Application Note

Scalable 16-48 Bit GPIO Expander for Modern Automotive ECU Design using TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1

TEXAS INSTRUMENTS

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ABSTRACT

Automotive electronic control unit (ECU) across body, zonal, infotainment, and driver-assistance subsystem are driving demand for flexible and increased general purpose input/output (GPIO) resources while maintaining compact form factors and predictable system behavior. The TXE family comprising of TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 automotive-qualified Serial Peripheral Interface (SPI) GPIO expanders provide a scalable and deterministic design for digital input and output expansion in space-constrained ECU designs. The TXE family offloads low-speed digital control and monitoring functions from the host MCU or SoC, thus, reducing MCU pin usage, simplifying system integration, and support distributed and zonal vehicle architectures.

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1 Introduction to SPI-Based GPIO Expanders

Modern automotive ECU must support a growing number of digital inputs and outputs while meeting stringent requirements for reliability, latency, and scalability. As I/O requirements increase, traditional approaches based on direct MCU GPIOs or discrete expansion logic become inefficient due to higher component count resulting in inefficient board space usage, and increased software complexity.

SPI-based GPIO expanders provide a structured and deterministic alternative by centralizing GPIO management over a higher bandwidth interface. The TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 are AEC-Q100 qualified, 16-bit, 24-bit, and 48-bit GPIO expanders for the four-wire SPI protocol supporting up to 10MHz and 1.65V to 5.5V operation, while enabling configurable digital input and output functions and built-in features such as programmable open-drain/push-pull outputs, integrated pull-up/pull-down resistors, smart interrupt register, glitch filter, fail-safe register mode, bus-hold that simplifies system design.

Typical automotive applications include:

- Body control module
- Zonal controllers
- Infotainment or driver-assistance peripheral control

2 Why SPI GPIO Expanders?

Traditional GPIO expansion methods typically rely on high pin-count MCUs, discrete shift registers, multiplexers, or latch-based logic to increase available I/O. While effective, these designs add PCB area, routing complexity, glue logic, and firmware overhead, and often depend on continuous polling to detect input changes which increases latency and power consumption. I^2C-based GPIO expanders improve this approach by integrating multiple GPIOs behind a simple two-wire interface, reducing pin-count and board complexity while enabling features such as register-based control and interrupt-driven monitoring for better efficiency. However, I^2C bandwidth and bus sharing can limit performance in higher-speed or latency-sensitive systems.

Modern SPI GPIO expanders address these constraints by providing higher throughput, lower latency communication, and more deterministic timing, along with integrated interrupts and scalable device architectures. The result is a compact, low-BOM, and software-efficient design that delivers faster response, simplified design, and robust GPIO scaling for today's distributed automotive applications.

2.1 SPI GPIO Expanders vs Discrete Approach

GPIO expansion techniques using shift registers, multiplexers, or discrete logic introduce limitations due to increased component count and complex PCB routing. These discrete-based GPIO designs result in increased system cost and inefficient PCB utilization for automotive applications such as zonal control modules where high channel density and limited board space are common challenges. Table 2-1 summarizes the system-level benefits supported by SPI GPIO expander versus discrete-based approach for cost-optimized and scalable ECU designs.

The TXE81xx-Q1 supports interrupt-based handling where open-drain interrupt (INT) output is activated when any input state differs from the last read state and is used to indicate to the system controller that an input state has changed. The device interrupt can be latched or masked for each device I/O. By sending an interrupt signal, the device can inform the processor if there is an incoming data on the remote I/O ports without having to communicate via the SPI bus. The device also features a Smart Interrupt where the interrupt clears if the I/O state goes back to the intial logic state or the interrupt reads the Interrupt Flag Status Register. This allows for simple monitoring of peripheral devices such as external switches, interrupts, ready signals.

As highlighted in Figure 2-1, the TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 enable compact, low-BOM IO management solution while minimizing routing congestion and simplifying multilayer PCB stack-up.

Table 2-1. SPI GPIO Expander vs Discrete-Based Approach

Parameter	Shift Register / Multiplexer / Discrete Logic	SPI GPIO Expander (TXE8116-Q1 / TXE8124-Q1 / TXE8148-Q1)
MCU GPIO Usage	High (Added clock, data, latch, enable signals)	✓ Low (Standard 4-pin SPI interface)
Scalability	Limited; Increases routing effort	✓ High; Add GPIOs without MCU pin changes
Latency & Determinism	Software dependent; State polling	✓ Interrupt-based, Event-driven
Power Consumption	High due to I/O polling for status scan	✓ Lower; I/O state changes reflected on Interrupt
Diagnostics & Control	Limited; Discrete handling required	✓ Integrated configuration and status registers

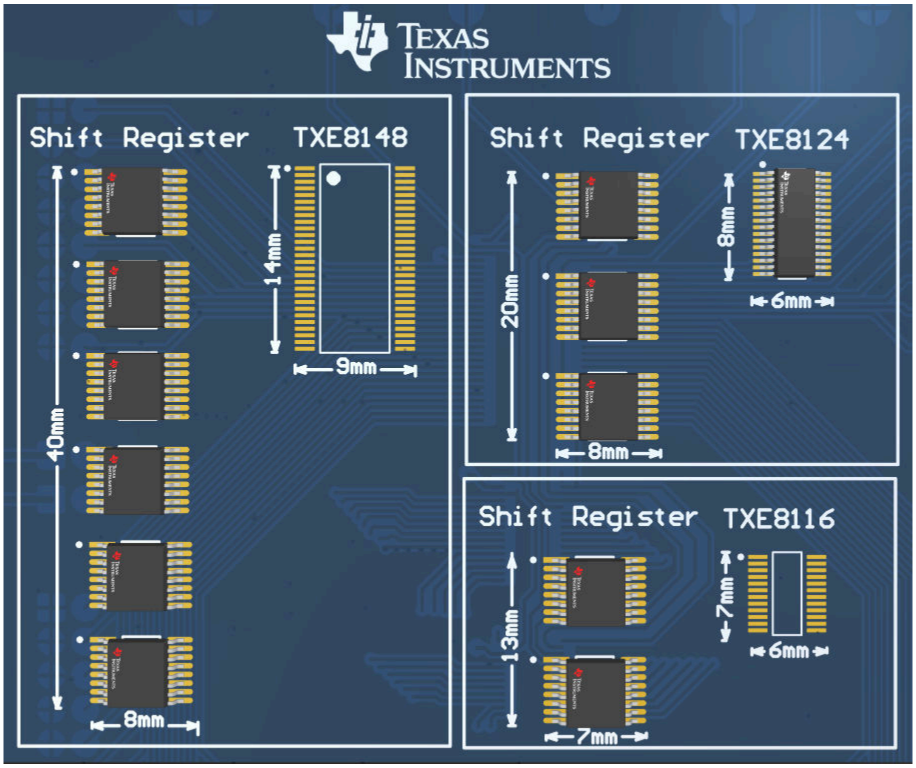

Figure 2-1. PCB space savings: SPI GPIO Expander vs Discrete-Based Approach

2.2 SPI GPIO Expanders vs I²C GPIO Expander

Both SPI and I²C GPIO expanders are widely used in automotive designs. Selecting the appropriate interface depends on system architecture and performance requirements.

I²C-based GPIO expanders use a simple two-wire interface, reducing pin count and board complexity while enabling features such as register-based control and interrupt-driven monitoring for better efficiency. However, I²C bandwidth and bus sharing can limit performance in higher-speed or latency-sensitive systems. By replacing I²C-based solutions with SPI GPIO expanders, designers can achieve system-level robustness, and reduce bus power consumption that helps to better align with zonal and software-defined vehicle architectures.

Table 2-2. SPI GPIO Expander vs I²C GPIO Expander

Parameter	I²C GPIO Expander (TCA9539A-Q1 / TCA9536-Q1 / TCAL9539-Q1)	SPI GPIO Expander (TXE8116-Q1 / TXE8124-Q1 / TXE8148-Q1)
No. of bits	4 to 16	16 to 48
Interface Bandwidth	400kHz (Standard) to 1MHz (Fast-mode Plus)	Up to 10MHz SPI
Scalability	I²C address based	Daisy-chain
Power Consumption	Low to moderate	Low standby (6μA)
System Noise	Susceptible to cross-talk due to open-drain I²C bus config	Resilient due to push-pull SPI bus
Input Glitch Filter	No	Yes
Fail-safe features	No	Yes
Use Case Fit	Low-speed control and monitoring	Zonal, BCM, Latency-sensitive control

3 Application Examples Using SPI GPIO Expanders

SPI GPIO expanders such as the TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 enable usage across a wide range of automotive ECU designs to offload low-speed digital control and monitoring functions from the host MCU or SoC.

3.1 Zonal Control Module

In *Zone Control Module* (ZCM) architectures, multiple functions are consolidated resulting in significantly increased localized GPIO requirements. SPI GPIO expanders enable scalable and modular I/O expansion without increasing MCU pin count. As shown in Figure 3-1, the daisy-chain capability of the TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 SPI IO expanders allow multiple devices to be connected on a single SPI bus, supporting flexible GPIO scaling as zonal architectures evolve. This approach reduces wiring complexity and supports platform reuse across multiple vehicle variants.

The TXE81xx-Q1 integrates easily with SoCs from TI (TIDA-020094: 48V Zone Reference Design) as well as other popular vendor for Zonal Control Module.

Key Design Considerations

- Plan GPIO scalability using the SPI daisy-chain capability supported by TXE81xx-Q1.
- Monitor peripheral interrupt signal state changes using TXE81xx-Q1 Smart Interrupt feature.
- Place expanders close to I/O loads to reduce wiring complexity.
- Balance SPI bus loading to maintain timing margins.
- Align GPIO partitioning with zonal diagnostics and safety concepts.

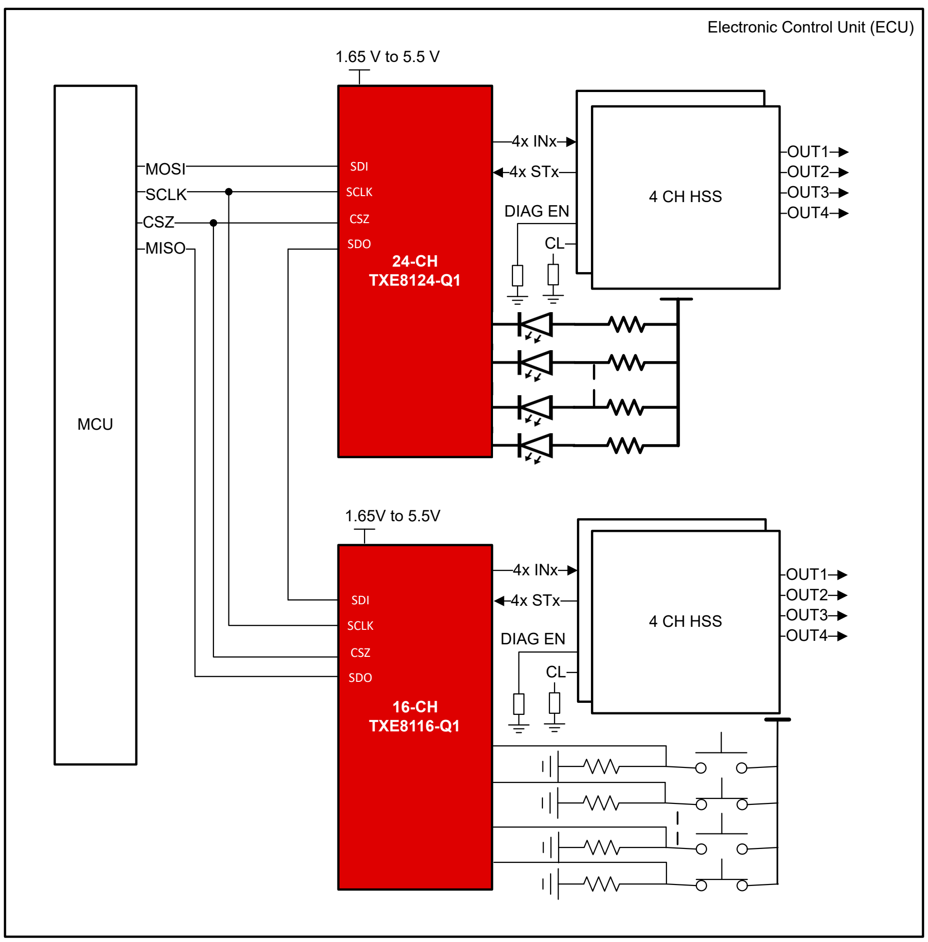

Figure 3-1. Block Diagram of GPIO Expansion using TXE8116-Q1 and TXE8124-Q1 for Zonal Controller

3.2 Infotainment and ADAS Peripheral Control

In modern infotainment and ADAS applications such as *Head Unit and Digital Cockpit Processing*, *ADAS & Infotainment Fusion Controller*, *Automotive Display*, and *High-performance Compute*, ECU integrate numerous peripherals that require low-speed enable, reset, mode-select, and status-monitoring signals. As shown in Figure 3-2, these signals are preferred for SPI GPIO expansion.

Key Design Considerations

- Use SPI GPIOs primarily for non–data-path control signals.
- Maintain deterministic startup and sequencing requirements.
- Isolate GPIO routing from high-speed interfaces such as CSI, FPD-Link, or LVDS.
- Consider power-domain sequencing across peripherals.

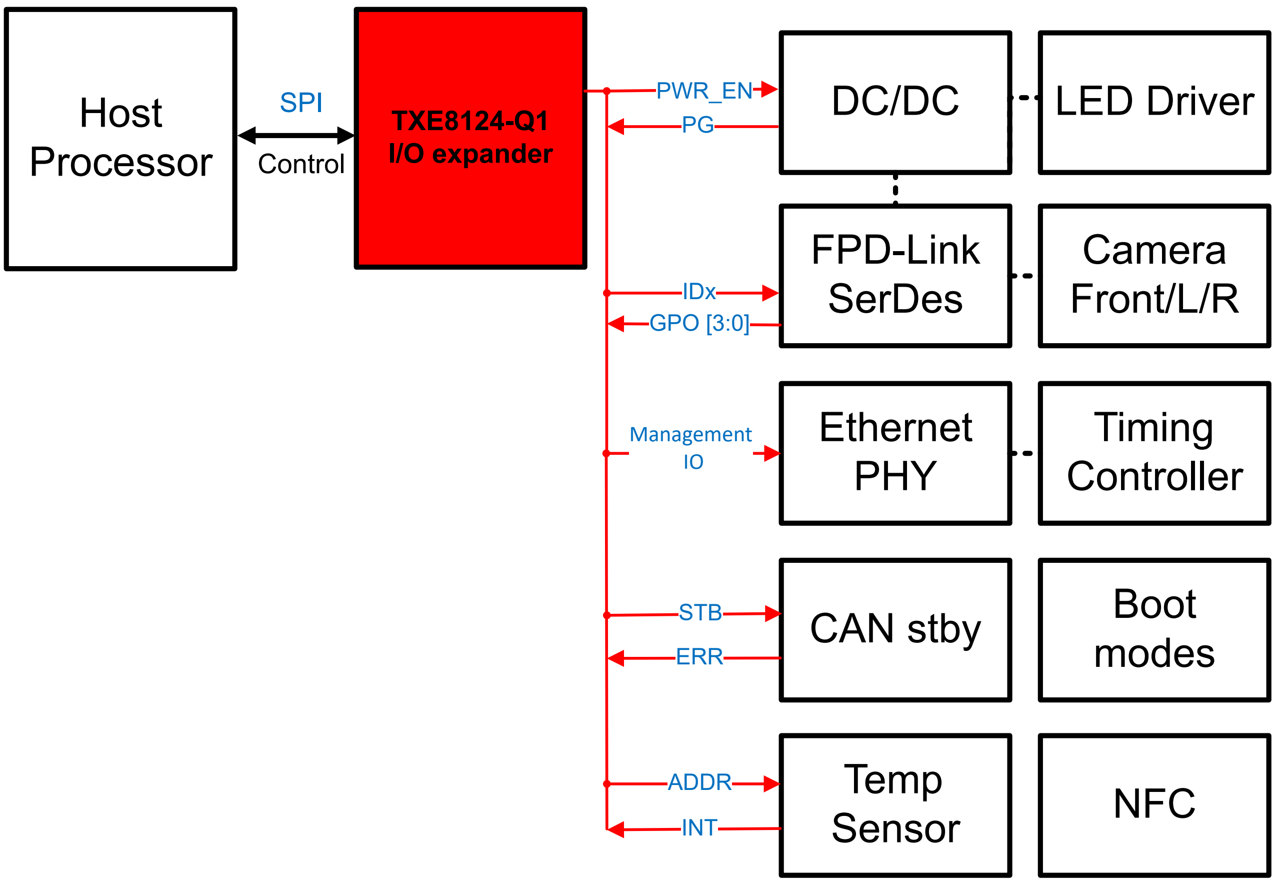

Figure 3-2. Block Diagram of GPIO Expansion for Infotainment and Driver Assistance

3.3 Automotive Body Control Module

In *Body Control Module* (BCM), GPIO availability is often constrained by increasing feature content such as exterior and interior lighting control, switch monitoring, relay and actuator enable, and diagnostics. As shown in Figure 3-3, the TXE8124-Q1 SPI GPIO expanders provide scalable I/O expansion while maintaining deterministic control behavior.

Key Design Considerations

- Verify GPIO drive strength and load compatibility for relays, LEDs, and external drivers.
- Define power-up and reset sequencing between the MCU and GPIO expander.
- Account for system-level diagnostics and fault handling.

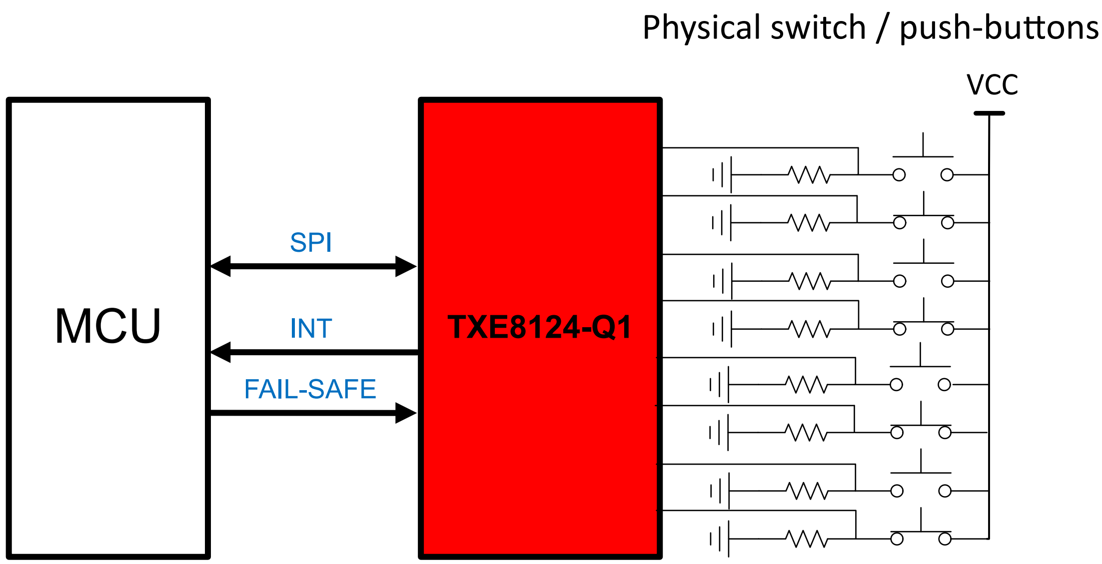

Figure 3-3. Block Diagram of GPIO Expansion for Automotive Body Control Module

3.4 Audio and Peripheral Monitoring

In *Automotive Audio Amplifier* systems, GPIOs are required for enable, mute, fault monitoring, and mode selection for codecs, amplifiers, and DSPs. As shown in Figure 3-4, these functions benefit from deterministic and reliable SPI-based GPIO control.

Key Design Considerations

- Separate low-speed GPIO control from high-speed audio data paths.
- Verify mute and enable timing meets audio subsystem requirements.
- Validate GPIO default states during power-up.
- Coordinate GPIO control with audio power sequencing.

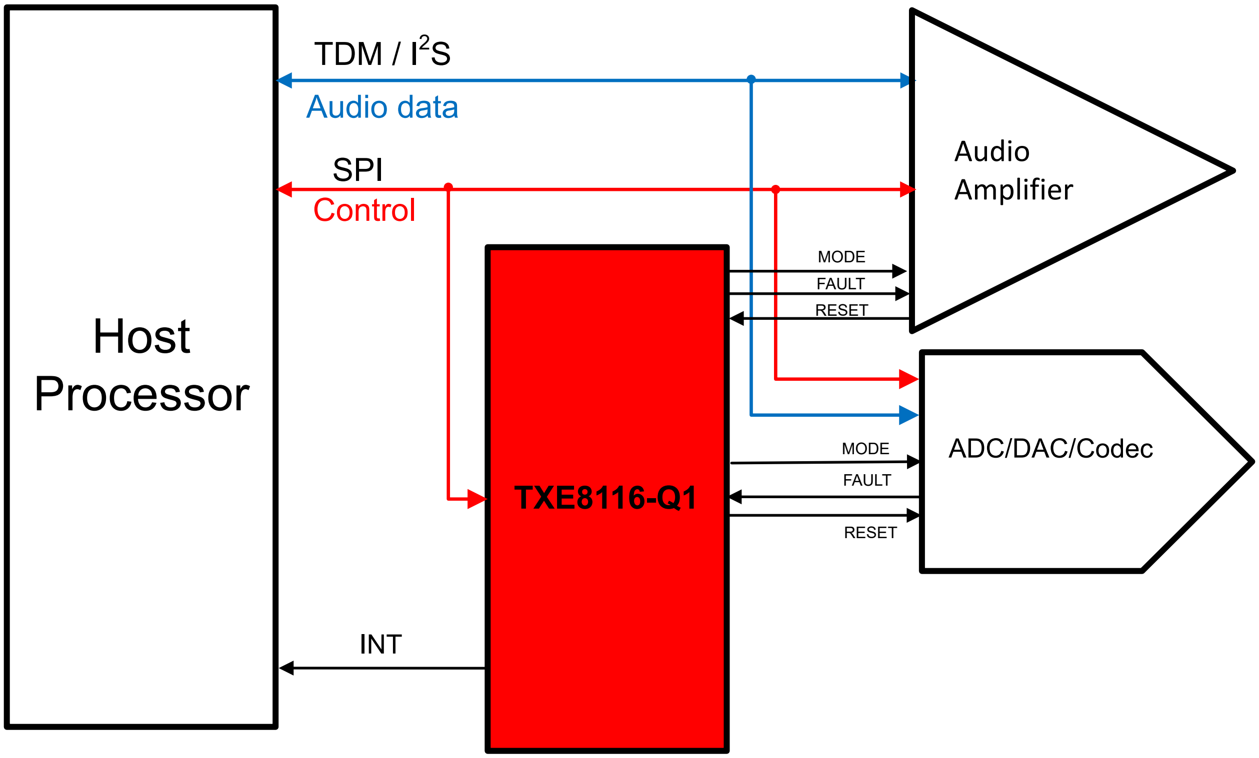

Figure 3-4. Block Diagram of GPIO Expansion for Automotive Audio and Peripheral Monitoring

4 Summary

Modern automotive ECU require scalable and deterministic GPIO expansion to support increasing digital control and monitoring needs across body, zonal, infotainment, and ADAS systems. Conventional approaches based on high pin-count MCUs or discrete logic increase board complexity, routing congestion, and software overhead, while I²C-based expanders may be constrained by bandwidth and bus loading in latency-sensitive applications. The TXE8116-Q1, TXE8124-Q1, and TXE8148-Q1 automotive SPI GPIO expanders provide a compact, high-performance design for 16-bit to 48-bit GPIO expansion. Leveraging a high-speed SPI interface up to 10MHz, these devices enable low-latency, deterministic communication with interrupt-driven operation, while integrating key features such as programmable I/O configuration, glitch filtering, and fail-safe functionality to simplify system design and improve robustness. With support for SPI daisy chaining and flexible configuration, the TXE family enables scalable and modular I/O expansion without increasing MCU pin count, supporting platform reuse across evolving zonal and software-defined vehicle architectures.

By offloading low-speed control and monitoring functions from the host processor, these devices help reduce system cost, minimize design complexity, and improve overall ECU efficiency across various automotive applications. Overall, the TXE81xx-Q1 family delivers a scalable, low-BOM, and software-efficient GPIO expansion solution that enables reliable, high-density I/O integration for next-generation automotive systems.

5 References

1. Texas Instruments, *TXE81XX-Q1 Automotive 16-Bit and 24-Bit SPI Bus I/O Expander with Interrupt Output, Reset Input, and I/O Configuration Registers*, datasheet.
2. Texas Instruments, *SPI Daisy Chaining with TXE81xx-Q1 GPIO Expander*, application note.
3. Texas Instruments, *48V Zone Reference Design*, reference design.
4. Texas Instruments, *Understanding the SPI Bus*, application brief.

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