst is not smooth enough or suddenly changes shape. If the control slope of a PA has an inflection point within the output power range or if the slope is simply too steep it is difficult to prevent switching transients. Controlling the output power by changing the collector voltage is as earlier described based on the physical relationship between voltage swing and output power. Furthermore, all stages are kept constantly biased so inflection points are nonexistent.

Harmonics are natural products of high efficiency power amplifier design. An ideal class "E" saturated power amplifier will produce a perfect square wave. Looking at the Fourier transform of a square wave reveals high harmonic content. Although this is common to all power amplifiers, there are other factors that contribute to conducted harmonic content as well. With most power control methods a peak power diode detector is used to rectify and sense forward power. Through the rectification process there is additional squaring of the waveform resulting in higher harmonics. The RF7188 address this by eliminating the need for the detector diode. In addition, the RF7188 provides integrated harmonic filtering. Therefore the harmonics coming out of the PA should represent the maximum power of the harmonics throughout the transmit chain. This is based upon proper harmonic termination of the transmit port.

Performance under VSWR

Often overlooked when designing transmitters is the fact that they normally operate under mismatch conditions while they are designed to operate only under perfect 50 ohm loads. This means that in the real application, performance is degraded. This performance degradation may include reduction in output power, increased harmonic levels, increased transient spectrum and catastrophic failures, breakdown. Traditionally designers have verified that the PA does not break during mismatch and this is all verification that has been carried out during mismatch. Modern antennas in handsets often present a load that significantly deviates from nominal impedance. A VSWR of 5:1 is not uncommon. In order not to disturb other phones in the same and close by cells, it is important that the ETSI specifications for transient spectrum, burst timing and spurious emission are fulfilled even during mismatch conditions. The RF7188 is designed to maintain its performance even under high antenna mismatch conditions.

The PowerStar™ methodology utilized in the RF7188 allows the transient spectrum in normal operation to be in the order of -35 dBm to -40 dBm but also both transient spectrum and the power versus time performance is unaffected even under mismatch conditions. Power output variation is minimized as well as the total current consumption. In addition, the harmonic level fluctuations are significantly decreased.

RF7188 has an integrate power flattening circuit that reduces the amount of current variation when a mismatch is presented to the output of the PA. When a mismatch is presented to the output of the PA, its output impedance is varied and could present a load that will increase output power. As the output power increases, so does current consumption. The current consumption can become very high if not monitored and limited. The power flattening circuit is integrated onto the CMOS controller and requires no input from the user. Into a mismatch, the current varies as the phase changes. The power flattening circuit monitors current through an internal sense resistor. As the current changes, the loop is adjusted in order to maintain current. The result is flatter power and reduced current into mismatch.

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TX/RX Switch

The pHEMT switch integrated in the RF7188 allows for a low loss connection between the antenna port and the two RX ports. The insertion loss in the TX and RX paths is lower than the loss for a traditional pin-diode switch solution, which means lower current consumption in TX mode and better receiver sensitivity. The integrated switch also allows for less design complexity since there is no need for power amplifier to antenna switch matching.

VBATT Tracking Circuit

The RF7188 also incorporates a VBATT tracking feature that eliminates the need for the transceiver/baseband to regulate the ramping signal as the supply voltage decreases. The internal circuit monitors the supply voltage and adjusts the ramping signal such that the switching spectrum is minimally impacted..

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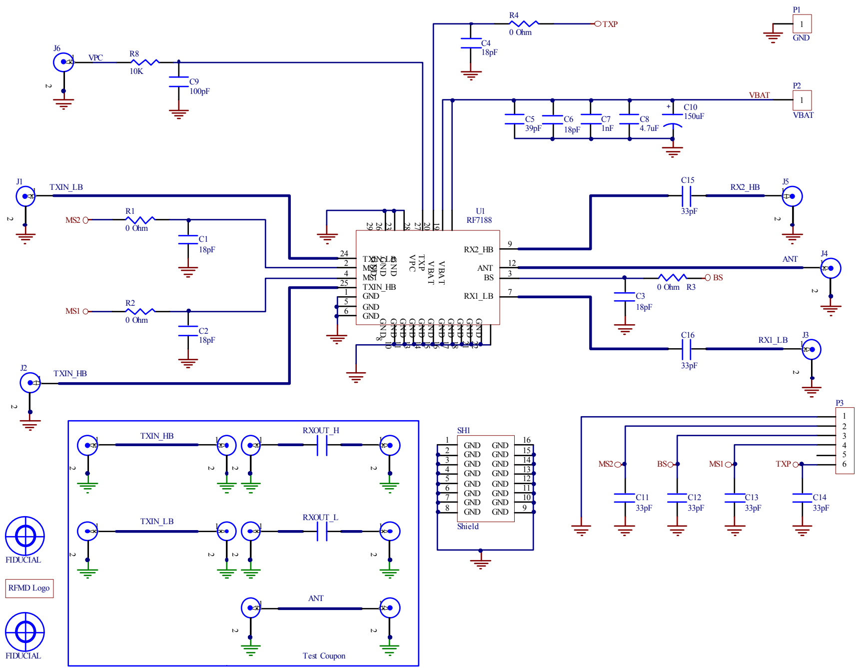
Evaluation Board Schematic



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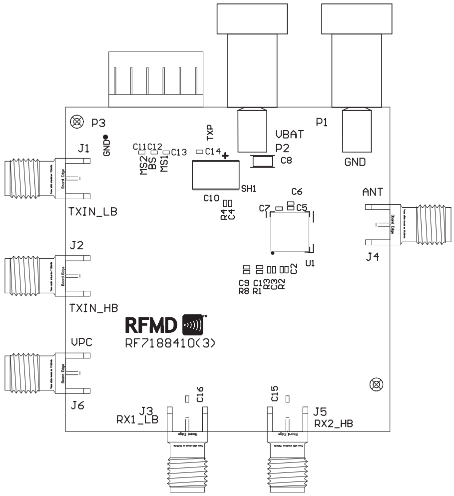
Evaluation Board Layout
Board Size 2.0" x 2.0"



7188410(3) Silkscreen Top

7188410(3) Assembly Top
7188410(3) Board Outline

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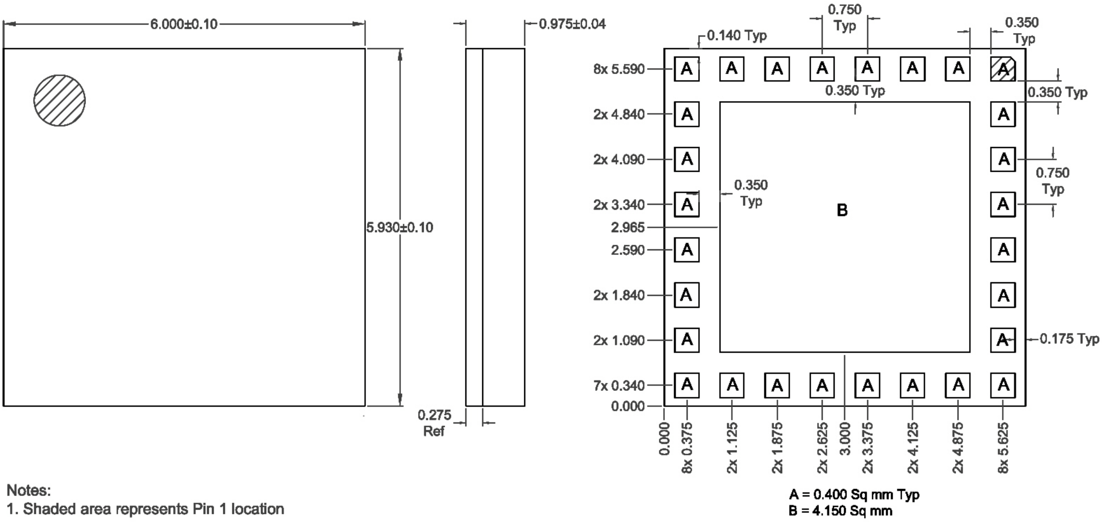
Package Drawing



Notes:
1. Shaded area represents Pin 1 location

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PCB Design Requirements

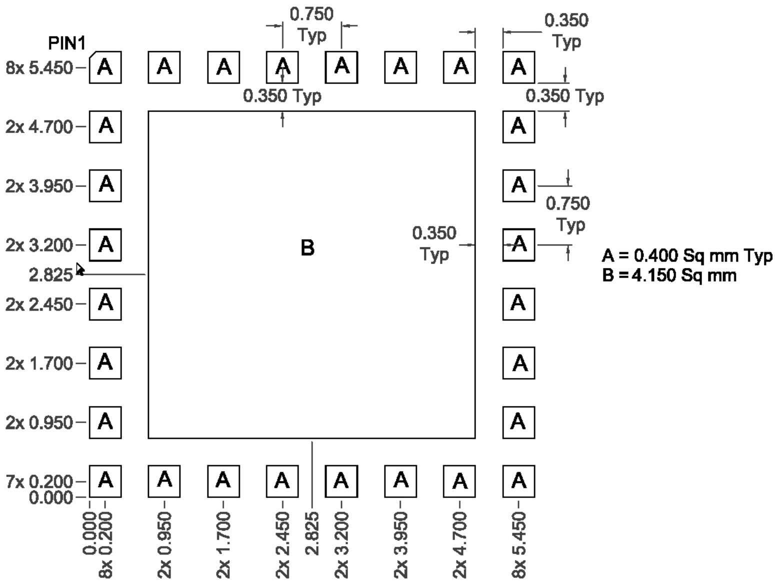
PCB Surface Finish

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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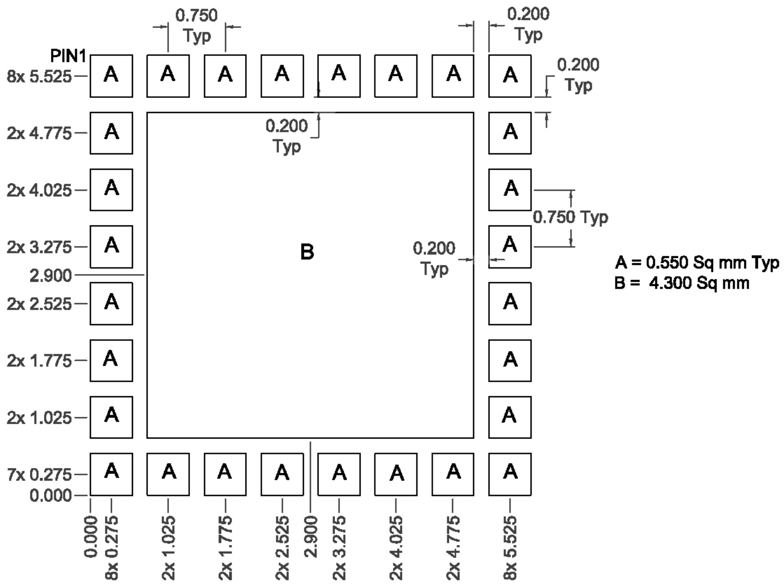
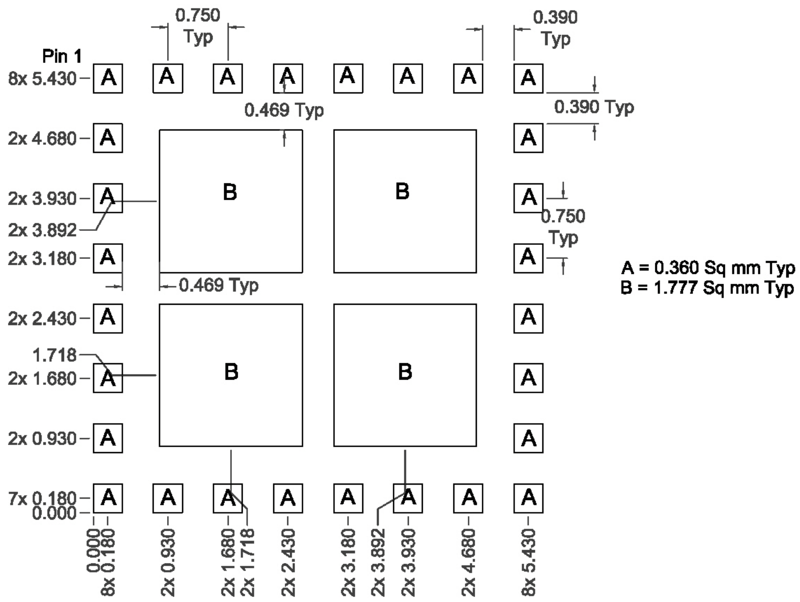
PCB Solder Mask Pattern



PCB Stencil Pattern



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