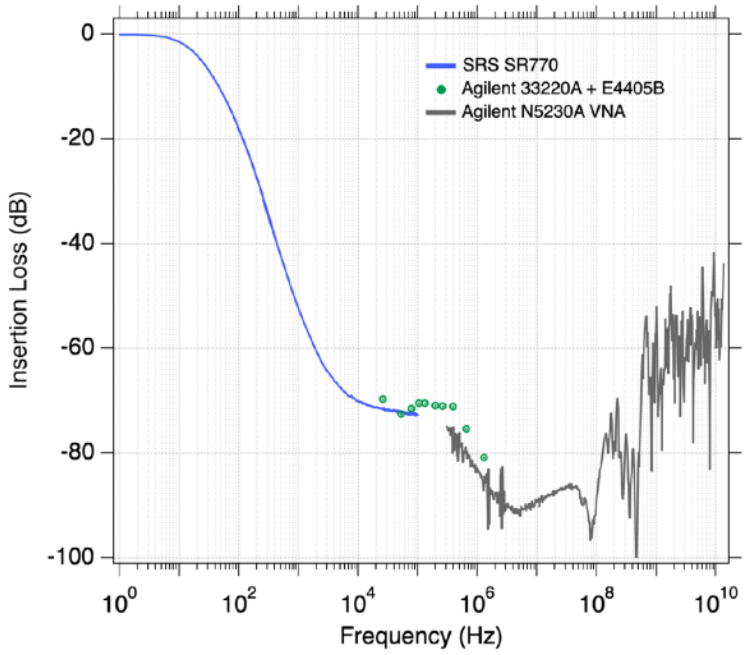
# ⟨g|q|e⟩ LPF

# Low-Pass Filter

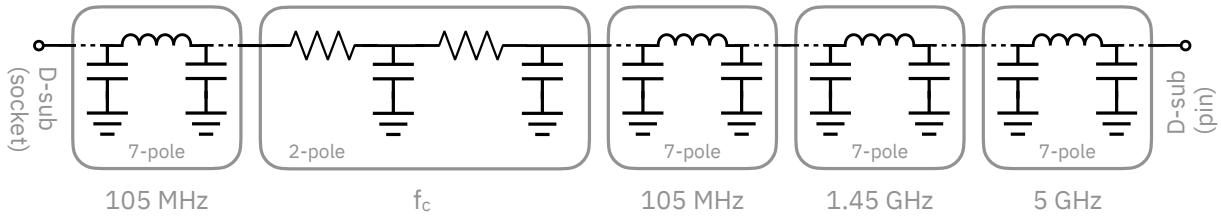

## Highlights

- Combination of multi-pole RC and LC filtering for rejection of unwanted frequencies up to >20 GHz.
- Multiple RC configurations available to accommodate every use-case.
- Designed with thermalization in mind: gold-plated oxygen-free copper enclosures and ceramic circuit boards for maximum heat transfer at millikelvin temperatures.
- Mounts to most commercial dilution refrigerators in multiple orientations.
- Industry standard 25-pin micro-D connectors.

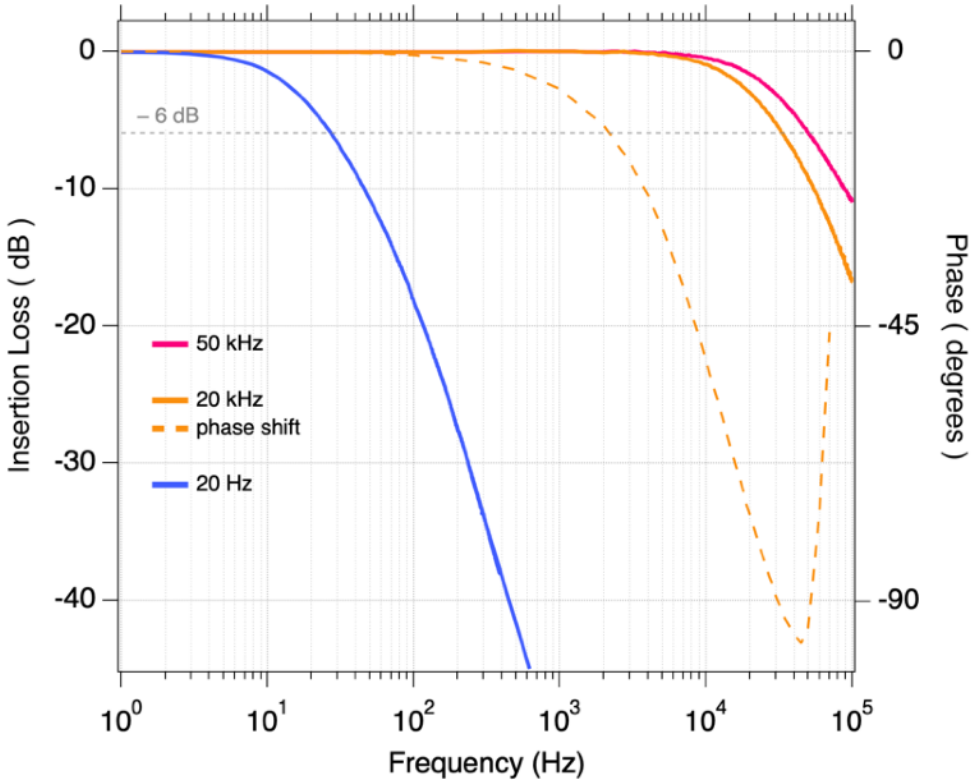
The GQE LPF was designed to reject high frequencies and thermalize DC wire sets to millikelvin temperatures in dilution refrigerators and other cryogenic systems. As low temperature physicists we recognize there is no one-size-fits-all filter, which is why we offer multiple configurations with different cutoff frequencies and in-line resistances that can be customized to meet the needs of any experiment.




Typical attenuation of a 20 Hz filter from 1 Hz to 14 GHz



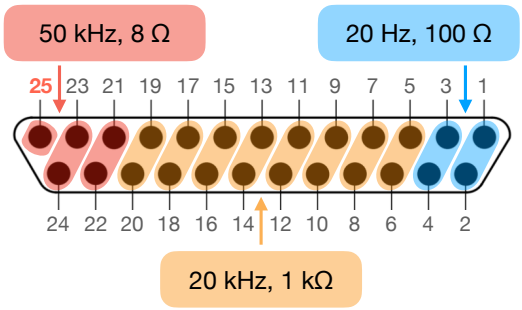

| Cutoff and in-line resistance | Recommended applications | Operating limits |
|---|---|---|
| 20 Hz, 103 Ω | Aggressive filtering of DC bias lines to qubits, quantum amplifiers, and other sensitive devices | Max: 10 V, 50 mA |
| 20 kHz, 1002 Ω | Low-frequency lock-in amplifier measurements | Max: 25 V, 15 mA |
| 50 kHz, 8 Ω | Designed to allow for filtering connections to electromechanical switches | Max: 25 V, 250 mA |



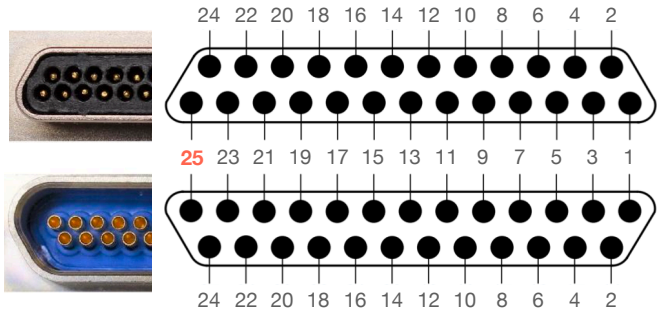

Low-frequency attenuation of standard filter configurations. Phase shift is shown for 20 kHz cutoff.

- GQE warrants a ground isolation of ≥ 1 GΩ for standard filter configurations. Typical isolation ≥ 10 GΩ.
- Cutoff frequencies may vary depending on load resistance.
- Operation at 4K is recommended for applications requiring significant (~mA) bias currents. For measurements requiring mK electronic temperatures, filter should be located on the mixing chamber plate and 20 kHz lines should be used.

## Standard Configuration

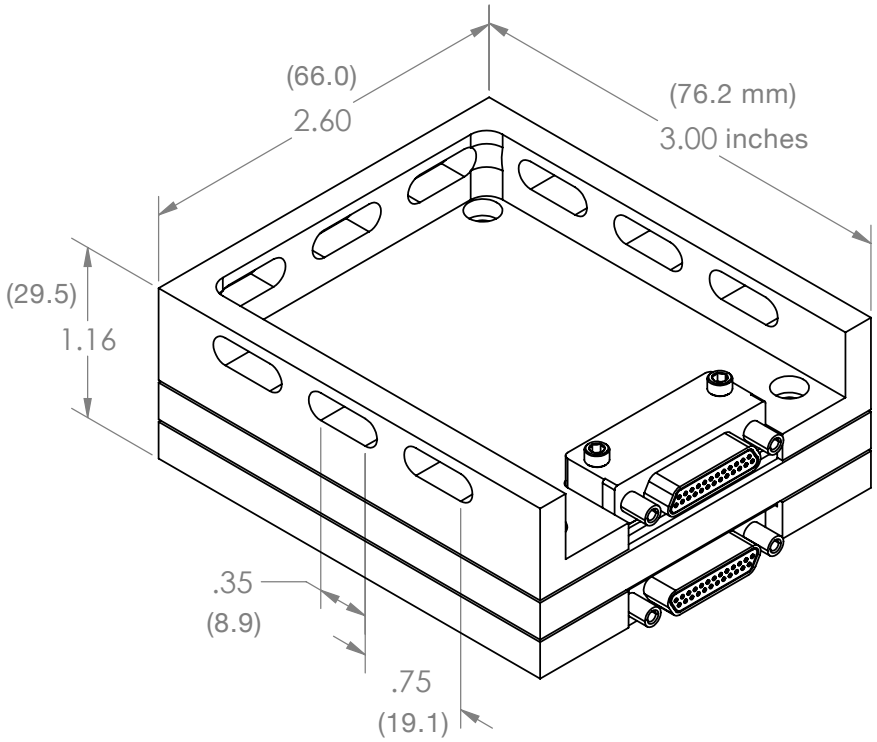


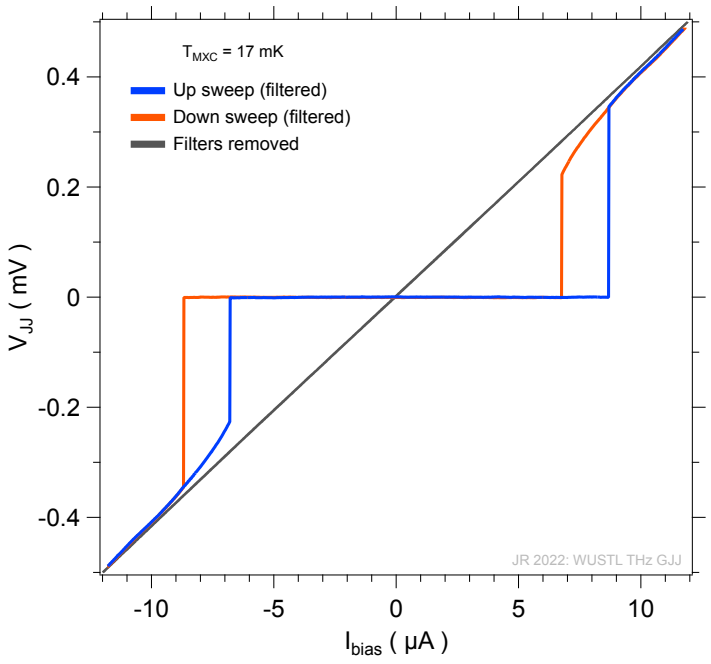

## Line Indices




LC output (pin)

RC input (socket)

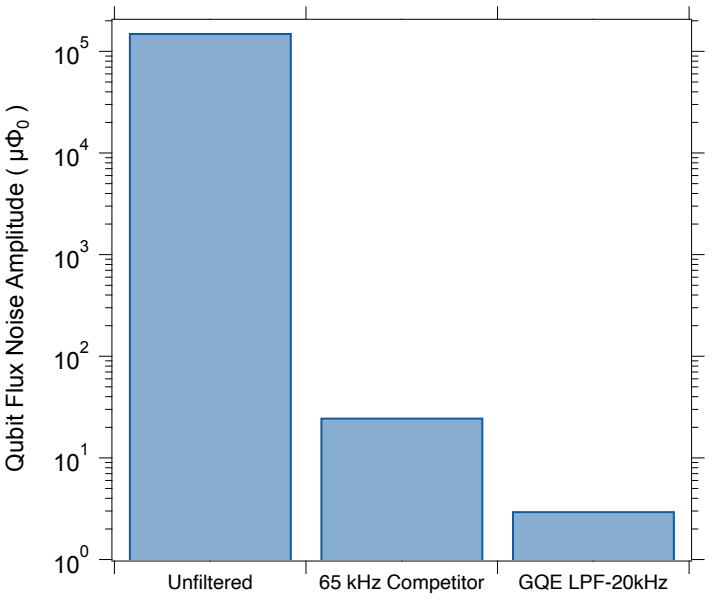





An SNS Josephson junction (JJ) with a graphene weak link was measured in two configurations: unfiltered, and using the GQE LPF with 20 kHz cutoff. The filter was operated at 4K, with the sample on the mixing chamber at 17 mK. When filtered, the JJ demonstrated hysteretic switching behavior characteristic of an underdamped SNS junction (blue, orange). In the absence of filtering, purely ohmic behavior (grey) was observed. An effective junction temperature > 8 K is inferred in the unfiltered case.

Credit: Henriksen lab at Washington University in St. Louis

[1] *Resistive states of superconducting channels in an alternating electromagnetic field*, Low Temp. Phys. **27** (3): 165–184 (2001), V. M. Dmitriev, I. V. Zolochevskiĭ, E. V. Khristenko




The flux noise of a superconducting transmon qubit was measured [2] in three DC wiring configurations: unfiltered, using a commercial cryogenic low pass filter with a 65 kHz cutoff, and using the GQE LPF with a 20 kHz cutoff. Both filters were located at 4K. Flux noise was reduced by nearly four orders of magnitude by a competitors' cryogenic low pass filter, while the GQE LPF achieved a reduction of nearly five orders of magnitude.

Credit: Murch lab at Washington University in St. Louis

[2] *Characterizing and Optimizing Qubit Coherence Based on SQUID Geometry*, Phys. Rev. Applied **13**, 054079 (2020), Jochen Braumüller, William Oliver, et al.