

## Pentium® Pro Controller

## FEATURES

- Combined DAC/Voltage Monitor and PWM Functions
- 4-Bit Digital-to-Analog Converter (DAC)
- 1.0% DAC/Reference
- Low Offset X20 Current Sense Amplifier
- 100kHz, 200kHz, 400kHz Oscillator Frequency Options
- Foldback Current Limiting
- Overvoltage and Undervoltage Fault Windows
- Undervoltage Lockout
- $2\Omega$  Totem Pole Output
- Chip Disable Function

## DESCRIPTION

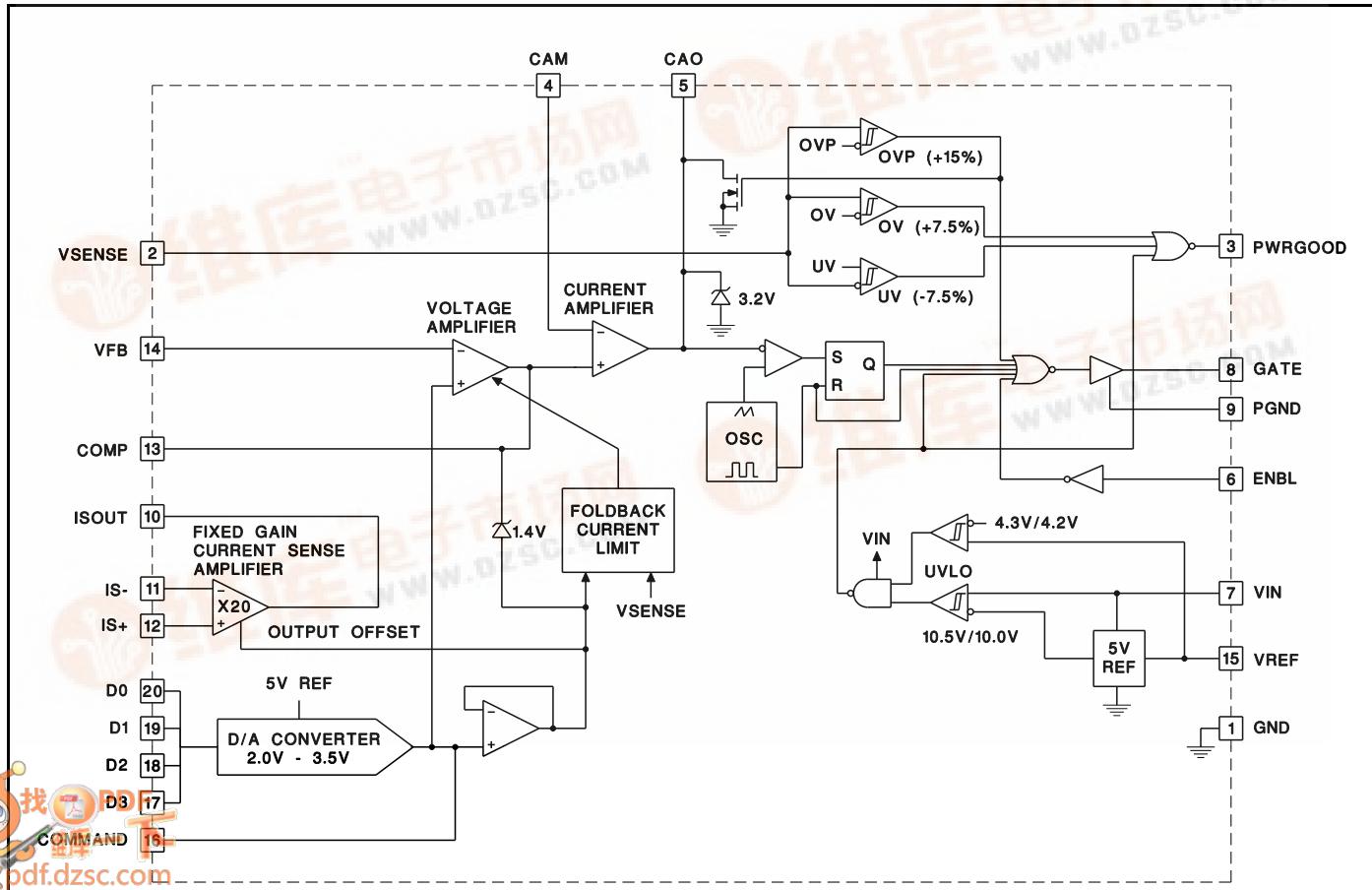
The UCC3880-4/-5/-6 combines high precision reference and voltage monitoring circuitry with average current mode PWM controller circuitry to power Intel Pentium Pro and other high-end microprocessors with a minimum of external components. The UCC3880-x converts 5VDC to an adjustable output, ranging from 2.0VDC to 3.5VDC in 100mV steps with 1% DC system accuracy.

The chip includes a precision 5V reference which is capable of sourcing current to an external load. The output voltage of the DAC is derived from this reference, and is programmed directly by Intel's VID pins (Table 1).

The accuracy of the DAC/reference combination is 1.0%. The overvoltage and undervoltage comparators monitor the system output voltage and indicate when it rises above or falls below its programmed value by more than 7.5%. A second overvoltage protection comparator pulls the current amplifier output voltage low to force zero duty cycle when the system output voltage exceeds its designed value by more than 15%. This comparator also terminates the cycle. Undervoltage lockout circuitry assures the correct logic states at the outputs during powerup and powerdown. Grounding the ENABLE pin forces the GATE output low.

(continued)

## BLOCK DIAGRAM



### DESCRIPTION (cont.)

The voltage and current amplifiers have a 4MHz gain bandwidth product to satisfy high performance system requirements. The internal current sense amplifier permits the use of a low value current sense resistor, minimizing power loss. The oscillator frequency is fixed internally at 100kHz, 200kHz, or 400kHz, depending upon the option selected. The foldback circuit reduces the converter short circuit current limit to 50% of its nominal value when the converter is short circuited. The gate driver is a  $2\Omega$  totem pole output stage capable of driving an external MOSFET.

This device is available in 20-pin dual in-line and surface mount packages. The UCC2880-x is specified for operation from  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the UCC3880-x is specified for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

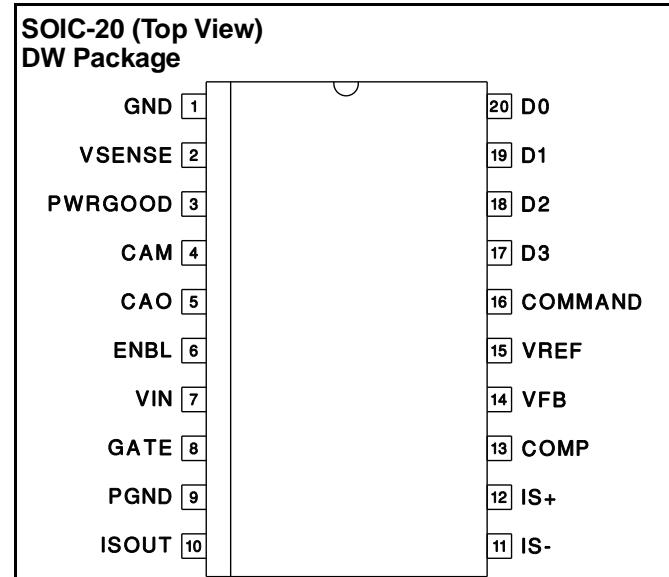
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### ORDERING INFORMATION

UCC  880  -   
 See Frequency Gain Table  
 Package  
 Temperature Range

Consult factory for temperature range or package options not shown.

### CONNECTION DIAGRAM



**Frequency Gain Table**

	Frequency		
	100kHz	200kHz	400kHz
UCC3880-4	X		
UCC3880-5		X	
UCC3880-6			X

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $\text{VIN} = 12\text{V}$ ,  $\text{VSENSE} = 3.5\text{V}$ ,  $\text{VENBL} = 5\text{V}$ ,  $\text{VD}0 = \text{VD}1 = \text{VD}2 = \text{VD}3 = 0\text{V}$ ,  $0^{\circ}\text{C} < \text{TA} < 70^{\circ}\text{C}$ ,  $\text{TA} = \text{TJ}$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Undervoltage Lockout</b>					
VIN UVLO Turn-on Threshold			10.5	10.8	V
VIN UVLO Turn-off Threshold		9.5	10		V
UVLO Threshold Hysteresis			500		mV
<b>Supply Current</b>					
$\text{I}_{\text{IN}}$			3.5		mA
<b>DAC/Reference</b>					
COMMAND Voltage Accuracy	$10.8\text{V} < \text{VIN} < 13.2\text{V}$ , $\text{IVREF} = 0\text{mA}$	-1	1	1	%
D0-D3 Voltage High	DX Pin Floating		5		V
D0-D3 Input Bias Current	DX Pin Tied to GND		-70	-20	$\mu\text{A}$
VREF Output Voltage		4.975	5	5.025	V
VREF Load Regulation	$\text{IVREF} = 0\text{mA}$ to $5\text{mA}$	-10	0		mV
VREF Sourcing Current	$\text{VREF} = 0\text{V}$		10		mA
<b>OVP Comparator</b>					
Trip Point	% Over COMMAND Voltage	10	15	20	%
Hysteresis			20	30	mV
VSENSE Input Bias Current	OV, OVP, UV Combined		-0.1		$\mu\text{A}$
Propagation Delay			1		$\mu\text{s}$

**ELECTRICAL CHARACTERISTICS (cont.):** Unless otherwise specified, VIN = 12V, VSENSE = 3.5V, VENBL = 5V, VD0 = VD1 = VD2 = VD3 = 0V, 0°C < TA < 70°C, TA = TJ.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>OV Comparator</b>					
Trip Point	% Over COMMAND Voltage (Note 1)		7.6	10	%
Return Point	% Over COMMAND Voltage (Note 1)	5	7.4		%
Hysteresis			20	30	mV
PWRGOOD Equivalent Resistance	VSENSE = 2.0V			470	Ω
Propagation Delay			1		μs
<b>UV Comparator</b>					
Trip Point	% Over COMMAND Voltage (Note 1)	-10	-7.6		%
Return Point	% Over COMMAND Voltage (Note 1)		-7.4	-5	%
Hysteresis			20	30	mV
Propagation Delay			1		μs
<b>Enable Pin</b>					
Pull-up Current	VENBL = 2.5V		-50	-20	μA
<b>Voltage Error Amplifier</b>					
Input Offset Voltage	VCOMP = 3.5V		0.0		mV
Input Bias Current	VCM = 3.0V		-0.02	0	μA
Open Loop Gain	1V < VCOMP < 4V		90		dB
Common Mode Rejection Ratio	2V < VCOMP < 3.5V		90		dB
Power Supply Rejection Ratio	10.8V < VIN < 15V		85		dB
Output Sourcing Current	VVF = 2V, VCOMMAND = VCOMP = 2.5V		-0.5		mA
Output Sinking Current	VVF = 3V, VCOMMAND = VCOMP = 2.5V		2.0		mA
Gain Bandwidth Product	F = 100kHz		3		MHz
<b>Current Sense Amplifier</b>					
Gain			20		V/V
Input Resistance			5		kΩ
Common Mode Rejection Ratio	0V < VCM < 4.5V		60		dB
Power Supply Rejection Ratio	10.8V < VIN < 15V		80		dB
Output Sourcing Current	Vis- = 2V, Visout = Vis+ = 2.5V		-0.5		mA
Output Sinking Current	Vis- = 3V, Visout = Vis+ = 2.5V		6.0		mA
-3dB Frequency	At GAIN = 20		1.75		MHz
<b>Current Amplifier</b>					
Input Offset Voltage	VCM = 3.0V		10		mV
Input Bias Current	VCM = 3.0V		0.15		μA
Open Loop Gain	1V < VCAO < 3V		90		dB
Output Voltage High	VCOMP = 3V, VCAM = 2.5V		3.2		V
Common Mode Rejection Ratio	1.5V < VCM < 4.9V		80		dB
Power Supply Rejection Ratio	10.8V < VIN < 15V		80		dB
Output Sourcing Current	VCAM = 2V, VCAO = VCOMP = 2.5V		-0.5		mA
Output Sinking Current	VCAM = 3V, VCAO = VCOMP = 2.5V		2.0		mA
Gain Bandwidth Product	F = 100kHz		3.5		MHz

**ELECTRICAL CHARACTERISTICS (cont.):** Unless otherwise specified, VIN = 12V, VSENSE = 3.5V, VENBL = 5V, VD0 = VD1 = VD2 = VD3 = 0V, 0°C < TA < 70°C, TA = TJ.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Oscillator</b>					
Frequency (-4)		85	100	115	kHz
Frequency (-5)			200		kHz
Frequency (-6)			400		kHz
Frequency Change With Voltage	10.8V < VIN < 15V		1		%
<b>Output Section</b>					
Maximum Duty Cycle		90	95	99	%
Output Low Voltage	IGATE = -100mA		0.20		V
Output High Voltage	IGATE = 100mA		11.8		V
Rise Time	CGATE = 3.3nF		20	80	ns
Fall Time	CGATE = 3.3nF		15	80	ns
Output Impedance	IGATE = 100mA		2		Ω
	IGATE = -100mA		2		Ω
<b>Foldback Current Limit</b>					
Clamp Level	Measured at Voltage EA Output; VSENSE = VCOMMAND = 3V		4.4		V
	VCOMMAND = 3V, VSENSE = 0		3.7		V

*Note 1: This percentage is measured with respect to the ideal COMMAND voltage programmed by the D0 - D3 pins.*

### PIN DESCRIPTIONS (cont.)

**CAM (Current Amplifier Inverting Input):** The average load current feedback from ISOUT is applied through a resistor to this pin. The current loop compensation network is also connected to this pin (see CAO below).

**CAO (Current Amplifier Output):** The current loop compensation network is connected between this pin and CAM. The voltage on this pin is the input to the PWM comparator and regulates the output voltage of the system. The GATE output is disabled (held low) unless the voltage on this pin exceeds 1V, allowing the PWM to force zero duty cycle when necessary. The PWM forces maximum duty cycle when the voltage on CAO exceeds the oscillator peak voltage (3V). A 3.2V clamp circuit prevents the CAO voltage from rising excessively past the oscillator peak voltage for excellent transient response.

**COMMAND (Digital-to-Analog Converter Output Voltage):** This pin is the output of the 4-bit digital-to-analog converter (DAC) and the noninverting input of the voltage amplifier. The voltage on this pin sets the switching regulator output voltage. Setting all input control codes low produces 3.5V at COMMAND; setting all codes high produces 2.0V at COMMAND. The DAC LSB step size (i.e. resolution) is 100mV (See Table 1). The COMMAND source impedance is typically 1.2kΩ and must therefore drive only high impedance inputs if accuracy is to be maintained. Bypass COMMAND with a 0.01μF, low ESR, low ESL capacitor for best circuit noise immunity.

Decimal Code	D3	D2	D1	D0	COMMAND Voltage
15	1	1	1	1	2.0
14	1	1	1	0	2.1
13	1	1	0	1	2.2
12	1	1	0	0	2.3
11	1	0	1	1	2.4
10	1	0	1	0	2.5
9	1	0	0	1	2.6
8	1	0	0	0	2.7
7	0	1	1	1	2.8
6	0	1	1	0	2.9
5	0	1	0	1	3.0
4	0	1	0	0	3.1
3	0	0	1	1	3.2
2	0	0	1	0	3.3
1	0	0	0	1	3.4
0	0	0	0	0	3.5

**Table 1. Programming the COMMAND Voltage**

**COMP (Voltage Amplifier Output):** The system voltage compensation network is applied between COMP and VFB.

**D0 - D3 (DAC Digital Input Control Codes):** These are the DAC digital input control codes, with D0 representing the least significant bit (LSB) and D3, the most significant bit (MSB). A bit is set low by being connected to GND. A

### **PIN DESCRIPTIONS (cont.)**

bit is set high by floating it, or connecting it to a 5V source. Each control pin is pulled up to approximately 5V by an internal 70 $\mu$ A current source.

**ENBL (Chip Enable Pin):** This input is used to disable the GATE and PWRGOOD outputs. Grounding this pin causes the GATE output to be held low; floating the pin or pulling it up to 5V ensures normal operation. ENBL is pulled up to 5V internally.

**GATE (PWM Output, MOSFET Driver):** This output provides a 2 $\Omega$  totem pole driver. Use a series resistor of at least 5 $\Omega$  between this pin and the gate of the external MOSFET to prevent excessive overshoot.

**GND (Signal Ground):** All voltages are measured with respect to GND. Bypass capacitors on the VCC and VREF pins should be connected directly to the ground plane near the GND pin.

**IS- (Current Sense Amplifier Inverting Input):** This pin is the inverting input to the current sense amplifier and is connected to the low side of the average current sense resistor.

**IS+ (Current Sense Amplifier Noninverting Input):** This pin is the noninverting input to the current sense amplifier and is connected to the high side of the average current sense resistor.

**ISOUT (Current Sense Amplifier Output):** This pin is the output of the current sense amplifier. The voltage on this pin is  $(\text{COMMAND} + \text{GCSA} \cdot I \cdot \text{RSENSE})$ , where COMMAND is the voltage on the COMMAND pin, GCSA is the fixed gain of the current sense amplifier, equal to 20, I is the current through the sense resistor, and RSENSE is the value of the average current sensing resistor.

**PGND (Power Ground):** This pin provides a dedicated ground for the output gate driver. The GND and PGND pins should be connected externally using a short printed

circuit board trace close to the IC. Decouple VIN to PGND with a low ESR capacitor  $\geq 0.10\mu\text{F}$ .

**PWRGOOD (Undervoltage/Lower Overvoltage Output):** This pin is an open drain output which is driven low to reset the microprocessor when VSENSE rises above or falls below its nominal value by 7.5%. The on resistance of the open drain switch will be no higher than 470 $\Omega$ . The OV and UV comparators' hysteresis is fixed at 20mV independent of the COMMAND voltage.

**VIN (Positive Supply Voltage):** This pin supplies power to the chip. Connect VIN to a stable voltage source of at least 10.8V. The GATE and PWRGOOD outputs will be held low until VCC exceeds the upper undervoltage lockout threshold. This pin should be bypassed directly to the GND pin.

**VFB (Voltage Amplifier Inverting Input):** This input is connected to COMP through a feedback network and to the power supply output through a resistor or a divider network.

**VREF (Voltage Reference Output):** This pin provides an accurate 5V reference and is internally short circuit current limited. VREF powers the D/A converter and also provides a threshold voltage for the UVLO comparator. For best reference stability, bypass VREF directly to GND with a low ESR, low ESL capacitor of at least 0.01 $\mu\text{F}$ .

**VSENSE (Output Voltage Sensing Input):** This pin is connected to the system output voltage through a low pass filter. When the voltage on VSENSE rises above or falls below the COMMAND voltage by 7.5%, the PWRGOOD output is driven low to reset the microprocessor. When the voltage on VSENSE rises above the COMMAND voltage by 15%, the OVP comparator pulls the current amplifier output voltage below the oscillator valley voltage to force zero duty cycle at the GATE output. This pin is also used by the foldback current limiting circuitry.

### **APPLICATION INFORMATION**

#### **Current Limit**

The short circuit current limit, Isc, is set according to:

$$\text{Isc} = \frac{1.4\text{V}}{\text{RSENSE} \cdot \text{GCSA}}$$

where RSENSE is the average current sense resistor and GCSA is the current sense amplifier gain, where GCSA equals 20. Example: Choose RSENSE to set the short circuit current limit at 16A using the UCC3880-5

$$\text{RSENSE} = \frac{1.4\text{V}}{16\text{A} \cdot 20} = 4.4\text{m}\Omega$$

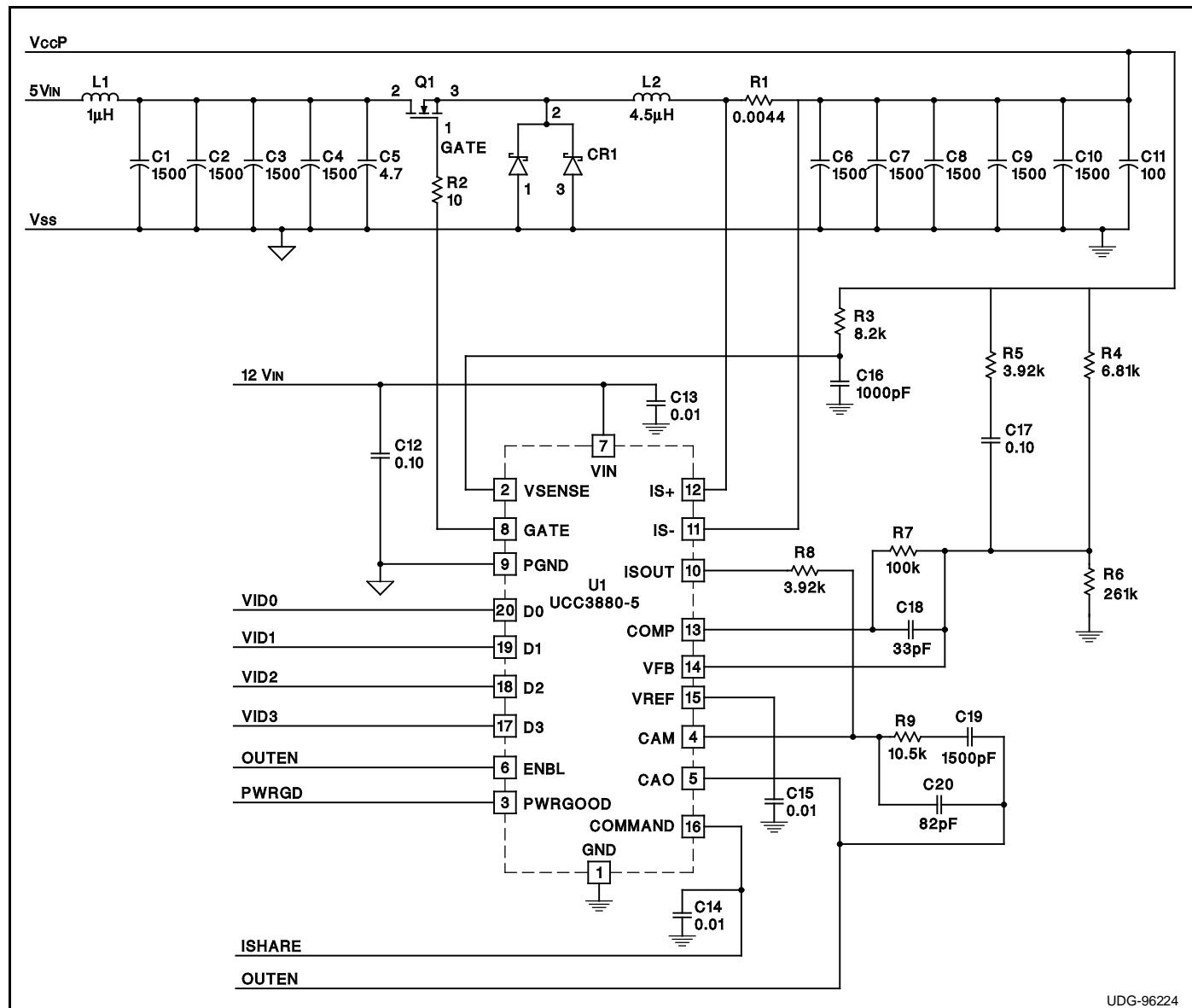
A lower resistance value may be needed if the AC ripple current in the inductor is more than 20% of the full load current.

#### **Related Publications**

U-156 and U-157 are Unitrode Application Notes describing the operation of the UC3886 and the UC3886/UC3910 together in a Pentium® Pro application.

## TYPICAL APPLICATION

The UCC3880-x is ideal for converting the 5.0V system bus into the required Pentium® Pro bus voltage.



## UCC3880 Configured for Powering the Pentium® Pro

**PARTS LIST**

REF.	DESCRIPTION	PACKAGE
U1	Unitrode UCC3830DWP-5 DAC/PWM	SOIC-20 Wide
C1	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C2	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C3	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C4	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C5	Sprague/Vishay 595D475X0016A2B, 4.7 $\mu$ F 16V Tantalum	SPRAGUE Size A
C6	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C7	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C8	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C9	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C10	Sanyo 6MV1500GX, 1500 $\mu$ F, 6.3V, Aluminum Electrolytic	10x20mm Radial Can
C11	Sprague 593D107X9010D2, 100 $\mu$ F, 6.3V Tantalum	EIA Size D SMD
C12	0.10 $\mu$ F Ceramic	1206 SMD
C13	0.01 $\mu$ F Ceramic	0603 SMD
C14	0.01 $\mu$ F Ceramic	0603 SMD
C15	0.01 $\mu$ F Ceramic	0603 SMD
C16	1000pF Ceramic	0603 SMD
C17	0.10 $\mu$ F Ceramic	1206 SMD
C18	33pF NPO Ceramic	0603 SMD
C19	1500pF Ceramic	0603 SMD
C20	82pF NPO Ceramic	0603 SMD
C21	0.10 $\mu$ F Ceramic	1206 SMD
C22	0.10 $\mu$ F Ceramic	1206 SMD
CR1	International Rectifier 32CTQ030 30V, 30A Schottky Diode	TO-220AB
L1	Micrometals T50-52B, 10 Turns #16AWG, 4.5 $\mu$ H	Toroid
Q1	International Rectifier IRL3103, 30V, 56A	TO-220AB
R1	Dale/Vishay WSR-2 0.005 $\Omega$ 1%	SMD Power Package
R2	10 $\Omega$ , 5%, 1/16 Watt	0603 SMD
R3	8.2k $\Omega$ , 5%, 1/16 Watt	0603 SMD
R4	6.81k $\Omega$ , 1%, 1/16 Watt	0603 SMD
R5	3.92k $\Omega$ , 1%, 1/16 Watt	0603 SMD
R6	261k $\Omega$ , 1%, 1/16 Watt	0603 SMD
R7	100k $\Omega$ , 1%, 1/16 Watt	0603 SMD
R8	3.92k $\Omega$ , 1%, 1/16 Watt	0603 SMD
R9	10.5k $\Omega$ , 1%, 1/16 Watt	0603 SMD
Q1-HS	AAVID 576802 TO-220 Heat Sink	TO-220AB
CR1-HS	AAVID 577002 TO-220 Heat Sink	TO-220AB

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