Optical front-ends for USRP radios

H. Boeglen[1], S. Joumessi[2], S. Sahuguède[2], P. Combeau[1], D. Sauveron[2] and A. Julien-Vergonjanne[2]

[1]XLIM Lab, UMR CNRS 6172, Université de Poitiers, France
[2]XLIM Lab, UMR CNRS 6172, Université de Limoges, France

French GNU Radio Days, Lyon

Outline:

1 – Introduction

2 – Design of 10MHz IR frontends for USRP radios

3 – Demonstration: IR car audio transmission system

4 – Conclusion and future work
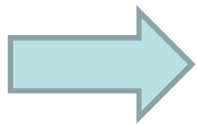
Outline:

1 – Introduction

2 –

3 –

4 –

❏ **Infrared (IR) optical communication is a good candidate for indoor wireless communications:**

➔ **large bandwidth available**
➔ **confined to the room where they are operated: advantage for secure communications**
➔ **less influence on the human body than RF technologies**

❏ **We are involved in the Aircraft Light Communication (ALC) Cleansky2 H2020 project:**

➔ **Goal: design of a secured and performant wireless connection based on light (LiFi) for Electronic Flight Bag (EFB), headset and other pilot connected devices.**
➔ **Need for a flexible IR transceiver to help for the design of efficient transmission schemes**

➔ **Software Defined Radio provides great flexibility for evaluating different optical wireless schemes. We therefore decided to design infrared optical front-ends for Ettus USRP radios.**

1

Outline:

1 –

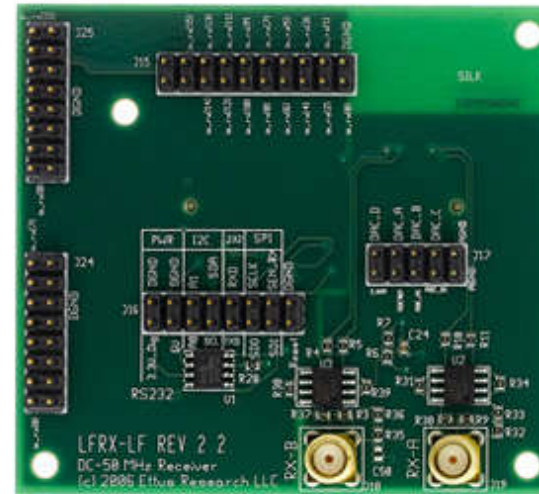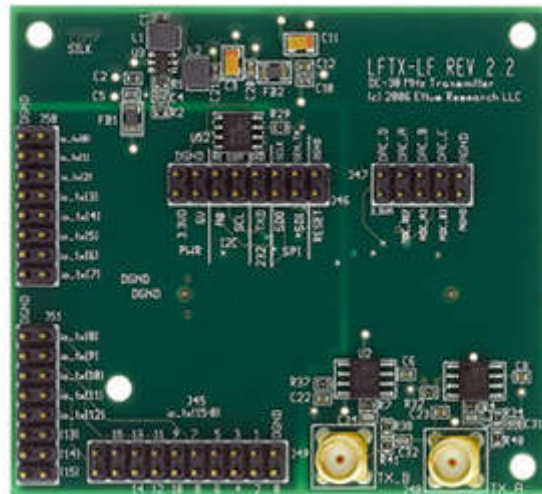2 – Design of 10MHz IR frontends for USRP radios

3 –

4 –

Design choices

❑ **A transmission bandwidth of 10MHz**
❑ **An IR link works in baseband with 0Hz (LED and Photodiode perform up/down conversion to the IR wavelength)**
➔ **LFTX and LFRX daugtherboards cover these needs**

➔ **0-30MHz bandwidth**
➔ **83€**
➔ **An USRP N210 can be fitted by 1 LFTX and 1 LFRX (full duplex)**

The transmitter

❑ **An infrared LED is current-driven**

➔ **LFTX voltage output (-1/+1V) has to be converted to 0-100mA**
➔ **Classical voltage to current converter structure with an high speed, high current operational amplifier (op amp)**
➔ **Only 6V output from USRP is able to source this current.**
➔ **An IR LED has a forward voltage of 1.7V thus we can connect up to 3 LEDs in series**

The transmitter

❑ **Schematic and designed board**
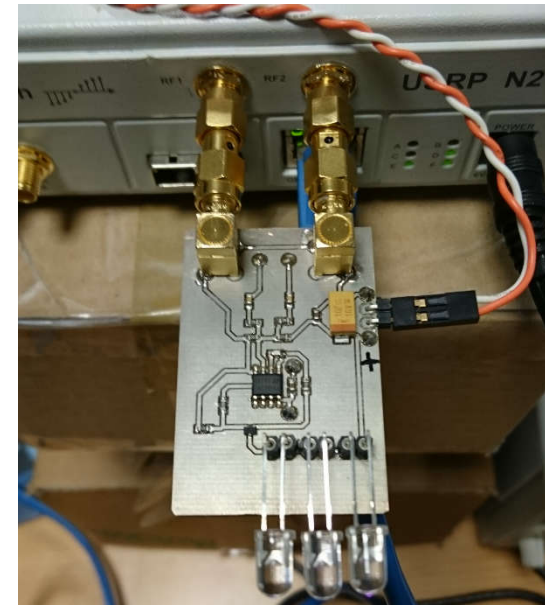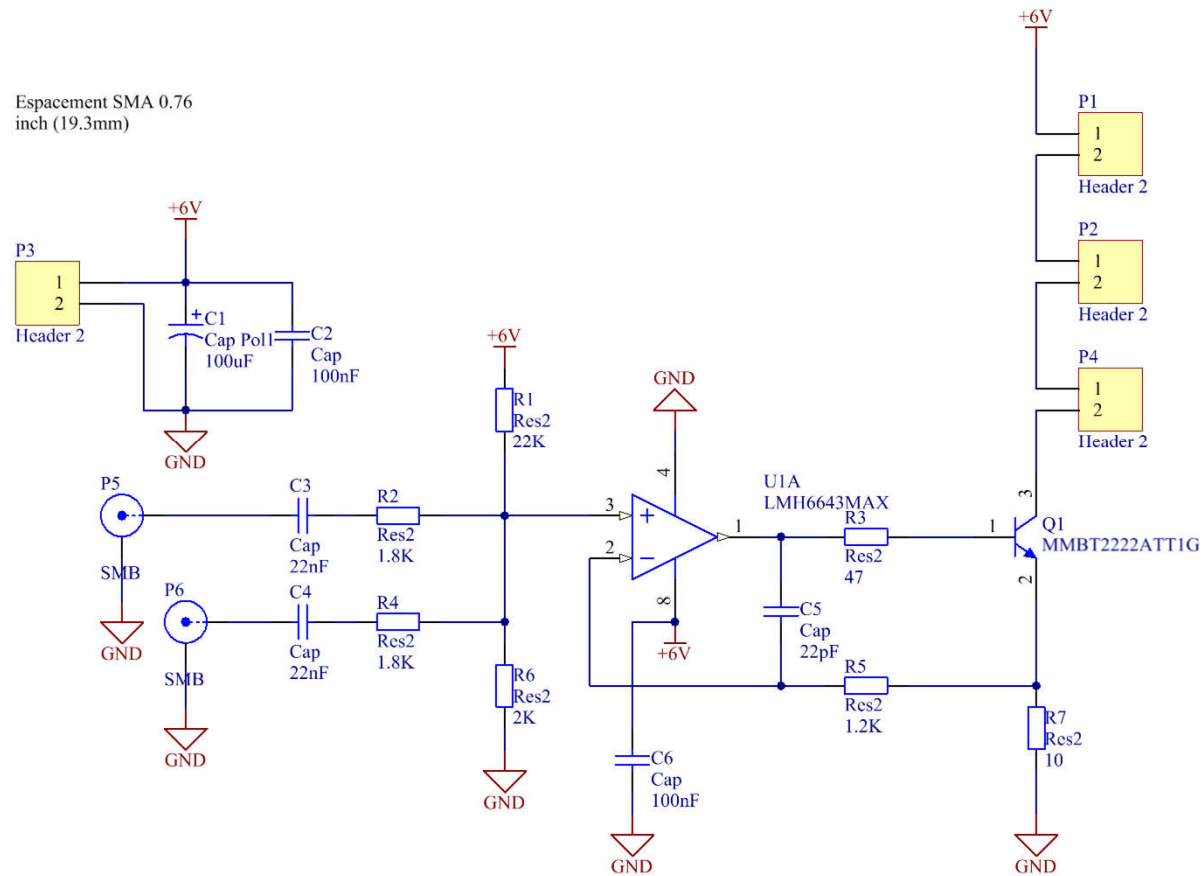
The receiver

❑ **A PIN photodiode is used**

Photodiode Model (Custom)
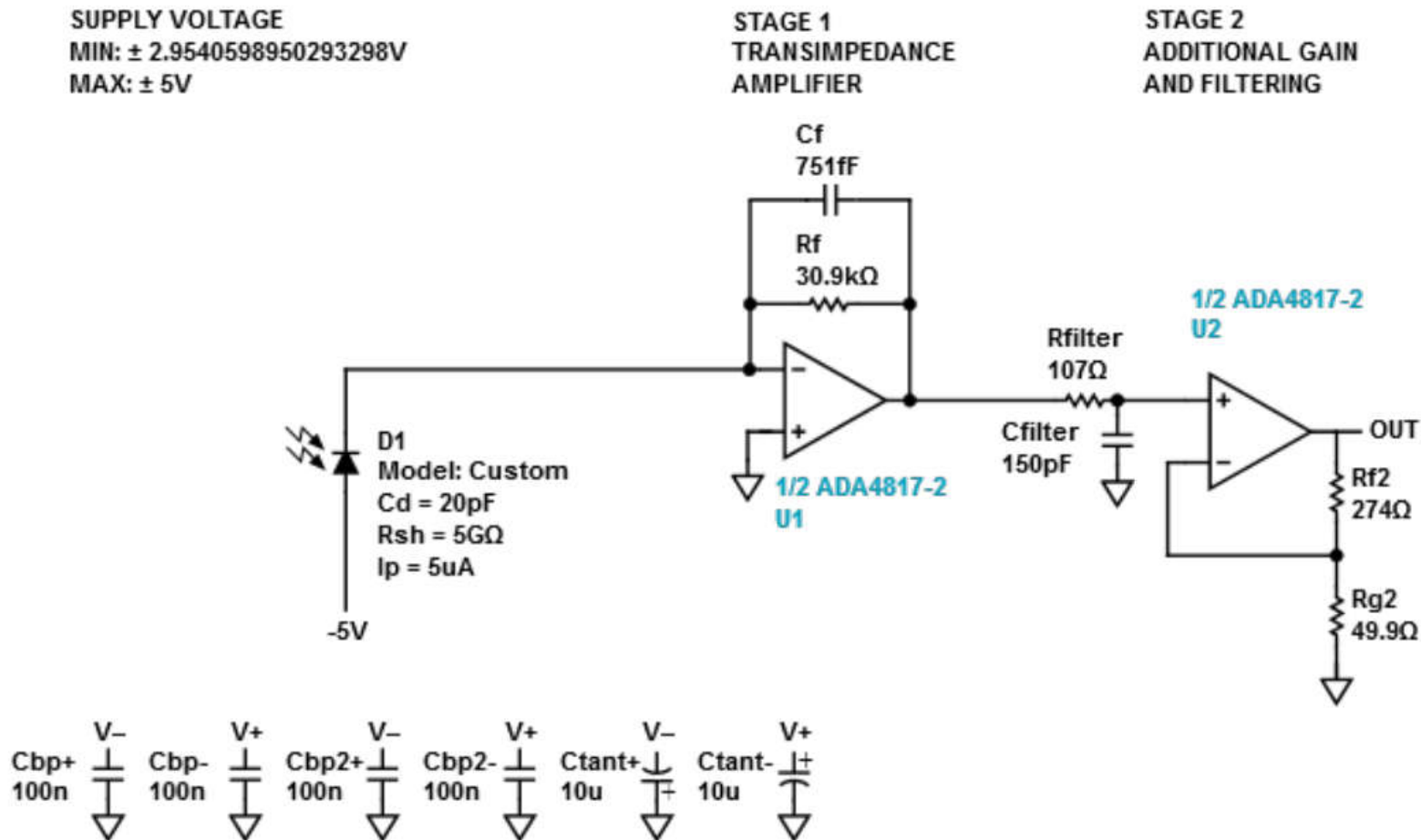
+
5V

⏚ 1.03uA   � 5GΩ   ⊣⊢ 20pF

−

-5V
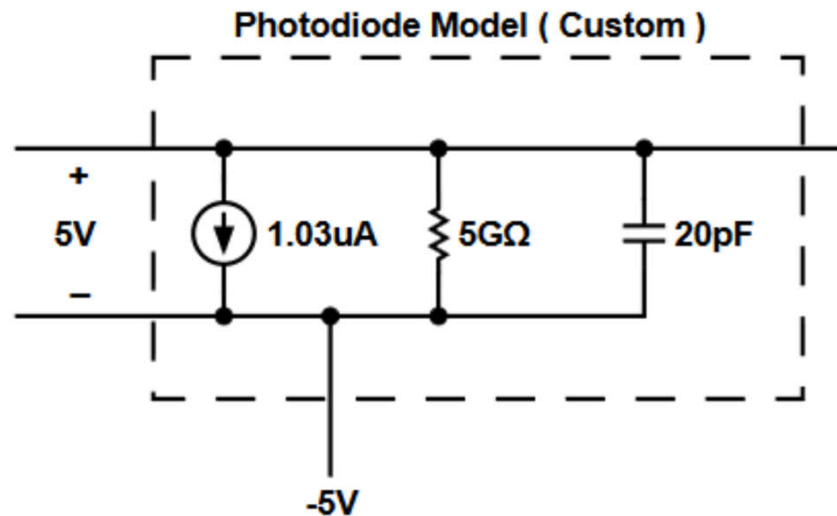
➔ **Converts light energy into a current**
➔ **A very low current (10uA) has to be converted to voltage**
➔ **The classical circuit is built around a Transimpedance Amplifier (TIA)**
➔ **There are specific op amps for this application (expensive ≈ 10€)**
  ➔ **Low input bias currents (JFET preamplifiers)**
  ➔ **Very high gain-product bandwidth (typically over 1GHz)**

The receiver

❑ **Using Analog Devices online Wizard:**

SUPPLY VOLTAGE
MIN: ± 2.9540598950293298V
MAX: ± 5V

STAGE 1
TRANSIMPEDANCE
AMPLIFIER

STAGE 2
ADDITIONAL GAIN
AND FILTERING

Cf
751fF

Rf
30.9kΩ

1/2 ADA4817-2
U2

Rfilter
107Ω

D1
Model: Custom
Cd = 20pF
Rsh = 5GΩ
Ip = 5uA

1/2 ADA4817-2
U1

Cfilter
150pF

OUT

Rf2
274Ω

-5V

Rg2
49.9Ω

V−		V+		V−		V+		V−		V+
Cbp+		Cbp-		Cbp2+		Cbp2-		Ctant+		Ctant-	
100n		100n		100n		100n		10u		10u	

➔ **Extreme care has to be taken when routing the design (751fF, smd)**

6

The receiver

❑ **Reducing costs:**

➔ **HF JFET transistor in front of a classical op amp (less than 1€)**
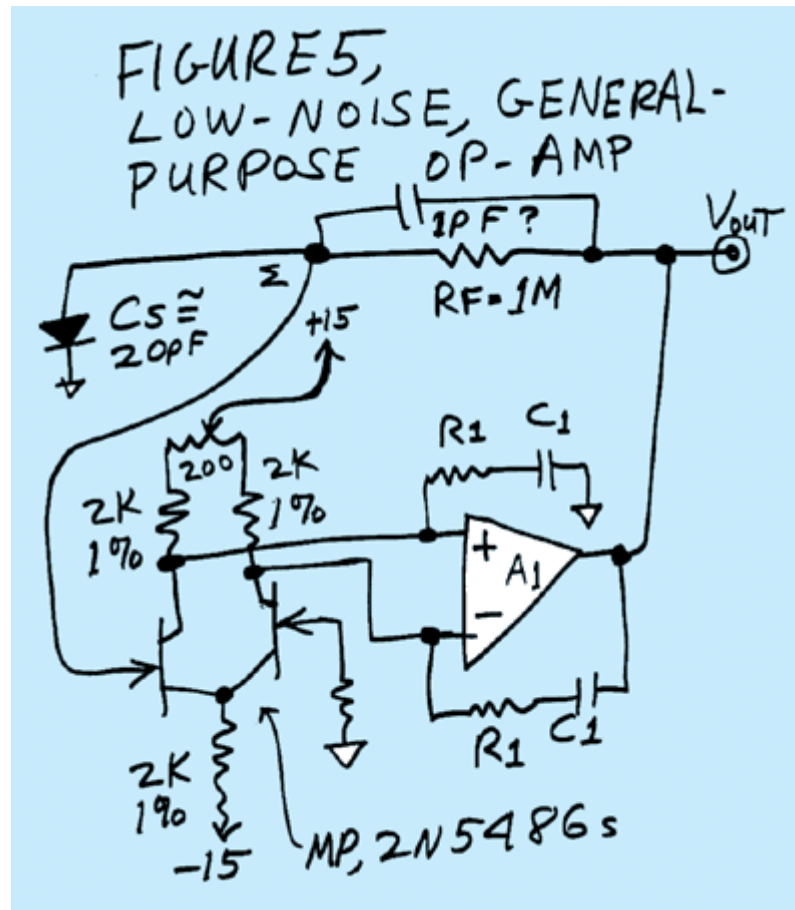
Outline:

1 –

2 –

3 – Demonstration: IR car audio transmission system

4 –

IR car audio entertainment system
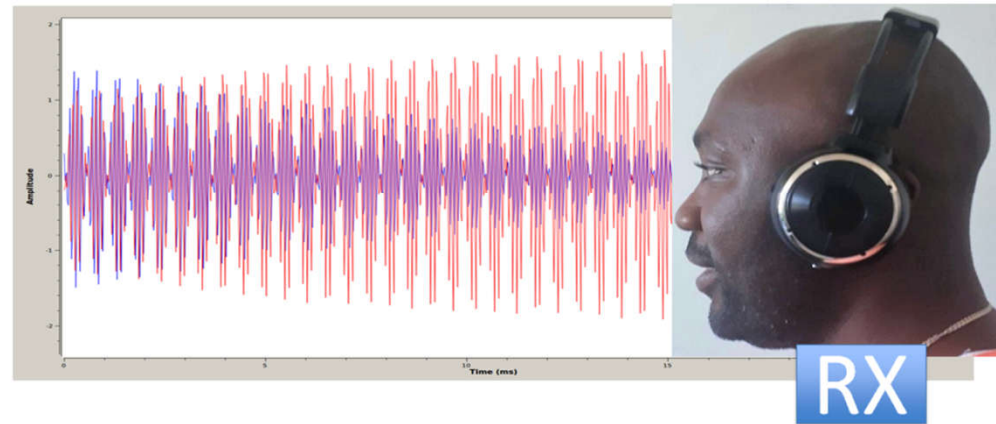
➜ **Stereo audio signal on two FM modulated carrier frequencies at 2.3MHz and 2.8MHz**

8

IR car audio entertainment system

❑ **Inside the headphones (10€ on the Internet):**
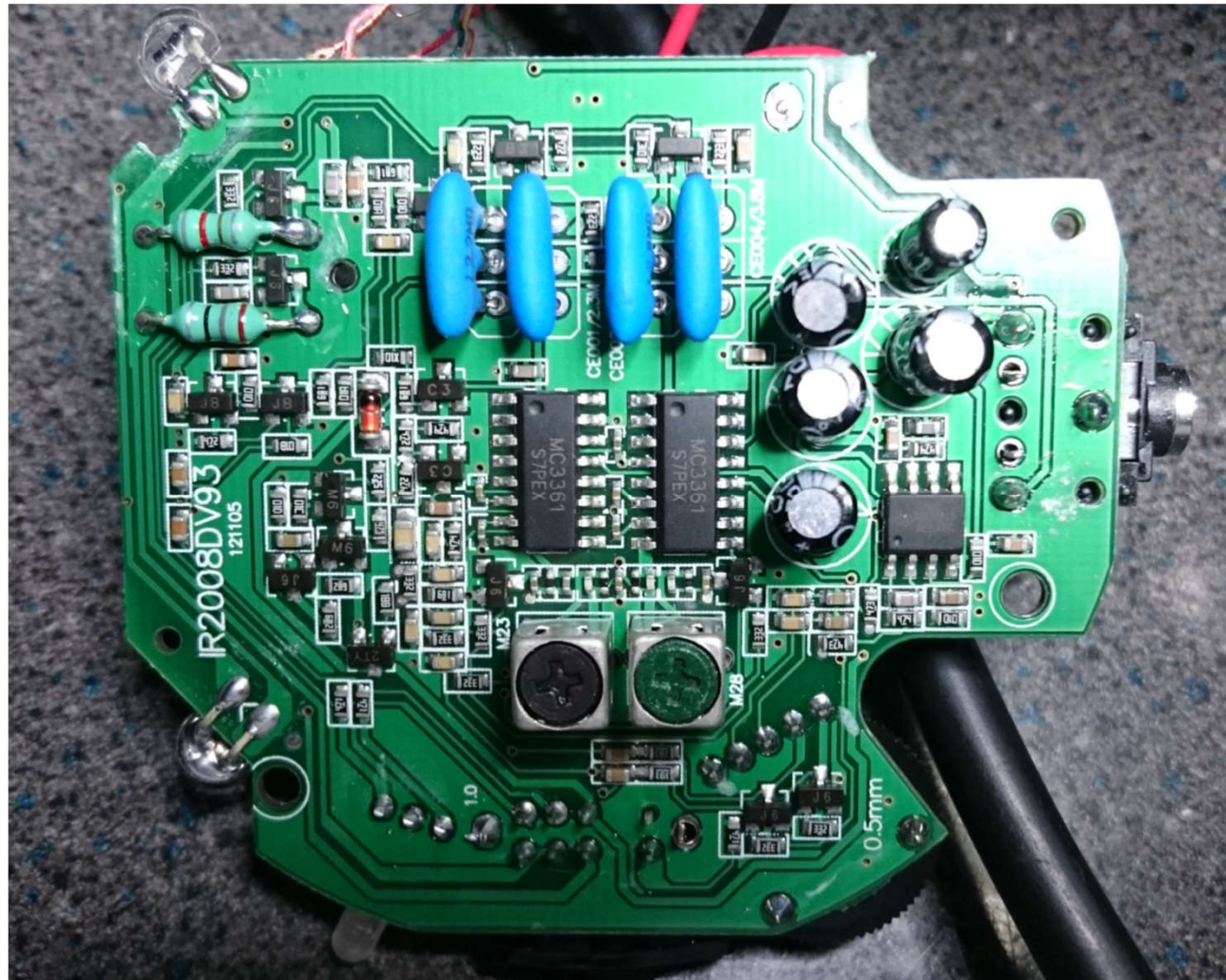
IR car audio entertainment system

❑ **GNU Radio flowgraph:**

10
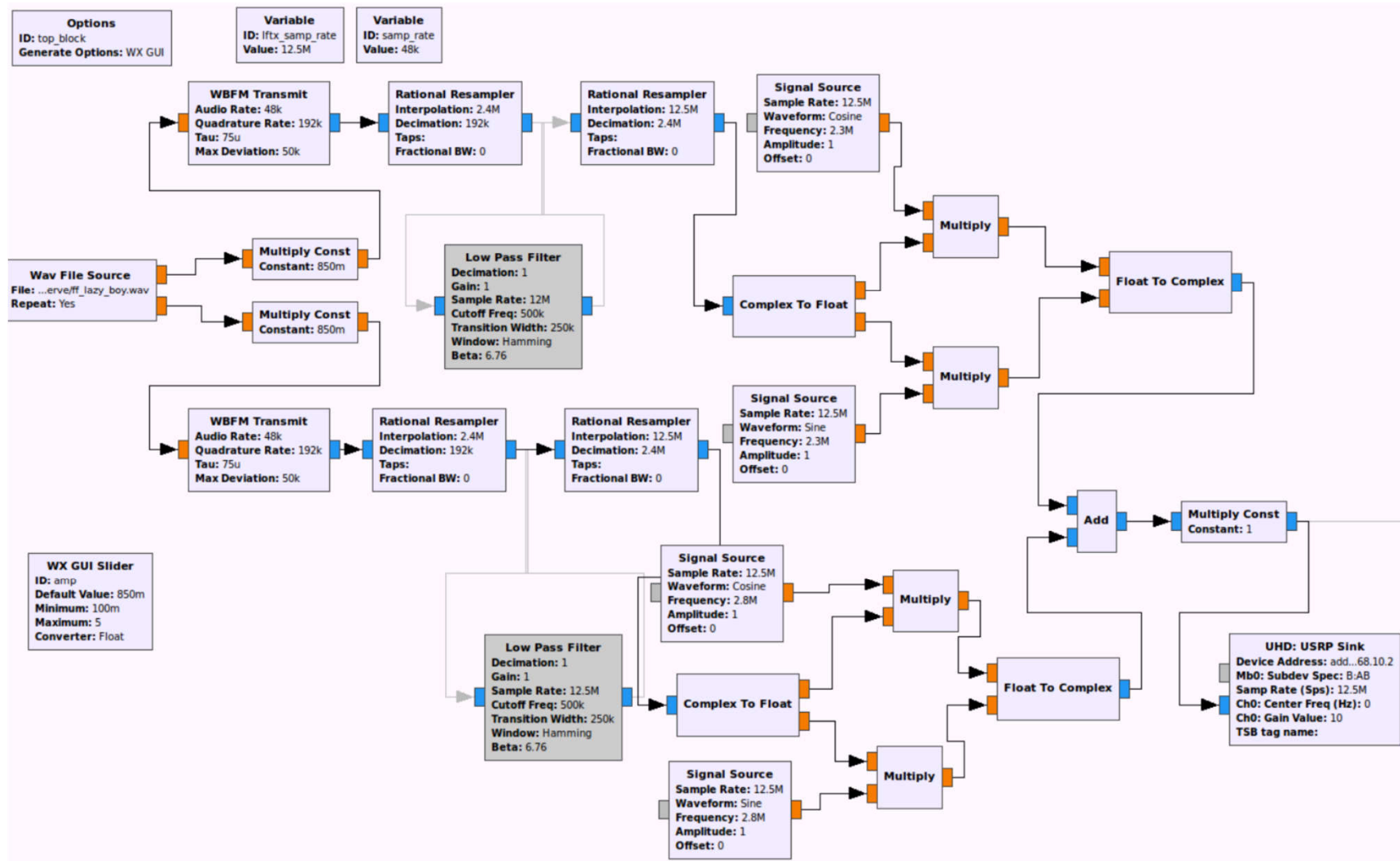
Outline:

1 –

2 –

3 –

4 – Conclusion and future work

❑ **Ettus Research offers a large range of RF daugtherboards**

❑ **However the daughterboard interface is quite generic**
➔ **easy to develop a custom board**

❑ **This permits to enter the GNU Radio world and its huge range of librairies**

❑ **Our IR boards cost less than 50€.**

❑ **Future work: design of a configurable AGC for the IR receiver.**

THANK YOU!

QUESTIONS?

References

[1] https://www.ettus.com/
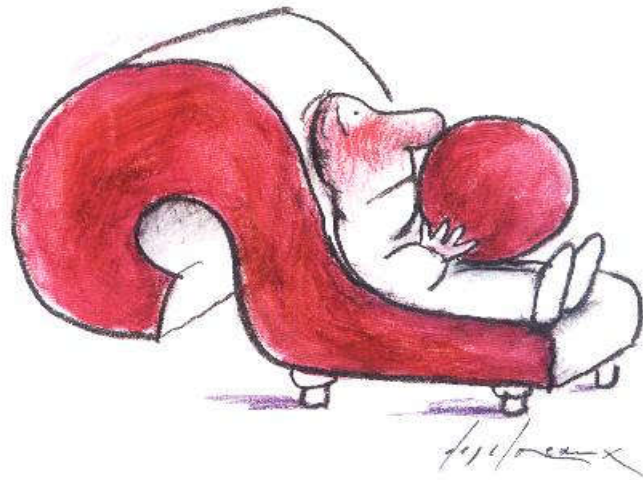
[2] A. Julien-Vergonjanne, S. Sahuguède, L. Chevalier, (2016) Optical Wireless Body Area Networks for Healthcare Applications, In: Uysal M., Capsoni C., Ghassemlooy Z., Boucouvalas A., Udvary E. (eds) Optical Wireless Communications. Signals and Communication Technology. Springer, Cham

[3] J. Ardizzoni, A Practical Guide to HighSpeed Printed-Circuit-Board Layout, Analog Dialogue, Vol. 39, Sep. 2005.

[4] J. Greame, "Photodiode amplifiers, op amp solutions", Mc Graw-Hill, 1996.