

**ON Semiconductor®**



**APPLICATION NOTE AND9313/D**

**AX5043**

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**Use as Analog FM  
Transceiver**

Revision 2



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## 1. Introduction

This application note describes how to use the AX5043 as an analog FM half-duplex transceiver. A modified AX-RadioLAB project, `ax5043_analog_FM_demo`, is used to demonstrate FM operation.



## 2. The AX5043\_analog\_FM\_demo Project

The AX5043\_analog\_FM\_demo\_v1.1 project is a modified AX-RadioLAB\_v2.3g project. The SLAVE firmware demonstrates analog FM receive, whereas MASTER firmware demonstrates analog FM transmit. AX-RadioLAB and the AXRadioV2API provide a basic setup, allowing to check for the AX5043 IC, to set some general parameters (e.g. carrier frequency) and to range the PLL.

The default configuration is for 200kHz wideband (broadcast) FM. For narrow band FM the following changes should be made: The RX bandwidth should be adjusted using AX-RadioLAB. The TX deviation should be adjusted by changing AX5043\_FSKDEV0 in COMMON/fm.c according to the formula in 4.2.

The following tables list those input parameters of AX-RadioLAB which are relevant here and the derived AX5043 registers relevant for FM operation.

Parameter	Panel	Comment
Ref Osc Config	Pin Configuration	A TCXO should be used for narrow band FM (25kHz channels). An XTAL is sufficient for common FM radio reception.
PA Config	Pin Configuration	Single ended or differential
VCO Config	Pin Configuration	Internal or external L, depending of carrier frequency.
Carrier frequency	PHY	
RFDIV	PHY	Depending of carrier frequency
Symbol Rate	PHY	AX5043_RXDATARATE is computed from this parameter. In FM RX mode this determines the rate at which the baseband signal is sampled. Typically 100kS/s.
Channel Spacing	PHY	
Fxtal	PHY	
XTALCAP	PHY	
Transmit Power	PHY	
RX Bandwidth	PHY	

Register
AX5043_FREQA3
AX5043_FREQA2
AX5043_FREQA1
AX5043_FREQA0
AX5043_DECIMATION
AX5043_RXDATARATE2
AX5043_RXDATARATE1
AX5043_RXDATARATE0
AX5043_AGCGAIN0
AX5043_AGCTARGET0



AX5043_PHASEGAIN0
AX5043_AMPLITUDEGAIN0
AX5043_FREQDEV10
AX5043_FREQDEV00
AX5043_BBOFFSRES0
AX5043_MODCFGF
AX5043_MODCFGGA
AX5043_TXPWRCOEFFB1
AX5043_TXPWRCOEFFB0
AX5043_PLLRNGCLK
AX5043_BBTUNE
AX5043_BBOFFSCAP
AX5043_TMGRXBOOST
AX5043_TMGRXSETTLE
AX5043_TMGRXOFFSACQ
AX5043_RSSIREFERENCE
AX5043_0xF10
AX5043_0xF11
AX5043_0xF1C
AX5043_0xF21
AX5043_0xF22
AX5043_0xF23
AX5043_0xF26
AX5043_0xF34
AX5043_0xF35
AX5043_0xF44
AX5043_PLLLOOP
AX5043_PLLCPI
AX5043_PLLVCODIV
AX5043_PLLVCOI
AX5043_XTALCAP
AX5043_0xF00
AX5043_REF
AX5043_0xF18

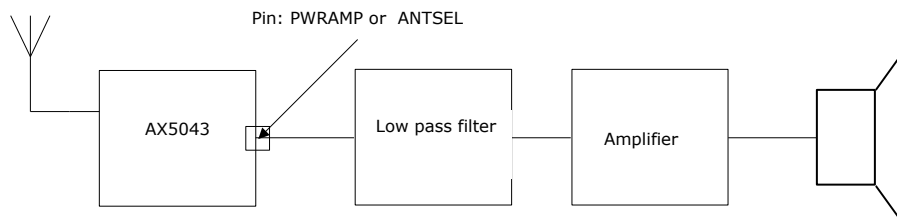
Further AX5043 register settings relevant for analog FM operation are hard coded in the COMMON/set\_fm\_tx() and COMMON/set\_fm\_rx() routines. They are described in the further sections of this document.

AX5043 registers related to preamble matching and the packet engine are irrelevant for analog FM operation.



### 3. Receive side

#### 3.1. Hardware setup



The AX5043 features a bitstream DAC, which can output a demodulated baseband signal. The output can be configured to be on pin ANTSEL or PWRAMP. On the AXSEM DVK2b modules PWRAMP is used. To convert the bitstream into an audio signal a low pass filter and an amplifier are required. The low pass filter on the DVK2b modules is first order with a cutoff frequency of 1.8 kHz. For better audio quality a higher order filter is required.

#### 3.2. Software configuration

Analog FM mode is selected by setting `AX5043_MODULATION = 0x0B`.

The following points have to be considered:

1. RX bandwidth and IF configuration function as in other receive modes.
2. The formula for `AX5043_RXDATARATE` is the same as for digital receive modes, except that `BITRATE` is replaced by  $f_{SR}$ , the sampling rate of the baseband signal.
3. `AX5043_RXPARAMSETS = 0x00` ensures that the RX parameter set 0 is used at all times. Therefore receiver parameter sets 1, 2 and 3 are not used. Registers related to preamble matching and the packet engine are not used.
4. Bit timing recovery should be disabled by setting `AX5043_TIMEGAIN0`, `AX5043_DRGAIN0` and `AX5043_MAXDROFFSET` to 0.
5. The AFC loop controlled by `AX5043_FREQGAINA` and `AX5043_FREQGAINB` (TRKFREQ) is used as an FM demodulator. The AFC loop controlled by `AX5043_FREQGAINC` and `AX5043_FREQGAIND` (TRKRFFREQ) is used for tracking static frequency offsets. `AX5043_FREQUENCYLEAK > 0` prevents the demodulator loop from tracking static frequency offsets.



6. In the formulas for AX5043\_IFFREQ, AX5043\_DECIMATION and AX5043\_RXDATARATE listed in the AX5043 Programming Manual, the quantity  $f_{\text{xtal}}$  should be replaced by  $f_{\text{xtal}}/2^{(\text{ADCCLKMUX})}$ , where  $\text{ADCLKMUX} = 0xF35[1:0]$ .



The following table shows register settings for FM radio reception with a 16 MHz reference.

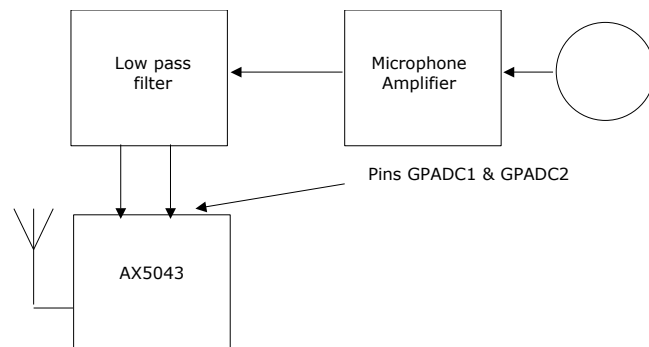
Register	Value	Calculation / Comment
AX5043_MODULATION	0x0B	Analog FM
AX5043_IFFREQ	0x0666	25kHz ( $f_{\text{xtal}} = 16\text{MHz}$ )
AX5043_RXPARAMSETS	0x00	only use receiver parameter set 0
AX5043_TIMEGAIN0	0x00	disable bit timing recovery, which would only add jitter
AX5043_DRGAIN0	0x00	off
AX5043_MAXDROFFSET	0x000000	off
AX5043_MAXRFOFFSET2	0x80CCCC	track at LO1, max 50kHz @ $f_{\text{xtal}} = 16\text{MHz}$
AX5043_FREQUENCYGAINA0	0x0F	off
AX5043_FREQUENCYGAINB0	0x02	bandwidth of "inner" AFC loop used for FM demodulation. $f_{\text{3dB}} = 0.115 \cdot \text{BR}$ . This is the fastest setting available
AX5043_FREQUENCYGAINC0	0x1F	off
AX5043_FREQUENCYGAIND0	0x08	bandwidth of "outer" AFC loop (tracking frequency mismatch), 78Hz @ $\text{BR}=100\text{kbps}$ , $f_{\text{xtal}}=16\text{MHz}$
AX5043_FREQUENCYLEAK	0x04	$\text{FREQUENCYGAINB0} + 2$ , prevents the demodulator AFC loop from tracking static frequency offsets
AX5043_DACCONFIG	0x03	output TRKFREQUENCY (=demodulated signal) on DAC
AX5043_DACVALUE1	0x00	
AX5043_DACVALUE0	0x0c	DACSHIFT = 12 bit. This gives maximum volume, downshifting further gives smaller volume
AX5043_PINFUNCPWRRAMP	0x05	Use PWRRAMP pin as DAC output
AX5043_PWRMODE	0x09	FULL RX

With this settings the AX5043 will output a FM radio channel at the set frequency. It is possible to connect a standard high impedance ear piece directly to the pins on the DVK2b module to listen to the radio.



## 4. Transmit side

### 4.1. Hardware setup



The baseband (audio) signal should be applied differentially to pins GPADC1 and GPADC2 (Pins 25 and 26) when using the standalone AX5043. The baseband (audio) signal should be applied differentially to pins TST2 and TST1 (Pins 27 and 28) when using the SoC AX8052F143.

The two single ended GPADC input signals should swing around the common mode voltage of 800mV. The maximum common mode range is +/- 100mV. The maximum differential input signal is 1Vpp. Thus the maximum negative input signal is  $((800\text{mV} - 250\text{mV}) - (800\text{mV} + 250\text{mV})) = -500\text{mV}$ , the maximum positive input signal is  $((800\text{mV} + 250\text{mV}) - (800\text{mV} - 250\text{mV})) = 500\text{mV}$ . The single ended input impedance of each GPADC pin is 50kOhm.

A microphone signal should be amplified to +/- 500mVpp differential signal.

### 4.2. Software configuration

Analog FM mode is selected by setting `AX5043_MODULATION = 0x0B`.

The register `FSKDEV` has a special meaning when FM modulation is selected. It defines the conditioning of the ADC signal prior modulation.

`AX5043_GPADCPERIOD` controls the rate at which the analog baseband signal is sampled. `AX5043_TXRATE` has no meaning in FM mode.




Register	Value	Calculation / Comment
AX5043_MODULATION	0x0B	Analog FM
AX5043_FSKDEV2	0x00	
AX5043_FSKDEV1	0xC0	GPADC13, enable sign extension and offset (=midcode) subtraction.
AX5043_FSKDEV0	0x07	$f_{\text{deviation}} = \pm 65\text{kHz}$ [max / min ADC value gives $f_{\text{deviation}} = \pm f_{\text{xtal}} / 2^{(\text{AX5043\_FSKDEV0}[2:0]+1)}$ , allowed values are 0..7
AX5043_GPADCPERIOD	0x07	$F_s = f_{\text{xtal}}/32/\text{GPADCPERIOD} \rightarrow 5$ gives 100kHz @ $f_{\text{xtal}}=16\text{MHz}$ . This determines the sampling rate, AX5043_TXRATE has no meaning in FM mode.
AX5043_GPADCCTRL	0x06	continuous sampling of GPADC13
AX5043_PINFUNCDATA	0x04	Enables continuous TX operation, rather than powering up the PA only if there is committed FIFO data. This is similar to wire mode, except that no data is read from the pin in FM mode.
AX5043_PWRMODE	0x0D	FULL TX



## 5. Conclusion

It is possible to implement FM audio and data transceivers with the AX5043.

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