Application Note

Z8 Encore! XP® Based BLDC Fan Control Reference Design

AN022802-0708

Abstract

This application note demonstrates the process of controlling Brushless DC (BLDC) fans using Zilog's 8-pin Z8 Encore! XP® MCU. The commutation is determined by the Hall sensor feedback signal. The speed of the BLDC fan is controlled by varying the potentiometer setting. This is analogues to taking an input from an external temperature sensor. Therefore, the speed of the motor can be controlled based on the object temperature.

Note: *The source code file associated with this application note (*`AN0228-SC01.zip`*) is available for download at* www.zilog.com.

Developing the application with Z8 Encore! XP

Figure 1 displays the block diagram of the BLDC fan controller. The hardware is built and tested with commonly available components. The main component of the hardware is Z8 Encore! XP 8-pin microcontroller. This microcontroller does not require any external crystal or RC network, as it uses the internal oscillator. For the schematic diagram of H- bridge BLDC fan controller, see Appendix B—Schematic Diagram on page 7.

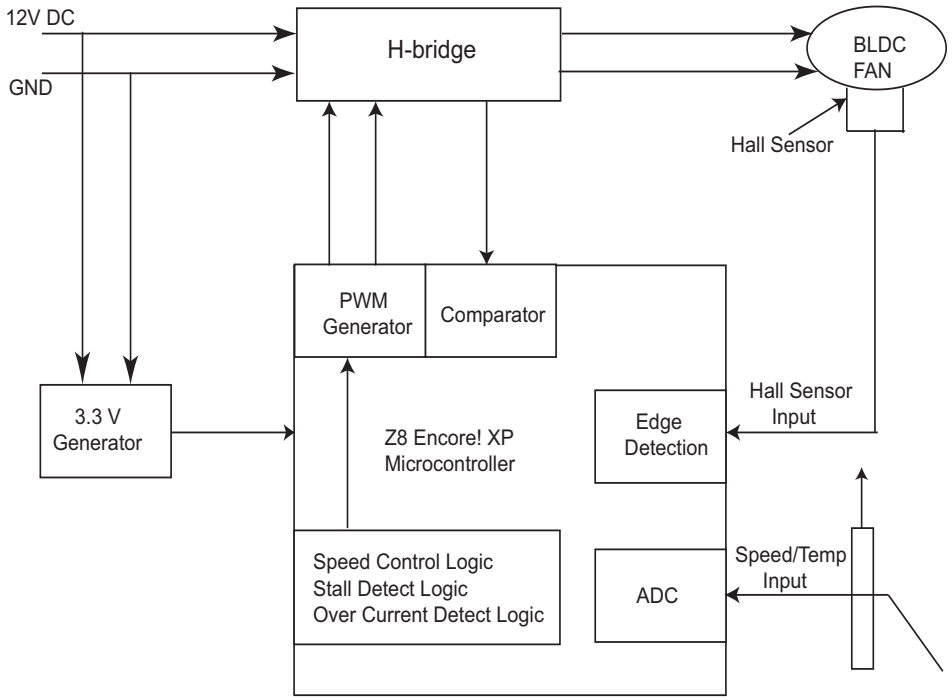

Figure 1. Block Diagram of BLDC Fan Controller

Features of BLDC Fan Control Reference Design

The features of BLDC fan reference design are:

- Uses Z8 Encore! XP® 8-pin chip.
- In-circuit programming to upgrade the firmware for evaluation purpose.
- Adjusting the fan motor speed by setting the potentiometer.
- Hall effect commutation.
- Motor stall detect condition.
- Over current detection.
- The speed control is achieved by its own ADC and PWM generation.

The following Z8 Encore! XP peripherals are used along with the hardware:

- Analog-to-Digital Converter
- Timer
- On-chip Oscillator

Analog-to-Digital Converter

The Z8 Encore! XP has an on-chip Sigma Delta ADC that converts an analog input signal to its digital representation. This ADC can be configured either for differential mode or for single-ended mode.

The ADC has 11-bit resolution in *differential mode* and 10-bit resolution in *single-ended mode*. The Z8 Encore! XP can take up to 8 single-ended analog input sources that are multiplexed with General-Purpose Input/Output (GPIO) ports. The ninth analog input is directly obtained from the on-chip temperature sensor peripheral. The ADCs can be configured either for a SINGLE SHOT or for a CONTINOUS mode.

Timer

The Z8 Encore! XP 4K Series products contain up to two 16-bit reloadable timers that can be used for timing, event counting, or generation of pulse width modulated (PWM) signals. The timers' features include:

- 16-bit reload counter.
- Programmable prescaler with prescale values from 1 to 128.
- PWM output generation.
- Capture and compare capability.
- External input pin for timer input, clock gating, or capture signal. External input pin signal frequency is limited to a maximum of one-fourth the system clock frequency.
- Timer output pin.
- Timer interrupt.

On-chip Oscillator

The Z8 Encore! XP 4K Series devices uses five possible clocking schemes, each of which is user selectable. The different clocking schemes are:

- On-chip precision trimmed RC oscillator.
- On-chip oscillator using off-chip crystal or resonator.
- On-chip oscillator using external RC network.
- External clock drive.
- On-chip low precision Watchdog Timer oscillator.

You have to select any one of the above oscillator. The oscillator control register (OSCCTL) enables/disables the various oscillator circuits, enables/disables the failure detection/recovery circuitry and selects the primary oscillator, which becomes the system clock. The oscillator control register must be unlocked before writing. Writing the two-step sequences E7h followed by 18h to the oscillator control register unlocks it.

The register gets locked on successful completion of a register write to the OSCCTL.

Software Details

The software offered with this application note is developed and tested on the hardware as per the schematic provided in Appendix B—Schematic Diagram on page 7. This section discusses the function of different software blocks used to control the BLDC fan.

The software provides the following functionalities:

- Initializing the Z8 Encore! XP® Peripheral
- Speed Command Input
- Measuring the Speed
- Hall Sensor Input Detection and Commutation
- Motor Stall Detection
- Over Current Detection

Initializing the Z8 Encore! XP® Peripheral

Port A pin 0 and pin 2 are initialized as GPIO ports. These pins are used to commutate the two different windings of the BLDC fan by driving an FET.

The `init_com` function initializes for port A pin 0 and pin 2 . These port pins are also used for enabling the high drive feature and as open drain outputs.

The `init_tach function` initializes the port A pin 3 to input mode. The tachometer input from the BLDC fan is fed to this pin and the software detects the rising and falling edge of the tachometer input.

The `init_comp` function initializes port A pin 5 as input pin to be used as a comparator input.

The `init_adc` function initializes port A pin 4 as an ADC channel. The input voltage is applied at this pin. The speed of the fan is controlled based on the input voltage applied at this pin.

The `init_pwm` function initializes port A pin 1 to generate the PWM output of different duty cycle. This sets TIMER0 to work in PWM mode.

Speed Command Input

A potentiometer is used to generate different voltages, through a voltage divider network at the ADC input channel. The `speed_in` function periodically reads the ADC data register. These ADC data register values are scaled and loaded to the PWM data register to generate PWM output of different duty cycles. This function is called from the while loop of the `main` function so as to read the ADC value and to change the PWM output, which in turn changes the fan speed.

Measuring the Speed

The on-chip ADC of Z8 Encore! XP is used in this application. An internal reference of 2 V is used as a reference voltage for analog to digital conversion. This conversion happens on continuous basis. The `main` function calls `speed_in` routine that reads the converted data from ADC data register. The ADC is configured for buffered, single-ended mode.

Hall Sensor Input Detection and Commutation

Commutation is achieved using two MCU pins: Port A pin2 and pin4 of the Z8 Encore! XP 8-pin microcontroller. These outputs are either high or low depending on the commutation timings. The Hall sensor input signal is applied to pin PA3, which is configured as an input port. The software detects the rising or falling edge (to detect the state changes) of the Hall sensor inputs and accordingly the commutation is done for the fan motor windings.

The software checks for the rising and falling edges of the Hall sensor and decides the logical state of the sensor input. If the Hall sensor input is logic *High*, the Commutation state is set to 1 else the Commutation state is set to 0. The function `commutation_a` or the function `commutation_b` is activated based on the Hall sensor input state. Calling the `commutation_a` function commutates one winding of the BLDC fan and `commutation_b` commutates the other winding of the BLDC fan.

Motor Stall Detection

If no Hall sensor edge is detected for a period of 300 ms, the firmware assumes that the motor is locked and stops commutating the motor for about 100 µs. Then after every 300 ms, the firmware tries to commutate the windings until the locked rotor comes back to normal or the power is switched off.

Over Current Detection

When the motor comes to a stall condition, the BLDC fan motor draws a very high current. The resultant voltage in the circuit is fed to ISENCE input (Port A pin 5). This input voltage is compared with the set voltage (200 mv) using the on-chip comparator of Z8 Encore! XP® microcontroller. When the input voltage exceeds the reference voltage, the comparator generates an interrupt. The `comp_intrp` interrupt service routine turns off the PWM generation from port A pin1 for about 100 us.

Testing the Application

This section discusses the equipments to use and procedure to follow for testing the Z8 Encore! XP based BLDC fan control application note.

Equipments Used

The following equipments are used for testing:

- H-bridge BLDC fan controller reference design board *Zilog PCA:99C0967*
- Zilog Developer Studio II - Z8 Encore! XP (ZDS II - IDE)
- 12 V Vdc 3A power supply
- Digital tachometer

Test Procedure

The H-bridge fan control reference design board is shown in Appendix B—Schematic Diagram on page 7. Supply 12 V DC power to the board and observe the speed of the motor by varying the potentiometer.

Test Results

You can observe that by changing the position of the potentiometer settings, the voltage at the ADC input pin changes and accordingly the speed of the fan is varied. The graph of fan speed verses the PWM duty cycle is presented below.

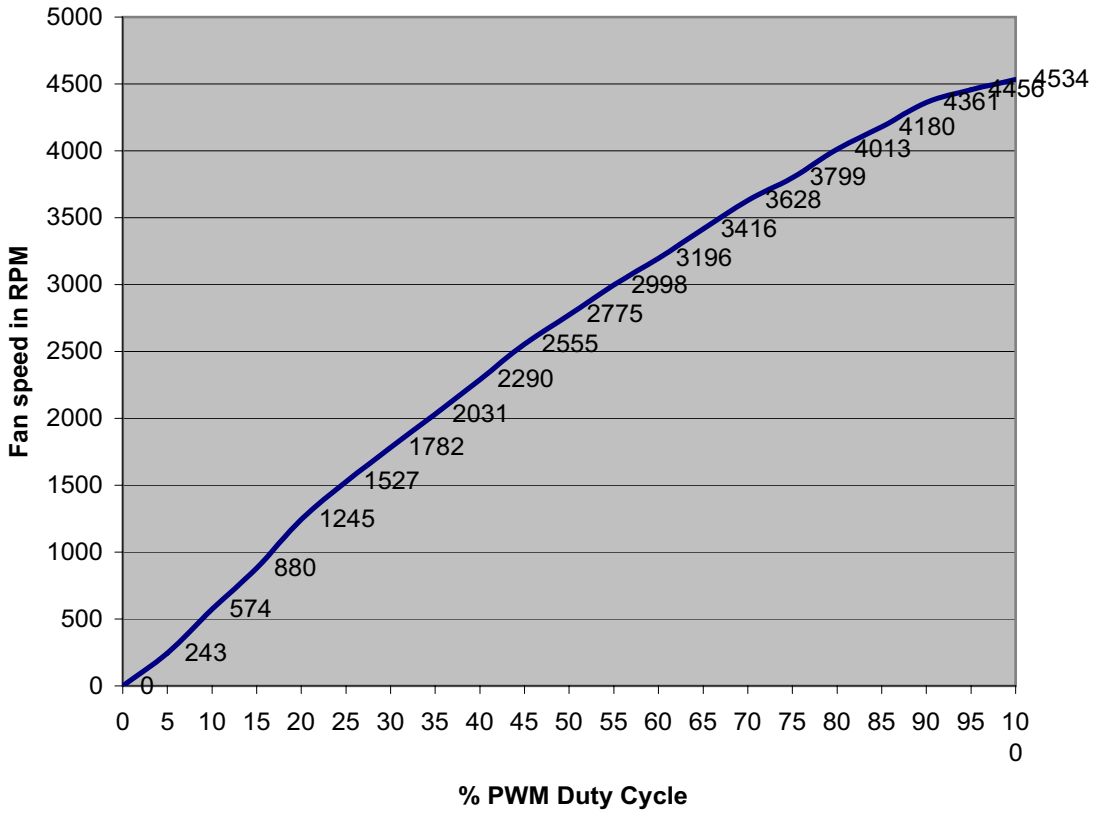

Figure 2. Fan speed in RPM_PWM percentage duty cycle

Summary

Z8 Encore! XP® 8-pin microcontroller consists of all the required on-chip peripheral suitable for speed control application of BLDC motors.

With the availability of in-circuit programming features, the evaluation can be done effectively by tuning the software based on the customer requirement such as selecting the PWM duty cycle, speed control etc. The source code associated with this application can be used directly without modification or with few modification by the customer to design a similar application/product.

Appendix A—H-bridge Fan Control

Figure 3 displays the photograph of the H-bridge Fan Control Reference Design Board.

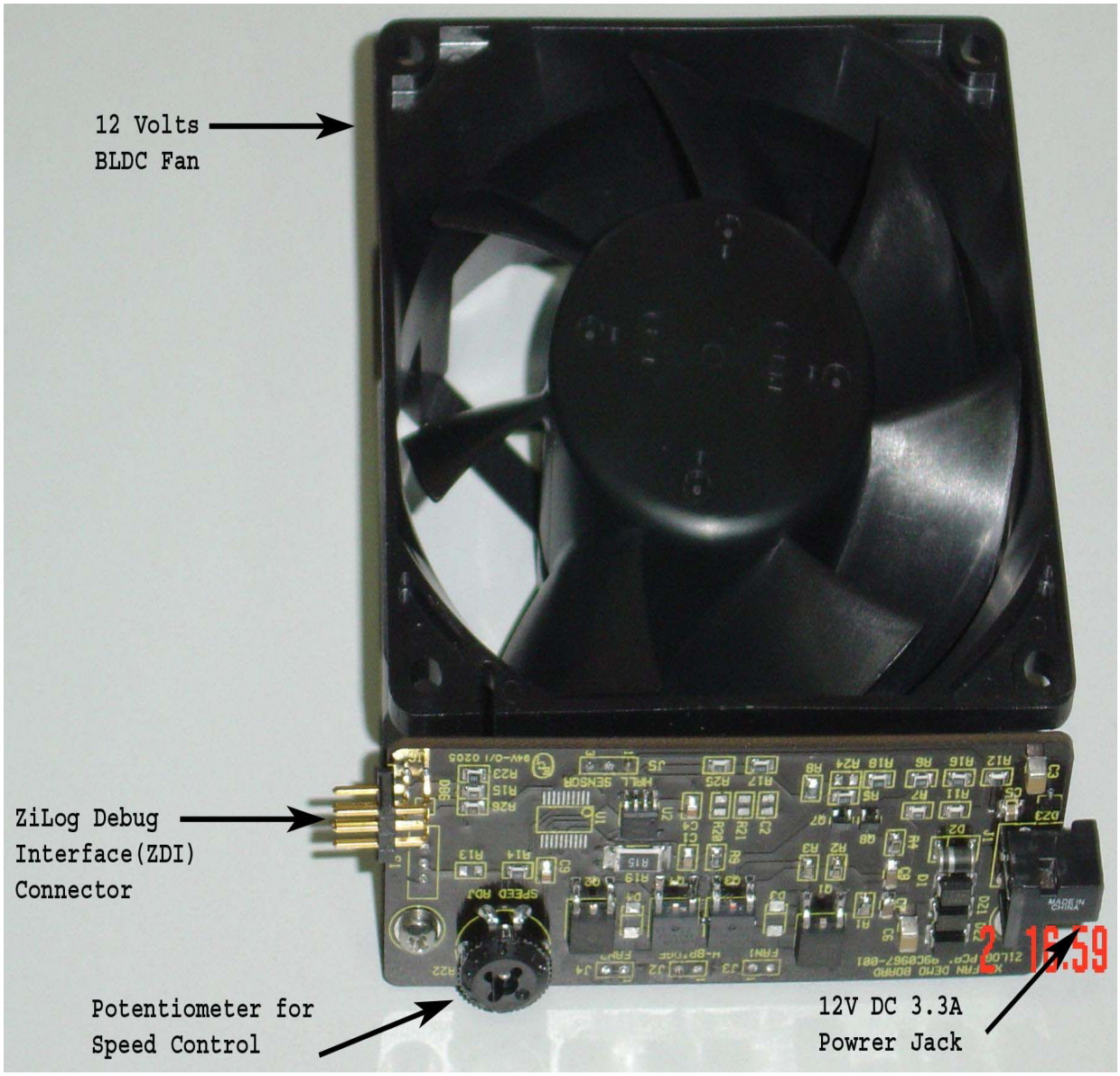

Figure 3. H-bridge Fan Control Reference Design Board

Appendix B—Schematic Diagram

Power supply to the BLDC fan and MCU

This reference design uses 12 V Vdc regulated power supply for fans. Zener diodes are used to generate the 3.3 V Vdd supply required for microcontroller unit.

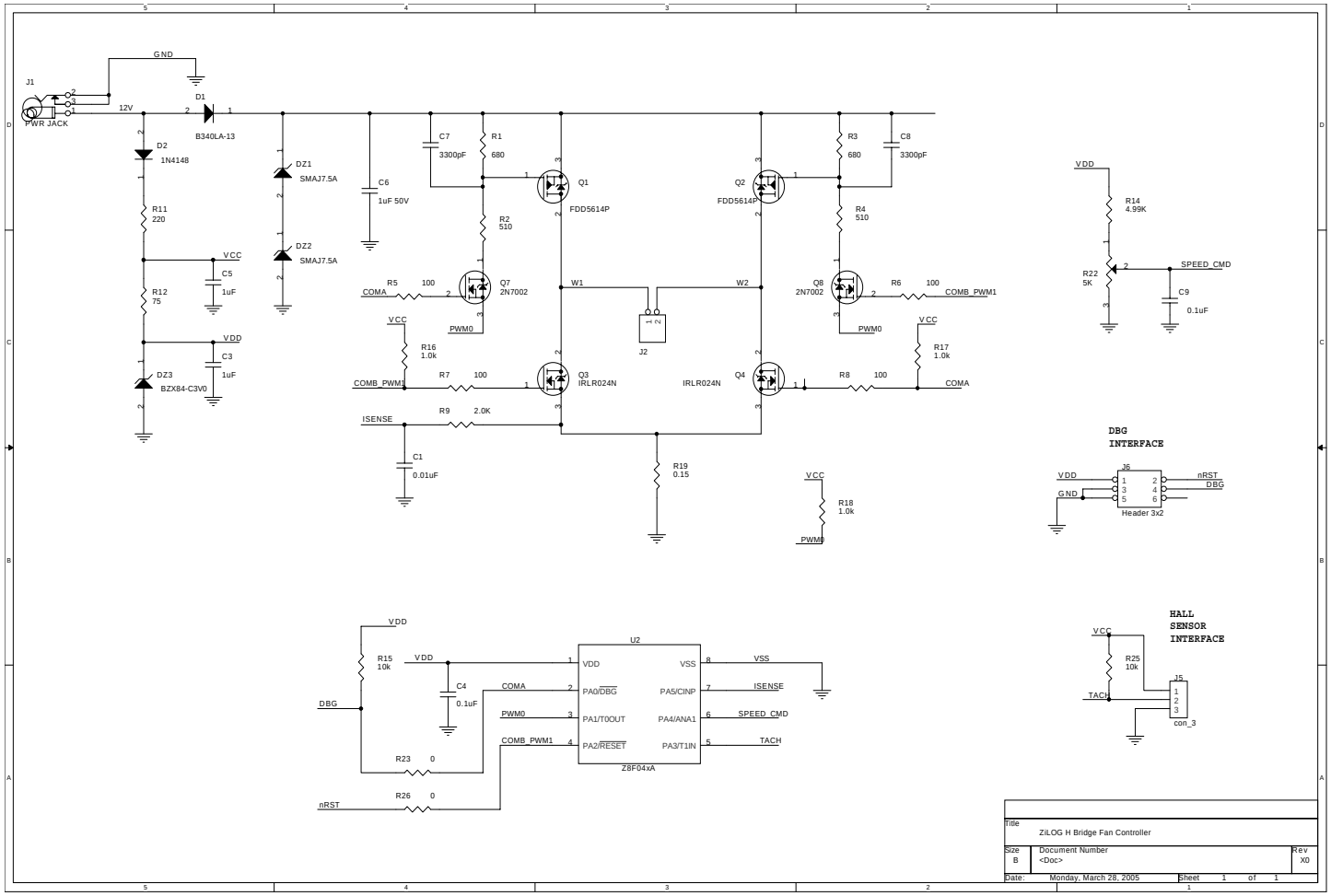

Figure 4. Schematic Diagram of H-bridge BLDC Fan Controller

Warning: DO NOT USE IN LIFE SUPPORT

LIFE SUPPORT POLICY

ZILOG'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF ZILOG CORPORATION.

As used herein

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

Document Disclaimer