A Versatile Timing Microsystem Based on Wafer-level Packaged XTAL/BAW Resonators with Sub-μW RTC Mode and Programmable HF Clocks


MEMS oscillators have recently successfully entered the timing market owing to the packaging revolution enabled by wafer scale technologies. This paper explores how XTAL resonators could similarly benefit from such technologies with the demonstration of a miniature generic timing module.

Over the past several years, the decades long quartz-dominated timing industry has been increasingly challenged by the introduction of new products or demonstration of prototypes based on silicon MEMS resonators. One of the true advantages of the technology is the fact that well-proven semiconductor manufacturing technologies amenable for high volume production are exploited to produce wafer-level encapsulated low-cost components. This paper explores how crystal (XTAL) resonators could benefit from similar packaging technologies and demonstrate superior stability performances.

Figure 1 presents the architecture of the proposed system [1]. A low frequency, 131 kHz, quartz-based oscillator associated intermittently to a low duty-cycled temperature sensitive 10 MHz RC oscillator is used to derive a temperature compensated 32768 Hz clock after fractional division (+R) for frequency adjustment that is fed to a conventional real time clock (RTC) circuit with calendar, alarm and timer functions.

Besides the RTC, HF clocks re-programmable between 1 to 50 MHz via a serial interface (I2C) can be generated in two ways depending on the jitter level and/or phase noise requirements. A low power version is derived with the help of a fully integrated RC PLL (osc RC, +Q, PD/PFD and LF) referenced to the 131 kHz quartz signal for applications requiring accurate frequency, with moderate jitter. Up to three independent clocks with much lower noise and jitter performance, such as required for radio applications or high DR converters, are obtained after integer (+M) or fractional division (+N; +P) of the signal derived from a temperature-compensated, ~2 GHz BAW DCO.

To avoid bulky ceramic packages associated with XTLs (and possibly ASICs in RTCS) and achieve extreme timing module miniaturization, air-tight silicon housings with electrical feed-through implemented with through silicon via (TSV) were developed in view of using ultimately the circuit as an active part of the package. Figure 2 shows a cross-section micrograph of a XTAL that is flip-chip bonded on a 100 μm interposer—ultimately the thinned CMOS wafer- and sealed at wafer level with a patterned cap wafer using electro-plated Au/Sn eutectic bonding.

![Figure 2: Cross-section of a XTAL packaged in a silicon housing](image)

Early system level validation was demonstrated with resonators packaged in a standard way. The frequency error of the 32.768 kHz temperature-compensated clock obtained after division of the 131 kHz XTAL oscillator signal over the industrial range -40 to 85°C and reduced range 0 to 50°C is shown in Figure 3 after a 5-points trim within the shown range.

![Figure 3: Temperature stability measurement after a 5-points trim](image)

The power is sub-μW in the temperature-compensated RTC mode, 8 μW when the 10 MHz RC temperature sensor clock is activated permanently, 100 μW with the RC PLL locked at 50 MHz and 10 mW when 48 MHz and 26 MHz clocks are generated by fractional division from the BAW DCO.

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