World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:19, No:02, 2025

Efficient Field-Oriented Motor Control on Resource-Constrained Microcontrollers for Optimal Performance without Specialized Hardware

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Abstract : The increasing demand for efficient, cost-effective motor control systems in the automotive industry has driven the need for advanced, highly optimized control algorithms. Field-Oriented Control (FOC) has established itself as the leading approach for motor control, offering precise and dynamic regulation of torque, speed, and position. However, as energy efficiency becomes more critical in modern applications, implementing FOC on low-power, cost-sensitive microcontrollers pose significant challenges due to the limited availability of computational and hardware resources. Currently, most solutions rely on high-performance 32-bit microcontrollers or Application-Specific Integrated Circuits (ASICs) equipped with Floating Point Units (FPUs) and Hardware Accelerated Units (HAUs). These advanced platforms enable rapid computation and simplify the execution of complex control algorithms like FOC. However, these benefits come at the expense of higher costs, increased power consumption, and added system complexity. These drawbacks limit their suitability for embedded systems with strict power and budget constraints, where achieving energy and execution efficiency without compromising performance is essential. In this paper, we present an alternative approach that utilizes optimized data representation and computation techniques on a 16-bit microcontroller without FPUs or HAUs. By carefully optimizing data point formats and employing fixed-point arithmetic, we demonstrate how the precision and computational efficiency required for FOC can be maintained in resource-constrained environments. This approach eliminates the overhead performance associated with floating-point operations and hardware acceleration, providing a more practical solution in terms of cost, scalability and improved execution time efficiency, allowing faster response in motor control applications. Furthermore, it enhances system design flexibility, making it particularly well-suited for applications that demand stringent control over power consumption and costs.

Keywords : field-oriented control, fixed-point arithmetic, floating point unit, hardware accelerator unit, motor control systems
Conference Title : ICECECE 2025 : International Conference on Electrical, Computer, Electronics and Communication Engineering
Conference Location : New Delhi, India
Conference Dates : February 24-25, 2025