# Soft Start Circuit for Tetrode Filament using TRIAC

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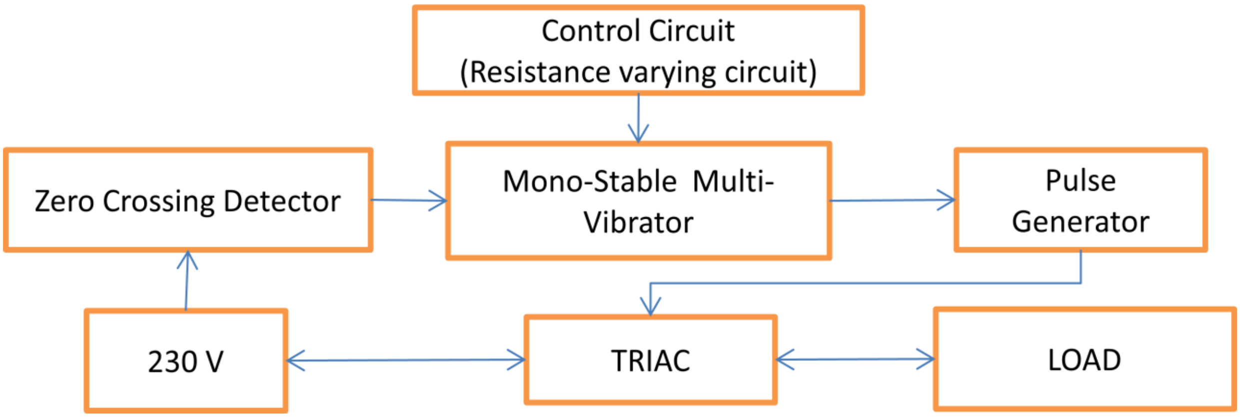
***Abstract* - This paper presents the creation of a soft start circuit that operates based on the current regulating property of TRIAC. TRIAC act as barrier in AC circuit preventing the current flow before being triggered. Supply voltage to the heater filament need to be increased step by step to rated value. By changing the firing angle (180-0) of triac, the voltage applied to the Heater filament can be varied. Using a zero crossing detector and mono-stable multi-vibrator circuit the firing angle is changed. Trigger pulse is given to the Triac using a photo-diac. The TRIAC is set into a conducting state and current flows through the Heater Filament soon after the trigger voltage is applied to the photodiac. The amount of voltage seen over the Heater Filament is determined by the firing angle of the triac which is fixed by RC time constant of the monostable circuit. Resistance is decreased step by step using the control circuit thus the firing angle is reduced and voltage across Filament is increased up to supply voltage. Using photo-diac and phototransistor load circuit is galvanic isolated from the control circuit.**

## INTRODUCTION

This paper describes the design, operation, and testing of a soft start circuit, using Device such as 555 timer, MOC3021, 74LS123 and triac, for tetrode filament. Tetrode is a vacuum tube it has a Heater for Electron emission, its supply voltage has to be increased step by step from low value to its rated value for safety and long life of vacuum tube. In this topology power flow is regulated to the Heater Filament by applying a AC supply voltage intermittently across the load during each half cycle. At starting only 20% of the input sine wave is applied across the LOAD. Step by step as the Resistance of RC circuit decreases, the RC time constant of Mono-stable multi-vibrator decreases, thus pulse width of output decreases. At the trailing edge of this pulse, pulse generating circuit will activate and it will give a pulse to the MOC3021 it will trigger the triac. Triac will start conducting from that point to the starting of next half cycle. The proportion of the sine wave applied across the load increases as the pulse width of the mono-stable output decreases. Circuit design, operation, test results, and the interpretations that were made during the experiments are shown below.

*Topology.*




*Main circuit.*
In the main circuit realized using a zero crossing detector circuit, its output pulse is used as triggering pulse for mono-stable multi-vibrator. It's a simple electronic circuit using the capacitor and a PnP transistor. As the sinusoidal voltage wave form crosses the zero point in every half cycle, it will apply adequate base voltage to the PNP transistor this will in turn put the transistor in saturation region from cutoff region, it act as a switching circuit. Using a photo transistor this pulse is galvanic isolated from the main supply voltage side to the controlling circuit; the isolated pulse is applied to the mono-stable. As the RC time constant of the mono-stable is decreased it will in turn reduce the firing angle, thus the overall voltage coming across the load will increase.

In the circuit diagram variable resistor is represented as AB with a resistance value of 60KΩ(10+10+10+20)+10KΩ initially full resistance is

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coming across the RC circuit thus the pulse width will be 6.6 msec. step by step resistance is decreased to 10KΩ thus the pulse width decreases to 1.1 msec, firing angle decreases to the minimum value. whenever the output of mono-stable goes from high to low, it will trigger 74LS123 it will give a pulse output of fixed width(<1msec).

It is used to give base voltage of a transistor, it in turn give pulse to the MOC3021 it will give gate triggering pulse to the triac. Triac will conduct from this point till the current through it goes below the holding current. After some time of starting the total resistance of the RC time constant will decrease to 10K from 60KΩ, thus the triggering pulse will trigger the triac exactly at starting of every half cycle. Full voltage will obtain across the Load.

Photo-diac MOC3021 is used to trigger the Triac, but the Triac may also be triggered to on state accidentally. This can cause by exceeding the maximum blocking voltage VDRM or by applying very steep rising signals to the output of Triac. Such transient signals or noise may surpass the dV/dt rating of the triac driver and henceforth cause the device into on state. The TRIAC dV/dt ratings and its driver and hence cause the device to proceed into ON state. The dV/dt ratings of the triac and its driver are very important when switching inductive loads since load voltage and current are not necessary in phase. Since a triac turns off when the load current equal zero, load voltage is not equal to zero. As a result, the triac produces a sudden rise in load voltage as an output, which
could exceed its dV/dt rating.

To increase voltage rise time, a snubber circuit may be used. In majority of the cases, single snubber circuit shall protect the main triac and the photodiac. Comprehensive knowledge about the load is necessary while designing the RC snubber network for triac drivers. With the knowledge of power factor PF, the maximum turn off voltage at the output can be predicted:

$VT\ \max = Vin\max * \sin(\arccos(PF))$

Assume Vtmax = 240 V

Choose R1 to limit the current peak at maximum voltage

R1=VinMax/Ifp,

339/1=339Ω. Standard value close to this is 360Ω.

As the peak current is limited by the resistor R1, time constant for limiting dV/dt has to be set using R2 and C:

dv/dt=Vtmax/ĩ = Vtmax/R2C.

Next, the value of R2 is set by determining the smallest trigger voltage requirement. Assuming a triac gate trigger current IGT = X mA and a required load voltage (Vint).

R1+R2=Vint/X , we already know the value of R1, so we can find out the value of R2.

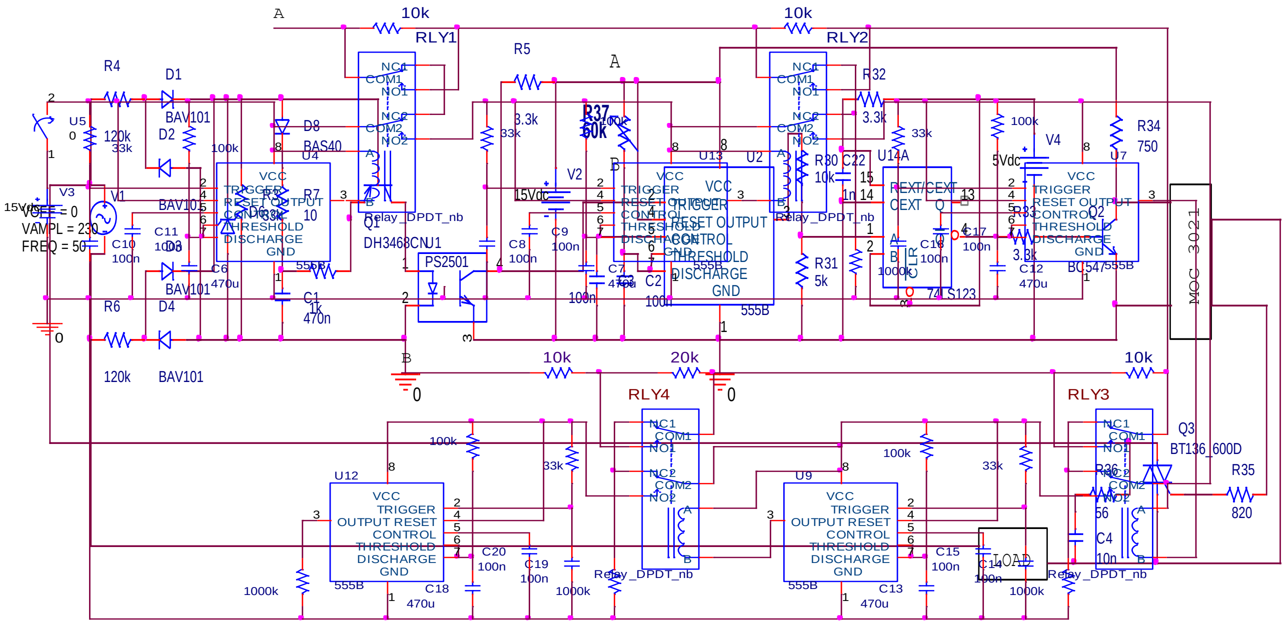
Value of ĩ can be find out from dv/dt and Vtmax values.

From values of R2 and ĩ we can find out the value of C.

The dV/dt rating of the main triac and the dV/dt rating of photo-diac shall be different. Thus, while designing the snubber circuit the worst case value must be selected.

*Control Circuit.*

Control circuit mainly consists of 4 relays and 555 timers. Its operated in mono-stable mode as the mono stable output goes low a voltage will come across the relay coil, it make the NO contacts to closed condition. It will remain in this condition it power off. Current sinking and sourcing property of 555 timer is used for this, each of the mono-stable timer output pulse width is set to 51.7 sec. Full voltage will be obtained after 3.5 minute at the Load side.



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the four relays connected in such a fashion that when output of the first 555 goes low the first relay coil will get energized thus relay NO(normaly open) contact become Closed voltage will come across the next 555 , after a fixed time output of 555 goes low it will energize the next relay. Simultaneously as each relay operates the total Resistance across the Mono-stable get decreased, each relay will bypass the resistance step by step.

*Experimental result.*

The voltage to the Triac was given using a variac. 230V, 50Hz supply was given as input, variac is set give 120V, 50Hz output voltage. As a load we have used 2K Ω, 40w resistor is used. one by one relays are operated the firing angle is decreased , the corresponding graphs are given below. Graph contains output voltage waveform and triac firing pulse. The output voltages are shown below:-

| Relay condition | Firing angle | Output voltage(V) |
|---|---|---|
| All Relay off | 119 | 45 |
| 1relay on | 99 | 72 |
| 1,2 relay on | 79 | 96 |
| 1,2,3 relay on | 59 | 112 |
| 1,2,3,4 relay on | 19 | 119 |

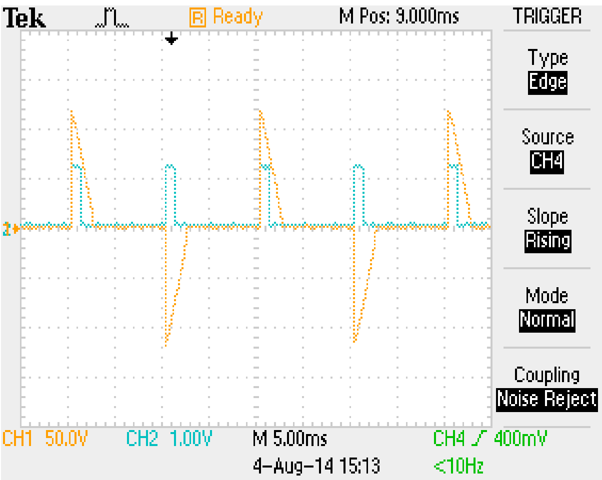


Figure 1

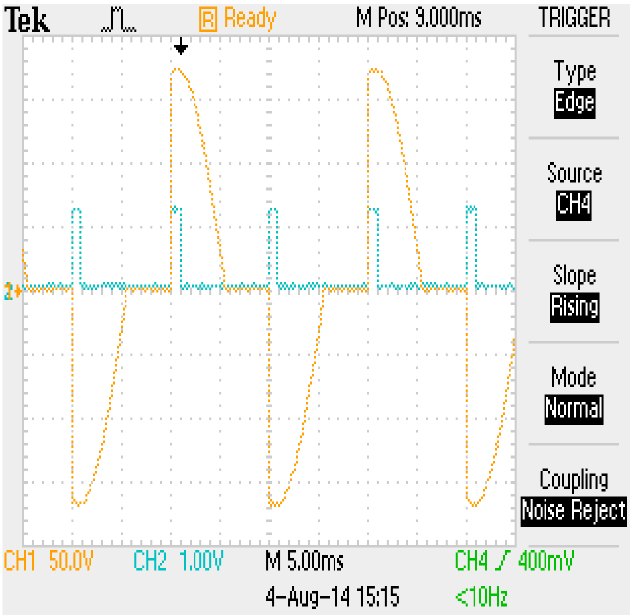


Figure 2

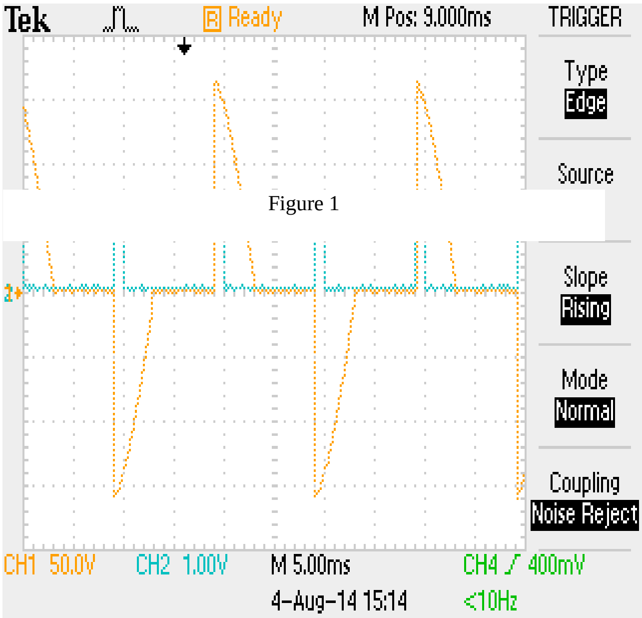


Figure 3

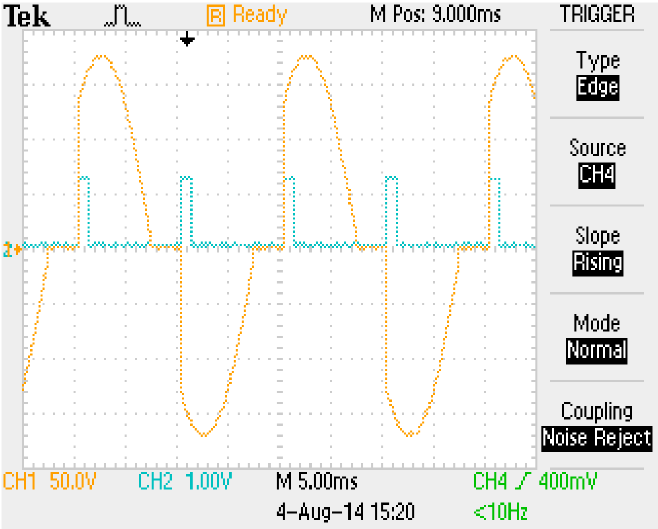


Figure 4

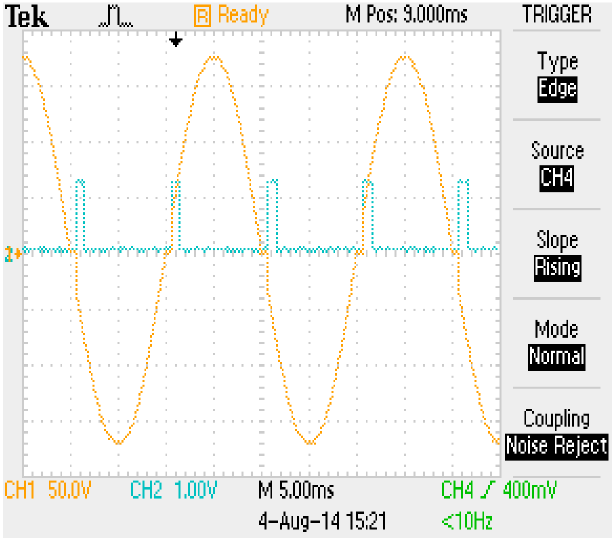


Figure 5

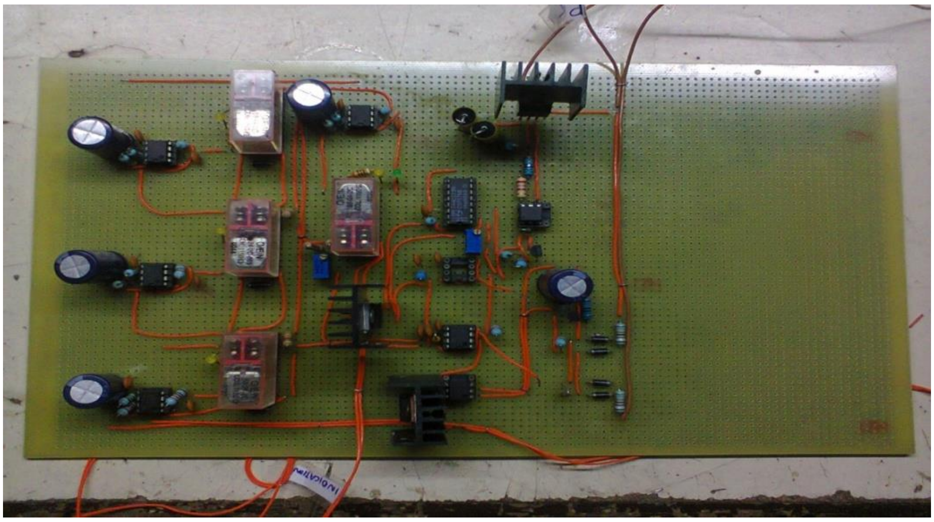

Figure 6

## CONCLUSION

Soft start circuit operation has been demonstrated successfully with triac, relays, 555 timers etc on a dummy load. With this circuit it's observed that one can increase the intensity of a voltage across the Tetrode Filament step by step in an automatic way. The RC time constant used to determine the point when triac conducts the AC wave through the Filament during each half cycle. The firing angle of Triac decreases as relays in the control circuit operates one by one thus voltage across the filament increases, when all the 4 relays operates full voltage will come across the filament .For the protection of Triac and photo-diac snubber circuit is implemented.

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