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The GAROP-2, a Radiation-Hard ASIC for Particle Beam Monitor Readout of the COMET Experiment

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The COMET (COherent Muon to Electron Transition) experiment at J-PARC requires particle detectors on the beam axis for proton and muon-pion flux monitoring. The GAROP-2 (GAted-ReadOut Proton 2) is thus dedicatedly developed as the read-out electronics for the diamond or SiC monitors. The detectors and GAROP-2 are gated off at the proton pulse phase to prevent it from saturation. Added to this version of GAROP-2 is an auto-tuning threshold circuit for each read-out channel, which can address the problem of inconsistent device baseline. We ordered fabrication and tested the performance of the GAROP-2.

Summary (500 words)

The COMET (COherent Muon to Electron Transition) experiment at J-PARC is dedicated for searching muon to electron transition processes. The COMET experiment uses the proton pulse-beam at J-PARC to hit a fixed target to produce high-intensity pion. The experiment requires a dedicated particle monitoring system to rule out proton beam leaks outside of the bunch structure and also to identify pion-muon mix beam status. Thus, charged particle beam monitors will be installed inside the beam pipeline on the axis of the beamline.

A straightforward conclusion is that, the monitor sensors must have strong radiation tolerance (8 GeV proton beam, 2.5e+12 protons per second and 1.6e+7 protons per bunch), as well as the readout electronics, although they are not in the beam-axis but close to it. Therefore, SiC sensors will be used, while diamond sensors will be an interesting alternative. The GAROP-2 (GAted Read-Out Proton 2) is the read-out circuit developed for this scenario. This chip has an area of 1mmˆ2 and uses TSMC 65nm technology. The analogue part of the GAROP-2 consists of a CSA (Charge Sensitive Amplifier), a CR-RC shaper, and an over-threshold discriminator, for the hit count matters the most for these monitors. It also has a DAC supporting automatic threshold tuning to compensate for threshold variation between devices.

Each GAROP-2 has eight analogue input channels separated into two analogue flavours with four channels in each. The two flavours share the same design except for the shaper. One uses a single-stage CR-RC circuit for the shaper, while the other uses a double-stage CR-RC-CR-RC circuit. A performance difference comparison will be accomplished.

Also, the GAROP-2 accepts an external gating signal, which can cut off the circuit at ˜1 MHz. This gate structure allows the CSA to shut down during the proton bunch phase, preventing from signal saturation and further damage.

The threshold auto-tuning circuit and the corresponding threshold offset setting are achieved by a daisy chain SPI (Serial Peripheral Interface). The auto-tuning can be also turned on or off, which decides whether the 8-bit DAC will approach the current output of the shaper. As designed, the GAROP-2 will turn on the threshold auto-tuning circuit when there's no hit, so that it can find the output baseline of the shaper. This circuit requires an external clock input to work.

The GAROP-2 design was frozen and submitted to the vendor in early January., 2024, and the chips arrived in KEK in late March, 2024. A PCB test board was designed and put into use for testing in April, 2024. By September, sufficient testing will be done on the GAROP-2. The functionality of the amplifier and threshold auto-tuning circuit will be verified. The noise level of the circuit will be measured. The readout performance will be tested.

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