Using the CC1190 Front End with CC1100E in the 470 MHz-510 MHz band

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Keywords

- *Range Extender*
- *External PA*
- *External LNA*
- *CC1100E*

1 Introduction

The CC1100E is a sub-GHz, high performance radio transceiver designed for very low power RF applications. It is intended for the Industrial, Scientific and Medical (ISM) and Short Range Device (SRD) frequency bands at 470-510 MHz and 950-960 MHz. The CC1100E is especially suited for wireless applications targeted at the Japanese ARIB STD-T96 and the Chinese Short Range Device Regulations at 470-510 MHz.

The CC1190 is a range extender for 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 CC1100E-CC1190 design in the 470-510 MHz frequency band used in China. The maximum allowed output power in the 470-510 MHz band is +17 dBm (50 mW),

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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 CC1100E datasheet [1] and the CC1190 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

Note that the characteristics in Chapter 4 are only valid when using the CC1100E-CC1190EM 470-510 MHz reference design [3] and register settings recommended by the SmartRF Studio software [4].

4.1 Operating Conditions

Parameter	Min	Max	Unit
Operating Frequency	470	510	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 if nothing else is stated. All parameters are measured on the CC1100E-CC1190EM 470 - 510 MHz reference design [3] with a 50 Ω load.

Parameter	Condition	Typical	Unit
Receive Current, HGM[1]	1.2 kbps, 2GFSK, ±5.2 kHz deviation	18.1	mA
Transmit Current @ 470 MHz	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	216 185 168 145 130 116 108 95	mA
Transmit Current @ 510 MHz	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	236 206 191 169 147 131 121 105	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, if nothing else is stated. All parameters are measured on the CC1100E-CC1190EM 470-510 MHz reference design [3] with a 50 Ω load.

Parameter	Condition	Typical	Unit
Sensitivity[2], HGM @470 MHz	1.2 kbps, 2GSK, ±5.2 kHz deviation, 58 kHz RX filter bandwidth. See Figure 4.4	-115	dBm
	2.4 kbps, 2GFSK, ±5.2 kHz deviation, 58 kHz RX filter bandwidth @470 MHz. See Figure 4.5	-113	dBm
	38.4 kbps, 2GFSK, ±20 kHz deviation, 100 kHz RX filter bandwidth. See Figure 4.6	-107	dBm
Sensitivity[2], HGM @510 MHz	1.2 kbps, 2GSK, ±5.2 kHz deviation, 58 kHz RX filter bandwidth. See Figure 4.1	-116	dBm
	2.4 kbps, 2GFSK, ±5.2 kHz deviation, 58 kHz RX filter bandwidth. See Figure 4.2	-113	dBm
	38.4 kbps, 2GFSK, ±20 kHz deviation, 100 kHz RX filter bandwidth. See Figure 4.3	-108	dBm

Table 4.3. Receive Parameters

4.3.1 Typical RX Performance vs. Temperature and VDD @510 MHz

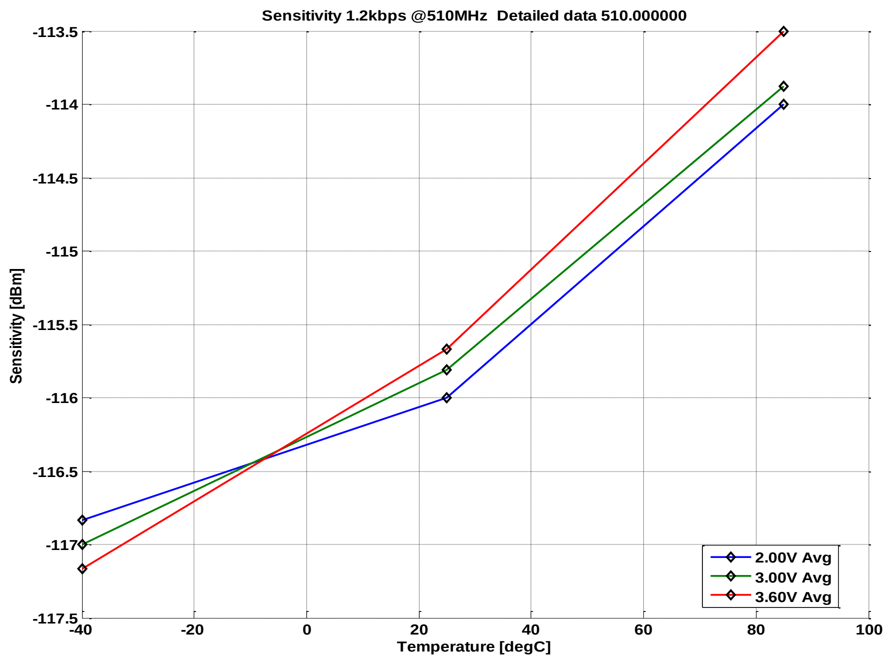

Figure 4.1. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 1.2 kbps

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

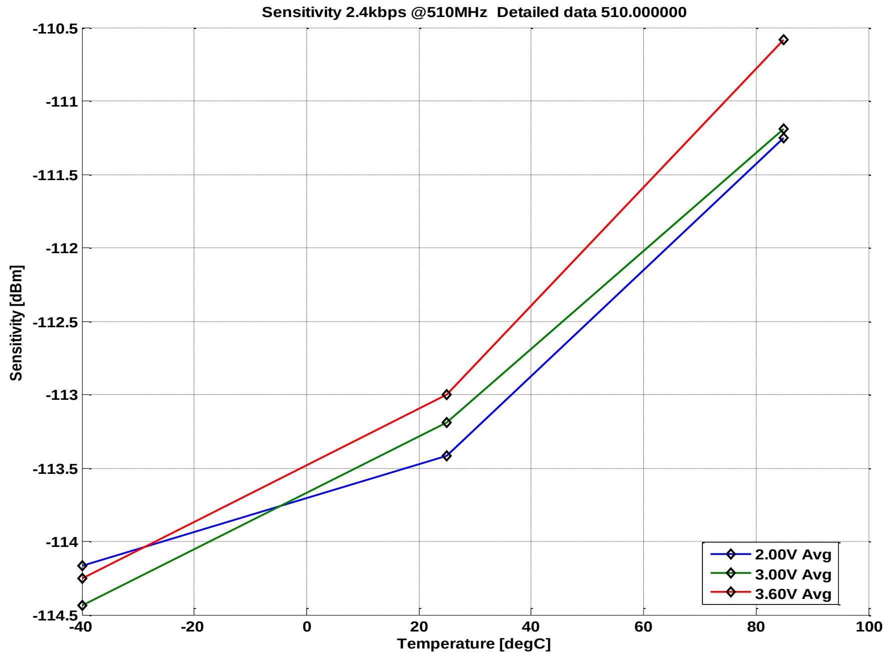

Figure 4.2. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 2.4 kbps

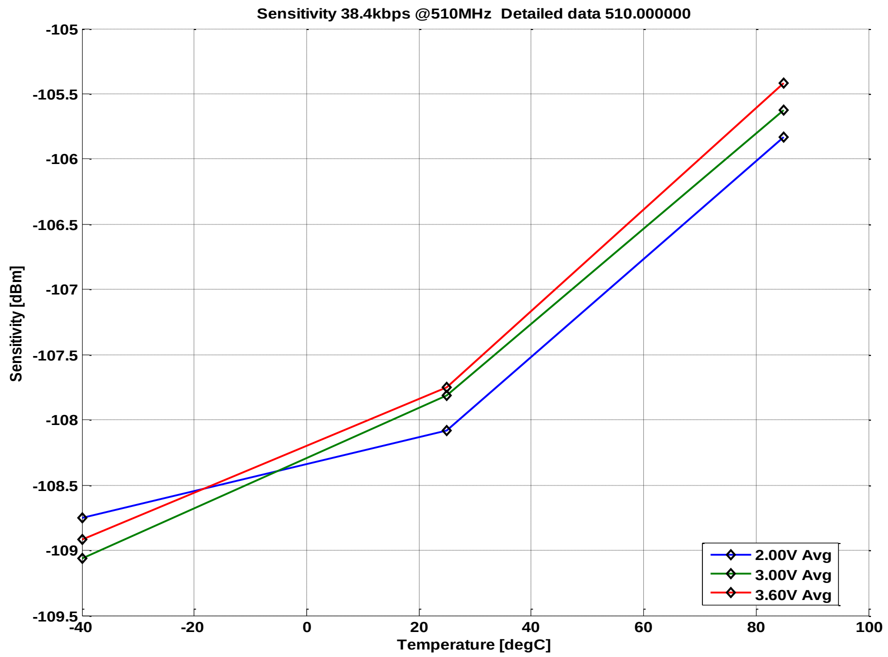

Figure 4.3. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 38.4 kbps

4.3.2 Typical RX Performance vs. Temperature and VDD @470 MHz

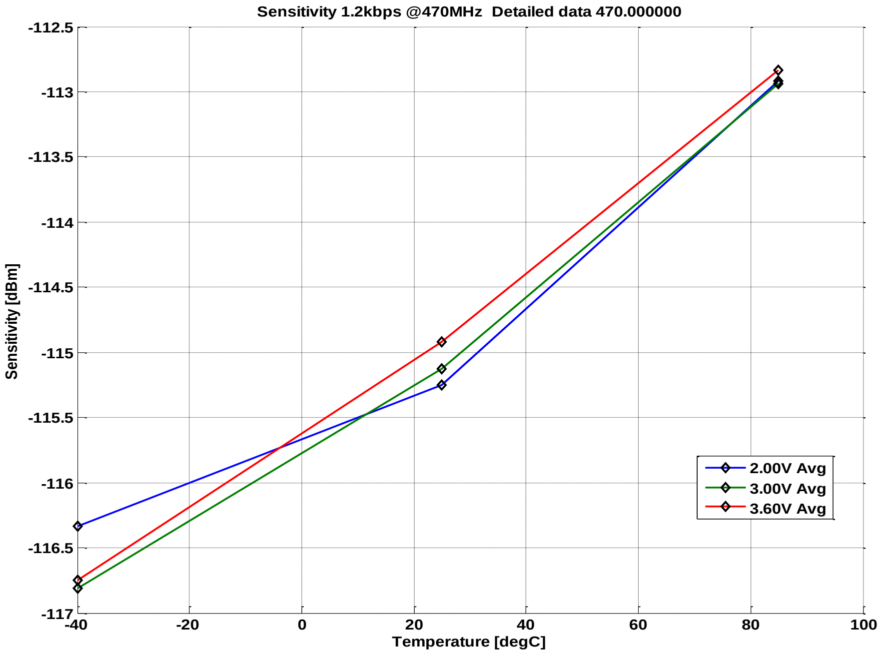

Figure 4.4. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 1.2 kbps

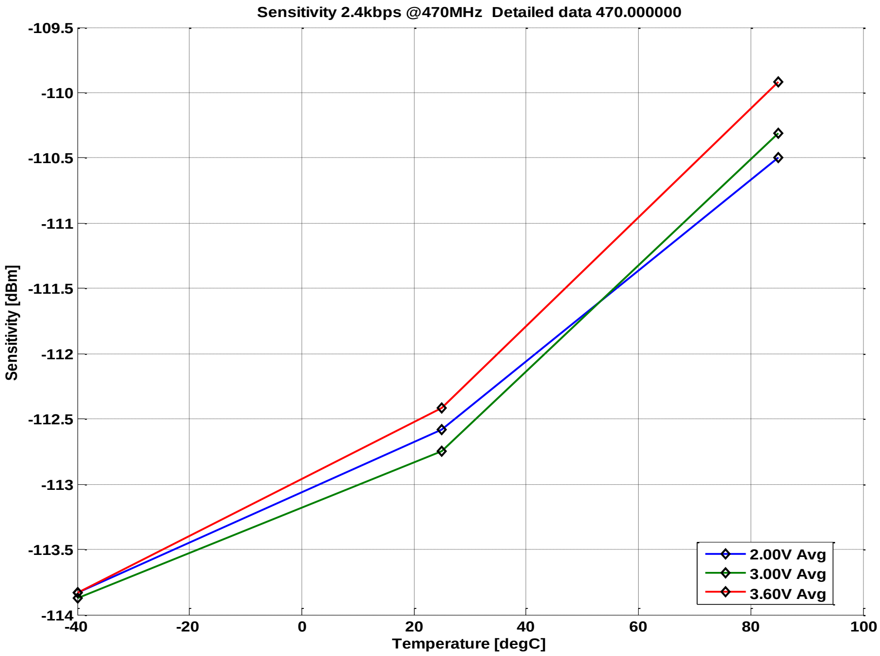

Figure 4.5. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 2.4 kbps

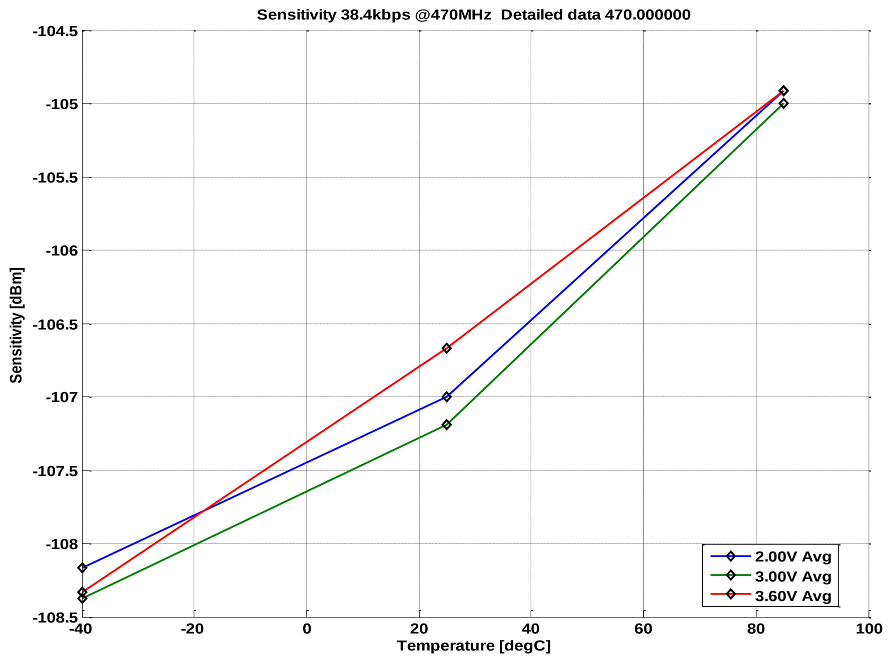

Figure 4.6. Typical Sensitivity vs. Temperature and Power Supply Voltage, HGM, 38.4 kbps

4.4 Transmit Parameters

T_C = 25°C, VDD = 3.0 V if nothing else is stated. All parameters are measured on the CC1100E-CC1190EM 470 - 510 MHz reference design [3] with a 50 Ω load

Parameter	Condition	Typical	Unit
Output Power; HGM	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	22.1 20.8 20.0 18.7 17.1 15.8 14.7 12.7	dBm
Spurious Emission Conducted 2nd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-34 -35 -35 -36 -38 -40 -41 -44	dBm
Spurious Emission Conducted 3rd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-33 -35 -36 -37 -40 -41 -43 -46	dBm

Table 4.4. Transmit Parameters @510MHz

Parameter	Condition	Typical	Unit
Output Power; HGM	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	21.3 19.6 18.6 17.0 15.7 14.3 13.3 11.3	dBm
Spurious Emission Conducted 2nd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-43 -44 -44 -46 -47 -49 -50 -53	dBm
Spurious Emission Conducted 3nd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-27 -29 -31 -33 -35 -37 -38 -42	dBm

Table 4.5. Transmit Parameters @490MHz

Parameter	Condition	Typical	Unit
Output Power; HGM	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	20.2 19.2 18.3 16.6 15.3 14.0 13.0 11.0	dBm
Spurious Emission Conducted 2nd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-37 -37 -39 -39 -40 -42 -43 -46	dBm
Spurious Emission Conducted 3nd Harmonic	PA_TABLE0 = 0x86 PA_TABLE0 = 0x8A PA_TABLE0 = 0x8C PA_TABLE0 = 0x8E PA_TABLE0 = 0x50 PA_TABLE0 = 0x40 PA_TABLE0 = 0x63 PA_TABLE0 = 0x66	-23 -27 -29 -32 -34 -36 -38 -42	dBm

Table 4.6. Transmit Parameters @470MHz

4.4.1 Typical TX Performance vs. Temperature and VDD

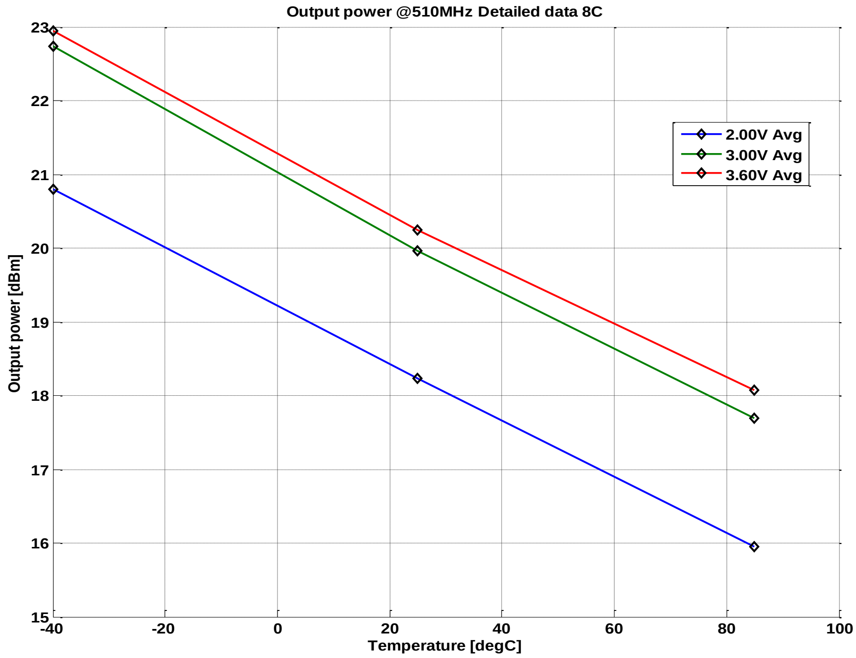

Figure 4.7. Typical TX Output Power vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @510MHz

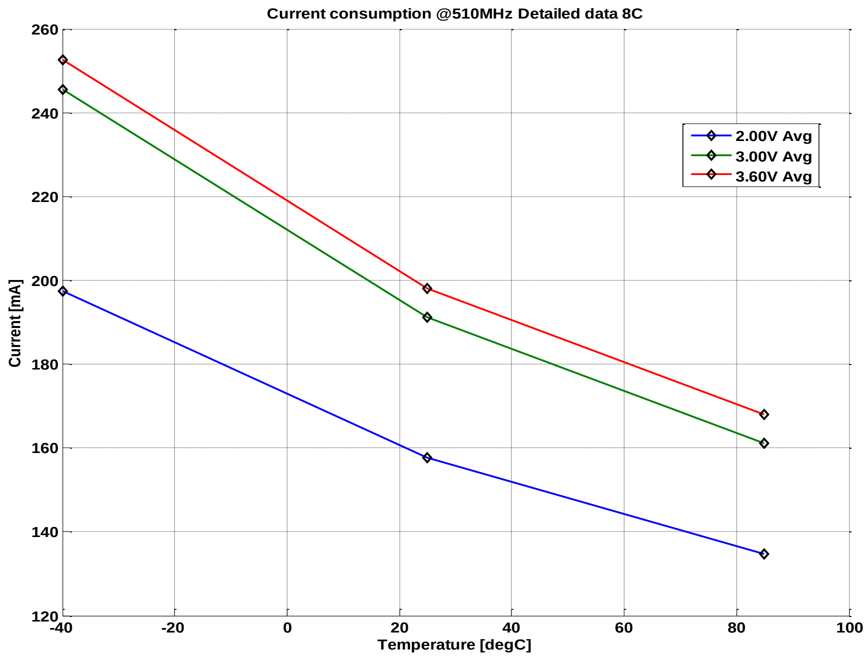

Figure 4.8. Typical TX Current Consumption vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @510MHz

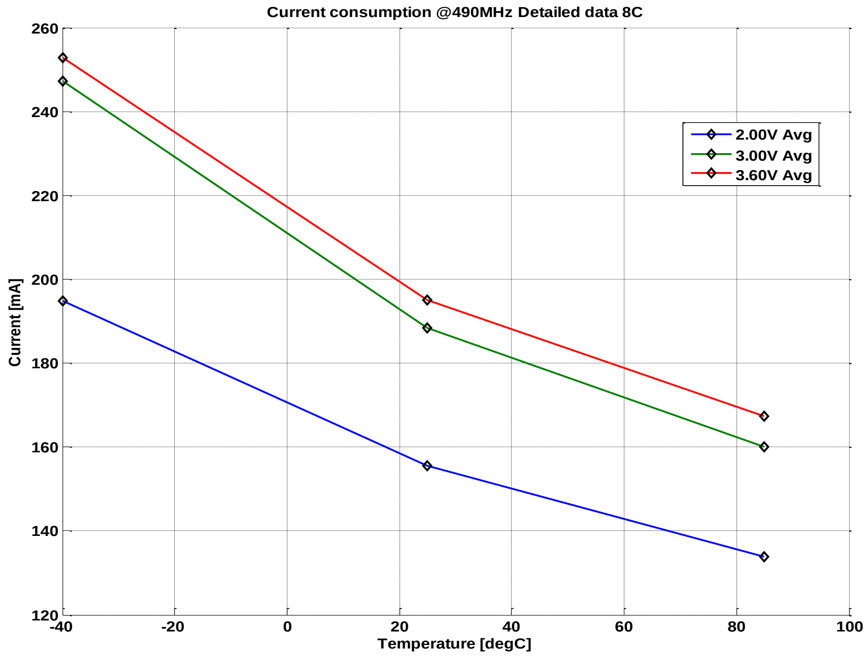

Figure 4.9. Typical Output Power vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @490MHz

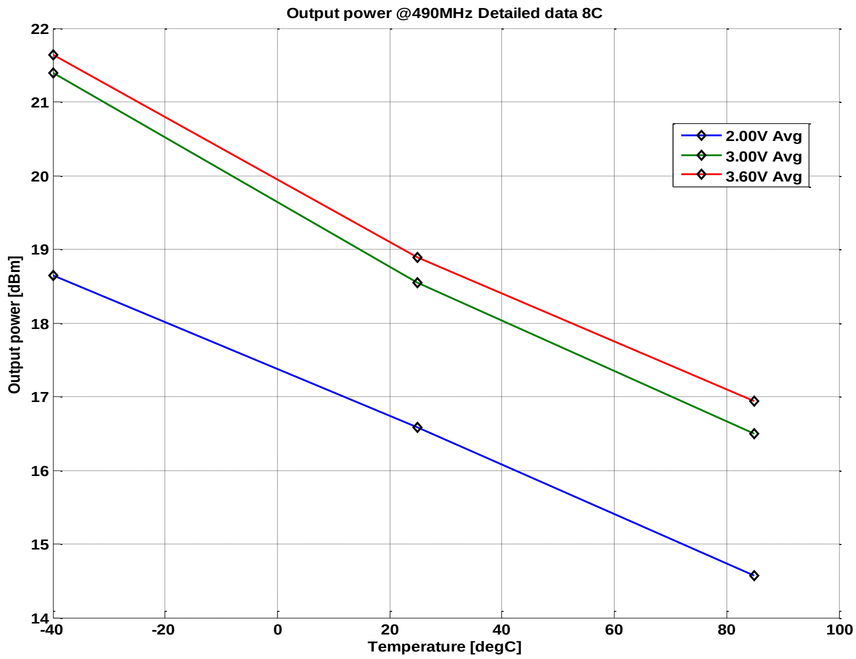

Figure 4.10. Typical TX Output Power vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @490MHz

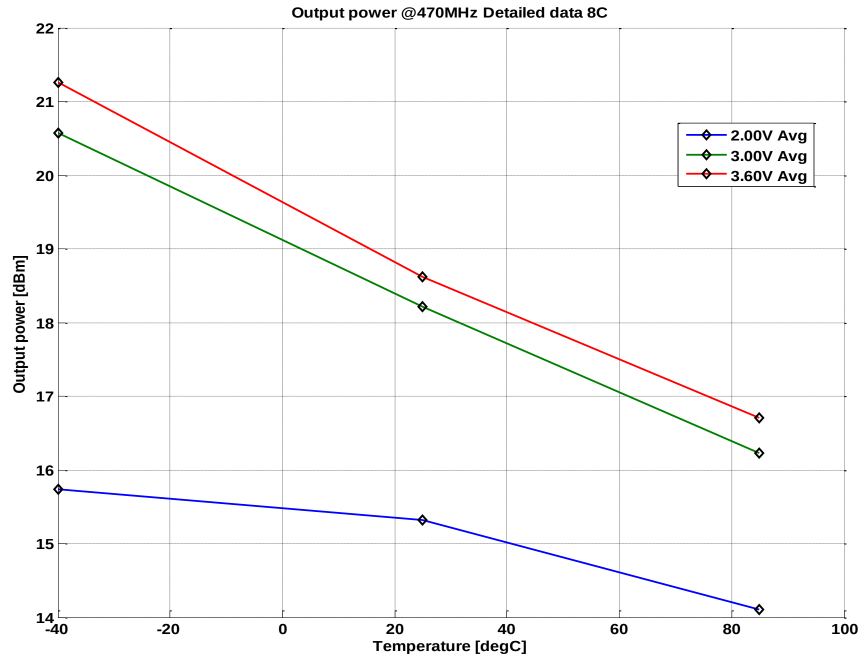

Figure 4.11. Typical TX Output Power vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @470MHz

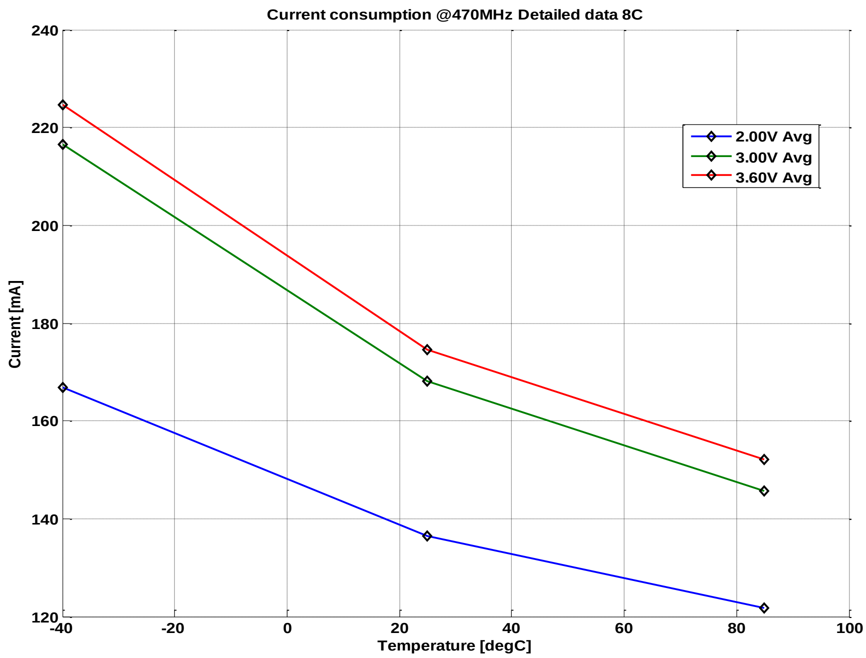

Figure 4.12. Typical Output Power vs. Temperature and Power Supply Voltage. PA_TABLE = 0x8C @470MHz

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 FSU26
RX/TX	Power Supply	Agilent E3631A
	Multimeter	Keithley 2000

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 CC1100E-CC1190 design.

- Using CC1100E GDO0/ GDO2 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 two (or all three) digital control signals is the recommended solution for a CC1100E-CC1190 design since GDO0 or GDO2 are typically programmed to provide a signal related to the CC1100E packet handler engine to the interfacing MCU and GDO1 is the same pin as the SO pin on the SPI interface. Figure 13 shows a simplified application circuit where an external MCU controls the HGM pin. LNA_EN and PA_EN may be controlled by external MCU or GDO pins on CC1100E.

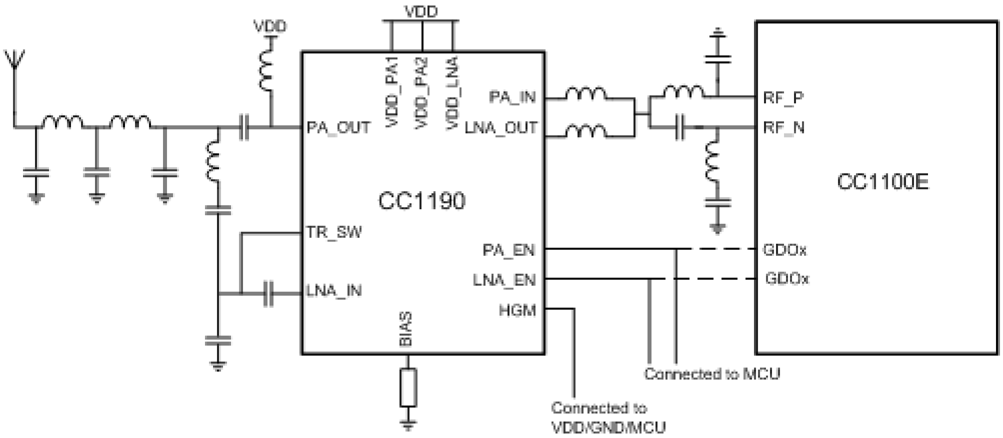

Figure 13: Simplified application circuit

6 SmartRF Studio and SmartRF04EB

The CC1100E-CC1190 470-510 MHz board together with SmartRF™ Studio 7 software [4] and SmartRF04EB can be used to evaluate performance and functionality.

6.1 SmartRF Studio

The CC1100E-CC1190 can be configured using the SmartRF Studio 7 software [4]. The SmartRF Studio software is highly recommended for obtaining optimum register settings. SmartRF Studio has not implemented direct support for the CC1100E-CC1190 board. For testing, the PA_EN and LNA_EN on CC1190 have to be controlled by GDO2 and GDO0 or they can be hardwired.

6.2 SmartRF04EB

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 position shown in Figure 6.1. The onboard voltage regulator supplies 3.3 V to the board, but has limited current source capability and cannot supply the CC1100E-CC1190 board. An external supply is therefore needed and shall be connected as shown in Figure 6.1, where the red wire is the positive supply and the black wire is GND. With the test setup in Figure 6.1 the SmartRF04EB is connected to a 3.3 V supply through the USB and voltage regulator and CC1100E-CC1190 is powered by the external supply. Since the SmartRF04EB is connected to a regulated 3.3 V supply the signals going from CC1100E-CC1190 to SmartRF04EB (and vice versa) need to be within 3.0 V to 3.6 V. The external supply connected to CC1100E-CC1190 when using the test setup in Figure 6.1 is therefore limited to 3.0 V to 3.6 V.

Figure 6.1. SmartRF04EB Connection

7 Reference Design

The CC1100E-CC1190EM 470 - 510 MHz reference design includes schematic and gerber files [3]. 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. The schematic is shown in Appendix – CC1100E-CC1190EM 470-510 MHz Schematic

7.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. The capacitors C33, C34 and C36 ensure good RF ground after L26 and thus prevent RF leakage into the power supply lines causing oscillations. The power supply filtering consisting of C5, C6 and L3 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 CC1100E to single ended output of the CC1190 PA. The values of the matching components between the C127 and the CC1190 PA input are chosen to present optimum source impedance to the CC1190 PA input with respect to stability. The PA_IN and the LNA_out require different impedances provided by C113, C111, C101

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 L26 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

R142 is a bias resistor. The bias resistor is used to set an accurate bias current for internal use in the CC1190.

7.4 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 CC1100E-CC1190EM 470 - 510 MHz reference design [3] 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 [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. Two different power planes for CC1100E 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.

8 Disclaimer

The CC1100E-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. It is the end user's responsibility to ensure that his system complies with applicable regulations.

9 References

[1] **CC1100E Datasheet (**cc1100E**)**

[2] **CC1190 Datasheet (**SWRS089.pdf**)**

[3] **CC1100E–CC1190EM 470 – 510 MHz Reference Design (swrr108)**

[4] **SmartRF™ Studio 7 (SWRC176.zip)**

10 General Information

10.1 Document History

Revision	Date	Description/Changes
SWRA412	2012.10.02	Initial release.

11 Appendix – CC1100E-CC1190EM 470-510 MHz Schematic

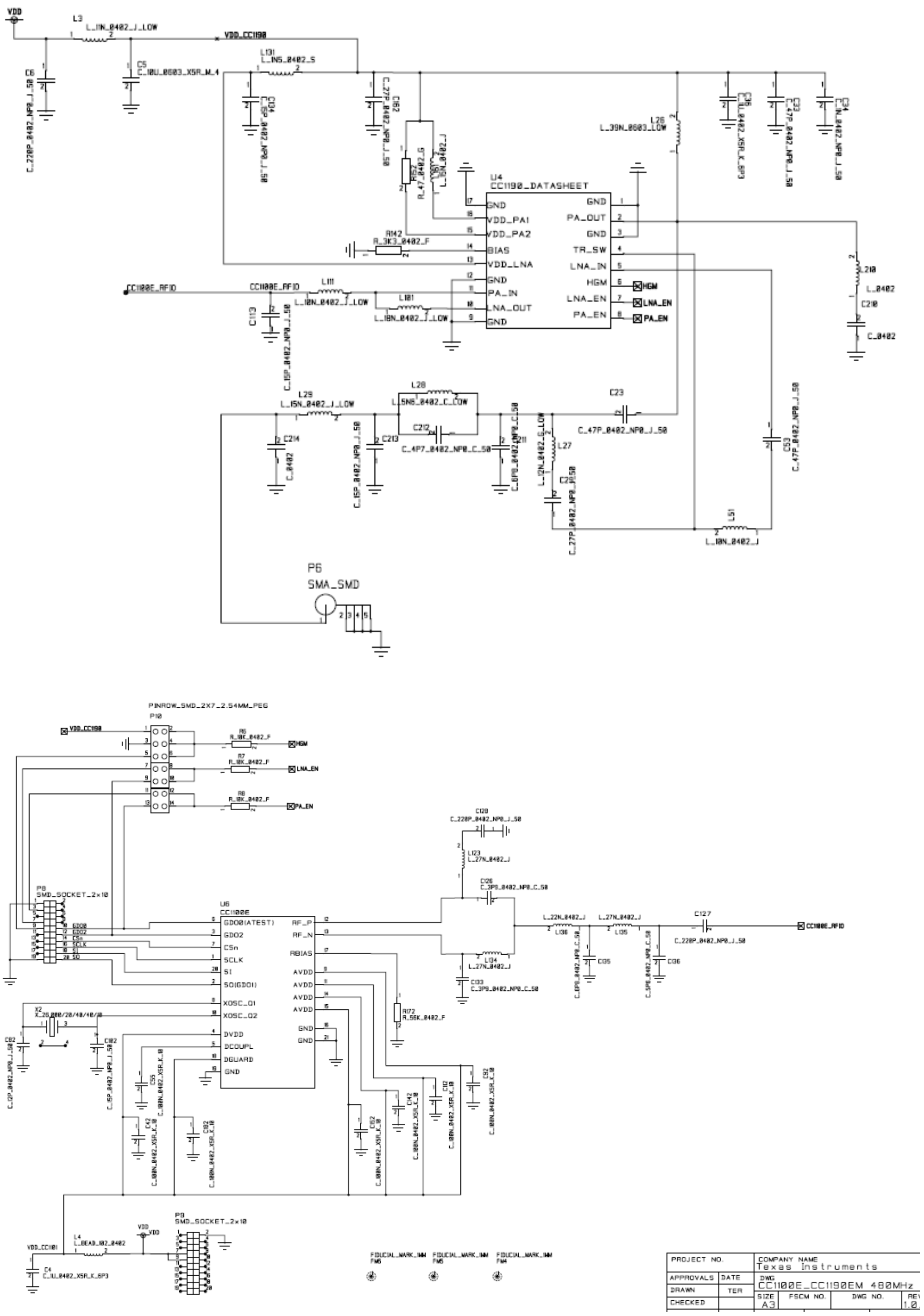

Figure 11.1. CC1100E-CC1190EM 470-510 MHz Schematic

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