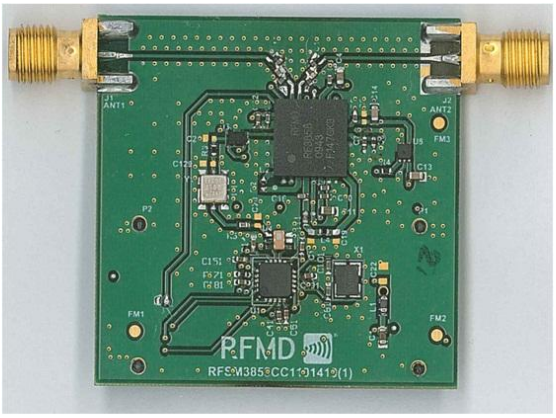
Using 1 W RF3858 Front End with CC1101 under FCC 15.247

By Timothy Peoples, RFMD

Features

- *1 Watt of Output Power*
- *Superior Sensitivity*
- *Low PA Harmonic Content*
- *Antenna Diversity*
- *Flexible Design*



Applications

- *Wireless Automated Metering Applications*
- *915 MHz ISM Band Applications*
- *Smart Grid Wireless Networks*

Keywords

- *Range Extender*
- *FCC Section 15.247*
- *External PA*
- *External LNA*
- *RF3858*
- *CC1101*
- *CC1100*
- *CC1110*
- *CC1111*
- *CC430*

1 Introduction

The CC1101 is a truly low-cost, highly integrated and very flexible RF transceiver. The CC1101 is primarily designed for use in low-power applications in the 315, 433, 868 and 915 MHz SRD/ISM bands.

The RF3858 is a single-chip front-end module that includes a 1 Watt power amplifier, a receive module with an impressive 21 dB of gain and a diversity transfer switch for applications in the 915 MHz ISM band [2]. The RF3858 is packaged in a 32-pin 8.0x8.0 mm^2 over-molded laminate package with backside ground, which greatly minimizes next level board space and allows for simplified integration.

The RF3858 can be used as a range extender for the CC1101 in the 915 MHz ISM band. It increases the link budget by providing a power amplifier (PA) for increased output power up to 1 Watt, and a low-noise amplifier (LNA) with low noise figure for improved receiver sensitivity. In addition to these features it provides switches and integrated RF matching for design in high performance wireless systems.

This application note outlines the expected performance when using an RF3858-CC1101 design under FCC Section 15.247 in the 902-928 MHz frequency band. This application note assumes the reader is familiar with the CC1101 [1] and FCC 15.247 regulatory limits [3].

The application note is also applicable for the CC1100, CC1110, CC1111 and CC430 when used with the RF3858 because these transceivers use the same radio as the CC1101.

For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com.

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2 Abbreviations

EB	Evaluation Board
EM	Evaluation Module
FCC	Federal Communications Commission
LNA	Low Noise Amplifier
PA	Power Amplifier
PCB	Printed Circuit Board
PER	Packet Error Rate
RX	Receive, Receive Mode
TrxEB	SmartRF Transceiver EB
TX	Transmit, Transmit Mode

3 Absolute Maximum Ratings

The absolute maximum ratings and operating conditions listed in the CC1101 datasheet [1] and the RF3858 datasheet [2] must be followed at all times. Stress exceeding one or more of these limiting values may cause permanent damage to any of the devices.

4 Electrical Specifications

4.1 Operating Conditions

Parameter	Min	Max	Unit
Operating Frequency	902	928	MHz
Operating Supply Voltage for RF3858-CC1101	3.0	3.6	V
Operating Temperature	-40	+85	°C

Table 4.1. Operating Conditions

4.2 Current Consumption

T_C = 25°C and frequency = 915 MHz. All parameters are measured on the RF3858-CC1101 reference design [5] with a 50 Ω load.

4.2.1 Supply Voltage = 3.6 V

Parameter	Typical	Max	Unit
DC Supply Current, TX Mode	750	800	mA
Quiescent Current (Idle)	125	150	mA
RX Mode Supply Current, HGM	40		mA

Parameter	Condition	Typical	Unit
Transmit Current[1], VDD = 3.6 V	PATABLE = 0xC0 (+30.0 dBm) PATABLE = 0xC3 (+30.0 dBm) PATABLE = 0xCC (+29.9 dBm) PATABLE = 0x84 (+29.8 dBm) PATABLE = 0x8E (+28.1 dBm) PATABLE = 0x38 (+24.5 dBm) PATABLE = 0x27 (+21.3 dBm)	750 745 730 715 595 410 295	mA

Table 4.2. Current Consumption at 3.6 V Supply

4.2.2 Supply Voltage = 3.0 V

Parameter	Typical	Max	Unit
DC Supply Current, TX Mode	585	600	mA
Quiescent Current (Idle)	115	150	mA
RX Mode Supply Current, HGM	30		mA

Parameter	Condition	Typical	Unit
Transmit Current[1], VDD = 3.0V	PATABLE = 0xC0 (+28.3dBm) PATABLE = 0xC3 (+28.2dBm) PATABLE = 0xCC (+28.1dBm) PATABLE = 0x84 (+28.0dBm) PATABLE = 0x8E (+26.9dBm) PATABLE = 0x38 (+22.3dBm) PATABLE = 0x27 (+19.0dBm)	600 595 585 575 515 315 230	mA

Table 4.3. Current Consumption at 3.0 V Supply

4.3 Transmit Parameters

T_C = 25°C and frequency = 915 MHz. All parameters are measured on the RF3858-CC1101 reference design [5] with a 50 Ω load.

4.3.1 Supply Voltage = 3.6 V

Parameter	Condition	Typical	Unit
Output power[1]	PATABLE = 0xC0 PATABLE = 0xC3 PATABLE = 0xCC PATABLE = 0x84 PATABLE = 0x8E PATABLE = 0x38 PATABLE = 0x27	30 30 29.9 29.8 28 24.5 21	dBm
Power Added Efficiency PATABLE = 0xC3		36.5	%
Conducted 2nd Harmonic Level PATABLE = 0xC3		-40	dBm/MHz
Conducted 3rd Harmonic Level PATABLE = 0xC3		-46	dBm/MHz
Conducted 4th through 10th Harmonic Levels PATABLE = 0xC3		<-60	dBm/MHz
Output Power variation over 40^{o}C to +85^{o}C temperature range. PATABLE = 0xC3		+/-1.2	dB
Stability, Output VSWR	PATABLE = 0xC3 All phase angles	>10:1	

Table 4.4. Transmit Parameters at 3.6 V Supply

[1] The RF output power of the RF3858-CC1101 is controlled by the 8 bit value in the CC1101 PATABLE register. The power settings are a small subset of all possible PATABLE register settings.

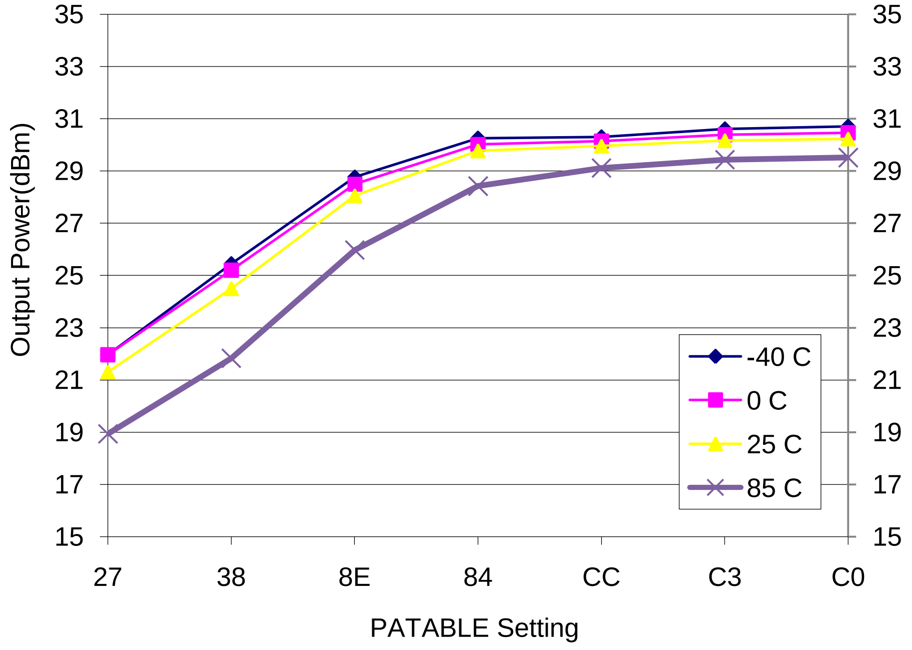

Figure 4.1. Typical Output Power vs CC1101 PATABLE over Temperature at 3.6 V Supply

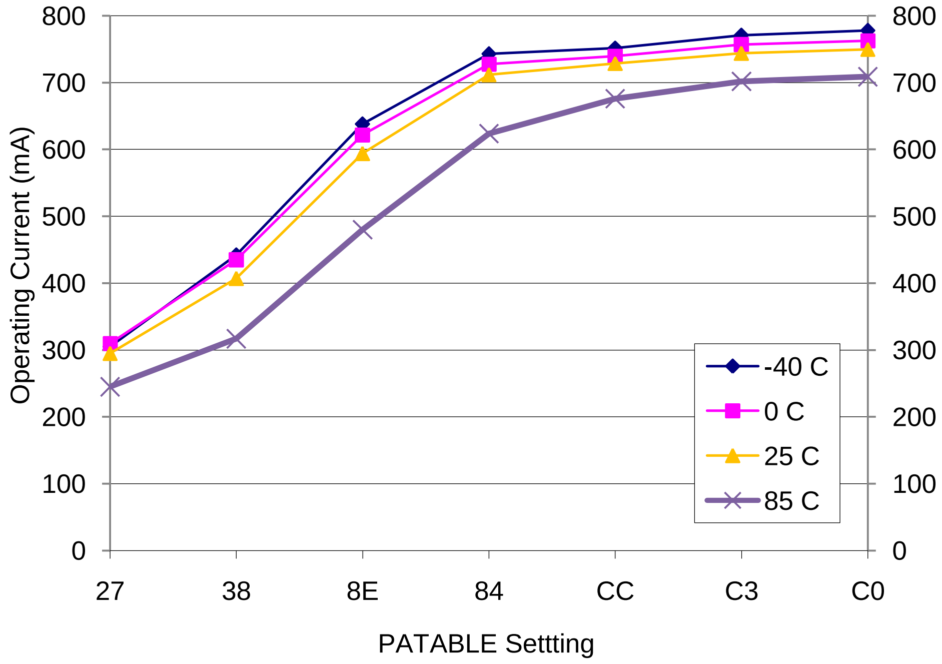

Figure 4.2. Typical TX Current Consumption vs CC1101 PATABLE over Temperature at 3.6 V Supply

4.3.2 Supply Voltage = 3.0 V

Parameter	Condition	Typical	Unit
Output power[1]	PATABLE = 0xC0 PATABLE = 0xC3 PATABLE = 0xCC PATABLE = 0x84 PATABLE = 0x8E PATABLE = 0x38 PATABLE = 0x27	28.2 28.2 28.1 28.0 26.5 23 19.8	dBm
Power Added Efficiency PATABLE = 0xC3		37	%
Conducted 2nd Harmonic Level PATABLE = 0xC3		-40	dBm/MHz
Conducted 3rd Harmonic Level PATABLE = 0xC3		-46	dBm/MHz
Conducted 4th through 10th Harmonic Levels PATABLE = 0xC3		<-60	dBm/MHz
Output Power variation over 40°C to +85°C temperature range. PATABLE = 0xC3		+/-1.2	dB
Stability, Output VSWR	PATABLE = 0xC3 All phase angles	>10:1	

Table 4.5. Transmit Parameters at 3.0 V Supply

4.4 Receive Parameters

T_C = 25°C, VDD = 3.6 V, and frequency = 915 MHz unless otherwise stated. All parameters are measured on the RF3858-CC1101 reference design [5] with a 50 Ω load.

Parameter	Condition	Typical	Unit
Sensitivity GFSK, 1% Packet Error Rate	1.2 kbps data rate, ±14.2 kHz deviation, 58 kHz RX filter BW	-121	dBm
	1.2 kbps data rate, ±5.2 kHz deviation, 58 kHz RX filter BW	-118	dBm
	2.4 kbps data rate, ±5.2 kHz deviation, 58 kHz RX filter BW	-117	dBm
	4.8 kbps data rate, ±25.4 kHz deviation, 100 kHz RX filter BW	-117	dBm
	10 kbps data rate, ±19 kHz deviation, 100 kHz RX filter BW	-113	dBm
	38.4 kbps data rate, ±19 kHz deviation, 100 kHz RX filter BW	-108	dBm
	76.8 kbps data rate, ±32 kHz deviation, 232 kHz RX filter BW	-108	dBm
	100 kbps data rate, ±47 kHz deviation, 325 kHz RX filter BW	-107	dBm
	500 kbps data rate, MSK, 812 kHz RX filter BW	-98	dBm
Saturation	Maximum input power level for 1% PER, 1.2 kbps data rate, ±5.2 kHz deviation	-32	dBm
RSSI Offset Value		88	

Table 4.6. Receive Parameters at 3.6 V Operation

5 SmartRF Studio and SmartRF04EB / TrxEB

The RF3858-CC1101 together with SmartRF™ Studio 7 software [4] and SmartRF04EB or TrxEB can be used to evaluate performance and functionality. See Appendix – Performance Verification for details on how to evaluate performance and functionality. The RF3858-CC1101 can be configured using the SmartRF Studio 7 software. The SmartRF Studio software is highly recommended for obtaining optimum register settings.

6 Reference Design Considerations

The RF3858-CC1101 reference design includes schematic, gerber files and a bill of materials [5]. It is highly recommended to follow the reference design for optimum performance. Figure 6.1 shows the RF3858-CC1101 schematic.

6.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. The capacitor C14 must be optimized to prevent RF leakage into the VREG line of the RF3858 which may cause oscillations.

6.2 Filtering

The values of L5, C25, C23, C17, C15, C24, C26, L2, L3 and LF1 and LF2 are for harmonics filtering purposes only. These components assist in the required filtering of harmonics to pass FCC regulatory requirements.

Figure 6.2 shows the RF3858-CC1101 using Murata part number LFL21902MTC1A018 low pass filter as an alternative for the harmonics filtering circuit.

6.3 Bias Resistor

R171 is a bias resistor. The bias resistor is used to set an accurate bias current for internal use in the CC1101.

6.4 SAW Filter

A SAW is recommended for the RF3858-CC1101 design to attenuate spurs below the carrier frequency that will otherwise violate spurious emission limits under FCC Section 15.209 and 15.205.

6.5 Voltage Regulator

U5 (TPS727285DSER) is a voltage regulator and used to set the VREG of the RF3858 to 2.85 volts.

6.6 Switch

U3 (RF1126) is an SPDT switch. The switch is used to control the traffic of the transmitted and received signals within the RF3858-CC1101 between the CC1101 and the RF3858.

6.7 PCB Layout Considerations

The top layer is used for components and signal routing. The areas under the two chips are used for grounding and must be well connected to the ground plane with multiple vias. Footprint recommendation for the RF3858 is given in the RF3858 datasheet [2].

Layer two is a complete ground plane and is not used for any routing. This is done to ensure short return current paths. The low impedance of the ground plane prevents any unwanted signal coupling between any of the nodes that are decoupled to it.

Layer three is a power plane. The power plane ensures low impedance traces at radio frequencies and prevents unwanted radiation from power traces.

Layer four is used for routing, and as for layer one, open areas are filled with metallization connected to ground using several vias.

6.8 Shielding

RF shielding is necessary to keep the radiated harmonics below the regulatory limits.

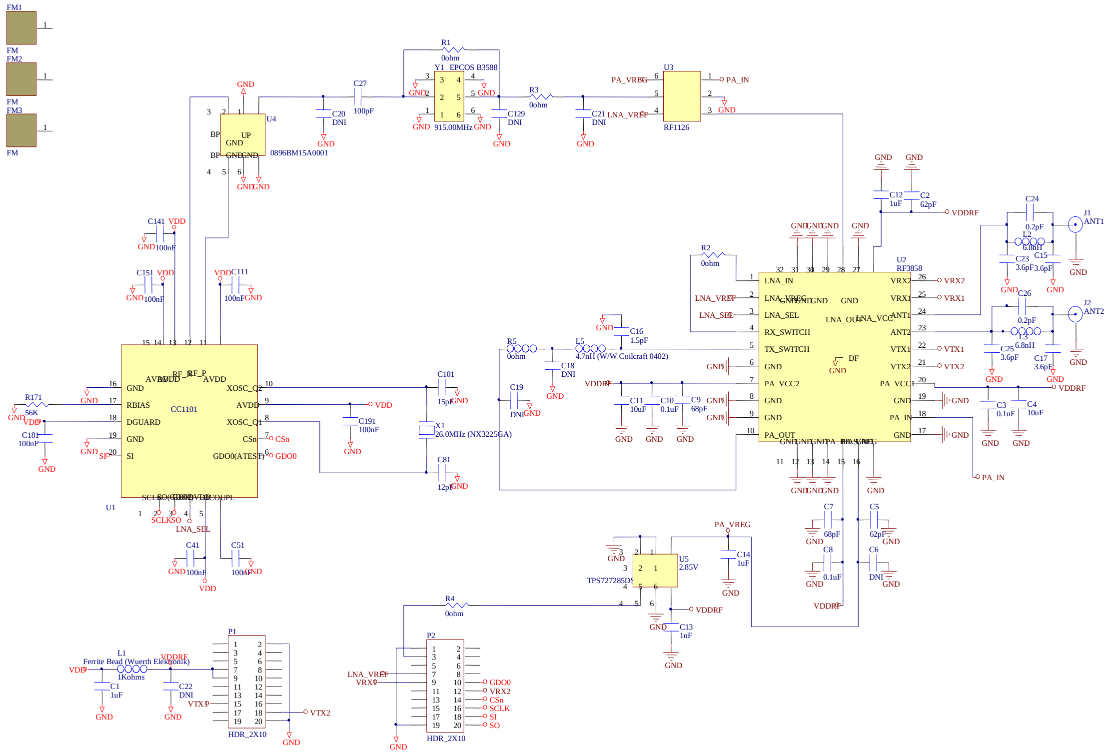

Figure 6.1. RF3858-CC1101 Schematic

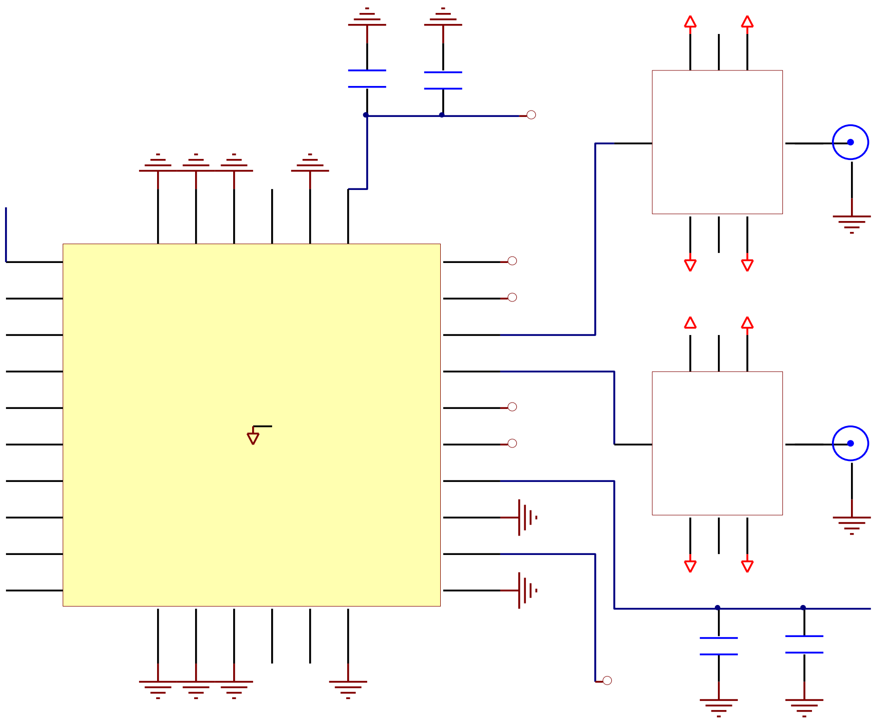

Figure 6.2. RF3858-CC1101 Schematic with Murata LFL21902MTC1A018 Low Pass Filter

7 Disclaimer

The RF3858-CC1101 reference board is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI or RFMD to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing –related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board has been tested against FCC regulations, but there has been no formal compliance testing at an external test house. It is the end user's responsibility to ensure that their system complies with applicable regulations. For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com.

8 References

[1] CC1101 Datasheet (SWRS061.pdf)

[2] RF3858 Datasheet (RF3858DS.pdf)

[3] FCC rules (www.fcc.gov)

[4] SmartRF™ Studio 7 (SWRC176.zip)

[5] RF3858-CC1101 Reference Design (SWRR085.zip)

[6] DN002 Practical Sensitivity Testing (SWRA097.pdf)

9 General Information

9.1 Document History

Revision	Date	Description/Changes
SWRA377	2011.07.29	Initial release.
SWRA377A	2011.08.03	Changed Application Note number to AN105

10 Appendix – Performance Verification

10.1 Equipment

(1) SmartRF Studio 7 installed on each PC used, which can be downloaded at [4].
(2) An RF generator with packet option; or a CC1101EM, or RF3858-CC1101 connected to a SmartRF04EB for packet transmission. Using the CC1101EM or RF3858-CC1101 as an RF generator will require a PC. The RF generator must be configured for the selected RF frequency, modulation format, deviation, and data rate.
(3) A RF3858-CC1101 connected to a SmartRF04EB and a PC for packet reception.
(4) Attenuators and cables
(5) A 3.6V DC supply and either a USB cable or a RS-232 cable.

10.2 General Setup

1) The firmware revision for SmartRF Studio 7 must first be downloaded onto the SmartRF04EB.
2) Place the RF3858-CC1101 board onto the SmartRF04EB via the evaluation module connectors as shown in Figure 10.1
3) Connect the USB or RS-232 cable from a PC to the SmartRF04EB. Note: If the SmartRF04EB is connected to a USB socket on a PC, it will draw power from the USB bus when the switch is in the 4 V to 10 V position. The onboard voltage regulator supplies 3.3 V to the board, but has limited current source capability and cannot supply the RF3858-CC1101. An external supply is therefore needed and shall be connected as shown in Figure 10.2.
4) Verify the supply selection switch is switched to the 3.3 V position as shown in Figure 10.2.
5) Supply 3.6 V DC to the SmartRF04EB via the power connector.
6) Switch the supply switch to the 4-10 V position as shown in Figure 10.2. This will turn on the module.
7) The chip type will appear in the test box labeled “List of Connected Devices” at the bottom of the SmartRF Studio Interface. This should read “USB device ID = 3807, firmware (revision = 0044), CC1101”.
8) Double click on the chip type in the device list to open up the SmartRF Studio7 device control panel for user interface.
9) Once the user interface is open find the “Range Extender” option, click on the arrow, scroll down to RF3858 and select it. Now the user is ready to evaluate the RF3858-CC1101.

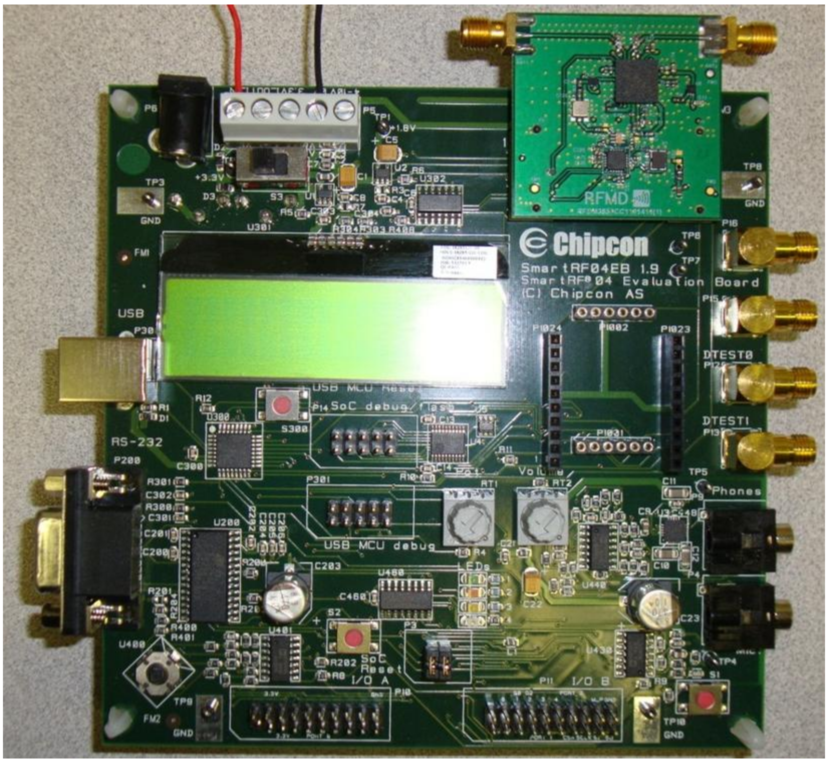

Figure 10.1. Smart RF04EB with RF3858-CC1101

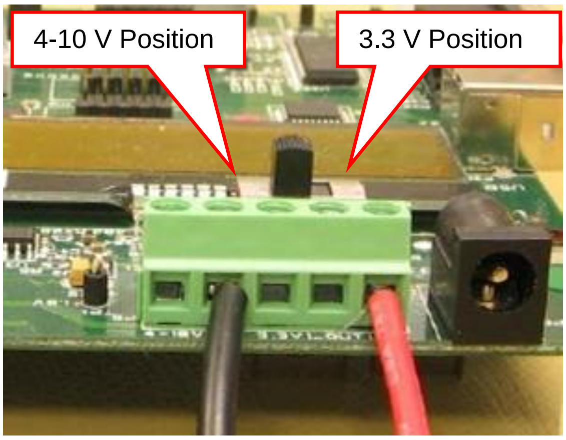

Figure 10.2. Connecting 3.6 V Supply to the RF3858

10.3 Transmission

10.3.1 Continuous Transmission

1) Complete steps 1 through 9 of the General Setup procedure.
2) Find the Continuous TX mode tab and select it as shown in Figure 10.3.
3) Adjust your desired TX power settings for the CC1101 using the “TX Power” box in the RF Parameters section or by modifying the PA_TABLE0 register value in the Register View.
4) Select between modulated and un-modulated and the modulated signal’s data format in the Continuous TX tab.
5) Select the frequency band to be used. Make sure that this is in accordance with the reference design module placed in the SmartRF04EB (e.g. 915 MHz for the RF3858-CC1101).
6) Be sure to select the correct antenna path, “Ant. Path” on the interface.
7) Click the Start button on the interface to begin frequency transmission. Click the Stop button on the interface to end frequency transmission.

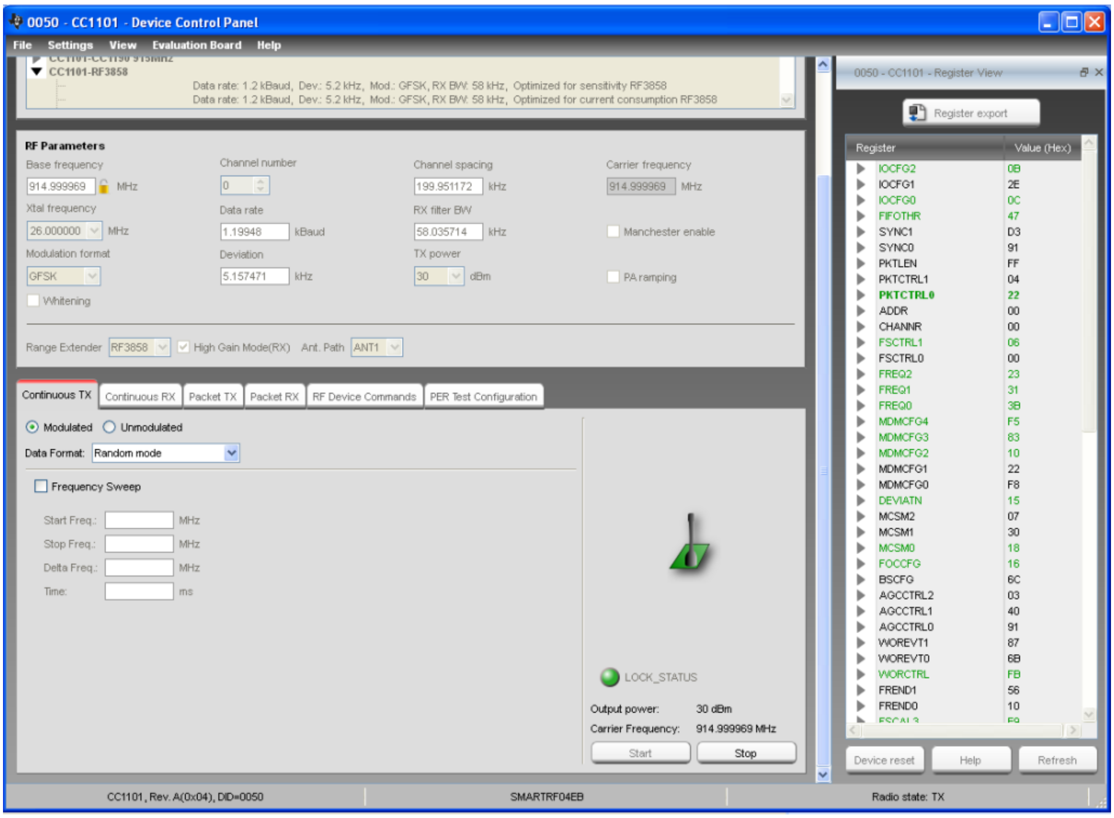

Figure 10.3. Continuous Transmission Tab

10.3.2 Packet Transmission

1) Complete steps 1 through 9 of the General Setup procedure.
2) Select the Packet TX mode tab as shown in Figure 10.4.
3) Set the number of packets to transmit.
4) Adjust for desired TX power level settings for the RF3858-CC1101 using the "TX Power" box in the RF Parameters section or by modifying the PA_TABLE0 register value in the Register View.
5) Select the correct antenna path, "Ant. Path" on the interface.
6) Verify the base frequency matches the frequency of the board that will be receiving the packets.
   Note: SmartRF Studio will recommend GFSK for the CC1101.
7) Click the "Start" button on the interface to begin transmitting packets. Click the Stop button to end packet transmission.
8) The packet transmission will continue until the number of packets programmed has been reached, or until 100 consecutive packets have been lost.

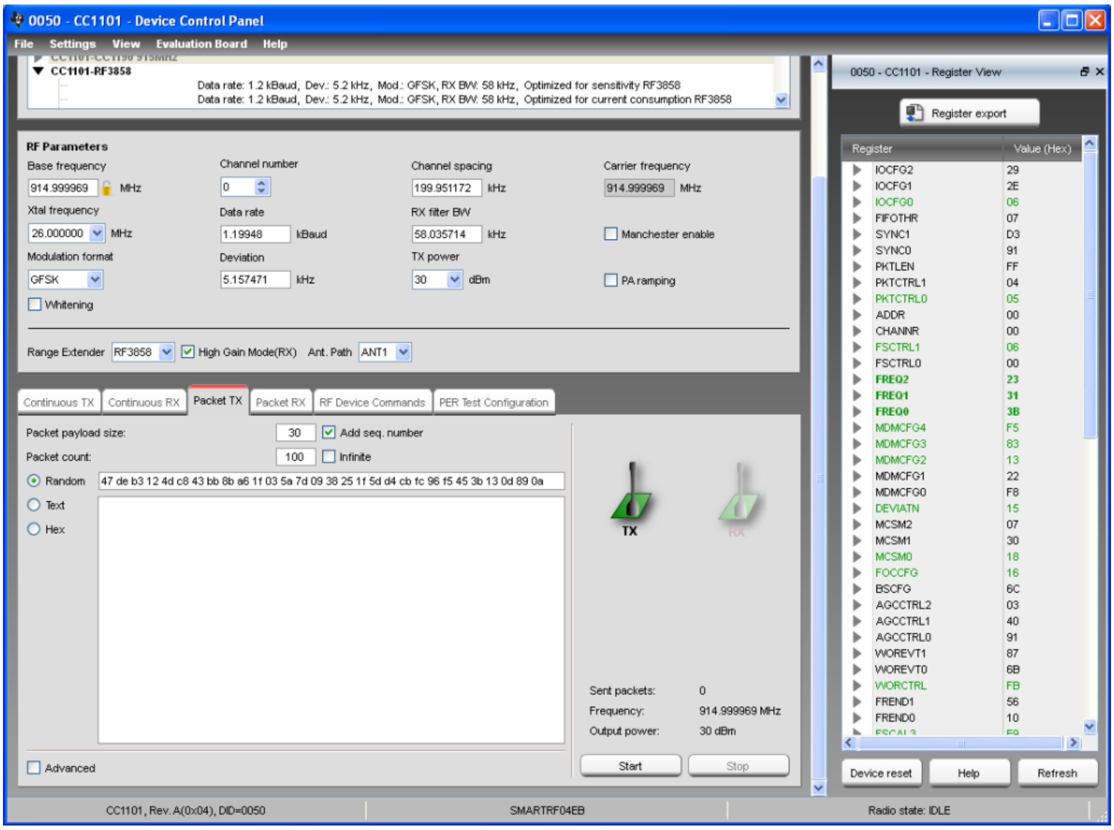

Figure 10.4. Packet Transmission Tab

10.4 Reception

10.4.1 Practical Sensitivity Testing

To properly evaluate the receiver performance of the RF3858-CC1101 reference design, it is necessary to be able to find the sensitivity threshold, i.e. the lowest input signal the receiver can decode with acceptable signal quality. This Application Note describes how to test the sensitivity using a PER (Packet Error Rate) test. For questions on testing sensitivity with SmartRF Studio please refer to [6].

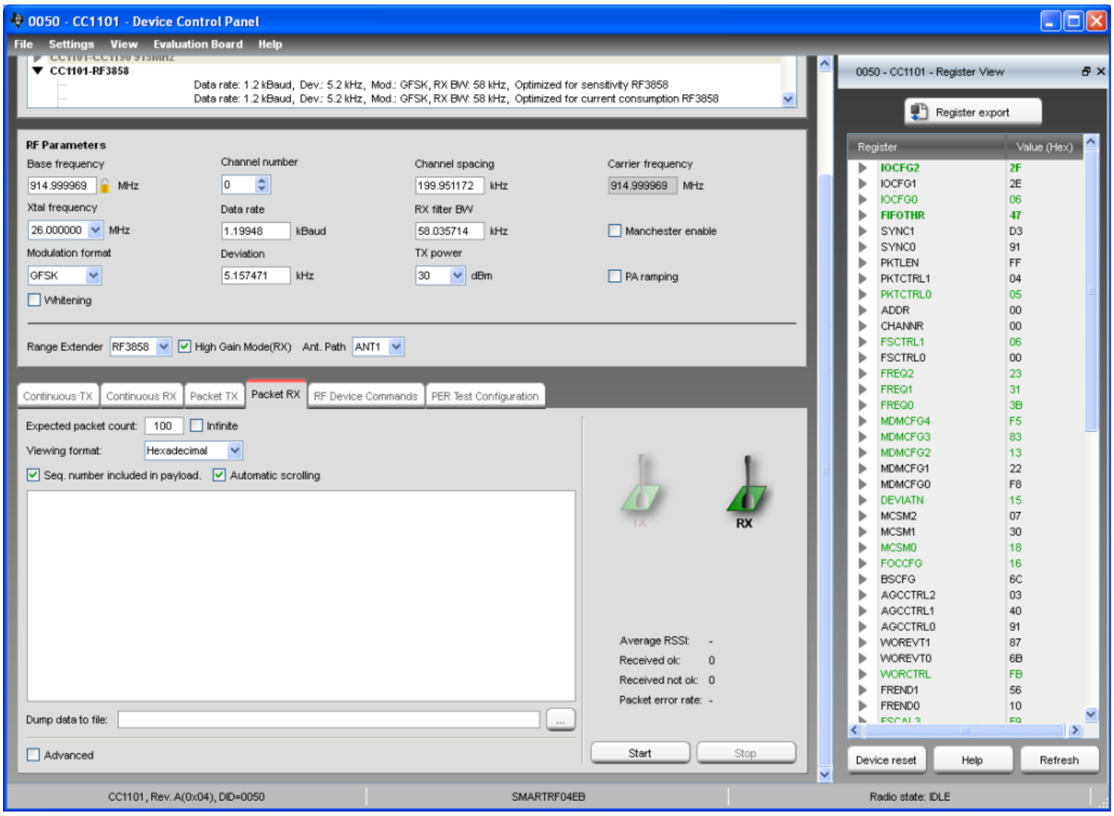

Figure 10.5. Packet Reception Tab

10.4.2 PER Test Setup

1) Setup the equipment as shown in the block diagram in Figure 10.6.
2) Complete steps 1 through 9 of the General Setup procedure.
3) If using a CC1101EM or the RF3858-CC1101 as the packet transmitter, use the Packet Transmission section in this application note to setup the module that will transmit packets. Otherwise, setup the RF generator and configure it for the selected RF frequency, modulation format, deviation, and data rate.
4) Select the Packet RX mode tab as shown in Figure 10.5.
5) Set the number of packets expected to receive.
6) Verify the antenna is correct on the interface and the base frequency matches the frequency of the board or RF generator that will be transmitting the packets.
7) Set attenuation level near the expected result.
8) Press Start to begin listening for packets before beginning to transmit packets.
9) Adjust the attenuation level until a 1% PER is achieved.
10) The Packet RX will continue until the number of packets programmed has been reached, or until 100 consecutive packets have been lost.

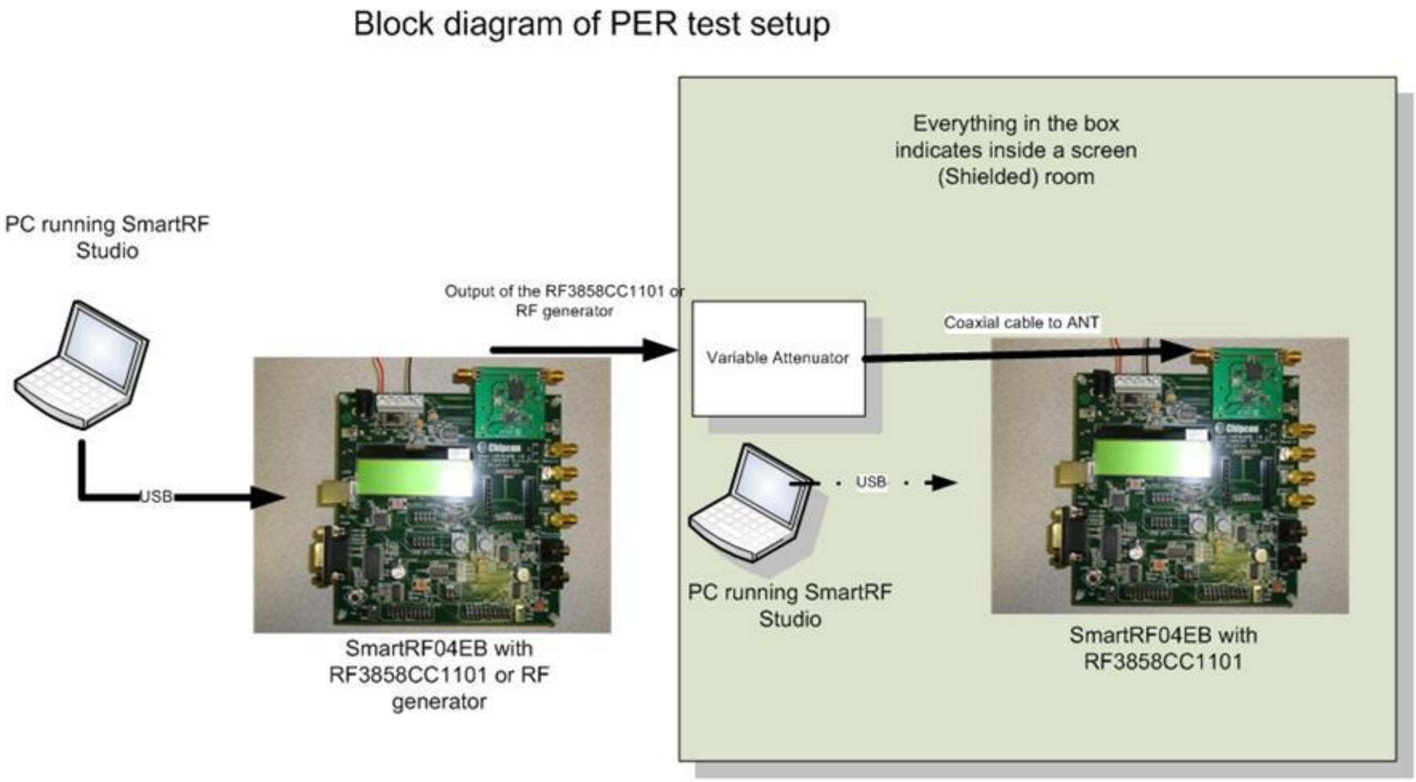

Figure 10.6. Block Diagram of PER Test Setup