A Simple Current-Share Paralleling Technique for Peak-Current-Mode Controlled Power Supplies

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Abstract-- **A simple technique is proposed to implement the current-share method for peak-current-mode controlled power supplies. By using two PWM control ICsin each paralleled unit of a power system, the requirements of current sharing and galvanic isolation can be both satisfied. Two 100W peak-current-mode controlled flyback power converters are paralleled for verification. The experiment results reveal that current sharing is achieved with stabilized output voltage.**

Index Terms—**current sharing, peak current mode, SMPS.**

I. INTRODUCTION

Paralleling of modular power supplies generally gains more advantages over using a single high-power one for high-current applications. For example, it is more economical for manufactures to make standardized units. Besides, a power system with redundant power supplies is always more reliable. To maximize the reliability of the total system, it is desirable to make current sharing among paralleled units. Many current-share schemes for switch-mode power supplies have been developed in the past [1]-[5]. Each of them has different current-share performance of the paralleled power system, and none of them is most suitable for all applications when it comes to the reliability of the paralleled system and the complexity of implementation. Recently, a current-share method for peak-current-mode (PCM) controlled power supplies has been proposed [6]. The method is simple and satisfies the general requirements of a paralleled power system. It takes advantage of the characteristic of such kind of power supplies that the error signal in the voltage feedback loop also implies the load information. By combining the error signals of all the paralleled units via diodes on a shared bus, only the largest one becomes active. Each power supply acts as a voltage controlled current source except the "master" one with the largest error signal, which is in charge of the voltage regulation. Besides, due to the diodes on the shared bus, error signals are isolated from each other, and the "master" unit is automatically selected, which enhances the reliability of the total system.

However, difficulty is encountered when the method is practiced. In an off-line power supply, the energy is transferred via a power transformer for galvanic isolation. The error signal in the feedback loop usually has also to be transmitted to the pulse-width-modulation (PWM) controller on the transformer primary side via a photo coupler. It is known that the current-transfer-ratio (CTR) of a photo coupler deviates with each other severely. If the error signals of the paralleled units are combined on the 'diode' side of the photo couplers via a shared bus, the balance of current sharing is deteriorated. However, if they are combined on the 'transistor' side, the shared bus is subject to high input voltage, and some safety requirements could be violated. To solve this problem, this paper proposed a simple technique. By using two PWM control ICs in each of the paralleled power unit, current sharing and the safety requirement can be both satisfied. Two 100W flyback converters are also constructed for verification. Both the steady-state and the step-response performances are checked. The experimental results reveal that balanced current sharing between paralleled units is achieved from light loads to heavy loads, and the output voltage stability remains unchanged.

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II. CONVENTIONAL CURRENT-SHARE SCHEME FOR PCM CONTROLLED POWER SUPPLIES

Referring to Fig. 1, in a PCM controlled power supply, there are an outer voltage feedback loop and an inner current loop for the output voltage regulation. The outer voltage loop generates an error signal from an error amplifier. The error signal is then compared with the input charging current signal by the current comparator. The resulted gate-control signal determines the charging time, which depends on the error signal level and so does the energy output to the load in each switching cycle. In fact, the average of the error signal level in the voltage feedback loop represents the load information. Thus, it is easy to achieve current sharing among such kind of paralleled power supplies just by combining all the error signals on a shared bus. Each unit shares the same error signal, and the peak value of the charging current is forced to be equal in every switching cycle. If each paralleled power supply is made identical, then balanced current sharing among units is resulted. In fact, the current-share performance depends mostly on the magnetic components, which is related to the slopes of the charging current waveforms. Each unit now acts as a voltage controlled current source except the "master" one with the largest error signal, which is in charge of the voltage regulation. The voltage regulation of the paralleled system should be the same as that of a single unit. Besides, due to the diodes on the shared bus, error signals are isolated from each other, and the "master" unit is automatically selected. Therefore, this kind of technique bears high reliability.

However, difficulty is encountered when the method is practiced. In an off-line power supply, the energy is transferred via a power transformer for galvanic isolation. The error signal in the feedback loop usually has also to be transmitted to the PWM controller on the primary side of the transformer via a photo coupler. It is known that the current-transfer-ratio (CTR) of a photo coupler not only decays with time but also deviates with each other severely. To achieve balanced current sharing, it is reasonable to build the shared bus on the 'transistor' side of the photo coupler close to the PWM control IC on the primary side of the power transformer. Unfortunately, this is not acceptable for the safety reason. The primary-side components of a power transformer are subject to high line voltage and belong to primary circuits [7]. They must be isolated by proper insulation and should not be accessible to users. However, the shared bus usually has to be built outside the grounded mechanical enclosure of each module for the purpose of swapping paralleled units. The exposed shared bus makes it difficult to meet the requirements by the safety standards, such as IEC 60950 and etc.

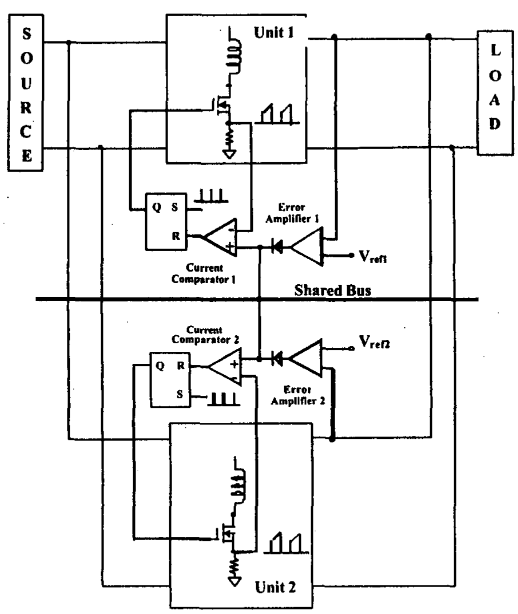


Fig. 1. Current-share method for PCM controlled power supplies

III. MODIFIED CURRENT-SHARE SCHEME FOR PCM CONTROLLED POWER SUPPLIES

A modified version of the current-share method mentioned above is reinvented to solve the safety problem. The shared bus is built on the low-voltage secondary side of the power transformers. The active error signal is still transmitted via photo couplers but in a different manner to avoid signal distortion. Referring to Fig. 2, an additional voltage-mode PWM control IC is used on the secondary side of the transformer in each unit to generate individual error signal. Remind that one of the main functions of a voltage-mode PWM IC is to transform the analog error signal to the pulse-like gate-control signal for switches. The pulse-width-modulated gate-control signal is not easily distorted by the CTR deviations when transmitted via photo the coupler. On the 'transistor' side of the photo coupler, demodulation is also easy to perform. A RC low-pass filter would be adequate. A current-mode PWM control IC is also used on the primary side of the power transformer to complete the inner current control loop. It compares the demodulated error signal and the input charging current signal, and generates the gate-control signal for the main switch. Balanced current sharing among paralleled power supplies can still be achieved in this way. Because the shared bus is directly connected to the low-voltage secondary circuits, there is no safety problem to build it outside the mechanical box of each power module.

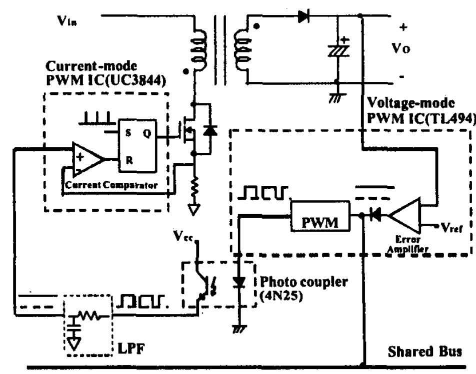


Fig. 2. Current sharing with PWM error signals

IV. EXPERIMENTAL RESULTS

Two 100W flyback power converters are paralleled for verification. The circuit diagram of each unit is shown in Fig. 2. The output voltage is regulated at 12V. A current-mode PWM IC UC3844 from Unitrode Corporation is used on the primary side of the power transformer as the main controller, while a low-cost voltage-mode PWM IC TL494 from Texas Instrument is adopted on the secondary as the PWM modulator in each converter. The inherent diode following the error amplifier in a TL494 IC makes it easy to be practiced in this kind of paralleled power supply circuits.

The output current waveforms at rated load of both units are shown in Fig. 3. The performance of current sharing is shown in Fig. 4. It can be seen that with the analog transmitted error signal, the performance of current sharing is about 1:0.8 or 55% : 45% at rated load. When the error signal is transmitted with pulse width modulation, the performance of current sharing is improved to be 1:0.9 or 52.5% : 47.5%. The improvement is remarkable especially at light loads. Thus, the current-share imbalance due to CTR deviations of photo couplers is successfully corrected. On the other hand, because the technique only guarantees equal peak input currents, when the power supplies are operated in the continuous-inductor-current mode, the deviation of magnetic components still causes the current-share imbalance. For comparison, the PWM error signals are also transmitted without the shared bus in another experiment. The power supplies are allowed to be free running now, and the results show that the current-share performance is poor. To further verify the stability performance of the proposed technique, the output load of the paralleled system is changed between 20% and 100% rated load periodically. The step responses in Fig. 5 show that under large load-change circumstances, the output voltage of the paralleled power system stabilizes as fast as that of a single power supply. The stability of the system is not deteriorated.

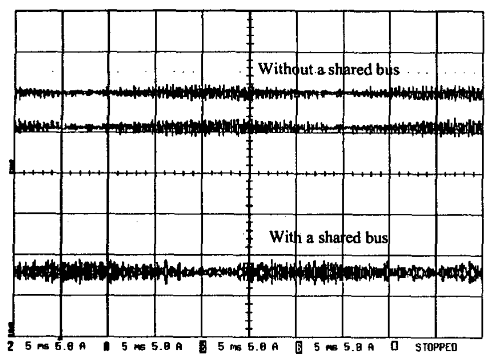


Fig. 3. Output current waveforms at rated load (16A)

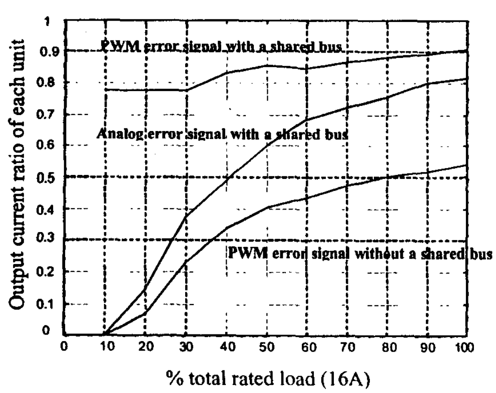
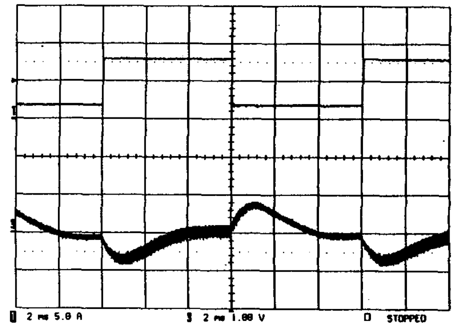
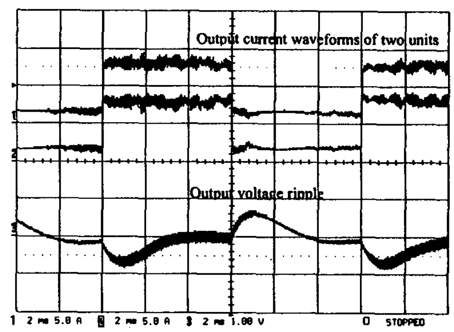


Fig. 4. Comparison of current-share performances



(a) Step response of single supply



(b) Step response of paralleled supplies

Fig. 5. Step response of paralleled power supplies

V. CONCLUSIONS

The error signal in the feedback loop of a PCM controlled power supply implies the load information. The conventional paralleling technique takes advantage of this characteristic to achieve load current sharing by combining the error signals on a shared bus. To build the shared bus on the low-voltage secondary side of the power transformer for the safety requirement and to overcome the CTR variations of photo couplers for balanced current sharing, a modified current-share paralleling technique for peak-current-mode controlled power supplies is presented in this paper. The error signal is pulse-width modulated and transmitted to avoid signal distortion. By using another voltage-mode PWM control IC on the secondary side of the power transformer in each paralleled unit, the technique can be implemented simply with low cost. The current sharing thus can be achieved with the safety requirement satisfied. Experimental results show that the current-share performance is improved when compared with the conventional paralleling technique without the PWM error signal. Step response of the paralleled system also proves that the stability of the paralleled system remains unchanged.

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