TIMING IS CRITICAL IN SOFTWARE-DEFINED VEHICLES

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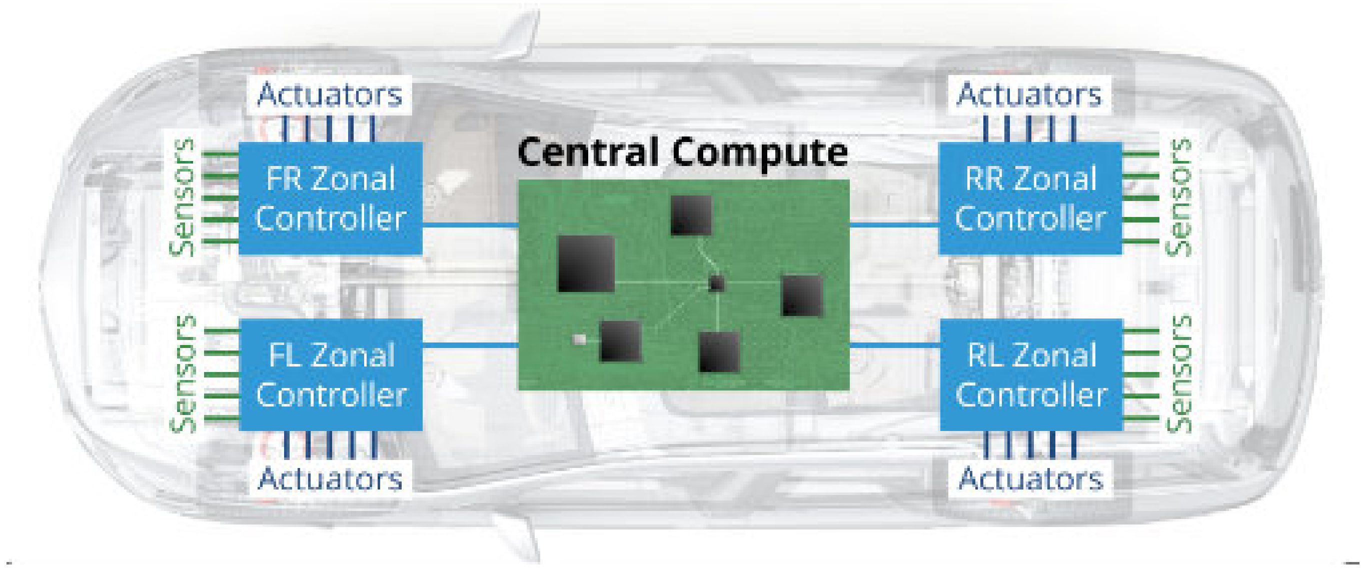
Software-defined vehicles (SDV) are awash with possibilities, as potential applications and functions continue to spring up. We are presented with a vast range of options to make the driving experience safer, more enjoyable and better connected. If ADAS and V2X are the buzzwords, Precision Timing is the baseline.

There is a key enabler that is underpinning the automotive user experience (UX) of SDVs, delivering consistency and reliability across many aspects of today's 'data centres on wheels'. That enabler is Precision Timing.

There are already 70-100 timing devices in the typical vehicle. This number is likely to increase - driven by transportation trends such as electrification and driving automation.



In this article, we will discuss how the adaptability and programmability afforded to engineers by the latest timing technologies are helping to overcome challenges.

Synchronisation – a non-negotiable for data-driven mobility

Four megatrends have converged to redefine automotive engineering. They are electrification, driving automation, shared mobility and active safety. The result of these developments is that high-performance electronics can now be found in every part of a vehicle.

In-vehicle networks now move an unprecedented volume of information at high speed. Automated vehicles can generate over 20 terabytes (TB) of data per hour. System complexity is rising, with modern designs incorporating hundreds of interconnected control units, cameras, radars and lidars. Architectures are becoming more centralised, as SDVs pull functions together into a powerful computing hub.

These characteristics all demand tighter synchronization, making Precision Timing a key enabler for safe and efficient operation in many cases. Silicon Microelectromechanical Systems (MEMS) technology, which is replacing traditional quartz timing, has paved the way for more sophisticated features in SDV design with a single MEMS clock chip that synchronises different clocks. This single chip integrates end-to-end monitoring of the clock signal's various functional blocks, alerting the system if there is a malfunction.

The end-to-end monitoring capability, as well as a lower failure rate compared to quartz, means that the superior synchronisation brought to the table by precision timing is achieving the two key deliverables for SDVs: safety and efficiency. In other words, Precision Timing has become 'mission critical' to SDVs.

Where milliseconds make the difference

Precision Timing has made itself indispensable in scenarios where milliseconds can make the difference in assuring safety and avoiding system failures.

An emergency braking event with advanced driving assistance systems (ADAS) is a case in point. A forward-facing radar identifies an obstacle, before the vision system classifies it, and the control ECU decides to apply the brakes. In the absence of precise synchronisation, even a slight misalignment may compromise the accuracy of sensor fusion and delay the braking command.

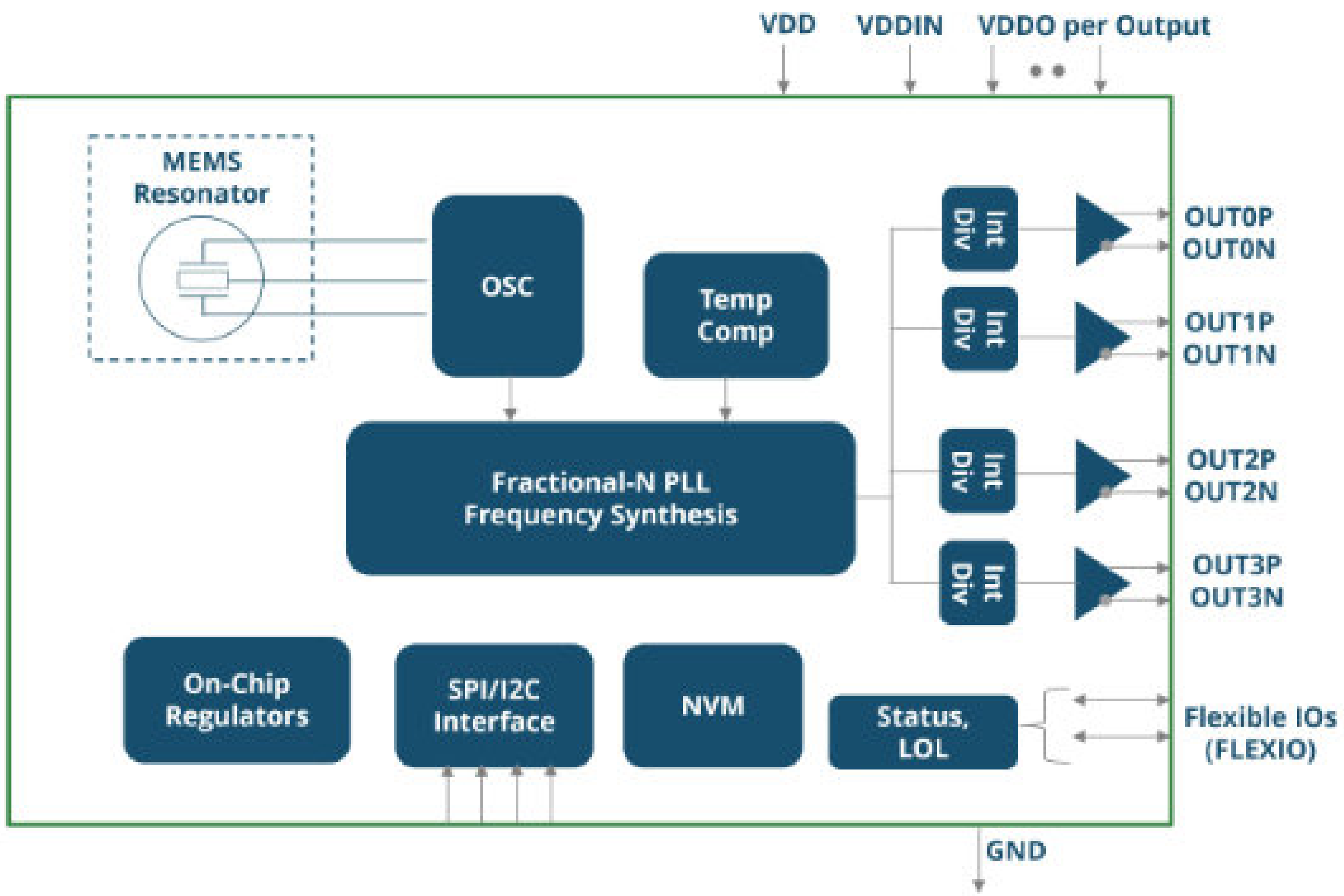
Timing instability has a spiral of negative consequences for safety in SDVs. It may corrupt high-speed Ethernet or PCIe data transfers, cause jitter that degrades camera, radar, or lidar performance, and trigger V2X or 5G communication dropouts, impacting situational awareness.

The end-to-end monitoring function enabled by a single MEMS clock chip allows failures to be detected early in the clock tree, reacting quickly to bring the system back to a safe state. Without this ability to report a fault within microseconds, hundreds of milliseconds would pass before a failure is manifested downstream, identified by a module, and reacted to. With the monitoring function in the latest MEMS devices, the system is in an unsafe state for no longer than it needs to be.

The harsh environments inhabited by automotive timing systems

Quartz crystal oscillators have long provided the heartbeat for automotive electronics. But as systems have become more complex and demanding, quartz systems' inferiorities in terms of size, resilience, and temperature stability are limiting.

Timing systems in SDVs must perform reliably in conditions characterised by extreme temperatures ranging from -40°C in winter to over 125°C in summer, engine bays, constant vibration and shock from rough roads and mechanical systems, and electromagnetic interference (EMI) from electric powertrains, charging systems, and increasingly dense electronics. Shared mobility models add further stress by keeping vehicles in service longer each day, increasing thermal cycling and component wear.



Silicon MEMS timing devices offer a far greater resistance to vibration and shock. They are vibration-insensitive and can cope with up to 20,000g of shock, making them up to 100x more effective than quartz in the face of vibration and shock. A high EMI immunity makes MEMS chips ideal for electric vehicles, and there is sub-ppm stability across the full automotive temperature range. In terms of size, the miniaturisation of MEMS devices - with resonators that have a 1,000x lower mass than quartz - allows them to fit into tightly packed sensor modules, enabling smaller timing footprints and increasing resilience.

Moving a 'data centre on wheels'

SiTime's Executive Vice President, Piyush Sevalia, recently took part in an expert panel discussion on SDVs for the Techsplicit platform. In it, the discussion centred on how SDVs are reshaping the entire supply chain - from OEMs and Tier 1 suppliers to semiconductor companies and software developers.

Historically, vehicles were designed with domain-based architectures, each with its own ECU optimised for a specific function, such as braking, infotainment, navigation, or engine control. Software used to be written to fit the hardware, but the SDV model flips this approach. One panellist recalled how he used to design hardware and optimise software for the hardware, whereas in the SDV era, the reverse is true.

This change is profound. Instead of incrementally adding functionality ECU by ECU, SDVs rely on a centralised compute platform that hosts multiple applications. The advantage is scalability and efficiency, but the complexity of developing secure, safe, and high-performance systems rises dramatically.

Precision Timing is addressing this pain point. Piyush Sevalia explained that the disparate systems inside SDVs must communicate with each other before aggregating that communication outside the car to the infrastructure. For synchronisation of all this data, a reliable timing signal is non-negotiable. As Piyush explained, Precision Timing at the physical layer ensures that data flows don't lose coherence, undermining not only performance but safety. Safety-critical systems in this software-centric architecture - such as anti-lock braking - are benefitting from faster response times afforded by the failsafe technology in products such as SiTime's Chorus™ Automotive Clock Generators, which combine a MEMS resonator, oscillator and advanced safety mechanisms in one single package.

Precision Timing goes further to allay engineer headaches by offering scalability across multiple vehicle platforms and ADAS levels, and interoperability in the absence of fully standardised timing protocols.

A future built on precision

Building better SDVs is not just about faster processors, smarter algorithms, or better sensors. It's also about ensuring that every one of those systems keeps perfect time. Precision Timing is the silent enabler of safety, reliability, and performance in the connected and automated vehicles of tomorrow.

As the SDV path winds towards an increasing focus on fully autonomous vehicles, the industry is confronting the twin challenges of rising complexity and uncompromising safety standards. In this software-oriented future where milliseconds matter more than ever, MEMS-based silicon timing is poised to become the heartbeat of automotive.