Lab 2 Midterm Report on the Kinetic Inductance Detector

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May 4, 2023

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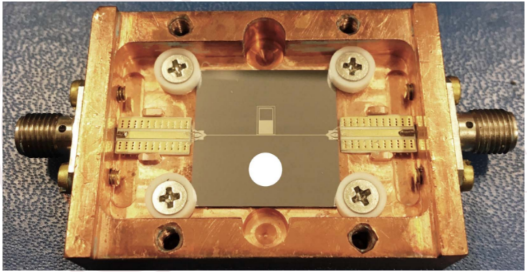
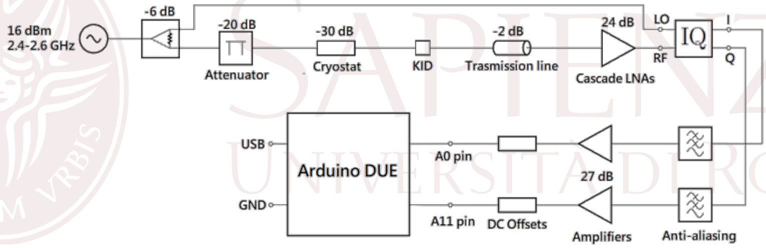
Kid Detector



- Kinetic Inductance Detector
- Used for photon detection in a wide range of frequencies.
- Very sensible to single **photon** interaction via Cooper pairs excitation.
- Works in a **cryogenic** setting, readout via electromagnetic field variation in a **SQUID**.

Our Objective

Develop a **readout system** for the detector using an Arduino Due.
Full read-out chain comprised of RF circuit at **GHz range** frequencies and analog amplifying **anti-aliasing** circuit.



Readout works by comparing reference signal to detector signal. This method is known as **homodyne detection**.

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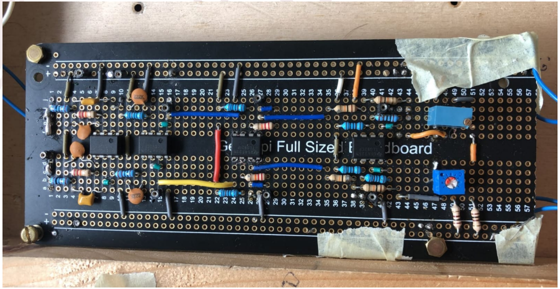
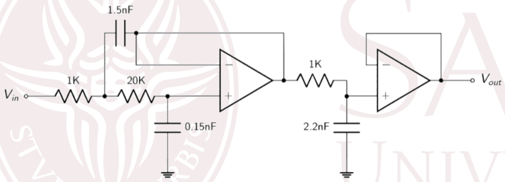
Low Frequency Circuit

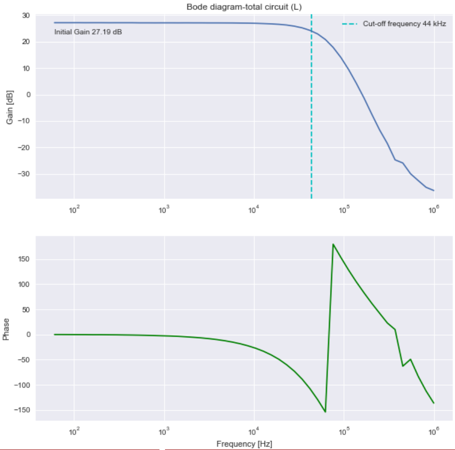
- Serves both as **Amplifier** and **Anti-aliasing** filter.
- Two identical channels corresponding to the I and Q signal from the RF part.
- Each channel is equipped with a **3rd order Sallen key filter**, a **27dB non inverting amplifier** and a **summing circuit**.
- **Built** by **last year's students**, we **improved** the design and **fixed** one of the two channels.



Low-pass Filter

The low pass filter functions as an **anti-aliasing** measure. The **sampling frequency** of the Arduino Due is about **100kHz** and as such, in order to satisfy the **Nyquist** theorem's condition for the acquisition, the **cutoff** frequency has been set at around **45 kHz**.

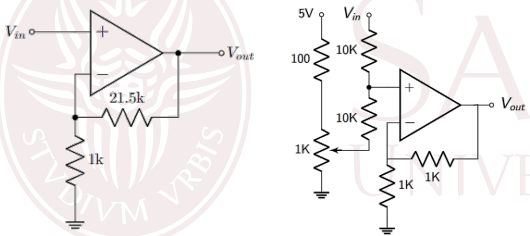


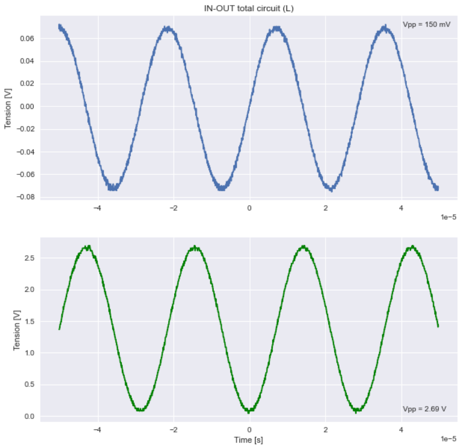


Filter schematic and frequency response analysis of the whole circuit. The filter architecture is a second order **Sallen-Key** filter coupled to an **RC** filter.

Amplificator and Summing Circuit

In order to boost signal strength, an **amplifier** has been built. The total **gain** from amplification is **27 dB**. A **summation circuit** has been built in order to place the signal in a **range** suitable to the **Arduino (0 - 3.3 V)**.





Amplifier and summation schematic.
On the right an example of signal boosting and voltage offsetting.

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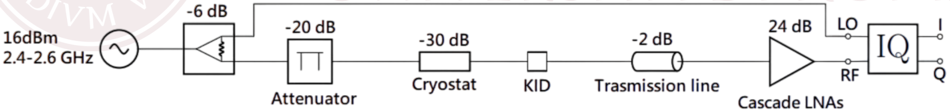
RF Circuit

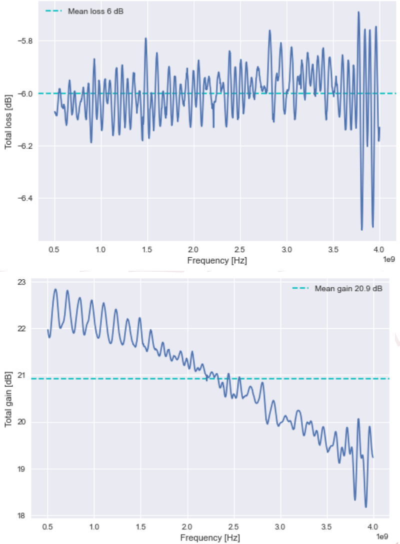
- DAQ module directly in contact with the experimental apparatus.
- Different components connected via **SMA cables**.
- **Inherent frequency response** on each component.
- Works by sending a **reference signal** to the detector and the **mixer** via a **splitter**.
- Mixer compares signals from, emits **output** to **low-frequency circuit**.
- **KID** has **inherent attenuation** of **30dB**, signal must be **amplified**.



Splitter and Amplifier

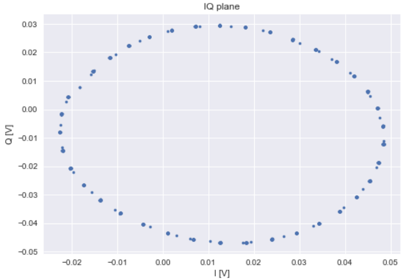
- **Splitter splits signal** in two channels.
- Using **Virtual Network Analyzer (VNA)**, measured **6 dB attenuation** due to non-ideal behavior.
- **amplifier** to **boost attuenuated signal** from **cryostat**, measured **gain** of around **21 dB** at desired range of frequencies.

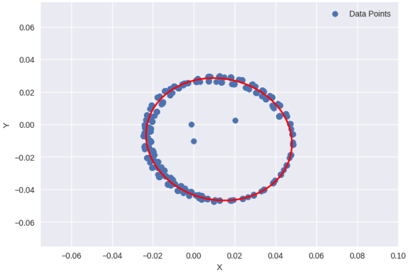
Above on the right, the FRA of one of the splitter outputs. Below on the right, the FRA of the RF amplifier.

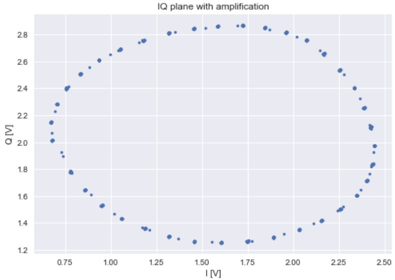


Mixer

- **Mixer**: **non linear component** with two signals input.
- **Outputs** I,Q signals with amplitude $A_1 \cdot A_2$ times, respectively, cos and sin of the phase difference.
- Successfully **simulated DAQ** substituting **cryostat** with **20 dB attenuator** and **2,5 meter line**.
- Expected **two signals** to have **90°phase difference**, observed by measuring and plotting the **I amplitude vs the Q amplitude**.
- Data taking using the Arduino has been performed but still too noisy.
- **Data shown** next **acquired** through **oscilloscope** both at the **output** of the **mixer** and the **output** of **DAQ assembly**.
- **Data** directly from **mixer fitted** using an **ellipse function**, showing an **eccentricity of 0.33**.







On the upper left the IQ data taken directly from the Mixer. On the lower left IQ data from mixer and low frequency circuit. On the right an ellipse fitting of the data taken by mixer's outputs. All data is acquired using a frequency sweep of the RF generator between 1.5 and 1.7 GHz.

Next steps:

- Remotely control the RF generator for automatic frequency sweeps.
- Data acquisition with the Arduino for the noise figure.
- Insertion of the KID in the cryostat and data analysis with the complete experimental setup.

Thank you for your attention!