B102: Ultrasound 40 kHz Low Noise Amplifier Experiments **Draft 1.1**
PAN, April 2nd, 2016

1. Introduction

The very weak 40 kHz FSK US signal received by a piezo microphone, at a distance > 10 meters from the US-speaker, should be amplified to be processed later by a PLL.

The main problem is to develop a low noise preamplifier. V.Janasek www.janascard.cz proposed several ultra-low noise AC amplifiers, with noise figure down to about 1.3nV/$\sqrt{Hz}$. There are some OP amplifiers with low noise figure, too, but only for supply voltages > +/- 5 V and supply current > 4 mA.

A very important factor is the signal source impedance. The experimental result Fig. 7 show a noise of 21 mVpp with the input terminated by 50 Ohm and 152 mVpp with a 2.2 nF Kobitone Mic. A simple NPN input stage is ok for our job, considering this fact!

Using an OP amplifier, the variation of the supply voltage shows little effect on the output signal, the PSRR (Power Supply Rejection Ratio) is typically 90 dB or better. However, if the power supply are provided by switched regulators, this might be not enough. Using a NPN preamplifier with almost no PSRR a supply filter is absolutely needed, see Q1 in the circuit Fig. 2; attenuating supply spikes by 50 dB (see NS Application Note 222, Fig. 4, July 1979)

At first glance it makes sense to design a very narrow bandwidth amplifier. However, in combination with a PLL with a lock-in detector this is a wrong idea: the remaining noise with a narrow spectrum at center frequency of 40 kHz might trigger the lock-in detector in silence.

In short: the presented circuit is a good compromise and operates in practice fine:
- Low Power: 5V/3mA
- High Gain: 81-83 dB at 40 kHz, Bandwidth 9 MHz
- Low Noise Figure: with Kobitone Mic 2.2nF 4.5 nV/$\sqrt{Hz}$ (Simulation), 11 nV/$\sqrt{Hz}$ (Practice)

2. Simulation

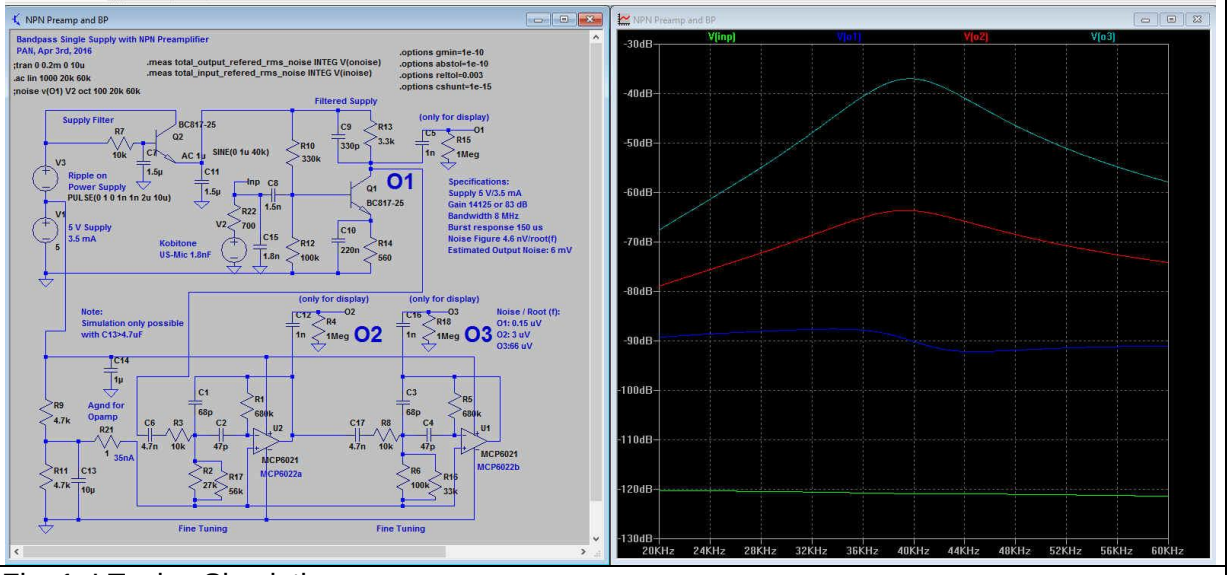

Fig. 1: LTspice Simulation
Total Gain 83 dB, Noise Figure 4.5 $nV/\sqrt{Hz}$ with high impedance source Kobitone Mic

3. Circuit Low Noise US-Amplifier PAN/Miru, Febr.6, 2016, Values PAN April 2nd, 2016

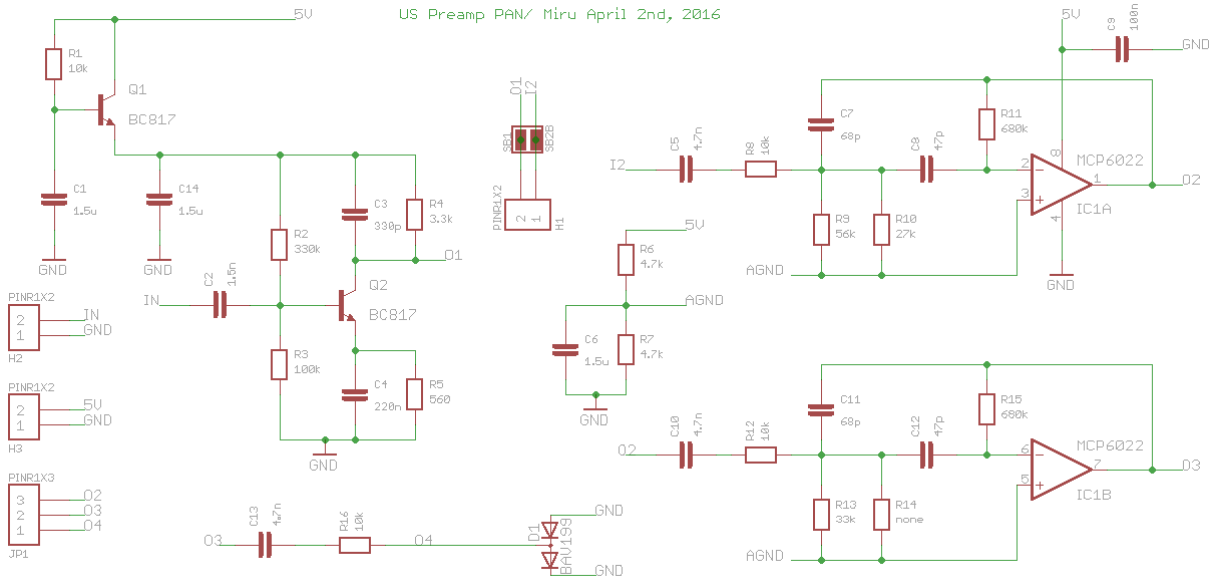

Fig. 2: Circuit low noise preamplifier with dual band pass amplifier

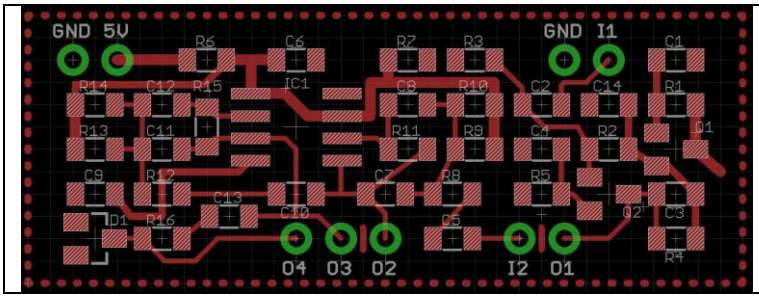

Fig. 3: PCB
Designed by Miru
1.6” x 0.6”

4. Test conditions and test points

Power Supply: 5.00 V, consumption 2.93 mA
Analog Gnd: 2.50 V
Power Supply Ripple attenuator: NPN Q1, Emitter=4.4 V, ripple attenuation about 50 dB
NPN Preamp Q2 test points: UB: 0.9V, UE: 0.32V, UC: 2.5V, all ok

5. Test Low Noise NPN Preamplifier (all Voltages in Vpp)

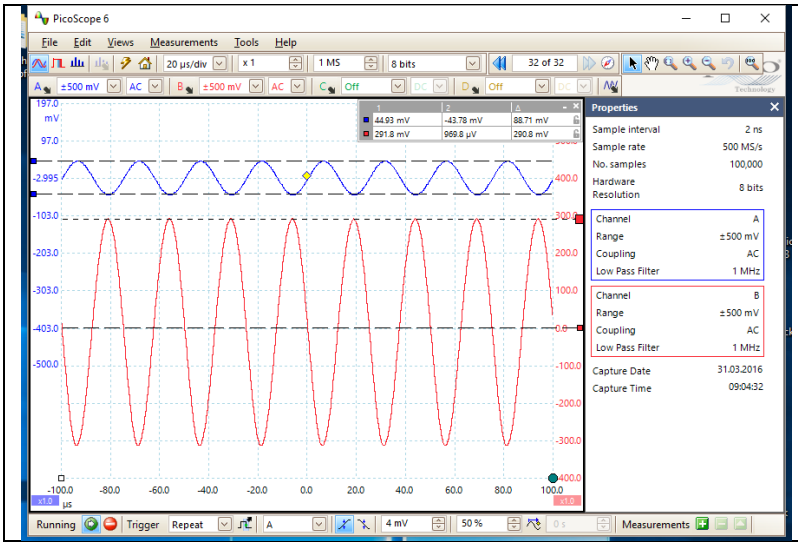

Fig. 4: Low Noise Preamplifier

A: Input 40kHz, 88.7 mV
Attenuator: -20 dB = 8.8 mV

B: Output O1: 2x290 mV,
Gain = 66, or 36.3 dB

- 3 dB Bandwidth:
13.9 -147 kHz

Noise: Input:
- 0 Ohm or 50 Ohm: 120 uV,
- Kobitone Mic 2.2nF: 400 uV,
- Open input: 600 uV

5. Test first BP, with direct input at first BP

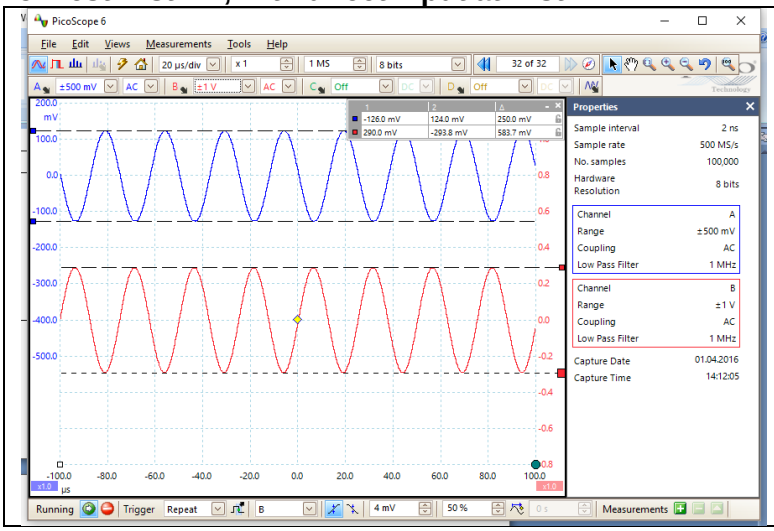

Fig. 5: First BP,
direct input at I2:

Components:
C 7= 68 pF,
R9 =56 k, R10=27 k

A: Input 40 kHz, 250 mV
Attenuator: - 20 dB= 25 mV

B: Out O2: 584 mV,
- Gain 23.4, or 27 dB
- 3dB Bandwidth:
  34.6-46.4 kHz,
- max gain at 40.4 kHz

6. Test with first and second BP in series, with direct input at first BP

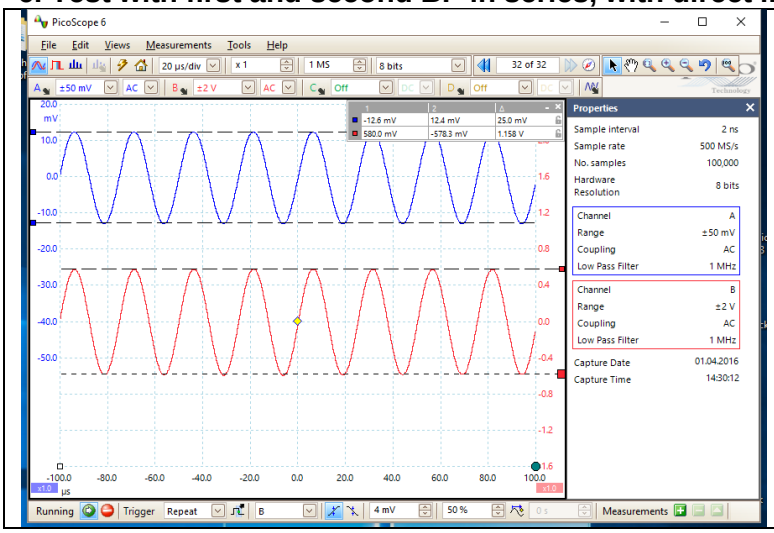

Fig. 6 : First with second BP
in series, direct input at I2

Components:
C11= 68 pF,
R13 =33 k, R14 not needed

A: Input 40 kHz, 25.2 mV
Attenuator -20dB = 2.5 mV;

B: Out O3: 1.158 mV,
- Gain 474, or 53.5 dB
-3dB Bandwidth:
  36.6-43.5 kHz.
- max gain at 40.1 kHz

7. Performance preamplifier with dual band pass, input at preamplifier

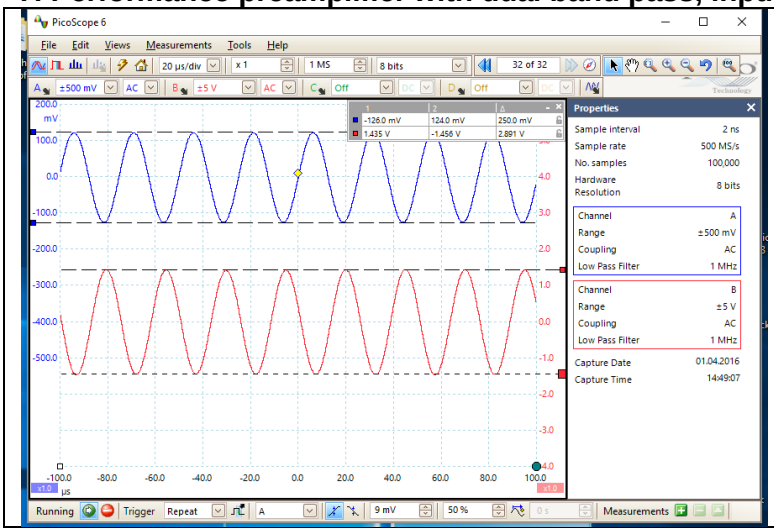

Fig. 7: Preamp and dual BP
A: Input 40 kHz, 250 mV
Attenuator – 60 dB= 0.25 mV;

B: Out O3: 2.891 mV,
Gain 11564, or 81.3 dB
- 3dB Bandwidth:
34.1-43.1 kHz, BP 9 kHz

Noise: (Very important!)
- with 50 Ohm Input: 21 mVpp,
- with Kobitone Mic: 152 mVpp
- measured with HP 974A
  true RMS: 12 mV eff.
- Noise Figure: 11 nV/$\sqrt{f}$

8. Final Comment:
Quite good fit with the simulation and fine performance in practice!