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# Enhancement of Half-Bridge LLC Resonant DC-DC Converter for LED Driver

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***ABSTRACT :*** *Demand for LED lights continues to grow across industries - indoor / outdoor lighting, supply sectors, and LED drivers for automotive lighting supplies constant voltage with the right voltage so that LED lighting solutions operate efficiently. They also protect the LEDs from any fluctuations in voltage or current. High brightness LEDs are great lighting devices due to their high reliability, color diversity and increased efficiency. As a result, a large number of solutions appear for supplying LED chains. The LED actuator must have the ability to provide constant current regardless of LED forward voltage changes. In this paper, a DC to DC converter is designed and controlled to operate in DC mode. The LED driver is designed and implemented to verify the proposed circuit. The proposed hardware model consists of a Half-bridge DC-DC converter, high frequency transformer, and a rectifier. The DC to DC converter is designed so that the solid-state switches of the LLC half-bridge converter operate under low thermal pressure to reduce switching losses. Its design is optimized based on the needs and characteristics of LED based street lighting applications. The proposed converter design improves the efficiency, thereby reducing switching losses in the MOSFETs and diode circuits. The experimental results obtained with a 10 watt prototype show high efficiency of 96% for this second stage and validate the proposed design procedure and the model.*

***KEYWORDS*** *Transformer High frequency, Zero Voltage Switching, Zero Current Switching, led emitting diode*

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## I. INTRODUCTION

The lighting accounts for approximately 20-30% of the electricity consumption all over the worldwide, and Light emitting diodes (LED) has been developed recently because of its this advantages. [1]

- It is distinguished by its long life compared to other lamps of short life.
- Its efficiency ranges between (5 - 10) times compared to incandescent and fluorescent lamps.
- Does not contain toxic substances.
- It does not produce harmful ultraviolet waves.
- Reducing the spread of carbon dioxide emitted from incandescent.

The solid state light producing diode (LED) is clearly be-ginning a new era in lighting equipment with its many unbeatable advantages above other lighting sources, and developed LED treats all defects in gas-discharge lamps in which contain mercury and substances and ultraviolet waves harmful produced from these bulbs. [2]

In this article, a development of high-efficiency resonant converter for led driver, to achieve the constant current drive and brightness control without a separate pulse width modulation (PWM) converter, the forward current of one LED string is sensed for feedback control to regulate the bus voltage, which is the input voltage of the CLL resonant converter. In contrast, the CLL converter is always working at the series resonant frequency to maintain high efficiency. [3]

In a series RLC circuit there becomes a frequency point were the inductive reactance of the inductor becomes equal in value to the capacitive reactance of the capacitor. In other words, XL = XC. The point at which this occurs is called the Resonant Frequency point, $(fr)$ of the circuit, and as we are analyzing a series RLC circuit this resonance frequency produces a Series Resonance. [4]

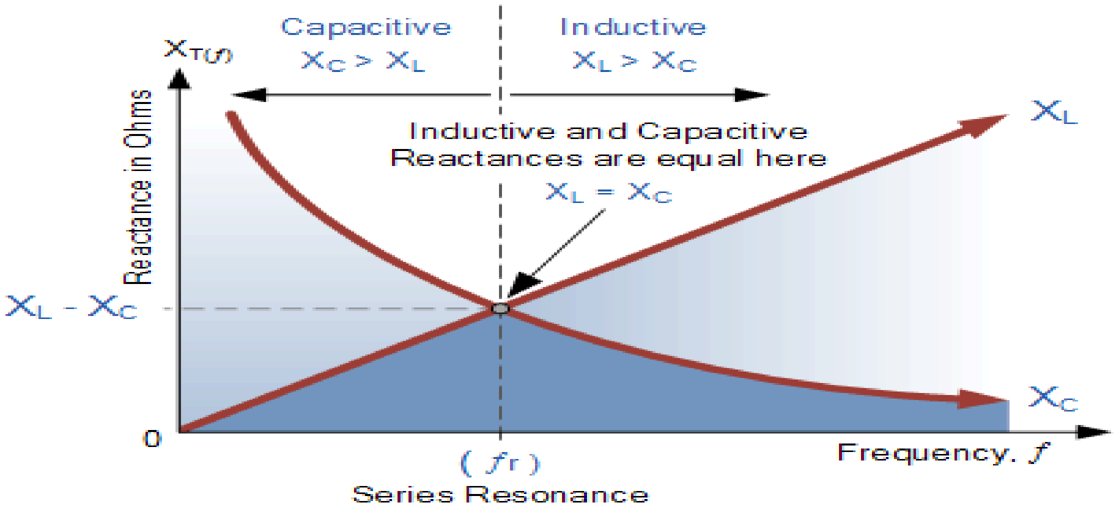



**Figure 1. Series Resonance Frequency**

The figure.1. Display the Series Resonance circuits are one of the most important circuits used electrical and electronic circuits. They can be found in various forms such as in AC mains filters, noise filters and also in radio and television tuning circuits producing a very selective tuning circuit for the receiving of the different frequency channels. [5]

Resonant transformers use a resonant circuit switch when are at the zero current or zero voltage point, and this reduces the stress on the switching and radio interference, and The (LLC) resonant converter can succeed (ZVS) for the primary- controls and (ZCE) for the secondary-side modifiers, Usually the best efficiency of (LLC) resonant converter can be achieved when switching the frequency (FS) equal to resonant frequency f0. Therefore, LLC is preferred at the point of resonant frequency in practice, Based on this consideration, the switching frequency of the (MC3LLC) resonant converter has been fixed and is always around the resonant frequency f0, For this two-stage (LED) driver, one transformer module drives 2 LED strings .[6] The major rule for operating multiple LED strings is the converter resonant.

## II. PROPOSED LED DRIVER

The drive of this work is to design a simple LED driving circuit and a secondary side LLC resonant controller IC in order to reduce both the difficulty and the circuit dimensions. The PFM controller is moved to the secondary side to minimize the number of additional circuits required for the feedback in the proposed simple LED driving circuit. A gate driving transformer is accepted to isolate the primary side and the secondary side of the LLC resonant converter. A drawback of secondary-side control is that it needs an additional secondary side supply voltage because the controls on secondary side which has to be fully isolated from the primary side [7]

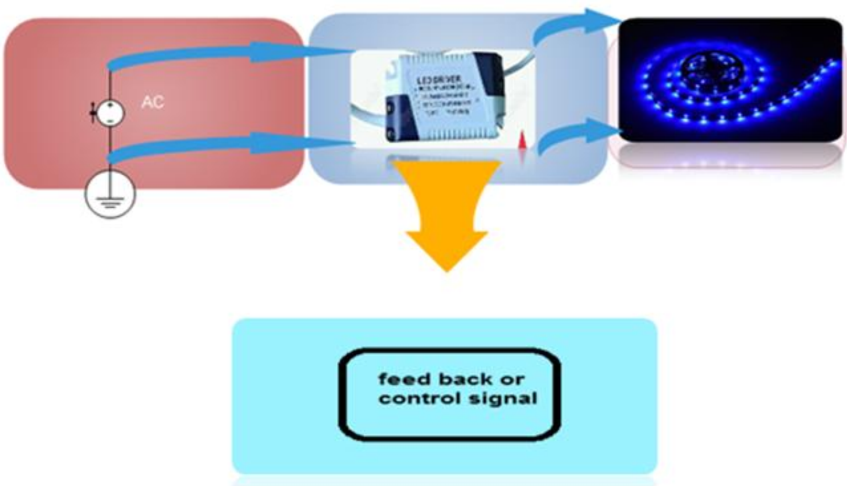



**Figure.2.scheme of multiple strings**

The LLC-based single-stage structures proposed the exchanging frequency of LLC converter is regulated when the LED dims or the load varies. Therefore, high efficiency cannot be definite with dimming and load variation because the LLC does not always work at the optimum point .Due to these anxieties, a two-stage LED driver is proposed, as shown in Fig. 1. It contains of a buck converter as the first stage and a MC3CLLresonant converter as the second stage. It can succeed good current balance among LED strings. Meanwhile, it is easy to dim the LEDs and adapt to the load difference. Furthermore, it maintains high efficiency over a wide load variety. [8]

In this paper, the operation values of the proposed two-stage LED driver are dis-cussed in figure [3-4], the characteristics and design procedure of the MC3CLLresonant converter are illustrated.

Finally, the experimental results of a 10-W two-stage LED driver prototype are present; this resonant frequency is named the series resonant frequency, which can be obtained from.(1)

.

$$(1)\quad f_0 = \frac{1}{2\pi\sqrt{CrL_{eq}}}$$

## III. OPERATION MODE

The structure of the proposed two-stage LED driver is very simple. It contains a half bridge as the first stage and a MC3CLLresonant converter as the second stage, as shown in Fig. 2. For the second stage, there is only one CLL resonant tank, which consists of Cr, Lr1, .In addition, the transformer modules are in series on the primary side. Meanwhile, the voltage doubler structure is adopted on the secondary side. Therefore, one transformer module can drive two LED strings at the same time. [9]

The currents of the two LED strings driven by the same transformer are balanced via a dc blocking capacitor C dc, which is in series with the secondary-side winding of the transformer. Whatever the voltage difference is, the currents of these two LED strings will be identical. Therefore, even the number of LEDs per string is different; the currents will be identical [10]

For example, the transformer module contains and tows strings. Each string has 28 LEDs in series.

In this case, the loads are balanced. Correspondingly. The bus voltage is tuned according to the dimming requirement. In contrast, the MC3CLL resonant converter is unregulated and always running at the series resonant frequency. From the efficiency point of view, the MC3CLLresonantconverter can maintain high efficiency over a wide load range since it is always working at the series resonant frequency. In the buck converter, Sic diode is applied as the free-wheeling diode in order to reduce the turn-on loss of the high-side switch. Meanwhile, the high-side switch is optimized according to the tradeoffs between conduction loss and switching loss. Buck converter is working in Continuous Conduction Mode over a wide load rang. [11]

It also maintains high efficiency. Therefore, this two-stage LED driver can guarantee high efficiency with in a wide load range. It is very suitable for the applications with multiple LED strings.

The LLC resonant converter can function at frequency below or above the resonance frequency ($f_0$), as illustrated in Figure 3. Figure 4 shows the waveforms of the flows in the transformer Primary side and secondary side for each action mode. Operation below the resonant frequency (79KHZ). [12]

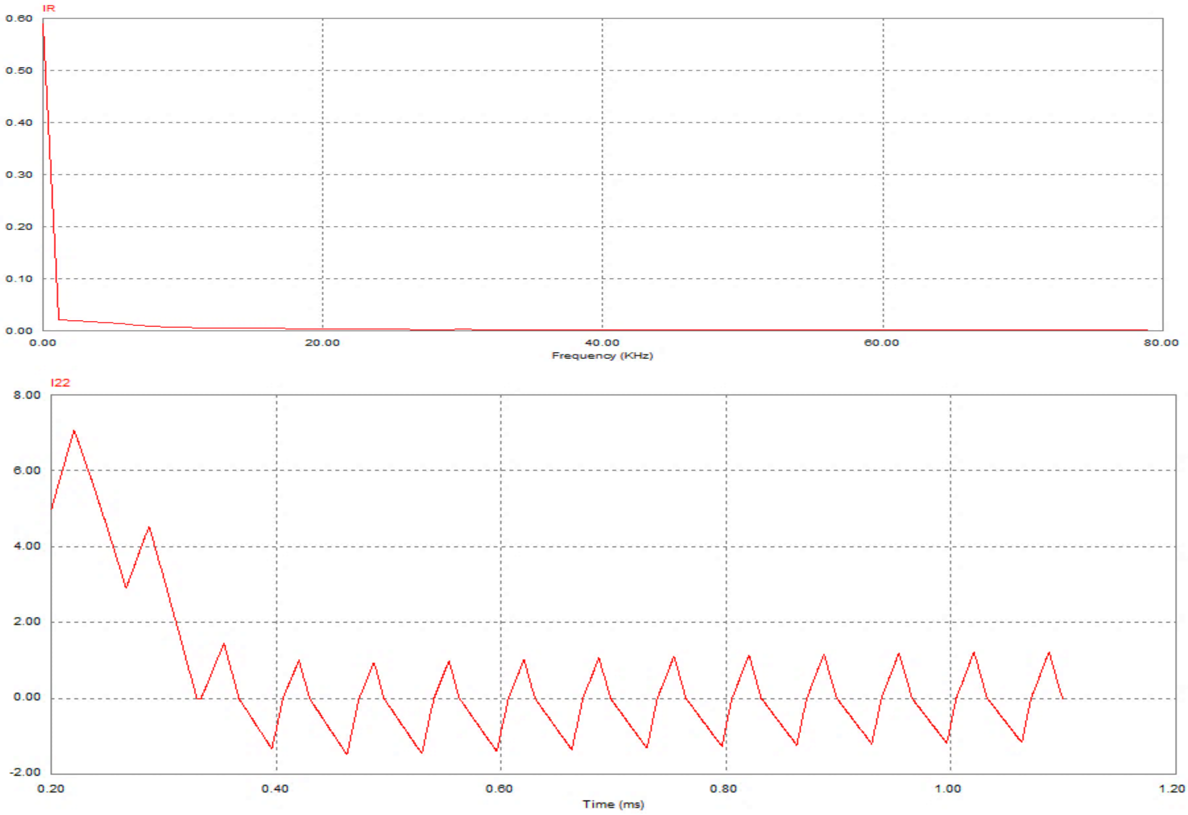



**Figure.3.4. Wave forms of each operation mode**

## IV. RESONANT CONVERTER AND FUNDAMENTAL APPROXIMATION

Figure. 2 shows a basic diagram of a half-bridge LLC resonant converter, where Lm is the influencing inductance that acts as a shunt inductor, Lr is the series resonant inductor, and Cr is the resonant capacitor. Figure 4 illuminates the characteristic waveforms of the LLC resonant converter. It is expected that the process frequency is equal as the resonance frequency, resolute by the resonance between Lr and Cr. Meanwhile the attracting inductor is comparatively small, a large amount of attracting current (Im) exists, which glides in the primary side without existence involved in the power transfer. The primary-side current (Ip) is sum of the attracting current and the secondary-side current referred to the primary. In overall, the LLC resonant topology contains of three stages shown in Figure 3; square-wave generator, resonant network, and rectifier network. [13]

♣The square-wave MOSFETs crop a square-wave voltage, Vd, by motivating switches Q1 and Q2 consecutively with 50% duty cycle for all switch. A small deceased time is ordinarily announced between the serial transitions. The square-wave MOSFETs point can be constructed as a full-bridge or half-bridge type. [14]

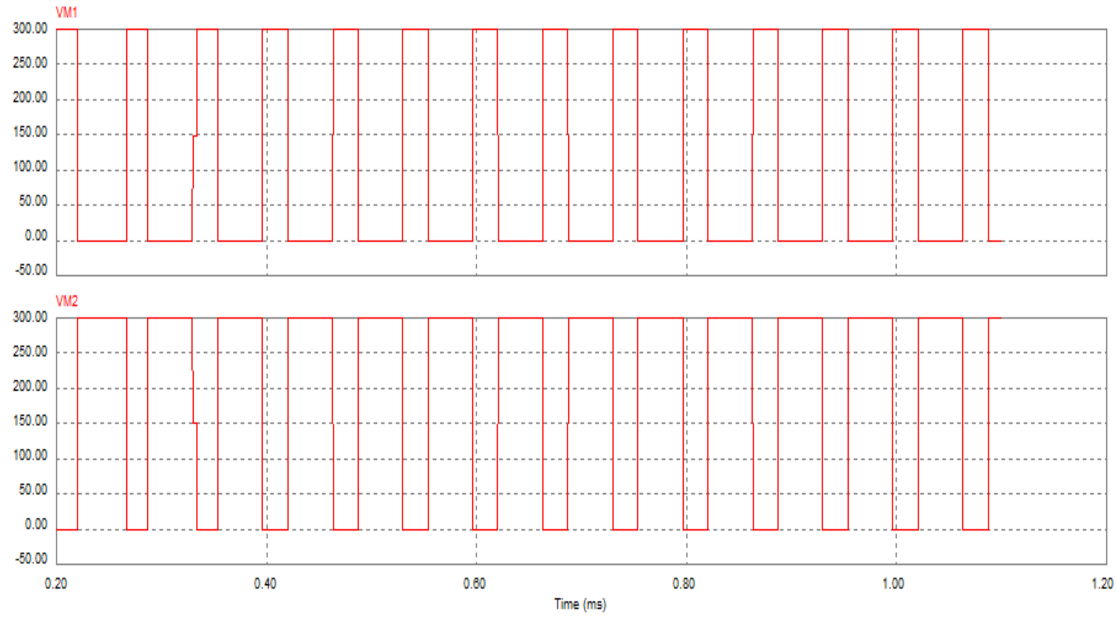



**Figure 5. Typical Waveforms of Half-Bridge LLC Resonant Converter**

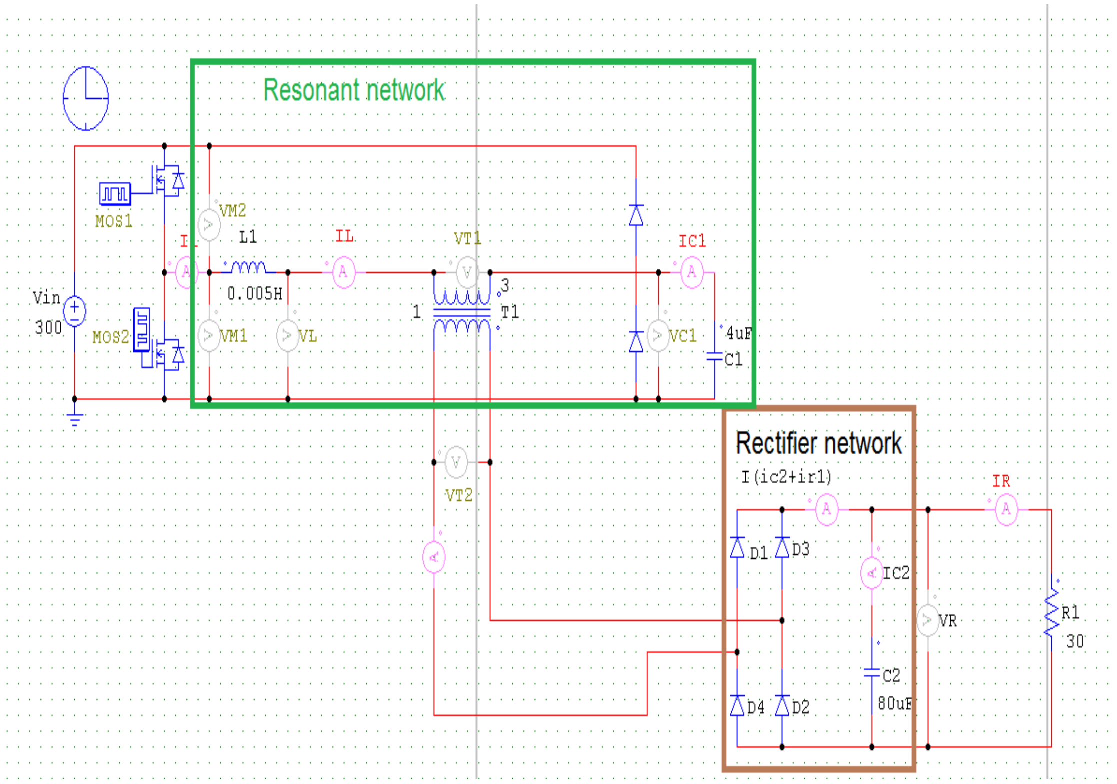



**Figure.6. Schematic of Half-Bridge LLC Resonant Converter**

♣The resonant network contains of a capacitor, seepage inductances, and the attracting inductance of the transformer. The resonant network filters the advanced consistent currents. Ultimately, only sinusoidal current is permissible to influx through the resonant the close out action of the resonant network permits use of the essential estimate to get the voltage earning of the resonant converter, which assumes that only the major component of the square-wave voltage input to the resonant network adds to the power transfer to the output. [15]

Since the rectifier circuit in the secondary side acts as an impedance transformer, the amounting to load resistance is various from present load network even however a square-wave voltage is practical to the resonant network. The current lags the voltage practicable to the resonant network (that is, the fundamental component of the square-wave voltage applied to the half-bridge totem pole), which permits the MOSFETs to be overturned on with zero voltage. As shown in Figure 3, the MOSFET turns on while the voltage across the MOSFET is zero by influx current through the anti-parallel diode. [16]

♣The rectifier network crops DC voltage by obviate the AC current with rectifier diodes and a capacitor. The rectifier network can be applied as a full-wave bridge or center-tapped arranging with capacitive output filter.

♣ The PWM inserted circuit (IC) number SG3524 was chosen in order to produce the control signal. The infectious and simulated control circuit is shown in figure 5. [17]

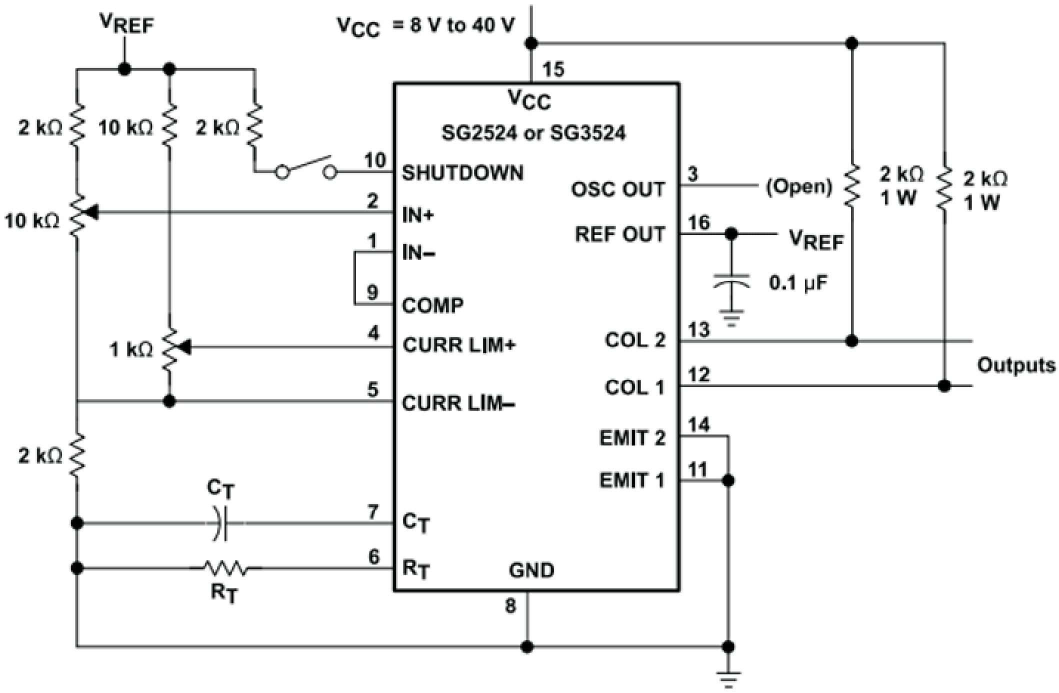



**Figure.7.control circuit implemented by SG3524**

## V. SIMULATION AND EXPERIMENTAL VERIFICATION.

Two project aspects are offered resonant converter both are carried out at an operating frequency of (79 KHz) and for an LED current of 600mA at 00 shift

The simulated waveforms for output LED voltage and current, the resonant tank voltage and current and voltage through filter capacitor are calculated in figures 3 and along with their experimental waveforms for effectiveness. The LED current can be set from600mAto a current as low as100mA by regulating the phase shift of the covering limb of the SRC from 0 to1800.Figure 5 shows the simulated and experimental wave forms of LED driver circuit for a designed value of 600mAat 00 phase shift. In this case, the SRC is operating with full duty cycle. The experimental and simulated waveforms are approving with theoretical analysis. The lamp voltage and current wave are very small and the tank current is lagging the tank voltage, representative that the ZVS operation for the resonant inverter circuit is also possible around operating point for low output power.[18]

In the table [1] and is practical that the resonant current had reduced along with surge in switching frequency and whole companions. This requires that the passage losses in the active switches can be much more reduced with the growth in operating frequency. Also the output current reductions with the increase in phase shift, so LED lamps can be lowered by changing the phase shift. The lamp current deviates from 600mAto100mAas the phase shift varies from 00 to1800. [19]

**TABLE I: SIMULATION CIRCUIT PARAMETERS**

| ITEM | VALUE |
|---|---|
| Input voltage | 300v |
| Rating of led | 10w:600Ma |
| Phase shift | 00:1100 |
| PWM dimming frequency | 15KHZ |
| Capacitor ratio resonant | 4Uf |
| Capacitor ratio | 80uF |
| Inductor ratio | 0.005H |
| Duty ratio .D | 0.5:0.5 |
| Frequency resonant | 79KHZ |

| | |
|---|---|
| Led internal resistance | 30Ω |
| Rectifier diode | MURS360(SMC) |
| High side switch of buck | STB11NM60FD |
| Low side switch of buck | C3D06060G |
| Primary side switch of llc | STB11NM60FD |
| secondary side switch of llc | PDS3200 |
| High side switch of buck | STB11NM60FD |
| Low side switch of buck | C3D06060G |

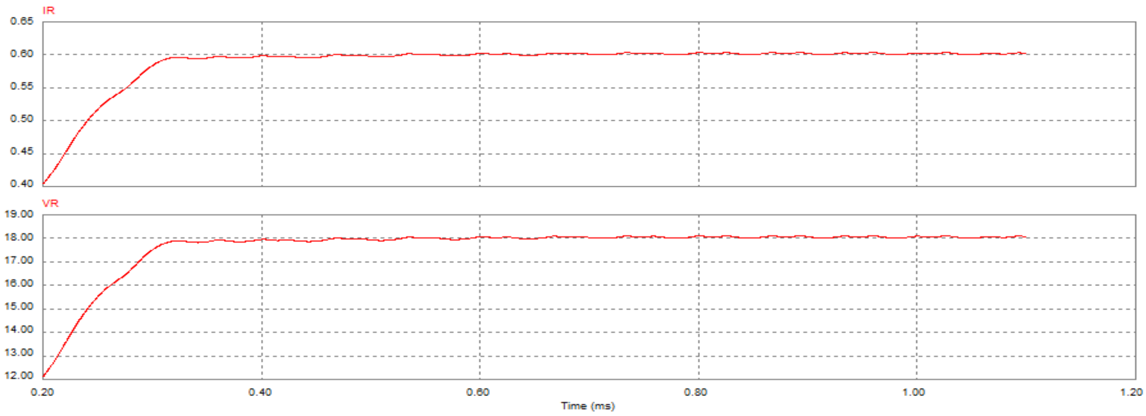



**Figure.7.The simulated waveforms for output LED voltage and current**

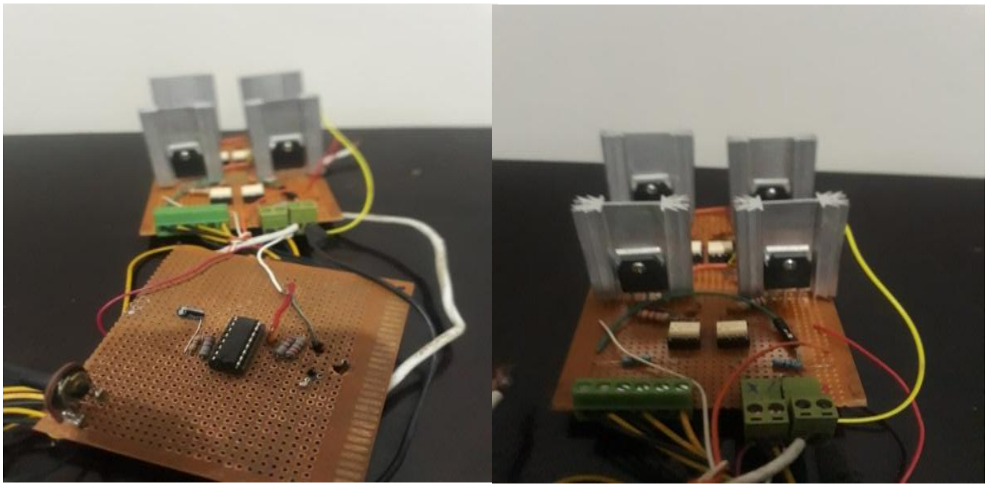
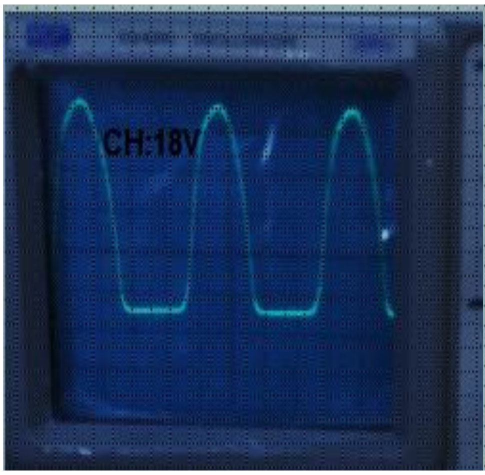


**Figure.6.** picture of the board assembly



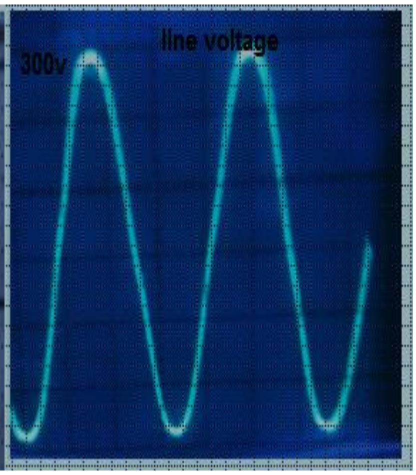




**Fig: 7.** the input AC mains voltage **fig: 8** .the output DC mains voltage

Fig. 7:8 displays waveforms in the input AC mains voltage (Vs) at 300v beneath normal implementation condition and displays waveforms in the output AC mains voltage (Vs) at 18v beneath normal implementation condition. [20]

## VI. CONCLUSION

This paper proposes connecting two LLC resonant converters in series to achieve a wide output voltage range. The first stage utilizes the unique characteristics of a diode-clamp to reduce the voltage gain found in a traditional LLC resonant converter, and hence the overload current. The second stage further shapes the current to obtain the desired constant current characteristic during normal operation. A design example is given and prototype built to show the feasibility of the proposed multi-stage converter, A 18W experimenter model is prepared. The experimental and simulation results revealed that a high efficiency can be achieved, even at high output power.

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