Construction of the UC2845 Simulation Model Based on Matlab/Simulink

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Abstract. MATLAB/Simulink has some gaps in the simulation of the internal structure of the integrated chip. The article analyzes the internal structure of the UC2845 peak current control integrated chip and divides its internal parts into four parts: startup section, oscillation section, feedback section and current sampling section. The working principle and working process of each part of the chip are analyzed. The simulation model of each part is built based on MATLAB/Simulink platform, and the UC2845 chip simulation model is completed. Based on the chip model, a simulation circuit of DC24V/15V switching power supply was built. Based on UC2845 chip, an experimental circuit of DC24V/15V switching power supply was built. The simulation waveform and experimental waveform were compared, and the accuracy and practicability of the chip simulation model were verified. The chip simulation model has reference and guidance value for the simulation of UC18, UC28, UC38 series integrated chips in MATLAB/Simulink.

1. Introduction
The UC2845 PWM mode integrated chip is a pulse width modulator which is controlled by current and developed by Unitrode [1-5]. UC2845 is a consummate PWM (Pulse Width Modulation) controller for improving the voltage regulation rate, load regulation ratio and transient response characteristics of the switching power supply due to the existence of a voltage loop and a current loop double loop control system in the structure [6-7]. So far, because of its advantages such as simple peripheral circuits and excellent performance, it is widely used in small and medium power DC-DC switching power supplies [8-10].

The MATLAB / Simulink simulation platform is very powerful in electrical engineering, but currently there is basically no simulation of the integrated control chip on the platform. One reason is that the manufacturer of the integrated chip only provides a simple logic framework inside the chip, and the another is that after the chip model is built, it is difficult to apply the chip model to the actual switching power supply circuit because some components in the library of MATLAB/Simulink may be incompatible. For example, when implementing a simple Buck Chopper, the voltage divider resistor in the feedback part of the circuit may not be able to connect with the integrated chip that controls the status of the switch, resulting in the entire circuit not working properly.
Thus, it is necessary to impact and build the simulation model of integrated chip in the MATLAB/Simulink simulation platform to obtain the productive simulation results. In this paper, the internal logic structure of the UC2845 is analyzed, the function of each pin of the chip is introduced, and the working principle and working process of the chip are analyzed in depth. Then we have built the simulation model of UC2845 in the MATLAB/Simulink simulation platform, include startup section, oscillation section, voltage feedback section and current sampling section and analyzed the working principle and working process of the chip base on the internal logic structure of the UC2845. Furthermore, a 24V/15V switching power supply simulation circuit based on flyback converter was designed, and the simulation and experiment waveform of this circuit are compared to verify the simulation model of this chip.

2. The method of model construction and experimental

2.1. Structure of UC2845

The oscillation frequency of UC2845 is set by the external RC network and the maximum duty cycle can be 50%. The chip contains a highly stable reference voltage source and can be used by external circuits. UC2845 uses “totem pole” output circuit, output current up to 1A, can directly drive bipolar transistors, MOSFETs and IGBTs, etc., UC2845 is a single-ended output, its application is very extensive, especially suitable for low-power switching power supply without power frequency transformers [11]. The UC2845 integrates an error amplifier, a current detection comparator, a PWM latch, an oscillator, an under-voltage protection circuit, a standard 5V reference power supply, and other auxiliary circuits [12]. The internal structure of the chip is shown in Figure 1.

![Figure 1. UC2845 internal structure](image1)

The UC2845 has three package types, namely DIL-8, SOIC-14 and PLCC-20. The DIL-8 package is used as an example to describe the functions of the pins on the chip. The pinouts are shown in Figure 2.

![Figure 2. UC2845 Pinout](image2)

The specific functions are as follows:
1) Pin 1 (COMP): Error amplifier output for external loop compensation;
2) Pin 2 (VFB): Error amplifier inverting input;

The specific functions are as follows:
1) Pin 1 (COMP): Error amplifier output for external loop compensation;
2) Pin 2 (VFB): Error amplifier inverting input;
3) Pin 3 (ISENSE): current detection and comparison input;
4) Pin 4 (RT/CT): oscillator timing element access. Through the external RC network, the maximum duty cycle and oscillation frequency can be adjusted;
5) Pin 5 (GROUND): signal ground;
6) Pin 6 (OUTPUT): pulse output terminal, generally connected to the MOSFET gate through an external resistor to directly drive the power switch;
7) Pin 7 (VCC): power access;
8) Pin 8 (VREF): reference voltage output terminal [13-15].

When the circuit is powered on, the external start-up circuit provides pin 7 with the required start-up voltage. Under the action of starting the power supply, the chip starts to work. The pulse signal generated by the pulse width modulation circuit is driven by the 6-pin output to drive an external switching power transistor. The signal generated by the work of the power tube is converted into a low-voltage DC signal via a sampling circuit and fed back to pin 3 to maintain the normal operation of the system. After the circuit works normally, the low-voltage DC signal fed back by the sampling circuit is sent to the internal error comparison amplifier via pin 2 and compared with the internal reference voltage. The resulting error signal is sent to the pulse width modulation circuit to complete the modulation of the pulse width so as to achieve the purpose of stabilizing the output voltage. If the output voltage becomes high for some reason, the sampling voltage of the pin 2 also becomes high, the width of the output pulse is narrowed by the pulse width modulation circuit, the on-time of the switching power transistor becomes shorter, and the output voltage becomes lower, making the output voltage is stable and vice versa [16-18]. Sawtooth wave oscillating circuit produces periodic sawtooth wave, its cycle depends on pin 4 external RC network [19]. The generated sawtooth wave is sent to the pulse width modulator as its duty cycle, the pulse cycle of the pulse width modulator output is unchanged, and the pulse width varies with the magnitude of the feedback voltage.

2.2. The method of model construction
The UC2845 can be roughly divided into four parts: the startup section, the oscillation section, the voltage feedback section, and the current sampling section. The working principles and working processes of the four parts are respectively analyzed. According to the internal logic diagram of the chip, based on the platform of MATLAB / Simulink, the simulation models of these four parts are built, and finally the model of the chip is completed through appropriate data conversion and logic cooperation.

2.2.1. Startup section. In normal operation, the UC2845 power supply is divided into two phases, which are the start-up phase and normal work phase. At startup, the starting capacitor voltage is charged to 8.4V through an external resistor. After starting, the normal operating voltage range is 7.6V to 34V. The auxiliary power supply consists of a feedback winding, a rectifier circuit and a filter. When the input voltage is not within the normal operating voltage range, the chip enters the undervoltage lockout state, limiting or closing the pulse output. To achieve the above functions, the power supply voltage is compared with the upper and lower thresholds of the power supply of the chip, and the result is input to the S-R flip-flop, and the power supply voltage is compared with the maximum value of the chip operating voltage of 34V to finally control the switching state of the chip. The model shown in Figure 3 was built on the MATLAB/Simulink platform.

![Figure 3. UC2845 startup section](image)
2.2.2. Oscillation section. After the chip is started, the 5V reference voltage output from pin 8 charges the timing capacitor through the timing resistor, and after charging to the maximum voltage value, it is discharged through an internal current source with a current of 5.1814 mA to form a sawtooth wave. The oscillator outputs a low level during the rise of the sawtooth wave, and outputs a high level during the discharge of the capacitor, thereby forming a clock signal of the chip [20]. In order to realize the oscillation function, a 5V DC source is built in the chip. After the chip starts, the ideal switch S1 is closed. The DC source supplies power to the RC network, and the capacitor voltage is compared with the 5V reference voltage adjusted by the gain module to control the SR triggering. The output of the device and the output of the SR flip-flop control the switching state of the ideal switch S2 to control the charging and discharging of the timing capacitor. The oscillation control logic diagram is shown in Figure 4.

![Figure 4. UC2845 oscillation section](image)

2.2.3. Feedback section. The feedback section is mainly composed of voltage feedback and error amplifier circuits. After the chip is started, the 5V reference voltage output from the pin 8 of the chip is divided into two voltages of 10 kiloohms to form a 2.5V reference voltage, which is connected to the non-inverting input terminal of the error amplifier, and the feedback voltage is connected to the inverting input terminal of the error amplifier. The feedback circuit is connected to a 1.2V inverting DC source. After two resistance values of 2:1 are divided, the voltage across the sampling resistor is compared with the voltage value at both ends of the sampling resistor. At the same time, the startup section and the oscillation section cooperate with appropriate logic to jointly control the duty cycle of the output pulse of the chip. Feedback control logic diagram shown in Figure 5.

![Figure 5. UC2845 feedback section](image)

2.2.4. Current sampling section. The current sampling part mainly collects the current flowing through the power switch tube and plays a role in limiting the current. During normal operation, the voltage across the sampling resistor of the chip should be clamped below 1V. When the chip detects
that the input voltage of pin 3 is higher than the threshold 1V, the chip turns off the output pulse to achieve the protection function [21]. The current sampling section is shown in Figure 6, where the pulse is output pin when the chip is not protected by current.

**Figure 6. UC2845 current sampling section**

2.2.5. _UC2845 chip model construction._ Based on the analysis and modeling of the UC2845 current-mode PWM mode integrated control chip startup section, oscillation section, voltage feedback section and current sampling section, this chip model is constructed, as shown in Figure 7, which shows the DIL-8 package of the chip. The Op-Amp-pin is added to the model, which is the inverting input of the error amplifier of the feedback part and used to implement the electrical connection of the chip in MATLAB/Simulink. The chip package built based on Matlab/Simulink platform is shown in Figure 8.

**Figure 7. UC2845 chip internal structure**

**Figure 8. UC2845 package**

2.3. _Simulation circuit details_  
A 24V/15V switching power supply simulation experiment circuit as shown in Fig. 9 was built to verify the practicability of the chip model.
Figure 9. Simulation circuit

In the main circuit, the input voltage is DC24V, the transformer turns ratio is 24:15 and the design duty cycle is 50%, the sampling resistance is 1.2 ohms. In order to prevent the over-current protection circuit from being triggered by mistake, the RC filter circuit is used to eliminate the current spike when the switch tube is turned on. A surge voltage buffer absorption circuit is set on the primary side of the transformer to reduce voltage spikes. In order to avoid excessive peaks in the current flowing through the switch tube, the UC2845 chip is prevented from false triggering, and a simple RC filter circuit is connected to the secondary side of the transformer. Diodes are used to control the rectification and the load is 15 ohms. The feedback side selects resistances of 50 kilo-ohms and 9.6 kilo-ohms respectively to realize the voltage division. The chip is powered by a DC15V regulator. A compensation network is added between pin 1 and pin 2 of the chip to improve the dynamic response of the error amplifier and improve the stability of the switching power supply. According to UC2845 chip frequency formula:

\[ f(kHz) = \frac{1.72}{R_T C_T} \quad (R_T > 5k\Omega) \]

Where:
- \( R_T \) = Timing resistor
- \( C_T \) = Timing capacitor

Select \( R_T = 6.52k\Omega \) and \( C_T = 2.2nF \), the chip oscillation frequency will be 120 kHz. Because the input and output are not common ground, the feedback voltage at the output end cannot be directly connected to the feedback end of the control chip. The simulation circuit expects an output voltage of 15V and a rated output power of 15W.

2.4. Experimental circuit details

Based on the UC2845, a DC24/15V flyback switching power supply experimental circuit was built. The three-terminal adjustable shunt reference source TL431 and the linear optocoupler PC817 are used to sample the output voltage to obtain the feedback voltage, and the feedback voltage is fed back. To the UC2845's voltage feedback port, thus changing the duty cycle of the UC2845 output drive signal, making the output voltage stable. The schematic diagram is shown in Figure 10.
3. Results and Discussion

3.1. Simulation results

Figure 11 to Figure 20 show the experimental waveforms of the simulation circuit.

Figure 11. COMP pin waveform

Figure 12. VFB pin waveform

Figure 13. ISENSE pin waveform

Figure 14. RT/CT pin waveform

Figure 15. OUTPUT pin waveform

Figure 16. VREF pin waveform
3.2. Experimental results

The waveforms of the key nodes of the switching power supply were measured experimentally, including the voltage waveforms of the various pins of the chip, the voltage waveforms of the original secondary side of the transformer, and the output voltage waveforms, respectively, as shown in Figure 21-31.

Figure 17. Transformer primary voltage waveform  
Figure 18. Transformer secondary voltage waveform

Figure 19. Switching tube drain source voltage waveform  
Figure 20. Output voltage waveform

Figure 21. COMP pin waveform  
Figure 22. VFB pin waveform

Figure 23. ISENSE pin waveform  
Figure 24. RT/CT pin waveform
Figure 25. OUTPUT pin waveform
Figure 26. VCC pin waveform
Figure 27. VREF pin waveform
Figure 28. Transformer primary voltage waveform
Figure 29. Transformer secondary voltage waveform
Figure 30. Switching tube drain source voltage waveform
Figure 31. Output voltage waveform
3.3. Result analysis
In the previous section, we respectively give the waveforms of the various pins of the chip in the simulation circuit and the experimental circuit, as well as the original secondary voltage and output voltage waveform of the transformer. According to the voltage waveform obtained at each key point in the simulation circuit, it can be calculated that the chip PWM pulse frequency is 120 kHz, the duty cycle is 50%, the output voltage is 14.99V, and the voltage ripple coefficient is negligible, which is in line with the expected design results. According to the voltage waveform obtained at each key point in the experimental circuit, it can be seen that the switching frequency is 113 kHz, the duty cycle is about 43%, the output voltage is 15V, which also meets design requirements. Comparing the simulation and experimental waveforms, we can see that the waveforms of each key point are basically the same. In summary, experiments have proved that the UC2845 chip simulation model built has complete function and high accuracy, and it can accurately simulate the working condition of the UC2845 in the circuit on the MATLAB/Simulink platform.

4. Conclusion
The internal structure of the UC2845 peak current control integrated chip is analyzed. The internal part of the chip is divided into four main parts, namely the startup section, the oscillation section, the feedback section and the current sampling section. In-depth analysis of the working principle and working process of each part, based on MATLAB / Simulink platform to build these four parts of the simulation model, completed the UC2845 chip model construction. The DC24V/15V simulation circuit was built using the chip model, and the experimental circuit of the switching power supply was built. The results show that the constructed UC2845 simulation model has fast response and complete functions in the simulation circuit. It can also well reflect the working condition of the chip in the actual circuit, and it has high practicality. At the same time, the UC18, UC28, and UC38 series chips have high similarities in the internal structure and function of the chip. Therefore, the UC2845 simulation model constructed has a high reference and guidance value for the simulation of UC series integrated chips in MATLAB/Simulink.

Acknowledgments
We acknowledge the financial support from University Student Science and Technology Innovation Fund Project of Hubei Collaborative Innovation Center for High-efficiency Utilization of Solar Energy.

References
[1] Cheng H L, Yu-Ren L I, Liang B. Design of a power supply converter based on UC3842 [J]. Chinese Journal of Power Sources, 2011, 35 (6): 720-722.
[2] Chuanshu L C L, Xin C X C. Design of Switching Power Supply for The Car-mounted Electric System [J]. 2006: 1684-1687.
[3] Hu R. The Improvement for the Peripheral Circuit of Current Mode Controller UC3842 [J]. Electrotechnical Journal, 2005.
[4] Wang X, Wang J. Design of a Three Output Small-Power Switching Power-Supply Based on UC3842 [J]. Chinese Journal of Electron Devices, 2015.
[5] Liu J, Chu J, Wang L. Design of a Multi-output Switching Power Supply Based on UC3844 [J]. Electronic Engineer, 2007.
[6] Wang X, Wang J. Design of a Three Output Small-Power Switching Power-Supply Based on UC3842 [J]. Chinese Journal of Electron Devices, 2015.
[7] Jin Y G, Jiang X X. Design of single-end fly-back switching power supply based on UCC3802 [J]. Information Technology, 2006.
[8] Xie Y Y, Qian Z M, Peng F Z. Output direct feedback of flyback switching power supply based on UC3842 [J]. Advanced Technology of Electrical Engineering & Energy, 2005.
[9] Xia Z Z. Design and Analysis of a Single Flyback Switching Power Supply Based on UC3842 [J]. Power Supply Technologies & Applications, 2008.
[10] Wang Z F, Liao X W, Wang S J, et al. Application circuit designed based on UC3842 [J]. Electronic Design Engineering, 2014.
[11] Wen L I, Lei H, Feng J J, et al. Design of Compact High Efficiency Low-power Switching Power Supply [J]. Power Electronics, 2006, 40 (5): 110-112.
[12] ZHU X Q. Design and Implementation of the UC3842 Multiple-Output Flyback Switching Power [J]. 2013, 02 (2): 18-22.
[13] Texas Instruments Incorporated. CURRENT MODE PWM CONTROLLER [M]. Texas: Texas Instruments Incorporated, 2007.
[14] Zhang H, Zhao Y. Design of multifunctional flyback switching power supply [J]. Electric Power Automation Equipment, 2011, 31 (1): 113-117.
[15] Wang X X, Hong L I, Navigation S O. A single-chip flyback power based on UC3842 integrated controller [J]. Chinese Journal of Power Sources, 2013.
[16] Chu Y B, Huang H H, Zhao B. Design of Flyback Multi-output Switching Regulated Power Supply Based on UC3842 [J]. Power Supply Technologies & Applications .2011 (8): 47-51.
[17] Chen D. Application of Pulse Width Modulators UC3842 in Switching Mode Power Supply [J]. Journal of Swust, 2005.
[18] Yaofu H, Chen F. Switching power supply based on UC3842 [J]. Electric Power Automation Equipment, 2009, 29 (9): 133-136.
[19] Cai L, Yang Z, Chen W. EMI reduction of switching power supply by frequency jitter [C] // Industry Applications Conference, 2005. Fourtieth Ias Meeting. Conference Record of the. IEEE, 2005: 2790-2793 Vol. 4.
[20] Luo W, Yang Y, Li H, et al. Design of intelligent battery charger based on SCM double closed-loop control [C] // IEEE International Conference on Mechatronics and Automation. IEEE, 2013: 1413-1418.
[21] Chen H J. A Design of Switch Power with UC3842 [J]. Instrumentation Technology, 2005.