Water jet/shower with electronically controlled flow and temperature setting

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Abstract:
The main objective of this design project is to design a Water jet/ shower where the temperature and flow of the jet can be controlled electronically by the user, using simple up-down buttons both temperature and flow of the water can be set independently according to user's choice.

Contents:

1. Introduction:

1.1 Motivation

The motivation behind creating a water jet/shower is to provide user with more flexibility in terms of controlling the temperature and flow of the water coming out of the jet, for various applications. The process that is used in normal household is heating the water in geysers and then mixing the hot and cold water to obtain the required temperature. Some prototypes of this equipment exists in foreign markets but they are too expensive for an Indian household use.

1.2 Design Approach

The flow and temperature of the jet is decided by the rpm of the motor and the current supplied to the heating coil respectively. Both of them can be controlled using the integral cycle control mechanism.

Temperature of the jet can change in two ways:-

1. When the user gives the required instruction to do so.
2. When the flow of the jet changes, since the amount of water getting out per second changes.

Since both of these changes can take place if the user instructs so, therefore the equipment can easily adjust the amount of current given to the heater coil accordingly in order to keep the temperature in accordance to the user's demands.

1.3 Integral Cycle Control

1.3.1 Mechanism for integral cycle control

In integral cycle control, control is achieved by applying supply voltage to the load for a specific period of time called on time (Ton) and then disconnecting the supply voltage for a 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 in that radio frequency interference is minimized.

Integral cycle control may be used in some applications such as heating, lighting, and ac and dc motor control.

1.3.2 Integral cycle control's application in our case and some issues

For inductive loads, as is our case a dc offset component will appear in the load current depending on the triac firing angle. This component is undesirable since it may cause magnetic saturation and large peak load current. We have used a feedback-controlled digital circuit that provides for integral cycle control of power in RL loads. The circuit eliminates the dc offset component of load current,
here we have developed a self-adjusting microprocessor-based system for ac power control of RL loads

Fig. 1.3.1 shows the circuit components of the system under investigation. It consists of a static RL load connected to an ac supply via a triac. The microprocessor system provides the firing pulses for the triac.
During conduction, the load current i can be expressed as

$$i = \frac{\sqrt{2}V}{Z}[\sin(wt - \phi) - \sin(\alpha - \phi)e^{(R/L)(\alpha/w - t)}] \quad \mathbf{A} \qquad (1)$$

where V is the r.m.s. supply voltage, a is the triac firing angle with respect to the supply zero voltage, and $Z\ L\phi$ is the load impedance. It is clear from (1) that in order to eliminate the dc offset component, should be very close to ø **.** The angle α can be set to an arbitrary value α (intial) ; during the first burst of conduction.
The microprocessor adjusts α closer to ø at every succeeding burst. If α(initial) ; is not chosen properly, high peak current value is obtained.
The microprocessor is programmed to measure the angle *ø1* (Fig. 2) at the last supply voltage cycle during the ON period. This will make *ø1*closer to ø since the dc component is allowed to decay before measurement

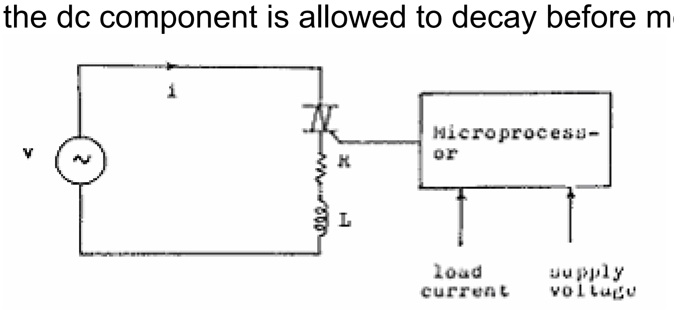

Fig.1.3.1 System under study

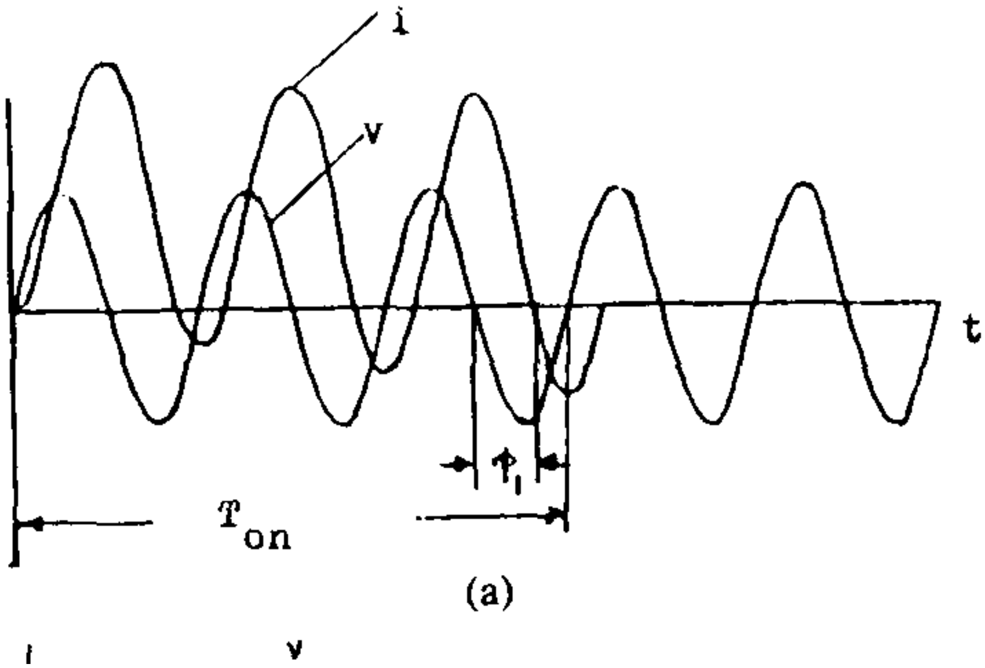

Fig. 1.3.2 Waveform of current and voltage

2. Hardware implementation

2.1 Zero crossing detector circuit

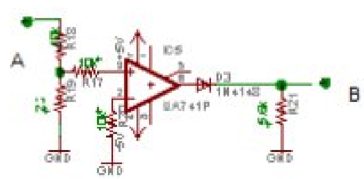

Fig 2.1 Squarer Circuit

As shown in Fig. 3 circuit consist of a Operation Amplifier based comparator circuit which converts the sinusoidal waveform into the square waveform such that zeros of the square are at the same location as that of original sinusoidal signal. But since microprocessor works at +5V,we operate our Operation Amplifiers also at -5V and +5V. So the resulting square wave is between -5V to +5V(i.e. 10V peak to peak). To rectify this signal for getting the square wave of 5V peak to peak, we use half wave rectifier (simply a diode to remove the lower part of the square wave.

Now these square wave (one each of voltage and current is given to microprocessor at pin p1.6(current) and pin p1.7(voltage).

Microprocessor use these signals to calculate the lag between the voltage supply and the current flowing in the circuit and to trigger the gate of Triac exactly at the point where current and the circuit crosses the zero line

2.4 Triac-Load circuit

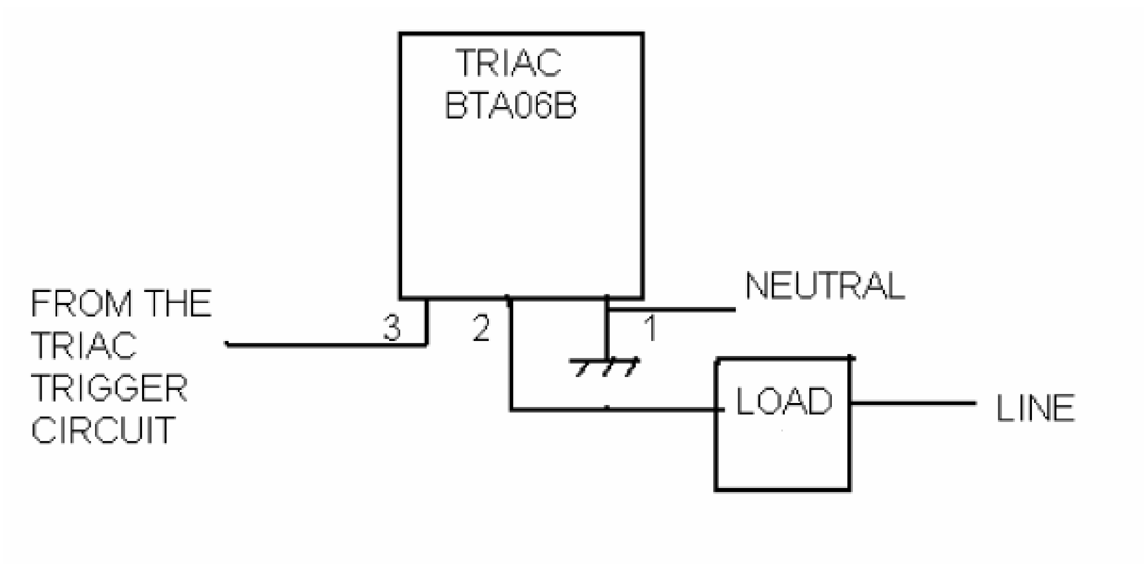

Fig 2.4 A general connection between a load and the TRIAC (BTA06B)

The neutral, of the power mains, goes to the common ground. The line of the Power Mains goes to one end of the bulb, the other end of the load being connected the pin A2 of the TRIAC (Fig 2.4). TRIAC is a three terminal semiconductor for controlling current in either direction. The main or power terminals are designated as MT1 and MT2. When the voltage on MT2 is positive with regard to MT1 and a positive gate is applied, the left SCR conducts. When the voltage is reversed and negative voltage is applied to the gate, the right SCR conducts. Minimum holding current must be maintained in order to keep a TRIAC conducting. A TRIAC operates in the same way as the Semiconductor Controlled rectifier; however, it operates in both the forward and reverse direction. Major considerations, when specifying a TRIAC, are:

a) Forward & Reverse break-over voltage
b) Maximum current
c) Minimum holding current
d) Gate Voltage and gate current trigger requirements
e) Switching speed

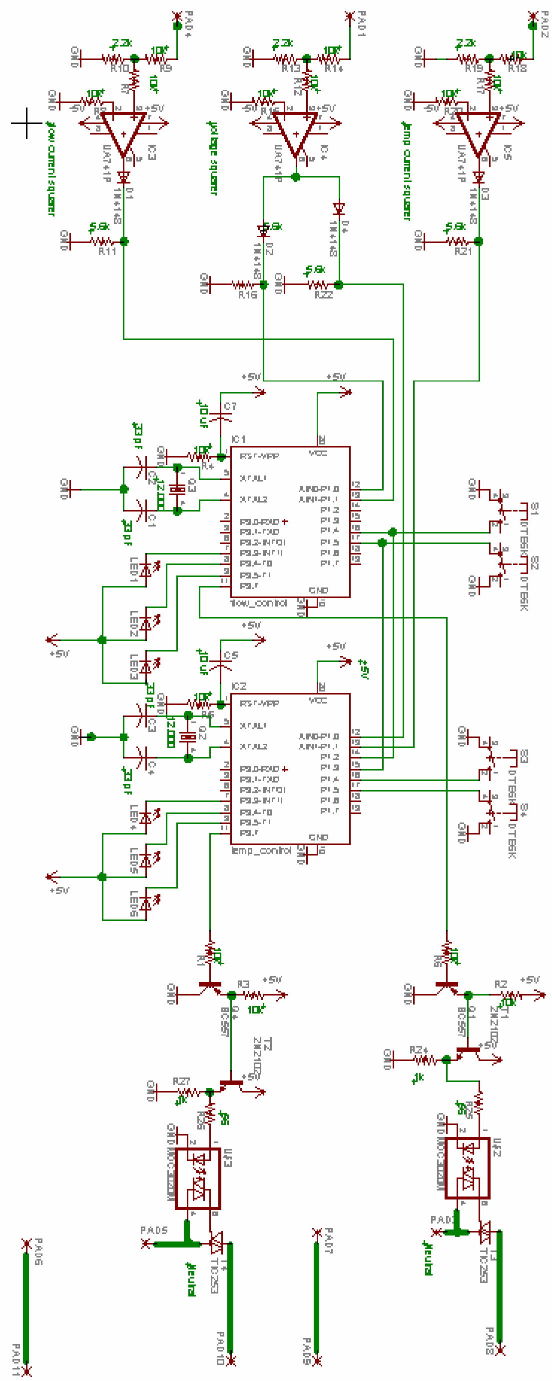

Fig. 2.5 Complete circuit diagram

3. Software

3.1 Algorithm for integral cycle control

Port p1 of the microprocessor is programmed to operate as an input port as well as output port (p1.4 and p1.5),whereas port p3 is programmed to operate as an output port. The flowchart of the program developed to control the system operation is shown in Fig. lookatno. When the system is started, the register R4 and R5 are loaded with its initial value. This initial value is a number representing a time delay that corresponds to an angle α initial*;* at the voltage supply frequency. This angle is equal to the chosen initial value of the triac angle. Afterwards, the microprocessor outputs a logic level 0 through bit 7 of port 3. After performing an input high test on input *A(Voltage square waveform)* at pin p1.7*,* registers R7*, R6,* and *R3* are loaded with their initial values. The initial values of *R7* and *R6* are, respectively, the values of the required ON and OFF supply cycles of the integral cycle power control circuit. The register *R3* is used as a counter, and therefore, its initial value is always zero. The input *A* is then tested for a low input. The reason for doing an input high test followed by an input low one, at the beginning, is to assure that the system is operating correctly, irrespective of the instant of switching on. When input *A* goes high at the end of the input low test, the microprocessor

starts a repeated loop of decrementing and testing R4 and R5*.* When both are zero, the microprocessor produces a logic level 1 through bit 7 of output port p3*.* Assuming that the loop time is equal to *D μs,* the number *N* to be loaded initially into *R4 and R5* to produce a delay angle of α initial ; degrees at 50 Hz is given by

N = (5 ms x α initial*;)/(D μs* x 90) = *500* α initial */9D.* (2)

The above sequence means that bit 7 of port p3 will go low for a time corresponding to α initial*;* and then goes high, producing a pulse with a duration equal to the number of ON cycles stored in *R7.* This is achieved by a repeated delay loop that decrements *R7* at every positive half supply voltage cycle. When *R7* = 0, this indicates the end of the last positive half of the ON cycles. At this instant, the microprocessor starts testing input *B(current square waveform)* at pin p1.6*,* which represents the load current, to measure an approximate value *ø1* of the angle *ø* between the load voltage and current (Fig. 5). This is done by looping and incrementing

R3 as long as input *B* is high. It is to be noted that this loop time must be equal to *D* to obtain correct results.The number obtained in *R3* at the end of this test is copied into *R4 and R5* to be its new initial value at the next cycle for executing the main program. An input low test is then performed on input *A* to indicate the completion of the required number of ON cycles. At this instant, bit 7 of port 3 goes low to end the triac triggering pulse. The output of bit 7 of port 3 is kept low for a duration equal to the number of the required OFF cycles. This is done by another repeated delay loop that decrements R6 at every supply cycle. At the end of this test,the microprocessor jumps back to set the initial value of *R7,R6,* and *R3,* and the above sequence is repeated.

Every new cycle will have a new value of α initial,which is equal to the value of *ø1* measured at the preceding cycle. After a few cycles, the measured value *ø1*, will be almost equal to the actual phase angle ø between load current and voltage,and hence, the dc component will be removed from the load current waveform.

Maximum no of on cycles are fixed to 7. Whenever the key to increase or decrease the TON cycle is pressed,number of TON cycles in R2 are incremented or decremented accordingly. After one TON and TOFF the value stored in R2 is used to update new number of TON cycles i.e. R7 and remaining TOFF cycles(after subtracting TON from 7) is stored in R6.

3.2 Polling mechanism to use keys

For making the device more user friendly we have used 4 up and down keys two each for water flow control and water temperature control respectively. Once a key press is detected by either of microcontroler the water flow/temperature level is increased or decreased according to the which key is pressed.

Polling mechanism for detecting the keypress and performing the action associated with this.

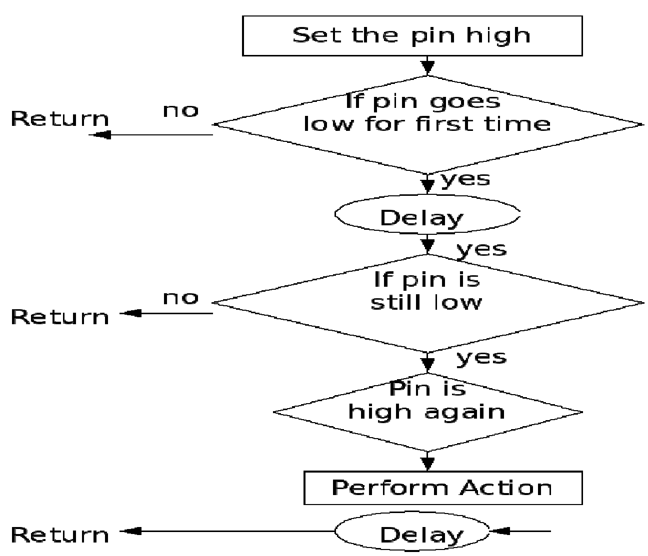

Fig.3.2 Keypress detection mechamism

3.3 Mechanism for showing current flow rate and temperature level using LEDs:

As described in section 3.1 R2 register is updated every time the key is pressed and this R2 register is used to update R6 and R7,which contains number of OFF cycles ad ON cycles respectively. We use the same R2 register to display Current flow and temperature level.

3 MSB of the R2 registers are sent to pin p3.5, p3.4 and p3.3 respectively. Using three LEDs we can know the current temperature/flow level.

5. COMPONENTS & DESCRIPTIONS

1. Microcontroller: AT89C2051 [2]

It is a low power, high performance CMOS 8 bit microcomputer with 4K bytes of flash programmable and erasable read only memory (EPROM). It has 40 pins and 4 ports. Port 0 is an 8 bit, bi-directional I/O port. Each pin can sink 8 TTL inputs. Port 1 is an 8 bit bi-directional I/O port with internal pull-ups. Its output buffers can sink 4 TTL inputs. Port 1 is an 8 bit bi-directional I/O port with internal pull-ups. Its output buffers can sink 4 TTL inputs. Port 3 is an 8 bit bidirectional I/O port with internal pull-ups. Its output buffers can sink 4 TTL inputs.

Absolute Maximum Ratings

Maximum Operating Voltage: 6.6 V

DC Output Current: 15.0 mA

Voltage on any pin (w.r.t., ground): -1.0V to 7.0V

2. UA741CN[3]

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip.

Features:

8 Pin IC

Supply voltage	±22V
Differential Input Voltage	±30V
Input Voltage	±15V
Power Dissipation	500W
Output Short-circuit Duration	Infinite

6. FUTURE SCOPE

Since we were unable to find thermistors as per our requirement and were able to devise a mechanism that made our task possible and fulfill the problem statement in the given time, we didn't use feedback mechanism although we had worked on forward feedback mechanism that will measure the current temperature and after comparing it with the temperature specified by the user it will adjust the heating levels.

Feedback mechanism remains one of the task that we look forward to complete as one of our top priorities.

Heating instantaneously and reaching the user specified temperature quickly, which was one of the main objective remains one of the biggest challenge, that we had to face due to some limitations like wattage that normal wiring can sustain, and to come over these limitations we plan to look into various other alternates for this task, some of them being using some other high power mechanisms like 3 phase power supply and heating through natural gas.

One approach which is also viable from commercial and as well as power point of view is first heating the water through solar heating then using that water as a input to the heater where using thermistors the temperature can be measured and after comparing with the user specified temperature temperature can be regulated upon which may also include mixing cold water with it based upon the instructions which microprocessor will generate.

7. REFERENCES

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