EE318 Electronic Design Lab Report, EE Dept., IIT Bombay, April 2006

Fan Regulation with Selectable Profile using Integer Cycle Control

Group No.: B12
Prateek Gupta (03007001)<prateekg@ee.iitb.ac.in>
Kaustubh Jain (03007017)<kaustubhj@ee.iitb.ac.in>
Mohit Gupta (03007018)<mohitgupta@ee.iitb.ac.in>

Supervised by: P. C. Pandey & V. K. Tandon

ABSTRACT

The report discusses the approach taken to solve the problem of harmonics introduced by the use of phase controlled regulators. The report discusses a solution based on integer cycle control. The objective of our design project is to build a fan regulator using integer cycle control. It also includes a user programmable linear profile so that speed could vary automatically once programmed by user. It provides regulation against input power supply voltage variation. The problem can be solved by blocking a certain fraction of cycles of the supply. The fraction blocked depends upon the speed to be obtained and line voltage. This was done by appropriately blocking the firing pulses to the triac using a micro-controller.

1 INTRODUCTION

Fractional cycle control for fan regulation is a widely accepted technique. But, there is a major drawback of presence of harmonics in supply current waveform due to switching. These harmonics cause radio frequency interference in neighboring devices and also drop voltage across the terminals.

Integer cycle control eliminates this problem as it does not have any harmonics. It has been successfully used as a regulation method for high power induction motors, heaters. But due to cost considerations it is not a viable alternative to cheaper fan regulators which use fractional cycle control. Thus, we planned to include extra features with the product to make it cost effective. The features added are, user interface which could be used both to display current speed of the fan or alternatively take the input from the user to change the speed either in normal mode or in linear profile mode, another feature is to include compensation for the effect of voltage fluctuations.

2 DESIGN APPROACH

Principle: Integral cycle control is achieved by applying full cycles of supply voltage to the load for a specific period of time called, on time ***(Ton)*** and then disconnecting the supply voltage for some period called, off time ***(Toff)***. ***Ton*** and ***Toff*** may be varied over the control range to control the effective values of voltage, current, and power applied to the load. Since sinusoidal current will flow in the load during the **ON** period, this method of control has the advantage over phase control (fractional cycle control) that is radio frequency interference is minimized here and less voltage distortion is produced on the ac supply. In addition, this technique has simplicity in control and gives reasonable performance. However, this form of control is unsuitable for normal lighting due to the irritating flicker that would be introduced.

In our case, we had considered a span of 120 cycles and according to speed which could vary in between 15 different levels, starting from minimum speed at first level to maximum speed at level 15. We accordingly vary the number of cycles to be passed in the span. Number of cycles to be passed in a particular level is same as the result of multiplication of that level number with 8 cycles, as we increase 8 cycles per level. These cycles are randomly passed over the span so as to get overall good current waveform when many of such regulators will be used simultaneously.

The integral-cycle control method is employed, using the anti-parallel thyristors or TRIACs as static contactors and alternatively switching ON and OFF the gate voltage for a number of cycles at a time. This triac is put in series with the load so as to control the power flow in the load. The gate pulses come from the microprocessor through a optocoupler to protect the control circuit which is at 5V digital supply from the main load circuit which is at AC mains voltage of 230V.

Zero crossing detector (ZCD) is used to signal the microcontroller the zero crossings of power supply. This signal signifies the beginning of a new power cycle. As microcontroller gets this interrupt, first of all it sets the timer to control the gate pulse width that is, it will make the gate pulse low after the timer overflows. Then, if it is the starting of the span, it calculates the voltage compensation required due to any fluctuations in the mains supply. It proportionally changes the number of cycles to be passed depending on the operating level of the fan. If it is a simple cycle, we check for the random number first of all and then according to it we decide whether we should fire the cycle or not. Also, if the count of cycles remaining to be fired becomes equal to the total remaining cycles in the span we pass all of the cycles.

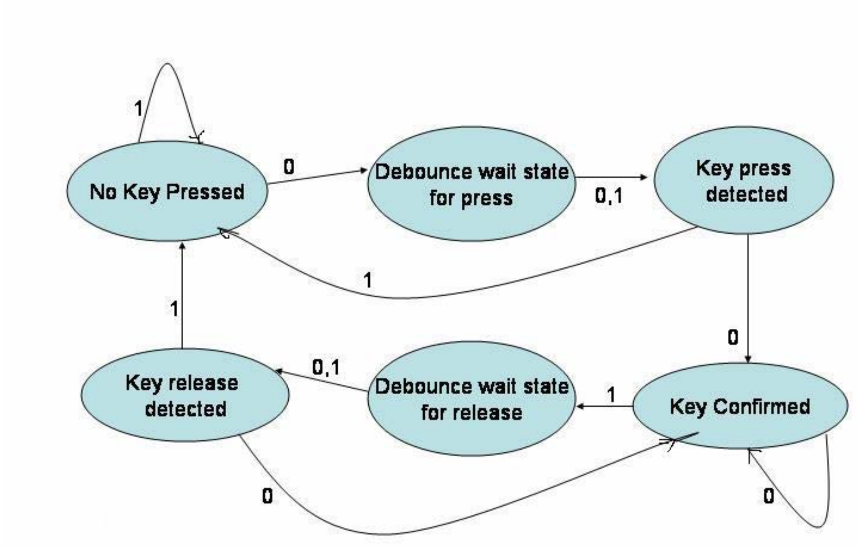

Figure 1: State Diagram for KeyBoard

Now when the interrupt from timer comes, we scan the keyboard according to state diagram presented in the Figure 1. At startup the system remains in “no key pressed” state. As soon as it detects pressing of a key it changes it state to “key press detected" again after one more debounce delay if the key still remains pressed the system changes its state to "key confirmed" and the value of the key is noted and stored. If the key remains pressed for more time the system doesn't change its state. Now when key is released, system changes its state to "key release detected" and then to "no key pressed".

Key 1	Key 2	Key 3	Key 4
Key 5	Key 6	Key 7	Key 8
Key 9	Key 10	Key 11	Key 12
Key 13	Key 14	Key 15	Key* Toggle

Figure 2: Keyboard Layout

As shown in Figure 2, there are 15 keys for the speed input and one special key to toggle between the modes named as "toggle key". If the detected key is toggle key, then instructions are sent to LCD subroutine and LCD displays messages to guide the user to select the desired mode and then give the input for the selected mode. Thus, if mode selected is normal mode only the new speed is needed to be entered. But if the new mode is linear mode then user has to tell the initial speed, the final speed and the time in between the variation in minutes. After the completion of all the above procedure the microprocessor goes in ideal mode and waits for next interrupt to come. The default starting speed is set to level 8 which corresponds to 50% duty cycle. As discussed above, there are 2 user modes for the microcontroller to run on:

1) *Normal mode*:- The speed input is directly taken and the speed instantaneously starts following the new speed. Its just like any normal regulator.
2) *Linear mode*:- This is the special feature included, and in this mode the speed varies linearly in between the initial speed to the final speed during the time interval specified. Thus, user has to specify all the three specifications. If at any point of specifying the input, the user changes his mind, he can again reset the system to the point where a choice is asked between the modes using the toggle key. While inputting the time a key is taken to be zero if its value is greater than 9. After the input of all parameters the settings are displayed for user to check whether the settings are desirable. The user can again change the settings by using the toggle key. Any other key will lead to implementing of the above settings. During the operation of linear mode all keys except the toggle key are de-activated. The full state diagram is shown in Figure 3.

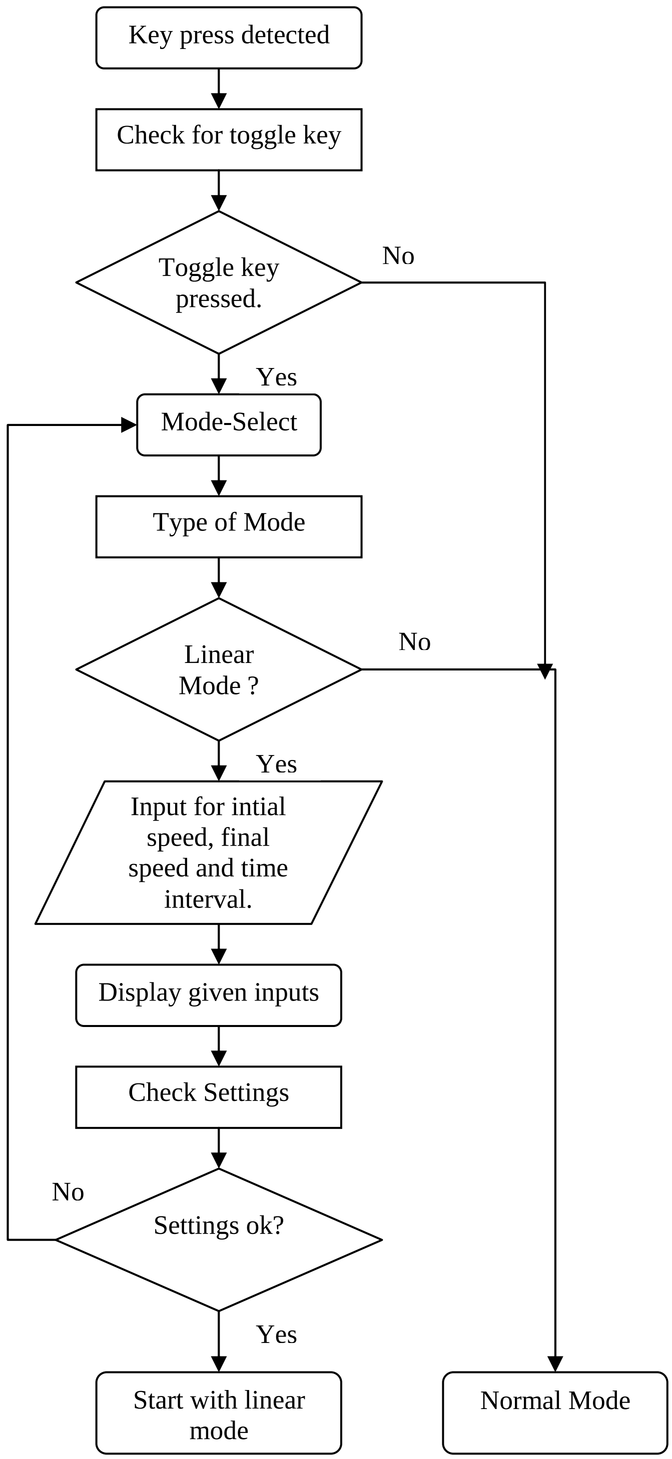

Figure 3 Flow diagram for mode selection.

3 DESIGN OF CIRCUIT

The circuit is divided into sub-circuits which when integrated perform the desired function. They have been described below.

3.1 Power supply voltage detection circuit

The low voltage side of the step down transformer (230V/9V) is connected to the full-bridge diode rectifier circuit and the high voltage side is connected to the power supply. The action of the full-bridge diode rectifier is to provide rectified full wave (ac to dc) conversion which is taken across a low pass filter consisting of a capacitor and resistor in parallel. The voltage across the capacitor is almost constant and has been used for two purposes, one for power to the rest of the circuit and the other for voltage measurement as an input to ADC. The first objective is achieved by a voltage regulator 7805 which provides a constant 5V supply. An 8-bit ADC-0809 has been used for the supply voltage measurement. Its voltage span has been adjusted to 0V-5.0V. A J, K Flip-Flop is used to divide the frequency of the ALE by 2 and then it is fed to the clock of ADC. ALE of the ADC is connected from the microcontroller through P3.6 pin. Pin 3.1 of microcontroller is asserted to give the start pulse to the ADC. After the conversion is completed, the microcontroller gets end of conversion signal through P3.7 pin. The digital values from are connected to port 1 with LSB connected to P1.0 and the MSB connected to P1.7 and the other bits in the same increasing order. The port is multiplexed with the data pins of the LCD controller.

3.2 Zero Crossing Detector

The two ends of the low voltage side of the step down transformer are further connected to resistor potential dividers. The voltage across the two legs of the resistor potential divider are connected to the inverting and non-inverting terminals of op-amp in LM324. The output pin of the LM324 is connected to P3.2 of the microcontroller. This provides the necessary interrupt to the microcontroller indicating the starting of a new cycle.

3.3 Microcontroller

Microcontroller basically does all the computation needed for the system to work. It is used to take input from keyboard about the mode of operation (single speed or settable user profile), speed (current, initial and final) and time gap between initial and final speeds, and then it accordingly provides firing pulses to the triac using the output of ZCD as reference and also calculated the voltage compensation. It displays the speed profile currently in use on the LCD display. Finally it keeps track of the number of supply cycles passed and the total number of cycles that has elapsed. The calculation of number of cycles to be passed and the decision whether a particular cycle is to be passed is taken every cycle. The number of cycles depends on the value fed back from ADC which gives an indication of the voltage applied. The randomization is done by implementing a 32 bit shift register.

3.4 LCD display

It displays the current speed profile in use, as well as displays messages to guide the user in selecting the desired profile. Port 3 pins of microcontroller are used to provide various control signals to LCD module. Port 1, multiplexed between ADC and LCD is used to give data to LCD from microcontroller.

3.5 Keyboard

It is used to take input from the user about the speed profile to use. One of the keys is used to toggle between constant speed operation and variable-speed operation. In the constant speed operation, the remaining keys select the desired speed (1 to 15). In case of variable-speed operation, first the initial speed is input, then the final speed and in the end, the time to reach the final speed (in minutes) is fed using the keys. The initial and final speeds can be from 1 to 15, whereas the time difference can be from 1 minute to 999 minutes (about 16-17 hours). Port 1 of microcontroller is interfaced with the keyboard. The keyboard is pulled high using a resistor bank. The keyboard scanning is done once every 20ms and decision is taken depending upon previous key pressed following the state diagram shown in Fig. 1.

3.6 Triac circuit

An opto-coupler (MOC3020) is used to provide the gate pulses to the triac BTA06, according to the control signal from the microcontroller and is also used to electrically isolate the 230 volts, load circuit side from the 5 volts, control circuit side.

4 TEST PROCEDURE

The testing is done by varying the speed by keyboard and observing the fan speed accordingly. Simultaneously, the waveform across the triac and pulses generated by the microcontroller were observed. Further the voltage compensation is tested by varying the input voltage using an autotransformer. It is easy to view for compensations only at minimum or maximum speed. At maximum speed, only the negative compensation, when voltage is increased could be observed as it is already at maximum speed so no more cycles could be added. The compensation could be seen by observing the speed or the corresponding increase (decrease) in the number of cycles passed when the voltage decreases (increases).

The testing was done for both the continuous and random firing of cycles. In continuous firing, all the cycles to be passed for that speed was passed in one go, while in random firing the cycles are spaced randomly over the span of 120 cycles.

The variable-speed user profile was tested by taking various combinations of the initial speed, final speed and the time difference. The speed varied linearly with time, according to the parameters specified.

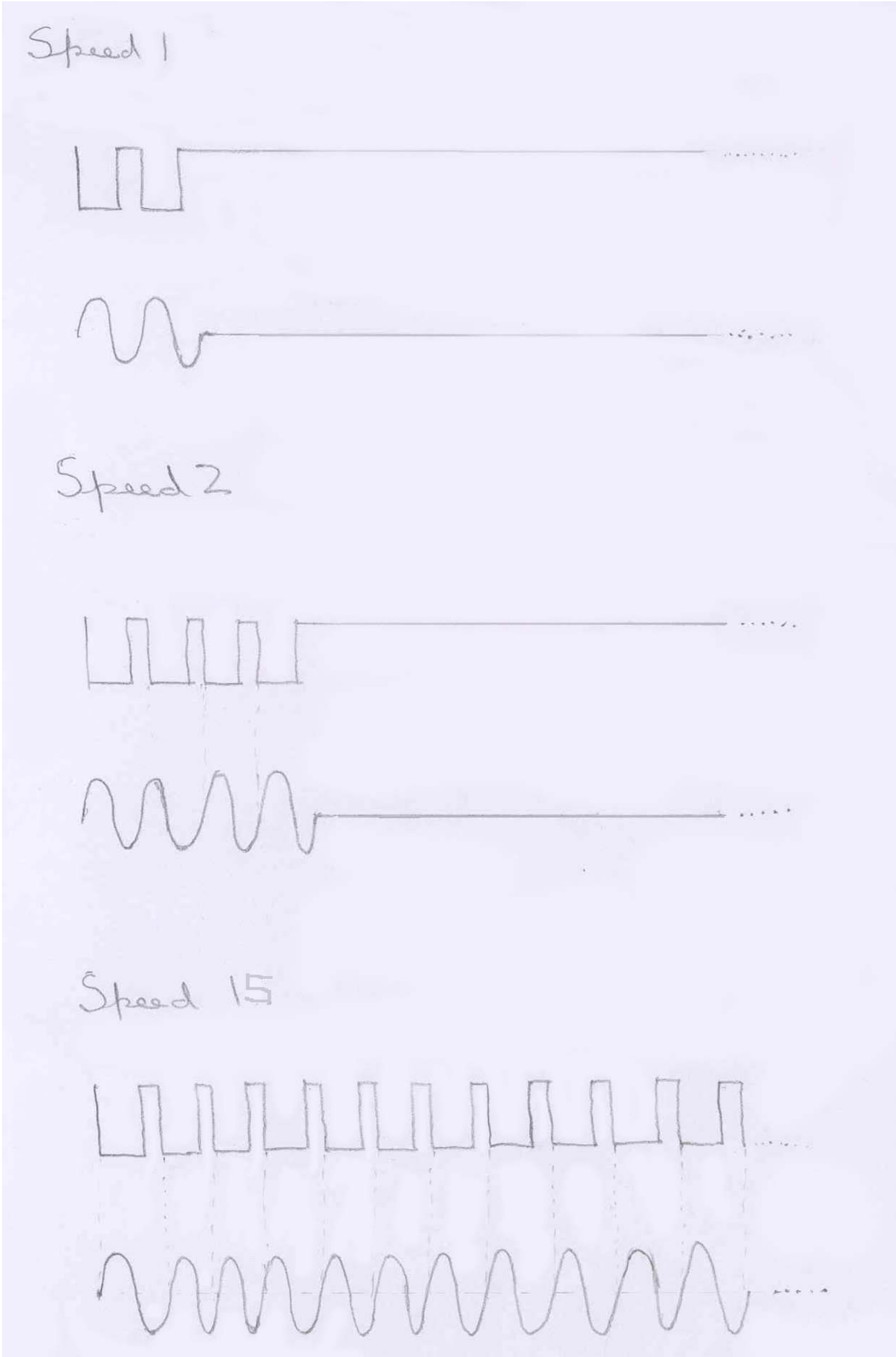

Figure 4 Cycle pattern for Continuous firing

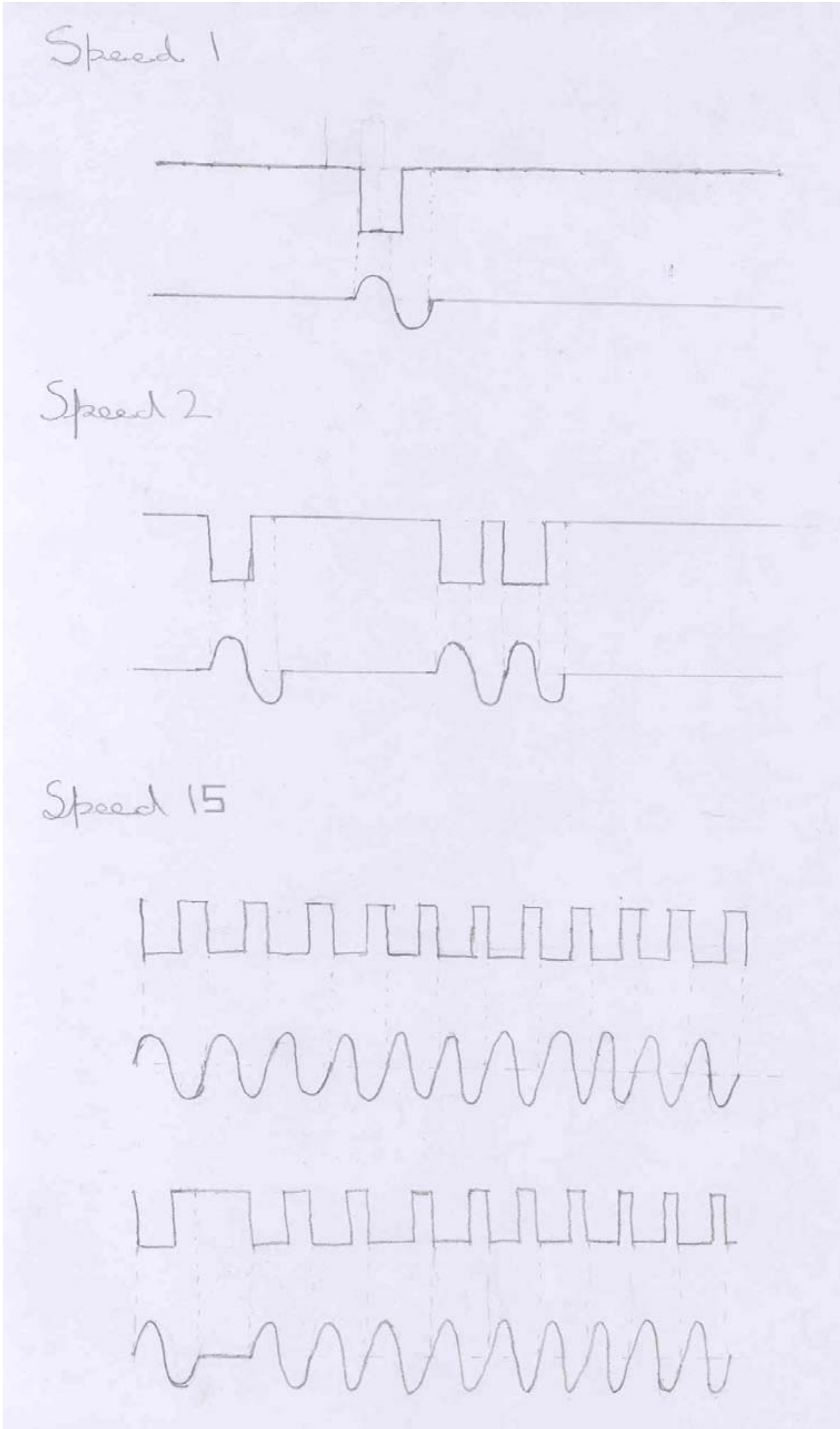

Figure 5 Cycle pattern for random cycles and compensation for speed 15

5 CIRCUIT DIAGRAM

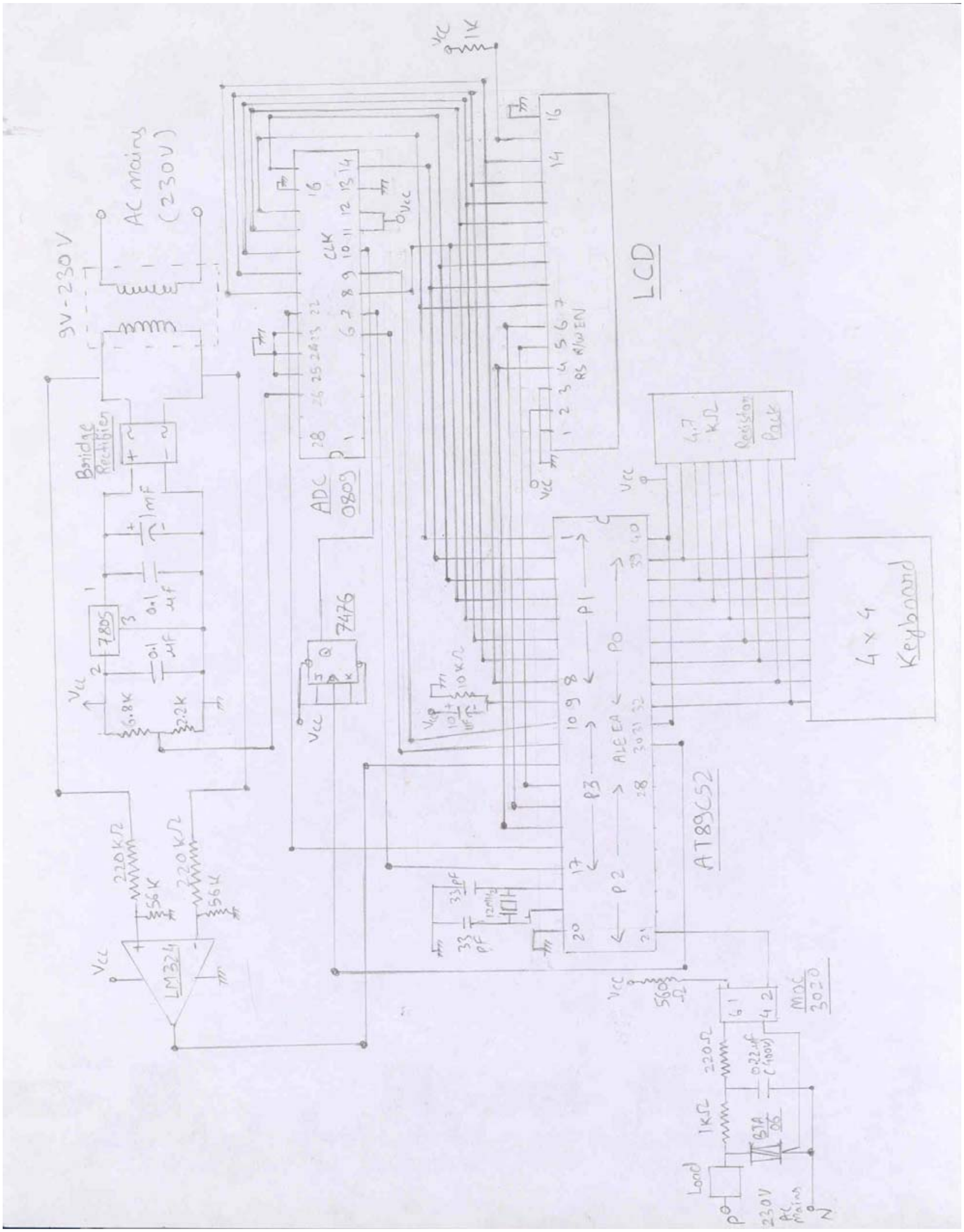

Figure 6 Circuit Diagram

6 TEST RESULTS AND INFERENCES

The results of the tests are shown in Fig 4 and 5 .The waveforms observed across the load were observed for both continuous and random firing of cycles. With random firing of cycles, the testing was done using both 8-bit linear shift register and 32-bit linear shift register. The knocking observed was much less with a 32-bit linear shift register compared to 8-bit shift register. This is due to the fact that 8-bit linear shift register repeats its output every 256 cycles which may lead to a periodic waveform causing resonance. There was knocking observed for both continuous and random firing. This knocking was less for continuous firing. This may be due to the fact that in continuous firing the motor is supplied voltage continuously for a certain number of cycles and the remaining cycles are blocked, while in case of random the same number of cycles will be distributed leading to larger number of switching between passed and blocked cycles.

7 CONCLUSIONS

The circuit was tested successfully in both the modes, normal and linear. The random firing and continuous firing was tested both for fan and bulb type of load. The results supported the fact that integer cycle control could be used for fan type of load but not for bulb type of load. In fact this control is more suitable for controlling heaters as the fan vibrates due to introduction of lower frequency harmonics. These vibrations were seen to reduce on using a 32 bit linear shift register instead of an 8 bit linear shift register for generating random numbers. User profile with linear variation in speed, and voltage regulation against line variation were successfully implemented.

The circuit can be modified to improve its performance and include more features. The circuit can be used to control multiple loads at same time providing a solution for a single fan regulator in halls. A real-time clock can be used with multiple alarms.

REFERENCES

[1] A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, Fourth edition (1982) New York, Oxford University Press, 2003.

[2] K. J. Ayala, *8051 Microcontroller, Architecture, Programming & Applications*, Mumbai, Penram International Publishing (India), 1997.

[3] Atmel Corporation, “8-bit Microcontroller with 8K Bytes Flash- 89c52”, www.atmel.com/dyn/resources/prod_documents/doc0313.pdf, last accessed on 21st April, 2006.

[4] National Semiconductor, “LM124/LM224/LM324/LM2902 Low Power Quad Operational Amplifiers”, http://cache.national.com/ds/LM/LM124.pdf, last accessed on 10th March, 2006.

[5] Fairchild Semiconductor, “6-Pin Dip Random-Phase Optoisolators Triac Driver Output”, http://www.fairchildsemi.com/ds/MO/MOC3020-M.pdf, last accessed on 22nd March, 2006.

[6] Fairchild Semiconductor, "KA78XXE/KA78XXAE 3-Terminal 1A Positive Voltage Regulator ", http://www.fairchildsemi.com/ds/KA/KA7805AE.pdf , last accessed on 16th March, 2006.