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Part 2

Highly Integrated Solution for AC Adapters: Experimental Results

A prototype of the highly-integrated boundary-conduction mode (BCM) PFC and quasi-resonant (QR) PWM combo controller exhibits efficiencies in the 90% range and harmonic distortion in the 3.75% to 14% range, depending on the ac input voltage and frequency.

A prototype of the highly-integrated boundary-conduction mode (BCM) PFC and quasi-resonant (QR) PWM combo controller exhibits efficiencies in the 90% range and harmonic distortion in the 3.75% to 14% range, depending on the ac input voltage and frequency.

The experimental platform for the BCM/QR converter was a 19-V/90-W, universal input-voltage notebook adapter. *Figs. 1* and *2* show the PFC switching waveform around the peak and valley of input voltage, V_g.

When the inductor current of the PFC choke discharges to zero, the inductor and parasitic capacitor of the PFC MOSFETs both resonate with each other. Then, the drain-to-source voltage, V_{DS}, of the PFC MOSFET starts to swing down, as does the voltage signal on the zero-current detection pin, F2.

Once the voltage is lower than the threshold voltage, the PFC gate will turn on. Around the peak of vg, the switching cycle begins at the valley of V_{DS}. In this condition, the MOSFET turns on with zero current switching (ZCS). Around the valley of V_g, as shown in *Fig. 2*, each of the switching cycles begin after the inhibit time.

If V_{DS} has not swung back, then the MOSFET also turns on with zero voltage switching (ZVS). The power factor and THD test results shown in Table 1 are less than the limit of IEC1000-3-2 Class D with great margin.

The switching behavior of the PWM MOSFET from full load to no load is shown in *Figs. 3* to *6*. At full-load conditions, $t_{OFF-MIN}$ is about 8 ms with the appropriate transformer design, and the PWM MOSFET will turn on at the first valley (*Fig. 3*). As the output loading is decreased, $t_{OFF-MIN}$ is extended internally.

TABLE 1. PF AND THD TEST RESULTS

INPUT VOLTAGE		PF	THD (%)
90 V/60 Hz	P_{in} = 75 W	0.998	5.00
	Max. Load	0.999	3.75
115 V/60 Hz	P_{in} = 75 W	0.996	5.54
	Max. Load	0.998	4.21
240 V/50 Hz	P_{in} = 75 W	0.965	11.37
	Max. Load	0.978	8.76
264 V/50 Hz	P_{in} = 75 W	0.951	14.04
	Max. Load	0.969	10.25

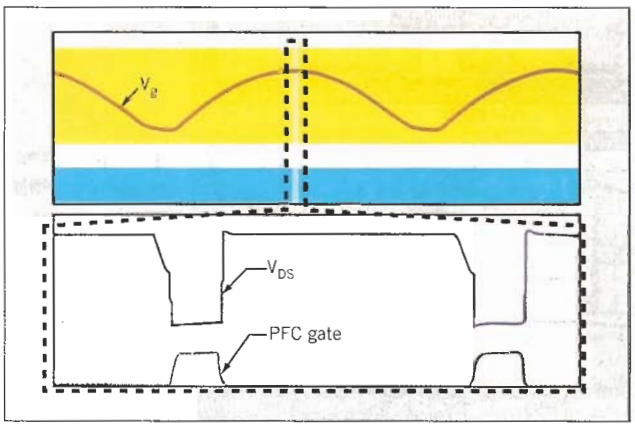

Fig. 1. BCM/QR controller performance with a 230-Vac full load, around the peak of input voltage, v_g.

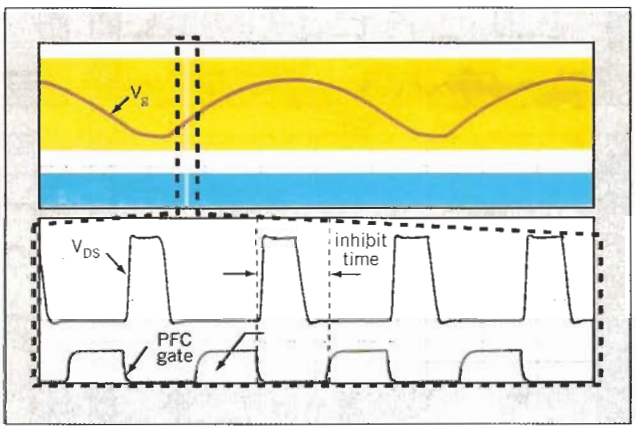

Fig. 2. BCM/QR controller performance with a 230-Vac full load, around the valley of input voltage, v_g.

During $t_{OFF-MIN}$, every valley signal is ignored. After $t_{OFF-min}$ is passed, the PWM MOSFET turns on as the valley is detected. As is shown in *Figs. 4* and 5, the valley of the PWM switch is extended as output loading is decreasing. Even the 14th valley can be detected at light-load condition.

Fig. 6 shows the PWM burst-mode operation at no-load condition. The switching frequency between each group of the PWM gate is about 60 Hz.

TABLE 2. NO-LOAD POWER SAVINGS AND LIGHT-LOAD EFFICIENCY

INPUT WATTAGE (W)	INPUT VOLTAGE (Vac)	INPUT WATTAGE (W)	OUTPUT WATTAGE (W)
0	115	0	0.162
	230	0	0.186
0.25	115	0.25	0.475
	230	0.25	0.493
0.5	115	0.509	0.779
	230	0.509	0.790
1	115	1.006	1.373
	230	1.006	1.380
1.15	115	1.152	1.539
	230	1.152	1.536
1.5	115	1.526	1.998
	230	1.526	2.003
1.7	115	1.7	2.196
	230	1.7	2.207

In each group, the switching frequency is decided by the level of V_{FB}, which is about 28 kHz, so the audible noise is extremely low. With extended-valley switching and burst-mode operation, the controller performs low-power consumption and low switching loss at no-load and light-load condition.

The test result is in Table 2. Table 3 shows the efficiency from 22.5% to 100% full load and from 90 to 264 Vac. Efficiency is in excess of 87% in each loading point.

This new combo solution (BCM PFC+QR PWM) has a simple and compact configuration. This converter can achieve high efficiency at high input voltages.

Besides very low switching loss, the power savings from this converter is lower than a traditional PFC+PWM converter because of the two-level PFC and deep extended valley detection. When looking at efficiency, the rectifier shows that this converter can achieve roughly a 1.5% to 2% improvement.

TABLE 3. EFFICIENCY

	22.5 W (25%)	45 W (50%)	67.5 W (75%)	90 W (100%)
90 Vac/ 60 Hz	88.92%	89.50%	89.39%	88.66%
115 Vac/ 60 Hz	90.60%	90.09%	90.29%	89.77%
230 Vac/ 50 Hz	90.20%	89.58%	90.60%	90.98%
264 Vac/ 50 Hz	90.19%	89.17%	90.64%	91.12%

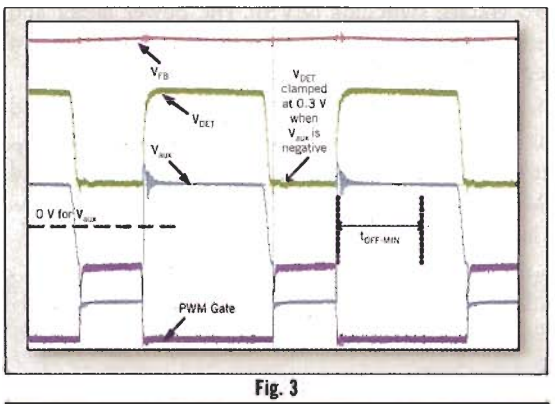

Fig. 3

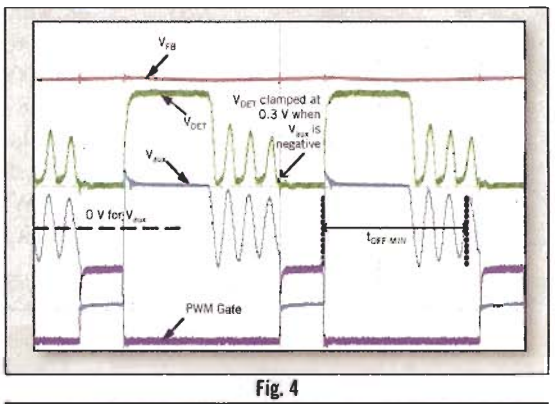

Fig. 4

Fig. 3. The switching behavior of the PWM MOSFET with a 115-Vac full load (left), while Fig. 4 (right) features a 115-Vac middle load.

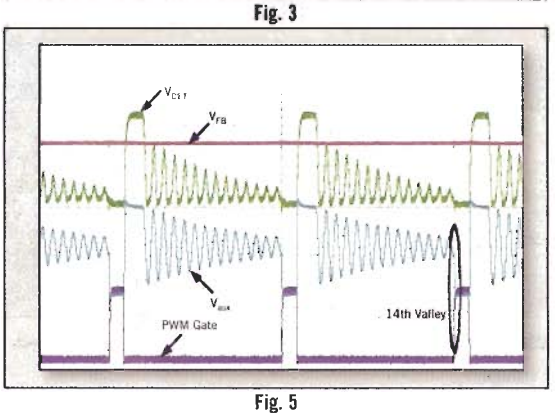

Fig. 5

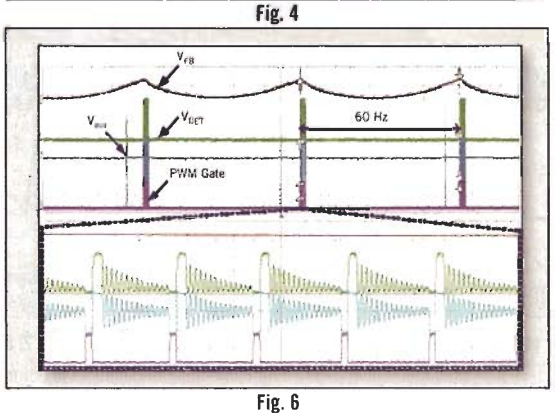

Fig. 6

Fig. 5. The switching behavior of the PWM MOSFET with a 115-Vac light load (left) and Fig. 6 (right) with a 115-Vac no load.