# The effects of changes in bath temperature on Kinetic Inductance Detectors

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***Abstract***—We present calculations of the effects on responsivity and noise of changes in bath temperature and bath temperature noise on a typical Kinetic Inductance Detector (KID), and how these might be affected by electrothermal feedback, or thermal isolation of the device. KIDs are a leading ultra low noise, large format superconducting detector technology for astrophysics at THz frequencies and above, with performance strongly determined by the superconductor quasiparticle effective temperature. Particularly for space deployments, which often require background limited detectors but have challenging constraints on cryosystem design, knowing exactly how fluctuations in fridge temperature affect measured noise is crucial.

Our calculations are derived from a general electrothermal model [1] applicable to KIDs and similar superconducting microresonator-based devices. We are able to calculate both the large-signal – steady-state operating point – and small-signal – responsivity and noise-equivalent power (NEP) limits – behaviour of an electrical resonator in a complex thermal circuit with a number of power flows. In particular, our model includes the effects of readout power heating of the superconducting quasiparticles – absorbed readout power affects quasiparticle effective temperature which changes readout power absorbed, the phenomenon we describe as electrothermal feedback in KIDs – using recent work on the detailed functional form of quasiparticle-phonon cooling in superconductors [2,3].

Using this model, we have explored how a changing bath temperature affects both the large and small-signal behaviour of a typical KID. We find when readout power heating at the steady state operating point has increased the effective quasiparticle temperature significantly above the bath temperature, this effective quasiparticle temperature is no longer sensitive to small changes in the bath temperature or thermal conductivity from the device to the bath. Consequently, the responsivity to a signal of interest and the intrinsic generation-recombination noise of the device are unchanged as bath temperature varies. In general, KID performance is significantly reduced by an increased quasiparticle effective temperature, but this result suggests allowing some heating may reduce the noise contribution from an unstable fridge temperature.

1. Thomas, C. N., Withington, S. & Goldie, D. J. Electrothermal model of kinetic inductance detectors. Supercond. Sci. Technol. 28, 45012 (2015).
2. Goldie, D. J. & Withington, S. Non-equilibrium superconductivity in quantum-sensing superconducting resonators. Supercond. Sci. Technol. 26, 15004 (2013).
3. Guruswamy, T., Goldie, D. J. & Withington, S. Nonequilibrium superconducting thin films with sub-gap and pair-breaking photon illumination. Supercond. Sci. Technol. 28, 54002 (2015).