

CC112X/CC120X On-Chip Battery Monitor

Fredrik Eriksen

ABSTRACT

This application report provides the necessary information in order to use the voltage sensor of the CC112x and CC120x family. The voltage sensor can be used to monitor the supply and battery voltage (V_{DD}).

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1 Acronyms Used in This Document

Acronym	Description
ADC	Analog-to-Digital Converter
DC	Direct Current
IF	Intermediate Frequency
IFAMP	Intermediate Frequency Amplifier
IFADC	Intermediate Frequency Analog-to-Digital Converter
RX	Receive (mode)

2 Digital Readout of Supply Voltage (V_{DD})

2.1 Operation

The IFADC in the receive chain is used to convert the analog sensor voltage to a digital value, which can be read from the `CHFILT` register.

In order to get a digital readout the following must be done:

- The chip must be in receive mode (RX).
- The DC filter must be disabled and the IF frequency set to zero. Otherwise the DC information is filtered out.
- The IFAMP must be off and this is done with the chip set in debug mode. For details about debug mode, see [Section 2.2](#). Note that the chip needs to be reset (by issuing an SRES strobe) to get out of debug mode.
- Optionally the `DVGA_GAIN` setting in the `MDMCFG1` register can be adjusted to increase/decrease the amplitude of the signal to prevent an overflow in the output value.
- [Table 1](#) and [Table 2](#) list the registers used to activate digital readout when using CC112x and CC120x, respectively. For details, see code in [Appendix A](#). All the SPI functions used in the code is found in the CC112x and CC120x software examples ([\[7\]](#) and [\[8\]](#)).

Table 1. Register Settings for Digital Readout Using CC112X

Register	Value	Comment
<code>DCFILT_CFG</code>	0x40	Turn off DCFILT
<code>MDMCFG1</code>	0x01	Only I-Channel
<code>CHAN_BW</code>	0x01	Channel filter on
<code>FREQ_IF_CFG</code>	0x00	Off
<code>ATEST</code>	0x2B	Battery sensor on
<code>ATEST_MODE</code>	0x08	Battery sensor on
<code>PA_IFAMP_TEST</code>	0x01	FAMP to test module
Debug Mode		
<code>WOR_EVENT0_LSB</code>	0x1F	Put IFAMP in PD - Must run SXOFF after to effectuate

Table 2. Register Settings for Digital Readout Using CC120X

Register	Value	Comment
DCFILT_CFG	0x40	Turn off DCFILT
MDMCFG1	0x01	Only I-Channel
CHAN_BW	0x01	Channel filter on
FREQ_IF_CFG	0x00	Off
ATEST	0x2B	Battery sensor on
ATEST_MODE	0x08	Battery sensor on
PA_IFAMP_TEST	0x01	FAMP to test module
Debug Mode		
WOR_EVENT0_LSB	0x1F	Put IFAMP in PD - Must run SXOFF after to effectuate

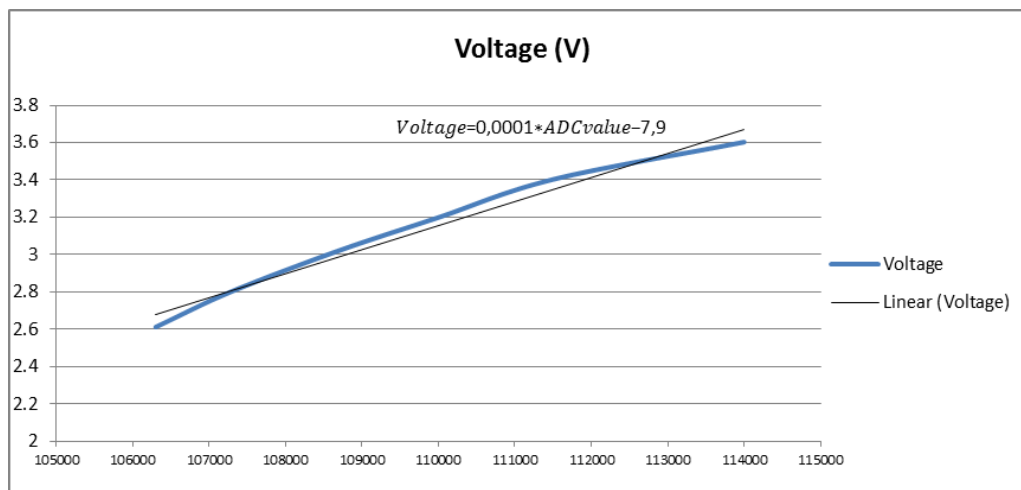
2.2 Debug Mode

In order to turn off the IFAMP the chip has to be set in Debug Mode. This is done by filling the TX FIFO with a specific string and writing 0x01 to the BIST register. With the radio in debug mode the IFAMP can be turned off for correct measurement of V_{DD} . Note that the radio has to be reset to get out of debug mode. Because of this the radio has to be reconfigured after exiting debug mode.

3 Calibration Example

The voltage offset in the ADC varies from chip to chip; therefore, it is necessary to do a calibration before use.

Figure 1 shows that the digital readout is quite linear to the related voltage and a simple linear equation is sufficient for coarse voltage measurement.


Figure 1. ADC Value vs Supply Voltage
Table 3. ADC Value vs Supply Voltage

Supply Voltage	ADC Value
2.612 V	106300
2.804 V	107300
3.022 V	108700
3.199 V	110000
3.403 V	111500
3.603 V	114000

The equation can be found by performing measurements across the wanted voltage range and make a trend line as shown [Table 3](#). The equation for the trend line can then be used in the software to calculate the supply and battery voltage. The equation found in this example is:

$$\text{Voltage} = 0.0001 * \text{ADCvalue} - 7.9 \quad (1)$$

4 References

1. *CC1120 High-Performance RF Transceiver for Narrowband Systems Data Sheet* ([SWRS112](#))
2. *CC1121 High-Performance Low-Power RF Transceiver Data Sheet* ([SWRS111](#))
3. *CC1125 Ultra-High Performance RF Narrowband Transceiver Data Sheet* ([SWRS120](#))
4. *CC112X/CC1175 Low-Power High Performance Sub-1 GHz RF Transceivers/Transmitter User's Guide* ([SWRU295](#))
5. *CC1200 Low-Power, High-Performance RF Transceiver Data Sheet* ([SWRS123](#))
6. *CC120X Low-Power High Performance Sub-1 GHz RF Transceivers User's Guide* ([SWRU346](#))
7. CC112x Software Examples (<http://www.ti.com/lit/zip/swrc219>)
8. CC120x Software Examples (<http://www.ti.com/lit/zip/swrc274>)

Appendix A CC120X Code for Digital Readout

The following code is for CC120x, but can easily be rewritten for use with the CC112x.

```

/*****
*   @fn          voltageRead
*
*   @brief       Reads voltage sensor
*
*   @param       none
*
*   @return      none
*/
static float voltageRead(void) {
    // Variables
    uint8 RegValue = 0;
    uint8 marcStatus;
    uint8 writeByte;
    float voltage = 0;

    // String to put radio in debug mode
    uint8 txBuffer[18] =
{0x0F,0x28,0x02,0x90,0x42,0x1B,0x7E,0x1F,0xFE,0xCD,0x06,0x1B,0x0E,0xA1,0x0E,0xA4,0x00,0x3F};

    // Configure ADC
    writeByte = 0x02;
    ccl20xSpiWriteReg( CC120X_IF_ADC2, &writeByte, 1);
    writeByte = 0xEE;
    ccl20xSpiWriteReg( CC120X_IF_ADC1, &writeByte, 1);
    writeByte = 0x10;
    ccl20xSpiWriteReg( CC120X_IF_ADC0, &writeByte, 1);

    // Set SINGLE_ADC_EN to "Only I-channel" &0x1
    // DVGA Gain to 6dB - This directly modifies the amplitude of the signal
    // and can be used to get the signal within range together with the CHAN_BW register.
    writeByte = 0x05;
    ccl20xSpiWriteReg( CC120X_MDMCFG1, &writeByte, 1);

    // ADC Decimation factor max
    writeByte = 0x88;
    ccl20xSpiWriteReg( CC120X_CHAN_BW, &writeByte, 1);

    // Zero-IF
    writeByte = 0x00;
    ccl20xSpiWriteReg( CC120X_IF_MIX_CFG, &writeByte, 1);

    // Disable DC_FILT
    writeByte = 0x40;
    ccl20xSpiWriteReg( CC120X_DCFILT_CFG, &writeByte, 1);

    // Make sure CHFILT_BYPASS is not set
    writeByte = 0x00;
    ccl20xSpiWriteReg( CC120X_MDMCFG0, &writeByte, 1);

    // Route ATEST MUX to battmon
    writeByte = 0x2B;
    ccl20xSpiWriteReg( CC120X_ATEST, &writeByte, 1);

    // Set ATEST to battmon
    writeByte = 0x08;
    ccl20xSpiWriteReg( CC120X_ATEST_MODE, &writeByte, 1);

    // Enable test at IFAMP output
    writeByte = 0x01;
    ccl20xSpiWriteReg( CC120X_PA_IFAMP_TEST, &writeByte, 1);

```

```

// Set chip in RX
trxSpiCmdStrobe(CC120X_SRX);

// Read marystate and wait until chip is in RX
do {
    ccl120xSpiReadReg(CC120X_MARCSTATE, &marcStatus, 1);
} while (marcStatus != 0x6D);

// Put radio in debug mode
// Write debug init to tx fifo
ccl120xSpiWriteTxFifo(txBuffer, sizeof(txBuffer));

// Run code from FIFO
writeByte=0x01;
ccl120xSpiWriteReg( CC120X_BIST, &writeByte, 1);

// Strobe IDLE
trxSpiCmdStrobe(CC120X_SIDLE);

// Set IF AMP in PD
writeByte=0x1F;
ccl120xSpiWriteReg( CC120X_WOR_EVENT0_LSB, &writeByte, 1);

// Strobe SXOFF to copy command over
trxSpiCmdStrobe(CC120X_SXOFF);

// Turn off VCO to save power and eliminate voltage
// drop on the reference voltage from different settings.
writeByte=0xFF;
ccl120xSpiWriteReg( CC120X_WOR_EVENT0_LSB, &writeByte, 1);

// Strobe SXOFF to copy command over
trxSpiCmdStrobe(CC120X_SFSTXON);

// Radio now in Debug Mode

// Wait until channel filter data is valid
do {
    ccl120xSpiReadReg(CC120X_CHFILT_I2, &RegValue, 1);
} while (!RegValue&0x08);

// Read ADC value from CHFILT_I registers
ccl120xSpiReadReg(CC120X_CHFILT_I2, &RegValue, 1);
ADCValue_I = ((int32)RegValue) << 16;
ccl120xSpiReadReg(CC120X_CHFILT_I1, &RegValue, 1);
ADCValue_I |= (((int32)RegValue)<< 8) & 0x0000FF00;
ccl120xSpiReadReg(CC120X_CHFILT_I0, &RegValue, 1);
ADCValue_I |= (int32)(RegValue) & 0x000000FF;

// Simple conversion of ADC value to voltage
voltage = (ADCValue_I * 0.0001) - 7.9;

// Return voltage
return voltage;

```

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