# Comparative Analysis, & Modeling Of A Current Balancing Scheme For High-Power Led Lighting Using Single-Switch Ac-Dc Converters For Power Factor And Efficiency Improvement

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**Abstract:** This paper addresses several issues concerning the analysis, design, modeling, simulation and development of Single-phase, single-switch, power factor corrected AC-DC high frequency switching converter topologies with Transformer isolation. A detailed analysis and design is presented for single-switch topologies, namely forward buck, Flyback, Cuk, Sepic and Zeta buck-boost converters, with high frequency isolation for discontinuous conduction modes (DCM) of operation. With an awareness of modern design trends towards improved performance, these switching Converters are designed for low power rating and low output voltage, typically 20.25W with 13.5V in DCM operation. Laboratory prototypes of the proposed single-switch converters in DCM operation are developed and test results are presented to validate the proposed design and developed model of the system.

**INTRODUCTION**

Single ended converters, such as the forward, flyback, Cuk, Sepic, Zeta and others, are often chosen for implementing simple low cost and low power converters. The use of only one switch and the relatively simple control circuit required are strong reasons for their choice. The discontinuous mode operation (DCM) of all single-switch topologies is most suitable for low power applications, where these converters present excellent characteristics of power factor correction using a very simple control scheme with only one voltage feedback loop. The conventional single-phase diode rectifier draws pulsating current due to the direct connection of the diode to an electrolytic capacitor. The amount of line current distortion produced by the single low power converter is minimal. However, a large number of electronic devices generate a large amount of current distortion, and these results in environmental pollution such as electromagnetic interference. For consumer electronics and other similar equipment with relatively low power, less than a hundred watts, a solution to suppress its input current distortion, i.e. to improve its power factor, is required. Therefore, a simple-structure PFC converter is desirable. On the other hand, sufficient suppression of the output-voltage ripple and high power efficiency are also required. Power Quality has become an important consideration when designing any converter. As a result, more attention has been given to the design of converters with good power Factor correction (PFC), reduced input harmonics and Better efficiency.

In this paper, Analysis, design, modeling, simulation and development of Single-phase single-switch ac-dc flyback, Cuk, Sepic, Zeta buck-boost and forward buck converters in DCM are carried out for power factor correction and efficiency Improvement. For wave shaping in single-phase Single-switch ac-dc converters different techniques are used with various combinations of inductors and Capacitors. The simulated results have also been verified experimentally.

**Circuit and Operation**

Fig.1 shows the block diagram of a single-phase AC-DC converter with power correction in DCM operation. As shown in Fig.1, discontinuous conduction mode (DCM) uses a very simple control feedback, which only requires output voltage sensing. The bridge rectifier is used at the input AC side with a power factor corrector using an inductor and capacitor combination. Now, a small value of output voltage, compared to the reference value and resulting value, passes through the output voltage controller G(s), which generates the PWM output and is used for switching the converter. It has inherent power factor correction characteristics with constant duty ratio and switching frequency, offering an attractive solution for lower power applications.

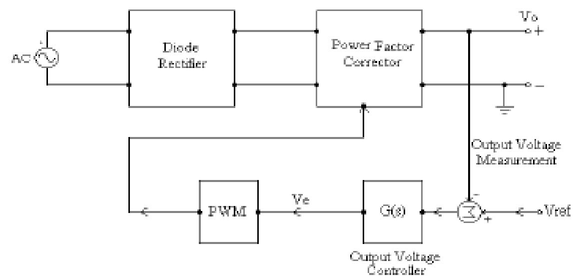



Fig. 1 Block diagram of single phase AC-DC converter with power factor correction and feedback control in DCM operation

The output voltage regulation is provided by the feedback loop as shown in Fig.2, where the output sensed voltage Vo is compared with a reference Voref value and the error is amplified in a proportional integral (PI) controller which is compared with a saw-tooth ramp Vs, thus providing the pulse to power switch. Therefore, this circuit is controlled by the difference in the on- time interval and the constant switching frequency fs.

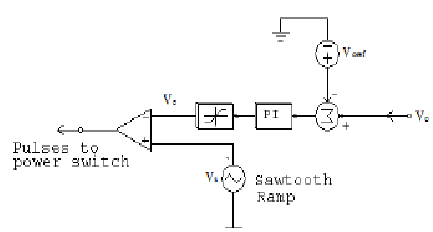



Fig. 2 Practical voltage follower approach for PWM control

### Design Equation for Single-Phase, Single-Switch AC-DC Converters

The different parts of all single-switch converter systems are modeled using basic equations and all equations are summarized in Table 1

Table 1 Basic equations for single switch AC-DC converters

| | Forward | Flyback | Cuk | SEPIC | Zeta |
|---|---|---|---|---|---|
| Voltage ratio, $V_o/V_{in}$ | $\frac{N_2}{N_1}D$ | $\frac{N_2}{N_1}\frac{D}{(1-D)}$ | $\frac{N_2}{N_1}\frac{D}{(1-D)}$ | $\frac{N_2}{N_1}\frac{D}{(1-D)}$ | $\frac{N_2}{N_1}\frac{D}{(1-D)}$ |
| Critical inductance $L_{cr}$ | $\frac{R_L(1-D)}{2f_s}$ | $\frac{R_L}{4f_s(\frac{N}{N}+\frac{V_o}{V_{in}})^2}$ | $\frac{R_L}{4f_s(\frac{N}{N}+\frac{V_o}{V_{in}})^2}$ | $\frac{V_{in(min)}}{\Delta I_L f_s}D$ | $\frac{R_L(1-D)^2}{2f_s}$ |
| Min. output capacitor $C_o$ | $\frac{(1-D)}{8Lf_s^2(\Delta V_o/V}$ [illegible] | $\frac{V_o}{r_v f_s R_L}$ | $\frac{V_o}{r_v L\omega_L R_L}$ | $\frac{1}{kf_s R_L}$ | $\frac{V_o}{\omega r_v R_L}$ |
| Voltage stress of switch, $V_{sw}$ | $\frac{2V_{in}}{(1-D)}$ | $\frac{V_{in}}{(1-D)}$ | $V_{in}+V_o$ | $V_{in}+V_o$ | $V_{in}+V$ [illegible] |
| Voltage stress of switch, $V_D$ | $\frac{V_o}{(1-D)}$ | $\frac{V_o}{D}$ | $V_{in}+V_o$ | $V_{in}+V_o$ | $V_{in}+V$ [illegible] |
| Coupling voltage, $V_{cp}$ | NA | NA | $V_{in}+V_o$ | $V_{in}$ | $V_{in}+V$ [illegible] |

Where N1 and N2 are the primary and secondary turns of the transformer, D is the duty ratio, fs is the switching frequency, rv is the peak to peak output voltage ripple, and Vo and Vin are output and input voltage, respectively.

### Modeling and Simulation

The importance of simulation is apparent for the preliminary design of any system. System behavior and performance can be predicted with the help of the simulation. To verify and investigate the design and performance of the preliminary stage, a simulation study of all converters is performed in DCM operation for input AC voltage 220V at 50 Hz and output DC voltage of 13.5V and 20.25W output power rating using the PSIM6.0 platform. Figs.3-7 show the PSIM models of forward, flyback, Cuk, Sepic and Zeta converters in DCM operation. Simulation results show high quality steady state performance from 20% to 100% loading conditions with good power factor and efficiency.

In order to demonstrate all converters performance in DCM operation, the design parameters and simulation results are summarized in Table 2 and Table 3, respectively. In order to observe the circuit performance at lower as well as at higher loads, simulation studies are divided into four categories:

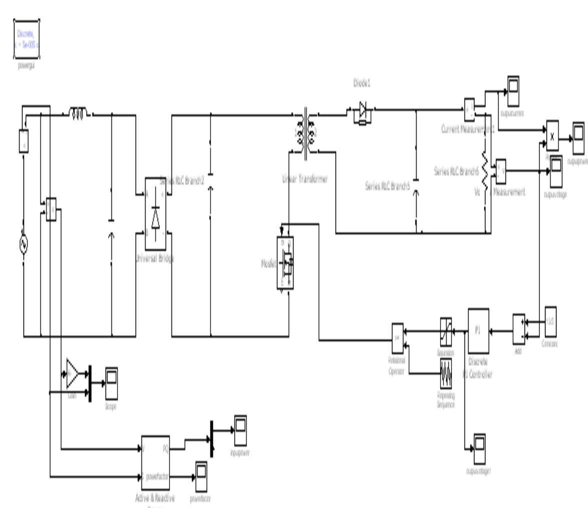
a) Steady state operation with 100% load.

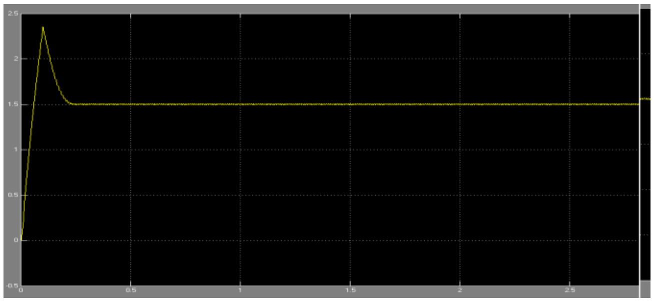
b) Steady state operation with 50% load

c) Steady state operation with 20% load

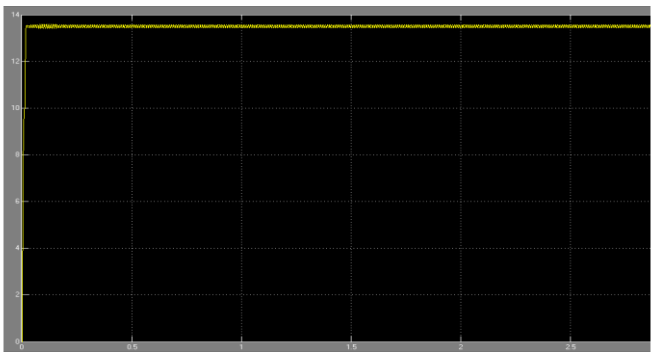
d) Sudden application and removal of load

### PSIM model of single switch flyback converter

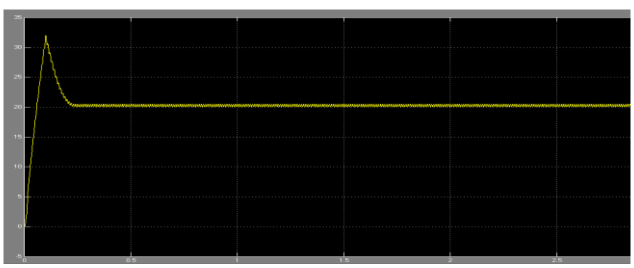




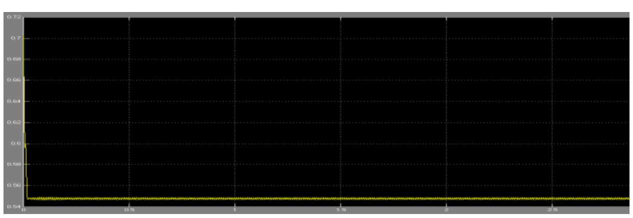
Output current



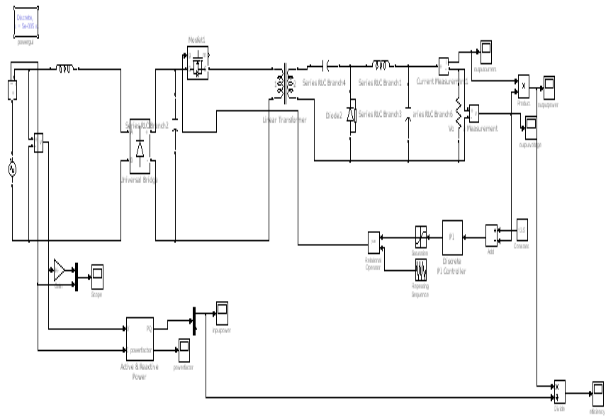
Output voltage

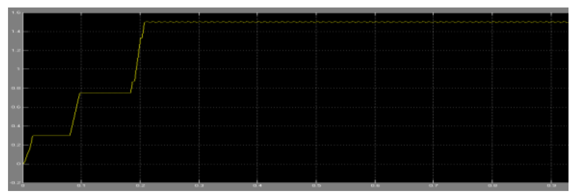


Output power

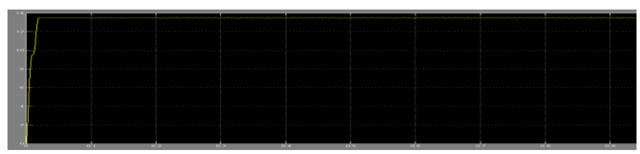


Output voltage 1

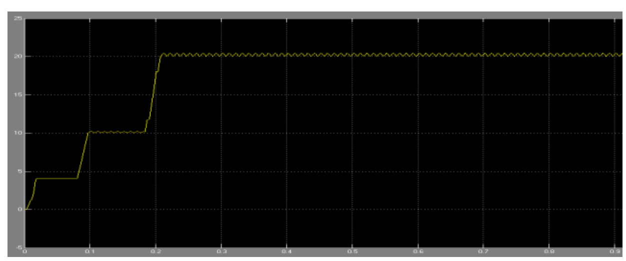




Output current

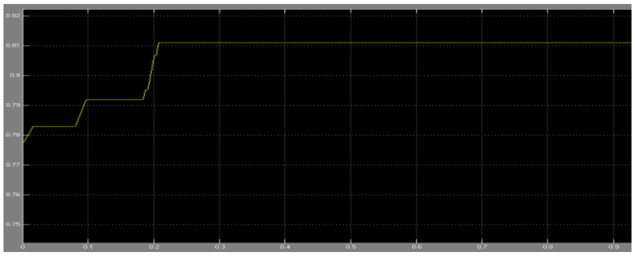


Output voltage



Output power

**PSIM model of single switch zeta converter**



Efficiency

## CONCLUSIONS

In this paper analysis, design, modeling, simulation and development of single-switch converters are carried out in DCM operation for 13.5V, 20.25W output. High power quality is obtained with design parameters with PF on the order of 0.99 and efficiency more than 80%. The flyback, Cuk, Sepic and Zeta converters show close to unity power factor at full load with more than 80% efficiency and very low output voltage ripple, which is observed close to 1%. On the other hand, the forward converter shows very good efficiency, which comes out to 82.6% and output voltage ripple, which is observed at 1.2%. So, depending on the requirements we can choose a converter for low power applications, but little compromise between efficiency, THD and Power Factor (PF) is required.

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