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ULTRA-LOW-POWER FULLY INTEGRATED CMOS REAL-TIME CLOCKS FOR AUTONOMOUS SENSORS FOR LUNAR EXTREME TEMPERATURES

Abstract

Driven by space agencies worldwide, there is currently a tremendous interest in lunar exploration and science. However, the harsh and extreme lunar environment poses significant challenges in building robust and reliable operational systems. The lunar surface is exposed to harsh temperatures (-253 C / +120 C), and, furthermore, energy is scarce and only intermittently available in such missions. To overcome these impediments, we aim to develop key enabling technologies for autonomous sensing nodes that can withstand these harsh conditions.

The main challenge for such a node is to keep operating while the on-board solar panels deliver minimal power, or even no power, e.g., during the 14-day-long lunar night. To address this, most of the node circuits will be kept in ultra-low-power deep sleep for most of the time and woken up by a real-time clock (RTC) only for periodically acquiring data with the on-chip sensors or for sending the data out via the antenna when enough power is available. Consequently, one of the crucial enabling components is an ultra-low-power fully integrated RTC with good time-keeping accuracy. In particular, as long sleep durations are required to save energy, the RTC must ensure long-term clock stability to enable various applications.

While quartz-based oscillators can deliver low power and high accuracy/stability, they are avoided in this application in favor of a fully integrated alternative to allow minimal node size and cost as required for large-scale deployment. As fully integrated clocks typically suffer from poor temperature stability and aging combined with relatively large power dissipation, this paper proposes an alternative approach for a time reference stable over an ultra-wide temperature range. We exploit the low temperature coefficient of a passive LC tank to accurately lock the frequency of an active oscillator. To limit the footprint of the LC resonator, a high frequency of oscillation is adopted, which results in a high power consumption. The LC-based oscillator is then heavily duty-cycled and only used to calibrate the frequency of an ultra-low-power always-on ring oscillator. In addition, clock synchronization algorithms can improve node synchronization over the entire mission duration.

The development of the proposed real-time clock will lay the foundation for low-cost miniature autonomous sensor nodes to be deployed in large numbers, exploiting redundancy to circumvent the node

power-limited functionality and performance, thus facilitating data acquisition in future lunar and planetary explorations.