Technical Article

Achieving smoother, quieter motor performance with highly integrated real-time control MCUs

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Consumers expect their appliances to run more quietly and exhibit greater mechanical and electrical durability. This holds true even for end equipment such as handheld tools, washing machines, fans, and heating, ventilation and air-conditioning (HVAC) units.

Historically, the way to improve acoustic performance, dynamic behavior and system longevity has been to improve the mechanical design, implement new materials, or employ thermal management or advanced control strategies. Many of these control strategies require implementations that span multiple devices: one for processing, another for sensing, and additional components for signal conditioning or protection. While technically effective, these implementations can introduce tightly coupled dependencies across hardware and software, increase latency and jitter, and require effort to integrate and tune. As a result, the challenge has shifted from meeting system performance targets to meeting them without increasing system complexity or cost.

Advancing motor control with a unified processing environment

Implementing advanced motor-control techniques such as sensorless field-oriented control (FOC) or vibration compensation within a unified processing environment can help minimize coordination efforts, reduce timing variability, and enable more predictable behavior. From a software perspective, highly integrated real-time control microcontrollers (MCUs) such as TI's F28E120SC provide a unified processing environment that designers can use to streamline the implementation of sensing, control and actuation functions in motor-control applications.

These MCUs support real-time motor-control algorithms such as sensorless FOC, helping designers meet timing budgets at low speeds when the rotor position is most difficult to estimate. More precise motor control enables smoother torque production, lower vibration and quieter operation, without relying on external sensors or specialized acceleration hardware. Figure 1 shows a block diagram of an F28E120SC MCU in a typical motor control design.

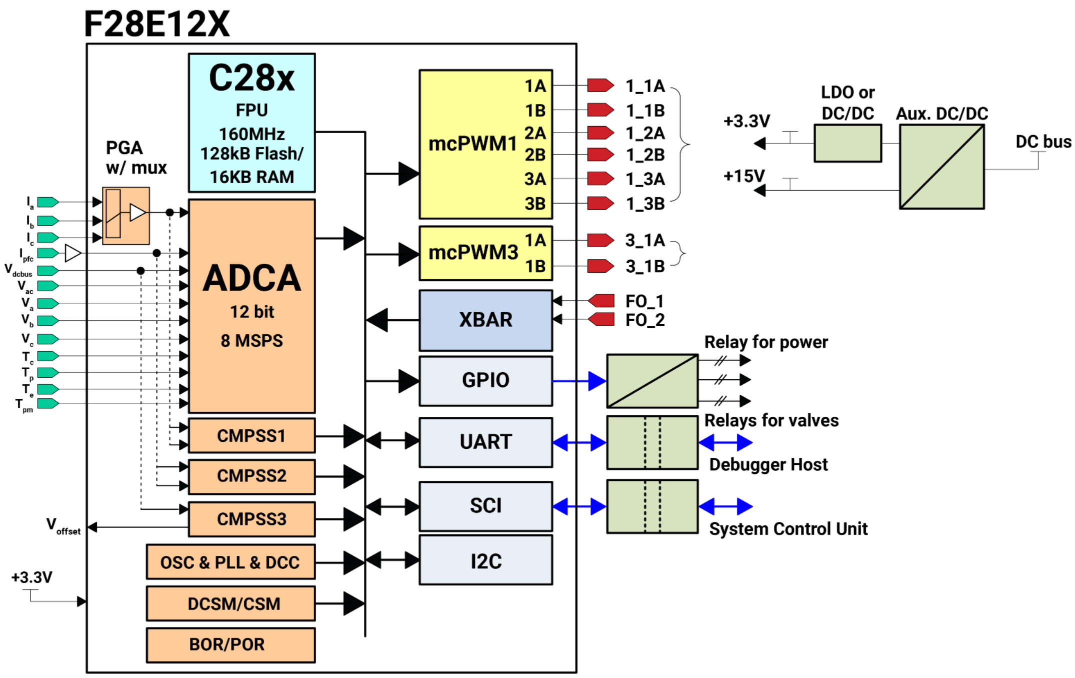

Figure 1. Simplified block diagram of an F28E120x MCU in a typical motor control design

From a hardware perspective, these MCUs feature integrated components including a high-speed analog-to-digital converter (ADC) along with an integrated programmable gain amplifier and analog comparators. These integrated components help designers simplify the system's signal chain, resulting in low-noise current feedback without the need for off-chip operational amplifiers or discrete analog integrated circuits.

Since this unified control architecture doesn't rely on manually coordinating timing across discrete devices, designers can reduce latency, jitter and time spent managing the system. This architecture also improves system response through synchronized pulse-width modulation (PWM) and ADC triggering to align sampling precisely with switching events.

Let's look at two examples that demonstrate the benefits of a unified processing environment for motor control.

Motor control in washing machines

In washing machines, motor-control algorithms need to adapt to real-world conditions such as open-loop startup, a sudden load imbalance during spin cycles, varying torque demands across wash stages, and precise speed and directional transitions for fabric care and water extraction. Traditional architectures often rely on external sensors, analog front ends and custom tuning logic to manage these transitions smoothly and quietly.

Real-time MCUs consolidate the entire control path into one device. Sensorless FOC enables smooth, reliable startup and acceleration without position sensors. It becomes possible to use software-based vibration compensation to reduce drum imbalance and acoustic noise instead of relying exclusively on mechanical balancing.

A more compact, deterministic control architecture results in a washing machine motor controller that runs more quietly, lasts longer and is easier to manufacture.

Motor control in HVAC systems

HVAC systems must operate their motors for long periods in tight, thermally constrained enclosures where airflow is limited, board space is tight and maintenance is infrequent. A reliable, efficient system includes motor-control functions such as quiet startup, stable airflow control and high overall efficiency.

HVAC systems can employ the same advanced control techniques used in appliances, but with the addition of thermal stability and long duty-cycle tolerance. Sensorless control strategies eliminate the need for Hall-effect sensors or encoders, simplifying the mechanical design and improving long-term reliability. MCUs such as the F28E120SC feature error correction code-protected flash memory and parity-protected static random access memory, which enhances system performance during long duty cycles. The high-bandwidth FOC operation and dead-time compensation of these MCUs help reduce total harmonic distortion by as much as 50%, enabling smoother airflow control and quieter operation.

The tight synchronization of PWM logic and ADC sampling within a single clock domain enables consistent control behavior even if switching frequencies increase or thermal conditions vary. Designers can then apply tighter loop control to compressor and fan loads, tune switching transitions to minimize audible noise, and forgo external components that would otherwise be stressed by heat or vibration.

Conclusion

For motor-driven applications where control behavior needs to be both predictable and efficient across varying load conditions, real-time control MCUs combine tight analog-to-digital integration with deterministic high-performance execution at cycle-level precision, while reducing design costs.

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