Application Note

Dimmer Application Using Z8 Encore! XP® 8-Pin Microcontroller

AN025102-0608

Abstract

This Application Note describes an implementation of a dimmer based on Zilog's Z8 Encore! XP® 8-pin microcontroller. The dimmer functions effectively for 230 V/50 Hz and 110 V/60 Hz AC power source. An incandescent lamp is used as the load in this dimmer and the intensity of this lamp is controlled using a potentiometer. An optical isolation is provided between control and power circuits to create an electrical isolation and to protect the control circuits.

On-chip peripherals such as Comparator, Analog-to-Digital Converter (ADC), Oscillator, and Timer in the Z8 Encore! XP MCU combined with its 8-pin foot print makes the MCU a best choice for dimmer application.

Note: *The source code associated with this Application Note is available in Z8 Encore! XP Applications Library under Application Sample Libraries at* www.zilog.com.

Z8 Encore! XP Flash Microcontrollers

Z8 Encore! XP F0823 Series products expand upon Zilog's extensive line of 8-bit microcontrollers. Flash Memory in-circuit programming capability allows faster development time and program changes in the field. The high-performance register-to-register based architecture of the Zilog's eZ8™ core maintains backward compatibility with Zilog's popular Z8® MCU. Featuring eZ8 CPU, the Z8 Encore! XP microcontrollers combine a 20 MHz core with Flash Memory, linear-register SRAM, and an extensive array of on-chip peripherals. These peripherals make the Z8 Encore! XP MCU suitable for various applications including motor control, security systems, home appliances, personal electronic devices, and sensors.

Discussion

Dimmer is used in theatres, industries, and also in house-hold lighting applications. The concept used in the design of dimmer is also applied to control motor speeds in fans and heaters. Different loads (for example, lamp, motors, heating coil) respond to different controlled parameters such as root mean square (rms) voltage, average voltage, and peak voltage. That is, the intensity of the lamp, speed of the motor, and amount of heat in the heating coil can be varied by controlling the parameters.

Theory of Operation

In this dimmer, the alternating current (AC) phase control method is used to control the intensity of an incandescent lamp, which is connected as a load. The rms value of the voltage supplied to the lamp is varied by controlling the firing angle of a Triac. The firing angle is the delay from the zero crossing of the AC to the time the Triac is fired. The firing angle is determined by the position of a potentiometer, which is interfaced to the Z8 Encore! XP MCU.

Figure 1 on page 2 displays the effective voltage applied to a load by controlling the firing angle, α. When the AC changes its direction, that is, at a point when AC voltage is zero, the Triac is turned OFF. This makes the load current zero at every AC half cycle. Therefore, to keep the lamp glowing continuously at the set intensity, the Triac needs to be fired during both halves of the AC sine wave, which ensures that the average load current is not zero. In ON condition, the voltage across Triac drops to zero and in OFF condition the line voltage appears across the Triac.

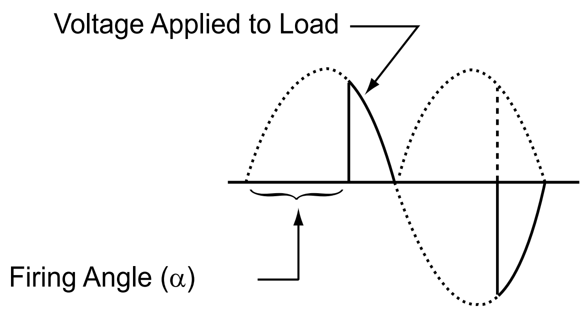

Figure 1. Phase Control on Full Wave Rectified Line Voltage

By controlling the firing angle, the rms voltage supplied to the load changes and according to the voltage light intensity of the bulb varies.

Hardware Architecture

Figure 2 displays the hardware architecture for the dimmer. The hardware is described in the following sections:

- Power Supply Section
- Optoisolator Triac Drive Section
- Dimming Control Section

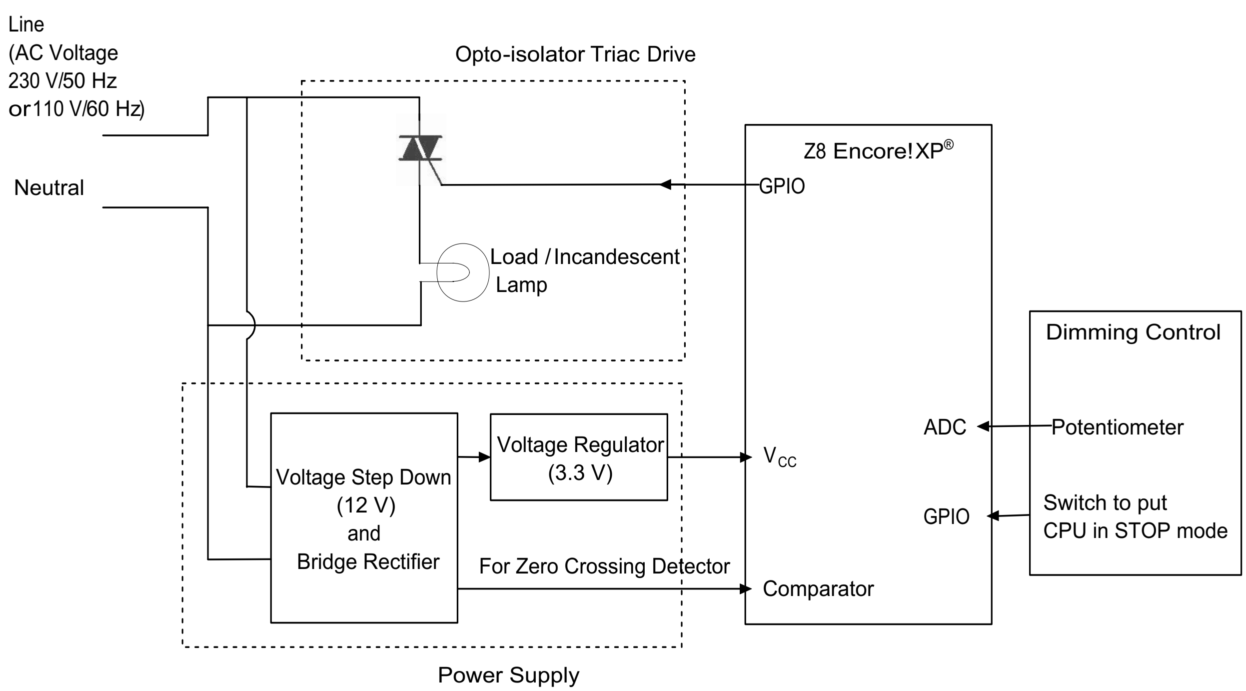

Figure 2. Hardware Block Diagram

Power Supply Section

The power supply section consists of a RC voltage dropper and zener diode followed by a bridge rectifier. The break down voltage of the zener diode is 12 V. A capacitor across the zener diodes provides smoother waveform to the rectifier. The rectifier output is tapped across two diodes as displayed in schematic (see Appendix B—Schematic Diagrams on page 8). Therefore, the rectified voltage varies between 0 V and 1.4 V.

This signal is used for zero crossing detection. Further, the rectified output is filtered and is provided as input to a 3.3 V regulator to power the MCU.

Note: *The value of C2 (see* Appendix B—Schematic Diagrams *on page 8) must be 0.6 µF for working with 110 V/60 Hz AC and 0.47 µF for 230 V/50 Hz power source.*

Optoisolator Triac Drive Section

An optoisolator Triac drive (MOC3021) is used for isolated Triac triggering. The Triac drive is connected to a General-Purpose Input/Output (GPIO) pin of Z8 Encore! XP® MCU through a current limiting resistor. A snubber circuit is also provided to avoid false triggering of the Triac due to rate of voltage change (dv/dt) exceeding the rating.

Dimming Control Section

you can control the dimmer through a potentiometer and a Switch. The potentiometer is used to control the intensity. The potentiometer is tied to the internal reference voltage of the ADC available on the V_{ref} pin of the Z8 Encore! XP MCU. The internal ADC reference is made available on V_{ref} pin by setting `REFOUT` bit in ADCCTL0 register and enabling alternate function for the associated GPIO. The Switch is used to put the system in STOP mode and also to recover from STOP mode and restart on subsequent press.

The voltage across the potentiometer is read in ADC Interrupt Service Routine (ISR). The ADC output is used to find the table offset required to load timer reload values. The timer reload value determines the firing angle of the Triac and the intensity of the lamp. The timer reload value is loaded in Comparator ISR.

Software Implementation

The following events constitute the dimmer application:

1. Initializes the Comparator, Timer0, ADC, and GPIO (see Initialization on page 4).
2. Measures AC line frequency (50 Hz/60 Hz).
3. Potentiometer position is read in ADC continuously and table offset for timer reload is determined.
4. Timer0 reload register is updated and the timer is started in Comparator ISR, that is, at the start of each half cycle of AC.
5. When the Timer expires, an interrupt is generated and the Triac is fired in the Timer0 ISR.
6. The program monitors the state of Switch SW1 tied to PA3 (Port A Pin 3) continuously and on a valid Switch press the CPU is put in STOP mode. PA3 is configured to generate an interrupt on falling edge.
7. CPU recovers from STOP mode on subsequent Switch press and resets and the sequence repeats.

The block diagram displayed in Figure 3 on page 4 provides an overview of the software architecture for the dimmer application. The description of each block is provided in the following sections:

- Initialization
- Line Frequency Detection
- Phase Control
- STOP Mode

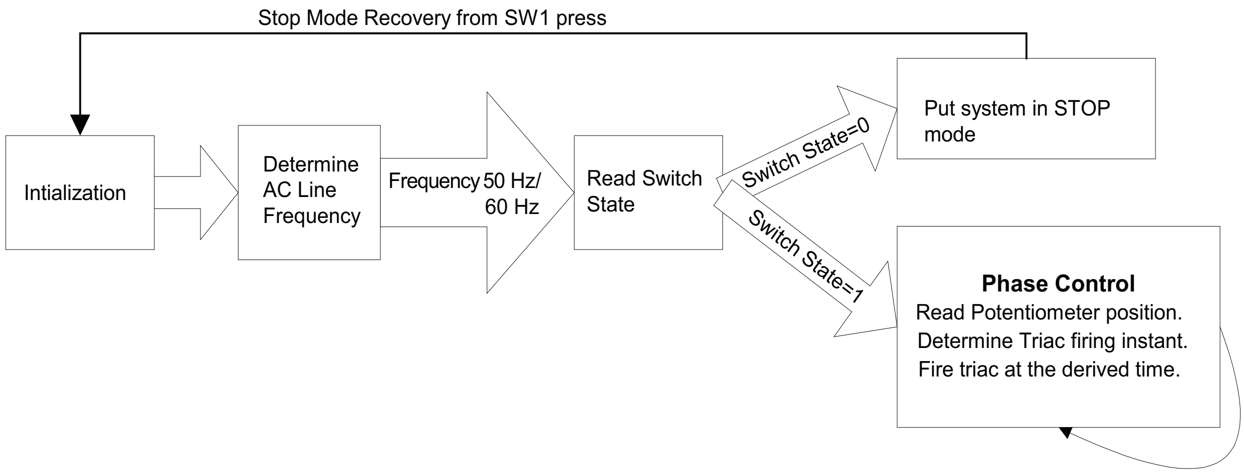

Figure 3. Software Architecture

Initialization

The initial state of the system is set to detect AC line frequency apart from initializing the on-chip peripherals. The main function calls the following APIs to initialize the Timer0, GPIO, Comparator, and ADC peripherals:

- `Init_Timer0()` — Initialize Timer0 for CONTINUOUS mode 0.5 ms timeout.
- `Init_GPIO()` — Initialize GPIO for comparator input (CINP\PA5), Switch input (PA3), ADC input (ANA1\PA4), Triac drive (PA2), and internal V_{ref} buffering to PA1.
- `Init_Comparator()` — Initialize comparator to accept non-inverting input through GPIO (PA5). For inverting input internal reference of 0.4 V is used.
- `Init_ADC()` — Initialize ADC for continuous conversion to read potentiometer input through ANA1 (PA4). ADC internal reference voltage source is 2 V.

Line Frequency Detection

The line voltage is stepped down, rectified, and fed to the non-inverting input (CINP pin on MCU) of the comparator on Z8 Encore! XP® MCU. The comparator is configured to generate interrupt when its non-inverting input voltage is greater than the set internal reference voltage (0.4 V). The internal reference forms the comparator inverting input (CINN). The timer is started in comparator ISR. At every 0.5 ms, a counter is incremented in Timer0 ISR. The line frequency is determined by capturing the value of this counter between two zero crossing points.

The comparator is configured to generate an interrupt when its positive input goes above a threshold voltage of 0.4 V. This is done to eliminate any spurious signal near the zero crossing to cause undesirable interrupts. The threshold voltage (comparator negative input) is set by the internal reference voltage generator in the MCU through CMP0 register.

On successful frequency detection, the system state is changed to phase control and Timer0 is reconfigured to operate in SINGLE SHOT mode.

Phase Control

At the zero crossing point (Comparator ISR) the timer is started with the new reload value and when the timer expires, the Triac is fired. Therefore, higher the intensity required lower will be the timer reload value, providing a larger conduction angle.

The timer reload value proportional to the voltage across the potentiometer is updated in Comparator ISR, which varies the lamp intensity.

The voltage across potentiometer that controls the lamp intensity is read by the ADC. For every change in 0.24 V at the ADC, input firing angle is changed by loading a corresponding timer reload value. The timer reload value is stored in a look-up table. A 0.24 V change is reflected as bit change in the higher three most significant bits that correspond to seven incremental changes in timer reload value and therefore, the look-up table has seven values.

The timer reload value look-up table is a two dimensional array with values for T0RH and T0RL registers. The values range from 30% to 90% of the reload value corresponding to the period of the rectified sine wave.

Example:

The period of full wave rectified signal for 50 Hz line frequency = 1/100 Hz = 10 ms.

The Timer Reload value for this period with prescale value 32 and Internal Precision Oscillator (IPO) as system clock = (0.01 x 5529600)/32 = 1728 = 0x06C0.

The array is filled with 90% to 30% of this maximum reload.

The ADC value read for a particular potentiometer position = 0x199 = 0110011001 (binary).

Table index (3 most significant bits) = 011 (binary).

Table index = 3 (decimal).

STOP Mode

When Switch SW1 is pressed, the controller is set to STOP mode and is configured for Stop Mode Recovery from PA3. On Stop Mode Recovery, the CPU resets and the program execution starts. For more details on the software flow, see Appendix C—Flowcharts on page 9.

Testing

This section provides details of the test setup, equipments used, and the procedure for testing the dimmer application.

Test Setup

Connect the circuit as displayed in the schematic (see Appendix B—Schematic Diagrams on page 9).

Equipment Used

The test setup consists of the following:

- Zilog Developer Studio II (ZDS II) for Z8 Encore! MCU.
- Oscilloscope for capturing waveform.
- PC with USB port to download dimmer application software to target board.

Test Procedure

Follow the steps below to test the Z8 Encore! XP®-based dimmer application:

1. Install the Z8 Encore! XP Applications Library available under Application Sample Libraries at www.zilog.com.
2. Launch ZDS II for Z8 Encore!, and open the `XP_Dimmer.zdsproj` file located in the source folder.
3. Switch ON the AC power supply.
4. Build the code and download to the development board.
5. Reset the CPU to execute the code.
6. Vary the potentiometer position and note the change in lamp intensity.

7. Press Switch SW1 and observe that the lamp is turned OFF, since CPU enters into the STOP mode.
8. Press Switch SW1 again to turn ON the lamp.

Test Results

The lamp intensity is observed to vary in accordance with the potentiometer position. The CPU enters the STOP mode on SW1 press and a subsequent press of SW1 causes Stop Mode Recovery and the system to restart, with the lamp intensity corresponding to current potentiometer position.

Summary

Z8 Encore! XP® 8-pin offers greater flexibility for dimmer application than any other conventional methods with the necessary on-chip peripherals such as Comparator, Timers with PWM capability, and ADC. The low pin count offers small footprint solution, thus, saving the PCB area. This application is designed for ohmic loads only. For inductive loads or any other loads, hardware changes are needed with minimum or no software changes. Thus, dimmer application can be designed for different loads quickly and accurately.

This dimmer application can be easily integrated into a bigger control system and additional features can also be incorporated in the application with minimal software changes.

References

The documents associated with Z8 Encore! XP® available on www.zilog.com are provided below:

- Z8 Encore! XP® F082A Series Product Specification (PS0228)
- eZ8™ CPU User Manual (UM0130)
- BTA12, Logic level Triac — BTA12 Datasheet (BTA12) (www.st.com)
- MOC3021, Optoisolator Triac Driver Output — MOC3021 Datasheet (MOC3021-m) (www.fairchildsemi.com)

Appendix A—Glossary

Table 1 lists the definitions for terms and abbreviations used in this Application Note.

Table 1. Glossary

Term/Abbreviation	Definition
MCU	Microcontroller Unit
IPO	Internal Precision Oscillator
ISR	Interrupt Service Routine
API	Application Programming Interface
GPIO	General-Purpose Input/Output
ADC	Analog-to-Digital Converter

Appendix B—Schematic Diagrams

Figure 4 displays the reference design for Z8 Encore! XP® dimmer application.

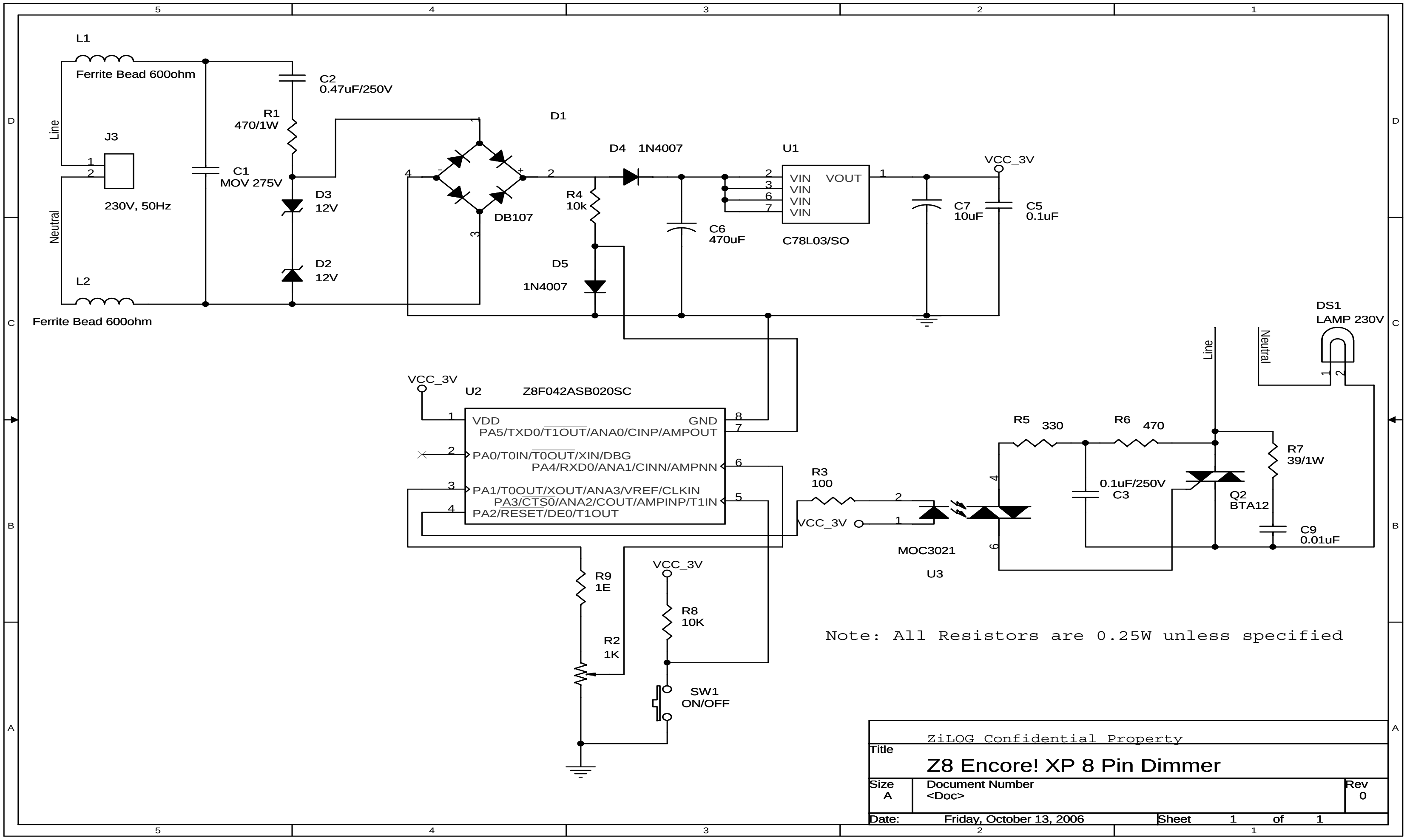

Figure 4. Z8 Encore! XP® Dimmer Application Reference Design

Appendix C—Flowcharts

This Appendix displays the following flowcharts for the dimmer application:

- Main Function (Figure 5)
- Comparator Interrupt Service Routine (ISR) (Figure 6)
- Timer0 ISR (Figure 7)
- ADC ISR (Figure 8)

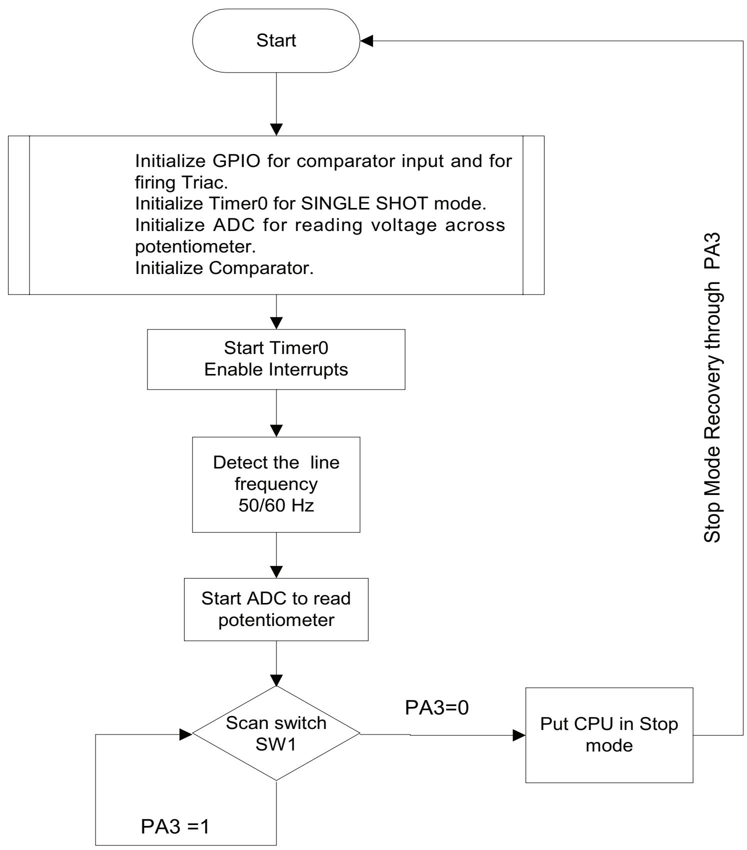

Figure 5. Main Function

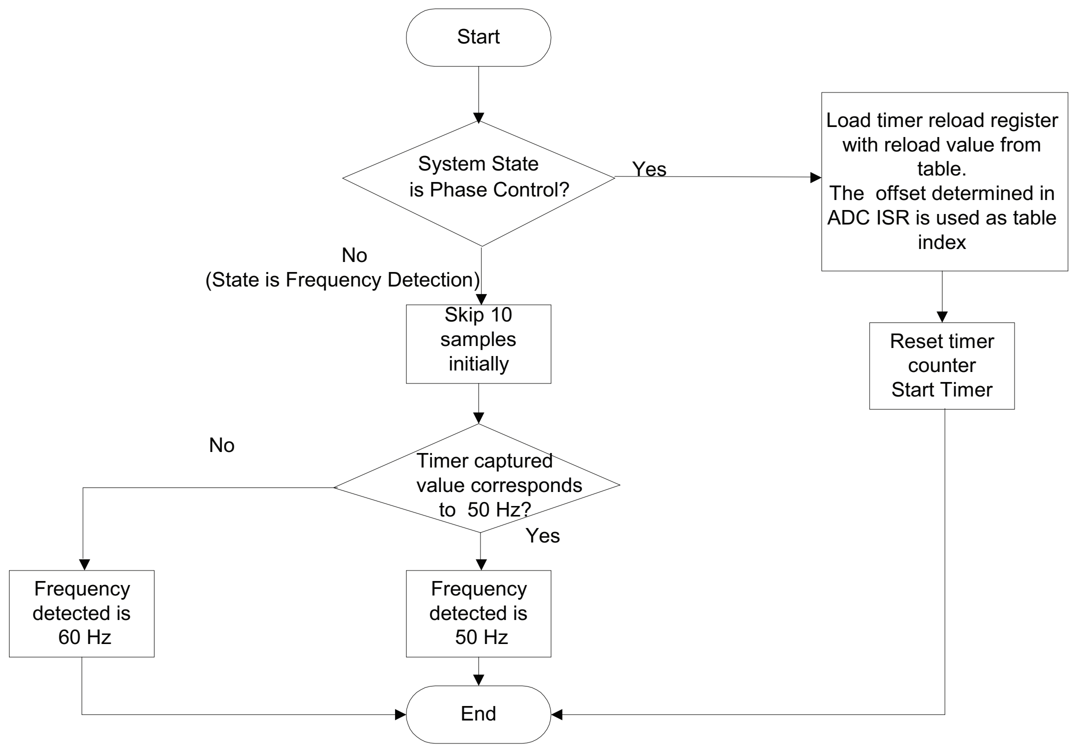

Figure 6. Comparator ISR

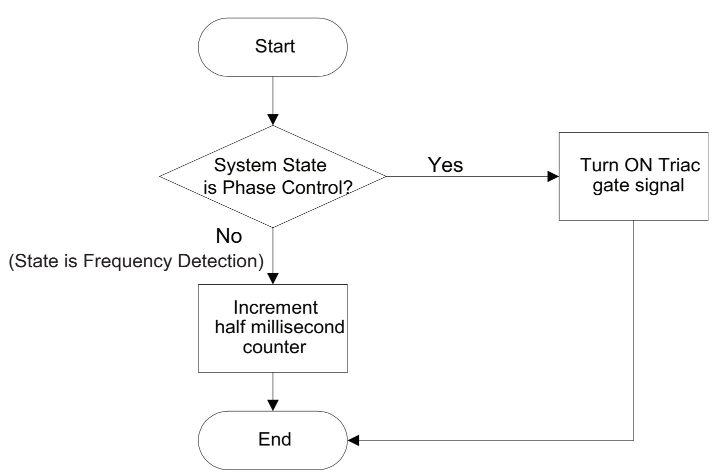

Figure 7. Timer0 ISR

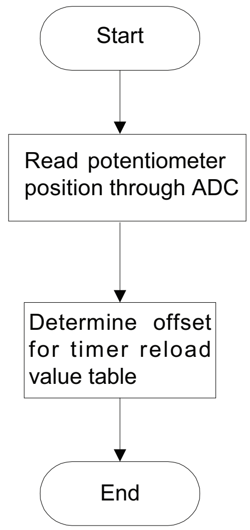

Figure 8. ADC ISR

Warning: DO NOT USE IN LIFE SUPPORT

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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.

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