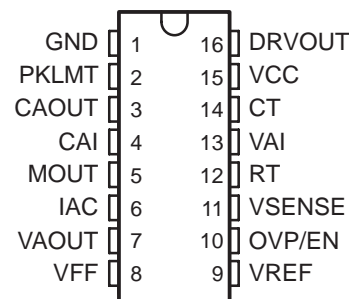


- Controls Boost Preregulator to Near-Unity Power Factor
- World Wide Line Operation
- Over-Voltage Protection
- Accurate Power Limiting
- Average Current Mode Control
- Improved Noise Immunity
- Improved Feed-Forward Line Regulation
- Leading Edge Modulation
- 150- $\mu$ A Typical Start-Up Current
- Low-Power BiCMOS Operation
- 10.8-V to 17-V Operation
- Programmable Output Voltage (Tracking Boost Topology)

D, DW, N, and PW PACKAGES  
(TOP VIEW)



## description

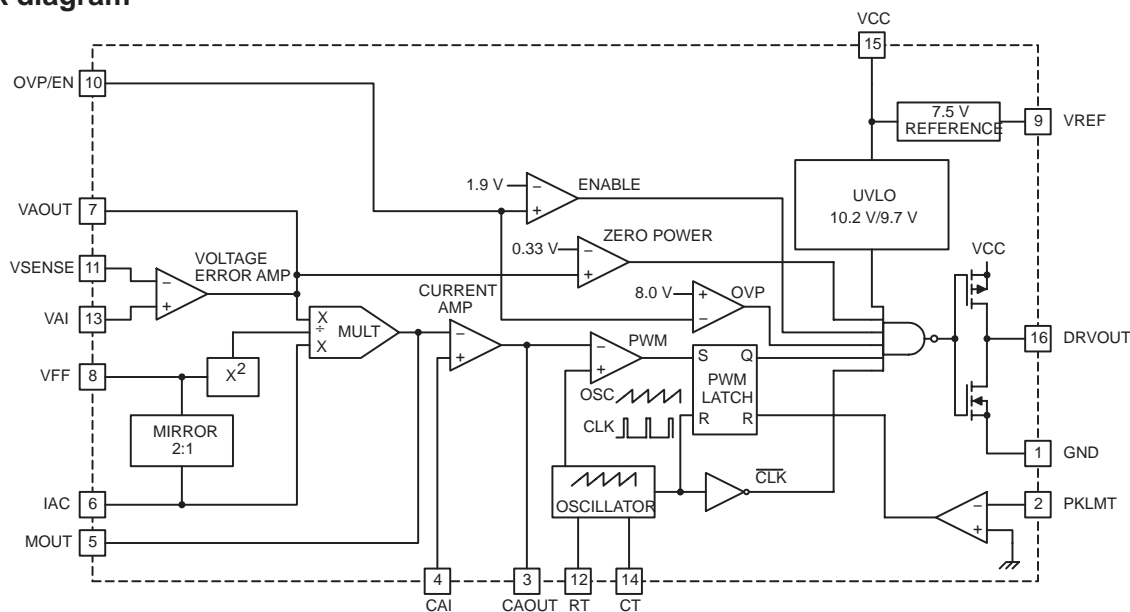
The UCC2819/UCC3819 provides all the functions necessary for active power factor corrected preregulators. The controller achieves near unity power factor by shaping the ac-input line current waveform to correspond to that of the ac-input line voltage. Average current mode control maintains stable, low distortion sinusoidal line current.

Designed in Texas Instrument's BiCMOS process, the UCC3819 offers new features such as lower start-up current, lower power dissipation, overvoltage protection, a shunt UVLO detect circuitry and a leading-edge modulation technique to reduce ripple current in the bulk capacitor.

The UCC3819 allows the output voltage to be programmed by bringing out the error amplifier noninverting input.

Available in the 16-pin D, DW, N, and PW packages.

## block diagram



UDG-01009



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

# UCC2819, UCC3819 PROGRAMMABLE OUTPUT POWER FACTOR PREREGULATOR

SLUS482B - APRIL 2001 – REVISED DECEMBER 2004

## absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, VCC	18 V
Gate drive current, continuous	0.2 A
Gate drive current	1.2 A
Input voltage, CAI, MOUT	8 V
Input voltage, PKLMT	5 V
Input voltage, VSENSE, OVP/EN, VAI	10 V
Input current, RT, IAC, PKLMT	10 mA
Maximum negative voltage, DRVOUT, PKLMT, MOUT	–0.5 V
Power dissipation	1 W

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## AVAILABLE OPTIONS

T <sub>J</sub>	PACKAGE DEVICES			
	D PACKAGE	DW PACKAGE	N PACKAGE	PW PACKAGE
0°C to 70°C	UCC3819D	UCC3819DW	UCC3819N	UCC3819PW
–40°C to 85°C	UCC2819D	UCC2819DW	UCC2819N	UCC2819PW

† The D, DW, and PW packages are available taped and reeled. Add TR suffix to device type (e.g. UCC3819DTR) to order quantities of 2500 devices per reel.

**electrical characteristics, T<sub>A</sub> = 0°C to 70°C for the UCC3819, –40°C to 85°C for the UCC2819, VCC = 12 V, R<sub>T</sub> = 22 kΩ, C<sub>T</sub> = 270 pF, (unless otherwise noted)**

## supply current

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Supply current, off	VCC = (VCC turnon threshold –0.3 V)		150	300	μA
Supply current, on	VCC = 12 V, No load on DRVOUT	2	4	6	mA

## UVLO

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
VCC turnon threshold		9.7	10.2	10.8	V
VCC turnoff threshold		9.4	9.7		V
UVLO hysteresis		0.3	0.5		V

## voltage amplifier

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
VIO	VAOUT = 2.75 V, VCM = 3.75 V	–15		15	mV
VAI bias current	VAOUT = 2.75 V, VCM = 3.75 V		50	200	nA
VSENSE bias current	VSENSE = VREF, VAOUT = 2.5 V		50	200	nA
CMRR	VCM = 1 V to 7.5 V	50	70		dB
Open loop gain	VAOUT = 2 V to 5 V	50	90		dB
High-level output voltage	I <sub>L</sub> = –150 μA	5.3	5.5	5.6	V
Low-level output voltage	I <sub>L</sub> = 150 μA	0	50	150	mV

electrical characteristics,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3819,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UCC2819,  $V_{CC} = 12\text{ V}$ ,  $R_T = 22\text{ k}\Omega$ ,  $C_T = 270\text{ pF}$ , (unless otherwise noted)

#### over voltage protection and enable

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Over voltage reference		VREF +0.48	VREF +0.50	VREF +0.52	V
Hysteresis		300	500	600	mV
Enable threshold		1.7	1.9	2.1	V
Enable hysteresis		0.1	0.2	0.3	V

#### current amplifier

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input offset voltage	$V_{CM} = 0\text{ V}$ , $V_{CAOUT} = 3\text{ V}$	-3.5	0	2.5	mV
Input bias current	$V_{CM} = 0\text{ V}$ , $V_{CAOUT} = 3\text{ V}$		-50	-100	nA
Input offset current	$V_{CM} = 0\text{ V}$ , $V_{CAOUT} = 3\text{ V}$		25	100	nA
Open loop gain	$V_{CM} = 0\text{ V}$ , $V_{CAOUT} = 2\text{ V}$ to $5\text{ V}$	90			dB
Common-mode rejection ratio	$V_{CM} = 0\text{ V}$ to $1.5\text{ V}$ , $V_{CAOUT} = 3\text{ V}$	60	80		dB
High-level output voltage	$I_L = -120\text{ }\mu\text{A}$	5.6	6.5	6.8	V
Low-level output voltage	$I_L = 1\text{ mA}$	0.1	0.2	0.5	V
Gain bandwidth product	See Note 1		2.5		MHz

#### voltage reference

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input voltage, (UCC3819)	$T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$	7.387	7.5	7.613	V
Input voltage, (UCC2819)	$T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$	7.369	7.5	7.631	V
Load regulation	$I_{REF} = 1\text{ mA}$ to $2\text{ mA}$	0		10	mV
Line regulation	$V_{CC} = 10.8\text{ V}$ to $15\text{ V}$ , See Note 2	0		10	mV
Short-circuit current	$V_{REF} = 0\text{ V}$	-20	-25	-50	mA

#### oscillator

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Initial accuracy	$T_A = 25^\circ\text{C}$	85	100	115	kHz
Voltage stability	$V_{CC} = 10.8\text{ V}$ to $15\text{ V}$	-1		1	%
Total variation	Line, temp, See Note 1	80		120	kHz
Ramp peak voltage		4.5	5	5.5	V
Ramp amplitude voltage (peak to peak)		3.5	4	4.5	V

NOTES: 1. Ensured by design, Not production tested.  
 2. Reference variation for  $V_{CC} < 10.8\text{ V}$  is shown in Figure 2.

# UCC2819, UCC3819

## PROGRAMMABLE OUTPUT

## POWER FACTOR PREREGULATOR

SLUS482B - APRIL 2001 – REVISED DECEMBER 2004

electrical characteristics,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3819,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UCC2819,  $V_{CC} = 12\text{ V}$ ,  $R_T = 22\text{ k}\Omega$ ,  $C_T = 270\text{ pF}$ , (unless otherwise noted)

### peak current limit

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
PKLMT reference voltage		-15		15	mV
PKLMT propagation delay		150	350	500	ns

### multiplier

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$I_{MOUT}$ , high line, low power output current, ( $0^\circ\text{C}$ to $85^\circ\text{C}$ )	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 1.25\text{ V}$	0	-6	-20	$\mu\text{A}$
$I_{MOUT}$ , high line, low power output current, ( $-40^\circ\text{C}$ to $85^\circ\text{C}$ )	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 1.25\text{ V}$	0		-23	$\mu\text{A}$
$I_{MOUT}$ , high line, high power output current	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 5\text{ V}$	-70	-90	-105	$\mu\text{A}$
$I_{MOUT}$ , low line, low power output current	$I_{AC} = 150\text{ }\mu\text{A}$ , $V_{FF} = 1.4\text{ V}$ , $VAOUT = 1.25\text{ V}$	-10	-19	-50	$\mu\text{A}$
$I_{MOUT}$ , low line, high power output current	$I_{AC} = 150\text{ }\mu\text{A}$ , $V_{FF} = 1.4\text{ V}$ , $VAOUT = 5\text{ V}$	-268	-300	-346	$\mu\text{A}$
$I_{MOUT}$ , IAC limited	$I_{AC} = 150\text{ }\mu\text{A}$ , $V_{FF} = 1.3\text{ V}$ , $VAOUT = 5\text{ V}$	-250	-300	-400	$\mu\text{A}$
Gain constant (K)	$I_{AC} = 300\text{ }\mu\text{A}$ , $V_{FF} = 3\text{ V}$ , $VAOUT = 2.5\text{ V}$	0.5	1	1.5	1/V
$I_{MOUT}$ , zero current	$I_{AC} = 150\text{ }\mu\text{A}$ , $V_{FF} = 1.4\text{ V}$ , $VAOUT = 0.25\text{ V}$		0	-2	$\mu\text{A}$
	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 0.25\text{ V}$		0	-2	$\mu\text{A}$
$I_{MOUT}$ , zero current, ( $0^\circ\text{C}$ to $85^\circ\text{C}$ )	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 0.5\text{ V}$		0	-3	$\mu\text{A}$
$I_{MOUT}$ , zero current, ( $-40^\circ\text{C}$ to $85^\circ\text{C}$ )	$I_{AC} = 500\text{ }\mu\text{A}$ , $V_{FF} = 4.7\text{ V}$ , $VAOUT = 0.5\text{ V}$		0	-3.5	$\mu\text{A}$
Power limit ( $I_{MOUT} \times V_{FF}$ )	$I_{AC} = 150\text{ }\mu\text{A}$ , $V_{FF} = 1.4\text{ V}$ , $VAOUT = 5\text{ V}$	-375	-420	-485	$\mu\text{W}$

### feed-forward

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{FF}$ output current	$I_{AC} = 300\text{ }\mu\text{A}$	-140	-150	-160	$\mu\text{A}$

### gate driver

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Pullup resistance	$I_O = -100\text{ mA}$ to $-200\text{ mA}$		5	12	$\Omega$
Pulldown resistance	$I_O = 100\text{ mA}$		2	10	$\Omega$
Output rise time	$C_L = 1\text{ nF}$ , $R_L = 10\text{ }\Omega$ , $V_{DRVOUT} = 0.7\text{ V}$ to $9\text{ V}$		25	50	ns
Output fall time	$C_L = 1\text{ nF}$ , $R_L = 10\text{ }\Omega$ , $V_{DRVOUT} = 9\text{ V}$ to $0.7\text{ V}$		10	50	ns
Maximum duty cycle		93	95	100	%
Minimum controlled duty cycle	At $100\text{ kHz}$			2	%

### zero power

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Zero power comparator threshold	Measured on $VAOUT$	0.20	0.33	0.50	V

## pin descriptions

**CAI:** (current amplifier noninverting input) Place a resistor between this pin and the GND side of current-sense resistor. This input and the inverting input (MOUT) remain functional down to and below GND.

**CAOUT:** (current amplifier output) This is the output of a wide bandwidth operational amplifier that senses line current and commands the PFC pulse-width modulator (PWM) to force the correct duty cycle. Compensation components are placed between CAOUT and MOUT.

**CT:** (oscillator timing capacitor) A capacitor from CT to GND sets the PWM oscillator frequency according to:

$$f \approx \left( \frac{0.6}{RT \times CT} \right)$$

The lead from the oscillator timing capacitor to GND should be as short and direct as possible.

**DRVOUT:** (gate drive) The output drive for the boost switch is a totem-pole MOSFET gate driver on DRVOUT. Use a series gate resistor to prevent interaction between the gate impedance and the output driver that might cause the DRVOUT to overshoot excessively. See characteristic curve (Figure 13) to determine minimum required gate resistor value. Some overshoot of the DRVOUT output is always expected when driving a capacitive load.

**GND:** (ground) All voltages measured with respect to ground. VCC and REF should be bypassed directly to GND with a 0.1-μF or larger ceramic capacitor.

**IAC:** (current proportional to input voltage) This input to the analog multiplier is a current proportional to instantaneous line voltage. The multiplier is tailored for very low distortion from this current input ( $I_{IAC}$ ) to multiplier output. The recommended maximum  $I_{IAC}$  is 500 μA.

**MOUT:** (multiplier output and current amplifier inverting input) The output of the analog multiplier and the inverting input of the current amplifier are connected together at MOUT. As the multiplier output is a current, this is a high-impedance input so the amplifier can be configured as a differential amplifier. This configuration improves noise immunity and allows for the leading-edge modulation operation. The multiplier output current is limited to  $(2 \times I_{IAC})$ . The multiplier output current is given by the equation:

$$I_{MOUT} = \frac{I_{IAC} \times (V_{VAOUT} - 1)}{V_{VFF}^2 \times K}$$

where  $K = \frac{1}{V}$  is the multiplier gain constant.

**OVP/EN:** (over-voltage/enable) A window comparator input that disables the output driver if the boost output voltage is a programmed level above the nominal or disables both the PFC output driver and resets SS if pulled below 1.9 V (typ).

**PKLMT:** (PFC peak current limit) The threshold for peak limit is 0 V. Use a resistor divider from the negative side of the current sense resistor to VREF to level shift this signal to a voltage level defined by the value of the sense resistor and the peak current limit. Peak current limit is reached when PKLMT voltage falls below 0 V.

**RT:** (oscillator charging current) A resistor from RT to GND is used to program oscillator charging current. A resistor between 10 kΩ and 100 kΩ is recommended. Nominal voltage on this pin is 3 V.

# UCC2819, UCC3819 PROGRAMMABLE OUTPUT POWER FACTOR PREREGULATOR

SLUS482B - APRIL 2001 – REVISED DECEMBER 2004

---

## pin descriptions (continued)

**VAI:** (voltage amplifier non-inverting input) This input can be tied to the VREF or any other voltage reference ( $\leq 7.5$  V) to set the boost regulator output voltage.

**VAOUT:** (voltage amplifier output) This is the output of the operational amplifier that regulates output voltage. The voltage amplifier output is internally limited to approximately 5.5 V to prevent overshoot.

**VCC:** (positive supply voltage) Connect to a stable source of at least 20 mA between 10 V and 17 V for normal operation. Bypass VCC directly to GND to absorb supply current spikes required to charge external MOSFET gate capacitances. To prevent inadequate gate drive signals, the output devices are inhibited unless  $V_{VCC}$  exceeds the upper under-voltage lockout voltage threshold and remains above the lower threshold.

**VFF:** (feed-forward voltage) The RMS voltage signal generated at this pin by mirroring 1/2 of the  $I_{AC}$  into a single pole external filter. At low line, the VFF roll should be 14 V.

**VSENSE:** (voltage amplifier inverting input) This is normally connected to a compensation network and to the boost converter output through a divider network.

**VREF:** (voltage reference output) VREF is the output of an accurate 7.5-V voltage reference. This output is capable of delivering 20 mA to peripheral circuitry and is internally short-circuit current limited. VREF is disabled and remains at 0 V when  $V_{VCC}$  is below the UVLO threshold. Bypass VREF to GND with a 0.1- $\mu$ F or larger ceramic capacitor for best stability. Please refer to Figures 8 and 9 for VREF line and load regulation characteristics.

---

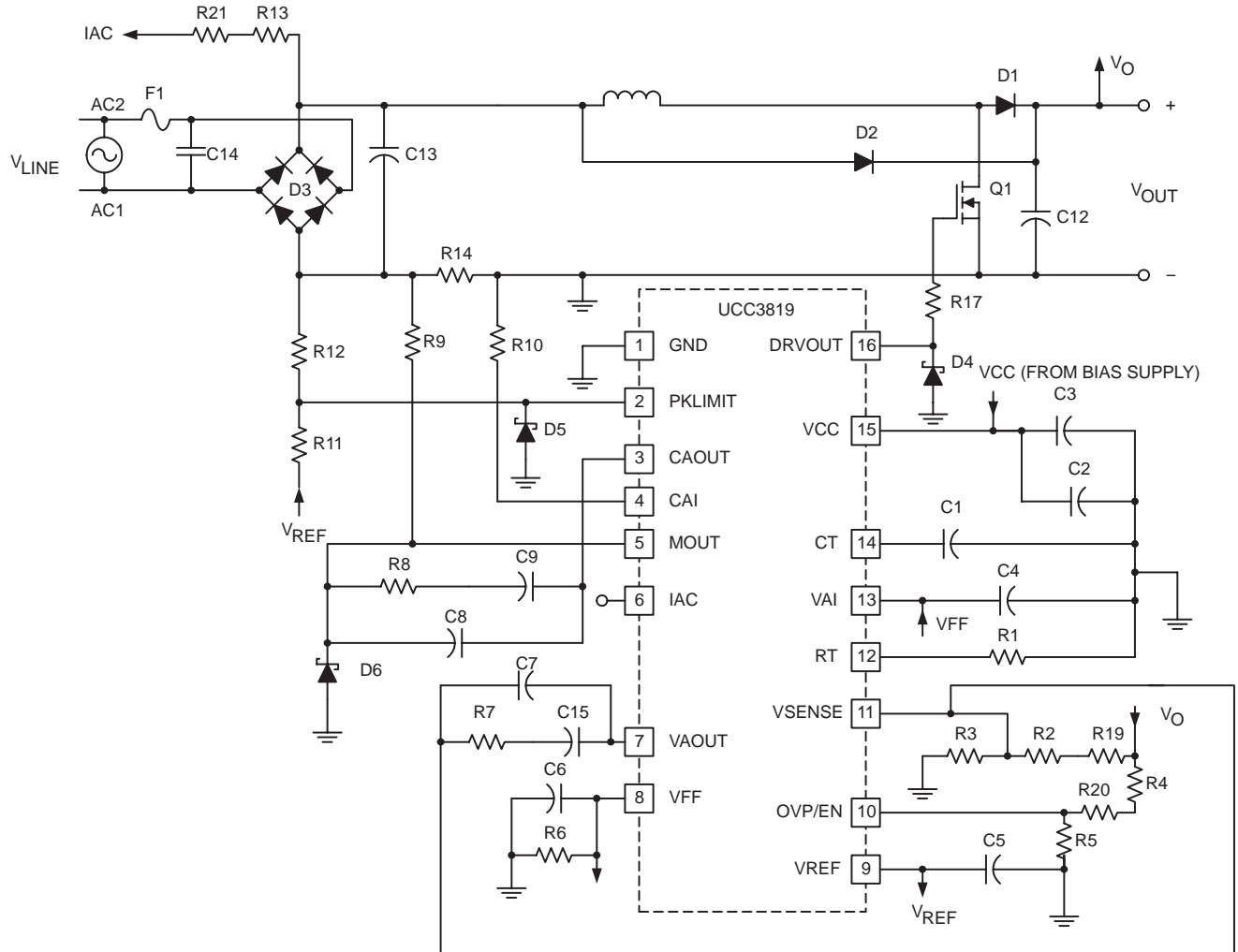
## APPLICATION INFORMATION

The UCC3819 is based on the UCC3818 PFC preregulator. For a more detailed application information for this part, please refer to the UCC3818 datasheet product folder.

The main difference between the UCC3818 and the UCC3819 is that the non-inverting input of the voltage error amplifier is made available to the user through an external pin (VAI) in the UCC3819. The SS pin and function were eliminated to accommodate this change.

The benefit of VAI pin is that it can be used to dynamically change the PFC output voltage based on the line voltage (RMS) level or other conditions. Figure 1 shows one suggested implementation of the tracking boost PFC converter as this approach is sometimes referred to. The VAI pin is tied to the VFF pin and hence output voltage scales up with the line voltage. The benefit of this approach is that at lower line voltages the output voltage is lower and that leads to smaller boost inductor value, lower MOSFET conduction losses and reduced component stresses. In order for this feature to work, the downstream converter has to operate over a wider input range.

## APPLICATION INFORMATION



UDG-01008

**Figure 1. Suggested Implementation of UCC3819 in a Tracking Boost PFC Preregulator**

## APPLICATION INFORMATION

REFERENCE VOLTAGE  
vs  
SUPPLY VOLTAGE

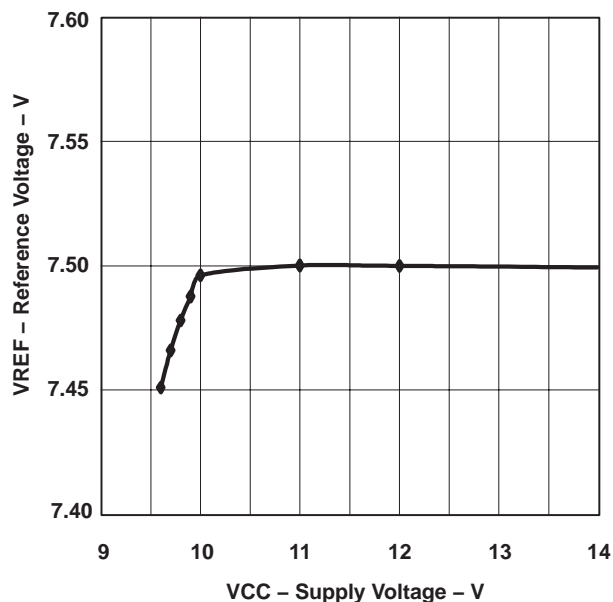


Figure 2

REFERENCE VOLTAGE  
vs  
REFERENCE CURRENT

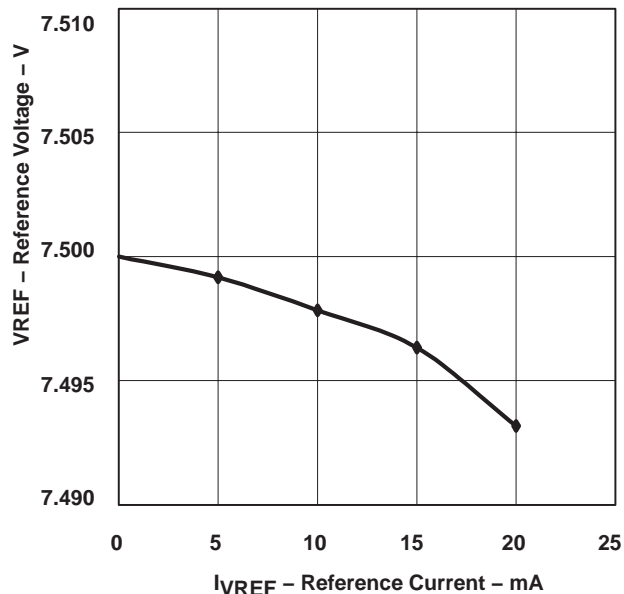


Figure 3

MULTIPLIER OUTPUT CURRENT  
vs  
VOLTAGE ERROR AMPLIFIER OUTPUT

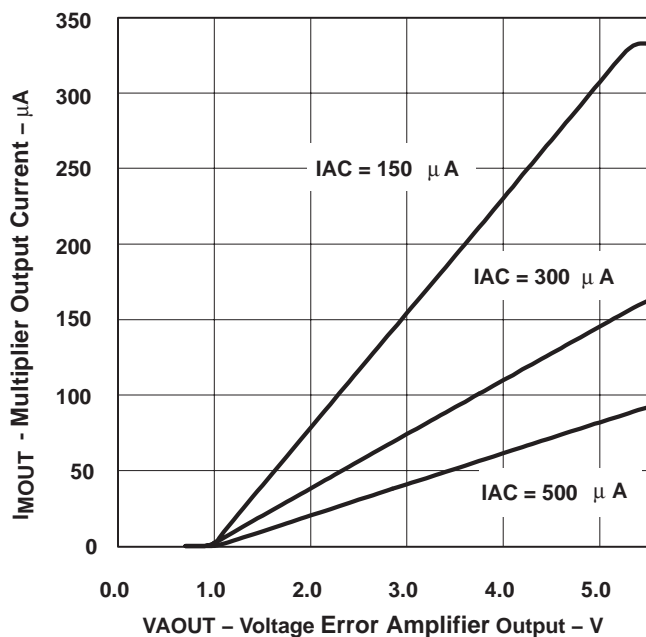


Figure 4

MULTIPLIER GAIN  
vs  
VOLTAGE ERROR AMPLIFIER OUTPUT

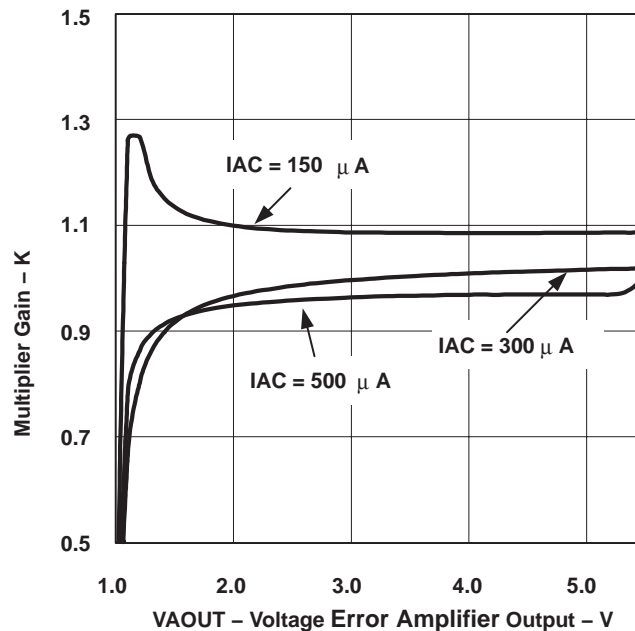
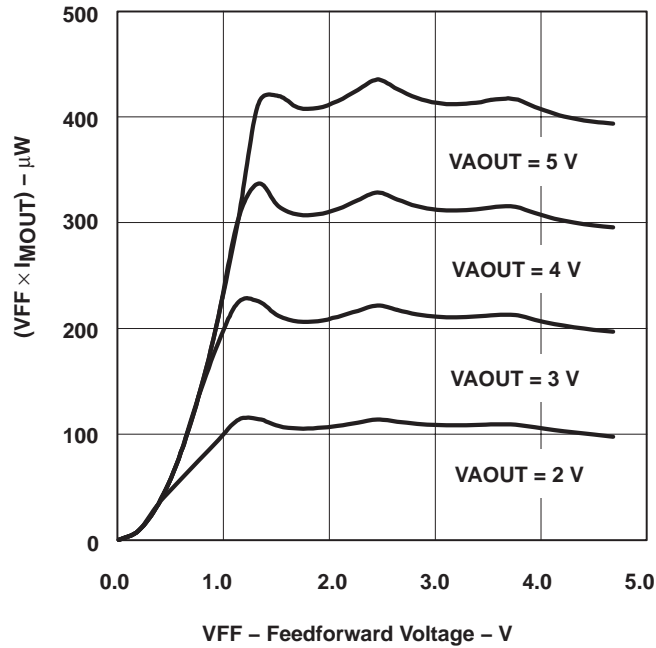


Figure 5



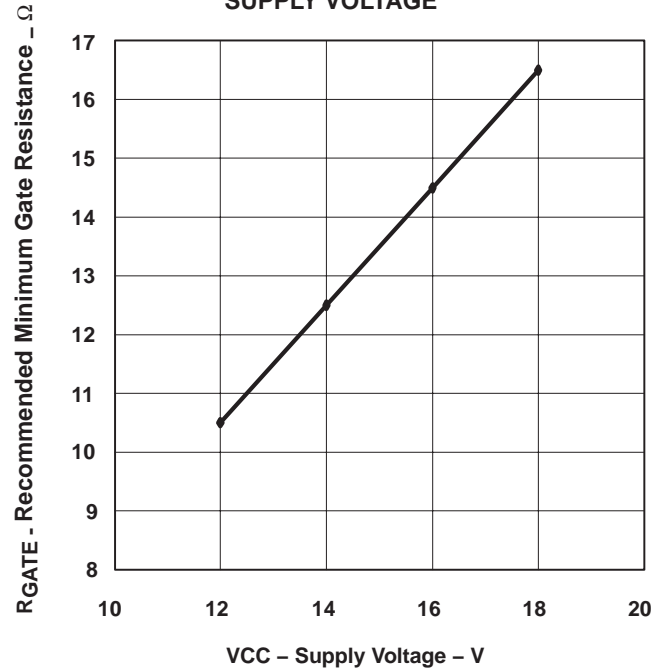
## APPLICATION INFORMATION

**MULTIPLIER CONSTANT POWER PERFORMANCE**



**Figure 6**

**RECOMMENDED MINIMUM GATE RESISTANCE  
 VS  
 SUPPLY VOLTAGE**



**Figure 7**

## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">UCC2819D</a>	Active	Production	SOIC (D)   16	40   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	UCC2819D
UCC2819D.A	Active	Production	SOIC (D)   16	40   TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	UCC2819D
<a href="#">UCC2819DTR</a>	Active	Production	SOIC (D)   16	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	UCC2819D
UCC2819DTR.A	Active	Production	SOIC (D)   16	2500   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	UCC2819D

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
UCC2819DTR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
UCC2819DTR	SOIC	D	16	2500	353.0	353.0	32.0

## TUBE



\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
UCC2819D	D	SOIC	16	40	507	8	3940	4.32
UCC2819D.A	D	SOIC	16	40	507	8	3940	4.32

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



4040047-6/M 06/11

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AC.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2025, Texas Instruments Incorporated

Last updated 10/2025