Application Brief

Optimize EPS System with C2000 F29 MCU

Susmitha Bumadi

The automotive market is ever evolving and always looking for more innovations with reliable and space-saving designs in safety-critical market niches, such as electric power steering (EPS). In today's new cars, electric power steering is a standard and advanced technology for highly automated driving. Power steering systems were introduced commercially in 1951 as a means to reduce driver's effort in steering a vehicle. Since then, most of the power steering systems have relied on hydraulic mechanisms or electro hydraulic mechanisms. More recently, pure electric power steering systems are being adopted. EPS system is more efficient and compact, getting rid of the hydraulic pump, hoses and fluid reservoir. Although effective, the early EPS systems lacked the road feel and sophistication of the more recent EPS systems. Today's EPS is tightly integrated with remarkable driver-assistance features while providing great road feel for the driver.

Modern vehicles require minimal force from the driver to steer the wheels because of the great assistance provided by the EPS system. EPS can be used in conjunction with ADAS (Advanced Driver Assistance Systems) to provide help with lane keeping assist, adaptive cruise control, and so on.

Fundamentally, EPS system measures the driver's input force, the steering wheel's position to provide an additional assistant force in proportion to the driver's input. In addition, the system also makes sure that steering angle matches the driver's intended direction. Given this, there are some obvious safety related concerns that arise:

1. The EPS system does not provide steering force when the driver is not intending the system to steer the vehicle
2. The system does not over steer or under steer with respect to the driver's input.

The main components of an EPS system are steering column, sensors, motor, battery, steering rack and an electronic sense-and-control mechanism. The inputs of the system are provided by the driver at the steering wheel interface. Sensors are responsible for detecting the movement (direction, speed, and angle) of the steering wheel and sending this data to a microcontroller. The data is processed and a signal is sent to the motor driver. Motor starts running and rotates steering gear with an applied force that reduces torque required from the driver. The motor has rotor position sensor to detect the position of rotor. There are torque and angle sensors in the EPS system (mostly with SENT interface) to measure the torque applied by the driver to the steering wheel and angle of the steering wheel.

EPS systems can be either fail-safe or fail-operational system. Under failure, the fail-safe EPS system does not offer assist anymore and the system turns to manual mode, while the fail-operational system can offer either full or partial assist to the driver. Dual or triple redundancy is incorporated to achieve the required safety ASIL level.

The central electronic elements of today's electric power steering systems are modern 32-bit and 64-bit microcontrollers (MCUs). Only high-performance MCUs can provide sufficient computing power and specialized peripherals for complex motor control functions. Since EPS system is related to driving safety, there is high functional safety requirement (ASIL- D) on the system. In systems with high level ADAS or autonomous driving equipped, fail operational feature is required. Redundant sampling and comparison are required for analog feedback integrity. Safety PMIC is required for detection of common cause failures with rail monitoring and Q/A watchdog functionality through SPI. For host communication, multiple CAN FD interfaces are used with AutoSAR and security requirements. In many cases, FOTA (Firmware Over The Air) and cybersecurity (EVITA full) requirement can also be required for the MCU.

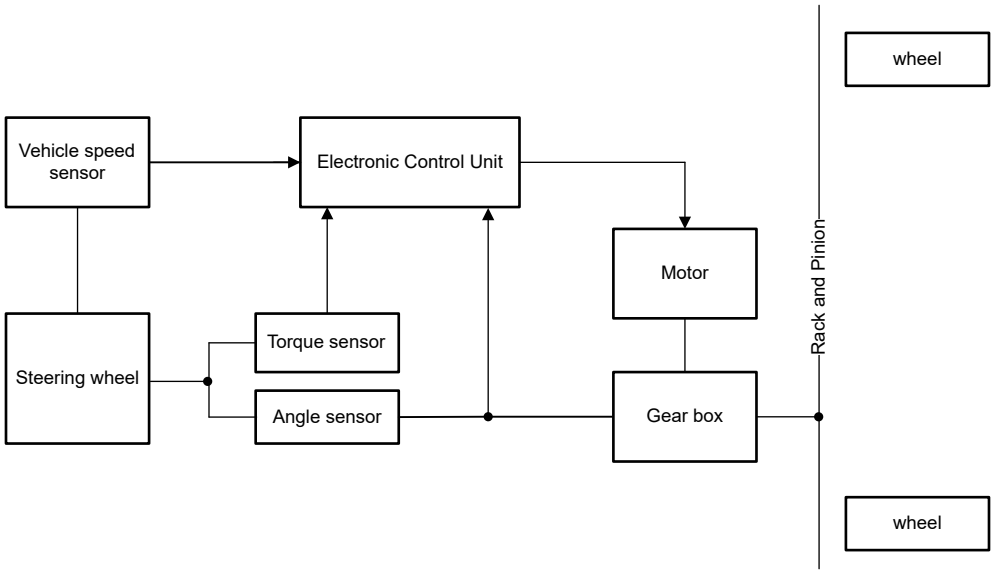

Figure 1. Electric Power Steering Block Diagram

F29x for EPS

F29x family of microcontrollers is the latest member of the C2000™ real-time microcontroller family. The F29x family are scalable and ultra-low latency devices designed for efficiency in power electronics. The real-time control subsystem has C29 DSP cores running at 200MHz, which are well-equipped to run the most demanding automotive and industrial control applications.

Many features are included to support a system-level ASIL-D functional safety design. The C29x CPU1 and CPU2 cores run in lockstep for detection of permanent and transient faults. Additionally, the device architecture features built-in ECC logic in the CPU, end-to-end safety in the bus interconnect, and an error signaling module for systematic aggregation and diagnosis of faults, in addition to other safety features. These features are critical to achieving the required safety capability for EPS applications.

The Safety and Security Unit (SSU) in concert with the C29 CPU, helps system designers meet the most rigorous modern standards for safety and security in the real-time control application, without compromising real-time performance. The SSU features a context-sensitive MPU mechanism that automatically switches access permissions in hardware based on currently executing thread or task. This way, EPS application can achieve true Freedom from Interference (FFI), secure task isolation in both control and communications while maintaining the same high-speed and low-latency processing needed for the most demanding real-time systems. Memories, peripherals and stacks are fully protected by the SSU for complete isolation.

The Hardware Security Manager (HSM) provides EVITA-full security support. The HSM enables secure key and code provisioning in untrusted factory environments, secure boot, run-time cryptographic services and supports Firmware-Over-The- Air updates of HSM with A/B swap.

F29x MCU integrates SENT receiver to support EPS application. SENT channels can be used to interface with the sensors. As of today, there are many sensors developed with SENT interface. Multiple sensors can be connected to single MCU. This can provide the freedom of choice to select their own sensors.

In EPS redundant system, MCUs often communicate to each other to monitor operational status. MCUs implementing EPS functions must be able to communicate over high speed, low latency, and synchronized link. Fast Serial Interface (FSI) module is a serial communication peripheral capable of robust high-speed communications across voltage isolation boundaries. The FSI fulfills the need of lower cost compared to other serial communication peripherals, along with additional features (CRC check) in hardware that improve data integrity across devices using only a few wires. The Fast Serial Interface (FSI) in C29 enables up to 200Mbps of robust communications across an isolation boundary. Thus, FSI can be used for inter-MCU communication in EPS application.

As this safety-critical system becomes the trend in automotive world, from EPS to steer-by-wire, small size redundancy system that equipped with safety and security enablers is required. F29 is the ideal family that gives the scalability in packages (100-pin QFP to 256-pin BGA) and device specifications (lockstep configurations and flash sizes) for different types of EPS system. The unique communication peripherals, such as FSI and SENT, have brought the advantage to F29 to be the leading product for these safety applications.

Trademarks

C2000™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265