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REVIEW OF POWER SAVING TECHNIQUES FOR DIMMABLE COMPACT FLUORESCENT LAMP (CFL)

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Abstract: Compact Fluorescent Lamps (CFLs) are replacing incandescent lamps now-a-days at a rapid rate due to their energy savings and longer lifetime. By dimming more energy saving can be achieved. The dimming function opens up a completely new family of CFL applications. Each dimming application presents a different set of new challenges, especially with interface circuit required. The dimming control loop required to regulate the lamp current is basically the same for each application. The challenge is to design each different interface circuit that converts the user dimming method to necessary DC dimming reference. There are many such interface available in area of integrated technology which includes functions like dimming, lamp ballast and also functions like an H-bridge. One of them is IRS2530D IC which greatly simplifies dimming designs and helps to close the gap between dimming and non-dimming designs. This will enable CFL products to compete with incandescent ones, while maintaining a small form factor and a low cost. Other ICs are LT1158, NCP1393B, IR2156 etc. So by dimming function we will be able to achieve higher power saving and efficiency.

Keywords: Electronic Ballast (EB), Compact Fluorescent Light (CFL).

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INTRODUCTION

First fluorescent lamp was invented by Peter Cooper Hewit in late 1890's as shown in fig 1(a).Edmund Germer, Hans spanner and Friedrich Meyer invented high-pressure vapour lamp and patented in 1927.Later German Inman teamed with General Electric to create a practical fluorescent lamp, patented in 1941 and sold in 1938.To reduce the length of fluorescent light fixtures, circular and U-shaped lamps were devised. The first fluorescent bulb and fixtures were discovered and displayed to general public in 1939 in New York World's Fair. An engineer with General Electric, Edward E Hammer was invented spiral CFL in 1976 in response to 1973 Oil Crisis.

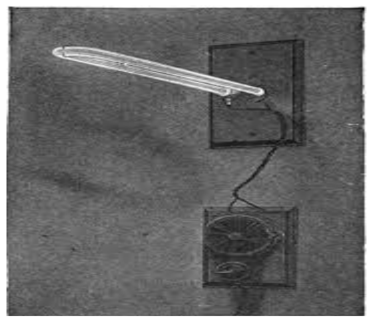

Fig 1 (a): One of the first invented fluorescent lamp by Peter

Cooper Hewit.

In recent years, governments of growing list of countries strongly imposed to use energy saving lamps such as compact fluorescent lamp (CFL) in an attempt to phase out conventional incandescent lamps to reduce energy usage[1].The basic difference between incandescence and fluorescence are as follows:

SR NO.	Incandescence	Fluorescence
1.	Conversion of heat to light.	**Conversion of Ultra violet light (UV) to visible light.**
2.	The lamp has filament inside to burn at high temperature (350^0F).	**Electron flows through lamp and collide with mercury atoms. They release light photon in the UV wavelength range. After passing through phosphor coating, UV light is converted to visible light.**
3.	5% of total energy consumed to generate light and remaining wasted in heat.	**25% of total energy consumed to generate light.**

4.	Lifetime is about 2,000 hours.	Lifetime is about 10,000 hours.

Table 1: Showing difference between incandescent and fluorescent lamp.

Though CFL is cost effective and energy saving lamp but it suffers through some drawbacks and those are, all CFL's are not dimmable, they are having slow warm up time, unable to achieve close to unity power factor and suffers through flickering due to which its life get decreased. Once the lamp arc established, lamp current stabilising element is required in order to provide sufficient voltage for proper lamp ignition which is called as ballast[2].There are various types of ballast but for compact and light weight solution Electronic ballasts are more suitable.[2]

It uses solid state electronic circuitry to provide proper starting as well as operating electrical conditions to power discharge lamps. Basically it contains rectifier, inverter and resonant filter tank circuit. Advanced electronic ballast allow dimming via PWM technique or via changing the frequency to higher value. Ballasts incorporating a microcontroller may offer remote control and monitoring via networks.

The stroboscopic effect of lamp is eliminated as rather than supply frequency the lamp operated at frequency 20KHz if EB is connected. EB often based on the SMPS technology, first rectifying and then chopping it at high frequency. There is no flickering of lamp as the output of EB refreshes the phosphor in CFL.

Initially when the gas is unionised, it offers a high resistance path to current. But after the ionization takes place and the arc is set up, the resistance drops to a very low value, almost acting like short circuit. If all this current is allowed to pass through the lamp, the lamp would either burn out or cause the power supply to fail. Thus the ballast needs to perform the current limiting so itself it act as capacitive for controlling lamp current. Essentially, the high frequency EB is an AC/DC power converter which converts line frequency power converter from the utility line to a high frequency AC power in order to drive the discharge lamp.

Analysis

While maintaining constant power for the fluorescent lamp against the fluctuating line voltage is an important feature, it is also desirable to provide dimming when it is needed. When a standard phase cut dimmer (i.e., TRIAC dimmer) is used for dimming the CFL, it is desirable to adjust the CFL's lamp power so that the brightness of the lamp can be adjusted according to the dimmer switch setting[1]. This TRIAC Dimmer can also provide dimming to incandescent lamp.

When the TRIAC Dimmer is connected practically with CFL, it starts to flicker so this cannot be the best option.

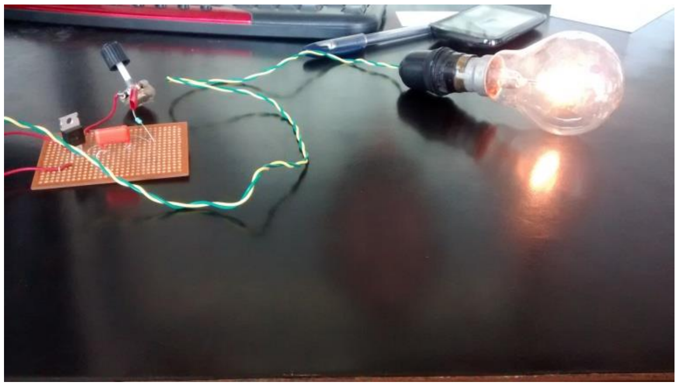

Fig 1(b): Circuit TRIAC dimmer for incandescent lamp.

Description of the proposed circuit

Dimming can be done by adding feeback loop to the existing ballast. Here ballast includes EMI filter, rectifier, half bridge, tank circuit. Actual dimming is achieved through feedback loop, it contains user dim input, resistors and capacitors to sense the lamp current.

EMI Filter

Electromagnetic interference is a disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. It may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. So in order to avoid this, an EMI filter is used which is nothing but an LC filter.

RECTIFIER

The circuit shown below shows the circuit of typical high frequency EB. The AC/DC rectifier contains four diodes and one bulk dc link capacitor. This simple rectification is still widely used because of its lower cost.

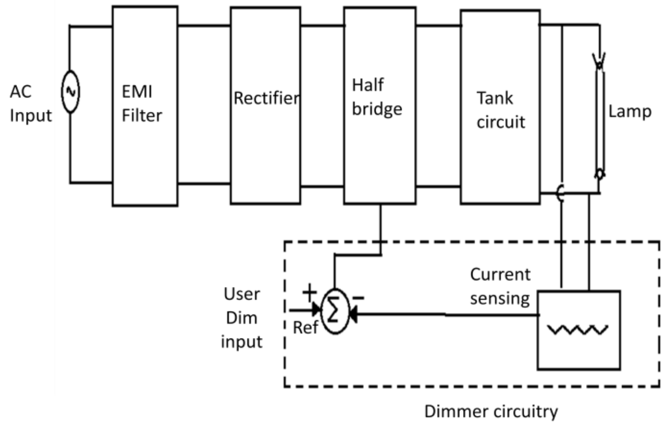

Fig2: Block Diagram of proposed circuitry.

H-BRIDGE

The DC/AC inverter is a half bridge series-resonant Parallel-loaded converter. The main design objective is to reduce number of switch count i.e. number of active component in the power circuit. Here two MOSFET,M1 and M2 is used which can be ON and OFF complementarily with a fixed dead time which generates a high frequency square waveform at point between the two MOSFETs. On the other hand, the voltage at another point is half of the bus voltage. As MOOSFET M1 turned on and MOSFFET M2 is turned OFF, a very high current flows through the MOSFET pair, since M2's body diode appears as a short circuit during its reverse recovery time. Other losses arises due to discharging M1's output capacitance and to reverse recovery in M2. These losses increases as the switching frequency or input voltage increases. Hence Zero Voltage Switching (ZVS) is used, which addresses the high turn ON losses of the conventional regulator.

TANK CIRCUIT

Resonant tank circuit means inductor, capacitor with lamp as a resistive load. Before the lamp is ignited, the lamp resistance is very large so that it can be treated as open circuit. The gain curve of the lamp voltage over Vin as a function of the switching frequency as shown below. The lamp operating point goes from a to b, which means switching frequency is decreasing. At point b, the lamp voltage reaches the lamp ignition level, so the lamp resistance drops quickly and the gain curve charges to the lower one. The operating point again moves from b to c, which is the steady state operating point.

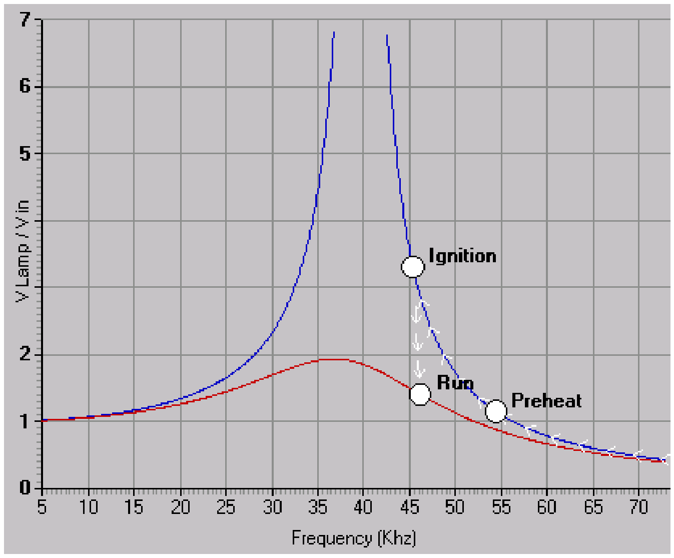

Fig 3: Gain curve of the lamp voltage over Vin as a function of the switching frequency.

OPERATION

The rectified full wave AC mains voltage is then peak charges a capacitor to produce a smooth DC bus voltage. Using a standard half bridge switching circuit with duty cycle of 50%, the dc bus voltage of high frequency is converted into AC square wave voltage. The high frequency AC square wave voltage then derives the resonant tank circuit performs filtering inorder to produce a sinusoidal current and voltage at the lamp terminals.

	Resonant tank circuit	Q- factor
Pre-ignition	Series LC circuit	High
After ignition and during running	Series L, parallel RC circuit	Between high and low (depending upon lamp dimming level).

Table 2: Showing different operation of CFL.

When the CFL is ON, the control IC decreases the half bridge frequency from the maximum frequency down towards the resonance frequency of the high Q- ballast output stage. As the frequency decreases the filament get preheated, the lamp voltage and load current increases. The frequency continue to decrease upto the point at which the voltage reaches the threshold ignition voltage level and ignites the lamp. Once the lamp ignites, as the current is controlled, it runs the lamp at desired power and brightness level. To dim the fluorescent lamp, the frequency of the H-bridge is increased, causing the gain of the resonant tank circuit to decrease and therefore lamp current to decrease.

A closed loop feedback circuit is then used to measure and adjust the lamp current with the dimming reference level by continuously adjusting the half bridge operating frequency. IRS2530D dimming control IC from International Rectifier includes such a feedback control circuit, as well as of the necessary functions to preheat and ignite the lamp and to protect against fault conditions such as open filament failures, mains brown out and lamp non-strike.

The dimming function is realised by combining the DC reference voltage with the AC lamp current measurement at a single node as shown in fig 5. The AC lamp current measurement across the sensing resistor Rcs is coupled onto the DC dimming reference through the feedback capacitor Cfb and resistor Rfb.

The dc dimming level is increased or decreased in the feedback circuit by continuously adjusting the frequency of half bridge such that it regulates the valley of AC+DC signal to COM. Due to which, for dimming the amplitude of lamp current get increase or decrease. If i) DC reference is increased, the gain of resonant tank circuit increases as the frequency circuit decrease and the valley of the AC+DC signal will increase above COM. ii) DC reference is decrease, valley will decrease below COM until the valley reaches COM again, the frequency in feedback circuit increases to decrease gain of the resonant tank circuit.

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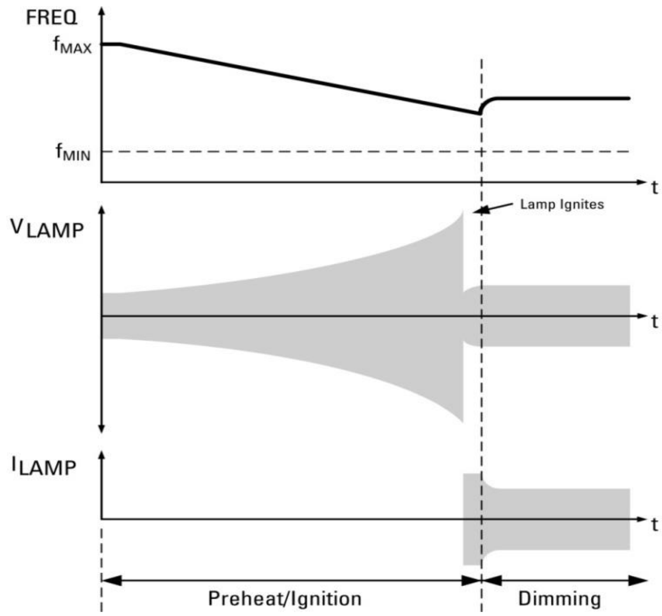

Fig 4: CFL operation timing diagram.

The interface required between the user dimming reference and DC dimming reference are achieved using different IC's. Many such IC's are available in market like IRS2530D, IR2156 etc among which IRS2530D is more compatible with our circuitry. It is basically a 8-pin IC and a separate pin for dimming is given. The main dimming feeback loop circuitry is shown below:

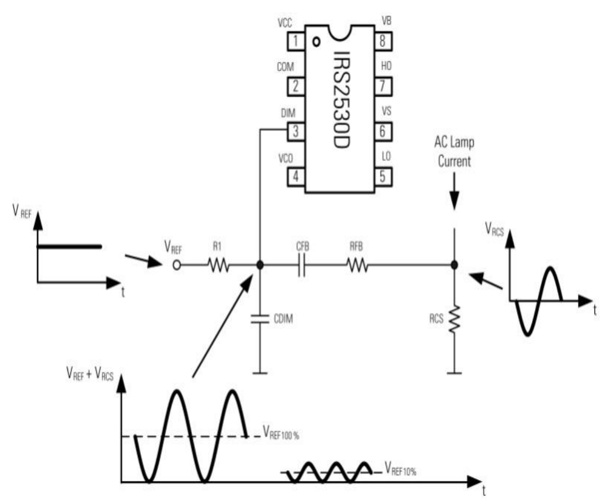

Fig 5: IRS2350D AC+DC dimming control scheme.

At the input stage four positions will be available to the user:

Position 1: OFF setting, when no filaments are connected.

Position 2: Connects first filament across the AC line for the lowest brightness setting.

Position 3: Connects second filament for the medium brightness setting.

Position 4: Connects both filaments in parallel for the highest brightness setting.

The overall circuit is shown below:-

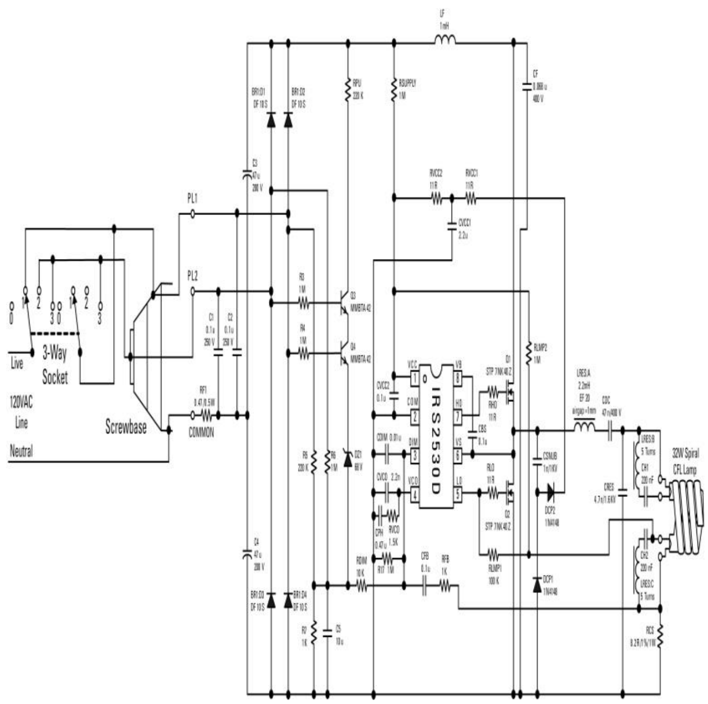

Fig 6(a): 3- way dimming circuit using IC IRS2530D.

CONCLUSIONS

By interfacing different IC's it opens up a completely new invention as the IC is having separate pin for dimming function and also it is connected with half bridge further. It maintain efficiency as the circuit work on 0-5V. If any fault occurs circuit will not get affect as the operating voltage of IC is very low. Future work includes remote or automatically controlling of dimming depending on any person present in that room or not.

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