Application Report

SWRA524A–September 2016–Revised December 2016

CC1310 Integrated Passive Component for 779-928 MHz

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ABSTRACT

This application report describes the IPC that has been specifically designed for the CC1310 operating in the 779 MHz (China), 868 MHz (Europe), 915 MHz (US) and 920 MHz ISM bands.

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Trademarks

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1 Introduction

With the CC1310 matched integrated passive component (IPC), the component count is significantly reduced as shown in Figure 1, while still obtaining high radio performance.

The existing discrete solution requires 11 passive components for the RF Front End filter. The IPC replaces these 11 discrete components with a single component as illustrated in Figure 2.

Measurement results of the IPC reference design are documented in this report.

Part number for the Johanson Technology (JTI) IPC is 0850BM14E0016, which is available from Johanson Technology [2] or their distributors.

The part number for the Murata IPC is LFB18868MBG9E212. This part is available from Murata or their distributors [8].

The size for the matched balun filter component is only 1.6 mm x 0.80 mm. It is highly recommended for compact designs and designs that are sensitive to production assembly pick-and-place costs.

All measurement results presented in this document are based on the CC1310IPC4XD-7793 EM Rev 1.0 Reference Design [6], shown in Figure 1.

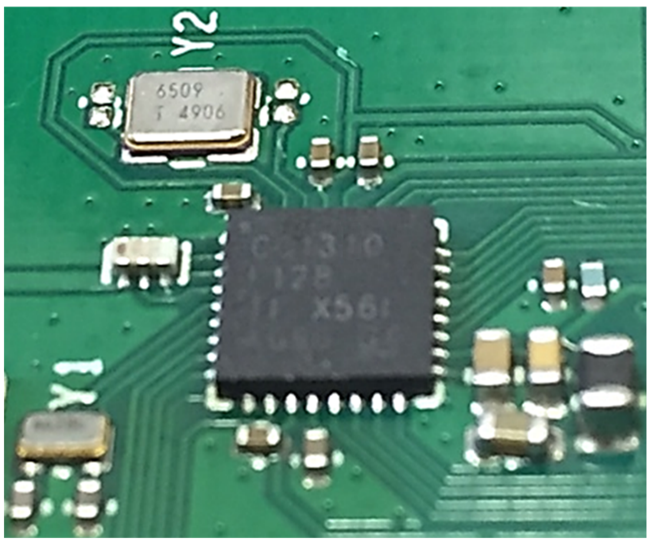

Figure 1. CC1310 IPC 4XD EM Reference Design

2 Reference Designs Available

The CC1310 [1] has a highly configurable RF front end. The CC1310 radio ports can be configured as differential or as single-ended. For best performance the differential configuration provides optimum link budget than the single-ended configuration.

2.1 Schematic for the Discrete Reference Design

The passive network connected to the RF_P and RF_N ports in the standard differential discrete reference design can be replaced by the IPC component, as shown in Figure 2. The discrete components shown within the green marking in Figure 2 are the components that can be replaced the IPC.

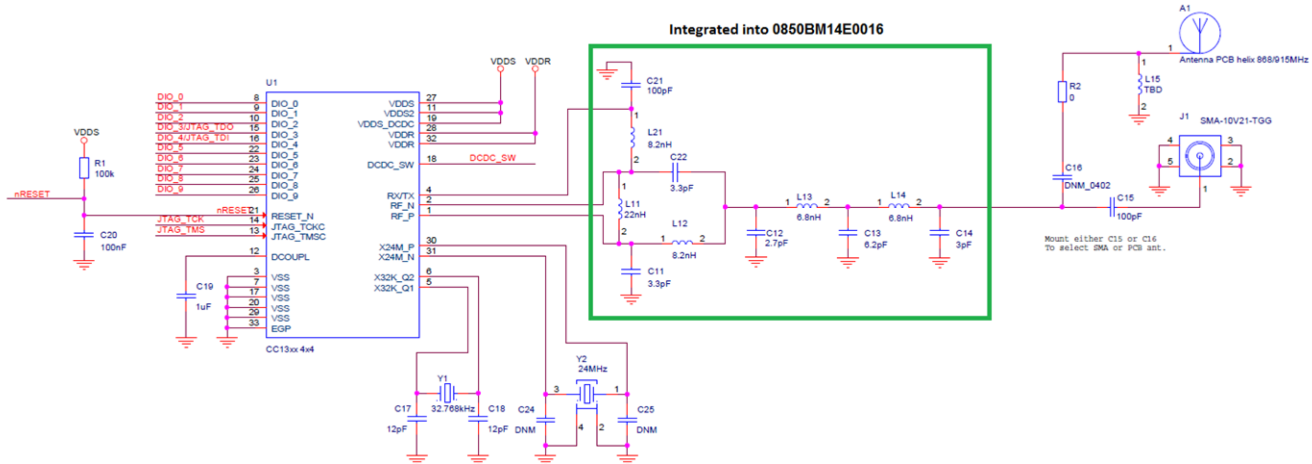

Figure 2. Discrete Reference Design for CC1310EM-4XD-7793

2.2 CC1310 IPC Reference Design

By using the Johanson or Murata IPC, 11 passive components are replaced in the standard differential discrete reference design by a single component. The IPC is 1.6 mm x 0.8 mm with 6 pad terminals. As shown in Figure 4, terminals 2, 3 and 4, are connected directly to the CC1310. Terminal 1 is connected towards the antenna and terminal 5 and 6 are GND connections.

Terminal Configuration			
No	**Function**	**No**	**Function**
1	Unbalanced Port	4	Balanced Port RF_P
2	RX/TX		
3	Balanced Port RF_N	5	GND
		6	GND

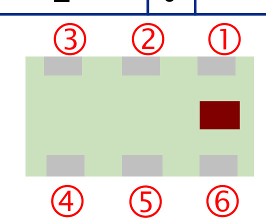

Figure 3. Pinout for CC1310

2.2.1 CC1310 IPC Reference Design

As shown in Figure 4, the schematic is simplified by using the IPC. Note that the DC blocking capacitor is not embedded into the IPC; this is still required if there is DC at the antenna or SMA port. In addition to the DC blocking function, C15 and C16 footprints are used to switch between the integrated antenna and the SMA connector. To connect to the integrated antenna: C16: 100 pF and C15: DNM. To connect to the SMA connector: C16: DNM and C15: 100 pF.

Components L15, R2 and L16 are a part of the antenna matching network for the integrated PCB helix antenna used on the EM. The unbalanced port impedance (terminal 1) from the IPC, pin 1 is 50 Ω.

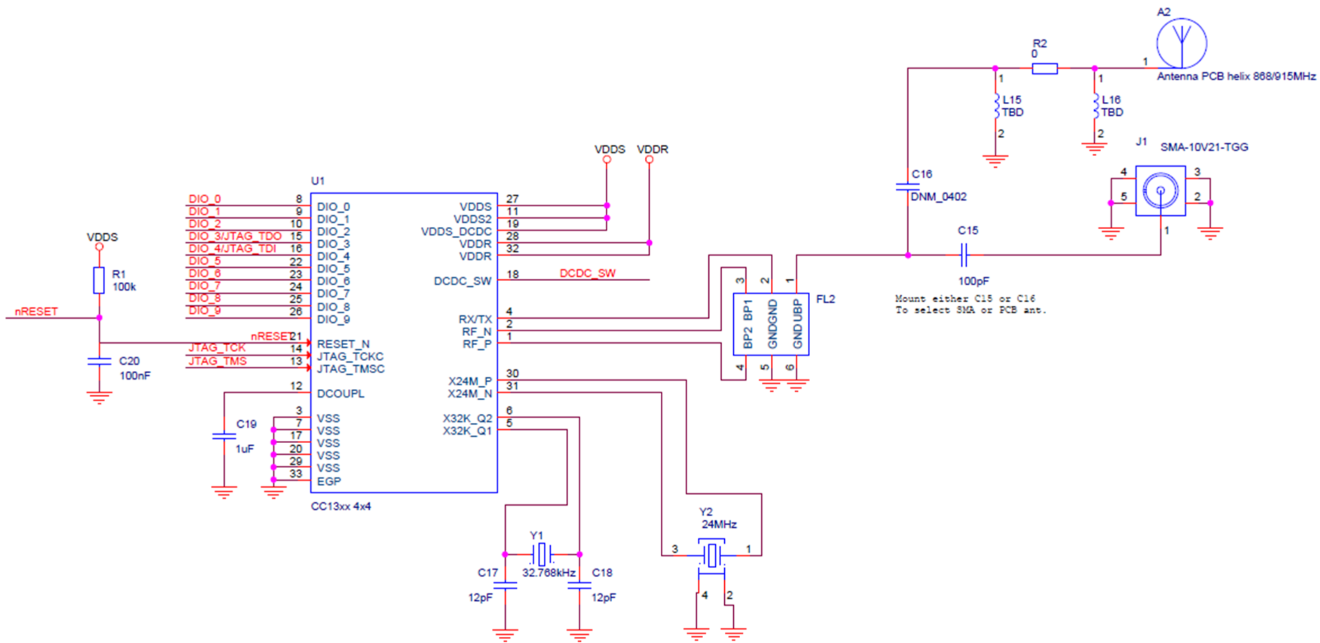

Figure 4. Schematic for the 4-Layer Reference Design

2.2.2 Component Placement

As shown in Figure 5, with the CC1310 4x4 QFN package and the IPC, the overall footprint area for all the required components is less than 0.94 mm^2.

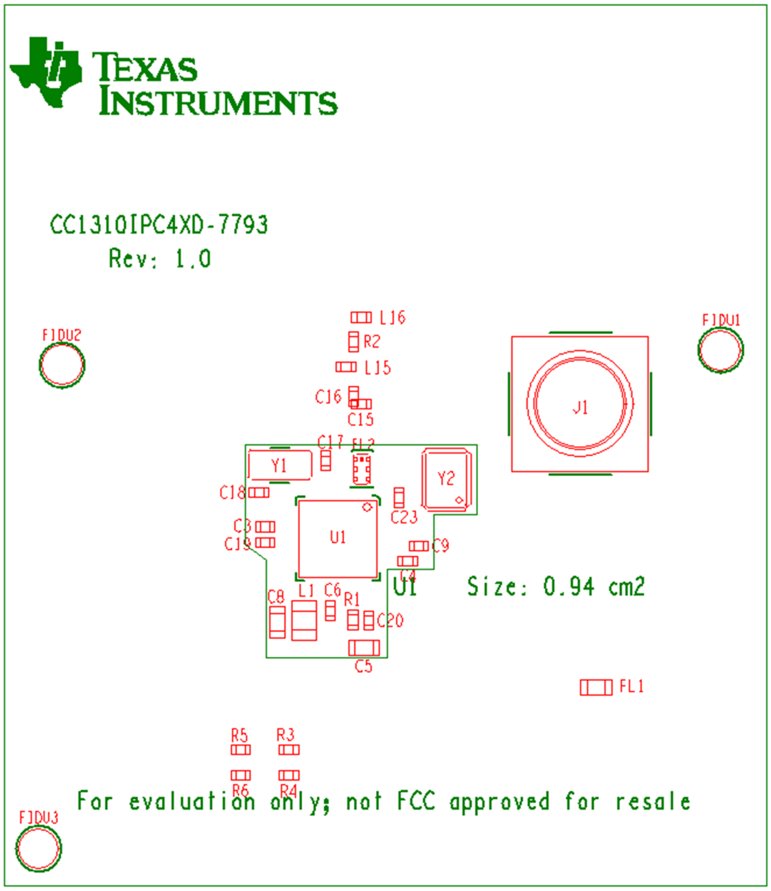

Figure 5. Component Placement for the 4-Layer Reference Design

2.2.3 Layout

The layout greatly influences the RF performance. TI recommends copying our reference design as closely as possible. The placement distance from the IPC to the CC1310 is critical. The IPC reference design has a distance of 0.55 mm from the balanced pads to the CC1310 RF_N and RF_P pads. This distance should be maintained, otherwise, there will be a phase alteration that can affect the filter characteristics. If the filter characteristics are altered too much then the output power can be reduced and increased third harmonic level.

The layout around the IPC should be copied, in particular the distance from the IPC to CC1310 (the TRX routing, line widths, and the GND via placements). For the exact footprint and dimensions, see Figure 6.

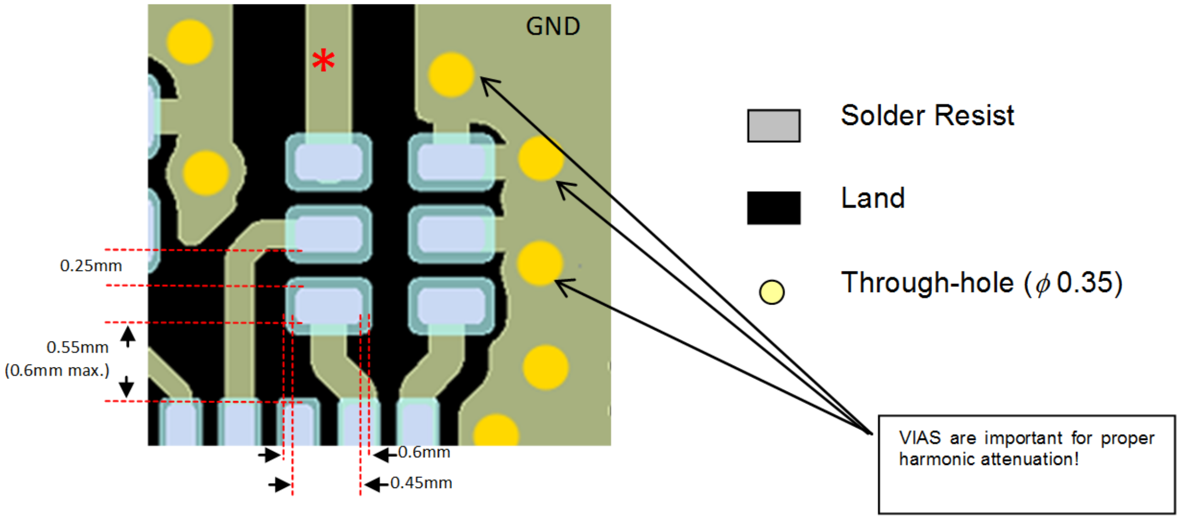

Figure 6. Recommended Layout and Footprint of IPC to the CC1310

In the event that the reference design cannot be copied, the routing from the RF pins RF_P and RF_N must be symmetrical to the IPC. The length of the tracks should be kept to a minimum and preferably the same length that is used in the reference design. If this routing is not symmetrical, the output power will be reduced and the harmonics will increase.

All component ground pads should have their own ground via, which should be positioned as close as possible to the ground pad. When positioning the ground vias for the component pad grounds, it is important to try to keep the return path loop to ground as little as possible in order to prevent unnecessary radiated emissions.

A 4-layer PCB is strongly recommended. The four layers of the reference design are shown in Figure 7, Figure 8, Figure 9, and Figure 10. On the layer directly underneath the RF network, it is important to have a solid ground plane and to avoid any routing, as shown in Figure 8. The power tracks must always be routed to the decoupling capacitor first, then from the decoupling capacitor to the pad of the CC1310.

2.2.3.1 4 Layer

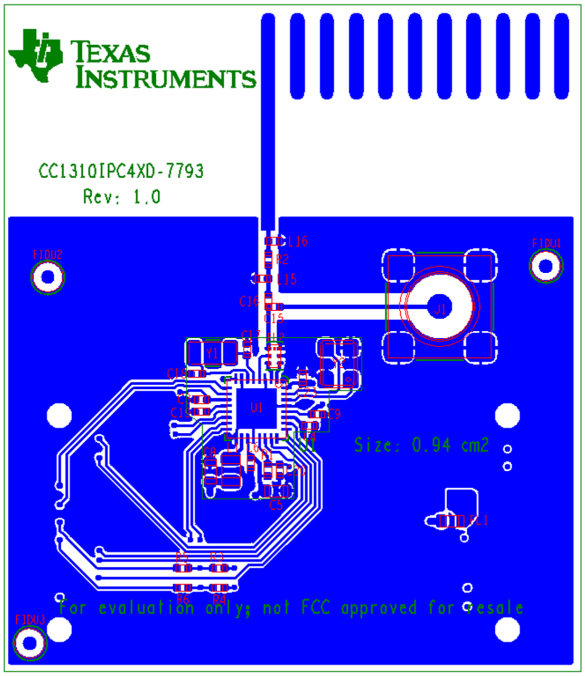

Figure 7. Layer 1 Layout of the 4-Layer IPC Reference Design

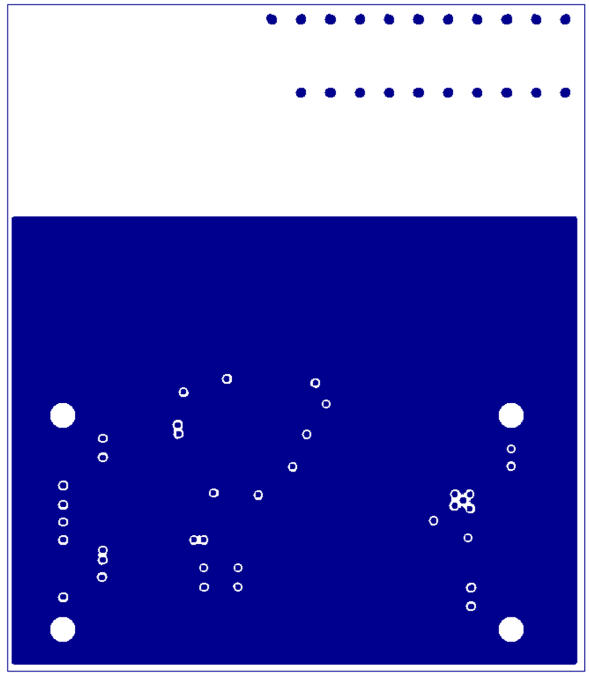

Figure 8. Layer 2 Layout of the 4-Layer IPC Reference Design

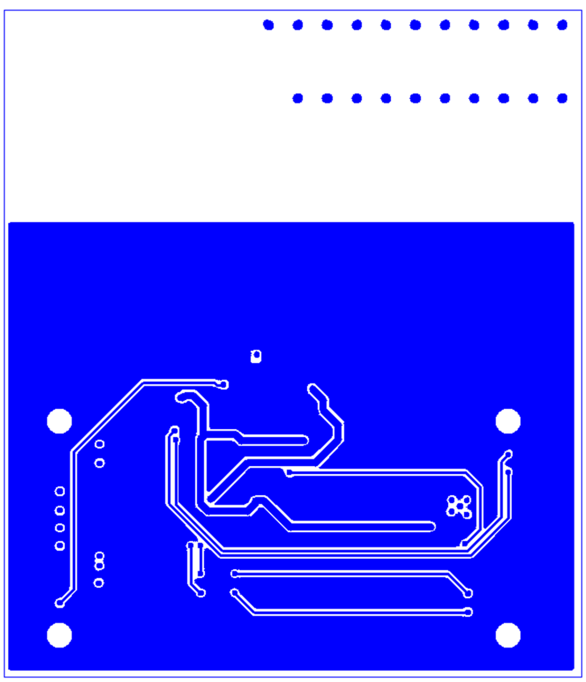

Figure 9. Layer 3 Layout of the 4-Layer IPC Reference Design

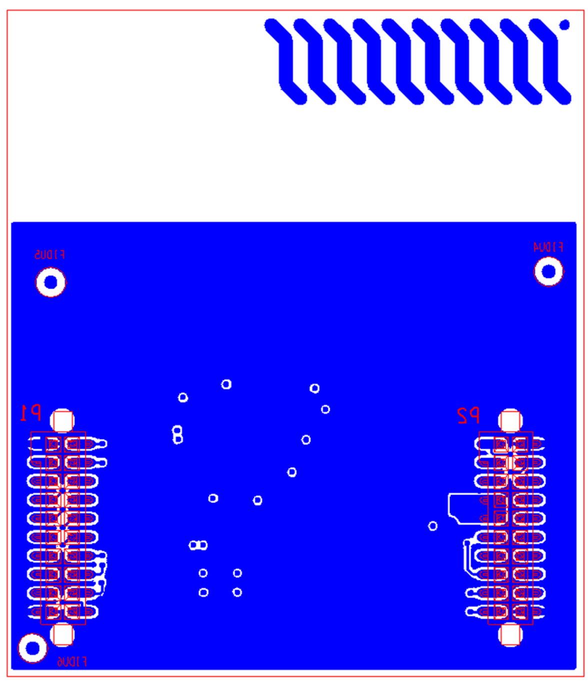

Figure 10. Layer 4 Layout of the 4-Layer IPC Reference Design

2.3 Johanson Technology IPC Measurement Results

All results presented in this section are based on measurements performed with CC1310IPC EM reference design. A minimum of five units were measured in order to obtain the average result that is presented in this report. The devices were tested at room temperature and the voltage was set to 3.0 V, unless otherwise specified. All values are in dBm, if not otherwise specified.

2.3.1 Current Consumption

Rx current consumption with 802.15.4g, 868 MHz, 50 kbps, DC-DC (3.6 V) setting:	5.4 mA
Tx current consumption at 10 dBm, 868 MHz, DC-DC (3.6 V) setting:	15.8 mA
Tx current consumption with BOOST mode, 868 MHz, DC-DC (3.6 V) setting:	32.9 mA

2.3.2 Rx Measurements

The average Rx sensitivity for the 802.15.14g, 50 kbps setting at 868 MHz is –108.0 dBm. For the same settings at 915 MHz, the average sensitivity is –107.2 dBm.

Figure 11 shows the packet error rate (PER) against signal level measurement with the 802.15.4g settings at 50 kbps, 868 MHz and with the DC-DC activated.

Figure 12 shows the received signal strength indicator (RSSI) error against signal level measurement with the 802.15.4g settings at 50 kbps, 868 MHz and with the DC/DC activated.

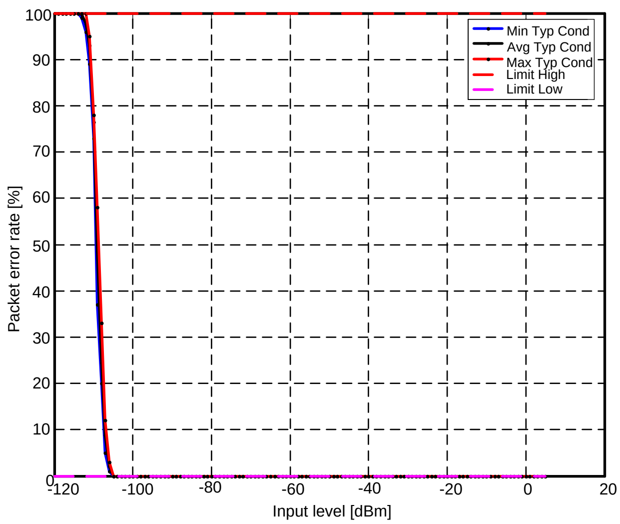

Figure 11. PER vs Level Measurement, 802.15.4g, 50 kbps, 868 MHz

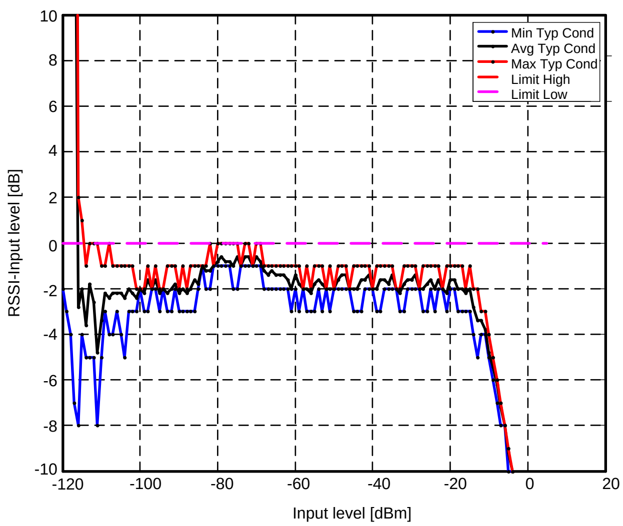

Figure 12. RSSI Error Level, 802.15.4g, 50 kbps, 868 MHz

2.3.3 Tx Measurements

The output power was set to maximum with the BOOST mode. For 868 MHz, the average output power is 14.3 dBm. For 915 MHz, the average output power is 13.7 dBm.

The harmonic levels are shown in Figure 13, Figure 14, Figure 15, and Figure 16.

For 868 MHz (EN 300 200), all the harmonic levels are under the regulatory limits of -30 dBm with good margin.

For 915 MHz (FCC 15.247), the maximum output power allowed is +30 dBm with frequency hopping. The second harmonic level requirement is -20 dBc and passes with good margin. The third, fourth and fifth harmonic requirements are -41.2 dBm. In order to fulfill these requirements, the duty cycle correction factor must be used for designs that require to perform conducted tests. If there is an integrated antenna and conducted tests are not required, then the correction factor can be reduced due to the antenna filter characteristics. For more information on the duty cycling correction factor, see Section 2.4.4.

For 915 MHz (FCC 15.249), the harmonic level requirement is -41.2 dBm with a maximum output of -1.2 dBm EIRP for non-frequency hopping (50 V/m at 3m is equivalent to -1.2 dBm output power). Duty cycling correction factor should not be required.

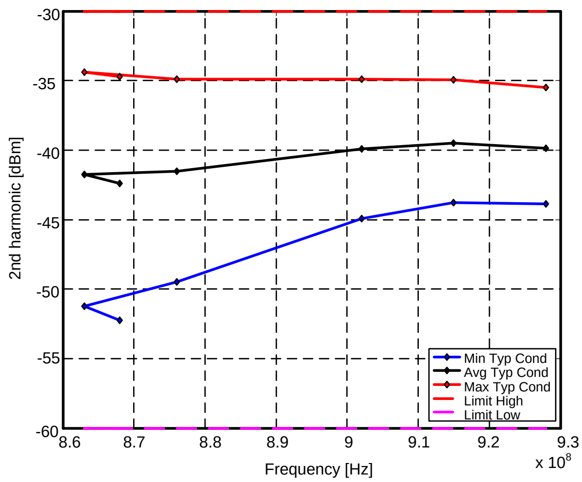

Figure 13. Second Harmonic Level vs Frequency

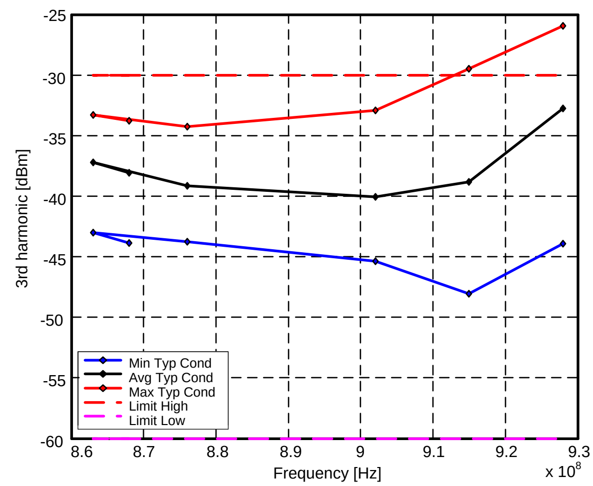

Figure 14. Third Harmonic Level vs Frequency

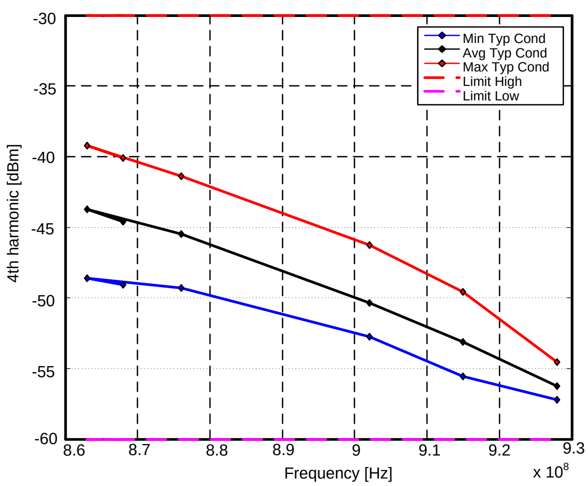

Figure 15. Fourth Harmonic Level vs Frequency

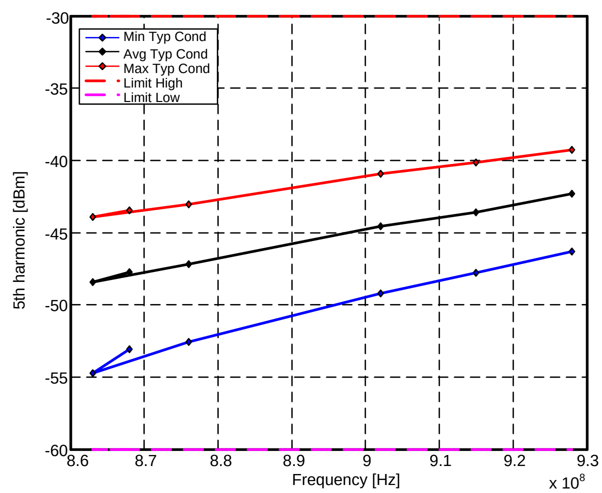

Figure 16. Fifth Harmonic Level vs Frequency

2.3.4 Tx ETSI EN 300 200 Compliance

The device with the lowest margins from the total number of units tested is presented here.

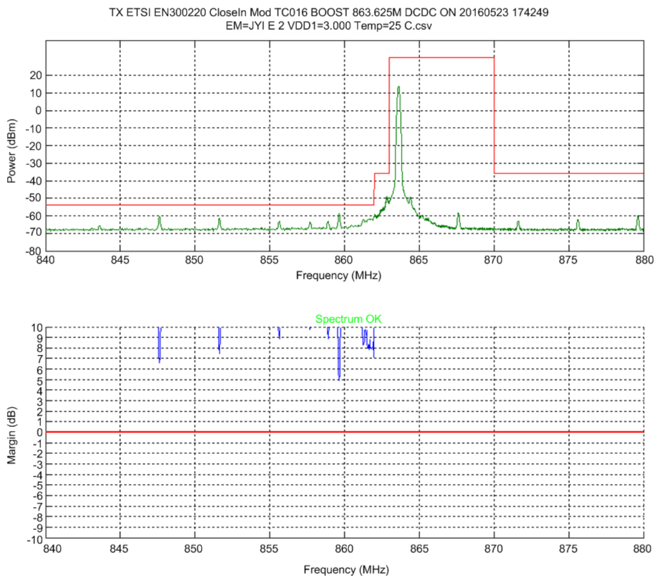

Figure 17. TX ETSI EN 300220 Mask Compliancy, 863 – 870 MHz

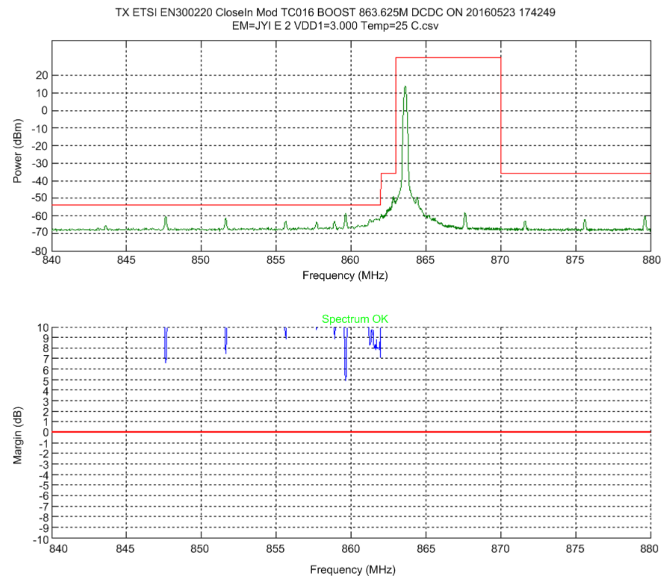

Figure 18. TX ETSI EN 300220 Mask Compliancy, 840 – 880 MHz

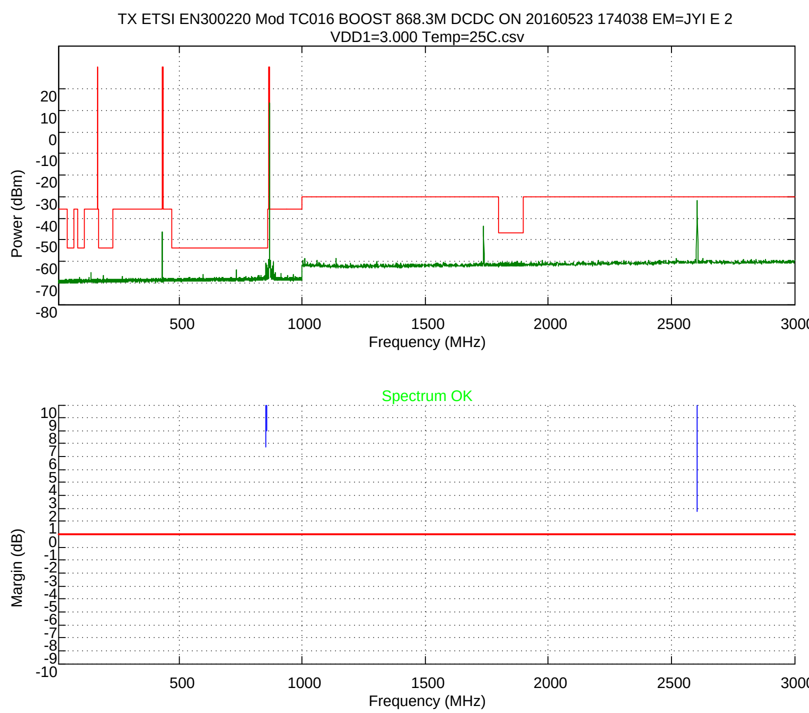

Figure 19. TX ETSI EN 300220 Mask Compliancy < 3 GHz

2.4 Murata IPC Measurement Results

All results presented in this subsection are based on measurements performed with CC1310IPC EM reference design. A minimum of five units have been measured to obtain an average result which is presented in this report. The devices have been tested at room temperature and the voltage was set to 3.0 V unless otherwise specified. All values are in dBm if not otherwise specified.

2.4.1 Current Consumption

Rx current consumption with 802.15.4g, 868 MHz, 50 kbps, DC-DC (3.6 V) setting:	5.4 mA
Tx current consumption at 10 dBm, 868 MHz, DC-DC (3.6 V) setting:	14.5 mA
Tx current consumption with BOOST mode, 868 MHz, DC-DC (3.6 V) setting:	29.1 mA

2.4.2 Rx Measurements

The average Rx sensitivity for the 802.15.14 g, 50-kbps setting at 868 MHz is –109-1 dBm. For the same settings at 915 MHz, the average sensitivity is –109.0 dBm.

Figure 20 shows the packet error rate (PER) against signal level measurement with 802.15.4 g settings at 50 kbps, 868 MHz, and with the DC-DC activated.

Figure 21 shows the received signal strength indicator (RSSI) error against the signal level measurement with the 802.15.4 g settings at 50 kbps, 868 MHZ, and with the DC-DC activated.

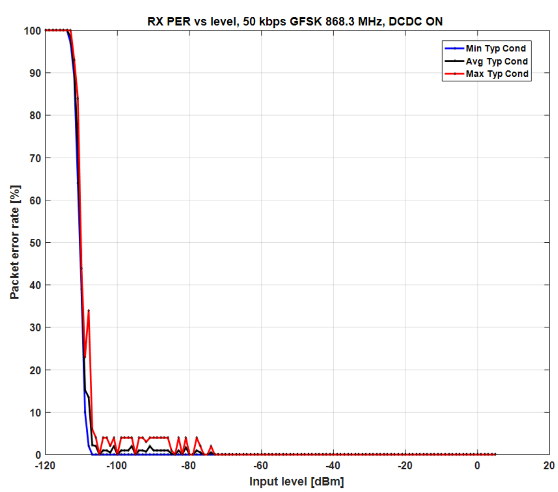

Figure 20. PER vs Level Measurement, 802.15.4g, 50 kbps, 868 MHz

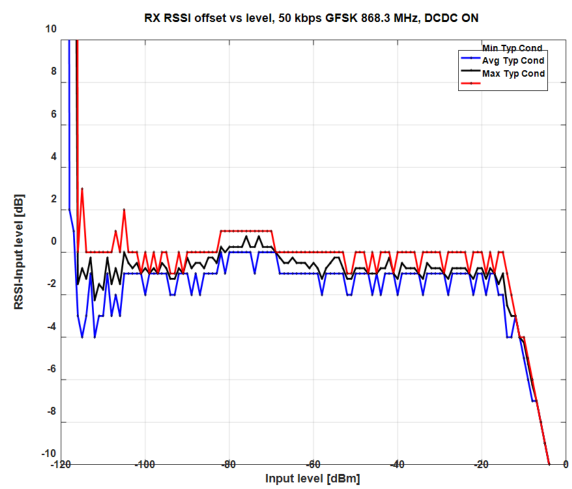

Figure 21. RSSI Error Level, 802.15.4g, 50 kbps, 868 MHz

2.4.3 Tx Measurements

The output power was set to maximum with the BOOST mode. For 868 MHz and 915 MHz, the average output power is 14.1 dBm.

The harmonic levels can be seen in Figure 22, Figure 23, Figure 24, and Figure 25.

For 868 MHz (EN 300 200), all of the harmonic levels are under the regulatory limits of –30 dBm with good margin.

For 915 MHz (FCC 15.247), the maximum output power allowed is +30 dBm with frequency hopping. The second harmonic level requirement is –20 dBc and passes with good margin. The third harmonic passes with good margin. The fourth and fifth harmonic requirements are –41.2 dBm. To fulfill these requirements, the duty-cycle correction factor must be used for designs that require to perform conducted tests. If there is an integrated antenna and conducted tests are not required, then the correction factor can be reduced due to the antenna filter characteristics. Refer to Section 2.4.4 for more information on the duty-cycling correction factor.

For 915 MHz (FCC 15.249), the harmonic level requirement is –41.2 dBm with a maximum output of –1.2 dBm EIRP for non-frequency hopping (50 V/m at 3 m is equivalent to –1.2 dBm output power). Duty cycling correction factor should not be required.

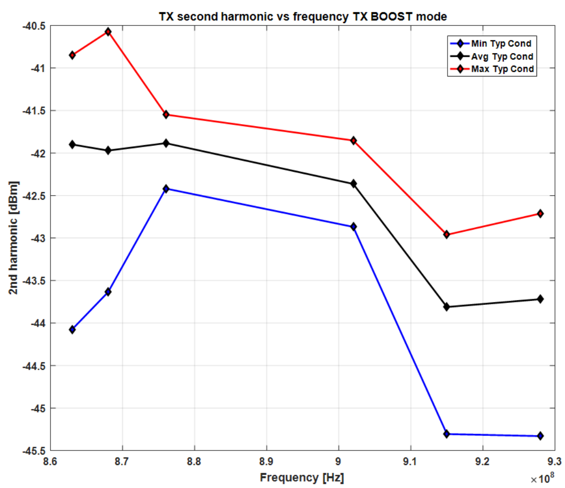

Figure 22. Second Harmonic Level vs Frequency

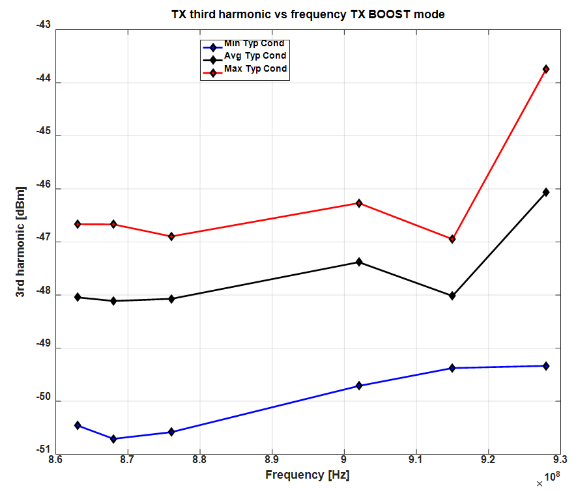

Figure 23. Third Harmonic Level vs Frequency

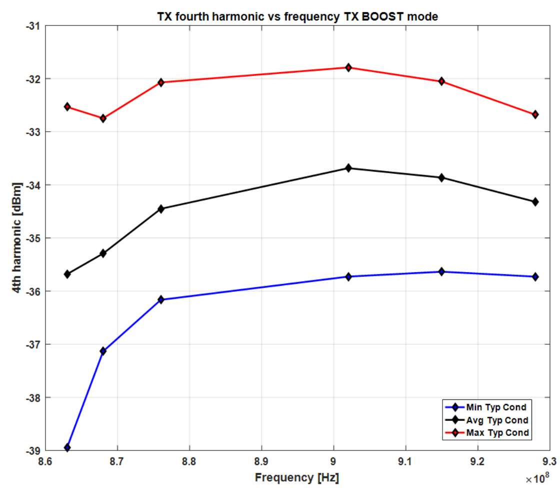

Figure 24. Fourth Harmonic Level vs Frequency

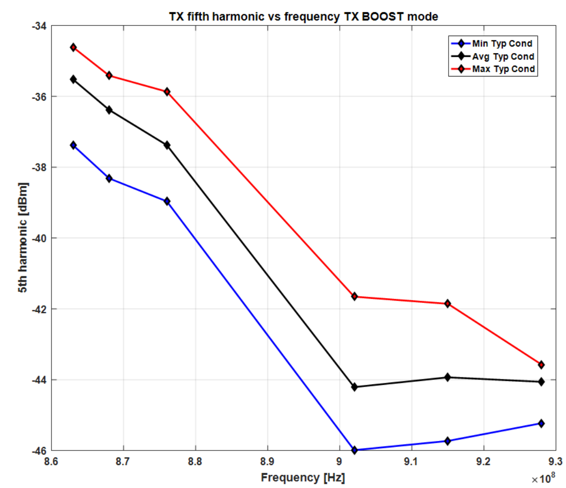

Figure 25. Fifth Harmonic Level vs Frequency

2.4.4 Overview of Harmonic Emission Regulatory Requirements

Harmonic emission will depend on ground plane geometry, encapsulation, and so forth. Table 1 shows the FCC- and ETSI limits. Above 1 GHz, FCC allows the radiation to be up to 20 dB above the limits given in Table 1, if duty cycling is being used.

Table 1. ETSI and FCC Limits for Output Power and Harmonic Radiation

	Output Power	Harmonics							
Limit	**fc**	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**	**Seventh**	**Eighth**	**Ninth**
FCC 15.249	50 V/m at 3m -1.2 dBm EIRP	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m	54 dBµV/m
FCC 15.247	30 dBc	20 dBc	54 dBµV/m	54 dBµV/m	54 dBµV/m	20 dBc	54 dBµV/m	54 dBµV/m	54 dBµV/m
ETSI EN 300 220	-30 dBc	-30 dBc	-30 dBc	-30 dBc	-30 dBc	-30 dBc	-30 dBc	-30 dBc	-30 dBc

The programmed output power and size of the ground plane will affect the level of the harmonics and thus determine the necessary duty cycling.

The allowed additional emission, or correction factor, is calculated based on maximum transmission time during 100 ms. Equation 1 can be used to calculate the correction factor, where “t” is equal to maximum transmission time during 100 ms. From Equation 1, it can be calculated that a maximum transmission time of 50 ms, during 100 ms, will permit all radiation above 1 GHz to be 6 dB above the given limits.

$$CF = -20 \times \log\left(\frac{t}{100ms}\right) \tag{1}$$

Even when an averaging detector is utilised, there is still a limit on emissions measured using a peak detector function with a limit 20 dB above the average limit.

3 Conclusion

As an alternative to the traditional discrete reference designs, the IPC reference design can match the performance of the discrete multi-layer inductor reference design with a lower component count (see [3], [4], [5], and [6]).

For best-in-class RF performance; the discrete wire-wound inductor solution is still recommended but for compact and lower component count solutions, the IPC reference designs should be considered. The complete area for all the required components is less than 0.94 mm^2 with the CC1310 4x4 mm QFN and IPC.

4 References

1. *CC1310 SimpleLink™ Ultralow Power Sub-1-GHz Wireless MCU Data Manual* (SWRS181)
2. JTI contact information: http://www.johansontechnology.com/index.php
3. *SimpleLink CC1310 4-Layer 4x4 Differential 779-930 MHz v1.0.0 Design Files* (SWRC316)
4. *SimpleLink CC1310 4-Layer 5x5 Differential 779-930 MHz v1.0.0 Design Files* (SWRC315)
5. *SimpleLink CC1310 4-Layer 7x7 Differential 779-930 MHz v1.0.1 Design Files* (SWRC310)
6. *SimpleLink CC1310 IPC 4-Layer 4x4 Differential 779-930 MHz v1.0.1 Design Files* (SWRC327)
7. 0850BM14E0016 Data Sheet
8. Murata contact information: www.murata.com

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (Septermber 2016) to A Revision	Page
• Added Section 2.4	11

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