Using the CC1190 Front End with CC112x under EN 300 220

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Keywords

- *Range Extender*
- *EN 300 220*
- *External PA*
- *External LNA*
- *CC1120*
- *CC1121*
- *CC1125*
- *CC1190*

1 Introduction

The CC112x family of devices is fully integrated single-chip radio transceivers designed for high performance at very low power and low voltage operation in cost effective wireless systems. All filters are integrated, removing the need for costly external IF filters. The device is mainly intended for the ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency bands at 164-192 MHz, 410-480 MHz and 820-960 MHz.

The CC1190 is a range extender for 850-950 MHz RF transceivers, transmitters, and System-on-Chip devices from Texas Instruments. It increases the link budget by providing a power amplifier (PA) for increased output power, and a low-noise amplifier (LNA) with low noise figure for improved receiver sensitivity in addition to switches and RF matching for simple design of high performance wireless systems.

This application note outlines the expected performance when using a CC1120-CC1190 design under EN 300 220-1 V2.3.1 [5] in the 869.4-869.65 MHz frequency sub-band (g3). The maximum allowed output power in the 869.4-869.65 MHz sub-band is +27 dBm (500 mW),

For details on the regulatory limits in the 863-870 MHz SRD frequency bands, please refer to the ETSI EN 300 220-1 V2.3.1 [5] and ERC Recommendation 70-03 [6]. These can be downloaded from www.etsi.org and www.ero.dk

The application note is also applicable for CC1121 and CC1125.

Table of Contents

2 Abbreviations

EB	Evaluation Board
EM	Evaluation Modul
HGM	High Gain Mode
LNA	Low Noise Amplifier
LGM	Low Gain Mode
PA	Power Amplifier
PCB	Printed Circuit Board
PER	Packet Error Rate
RF	Radio Frequency
RSSI	Receive Signal Strength Indicator
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 CC1120 datasheet [1] and the CC1190 datasheet [3] 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

Note that the characteristics in Chapter 4 are only valid when using the CC1120-CC1190EM 868 MHz reference design [4] and register settings recommended by the SmartRF Studio software [7].

4.1 Operating Conditions

Parameter	Min	Max	Unit
Operating Frequency	850	950	MHz
Operating Supply Voltage	2.0	3.6	V
Operating Temperature	-40	+85	°C

Table 4.1. Operating Conditions

4.2 Current Consumption

T_C = 25°C, VDD = 3.0 V, f = 869.525 MHz if nothing else is stated. All parameters are measured on the CC1120-CC1190EM 868 MHz reference design [4] with a 50 Ω load.

Parameter	Condition	Typical	Unit
Receive Current, HGM[1]	1.2 kbps, 2FSK, ±4 kHz deviation	24	mA
	50 kbps, 2GFSK, ±25 kHz deviation	25	mA
	200 kbps, 4GFSK, ±82.76 kHz deviation	25	mA
Receive Current, LGM	1.2 kbps, 2FSK, ±4 kHz deviation	21	mA
	50 kbps, 2GFSK, ±25 kHz deviation	22	mA
	200 kbps, 4GFSK, ±82.76 kHz deviation	22	mA
Transmit Current	PA_CFG2 = 0x77 (+27dBm) PA_CFG2 = 0x6F (+26dBm) PA_CFG2 = 0x6B (+25dBm) PA_CFG2 = 0x66 (+24dBm) PA_CFG2 = 0x63 (+23dBm) PA_CFG2 = 0x60 (+22dBm) PA_CFG2 = 0x5D (+21dBm) PA_CFG2 = 0x5A (+20dBm) PA_CFG2 = 0x58 (+19dBm) PA_CFG2 = 0x55 (+18dBm) PA_CFG2 = 0x53 (+17dBm)	475 411 376 324 295 266 239 213 197 176 163	mA
Power Down Current		370	nA

Table 4.2. Current Consumption

[1] Input signal at -80 dBm

4.3 Receive Parameters

T_C = 25°C, VDD = 3.0 V, f = 869.525 MHz if nothing else is stated. All parameters are measured on the CC1120-CC1190EM 868 MHz reference design [4] with a 50 Ω load.

Parameter	Condition	Typical	Unit
Sensitivity[2], HGM	1.2 kbps, 2FSK, ±4 kHz deviation, 10 kHz RX filter bandwidth. See Figure 4.1	-126	dBm
	50 kbps, 2GFSK, ±25 kHz deviation, 100 kHz RX filter bandwidth. See Figure 4.2	-113	dBm
	150 kbps, 4GFSK, ±82.76 kHz deviation, 200 kHz RX filter bandwidth	-107	dBm
	200 kbps, 4GFSK, ±82.76 kHz deviation, 200 kHz RX filter bandwidth. See Figure 4.3	-106	dBm
	4.8 kbps, ASK, 66.6 kHz RX filter bandwidth	-117	dBm
Sensitivity[2], LGM	1.2 kbps, 2FSK, ±4 kHz deviation, 10 kHz RX filter bandwidth. See Figure 4.4	-116	dBm
	50 kbps, 2GFSK, ±25 kHz deviation, 100 kHz RX filter bandwidth. See Figure 4.5	-102	dBm
	200 kbps, 4GFSK, ±82.76 kHz deviation, 200 kHz RX filter bandwidth. See Figure 4.6	-98	dBm
Saturation, HGM	Maximum input power level for 1% BER	+10	dBm
Saturation, LGM	Maximum input power level for 1% BER	+10	dBm
Selectivity and Blocking, HGM	1.2 kbps, 2FSK, ±4 kHz deviation (see Figure 4.7 and Figure 4.8) ±2 MHz from wanted signal ±10 MHz from wanted signal	 80 94	dB
	50 kbps, 2GFSK, ±25 kHz deviation (see Figure 4.9 and Figure 4.10) ±2 MHz from wanted signal ±10 MHz from wanted signal	 67 81	dB
Spurious emission, HGM	Radiated measurement @3.6 GHz	-61	dBm

Table 4.3. Receive Parameters

[2] Sensitivity limit is defined as 1% bit error rate (BER). Packet length is 3 bytes.

4.3.1 Typical RX Performance vs. Temperature and VDD

T_C = 25°C, VDD = 3.0 V, f = 869.525 MHz if nothing else is stated. All parameters are measured on the CC1120-CC1190EM 868 MHz reference design [4] with a 50 Ω load.

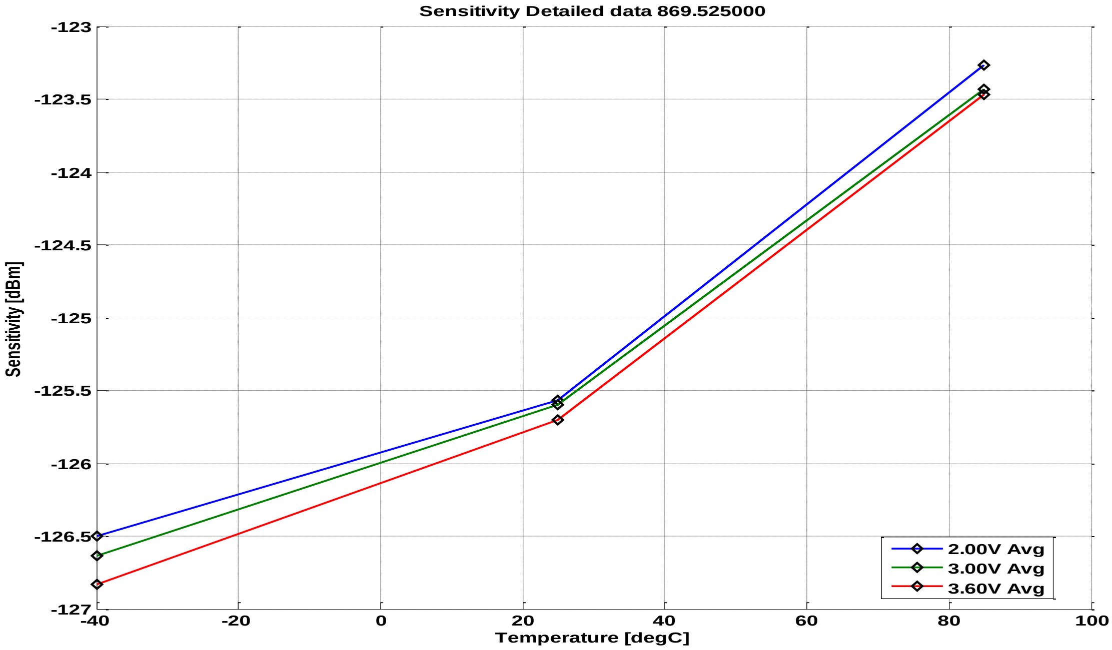

Figure 4.1. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 1.2 kbps

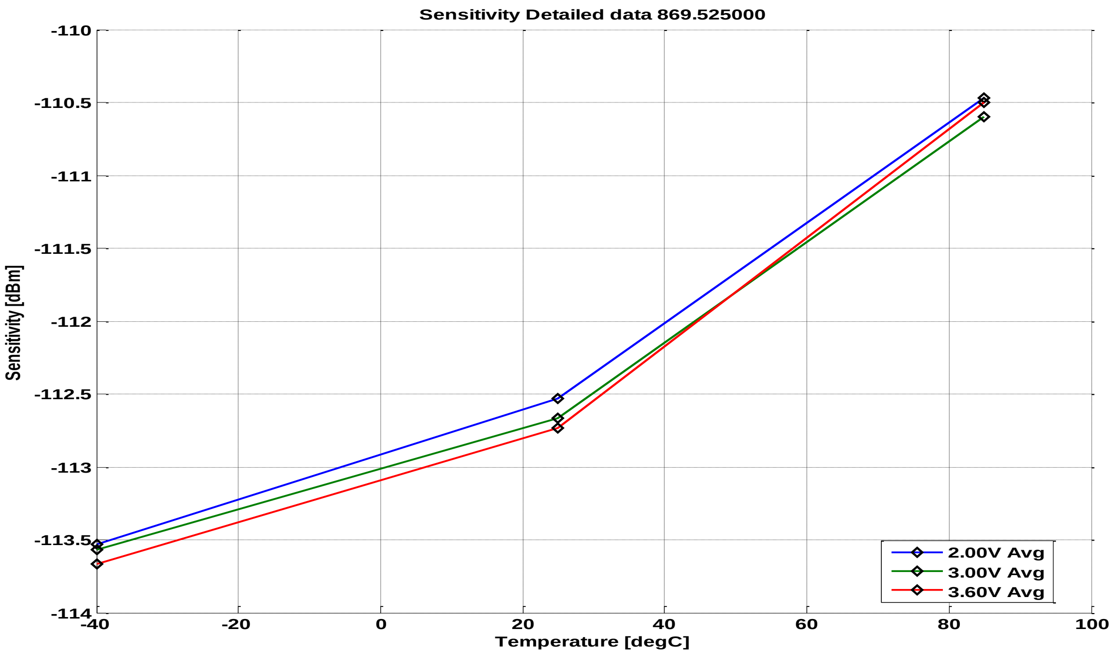

Figure 4.2. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 50 kbps

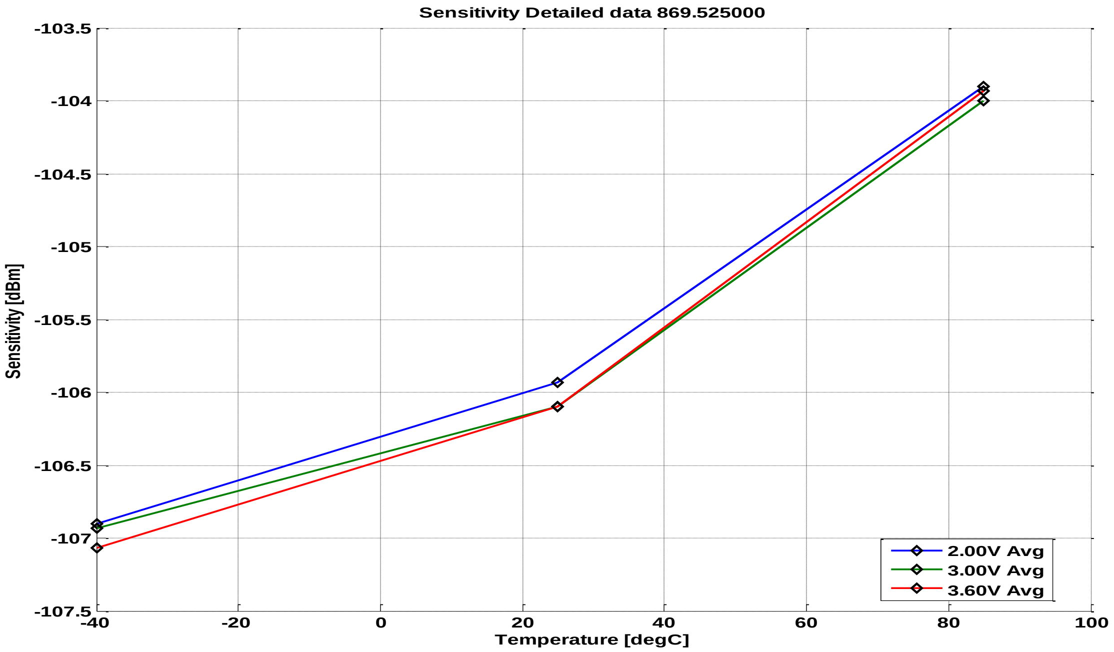

Figure 4.3. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 200 kbps

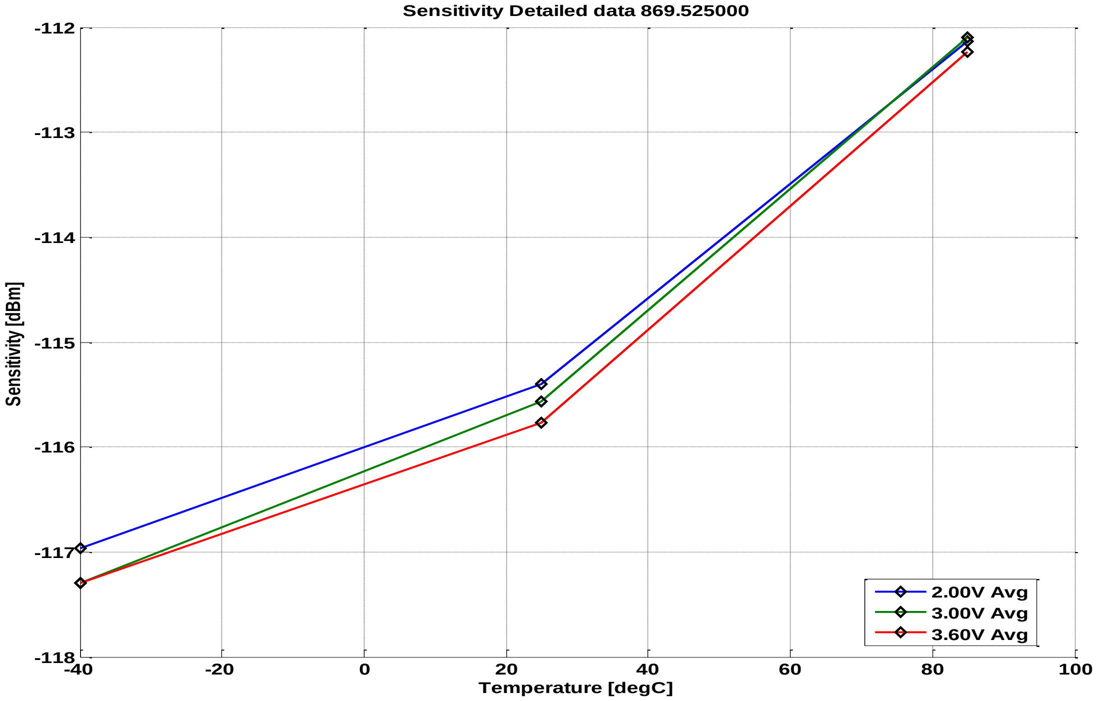

Figure 4.4. Typical Sensitivity vs. Temperature and Power Supply Voltage, LGM, 1.2 kbps

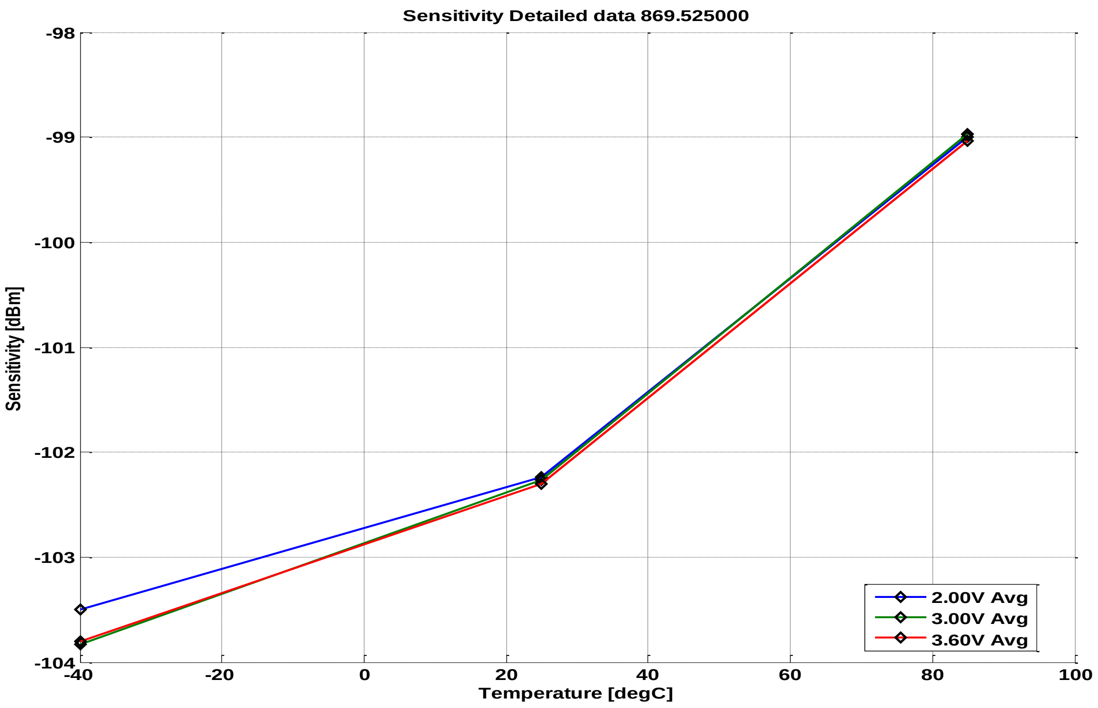

Figure 4.5. Typical Sensitivity vs. Temperature and Power Supply Voltage, LGM, 50 kbps

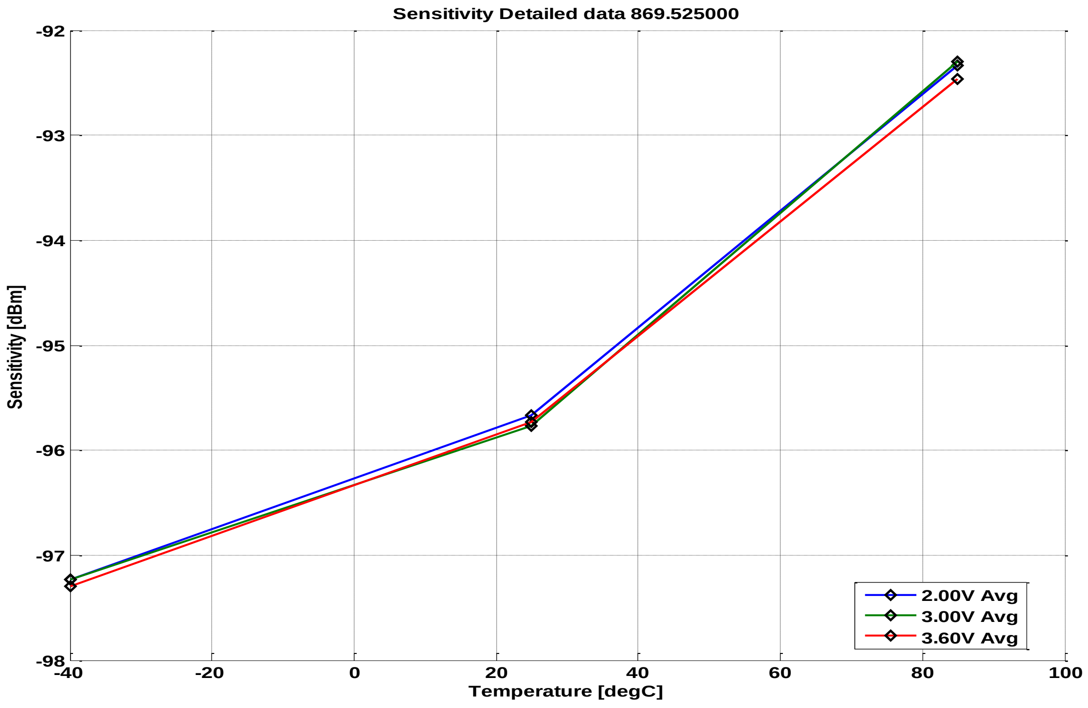

Figure 4.6. Typical Sensitivity vs. Temperature and Power Supply Voltage, LGM, 200 kbps

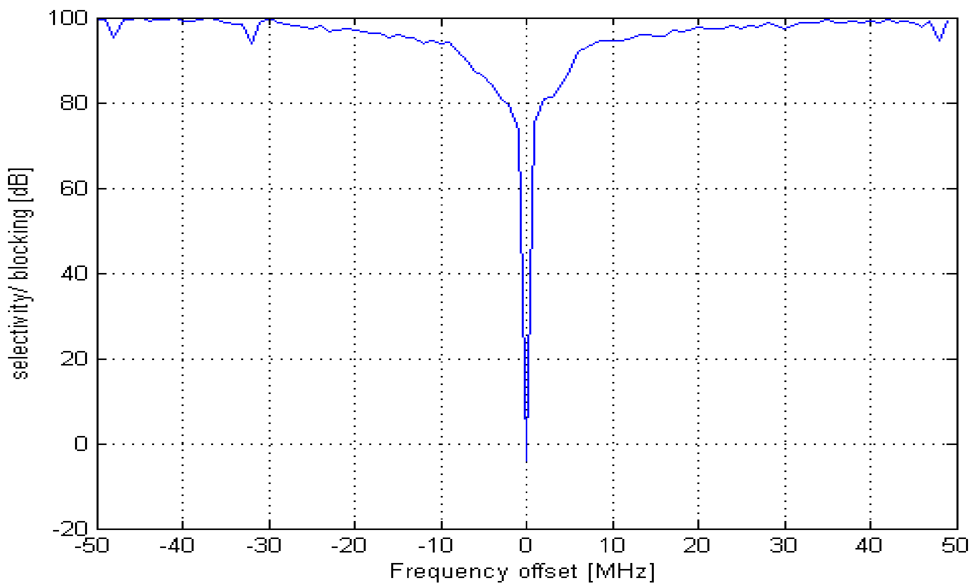

Figure 4.7. Typical Blocking, 1.2 kbps

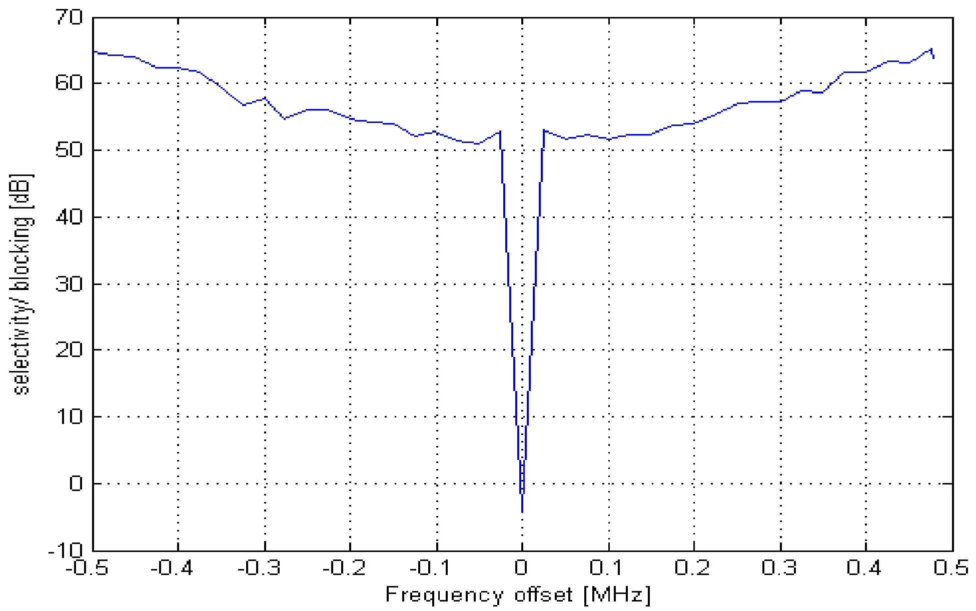

Figure 4.8. Typical Selectivity, 1.2 kbps

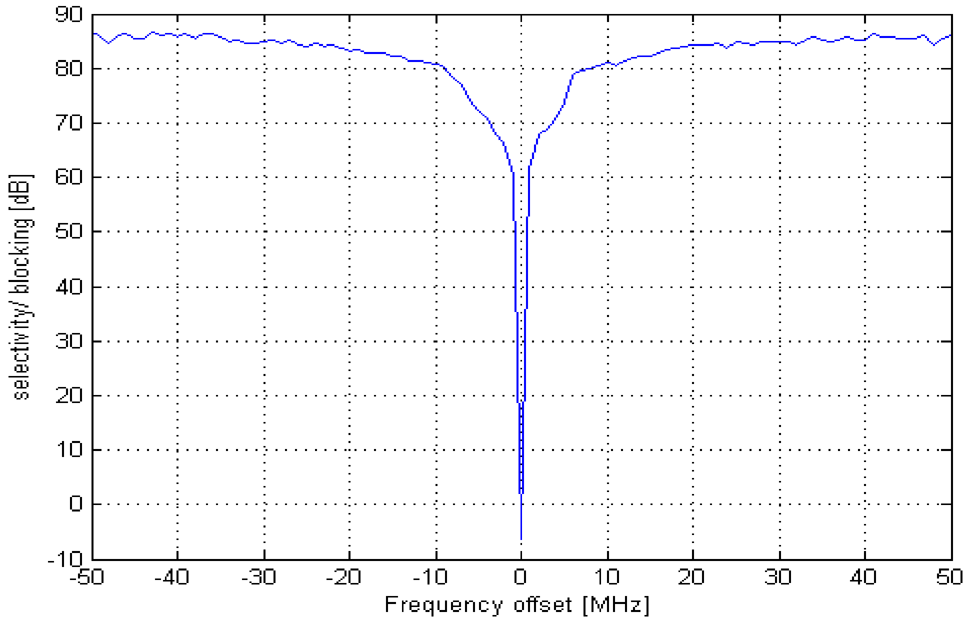

Figure 4.9. Typical Blocking, 50 kbps

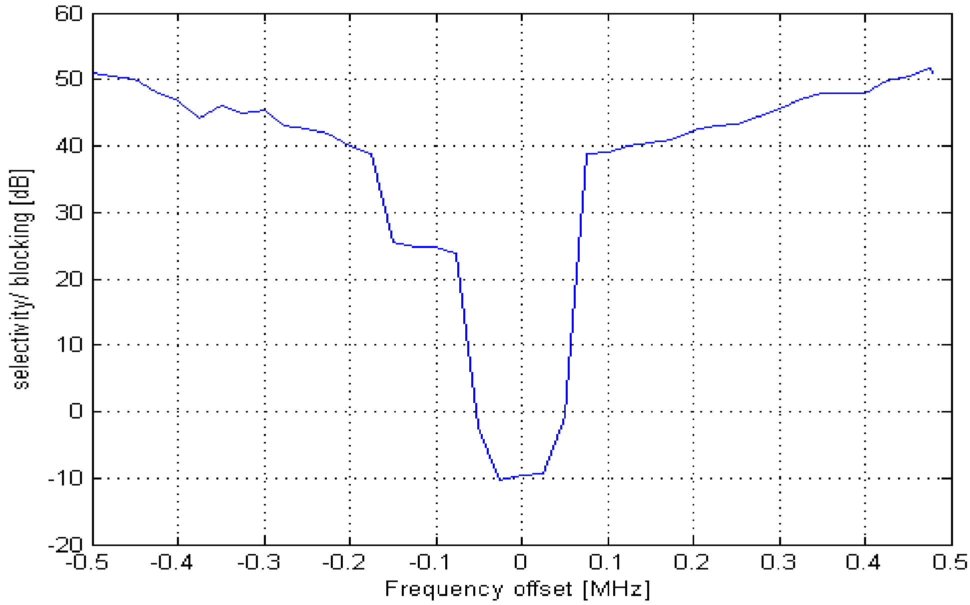

Figure 4.10. Typical Selectivity, 50 kbps

4.3.2 Received Signal Strength Indicator (RSSI)

The CC1120-CC1190 RSSI readouts can be converted to an absolute level in dBm by subtracting an offset. A CC1120-CC1190 design has a different offset value compared to a standalone CC1120 design due to the CC1190 external LNA gain and the SAW filter insertion loss. Table 4.4 gives the typical offset value for HGM and LGM. Refer to the CC1120 data sheet [1] for more details on how to convert the RSSI readout to an absolute power level in dBm.

HGM	LGM
107.5	91.5

Table 4.4. Typical RSSI Offset Values

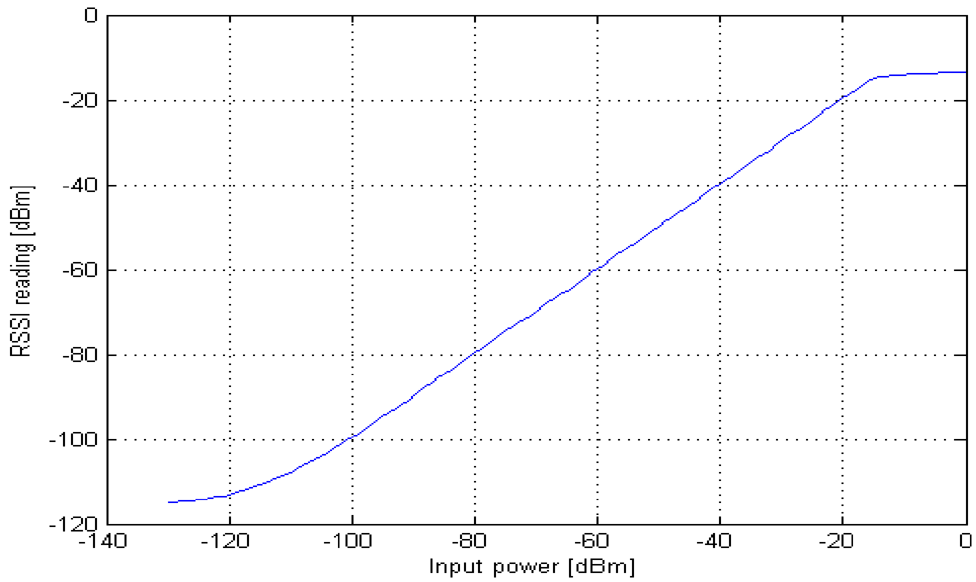

Figure 4.11. Typical RSSI vs. Input Power Level, HGM, 1.2 kbps, 20 kHz RX BW

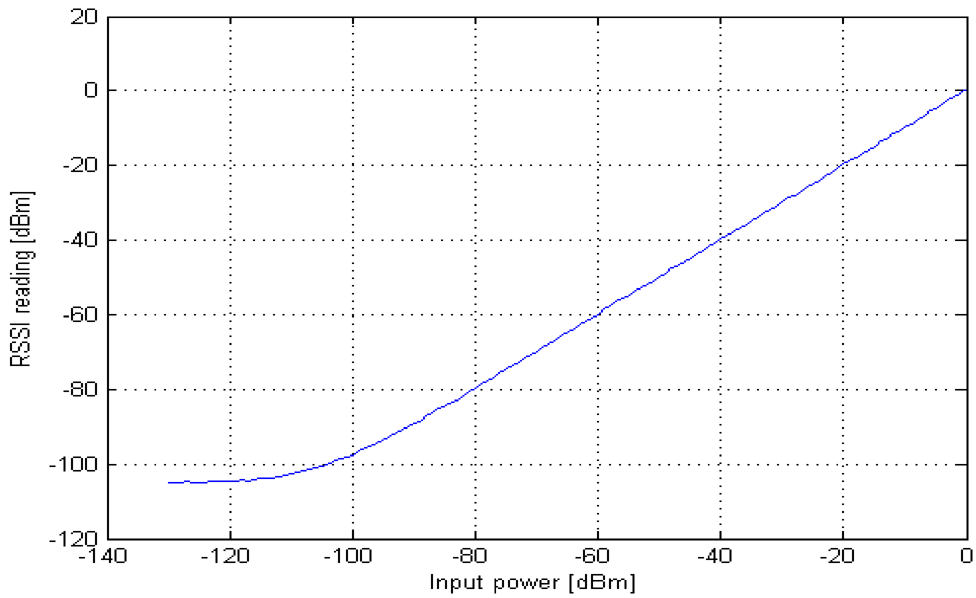

Figure 4.12. Typical RSSI vs. Input Power Level, LGM, 1.2 kbps, 20 kHz RX BW

4.4 Transmit Parameters

T_C = 25°C, VDD = 3.0 V, f = 869.525 MHz if nothing else is stated. All parameters are measured on the CC1120-CC1190EM 868 MHz reference design [4] with a 50 Ω load, except for the load-pull measurements. Radiated measurements are done with the kit antenna.

Parameter	Condition	Typical	Unit
Output power; HGM	PA_CFG2 = 0x77 PA_CFG2 = 0x6F PA_CFG2 = 0x6B PA_CFG2 = 0x66 PA_CFG2 = 0x63 PA_CFG2 = 0x60 PA_CFG2 = 0x5D PA_CFG2 = 0x5A PA_CFG2 = 0x58 PA_CFG2 = 0x55 PA_CFG2 = 0x53	27 26 25 24 23 22 21 20 19 18 17	dBm
Efficiency, HGM	PA_CFG2 = 0x77 PA_CFG2 = 0x6F PA_CFG2 = 0x6B PA_CFG2 = 0x66 PA_CFG2 = 0x63 PA_CFG2 = 0x60	35 32 29 26 23 21	%
Spurious emission with PATABLE = 0x6B, HGM	Conducted below 1 GHz Conducted above 1 GHz Conducted 2nd harmonic Conducted 3nd harmonic Radiated 2nd harmonic Radiated 3nd harmonic	-56 -45 -47 -42 -30 -37	dBm
Modulation bandwidth, HGM	Figure 4.17		
Stability, HGM Maximum VSWR with PA_CFG = 0x6B	**+85˚C:** VDD: 3.6 V VDD: 3.0 V **+25˚C:** VDD: 3.6 V VDD: 3.0 V **-40˚C:** VDD: 3.6 V VDD: 3.0 V	 10 10 3.6 6 2.5 2.5	

Table 4.5. Transmit Parameters

4.4.1 Typical TX Performance vs. Temperature and VDD

T_C = 25°C, VDD = 3.0 V, f = 869.525 MHz if nothing else is stated. All parameters are measured on the CC1120-CC1190EM 868 MHz reference design [4] with a 50 Ω load.

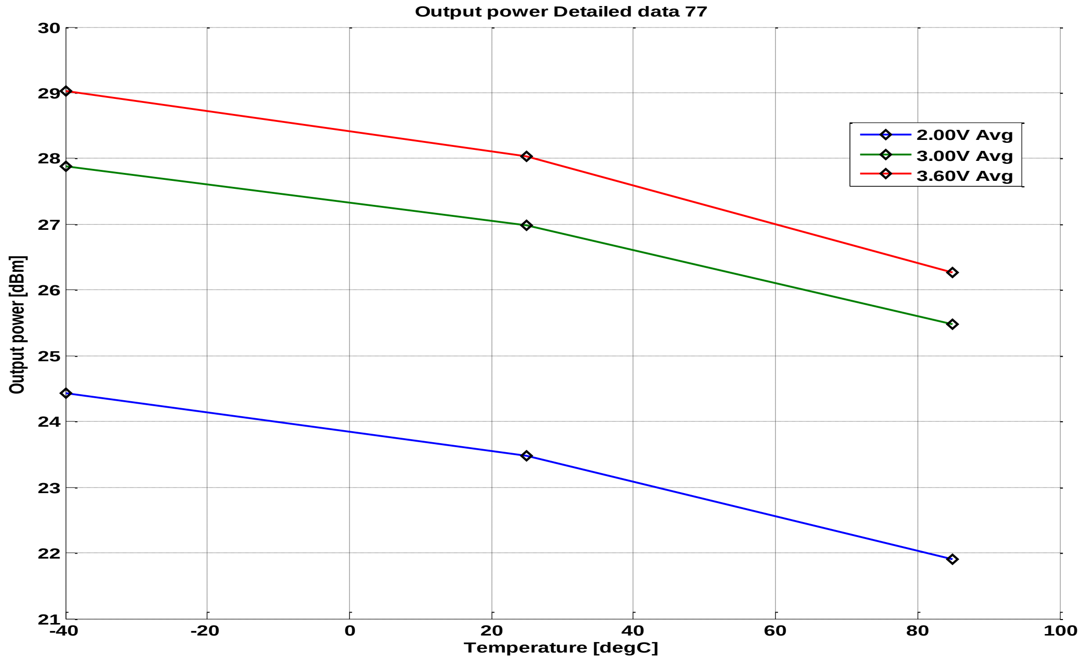

Figure 4.13. Typical Output Power vs. Temperature and Power Supply Voltage. PA_CFG2 = 0x77

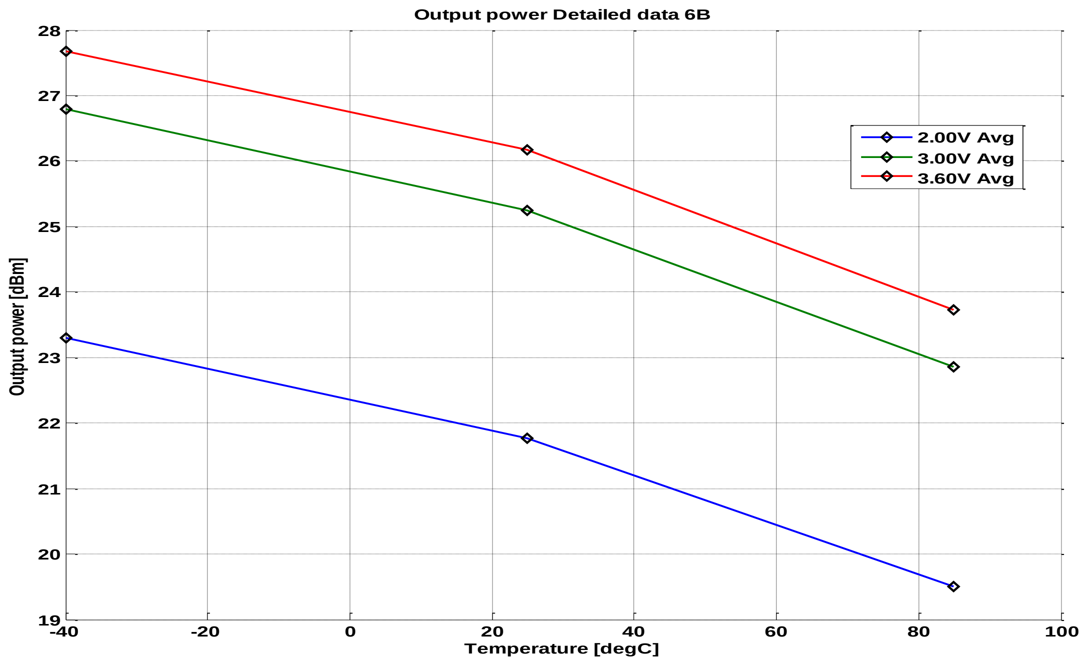

Figure 4.14. Typical Output Power vs. Temperature and Power Supply Voltage. PA_CFG2 = 0x6B

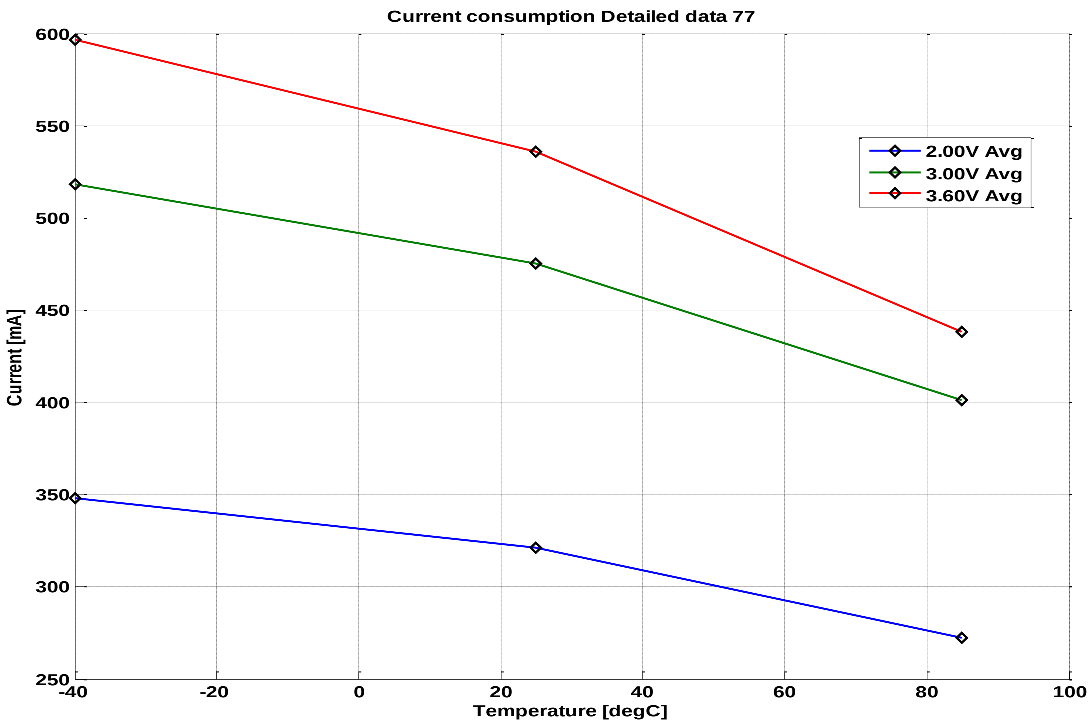

Figure 4.15. Typical TX Current Consumption vs. Temperature and Power Supply Voltage. PA_CFG2 = 0x77

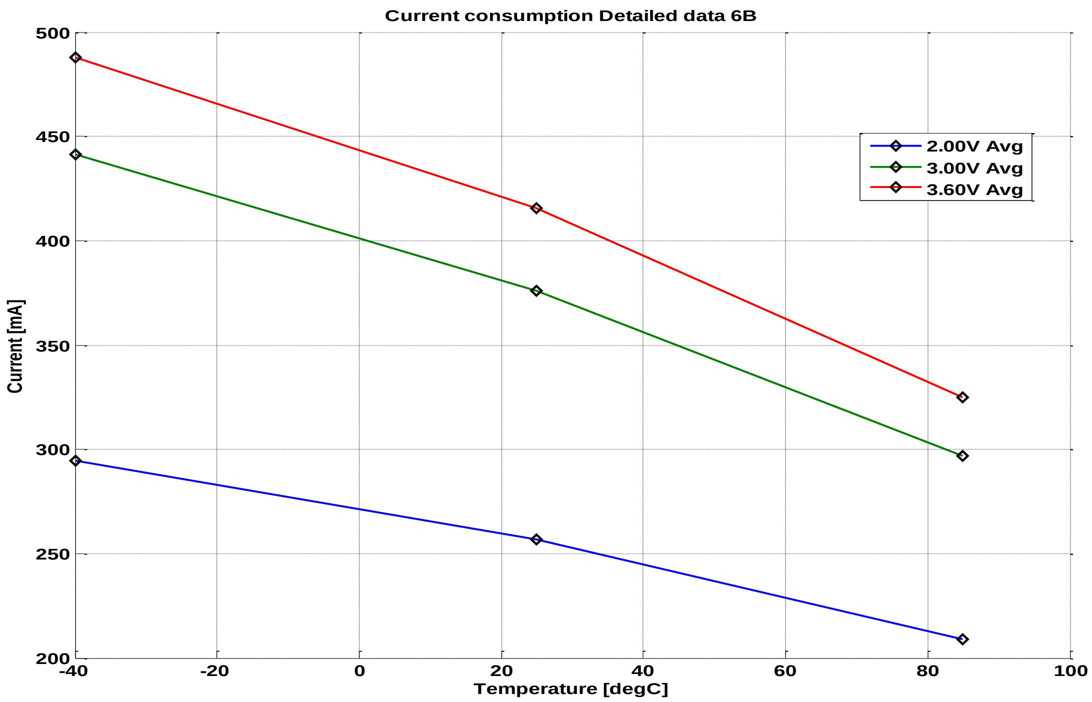

Figure 4.16. Typical TX Current Consumption vs. Temperature and Power Supply Voltage. PA_CFG2 = 0x6B

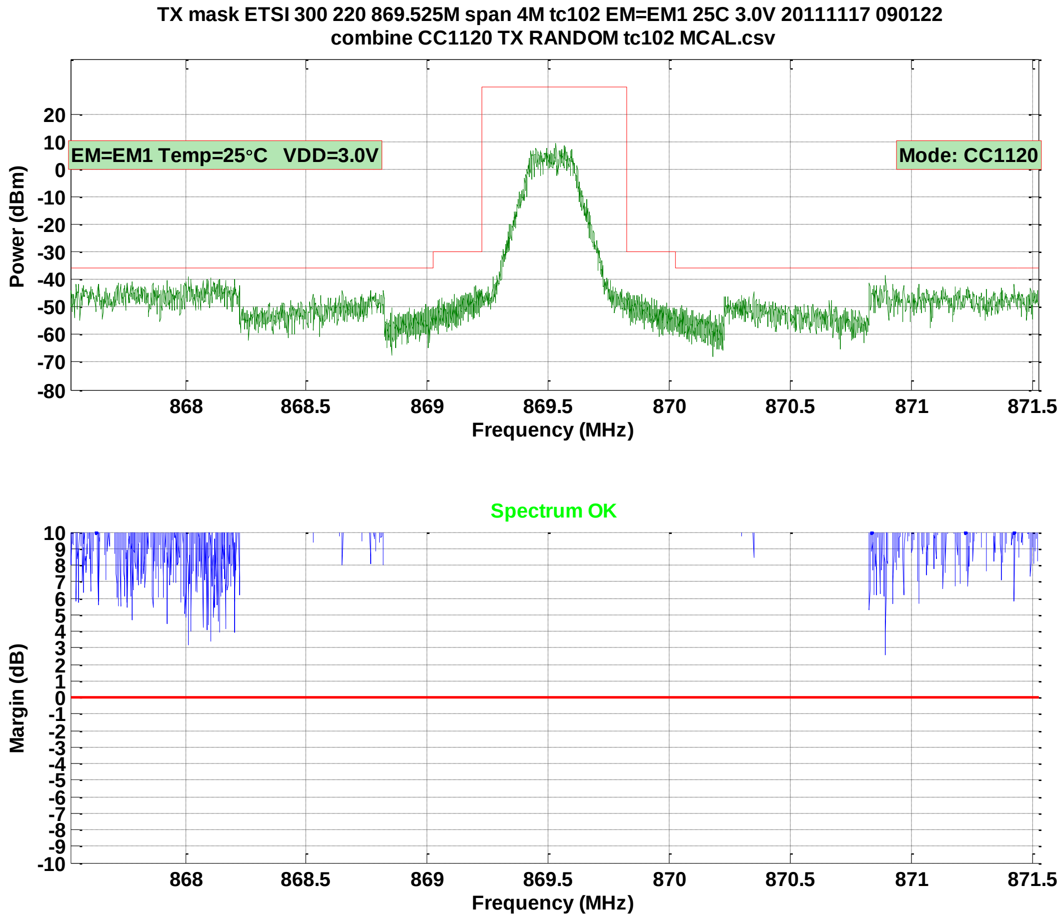

Figure 4.17. ETSI 300 220, Modulation Bandwidth, conducted, 200 kbps, PA_CFG2 = 0x6B

4.4.2 Typical TX Parameters vs. Load Impedance

The load impedance presented to the CC1190 PA output is critical to the TX performance of the reference design. The load impedance is selected as a compromise between several criteria, such as output power, efficiency and the level of the harmonics. The matching components between the PA output and the antenna should transform 50 ohm antenna impedance to the selected impedance which the CC1190 PA should see. This is taken care of by the reference design and the user should provide a well matched antenna to get the required performance.

In order to measure the performance under different mismatch conditions the CC1120-CC1190EM 868 MHz reference design is loaded with different impedances at the SMA connector reference plane. A well matched antenna will have impedance inside the black circle in the Smith chart, which illustrates the limit for 10 dB return loss. At each load the output power, current and spurious frequency components are measured. These measurements are known as load-pull measurements.

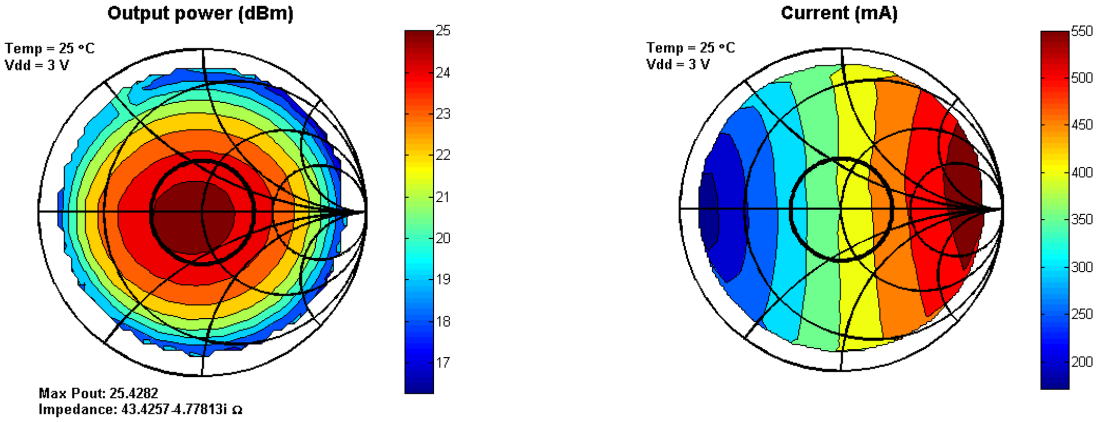

Figure 4.18. Output Power (left) and Current (right) vs. Load Impedance at SMA Connector at 25°C. PA_CFG2 = 0x6B.

Most PAs have the ability to oscillate at unwanted frequencies under certain conditions. The worst conditions are usually high output power, low temperatures, and high VDD. The spurious frequency components are measured under different mismatch conditions as illustrated in Figure 4.19 and Figure 4.20. The blue colors indicate that the spurious levels are at the noise floor. The CC1120-CC1190EM 868 MHz reference design is a very robust design which tolerates high mismatch ratios at high output power, low temperatures and high VDD.

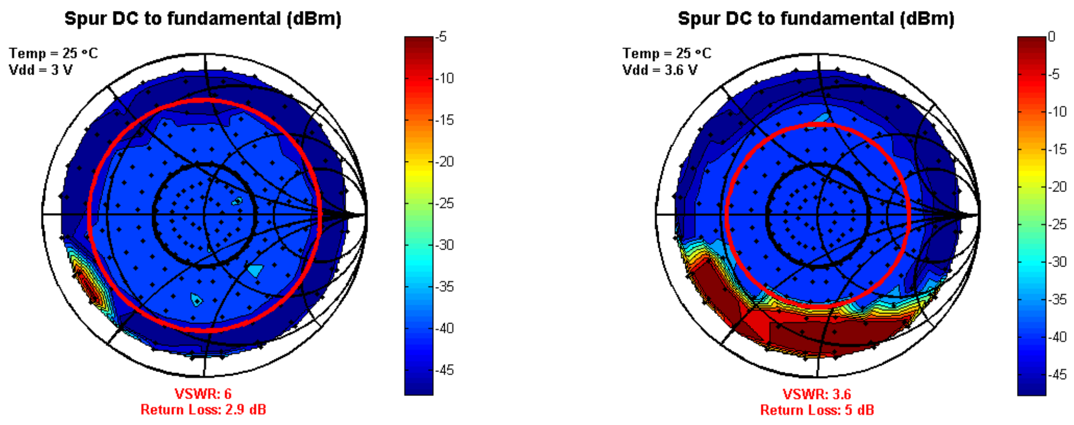

Figure 4.19. Spurious Frequency Components vs. Load Impedance at SMA Connector at 25°C. PA_CFG2 = 0x6B.

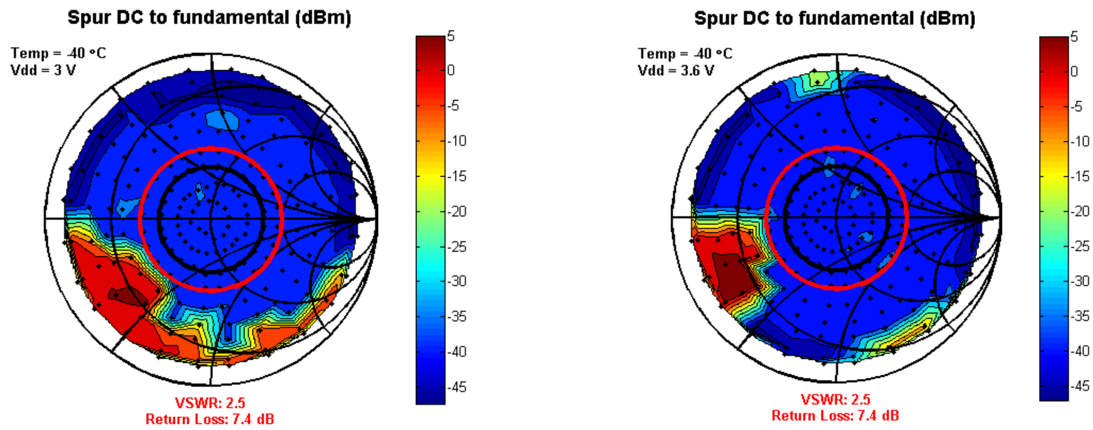

Figure 4.20. Spurious Frequency Components vs. Load Impedance at SMA Connector at -40°C. PA_CFG2 = 0x6B.

4.5 Measurement Equipment

The following equipment was used for the measurements.

Measurement	Instrument Type	Instrument Model
RX	Signal Generator	Rohde & Schwarz SMIQ 3B
TX	Signal Analyzer	Rohde & Schwarz FSG
RX/TX	Power Supply	Agilent E3631A
	Multimeter	Keithley 2000
Stability	Automatic Tuner	Maury MT986EU32
Radiated spurious Emissions	EMC chamber	

Table 4.6. Measurement Equipment

5 Controlling the CC1190

There are three digital control pins (PA_EN, LNA_EN, and HGM) that sets the CC1190 mode of operation.

PA_EN	LNA_EN	HGM	Mode of Operation
0	0	X	Power Down
0	1	0	RX LGM
0	1	1	RX HGM
1	0	0	TX LGM
1	0	1	TX HGM

Table 5.1. CC1190 Control Logic

There are different ways of controlling the CC1190 mode of operation in a CC1120-CC1190 design.

- Using CC1120 GPIO0/ GPIO2/ GPIO3[3] pins to set two of the CC1190 control signals (e.g. PA_EN and LNA_EN). The third control signal (e.g. HGM) can be hardwired to GND/VDD or connected to an external MCU.
- Using an external MCU to control PA_EN, LNA_EN, and HGM.

Using an external MCU to set one (or more) digital control signals is the recommended solution for a CC1120-CC1190 design since GPIO0 or GPIO2 are typically programmed to provide a signal related to the CC1120 packet handler engine to the interfacing MCU and GPIO1 is the same pin as the SO pin on the SPI interface. The GPIO pin not used to provide information to the interfacing MCU can be used to control the CC1190.

6 SmartRF Studio and TrxEB

The CC1120-CC1190EM 868 MHz together with SmartRF™ Studio 7 software [7] and TrxEB can be used to evaluate performance and functionality.

6.1 SmartRF Studio

The CC1120-CC1190 can be configured using the SmartRF Studio 7 software [7]. The SmartRF Studio software is highly recommended for obtaining optimum register settings. A screenshot of the SmartRF Studio user interface for CC1120-CC1190 is shown in Figure 6.1.

[3] GPIO1 is not used since this is the same pin as the SO pin on the SPI interface. The output programmed on this pin will only be valid when CSn is high. For a system where eWOR is used the LNA_EN pin on the CC1190 should be controlled by GPIO3. This is related to the polarity of the CC1120 GPIO pins in SLEEP.

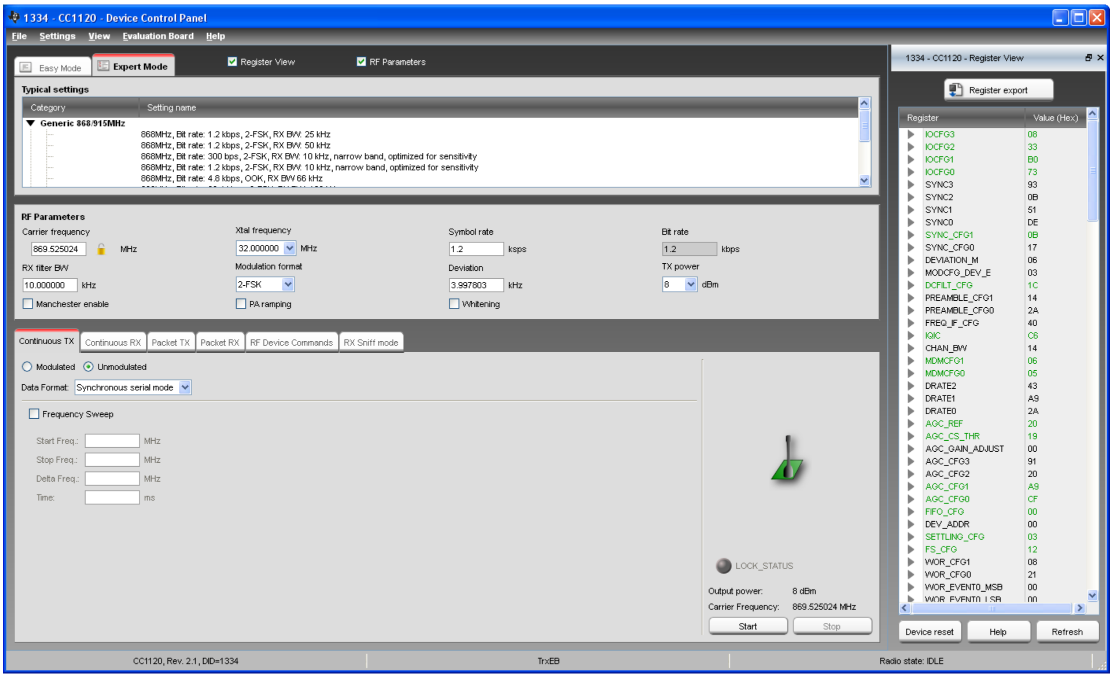

Figure 6.1. SmartRF Studio 7 [7] User Interface

In order to control the CC1190 the user needs to set GPIO2=0x33 and GPIO0=0x73 to set CC1190 in TX and GPIO2=0x73 and GPIO0=0x33 to set CC1190 in RX.

6.2 TRxEB

If CC1120-CC1190 is used with the TrxEB and the USB controller the supply range is 3.0 V to 3.6 V.

7 Reference Design

The CC1120-CC1190EM 868 MHz reference design includes schematic and gerber files [4]. It is highly recommended to follow the reference design for optimum performance. The reference design also includes bill of materials with manufacturers and part numbers.

7.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. The capacitors C26, C27 and C30 ensure good RF ground after L21 and thus prevent RF leakage into the power supply lines causing oscillations. The power supply filtering consisting of C2, C3 and L2 ensure well defined impedance looking towards the power supply.

7.2 Input/ Output Matching and Filtering

The PA and the LNA of the CC1190 are single ended input/output. A balun is required to transform the differential LNA input of the CC1120 to single ended output of the CC1190 PA. The values of the matching components between the SAW filter and the CC1190 PA input are chosen to present optimum source impedance to the CC1190 PA input with respect to stability.

The CC1190 PA performance is highly dependent on the impedance presented at the output, and the LNA performance is highly dependent on the impedance presented at the input. The impedance is defined by L21 and all components towards the antenna. These components also ensure the required filtering of harmonics to pass regulatory requirements.

The layout and component values need to be copied exactly to obtain the same performance as presented in this application note.

7.3 Bias Resistor

R141 is a bias resistor. The bias resistor is used to set an accurate bias current for internal use in the CC1190.

7.4 SAW Filter

A SAW is recommended for the CC1120-CC1190 design to attenuate spurs below the carrier frequency that will otherwise violate spurious emission limits under ETSI 300-220. The SAW filter is matched to the CC1190 PA input/LNA output impedance using a series inductor and a shunt capacitor.

7.5 PCB Layout Considerations

The Texas Instruments reference design uses a 1.6 mm (0.062”) 4-layer PCB solution. Note that the different layers have different thickness. It is recommended to follow the recommendation given in the CC1120–CC1190EM 868 MHz reference design [4] to ensure optimum performance.

The top layer is used for components and signal routing, and the open areas are filled with metallization connected to ground using several vias. 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 CC1190 is given in the CC1190 datasheet [3].

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. Two different power planes for CC1120 and CC1190 are used and they are surrounded by ground to reduce unwanted radiation from the board.

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

7.6 Shielding

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

8 Disclaimer

The CC1120-CC1190EM evaluation board is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI 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 ETSI 300-220 regulations, but there has been no formal compliance testing at an external test house. It is the end user's responsibility to ensure that his system complies with applicable regulations.

9 References

[1] CC1120 Datasheet (SWRS112.pdf)

[2] CC1120 User Guide (SWRU295.pdf)

[3] CC1190 Datasheet (SWRS089.pdf)

[4] CC1120–CC1190EM 868 MHz Reference Design (SWRR092.zip)

[5] ETSI EN 300 220 V2.3.1: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW”

[6] CEPT/ERC/Recommendation 70-03: “Relating to the use of Short Range Devices (SRD)”

[7] SmartRF™ Studio 7 (SWRC176.zip)

10 General Information

10.1 Document History

Revision	Date	Description/Changes
SWRA393	2011.11.24	Initial release.
SWRA393A	2012.02.03	Changes to RSSI offset values (Table 4.4)