Close-in Reception with CC1101

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Keywords

- ***CC1101***
- *Close-in reception*
- *Saturation*

1 Introduction

This document describes how the ***CC1101*** can be used in close-range applications. The chip has a saturation limit of approximately -15 dBm at 250 kbps, which might be a challenge for some short-range applications.

Two suggested solutions are presented, the first is a double-transmit scheme and the second is to shift the receivers dynamic range during close-range reception.

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2 Abbreviations

ACK	Acknowledgement
CS	Carrier Sense

3 Workaround 1: Double Transmit

The work-around is to perform a double transmit for each transmit packet. First, the data is transmitted with typical output power, e.g. +10 dBm, and then repeated with reduced output power, e.g. -30 dBm. This will ensure that either the data transmitted with typical output power will be received at medium to long ranges (the receiver may be saturated if close-in), while the second transmit with reduced output power will be received close-in.

This workaround may or may not be suitable, depending on the application. It may not be suitable e.g. in applications where a single sender transmits to multiple receivers placed at various distances from the sender. For such applications, workaround 2 should be used.

3.1 Example 1: One-way Solution

Assume a sender transmits the same packet 10 times to ensure that at least one packet is received by the receiver. With this workaround the sender transmits the same packet 10 times with typical output power and 10 times with reduced output power. The packets can be sent back-to-back.

This solution will increase the transmit current consumption by approximately 37 % (32.4 mA @ +10 dBm; 12.1 mA @ -30 dBm; (32.4 + 12.1) / 32.4 = 37 %).

3.2 Example 2: Two-way Solution

The sender transmits the same packet alternatively with typical and reduced output power until an ACK is received. When an ACK is received the sender continues to transmit at that output power until an ACK is not received. If an ACK is not received, the sender retransmits with the same output power a few times before it again transmits alternatively with typical and reduced output power.

Note that the receiver also must transmit the ACK messages with alternating typical and reduced output power. The receiver knows that the ACK was successfully transmitted when the next packet in sequence is received.

This solution will ensure that the sender and receiver are transmitting with an output power adjusted to the each other and thus reduce the power consumption. Data throughput is not significantly affected.

The two-way solution will have more robust communication and lower power consumption.

4 Workaround 2: Change Receiver Dynamic Range

The workaround is to shift the receiver dynamic range, by introducing programmable attenuation in the receiver. This will shift both the saturation level and the sensitivity level upwards. For medium to long range operation, the system must use the original settings with high sensitivity and moderate saturation levels. Table 1 shows how the RX chain attenuation can be programmed:

`FIFOTHR.CLOSE_IN_RX[1:0]`	**Attenuation**
00	0 dB
01	6 dB
10	12 dB
11	18 dB

Table 1. Receive Chain Attenuation

Note that the values in the table above are typical values.

Introducing attenuation in the receiver shifts both the sensitivity and the saturation level as mentioned above. A typical example is Table 2.

FIFOTHR.CLOSE_IN_RX[1:0]	Sensitivity, 250kbps, MSK	Saturation, 250kbps, MSK
00	-92 dBm	-15 dBm
11	-74 dBm	+3 dBm

Table 2. Change in Sensitive and Saturation when using Attenuation in the RX Chain

By using the programmable attenuation function together with the carrier sense (CS) signal, it is possible to implement a simple solution for close range applications.

Note that the RX filter bandwidth cannot be greater than 541.7 kHz for the CS signal to function properly, see section 5.

4.1 Implementation

Sender

No changes are necessary, the sender transmits with typical output power.

Receiver

Below are the steps needed for the receiver:

1. Setup one GDO pin to reflect the CS signal. Example code to setup CS on GDO2:

```
// 0x0E = Carrier sense. High if RSSI level is above threshold.
halSpiWriteReg(CCxxx0_IOCFG2, 0x0E);
```

2. Enter RX mode with no attenuation, i.e. `FIFOTHR.CLOSE_IN_RX[1:0]=00`.
3. When the preamble is detected by the radio the CS signal is set. The MCU should be setup such that this triggers an interrupt (polling is not recommended).
4. *Interrupt routine:* The MCU reads the RSSI value and determines if attenuation should be enabled. If the MCU is fast enough, this step can be done within the preamble period so that the packet is successfully received. If a slower MCU is used, either the preamble must be extended (more than 4 bytes) or the packet must be retransmitted. A suitable RSSI threshold is approximately -39 dBm, which is equal to a RSSI register value of 70. Example code for interrupt routine:

```
// Read RSSI and check if RSSI is above -39 dBm (=70)
if ((INT8)halSpiReadReg(CCxxx0_RSSI) > 70){
    // RSSI is above -39 dBm enable attenuation
    halSpiWriteReg(CCxxx0_FIFOTHR, 0x37);}
// 0x0E = Carrier sense. High if RSSI level is above threshold.
halSpiWriteReg(CCxxx0_IOCFG2, 0x0E);
```

Since the RSSI register represents a 2's complement signed value, it is important to cast the returned value for correct comparison.

5. When the packet has been received, or when the transmission is complete, or after a time-out period, the attenuation is disabled to enable reception at medium and long ranges.

```
// Disable attenuation
halSpiWriteReg(CCxxx0_FIFOTHR, 0x07);
```

4.2 Timing

It is important that step 4 or the interrupt routine is executed fast enough if the packet is to be successfully received without the need for retransmissions. This is especially critical when using high bitrates. Four factors influence this timing:

1. **Preamble length.** A longer preamble puts fewer requirements on the 3 items below.
2. **CS signal delay.** The CS signal delay is the time it takes for the CS signal to be set after the start of the transmission of the preamble. Table 3 shows the typical maximum delays.

Data Rate [kbps]	Time [us]	# of bits
100	80	8
250	72	18

Table 3. CS Signal Delay

3. **MCU processing time.** This is the time it takes for the interrupt routine to:
   a. Read the RSSI value
   b. Decide if RX attenuation is needed
   c. If yes, write the new RX attenuation setting.

   With a 6 Mbaud SPI interface, each read and write operation requires approximately 3 – 4 us. In addition the MCU will need some time to decide if attenuation is needed. Assuming this will take approximately 2 – 4 us, total time for this step will be approximately 10 us. This is equal to 1 bit period at 100 kbps and 2.5 bit periods at 250 kbps.
4. **Bit Synchronization and Frequency Offset Compensation.**
   16 bits are recommended for this, even though 8 bits are possible if the crystal frequencies are very close.

The preamble needs to be at least as long as the time that is required to execute steps 2, 3, and 4. See Figure 1 for an example.

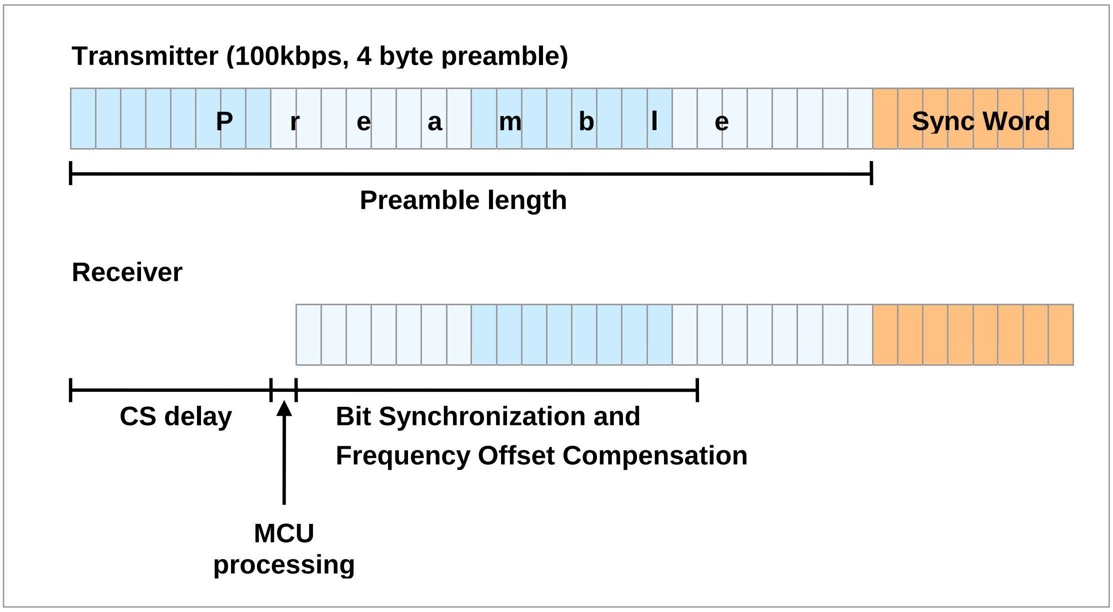

Figure 1. Minimum Preamble Length

5 Notes

CS cannot be used with a larger RX filter bandwidth than 541.7 kHz. Using a larger bandwidth will immediately set CS. This is due to large amounts of noise being received when using a large RX filter bandwidth.

6 General Information

6.1 Document History

Revision	Date	Description/Changes
SWRA147	2007.06.29	Initial Release

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