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Leveraging BLE-Enabled MCUs in Power Tool Applications

Power tools come in various shapes, sizes, and power ranges, catering to a plethora of tasks, such as building, plumbing, electrical installations, gardening, and home repair. From heavy-duty construction tools like hammer drills and grinders to cordless hand-drills for hobbyists, the power tool market offers a broad range of products.

This Case Study will explore the role of MCUs in power tools and explain how Bluetooth Low Energy (BLE) and Security-enabled MCUs equip manufacturers to develop smarter, safer, and more user-friendly products. It will also introduce Alif Semiconductor's BLE-enabled MCUs and discuss how they are enabling innovation in power tool applications.

Used in a variety of tasks, from complex building jobs to simple home improvement projects, power tools leveraging BLE and Security-enabled MCUs are becoming smarter, safer, and more user-friendly. Image credit: Shutterstock

The Role of MCUs in Power Tools

Microcontrollers (MCUs) are essential components in modern power tools, serving as the central processing unit that controls and coordinates various functions. One of their primary functions in power tools is for efficient motor control. For example, in cordless tools, MCUs implement motor control algorithms, like field-oriented control (FOC) or space vector modulation (SVM), to drive the low-voltage brushless DC (BLDC) motors and monitor parameters such as position, current, and voltage to make real-time adjustments to optimize their performance. In cordless drills, an MCU receives input from the user and sends control signals to the motor to increase or reduce the power delivered to the drill bit. This ability enables precise speed control, allowing users to adjust the speed based on the material type and task at hand.

Another function of MCUs in power tools is sensor data processing and tool intelligence. Power tools often incorporate various sensors, such as accelerometers, gyroscopes, and temperature sensors, to gather real-time data about a tool's performance and operating conditions.

Collecting and analyzing a constant stream of sensor data can be made even more efficient by leveraging artificial intelligence, as long as the microcontroller used is designed to be power efficient even while handling compute intensive AI/ML workloads. Dedicated Neural Processing Units (NPUs) rise to meet this requirement, offering hardware accelerated machine learning while remaining within the power budget. The MCU then processes this data using sophisticated algorithms to enable smart features and enhance user safety. For instance, in a cordless impact driver, an MCU can utilize accelerometer data to detect and prevent "kickback," which occurs when a tool binds or stalls, a potential hazard to the user.

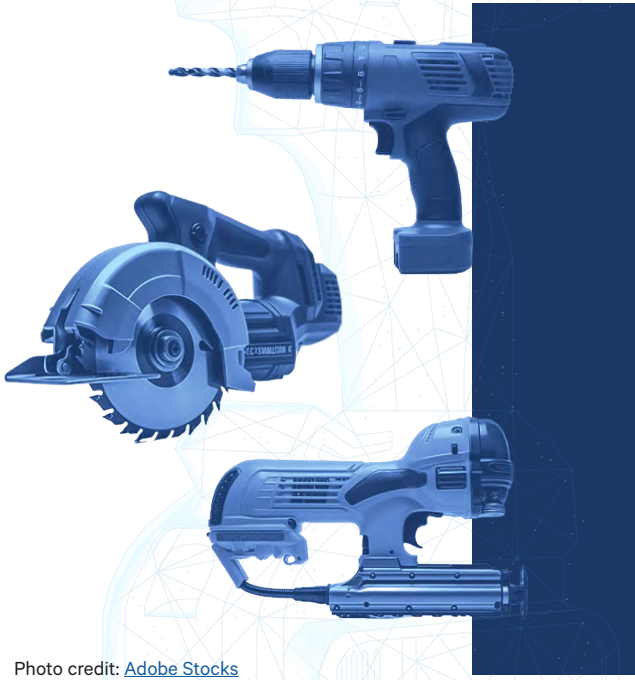
By continuously monitoring the tool's acceleration and orientation, the MCU can detect abnormal situations and take corrective actions, like reducing the motor's power or switching the device off. MCUs also provide smart features that can adapt to users' preferences. For example, in smart cordless jigsaws, an MCU can analyze cutting speeds or vibration patterns to ascertain the optimal blade stroke and speed settings for different materials.

BLE and Security-enabled MCUs also provide advanced theft prevention and security features in power tools. These mechanisms may include authentication methods such as specific codes, keys, or biometric data like fingerprints or facial recognition. These MCUs can track the location of power tools in real-time using Bluetooth technologies, and where unauthorized movement or theft is detected, the MCU can send alerts to the owner, disable the tool, or activate alarms.

Designing Smarter, Safer Power Tools with BLE-enabled MCUs

The integration of BLE connectivity into MCUs has reshaped the way power tools communicate and interact with external devices. BLE is a wireless communication protocol designed for low power consumption and short-range data transfer, offering benefits for power tool applications. Some of these including fast connectivity, mesh networking capabilities, low power operation, and encryption and authentication mechanisms for secure communications enable the development of power tools that are smarter, more efficient, and user-friendly.

In addition to connectivity, the security features provided by BLE-enabled MCUs are particularly valuable for ensuring the safety and reliability of power tools. For example, a cordless drill equipped with a secure MCU can validate that an attached battery is a genuine battery from the manufacturer, rather than a clone that might cause problems or injury due to not being built to the manufacturer's specifications. By authenticating accessories, the power tool can prevent the use of counterfeit or substandard components that could compromise its performance or put the user at risk. Similarly, requiring users to authenticate with a physical token, such as a smart key, before operating a tool can prevent unauthorized use and potential accidents. This can be useful in industrial or commercial settings where multiple users have access to the same tools. This added layer of security helps to maintain the integrity of the power tool and protect the user.



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Some applications for these MCUs in developing smarter and safer tools include asset tracking and anti-theft, intelligent protection and software updates, maintenance and monitoring, and smart battery management.

Asset Tracking and Anti-Theft

Incorporating BLE-enabled MCUs in power tools opens up new possibilities for theft prevention and security. These components can implement advanced user authentication mechanisms to ensure that only authorized individuals can operate power tools; for instance, requiring a specific code or key to activate. Similarly, a MCU can enable biometric authentication such as fingerprint recognition or facial recognition, where a user's data is captured by sensors and compared with pre-registered templates warehoused in the MCU's memory. Additionally, by incorporating signal strength measurement and direction finding Bluetooth technologies, such as Received Signal Strength Indications (RSSI), Angle of Arrival (AoA)/Angle of Departure (AoD) and High Accuracy Distance Measurement (HADM), MCUs can track and monitor power tools' location in real-time, facilitating quick recovery in case of theft.

When the MCU detects unauthorized movement or theft, it can trigger various actions, such as:

- Sending alerts: The MCU sends immediate notifications to an owner's mobile device or security system, informing them about the tool's location and the suspected theft.
- Disabling the tool: The MCU disables or locks the tool, rendering it inoperable until a valid authentication code is provided. This prevents the thief from using the stolen tool.
- Activating alarms: The MCU triggers audible or visual alarms, drawing attention to the theft attempt and potentially deterring the thief.

Intelligent Protection and Software Updates

In addition to enhanced functionality, BLE-enabled MCUs also contribute to improved safety in power tools. By integrating sensors and intelligent algorithms, these MCUs can detect abnormal tool behavior or potentially dangerous conditions. For example, if a tool experiences excessive vibration or overheating, it can automatically shut down to prevent damage or injury to the user. BLE-enabled MCUs can also provide over-the-air (OTA) firmware updates; manufacturers can push software updates wirelessly to the tools, adding new features, improving performance, and fixing bugs. Connecting wirelessly avoids

the need for users to physically connect their tools to a computer, saving time and ensuring that tools are always up to date with the latest software.

Smart Battery Management

BLE-enabled MCUs allow designers to develop smart battery management systems (BMS) that optimize charging and discharging cycles and minimize unexpected downtime. For instance, an MCU can monitor critical parameters such as voltage, current, temperature, and state of charge (SoC) and real-time data is transmitted wirelessly via Bluetooth to a user's smartphone or tablet. For some tools, users can receive notifications when the battery is running low or when it's time to replace the battery, minimizing unexpected downtime. During charging, the MCUs ensure that the battery is charged at an optimal rate based on charge state and condition. They also utilize algorithms, such as multi-stage or pulse charging, to minimize stress and prevent overcharging. Similarly, during discharging, the MCU monitors the battery performance and adjusts the output to optimize runtime and avoid over-discharging.

Monitoring and Predictive Maintenance

One of the most significant benefits of integrating BLE-enabled MCUs into power tools is the ability to establish a wireless connection between the tools and mobile devices. This connectivity allows for collection and transmission of usage data from the power tool to connected devices. The data collected can include various metrics, such as runtime, speed, torque, and the number of times the tool has been used. By analyzing this information, users can gain valuable insights into their tool usage patterns and make data-driven decisions to optimize their work processes, ultimately leading to increased efficiency and productivity. The collected data can also be used to implement predictive maintenance based on the actual usage of the tool, rather than relying on fixed time intervals. For instance, if data indicates that a tool has been subjected to extensive use or has been operating under high-stress conditions, the user can schedule maintenance to prevent issues and extend the tool's lifespan.

Intelligent Power Tools with the Alif Balletto™ Family of MCUs

Alif Semiconductor's Balletto family of wireless MCUs is designed to accommodate the needs of a variety of power conversion and motor control applications. The built-in peripherals include:

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With the benefits of the Alif Balletto family of MCUs, power tools can perform more efficiently, optimize battery performance and improve wireless communication. Image credit: Shutterstock.

- Highly-configurable timers that can generate PWM outputs with independent or complementary control of power inverters. The timers feature dead-time insertion, fault inputs, ADC conversion synchronization, double buffering and integration with the DMA controller for building sophisticated state machines.

- High-speed comparators with programmable reference voltage suitable for zero-cross detection in trapezoidal motor control applications.

- Fast 12-bit ADC that can be used for current feedback and implementation of Sensorless motor control.

- High-performance Cortex-M55 with Helium extensions and high-bandwidth TCM handles Field-Oriented-Control algorithms and Velocity Observers efficiently.

Working in parallel with the M55 core, Ethos-U55 NPU can accelerate the inference on ML models dedicated to anomaly-detection or other characteristics based on time-series of ADC samples.

These MCUs cater to the demanding needs of power tools, providing a balance of performance, energy efficiency, and integrated connectivity. Balletto MCUs comprise a Cortex-M55 core for real-time control and digital signal processing as well as an Ethos-U55 microNPU (neural processing unit) for executing machine learning workloads.

Balletto MCUs use BLE connectivity to simplify wireless communication for data access, control, and updates. These features allow users to monitor and control their power tools remotely, while also allowing manufacturers to push software updates and improvements directly to power tools, ensuring optimal performance and security.

These MCUs also utilize Alif Semiconductor's Autonomous Intelligent Power Management (aiPM™) technology which intelligently manages operating regions and CPU states to optimize power consumption based on workload and system requirements. They can intelligently determine when to switch between regions, put cores into sleep mode, or power off unused sub-systems. This power management mechanism ensures that processors operate efficiently without compromising performance.

Conclusion

BLE-enabled MCUs are not only transforming how power tools are designed and manufactured, but also redefining the user experience and unlocking possibilities for innovation in the industry. The benefits of wireless connectivity, data-driven insights, and enhanced safety are compelling reasons for manufacturers to integrate this technology into their products. The Balletto family of processors from Alif Semiconductor include a robust suite of BLE-enabled MCUs, offering high performance, energy efficiency, and integrated wireless connectivity for various power tool applications.

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For more information on Alif Semiconductor's solutions or application-specific inquiries, please visit our website.