XE1201A/XE3005-WHK2 315 MHz Wireless Headset Reference Design User's Guide

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1. Introduction

The Wireless Headset Kit 2 (WHK2) is based on the XE1201A and XE3005 XEMICS integrated circuits. This WHK allows the user to be hands free while using their cell phone. There are no wires between the headset and the cell phone. The voice over RF link emulates a full duplex communication, with an audio quality comparable to the standard wired-line phone network.

The WHK consists of two devices: the earpiece (user interface) and the dongle (phone interface). Both modules have a small form-factor, which can be easily integrated into various headset shapes. Thanks to its low current consumption and robust technology, this design provides key features for portable communication devices: a reliable wireless voice link and an extended talk time.

Features:

- Emulated full duplex (bi-directional communication).
- ISM license free bands 300-500MHz single frequency.
- Voice quality (phone) transmission.
- Secure communication link (unique ID for both transmitter and receiver).
- Broadcasting range from 3 to 5 meters.
- Only 12mA typical current consumption in operation and 600µA@3.6V in standby mode.
- Rechargeable battery (power supplied by the cell-phone charger: 4 – 14V)
- Up to 2.5 hours talk time and about 80 hours in standby with a 40mAh battery.
- Battery monitoring ("Low battery" indicator and on-board charger socket).
- Remote pick-up directly from earpiece.
- Volume control.

2. Application Basics

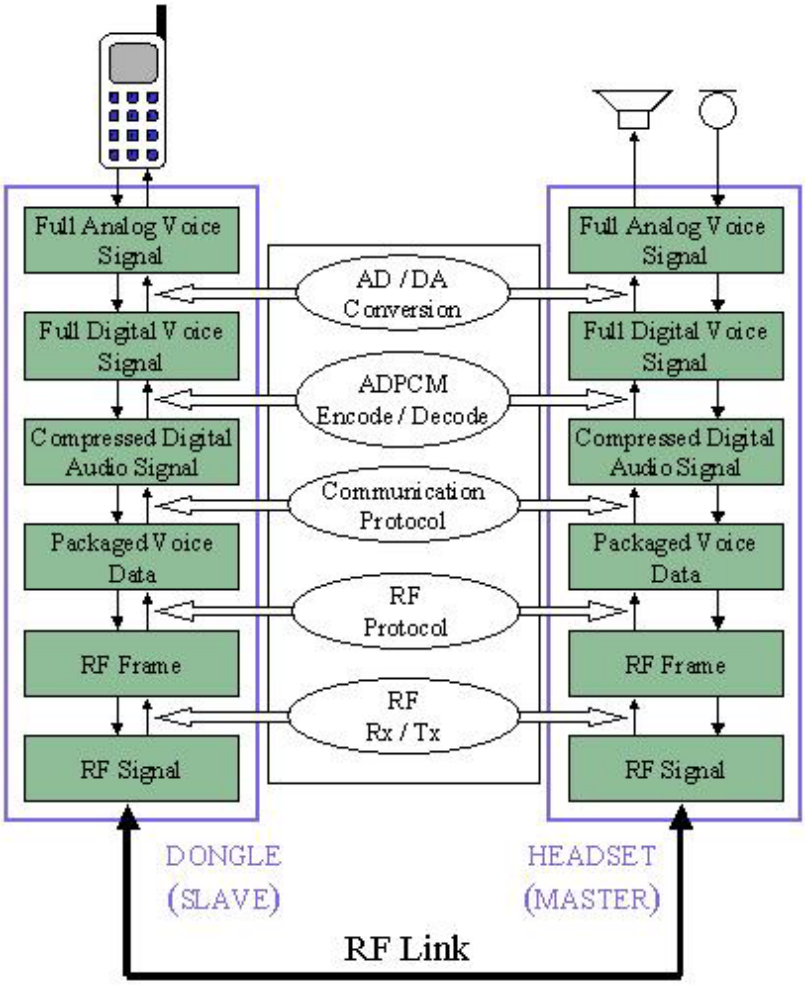
This application's purpose is to replace the wire of a cell phone hands free kit by a RF link. To get best performances, reliability and security, a digital communication is used between the cell phone and the earpiece. The first step is to convert the analog phone audio signal to digital audio signal in order to transmit it in digital format.

The audio signal coming from the phone is a voice signal. We can consider that its frequency range is approximately between 300Hz and 3.4kHz. Covering this band needs at least a 6.8kHz sampling frequency; the sample is taken at 8kHz. As people all have different voice strength and level, the resolution of the conversion should allow a large dynamic of signal. This can be achieved by using 16-bit sampling resolution for the AD and DA conversions.

To transmit 16bits 8000 times per second in one way, we use a data rate of 128 kb/s. To achieve a pseudo full duplex operation, the same amount of data has to be transmitted in the opposite direction. This feature needs 256 kb/s for data. By using a 16 to 3 compression algorithm, the amount of data transferred can be reduced to 48 kb/s. This reduces the power consumption and enables a longer battery lifetime.

A strong RF protocol achieves a secured link with a perceived full duplex. This protocol builds voice data packets and includes them in a complete RF frame. Both the earpiece's microphone signal and the phone's output signal are treated the same way.

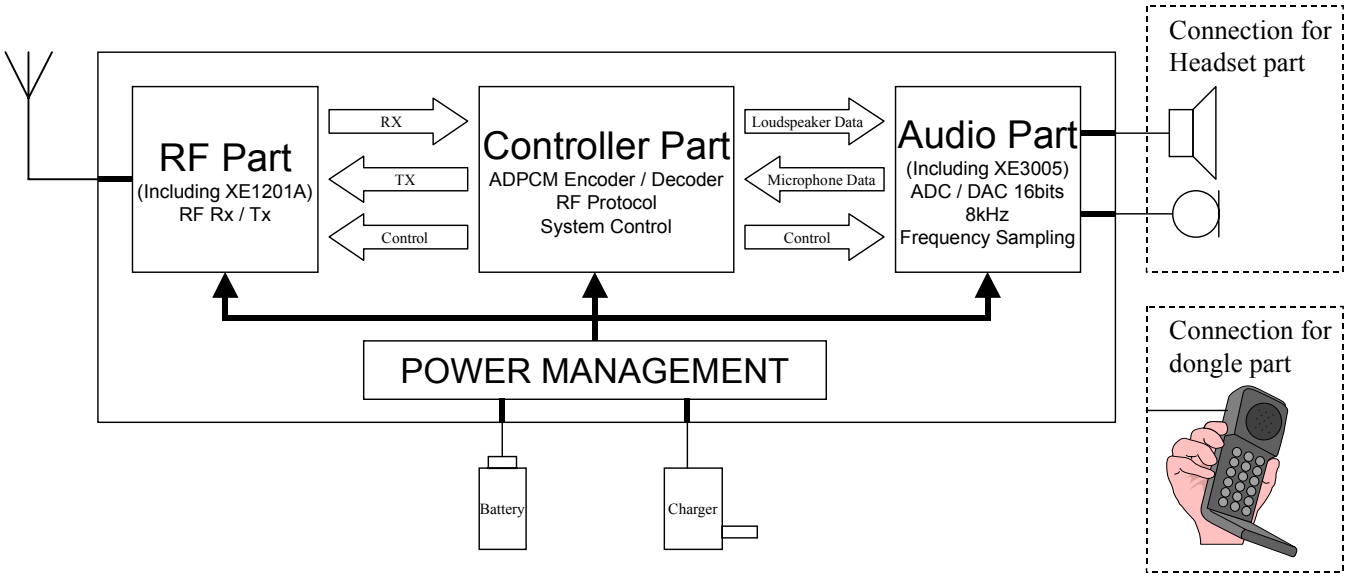
The following diagram shows the different steps to achieve a reliable communication between the cell phone and the earpiece.



From this analysis all the functions described can be implemented on a concrete board. As the power consumption is the key parameter of the system, the ultra low power XEMICS chips are the best candidates to realize the different functions.

The AD/DA conversion is processed by the XE3005, XEMICS low power 16 bits conversion audio CODEC. The XE1201A RF transceiver, which combines low power consumption and high data rate, will be used for RF transmission and reception. The ADPCM algorithm, CODEC routines and RF protocol will be embedded into a microcontroller.

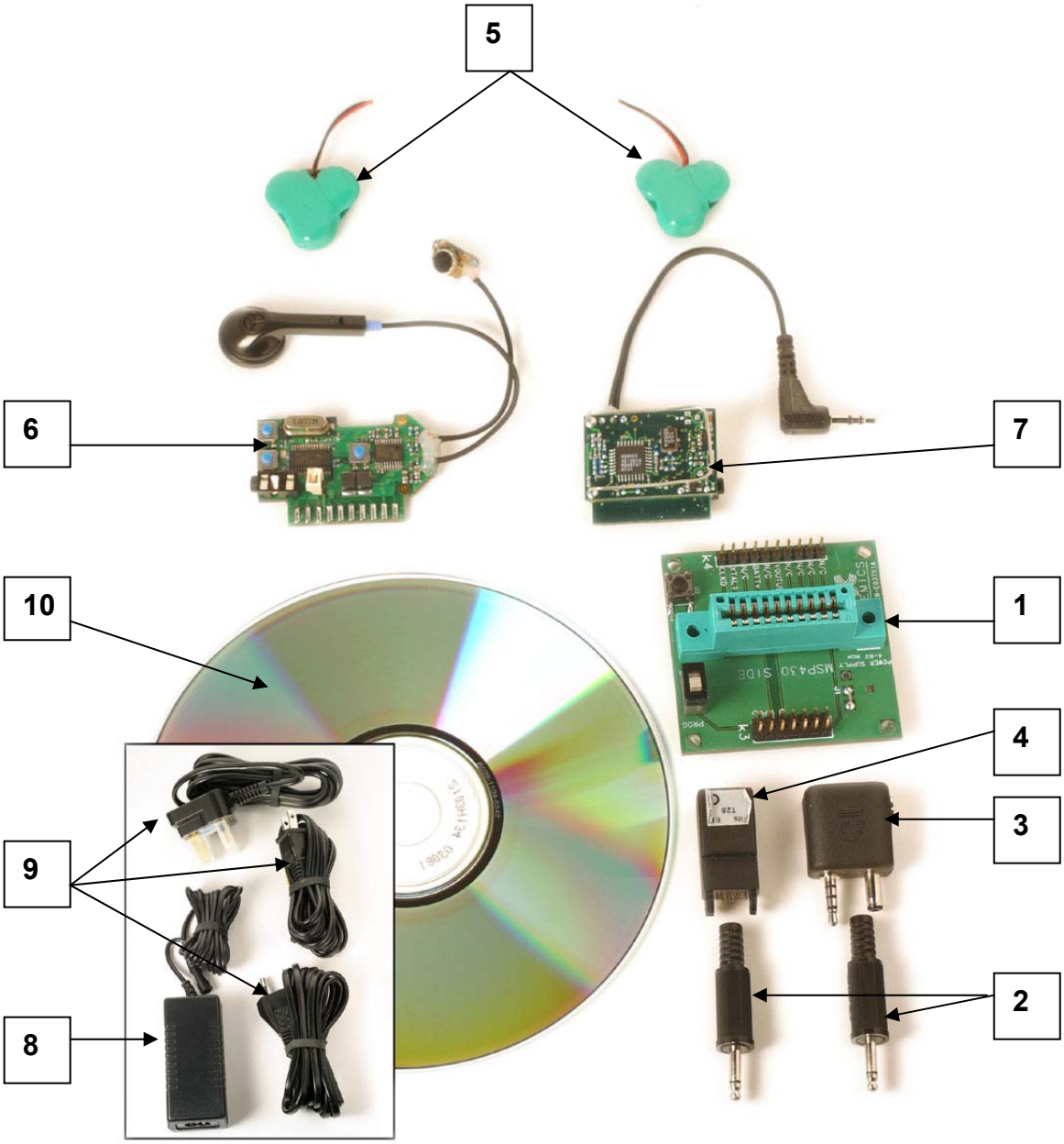
Both parts of the system (dongle and earpiece) are based on the same hardware architecture. There is only a small difference between them due to the audio interface and command buttons. The software also implements small differences as the headset module acts as the master and the dongle module as the slave.



As described in the previous figure, the device is divided into 4 parts:

- The first is the power management part. It has to be connected to a 3.6V/40mAh battery (this is the main board power supply). The battery charge is realised when connecting a 5.5V power supply through the jack socket.
- The second part is the microcontroller. It controls, provides and processes data, it also synchronises the audio and RF parts.
- The RF part provides the wireless link through the antenna.
- The dongle audio part is connected to the cell phone audio interface while the earpiece audio part is connected to a microphone and a loudspeaker. The audio part converts the analogue input signal into digital data, and converts the digital data into an analogue output signal. The analogue output signal is single-ended on the dongle device and differential on the earpiece device.

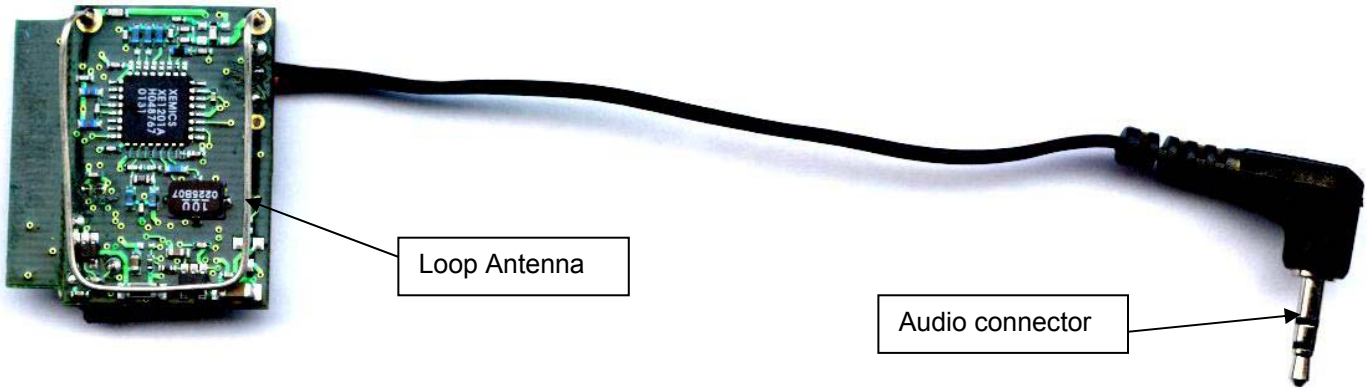
3. Kit Contents



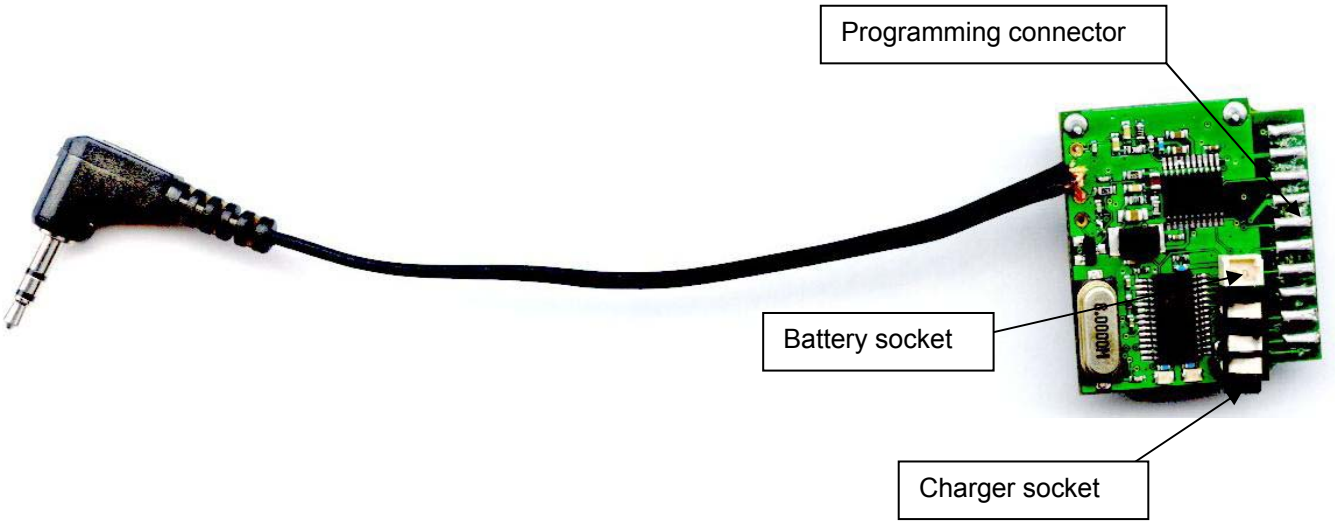
1. **Programming Socket** - This socket allows a developer to load other software into the on-board MSP430 microcontroller.
2. **Battery Inhibitors -** These inhibitors should be plugged, then unplugged to perform a complete and clean reset of the system for example at first use, right after plugging the batteries.
3. **Nokia Adapter -** This adapter must be connected between the phone and the dongle when using a Nokia phone.
4. **Ericsson Adapter -** This adapter must be connected between the phone and the dongle device when using an Ericsson phone.
5. **Batteries -** These 3.6V-40mAh batteries supply the necessary power to the system. Each of them must be connected to the on-board battery sockets. Note that they can be received directly soldered onto the PCB.
6. **Earpiece Device -** Detailed in paragraph 5.
7. **Dongle Device -** Detailed in paragraph 4.
8. **Batteries Charger** - When the batteries are connected on the boards, this charger lets the user charge them both via the on-board charger socket. When plugged, the charger switches the system in charging mode and inhibits its normal operation.
9. **Power Supply Cables For Battery Charger -** While in charging mode, one of these cables (depending on your country) must be plugged between the charger and a high voltage source for battery charging to proceed.
10. **WHK reference design Development Folder –** This CD contains full reference design details: schematics, BOM, Gerber files and PowerPCB Pads files.

4. Dongle Device Overview

4.1 RF side

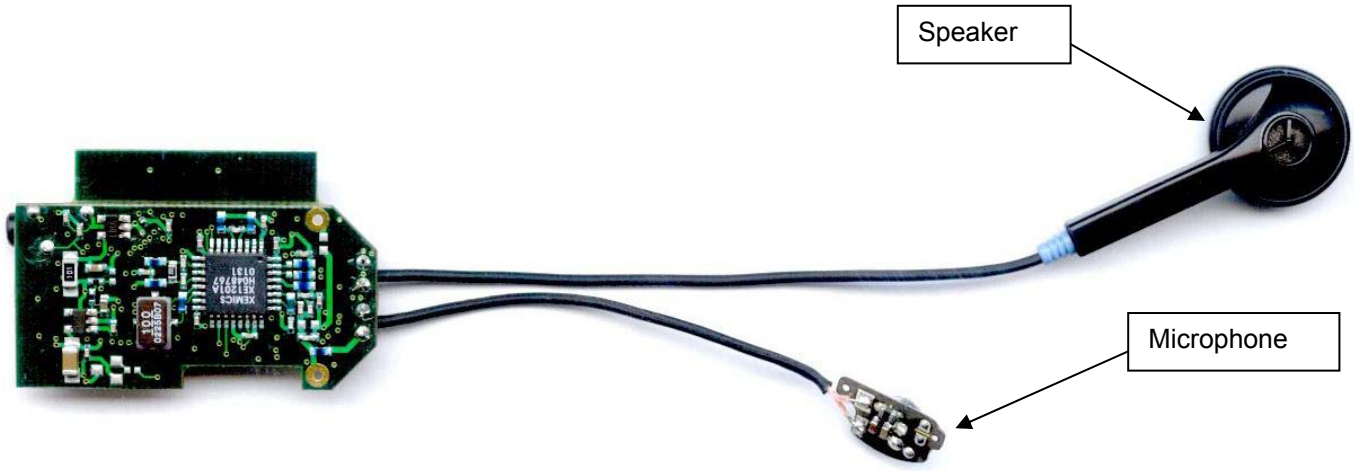


4.2 Audio side

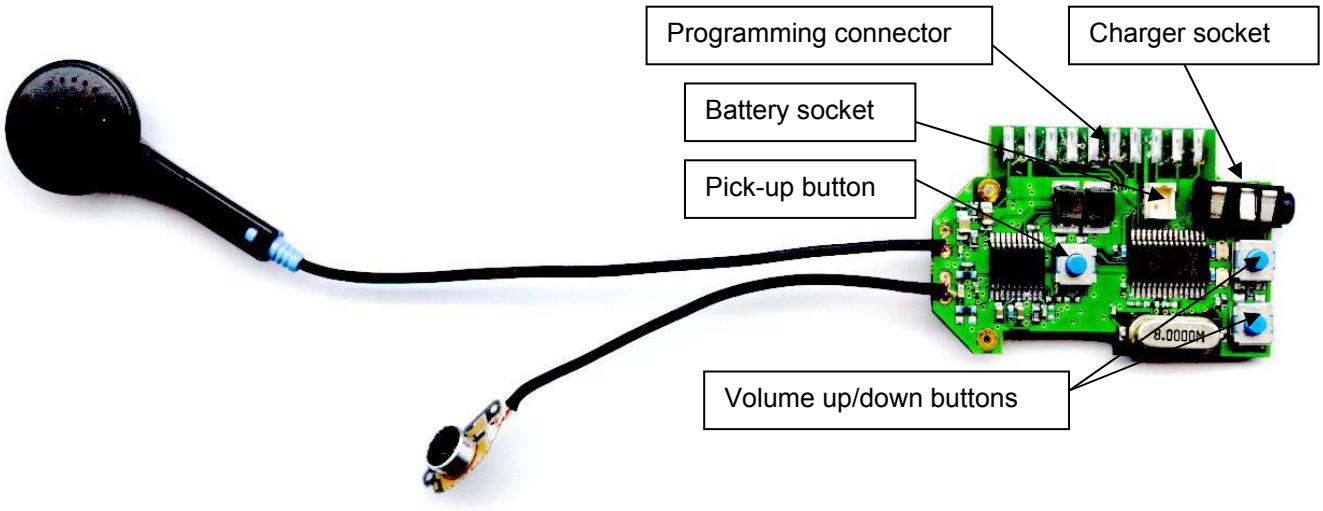


5. Earpiece Device Overview

5.1 RF side



5.2 Audio side



6. System operation

6.1 Kit Installation

a. Plug one of the batteries into the corresponding earpiece device socket.
b. Plug the other battery into the corresponding dongle device socket.
c. Before first use, batteries need to be charged for a few hours (Cf. "Batteries charging" section of the document).
d. Connect the audio connector of the dongle device to the cell phone via the correct adapter. (See figures below)

With the Nokia adapter

With the Ericsson adapter

e. The two earpiece device LEDs should be off. Your Wireless Headset is now in standby mode and ready to operate.

6.2 Making a call

a. From standby mode, press the pick-up button on the earpiece device. After a few seconds, both green LEDs on each device will blink at the same frequency indicating that the RF link is established.
b. Dial the number on your cell phone, then speak and listen normally in the earpiece mike and speaker while staying within the broadcasting range of the system. Limit of range is indicated by a single tone warning beep on earpiece and the automatic muting of audio; the user must come back into the range to get audio unmuted.
c. To end the call and go back to standby mode, press the pick up button.

From standby mode, voice dial can be proceeded by performing a long press (>3seconds) on the pick-up button. The green LED then blinks at a fast pace for a few seconds.

6.3 Receiving a call

a. From standby mode, when the phone rings, press the pick-up button of the earpiece device. Both green LEDs on each device now blink, indicating that the RF link is established.
b. Speak and listen normally in the earpiece mike and speaker while staying within the broadcasting range of the system.
c. To end the call and go back to standby mode, press the pick up button.

6.4 Volume control

During the communication, the user can adjust the volume of the speaker by pressing the earpiece device volume buttons as many times as necessary to reach the suitable comfort.

6.5 Microphone mute function

During the communication, the user can mute the microphone with a long press (>3 seconds) on both volume buttons. The red LED then blinks at a fast pace indicating that the muting function is on. Pressing one of the volume buttons turns off the mute on the microphone.

6.6 Charging batteries

When batteries are low the red LED automatically turns on and a three tones warning beep is sent to the earpiece speaker. To charge them, the power supply cable must be connected to the battery charger. Then, the two low voltage extremities of the battery charger can be plugged into the charger socket of the pair of devices (earpiece and dongle). Note that while charging, the system is not functional.

7. Technical Hints

7.1 Specifications

7.1.1 General

Symbol	Specification	Min	Typ	Max	Unit	Comment
VBAT	Battery supply voltage	3.4	3.6	4.5	V	NiMh or NiCd *
Vch	Charger input voltage	5.0	9	12	V	
Tstg	Storage temperature	-40		85	°C	
Top	Operating temperature	-10		55	°C	
Istb	Stand-by current		0.6		mA	
Iop	Operating current		12		mA	Volume dependent

* For Li-Ion, the battery must include a self-protection circuit.

7.1.2 RF section

Symbol	Specification	Min	Typ	Max	Unit	Comment
Fout	Frequency operation	314.9	315	315.1	MHz	
Pout	Output power			0	dBm	Radiated

Typical antenna gain: -10dBi for a loop or HEMT.

7.1.3 Audio section

Symbol	Specification	Min	Typ	Max	Unit	Comment
Vophone	Telephone audio output			1.5	Vpp	Designed for Nokia. Above, saturation occurs
Viphone	Telephone audio input			50	mVpp	
Zear	Speaker impedance	25	30	35	Ω	
Rdetect	Headset detection res	4.2	4.7	5.2	kΩ	
Zout	Dongle output audio Impedance	0.7		1	kΩ	
Vmic	Microphone supply voltage	1.5	1.6	1.7	V	Without load
Rmic	Microphone pull-up res (connected to Vmic)	3	3.3	3.6	kΩ	
HPF	High-pass cut-off freq		160	200	Hz	
LPF	Low-pass cut-off freq		3.4		kHz	
DR	Dynamic range	70	80		dB	At 1kHz

7.2 Detailed schematics

7.2.1 Power supply

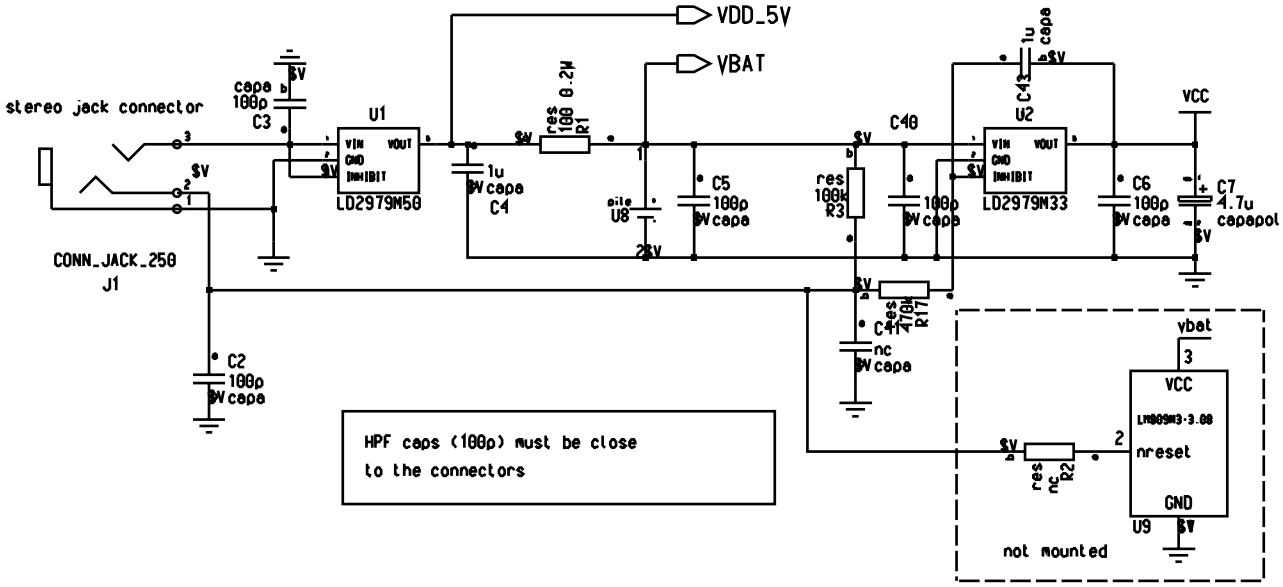


Figure 1: Power supply

This block uses a 5V regulator to charge the battery across a 100ohm resistor. When the charger jack mono connector is inserted into the stereo female connector, pins 1 and 2 are shorted and the circuit is turned OFF. This is an important function because the system can hang when the battery voltage goes below 3.3V. With this, a clean reset is generated when the charger is removed.

Though it should not be necessary, an external POR: MAX 803 with open collector can be mounted (optional).

RF caps C2 C3 C5 C36 will shunt to ground any RF signal received by the battery wires or charger; C5 must be mounted close to the battery connector and C36 close to the 3.3V regulator. Strong RF signals can be "AM demodulated" by the regulators: output voltage falls down during GSM frames, which may result in a sound at 160Hz.

7.2.2 Dongle controller part

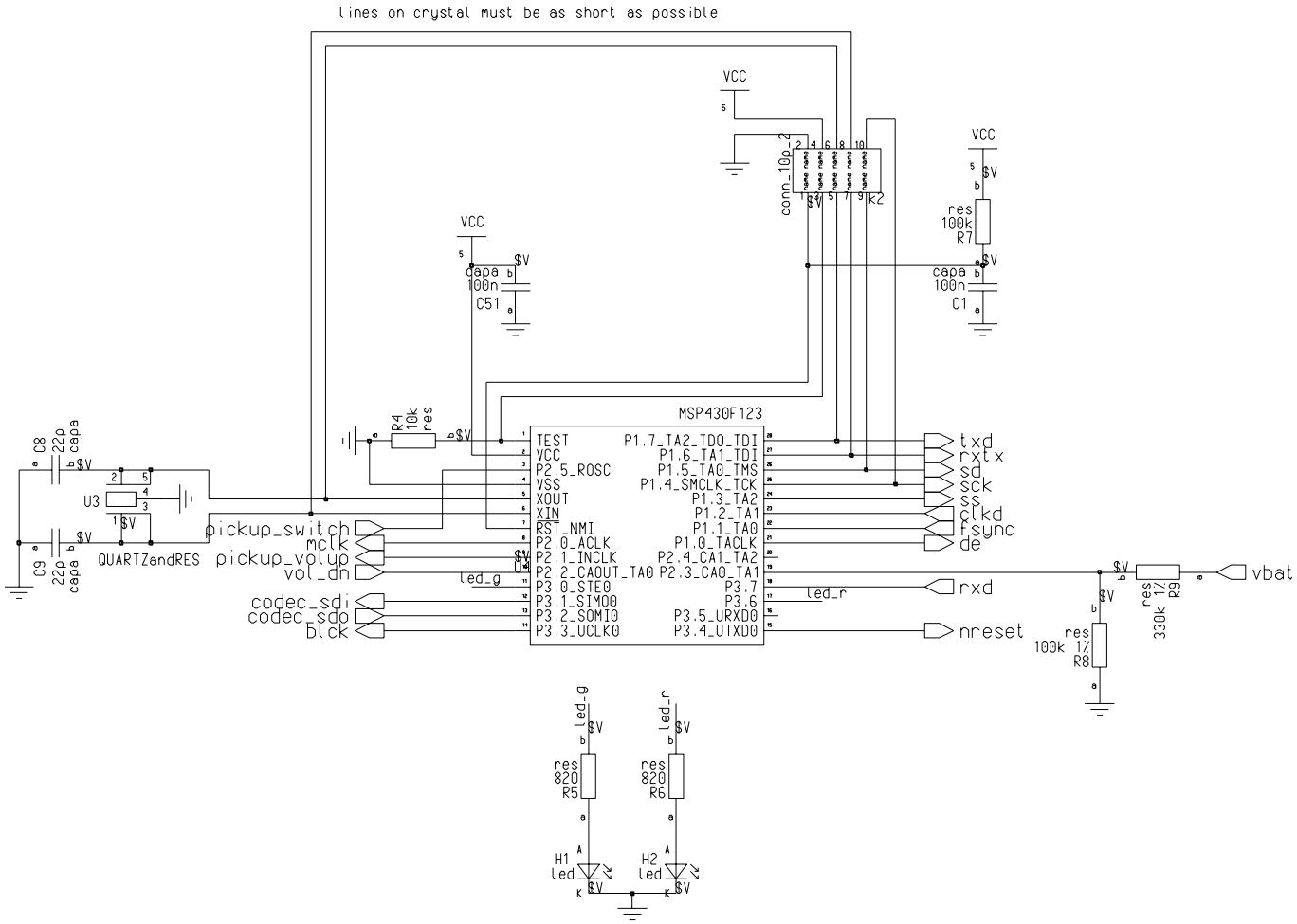


Figure 2: Dongle controller part

The controller part includes the micro-controller and all the necessary hardware for it to run properly. The crystal, some decoupling capacitors, an RC power supply filter (R7 and C1) creates an external POR and a battery voltage monitoring using R8 R9. 2 LEDs are used for indicating the mode and the system connections.

7.2.3 Earpiece controller part

Same as the dongle, but with 3 additional switches for pickup and volume control.

7.2.4 Dongle audio part

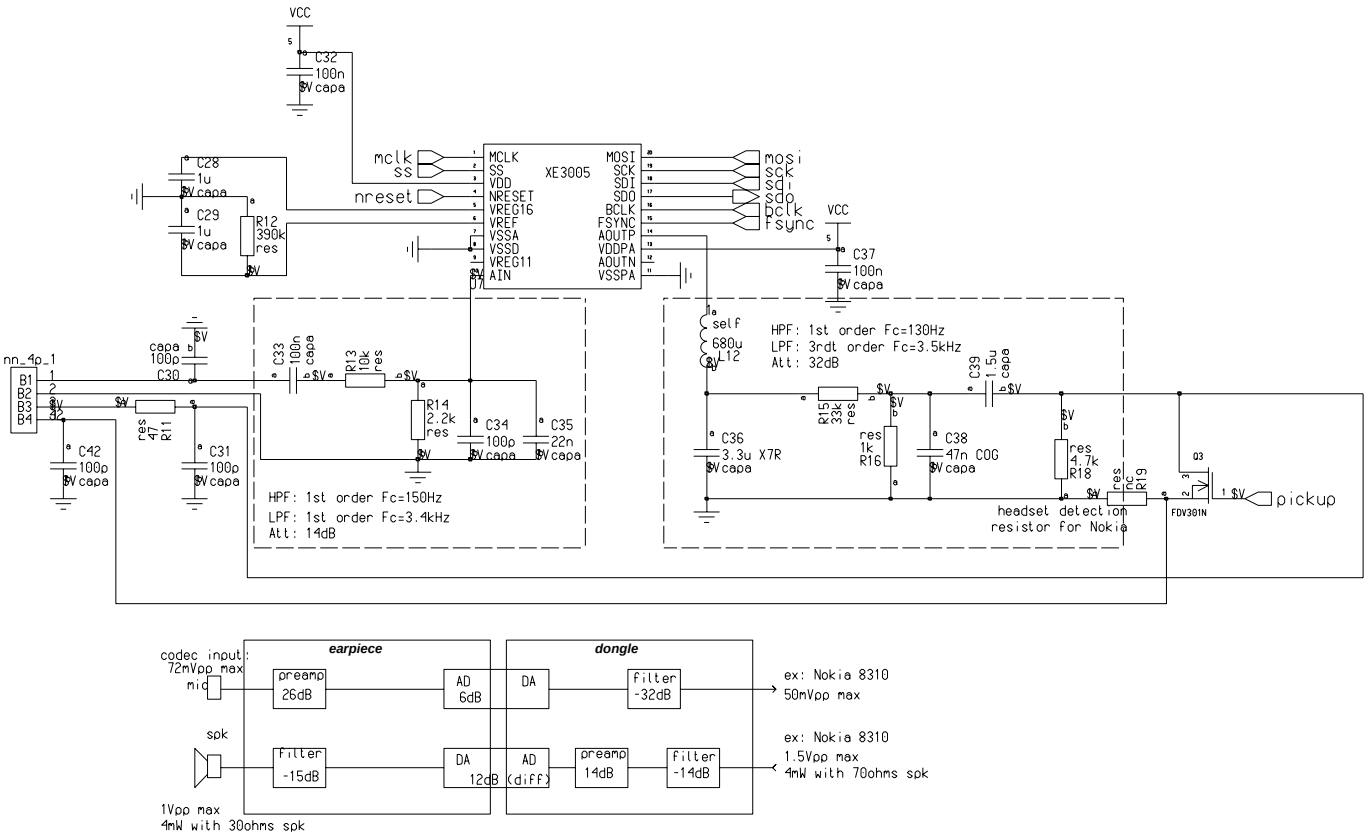


Figure 3: Dongle audio part

The input filter is a first order band pass filter. High pass function is needed because the phone output DC voltage could exceed the Vreg 1.6V voltage. Special care has been taken to shunt any RF signal. The output stage of the CODEC is used as a D class instead of an H class (two outputs in push-pull configuration). The theoretical SNR and gain reduction is 6dB but in practice the solution is slightly better than a conversion to single-ended with an OA (limited by the speed and precision of the operational amplifier). The third order low pass filter is made by an RLC filter. The first 2-pole stage is designed to have an overshoot near the cut-off frequency to compensate the –3dB of the third pole. The 680uH inductor has a 14 Ω serial parasitic resistance (Q=0.3 at 1 kHz). The package must be a 1218 form factor; a smaller size will reduce the Q even more. The 3.3u X7R cap is specified with 2.5% dissipation factor at 1 kHz: 1.2 Ω serial resistor.

The filter is designed to have 32dB attenuation, a low AC output impedance (800Ω) to be less sensitive to the phone input impedance and a 4.7kΩ DC impedance to be detected as a headset by Nokia phones. The filter has a 48uA DC current consumption due to R15 which is very low compared to 12mA (no need for an extra cap. In stand-by mode (V (OUTP) =0). The input reactance is about 280Ω at the PWM output frequency (64 kHz) and the global filter consumption is mainly determined by losses inside the Rs of the inductor. The pickup function is realized by the transistor Q3 and the resistor R11. C30, C31 are RF caps.

7.2.5 Input Level Matching

The values of the components are based on the Nokia 8310: 50mVpp max input and 1.5Vpp max phone output. If the phone output is higher (ex: 3Vpp) R13, R14 and C35 must be adjusted:

Phone max output (Vpp)	R13	R14	C35
1	8.2k	3.3k	15n
1.5	**10k**	**2.2k**	**22n**
2	15k	2.2k	22n
3	18k	1.8k	27n
4	18k	1.2k	33n

How to determine device value:

- Maximum XE3005 input voltage is 270mVpp
- The pole frequency must be between 3.4 and 4.5kHz

7.2.6 RF Part XE1201A

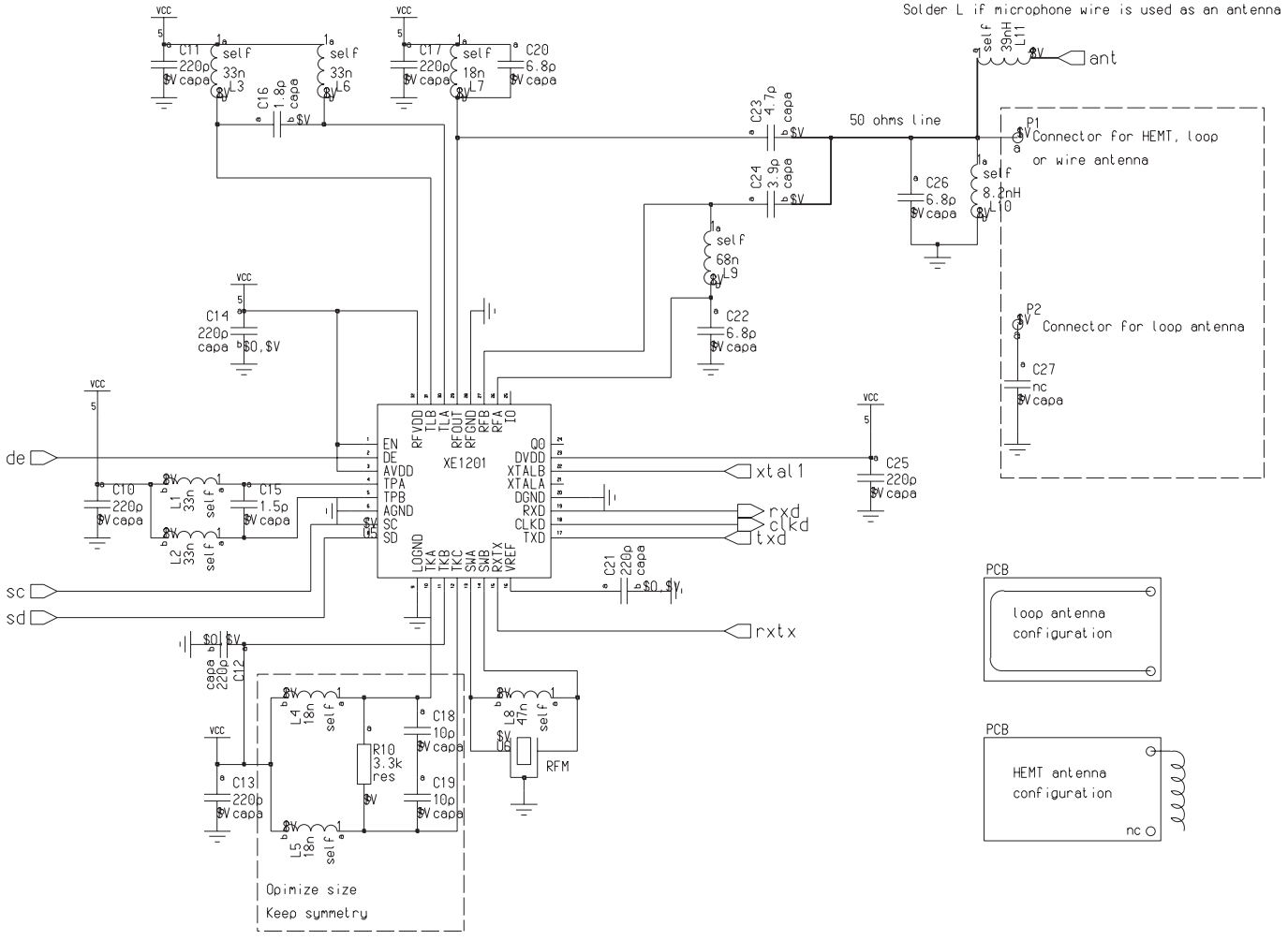


Figure 4: RF part

The RF part is the most critical part of the design, as the matching changes from one layout to another. We strongly recommend copying the RF part layout as implemented in the Gerber files included in the kit (PCB-E043V03A.ZIP and PCB-E044V03A.ZIP). If these recommendations are respected, the matching network of the LNA and PA will be very near to the value indicated in this schematic. But in any case, the schematic of each new layout will require changes based on RF matching measurements to ensure correct performance.

4 antennas can be used and matched to 50 Ohms:

1. Microphone wire used as a wire antenna (for earpiece only). Match this antenna with a serial inductor and a parallel cap.
2. Loop antenna. Match this antenna with a serial cap C27 and a parallel cap.
3. HEMT antenna. No matching if correct antenna.
4. Wire antenna.

The two key parameters for the antenna are:

- Gain
- Directivity

The directivity must be kept as low as possible otherwise there will be a big difference between Min and Max distance, for example 2m with parallel HEMT antennas and 10m with well aligned HEMT antennas. Here the HEMT antenna is the smallest antenna but also the most directive, it should not be used at the same time in the dongle and in the earpiece. A configuration with an HEMT in the dongle and a wire antenna in the earpiece works well.

7.2.7 Earpiece audio part

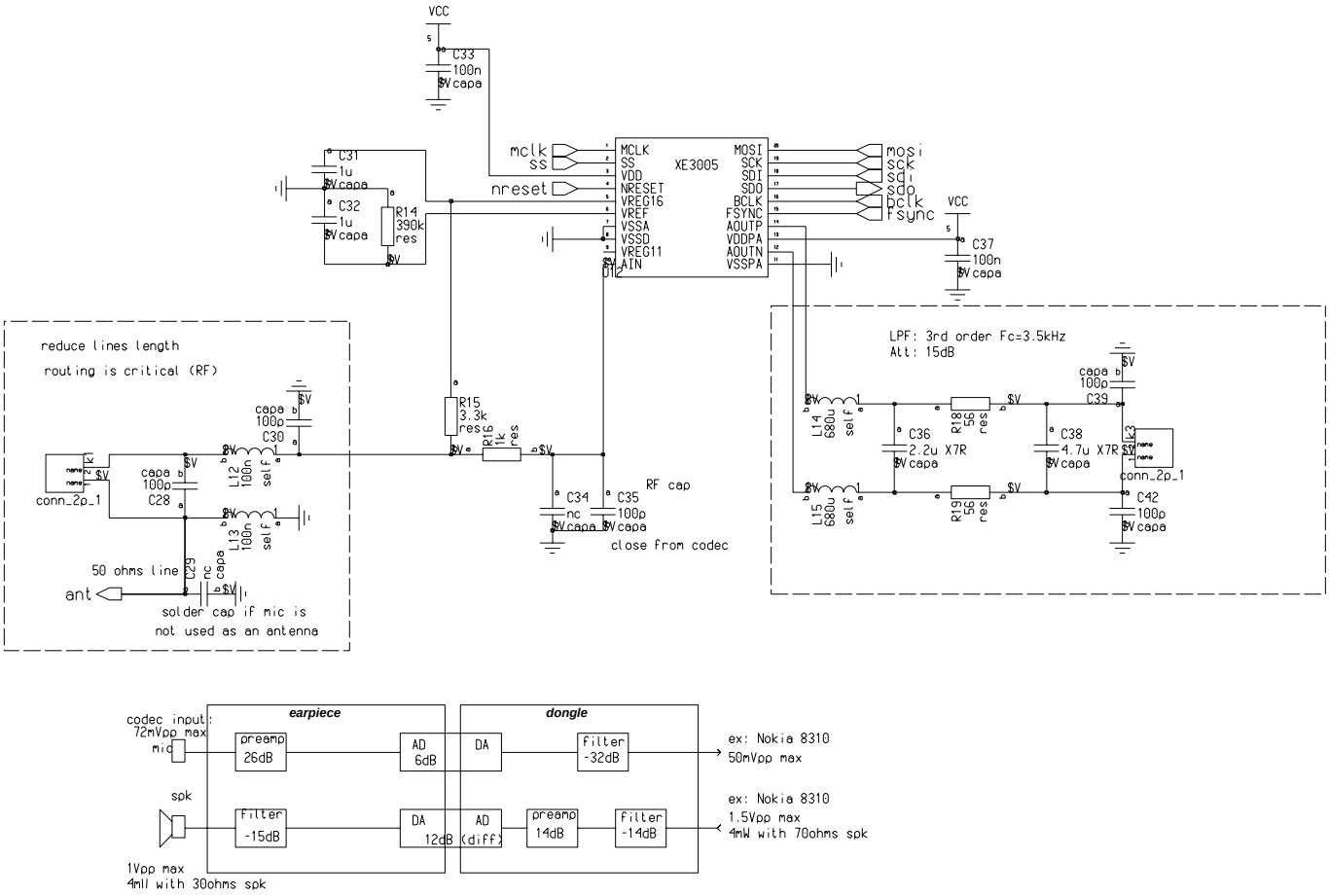


Figure 5: Earpiece audio part

The ear audio part is similar to the dongle audio part. Differences are the following. There is a differential audio output for driving the speaker, and the microphone wire can be used as an antenna. For that reason the microphone ground must have a high RF impedance but a low BF impedance. To avoid the ”hamming” low frequency sound coming either from the xe1201 or from the GSM, the microphone wire must be a coaxial one or a 100pf cap must be soldered directly to the microphone connections. Any RF signal coming inside the microphone or inside the codec will be AM demodulated and create a 160Hz sound coming from the 6ms frame.

If the microphone is not used as an antenna, replace L12 L13 by 0Ω resistors. 330Ω resistors could replace L12 L13 without too much degradation, but this configuration must be retested on the final board. C28, C30 are SMD 603 size due to their lower parasitic resistance. They have also better performances at these frequencies (<2GHz).

The output filter is a third order one designed to have 15dB attenuation. The 680uH inductor has a 14 Ω serial parasitic resistance (Q=0.3 at 1 kHz). The package must be a 1218 one, a smaller size will reduce the Q even more. The 1.5u X7R cap is specified with 2.5% dissipation factor at 1 kHz: 2.6 Ω serial resistor. A better subjective audio quality can be achieved by lowering the first pole of the filter (C42 increased to 4,7u). In that case the transfer function is no longer flat. Comprehension tests must be done with different voices to determine if this is a satisfactory solution.

The microphone is powered even in sleep mode. This is not a problem because the sleep mode of the earpiece (master) and dongle (slave) are about the same, so the user will have to charge the battery at the same time.

7.2.8 Antenna re-matching in plastic housings

The unit as supplied has correctly matched antennae for free-space propagation. Please note that if the units are enclosed in plastic casing the permeability of the plastic may require that the antennae are re-matched. Please refer to section 7.2.6 or contact XEMICS for further assistance.

7.3 Phone connectors

For the demonstration, the kit includes a 2.5mm stereo male jack connector and with 2 adapters: one for Nokia and the other for Ericsson phones.

The dongle pin B1 is the audio input and must be connected to phone output
The dongle pin B2 must be connected to ground
The dongle pin B3 is the audio output and must be connected to phone input
The dongle pin B4 is a pickup sense line. It must be connected to ground when using the 2.5mm stereo male jack connector or the Ericsson connector and must be connected to the MIC- pin (see fig) when the Nokia special connector is used.

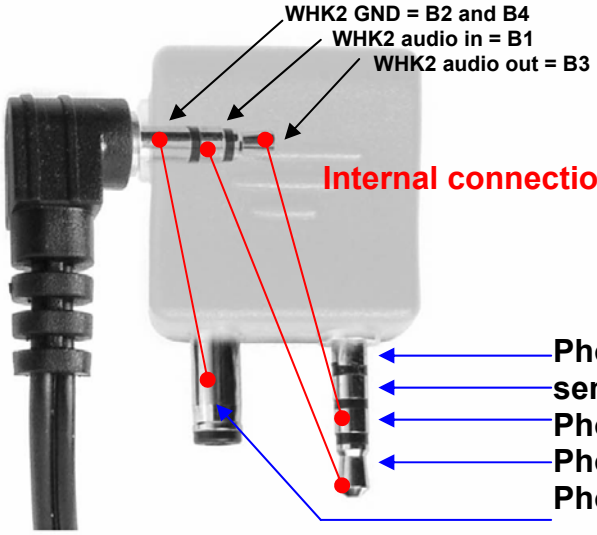
If a dedicated connector is used: (see picture below for Ericsson)

Dongle Pin	Nokia pin name	Ericsson pin number
B1	Audio out +	2
B2	Ground	7 8 10
B3	Audio in +	1
B4	Audio in- / pickup sense	7 8 10 or solder R19

Ericsson pin 7 is used to sense the headset when connected to ground
Ericsson pin 11 is the +5V. It is connected to +Vbat. No additional battery is needed on Ericsson dongles.

Note: Pickup function is not available with Nokia standard adapter.

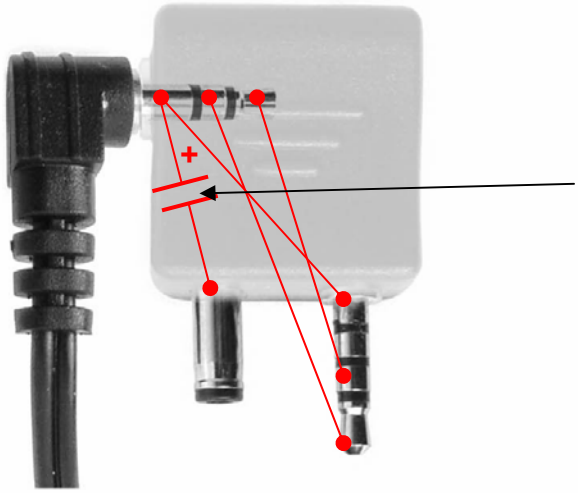
WHK2 with standart Nokia adapter (NOKIA 3310 and 8310)



Phone audio in - / pick-up sense
Phone audio out -
Phone audio in +
Phone audio out +

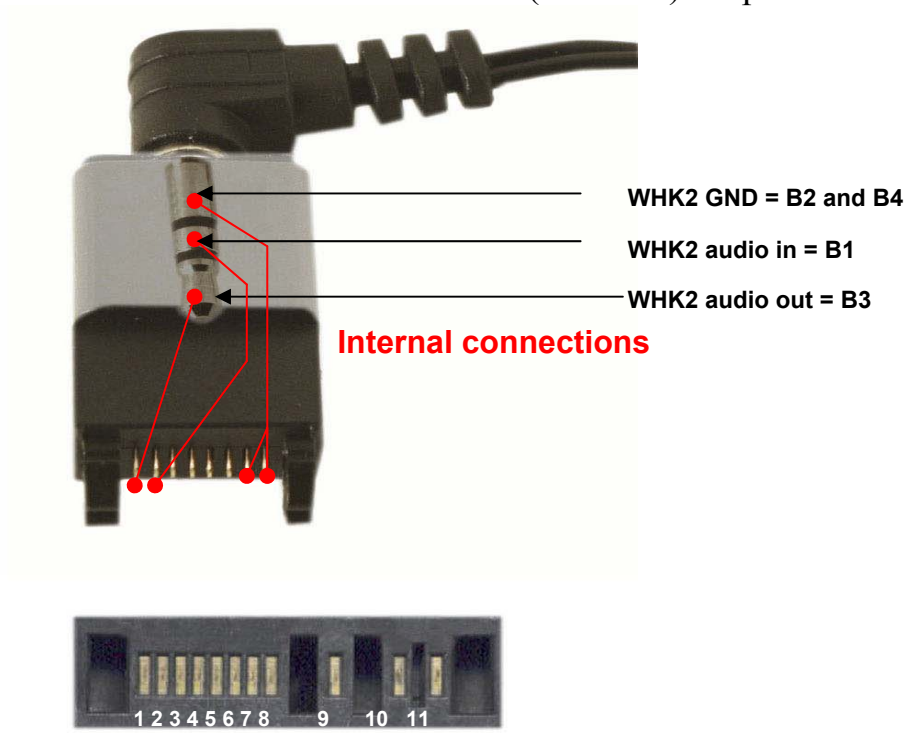
GROUND

WHK2 with modified Nokia adapter



3.3uf capacitor

WHK2 with standard Ericsson (T28 T29) adapter



WHK2 with dedicated (T28 T29) adapter