Chipcon

SmartRF® CC1000

CC1000
Single Chip Very Low Power RF Transceiver

Applications

- *Very low power UHF wireless data transmitters and receivers*
- *315 / 433 / 868 and 915 MHz ISM/SRD band systems*
- *RKE – Two-way Remote Keyless Entry*

- *Home automation*
- *Wireless alarm and security systems*
- *AMR – Automatic Meter Reading*
- *Low power telemetry*
- *Game Controllers and advanced toys*

Product Description

CC1000 is a true single-chip UHF transceiver designed for very low power and very low voltage wireless applications. The circuit is mainly intended for the ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency bands at 315, 433, 868 and 915 MHz, but can easily be programmed for operation at other frequencies in the 300-1000 MHz range.

The main operating parameters of *CC1000* can be programmed via a serial bus, thus making *CC1000* a very flexible and easy to use transceiver. In a typical system *CC1000* will be used together with a microcontroller and a few external passive components.

CC1000 is based on Chipcon's SmartRF® technology in 0.35 μm CMOS.

Features

- True single chip UHF RF transceiver
- Very low current consumption
- Frequency range 300 – 1000 MHz
- Integrated bit synchroniser
- High sensitivity (typical -110 dBm at 2.4 kBaud)
- Programmable output power –20 to 10 dBm
- Small size (TSSOP-28 or UltraCSP™ package)
- Low supply voltage (2.1 V to 3.6 V)
- Very few external components required
- No external RF switch / IF filter required

- RSSI output
- Single port antenna connection
- FSK data rate up to 76.8 kBaud
- Complies with EN 300 220 and FCC CFR47 part 15
- Programmable frequency in 250 Hz steps makes crystal temperature drift compensation possible without TCXO
- Suitable for frequency hopping protocols
- Development kit available
- Easy-to-use software for generating the *CC1000* configuration data

Table of Contents

1. Absolute Maximum Ratings

Parameter	Min.	Max.	Units	Condition
Supply voltage, VDD	-0.3	5.0	V	
Voltage on any pin	-0.3	VDD+0.3, max 5.0	V	
Input RF level		10	dBm	
Storage temperature range (TSSOP)	-50	150	°C	
Shelf life (UltraCSP™)		1	year	Room temperature and oxygen free cabinet
Reflow soldering temperature (TSSOP)		260	°C	IPC/JEDEC J-STD-020B
Peak reflow soldering temperature (UltraCSP™)		251	°C	IPC/JEDEC J-STD-020A

Under no circumstances the absolute maximum ratings given above should be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.
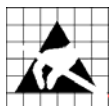
Caution! ESD sensitive device. Precaution should be used when handling the device in order to prevent permanent damage.

2. Operating Conditions

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
RF Frequency Range	300		1000	MHz	Programmable in steps of 250 Hz
Operating ambient temperature range	-40		85	°C	
Supply voltage	2.1	3.0	3.6	V	Note: The same supply voltage should be used for digital (DVDD) and analogue (AVDD) power.

3. Electrical Specifications

Tc = 25°C, VDD = 3.0 V if nothing else stated

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
Transmit Section					
Transmit data rate	0.6		76.8	kBaud	NRZ or Manchester encoding. 76.8 kBaud equals 76.8 kbit/s using NRZ coding. See page 16.
Binary FSK frequency separation	0		65	kHz	The frequency separation is programmable in 250 Hz steps. 65 kHz is the maximum guaranteed separation at 1 MHz reference frequency. Larger separations can be achieved at higher reference frequencies.

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
Output power 433 MHz 868 MHz	-20 -20		10 5	dBm dBm	Delivered to 50 Ω load. The output power is programmable.
RF output impedance 433/868 MHz		140 / 80		Ω	Transmit mode. For matching details see "Input/ output matching" p.31.
Harmonics		-20		dBc	An external LC or SAW filter should be used to reduce harmonics emission to comply with SRD requirements. See p.36.
Receive Section					
Receiver Sensitivity, 433 MHz Optimum sensitivity (9.3 mA) Low current consumption (7.4 mA)		-110 -109		dBm dBm	2.4 kBaud, Manchester coded data, 64 kHz frequency separation, BER = 10^{-3}
Receiver Sensitivity, 868 MHz Optimum sensitivity (11.8 mA) Low current consumption (9.6 mA)		-107 -105		dBm dBm	See Table 6 and Table 7 page 22 for typical sensitivity figures at other data rates.
System noise bandwidth		30		kHz	2.4 kBaud, Manchester coded data
Cascaded noise figure 433/868 MHz		12/13		dB	
Saturation	10			dBm	2.4 kBaud, Manchester coded data, BER = 10^{-3}
Input IP3		-18		dBm	From LNA to IF output
Blocking		40		dBc	At +/- 1 MHz
LO leakage			-57	dBm	
Input impedance		88-j26 70-j26 52-j7 52-j4		Ω Ω Ω Ω	Receive mode, series equivalent at 315 MHz at 433 MHz at 868 MHz. At 915 MHz For matching details see "Input/ output matching" p. 31.
Turn on time	11		128	Baud	The turn-on time is determined by the demodulator settling time, which is programmable. See p. 19
IF Section					
Intermediate frequency (IF)		150	10.7	kHz MHz	Internal IF filter External IF filter
IF bandwidth		175		kHz	
RSSI dynamic range	-105		-50	dBm	
RSSI accuracy		$\pm$ 6		dB	See p.33 for details

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
RSSI linearity		± 2		dB	
Frequency Synthesiser Section					
Crystal Oscillator Frequency	3		16	MHz	Crystal frequency can be 3-4, 6-8 or 9-16 MHz. Recommended frequencies are 3.6864, 7.3728, 11.0592 and 14.7456. See page 35 for details.
Crystal frequency accuracy requirement		± 50 ± 25		ppm	433 MHz 868 MHz The crystal frequency accuracy and drift (ageing and temperature dependency) will determine the frequency accuracy of the transmitted signal.
Crystal operation		Parallel			C171 and C181 are loading capacitors, see page 35
Crystal load capacitance	12 12 12	22 16 16	30 30 16	pF pF pF	3-4 MHz, 22 pF recommended 6-8 MHz, 16 pF recommended 9-16 MHz, 16 pF recommended
Crystal oscillator start-up time		5 1.5 2		ms ms ms	3.6864 MHz, 16 pF load 7.3728 MHz, 16 pF load 16 MHz, 16 pF load
Output signal phase noise		-85		dBc/Hz	At 100 kHz offset from carrier
PLL lock time (RX / TX turn time)		200		μs	Up to 1 MHz frequency step
PLL turn-on time, crystal oscillator on in power down mode		250		μs	Crystal oscillator running
Digital Inputs/Outputs					
Logic "0" input voltage	0		0.3*VDD	V	
Logic "1" input voltage	0.7*VDD		VDD	V	
Logic "0" output voltage	0		0.4	V	Output current -2.5 mA, 3.0 V supply voltage
Logic "1" output voltage	2.5		VDD	V	Output current 2.5 mA, 3.0 V supply voltage
Logic "0" input current	NA		-1	μA	Input signal equals GND
Logic "1" input current	NA		1	μA	Input signal equals VDD
DIO setup time	20			ns	TX mode, minimum time DIO must be ready before the positive edge of DCLK

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
DIO hold time	10			ns	TX mode, minimum time DIO must be held after the positive edge of DCLK
Serial interface (PCLK, PDATA and PALE) timing specification					See Table 2 page 14
Current Consumption					
Power Down mode		0.2	1	μA	Oscillator core off
Current Consumption, receive mode 433/868 MHz		7.4/9.6		mA	Current is programmable and can be increased for improved sensitivity
Current Consumption, average in receive mode using polling 433/868 MHz		74/96		μA	Polling controlled by micro-controller using 1:100 receive to power down ratio
Current Consumption, transmit mode 433/868 MHz:					
P=0.01mW (-20 dBm)		5.3/8.6		mA	The ouput power is delivered to a 50Ω load, see also p. 32
P=0.3 mW (-5 dBm)		8.9/13.8		mA	
P=1 mW (0 dBm)		10.4/16.5		mA	
P=3 mW (5 dBm)		14.8/25.4		mA	
P=10 mW (10 dBm)		26.7/NA		mA	
Current Consumption, crystal osc.		30 80 105		μA μA μA	3-8 MHz, 16 pF load 9-14 MHz, 12 pF load 14-16 MHz, 16 pF load
Current Consumption, crystal osc. And bias		860		μA	
Current Consumption, crystal osc., bias and synthesiser, RX/TX		4/5 5/6		mA mA	< 500 MHz > 500 MHz

4. Pin Assignment

Pin no.	UltraCSP pin no.	Pin name	Pin type	Description
1	G3	AVDD	Power (A)	Power supply (3 V) for analog modules (mixer and IF)
2	F2	AGND	Ground (A)	Ground connection (0 V) for analog modules (mixer and IF)
3	G2	RF_IN	RF Input	RF signal input from antenna
4	G1	RF_OUT	RF output	RF signal output to antenna
5	F1	AVDD	Power (A)	Power supply (3 V) for analog modules (LNA and PA)
6	E2	AGND	Ground (A)	Ground connection (0 V) for analog modules (LNA and PA)
7	E1	AGND	Ground (A)	Ground connection (0 V) for analog modules (PA)
8	D1	AGND	Ground (A)	Ground connection (0 V) for analog modules (VCO and prescaler)
9	C1	AVDD	Power (A)	Power supply (3 V) for analog modules (VCO and prescaler)
10	B1	L1	Analog input	Connection no 1 for external VCO tank inductor
11	A1	L2	Analog input	Connection no 2 for external VCO tank inductor
12	B2	CHP_OUT (LOCK)	Analog output	Charge pump current output. The pin can also be used as PLL Lock indicator. Output is high when PLL is in lock.
13	C2	R_BIAS	Analog output	Connection for external precision bias resistor (82 kΩ, $\pm$ 1%)
14	F3	AGND	Ground (A)	Ground connection (0 V) for analog modules (backplane)
15	A2	AVDD	Power (A)	Power supply (3 V) for analog modules (general)
16	B3	AGND	Ground (A)	Ground connection (0 V) for analog modules (general)
17	A3	XOSC_Q2	Analog output	Crystal, pin 2
18	A4	XOSC_Q1	Analog input	Crystal, pin 1, or external clock input
19	B4	AGND	Ground (A)	Ground connection (0 V) for analog modules (guard)
20	C3	DGND	Ground (D)	Ground connection (0 V) for digital modules (substrate)
21	C4	DVDD	Power (D)	Power supply (3 V) for digital modules
22	D4	DGND	Ground (D)	Ground connection (0 V) for digital modules
23	E4	DIO	Digital input/output	Data input/output. Data input in transmit mode. Data output in receive mode
24	F4	DCLK	Digital output	Data clock for data in both receive and transmit mode
25	G4	PCLK	Digital input	Programming clock for 3-wire bus
26	D3	PDATA	Digital input/output	Programming data for 3-wire bus. Programming data input for write operation, programming data output for read operation
27	D2	PALE	Digital input	Programming address latch enable for 3-wire bus. Internal pull-up.
28	E3	RSSI/IF	Analog output	The pin can be used as RSSI or 10.7 MHz IF output to optional external IF and demodulator. If not used, the pin should be left open (not connected).

A=Analog, D=Digital

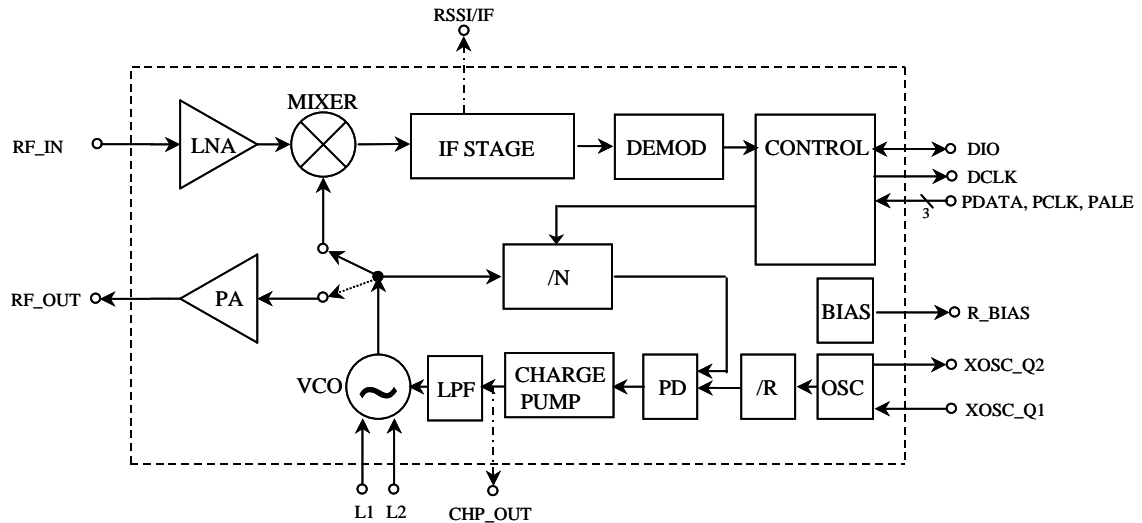(Top View)
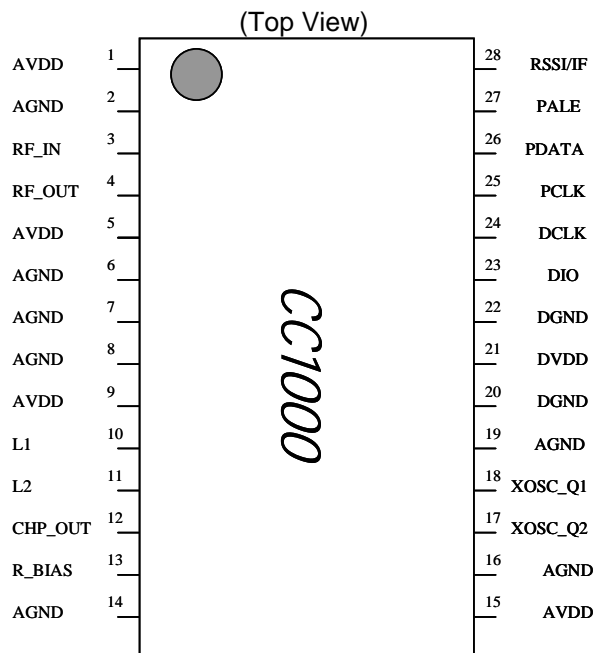
5. Circuit Description

Figure 1. Simplified block diagram of the *CC1000*

A simplified block diagram of *CC1000* is shown in Figure 1. Only signal pins are shown.

In receive mode *CC1000* is configured as a traditional superheterodyne receiver. The RF input signal is amplified by the low-noise amplifier (LNA) and converted down to the intermediate frequency (IF) by the mixer (MIXER). In the intermediate frequency stage (IF STAGE) this downconverted signal is amplified and filtered before being fed to the demodulator (DEMOD). As an option a RSSI signal, or the IF signal after the mixer is available at the RSSI/IF pin. After demodulation *CC1000* outputs the digital demodulated data on the pin DIO. Synchronisation is done on-chip providing data clock at DCLK.

In transmit mode the voltage controlled oscillator (VCO) output signal is fed directly to the power amplifier (PA). The RF output is frequency shift keyed (FSK) by the digital bit stream fed to the pin DIO. The internal T/R switch circuitry makes the antenna interface and matching very easy.

The frequency synthesiser generates the local oscillator signal which is fed to the MIXER in receive mode and to the PA in transmit mode. The frequency synthesiser consists of a crystal oscillator (XOSC), phase detector (PD), charge pump (CHARGE PUMP), VCO, and frequency dividers (/R and /N). An external crystal must be connected to XOSC, and only an external inductor is required for the VCO.

The 3-wire digital serial interface (CONTROL) is used for configuration.

6. Application Circuit

Very few external components are required for the operation of *CC1000*. A typical application circuit is shown in Figure 2. Component values are shown in Table 1.

6.1 Input / output matching
C31/L32 is the input match for the receiver. L32 is also a DC choke for biasing. C41, L41 and C42 are used to match the transmitter to 50 Ω. An internal T/R switch circuit makes it possible to connect the input and output together and match the *CC1000* to 50 Ω in both RX and TX mode. See "Input/output matching" p.31 for details.

6.2 VCO inductor
The VCO is completely integrated except for the inductor L101.

Component values for the matching network and VCO inductor are easily calculated using the SmartRF® Studio software.

6.3 Additional filtering
Additional external components (e.g. RF LC or SAW-filter) may be used in order to improve the performance in specific applications. See also "Optional LC filter" p.36 for further information.

6.4 Power supply decoupling
Power supply decoupling and filtering must be used (not shown in the application circuit). The placement and size of the decoupling capacitors and the power supply filtering are very important to achieve the optimum performance. Chipcon provides reference designs (CC1000PP and CC1000uCSP_EM) that should be followed very closely.
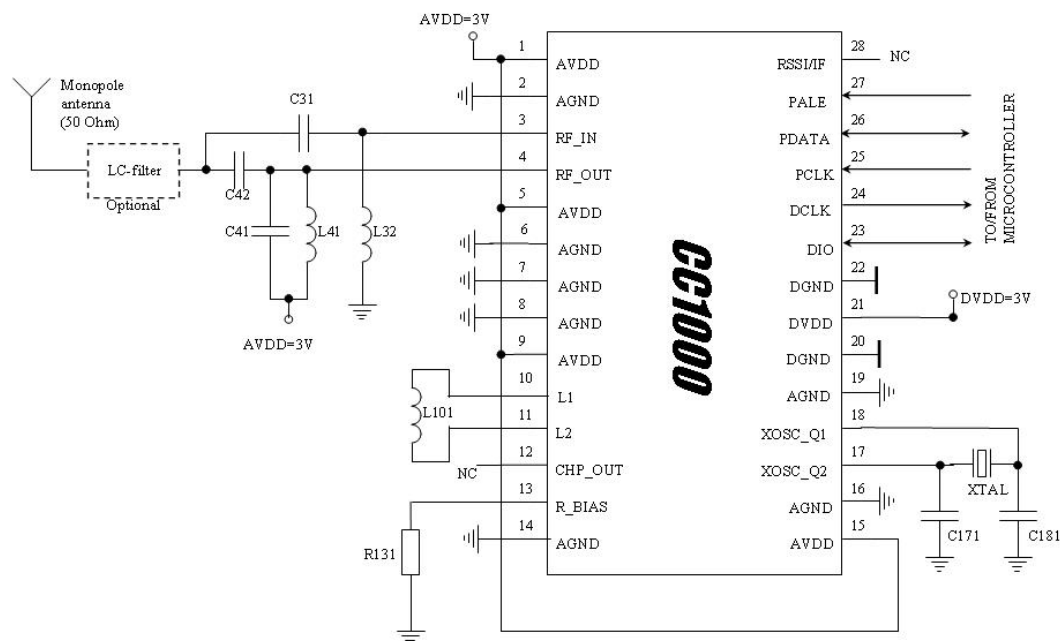

Figure 2. Typical *CC1000* **application circuit (power supply decoupling not shown)**

CC1000 TSSOP package				
Item	315 MHz	433 MHz	868 MHz	915 MHz
C31	8.2 pF, 5%, C0G, 0603	15 pF, 5%, C0G, 0603	10 pF, 5%, C0G, 0603	10 pF, 5%, C0G, 0603
C41	2.2 pF, 5%, C0G, 0603	8.2 pF, 5%, C0G, 0603	Not used	Not used
C42	5.6 pF, 5%, C0G, 0603	5.6 pF, 5%, C0G, 0603	4.7 pF, 5%, C0G, 0603	4.7 pF, 5%, C0G, 0603
C171	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603
C181	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603	18 pF, 5%, C0G, 0603
L32	39 nH, 10%, 0805 (Coilcraft 0805CS-390XKBC)	68 nH, 10%, 0805 (Coilcraft 0805CS-680XKBC)	120 nH, 10%, 0805 (Coilcraft 0805CS-121XKBC)	120 nH, 10%, 0805 (Coilcraft 0805CS-121XKBC)
L41	20 nH, 10%, 0805 (Coilcraft 0805HQ-20NXKBC)	6.2 nH, 10%, 0805 (Coilcraft 0805HQ-6N2XKBC)	2.5 nH, 10%, 0805 (Coilcraft 0805HQ-2N5XKBC)	2.5 nH, 10%, 0805 (Coilcraft 0805HQ-2N5XKBC)
L101	56 nH, 5%, 0805 (Koa KL732ATE56NJ)	33 nH, 5%, 0805 (Koa KL732ATE33NJ)	4.7 nH, 5%, 0805 (Koa KL732ATE4N7C)	4.7 nH, 5%, 0805 (Koa KL732ATE4N7C)
R131	82 kΩ, 1%, 0603	82 kΩ, 1%, 0603	82 kΩ, 1%, 0603	82 kΩ, 1%, 0603
XTAL	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load

CC1000 UltraCSP™ package				
Item	315 MHz	433 MHz	868 MHz	915 MHz
C31	8.2 pF, 5%, C0G, 0402	15 pF, 5%, C0G, 0402	10 pF, 5%, C0G, 0402	10 pF, 5%, C0G, 0402
C41	Not used	Not used	Not used	Not used
C42	4.7 pF, 5%, C0G, 0402	4.7 pF, 5%, C0G, 0402	6.8 pF, 5%, C0G, 0402	6.8 pF, 5%, C0G, 0402
C171	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402
C181	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402	18 pF, 5%, C0G, 0402
L32	39 nH, 5%, 0402 (Ceramic multilayer)	68 nH, 5%, 0402 (Ceramic multilayer)	120 nH, 5%, 0402 (Ceramic multilayer)	120 nH, 5%, 0402 (Ceramic multilayer)
L41	22 nH, 5%, 0402 (Ceramic multilayer)	15 nH, 5%, 0402 (Ceramic multilayer)	2.7 nH, 5%, 0402 (Ceramic multilayer)	2.7 nH, 5%, 0402 (Ceramic multilayer)
L101	56 nH, 5%, 0402 (Thin film inductor)	33 nH, 5%, 0402 (Thin film inductor)	7.5 nH, 5%, 0402 (Thin film inductor)	7.5 nH, 5%, 0402 (Thin film inductor)
R131	82 kΩ, 1%, 0402	82 kΩ, 1%, 0402	82 kΩ, 1%, 0402	82 kΩ, 1%, 0402
XTAL	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load	14.7456 MHz crystal, 16 pF load

Note: Items shaded are different for different frequencies

Table 1. Bill of materials for the application circuit

Note that the component values for 868/915 MHz can be the same. However, it is important the layout is optimised for the selected VCO inductor in order to centre the tuning range around the operating frequency to account for inductor tolerance. The VCO inductor must be placed very close and symmetrical with respect to the pins (L1 and L2).

Chipcon provide reference layouts that should be followed very closely in order to achieve the best performance. The reference design can be downloaded from the Chipcon website.

7. Configuration Overview

CC1000 can be configured to achieve the best performance for different applications. Through the programmable configuration registers the following key parameters can be programmed:

- Receive / transmit mode
- RF output power
- Frequency synthesiser key parameters: RF output frequency, FSK

frequency separation (deviation), crystal oscillator reference frequency

- Power-down / power-up mode
- Crystal oscillator power-up / power down
- Data rate and data format (NRZ, Manchester coded or UART interface)
- Synthesiser lock indicator mode
- Optional RSSI or external IF

8. Configuration Software

Chipcon provides users of CC1000 with a software program, SmartRF® Studio (Windows interface) that generates all necessary CC1000 configuration data based on the user's selections of various parameters. These hexadecimal numbers will then be the necessary input to the microcontroller for the configuration of

CC1000. In addition the program will provide the user with the component values needed for the input/output matching circuit and the VCO inductor.

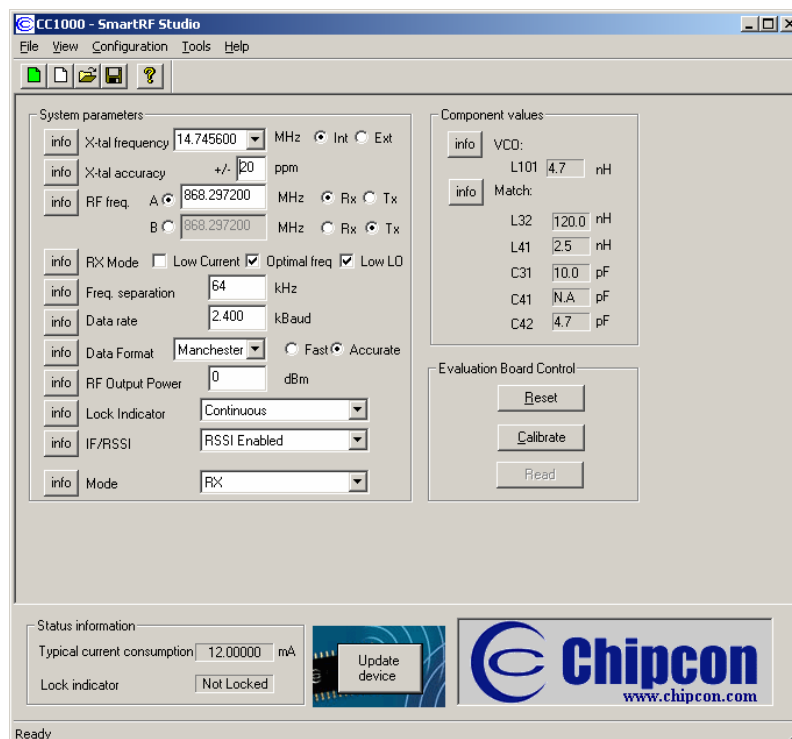Figure 3 shows the user interface of the CC1000 configuration software.

Figure 3. SmartRF® Studio user interface

9. 3-wire Serial Configuration Interface

CC1000 is configured via a simple 3-wire interface (PDATA, PCLK and PALE). There are 28 8-bit configuration registers, each addressed by a 7-bit address. A Read/Write bit initiates a read or write operation. A full configuration of *CC1000* requires sending 22 data frames of 16 bits each (7 address bits, R/W bit and 8 data bits). The time needed for a full configuration depend on the PCLK frequency. With a PCLK frequency of 10 MHz the full configuration is done in less than 46 µs. Setting the device in power down mode requires sending one frame only and will in this case take less than 2 µs. All registers are also readable.

In each write-cycle 16 bits are sent on the PDATA-line. The seven most significant bits of each data frame (*A6:0*) are the address-bits. *A6* is the MSB (Most Significant Bit) of the address and is sent as the first bit. The next bit is the R/W bit (high for write, low for read). During address and R/W bit transfer the PALE (Program Address Latch Enable) must be kept low. The 8 data-bits are then transferred (*D7:0*). See Figure 4.

The timing for the programming is also shown in Figure 4 with reference to Table 2. The clocking of the data on PDATA is done on the negative edge of PCLK. When the last bit, *D0*, of the 8 data-bits has been loaded, the data word is loaded in the internal configuration register.

The configuration data is stored in internal RAM. The data is retained during power-down mode, but not when the power-supply is turned off. The registers can be programmed in any order.

The configuration registers can also be read by the microcontroller via the same configuration interface. The seven address bits are sent first, then the R/W bit set low to initiate the data read-back. *CC1000* then returns the data from the addressed register. PDATA is in this case used as an output and must be tri-stated (or set high n the case of an open collector pin) by the microcontroller during the data read-back (D7:0). The read operation is illustrated in Figure 5.
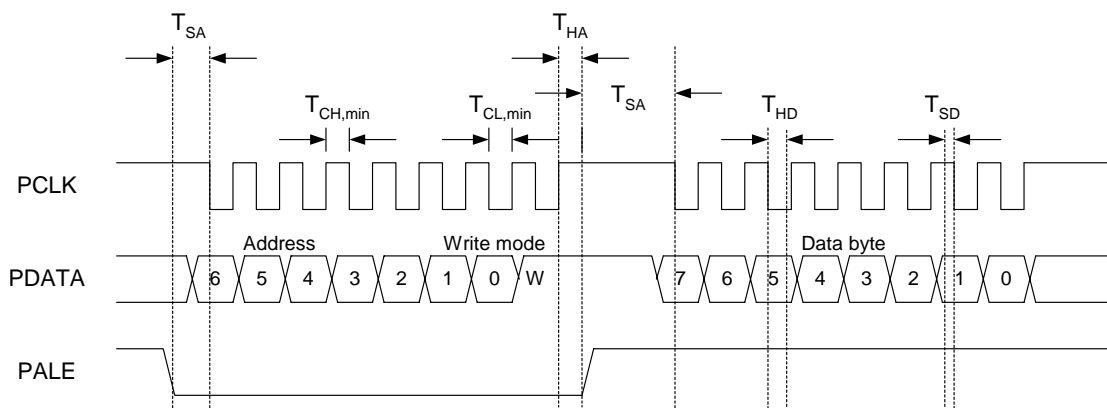
Figure 4. Configuration registers write operation
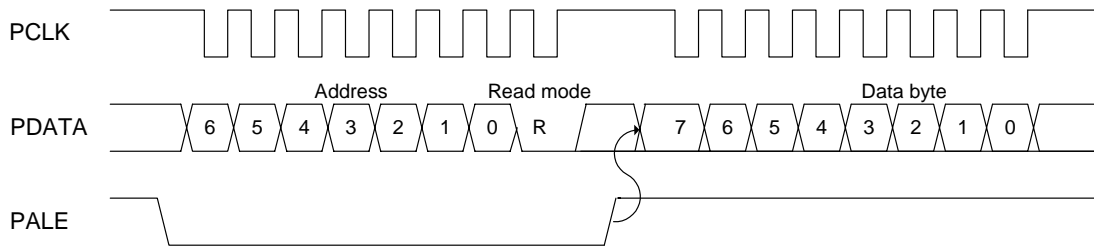
Figure 5. Configuration registers read operation

Parameter	Symbol	Min	Max	Units	Conditions
PCLK, clock frequency	F_{CLOCK}	-	10	MHz	
PCLK low pulse duration	$T_{CL,min}$	50		ns	The minimum time PCLK must be low.
PCLK high pulse duration	$T_{CH,min}$	50		ns	The minimum time PCLK must be high.
PALE setup time	T_{SA}	10	-	ns	The minimum time PALE must be low before negative edge of PCLK.
PALE hold time	T_{HA}	10	-	ns	The minimum time PALE must be held low after the *positive* edge of PCLK.
PDATA setup time	T_{SD}	10	-	ns	The minimum time data on PDATA must be ready before the negative edge of PCLK.
PDATA hold time	T_{HD}	10	-	ns	The minimum time data must be held at PDATA, after the negative edge of PCLK.
Rise time	T_{rise}		100	ns	The maximum rise time for PCLK and PALE
Fall time	T_{fall}		100	ns	The maximum fall time for PCLK and PALE

Note: The set-up- and hold-times refer to 50% of VDD.

Table 2. Serial interface, timing specification

10. Microcontroller Interface

Used in a typical system, *CC1000* will interface to a microcontroller. This microcontroller must be able to:

- Program *CC1000* into different modes via the 3-wire serial configuration interface (PDATA, PCLK and PALE).
- Interface to the bi-directional synchronous data signal interface (DIO and DCLK).

- Optionally the microcontroller can do data encoding / decoding.
- Optionally the microcontroller can monitor the frequency lock status from pin CHP_OUT (LOCK).
- Optionally the microcontroller can monitor the RSSI output for signal strength acquisition.

10.1 Connecting the microcontroller

The microcontroller uses 3 output pins for the configuration interface (PDATA, PCLK and PALE). PDATA should be a bi-directional pin for data read-back. A bi-directional pin is used for data (DIO) to be transmitted and data received. DCLK providing the data timing should be connected to a microcontroller input. Optionally another pin can be used to monitor the LOCK signal (available at the CHP_OUT pin). This signal is logic level high when the PLL is in lock. See Figure 6.

Also the RSSI signal can be connected to the microcontroller if it has an analogue ADC input.

The microcontroller pins connected to PDATA and PCLK can be used for other purposes when the configuration interface is not used. PDATA and PCLK are high impedance inputs as long as PALE is high.

PALE has an internal pull-up resistor and should be left open (tri-stated by the microcontroller) or set to a high level during power down mode in order to prevent a trickle current flowing in the pull-up. The pin state in power down mode is summarized in Table 3.

Pin	Pin state	Note
PDATA	Input	Should be driven high or low
PCLK	Input	Should be driven high or low
PALE	Input with internal pull-up resistor	Should be driven high or high-impedance to minimize power consumption
DIO	Input	Should be driven high or low
DCLK	High-impedance output	

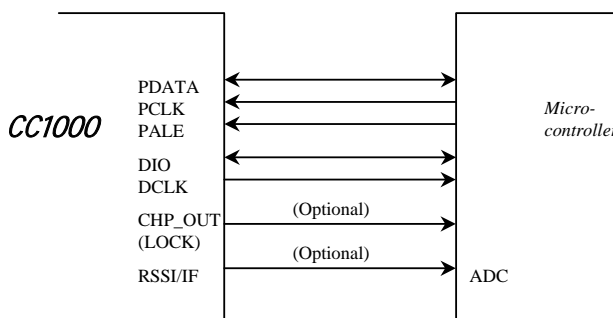**Table 3. CC1000 pins in power-down mode**

Figure 6. Microcontroller interface

11. Signal interface

The signal interface consists of DIO and DCLK and is used for the data to be transmitted and data received. DIO is the bi-directional data line and DCLK provides a synchronous clock both during data transmission and data reception.

The *CC1000* can be used with NRZ (Non-Return-to-Zero) data or Manchester (also known as bi-phase-level) encoded data. *CC1000* can also synchronise the data from the demodulator and provide the data clock at DCLK.

CC1000 can be configured for three different data formats:

Synchronous NRZ mode. In transmit mode *CC1000* provides the data clock at DCLK, and DIO is used as data input. Data is clocked into *CC1000* at the rising edge of DCLK. The data is modulated at RF without encoding. *CC1000* can be configured for the data rates 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, 38.4 or 76.8 kbit/s. For 38.4 and 76.8 kbit/s a crystal frequency of 14.7456 MHz must be used. In receive mode *CC1000* does the synchronisation and provides received data clock at DCLK and data at DIO. The data should be clocked into the interfacing circuit at the rising edge of DCLK. See Figure 7.

Synchronous Manchester encoded mode. In transmit mode *CC1000* provides the data clock at DCLK, and DIO is used as data input. Data is clocked into *CC1000* at the rising edge of DCLK and should be in NRZ format. The data is modulated at RF with Manchester code. The encoding is done by *CC1000*. In this mode *CC1000* can be configured for the data rates 0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2 or 38.4 kbit/s. The 38.4 kbit/s rate corresponds to the maximum 76.8 kBaud due to the Manchester encoding. For 38.4 and 76.8 kBaud a crystal frequency of 14.7456 MHz must be used. In receive mode *CC1000* does the synchronisation and provides received data clock at DCLK and data at DIO. *CC1000* does the decoding and NRZ data

is presented at DIO. The data should be clocked into the interfacing circuit at the rising edge of DCLK. See Figure 8.

Transparent Asynchronous UART mode. In transmit mode DIO is used as data input. The data is modulated at RF without synchronisation or encoding. In receive mode the raw data signal from the demodulator is sent to the output. No synchronisation or decoding of the signal is done in *CC1000* and should be done by the interfacing circuit. The DCLK pin is used as data output in this mode. Data rates in the range from 0.6 to 76.8 kBaud can be used. For 38.4 and 76.8 kBaud a crystal frequency of 14.7456 MHz must be used. See Figure 9.

11.1 Manchester encoding and decoding
In the *Synchronous Manchester encoded mode* *CC1000* uses Manchester coding when modulating the data. The *CC1000* also performs the data decoding and synchronisation. The Manchester code is based on transitions; a "0" is encoded as a low-to-high transition, a "1" is encoded as a high-to-low transition. See Figure 10.

The *CC1000* can detect a Manchester decoding violation and will set a Manchester Violation Flag when such a violation is detected in the incoming signal. The threshold limit for the Manchester Violation can be set in the *MODEM1* register. The Manchester Violation Flag can be monitored at the CHP_OUT (LOCK) pin, configured in the *LOCK* register.

The Manchester code ensures that the signal has a constant DC component, which is necessary in some FSK demodulators. Using this mode also ensures compatibility with CC400/CC900 designs.

Transmitter side:

DIO   Data provided by microcontroller

DCLK   Clock provided by CC1000

"RF"   FSK modulating signal (NRZ),
internal in CC1000

Receiver side:

"RF"   Demodulated signal (NRZ),
internal in CC1000

DCLK   Clock provided by CC1000

DIO   Data provided by CC1000
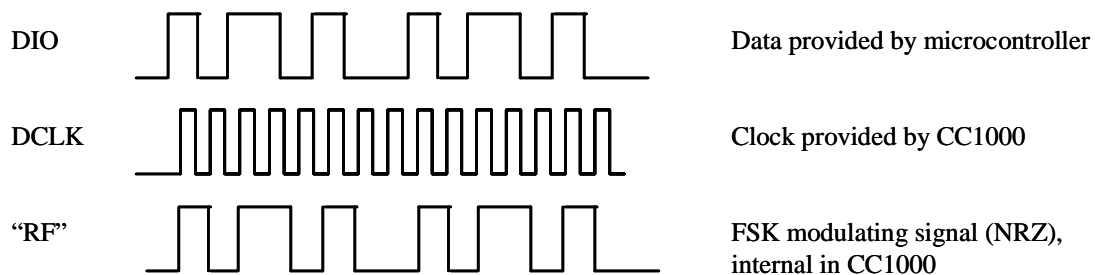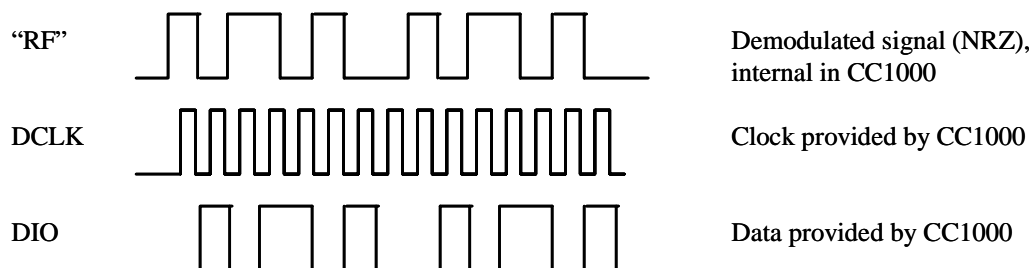
Figure 7. Synchronous NRZ mode

Transmitter side:

DIO   Data provided by microcontroller (NRZ)

DCLK   Clock provided by CC1000

"RF"   FSK modulating signal (Manchester encoded),
internal in CC1000

Receiver side:

"RF"   Demodulated signal (Manchester encoded),
internal in CC1000

DCLK   Clock provided by CC1000

DIO   Data provided by CC1000 (NRZ)
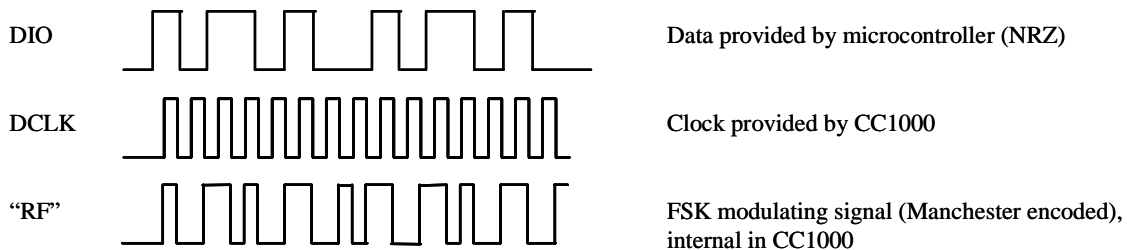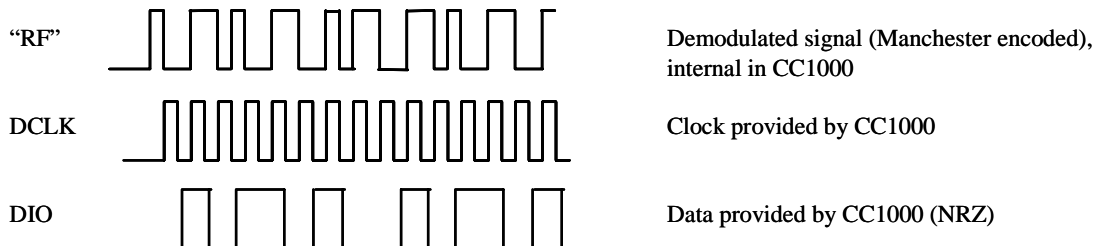
Figure 8. Synchronous Manchester encoded mode

Transmitter side:

DIO ⊓⊔⊓⊔⊓⎍⊓⊔⊓⊔⊓ Data provided by UART (TXD)

DCLK ─────────── DCLK is not used in transmit mode.
Used as data output in receive mode.

"RF" ⊓⊔⊓⊔⊓⊔⊓⊔⊓⊔⊓⊔⊓ FSK modulating signal,
internal in CC1000

Receiver side:

"RF" ⊓⊔⊓⊔⊓⎍⊓⊔⊓⊔⊓ Demodulated signal,
internal in CC1000

DIO ─────────── DIO is not used in receive mode. Used only
as data input in transmit mode.

DCLK ⊓⊔⊓⊔⊓⊔⊓⊔⊓⊔⊓⊔⊓ Data output provided by CC1000.
Connect to UART (RXD).
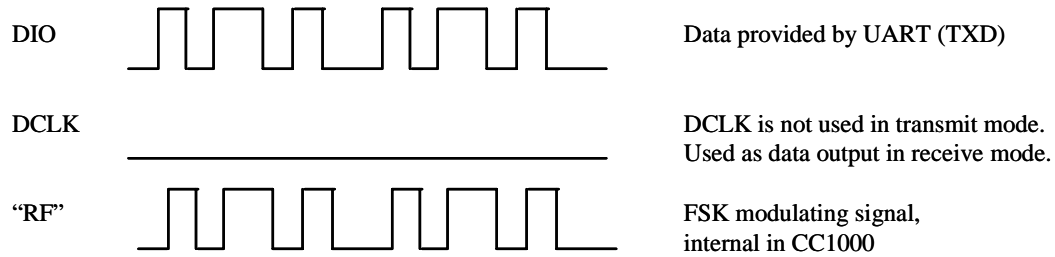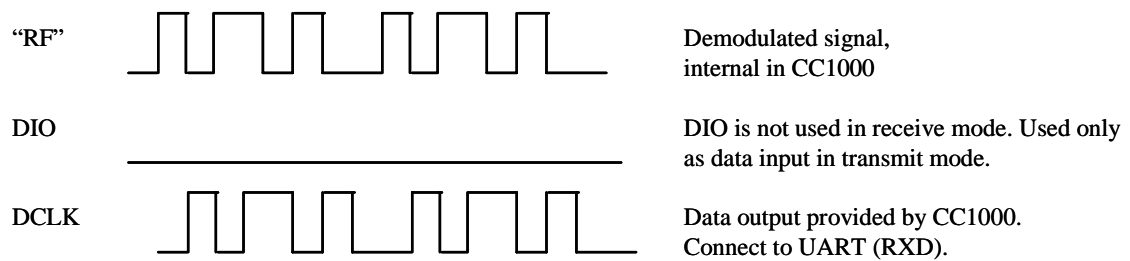
Figure 9. Transparent Asynchronous UART mode

1 0 1 1 0 0 0 1 1 0 1

TX data

Time

Figure 10. Manchester encoding

12. Bit synchroniser and data decision

Figure 11. Demodulator block diagram

A block diagram of the digital demodulator is shown in Figure 11. The IF signal is sampled and its instantaneous frequency is detected. The result is decimated and filtered. In the data slicer the data filter output is compared to the average filter output to generate the data output.
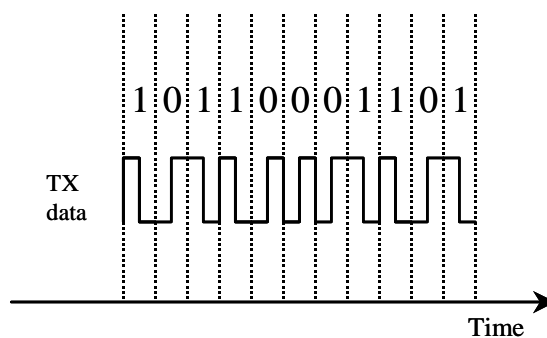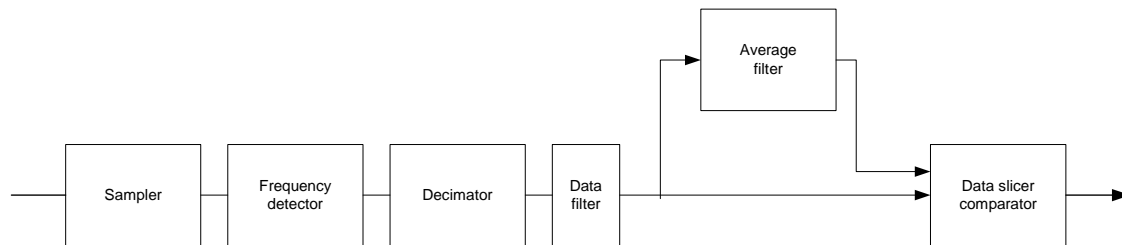
The averaging filter is used to find the average value of the incoming data. While the averaging filter is running and acquiring samples, it is important that the number of high and low bits received is equal (e.g. Manchester code or a balanced preamble).

Therefore all modes, also synchronous NRZ mode, need a DC balanced preamble for the internal data slicer to acquire correct comparison level from the averaging filter. The suggested preamble is a '010101…' bit pattern. The same bit pattern should also be used in Manchester mode, giving a '011001100110…chip pattern. This is necessary for the bit synchronizer to synchronize correctly.

The averaging filter must be locked before any NRZ data can be received. If the averaging filter is locked (MODEM1.LOCK_AVG_MODE='1'), the

acquired value will be kept also after Power Down or Transmit mode. After a modem reset (*MODEM1.MODEM_RESET_N*), or a main reset (using any of the standard reset sources), the averaging filter is reset.

In a polled receiver system the automatic locking can be used. This is illustrated in Figure 12. If the receiver is operated continuously and searching for a preamble, the averaging filter should be locked manually as soon as the preamble is detected. This is shown in Figure 13. If the data is Manchester coded there is no need to lock the averaging filter (*MODEM1.LOCK_AVG_IN*='0'), as shown in Figure 14.

The minimum length of the preamble depends on the acquisition mode selected and the settling time. Table 4 gives the minimum recommended number of chips for the preamble in NRZ and UART modes. In this context 'chips' refer to the data coding. Using Manchester coding every bit consists of two 'chips'. For Manchester mode the minimum recommended number of chips is shown in Table 5.

Settling	Manual Lock		Automatic Lock	
	NRZ mode	UART mode	NRZ mode	UART mode
MODEM1. SETTLING (1:0)	MODEM1.LOCK_ AVG_MODE='1' MODEM1.LOCK_ AVG_IN='0'=→'1'**	MODEM1.LOCK_ AVG_MODE='1' MODEM1.LOCK_ AVG_IN='0'=→'1'**	MODEM1.LOCK_ AVG_MODE='0' MODEM1.LOCK_ AVG_IN='X'***	MODEM1.LOCK_ AVG_MODE='0' MODEM1.LOCK_ AVG_IN='X'***
00	14	11	16	16
01	25	22	32	32
10	46	43	64	64
11	89	86	128	128

Notes:

** The averaging filter is locked when MODEM1.LOCK_AVG_IN is set to 1

*** X = Do not care. The timer for the automatic lock is started when RX mode is set in the RFMAIN register

Also please note that in addition to the number of bits required to lock the filter, you need to add the number of bits needed for the preamble detector. See the next section for more information.

Table 4. Minimum preamble bits for locking the averaging filter, NRZ and UART mode

Settling	Free-running Manchester mode
MODEM1. SETTLING (1:0)	MODEM1.LOCK_ AVG_MODE='1' MODEM1.LOCK_ AVG_IN='0'
00	23
01	34
10	55
11	98

Table 5. Minimum number preamble chips for averaging filter, Manchester mode

Data package to be received

| Noise | Preamble | NRZ data | Noise |

RX | PD | RX

Averaging filter locked

Averaging filter
free-running / not used

Automatically locked after a short period depending on "SETTLING"
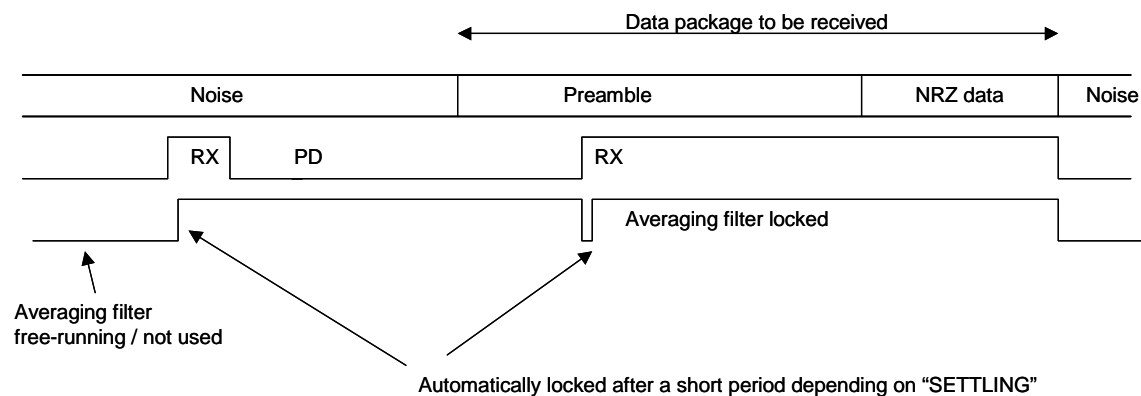
Figure 12. Automatic locking of the averaging filter

Data package to be received

| Noise | Preamble | NRZ data | Noise |

PD | RX

Averaging filter free-running | Averaging filter locked

Manually locked after preamble is detected
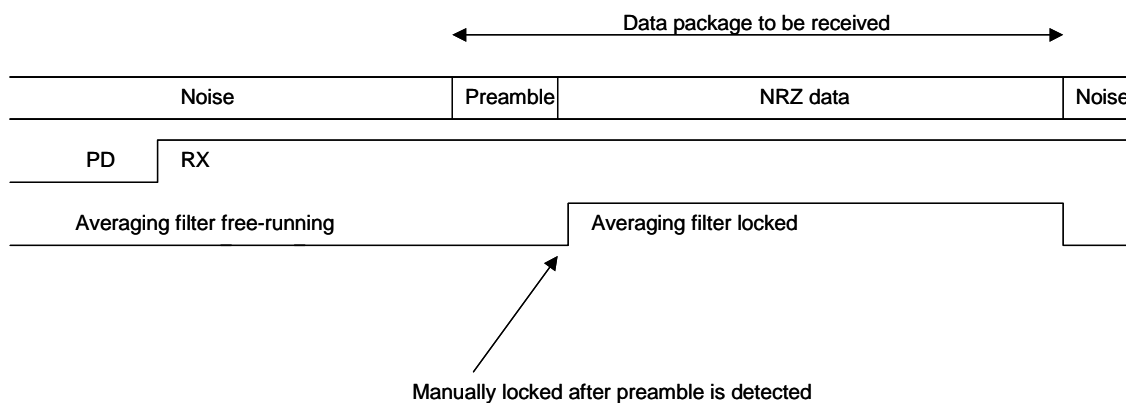
Figure 13. Manual locking of the averaging filter

Data package to be received

| Noise | Preamble | Manchester encoded data | Noise |

PD | RX

Averaging filter always free-running

Figure 14. Free-running averaging filter

13. Receiver sensitivity versus data rate and frequency separation

The receiver sensitivity depends on the data rate, the data format, FSK frequency separation and the RF frequency. Typical figures for the receiver sensitivity (BER = 10^{-3}) are shown in Table 6 for 64 kHz frequency separations and Table 7 for 20 kHz separations. Optimised sensitivity configurations are used. For best performance the frequency separation should be as high as possible especially at high data rates. Table 8 shows the sensitivity for low current settings. See page 28 for how to program different current consumption.

Data rate [kBaud]	Separation [kHz]	433 MHz			868 MHz		
		NRZ mode	Manchester mode	UART mode	NRZ mode	Manchester mode	UART mode
0.6	64	-113	-114	-113	-110	-111	-110
1.2	64	-111	-112	-111	-108	-109	-108
2.4	64	-109	-110	-109	-106	-107	-106
4.8	64	-107	-108	-107	-104	-105	-104
9.6	64	-105	-106	-105	-102	-103	-102
19.2	64	-103	-104	-103	-100	-101	-100
38.4	64	-102	-103	-102	-98	-99	-98
76.8	64	-100	-101	-100	-97	-98	-97
Average current consumption		9.3 mA			11.8 mA		

Table 6. Receiver sensitivity as a function of data rate at 433 and 868 MHz, BER = 10^{-3}, frequency separation 64 kHz, normal current settings

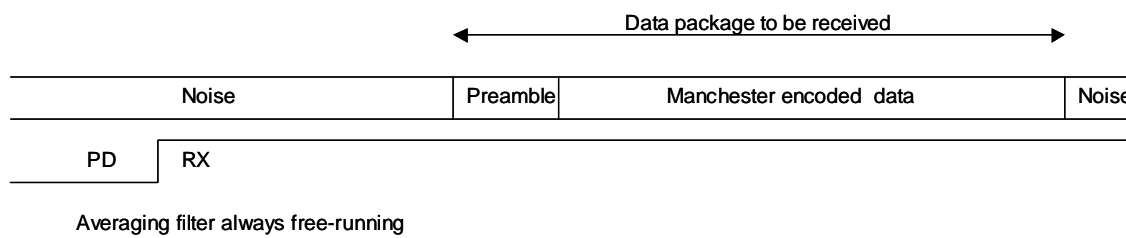| Data rate [kBaud]	Separation [kHz]	433 MHz			868 MHz		
		NRZ mode	Manchester mode	UART mode	NRZ mode	Manchester mode	UART mode
0.6	20	-109	-111	-109	-106	-108	-106
1.2	20	-108	-110	-108	-104	-106	-104
2.4	20	-106	-108	-106	-103	-105	-103
4.8	20	-104	-106	-104	-101	-103	-101
9.6	20	-103	-104	-103	-100	-101	-100
19.2	20	-102	-103	-102	-99	-100	-99
38.4	20	-98	-100	-98	-98	-99	-98
76.8	20	-94	-98	-94	-94	-96	-94
Average current consumption		9.3 mA			11.8 mA		

Table 7. Receiver sensitivity as a function of data rate at 433 and 868 MHz, BER = 10^{-3}, frequency separation 20 kHz, normal current settings

Data rate [kBaud]	Separation [kHz]	433 MHz			868 MHz		
		NRZ mode	Manchester mode	UART mode	NRZ mode	Manchester mode	UART mode
0.6	64	-111	-113	-111	-107	-109	-107
1.2	64	-110	-111	-110	-106	-107	-106
2.4	64	-108	-109	-108	-104	-105	-104
4.8	64	-106	-107	-106	-102	-103	-102
9.6	64	-104	-105	-104	-100	-101	-100
19.2	64	-102	-103	-102	-98	-99	-98
38.4	64	-101	-102	-101	-96	-97	-96
76.8	64	-99	-100	-99	-95	-96	-95
Average current consumption		7.4 mA			9.6 mA		

Table 8. Receiver sensitivity as a function of data rate at 433 and 868 MHz, BER = 10^{-3}, frequency separation 64 kHz , low current settings
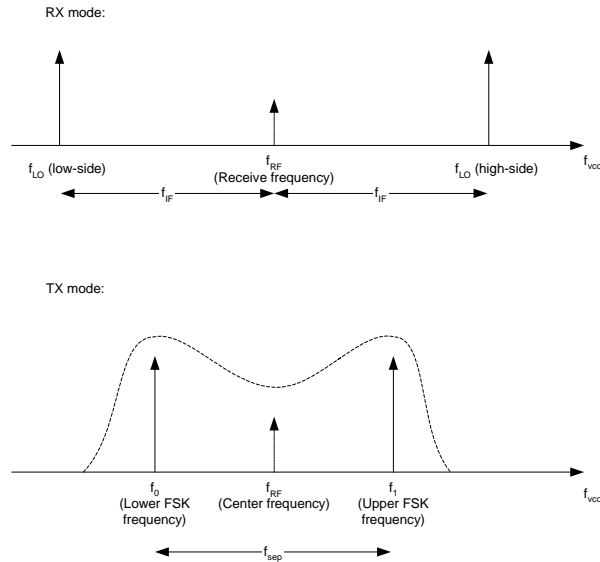
14. Frequency programming

Figure 15. Relation between f_{vco}, f_{if}, and LO frequency

The frequency synthesiser (PLL) is controlled by the frequency word in the configuration registers. There are two frequency words, *A* and *B*, which can be programmed to two different frequencies. One of the frequency words can be used for RX (local oscillator frequency) and the other for TX (transmitting frequency, f_0). This makes it possible to switch very fast between RX mode and TX mode. They can also be used for RX (or TX) on two different channels. The MAIN.F_REG control bit performs selection of frequency word A or B.

The frequency word, *FREQ*, is 24 bits (3 bytes) located in *FREQ_2A:FREQ_1A:FREQ_0A* and *FREQ_2B:FREQ_1B:FREQ_0B* for the *A* and *B* word, respectively.

The frequency word *FREQ* can be calculated from:

$$f_{VCO} = f_{ref} \cdot \frac{FREQ + FSEP \cdot TXDATA + 8192}{16384},$$

where *TXDATA* is 0 or 1 in transmit mode depending on the data bit to be transmitted on DIO. In receive mode *TXDATA* is always 0.

The reference frequency f_{ref} is the crystal oscillator clock divided by *PLL.REFDIV*, a number between 2 and 14 that should be chosen such that:

$$1.0 \ \text{MHz} \le f_{ref} \le 2.46 \ \text{MHz}$$

Thus, the reference frequency f_{ref} is:

$$f_{ref} = \frac{f_{xosc}}{REFDIV}$$

f_{VCO} is the Local Oscillator (LO) frequency in receive mode, and the f_0 frequency in transmit mode (lower FSK frequency). The LO frequency must be $f_{RF} - f_{IF}$ or $f_{RF} + f_{IF}$ giving low-side or high side LO injection respectively. Note that the data on DIO will be inverted if high-side LO is used.

The upper FSK transmit frequency is given by:

$$f_1 = f_0 + f_{sep} \,,$$

where the frequency separation f_{sep} is set by the 11 bit separation word (*FSEP1:FSEP0*):

$$f_{sep} = f_{ref} \cdot \frac{FSEP}{16384}$$

Clearing *PLL.ALARM_DISABLE* will enable generation of the frequency alarm bits *PLL.ALARM_H* and *PLL.ALARM_L*. These bits indicate that the frequency synthesis PLL is near the limit of generate the frequency requested, and the PLL should be recalibrated.

It is recommended that the *LOCK_CONTINOUS* bit in the LOCK register is checked when changing frequencies and when changing between RX and TX mode. If lock is not achieved, a calibration should be performed.

15. Recommended RX settings for ISM frequencies

Shown in Table 9 are the recommended RX frequency synthesiser settings for a few operating frequencies in the popular ISM bands. These settings ensure optimum configuration of the synthesiser in receive mode for best sensitivity. For some settings of the synthesiser (combinations of RF frequencies and reference frequency), the receiver sensitivity is degraded. The FSK frequency separation is set to 64 kHz. The SmartRF® Studio can be used to generate optimised configuration data as well. Also an application note (AN011) and a spreadsheet are available from Chipcon generating configuration data for any frequency giving optimum sensitivity.

ISM Frequency [MHz]	Actual frequency [MHz]	Crystal frequency [MHz]	Low-side / high- side LO*	Reference divider REFDIV (decimal)	Frequency word RX mode FREQ (decimal)	Frequency word RX mode FREQ (hex)
315	315.037200	3.6864	High-side	3	4194304	400000
		7.3728		6	4194304	400000
		11.0592		9	4194304	400000
		14.7456		12	4194304	400000
433.3	433.302000	3.6864	Low-side	3	5775168	580000
		7.3728		6	5775168	580000
		11.0592		9	5775168	580000
		14.7456		12	5775168	580000
433.9	433.916400	3.6864	Low-side	3	5775360	582000
		7.3728		6	5775360	582000
		11.0592		9	5775360	582000
		14.7456		12	5775360	582000
434.5	434.530800	3.6864	Low-side	3	5783552	584000
		7.3728		6	5783552	584000
		11.0592		9	5783552	584000
		14.7456		12	5783552	584000
868.3	868.297200	3.6864	Low-side	2	7708672	75A000
		7.3728		4	7708672	75A000
		11.0592		6	7708672	75A000
		14.7456		8	7708672	75A000
868.95	868.918800	3.6864	High-side	2	7716864	75C000
		7.3728		4	7716864	75C000
		11.0592		6	7716864	75C000
		14.7456			7716864	75C000
869.525	869.526000	3.6864	Low-side	3	11583488	B0C000
		7.3728		6	11583488	B0C000
		11.0592		9	11583488	B0C000
		14.7456		12	11583488	B0C000
869.85	869.840400	3.6864	High-side	2	7725056	75E000
		7.3728		4	7725056	75E000
		11.0592		6	7725056	75E000
		14.7456		8	7725056	75E000
915	914.998800	3.6864	High-side	2	8126464	7C0000
		7.3728		4	8126464	7C0000
		11.0592		6	8126464	7C0000
		14.7456		8	8126464	7C0000

*Note: When using high-side LO injection the data at DIO will be inverted.

Table 9. Recommended settings for ISM frequencies

16. VCO

Only one external inductor (L101) is required for the VCO. The inductor will determine the operating frequency range of the circuit. It is important to place the inductor as close to the pins as possible in order to reduce stray inductance. It is recommended to use a high Q, low tolerance inductor for best performance.

Typical tuning range for the integrated varactor is 20-25%.

Component values for various frequencies are given in Table 1. Component values for other frequencies can be found using the SmartRF® Studio software.

17. VCO and PLL self-calibration

To compensate for supply voltage, temperature and process variations the VCO and PLL must be calibrated. The calibration is done automatically and sets maximum VCO tuning range and optimum charge pump current for PLL stability. After setting up the device at the operating frequency, the self-calibration can be initiated by setting the *CAL_START* bit. The calibration result is stored internally in the chip, and is valid as long as power is not turned off. If large supply voltage variations (more than 0.5 V) or temperature variations (more than 40 degrees) occur after calibration, a new calibration should be performed.

The self-calibration is controlled through the *CAL* register (see configuration registers description p. 39). The *CAL_COMPLETE* bit indicates complete calibration. The user can poll this bit, or simply wait for 34 ms (calibration wait time when *CAL_WAIT* = 1). The wait time is proportional to the internal PLL reference frequency. The lowest permitted reference frequency (1 MHz) gives 34 ms wait time, which is therefore the worst case.

Reference frequency [MHz]	Calibration time [ms]
2.4	14
2.0	17
1.5	23
1.0	34

The *CAL_COMPLETE* bit can also be monitored at the CHP_OUT (LOCK) pin (configured by *LOCK_SELECT[3:0])* and used as an interrupt input to the microcontroller.

The CAL_START bit must be set to 0 by the microcontroller after the calibration is done.

There are separate calibration values for the two frequency registers. If the two frequencies, A and B, differ more than 1 MHz, or different VCO currents are used (*VCO_CURRENT[3:0]* in the *CURRENT* register) the calibration should be done separately. When using a 10.7 MHz external IF the LO is 10.7 MHz below/above the transmit frequency, hence separate calibration must be done. The *CAL_DUAL* bit in the *CAL* register controls dual or separate calibration.

The single calibration algorithm, using separate calibration for RX and TX frequency, is illustrated in Figure 16.

In Figure 17 the dual calibration algorithm is shown for two RX frequencies. It could also be used for two TX frequencies, or even for one RX and one TX frequency if the same VCO current is used.

In multi-channel and frequency hopping applications the PLL calibration values may be read and stored for later use. By reading back calibration values and frequency change can be done without doing a re-calibration which could take up to 34 ms. The calibration value is stored in the *TEST0* and *TEST2* registers after a calibration is completed. Note that when using single calibration, calibration values are stored separately for frequency registers A and B. This means that the *TEST0* and *TEST2* registers will contain calibration settings for the currently selected frequency register (selected by *F_REG* in the *MAIN* register). The calibration value can later be written into TEST5 and TEST 6 to bypass the calibration. Note that you must set VCO_OVERRIDE=1 in TEST5 and CHP_OVERRIDE=1 in the TEST6 register.
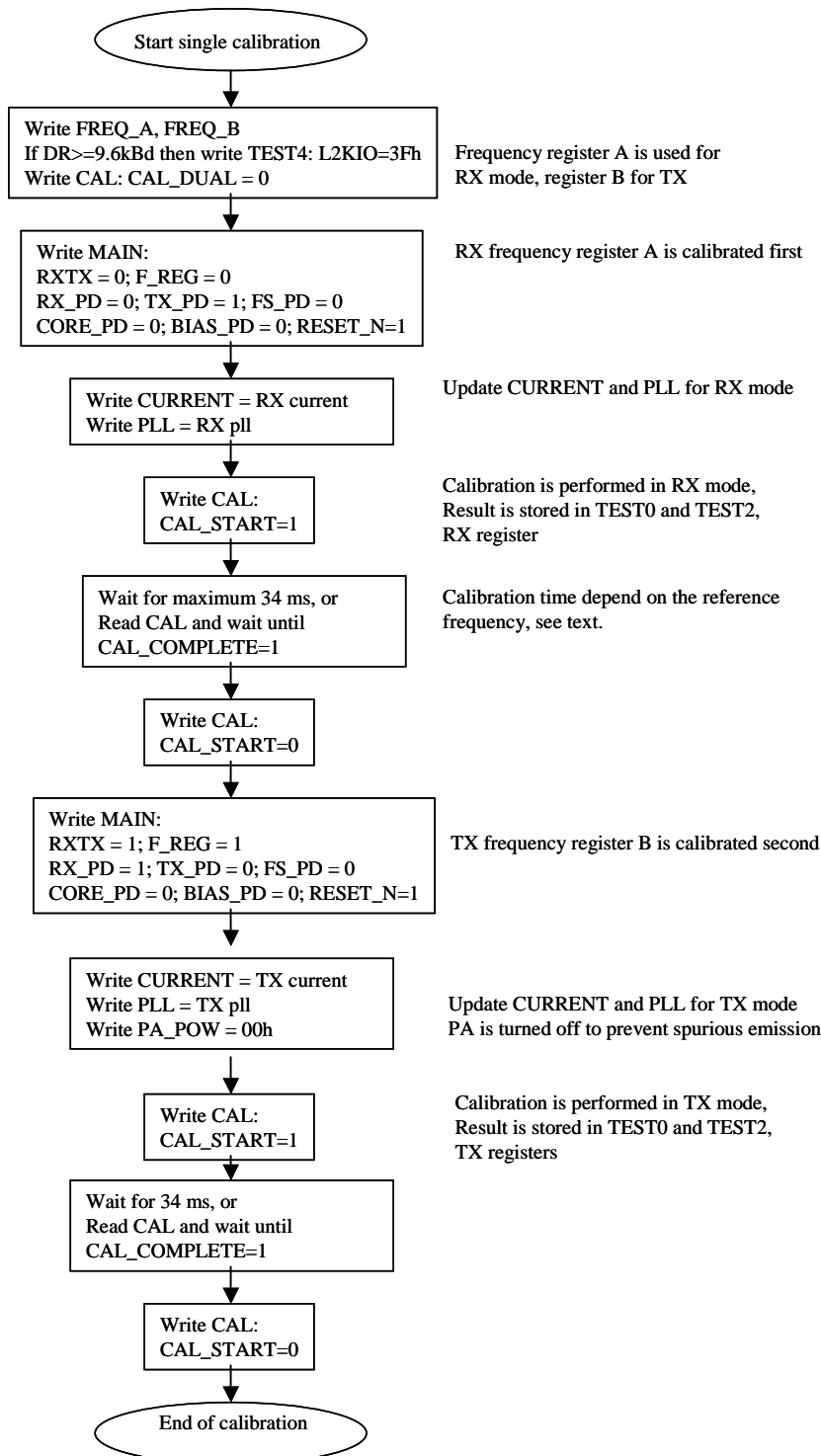

```
            ┌─────────────────────────┐
            (  Start single calibration )
            └─────────────────────────┘
                         │
                         ▼
   ┌──────────────────────────────────────────┐
   │ Write FREQ_A, FREQ_B                      │   Frequency register A is used for
   │ If DR>=9.6kBd then write TEST4: L2KIO=3Fh  │   RX mode, register B for TX
   │ Write CAL: CAL_DUAL = 0                    │
   └──────────────────────────────────────────┘
                         │
                         ▼
   ┌──────────────────────────────────────────┐
   │ Write MAIN:                               │   RX frequency register A is calibrated first
   │ RXTX = 0; F_REG = 0                       │
   │ RX_PD = 0; TX_PD = 1; FS_PD = 0           │
   │ CORE_PD = 0; BIAS_PD = 0; RESET_N=1       │
   └──────────────────────────────────────────┘
                         │
                         ▼
        ┌───────────────────────────────┐   Update CURRENT and PLL for RX mode
        │ Write CURRENT = RX current     │
        │ Write PLL = RX pll             │
        └───────────────────────────────┘
                         │
                         ▼
           ┌─────────────────────┐       Calibration is performed in RX mode,
           │ Write CAL:          │       Result is stored in TEST0 and TEST2,
           │ CAL_START=1         │       RX register
           └─────────────────────┘
                         │
                         ▼
        ┌───────────────────────────────┐   Calibration time depend on the reference
        │ Wait for maximum 34 ms, or     │   frequency, see text.
        │ Read CAL and wait until        │
        │ CAL_COMPLETE=1                 │
        └───────────────────────────────┘
                         │
                         ▼
           ┌─────────────────────┐
           │ Write CAL:          │
           │ CAL_START=0         │
           └─────────────────────┘
                         │
                         ▼
   ┌──────────────────────────────────────────┐
   │ Write MAIN:                               │   TX frequency register B is calibrated second
   │ RXTX = 1; F_REG = 1                       │
   │ RX_PD = 1; TX_PD = 0; FS_PD = 0           │
   │ CORE_PD = 0; BIAS_PD = 0; RESET_N=1       │
   └──────────────────────────────────────────┘
                         │
                         ▼
        ┌───────────────────────────────┐   Update CURRENT and PLL for TX mode
        │ Write CURRENT = TX current     │   PA is turned off to prevent spurious emission
        │ Write PLL = TX pll             │
        │ Write PA_POW = 00h             │
        └───────────────────────────────┘
                         │
                         ▼
           ┌─────────────────────┐       Calibration is performed in TX mode,
           │ Write CAL:          │       Result is stored in TEST0 and TEST2,
           │ CAL_START=1         │       TX registers
           └─────────────────────┘
                         │
                         ▼
        ┌───────────────────────────────┐
        │ Wait for 34 ms, or             │
        │ Read CAL and wait until        │
        │ CAL_COMPLETE=1                 │
        └───────────────────────────────┘
                         │
                         ▼
           ┌─────────────────────┐
           │ Write CAL:          │
           │ CAL_START=0         │
           └─────────────────────┘
                         │
                         ▼
            ┌─────────────────────────┐
            (    End of calibration    )
            └─────────────────────────┘
```

Figure 16. Single calibration algorithm for RX and TX

Start dual calibration

Write FREQ_A, FREQ_B
If DR>=38kBd then write TEST4: L2KIO=3Fh
Write CAL: CAL_DUAL = 1

Frequency registers A and B are both used for RX mode

Write MAIN:
RXTX = 0; F_REG = 0
RX_PD = 0; TX_PD = 1; FS_PD = 0
CORE_PD = 0; BIAS_PD = 0; RESET_N=1

Either frequency register A or B is selected

Write CURRENT= RX current
Write PLL= RX pll

Update CURRENT and PLL for RX mode

Write CAL:
CAL_START=1

Dual calibration is performed.
Result is stored in TEST0 and TEST2,
for both frequency A and B registers

Wait for maximum 34 ms, or
Read CAL and wait until
CAL_COMPLETE=1

Calibration time depend on the reference frequency, see text.

Write CAL:
CAL_START=0

End of calibration

Figure 17. Dual calibration algorithm for RX mode

18. VCO and LNA current control

The VCO current is programmable and should be set according to operating frequency RX/TX mode and output power. Recommended settings for the *VCO_CURRENT* bits in the *CURRENT* register are shown in the tables on page 41.

The bias current for the LNA, and the LO and PA buffers are also programmable. Table 10 shows the current consumption and receiver sensitivity for different settings (2.4 kBaud Manchester encoded data).

RF freq-uency [MHz]	Current consumption [mA]	Sensitivity [dBm]	CURRENT register			FRONT_END register	
			VCO_CURRENT [3:0]	LO_DRIVE [1:0]	PA_DRIVE [1:0]	BUF_CURRENT	LNA_CURRENT[1:0]
433	9.3	-110	0100	01	00	0	10
433	7.4	-109	0100	00	00	0	00
868	11.8	-107	1000	11	00	1	10
868	9.6	-105	1000	10	00	0	00

Note: Current consumption and sensitivity are typical figures at 2.4 kBaud Manchester encoded data, BER 10^{-3}

Table 10. Receiver sensitivity as function of current consumption

19. Power management

CC1000 offers great flexibility for power management in order to meet strict power consumption requirements in battery operated applications. Power Down mode is controlled through the *MAIN* register. There are separate bits to control the RX part, the TX part, the frequency synthesiser and the crystal oscillator (see page 39). This individual control can be used to optimise for lowest possible current consumption in a certain application.

A typical power-on and initialising sequence for minimum power consumption is shown in Figure 18 and Figure 19.

PALE should be tri-stated or set to a high level during power down mode in order to prevent a trickle current from flowing in the internal pull-up resistor.

PA_POW should be set to 00h before power down mode to ensure lowest possible leakage current.
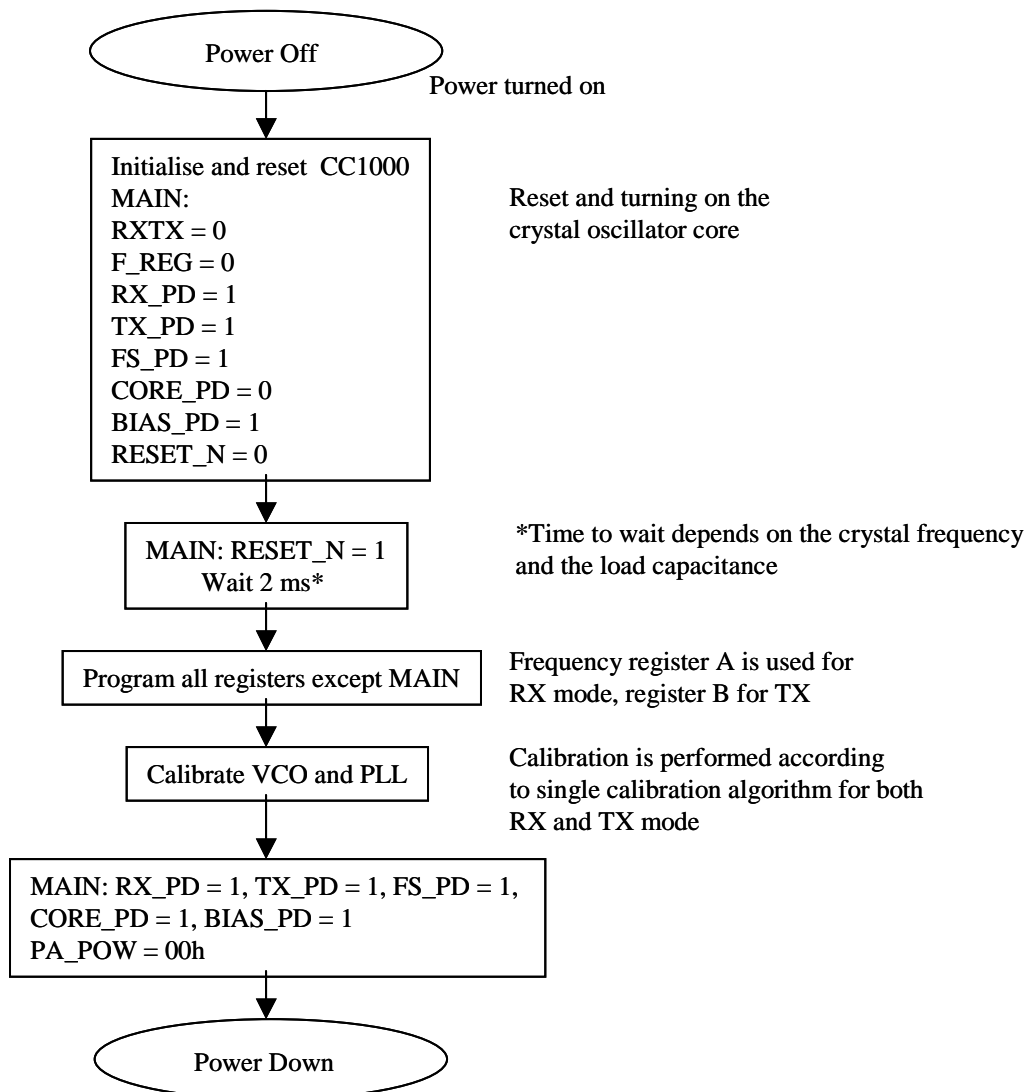
Figure 18. Initializing sequence

*Time to wait depends on the crystal frequency and the load capacitance
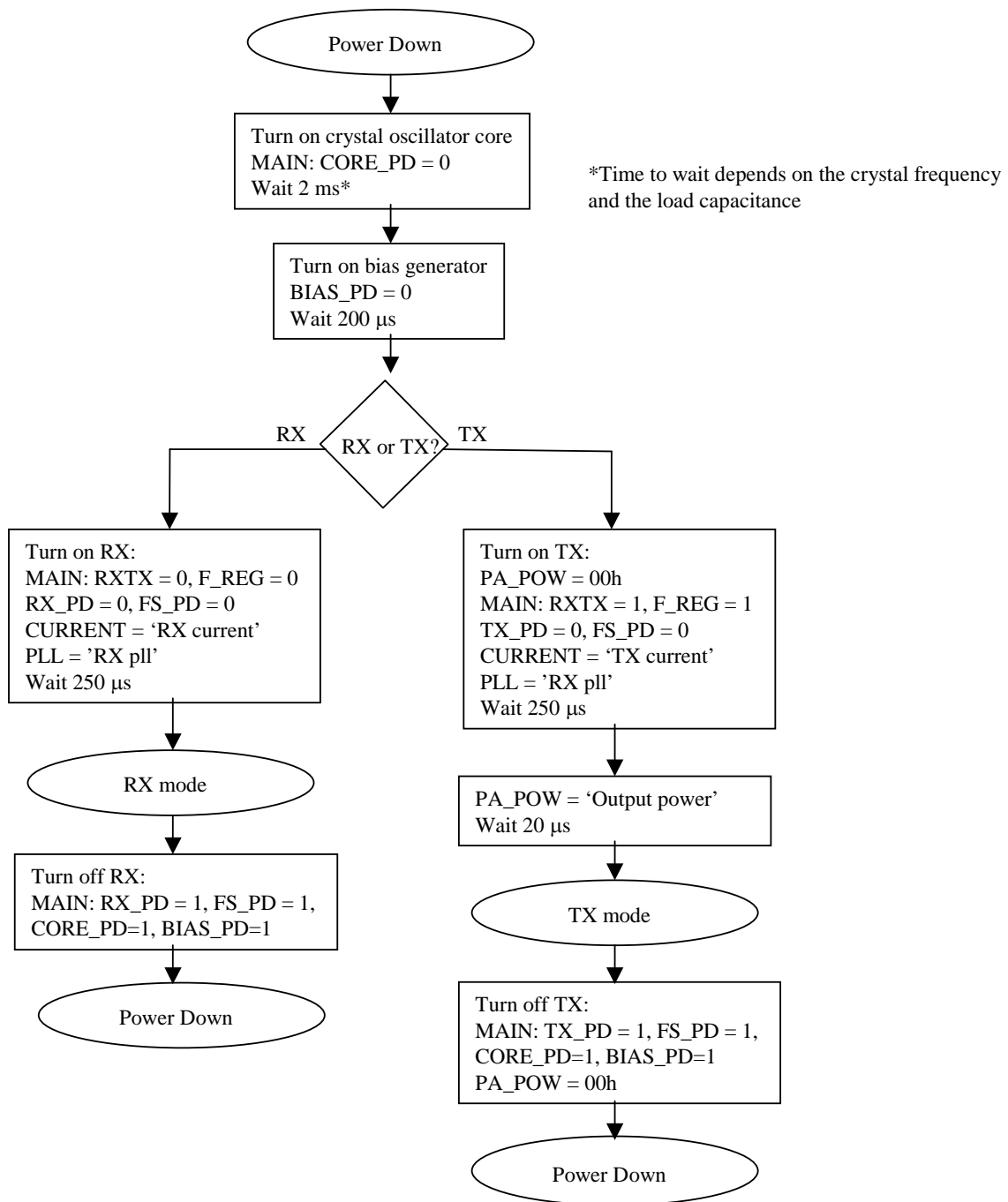
Figure 19. Sequence for activating RX or TX mode

20. Input / Output Matching

A few passive external components combined with the internal T/R switch circuitry ensures match in both RX and TX mode. The matching network is shown in Figure 20.

Component values for various frequencies are given in Table 1. Component values for other frequencies can be found using the configuration software.
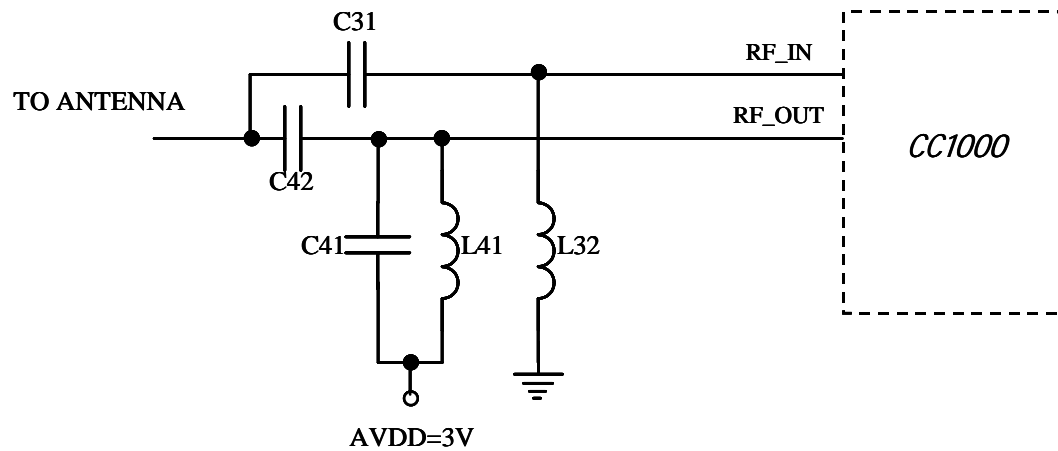
Figure 20. Input/output matching network

21. Output power programming

The RF output power is programmable and controlled by the PA_POW register. Table 11 shows the closest programmable value for output powers in steps of 1 dB. The typical current consumption is also shown.

In power down mode the PA_POW should be set to 00h for minimum leakage current.

Output power [dBm]	RF frequency 433 MHz		RF frequency 868 MHz	
	PA_POW [hex]	Current consumption, typ. [mA]	PA_POW [hex]	Current consumption, typ. [mA]
-20	01	6.9	02	8.6
-19	01	6.9	02	8.8
-18	02	7.1	03	9.0
-17	02	7.1	03	9.0
-16	02	7.1	04	9.1
-15	03	7.4	05	9.3
-14	03	7.4	05	9.3
-13	03	7.4	06	9.5
-12	04	7.6	07	9.7
-11	04	7.6	08	9.9
-10	05	7.9	09	10.1
-9	05	7.9	0B	10.4
-8	06	8.2	0C	10.6
-7	07	8.4	0D	10.8
-6	08	8.7	0F	11.1
-5	09	8.9	40	13.8
-4	0A	9.6	50	14.5
-3	0B	9.4	50	14.5
-2	0C	9.7	60	15.1
-1	0E	10.2	70	15.8
0	0F	10.4	80	16.8
1	40	11.8	90	17.2
2	50	12.8	B0	18.5
3	50	12.8	C0	19.2
4	60	13.8	F0	21.3
5	70	14.8	FF	25.4
6	80	15.8		
7	90	16.8		
8	C0	20.0		
9	E0	22.1		
10	FF	26.7		

Table 11. Output power settings and typical current consumption

22. RSSI output

CC1000 has a built-in RSSI (Received Signal Strength Indicator) giving an analogue output signal at the RSSI/IF pin. The *IF_RSSI* bits in the *FRONT_END* register enable the RSSI. When the RSSI function is enabled, the output current of this pin is <u>inversely</u> proportional to the input signal level. The output should be terminated in a resistor to convert the current output into a voltage. A capacitor is used in order to low-pass filter the signal.

The RSSI voltage range from 0 – 1.2 V when using a 27 kΩ terminating resistor, giving approximately 50 dB/V. This RSSI voltage can be measured by an A/D converter. Note that a higher voltage means a lower input signal.

The RSSI measures the power referred to the RF_IN pin. The input power can be calculated using the following equations:

$P = -51.3 \ V_{RSSI} - 49.2$ [dBm] at 433 MHz
$P = -50.0 \ V_{RSSI} - 45.5$ [dBm] at 868 MHz

The external network for RSSI operation is shown in Figure 21. R281 = 27 kΩ, C281 = 1nF.

A typical plot of RSSI voltage as function of input power is shown in Figure 22.
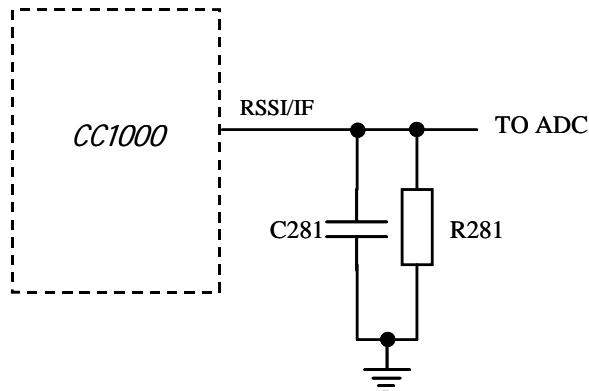
Figure 21. RSSI circuit
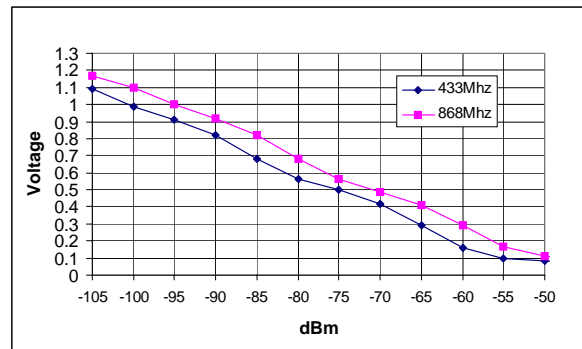
Figure 22. RSSI voltage vs. input power

23. IF output

CC1000 has a built-in 10.7 MHz IF output buffer. This buffer could be applied in narrowband applications with requirements on mirror image filtering. The system is then built with *CC1000*, a 10.7 MHz ceramic filter and an external 10.7 MHz demodulator. The external network for IF output operation is shown in Figure 23. R281 = 470 Ω, C281 = 3.3nF.

The external network provides 330 Ω source impedance for the 10.7 MHz ceramic filter.
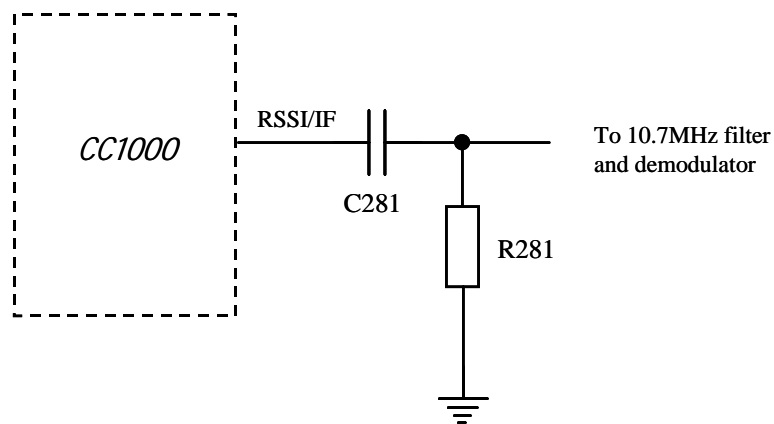
Figure 23. IF output circuit

24. Crystal oscillator

CC1000 has an advanced amplitude regulated crystal oscillator. A high current is used to start up the oscillations. When the amplitude builds up, the current is reduced to what is necessary to maintain a 600 mVpp amplitude. This ensures a fast start-up, keeps the current consumption as well as the drive level to a minimum and makes the oscillator insensitive to ESR variations.

An external clock signal or the internal crystal oscillator can be used as main frequency reference. An external clock signal should be connected to XOSC_Q1, while XOSC_Q2 should be left open. The *XOSC_BYPASS* bit in the *FRONT_END* register should be set when an external clock signal is used.

The crystal frequency should be in the range 3-4, 6-8 or 9-16 MHz. Because the crystal frequency is used as reference for the data rate (as well as other internal functions), the following frequencies are recommended: 3.6864, 7.3728, 11.0592 or 14.7456 MHz. These frequencies will give accurate data rates. The crystal frequency range is selected by *XOSC_FREQ1:0* in the *MODEM0* register.

To operate in synchronous mode at data rates different from the standards at 1.2, 2.4, 4.8 kBaud and so on, the crystal frequency can be scaled. The data rate (DR) will change proportionally to the new crystal frequency (f). To calculate the new crystal frequency:

$$f_{xtal\_new} = f_{xtal} \frac{DR_{new}}{DR}$$

Using the internal crystal oscillator, the crystal must be connected between XOSC_Q1 and XOSC_Q2. The oscillator is designed for parallel mode operation of the crystal. In addition loading capacitors (C171 and C181) for the crystal are required. The loading capacitor values depend on the total load capacitance, C_L, specified for the crystal. The total load capacitance seen between the crystal terminals should equal C_L for the crystal to oscillate at the specified frequency.

$$C_L = \frac{1}{\dfrac{1}{C_{171}} + \dfrac{1}{C_{181}}} + C_{parasitic}$$

The parasitic capacitance is constituted by pin input capacitance and PCB stray capacitance. Typically the total parasitic capacitance is 8 pF. A trimming capacitor may be placed across C171 for initial tuning if necessary.

The crystal oscillator circuit is shown in Figure 24. Typical component values for different values of C_L are given in Table 12.

The initial tolerance, temperature drift, ageing and load pulling should be carefully specified in order to meet the required frequency accuracy in a certain application. By specifying the *total* expected frequency accuracy in SmartRF® Studio together with data rate and frequency separation, the software will calculate the total bandwidth and compare to the available IF bandwidth.
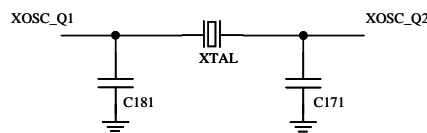

Figure 24. Crystal oscillator circuit

Item	C_L= 12 pF	C_L= 16 pF	C_L= 22 pF
C171	6.8 pF	18 pF	33 pF
C181	6.8 pF	18 pF	33 pF

Table 12. Crystal oscillator component values

25. Optional LC Filter

An optional LC filter may be added between the antenna and the matching network in certain applications. The filter will reduce the emission of harmonics and increase the receiver selectivity.

The filter topology is shown in Figure 25. Component values are given in Table 13. The filter is designed for 50 Ω terminations. The component values may have to be tuned to compensate for layout parasitics.
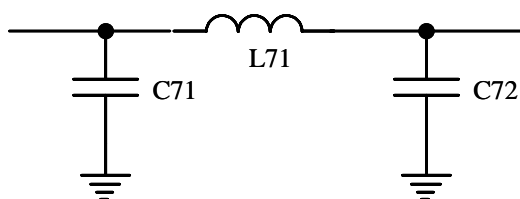

Figure 25. LC filter

Item	315 MHz	433 MHz	868 MHz	915 MHz
C71	30 pF	20 pF	10 pF	10 pF
C72	30 pF	20 pF	10 pF	10 pF
L71	15 nH	12 nH	5.6 nH	4.7 nH

Table 13. LC filter component values

26. System Considerations and Guidelines

26.1 SRD regulations
International regulations and national laws regulate the use of radio receivers and transmitters. SRDs (Short Range Devices) for licence free operation are allowed to operate in the 433 and 868-870 MHz bands in most European countries. In the United States such devices operate in the 260–470 and 902-928 MHz bands. *CC1000* is designed to meet the requirements for operation in all these bands. A summary of the most important aspects of these regulations can be found in Application Note *AN001 SRD regulations for licence free transceiver operation*, available from Chipcon's web site.

26.2 Low cost systems
In systems where low cost is of great importance the *CC1000* is the ideal choice. Very few external components keep the total cost at a minimum. The oscillator crystal can then be a low cost crystal with 50 ppm frequency tolerance.

26.3 Battery operated systems
In low power applications the power down mode should be used when not being active. Depending on the start-up time requirement, the oscillator core can be powered during power down. See page 28 for information on how effective power management can be implemented.

26.4 Crystal drift compensation
A unique feature in *CC1000* is the very fine frequency resolution of 250 Hz. This can be used to do the temperature compensation of the crystal if the temperature drift curve is known and a temperature sensor is included in the system. Even initial adjustment can be done using the frequency programmability. This eliminates the need for an expensive TCXO and trimming in some applications. In less demanding applications a crystal with low temperature drift and low ageing could be used without further compensation. A trimmer capacitor in the crystal oscillator circuit (in parallel with C171) could be used to set the initial frequency accurately. The fine frequency step programming cannot be used in RX mode if optimised frequency settings are required (see page 24).

26.5 High reliability systems
Using a SAW filter as a preselector will improve the communication reliability in harsh environments by reducing the probability of blocking. The receiver sensitivity and the output power will be reduced due to the filter insertion loss. By inserting the filter in the RX path only, together with an external RX/TX switch, only the receiver sensitivity is reduced, and output power is remained. The CHP_OUT (LOCK) pin can be configured to control an external LNA, RX/TX switch or power amplifier. This is controlled by *LOCK_SELECT* in the *LOCK* register.

26.6 Frequency hopping spread spectrum systems
Due to the very fast frequency shift properties of the PLL, the *CC1000* is also suitable for frequency hopping systems. Hop rates of 1-100 hops/s are usually used depending on the bit rate and the amount of data to be sent during each transmission. The two frequency registers (*FREQ_A* and *FREQ_B*) are designed such that the 'next' frequency can be programmed while the 'present' frequency is used. The switching between the two frequencies is done through the *MAIN* register.

27. PCB Layout Recommendations

Chipcon provide reference layouts that should be followed in order to achieve the best performance. The Chipcon reference design (CC1000PP and CC1000uCSP_EM) can be downloaded from the Chipcon website.

A two layer PCB is highly recommended. The bottom layer of the PCB should be the "ground-layer".

The top layer should be used for signal routing, and the open areas should be filled with etallization connected to ground using several vias.

The ground pins should be connected to ground as close as possible to the package pin using individual vias. The de-coupling capacitors should also be placed as close as possible to the supply pins and connected to the ground plane by separate vias.

The external components should be as small as possible and surface mount devices are required. The VCO inductor must be placed as close as possible to the chip and symmetrical with respect to the input pins.

Precaution should be used when placing the microcontroller in order to avoid interference with the RF circuitry.

In certain applications where the ground plane for the digital circuitry is expected to be noisy, the ground plane may be split in an analogue and a digital part. All AGND pins and AVDD de-coupling capacitors should be connected to the analogue ground plane. All DGND pins and DVDD de-coupling capacitors should be connected to the digital ground. The connection between the two ground planes should be implemented as a star connection with the power supply ground.

A development kit with a fully assembled PCB is available, and can be used as a guideline for layout.

28. Antenna Considerations

CC1000 can be used together with various types of antennas. The most common antennas for short range communication are monopole, helical and loop antennas.

Monopole antennas are resonant antennas with a length corresponding to one quarter of the electrical wavelength (λ/4). They are very easy to design and can be implemented simply as a "piece of wire" or even integrated into the PCB.

Non-resonant monopole antennas shorter than λ/4 can also be used, but at the expense of range. In size and cost critical applications such an antenna may very well be integrated into the PCB.

Helical antennas can be thought of as a combination of a monopole and a loop antenna. They are a good compromise in size critical applications. But helical antennas tend to be more difficult to optimise than the simple monopole.

Loop antennas are easy to integrate into the PCB, but are less effective due to difficult impedance matching because of their very low radiation resistance.

For low power applications the λ/4-monopole antenna is recommended giving the best range and because of its simplicity.

The length of the λ/4-monopole antenna is given by:

$$L = 7125 / f$$

where f is in MHz, giving the length in cm. An antenna for 869 MHz should be 8.2 cm, and 16.4 cm for 434 MHz.

The antenna should be connected as close as possible to the IC. If the antenna is located away from the input pin the antenna should be matched to the feeding transmission line (50 Ω).

For a more thorough primer on antennas, please refer to Application *Note AN003 SRD Antennas* available from Chipcon's web site.

29. Configuration registers

The configuration of _CC1000_ is done by programming 22 8-bit configuration registers. The configuration data based on selected system parameters are most easily found by using the SmartRF®

Studio software. A complete description of the registers are given in the following tables. After a RESET is programmed all the registers have default values.

REGISTER OVERVIEW

ADDRESS	Byte Name	Description
00h	MAIN	MAIN Register
01h	FREQ_2A	Frequency Register 2A
02h	FREQ_1A	Frequency Register 1A
03h	FREQ_0A	Frequency Register 0A
04h	FREQ_2B	Frequency Register 2B
05h	FREQ_1B	Frequency Register 1B
06h	FREQ_0B	Frequency Register 0B
07h	FSEP1	Frequency Separation Register 1
08h	FSEP0	Frequency Separation Register 0
09h	CURRENT	Current Consumption Control Register
0Ah	FRONT_END	Front End Control Register
0Bh	PA_POW	PA Output Power Control Register
0Ch	PLL	PLL Control Register
0Dh	LOCK	LOCK Status Register and signal select to CHP_OUT (LOCK) pin
0Eh	CAL	VCO Calibration Control and Status Register
0Fh	MODEM2	Modem Control Register 2
10h	MODEM1	Modem Control Register 1
11h	MODEM0	Modem Control Register 0
12h	MATCH	Match Capacitor Array Control Register for RX and TX impedance matching
13h	FSCTRL	Frequency Synthesiser Control Register
14h		Reserved
15h		Reserved
16h		Reserved
17h		Reserved
18h		Reserved
19h		Reserved
1Ah		Reserved
1Bh		Reserved
1Ch	PRESCALER	Prescaler and IF-strip test control register
40h	TEST6	Test register for PLL LOOP
41h	TEST5	Test register for PLL LOOP
42h	TEST4	Test register for PLL LOOP (must be updated as specified)
43h	TEST3	Test register for VCO
44h	TEST2	Test register for Calibration
45h	TEST1	Test register for Calibration
46h	TEST0	Test register for Calibration

MAIN Register (00h)

REGISTER	NAME	Default value	Active	Description
MAIN[7]	RXTX	-	-	RX/TX switch, 0 : RX , 1 : TX
MAIN[6]	F_REG	-	-	Selection of Frequency Register, 0 : Register A, 1 : Register B
MAIN[5]	RX_PD	-	H	Power Down of LNA, Mixer, IF, Demodulator, RX part of Signal Interface
MAIN[4]	TX_PD	-	H	Power Down of TX part of Signal Interface, PA
MAIN[3]	FS_PD	-	H	Power Down of Frequency Synthesiser
MAIN[2]	CORE_PD	-	H	Power Down of Crystal Oscillator Core
MAIN[1]	BIAS_PD	-	H	Power Down of BIAS (Global_Current_Generator) and Crystal Oscillator Buffer
MAIN[0]	RESET_N	-	L	Reset, active low. Writing RESET_N low will write default values to all other registers than MAIN. Bits in MAIN do not have a default value, and will be written directly through the configurations interface. Must be set high to complete reset.

FREQ_2A Register (01h)

REGISTER	NAME	Default value	Active	Description
FREQ_2A[7:0]	FREQ_A[23:16]	01110101	-	8 MSB of frequency control word A

FREQ_1A Register (02h)

REGISTER	NAME	Default value	Active	Description
FREQ_1A[7:0]	FREQ_A[15:8]	10100000	-	Bit 15 to 8 of frequency control word A

FREQ_0A Register (03h)

REGISTER	NAME	Default value	Active	Description
FREQ_0A[7:0]	FREQ_A[7:0]	11001011	-	8 LSB of frequency control word A

FREQ_2B Register (04h)

REGISTER	NAME	Default value	Active	Description
FREQ_2B[7:0]	FREQ_B[23:16]	01110101	-	8 MSB of frequency control word B

FREQ_1B Register (05h)

REGISTER	NAME	Default value	Active	Description
FREQ_1B[7:0]	FREQ_B[15:8]	10100101	-	Bit 15 to 8 of frequency control word B

FREQ_0B Register (06h)

REGISTER	NAME	Default value	Active	Description
FREQ_0B[7:0]	FREQ_B[7:0]	01001110	-	8 LSB of frequency control word B

FSEP1 Register (07h)

REGISTER	NAME	Default value	Active	Description
FSEP1[7:3]	-	-	-	Not used
FSEP1[2:0]	FSEP_MSB[2:0]	000	-	3 MSB of frequency separation control

FSEP0 Register (08h)

REGISTER	NAME	Default value	Active	Description
FSEP0[7:0]	FSEP_LSB[7:0]	01011001	-	8 LSB of frequency separation control

CURRENT Register (09h)

REGISTER	NAME	Default value	Active	Description
CURRENT[7:4]	VCO_CURRENT[3:0]	1100	-	Control of current in VCO core for TX and RX 0000 : 150μA 0001 : 250μA 0010 : 350μA 0011 : 450μA 0100 : 950μA, use for RX, f= 400 – 500 MHz 0101 : 1050μA 0110 : 1150μA 0111 : 1250μA 1000 : 1450μA, use for RX, f<400 MHz and f>500 MHz; and TX, f= 400 – 500 MHz 1001 : 1550μA, use for TX, f<400 MHz 1010 : 1650μA 1011 : 1750μA 1100 : 2250μA 1101 : 2350μA 1110 : 2450μA 1111 : 2550μA, use for TX, f>500 MHz
CURRENT[3:2]	LO_DRIVE[1:0]	10		Control of current in VCO buffer for LO drive 00 : 0.5mA, use for TX 01 : 1.0mA , use for RX, f<500 MHz* 10 : 1.5mA, 11 : 2.0mA, use for RX, f>500 MHz * * LO_DRIVE can be reduced to save current in RX mode. See Table 10 for details
CURRENT[1:0]	PA_DRIVE[1:0]	10		Control of current in VCO buffer for PA 00 : 1mA, use for RX 01 : 2mA, use for TX, f<500 MHz 10 : 3mA 11 : 4mA, use for TX, f>500 MHz

FRONT_END Register (0Ah)

REGISTER	NAME	Default value	Active	Description
FRONT_END[7:6]	-	00	-	Not used
FRONT_END[5]	BUF_CURRENT	0	-	Control of current in the LNA_FOLLOWER 0 : 520uA, use for f<500 MHz 1 : 690uA, use for f>500 MHz * *BUF_CURRENT can be reduced to save current in RX mode. See Table 10 for details.
FRONT_END[4:3]	LNA_CURRENT [1:0]	01	-	Control of current in LNA 00 : 0.8mA, use for f<500 MHz * 01 : 1.4mA 10 : 1.8mA, use for f>500 MHz * 11 : 2.2mA *LNA_CURRENT can be reduced to save current in RX mode. See Table 10 for details.
FRONT_END[2:1]	IF_RSSI[1:0]	00	-	Control of IF_RSSI pin 00 : Internal IF and demodulator, RSSI inactive 01 : RSSI active, RSSI/IF is analog RSSI output 10 : External IF and demodulator, RSSI/IF is mixer output. Internal IF in power down mode. 11 : Not used
FRONT_END[0]	XOSC_BYPASS	0	-	0 : Internal XOSC enabled 1 : Power-Down of XOSC, external CLK used

PA_POW Register (0Bh)

REGISTER	NAME	Default value	Active	Description
PA_POW[7:4]	PA_HIGHPOWER[3:0]	0000	-	Control of output power in high power array. Should be 0000 in PD mode . See Table 11 page 32 for details.
PA_POW[3:0]	PA_LOWPOWER[3:0]	1111	-	Control of output power in low power array Should be 0000 in PD mode. See Table 11 page 32 for details.

PLL Register (0Ch)

REGISTER	NAME	Default value	Active	Description
PLL[7]	EXT_FILTER	0	-	1 : External loop filter 0 : Internal loop filter 1-to-0 transition samples F_COMP comparator when BREAK_LOOP=1 (TEST3)
PLL[6:3]	REFDIV[3:0]	0010	-	Reference divider 0000 : Not allowed 0001 : Not allowed 0010 : Divide by 2 0011 : Divide by 3 .... 1111 : Divide by 15
PLL[2]	ALARM_DISABLE	0	h	0 : Alarm function enabled 1 : Alarm function disabled
PLL[1]	ALARM_H	-	-	Status bit for tuning voltage out of range (too close to VDD)
PLL[0]	ALARM_L	-	-	Status bit for tuning voltage out of range (too close to GND)

LOCK Register (0Dh)

REGISTER	NAME	Default value	Active	Description
LOCK[7:4]	LOCK_SELECT[3:0]	0000	-	Selection of signals to CHP_OUT (LOCK) pin 0000 : Normal, pin can be used as CHP_OUT 0001 : LOCK_CONTINUOUS (active high) 0010 : LOCK_INSTANT (active high) 0011 : ALARM_H (active high) 0100 : ALARM_L (active high) 0101 : CAL_COMPLETE (active high) 0110 : IF_OUT 0111 : REFERENCE_DIVIDER Output 1000 : TX_PDB (active high, activates external PA when TX_PD=0) 1001 : Manchester Violation (active high) 1010 : RX_PDB (active high, activates external LNA when RX_PD=0) 1011 : Not defined 1100 : Not defined 1101 : LOCK_AVG_FILTER 1110 : N_DIVIDER Output 1111 : F_COMP
LOCK[3]	PLL_LOCK_ ACCURACY	0	-	0 : Sets Lock Threshold = 127, Reset Lock Threshold = 111. Corresponds to a worst case accuracy of 0.7% 1 : Sets Lock Threshold = 31, Reset Lock Threshold =15. Corresponds to a worst case accuracy of 2.8%
LOCK[2]	PLL_LOCK_ LENGTH	0	-	0 : Normal PLL lock window 1 : Not used
LOCK[1]	LOCK_INSTANT	-	-	Status bit from Lock Detector
LOCK[0]	LOCK_CONTINUOUS	-	-	Status bit from Lock Detector

CAL Register (0Eh)

REGISTER	NAME	Default value	Active	Description
CAL[7]	CAL_START	0	↑	↑ 1 : Calibration started 0 : Calibration inactive CAL_START must be set to 0 after calibration is done
CAL[6]	CAL_DUAL	0	H	1 : Store calibration in both A and B 0 : Store calibration in A or B defined by MAIN[6]
CAL[5]	CAL_WAIT	0	H	1 : Normal Calibration Wait Time 0 : Half Calibration Wait Time The calibration time is proportional to the internal reference frequency. 2 MHz reference frequency gives 14 ms wait time.
CAL[4]	CAL_CURRENT	0	H	1 : Calibration Current Doubled 0 : Normal Calibration Current
CAL[3]	CAL_COMPLETE	0	H	Status bit defining that calibration is complete
CAL[2:0]	CAL_ITERATE	101	H	Iteration start value for calibration DAC 000 – 101: Not used 110 : Normal start value 111 : Not used

MODEM2 Register (0Fh)

REGISTER	NAME	Default value	Active	Description
MODEM2[7]	PEAKDETECT	1	H	Peak Detector and Remover disabled or enabled 0 : Peak detector and remover is disabled 1 : Peak detector and remover is enabled
MODEM2[6:0]	PEAK_LEVEL_OFFSET[6:0]	0010110	-	Threshold level for Peak Remover in Demodulator. Correlated to frequency deviation, see note.

Note: PEAK_LEVEL_OFFSET[6:0] = $\dfrac{Fs}{IF_{low}} - \dfrac{Fs}{IF_{low} + \Delta f / 2} \cdot \dfrac{5}{8}$ where $Fs = \dfrac{f\_xosc}{XOSC\_FREQ + 1}$

and $IF_{low} = 150kHz - 2 \bullet f\_rf \bullet XTAL\_accuracy$ and Δf is the separation

MODEM1 Register (10h)

REGISTER	NAME	Default value	Active	Description
MODEM1[7:5]	MLIMIT	011	-	Sets the limit for the Manchester Violation Flag. A Manchester Value = 14 is a perfect bit and a Manchester Value = 0 is a constant level (an unbalanced corrupted bit) 000 : No Violation Flag is set 001 : Violation Flag is set for Manchester Value < 1 010 : Violation Flag is set for Manchester Value < 2 011 : Violation Flag is set for Manchester Value < 3 100 : Violation Flag is set for Manchester Value < 4 101 : Violation Flag is set for Manchester Value < 5 110 : Violation Flag is set for Manchester Value < 6 111 : Violation Flag is set for Manchester Value < 7
MODEM1[4]	LOCK_AVG_IN	0	H	Lock control bit of Average Filter 0 : Average Filter is free-running 1 : Average Filter is locked
MODEM1[3]	LOCK_AVG_MODE	0	-	Automatic lock of Average Filter 0 : Lock of Average Filter is controlled automatically 1 : Lock of Average Filter is controlled by LOCK_AVG_IN
MODEM1[2:1]	SETTLING[1:0]	11	-	Settling Time of Average Filter 00 : 11 baud settling time, worst case 1.2dB loss in sensitivity 01 : 22 baud settling time, worst case 0.6dB loss in sensitivity 10 : 43 baud settling time, worst case 0.3dB loss in sensitivity 11 : 86 baud settling time, worst case 0.15dB loss in sensitivity
MODEM1[0]	MODEM_RESET_N	1	L	Separate reset of MODEM

MODEM0 Register (11h)

REGISTER	NAME	Default value	Active	Description
MODEM0[7]	-	-	-	Not used
MODEM0[6:4]	BAUDRATE[2:0]	010	-	000 : 0.6 kBaud 001 : 1.2 kBaud 010 : 2.4 kBaud 011 : 4.8 kBaud 100 : 9.6 kBaud 101 : 19.2, 38.4 and 76.8 kBaud 110 : Not used 111 : Not used
MODEM0[3:2]	DATA_FORMAT[1:0]	01	-	00 : NRZ operation. 01 : Manchester operation 10 : Transparent Asyncronous UART operation 11 : Not used
MODEM0[1:0]	XOSC_FREQ[1:0]	00	-	Selection of XTAL frequency range 00 : 3MHz – 4MHz crystal, 3.6864MHz recommended Also used for 76.8 kBaud, 14.7456MHz 01 : 6MHz – 8MHz crystal, 7.3728MHz recommended Also used for 38.4 kBaud, 14.7456MHz 10 : 9MHz – 12MHz crystal, 11.0592 MHz recommended 11 : 12MHz – 16MHz crystal, 14.7456MHz recommended

MATCH Register (12h)

REGISTER	NAME	Default value	Active	Description
MATCH[7:4]	RX_MATCH[3:0]	0000	-	Selects matching capacitor array value for RX, step size is 0.4 pF 0001: Use for RF frequency > 500 MHz 0111: Use for RF frequency < 500 MHz
MATCH[3:0]	TX_MATCH[3:0]	0000	-	Selects matching capacitor array value for TX, step size is 0.4 pF

FSCTRL Register (13h)

REGISTER	NAME	Default value	Active	Description
FSCTRL[7:4]	-	-	-	Not used
FSCTRL[3:1]				Reserved
FSCTRL[0]	FS_RESET_N	1	L	Separate reset of frequency synthesizer

PRESCALER Register (1Ch)

REGISTER	NAME	Default value	Active	Description
PRESCALER[7:6]	PRE_SWING[1:0]	00	-	Prescaler swing. Fractions for PRE_CURRENT[1:0] = 00 00 : 1 * Nominal Swing 01 : 2/3 * Nominal Swing 10 : 7/3 * Nominal Swing 11 : 5/3 * Nominal Swing
PRESCALER[5:4]	PRE_CURRENT [1:0]	00	-	Prescaler current scaling 00 : 1 * Nominal Current 01 : 2/3 * Nominal Current 10 : 1/2 * Nominal Current 11 : 2/5 * Nominal Current
PRESCALER[3]	IF_INPUT	0	-	0 : Nominal setting 1 : RSSI/IF pin is input to IF-strips
PRESCALER[2]	IF_FRONT	0	-	0 : Nominal setting 1 : Output of IF_Front_amp is switched to RSSI/IF pin
PRESCALER[1:0]	-	00	-	Not used

TEST6 Register (for test only, 40h)

REGISTER	NAME	Default value	Active	Description
TEST6[7]	LOOPFILTER_TP1	0	-	1 : Select testpoint 1 to CHP_OUT 0 : CHP_OUT tied to GND
TEST6 [6]	LOOPFILTER_TP2	0	-	1 : Select testpoint 2 to CHP_OUT 0 : CHP_OUT tied to GND
TEST6 [5]	CHP_OVERRIDE	0	-	1 : use CHP_CO[4:0] value 0 : use calibrated value
TEST6[4:0]	CHP_CO[4:0]	10000	-	Charge_Pump Current DAC override value

TEST5 Register (for test only, 41h)

REGISTER	NAME	Default value	Active	Description
TEST5[7:6]	-	-	-	Not used
TEST5[5]	CHP_DISABLE	0	-	1 : CHP up and down pulses disabled 0 : normal operation
TEST5[4]	VCO_OVERRIDE	0	-	1 : use VCO_AO[2:0] value 0 : use calibrated value
TEST5[3:0]	VCO_AO[3:0]	1000	-	VCO_ARRAY override value

TEST4 Register (for test only, 42h)

REGISTER	NAME	Default value	Active	Description
TEST4[7:6]	-	-	-	Not used
TEST4[5:0]	L2KIO[5:0]	100101	h	Constant setting charge pump current scaling/rounding factor. Sets Bandwidth of PLL. Use 3Fh for 9.6 kBaud and higher

TEST3 Register (for test only, 43h)

REGISTER	NAME	Default value	Active	Description
TEST3[7:5]	-	-	-	Not used
TEST3[4]	BREAK_LOOP	0	-	1 : PLL loop open 0 : PLL loop closed
TEST3[3:0]	CAL_DAC_OPEN	0100	-	Calibration DAC override value, active when BREAK_LOOP =1

TEST2 Register (for test only, 44h)

REGISTER	NAME	Default value	Active	Description
TEST2[7:5]	-	-	-	Not used
TEST2[4:0]	CHP_CURRENT [4:0]	-	-	Status vector defining applied CHP_CURRENT value

TEST1 Register (for test only, 45h)

REGISTER	NAME	Default value	Active	Description
TEST1[7:4]	-	-	-	Not used
TEST1[3:0]	CAL_DAC[3:0]	-	-	Status vector defining applied Calibration DAC value

TEST0 Register (for test only, 46h)

REGISTER	NAME	Default value	Active	Description
TEST0[7:4]	-	-	-	Not used
TEST0[3:0]	VCO_ARRAY[3:0]	-	-	Status vector defining applied VCO_ARRAY value

30. Package Description (TSSOP-28)
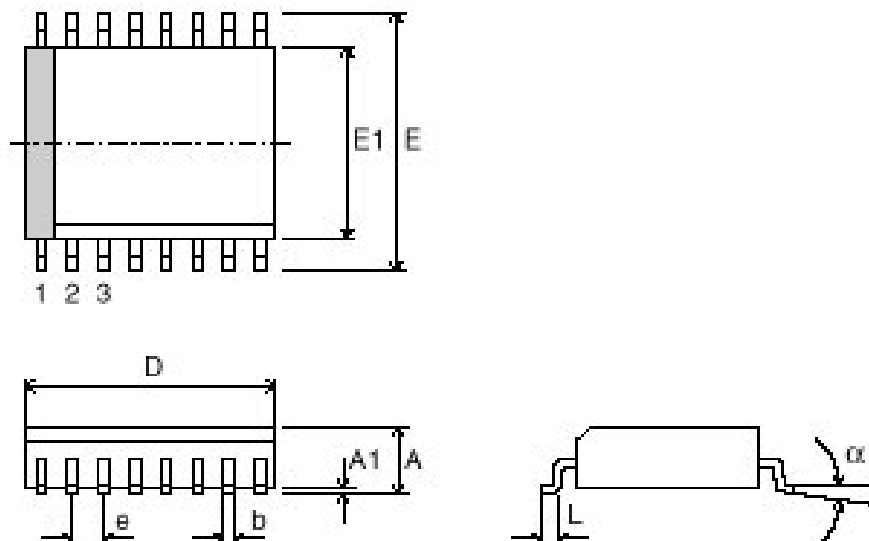
Note: The figure is an illustration only.

Thin Shrink Small Outline Package (TSSOP)										
		D	E1	E	A	A1	e	B	L	Copl.	α
TSSOP 28	Min	9.60	4.30	6.40		0.05	0.65	0.19	0.45		0°
	Max	9.80	4.50		1.20	0.15		0.30	0.75	0.10	8°
All dimensions in mm										

31. Package Description (UltraCSP™)

Top view
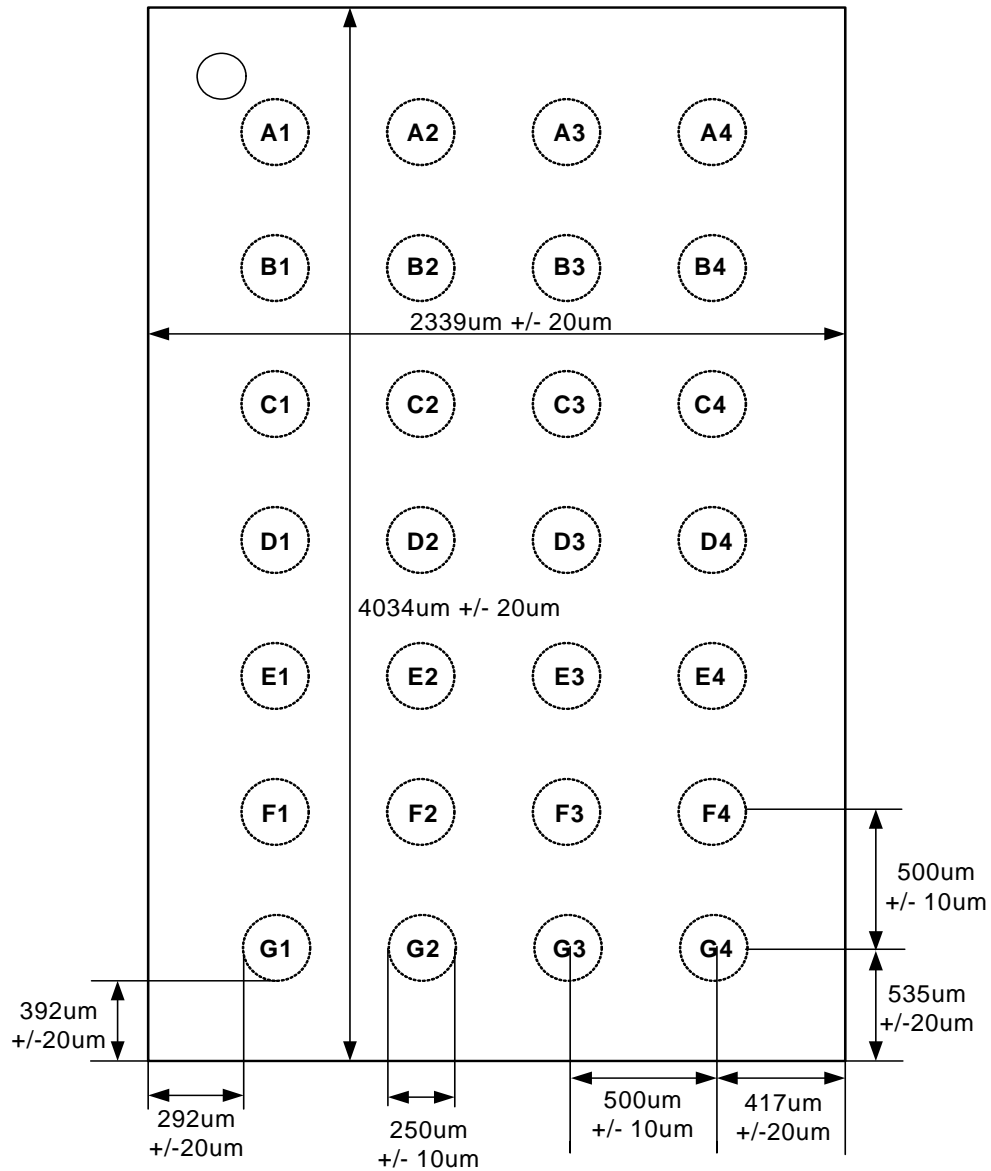
Bump pitch is 500um centre to centre in both directions.

Chipcon

Vertical cross section (UltraCSP™)

Before assembly on PCB:

A

Die

h1

Solder bumps (Pb free)

After assembly on PCB:

A

Die

h2

PCB mounting pads
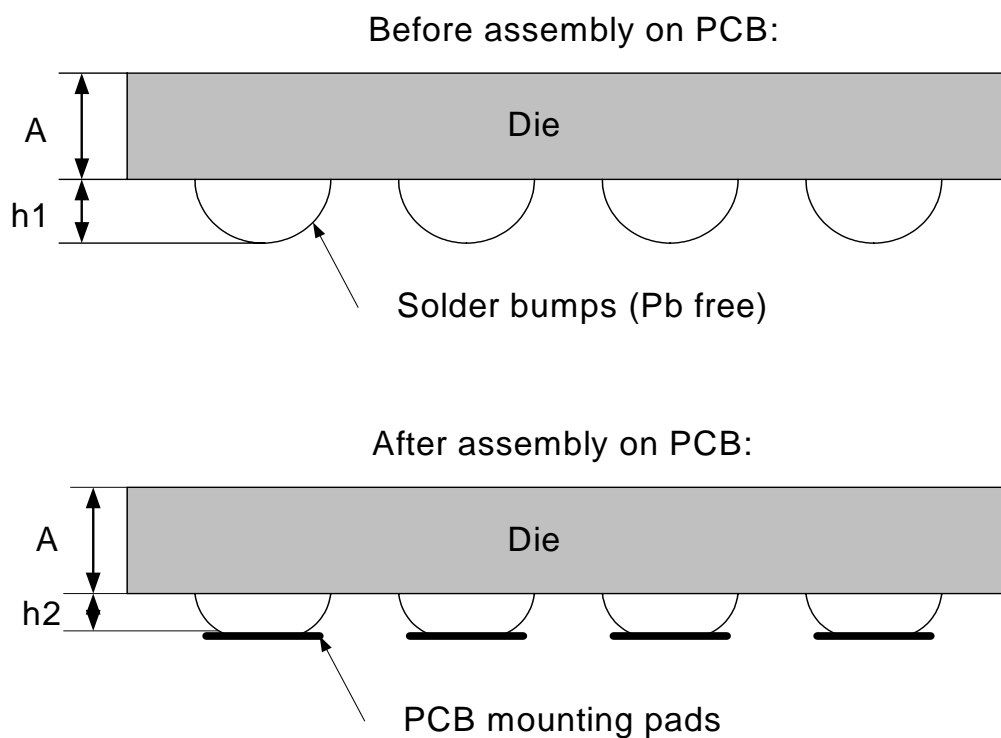
Die thickness (**A**)	Bump height before assembly (**h1**)	Bump height after assembly (**h2**)	**Total height before assembly**	**Total height after assembly**
432um	200um +/- 20um	140um +/- tbd um	**632um +/- 20um**	**572um +/- tbd um**

Table 14: Height budget

32. Plastic Tube Specification

TSSOP 4.4mm (.173") antistatic tube.

Tube Specification				
Package	Tube Width	Tube Height	Tube Length	Units per Tube
TSSOP 28	268 mil	80 mil	20"	50

33. Carrier Tape and Reel Specification

Carrier tape and reel is in accordance with EIA Specification 481.

Tape and Reel Specification					
Package	Tape Width	Component Pitch	Hole Pitch	Reel Diameter	Units per Reel
TSSOP 28	16 mm	8 mm	4 mm	13"	2500
UltraCSP™	12 mm	8 mm			2500
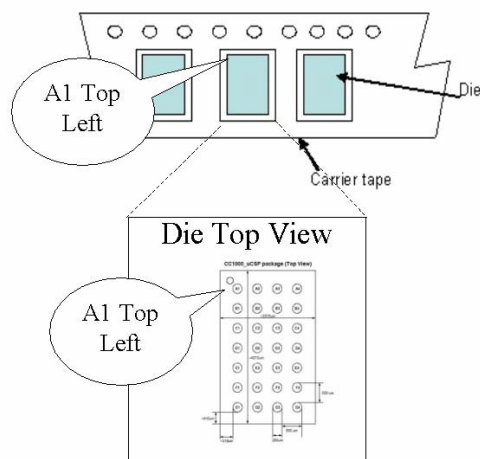
Note: UltraCSP™ Tape and reel illustration only

34. Ordering Information

Ordering part number	Description	MOQ
CC1000	Single Chip RF Transceiver	50 (tube)
CC1000/T&R	Single Chip RF Transceiver	2500 (tape and reel)
CC1000_uCSP/T&R	Single Chip RF Transceiver UCSP™	2500 (tape and reel)
CC1000DK-433	CC1000 Development Kit, 433 MHz	1
CC1000DK-868	CC1000 Development Kit, 868/915 MHz	1
CC1000SK	CC1000 Sample Kit (5 pcs)	1
CC1000SK_uCSP	CC1000 UCSP™ Sample Kit (5 pcs)	1

MOQ = Minimum Order Quantity

35. General Information

Document Revision History

Revision	Date	Description/Changes
2.2	April 2004	Shaping feature removed Application circuit simplified Additional information added for the demodulator Additional information added for frequency calculation Additional information added for calibration Additional information added for crystal oscillator Preliminary version removed Narrow band information removed REFDIV different in RX and TX Minor corrections and editorial changes
2.3	August 2005	UltraCSP™ package included Minor corrections and editorial changes

Disclaimer
Chipcon AS believes the information contained herein is correct and accurate at the time of this printing. However, Chipcon AS reserves the right to make changes to this product without notice. Chipcon AS does not assume any responsibility for the use of the described product; neither does it convey any license under its patent rights, or the rights of others. The latest updates are available at the Chipcon website or by contacting Chipcon directly.

As far as possible, major changes of product specifications and functionality, will be stated in product specific Errata Notes published at the Chipcon website. Customers are encouraged to sign up to the Developers Newsletter for the most recent updates on products and support tools.

When a product is discontinued this will be done according to Chipcon's procedure for obsolete products as described in Chipcon's Quality Manual. This includes informing about last-time-buy options. The Quality Manual can be downloaded from Chipcon's website.

Compliance with regulations is dependent on complete system performance. It is the customer's responsibility to ensure that the system complies with regulations.

Trademarks
SmartRF ® is a registered trademark of Chipcon AS. SmartRF® is Chipcon's RF technology platform with RF library cells, modules and design expertise. Based on SmartRF® technology Chipcon develops standard component RF circuits as well as full custom ASICs based on customer requirements and this technology.

UltraCSP™ is a trademark registered to FlipChip International, LLC.

All other trademarks, registered trademarks and product names are the sole property of their respective owners.

Life Support Policy
This Chipcon product is not designed for use in life support appliances, devices, or other systems where malfunction can reasonably be expected to result in significant personal injury to the user, or as a critical component in any life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness. Chipcon AS customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Chipcon AS for any damages resulting from any improper use or sale.

36. Address Information

Web site: http://www.chipcon.com
E-mail: wireless@chipcon.com
Technical Support Email: support@chipcon.com
Technical Support Hotline: +47 22 95 85 45

Headquarters:

Chipcon AS
Gaustadalléen 21
NO-0349 Oslo
NORWAY
Tel: +47 22 95 85 44
Fax: +47 22 95 85 46
E-mail: wireless@chipcon.com

US Offices:

Chipcon Inc., Western US Sales Office
19925 Stevens Creek Blvd.
Cupertino, CA 95014-2358
USA
Tel: +1 408 973 7845
Fax: +1 408 973 7257
Email: USsales@chipcon.com

Figure 8 Wireless
10509 Vista Sorrento Parkway, Suite 420
San Diego, CA 92121
USA
Tel: +1 858 522 8500 ext.6
Fax: +1 858 552 8501
Email: sales@f8w.com

Chipcon Inc., Eastern US Sales Office
35 Pinehurst Avenue
Nashua, New Hampshire, 03062
USA
Tel: +1 603 888 1326
Fax: +1 603 888 4239
Email: eastUSsales@chipcon.com

Sales Office Germany:

Chipcon AS
Riedberghof 3
D-74379 Ingersheim
GERMANY
Tel: +49 7142 9156815
Fax: +49 7142 9156818
Email: Germanysales@chipcon.com

Sales Office Asia:

Chipcon AS
Unit 503, 5/F
Silvercord Tower 2, 30 Canton Road
Tsimshatsui, Hong Kong
Tel: +852 3519 6226
Fax: +852 3519 6520
Email: Asiasales@chipcon.com

Sales Office Japan

Chipcon AS
#403, Bureau Shinagawa
4-1-6, Konan, Minato-Ku
Tokyo, Zip 108-0075
Tel: +81 3 5783 1082
Fax: +81 3 5783 1083
Email: Japansales@chipcon.com

Chipcon AS is an ISO 9001:2000 certified company

PW (R-PDSO-G**)　　　　　　　　　　　　　　　　　　**PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN

PINS ** DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES:　A.　All linear dimensions are in millimeters.
　　　　　B.　This drawing is subject to change without notice.
　　　　　C.　Body dimensions do not include mold flash or protrusion not to exceed 0,15.
　　　　　D.　Falls within JEDEC MO-153