Configurable Mixed-signal ICs Enable Safe, Flexible & Low-Cost Automotive Designs

Author(s)	Trang Nguyen, Automotive Marketing Manager
Revision	Rev. A
Release Date	May 1st, 2019

Dialog Semiconductor

2560 Mission College Blvd
Santa Clara, CA 95054
United States

Phone: +1 408 845 8500
Fax: +1 408 727 3205

Neue Straße 95
73230 Kirchheim/Teck
Germany

Phone: +49 7021 805-0
Fax: +49 7021 805-100

Abstract

Electronic circuits within automobiles continue to grow as the industry uses increasingly complex system to offer better safety, comfort and efficiency to drivers. This paper describes a new category of semiconductors, Configurable Mixed-signal ICs (CMICs), which offer a better way to implement these automotive circuits. CMICs can play an important role in providing low latency response for safety critical functions, lowering system failure rates, enabling flexible automotive designs, and reducing size, cost, and sourcing issues.

Introduction

Today's luxury vehicles include 50 to 200 ECUs which are becoming increasingly complex to meet the evolving demands of the automotive market. Even ECUs with the most sophisticated SoCs and MCUs still require additional circuitry for safety monitoring, interrupt control, sensor interface, power management, etc. As a result, there are many circuits outside of the SoC and MCU made of analog, logic, and discrete components. Not only do these numerous components take up space and require extensive qualification, but these circuits are also prone to changing as customizations and iterative improvements are made to differentiate varying vehicle models. CMICs can help address these ever-changing automotive innovations while minimizing reliability issues, development time, footprint and cost.

Configurable Mixed-signal ICs

CMICs are a programmable matrix of analog and digital resources that can be configured into mixed-signal circuits through One-Time-Programmable (OTP) or Multi-Time-Programmable (MTP) NVM. Dialog Semiconductor is the leading provider of this category of devices with its GreenPAK (CMIC) product family. The resources available in GreenPAK ICs include asynchronous state machines, comparators, timing delays, oscillators, ADCs, voltage monitors, pulse width modulators, glue logic, level shifters, and much more.

Designers can use the intuitive GreenPAK Designer Software GUI to select the required resources, "wire up" their design in a schematic capture-based environment, and run SPICE simulations. Emulation can be performed using the GreenPAK Development Hardware. When designers are satisfied with the functionality of their circuit, clicking the "Program" button in the software GUI will immediately program the NVM of the GreenPAK IC. The customized CMIC can then be ready for use in less than a day.

Each automotive grade GreenPAK base die part can be programmed to implement hundreds of different AEC-Q100 qualified ICs performing varied functions like voltage monitoring, system reset, LED control, power sequencing, frequency detection, sensor interfacing, etc. Each customized CMIC design will be issued its own unique part number, top marking, confidential automotive grade datasheet and PPAP. In production, the customer's unique GreenPAK configuration will be factory programmed and the IC will be tested per its unique functional design and datasheet specifications.

Reliable, Low Latency Interrupt Control

CMICs are excellent at quickly and efficiently processing asynchronous inputs. This makes them ideal for safety critical functions in the automobile that require fast reaction times to ensure that a given system stays within a known safe state. Microcontrollers and SOCs are capable of processing asynchronous inputs through dedicated interrupt service routines (ISRs). However, an MCU's interrupt latency, which is the time from when an interrupt signal is triggered until the core is executing the first instruction of the ISR, is at best 5-10μs. A CMIC's equivalent of interrupt latency is measured in the tens of nanoseconds.

Additionally, CMICs are extremely robust due to their asynchronous architectures. Poorly written software, timing issues, miscalculations of interrupt latency, running out of stack memory, memory leakages, and accidental writes in program memory are some common pitfalls that make MCUs and SOCs prone to crashing. Interrupt control that is configured in the CMIC with NVM bits have no timing issues, latency measured in ns, no stack memory, no ability for memory leakage, and no ability to unintentionally over write program memory. It is, therefore, common to find CMICs acting as crash monitors for large MCUs and SOCs. Some GreenPAKs are also used to operate the failure mode notifications, error LEDs, and other functions that must remain operational while the main processor is malfunctioning. The CMIC's robust architecture makes it a great companion chips for MCUs and SOCs since it can quickly respond to asynchronous inputs and can reliably handle system crashes.

FIT Rate and Functional Safety

Systems implemented with discrete and analog components can have high failure rates as each device is vulnerable to reliability issues, cold solder joints and assembly related problems. System FIT rates for circuits created in discretes can also be difficult to calculate as the unique mission profiles of each component must be considered. This task becomes increasingly complex with each component that is added to the board.

A CMIC can replace dozens of components and its programmed functions are 100% tested before shipping. This not only eliminates the failures associate with each displaced component, but it simplifies FIT rate calculations as well. Dialog Semiconductor generates customized reliability reports to show CMIC FIT rates based on a customer's specific mission profile. This becomes a very nice benefit in applications concerned with functional safety as FIT rate is one of the failure metrics that must be considered to achieve a target Automotive Safety Integrity Level (ASIL). (Shown in Table 1).

ASIL	Failure Rate
A	< 1000 FIT
B	< 100 FIT
C	< 100 FIT
D	< 10 FIT

Table 1: Failure metric for ASIL level

CMICs can be used as part of an overall system designed to operate in a functionally safe environment because they offer a good level of diagnostic coverage from random hardware failures. Of course, as CMICs are a Safety Element out of Context (SEooC), actual compliance level of the device will also depend on the target application.

Working with a leading SoC supplier and its FuSa architects, Dialog has developed documentation showing how GreenPAKs can be used to implement a system designed to meet functionally safe automotive requirements in an SoC based application. The documentation of this design can be provided to customers upon request.

Flexible Designs

In automotive designs, significant amounts of efforts are often dedicated upfront to develop reliable platforms that can be shared over a number of outwardly distinct models. Platform sharing allows reduced R&D spend, a more efficient product development process, and reduction of cost due to increased economies of scale. In order to keep product uniqueness, however, circuitry must be added or modified between varying designs to enable vehicle differentiation. CMICs are excellent for implementing these circuit modifications due to their inherent flexibility.

Once the appropriate GreenPAK base die is selected, circuits can be quickly implemented and changed within the CMIC at no cost to the designer. CMICs can be debugged and prototyped in less than a day and changes to the CMIC can be quickly implemented throughout the development process without spinning a new board, sourcing new components, or changing the SOC or MCU code. GreenPAKs that offer the In-System-Debug feature, provide even greater flexibility as they can be programmed up to 1000 times via I2C all throughout the development cycle. Hence, these easily programmable ICs allow Tier-1s to create flexible base platforms that can be easily changed to enhance and differentiate their automotive designs. OEMs can also quickly add new circuitry to existing platforms while keeping footprint and BOM cost at a minimum.

Lowering Cost, Footprint & Sourcing Issues

System designers can benefit from a scalable portfolio of CMICs varying in footprint, cost, and available resources. Dialog Semiconductor offers various automotive GreenPAK base die parts with price points between $0.25 to $0.50 in volume and packages as small as 2.25mm^2. The scalable automotive GreenPAK portfolio allows customers to choose the CMIC that best fits their needs and cost points. In doing so, system designers have seen reduced BOM cost and board space reductions of 60-90% by displacing up to 10-30 discrete components. Displacing these components also results in less sourcing issues as it means fewer parts to qualify, order, and stock.

CMICs manufacturing and inventory process is set up to eliminate the need for 2nd sourcing. GreenPAK's unique manufacturing process has enabled the shipment of over 4 billion CMICs without out a single shipment issue. This is possible because many custom CMIC part numbers can be built using a single base die. As a result, overbuilding unprogrammed CMIC inventory has become standard practice and does not result in the costly consequences typically associated with overbuilding material. Large reserves of CMIC base die wafers are built up at TSMC and kept in assembly bank for both present and future opportunities. This allows even small volume customers to address potential fab downtimes with large wafer reserves.

The base die can then be factory programmed in just 4-6 weeks at various assembly houses. If one assembly house encounters a lines down situation, Dialog Semiconductor is set up to program and assemble the base die at the other site.

This is a reliable manufacturing system that other custom IC providers do not offer, and it is what allows CMIC customers to use factory programmed GreenPAKs without concern for 2nd sourcing. Additionally, the CMIC's short and reliable 4-6 week lead-time allows for easier inventory control.

Conclusion

CMICs can be implemented alone or together with SOCs and MCUs in many automotive applications. They are robust system monitors that can lower failure rates and react quickly to MCU crashes and asynchronous interrupts for safety critical applications.

Circuits implemented in GreenPAK can be quickly created and modified throughout the development cycle, improving the customizability of automotive platforms. The scalable CMIC portfolio allows designers to displace dozens of discrete components with a single factory programmed AECQ-100 qualified IC that is tailored to fit the size and cost requirements of a specific design.

CMICs lower project cost, by integrating and reducing external components, accelerating time-to-market, and unifying the development flow. Since CMICs can displace dozens of components, they benefit procurement in reducing the number of parts to order, qualify, and stock. This, paired with the common practice of overbuilding CMIC base die inventory, leads to large amounts of GreenPAK buffer stock to cover lines down situations. Dialog, as a result, is able to achieve industry leading shipment reliability with CMICs.

Collectively, these factors make CMICs an excellent choice in automotive applications where safety, flexibility, footprint and cost are critical.

