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Expanding the Capability of Microwave Multiplexed Readout for Fast Signals in Microcalorimeters

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Microwave multiplexing has become a key technology for reading out large arrays of x-ray and gamma ray microcalorimeters with mux factors of 100 or more. However, the desire for large mux factors and fast x-ray pulses for high photon counting rates drives system design towards high sensor current slew rate, which is typically handled by using a high sampling rate. Future experiments like the LCLS-II soft x-ray spectrometer and the LYNX x-ray microcalorimeter are expected to require sampling rates of 1 MHz or faster in order to meet count rate, mux factor, and x-ray energy range requirements.

In our microwave multiplexed readout scheme, the effective sampling rate is set by the frequency of the flux ramp modulation (f_r) used to linearize the SQUID response, and is generally limited to half the resonator bandwidth. The maximum current slew rate between samples is then nominally $\Phi_0 f_r/2\mathrm{M}_{in}$ (where M_{in} is the input coupling) because it is generally not possible to distinguish phase shifts of >π from negative phase shifts of <-π. However, during a pulse, we know which direction the current ought to slew, and this makes it possible to reconstruct pulses where phase shifts are >π or even >2π. We show that if the slew rate on falling edge of the pulse is less than the nominal $\Phi_0 f_r/2\mathrm{M}_{in}$ limit, we can use a straightforward algorithm to identify and reconstruct pulses that exceed that limit on the rising edge. We demonstrate this on pulses produced by x-ray transition edge sensors, and find that the pulse reconstruction has minimal impact on energy resolution compared to arrival time effects induced by under-sampling the rising edge. If the rising edge is sufficiently sampled, this technique can increase the effective slew rate limit by more than a factor of two, thereby either reducing the bandwidth required or extending the energy range of measurable photons. The extra margin could also be used to improve crosstalk or decrease readout noise.

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