CC11xx Settings for FCC 15.247 Solutions

By Kristian Skogvang and Sverre Hellan

Keywords

- *FCC 15.247 and 15.249*
- *Wideband Requirements*
- *CC11xx System Parameters*
- *AN001 SRD Regulations*
- *Digital Modulation*
- *CC1100*
- *CC1101*
- *CC1110*
- *CC1111*
- *CC1150*
- *CC430*

1 Introduction

FCC CRF Section 15.249 restricts the fundamental radiated power to 50 mV/m at 3 meters distance (approximately -1 dBm EIRP) in the US 902-928 MHz ISM band.

FCC CRF Section 15.247 specifies requirements that allow for up to 1 W transmit output power. High output power can be used if the system employs Frequency Hopping Spread Spectrum (FHSS) or uses a digital modulation technique that gives a 6 dB bandwidth of minimum 500 kHz [1][1].

This design note shows how CC11xx can be configured for output powers above -1 dBm and meet FCC Section 15.247 requirements without the need for frequency hopping.

The CC1101EM 868-915 MHz reference design [2] is used as an example in this design note, but the results are also applicable for CC1100, CC1110, CC1111, CC430, or CC1150.

Table of Contents

2 Abbreviations

CRF	Code of Federal Regulations
EM	Evaluation Module
FCC	Federal Communications Commission
FHSS	Frequency hopping Spread Spectrum
IF	Intermediate Frequency
ISM	Industrial, Scientific, Medical
PSD	Power Spectral Density
RBW	Resolution Bandwidth
VBW	Video Bandwidth

3 FCC 15.247 Measurements

Table 1 gives the FCC 15.247 digital modulation requirements

Section	Requirement
15.247a2	The 6 dB bandwidth shall be at least 500 kHz
15.247b3	The maximum conducted power shall not exceed 1 W (+30 dBm)
15.247e	The power spectral density (PSD) shall not be greater than 8 dBm in any 3 kHz band during any time interval during continuous transmission

Table 1. FCC 15.247 Digital Modulation Requirements

In this design note the PSD sets an upper limit on the maximum output power.

3.1 FCC 15.247a2 Bandwidth Measurement

Most spectrum analyzers have a measurement option that automatically measures a fixed dB bandwidth. If this is not available the 6 dB bandwidth must be measured manually by setting up markers. The spectrum analyzer should be configured as shown in Figure 1.

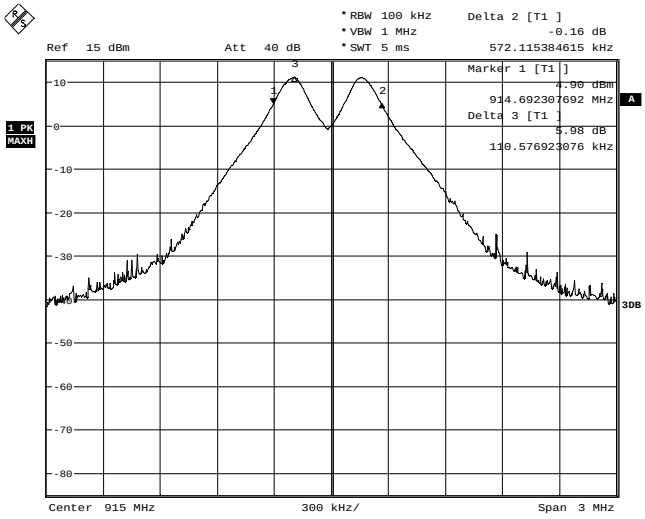
Spectrum Analyzer Plot	Spectrum Analyzer Setting
	RBW=100 kHz VBW=1 MHz Max hold on Measure the 6 dB Bandwidth In the plot CC1101 is configured for 100 kbps data rate and PATABLE = 0xC0.

Figure 1. Test Setup for FCC 15.247a2

3.2 FCC 15.247b Power Measurement

The maximum allowed output power is 1 W, but when a wideband digital modulation technique is used the Power Spectral Density (PSD) described in Section 3.3 will limit the output power to less than 1 W.

Output power is measured by setting the RBW higher than the measured 6 dB bandwidth. The spectrum analyzer should be configured as described in Figure 2.

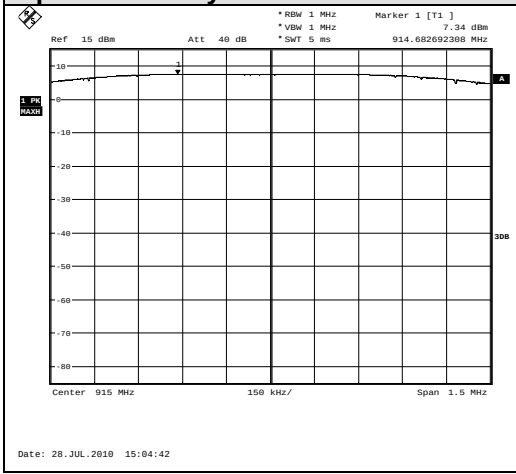
Spectrum Analyzer Plot	Spectrum Analyzer Setting
	Set RBW= 1 MHz Set VBW= 1 MHz Measure the output power In the plot CC1101 is configured for 38.4 kbps data rate and PATABLE = 0xCA.

Figure 2. Test Setup for FCC 15.247b

3.3 FCC 15.247d Power Spectral Density Measurement

The peak power spectral density at any 3 kHz bandwidth shall not exceed +8 dBm. This should be measured over at least 3 times the modulation bandwidth. The spectrum analyser should be configured as given in Figure 3.

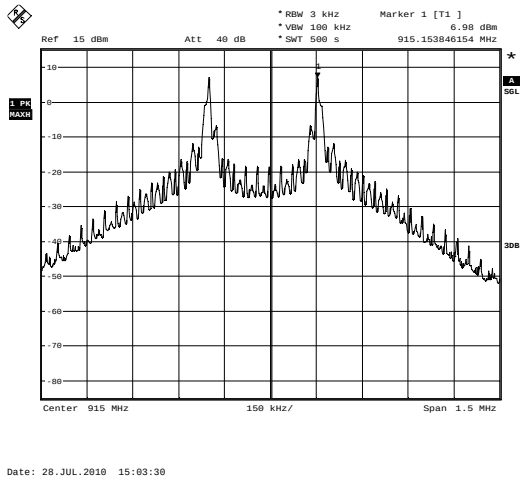
Spectrum Analyzer Plot	Spectrum Analyzer Setting
	Set RBW = 3 kHz Set VBW = 100 kHz Set Span = 1.5 MHz Set Sweep = 500 seconds Set Max hold on Set single sweep Measure the power spectral density on the highest peak in the span. In the plot CC1101 is configured for 38.4 kbps data rate and PATABLE = 0xCA.

Figure 3. Test Setup for FCC 15.247d

Note that the sweep time is slow in order to ensure that the max peak is captured. A faster test approach with more or less same results could be to reduce the sweep time to 300 us and use max hold instead. The official test however, requires a sweep time of 500 seconds.

4 Measurement Setup

- 5 devices were tested
- All measurements were performed at 3V, 25°C
- Measurements were performed on the CC1101EM 868-915 MHz reference design [2]
- An automated test setup was used and LabView was used to control the measuring equipment
- The results presented in Section 5 are the average numbers of the 5 devices tested

5 CC1101 Test Results for FCC 15.247

The SmartRF® Studio Software tool from Texas Instruments includes a list of preferred settings for a wide range of data rates. However to comply with the FCC 15.247 minimum 500 kHz 6 dB bandwidth requirement, the frequency deviation needs to be wider compared to the preferred settings. When increasing the frequency deviation the RX filter bandwidth needs to be increased. The IF frequency (register FSCTRL1) and registers FREND1, TEST2, TEST1, AGCCTRL2, AGCCTRL1 as well as AGCCTRL0 must be set depending on the RX filter bandwidth for optimum performance. For data rates at and below 250 kbps, the 250 kbps preferred settings were used as a starting point and the data rate and frequency deviation changed for the different test cases.

Data Rate	Modulation	Deviation	PATABLE	6 dB BW (15.247 a2)	Power (15.247 b)	PSD (15.247 d)
500 kbps	MSK	Phase 0	C0	650 kHz	11.4 dBm	0.00 dBm
250 kbps	2-FSK	165 kHz	C0	647 kHz	11.4 dBm	3.10 dBm
100 kbps	2-FSK	177 kHz	C0	577 kHz	11.4 dBm	6.68 dBm
76.8 kbps	2-FSK	177 kHz	C2	547 kHz	10.5 dBm	7.27 dBm
38.4 kbps	2-FSK	177 kHz	C9	523 kHz	8.1 dBm	7.70 dBm
10 kbps	2-FSK	177 kHz	CA	516 kHz	7.8 dBm	7.74 dBm
4.8 kbps	2-FSK	177 kHz	CA	505 kHz	7.8 dBm	7.74 dBm
2.4 kbps	2-FSK	177 kHz	CB	513 kHz	7.5 dBm	7.47 dBm

Table 2. CC1101 TX Test Results for FCC 15.247

Data Rate	Modulation	Deviation	RX Filter	Sensitivity
500 kbps	MSK	Phase 0	812 kHz	-89 dBm
250 kbps	2-FSK	165 kHz	650 kHz	-95 dBm
100 kbps	2-FSK	177 kHz	540 kHz	-96 dBm
76.8 kbps	2-FSK	177 kHz	540 kHz	-98 dBm
38.4 kbps	2-FSK	177 kHz	540 kHz	-100 dBm
10 kbps	2-FSK	177 kHz	540 kHz	-104 dBm
4.8 kbps	2-FSK	177 kHz	540 kHz	-107 dBm
2.4 kbps	2-FSK	177 kHz	540 kHz	-108 dBm

Table 3. CC1101 RX Test Results for FCC 15.247

Data Rate	Modulation	Deviation	RX Filter	Sensitivity
500 kbps	MSK	Phase 0	812 kHz	-89 dBm
250 kbps	2-FSK	127 kHz	540 kHz	-96 dBm
100 kbps	2-FSK	47 kHz	325 kHz	-100 dBm
76.8 kbps	2-FSK	32 kHz	232 kHz	-101 dBm
38.4 kbps	2-FSK	20 kHz	100 kHz	-104 dBm
10 kbps	2-FSK	19 kHz	100 kHz	-105 dBm
4.8 kbps	2-FSK	25.4 kHz	100 kHz	-110 dBm
2.4 kbps	2-FSK	5.2 kHz	58 kHz	-109 dbm

Table 4. CC1101 RX Test Results Preferred Settings

6 Conclusion

This design note has shown that CC11xx is suited for systems targeting compliance with digital modulation systems defined under FCC Section 15.247. Comparing Table 5 and Table 6 we see that there is a significant improvement in link budget, and hence range, when operating under FCC Section 15.247 compared to FCC Section 15.249. As an example, at 500 kbps the difference in link budget is 12 dB, which corresponds to a *theoretical* improvement in range of a factor 4. Note also from Table 2 that for data rates above 100 kbps it is possible to increase the output power further by using an external power amplifier and still meet PSD requirements. As an example, for 500 kbps it is possible to transmit at +18 dBm, using an external power amplifier, and still comply with FCC Section 15.247.

Data Rate	Sensitivity	Output power	Link Budget
500 kbps	-89 dBm	11.4 dBm	100 dB
250 kbps	-95 dBm	11.4 dBm	106 dB
100 kbps	-96 dBm	11.4 dBm	107 dB
76.8 kbps	-98 dBm	10.5 dBm	108.5 dB
38.4 kbps	-100 dBm	8.1 dBm	108 dB
10 kbps	-104 dBm	7.8 dBm	112 dB
4.8 kbps	-107 dBm	7.8 dBm	115 dB
2.4 kbps	-108 dBm	7.5 dBm	115.5 dB

Table 5. CC1101 FCC 15.247 Settings Link Budget

Data Rate	Sensitivity	Output power	Link Budget
500 kbps	-89 dBm	-1 dBm	88 dB
250 kbps	-96 dBm	-1 dBm	95 dB
100 kbps	-100 dBm	-1 dBm	99 dB
76.8 kbps	-101 dBm	-1 dBm	100 dB
38.4 kbps	-104 dBm	-1 dBm	103 dB
10 kbps	-105 dBm	-1 dBm	104 dB
4.8 kbps	-110 dBm	-1 dBm	109 dB
2.4 kbps	-109 dbm	-1 dBm	108 db

Table 6. CC1101 Preferred Settings Link Budget

7 References

[1] SRD regulations for license free transceiver operation (swra090.pdf)
[2] CC1101EM 868-915MHz Reference Design (swrr045.zip)

8 General Information

8.1 Document History

Revision	Date	Description/Changes
SWRA123B	2010.08.17	Significant update to the design note. - Measurements performed on CC1101 - Changes to frequency deviation to meet 6 dB BW requirement - Updated PSD and output power measurement results - Sensitivity figures significantly improved. Non-optimum register settings used in previous revision - Added CC430 to keywords
SWRA123A	2007.12.17	Added CC1100, CC1101, CC1110, CC1111, CC1150 to keywords Removed logo from header
SWRA123	2007.01.04	Initial release.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Communications and Telecom	www.ti.com/communications
DSP	dsp.ti.com	Computers and Peripherals	www.ti.com/computers
Clocks and Timers	www.ti.com/clocks	Consumer Electronics	www.ti.com/consumer-apps
Interface	interface.ti.com	Energy	www.ti.com/energy
Logic	logic.ti.com	Industrial	www.ti.com/industrial
Power Mgmt	power.ti.com	Medical	www.ti.com/medical
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Space, Avionics & Defense	www.ti.com/space-avionics-defense
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video and Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless-apps

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265