# SQUID Characterization RUN 18 and RUN 19, measurements taken on 15.05.2024 and 24.05.2024, respectively

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**Abstract**—The following paper presents the results of the latest characterization of SQUID sensors for the Nucleus experiment.

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## 1. Introduction

The previous characterization indicates that the SQUID-noise patterns depend on the circuit setup. Currently, there are four configurations installed in the SQUID system:

- A SQUID with a short installed (see Figure 1).
- A SQUID connected to the breakout box but not to a detector (see Figure 2), also referred to a Shunt-shorted circuit.
- A SQUID with a bias current flowing entirely through the shunt resistances (see Figure 3), also referred as an Open circuit.
- A SQUID with a TES detector in operation (see Figure 4).

| | | | | | | |
|---|---|---|---|---|---|---|
| | | SQUID | | | | |
| | | 1 | 2 | 3 | 4 | |
| | | 5 | 6 | 7 | 8 | |
| | | Breakout box | | | | |
| SCSI 1 | **QUAD 185** | O | O | O | O | TUM |
| | **QUAD 186** | O | SH | SH | SH | TUM |
| SCSI 3 | **QUAD 190** | SH | SH | D | SH | STAR |
| | **QUAD 191** | SH | SH | SH | SH | STAR |
| SCSI 2 | **QUAD 107** | S | S | S | S | STAR |
| | **QUAD 189** | S | S | S | S | STAR |

**Table 1.** Measured detector configuration **O** stands for Open, **SH** stands for Shunt, **S** stands for Short, and **D** for Detector

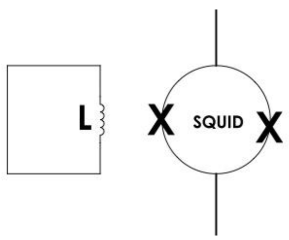


**Figure 1.** Shorted Circuit

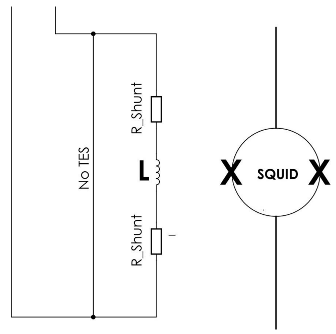


**Figure 2.** Circuit connected to the Shunt resistances, without a detector

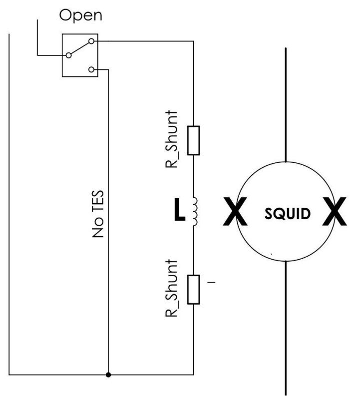


**Figure 3.** Open Circuit, entire Bias current flowing through the shunt resistances

## 2. RUN 15

The SQUID noise of QUADS 107 and 189 with STAR Cryogenic wiring was measured with the Pulse Tube on and with the Pulse Tube off.

**Table 2.** Amplitude of the SQUID patterns

| | **SQUID 1** [V] | **SQUID 2** [V] |
|---|---|---|
| **QUAD 107** | 4,680 | 5,893 |
| **QUAD 189** | 3,459 | 4,184 |
| | **SQUID 3** [V] | **SQUID 4** [V] |
| **QUAD 107** | 3,591 | 3,545 |
| **QUAD 189** | 4,870 | 4,372 |

Both QUADs (107, 189) were installed with a short attached to the breakout box

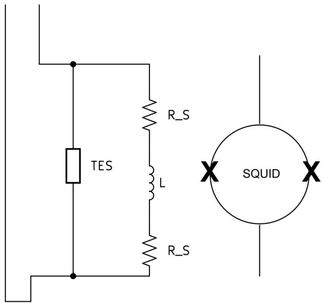


**Figure 4.** Circuit with a TES Detector

**Table 3.** Mean SQUID noise for QUAD 107 and 189 around 10 Hz, with pulse tube **ON**

| | **SQUID 1** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 2** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
|---|---|---|
| **QUAD 107** | 118 | 84 |
| **QUAD 189** | 150 | 125 |
| | **SQUID 3** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 4** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| **QUAD 107** | 6 | 114 |
| **QUAD 189** | 146 | 97 |

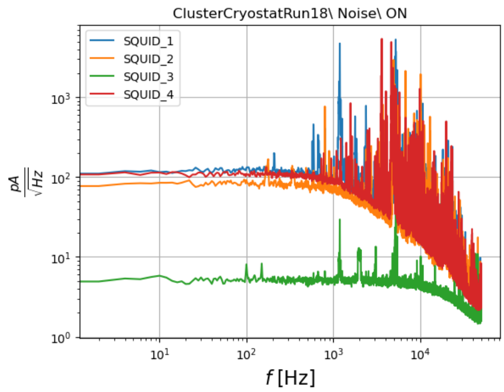


**Figure 5.** Noise of **QUAD 107** with pulse tube **ON**

**Table 4.** Mean SQUID noise for QUAD 107 and 189 around 10 Hz, with pulse tube **OFF**

| | **SQUID 1** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 2** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
|---|---|---|
| **QUAD 107** | 126 | 95 |
| **QUAD 189** | **N/A** | **N/A** |
| | **SQUID 3** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 4** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| **QUAD 107** | 5 | **N/A** |
| **QUAD 189** | **N/A** | 117 |

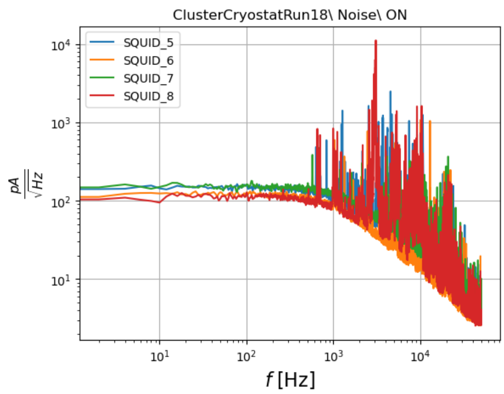


**Figure 6.** Noise of **QUAD 189** with pulse tube **ON**

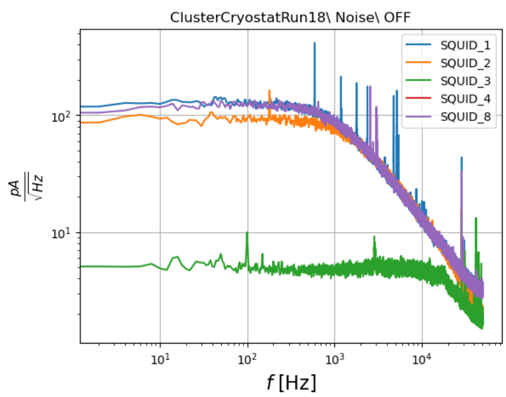


**Figure 7.** Noise of **QUAD 189** and **QUAD 107** with pulse tube **OFF**

### 2.1. QUAD 190

Additionally, the noise of **SQUID 3** from **QUAD 190** with pulste on and off was measured.

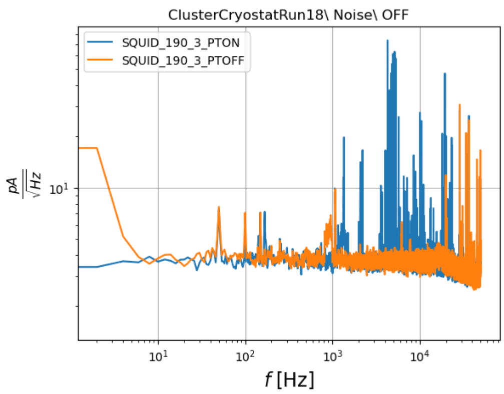


**Figure 8.** Noise of **SQUID 3** from **QUAD 190** with pulste on and off

**Table 5.** Mean SQUID noise of SQUID 3 in QUAD 190 around 10 Hz, with pulse tube ON and OFF

| | **SQUID 3** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
|---|---|
| **ON** | 3.8 |
| **OFF** | 3.7 |

## 3. RUN 19

In Run 19 the noise of QUADs **185**, **186**, **190** and **191** was measured.

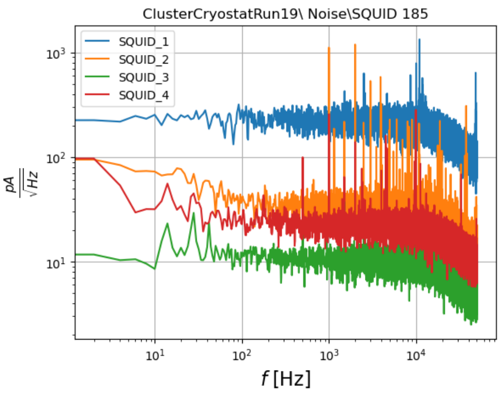


**Figure 9.** Noise of **QUAD 185**

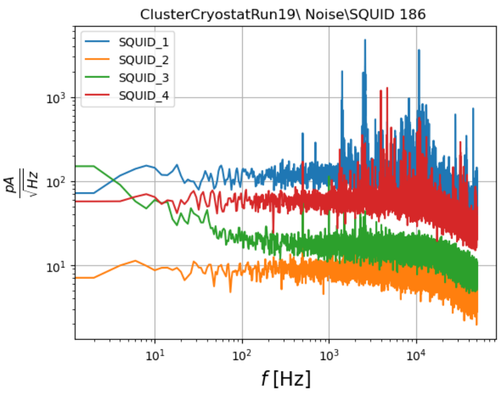


**Figure 10.** Noise of **QUAD 186**

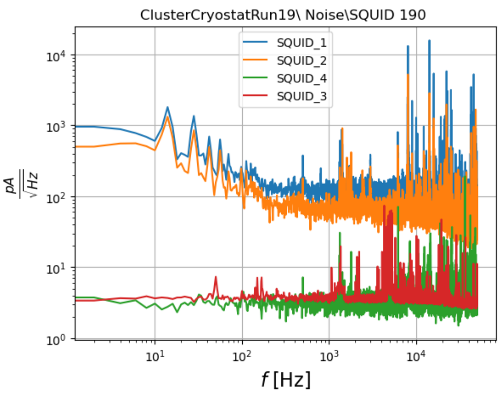


**Figure 11.** Noise of **QUAD 190**

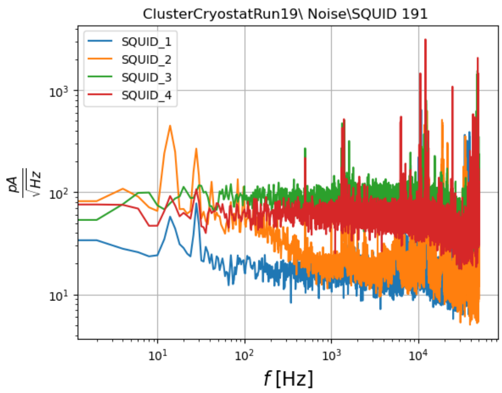


**Figure 12.** Noise of **QUAD 191**

**Table 6.** Mean SQUID noise at 10 Hz for QUAD 185, 186, 190 and 191 from **RUN 19**

| | **SQUID 1** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 2** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
|---|---|---|
| **QUAD 185** | 275 | 82 |
| **QUAD 186** | 150 | 9 |
| **QUAD 190** | 613 | 451 |
| **QUAD 191** | 26 | 75 |
| | **SQUID 3** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 4** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| **QUAD 185** | 10 | 31 |
| **QUAD 186** | 57 | 64 |
| **QUAD 190** | 3.7 | 2.7 |
| **QUAD 191** | 95 | 45 |

**Table 7.** Mean SQUID noise for each QUAD around 10 Hz, from **RUN 8** cells in blue are the SQUIDs in which a detector is connected: Table from [1]

| | **SQUID 1** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 2** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
|---|---|---|
| **QUAD 185** | 133.50 | 8.6462 |
| **QUAD 186** | 125.73 | 15.381 |
| **QUAD 190** | 150.22 | 262.83 |
| **QUAD 191** | 4.8968 | 4.1133 |
| | **SQUID 3** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ | **SQUID 4** $\frac{\text{pA}}{\sqrt{\text{Hz}}}$ |
| **QUAD 185** | 7.0264 | 98.251 |
| **QUAD 186** | 100.79 | 6.7787 |
| **QUAD 190** | 5.1965 | 7.4317 |
| **QUAD 191** | 8.9389 | 5.9237 |

## 4. Noise Code Run 18

Since the data taken from Run 18 was saved as int32, some modifications had to be made to the conversion factors to account for the VDAQ values.

```
nhead = 6
toVolt = 39.3216/((2**24) -1)
touAmp= (77/55)*toVolt
```

**Code 1.** ToVolt conversion value for Int32.

Here is an example code for the Fourier transform which allows for the measurement of the noise:

```
for i in range(4):
    file_path = r"C:\Users\n1cos\Downloads\
     clusterCryostatRun18\noise\noise_SQ"+ str(i + 1) +
      "_000.bin"
```

```
    #print("squidchar_noise_186" + str(i+1)+"M")
    fs=100e3
    nperseg=int(0.5*fs)

    if os.path.isfile(file_path):
        #readRDT(file_path)
        fd = open(file_path, 'rb')
        read_data = np.fromfile(file=fd, dtype=np.int32)
        fd.close()
        read_data= toVolt*read_data[12:]/1.70
        f, pxx = sig.welch(read_data, fs=fs, nperseg=nperseg)
        f = f[:-1]
        ppx = 1e6 * np.sqrt(pxx[:-1])
        P10 = np.mean(ppx[(f >= 7) & (f <= 11)])
        P103 = np.mean(ppx[(f >= 900) & (f <= 1100)])
        print(P10)
        plt.plot(f, ppx,label=f"SQUID_"+ str(i + 1))

    else:
        print("No data taken")
#plt.title("QUAD 185",fontsize= 16)
#plt.axhline(y=4, color='r', linestyle='--', linewidth=5,label=" Shunt Noise")
plt.legend()
plt.title("QUAD 107")
plt.yscale("log")
plt.xscale("log")
plt.grid(True)
plt.xlabel(r'$f$ [Hz]', fontsize= 16)
plt.ylabel(r'$ \frac{p A}{\sqrt{Hz}}$', fontsize= 16)
plt.show()
```

**Code 2.** Noise Code for QUAD 185.

## 5. Noise Code Run 19

Run 19 was saved as int16, some modifications had to be made to the conversion factors to account for the VDAQ values.

```
nhead = 12
toVolt = 39.3216/((2**16) -1)
touAmp= (77/55)*toVolt
```

**Code 3.** ToVolt conversion value for Int16.

## References

[1] N. S. Manrique, *Characterization of squid sensors for the nucleus experiment*, 2024.