Control of Electrical Lights and Fans using TV Remote

Group No. D07
Anshu Jain (03d07005) <anshuj@ee.iitb.ac.in>
Sandeep Gupta (03d07014) <sandeepg@ee.iitb.ac.in>
Durga Prasad (03d07033) <dprasad@ee.iitb.ac.in>

Supervisor: Prof. P.C.Pandey

Course Instructors: Prof. P.C.Pandey & Prof. V.K.Tandon

Abstract

The objective of this design project is to build a system for controlling light intensity of an electrical bulb or speed of fan using a TV remote or using serial port interface. The system provides regulation against input power supply. Intensity/speed of the load is controlled by changing the RMS voltage across the load using triac circuitry that is by changing the corresponding firing angle at the gate of the triac. An ADC circuit monitors the unregulated input voltage, followed by software to check for voltage variation and provide regulation.

1. Introduction

The main aim of this project is to design an electronic circuit which can control intensity of an electric bulb and speed of a fan using infrared TV remote or using serial port interface.
RMS voltage across a triac is related to the RMS voltage of the mains according to the following relation

$$V_{rms(load)} = V_{rms(mains)}(1 - \theta/\pi)^{0.5}$$

Here, θ is the firing angle of the triac measured from the zero crossing point. Thus by changing the firing angle we can regulate the voltage across the load. Hence we can vary the intensity/speed of the light/fan. If θ is zero i.e. if triac is fired at the zero crossing, then maximum power is transferred to the load similarly if triac is fired at the peak of the cycle (i.e. $\theta = \pi/2$) then only half of the power is transferred to the load. Thus our main job was to generate these pulses according to the signal from the TV remote or serial port. We are also monitoring the attenuated unregulated DC input voltage using an ADC, so as to provide voltage regulation against the mains voltage. For regulation against the mains frequency we are changing the instance of firing of the triac.

2. Design approach: -

2.1 Block Diagram:

The block diagram (fig. 1) consists of:
- Power supply consisting of 230V/9V step down transformer followed by a bridge rectifier, a low pass filter and a 5V voltage regulator (7805).
- IR receiver for receiving the signals from TV remote.
- RS 232 level shifter for serial port interfacing.
- Two microcontrollers one for decoding the signals (40 pin) and other (20 pin) for generating the trigger pulse for triac.
- A zero crossing detector.
- ADC for voltage regulation.
- LCD for displaying the current status of the loads.
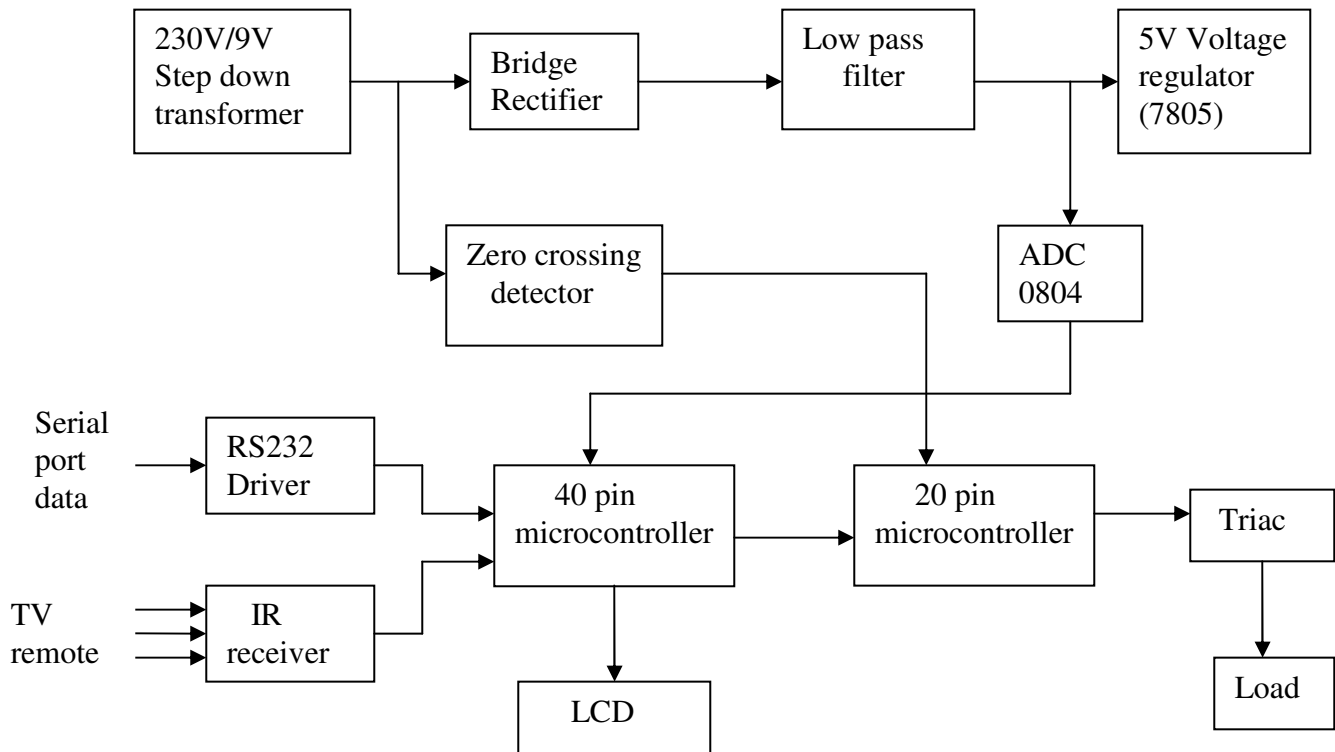- Triac circuitry.

Fig. 1 Block diagram

2.2 Description of the various blocks:

a) 5V Power supply

Fig. 2 shows the circuit to generate 5V DC supply from mains supply. For this purpose we used 230V/9V step down transformer followed by a bridge rectifier consisting of IN4001 diodes, low pass filter and 5V voltage regulator LM7805 (IC1). Output from transformer is also used to detect zero crossing. Capacitor C1 is used to filter the output

from bridge rectifier to generate unregulated DC supply (Vx) which serves as input for ADC and voltage regulator. C2 and C3 are used for frequency stabilization. This 5V DC supply is used for power supply for various chips in the whole circuit.
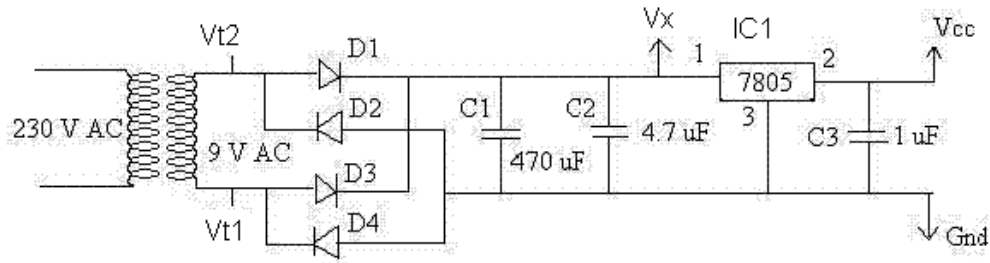

Fig. 2: DC power Supply Circuit

b) IR Receiver

We are using RC5 encoded remote. Every time a button is pressed at the remote control, it sends a train of 14 bits, 1.728ms per bit, the whole train is repeated every 130 ms if the button is kept pressed.
TSOP 1738 (IC2) is used as an infrared receiver. It's a 3 pin module with active low output. When no key is pressed on remote, it shows high output. Fig. 3 shows the pin diagram of TSOP. Output pin of TSOP is connected to pin 3.2 of 40 pin microcontroller AT89c42 (IC5).
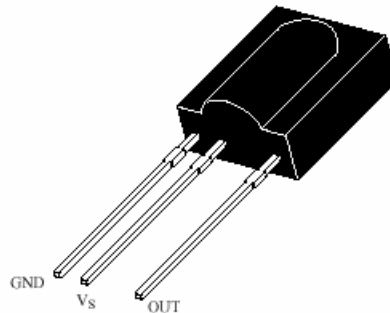
Fig. 3: IR receiver TSOP 1738 (IC2)

Fig. 4 shows the output signal from TSOP. This type of coding is called Manchester coding technically known as return to zero (RZ) format. In this coding each bit is divided into 2 half bits one as left bit and second one right bit. Bit value is determined by the transition at the center of the bit. If there is downward transition i.e. bit is changing from high to low at the center then bit value is one (Logic 1) and if there is upward transition at the center then value of that bit is zero (Logic 0).

Fig. 4: Output from TSOP

The first two bits in the bit train, #1 and #2, are called Auto Gain Control (AGC) calibration. They are ON on the left side or takes transition fro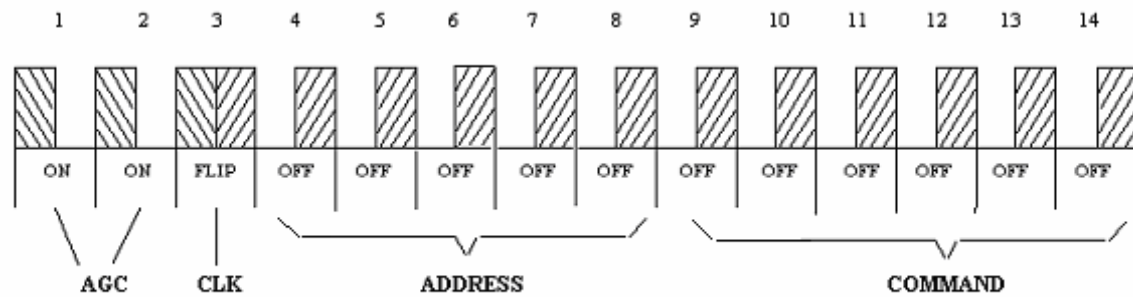m 1 to 0 at the center (Logic 1), and serve to calibrate the IR receiver's AGC. The bit #3 is the CHECK bit, every time a key is pressed at the remote (even repeatedly the same key) this bit flips state. The next 5 bits, #4 to #8, are used for SYSTEM ADDRESS, or to identify which kind of device should execute the COMMAND bits. The next 6 bits, #9 to #14, are used for COMMAND information to the device selected by the ADDRESS bits. Bit #14 is the LSB.

c) RS232 Driver

As we have to receive data so we are using only receiver part of RS232 driver. The level shifting of RS232 input for interfacing to the microcontroller has been carried out using IC3 (MAX232) as shown in Fig. 5. Pin 3 (TXD) of Male D9 connector is connected to pin 13 of MAX232 and pin 12 in connected to pin 3.0 of microcontroller 89c52.

d) IR Decoder

40-pin microcontroller AT89C52 is used to decode the IR signal from the TV remote and RS232. Here we are using a crystal of 11.0562 MHz so as to get a baud rate of 9600. The output of the TSOP is connected to pin P3.2 (external interrupt 0) and the serial data from Max232 is connected to pin P3.0 (serial interrupt).Whenever an interrupt comes at pin P3.2 the microcontroller first give a delay of 0.433ms so that we can read the mid point of any particular bit. Now as we don't need first 6 bits we skip the first 6 bits and read the next 8 bits by sampling the command bits (14 bit train) receive from the TV remote. Flow chart for decoding signal from TV remote is shown in Fig. 12.

This microcontroller is also being interrupted whenever computer sends a command over the serial port. The command consists of a train of 11 bits including the start bit and the stop bit with baud rate 9600.Microcontroller decodes this data by using the serial receiver (Rx) of the microcontroller.

After decoding the signal from the TV remote or from serial port this microcontroller also sends the instruction to the next microcontroller. This is done by setting the port 2 pins accordingly. First 3 bits P2.0, P2.1 and P2.2 denotes which load
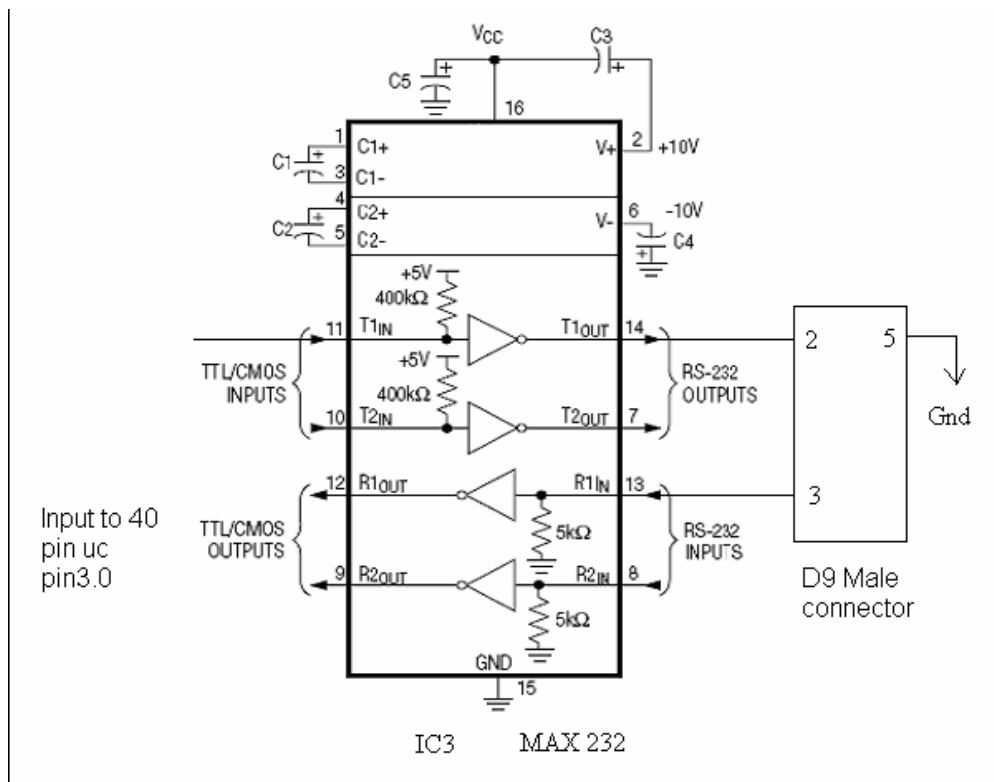
Fig. 5: RS232 Driver

to be executed. In our case we are using only 2 loads thus we need only 1 bit (P2.2). P2.2 is set if load is fan and is reset if load is light. But we can control 8 loads using this scheme. Next two bits are for the instruction to be executed which is coded as follows:

	P2.3	P2.4
OFF	0	0
ON	0	1
Decrease	1	0
Increase	1	1

Pin P2.5 is used to send a signal to the next microcontroller to show that a new key is pressed. P2.5 is complemented whenever a key is pressed on a TV remote or whenever a new data comes at the serial port. Remaining two bit i.e. P2.6 and P2.7 are not used thus can be used for some other purpose.

e) Zero Crossing Detector

Fig. 7 is circuit for zero crossing. Zero crossing is used as a reference for measuring firing angle of the triac. Output from transformer serves as input for low power quad OPAMP LM324 (IC4) (Fig. 6).

5

Connection Diagrams

Dual-In-Line Package
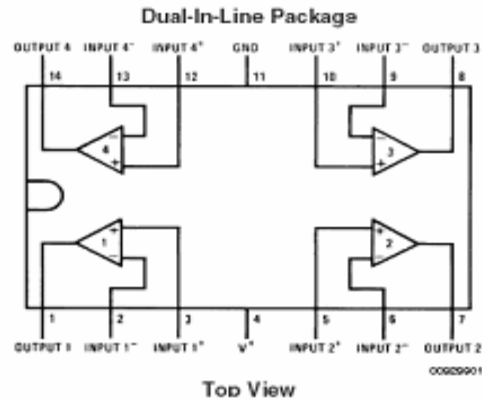
Fig. 6: Low power quad Opamp LM324 (IC4)
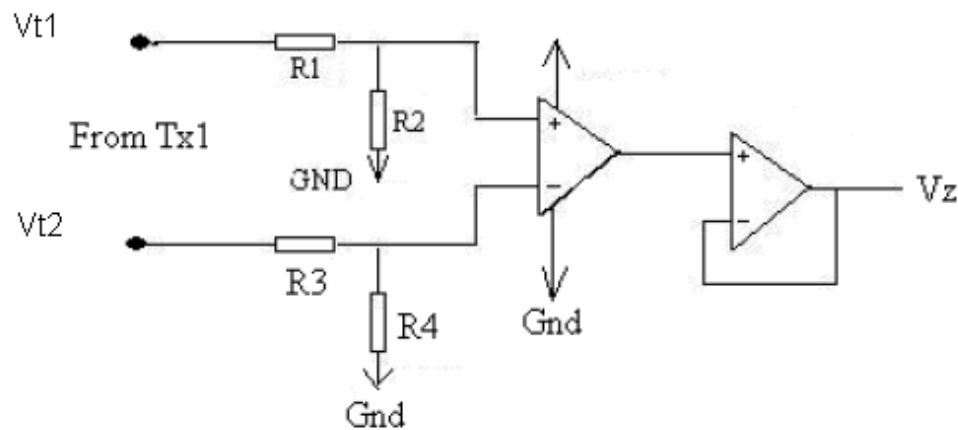
Fig. 7: Zero crossing detector circuit

LM 324 has four opamps. One of them was used as comparator with input as output from transformer followed by potential divider while 2nd opamp was used as a buffer which avoids comparator output getting loaded by microcontroller. Because the output of LM741 is bipolar and thus it can damage microcontroller so we used LM324.

Output from the buffer Vz is connected to pin 1.0 of 20 pin microcontroller AT89c2051(IC6).

R1 = R2 = R3 = R4 = 1K ohm.

f) Voltage Regulation against mains power supply

For regulation against voltage supply we used ADC0804 which is one channel input ADC. It's a 20 pin chip with differential input voltage range 0V-5V. Unregulated DC voltage (Vx) followed by a potential divider is used as input for ADC (pin 6). A register R of 10K and capacitor C of 150uf are used to generate a clock frequency of 640
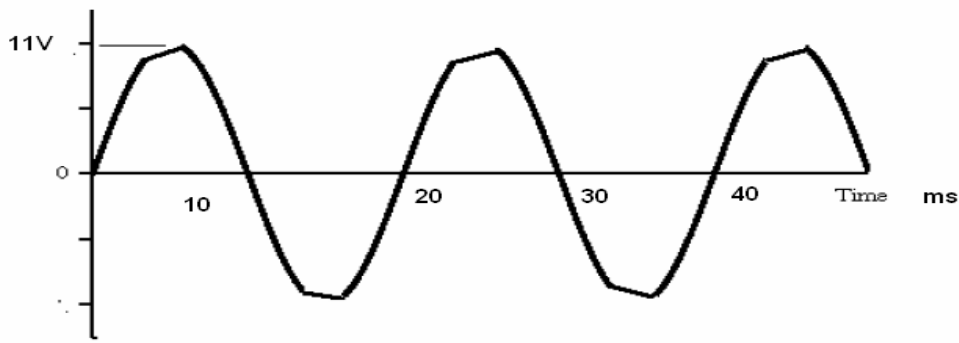
Fig 8 (a): Ouptput waveform across transformer

Fig. 8 (b): Output waveforms of zero crossing detector
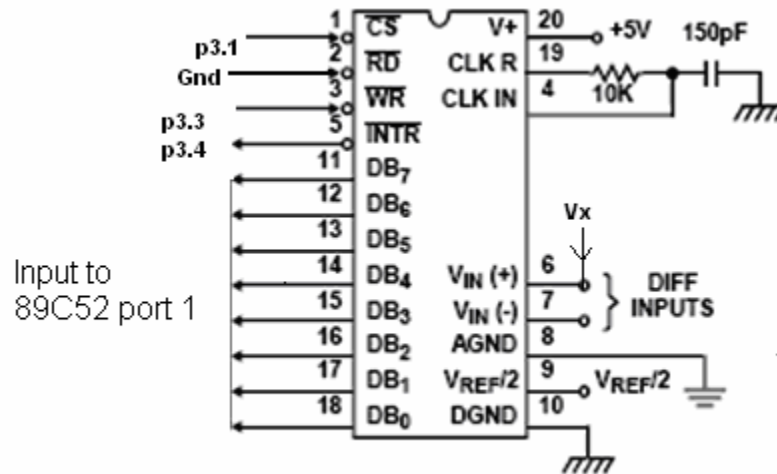
Fig. 9: ADC0804

KHz. Because Vx has magnitude about 10V so we used potential divider to make the input for ADC with in chip's input voltage range.

Voltage span of ADC is made 2.2V to 7.2 volts by providing constant 2.2V to the negative input pin of ADC. Here we are assuming voltage variation from 200V to 250V with 230V normal voltage. So our input voltage to ADC changes from 2.2V to 2.9V. We used a limiter circuit followed by a zener diode of 2.2V breakdown voltage for this purpose. Chip select low pin of ADC is connected to pin 3.1 of 89c52, write low to pin 3.4 and INTR low to pin 3.5. Output from ADC pin 11 to 18 are multiplexed with LCD and connected to pin p1.0 to p1.7 of the microcontroller 89c52. When ADC subroutine is

called in the program p3.1 is made active low. Thus ADC chip is selected. p3.4 is made active low for some time interval (about 10 us) and then made active high. ADC starts conversion after 1 to 8 clock periods and when conversion is completed it interrupts microcontroller. Interrupt pin is connected to p3.5 of 89c52. We are comparing output of ADC (pin 11 to pin 18) with output corresponding to 230V and changing the firing angle of triac accordingly.

g) Firing pulse generation

20 pin microcontroller AT89C2051 processes the instruction form the first microcontroller and generates the triac firing pulses accordingly. Output from the zero crossing detector is connected to pin p1.0 and is used to get the count for the half cycle. This count is then used to get the counts for the various levels. Zero crossing detector output is also used to synchronize the triac pulse with the input supply frequency. Fig. 13 shows the flowchart for its working.

h) Triac:
A triac is a three terminal semiconductor device that is triggered by a low-energy signal applied to its gate. The supply to the triac is an AC signal and it will always turn off when the applied voltage reaches zero at the end of the current half cycle. If a turn on pulse is applied, the triac goes from a high-impedance state to a conductive state, and it starts conducting current through the load. So the position at which this turn on pulse is fired (firing angle) directly control the percentage power of that half-cycle transmitted to the load.

$$\mathbf{P}_{load} = \mathbf{P}_{main}\,(1-\theta/\pi)$$
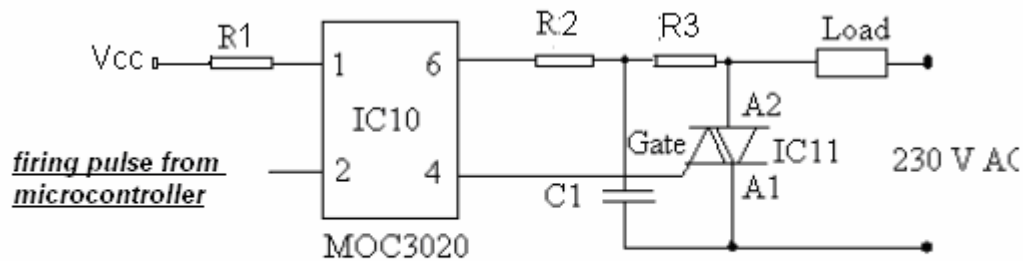
Fig. 10: Triac circuit

The pulses from the microcontroller are connected to the pin 1(the anode of the photodiode) of the opto-coupler MOC3020 and the cathode (pin 2) is connected to the ground. On the pulses, the photodiode radiates and drives the triac inside MOC3020. In this part the pulses are in optical form hence providing the optical isolation between the triac load circuit and the electronic circuit. The diac of the opto-coupler further drives the triac with the load connected between a power supply terminal and A2 terminal of the triac and the other power supply terminal and A1 are shorted.
R1 = 560 Ω; R2 = 250 Ω; R3 = 1k Ω; C1 = 0.22μF.

i) LCD Display:

The LCD display contains two internal byte wide registers, one for commands (RS=0) and the second for characters to be displayed (RS=1). Pins 1 and 3 are connected to the ground, and pins 7 to 14 are connected to Port 1 of the microcontroller AT89C52 to furnish the command or data byte, and pins 4,5 and 6 (register select, read/write and enable high signals respectively) are connected to 3.5,3.6 and 3.7. Pin 14 of LCD is monitored for logic high (busy) to ensure the display is not overwritten.
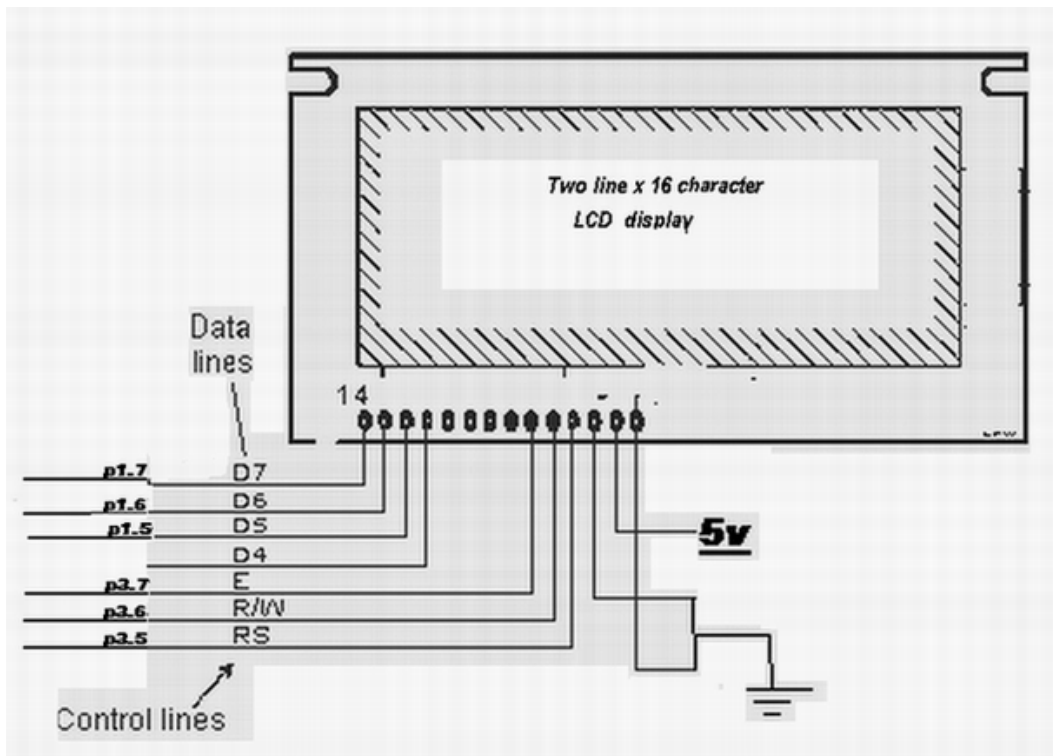
Fig. 11: LCD display

Each time a remote key is pressed it displays the respective levels of each load and holds till a new signal is received by an IR receiver.

9

```
                    ┌─────────────┐
                    │    START    │
                    └─────────────┘
                           │
                           ▼
                  ┌──────────────────┐
                  │  Wait for falling│
                  │  edge at IR output│
                  └──────────────────┘
                           │
        ┌──────────────────┤
        │                  ▼
        │              ◇ If IR ◇
  No ───┘              receiver
                       output=0
                           │ Yes
                           ▼
                  ┌──────────────────┐
                  │  Give a delay of │
                  │  0.433ms, count = 8│
                  └──────────────────┘
                           │
                           ▼
                  ┌──────────────────┐
                  │  Skip first six bits│
                  │  i.e. give a delay of 6 x│
                  │  1.732 ms         │
                  └──────────────────┘
                           │
                           ▼
                  ┌──────────────────┐
                  │  Move IR output into C│
                  │  bit and RLC through │◄───┐
                  │  accumulator.     │    │
                  └──────────────────┘    │
                           │              │
                           ▼              │
                  ┌──────────────────┐    │
                  │  Give a delay of 1.732│  │
                  │  ms, decrement count │ │
                  └──────────────────┘    │
                           │              │
                           ▼         No   │
                       ◇  If  ◇───────────┘
                       Count=0
                           │ Yes
                           ▼
                    ┌─────────────┐
                    │    STOP     │
                    └─────────────┘
```

Fig. 12: Flowchart for IR decoding

```
                    ┌─────────┐
                    │  START  │
                    └─────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │ Get the count for one half cycle  │
        │ from zero crossing detector       │
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │ Get the count corresponding to    │
        │ various levels                    │
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │ Wait for the instruction from     │
        │ the first microcontroller         │
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │ Synchronize with the mains        │
        │ frequency                         │
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │ Load the count according to       │
        │ instruction from first            │
        │ Microcontroller and run timer     │
        └──────────────────────────────────┘
                         │
                         ▼
        ┌─────────────┐  Yes      ╱╲
        │ Set the firing│◄────────╱    ╲
        │ angle pulse at│        ╱ Interrupt ╲
        │ port pin      │        ╲  from    ╱
        └─────────────┘         ╲ timers ╱
                │                  ╲╱
                │                   │ No
                └──────────────────►│
                                    ▼
                          ╱╲
                Yes      ╱    ╲
        ◄───────────────╱ New key is ╲
                        ╲  pressed   ╱
                         ╲          ╱
                          ╲╱
                           │ No
                           ▼
```
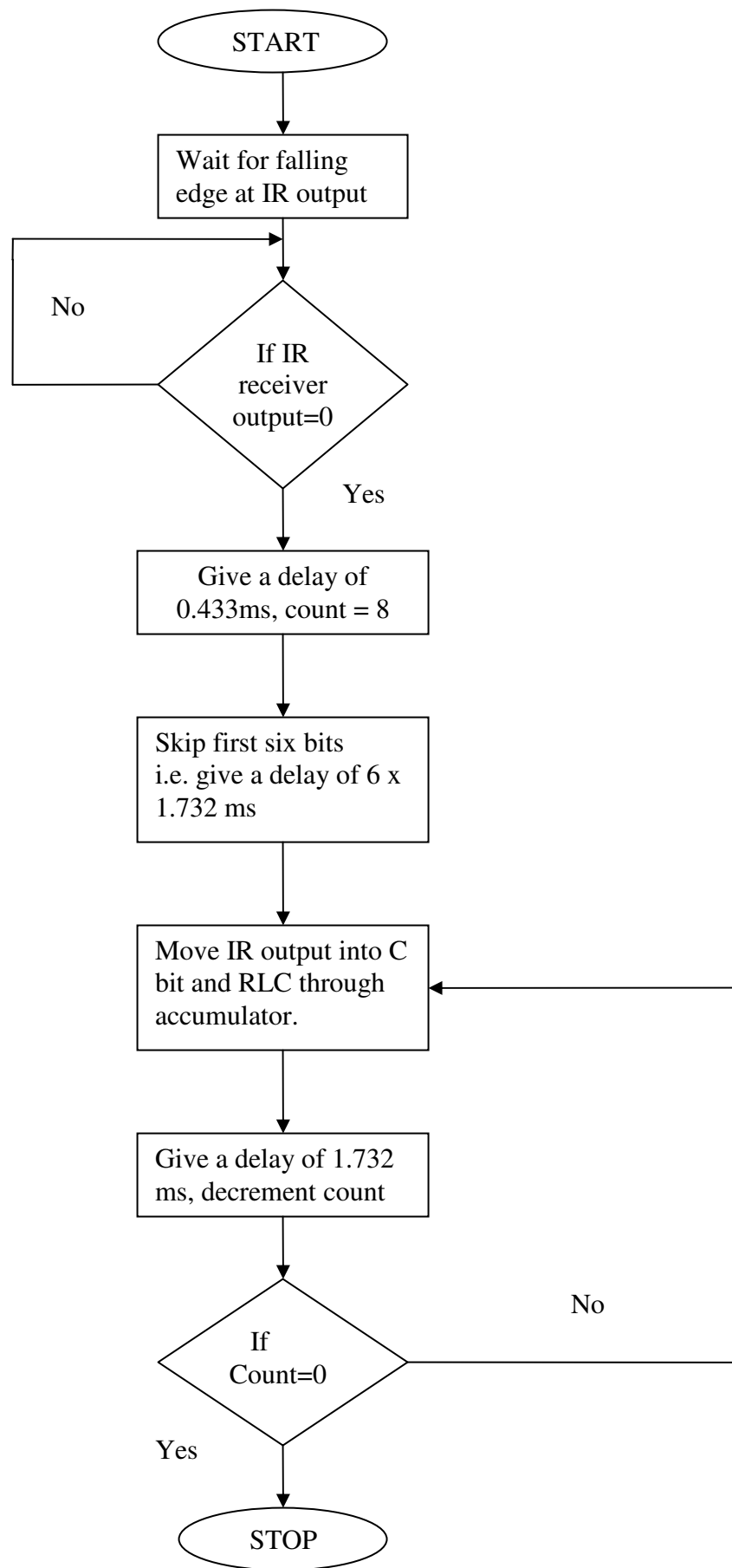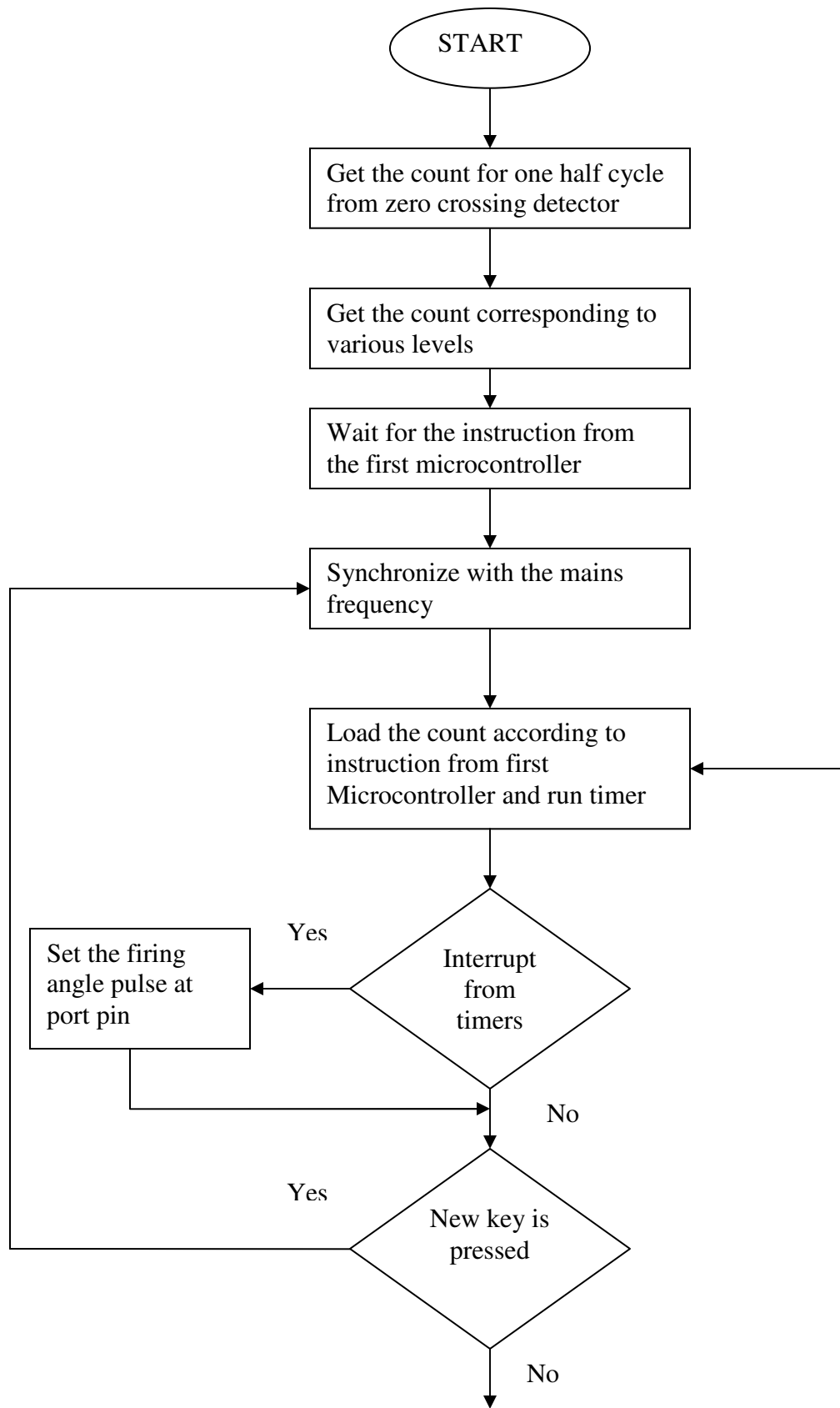
Fig. 13: Flowchart for the generation of triac pulses

11

Fig. 14: Complete Circuit Diagram

Voltage
240.5V peak
to peak

0

10   20   30   40   50 →
                    time (ms)

a

b

↑
V +

194V peak
to peak

0

10   20   30   40   50
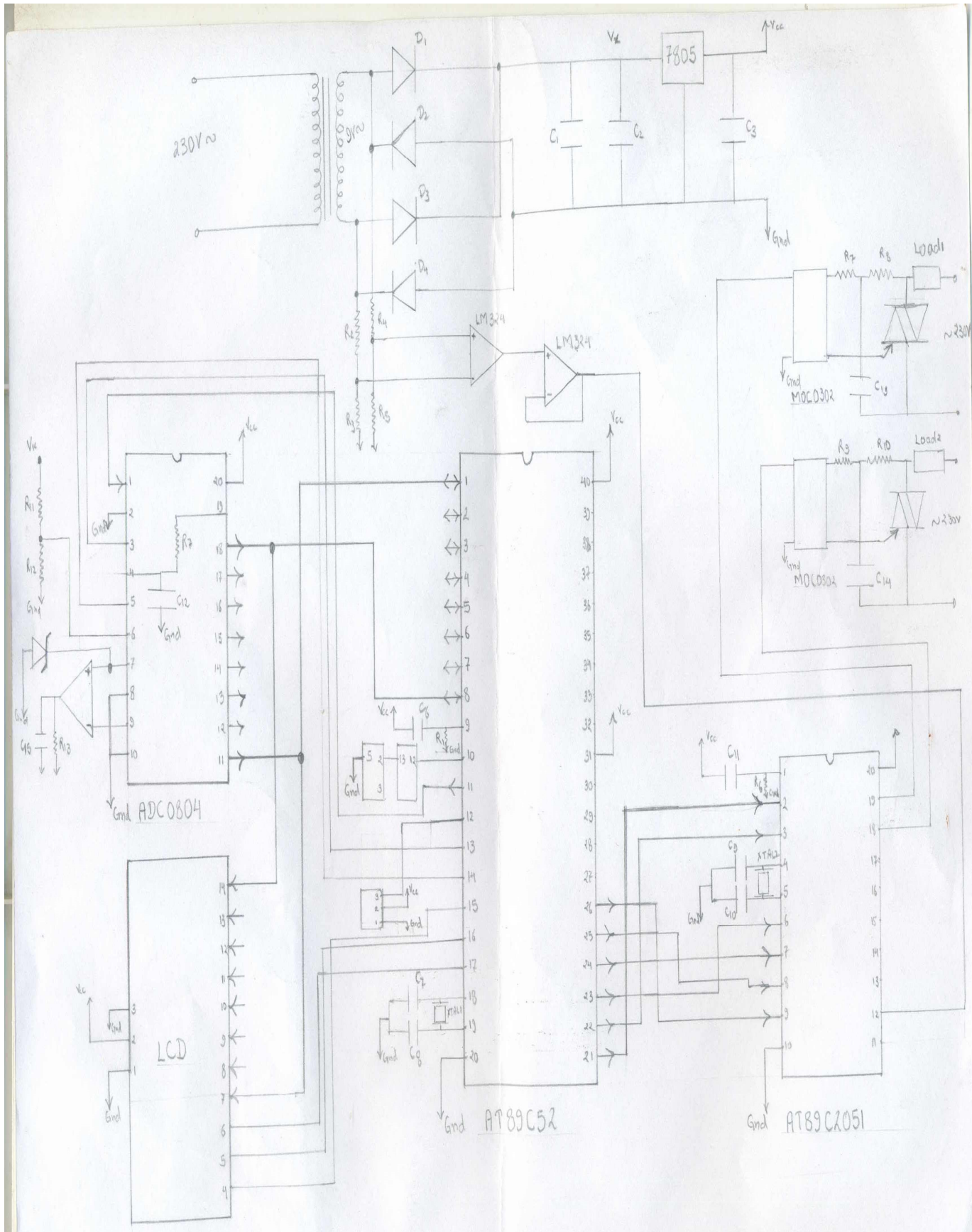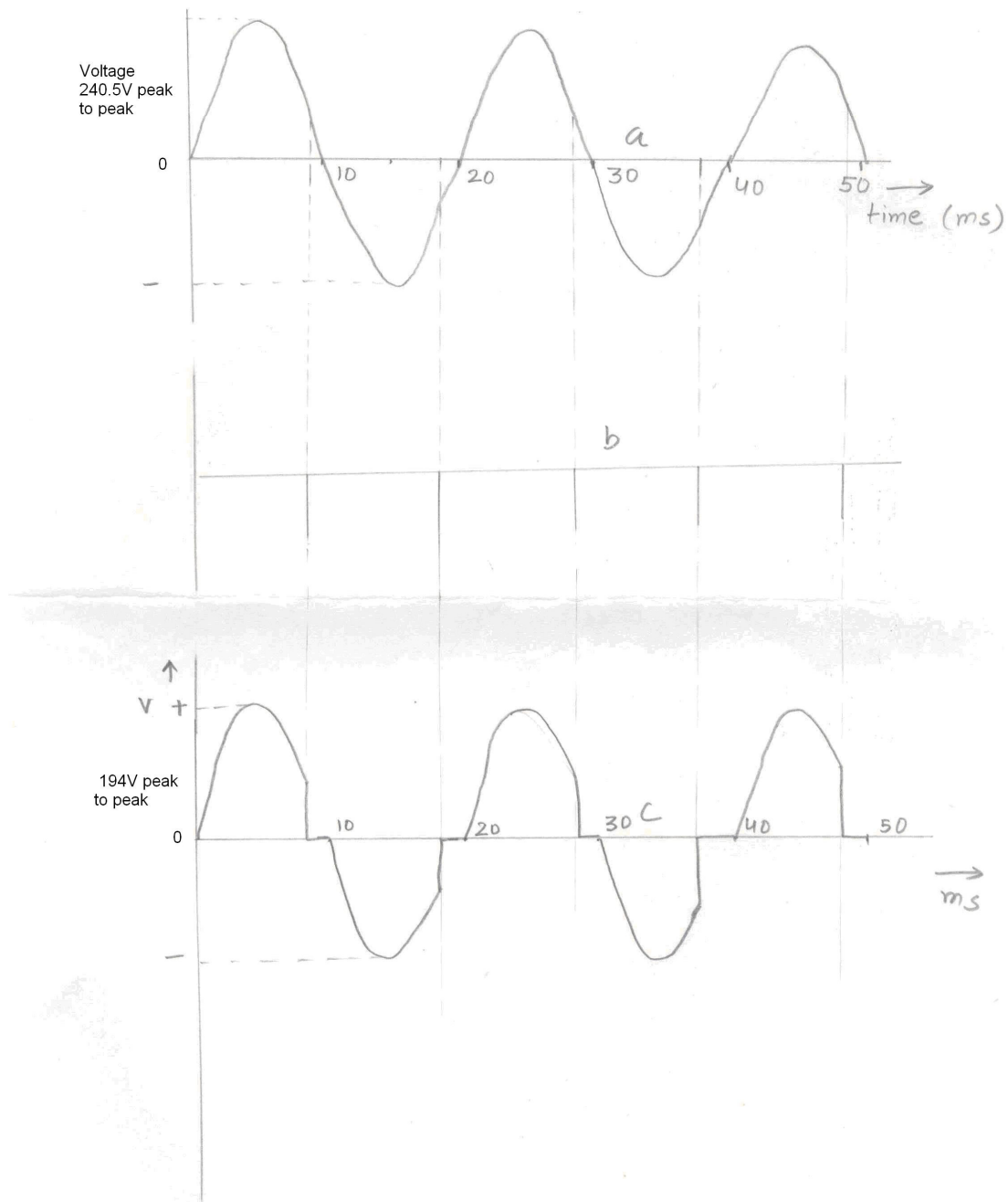
C

→
ms

Fig. 15: a) Voltage waveform of mains supply
b) Pulse pattern at the gate of triac at level 1
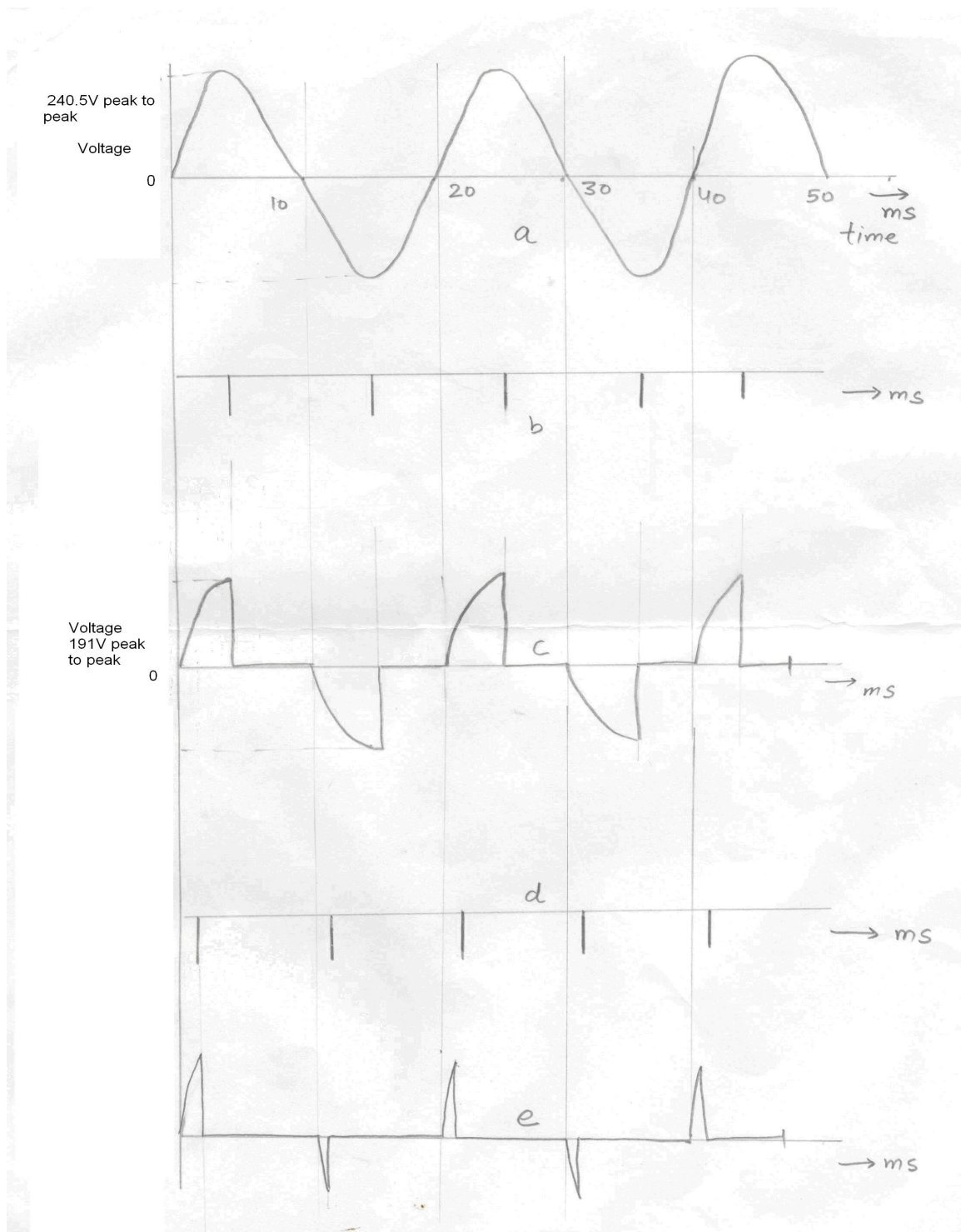c) Voltage across triac at level 1

Fig. 16: a) Voltage waveform of mains supply
b) Pulse pattern at the gate of triac at level 4
c) Voltage across triac at level 4
d) Pulse pattern at the gate of triac at level 7
e) Voltage across triac at level 7

3. Implementation

Fig. 14 shows the complete circuit diagram. Figs. 15 and 16 show voltage waveforms for mains supply, pulse at triac and voltage across triac for level 1 (ON), 4 and 7 (maximum speed/intensity).

4. Conclusion

Intensity of a bulb and speed of the fan can be controlled in 8 different levels including ON and OFF using a TV Remote or a Serial port interface. The level at which different loads are operating is displayed on a LCD.

5. Further Scope

As one of the ports of AT89c52 is still unused, a keypad can be provided to control this system or this port can also be used to provide internet connectivity to the system. A little beyond this can also be thought of, where the device is instructed through the instructions, sent in an SMS, from a cellular phone.

References

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

[2] K. J. Ayala, "8051 Microcontroller, Architecture, Programming and Applications", Penram International Publishing (India) (2001).

[3] National Semiconductors, "National Analog and Interface Products Databook", National Semiconductors (2001).

[4] http://symlink.dk/electro/hd44780/

[5] 8052 Resources, Vault Information Services. [Online]. Available: http://www.8052.com

[6] Infrared Remote Control Tutorial, Universal Solution Technology Research Inc. - Orlando, FL USA 32837-5314. [Online]. Available: http://www.ustr.net/infrared/infrared1.shtml

[7] AT89C51 Datasheet, Atmel Corporation, [Online]. Available: http://www.atmel.com/dyn/resources/prod_documents/doc0265.pdf

[8] TRIAC tutorial, American Microsemiconductor Inc., [Online]. Available: http://www.americanmicrosemi.com/tutorials/triac.htm

[9] LM324 Datasheet, National Semiconductor Corporation, [Online]. Available: http://www.national.com/pf/LM/LM324.html

[10] Building a 5 Volt power supply, Iguana Labs, [Online]. Available: http://www.iguanalabs.com/7805kit.htm

[11] IN4001 Datasheet, ChipDocs, [Online]. Available: http://www.chipdocs.com/pndecoder/datasheets/ZOWIE/1N4001.html

[12] TSOP1738 IR Receiver Datasheet, Vishay, [Online]. Available: http://www.vishay.com/docs/tsop17.pdf

6. APPENDIX:

User Manual
    a) For Remote

1	Light ON
2	Light OFF
3	Fan ON
4	Fan OFF
Ch up	Increase Light Intensity
Ch down	Decrease Light Intensity
Vol up	Increase Fan speed
Vol down	Decrease Fan speed

    b) For Computer

1	Light ON
2	Light OFF
3	Fan ON
4	Fan OFF
5	Increase Light Intensity
6	Decrease Light Intensity
7	Increase Fan Speed
8	Decrease Fan Speed