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Design of an Integrated Self bias Power Supply in a Constant Current Buck Type SMPS

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Abstract: Recently AC-DC power electronics are becoming high efficient and cost effective, but there is always a room left for amendment. This research paper deals with design and analysis of an integrated self bias power supply in APFC constant current buck-type switch mode power supply. It proposes an integrated self bias VCC supply in an active power factor correction (APFC) low side constant current buck type SMPS IC with no external magnetic core and winding of copper wire. The designed circuit is evaluated and validated using 7W LED driver of low side constant current buck converter. The experimental results suggest that the IC based on proposed scheme has an excellent efficiency, EMI performance and consumes less power. The application of proposed supply circuit can be extended to other converters as well, like Buck, Buck-boost, flyback and Zeta.

***Index Terms* -** APFC low side CC buck converter, self bias VCC, charge-pump cell.

I. INTRODUCTION

This paper presents implementation of an integrated self biasing power supply in a constant current buck type topology. The constant current buck type SMPS converter is used to step down the input DC voltage of an unregulated DC source to a regulated low output voltage. It is a low side constant current buck type SMPS, especially, compared with linear voltage regulators, and the most unique advantage of low side buck switching power supplies is providing higher efficiency than conventional linear power supplies. Low side buck converter is one of the preferred choices for low power applications due to its low cost and wide dynamic range. Therefore, low side buck converter is widely used in small and medium power applications such as consumer lighting, electronic gadgets, mobile chargers, solar charger lighting, and automotive industries.

This paper proposes the integration of VCC supply to the IC without the help of a transformer magnet, which saves space on PCB layout design, less number of BOM components, reduction of cost and increased reliability of the overall product system. So, the solution circuit is evaluated as per electrical performance and all technical critical testing processes of LED driver.

Generally, semiconductor industries are using three terminal charge-pump cells, which are described in schematic fig 1.

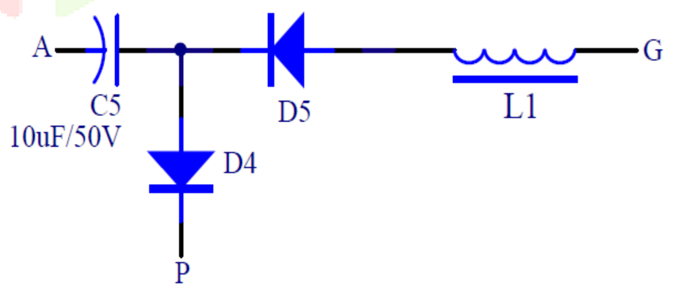

Figure 1 Schematic of three terminal charge-pump cell

Basically a low side constant current buck converter SMPS has a power switch like as a MOSFET/BJT that acts as a switch to control chips PWM pulses. The schematic which is shown in Fig. 2 moves the high level DC voltage to the low level DC voltage and output voltage of this circuit is always smaller than the input voltage. The purpose of this circuit is to produce output which is purely DC. So, filters like low pass filter (LPF) were added to the original circuit to smooth the DC bus and produce pure DC output voltage. In buck topology when the MOS/BJT switch is ON the freewheeling diode will become reverse bias and input voltage pass through to the inductor and output capacitor then both energized and provide current to output load and when the MOS/BJT switch is OFF the freewheeling diode will become forward bias and the inductor current will flow through the freewheeling diode. It can also be used in high range step down switch mode power supply converter.

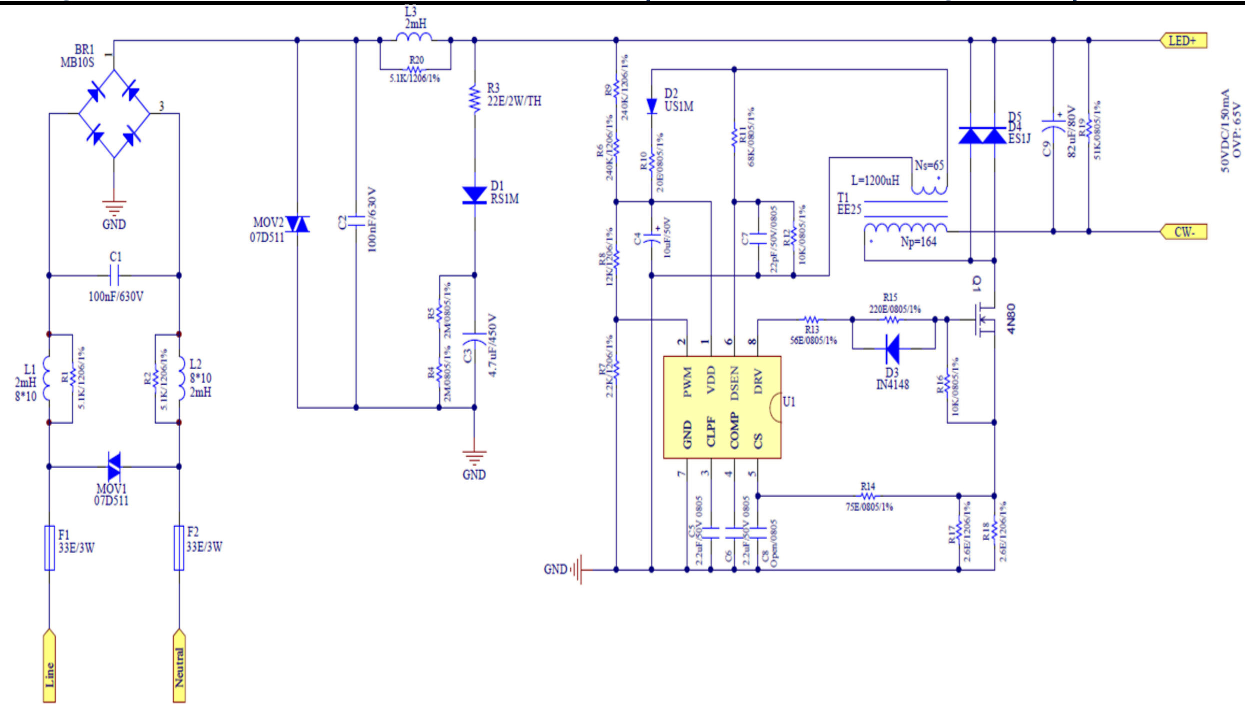

Figure 2 Schematic of constant current buck type SMPS with auxiliary winding

II. LITERATURE REVIEW

Various technologies had been introduced for delivering auxiliary power supply to the chip with a wide of range of Led converters (Ray-lee lin & Hung Ming Chen), [2] & [3] but these include high cost and large size. More efficient Primary-Side Regulation scheme has also been developed to eliminate the use of auxiliary winding for power supply in control circuit which is used in many low power applications [4]. But recently, various self-bias supply schemes has been introduced for the IC in power converters to improve efficiency and more stable DC voltage source [4] & [5].

The proposed paper also integrates a circuit that helps generate self-bias power supplies. which reduce the number of BOM costs, reduce stable power supply and achieves better EMI results as well as greater efficiency.

III. OPERATIONAL PRINCIPLE OF AUXILIARY WINDING SUPPLY OF A CONSTANT CURRENT BUCK TYPE SMPS

An auxiliary winding supply is used as a constant DC source which provides power supply to the buck converter IC, as shown in fig.3. The auxiliary winding supply includes a winding, resistors, capacitor and diode in order to provide staring current and voltage to power IC.

- **Switch ON** – When the MOS switch is turned on, the input current flows through R2, R3, and R4 resistor provide the start-up current to the IC. Meanwhile, C1 capacitor are charged and after that voltage is developed on auxiliary winding which then continuously supply power to the switching IC.
- **Switch OFF** – When the MOS switch is turned off, the diode starts to conduct and C1 capacitor discharges with the help of R1 resistor and provide power supply to IC.

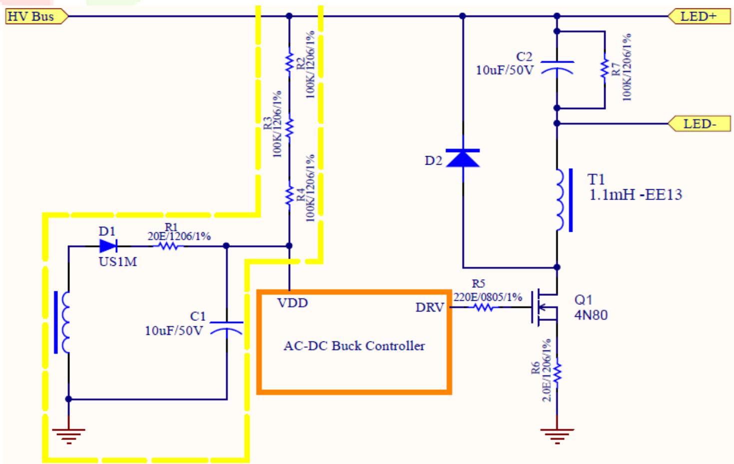

Figure 3 Schematic of auxiliary power supply

Figure 4 represents the waveform of voltage and current while using auxiliary winding based power supply for the IC. In this schematic, the power consumption of chip (IC) is evaluated which is developed in the auxiliary winding. As per analysis with the use of oscilloscope, the values Vdd-17dc and IC current - 5.9mA are found to be sufficient for chip operation during universal input voltage range from 90Vac to 265Vac. The IC protection function like overvoltage protection (OVP), over-current protection (OCP), short-circuits protection (SCP), over temperature compensation and under-voltage lockout (UVLO) working fine as well.

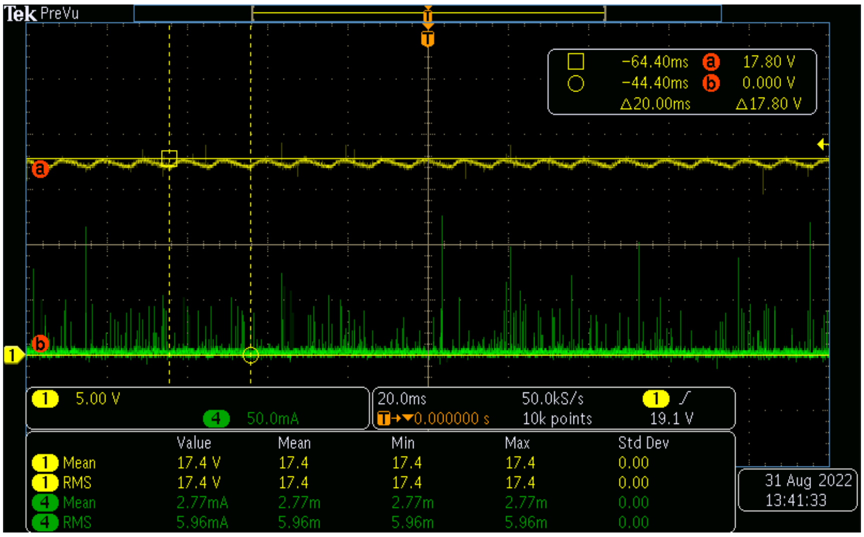

Figure 4 Auxiliary power supply waveform of constant current buck type SMPS

Mathematical calculation:

1. The inductor L is calculated as follows

$$L = \frac{\sqrt{2} \times (V_{acmin} - 0.58 \times V_O)^2 \times T_{ONMAX} \times \eta}{\pi \times V_{acmin} \times I_o}$$

2. The maximum inductor current I_{pk} is equated and calculated as follows

$$I_{PK} = \frac{V_{acmin} \times \sqrt{2} - V_O}{L} \times T_{ONMAX}$$

3. The minimum winding turns of power inductor is calculated as follows

$$N = \frac{I_{dspk} \times L}{A_e \times B_{max}}$$

4. The auxiliary winding turns Na is calculated as follows

$$N = N \times \frac{V_{dd}}{V_O}$$

5. The voltage across the auxiliary winding can be expressed as follow

$$V_{AUX} = (V_{OUT} + V_f) \times \frac{N_{AUX}}{N}$$

Where,

- V_{acmin} lowest AC input voltage (RMS)
- B_{max} B_{max} is in T (usually around 0.20T~0.31T)
- Ae Core effective area
- N Primary Winding
- V_{dd} Required voltage of chip (IC)
- V_O Output voltage of converter
- N_{AUX} Turns of auxiliary winding,
- N Turns of primary winding and
- V_f The forward diode voltage drop of the primary side diode

IV. Operational Principle Of Proposed Integrated Self Bias Power Supply In A Constant Current Buck Type SMPS

In this proposed scheme, a self bias power supply is integrated as a constant DC source in a constant current buck type SMPS IC. The complete model of the novel IC is based on the block diagram given below:

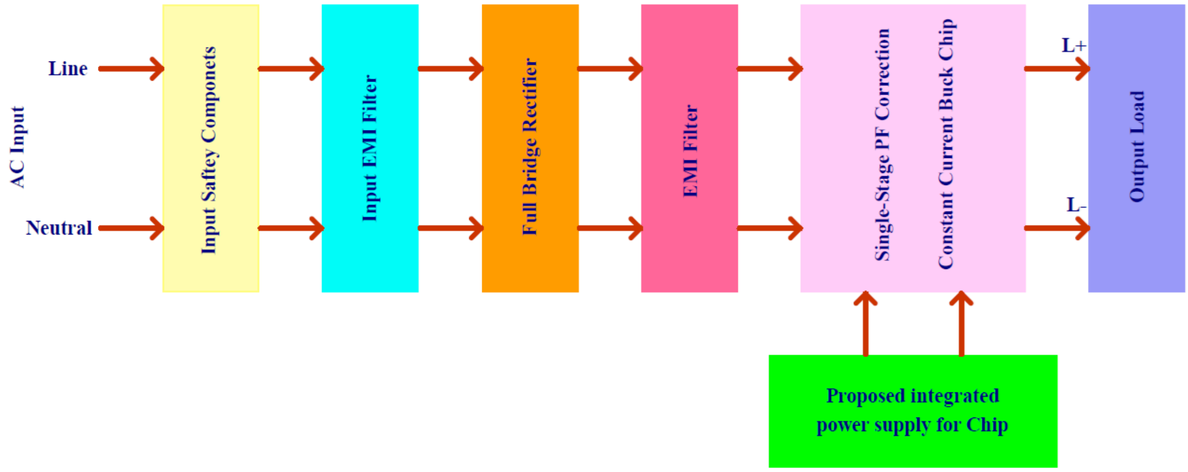

Figure 5 Proposed integrated self-bias power supply block diagram for constant current buck type SMPS

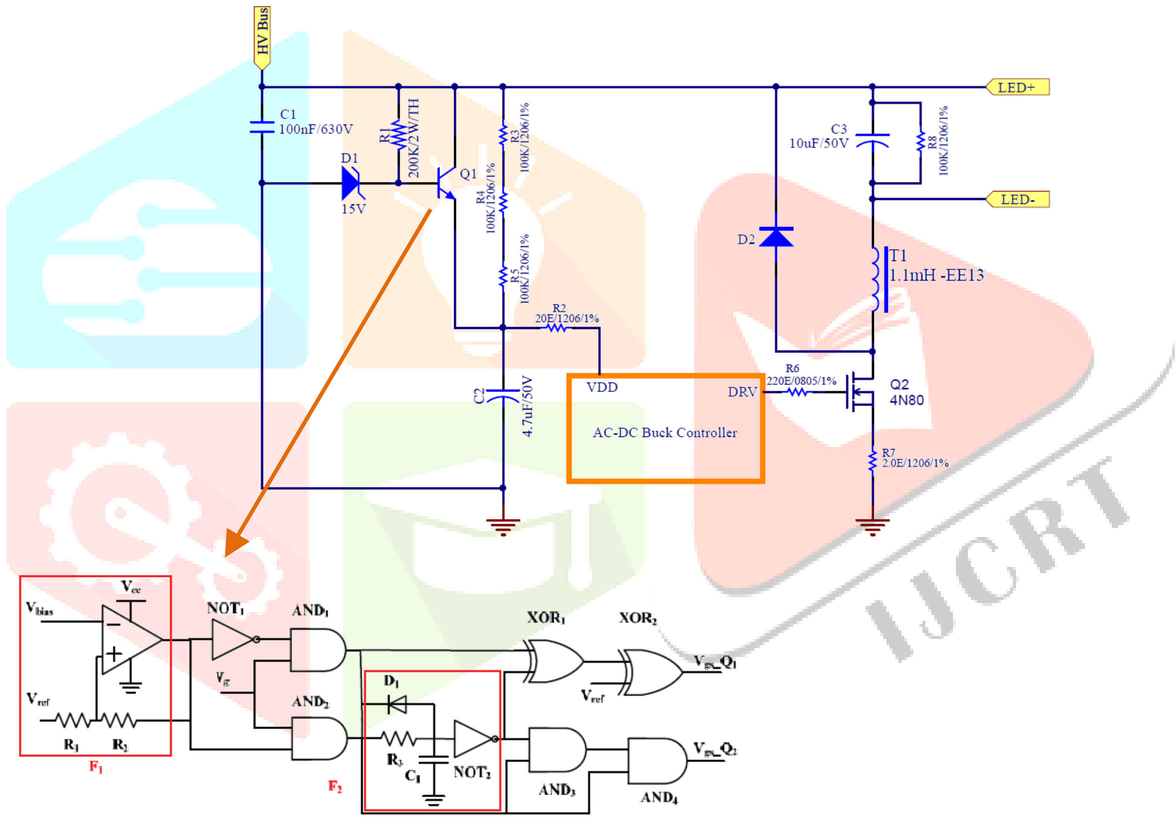

Figure 6 Proposed integrated self bias power supply schematic for APFC constant current buck type SMPS

Before the main MOS/Q2 is turned ON, chip gets startup current from ladder of R3, R4 and R5 resistor and Q1 is energized and conducted with the help of a resistor R1 and Zener diode D1. Resistor R1 connected to the high voltage DC-Bus at one end and Q1 base at another end. Zener diode D1 cathode connected to the base of Q1 and the anode connected to the star ground of the full bridge rectifier. During switching of Q1, the cathode reaches its threshold voltage of 15V and the Zener diode conducts current in reverse. When Zener threshold voltage is reached, the Q1 base gets activated and voltage passes from collector to emitter. Then, the C2 Bias capacitor is charged with the help of Q1 switching and IC gets ON. Due to which, Q2 switching operation works smoothly.

V. Experimental Results

The new designed power IC based on the proposed schematic (fig.5) is verified and validated with 7W APFC buck type LED driver. System parameters and results verifying the schematic are shown in table-1 and 2.

Table 1 Parameters of the proposed system

Input Specs	Pin - 7W, Line and Neutral 2 wire, 90Vac – 265Vac with 50Khz
Output	50Vdc-150mA,
EMC and leakage current	EN55022 class B limits, Leakages current <0.1mA
Size	L - 50mm, W - 45, H – 15mm
Switching frequency	Quasi-Resonant buck with 55khz at full load in 230Vac

Table 2 Test results of proposed self-bias supply system using 7W LED driver

Electrical Test of 7W LED Driver Report with Purposed self-bias supply									
Sr. No.	**V_{IN}**	**P_{IN}(W)**	**PF**	**iTHD**	**V_{OUT}**	**I_{OUT}(mA)**	**P_{OUT}(W)**	**η(%)**	**Aux-VDD**
1	90	6.75	0.97	19.4	40	145	5.80	85.93	17.23
2	230	6.67	0.94	30	40.02	143	5.72	85.80	17.24
3	265	6.76	0.92	32.6	40.1	144	5.77	85.45	17.31

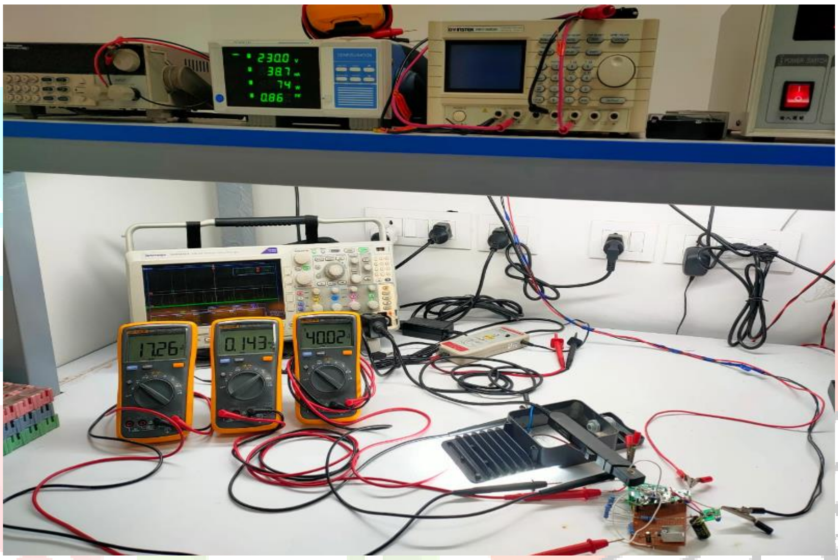

Figure 7 Prototype sample IC testing lab

Figure 8 Actual measured voltage and current waveform in integrated power supply using oscilloscope

VI. Silicon Components Integration In Chip (IC)

In this scheme, three components are integrated in one small chip with proprietary IC package size technique. This integration reduces the PCB size cost, offers quite easy PCB layout design and provides better EMI performance.

Proposed assembly structure is suitable for high voltage and low output current application solution. It will cause less conduction loss and can support maximum power under the same or rising temperature.

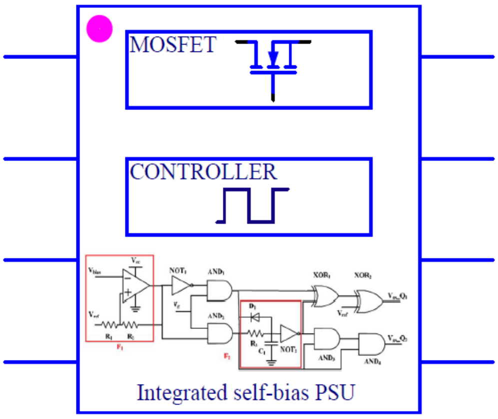

Figure 9 Proposed self bias power supply assembly structure

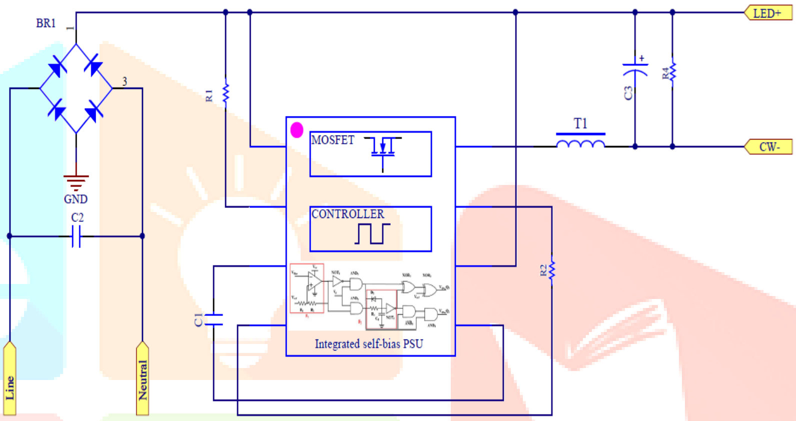

Figure 10 Final schematic of proposed self bias power supply in APFC Buck converter SMPS

VII. Conclusion

In this paper, design of an integrated self bias power supply in a constant current buck type SMPS is presented to eliminate the auxiliary winding of transformer. The proposed solution is provided with high quality, less BOM components, improved over all product efficiency and EMI performance as well as easier designing of PCB layout. The developed chip fabricated and gives excellent load regulation and low power consumption.

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