ABSTRACT
This paper presents an alternative means of communicating the load-sharing information among parallel-connected converters through the use of a wireless digital communication technique. The idea is experimentally tested using two buck converters parallelled under the Master/Slave current sharing configuration. The results show current distribution property of the converter system under the proposed wireless control scheme are similar to those obtained from a fixed-wire controller.

KEY WORDS
Parallel-connected power converters, wireless communication, active current sharing.

1. INTRODUCTION
Paralleling power converters has become a popular technique in power supply design for improving power processing capability, reliability, and flexibility [1] - [9]. The main design issue in paralleling converters is the control of the current sharing among the constituent converters. Over the past two decade, many effective control schemes have been proposed [1], [2], [4], [10], [11]. Among these, the active current sharing control methods are preferred for their superiority in achieving near uniform current distribution [2], [4], [10]. Unfortunately, active current sharing can only be performed if load sharing information (normally the output current of each converter) are known by the controllers. Consequently, connection cables are required between converter modules and their controllers to communicate these information, as shown in Fig. 1.

However, these interconnections introduce some drawbacks. Firstly, the direct interconnection of converters in parallel is a source of single point failure, which can bring the entire converter system down [5]. Secondly, the presence of interconnection cables can easily pick up noise which affects the performance of the system, as well as restricts the location in which the converter units are placed [9]. Thirdly, power expansion and modification can sometimes be cumbersome if there are many interconnection cables attached to controllers or converter modules. Hence, there is a need for active current sharing control schemes that does not require any direct interconnection to communicate the information signals [5] - [9].

Thus, in this paper, an alternative means of communicating the load-sharing information in paralleled converters, which requires no control interconnection among the converter modules, is proposed. The proposed method employs analog to digital conversion (ADC) to convert the load-sharing information into digital form before frequency shift keying (FSK) modulation, and the current information is then retrieved by using digital to analog conversion.
(DAC) after the FSK demodulation. The main advantage of this solution is that while eliminating the problems associated with control interconnections, it retains the design freedom over the choice of control scheme and theory.

This paper is organized as follow. Section 2 of the paper describes the proposed wireless active current method. Section 3 details the prototype design and its implementation. An experimental evaluation of the prototype system is presented in Section 4. Finally, Section 5 summarizes the findings of the paper.

2. PROPOSED WIRELESS CONTROL MODULES

The basic idea of this scheme is to incorporate wireless digital communication into parallelled converters, so that no control interconnection is required for the communication of load-sharing information. An overview of the proposed solution for distributed current sharing paralleled converters is shown in Fig. 2.

The proposed wireless converter system is primarily an enhanced conventional paralleled converters with an additional transmitter-receiver (or transreceiver) module in each converter. There is no topological difference between their converter circuits otherwise. Hence, the proposed scheme offers a simple solution which requires no further modification to existing converter topology, and it is therefore feasible on any control methodology.

The functionality of the transreceiver module is to encode the load-sharing information of the converter into a data packet before transmitting by a FSK modulator. Concurrently, it is also receiving the transmitted signals by a FSK demodulator from all the converters and decode them into information signals, as illustrated in Fig. 3. These signals are then sent to the current sharing controller for its control.

3. PROTOTYPE SYSTEM

To verify the feasibility of the idea, a two cells paralleled buck converters under the Master/Slave current sharing configuration was constructed, tested, and analyzed. The schematic diagram of the single power converter module of the system is shown in Fig. 4.

The buck converter is designed to operate at a fixed switching frequency of 200 kHz. The input voltage is $V_{IN} = 24$ V, the output voltage is $V_{OUT} = 12$ V, and the total external loading for the paralleled converters is $R_{LOAD} = 3$ Ω to 240 Ω. The filter is chosen as $C = 150 \mu$F and $L = 100 \mu$H. A resistor of 0.1 Ω is used to sense the output current. The sensed current signal is sent to both the controller (for control) and transreceiver (for wireless communication).

The Master/Slave current sharing controller is constructed with the UC3907 load share controller IC and the UC3842 current mode pulse width modulator IC. Here, pin 15 of UC3907, which is normally connected to common share buses of the same IC pins from the other power converters, is now connected only to the receiver part of the transreceiver module (see Fig. 4). The removal of this control signal share bus forms the basis for the wireless paralleled converters. With the received load-sharing information from the transceiver, load sharing is accomplished by controlling the power stage of the each converter through monitoring the current from the other module.

The transreceiver module consists of three parts: ADC, DAC, and wireless communication. For ADC, TLC0831 from Texas Instruments (TI) is adopted to convert the instant analog voltage into a 8-bit binary data format. The DAC is done by the build-in DAC of the TI TLV5624 receiver to retrieve the load-sharing information.

As for wireless communication, TX4915 FSK transmitter from Keymark Technology and TI TLV5624 receiver are used. They were implemented in such a way that each transmitter/receiver pair is placed in different converter so that when one converter transmits its information, the other receives. Fig. 5 shows the experimental data of output voltage versus input voltage which gives the linearity characteristic.
Figure 4: Simplified schematic diagram of a single module of the wireless paralleled power converters.

Figure 5: Output voltage versus input voltage linearity characteristics after and before wireless transmission.

The relationship is quite linear.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Fig. 6 shows the results of the current sharing behavior of the prototype system with control interconnections (a and b) and wireless communication (c and d). The experimental setup with control interconnections is performed by connecting together pin 15 (UC3907) of both converters with a cable and removing the connections to the transreceivers.

Fig. 6(a) shows the output current waveform of each converter operated under a step load increment from 1 A to 2.5 A. The transient response is very stable with little oscillation. The output of two converters indicates excellent current sharing property with only 0.01 A (at 1 A) and 0.02 A (at 2.5 A). The output voltage reaches steady state with a time of 25 mS. Fig. 6(b) shows the same waveforms under step load decrement from 2.5 A to 1 A. In this case, the time for the output voltage reaching steady state is 50 mS.
Figure 6: Experimental results showing (a) step load change from 1 A to 2.5 A and (b) step load change from 2.5 A to 1 A with interconnected load sharing; (c) step load change from 1 A to 2.5 A and (d) step load change from 2.5 A to 1 A with wireless load sharing.

The same step change conditions were applied for the experiments performed on the prototype system with wireless control. Fig. 6(c) and 6(d) are the results respective to 6(a) and 6(b). Although there are some oscillations, the dc current sharing property of the converters is considerably good with current differences between the two converters of about 0.015 A for the load current at 1 A and at 2.5 A. For both cases, the times for the output voltage reaching steady state are comparable to those of interconnected load sharing.

5. CONCLUSION

The proposed wireless control scheme eliminates the problems associated with control interconnections in paralleled converters. The scheme offers a simple solution which requires no further modification to existing converter topology and therefore can be used for any control methodology.

6. REFERENCES


