Simulation of Switching Power Based on WEBENCH Tool

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ABSTRACT: Nowadays, there are a lot of EDA simulation tools. Each of them has its own functions and features. WEBENCH is a web based, and easy to use, design and simulation tool. The design and simulation method of switching power using WEBENCH tool is given in this paper. A complete boost topology design example of switching power is introduced. Electrical simulations of output voltage are given. Compensation for current mode switching power is also discussed and calculated by WEBENCH tool. Thermal simulations of print circuit board are analyzed.

KEYWORDS: Switching power; Simulation; WEBENCH

1 INTRODUCTION

WEBENCH is a web-base design tool for customized power, lighting, filtering, clocking and sensing designs. It can help you generate, optimize and simulate designs that conform to your unique specifications. (PAM et al. 2016) proposed a compensation design of power converters using hybrid optimization by WEBENCH. There are also other EDA tools from different companies. Multisim from NI company is an electronic schematic capture and simulation program. (Abad et al. 2015) simulated a power surge monitoring and suppression system using Lab VIEW and Multisim co-simulation tool. (SUN & JIN 2015) proposed a PSpice model for adjustable voltage regulator and simulated by Orcad. Cheng (2011) introduced the application of Multisim in power electronic technology. This paper only focuses on switching power design and simulation by WEBENCH tool.

2 DESIGN FLOW

With only four steps, we can create a custom design that matches our specifications by WEBENCH tool. Entering input voltage range, output voltage, load current and ambient temperature, we already start our design. The solutions are calculated based on our design inputs including the optimizer setting. Choose one solution in the designs that best meet system requirements. In second step, we can view or edit the schematic of design and then customize the components of design. In the follow step, we can evaluate the design performance and analyze electrical behavior with built-in simulation tools. Check critical operating values, such as efficiency and duty cycle or improve the design if needed. Thermal performance of switching power can also be investigated. Finally, we can export schematic, board layout, simulation and reports documents.

Figure 1. A typical design flow by WEBENCH tool.
### 3 DESIGN OF SWITCHING POWER

Suppose that DC-DC switching power we need are as following. The source input is limited to between 8 to 14 voltage. We hope to get a source output with 24.5 voltage and 1.5 ampere load capacity. There are dozens of custom designs matching our needs. In this paper, TPS40210, a current mode boost controller, is chosen. TPS40210 is suitable for topologies which require a grounded source N-channel FET including boost, fly back, SEPIC. Not only that, current mode control can provide improved transient response and simplified loop compensation. The schematic of switching power design by WEBENCH tool is as Figure 2.

#### 3.1 Output voltage of switching power

The output voltage of the switching power is set by a resistor divider (Rfb1 and Rfb2) from the output to the FB pin in Figure 2. Calculate the output voltage of switching power using Equation 1:

\[
V_{out} = V_{ref} \left(1 + \frac{R_{fb2}}{R_{fb1}}\right)
\]

(1)

Where \(V_{ref}\) represents reference voltage, equals to 0.7 volts. \(R_{fb1}\) and \(R_{fb2}\) represent feedback resistors, equal to 1.5kOhm, 51kOhm respectively.

From Equation 1, the output voltage should be 24.5 volts.

If you change the value of any of these two resistors, the output voltage will change accordingly. We will check this result in simulation part of paper.

#### 3.2 Oscillator frequency

The oscillator frequency is determined by a resistor and capacitor to the RC pin of the controller. The frequency is adjustable from 35 kHz to 1000 kHz. For most applications, a capacitor in the range of 68 pF to 120 pF gives the best results. In our design, the value of capacitor is 91 pF and value of resistor is 348 kOhm. The oscillator frequency is 458.7 kHz.

#### 3.3 Compensation

Compensation design for DC-DC power converters is often considered as difficult and time consuming. It needs lots of iterations to meet all the desired specifications. There are two methods to design a suitable compensation. The first option is to use a frequency response analyzer to measure the open loop modulator and power stage gain and to then design compensation to fit that. The second option is to make an initial guess at compensation, and then evaluate the transient response of the system to see if the compensation is acceptable to the application or not.

An adequate response can be obtained by placing a series resistor and capacitor (Rcomp and Ccomp) from the COMP pin to the FB pin as shown in Figure 2. Though not strictly necessary, it is recommended that a capacitor be added between COMP and FB to provide high-frequency noise attenuation in the control loop circuit. This capacitor...
introduces another pole in the compensation response. The initial compensation selection can be done more accurately with aid of WEBENCH to select the components.

From Figure 2, we know that the value of compensation resistor is 26.1kΩ, the value of compensation capacitor is 8.2nF, the value of high frequency compensation capacitor (CComp2) is 360pF. These parameters of schematic are calculated and choose by WEBENCH tool.

4 SIMULATIONS

Electrical simulation and thermal simulation are given in this paper. Compensation of switching power is also investigated.

4.1 Electrical simulation

By simulating circuit’s behavior before actually building it can greatly improve efficiency and provide insights into the behavior and stability of designs. Simulation of steady state for switching power is as Figure 3.

![Figure 3. Simulation of steady state.](image)

From Equation 1, we already calculated that the output of switching power was 24.5 volts. The duty cycle of controller is 68.53% and the total output power is 36.75W. The peak-to-peak output ripple voltage is 126.284mV in our design.

4.2 Compensation

The bode plots of power stage, compensator and total loop are shown as Figure 4.

![Figure 4. Bode plots of compensation.](image)

With compensation circuits, stability of switching power system gets stronger. The cross over frequency is changed to 3.48 kHz now. Gain margin is -11.16 dB and Phase margin is 55.2 degree.

4.3 Efficiency

The efficiency of switching power are shown as Figure 5. The greater the input voltage is, the higher the output efficiency.

![Figure 5. Plots of Efficiency.](image)

In our design, efficiency is 96.398% when input source is 14 volts and output current is 1.5 ampere.

4.4 Thermal simulation

We can identify heat problems on the PCB early in the design process by thermal simulation.
From Figure 6, we found that temperature of M1 device is too high. M1 component is a MOSFET. We check M1 in Table 1, the temperature of M1 is 126°C. The temperature is beyond the upper limitation of component.

Table 1. Operating temperatures of simulator.

<table>
<thead>
<tr>
<th>Components</th>
<th>Max Temp.</th>
<th>Power</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
<td>47°C</td>
<td>5.36e-2W</td>
<td>TPS40210</td>
</tr>
<tr>
<td>Cout</td>
<td>49°C</td>
<td>8.69e-2W</td>
<td>35SVPF82M</td>
</tr>
<tr>
<td>Cin</td>
<td>50°C</td>
<td>3.63e-5W</td>
<td>GRM21BR61E475</td>
</tr>
<tr>
<td>D1</td>
<td>57°C</td>
<td>0.75W</td>
<td>B240A-13-F</td>
</tr>
<tr>
<td>L1</td>
<td>51°C</td>
<td>0.24W</td>
<td>PM2110-180K-RC</td>
</tr>
<tr>
<td>M1</td>
<td>126°C</td>
<td>0.51W</td>
<td>CSD18504Q5A</td>
</tr>
</tbody>
</table>

If we change the thickness of the copper to 2 OZ, temperature of M1 component is changed to 108°C. The temperature is still a little high. If we keep the thickness of the copper as 1 OZ, and change input voltage to 11 voltage, temperature of M1 change to 92°C, this temperature can be accepted.

From thermal simulation, we can know which components we should pay attention to in the design. If the input voltage must be 8 voltage, we can consider the use of fan cooling.

5 CONCLUSIONS

Switching power can be designed and simulated easily with the aid of WEBENCH tool. Stability of switching power can be improved by using compensation circuit. The design problems can be found as early as possible by using electrical and thermal simulation. WEBENCH features more than these, this article only describes a small part of them.

6 ACKNOWLEDGEMENT

This work is supported by “the Fundamental Research Funds for the Central Universities”. We would also like to thank Xie Sheng-xiang from Texas Instruments Semiconductor Technologies (Shanghai) Co., Ltd. for his technical assistance.

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