

CC112X RSSI and CS Response Time

By Fredrik Eriksen

Keywords

CC1120

RSSI

CC1121

CS

CC1125

1 Introduction

In most wireless applications there is a need for low current draw, and one of the features implemented in the CC112X (CC1120, CC1121, CC1125) to facilitate this, is to terminate RX if there is no carrier on the air. The time it takes before RX is terminated varies based on different settings, which will be discussed further in this design note.

The time the radio will be in RX state when RX termination based on Carrier Sense (CS) is enabled, is the CS response time.

The AGC module returns an estimate on the signal strength received at the antenna called RSSI (Received Signal Strength Indicator). CS is asserted when the RSSI is above a set threshold.

This design note shows how the CS response time differs with various radio settings. Low CS response times can help reduce power consumption. Project collateral discussed in this application report can be downloaded from the following URL: <http://www.ti.com/lit/zip/SWRA413>.

Table of Contents

KEYWORDS	1
1 INTRODUCTION	1
2 ABBREVIATIONS	2
3 RSSI REGISTER INTERPRETATION	3
4 CARRIER SENSE	4
5 TEST SETUP	7
6 MEASUREMENTS	8
6.1 CS RESPONSE TIME.....	8
6.2 MEASUREMENTS WITH STANDARD SETTINGS FROM SMARTRF STUDIO.....	13
7 EXCEL WORKSHEET FOR CALCULATING CS RESPONSE TIMES	14
8 CONCLUSION	15
9 REFERENCES	16
9.1 DOCUMENT HISTORY.....	17

2 Abbreviations

AGC	Automatic Gain Control
CS	Carrier Sense
LSB	Least Significant Bit
MSB	Most Significant Bit
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
RX	Receive, Receive Mode
eWor	Enhanced Wake on Radio

3 RSSI Register Interpretation

RSSI is important in terms of CS, because CS is asserted when the RSSI is above a programmable threshold. CS indication will also be affected by the setting of `AGC_CFG0.RSSI_VALID_CNT`, because this register dictates how many new input samples is needed before the next RSSI update. When the RSSI is valid it will be continuously compared to the CS threshold set in the `AGC_CS_THR` register, but since the RSSI update rate is given by the `RSSI_VALID_CNT` register field, this will in practice limit the CS update rate as well.

The RSSI value read from the RSSI status registers (`RSSI1.RSSI_11_4` and `RSSI0.RSSI_3_0`) is a 2's complement number and is in dBm with 1 dB and 0.0625 dB resolutions, depending on how many bits are used (8 or 12). However it should be noted that for most applications using the 8 MSB bits of the RSSI, with 1 dB resolution, is good enough.

To get a correct RSSI value a calibrated RSSI offset value should be subtracted from the value given by `RSSI [11:0]`. The RSSI offset value can be found by input a signal of known strength to the radio when `AGC_GAIN_ADJUST.GAIN_ADJUSTMENT` is `0x00`.

The following procedure can be used to convert the RSSI reading to an absolute power level (in dBm) when reading the 8 MSB from `RSSI [11:0]`.

Assume that the RSSI offset is 102 dB and that `11111010b` is read from the `RSSI1` register.

If `11111010b` is interpreted as a 2's complement number it has the value -3.

This means that the RSSI value, before taking the offset into account, is -3 dBm. Subtracting the RSSI offset, the RSSI value in dBm ends up at $-3 \text{ dBm} - 102 \text{ dB} = -105 \text{ dBm}$.

Figure 1 shows an example for reading the MSB of the RSSI value, and converting it to a decimal value.

```
int Read8BitRssi(void){
    uint8 rssi2compl,rssiValid;
    uint8 rssiOffset = 102;
    int8 rssiConverted;

    // Read RSSI_VALID from RSSI0
    cc112xSpiReadReg(CC112X_RSSI0, &rssiValid, 1);

    // Check if the RSSI_VALID flag is set
    if(rssiValid & 0x01){
        // Read RSSI from MSB register
        cc112xSpiReadReg(CC112X_RSSI1, &rssi2compl, 1);
        rssiConverted = (int8)rssi2compl - rssiOffset;
        return rssiConverted;
    }
    // return 0 since new value is not valid
    return 0;
}
```

Figure 1: Code Example for Reading 8-bit RSSI

To get the full 12 bit RSSI value the 4 LSB can be read from `RSSI0` and added to the 8 MSB from `RSSI0`.

Figure 2 shows an example of how to read the full 12 bit RSSI value.

```
float Read12BitRssi(void) {
    uint8 rssiValid, rssi2complMSB, rssi2complLSB;
    int16 rssi2compl;
    uint8 rssiOffset = 102;
    float rssiConverted;

    cc112xSpiReadReg(CC112X_RSSI0, &rssiValid, 1);
    if(rssiValid & 0x01){
        // Read RSSI from MSB register
        cc112xSpiReadReg(CC112X_RSSI1, &rssi2complMSB, 1);
        // Read RSSI from LSB register
        cc112xSpiReadReg(CC112X_RSSI0, &rssi2complLSB, 1);
        // Shift the bits in place and add the 4 last bits
        rssi2compl = ((int8)(rssi2complMSB) << 4) | ((int8)(rssi2complLSB) >> 3);
        rssiConverted = (float)(rssi2compl) * 0.0625 - rssiOffset;
        return rssiConverted;
    }
    // return 0 since new value is not valid
    return 0;
}
```

Figure 2: Code Example for Reading 12-bit RSSI

4 Carrier Sense

The optional enhanced Wake on Radio (eWOR) functionality enables CC112X to periodically wake up from SLEEP and listen for incoming packets without MCU interaction. It is possible to combine this function with RX termination based on CS to get what is called RX Sniff mode. This in turn reduces power consumption because the radio stays in RX much shorter when there is no carrier on the air. The CS response time is the time the radio will be in RX state when RX termination based on CS is enabled (`RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 0x01`), and is therefore an important factor in terms of current consumption.

Figure 3 shows a plot of the current draw and logic outputs when looking for data in RX Sniff mode. Settings used are 868 MHz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 25 kHz from SmartRF Studio. When the `IOCFGx.GPIOx_CFG` setting is less than 0x30 and `IOCFGx.GPIOx_INV` is 0 (1) the `GPIO2(CARRIER_SENSE_VALID)` pin will be hardwired to 0 (1), and `GPIO1(MARC_2PIN_STATUS[0])` and `GPIO3(AGC_UPDATE)` will be hardwired to 1 (0) in the SLEEP state.

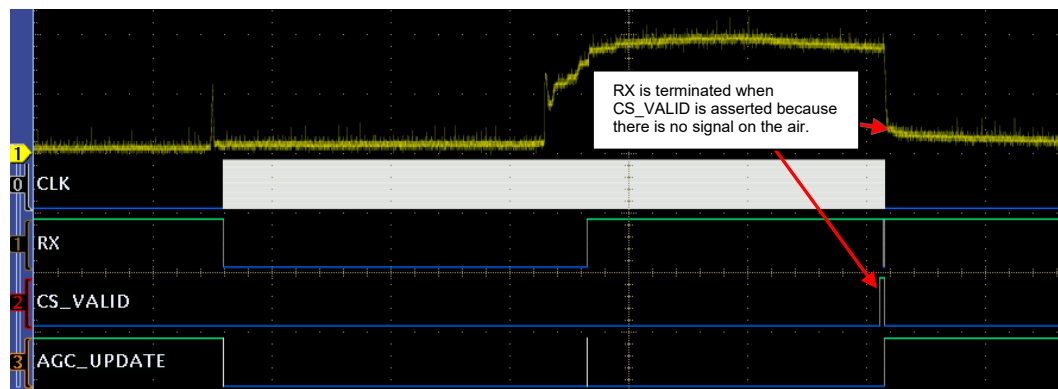


Figure 3: Plot from Oscilloscope Showing Current Draw and Logic Outputs. The number to the left of each signal represents the corresponding GPIO number.

Design Note DN510

Below are the equations which form the total CS response time.

T0: Start-up delay before RSSI measurements can begin. This delay is dependent on demodulator settings and can be found using Table 1, Table 2, and Equation 3.

T1: The time the AGC waits after adjusting the front end gain to allow signal transients to decay before the next signal strength measurement can take place. T1 can be calculated using Equation 1.

T2: The time the AGC uses to measure the signal strength and potentially adjust the gain. T2 can be calculated using Equation 2.

$$T1 = \frac{(16 \cdot \text{AGC_SETTLE_WAIT} + 48) \cdot \text{BB_CIC_DECFACT} \cdot \text{Decimation Factor} + 46}{f_{XOSC}}$$

Equation 1: T1

$$T2 \leq \frac{2^{\text{AGC_WIN_SIZE}4} \cdot \text{BB_CIC_DECFACT} \cdot \text{Decimation Factor} + 46}{f_{XOSC}}$$

Equation 2: T2

Configuration Register Fields/Conditions		T0
CHAN_BW.CHFILT_BYPASS	CHAN_BW.BB_CIC_DECFACT > 0x01	
0	0	D ₀ + D ₂ + D ₄
0	1	D ₀ + D ₁ + D ₃ + D ₅
1	0	D ₀
1	1	D ₀ + D ₁ + D ₆

Table 1: T0 Matrix

Delay	Equation
D ₀	$\frac{16 \text{ Decimation Factor} - 74}{f_{XOSC}}$
D ₁ ¹	$\frac{\{1 - \text{DCFILT_FREEZE}\} (62 - \text{CARRIER_SENSE_GATE} (2^{(5-x)} - 1)) \text{ Decimation Factor} \cdot 2}{f_{XOSC}}$
D ₂ ¹	$\frac{(62 + \text{CARRIER_SENSE_GATE} (2^{(5-x)} - 1)) \cdot \text{Decimation Factor} \cdot 2}{f_{XOSC}}$
D ₃	$\frac{(16 \cdot \text{BB_CIC_DECFACT} - 2) \cdot \text{Decimation Factor} \cdot 2}{f_{XOSC}}$
D ₄	$\frac{(35 - \text{DCFILT_FREEZE_COEFF}) \cdot \text{Decimation Factor} \cdot 2}{f_{XOSC}}$
D ₅	$\frac{(68 \cdot \text{BB_CIC_DECFACT}) \cdot \text{Decimation Factor}}{f_{XOSC}}$
D ₆	$\frac{(\text{BB_CIC_DECFACT} - 2) \cdot \text{Decimation Factor} \cdot 2}{f_{XOSC}}$

Table 2: D₀ - D₆

$$T_0 \leq \sum \text{Applicable Delays} \Big|_{\text{Current Configuration}}$$

Equation 3: T₀

The maximum carrier sense response time is given by Equation 4.

$$\text{CS Response Time} \leq T_0 + (T_1 + T_2) \cdot (2^{\text{RSSI_VALID_CNT}} + 1)$$

Equation 4: Max CS Response Time

If number of AGC_UPDATE pulses before the first RSSI update is known, the CS response time is given by Equation 5, where x = # of AGC_UPDATE pulses before first RSSI_UPDATE (X is greater or equal to 1).

$$\text{CS Response Time} \leq T_0 + T_1 \cdot x + T_2 (2^{\text{RSSI_VALID_CNT}} + 1)$$

Equation 5: CS Response Time (# of gain reductions is known)

¹ x = DCFILT_CFG.DCFILT_BW when DCFILT_CFG.DCFILT_BW < 5, else it is 4

5 Test Setup

Figure 4 shows the test setup that was used to measure the CS response time.

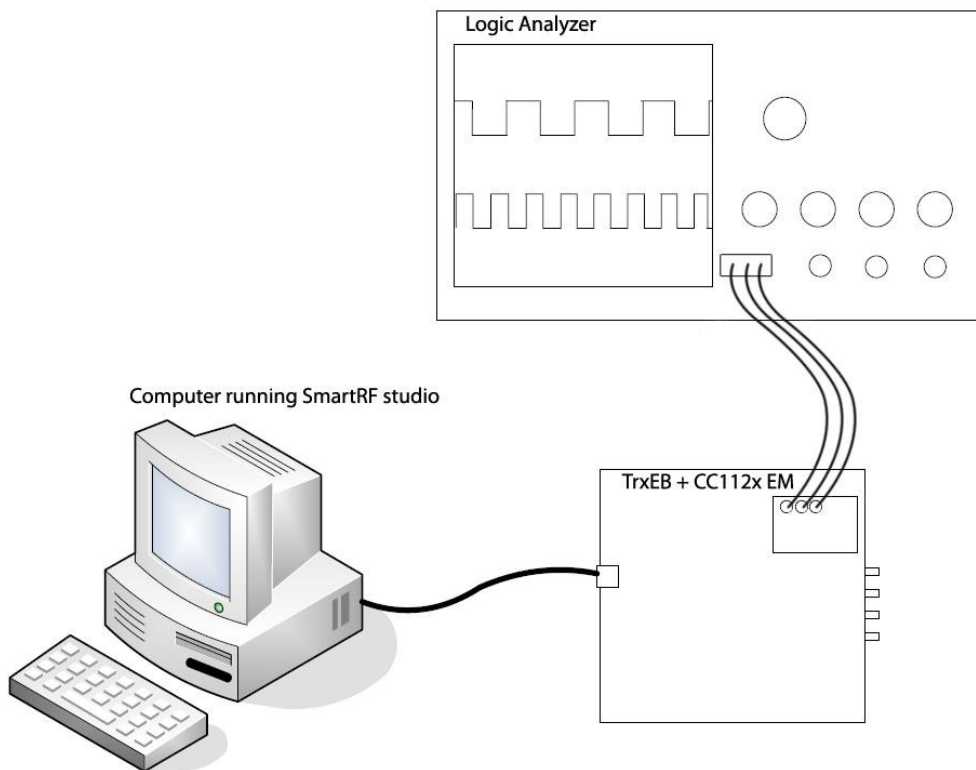


Figure 4: Test Setup for Measuring the CS Response Time

Figure 5 shows the measurements done with the logic analyzer.

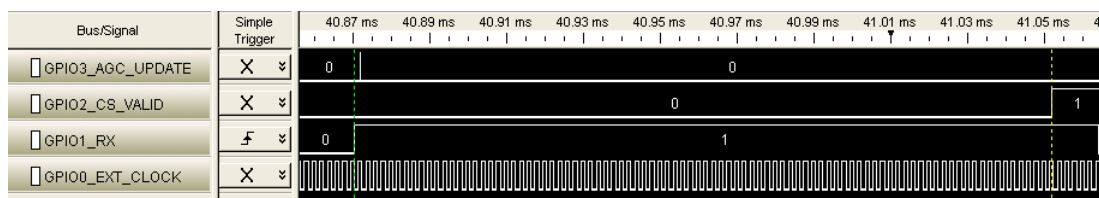


Figure 5: Plot from Logic Analyzer

6 Measurements

6.1 CS Response Time

Table 4, Table 5, Table 6, and Table 7 are measurements used to confirm the equations for CS Response Time. There is one table for each value of `RSSI_VALID_CNT`. In these measurements the `CHAN_BW.CHFILT_BYPASS` is disabled. This prolongs the `T0` value a bit, but increases sensitivity because of the narrower bandwidth. Tests have also been done with `CHAN_BW.CHFILT_BYPASS` enabled which confirms the equations for that as well.

The settings used are based on standard settings from SmartRF™ Studio [1], 868 MHz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 25 kHz, which can be seen below in Figure 6.

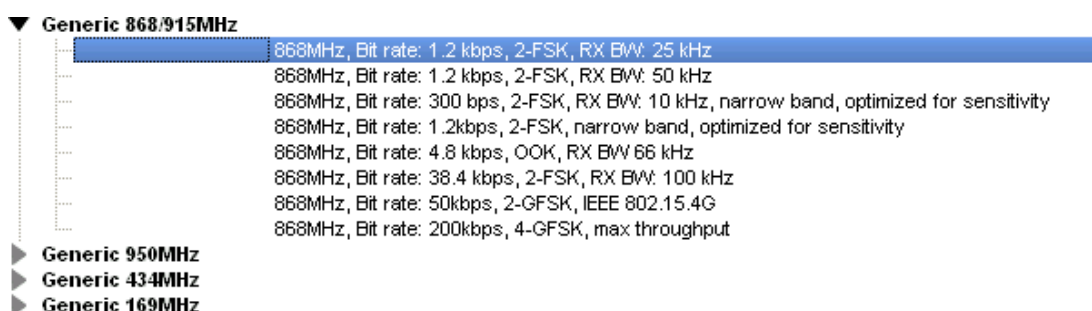


Figure 6: Standard Settings from SmartRF Studio

Table 3 shows how the `CHFILT_BYPASS` affects `T0`.

CHAN_BW.CHFILT_BYPASS = 0	
BB_CIC_DECFACT = 1	$T0 = D0 + D2 + D4$
BB_CIC_DECFACT = 25	$T0 = D0 + D1 + D3 + D5$
CHAN_BW.CHFILT_BYPASS = 1	
BB_CIC_DECFACT = 1	$T0 = D0 + D1$
BB_CIC_DECFACT = 25	$T0 = D0 + D1 + D6$

Table 3: How CHFILT_BYPASS affects T0

The only settings changed in the following tables are `AGC_WIN_SIZE`, `AGC_SETTLE_WAIT`, `BB_CIC_DECFACT` and the decimation factor (20 when `CHAN_BW.ADC_CIC_DECFACT = 0` and 32 when `CHAN_BW.ADC_CIC_DECFACT = 1`). The following abbreviations are used in table 4, 5, 6, and 7:

- A* = `AGC_WIN_SIZE`
- B* = `AGC_SETTLE_WAIT`
- C* = `BB_CIC_DECFACT`
- D* = *Decimation factor*

Design Note DN510

Register Settings								CS Response Time			
A	B	C	D	T2 [μ]	T1 [μ]	T0 [μ]	Calculated Max Response Time [μ s]	# of AGC_UPDATE pulses	Calculated CS Response Time [μ s] ²	Measured [μ s] ²	Diff[%] ³
0	0	1	20	11,438	30,000	133,563	216,438	1	186,438	181,200	2,81 %
0	0	1	32	17,438	48,000	212,313	343,188	1	295,188	288,440	2,29 %
0	0	25	20	251,438	750,000	1649,813	3652,688	1	2902,688	2897,760	0,17 %
0	1	1	20	11,438	40,000	133,563	236,438	1	196,438	191,190	2,67 %
0	1	1	32	17,438	64,000	212,313	375,188	1	311,188	304,440	2,17 %
0	1	25	20	251,438	1000,000	1649,813	4152,688	1	3152,688	3147,770	0,16 %
0	2	1	20	11,438	50,000	133,563	256,438	1	206,438	201,190	2,54 %
0	2	1	32	17,438	80,000	212,313	407,188	1	327,188	320,440	2,06 %
0	2	25	20	251,438	1250,000	1649,813	4652,688	1	3402,688	3397,770	0,14 %
0	3	1	20	11,438	60,000	133,563	276,438	1	216,438	211,200	2,42 %
0	3	1	32	17,438	96,000	212,313	439,188	1	343,188	336,450	1,96 %
0	3	25	20	251,438	1500,000	1649,813	5152,688	1	3652,688	3647,850	0,13 %
5	0	1	20	321,438	30,000	133,563	836,438	1	806,438	801,200	0,65 %
5	0	1	32	513,438	48,000	212,313	1335,188	1	1287,188	1280,450	0,52 %
5	0	25	20	8001,438	750,000	1649,813	19152,688	1	18402,688	18397,812	0,03 %
5	1	1	20	321,438	40,000	133,563	856,438	1	816,438	811,195	0,64 %
5	1	1	32	513,438	64,000	212,313	1367,188	1	1303,188	1296,450	0,52 %
5	1	25	20	8001,438	1000,000	1649,813	19652,688	1	18652,688	18647,815	0,03 %
5	2	1	20	321,438	50,000	133,563	876,438	1	826,438	821,198	0,63 %
5	2	1	32	513,438	80,000	212,313	1399,188	1	1319,188	1312,448	0,51 %
5	2	25	20	8001,438	1250,000	1649,813	20152,688	1	18902,688	18897,813	0,03 %
5	3	1	20	321,438	60,000	133,563	896,438	1	836,438	831,200	0,63 %
5	3	1	32	513,438	96,000	212,313	1431,188	1	1335,188	1328,450	0,50 %
5	3	25	20	8001,438	1500,000	1649,813	20652,688	1	19152,688	19147,818	0,03 %

Table 4: CS Response Time (RSSI_VALID_CNT= 0)

² # of AGC_UPDATE pulses are known and it is 1 for all the cases

³ How much the measured value differs from the calculated one in percent (positive numbers means that the measured time is shorter than the calculated one)

Design Note DN510

Register Settings								CS Response Time			
A	B	C	D	T2 [μ]	T1 [μ]	T0 [μ]	Calculated Max Response Time [μ s]	# of AGC_UPDATE pulses	Calculated CS Response Time [μ s] ⁴	Measured [μ s] ⁴	Diff[%] ⁵
0	0	1	20	11,438	30,000	133,563	257,875	1	197,875	191,198	3,37 %
0	0	1	32	17,438	48,000	212,313	408,625	1	312,625	304,445	2,62 %
0	0	25	20	251,438	750,000	1649,813	4654,125	1	3154,125	3147,675	0,20 %
0	1	1	20	11,438	40,000	133,563	287,875	1	207,875	201,198	3,21 %
0	1	1	32	17,438	64,000	212,313	456,625	1	328,625	320,448	2,49 %
0	1	25	20	251,438	1000,000	1649,813	5404,125	1	3404,125	3397,768	0,19 %
0	2	1	20	11,438	50,000	133,563	317,875	1	217,875	211,198	3,06 %
0	2	1	32	17,438	80,000	212,313	504,625	1	344,625	336,448	2,37 %
0	2	25	20	251,438	1250,000	1649,813	6154,125	1	3654,125	3647,770	0,17 %
0	3	1	20	11,438	60,000	133,563	347,875	1	227,875	221,195	2,93 %
0	3	1	32	17,438	96,000	212,313	552,625	1	360,625	352,448	2,27 %
0	3	25	20	251,438	1500,000	1649,813	6904,125	1	3904,125	3897,770	0,16 %
5	0	1	20	321,438	30,000	133,563	1187,875	1	1127,875	1121,200	0,59 %
5	0	1	32	513,438	48,000	212,313	1896,625	1	1800,625	1792,453	0,45 %
5	0	25	20	8001,438	750,000	1649,813	27904,125	1	26404,125	26397,838	0,02 %
5	1	1	20	321,438	40,000	133,563	1217,875	1	1137,875	1131,200	0,59 %
5	1	1	32	513,438	64,000	212,313	1944,625	1	1816,625	1808,450	0,45 %
5	1	25	20	8001,438	1000,000	1649,813	28654,125	1	26654,125	26647,840	0,02 %
5	2	1	20	321,438	50,000	133,563	1247,875	1	1147,875	1141,200	0,58 %
5	2	1	32	513,438	80,000	212,313	1992,625	1	1832,625	1824,453	0,45 %
5	2	25	20	8001,438	1250,000	1649,813	29404,125	1	26904,125	26897,840	0,02 %
5	3	1	20	321,438	60,000	133,563	1277,875	1	1157,875	1151,200	0,58 %
5	3	1	32	513,438	96,000	212,313	2040,625	1	1848,625	1840,450	0,44 %
5	3	25	20	8001,438	1500,000	1649,813	30154,125	1	27154,125	27147,840	0,02 %

Table 5: CS Response Time (RSSI_VALID_CNT= 1)

⁴ # of AGC_UPDATE pulses are known and it is 1 for all the cases

⁵ How much the measured value differs from the calculated one in percent (positive numbers means that the measured time is shorter than the calculated one)

Design Note DN510

Register Settings								CS Response Time			
A	B	C	D	T2 [μ]	T1 [μ]	T0 [μ]	Calculated Max Response Time [μ s]	# of AGC_UPDATE pulses	Calculated CS Response Time [μ s] ⁶	Measured [μ s] ⁶	Diff[%] ⁷
0	0	1	20	11,438	30,000	133,563	340,750	1	220,750	212,445	3,76 %
0	0	1	32	17,438	48,000	212,313	539,500	1	347,500	336,438	3,18 %
0	0	25	20	251,438	750,000	1649,813	6657,000	1	3657,000	3647,760	0,25 %
0	1	1	20	11,438	40,000	133,563	390,750	1	230,750	221,188	4,14 %
0	1	1	32	17,438	64,000	212,313	619,500	1	363,500	352,438	3,04 %
0	1	25	20	251,438	1000,000	1649,813	7907,000	1	3907,000	3897,763	0,24 %
0	2	1	20	11,438	50,000	133,563	440,750	1	240,750	232,438	3,45 %
0	2	1	32	17,438	80,000	212,313	699,500	1	379,500	368,438	2,92 %
0	2	25	20	251,438	1250,000	1649,813	9157,000	1	4157,000	4147,760	0,22 %
0	3	1	20	11,438	60,000	133,563	490,750	1	250,750	241,185	3,81 %
0	3	1	32	17,438	96,000	212,313	779,500	1	395,500	384,438	2,80 %
0	3	25	20	251,438	1500,000	1649,813	10407,000	1	4407,000	4397,763	0,21 %
5	0	1	20	321,438	30,000	133,563	1890,750	1	1770,750	1761,193	0,54 %
5	0	1	32	513,438	48,000	212,313	3019,500	1	2827,500	2816,445	0,39 %
5	0	25	20	8001,438	750,000	1649,813	45407,000	1	42407,000	42397,875	0,02 %
5	1	1	20	321,438	40,000	133,563	1940,750	1	1780,750	1771,193	0,54 %
5	1	1	32	513,438	64,000	212,313	3099,500	1	2843,500	2832,445	0,39 %
5	1	25	20	8001,438	1000,000	1649,813	46657,000	1	42657,000	42647,870	0,02 %
5	2	1	20	321,438	50,000	133,563	1990,750	1	1790,750	1781,193	0,53 %
5	2	1	32	513,438	80,000	212,313	3179,500	1	2859,500	2848,445	0,39 %
5	2	25	20	8001,438	1250,000	1649,813	47907,000	1	42907,000	42897,875	0,02 %
5	3	1	20	321,438	60,000	133,563	2040,750	1	1800,750	1791,193	0,53 %
5	3	1	32	513,438	96,000	212,313	3259,500	1	2875,500	2864,445	0,38 %
5	3	25	20	8001,438	1500,000	1649,813	49157,000	1	43157,000	43147,878	0,02 %

Table 6: CS Response Time (RSSI_VALID_CNT= 2)

⁶ # of AGC_UPDATE pulses are known and it is 1 for all the cases

⁷ How much the measured value differs from the calculated one in percent (positive numbers means that the measured time is shorter than the calculated one)

Design Note DN510

Register Settings								CS Response Time			
A	B	C	D	T2 [μ]	T1 [μ]	T0 [μ]	Calculated Max Response Time [μ s]	# of AGC_UPDATE pulses	Calculated CS Response Time [μ s] ⁸	Measured [μ s] ⁸	Diff[%] ⁹
0	0	1	20	11,438	30,000	133,563	506,500	1	266,500	252,438	5,28 %
0	0	1	32	17,438	48,000	212,313	801,250	1	417,250	400,440	4,03 %
0	0	25	20	251,438	750,000	1649,813	10662,750	1	4662,750	4647,785	0,32 %
0	1	1	20	11,438	40,000	133,563	596,500	1	276,500	261,190	5,54 %
0	1	1	32	17,438	64,000	212,313	945,250	1	433,250	416,440	3,88 %
0	1	25	20	251,438	1000,000	1649,813	12912,750	1	4912,750	4897,788	0,30 %
0	2	1	20	11,438	50,000	133,563	686,500	1	286,500	271,190	5,34 %
0	2	1	32	17,438	80,000	212,313	1089,250	1	449,250	432,443	3,74 %
0	2	25	20	251,438	1250,000	1649,813	15162,750	1	5162,750	5147,790	0,29 %
0	3	1	20	11,438	60,000	133,563	776,500	1	296,500	282,440	4,74 %
0	3	1	32	17,438	96,000	212,313	1233,250	1	465,250	448,440	3,61 %
0	3	25	20	251,438	1500,000	1649,813	17412,750	1	5412,750	5397,790	0,28 %
5	0	1	20	321,438	30,000	133,563	3296,500	1	3056,500	3041,210	0,50 %
5	0	1	32	513,438	48,000	212,313	5265,250	1	4881,250	4864,475	0,34 %
5	0	25	20	8001,438	750,000	1649,813	80412,750	1	74412,750	74398,305	0,02 %
5	1	1	20	321,438	40,000	133,563	3386,500	1	3066,500	3051,210	0,50 %
5	1	1	32	513,438	64,000	212,313	5409,250	1	4897,250	4880,475	0,34 %
5	1	25	20	8001,438	1000,000	1649,813	82662,750	1	74662,750	74648,305	0,02 %
5	2	1	20	321,438	50,000	133,563	3476,500	1	3076,500	3061,213	0,50 %
5	2	1	32	513,438	80,000	212,313	5553,250	1	4913,250	4896,473	0,34 %
5	2	25	20	8001,438	1250,000	1649,813	84912,750	1	74912,750	74898,308	0,02 %
5	3	1	20	321,438	60,000	133,563	3566,500	1	3086,500	3071,213	0,50 %
5	3	1	32	513,438	96,000	212,313	5697,250	1	4929,250	4910,850	0,37 %
5	3	25	20	8001,438	1500,000	1649,813	87162,750	1	75162,750	75148,310	0,02 %

Table 7: CS Response Time (RSSI_VALID_CNT= 3)

⁸ # of AGC_UPDATE pulses are known and it is 1 for all the cases

⁹ How much the measured value differs from the calculated one in percent (positive numbers means that the measured time is shorter than the calculated one)

6.2 Measurements with Standard Settings from SmartRF Studio

Table 8 shows the measured and calculated CS response times for all typical settings from SmartRF studio 1.9.1.

Settings	Calculated Max Response Time [μs]	Calculated CS Response Time [μs] ¹⁰	Measured [μs] ¹⁰	Diff[%] ¹¹
868Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 25 kHz	1230,188	990,188	985,260	0,498 %
868Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 50 kHz	660,188	540,188	535,193	0,925 %
868Mhz, Bit rate: 300 bps, 2-FSK, RX BW: 10 kHz ¹²	2940,188	2340,188	2335,270	0,210 %
868Mhz, Bit rate: 1.2 kbps, 2-FSK ¹²	2940,188	2340,188	2335,270	0,210 %
868Mhz, Bit rate: 38.4 kbps, 2-FSK, RX BW: 100kHz	375,188	315,188	310,190	1,586 %
868Mhz, Bit rate: 50 kbps, 2-GFSK ¹³	375,188	315,188	310,190	1,586 %
868Mhz, Bit rate: 200 kbps, 4-GFSK, max throughput	216,438	186,438	181,128	2,848 %
950Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 25 kHz	1230,188	990,188	985,258	0,498 %
950Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 50 kHz	660,188	540,188	535,193	0,925 %
950Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 10 kHz ¹²	2940,188	2340,188	2335,268	0,210 %
950Mhz, Bit rate: 50 kbps, 2-GFSK, RX BW: 100 kHz ¹³	375,188	315,188	310,190	1,586 %
950Mhz, Bit rate: 200 kbps, 4-GFSK, RX BW: 200 KHz	216,438	186,438	181,125	2,849 %
434Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 25 kHz	1230,188	990,188	985,260	0,498 %
434Mhz, Bit rate: 1.2 kbps, 2-FSK, RX BW: 50 kHz	660,188	540,188	535,190	0,925 %
434Mhz, Bit rate: 1.2 kbps, 2-FSK ¹²	2940,188	2340,188	2335,268	0,210 %
434Mhz, Bit rate: 50kbps, 2-GFSK ¹³	375,188	315,188	310,190	1,586 %
169Mhz, Bit rate: 1.2kbps, 2-FSK, RX BW: 25 kHz	1230,188	990,188	985,258	0,498 %
169Mhz, Bit rate: 1.2kbps, 2-FSK, RX BW: 50 kHz	660,188	540,188	535,190	0,925 %
169Mhz, Bit rate: 1.2kbps, 2-FSK ¹²	2940,188	2340,188	2335,268	0,210 %

Table 8: CS Response Time (Standard Settings from SmartRF Studio)

¹⁰ # of AGC_UPDATE pulses are known and it is 1 for all the cases

¹¹ How much the measured value differs from the calculated one in percent (positive numbers means that the measured time is shorter than the calculated one)

¹² Narrow band, optimized for sensitivity

¹³ IEEE 802.15.4g

7 Excel Worksheet for Calculating CS Response Times

Settings	
XOSC frequency [MHz]	32
DCFILT_CFG.DCFILT_BW	4
DCFILT_CFG.DCFILT_FREEZE_COEFF	0
MDMCFG1.CARRIER_SENSE_GATE	0
CHAN_BW.BB_CIC_DECFACT	25
CHAN_BW.ADC_CIC_DECFACT	0
Decimation factor	20
CHAN_BW.CHFILT_BYPASS	0
AGC_CFG1.AGC_WIN_SIZE	0
AGC_CFG1.SETTLE_WAIT	1
AGC_CFG0.RSSI_VALID_CNT	0
# of AGC_UPDATE pulses	1
Channel Bandwidth [kHz]	8
Results	
D0 [us]	12,313µs
D1 [us]	77,500µs
D2 [us]	77,500µs
D3 [us]	497,500µs
D4 [us]	43,750µs
D5 [us]	1062,500µs
D6 [us]	28,750µs
T0 = D0+D1+D3+D5	1649,813µs
T1	1000,000µs
T2	251,438µs
CS response time (AGC_UPDATE pulses is known)	3152,688µs
Max CS Response Time	4152,688µs

Together with this design note there is an Excel worksheet for calculating the CS response times. To use it plot in the desired register settings and the resulting time delays will be calculated. The gray fields are locked because they contain formulas and should not be edited. It is the users own responsibility to make sure only valid¹⁴ settings are used.

¹⁴ Settings that does not create any warnings in SmartRF Studio.

8 Conclusion

Measurements in this design note show that the formulas give a good estimate of the CS response time. The CS response time is the same as the time from RX is entered until CS_VALID is asserted, and RX is terminated due to lack of CS.

9 References

- [1] SmartRF™ Studio ([swrc176.zip](#))
- [2] Excel Worksheet ([swra413.zip](#))

10 General Information

10.1 Document History

Revision	Date	Description/Changes
SWRA413	2012.12.06	Initial release.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated