A Compact Control Circuit for Electric Furnace

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Abstract- This paper presents a design of a compact control circuit for electric furnace, a low voltage power supply (6V unregulated) is utilized to supply the dc Voltages of the system, the circuit is design to produce a fixed selected time frame of 200ms containing 10 complete cycle of main ac voltage. In this time frame on (high) period is 194 ms and off (low) period is 6ms. During the on period a selected short burst of ac cycles can be made to pass through the load by triggering the power triac.

Index Terms- phase control, zero point Switching, design, input and output waveforms.

I. Introduction

Electric furnace using heating element (nichrome) can be controlled in the following manners;

a) By varying ac voltage or current.
b) By intermittent Switching of the ac power supply.
c) By zero point Switching.

First case: The ac power dissipation is controlled by varying the load current

Here, the power $P = I^2R$, Where I = Load

R = Hot Resistance of the heating element

Since the load current I can be varied by the controlling circuit, the power P can also be varied correspondingly. During a specified time frame 't' the heat energy conversion 'H' is given by

H = (Electrical work done divided by mechanical equivalent of heat energy)

$H = (I^2Rt)/j$, (Where j = mechanical equivalent of heat energy = 4200Kcal./joules)

Therefore, $H = (I^2Rt)/4200\text{Kcal}$ (1)

Here, $H \propto I_2$ (2)

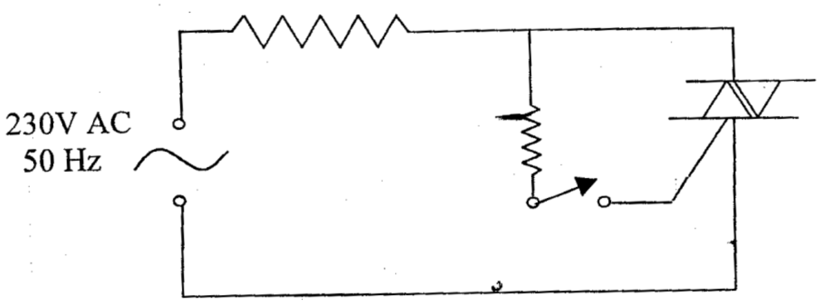
Disadvantage: 1) IR drop (Which result in loss of power)

2) Use of torroidal variac transformer (which is bulky and costly)

Second Case: The time 't' during which the full load current I_0 flowing through the heating element is varied in a controlled quantum according to our requirement of heat energy

Thus the heat energy conversion is directly controlled as per our requirement by varying the on time 't_{on}' of a switch connected in series with the load an ac power supply

Now the Eqn.1 becomes $H \propto t_{on}$ (3)



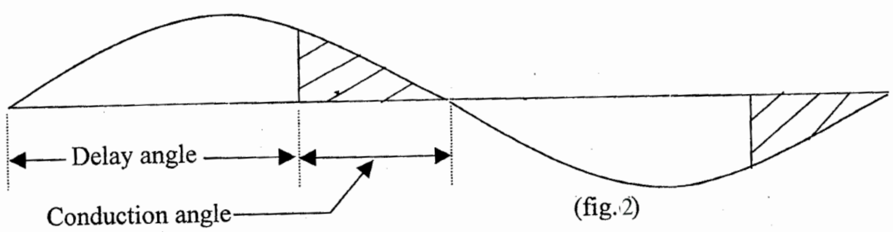
(Fig. 1)

Disadvantage; 1) Frequently on and Off of a switch, which is not desirable.

Third Case: The switching arrangement is improved by using a zero crossing ac switch and keeping a selected time frame constant and periodical. The time frame consist of on and off time of the heat controlling switch which are variable. The on time ʿton' is varied accordingly to our heat energy requirement. The eqn. 3 still stands for heat energy conversion.

Method of Control:

Phase control: Here the triac switch on the ac voltage to the load for a controlled fraction of each cycle, in this mode of operation the ,device is held in off state for a fraction of both the positive and negative half cycle and then is triggered into on state at the instants In both the half cycle as determine by the control circuit as shown in figure 2 .In the on state condition the circuit current limited by the load resistance and the rms value of the conducting fraction of the cycle less by the forward voltage drop of the device is applied to the load.



(fig. 2)

As shown in fig.2, the delay angle is the angle measure in electrical degrees during which the triac is blocking the line voltage. The period during which the triac is in on state is called the conduction angle.

Disadvantage: 1) Generation of unwanted EMI noise.
2) Power loss during the on-off transients is also maximum

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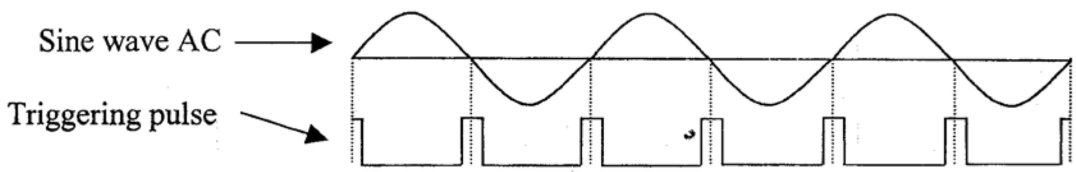
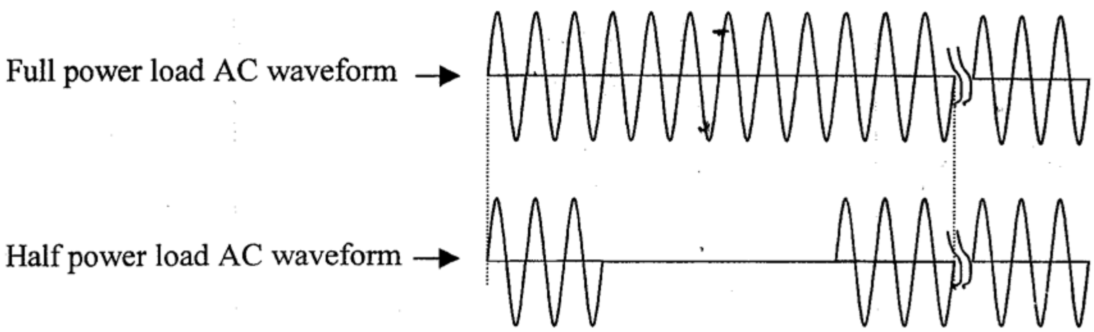
Zero point switching: This method minimized the power loss as well as the EMI which is often usable .In this technique the control element is gated on at the instant, the sine wave voltage goes through Zero. This reduces or eliminate the turn on transient loss and EMI . Power to the load is controlled by providing a suitable length of bursts of complete sine wave to the load as shown in fig. 3.



(Fig. 3a) Zero point triggering



(Fig.3b)

So, for the effective control of heat energy of an electric furnace, Zero point switching circuit is the best option

CIRCUIT

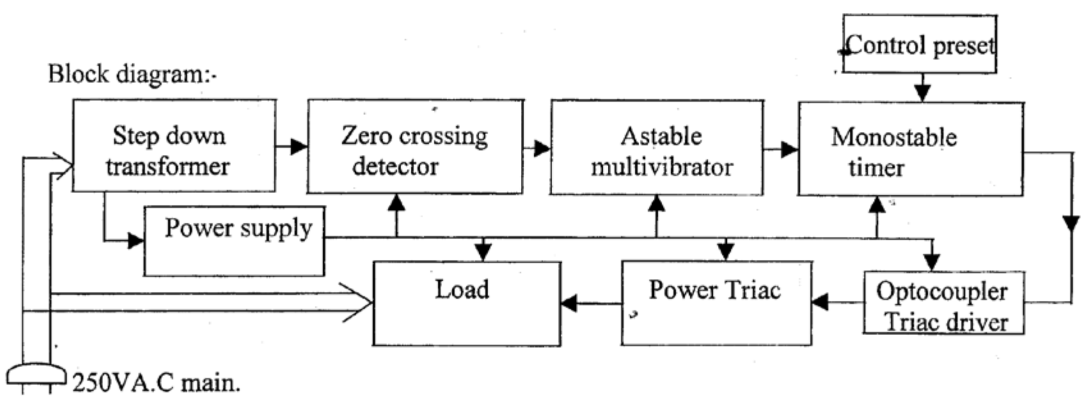


Fig. 4 Zero point switching circuit

DECRIPTION :

A 6V -0- 6V step down transformer is used to derive the working dc voltages of the following stages. Diode D1, D2 full wave rectified the secondary ac to give a pulsating dc of twice the light frequency at the point A. A 470 µF capacitor filtered the ac component to give an unregulated working dc voltage of approx. 7.8V under the loaded condition. The diode D3 prevent the filtering of pulsating dc at the point A by the filtering capacitor of the circuit.

An NPN transistor Q1 as zero crossing detector of the main ac waveform .At the point B, a narrow pulse of 2ms produced exactly at the zero points of the.IC555 forms an astable multivibrator, which determined the time frame of the triac switching, the time frame

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is 200ms.This time frame consists of 194ms high period and 6ms low period at the point D is phase synchronized with the rising edge of the zero point pulses available at the point B .It done by giving a differential pulse to the point C at which the frequency determining voltage of the astable circuit is controlled.

Again the falling edge of the 6ms low period of the time frame triggers the monostable circuit of the IC555.A 555IC have no facilities of triggering during its quasistable period. However the set pin is protected from false triggering by unwanted transients with the help of networks D4(IN4148),1KΩ and 0.01μf .

The quasistable time $\tau = R_T C_T$ (4)

The maximum value of τ is limited to 200ms so as not to create false aliasing effect of the system.

CIRCUIT DESIGN:

Q1 is the zero crossing detector its design is very simple. Every time the dc crossing points it is in cut off mode. For this we select suitable value of collector current(I_c) in the saturation mode.

For a full wave rectification the average value is,

$V_{av}=(2V_m)/\pi$
$=(2x\sqrt{2}.6)/\pi$
$=5.4dc$

We select I_c=5.1mA for simplicity of the calculation.

So,that $R_c=V_{cc}/I_c$
$=7.8V/5.2mA$
=1.5kΩ exactly.

Taking $I_b=I_c/10mA$ for hard saturation

$R_b=5.4/I_b$
$=(5.4x10x10^{-6})$**/5.2**
=10.38kΩ

astable multivibrator;

Taking C=100μF

Discharge time

$T_D=0.693*R_2C$
$6*10^{-3}=0.693*R_2*100*10^{-6}$
$R_2=86.6\Omega$
$R_2=1K\Omega$

Charge time (for high o/p)

$T_c=0.693*(R_1+R_2)C$
$194*10^{-3}=0.693*(R_1+1000)100*10^{-6}$
$R_1=1799.42\Omega$
$R_1=2K\Omega$

For, monostable circuit the quasistable time,

τ = 200ms (limited) max

But, from the equation (12)

$\tau = R_{T.}C_T$

Therefore, $200*10^{-3}= R_T * 2*10^{-6}$

R_T= 100 KΩ (for the Maximum limited value when C_T is taken as 2uF).

But most of the potentiometer available in the market does not give the exact rated value. Hence for the correction of the potmeter value a fixed resistor of suitable value is selected for the connection in series with it.

For the triac driver circuit the pin no.2 of the MOC6041 needs an inverted drive pulse for the conduction of the associated photodiode inside the IC. Q_4 is used to drive the forward current of it. As given in the data sheet of the IC the reverse voltage is limited to 5V (designed value is taken less than the maximum value) by clipping the d.c voltage given to the pin no.1 at 5V using a zener diode and 100uF capacitor. The diode forward current I_F is limited to 50mA (less than the maximum value) by a 100Ω limiter

For the selection of power triac, the load is selected as 1000W heater.

Therefore, the full power load current,

I_0= 1000W/250V =4A

For safety operation I_0 is selected as ½ the rated continuous maximum current of the device .The most suitable device no. is 2N6344 or 2N6348.

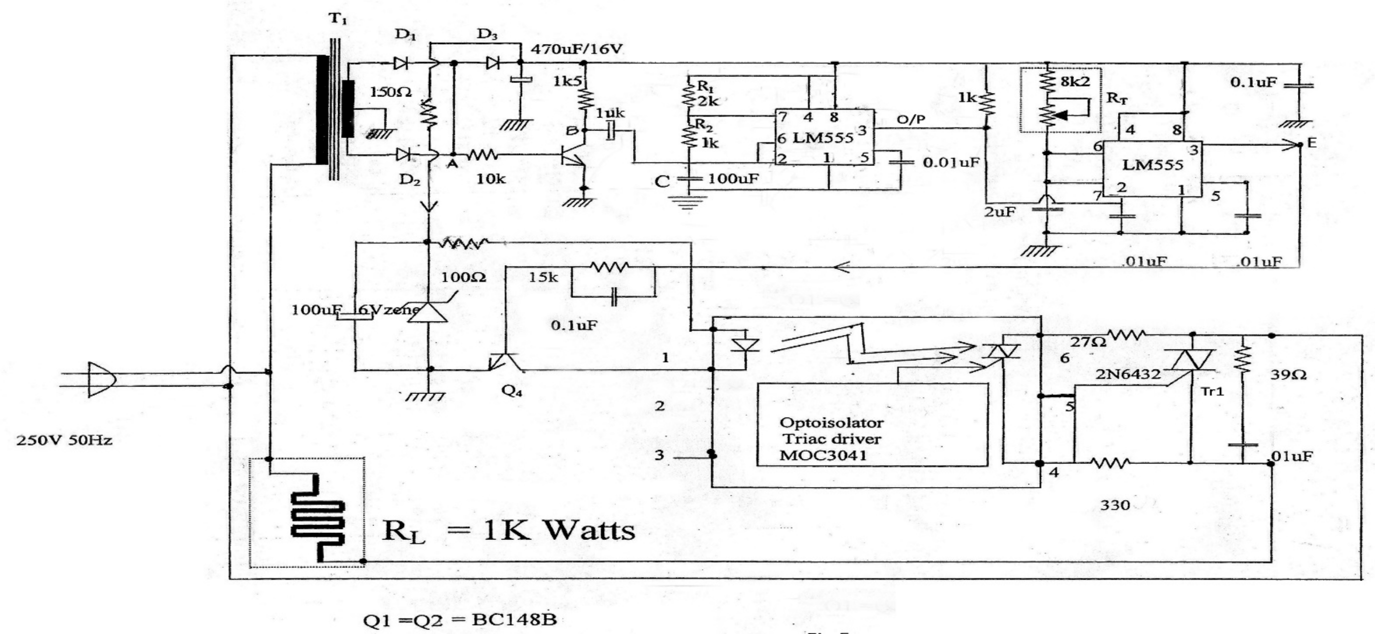

Fig:5

TABLE
List of Component:

Resistor:-

1) 27 Ω	0.25Watts	1 no.
2) 39 Ω	0.25Watts	1 no.
3) 100 Ω	0.25Watts	1 no.
4) 330 Ω	0.5 Watts	1 no.
5) 1 KΩ	0.25 Watts	1 no.
6) 1.5 K Ω	0.25 Watts	1 no.
7) 1.5 K Ω	0.25 Watts	1 no.
8) 8.2 KΩ	0.25 Watts	1 no.
9) 2KΩ	0.25 Watts	1 no.
10) R_{B2} =(39KΩ+37KΩ)	0.25 Watts	1 no.
11) R_{B2}= (33KΩ+12KΩ)	0.25 Watts	1 no.

Transformer :

1) T1 = 6V-0-6V(500mA)	0.25 Watts	1 no.

Capacitor :

2) 470 μF/16 V	0.25 Watts	1 no.
3) 1μF/25V	0.25 Watts	1 no.
4) 100μF/16V	0.25 Watts	1 no.
5) 0.1μF	0.25 Watts	1 no.
6) 0.01μF	0.25 Watts	2 no.
7) C_T=2μF/25V	0.25 Watts	1 no.

IC :

8) LM555	0.25 Watts	2 no.
9) MOC3041	0.25 Watts	2 no.

Triac:

10) 2N6432	0.25 Watts	2 no.

Transistor:

11) BC148B	0.25 Watts	2 no.

POINT REPRESENTATION:

Point A: Shows a pulsating of dc of twice the line frequency (2*50=100Hz).
Point B: Shows a narrow pulse of 2ms produced exactly at the zero points of the ac cycles.
Point C: A differential pulse is provided at point C at which the frequency determining voltage of the astable circuit is controlled.
Point D: Shows the time frame of the triac switching determined by the astable multivibrator.
Point E: Shows the change in time frame of 250ms high and 150ms low periods.

The phenomenon of physical verification is explained in fig.6

OUTPUT AND RESULTS:

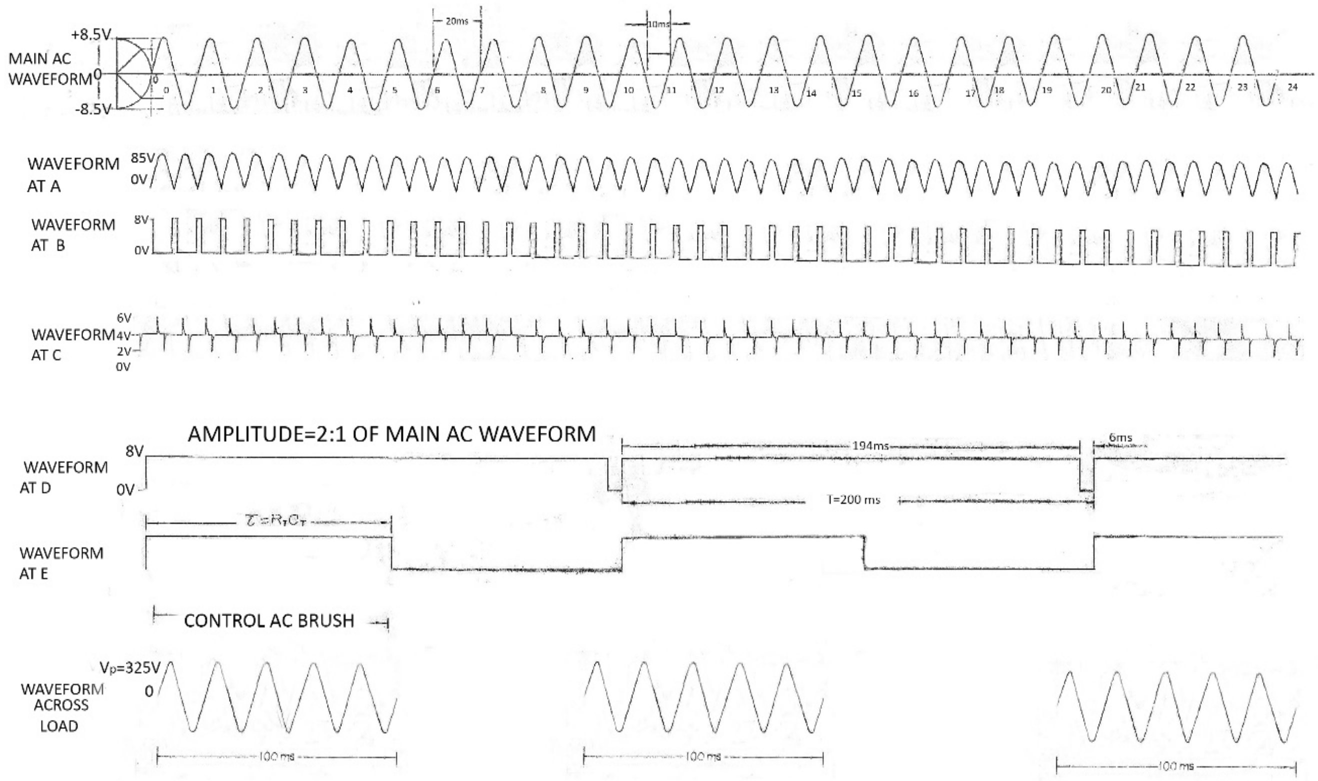

FIG:6- WAVEFORM DIAGRAM SHOWING THE AC BURST CONTROLLED LENGTH

II. CONCLUSION

A compact electric furnace control circuit is proposed in this paper. The circuit is modified from earlier version by using 555 timer instead of BJT for the design of astable multivibrator. The circuit produces good result thereby reducing the size and complexity of the circuit.

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