## Features

- Integrated 2.4GHz to 2.5GHz b/g/n Amplifier, LNA, SP3T Switch, and Power Detector Coupler
- Single Supply Voltage 3.0V to 4.8V
- $P_{OUT}$ = 19.5dBm, 11g, OFDM at <3.3% EVM, 22dBm 11b Meeting 11b Spectral Mask
- Low Height Package, Suited for SiP and CoB Designs

## Applications

- Cellular handsets
- Mobile devices
- Tablets
- Consumer electronics
- Gaming
- Netbooks/Notebooks
- TV/monitors/video
- SmartEnergy
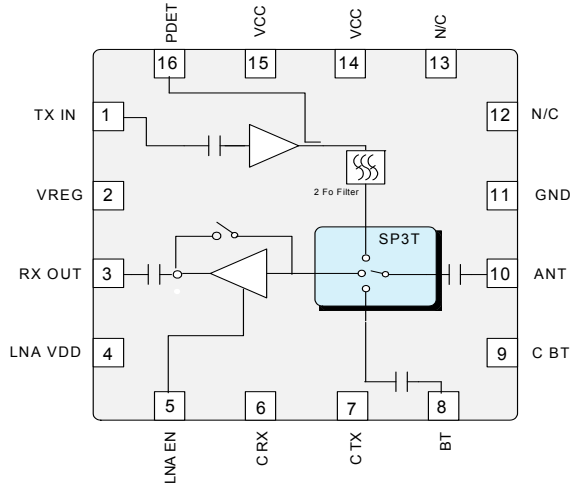


Functional Block Diagram

## Product Description

The RF5565 provides a complete integrated solution in a single Front End Module (FEM) for WiFi 802.11b/g/n and *Bluetooth*® systems. The ultra small form factor and integrated matching greatly reduces the number of external components and layout area in the customer application. This simplifies the total Front End solution by reducing the bill of materials, system footprint, and manufacturability cost. The RF5565 integrates a 2.4GHz Power Amplifier (PA), Low Noise Amplifier (LNA) with bypass mode, power detector coupler for improved accuracy, and some filtering for harmonic rejection. The device is provided in a 3mm x 3mm x 0.5mm, 16-pin package. This module meets or exceeds the RF Front End needs of IEEE 802.11b/g/n WiFi RF systems.

## Ordering Information

| | |
|---|---|
| RF5565SQ | Standard 25 pieces sample bag |
| RF5565SR | Standard 100 pieces reel |
| RF5565TR7 | Standard 2500 pieces reel |
| RF5565PCK-410 | Fully assembled evaluation board with 5-piece bag |

## 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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# RF5565

## Absolute Maximum Ratings

| Parameter | Rating | Unit |
|---|---|---|
| DC Supply Voltage (Continuous with No Damage) | 5.4 | V |
| DC Supply Current | 500 | mA |
| Case Temperature (Full Spec. Compliant) | -10 to +70 | °C |
| Extreme Operating Case Temperature (Reduced Performance) | -40 to -10 +70 to +85 | °C |
| Storage Temperature | -40 to +150 | °C |
| Maximum TX Input Power into 50 Ω Load for 11b/g/n (No Damage) | 0 | dBm |
| Maximum RX Input Power (No Damage) | 0 | dBm |
| Moisture Sensitivity | MSL2 | |

**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 EU Directive 2002/95/EC (at time of this document revision).

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| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **2.4 GHz Transmit Parameters** | | | | | |
| Compliance | | | | | IEEE 802.11b, IEEE 802.11g, FCC CFG 15.247,.205,.209, EN, and JDEC |
| Nominal Conditions | | | | | $V_{CC}$=3.3V to 4.2V; $V_{REG}$=3V to 3.2V; Switch Control voltage=3V to 3.6V; Temp=-10°C to +70°C; Unless noted otherwise. |
| Frequency | 2.4 | | 2.5 | GHz | |
| Power Supply | 3.0 | 3.3 | 4.8 | V | Voltage Supply Operating Range |
| $V_{REG}$ Voltage | | | | | |
| ON | 3.0 | 3.1 | 3.2 | V | PA in "ON" state |
| OFF | | 0.00 | 0.20 | V | PA in "OFF" state |
| Output Power | | | | | |
| 11g | 18 | 18.5 | | dBm | 54 Mbps, OFDM 54 Mbps, $V_{CC} \geq 3.0V$ |
| | 18.5 | 19.5 | | dBm | 54 Mbps, OFDM 54 Mbps, $V_{CC} \geq 3.3V$ |
| 11b | 20 | 22 | | dBm | 11 Mbps, CCK, $V_{CC} \geq 3.0V$ |
| EVM | | 3.3 | 4.0 | % | $P_{OUT(g)}$=Rated Output Power, 54 Mbps OFDM, 50 Ω, see note 1 |
| Adjacent Channel Power | | | | | $P_{OUT(b)}$=20 dBm 11 Mbps CCK, note 2 |
| ACP1 | | -36 | -33 | dBc | Nominal conditions, meeting 11b spectral mask requirements |
| ACP2 | | -56 | -51 | dBc | |
| Gain | 26 | 30 | 34.5 | dB | |
| Gain Variation Slope | | | | | At rated power and a given supply voltage |
| Range | 3.0 | | 4.2 | V | |
| $V_{CC}$ (Average) | | | 0.5 | dB/V | |
| $V_{CC}$ (Instantaneous) | | | 1 | dB/V | |
| Frequency | -0.5 | | +0.5 | dB | 2.4 GHz to 2.5 GHz |

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| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **2.4GHz Transmit Parameters, cont.** | | | | | |
| Typical Input Power | | | | | |
| 11g | | -9 | | dBm | |
| 11b | | -5 | | dBm | |
| Power Detect | | | | | |
| Power Range | 0 | | 23 | dBm | |
| Voltage Range | 0.1 | | 1.5 | V | |
| Resistance | | 10 | | kΩ | |
| Capacitance | | | 10 | pF | |
| Sensitivity | | | | | |
| $0 < P_{OUT} < 6\,dBm$ | 3 | | | mV/dB | |
| $6 < P_{OUT} < 23\,dBm$ | 8 | | 350 | mV/dB | |
| Current Consumption | | | | | $V_{CC}$=3.3V, $V_{REG}$=3.1V, T=25°C |
| $I_{CC}$ | | 170 | 200 | mA | RF $P_{OUT}$=18.5dBm, 11g, 50Ω |
| | | 220 | 250 | mA | RF $P_{OUT}$=20dBm, 11b, 50Ω |
| Quiescent Current | | 90 | | mA | RF="OFF" |
| $I_{REG}$ | | | 3 | mA | $V_{REG}$>3.0V |
| $V_{CC}$ Leakage Current | | 2 | 10 | µA | $V_{CC}$=4.8V, $V_{REG}$=C_BT=C_RX=C_BWRX$\leq$0.2V |
| Input Port Impedance | | 50 | | Ω | |
| Input Port Return Loss | 10 | 15 | | dB | |
| Ruggedness | | | | | No Damage Conditions: max operating voltage, max input power, max temperature |
| Output VSWR | | | 10:1 | | |
| Input Power | | | -5 | dBm | |
| Stability | | | | | PA must be stable (no spurs above -43dBm) from 0 to 20dBm, All phase angles, no spurious or oscillations |
| Output VSWR | 6:1 | | | | |
| Out-of-Band Emissions 2310MHz to 2390MHz and 2483.5MHz to 2500MHz | | | -41.25 | dBm/MHz | $P_{OUT}$=16.5dBm, 54Mbps OFDM Modulation, 64QAM, RBW=1MHz, VBW=100kHz, $V_{CC}$=3.3V, $V_{REG}$=3.1V |
| | | | -41.25 | dBm/MHz | $P_{OUT}$=20.5dBm, 11Mbps CCK Modulation, RBW=1MHz, VBW=100kHz, $V_{CC}$=3.3V, $V_{REG}$=3.1V |
| Thermal Resistance | | 20 | | °C/W | $V_{CC}$ = 4.8, $V_{REG}$ = 3.2V, $P_{OUT}$=20dBm, $T_{REF}$=85°C |
| Harmonics | | | | | 11b modulation, 1Mbps, BW=1MHz, up to 3:1 load |
| Second | | | -23 | dBm | 4.80GHz to 5.00GHz |
| Third | | | -20 | dBm | 7.20GHz to 7.50GHz |
| Turn-on/off Time | | 0.5 | 1.0 | µS | Output stable to within 90% of final gain, Note 1 |

# RF5565

| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **2.4 GHz Receive Parameters** | | | | | |
| Compliance | | | | | IEEE802.11b, IEEE802.11g, FCC CFG 15.247,.205,.209, EN, and JDEC |
| Frequency | 2.4 | | 2.5 | GHz | |
| LNA Voltage Supply | 3.0 | 3.3 | 4.8 | V | LNA $V_{DD}$ tied to $V_{BATT}$ at all times |
| LNA Current | 5 | 12 | 20 | mA | LNA in "ON" state |
| | 0 | | 5 | µA | LNA in "OFF" state (C_RX=low, LNA $V_{DD}$=ON) |
| LNA Input P1dB | -9 | -5 | | dBm | |
| Gain | | | | | |
| WiFi RX Gain | 11 | 14 | 16 | dB | WiFi RX mode |
| Bypass Mode | -4 | | | dB | WiFi Bypass Mode |
| Noise Figure | | | | | $V_{CC} \geq 3.3V$, including switch |
| WiFi RX | | 2.2 | 3.5 | dB | |
| Bypass Mode | | 2.6 | 4 | dB | |
| Passband Ripple | -0.5 | | +0.5 | dB | WiFi RX Mode |
| | -0.5 | | +0.5 | dB | WiFi Bypass Mode |
| WiFi RX Output Return Loss | 9.6 | | | dB | |
| WiFi RX Input Return Loss | 5 | 7 | | dB | Measured at antenna port |
| WiFi RX Port Impedance | | 50 | | Ω | No external matching |
| **Bluetooth Parameters** | | | | | |
| Frequency | 2.4 | | 2.5 | GHz | |
| Insertion Loss | | | | | |
| BT TX/RX | | 0.9 | 1.2 | dB | Bluetooth mode (measured ANT to BT port) |
| Passband Ripple | -0.2 | | +0.2 | dB | Bluetooth mode |
| Bluetooth Output Return Loss | 9.6 | | | dB | Switch in Bluetooth Mode |
| Input P1dB | | 28 | | dBm | |
| **Other Requirements** | | | | | |
| Antenna Port Impedance | | | | | |
| Output | | 50 | | Ω | |
| Return Loss | 5 | 7 | | dB | |
| Isolation | | | | | |
| Antenna to Receive | 20 | | | dB | In BT Mode (measured from ANT to RX port) |
| Antenna to *Bluetooth*® | 20 | | | dB | In TX Mode (measured from ANT to BT port) |
| Antenna to Receive | 20 | | | dB | In TX Mode (measured from ANT to RX port) |
| Switch Control Voltage | | | | | C RX, C BT, and C_TX control lines |
| Low | | 0 | 0.2 | V | Switch is in the low state (L) |
| High | 3.0 | | 3.6 | V | Switch is in the high state (H) |
| Switch Control Current | | 2 | 10 | µA | Per control line |
| LNA_EN Control Current | | 60 | 100 | µA | Over $V_{CC}$, Frequency and Temperature. |
| Switch Control Speed | | | 10 | nsec | |
| Switch P1dB | | 28 | | dBm | |

| Parameter | Specification | | | Unit | Condition |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| **Other Requirements, cont.** | | | | | |
| ESD | | | | | |
| Human Body Model | 500 | | | V | EIA/JESD22-114A RF pins |
| | 1000 | | | V | EIA/JESD22-114A DC pins |
| Charge Device Model | 500 | | | V | JESD22-C101C all pins |

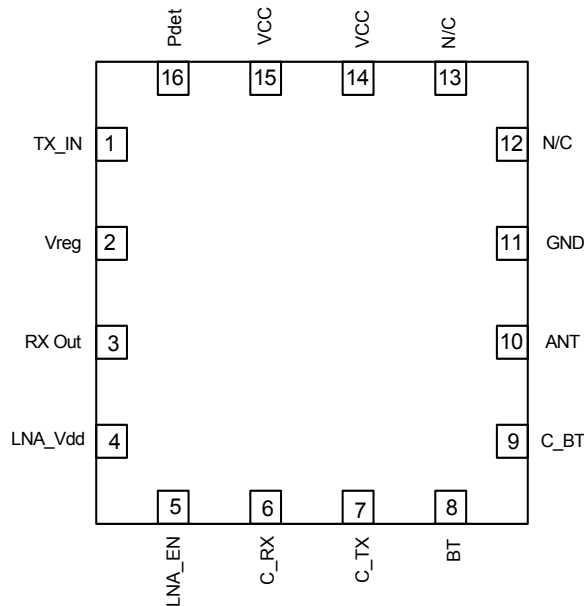Note 1: The PA module must operate with gated bias voltage input at 1% to 99% duty cycle.
Note 2: The output power for channels 1 and 11 may be reduced to meet FCC restricted band requirements.
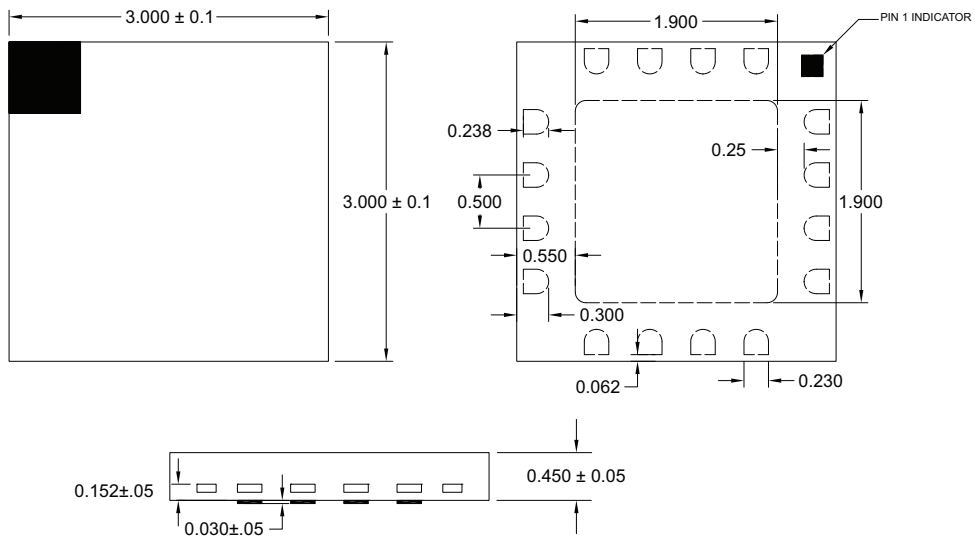
## Switch Control Logic

| Mode | C_TX | C_RX | C_BT | VREG | LNA_EN |
|---|---|---|---|---|---|
| Transmit | H | L | L | H | L |
| Receive | L | H | L | L | H |
| Bypass | L | H | L | L | L |
| Bluetooth | L | L | H | L | L |
| Standby | L | L | L | L | L |
| Logic Voltage Levels | H | 3.0V to 3.6V | | | |
| | L | <0.2V | | | |

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# RF5565

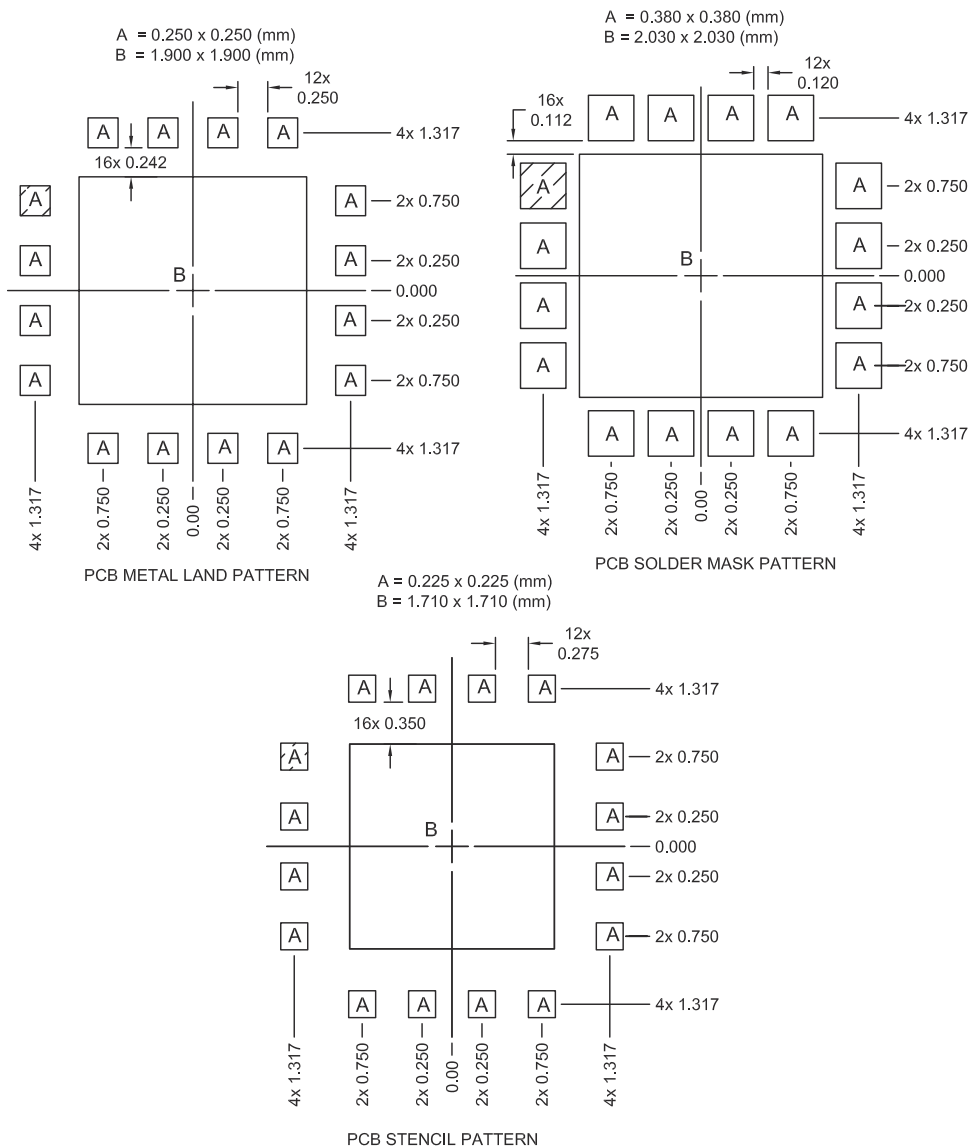| Pin | Function | Description |
|-----|----------|-------------|
| 1 | TX_IN | RF input for the 802.11b/g PA. Input is matched to 50Ω and DC block is provided. |
| 2 | VREG | Regulated voltage for the bias control circuit. An external bypass capacitor may be needed on the $V_{REG}$ line for decoupling purposes. |
| 3 | RX OUT | Receive port for 802.11b/g band. Internally matched to 50Ω. DC block provided. |
| 4 | LNA VDD | Voltage supply for the LNA. |
| 5 | LNA_EN | Control voltage for the LNA. When this pin is set to a LOW logic state, the bypass mode is enabled. |
| 6 | C RX | Receive switch control pin. See switch truth table for proper level. |
| 7 | C_TX | Switch control voltage for the transmit branch. See logic control table for proper settings. |
| 8 | BT | RF bidirectional port for *Bluetooth*®. Input is matched to 50Ω and DC block is provided. |
| 9 | C_BT | *Bluetooth*® switch control pin. See truth table for proper level. |
| 10 | ANT | Port matched to 50Ω and is DC blocked internally. |
| 11 | GND | Ground. |
| 12 | N/C | No connect. |
| 13 | N/C | No connect. |
| 14 | VCC | Supply voltage for the PA. |
| 15 | VCC | Supply voltage for the PA. |
| 16 | PDETECT | Power detector voltage for TX section. PDET voltage varies with output power. May need external decoupling capacitor for noise bypassing. May need external circuitry to bring output voltage to desired level. |

## Pin Out

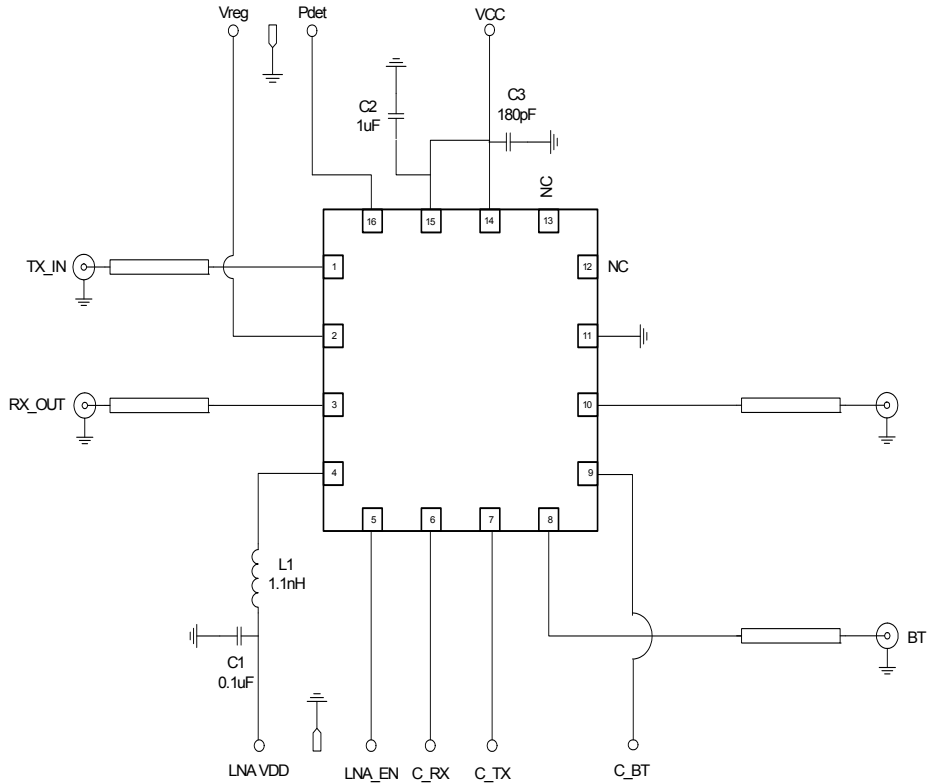DS120214

## Package Drawing



NOTES:
1    Shaded Area is Pin 1 Indicator

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## RF5565 PCB Footprint and Stencil Recommendations

A = 0.250 x 0.250 (mm)
B = 1.900 x 1.900 (mm)

PCB METAL LAND PATTERN

A = 0.380 x 0.380 (mm)
B = 2.030 x 2.030 (mm)

PCB SOLDER MASK PATTERN

A = 0.225 x 0.225 (mm)
B = 1.710 x 1.710 (mm)

PCB STENCIL PATTERN

Shaded are represents Pin 1 location.

Thermal vias for center slug "B" should be incorporated into the PCB design. The number and size of thermal vias will depend on the application, the power dissipation, and the electrical requirements. Example of the number and size of vias can be found on the RFMD evaluation board layout.

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# Evaluation Board Schematic

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# RF5565

## Theory of Operation

The RF5565 Front End Module (FEM) is designed for WiFi applications in the 2.5 GHz ISM band. It can be applied in many portable applications such as handsets, Personal Media Players, and portable battery power equipment. This highly integrated module can be connected directly to the battery without additional voltage regulators.

### WiFi TRANSMIT MODE

The RF5565 requires a single positive supply ($V_{CC}$), a positive supply for switch controls, and a regulated supply for the $V_{REG}$ to maintain nominal bias current. The RF5565 transmit path has a typical gain of 30 dB from 2.4 GHz to 2.5 GHz, and delivers 20 dBm typical output power under 54 Mbps OFDM modulation and 22 dBm under 1 Mbps 11b modulation. The RF5565 contains basic filter components to produce a bandpass response for the transmit path. Due to space constraints inside the module, filtering is limited to a few resonant poles and additional filters may be required depending upon the end-user's application. While in transmit mode, the active components are the Power Amplifier (PA) and the TX branch of the SP3T switch. Refer to the logic control table for proper settings.

TX Biasing Instructions

- Connect the TX input to a signal generator and a spectrum analyzer at the Antenna output.

- Set $V_{CC}$ to 3.3 V with $V_{REG}$ set to 0 V.

- Turn $V_{REG}$ ON and set voltage to 3.1 V. $V_{REG}$ controls the current drawn by the PA and it should quickly reach a quiescent current of approximately 90 mA±20 mA. Care must be exercised not to exceed 3.5 V on the $V_{REG}$ pin or the part may be damaged.

- Next set C_TX high. This pin controls the transmit branch of the SP3T.

- The SP3T controls for the off branches (C_RX and C_BT) must be set to a logic "low" (0.2 V max) or grounded. In the event that one of these branches is left floating or in a logic "high" the performance of the PA will degrade significantly. Likewise, unused RF Ports must be terminated in 50Ω to simulate actual system conditions and prevent RF signals from coupling back to the PA.

- Turn RF ON.

### WiFi RECEIVE MODE

Within the frequency band of operation 2.4 GHz to 2.5 GHz, the RF5565 WiFi receive path has a typical gain of 14 dB and a NF of 2.2 dB with about 12 mA of current. In RX mode, only the RX branch of the SP3T and the LNA are active. Refer to the logic control table for proper settings.

RX Biasing Instructions

- Connect the RX input (ANT/pin-10) to a signal generator and a spectrum analyzer at the RX output. A VNA may be used as well.

- Turn LNA voltage supply ON and set the voltage to 3.3 V.

- Set C_RX and LNA_EN high. This turns the LNA and the receive branch of the SP3T ON.

- The SP3T controls for the off branches (C_TX and C_BT) must be set to a logic "low" (0.2 V max) or grounded. In the event that one of these branches is left floating or in a logic "high" the performance will degrade. It is recommended to terminate unused RF Ports in 50Ω.

- Turn RF ON.

**Bypass Mode for WiFi Receive Operation**

- Connect the RF input (ANT/pin-10) to a signal generator and a spectrum analyzer at the RX output. A multiport VNA may be used as well.

- Set LNA_EN low. By applying a voltage <0.2V to this pin it enables the bypass switch of the LNA.

- Set C_RX high. This turns the receive branch of the SP3T ON.

- The SP3T controls for the off branches (C_TX and C_BT) must be set to a logic "low" (0.2V max) or grounded. In the event that one of these branches is left floating or in a logic "high" the performance will degrade. It is recommended to terminate unused RF Ports in 50Ω.

- Turn RF ON.

## *BLUETOOTH*® MODE

The RF765 *Bluetooth*® only mode is implemented through the SP3T switch by setting C_BT "high." Typical insertion loss is about 1dB.

*Bluetooth*® Biasing Instructions

- Connect the RF input (ANT/pin-10) to a signal generator and a spectrum analyzer at the BT (pin-8) RF port. A VNA may be used in place of the Sig Gen and SA.

- Set C_BT "high." This turns the *Bluetooth*® branch of the SP3T switch ON.

- The SP3T controls for the off branches (C_TX and C_RX) must be set to a logic "low" (0.2V max) or grounded. Do not leave floating.
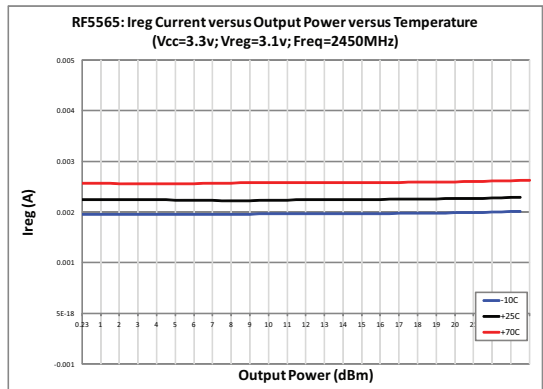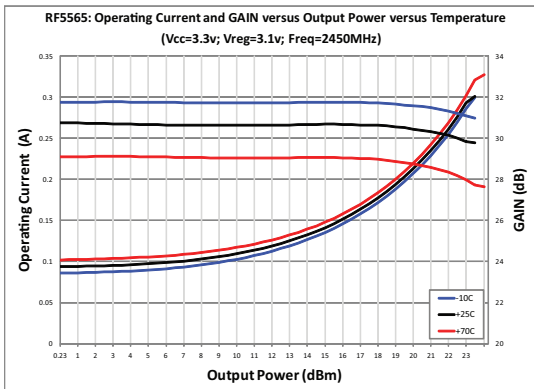
- Terminate unused RF Ports in 50Ω
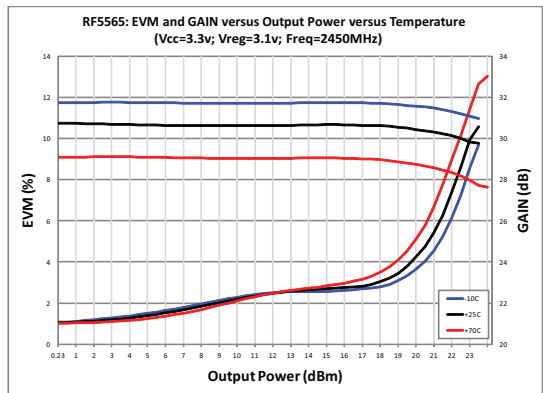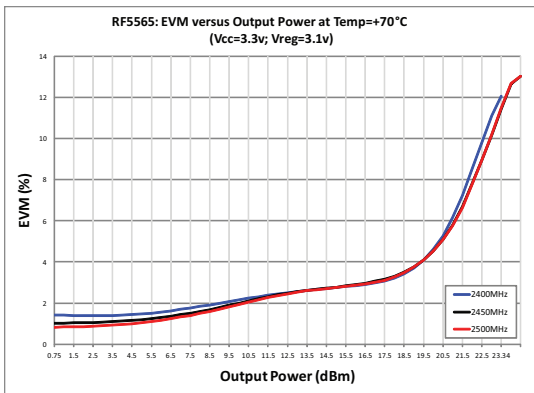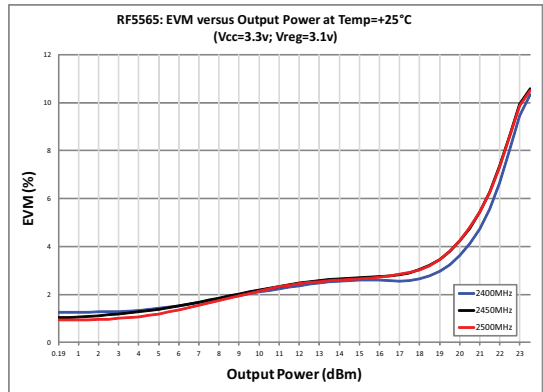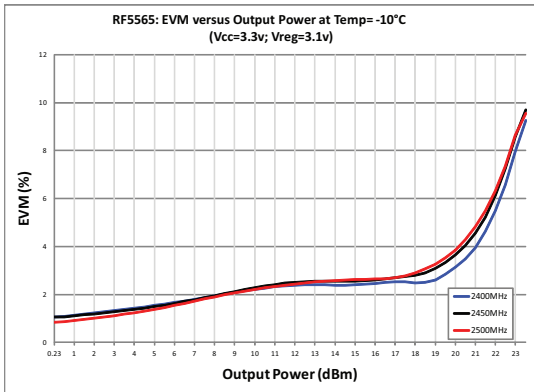
- Turn RF ON.

## APPLICATION CIRCUIT AND LAYOUT RECOMMENDATIONS

The RF5565 integrates the matching networks and DC blocking capacitors for all RF ports. This greatly reduces the number of external components and layout area needed to implement this FEM. Typically only a total of four external components are required to achieve nominal performance. However, depending on board layout and the many noise signals that could potentially couple to the RF5565, additional bypassing capacitors may be required to properly filter out unwanted signals that might degrade performance.
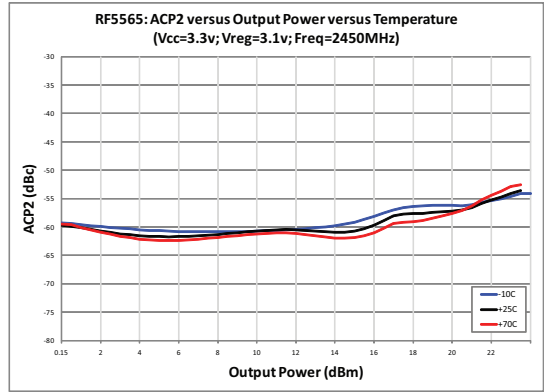
The LNA bias components consist of an inductor and a decoupling capacitor. The inductor value is critical to optimize NF and return loss at the RX output. For best performance and trade off between critical parameters such as NF, Gain, and IP3, the total inductance including board trace should be approximately 1.2nH. The last components needed in the application circuit are low frequency bypass capacitors on the VCC line. In general, it is good RF practice to have proper decoupling of supply lines to filter noise out. Occasionally, depending on the level of coupling or parasitics of the board, a high frequency bypass capacitor must be added as well.

In order to optimize performance for both the Transmit and Receive paths, best known RF practices for PCB layout must be followed. All RF traces must be 50Ω. Adequate grounding along the RF traces and on the FEM ground slug must be exercised. This will minimize coupling and provide good thermal dissipation when the PA is operating at high power. For reference, RFMD evaluation board gerbers are available upon request.

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# RF5565

## RF5565 WiFi Transmit Performance Plots



RF5565: EVM versus Output Power at Temp= -10°C (Vcc=3.3v; Vreg=3.1v)



RF5565: EVM versus Output Power at Temp=+25°C (Vcc=3.3v; Vreg=3.1v)



RF5565: EVM versus Output Power at Temp=+70°C (Vcc=3.3v; Vreg=3.1v)



RF5565: EVM and GAIN versus Output Power versus Temperature (Vcc=3.3v; Vreg=3.1v; Freq=2450MHz)



RF5565: Operating Current and GAIN versus Output Power versus Temperature (Vcc=3.3v; Vreg=3.1v; Freq=2450MHz)



RF5565: Ireg Current versus Output Power versus Temperature (Vcc=3.3v; Vreg=3.1v; Freq=2450MHz)

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## RF5565 WiFi Transmit Performance Plots (continued)

**RF5565: ACP1 versus Output Power versus Temperature**
**(Vcc=3.3v; Vreg=3.1v; Freq=2450MHz)**

*ACP1 (dBc)* vs *Output Power (dBm)*

Legend: —10C, —+25C, —+70C

**RF5565: ACP2 versus Output Power versus Temperature**
**(Vcc=3.3v; Vreg=3.1v; Freq=2450MHz)**

*ACP2 (dBc)* vs *Output Power (dBm)*

Legend: —10C, —+25C, —+70C

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# RF5565

## RF5565 WiFi Receive and BT Performance Plots

**RF5565: RECEIVE GAIN**
(LNA Vdd=3.3v; LNA_EN=3.3v; C_RX=3.3v)



**RF5565: RECEIVE OPERATING CURRENT**
(LNA Vdd=3.3v; LNA_EN=3.3v; C_RX=3.3v)



**RF5565: RECEIVE NOISE FIGURE**
(LNA Vdd=3.3v; LNA_EN=3.3v; C_RX=3.3v)



**RF5565: RECEIVE BYPASS MODE GAIN**
(LNA Vdd=3.3v; LNA_EN=0.2v; C_RX=3.3v)



**RF5565: TRANSMIT TO RECEIVE ISOLATION**
(Vcc=3.3v; C_TX=3.3v; Vreg=3.1v; C_RX=0.2; C_BT=0.2v)



**RF5565: TRANSMIT TO BLUETOOTH ISOLATION**
(Vcc=3.3v; C_TX=3.3v; Vreg=3.1v; C_RX=0.2; C_BT=0.2v)