Electronic Control Unit for electric bicycle with an 8-bit MCU

This article discusses the implementation of an ECU in electric bicycles and the issues that can be handled by the 8-bit microcontroller XC866 from Infineon.

■ A basic electric bicycle runs on a brushless DC (BLDC) motor, is powered by batteries and controlled from an ECU. The BLDC motor for the electric bicycle is of the standard three-phase trapezoidal type, typically rated at a few hundred watts and the battery voltage is usually 36V or 48V. Almost all the electronics in the electric bicycle are found in the ECU, it contains the inverter circuit for the motor; temperature sensor; fault detection; SMPS; analog and digital IOs; and finally the controller itself. Some ECUs have advanced features such as Remote Key Entry (RKE) and electric horn as well. All of these as well as the wiring packed into a metal box of typical dimensions 10x7x3 cm^3. Most electric bicycle manufacturers prefer an inverter circuit designed with discrete components for cost consideration, this circuit takes up about half of the PCB leaving even less space for the rest of the circuit. This gives you an idea of the challenge facing the designers. From the MCU point of view, not only must it be functionally acceptable, it must be able to withstand the harsh environment within the box.

The XC866 microcontroller has an enhanced 8051 core with a minimum of 2 clocks per machine cycle rather than the standard 12 clocks per machine cycle. The memory size is 4/8/16K bytes, enough for all types of electric bicycles. It has a powerful capture compare unit (CCU6) designed specifically for motor drive application. To complement the CCU6 is a feature-rich 10-bits, 8-channel ADC module that is designed to work closely with the CCU6 and can be programmed to perform some tasks automatically. This is an important characteristic for sensorless BLDC control, as this not only reduces the code size, more importantly it reduces the CPU load. The trend now for electric bicycles is towards sensorless BLDC control. The weakness of the sensor BLDC control is vulnerability of the Hall sensors, which can be spoiled by extreme temperature, humidity, wetness, vibration etc. The electric bicycle, being an outdoor vehicle, will be subjected to these things regularly. Even bad wiring can incapacitate the electric bicycle. Most electric bicycle failures are related to the Hall sensors of the motor. Apart from the Hall sensors, the rest of the motor is very rugged, the magnet, coil and the metal casing do not spoil easily. Another advantage of the sensorless BLDC control is the higher efficiency as compared to the sensor control. Badly placed hall sensors in a motor can cause lower than expected efficiency.

Sensorless control for electric bicycles presents a great challenge, as it must be able to reach acceptable levels of performance as compared to sensor control. A major topic in sensorless control of electric bicycles is the starting of the motor. The sensorless control is based on the BEMF which is only observable when the motor has achieved a certain speed. For the pedal type of electric bicycle, the motor can be started after the bicycle has started moving, usually with a push of the pedals. Once the BEMF is detected and the rotor position is known, the sensorless control can be started. In China, there is a type of electric bicycle that does not have pedals, so there is a need for a motor start algorithm from stall position. Traditional forced commutation methods are not very useful due to the unpredictable conditions. More elaborate methods, usually a combination of a few methods are used. Other major topics are the minimum speed and the ability to recover from loss of BEMF detection or synchronization e.g. due to hitting a bump. Again, a single scheme will not be able to handle all these, the program needs to either combine a few methods or have a different mode or method for every condition. The XC866 is ideal for this as the modes of CCU6 and the ADC can be changed easily. Since the XC866 uses hardware to automate as much of the process as possible, increased complexity of the solution may not mean equal increase in code size or CPU load.

The XC866 is capable of handling BLDC motor control with Hall sensors or sensorless. For the hall sensor, there is a special mode in the CCU6 that handles the commutation logic with minimal software. Motors with Hall sensors that are placed 60 or 120 electrical degrees apart can be handled. Whether it is sensor or sensorless, various pulse width modulation (PWM) methods can be implemented with minimum software see figure1. The trapezoidal control of a BLDC means that at any time, only two of the three phases are energized, the other phase is left floating. In (a), the unenergized phase and half bridge are shown in dots. (b) shows the current flow during PWM on period. The 'slow decay' method is the usual modulation method where during the off period of the PWM, the load current is allowed to circulate in the bottom

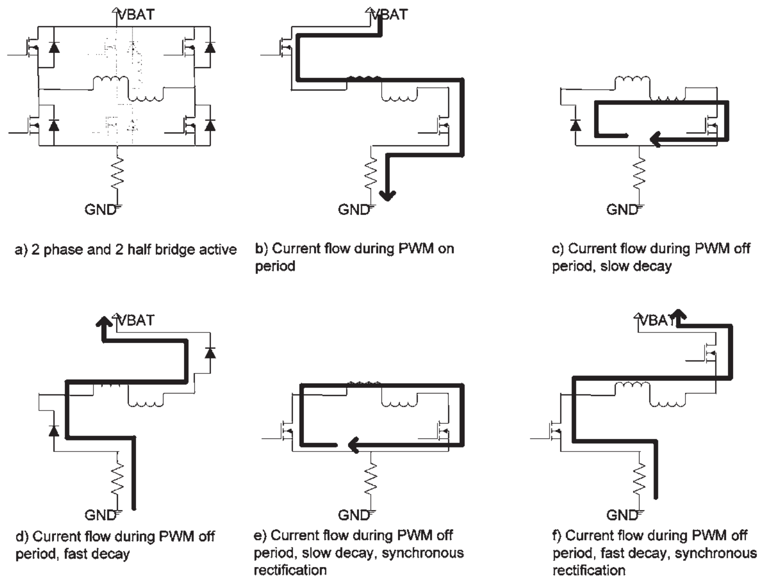

Figure 1. Pulse Width Modulation methods

switches as illustrated in (c). The 'fast decay' method where all the switches are off during the off period of the PWM shown in (d), has the drawback of high load current spikes. To improve the efficiency of the system, the synchronous rectification method can be used during high load. Instead of letting the load current circulate in the body diode during the off PWM period, it is more efficient to let the current circulate in the switch itself. This means that both the top and bottom switches of the same bridge need to be modulated instead of just the top switch. To implement this, some care must be taken to avoid a current shoot-through during the transition period where one switch is turned on while the other is turned off. The current shoot-through is avoided with the introduction of deadtime. During the period of the deadtime, the current circulation is through the body diode as in (c) but after the deadtime, the current circulation is through the bottom switch, as in (e). The synchronous rectification can be used for the 'fast decay' as shown in (f). There is also the fault detection capability of the CCU6 where the output to the three-phase drivers can be immediately turned off when a fault is detected. As mentioned earlier, most manufacturers design the inverter drive circuit with discrete components, not the specialized motor drive ICs that have built in protection circuits, so this is an important feature as it complements the discrete inverter drive design with a protection capability. The ADC conversions can be automatically triggered by the CCU6 timers. It can be set to perform conversions at the ends of the on or off periods of the PWM. If the conversion needs to be performed at another point of the PWM, another timer can be configured in the single shot mode to start counting at the beginning of every PWM. Once configured and started, the whole process can be automated to a point where the program is only read in the conversion results. The completion of the ADC conversions can also be programmed to trigger an interrupt for the more timing critical algorithm. An example of the usage is the sensorless BLDC control where the ADC is used for zero crossing detection. The interrupt can also be programmed to happen only if the result is within a certain range. For the classical method where the zero crossing detection is done at the on period of the PWM, and for the case where the BEMF signal is an increasing one, the interrupt can be programmed to happen only after the voltage is above the zero crossing point. For the zero crossing detection during the off period of the slow decay type of modulation, the range can be changed to near ground voltage. Apart from the 3 ADC pins needed for the zero crossing detection of the three phases, another 5 more ADC pins can be used to read the load current, battery voltage, temperature sensor, handlebar etc.

To prevent the software from being copied without permission, the code memory can be protected so that it cannot be uploaded. This is important as the drive circuit for the electric bicycle is quite standard, and the innovation is usually implemented in the software. The flash can also be programmed in-system for storage of runtime data. ■

Product News

■ Tensilica: Xtensa LX2 and Xtensa 7 configurable processors

Tensilica introduced its seventh-generation of Xtensa configurable processors, the Xtensa LX2 and Xtensa 7 cores. Both processors feature several architectural enhancements, and are the first configurable licensable core families available with built-in, on-the-fly Error Correcting Code, which is important in storage, networking, automotive and transaction processing applications.

News ID 10153

■ Evatronix: configurable 8051 core supported by Keil developer's kit

Evatronix has partnered with Keil to extend the Keil 8051 Professional Developer's Kit PK51, with an extensive support for the Evatronix high-speed configurable 8-bit R8051XC microcontroller core. The enhancements to the Keil PK51 toolchain enable embedded software developers to make full use of the Evatronix R8051XC advanced features with regard to the code generated by Keil C compiler.

News ID 10131

■ Holtek: USB 1.1 OTP microcontrollers

Holtek announces the HT82M9AE and HT82M9BE low speed USB OTP MCU devices that conform to the USB HID 1.1 specification and compatibility requirements. As the devices have the ability to automatically detect, USB or PS/2 interfaces, they are suitable for dual USB+PS/2 interface products. The HT82M9AE has a Program Memory size of 4Kx15, a 224x8 Data Memory capacity, 16 I/Os and 3 Endpoints.

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