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Design and Implementation of Pic16F877A Microcontroller Based Thyristor Firing Controller

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Abstract

Controlled power is a fundamental prerequisite of various sectors. Silicon-controlled rectifiers (SCR) are solid-state semiconductor devices that are usually used in power switching circuits. SCR controls the output signal by switching it 'on' or 'off,' thereby controlling the power to the load in context. This paper describes the design and development of microcontroller based firing angle control, using PIC16F877A microcontroller. The microcontroller is used as the firing controller. This IC chip takes input from a variable resistor, convert it to digital data, calculate delay time and trigger thyristors accordingly. The firing angle is adjustable from zeroto 180°.

1. Introduction:

Power electronics is one of the key topical areas within the electrical engineering discipline. In industrial, agronomic production and house hold applications the controlled powers through electronic technology have been widely used. The power is provided to the application via rectifier, cycleconverter, frequency converter and inverter. [1] Among these four types, rectifier is generally usedin the equipment, where in trigger circuit is very important. Because of advances in the switching technology the analog trigger circuits are replaced by digital trigger circuits [2]. The circuit like converter, cycloconverter, rectifier and inverter make use of thyristor as an elementary unit. Theare three terminal thyristors having additional terminal gate, along with anode and cathode; is employed to trigger the thyristor at a precise angle, known as firing mechanism [3]. It is observed that in analog triggering circuit, trigger circuit is too complex with many components; which may lead to debugging difficulties, uneven spacing of the adjacent trigger pulses and shifting phase inaccuracies. Hence digital trigger mechanismsdesigned which overcomes the limitations of analog trigger circuit. Simple, reliable gate drives for interfacing logic to power devices enhanced the control of large amounts of power [4]. Recently, advances in microcontroller technology have led to self-contained systems capable of performing much more than mere computation. Peripheral tasks so necessary to high speed, real time control can now be incorporated with a microprocessor onto a single controller chip. These include high speed data collection, analog-to-digital data conversion, timing (including sampling rates), multiplexing, and high speed output of digital data. Microcontrollers perform such high speed control functions plus microprocessor computation at reasonable cost and as an easily interfacedto a larger control system [5].

2. Hardware Description:

The complete hardware system is divided into three sections:

1. Firing angle adjustment circuit section
2. Zero crossing detector circuit section
3. Control Circuit section

2.1. Firing angle adjustment:

Analog voltage (0-5V) is used for adjusting the firing angle. ADC of PIC microcontroller in 10 bit resolution mode is used for converting the analog voltage. Pin RA1 of port A is used for accepting analog voltage. Analog voltage (0-5V) is converted into (0-1023) count. As per variation of analog input there is a change of digital count. According to this digital count microcontroller calculate the required delay of triggering. A three phase PWM signal is generated to the PORTB. ADC conversion takes around 250 micro second. PWM duty cycle

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iscontrolled with the help of variable controlling voltage.

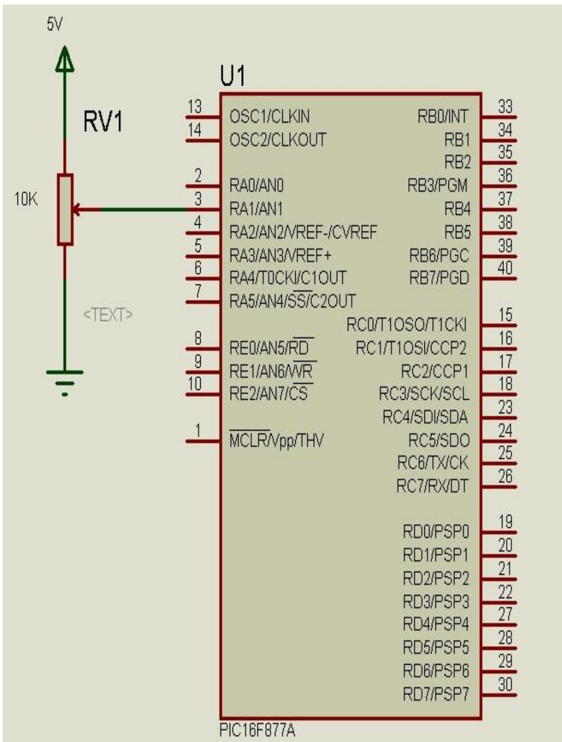


Figure: Firing angle adjustment

2.2. Zero crossing detector:

Zero Crossing Detector circuit distinguishes between start of positive half cycle or negative half cycles. To have full control over the firing angle of the SCR, it is necessary to precisely detect the zero crossing of the sinusoidal input. Fig.1 shows the circuit diagram of the zero-crossing detector and the power supply. The main sections of the circuit are a rectifier, regulated power supply and zero-crossing detector. The 230V AC mains are stepped down by transformer X1 to deliver the secondary output of 9V, 500 mA. The transformer output is rectified by a full-wave bridge rectifier comprising diodes D1 through D4 and then regulated by IC 7805 (IC3). Capacitors C2 and C3 are used for bypassing the ripples present in the regulated 5V power supply. A capacitor above 10µF is connected across the output of the regulator IC, while diode D6 protects the regulator IC in case their input is short to ground. LED5 acts as the power-on indicator and resistor R5 limits the current through LED5.This regulated 5V is also used as biasing voltage for both transistors (T1 and T2) and the control section. A pulsating DC voltage is applied to the base of transistor T1 through diode D5 and resistors R1 and R2. When the pulsating voltage goes to zero, the collector of transistor T1 goes high. This is used for detecting the pulse when the voltage is zero. Finally, the detected pulse from 'C' is fed to the microcontroller interrupt pin (RB0/INT)[6].

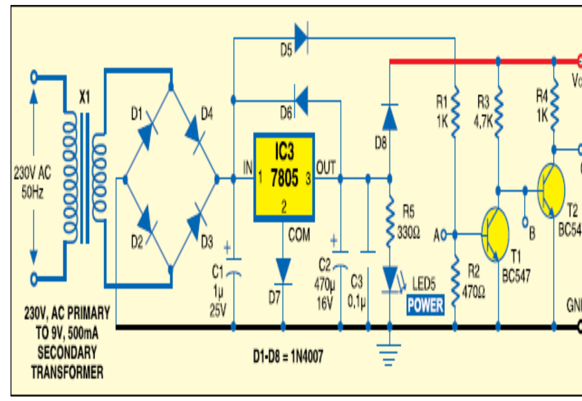


Figure1: Power supply and zero-crossing detector circuits

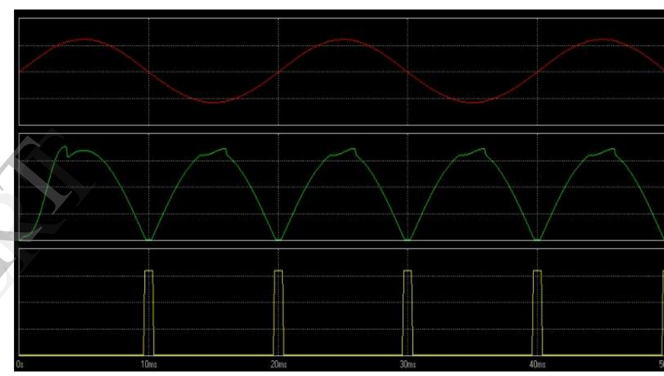


Figure2: Waveform of ZCD

2.3. Control section:

Figur-3 shows the circuit diagram of the control section for the phase-angle control of SCR. It comprises a microcontroller PIC16F877A, LCD module and a few discrete components. PORTD is used for interfacing to the LCD module. PORTB pin RB1- RB6 of the microcontroller is used for controlling three phase rectifier circuit. Preset VR1 is used for controlling the timing of triggering. External hardware interrupt pin INT0/RB0 of the microcontroller is connected to output 'C' of the zero-crossing detector.

A 10MHz crystal is connected to the microcontroller pins 13 and 14 to provide the basic clock to the microcontroller. Switch S1 is used for a manual reset. Preset VR2 is used for controlling the contrast of LCD module.

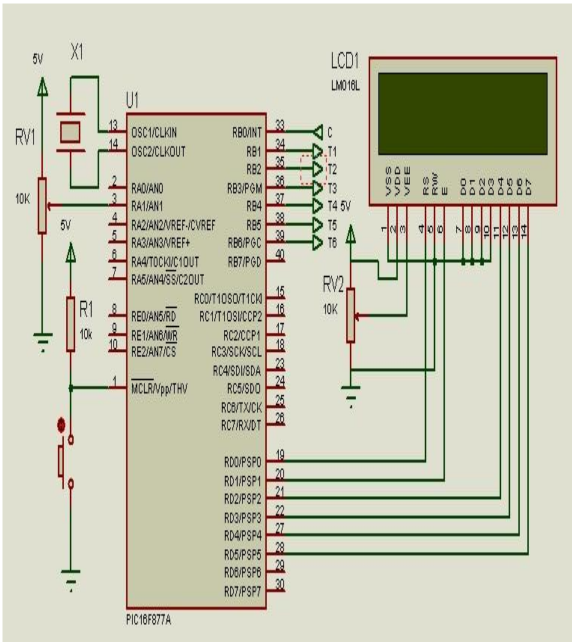
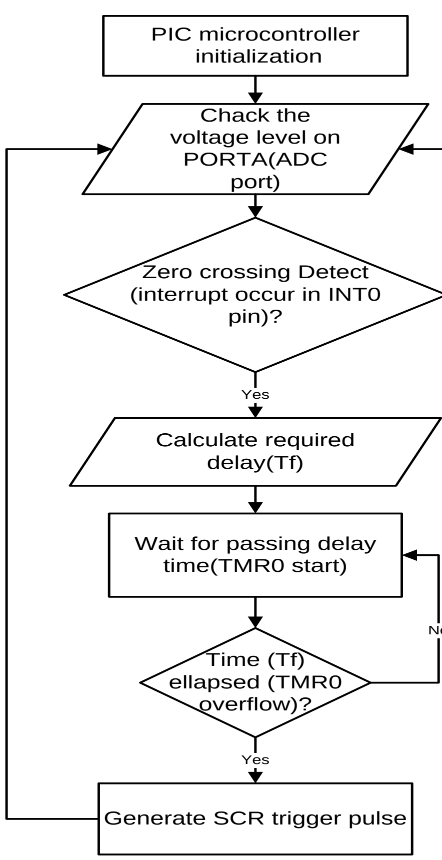


Figure 3: Control circuit

3. Software algorithm:

The flowchart given shows the sequence of event undertaken.



4. Operation and Results:

At any time when zero crossing (falling edge of square wave) is detected on the AC mains, microcontroller is interrupted and the latest values of ADC is used to manipulate firing (T_f shown in figure)delay which is use to determine firing angle with proper mathematical calculations. According to the firing angle, the triggering pulse is generated for gate terminal of SCR to trigger the thyristor. On LCD, ADC output and firing angle which is calculated from ADC reading is displayed for the observer who is controlling the converters output.

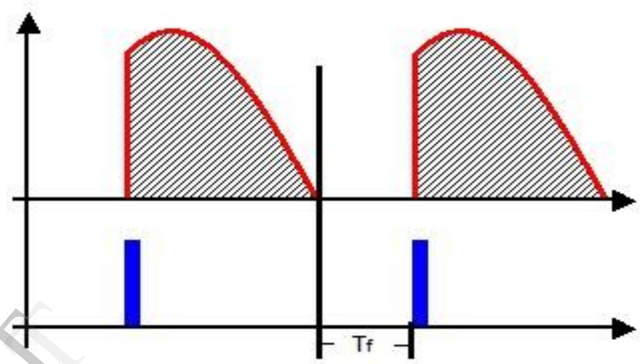


Figure 4: Delay time (T_f) from zero crossing to firing pulse

ADC output is 0-1023 which is used to control firing angle 0^0-180^0. Let ADC is the output from analog to digital converter and α is the firing angle. So the relationship between firing angle and ADC is given in equation (i). α = ADC/5.68 (i) [7]. Now it is needed to calculate the delay(T_f) as per the firing angle which is based on the ADC output and ADC output is based on the analog voltage (0-5V). Here relationship between delay in the generation of firing pulse and ADC output is determined. Converter output is controlled up to 180^0, as AC supply is 50Hz it have the time period of 20ms and for positive half cycle time period is 10ms, As ADC of PIC16F877A is of 10-bit resolution hence the maximum value from the ADC with +5 volts reference will be 1023 for which 10ms delay is required. ADC reading is converted into a delay after which firing pulse is to be generated. Relationship between ADC reading and firing angle delay is shown in (ii). If ADC is output of ADC and d is the delay in microseconds, then,

d= (ADC*5)*1.955 (ii)

1.955 here is the scaling up factor for the ADC reading and 5 is the reference voltage. Hence for ADC = 1023, the delay d will be 9999.825 microseconds which is nothing but time period of half positive cycle. MCU generates firing pulses on its output port with on-time of 100 microseconds. Figure 5 shows the firing pulse for 1ms, 2ms, 4ms, and 5ms.

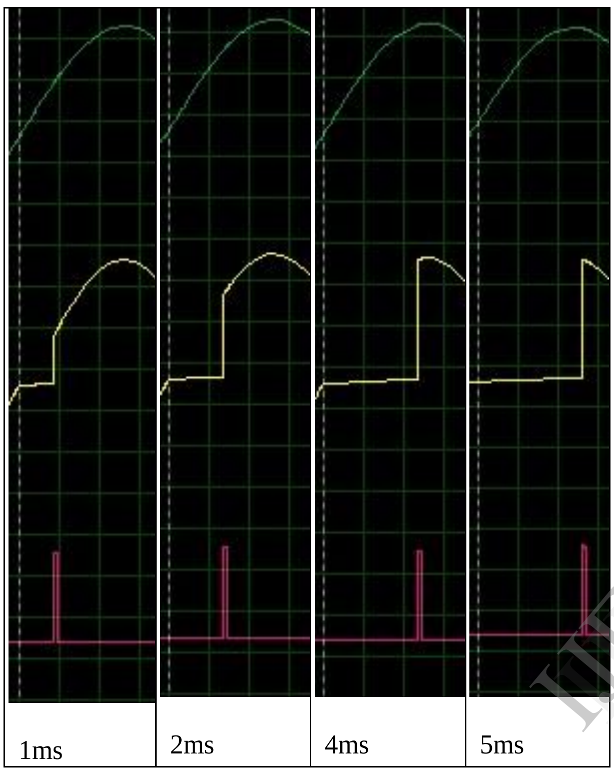


Figure 5: Firing at different angle

5. Conclusion:

Power control is possible from 0-180^0 with controlling voltage. Very few components are use in this design which are easily available and are cheap. The design is software based hence can be easily upgraded to control other power devices for controlling power.

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