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}).

Contents

List of Tables

Submit Documentation Feedback

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
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

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 VDD. 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 on the graph:

$$Voltage = 0{,}0001 * ADCvalue - 7{,}9$$
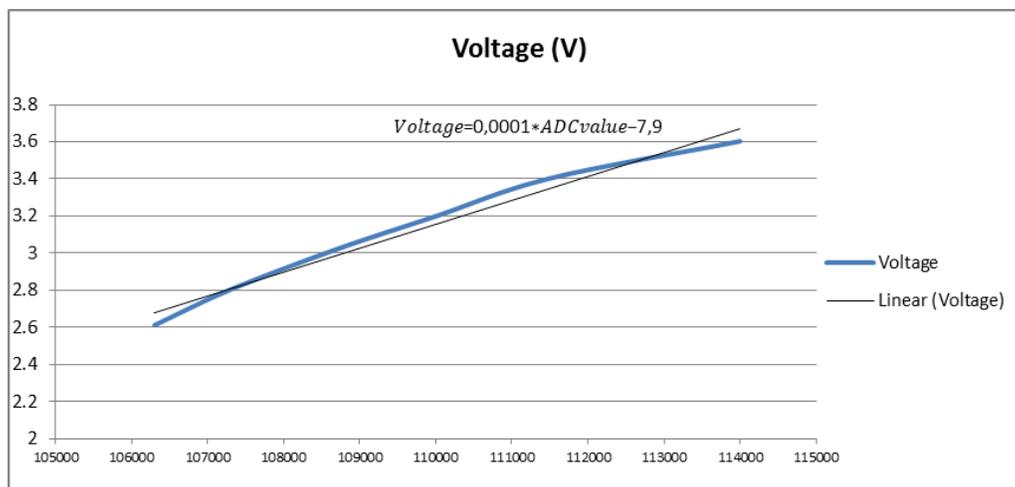
Figure 1. ADC Value vs Supply Voltage

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:

$$Voltage = 0.0001 * ADCvalue - 7.9 \tag{1}$$

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;
  cc120xSpiWriteReg( CC120X_IF_ADC2, &writeByte, 1);
  writeByte = 0xEE;
  cc120xSpiWriteReg( CC120X_IF_ADC1, &writeByte, 1);
  writeByte = 0x10;
  cc120xSpiWriteReg( 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;
  cc120xSpiWriteReg( CC120X_MDMCFG1, &writeByte, 1);

  // ADC Decimation factor max
  writeByte = 0x88;
  cc120xSpiWriteReg( CC120X_CHAN_BW, &writeByte, 1);

  // Zero-IF
  writeByte = 0x00;
  cc120xSpiWriteReg( CC120X_IF_MIX_CFG, &writeByte, 1);

  // Disable DC_FILT
  writeByte = 0x40;
  cc120xSpiWriteReg( CC120X_DCFILT_CFG, &writeByte, 1);

  // Make sure CHFILT_BYPASS is not set
  writeByte = 0x00;
  cc120xSpiWriteReg( CC120X_MDMCFG0, &writeByte, 1);

  // Route ATEST MUX to battmon
  writeByte = 0x2B;
  cc120xSpiWriteReg( CC120X_ATEST, &writeByte, 1);

  // Set ATEST to battmon
  writeByte = 0x08;
  cc120xSpiWriteReg( CC120X_ATEST_MODE, &writeByte, 1);

  // Enable test at IFAMP output
  writeByte = 0x01;
  cc120xSpiWriteReg( CC120X_PA_IFAMP_TEST, &writeByte, 1);
```

```
   // Set chip in RX
   trxSpiCmdStrobe(CC120X_SRX);

// Read marcstate and wait until chip is in RX
   do {
     cc120xSpiReadReg(CC120X_MARCSTATE, &marcStatus, 1);
   } while (marcStatus != 0x6D);

   // Put radio in debug mode
   // Write debug init to tx fifo
   cc120xSpiWriteTxFifo(txBuffer,sizeof(txBuffer));

   // Run code from FIFO
   writeByte=0x01;
   cc120xSpiWriteReg( CC120X_BIST, &writeByte, 1);

   // Strobe IDLE
   trxSpiCmdStrobe(CC120X_SIDLE);

   // Set IF AMP in PD
   writeByte=0x1F;
   cc120xSpiWriteReg( 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;
   cc120xSpiWriteReg( 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 {
     cc120xSpiReadReg(CC120X_CHFILT_I2, &RegValue, 1);
   } while (!RegValue&0x08);

   // Read ADC value from CHFILT_I registers
   cc120xSpiReadReg(CC120X_CHFILT_I2, &RegValue, 1);
   ADCValue_I = ((int32)RegValue) << 16;
   cc120xSpiReadReg(CC120X_CHFILT_I1, &RegValue, 1);
   ADCValue_I |= (((int32)RegValue) << 8) & 0x0000FF00;
   cc120xSpiReadReg(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;
```

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have *not* been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		Applications	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		