*Application Report*

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# *Reduce Electrical Stresses in a PFC Stage during an AC Drop Test with UCD3138*

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**ABSTRACT**

The design of an active Power Factor Corrector (PFC) leads to slow transient response. The reason for this is that the compensator placed in the output-voltage feedback loop is normally designed to have a low bandwidth to filter the voltage ripple at twice line frequency from the PFC output voltage. The slow transient response caused by this low bandwidth feedback loop causes high voltage and current stresses on the PFC stage during AC Input Drop test. This application note provides an algorithm to reduce the electrical stress on the PFC stage during AC Input Drop tests with the UCD3138 without compensator optimization of PFC.

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# 1 Introduction

Power quality disturbances create major problems in continuous process industries. Momentary interruptions, voltage dips, and dropouts are some of the most serious power quality problems faced by industrial customers.

AC voltage drop is one major type of power quality disturbance. In server power applications, there are detailed specifications for AC voltage drop tests from different server companies. The specifications include AC voltage drop amplitude, AC voltage drop duration, and the input current stress after AC recovery.

This application note proposes an algorithm to reduce the electrical stress on the PFC stage during server power AC voltage drops with the UCD3138.

# 2 AC Drop Test Procedure and Specification

## *2.1 AC drop test procedure*

During validation of server power designs, the performance of the AC drop test is vital to evaluating the reliability of the server power.

The AC drop is applied at AC input voltages to the PFC of 90 $V_{AC}$, 115 $V_{AC}$, 230 $V_{AC}$ , and 264 $V_{AC}$. The AC drop angle is 0°, 45° and 90°. The AC drop period is normally 10 ms. The detail of the AC drop test condition and AC input voltage waveform during AC drop are shown in Table 1, Figure 1 and Figure 2.

**Table 1. AV Drop Test Condition**

| Input voltage | AC drop angle | AC drop period |
|---|---|---|
| 90 V, 115 V, 230 V, 264 V | 0°, 45°, 90° | 10 ms |

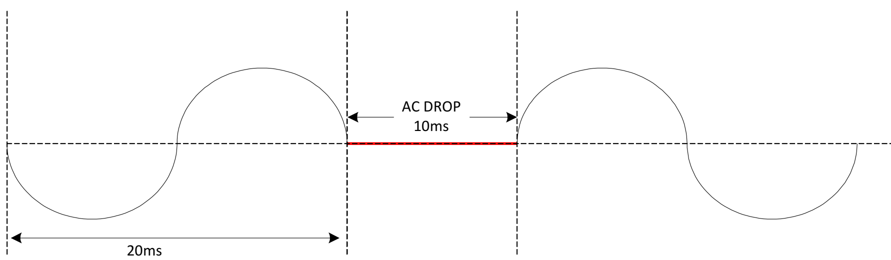


**Figure 1. AC Input Voltage Waveform during AC Drop 10 ms at 0°**

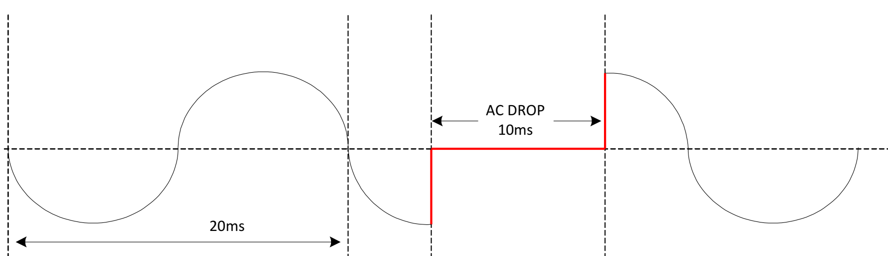


**Figure 2. AC Input Voltage Waveform during AC Drop 10 ms at 90°**

### 2.2 Typical AC Drop Specification

The typical specification includes the AC input current after AC voltage recovery, the minimum PFC output voltage during AC drop, the recovery time of AC input current, and the PFC output voltage.

- The AC input current should less than 25 A after AC voltage recovery, peak charge current (the inrush current when the AC voltage is larger than the PFC output voltage) is not included.
- The AC input current and PFC voltage should recover to a stable state in less than 100 ms.
- The minimum PFC voltage should be greater than 350 V during the AC drop test.

## 3 Proposed Method to Reduce Electrical Stress of PFC during AC Drop

The proposed method includes the AC drop detection, the procedure when an AC drop is detected, and the procedure after AC drop recovery.

1. When an AC drop is detected with the UCD3138:
   1. Freeze PFC current loop calculation and preset KI of the current loop to 0
   2. Freeze PFC voltage loop calculation
   3. Freeze calculation of $V_{IN\_RMS}$
2. When an AC drop recovery is detected, force the PFC state machine into soft start status, unfreeze the PFC current and voltage loop calculation and the calculation of $V_{IN\_RMS}$.
3. When AC recovery is detected, generate a preset value with Equation 1 and send to KI of current loop.

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} \tag{1}$$

In Equation 1 $V_{OUT}$ is the instantaneous output voltage of PFC when AC drop recovery is detected, as shown in Figure 3.

In Equation 1 $V_{IN}$ is the instantaneous input voltage of PFC when AC drop recovery is detected , as shown in Figure 3.

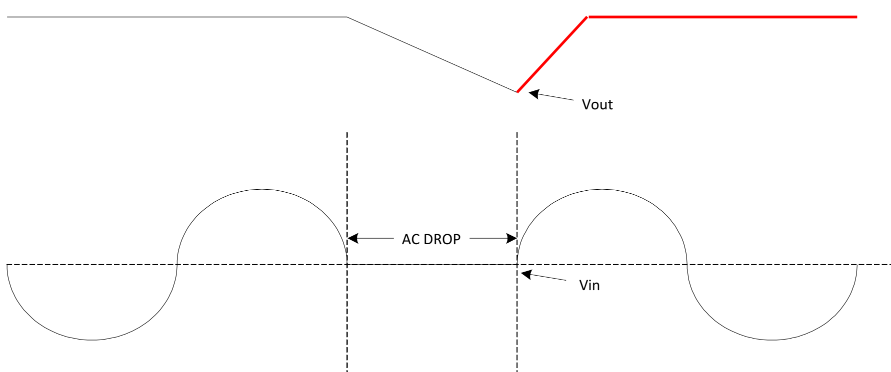


**Figure 3. The Typical Waveform of Output Voltage and AC Input Voltage during AC Drop**

Figure 4 displays the Firmware code run when an AC drop recovery is detected.

```
inline void check_ac_drop(void) //do one time/100us
{

	if(iv.vin_average > AC_DROP_V_RECT_THRESHOLD)//(iv.vin_squared_for_ac_drop > AC_UNDROPPEI
	{
	#ifdef AC_DROP_OPTIMIZATION
		if((iv.supply_state == STATE_PFC_ON)&&(iv.ac_drop)&&(iv.ac_drop_continue == 0))
		{
			Uint32 temp_preset;
			unsigned long long temp_vin, temp_vout;
			temp_vin = iv.vin_raw * 152;

			temp_vout =  iv.vbus_avg*223;

			temp_preset = (Uint32)(((temp_vout - temp_vin)<<23)/temp_vout);

			Filter1Regs.FILTERCTRL.bit.KI_STALL = 0;
			preset_filter1(temp_preset); //calculate filter ki

			iv.interrupt_counter_1 = iv.vbus_avg << 8;

			iv.ramp_up_step = 80;//0x50;

			iv.supply_state = STATE_RAMP_UP;
			//Run "ramp_up" funciton
			//iv.start_ramp_up_flag = 1; //20150311T1
		}
	#endif
		iv.ac_drop = 0;
	}
}
```

AC drop recovery detection
Calculate preset value
Unfreeze PFC current loop
Force PFC to soft start status

**Figure 4. Firmware Code Run when an AC Drop Recovery is Detected**

## 4 Test Result

By using the method proposed in Section 3, the initial duty cycle after an AC drop recovery equals the result of the calculation of the equation because the calculated duty cycle is very close to the expected duty cycle when the AC drop is finished, and the set output voltage of PFC has increased very slowly since the state machine is in soft start status. The output voltage of PFC is close to the set output voltage, there is no dynamic status for the PFC, and the electrical stress reduces drastically.

### *4.1 AC Drop Test Without the Proposed Method*

Test condition: 264 $V_{AC}$ AC drop 10 ms at 0° only with 20% load of 750 W.

An AC drop test waveform without the proposed method is shown in Figure 5. The peak input current is 20.4 A even with only 20% load of 750 W. The PFC is damaged with loads above 50%. The input current and PFC output voltage are unstable in 100 ms. The specification cannot pass without the proposed method.

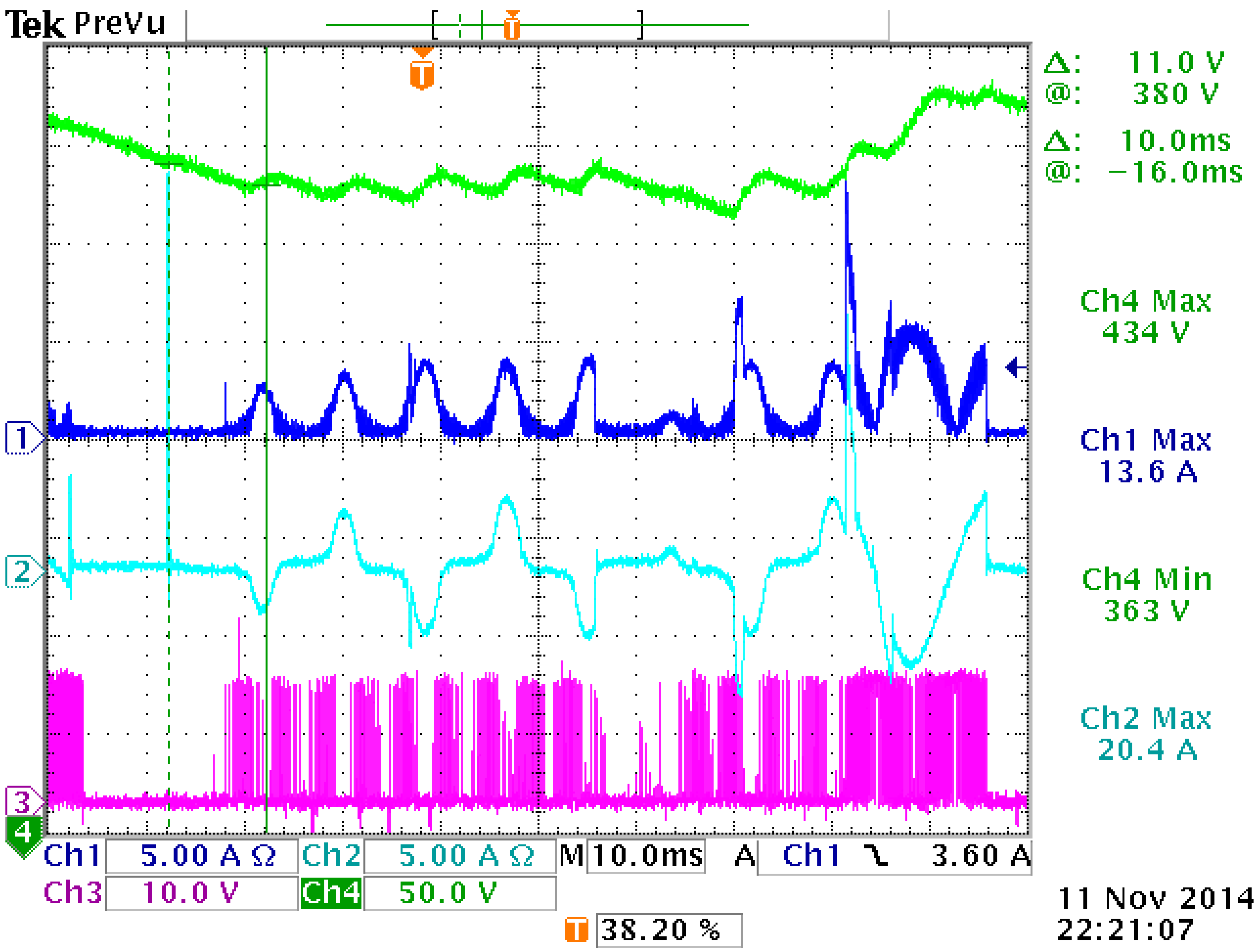


**Figure 5. AC Drop Test without Proposed Method**

### 4.2 AC Drop Test With Proposed Method

Test condition: 264 $V_{AC}$ AC drop 10 ms at 0° with 100% load of 750 W.

An AC drop test waveform with the proposed method is shown in Figure 6. The peak input current is only 6.2 A even with a full load of 750 W, the minimum PFC output voltage is greater than 356 V and the input current and PFC output plots are stable in 100 ms. The specification passes with the proposed method.

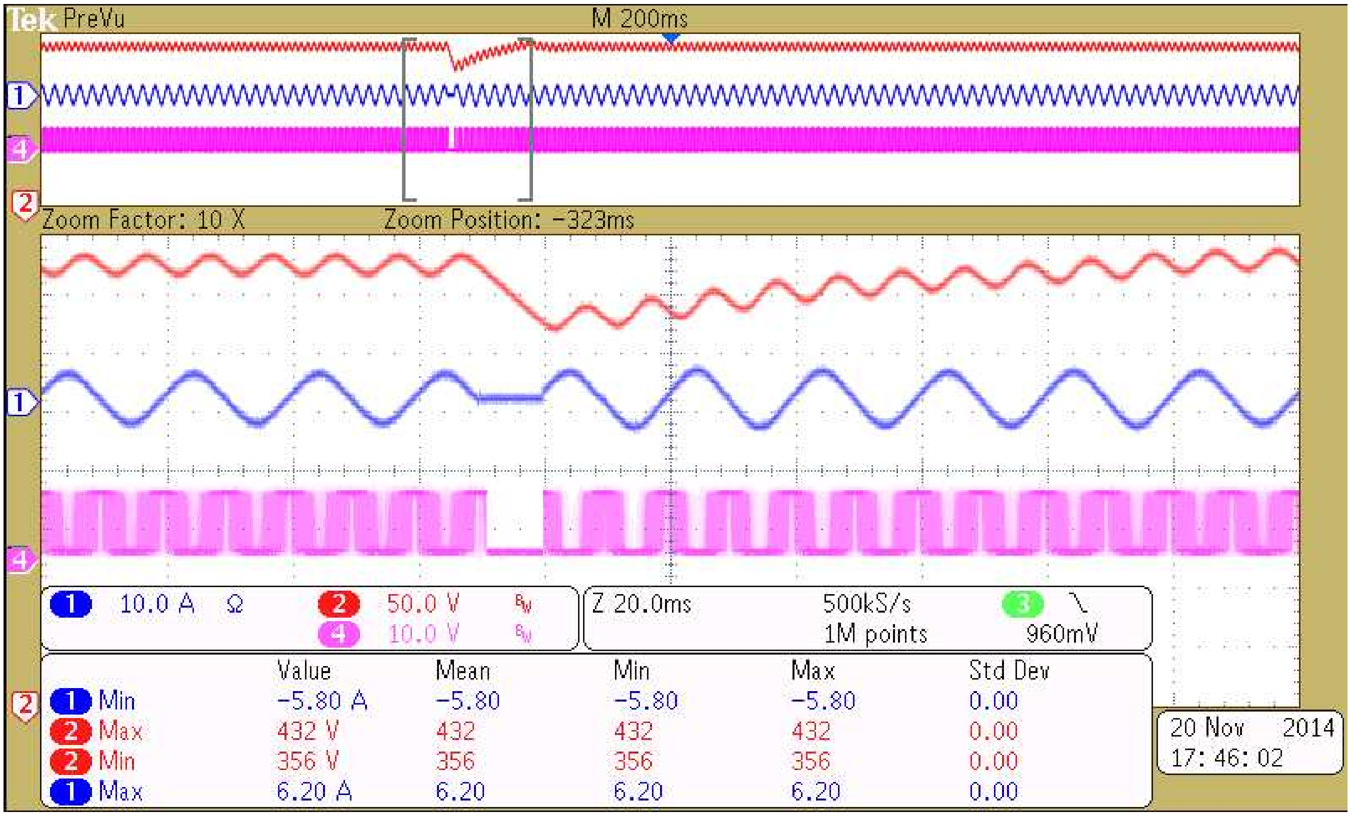


**Figure 6. AC Drop Test with Proposal Method**

## 5 Conclusion

This Application Note shows how to apply a Firmware method with the UCD3138 to reduce electrical stresses during an AC drop test, but the PFC voltage and current loop compensators do not need optimization. With simple code, the electrical stresses on the PFC stage during an AC drop test are significantly reduced.

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.