Application Note

AN1201.02

The XE1201 operation in the 315MHz band

Author: Gaël CORON

For further information please contact:

XEMICS SA, Gaël Coron
Tel: +41 32 720 5192 **Fax:** +41 32 720 5770
Web: http://www.xemics.ch **E mail:** gael.coron@xemics.ch

TABLE OF CONTENTS

INTRODUCTION

This application note describes the operations of the XE1201 in the 315MHz band. The XE1201 is a half-duplex FSK single chip transceiver that is normally built to work on both the 433MHz ISM band and on the 390-470MHz band. By using a SAW Resonator at 315MHz (carrier frequency), the XE1201 can be set to work properly without losing its advantages (Low power consumption, Direct Digital Synthesizer function, Bit Synchronizer…). For more details about the XE1201 transceiver please refer to the Datasheet and the Application Information (http://www.xemics.ch).

The values of the internal capacitors have been measured at 433.92MHz. Trimmer capacitors are used to adjust and to compensate the differences between 433.92MHz and the new carrier frequency (315MHz in this application note).

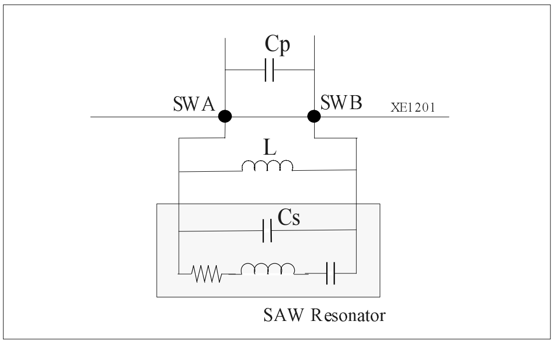
I - EXTERNAL COMPONENTS

In order to adapt the transceiver to the 315MHz band, values of some of the external components must be modified. The most important of these is the SAW Resonator, this determines the carrier frequency. The tank circuits need to be adapted according to this frequency. Moreover, the matching network (RFin and RFout) needs to be modified.

SAW Resonator

A negative resistor is created inside the XE1201, between SWA and SWB pins with a parallel parasitic capacitor (Cp). The RF Equivalent RLC Model of the SAW Resonator shows a parallel parasitic capacitance Cs (Transducer Static Capacitance). To compensate for the influence of the two parasitic capacitors (Cp and Cs), an inductor is placed in parallel with the SAW Resonator (Figure 1).

FIGURE 1: SAW RESONATOR CIRCUIT



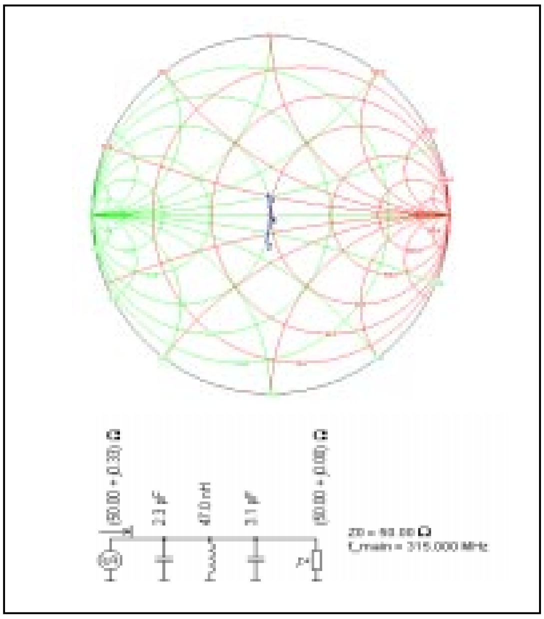
The SAW Resonator RO2073A (RFM) designed for 315MHz application has a Transducer Static Capacitance that equals to 2.3pF. The value of the internal parallel parasitic capacitor, Cp, is 3.1pF.

The value of the inductor can be found by using the Smith Chart (Figure 2).

By using the SAW Resonator RO2073A and placing it in parallel with the inductor of 47nH, the XE1201 transceiver can be adapted into the 315MHz band.

L= 47nH	
Cs =2.3pF	Cp=3 .1pF

FIGURE 2: SAW RESONATOR ADAPTATION



LNA tank circuit

The external components of the LNA tank circuit depend on the carrier frequency. The function of this tank circuit is to maximize the available power gain. In order to do this, a current source is created inside the XE1201 between the TLA and TLB pins. This architecture also creates a parasitic capacitor (Cp). An inductor L (L_1+L_2) is placed in parallel to compensate it (Figure 3). Moreover, the tank circuit needs to resonate at the carrier frequency defined by the SAW Resonator. To reduce the value of the inductor, a capacitor is placed in parallel with Cp to obtain:

$$Ceq = Cp + C$$

One of the external components needs to be fixed L or Ceq. For example L at 36nH (L=18nH + 18nH, a common value). It is possible to optimize the tank circuit by replacing the capacitor by a trimmer.

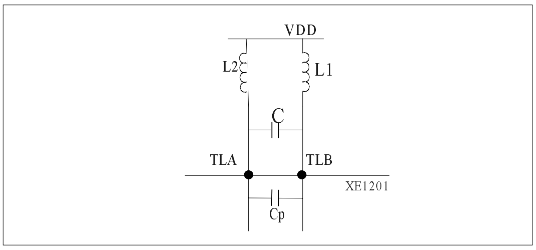
According to the following equation:

$$L\,Ceq\,\varpi^2=1$$

the external components for the tank circuits are defined as:

$L_1=L_2$ = 18nH	
C=4pF	with a trimmer C=3 – 5pF

FIGURE 3: LNA TANK CIRCUIT

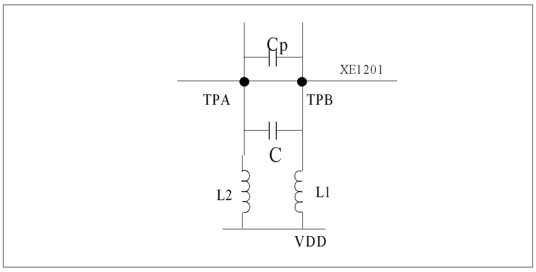


Up Converter tank circuit

The Up-converter tank circuit (Figure 4) serves the same purpose as the LNA tank circuit. However, the values of the external components stay the same.

L_1=L_2 = 18nH C=4pF with a trimmer C=3 – 5pF

FIGURE 4: UP-CONVERTER TANK CIRCUIT

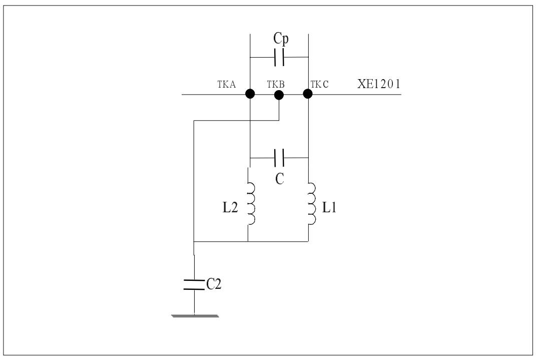


LO tank circuit

The internal LO block must be connected to the following external tank circuit (Figure 5). The LC resonance is created between TKA and TKC pins, TKB (internal biasing) must be grounded via C2.

The external components are defined as follows: L_1=L_2 = 18nH C=4pF with a trimmer C=3 – 5pF

FIGURE 5: LOCAL OSCILLATOR TANK CIRCUIT



RFout Matching Network

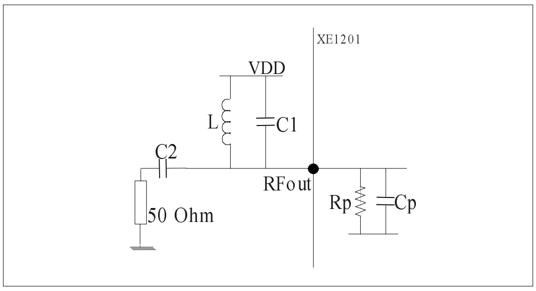
Topology

A matching network is needed to transfer the maximum power from the RFout to the antenna. The values of the external components of this match are dependent on the carrier frequency.

The output impedance of the transceiver XE1201 (RFout) can de defined by its parallel model (Rp and Cp), with Cp=2.4pF

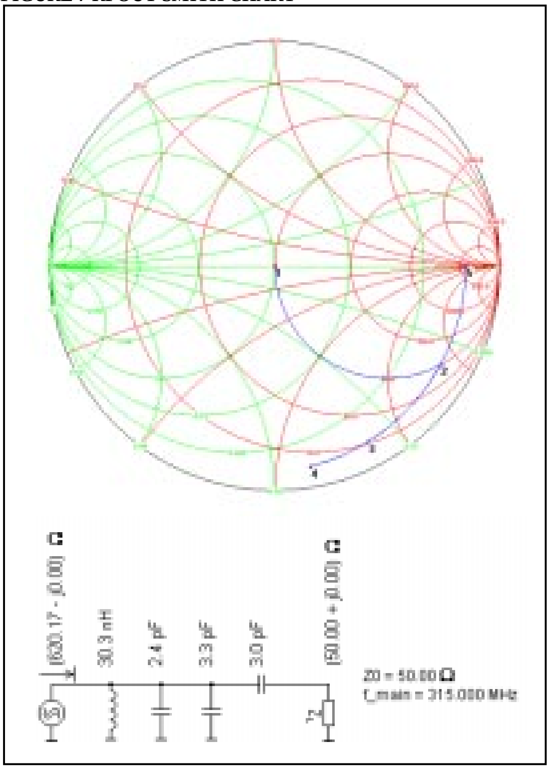
The RF output is a current source (open collector). It must be biased to a positive voltage via an inductor connected to Vdd. A maximum of power can be transferred to a 50Ω antenna if an up-impedance converter is achieved from 50Ω to 600Ω, (RFout pin impedance =(600 +j0) Ω). The RFout matching network architecture (Figure 6) is shown below:

FIGURE 6: RFOUT MATCHING NETWORK



The values of the external components can be defined by using the Smith Chart (Figure 7).

FIGURE 7 RFOUT SMITH CHART



Components values:
L=30nH
C1=3.3pF with a trimmer C=5pF
C2=3p

RFin matching Network

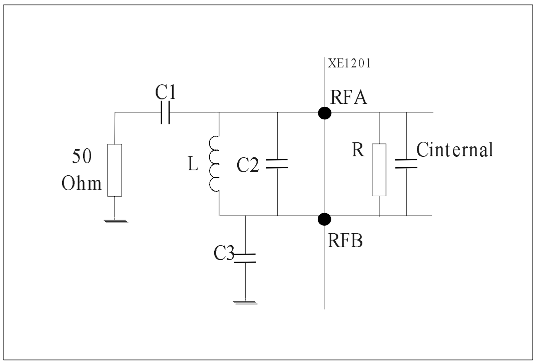
Topology

This function allows an impedance transformation, as well as converting a single ended input to a differential transformation. Two inputs are created, one being with a phase of π.

The input real impedance of the LNA block is 1KΩ, in parallel model. An up converter is achieved from 1KΩ to 50Ω at the local frequency (in this Application note, the carrier frequency is 315MHz).

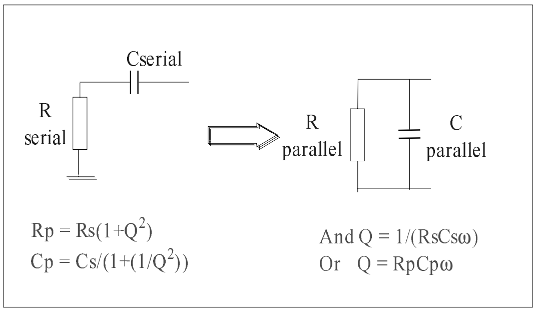
The Rfin matching network (Figure 8) is shown below

FIGURE 8: RFIN MATCHING NETWORK



To determine the values of the external components, different steps need to be followed. The first step is to transform the antenna to a parallel equivalent schematic (Figure 9).

FIGURE 9: SERIAL TO PARALLEL TRANFORMATION



Rserial and Cserial are defined by:

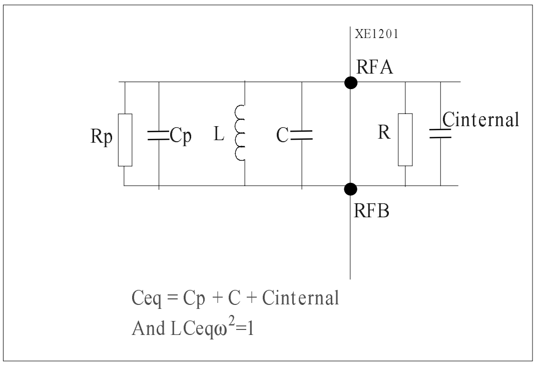
- Rs=50
- Cs=1.1pF (it is a choice)

So, the values of the components are:

- Q=9.2
- Rp=4282
- Cp=1.1pF

The second step is to add an inductor to resonate at the carrier frequency (Figure 10). Furthermore, an external capacitor is added to minimize the internal parasitic capacitor effect (its value can not be easily controlled). This component also reduces the value of the inductor (in HF, the inductors have low values).

FIGURE 10: RESONANCE CIRCUIT



Components values:
L =22nH
So Ceq =14.2pF

With C=2.2pF and Cinter=4pF

- Cp=8pF

By using Cs=Cp/(1+(1/Q2)

- Cs=7.9pF

By identification, the components values

- Input impedance measure
- Parallel real part: Rp=1K
- Parallel capacitor part: Cp=4pF
- C=C1+C3
- C1=Cs/2=4pF
- C3=Cs/2=4pF
- C2=2.2pF

II- ADJUSTEMENT AND PERFORMANCES

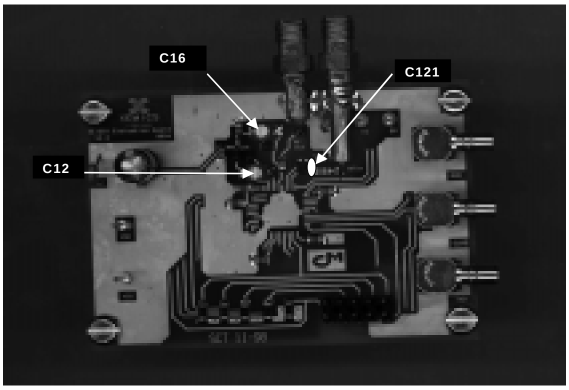
Adjustment

A test board has been made to evaluate its performance on 315MHz. This test board is based on the Evaluation kit (refer to board on 433.92MHz) where the external components have been modified according to calculation. A trimmer capacitor has also been added in the RFin matching network block. The complete schematic is given in Annex.

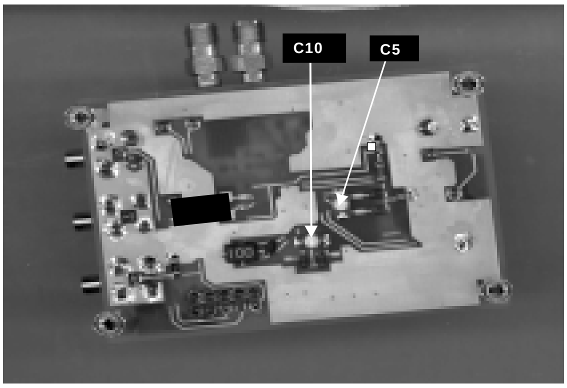
The first capacitor to trim is the Local Oscillator tank circuit (C10). A spectrum analyzer is connected to the Rfout and the capacitor is adjusted to obtain the carrier frequency on 315MHz. To perform this operation, the XE1201 must be set as a receiver.

Data is present on the TXD pin once the XE1201 transmitter is set. The capacitor C5 is trimmed to obtain maximum power level on RFout port. This adjustment is important because it has an influence on the receiver and transmitter functionary mode.

On the transmitter mode, the capacitor C16 is set to obtain the maximum power performance on a 50 Ohm load. On the receiver mode, C12 and C121 are adjusted to obtain maximum voltage amplitude at IO and QO pins. When all the trimmers are set, the board is ready to transmit or receive. and performance evaluation can be done.



Top view



Bottom view

Spectrum Waveforms

Verification of the RF output signal can be made by using a spectrum analyzer. The figures 11a and 11b show the spectrum of a FSK signal measured at transmitter output (RFout). A pseudo random bit sequence is applied on the TX pin. The configuration is the following:
125kHz as frequency deviation and the output power set to -5dBm.

In figure 11a, the markers show the value of the frequency deviation (2*125kHz). With the Reference Level at 0dBm and 10dB/Div, the output power at –5dBm is verified.

In figure (11b) below, the marker shows the center frequency: 315MHz.

FIGURE 11a: FSK DEVIATION

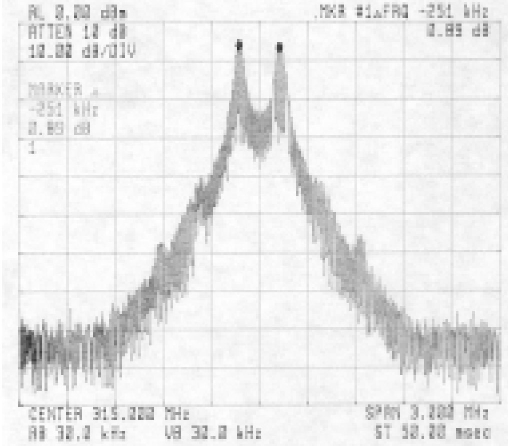
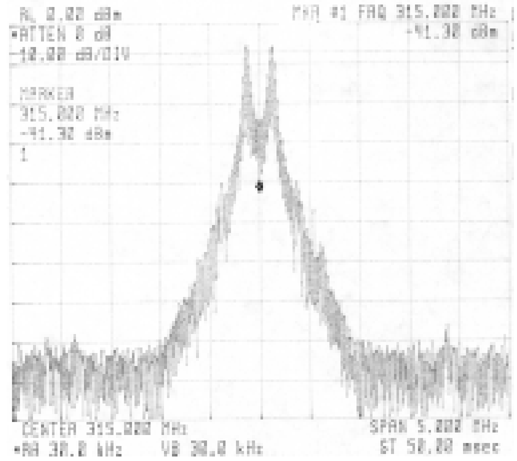
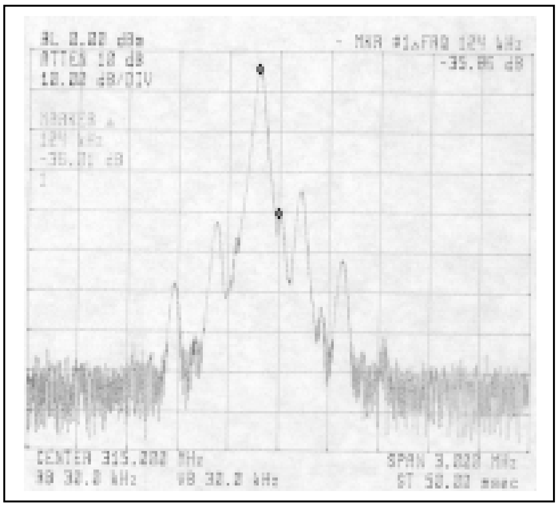


FIGURE 11b: FSK DEVIATION



The figure 11c shows the spectrum of a FSK signal when a "0" is transmitted. In this case, the spur is at 315Mhz minus the frequency deviation, so 314.875MHz.

FIGURE 11c: FSK DEVIATION, "0" TRANSMIT



- The markers show the frequency deviation (125kHz) between the carrier frequency (315MHz) and the first harmonic (information)
- Power level:
  - Local oscillator fed through 36dBc
  - Fdev image <-30dBc
  - 2nd harmonic <50dBc

Sensitivity

The sensitivity depends on the modulation index. The following parameter can be defined according to the formulas below:

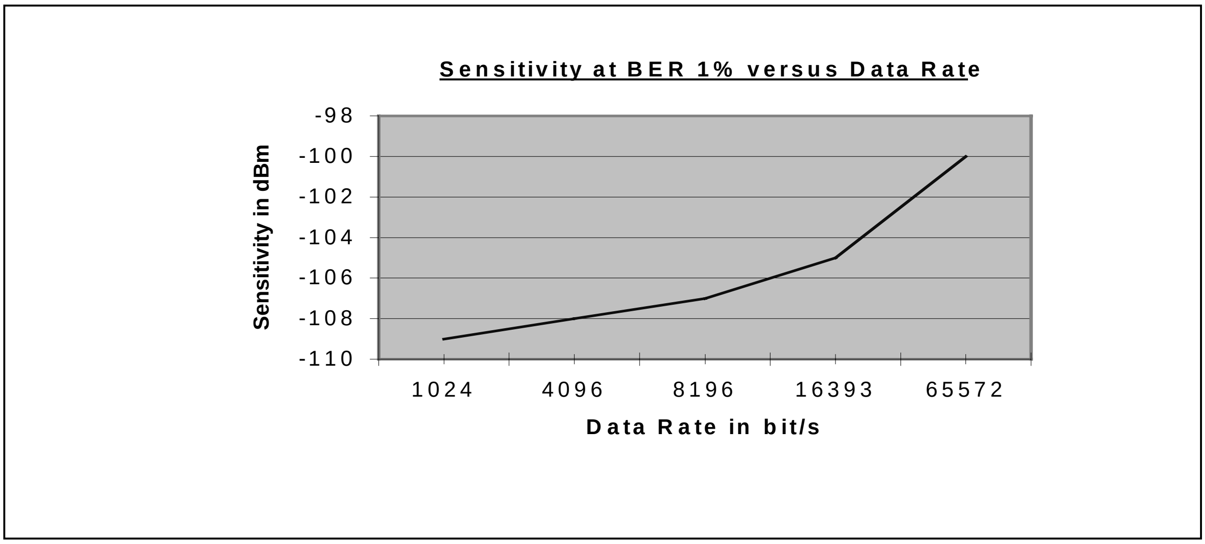
$$\beta = \frac{fdev}{Data\_Rate} \quad \text{OR} \quad Data\_Rate = \frac{fdev}{\beta}$$

The parameter β serves as the modulation index and fdev is the frequency deviation.

These equations show that a relationship exists between modulation index, frequency deviation and data rate. Therefore, the sensitivity depends on the data rate. Figure 12 and the table below show the measurement of the sensitivity with a bit error rate less than 10E-2 versus Data rate (or modulation index) with a fix frequency deviation (fdev=125kHz)

Table 1: Sensitivity at 315MHz

Data Rate (Bit/s)	Sensitivity at BER 1%
1024	-109dBm
4096	-108dBm
8196	-107dBm
16393	-105dBm
65572	-100dBm

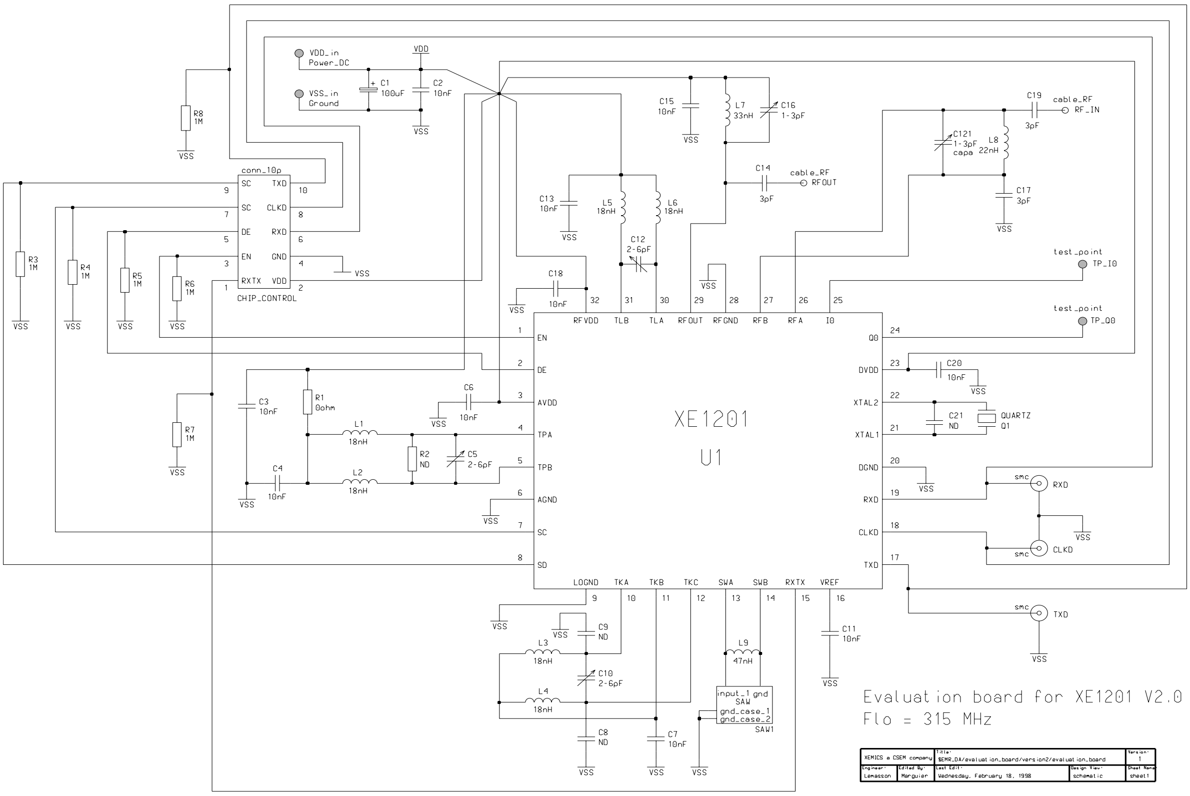


CONCLUSION

As observed, even with the use of a SAW resonator at 315 MHz, the transceiver XE1201 works properly. To achieve a transmission with this carrier frequency, only few component values need to be modified.

The sensitivity at –108dBm, with 4kbit/s, allows the transceiver use with a good communication range. (Similar to the one obtained at 433.92MHz).

ANNEX I: Schematic



ANNEX II: Bill Of Materials

GCO - JUN 99	BOM - XEMICS Evaluation kit XE1201 : 315MHz band					
	Components	References	value	Form	Origin	Qty
RF board						
U1	Transceiver circuit	XE1201	NAP	TQFP32	Xemics	1
Q1	XTAL Quartz	S0409745	4.00 MHz	-	Samix	1
SAW1	SAW resonator	RO-2073A	315 MHz	SM-2	RFM	1
C1	Decoupling capacitor VDD chemical	Any one (not critical)	100 uF	-	Philips or eq	1
C2	Decoupling capacitor ceramic	Any one (not critical)	100 nF	-	Any one	1
C3,C4,C6,C7,C11	Decoupling capacitors	0805 X7R Ni +/-10%, 50v	10 nF	SMD 0805	Philips or eq	9
C5	Adjustment tank PA trim-capacitor	TZC03Z060A110	2 to 6 pF	SMD	Murata or eq	1
C10	Adjustment tank LO trim-capacitor	TZC03Z060A110	2 to 6 pF	SMD	Murata or eq	1
C12	Adjustment tank LNA trim-capacitor	TZC03Z060A110	2 to 6 pF	SMD	Murata or eq	1
C121	Adjustment matching RF-in cap	TZC03Z030A110	1.4 to 3 pF	SMD	Murata or eq	
C14	Adaptation matching RF-out cap	0805 NPO Ni, +/-0.25pF, 50 v	3 pF	SMD 0805	Philips or eq	1
C16	Adjustment matching RF-out cap	TZC03Z030A110	1.4 to 3 pF	SMD	Philips or eq	1
C17	Adaptation matching RF-in cap	0805 NPO Ni, +/-0.25pF, 50 v	3 pF	SMD 0805	Philips or eq	1
C19	Coupling RF-in capacitor	0805 NPO Ni, +/-0.25pF, 50 v	3 pF	SMD 0805	Philips or eq	1
R3,R4,R5,R6,R7,R8	Pull-down resistors digital inputs	Any one (not critical)	1 MOhm	SMD 1206	Philips or eq	6
L1,L2,L3,L4,L5,L6	Inductors for tanks	0805 CS-180-X JBC 5%	18 nH	SMD 0805	Coilcraft or eq	6
L7	Matching RF-out inductor	0805 CS-330-X JBC 5%	33 nH	SMD 0805	Coilcraft ou eq	1
L8	Matching RF-in inductor	0805 CS-220-XJBC 5%	22 nH	SMD 0805	Coilcraft ou eq	1
L9	SAW resonator tuning inductor	0805 CS-470-XJBC 5%	47 nH	SMD 0805	Coilcraft ou eq	1
Conn_10p	Connector 10 pins male double sides	SUBD barette double	0.1 inch			1
RF_in, RF_out	RF SMA connectors	21 SMA-50-3-15/111	-			2
	Semi-rigid coax cable for SMA connection	E2 141	20.5 mm		Huber&Shuhner	1
	Semi-rigid coax cable for SMA connection	E2 141	12.5 mm		Huber&Shuhner	1
VDD-in, VSS-in, IO, QO	Test pins					4
TXD, RXD, CLKD	SMC connectors (digital data)	85 SMC-50-0-1/111	-			3
	Interboards flat cable					1
	Connector 10 pins dipole female	DIN 41651 dipole female			3M, Arting or eq	2
PCB board	Double sides		70 mm x 50 mm			

Printed in Switzerland

Date of release 06.99

A906.049 - AN1201.02 Application Note: operation in 315 MHz XE1201 single chip transceiver