Application Report
SWRA542–March 2017

Using CC1190 Front End With CC13xx Under EN300220

Torstein Ermesjo

ABSTRACT

The CC1190 device is a range extender for 850- to 950-MHz RF transceivers, transmitters, and wireless MCUs from Texas Instruments™. The device 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 the CC1310-CC1190 LaunchPad™ Development Kit design under EN 300 220-1 V2.4.1 (see [1]) in the 869.4- to 869.65-MHz frequency subband (g3). The maximum allowed output power in the 869.4- to 869.65-MHz subband is +27 dBm (500 mW).

For details on the regulatory limits in the 863- to 870-MHz SRD frequency bands, see the ETSI EN 300 220-1 V2.4.1 (see [1]) and ERC Recommendation 70-03 (see [2]). These documents can be downloaded from www.etsi.org and www.erodocdb.dk.

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1 Abbreviations

Table 1 lists abbreviations used throughout this document.

Table 1. Abbreviations

Abbreviation	Full Term
BER	Bit Error Rate
HGM	High Gain Mode
LP	LaunchPad
PCB	Printed-Circuit Board
PER	Packet Error Rate
RF	Radio Frequency
RSSI	Receive Signal Strength Indicator
RX	Receive, Receive Mode
TX	Transmit, Transmit Mode

2 Electrical Specifications

NOTE: The characteristics in this section are valid only when using the CC1310-CC1190 LaunchPad reference design version 1.1.1 (EU version, see [3]) with a 50-Ω load and settings recommended by the SmartRF™ Studio software (see [4]). For all measurements, the HGM pin on CC1190 device is set high to get the best possible sensitivity.

All measurements are done with the following conditions if nothing else is stated:

- T_C = 25°C
- V_{DD} = 3.3 V
- f = 869.525 MHz

2.1 Operating Conditions

Table 2. Operating Conditions

Parameter	Minimum	Maximum	Unit
Operating frequency(1)	869.4	869.65	MHz
Operating supply voltage	2.0	3.6	V
Operating temperature	–40	85	°C

(1) EN 300 220 v2.4.1 allows up to 27 dBm in a 250-kHz-wide frequency band.

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2.2 Current Consumption

The current is measured for the radio part of the board only. The jumpers to the XDS110 part are removed.

Table 3. Current Consumption

Parameter	Condition	Typical	Unit
Receive current, HGM[1]	50 kbps, 2GFSK, ±25-kHz deviation	10.9	mA
Transmit current	txPower = 0x00CB (26 dBm)	441	mA
	txPower = 0x00C6 (25 dBm)	384	
	txPower = 0x00C4 (24 dBm)	335	
	txPower = 0x00C3 (23 dBm)	298	
	txPower = 0x00C2 (21 dBm)	246	
	txPower = 0x00C1 (18 dBm)	179	
	txPower = 0x00C0 (12 dBm)	106	

(1) Input signal at –100 dBm. V_{DD} = 3.6 V.

2.3 Receive Parameters

Table 4. Receive Parameters

Parameter	Condition	Typical	Unit
Sensitivity[1], HGM	50 kbps 2-GFSK	–111	dBm
	SimpleLink LRM 5 kbps	–121	dBm
Saturation, HGM	Maximum input power level for 1% BER	+10	dBm
Selectivity and blocking, HGM	±1 MHz from wanted signal	54	dB
	±2 MHz from wanted signal	59	
	±5 MHz from wanted signal	65	
	±10 MHz from wanted signal	80	

(1) Sensitivity limit is defined as 1% BER. Packet length is 3 bytes.

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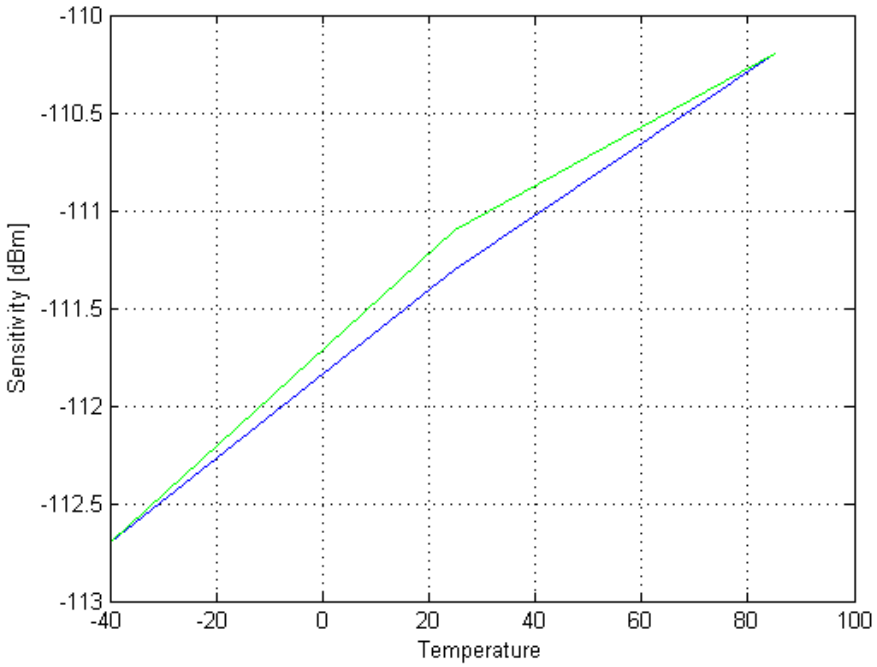
2.3.1 Typical RX Performance vs Temperature and VDD

Figure 1 shows the typical sensitivity versus temperature.



(1) Blue is V_{DDS} = 3.3 V

(2) Green is V_{DDS} = 3.6 V

Figure 1. Typical Sensitivity vs Temperature, HGM, 50 kbps

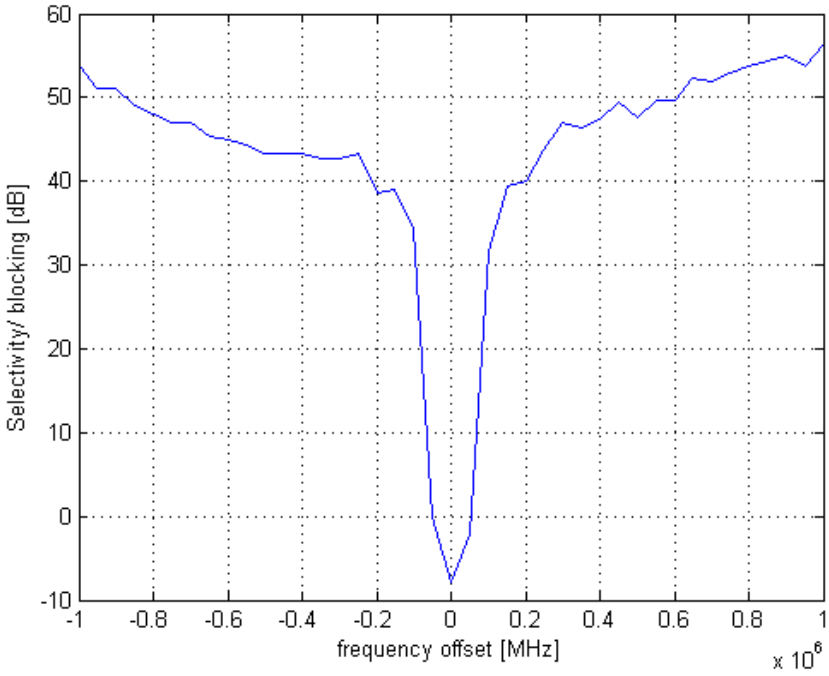


Figure 2. Typical Selectivity

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2.3.2 Receive Signal Strength Indicator (RSSI)

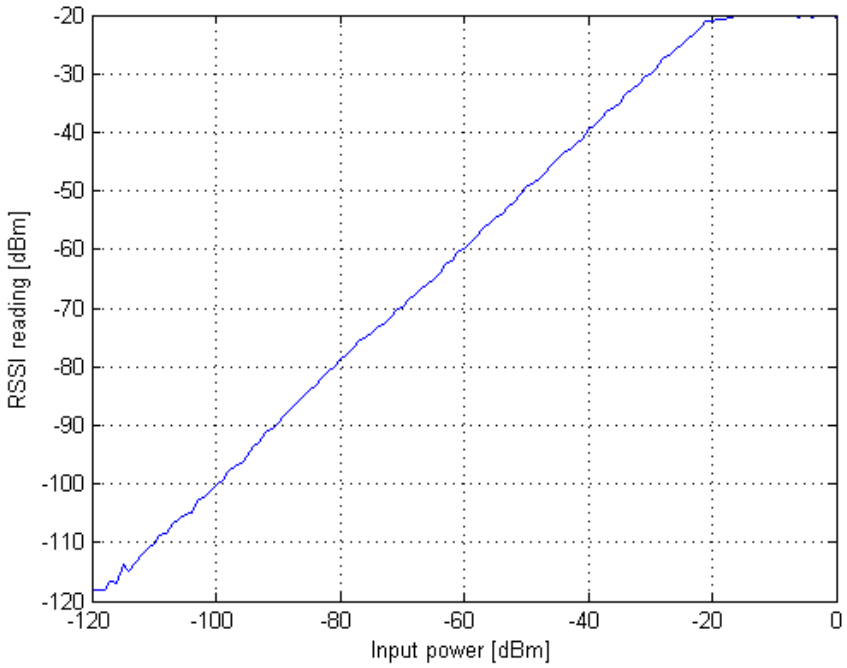

Figure 3. Typical RSSI vs Input Level, HGM, 50 kbps

PER versus level was run, and the reported RSSI was compared with the signal generator level. The RSSI level saturates when the input power level is above –24 dBm. To get the correct RSSI offset, the following override must be modified:

Change 0x00FB88A3 to 0x000188A3.

This override is part of the pOverrides[] structure when doing a code export from SmartRF Studio.

2.4 Transmit Parameters

The output power variation as a function of temperature will be a combination of the CC1310 output power variation and the CC1190 output power variation. Since CC1190 operate in saturation the CC1190 variation will have the largest contribution. For this reason the temperature compensation of the CC1310 output power is turned off.

Due to the current consumption and long power cables the test system has a given IR drop from the power supply to the DUT. The voltage on the supply was therefore increased some to give the stated voltage on the power pins on the Launchpad for 25-dBm output power (see Table 5 for the power amplifier values).

Table 5. PA Table

Parameter	Condition	Typical	Unit
Output power, HGM	txPower = 0x00CB	26.0	dBm
	txPower = 0x00C6	25.0	
	txPower = 0x00C4	23.8	
	txPower = 0x00C3	22.8	
	txPower = 0x00C2	21.0	
	txPower = 0x00C1	17.8	
	txPower = 0x00C0	11.8	

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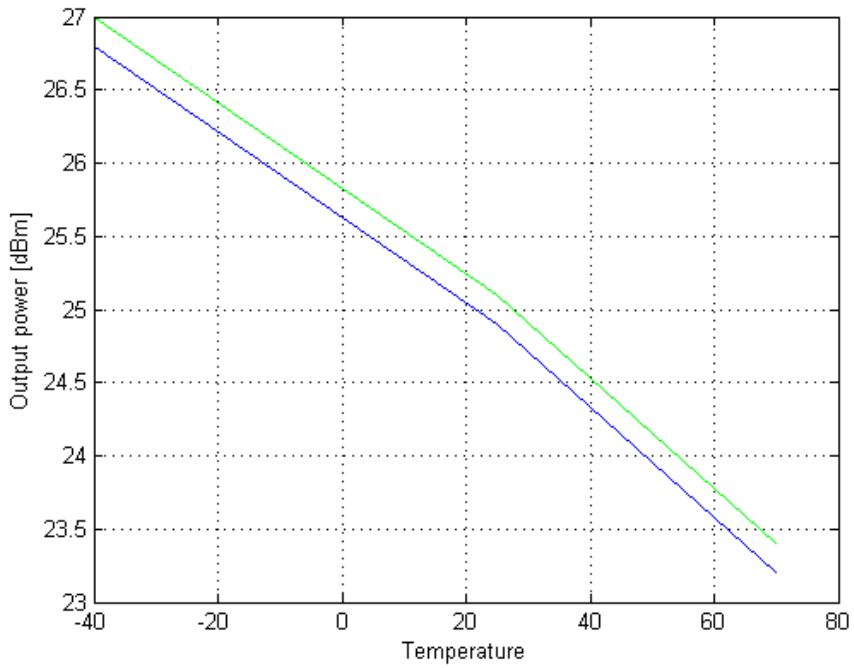
Table 6 lists the spurious emission values.

Table 6. Spurious Emission

Parameter	Condition	Typical	Unit
Spurious emission with txPower = 0x00C6, HGM	Conducted below 1 GHz	–60	dBm
	Conducted above 1 GHz	–49	
	Conducted second harmonic	–41	
	Conducted third harmonic	–38	
	Radiated second harmonic	–30	
	Radiated third harmonic	–30	

2.4.1 Typical TX Performance vs Temperature and V_{DD}

Figure 4 shows the output power versus temperature for txPower = 0x00C6.



(1) Blue is V_{DDS} = 3.3 V

(2) Green is V_{DDS} = 3.6 V.

Figure 4. Output Power vs Temperature txPower = 0xC6

2.4.2 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-Ω antenna impedance to the selected impedance, which the CC1190 PA should detect. This is taken care of by the reference design (see [3]) and a well-matched antenna should be used to get the required performance.

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2.4.3 Modulation Bandwidth

Figure 5 shows modulation bandwidth, conducted, 50 kbps, txPower = 0x00C6.

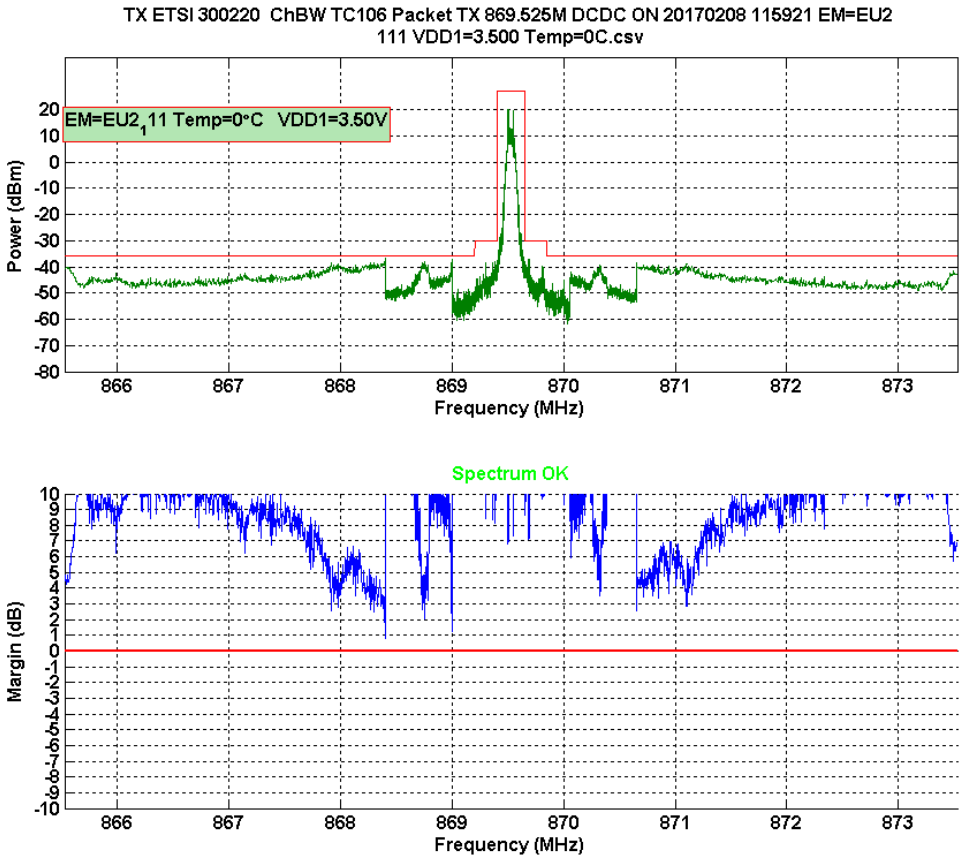

Figure 5. EN 300 220 Modulation Bandwidth, Conducted, 50 kbps, txPower = 0x00C6

The measurement is done with a continuous modulated signal. For the measurement the frequency offset caused by crystal tolerance is removed.

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2.5 Measurement Equipment

The measurement equipment used is as follows:

- Spectrum analyzer: Rohde and Schwarz® FSU
- Signal generator: SMIQ 03B

3 Controlling the CC1190

Three digital control pins (PA_EN, LNA_EN, and HGM) set the CC1190 mode of operation. See Table 7.

Table 7. CC1190 Control Logic

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

On the CC1310-CC1190 LaunchPad, the control signals are mapped to DIOs as follows:

- DIO28 – HGM
- DIO29 – LNA_EN
- DIO30 – PA_EN

HGM should be tied high or low using the pin driver. LNA_EN should be tied to RFC_GPO0 (portID 0x2F) and PA_EN should be tied to RFC_GPO1 (portID 0x30) as described in the *Control External LNA/PA (Range Extender) With I/Os* section in the CC1310 technical reference manual, *CC13x0, CC26x0 SimpleLink™ Wireless MCU*.

Set the I/Os with the following code:

```
#include <ti/drivers/pin/PINCC26XX.h>
•
•
// LNA
PINCC26XX_setMux(<Handle>, <DIO_LNA>, PINCC26XX_MUX_RFC_GPO0);

//PA
PINCC26XX_setMux(<Handle>, <DIO_PA>, PINCC26XX_MUX_RFC_GPO1);
```

Where <Handle> is the handle returned by PIN_open() and <DIO_LNA> and <DIO_PA> are the pins used to control the LNA_EN and the PA_EN, respectively, on the CC1190.

See the Packet Error Rate example as an example how to control CC1190 from CC1310.

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4 SmartRF™ Software Studio

The CC1310-CC1190 LaunchPad can be configured using the SmartRF Software Studio 7 (see [4])

Version 2.4.3 of SmartRF Studio does not have direct support for CC1310-CC1190. To set the CC1190 control signals, click on the *Configure Target* button and set the DIOs as shown in Figure 6. In addition, the frequency must be set to 869.525 MHz and the correct txPower written in the CMD_PROP_RADIO_DIV_SETUP command.

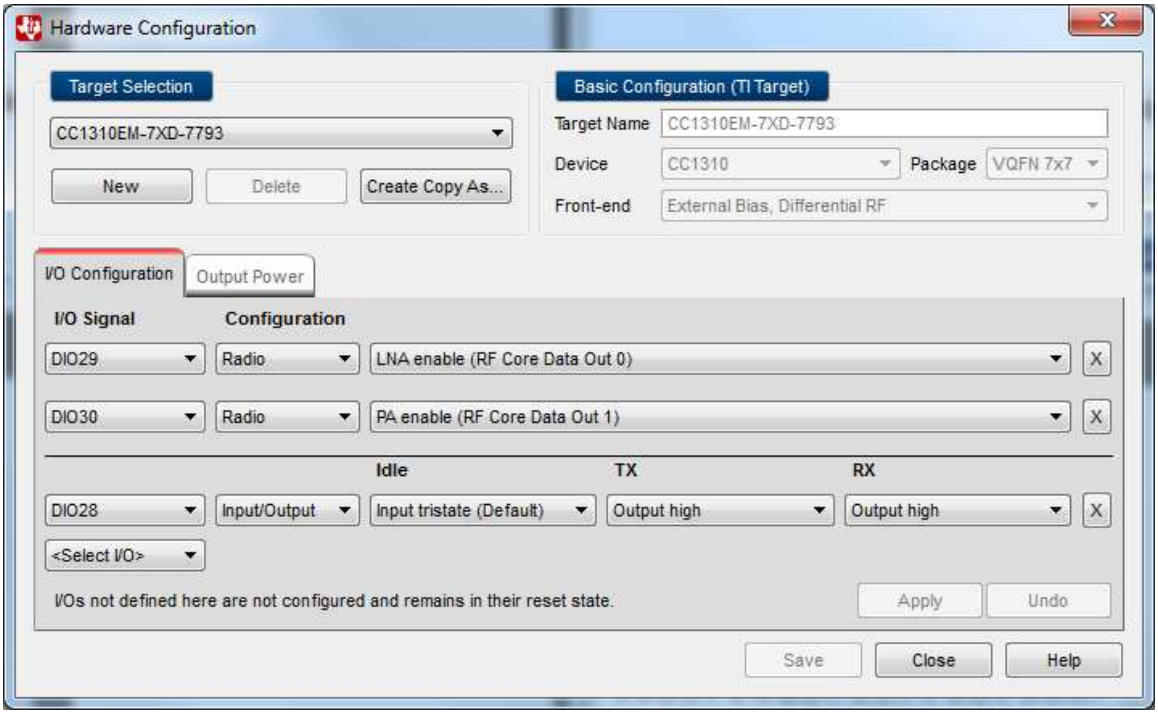

Figure 6. Hardware Configuration

5 Reference Design With Integrated Passive Component (IPC)

The CC1310-CC1190 868-MHz reference design includes schematics and Gerber files (see [3]). TI highly recommends following the reference design for optimum performance. The reference design also includes a bill of materials (BOM) with manufacturers and part numbers.

5.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. 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 C216, C217, and L163 ensure well-defined impedance looking toward the power supply.

5.2 I/O Matching and Filtering

The PA and the LNA of the CC1190 are single-ended I/O. A balun is required to transform the differential impedance required by the RF_P/N pins to a single-ended 50-Ω interface. 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.

If a SAW filter is not needed in both RX and TX, the RX and TX path can be split between CC1310 and CC1190.

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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 toward the antenna. These components also ensure the required filtering of harmonics to pass regulatory requirements.

L25/C210 and C24/L27 form two notches to filter the second harmonic. The capacitors should have a narrow tolerance to ensure that the notches are on the correct frequency. If the layout is done differently from the reference design, it should be determined if the notches need to be tuned. The radiated second harmonic is higher than the conducted harmonic, therefore it is important with good attenuation on this frequency.

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

5.3 Bias Resistor

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

5.4 SAW Filter

A SAW filter is recommended for the CC1310-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.

A footprint for a 0603 component is placed below the SAW filter to enable testing without the SAW filter.

5.5 PCB Layout Considerations

The TI reference design uses a 1.6-mm (0.062”) 4-layer PCB solution.

NOTE: The different layers have different thickness. TI recommends following the recommendation given in the CC1310-CC1190 LaunchPad reference design (EU version, see [3]) to ensure optimum performance.

The top layer (layer 1) 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 data sheet [9].

Layer 2 is a complete ground plane and is not used for routing. This is done to ensure short return current paths. The low impedance of the ground plane prevents any unwanted signal coupling between any nodes that are decoupled to it.

Layer 3 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 are used for CC1310 and CC1190; the power planes are surrounded by ground to reduce unwanted radiation from the board.

Layer 4 is used for routing and ground.

5.6 Shield

TI recommends placing a shield over the CC1190 part of the design to attenuate the radiated third harmonic.

5.7 Attenuation

The CC1310 PA table has few settings that give lower output power than 5 dBm. If larger dynamic range of output levels is needed, attenuation between the CC1310 and CC1190 can be added.

Attenuation could be achieved by a resistive pi attenuator formed by R154, R155, and R156. The attenuator must be designed as 50-Ω in, 50-Ω out. The sensitivity will be a function of the value of the shunt resistors. If R155 and R156 are mounted, C218 and C219 should be 47 pF.

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If attenuation is not needed R154, R155, R156, C218, and C219 can be removed and L111 can be connected directly to pin 10 (LNA_OUT) and pin 11 (PA_IN) on CC1190.

5.8 Antenna

The antenna used is described in DN024 (see [7]). Placeholders for a pi filter are included for antenna matching purposes.

6 Reference Design With Discrete Components

The CC1310-CC1190 LaunchPad uses the IPC due to space restrictions. However, the first version (TI internal, version 1.0.1) of the LaunchPad used discrete components for the balun on CC1310. The results listed in this section are from measurements on v1.0.1 of the LaunchPad. The schematics for the CC1310 and CC1190 part of this version are shown in Appendix A.

The following sections list the measurement results measured for this version of the LaunchPad. The results are average over five LaunchPads.

6.1 Current Consumption

Table 8. Current Consumption

Parameter	Condition	Typical	Unit
Receive current, HGM	50 kbps, 2GFSK, ±25-kHz deviation	11.2	mA
Transmit current	txPower = 0x00C7 (26.4 dBm)	498	mA
	txPower = 0x00C6 (26.6 dBm)	471	
	txPower = 0x00C5 (27.0 dBm)	433	
	txPower = 0x00C4 (26.7 dBm)	403	
	txPower = 0x00C3 (26.0 dBm)	374	
	txPower = 0x00C2 (25.0 dBm)	330	
	txPower = 0x00C1 (22.8 dBm)	264	
	txPower = 0x00C0 (17.6 dBm)	164	

6.2 Receive Parameters

50 kbps, 2GFSK, ±25-kHz deviation, 100-kHz RX filter bandwidth if nothing else is stated.

Table 9. Receive Parameters

Parameter	Condition	Typical	Unit
Sensitivity[1], HGM		–112	dBm
Saturation, HGM	Maximum input power level for 1% BER	10	dBm
Selectivity and blocking, HGM	±200 kHz from wanted signal	38	dB
	±1 MHz from wanted signal	53	
	±2 MHz from wanted signal	60	
	±5 MHz from wanted signal	65	
	±10 MHz from wanted signal	79	

(1) Sensitivity limit is defined as 1% BER. Packet length is 3 bytes.

PER versus level was run and the reported RSSI was compared with the signal generator level. The RSSI level saturates when the input power level is above –24 dBm. To get the correct RSSI offset, the following override must be modified:

Change 0x00FB88A3 to 0x000388A3.

When doing a code export from SmartRF Studio, this override is part of the pOverrides[] structure.

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6.3 Transmit Parameters

The output power variation as a function of temperature will be a combination of the CC1310 output power variation and the CC1190 output power variation. Because the CC1190 device operates in saturation, the CC1190 variation will have the largest contribution. For this reason, the temperature compensation of the CC1310 output power is turned off.

At the time of measurement, high-quality cables fitting the JSC connector were not available, so semirigid cables were used. These semirigid cables typically have a loss equal to 0.2 to 0.25 dB, which is not accounted for in Table 10.

A CC1190 device was moved from a CC1310-CC1190 LaunchPad version 1.0.1 to a CC1310-CC1190 LaunchPad version 1.1.1 and the output power was increased by 1 dB (from 26 dBm to 27 dBm) with all other settings equal. This indicates that the 1.0.1 version of the LP was populated with a production batch of CC1190 that gives higher output power than the production batch that was used on the 1.1.1 version of the board.

Table 10. PA Table

Parameter	Condition	Typical	Unit
Output power, HGM	txPower = 0x00C7	26.4	dBm
	txPower = 0x00C6	26.6	dBm
	txPower = 0x00C5	27.0	dBm
	txPower = 0x00C4	26.7	dBm
	txPower = 0x00C3	26.0	dBm
	txPower = 0x00C2	25.0	dBm
	txPower = 0x00C1	22.8	dBm
	txPower = 0x00C0	17.6	dBm

Table 11 lists the spurious emission values.

Table 11. Spurious Emission

Parameter	Condition	Typical	Unit
Spurious emission with txPower = 0x00C4, HGM	Conducted below 1 GHz	–50	dBm
	Conducted above 1 GHz	–49(1)	dBm
	Conducted second harmonic	–41.9	dBm
	Conducted third harmonic	–41.1	dBm

(1) Excluding harmonics.

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7 Disclaimer

The CC1310-CC1190 Launchpad 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 products 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.

8 References

The references for this document follow:

1. *Final draft ETSI EN 300 220-1 V2.4.1 (2012-01)*
2. *ERC Recommendation 70-03*
3. CC1310-CC1190 Reference Design EU
4. SmartRF Studio
5. Texas Instruments CC1190 Data Sheet *850-MHz to 950-MHz RF Front End*
6. *CC-Antenna-DK2 and Antenna Measurements Summary application report*
7. *DNO24—Monopole PCB Antenna with Single or Dual Band Option design note*
8. *CC1310 SimpleLink™ Ultra-Low-Power Sub-1 GHz Wireless MCU data sheet*
9. Texas Instruments™ CC1190 Data Sheet *850-MHz to 950-MHz RF Front End*

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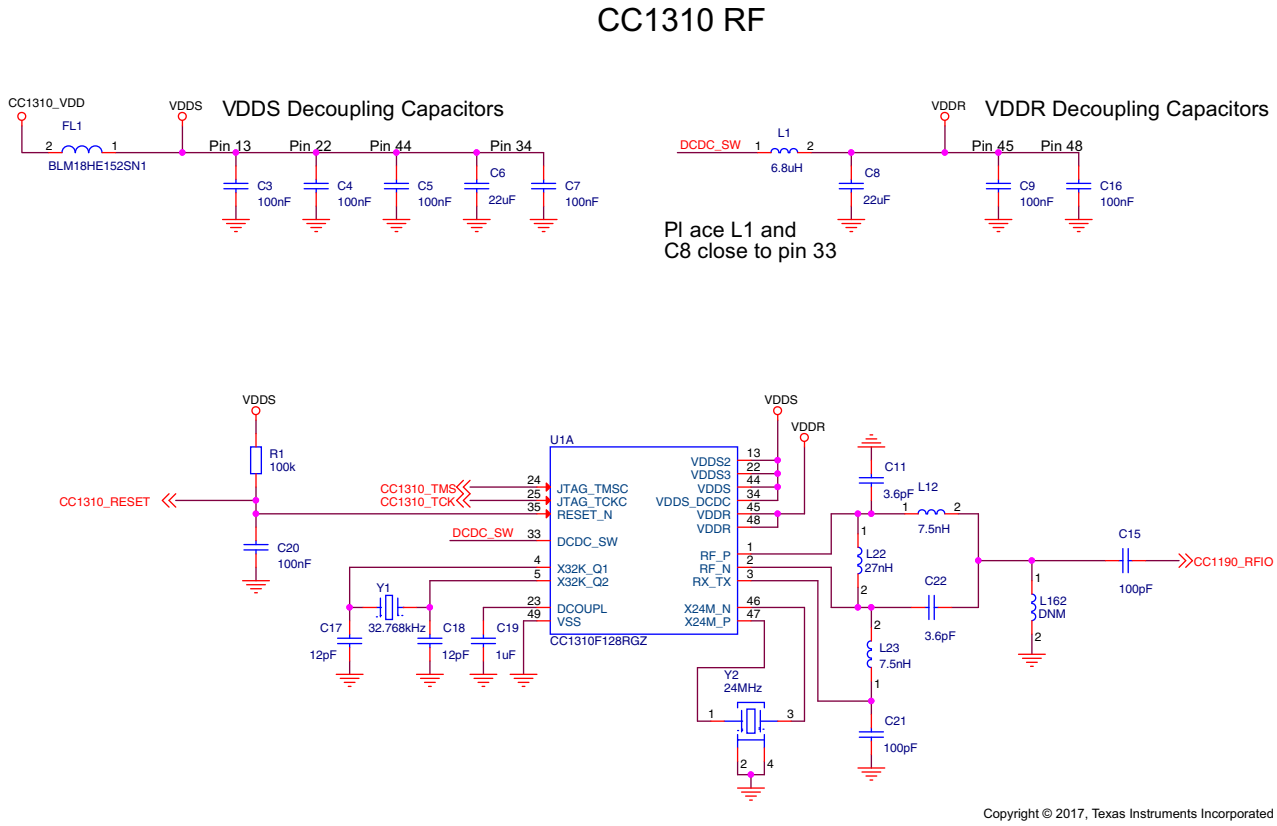
Schematics

A.1 Schematics



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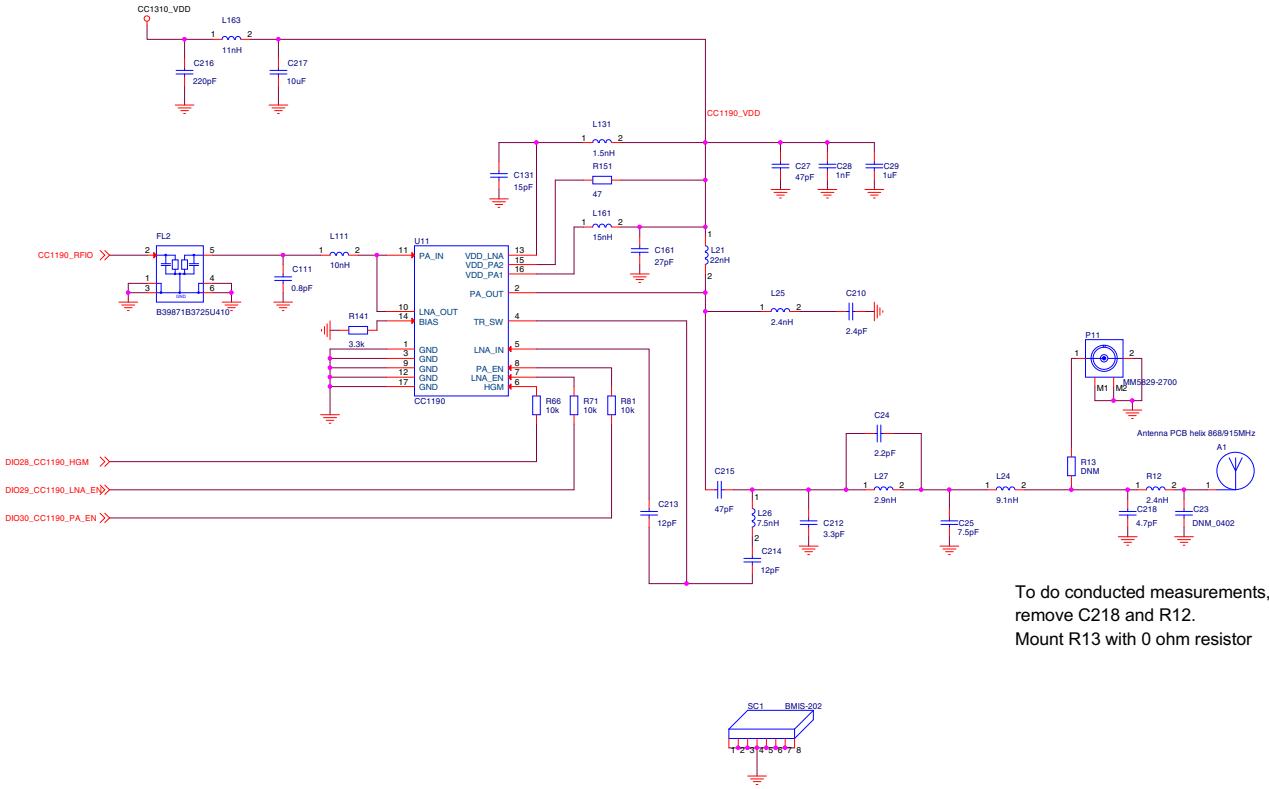

To do conducted measurements,
remove C218 and R12.
Mount R13 with 0 ohm resistor

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