

XE1218A

Low power single die FM receiver

General Description

The XE1218 is a single die, low power, FM receiver operating in the VHF band from 130MHz to 230MHz. Its highly integrated architecture allows for RF and audio functions on the same die, whilst minimizing the external components needed to build a complete application at the same time.

The XE1218A enables single chip, complete audio transmission solutions, where the antenna feeds the incoming RF signal directly into the XE1218A and an amplified audio signal can be fed to an earphone directly from the XE1218A's output.

Flexibility has been built into the XE1218A: various different transmission channels can be selected, the audio output can also be fed to a post processing circuit such as sound de-emphasis or an external power amplifier.

The XE1218A is optimized for battery powered applications, it can be operated directly on one lithium 1.5V battery cell.

Applications

- Wireless phone headset
- Local area voice paging
- FM broadcasting miniature receiver
- Toys

Main features

- Tuneable from 130MHz to 230 MHz
- High reception sensitivity: -100dBm
- Integrated RF filtering
- Low voltage operation: down to 1.1V
- Low power consumption: typical 2.5mA
- 6 kHz audio bandwidth
- 40 dB audio SNR
- Integrated earphone audio amplifier
- Line out for external audio amplifier
- Mute function

Ordering Information

Part Number	Temperature range	Package
XE1218AS000BF	-10°C to 40°C	Bare die

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1. Functional description

1.1 General description

The XE1218A is an integrated FM receiver including all the necessary functions to process a modulated RF signal at its input and deliver a “speech quality” audio signal at its output. The XE1218A was designed for maximum system simplicity thus it requires only 12 external components to offer antenna in, audio out functionality. The XE1218A also offers design flexibility. A direct connection to an earphone is possible through the pin EAR, this takes advantage of the internal audio power amplifier or an external audio amplifier, or an audio processing device can be connected via the OUT (line out) pin.

1.2 RF front end

The FM signal received through the antenna is delivered to an integrated LNA via an external matching circuit. A low IF architecture is implemented to down-convert the incoming signal to an intermediate frequency (IF) of 25kHz. This IF signal is then filtered to remove any DC components and equalized to offer a clean digital signal to the demodulator. The FM demodulator uses digital delay line architecture to convert the signal to a pulse width modulated signal at twice the IF frequency. The XE1218A has an integrated AFC which is used for the demodulator to have its clock frequency track the IF frequency.

1.2.1 LNA

The noise figure (NF) for this block is less than 6dB, for an antenna impedance in the 1 to 2 k Ω range. Out of the 6dB, 3dB is due to the noise of the image frequency that is not rejected. The sensitivity is –100dBm (SINAD=10 dB, fdev = 3kHz).

1.2.2 Mixer, down-conversion

The down-conversion is implemented as a Gilbert cell. This implementation uses low IF and does not have provisions for integrated image rejection. The incoming audio channel will be demodulated at $F_{lo} = F_{IN} - 25\text{kHz}$. This is to say that the image frequency will be located at $F_{IN} - 50\text{kHz}$ and will not be attenuated by the XE1218A's RF receiving circuitry. For multi-channel operation within reception range of several XE1218A receivers, it is recommended that the various carrier frequencies be spaced by at least 100kHz, better yet 200kHz.

1.2.3 DC offset cancellation, IF amplifier chain

DC components are attenuated in an off-set cancellation block. An on-chip low pass filter provides attenuation greater than 65dBm measured $F_{IF} + 100\text{kHz}$

1.2.4 Demodulation and AFC circuitry

The demodulator converts the signal from the IF amplifier into a pulse width modulated signal at twice the IF frequency. A follow-on block generates the AFC to track the IF frequency. Proper tracking of the IF frequency is necessary for the stability of the RF link as the XE1218A operates in narrow band mode.

1.2.5 Crystal and local oscillator

The local oscillator provides the XE1218A's down-converter mixer with the proper frequency: F_{lo} . It is implemented with a crystal oscillator working on the external crystal's overtone harmonic.

1.3 Audio stage

1.3.1 Audio processing

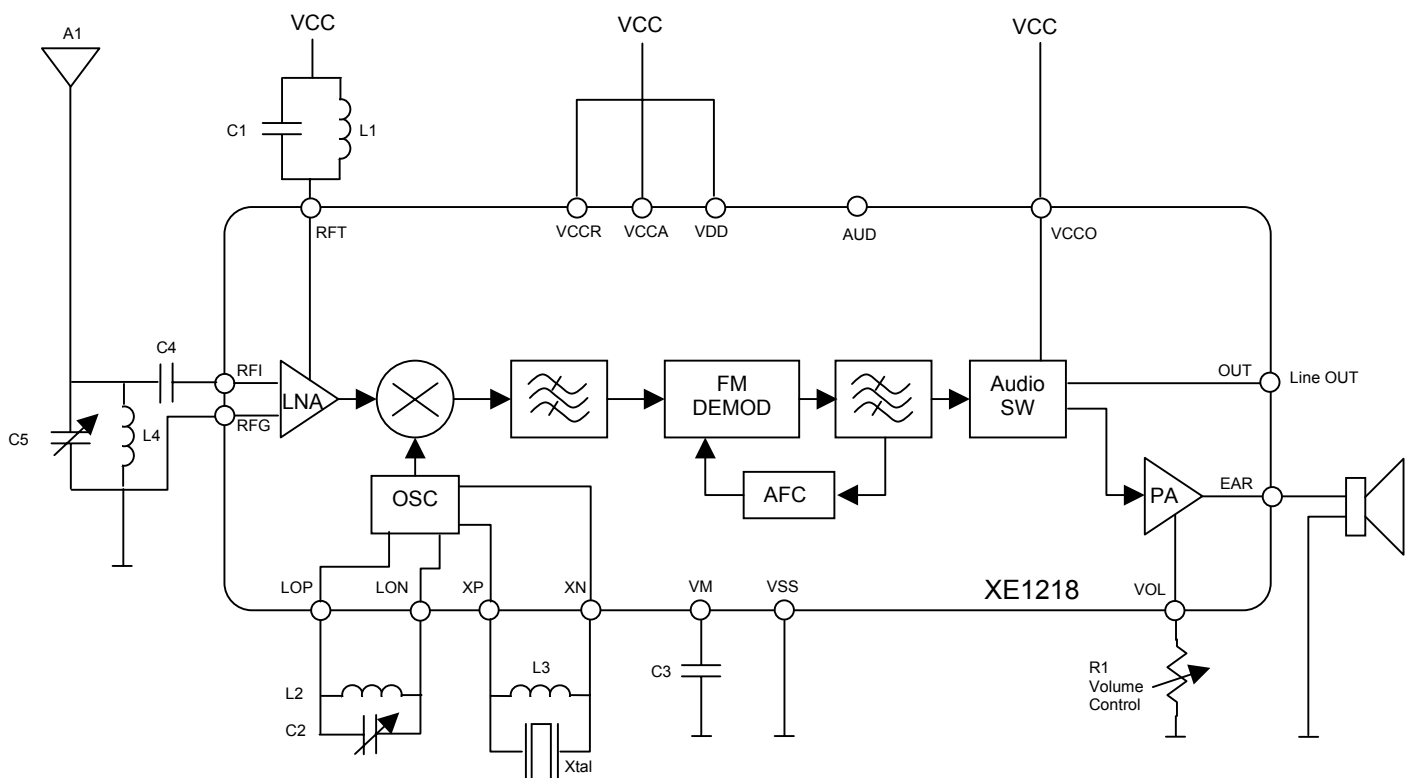
The XE1218A integrated audio processing circuitry filters the input pulse width modulated (PWM) signal from the demodulator and provides for two different output feeds. All necessary bias currents and voltages for this analog block are on-chip, including a voltage multiplier circuit. When the incoming RF signal becomes low, the signal to noise ratio at the audio output decreases, which drastically reduces the sound quality and intelligibility. For user convenience, a mute function is implemented in the audio section. When the signal to noise ratio at the output is too low (typ. 10 to 15 dB) the audio output is shut down.

1.3.2 Audio output stage

An integrated power amplifier (PA) allows for a direct connection to an earphone. Controlled by an external potentiometer (100kΩ) a maximum attenuation of 10dB is achievable on the EAR output, 21.5dB with 1MΩ. A high impedance line out (10kΩ) is available through the pad OUT.

2. Functional implementation

2.1 Block diagram



2.2 Operation overview

While the XE1218A is a single channel receiver, various fixed frequencies can be selected between 130MHz and 230MHz. This is achieved by changing the external RF front-end components: L1, L2, L3, L4, C1, C2, C4, C5 and Xtal. The XE1218A FM receiver connects to the antenna via a differential input: pins RFI and RFG. The external components L4, C4 and C5 must tune the circuit to the incoming carrier frequency. L2 and C2 are calculated to tune the oscillator to the desired incoming carrier frequency. Xtal is selected according to the desired input carrier frequency, L3 relaxes the oscillator's Q factor to insure greater reception stability. Reception sensitivity is determined through the LNA's external tank circuit: C1 and L1.

Two types of audio outputs can be selected: OUT (line out, 10kΩ output impedance) to connect to an external audio processing circuit or amplifier and EAR for direct connection to an earphone. An external R1 is used to adjust the volume through pin VOL. The internal RF and audio blocks each have their own supply voltage as well as a common VDD. Clean voltage must be supplied to each of these supplies (VCCR, VCCA, VCCO and VDD).

2.3 Application example

To tune the above circuit to a carrier frequency of 160.325MHz, the following external components must be implemented:

L1	56nH-5%	C1	12pF-5%	C5	2pF - 6pF-5%
L2	56nH-5%	C2	10pF- 15pF-5%	R1	100k Ω - 10%
L3	180nH-5%	C3	10nF-5%	Xtal	160.325MHz
L4	120nH – 5%	C4	22pF-5%	A1	Wire l > 40mm

The value of the capacitors given here may change slightly for different PCBs.

3. Electrical characteristics

3.1 Absolute maximum ratings

Parameter	Min	Max
Supply voltage	-0.3V	2.5V
Storage Temperature	-55°C	+125°C

Stress beyond those listed under absolute maximum ratings may cause permanent damage to the XE1218 device. These are stress ratings only, and functional operation of the device at these or any other condition beyond those under “recommended operating conditions” is not implied. Exposure to “absolute maximum ratings” conditions for extended periods may affect the device reliability.

3.2 Recommended operating conditions and electrical specifications

General conditions: Temp = 25°C, VDD= 1.3V, Carrier Frequency=160MHz, unless otherwise specified

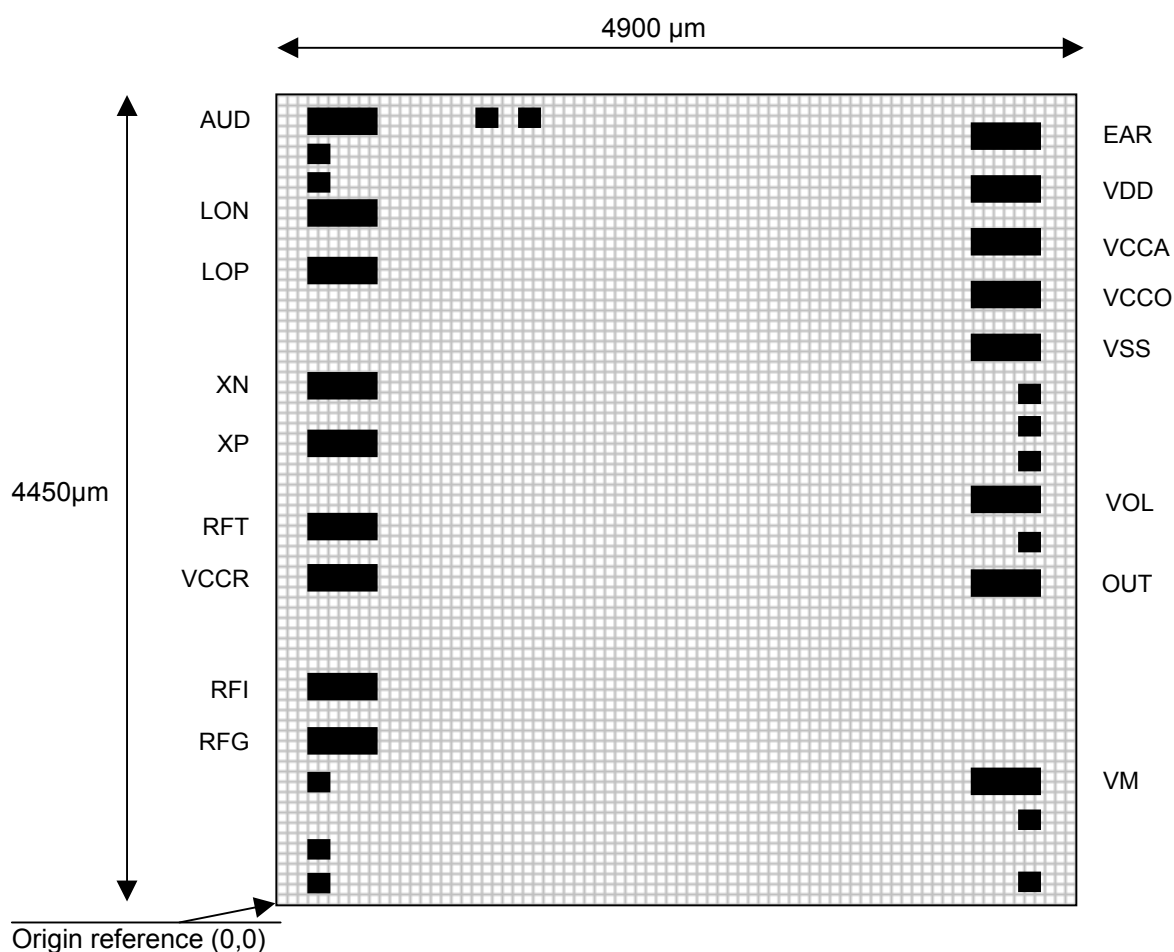
Symbol	Description	Condition	Min	Typ.	Max	Unit
Electrical supply parameters						
VDD	Power supply		1.1	1.3	1.6	V
IDD	Supply current	Receiver ON, without earphone PA enabled		2.5	4.5	mA
TEMP		Operating temperature range	-10		+40	°C
Radio Frequency parameters						
RF-IN	Carrier frequency	Input range	130		230	MHz
F-DEV	Deviation frequency	Maximum deviation of the incoming modulated signal			8	kHz
LO-D	Local Oscillator shift	Crystal ageing and temperature drift not accounted for			± 20	ppm
RFS	RF input sensitivity	$f_{\text{modulated}} = 1\text{kHz}$, $f_{\text{dev}} = 3\text{kHz}$		-100		dBm
ACR	Adjacent channel rejection	$f_{\text{unwanted}} = f_{\text{Rfin}} + 100\text{kHz}$ $f_{\text{modulated}} = 1\text{kHz}$, $f_{\text{dev}} = 3\text{kHz}$ $P_{\text{in}} = \text{RFS} + 10\text{dBm}$ $\text{SINAD} = 10\text{dB}$		50		dB
Audio parameters						
AOB	Audio Output bandwidth (typical)	Fdev = 3kHz	0.1		6	kHz
AOD	Audio distortion on PA output (EAR)	Only relevant if using the direct earphone connection $f_{\text{modulated}} = 1\text{kHz}$, $f_{\text{dev}} = 5\text{kHz}$ $R_{\text{vol}} = 100\text{k}\Omega$ $P_{\text{in}} = -60\text{dBm}$, BW = 20kHz		2	8	%

Symbol	Description	Condition	Min	Typ.	Max	Unit
Audio parameters cont.						
ASN	Audio SNR on PA output (EAR)	$f_{\text{modulated}} = 1\text{kHz}$, $f_{\text{dev}} = 3\text{kHz}$ $R_{\text{vol}} = 100\text{k}\Omega$ $P_{\text{in}} = -60\text{dBm}$, $\text{BW} = 6\text{kHz}$		40		dB
DC-EAR	DC voltage on EAR output	Only in use for direct earphone connection to the PA (EAR)	150		450	mV
Z-EAR	External earphone impedance	Impedance of the earphone that directly connects to the EAR output	200		1000	Ω

4. Interconnections

The XE1218A is delivered in bare die. The complete FM receiver functionality requires 16 bond wire connections from the die to the 1st level substrate (for EAR functionality, 18 wire bonds for the line out connection). The die measures 21.8mm^2 ($4.9\text{mm} \times 4.45\text{mm}$). For prototyping purposes, the XE1218A is also available in a TQFP44 package, see details on the next page.

4.1 Bare die pad out



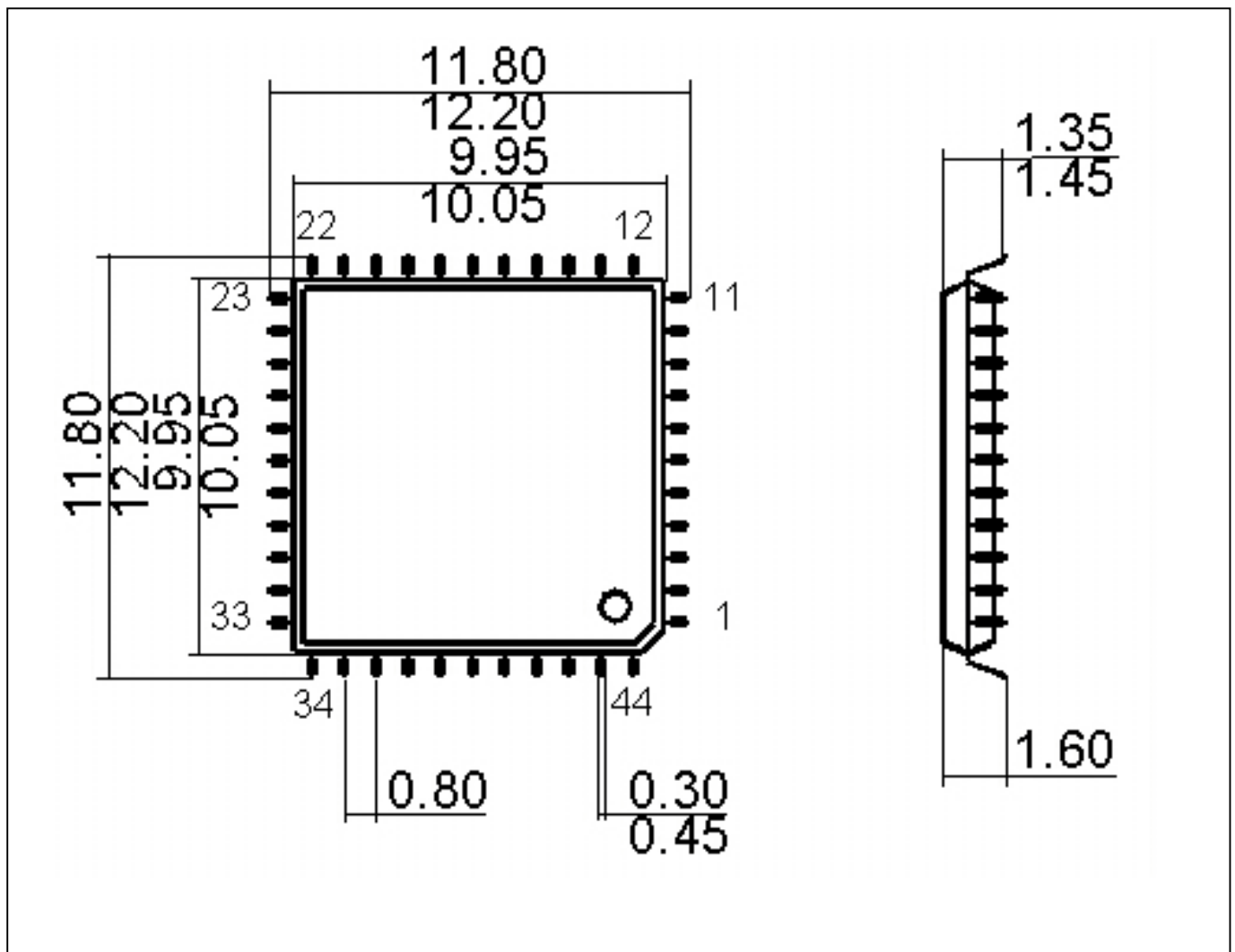
4.2 Pad coordinates

The pad coordinates below are referenced to the lower left corner of the die (see picture above). The reference is to the center of the bond pad.

Pad name	X,Y coordinates (μm)	Pad name	X,Y coordinates (μm)
LON	145, 3569	AUD	145, 4166
LOP	145, 3391	EAR	4629, 4141
XN	145, 2843	VDD	4629, 3962
XP	145, 2664	VCCA	4629, 3782
RFT	145, 1944	VCCO	4629, 3526
VCCR	145, 1765	VSS	4629, 3270
RFI	145, 1283	VOL	4629, 2323
RFG	145, 1105	OUT	4629, 1809
		VM	4629, 757

4.3 XE1218A packaging

The following TQFP package is not currently qualified for production volumes. It serves solely prototyping purposes.



4.4 TQFP44 pin-out

Only the relevant signals are listed below. All other pins should remain N.C. (not connected)

Pin name	Pin number	Pin name	Pin number
LON	4	EAR	34
LOP	3	VDD	33
XN	6	VCCA	32
XP	5	VCCO	31
RFT	7	VSS	30
VCCR	8	VOL	26
RFI	10	OUT	24
RFG	11	VM	23
		AUD	44

5. Input – output signal description

Pin Name	Description	Functionality	Type
LOP	Local oscillator tank	The integrated local oscillator is used to produce the mixer frequency to down convert the incoming carrier frequency. This local oscillator requires an external tank circuit, which must be tuned to select the desired crystal overtone.	Analog I/O
LON	Local oscillator tank		Analog I/O
XP	Crystal oscillator connection	The crystal is connected between pins XP and XN. An inductance must be put in parallel.	Analog I/O
XN	Crystal oscillator connection		Analog I/O
RFI	RF signal input (differential to RFG)	The incoming carrier frequency is fed to the LNA via a differential input (RFI and RFG). For best results, an external capacitive impedance matching circuit is required.	Analog Input
RFG	RF signal ground (differential to RFI)		Analog ground
RFT	LNA tank circuit	The LNA has an external tank circuit to optimize its gain. The resonance frequency of this tank circuit must be adjusted to be the same as the incoming carrier frequency	Analog I/O
VCCR	Supply voltage to the RF circuitry	This is the supply voltage for the RF section of the XE1218A. It must be clean and de-coupled properly.	Analog supply
VDD	Supply voltage to the digital circuitry	This is the supply voltage for the digital and control circuitry of the XE1218A. It must be clean and de-coupled properly.	Digital supply
VSS	Ground reference	This is the ground reference. VDD, VCCA and VCCR are referenced to this pin.	Digital ground
VCCA	Supply voltage to the analog circuitry	This is the supply voltage for the analog section of the XE1218A. It must be clean and de-coupled properly.	Analog supply
VM	External capacitor for voltage multiplier	The XE1218A audio circuitry requires an internal voltage multiplier. This multiplier requires an external capacitor to be connected to VM	Analog I/O
VCCO	Supply for audio circuitry	This pin must be connected to VDD	Supply input
VOL	Volume control	This is used when the integrated PA is in use. An external potentiometer (100k Ω to 1M Ω) will allow varying the volume at the EAR output. 100k Ω will give you a tuning range of 0dB to –10dB and 1M Ω will equate to 0dB to –21.5dB	Analog input
OUT	Line out	High impedance audio output: impedance = 10k Ω	Analog output
EAR	Earphone out	Earphone output, average 250mV, \pm 3dB, speaker impedance must be between 200 Ω and 1k Ω	Analog output
AUD	Audio out de-coupling	This pin is only used when the line out (OUT) is selected. An additional de-coupling capacitor is needed for line out best performance	Analog output

6. Application information

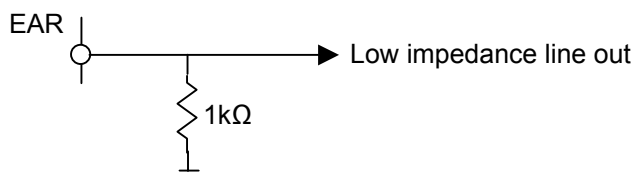
6.1 Recommended crystal oscillator

The recommended characteristics of the crystal used for generating the local oscillator frequency (LO) are the following:

- Supplier: Telequarz
- Type: HSLX5132
- Frequency: 160.325 MHz (7th overtone)
- Motional capacitance $C_s = 0.2 \text{ fF} \pm 0.15 \text{ fF}$
- Calibration tolerance at 25 °C: $\pm 10 \text{ ppm}$
- Stability over temperature range: $\pm 5 \text{ ppm}$
- Ageing in the first year: $\pm 3 \text{ ppm}$

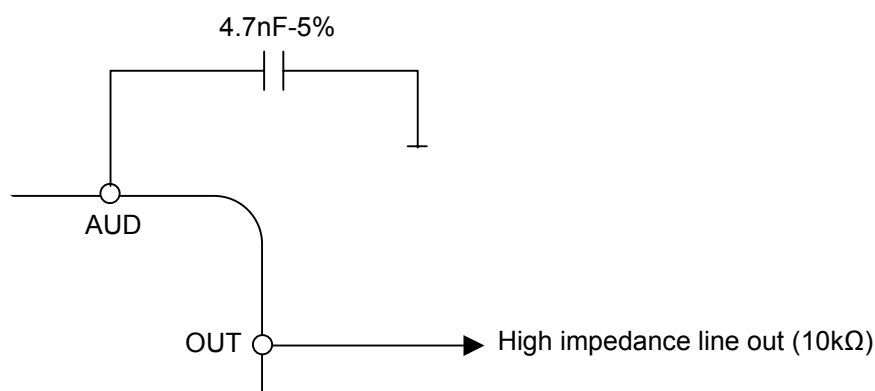
6.2 Using a low impedance audio output

The XE1218A provides two possible audio outputs: a) direct connection to an earphone and b) a high impedance line out (10k Ω). Should a low impedance output be required to interface with an audio post processing stage, this output can be matched by using the EAR output of the XE1218A. The adaptation should be as follows:



6.3 Using the high impedance line out OUT

If the line out OUT pin is used on the XE1218A to interface to an analog audio post processing circuit such as a sound de-compounder or external power amplifier, a de-coupling capacitor must be connected to the pin AUD of the XE1218A. Please note that this capacitor is only necessary when the system uses the OUT connection. When the internal amplifier is used and an earphone is directly connected to the output EAR, the pin AUD must not remain connected.



6.4 Recommended antenna

All antenna types need to be adapted with regards to the selected operating frequency. In the examples below the antennas are tuned for an incoming frequency of 160.350MHz ($F_O + F_{IF}$: 160.325MHz + 25kHz). The antenna can be a printed wire on the PCB, or real estate permitting a wire or a coil.

In the case of a wire antenna, its length should be slightly above 40mm (Figure 1). It can either be printed straight on the PCB or a loose wire can be used. A magnetic coil antenna however is recommended because unlike a wire antenna, it is less sensitive to de-tuning by the proximity of the body.

The coil is made of 1.8 turns of a 0.4mm diameter copper wire. The diameter of the antenna is 14mm for a typical coil inductance of 140nH (Figure 2). The coil is soldered in such a way as to be elevated from the PCB by at least 10mm, this is to reduce losses due to the ground plane effect of the board.

The value of the capacitors given here may change slightly for different PCBs.

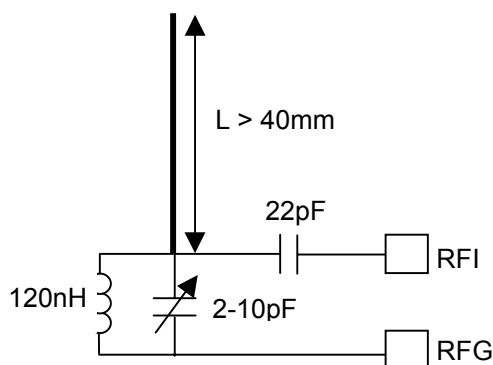


Figure 1

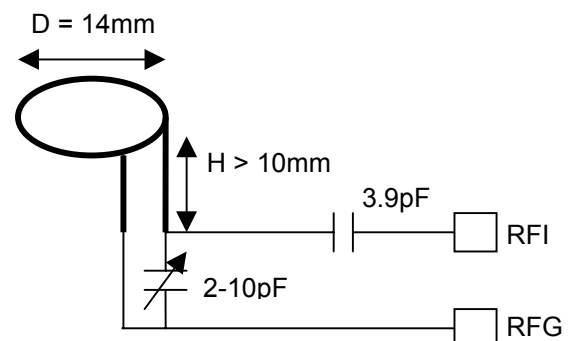


Figure 2

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