SLUS488A – SEPTEMBER 2002 – REVISED NOVEMBER 2002

8-PIN CURRENT MODE PUSH-PULL PWM CONTROLLERS WITH PROGRAMMABLE SLOPE COMPENSATION

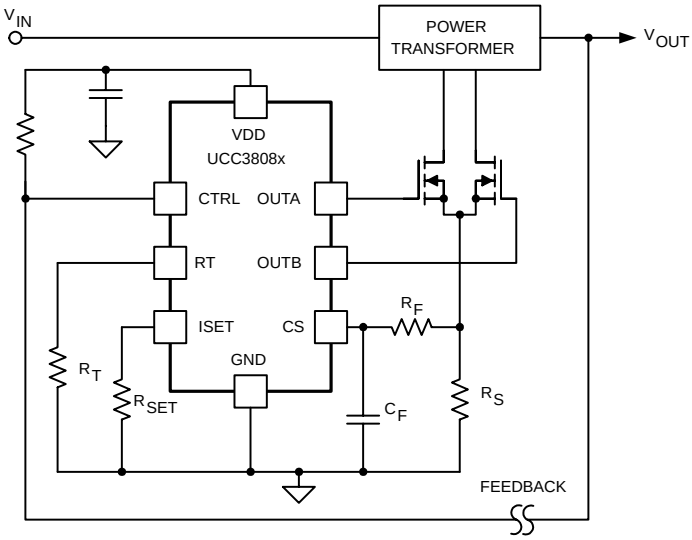
FEATURES

- **Programmable Slope Compensation**
- **Internal Soft-Start on the UCC38083/4**
- **Cycle-by-Cycle Current Limiting**
- **Low Start-Up Current of 120 μA and 1.5 mA Typical Run Current**
- **Single External Component Oscillator Programmable from 50 kHz to 1 MHz**
- **High-Current Totem-Pole Dual Output Stage Drives Push-Pull Configuration with 1-A Sink and 0.5-A Source Capability**
- **Current Sense Discharge Transistor to Improve Dynamic Response**
- **Internally Trimmed Bandgap Reference**
- **Undervoltage Lockout with Hysteresis**

APPLICATIONS

- **High-Efficiency Switch-Mode Power Supplies**
- **Telecom dc-to-dc Converters**
- **Point-of-Load or Point-of-Use Power Modules**
- **Low-Cost Push-Pull and Half-Bridge Applications**

BASIC APPLICATION



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DESCRIPTION

The UCC38083/4/5/6 is a family of BiCMOS pulse width modulation (PWM) controllers for dc-to-dc or off-line fixed-frequency current-mode switching power supplies. The dual output stages are configured for the push-pull topology. Both outputs switch at half the oscillator frequency using a toggle flip-flop. The dead time between the two outputs is typically 110 ns, limiting each output's duty cycle to less than 50%.

The new UCC3808x family is based on the UCC3808A architecture. The major differences include the addition of a programmable slope compensation ramp to the CS signal and the removal of the error amplifier. The current flowing out of the ISET pin through an external resistor is monitored internally to set the magnitude of the slope compensation function. This device also includes an internal discharge transistor from the CS pin to ground, which is activated at each clock cycle after the pulse is terminated. This discharges any filter capacitance on the CS pin during each cycle and helps minimize filter capacitor values and current sense delay.

The UCC38083 and the UCC38084 devices have a typical soft-start interval time of 3.5 ms while the UCC38085 and the UCC38086 has less than 100 μs for applications where internal soft-start is not desired.

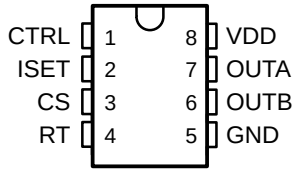
The UCC38083 and the UCC38085 devices have the turn on/off thresholds of 12.5 V / 8.3 V, while the UCC38084 and the UCC38086 has the turn on/off thresholds of 4.3 V / 4.1 V. Each device is offered in 8-pin TSSOP (PW), 8-pin SOIC (D) and 8-pin PDIP (P) packages.

AVAILABLE OPTIONS

T_A	INTERNAL SOFT START	UVLO		PACKAGES		
		ON	OFF	SOIC-8 (D)	PDIP-8 (P)	TSSOP-8 (PW)
–40°C to 85°C	3.5 ms	12.5 V	8.3 V	UCC28083D	UCC28083P	UCC28083PW
		4.3 V	4.1 V	UCC28084D	UCC28084P	UCC28084PW
	75 µs	12.5 V	8.3 V	UCC28085D	UCC28085P	UCC28085PW
		4.3 V	4.1 V	UCC28086D	UCC28086P	UCC28086PW
0°C to 70°C	3.5 ms	12.5 V	8.3 V	UCC38083D	UCC38083P	UCC38083PW
		4.3 V	4.1 V	UCC38084D	UCC38084P	UCC38084PW
	75 µs	12.5 V	8.3 V	UCC38085D	UCC38085P	UCC38085PW
		4.3 V	4.1 V	UCC38086D	UCC38086P	UCC38086PW

† The D and PW packages are available taped and reeled. Add R suffix to device type, e.g. UCC28083DR (2500 devices per reel) or UCC38083PWR (2000 devices per reel).

D OR P PACKAGE
(TOP VIEW)



PW PACKAGE
(TOP VIEW)

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

Supply voltage, V_{DD} (I_{DD} < 10 mA) . . . . . 15 V
Supply current, I_{DD} . . . . . 20 mA
Sink current (peak): OUTA . . . . . 1.0 A
OUTB . . . . . 1.0 A
Source current (peak): OUTA . . . . . –0.5 A
OUTB . . . . . –0.5 A
Analog inputs: CTRL . . . . . –0.3 V to V_{DD} +0.3 V
CS . . . . . –0.3 V to V_{DD} +0.3 V, not to exceed 6 V
R_{SET} (minimum) . . . . . >5 kΩ
R_T (–100 µA < I_{RT} < 100 µA) . . . . . –0.3 V to 2.0 V
Power dissipation at T_A = 25°C (P package) . . . . . 1 W
Power dissipation at T_A = 25°C (D package) . . . . . 650 mW
Power dissipation at T_A = 25°C (PW package) . . . . . 400 mW
Junction operating temperature, T_J . . . . . –55°C to 150°C
Storage temperature, T_{stg} . . . . . –65°C to 150°C
Lead temperature (soldering 10 seconds) . . . . . 300°C

† 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. All voltages are with respect to GND. Currents are positive into, and negative out of the specified terminal.

electrical characteristics over recommended operating virtual junction temperature range, V_{DD} = 10 V (See Note 1),1-μF capacitor from VDD to GND, RT = 165 kΩ, RF = 1 kΩ, CF = 220 pF, RSET = 50 kΩ, T_A = –40°C to 85°C for UCC2808x, T_A = 0°C to 70°C for UCC3808x, T_A = T_J (unless otherwise noted)

overall

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Start-up current	VDD < UVLO start threshold voltage		120	200	μA
Supply current	CTRL = 0 V, CS = 0 V, See Note 1		1.5	2.5	mA

undervoltage lockout

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
Start threshold voltage	UCC38083/5	See Note 1	11.5	12.5	13.5	V
	UCC38084/6		4.1	4.3	4.5	
Minimum operating voltage after start	UCC38083/5		7.6	8.3	9.0	
	UCC38084/6		3.9	4.1	4.3	
Hysteresis voltage	UCC38083/5		3.5	4.2	5.1	
	UCC38084/6		0.1	0.2	0.3	

oscillator

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Frequency	2 x f(OUTA)	180	200	220	kHz
Voltage amplitude	See Note 2	1.4	1.5	1.6	V
Oscillator fall time (dead time)			110	220	ns
RT pin voltage		1.2	1.5	1.6	V

current sense

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Gain	See Note 3	1.9	2.2	2.5	V/V
Maximum input signal voltage	CTRL = 5 V, See Note 4	0.47	0.52	0.57	V
CS to output delay time	CTRL = 3.5 V, 0 mV ≤ CS ≤ 600 mV		100	200	ns
Source current		–200			nA
Sink current	CS = 0.5 V, RT = 2.0 V, See Note 5	3	7	12	mA
Overcurrent threshold voltage		0.70	0.75	0.80	V
CTRL to CS offset voltage	CS = 0 V, 25°C	0.55	0.70	0.90	V
	CS = 0 V	0.37	0.70	1.10	V

NOTE 1: For UCCx8083/5, set VDD above the start threshold before setting to 10 V.
NOTE 2: Measured at ISET pin.
NOTE 3: Gain is defined by $A = \frac{\Delta V_{CTRL}}{\Delta V_{CS}}$, $0 \le V_{CS} \le 0.4$ V.
NOTE 4: Measured at trip point of latch with CS ramped from 0.4 V to 0.6 V.
NOTE 5: This internal current sink on the CS pin is designed to discharge and external filter capacitor. It is not intended to be a dc sink path.

electrical characteristics over recommended operating virtual junction temperature range, V_{DD} = 10 V (See Note 1),1-μF capacitor from VDD to GND, RT = 165 kΩ, RF = 1 kΩ, CF = 220 pF, RSET = 50 kΩ, T_A = –40°C to 85°C for UCC2808x, T_A = 0°C to 70°C for UCC3808x, T_A = T_J (unless otherwise noted)

pulse width modulation

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Maximum duty cycle	Measured at OUTA or OUTB	48%	49%	50%	
Minimum duty cycle	CTRL = 0 V			0%	

output

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Low-level output voltage (OUTA or OUTB)	I_{OUT} = 100 mA		0.5	1.0	V
High-level output voltage (OUTA or OUTB)	I_{OUT} = –50 mA, (VDD – VOUT), See Note 6		0.5	1.0	
Rise time	C_{LOAD} = 1 nF		25	60	ns
Fall time	C_{LOAD} = 1 nF		25	60	

soft-start

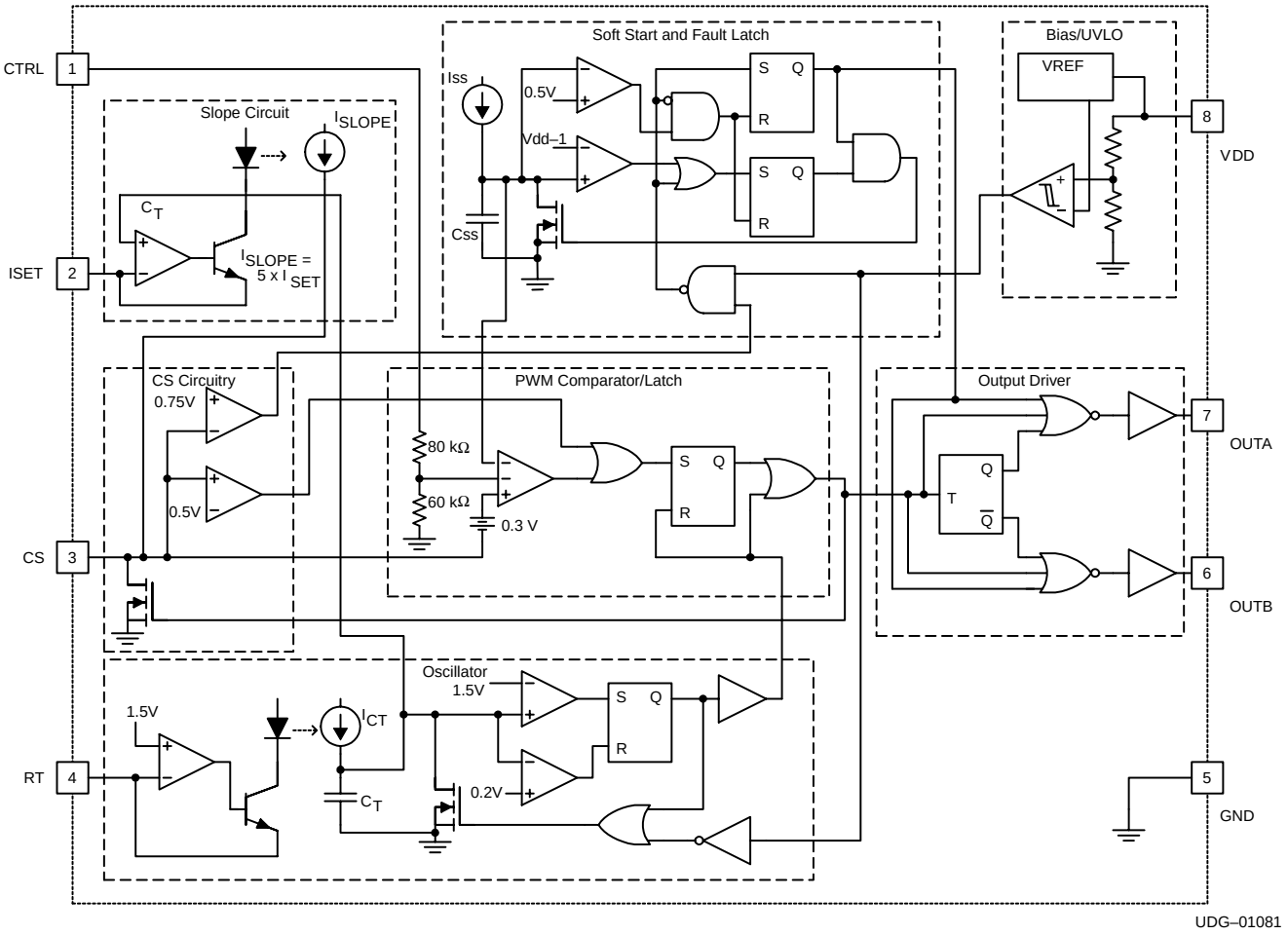
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
OUTA/OUTB soft-start interval time, UCC38083/4	CTRL = 1.8 V, CS = 0 V, Duty cycle from 0 to full	1.3	3.5	8.5	ms
OUTA/OUTB soft-start interval time, UCC38085/6	CTRL = 1.8 V, CS = 0 V, Duty cycle from 0 to full	30	75	110	μs

slope compensation

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_{RAMP}, peak	I_{SET}, peak = 30 μA, Full duty cycle	125	150	175	μA

NOTE 1: For UCCx8083/5, set VDD above the start threshold before setting to 10 V.
NOTE 6: Not 100% production tested. Ensured by design and also by the rise time test.

functional block diagram



Terminal Functions

TERMINAL		I/O	DESCRIPTION
NAME	PACKAGE D OR P		
CS	3	I	The current-sense input to the PWM comparator, the cycle-by-cycle peak current comparator, and the overcurrent comparator. The overcurrent comparator is only intended for fault sensing. Exceeding the overcurrent threshold causes a soft-start cycle. An internal MOSFET discharges the current-sense filter capacitor to improve dynamic performance of the power converter.
CTRL	1	I	Error voltage input to PWM comparator.
GND	5	–	Reference ground and power ground for all functions. Due to high currents, and high-frequency operation of the IC, a low-impedance circuit board ground plane is highly recommended.
ISET	2	I	Current selection for slope compensation.
OUTA	7	O	Alternating high-current output stages.
OUTB	6	O	
RT	4	I	Programs the oscillator.
VDD	8	I	Power input connection.

detailed pin descriptions

CTRL: The error voltage is typically generated by a secondary-side error amplifier and transmitted to the primary-side referenced UCC3808x by means of an opto-coupler. CTRL has an internal divider ratio of 0.45 to maintain a usable range with the minimum V_{DD} of 4.1 V. The UCC38083/UCC38084 family features a built-in full-cycle soft start while the UCC38085/6 does not.

For the UCC38083/4, soft-start is implemented as a clamp at the input to the PWM comparator. This causes the output pulses to start near 0% duty cycle and increase until the clamp exceeds the CTRL voltage.

ISET: Program the slope compensation current ramp by connecting a resistor, RSET, from ISET to ground. The voltage of the ISET pin tracks the 1.5V internal oscillator ramp, as shown in Figure 1.

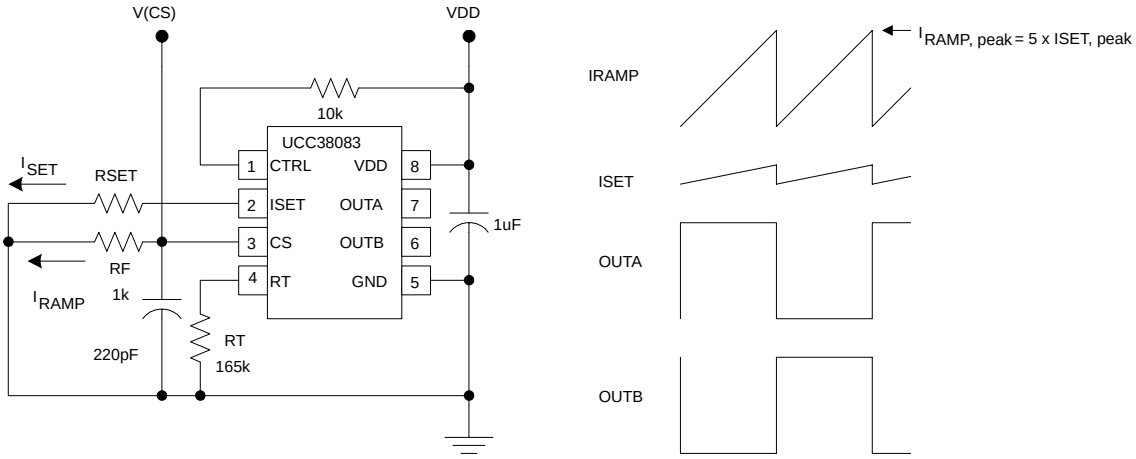


Figure 1. Full Duty Cycle Output

The compensating current source, I_{SLOPE}, at the CS pin is proportional to the ISET current, according to the relation:

$$I_{SLOPE} = 5 \times I_{SET} \quad (1)$$

The ramping current due to I_{SLOPE} develops a voltage across the effective filter impedance that is normally connected from the current sense resistor to the CS input. In order to program a desired compensating slope with a specific peak compensating ramp voltage at the CS pin, use the RSET value in the following equation:

$$RSET = V_{OSC(peak)} \times \left(\frac{5 \times RF}{\text{RAMP VOLTAGE HEIGHT}} \right) \quad (2)$$

Where $V_{OSC(peak)} = 1.5\ V$

Notice that the PWM Latch drives an internal MOSFET that will discharge an external filtering capacitor on the CS pin. Thus, I_{SLOPE} will appear to terminate when the PWM comparator or the cycle-by-cycle current limit comparator sets the PWM latch. The actual compensating slope is not affected by premature termination of the switching cycle.

detailed pin descriptions (continued)

OUTA and OUTB: Alternating high-current output stages. Both stages are capable of driving the gate of a power MOSFET. Each stage is capable of 500-mA peak-source current, and 1-A peak-sink current.

The output stages switch at half the oscillator frequency, in a push-pull configuration. When the voltage on the internal oscillator capacitor is rising, one of the two outputs is high, but during fall time, both outputs are off. This dead time between the two outputs, along with a slower output rise time than fall time, ensures that the two outputs cannot be on at the same time. This dead time is typically 110 ns.

The high-current output drivers consist of MOSFET output devices, which switch from VDD to GND. Each output stage also provides a very low impedance to overshoot and undershoot. This means that in many cases, external Schottky clamp diodes are not required.

RT: The oscillator programming pin. The oscillator features an internal timing capacitor. An external resistor, R_T, sets a current from the RT pin to ground. Due to variations in the internal C_T, nominal V_{RT} of 1.5 V can vary from 1.23 V to 1.57 V

Selecting RT as shown programs the oscillator frequency:

$$RT = \frac{1}{28.7 \times 10^{-12}} \left(\frac{1}{f_{OSC}} - 2.0 \times 10^{-7} \right) \tag{3}$$

where f_{OSC} is in Hz, resistance in Ω. The recommended range of timing resistors is between 25 kΩ and 698 kΩ.

For best performance, keep the timing resistor lead from the RT pin to GND (pin 5) as short as possible.

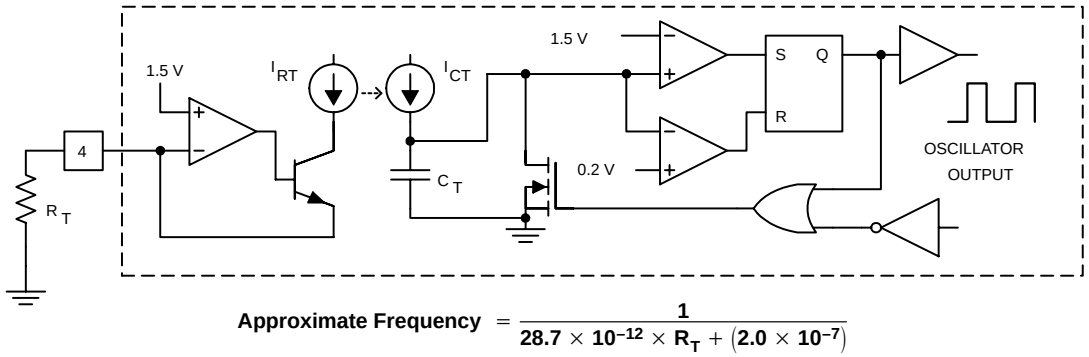


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Figure 2. Block Diagram for Oscillator

VDD: The power input connection for this device. Although quiescent VDD current is very low, total supply current may be higher, depending on OUTA and OUTB current, and the programmed oscillator frequency. Total VDD current is the sum of quiescent VDD current and the average OUT current. Knowing the operating frequency and the MOSFET gate charge (Q_G), average OUT current can be calculated from:

$$I_{OUT} = Q_G \times f_{OSC} \tag{4}$$

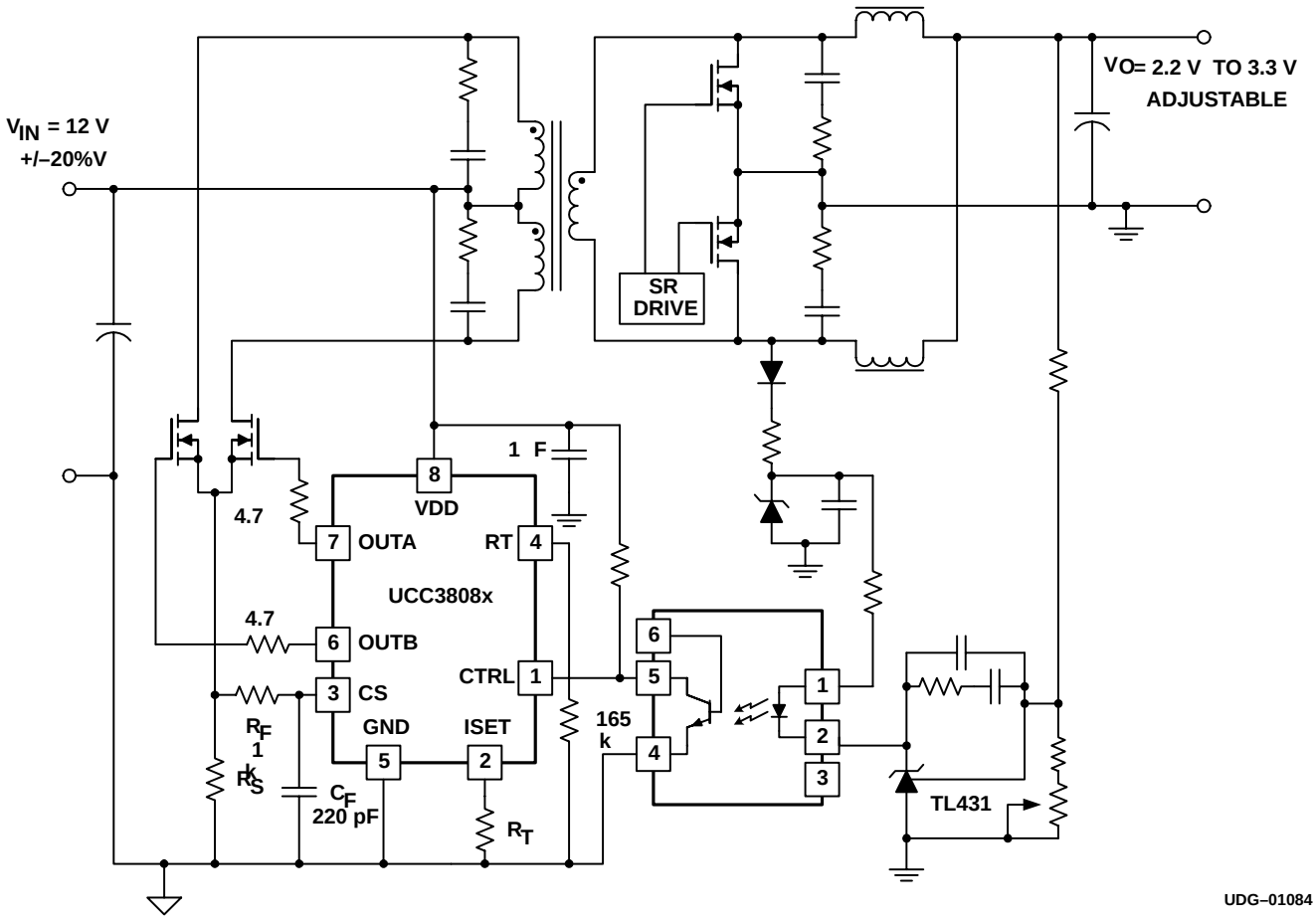
where f is the oscillator frequency.

To prevent noise problems, bypass VDD to GND with a ceramic capacitor as close to the chip as possible along with an electrolytic capacitor. A 1-μF decoupling capacitor is recommended.

APPLICATION INFORMATION

The following application circuit shows an isolated 12-V_{IN} to 2.5 V_{OUT} push-pull converter with scalable output power (20 W to 200 W). Note that the pinout shown is for SOIC-8 and PDIP-8 packages.

typical application



APPLICATION INFORMATION

operational waveforms

Figure 3 illustrates how the voltage ramp is effectively added to the voltage across the current sense element V_{CS}, to implement slope compensation.

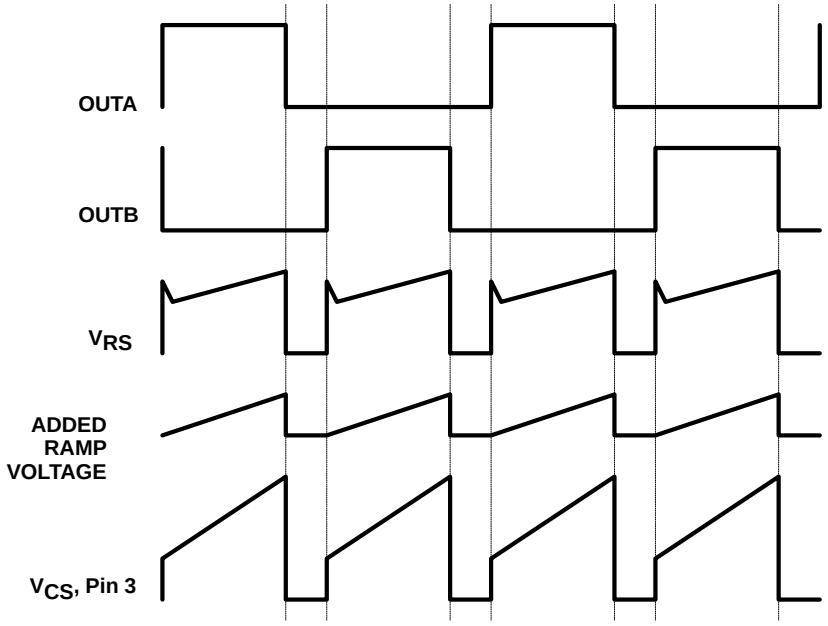


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Figure 3. Typical Slope Compensation Waveforms at 80% Duty Cycle

In Figure 3, OUTA and OUTB are shown at a duty cycle of 80%, with the associated voltage VRS across the current sense resistor of the primary push-pull power MOSFETs. The current flowing out of CS generates the ramp voltage across the filter resistor R_F that is positioned between the power current sense resistor and the CS pin. This voltage is effectively added to VRS to provide slope compensation at VCS, pin 3. A capacitor C_F is also recommended to filter the waveform at CS.

layout considerations

To prevent noise problems, bypass VDD to GND with a ceramic capacitor as close to the chip as possible along with an electrolytic capacitor. A 1-µF decoupling capacitor is recommended.

Use a local ground plane near the small signal pins (CTRL, ISET, CS and RT) of the IC for shielding. Connect the local ground plane to the GND pin with a single trace. Do not extend the local ground plane under the power pins (VDD, OUTA, OUTB and GND). Instead, use signal return traces to the GND pin for ground returns on the side of the integrated circuit with the power pins.

For best performance, keep the timing resistor lead from RT pin (pin 4) to GND (pin 5) as short as possible.

special layout considerations for the TSSOP package

Due to the different pinout and smaller lead pitch of the TSSOP package, special attention must be paid to minimize noise problems. The pinout is different because the device had to be rotated 90° to fit into the smaller TSSOP package.

For example, the two output pins are now on opposite sides of the package. The traces should not run under the package together as they will couple switching noise into analog pins.

Another common problem is when RT and OUTB (pins 6 and 8) are routed together for some distance even though they are not immediate side by side pins. Because of this, when OUTB rises, a voltage spike of upto 400 mV can couple into the RT. This spike causes the internal charge current into CT to be turned off momentarily resulting in lower duty cycle. It is also important that note that the RT pin voltage cannot be stabilized with a capacitor. The RT pin is just a dc voltage to program the internal CT. Instead, keep the OUTB and RT runs short and far from each other and follow the printed wiring board layout suggestions above to fix the problem.

reference design

A reference design is discussed in *50-W Push-Pull Converter Reference Design Using the UCC38083*, TI Literature Number SLUU135. This design controls a push-pull synchronous rectified topology with input range of 18 V to 35 V (24 nominal) and 3.3-V output at 15 A. The schematic is shown in Figure 5 and the board layout for the reference design is shown in Figure 4. Refer to the document for further details.

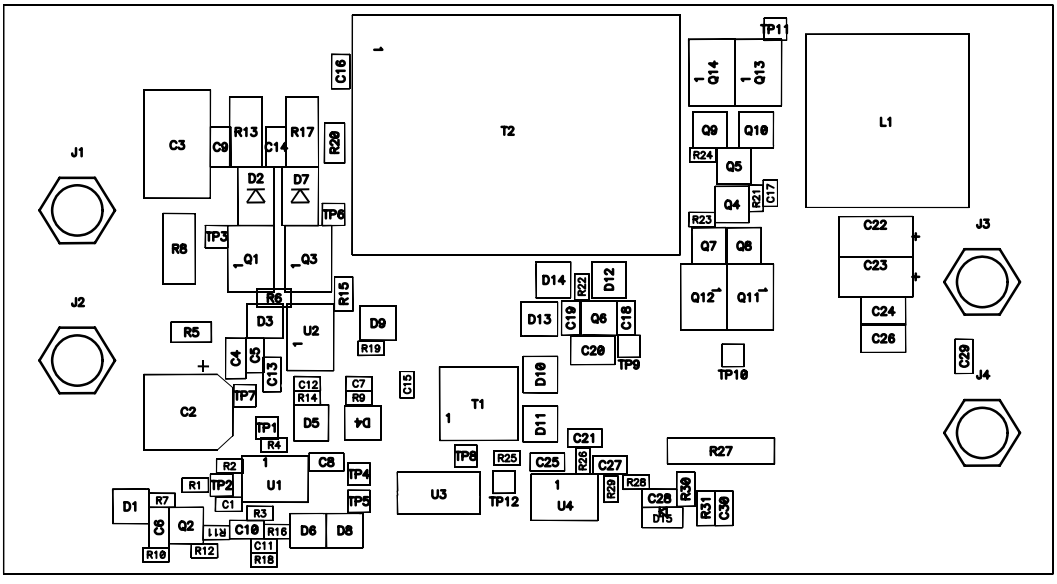
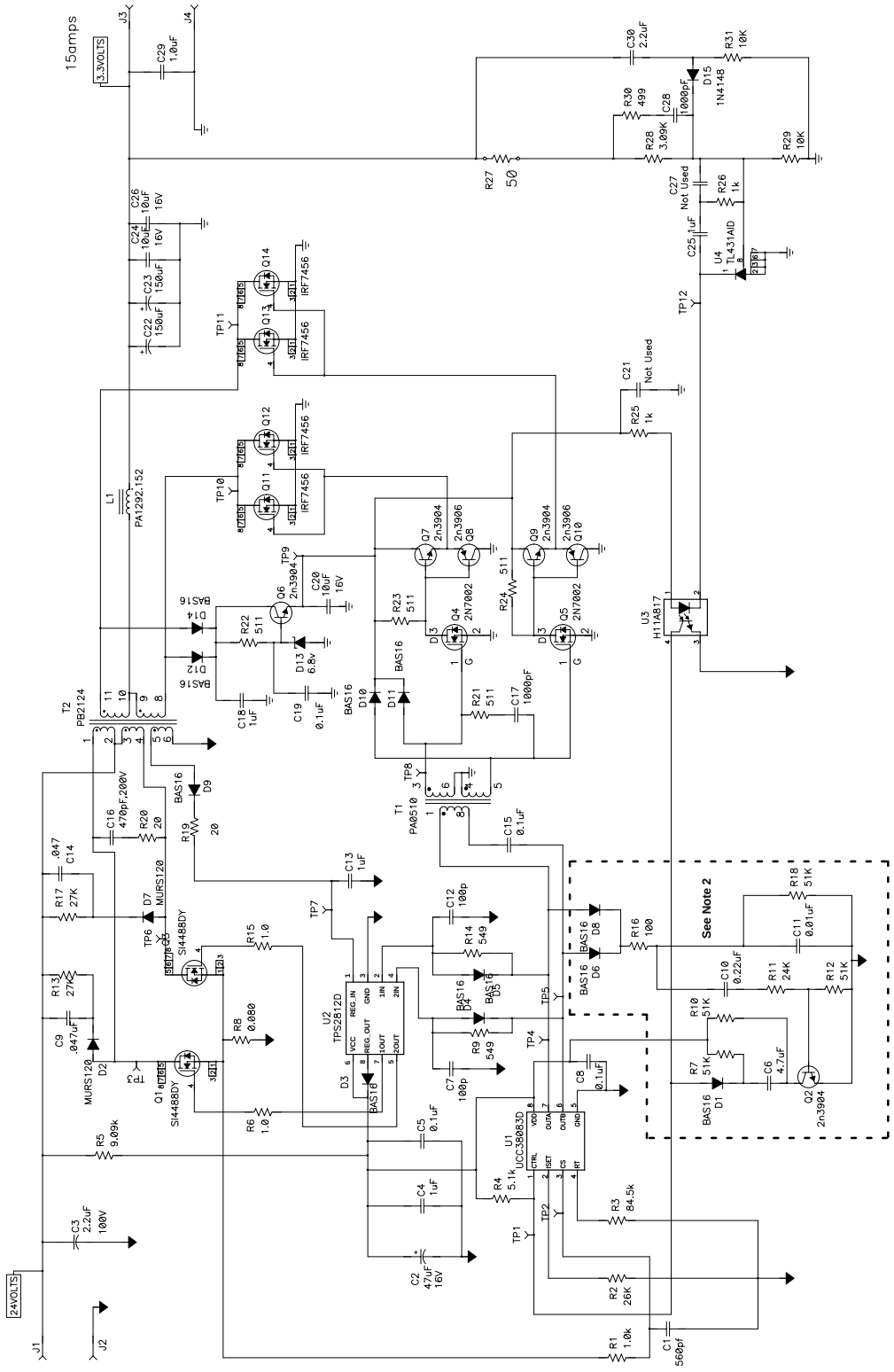


Figure 4. Reference Design Layout

APPLICATION INFORMATION



Note 1. C28, R25, and D12 accelerate the control to the secondary side feedback at start-up and prevent output voltage overshoot. See Figure 3. for start-up trajectory.
Note 2. Components used for the UCC38085 only.

Figure 5. Reference Design Schematic

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY
vs
RT

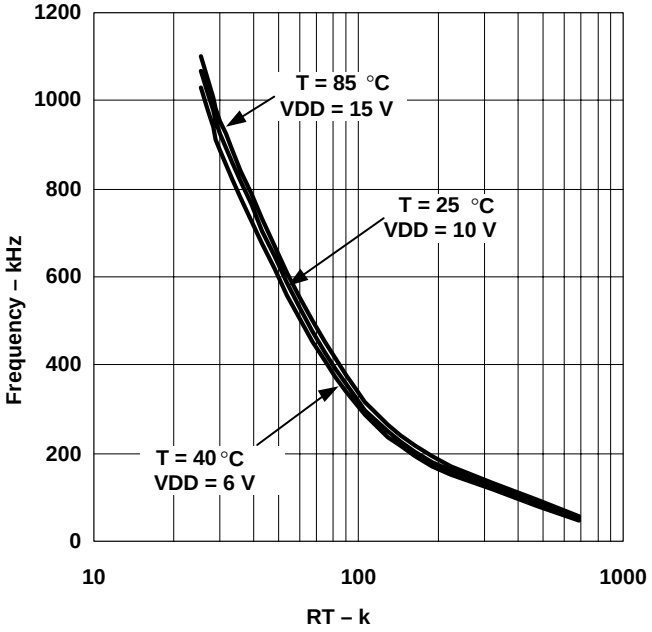


Figure 6

OSCILLATOR FREQUENCY
vs
TEMPERATURE

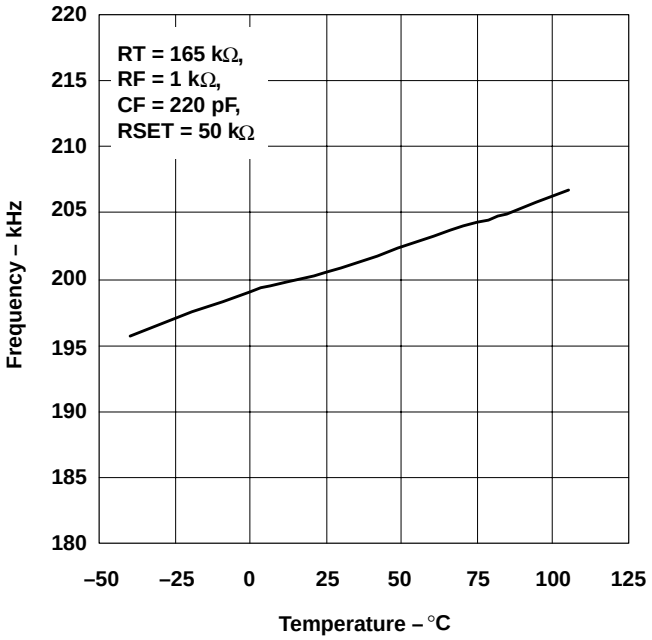


Figure 7

IDD
vs
OSCILLATOR FREQUENCY, (NO LOAD)

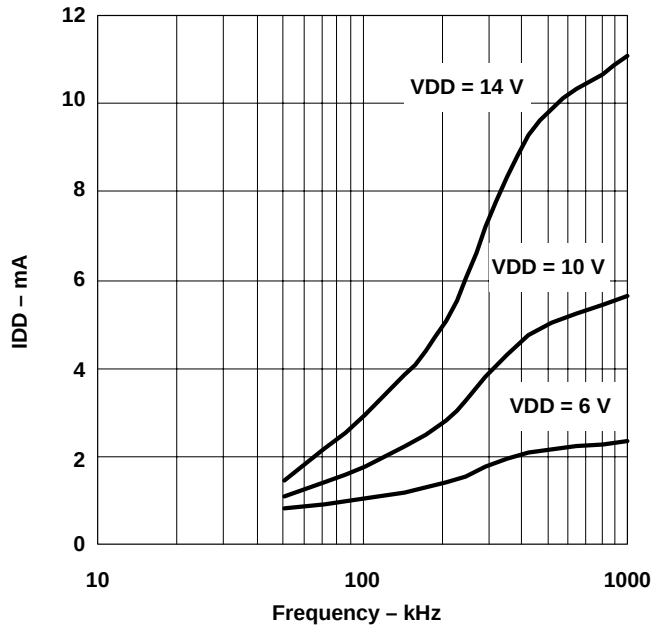


Figure 8

IDD
vs
OSCILLATOR FREQUENCY, 1 nF LOAD

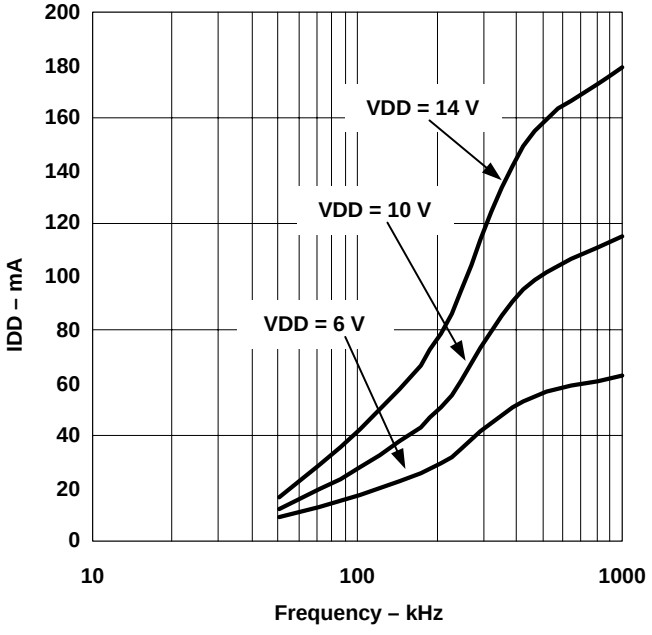


Figure 9

TYPICAL CHARACTERISTICS

DEAD TIME vs RT OVER VDD

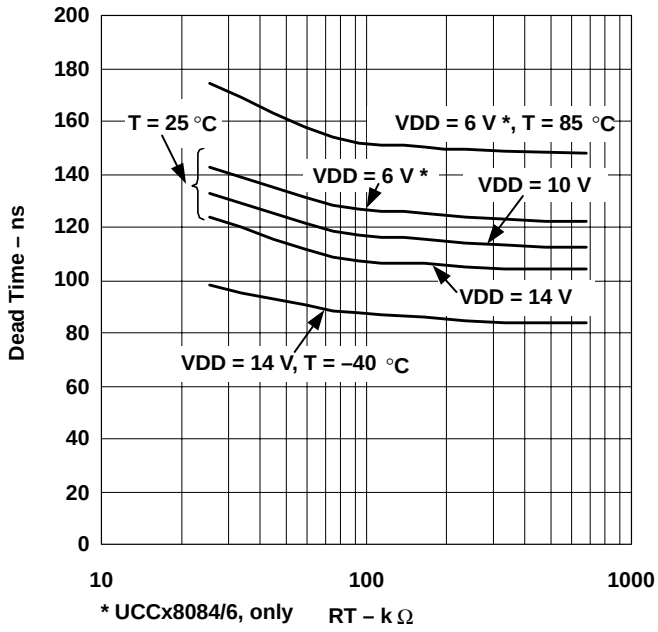


Figure 10

DEAD TIME vs TEMPERATURE

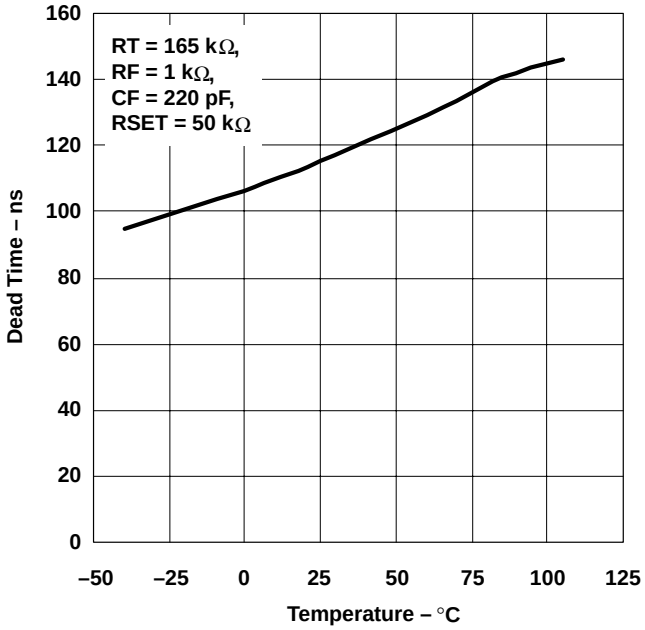


Figure 11

CTRL TO CS OFFSET vs TEMPERATURE

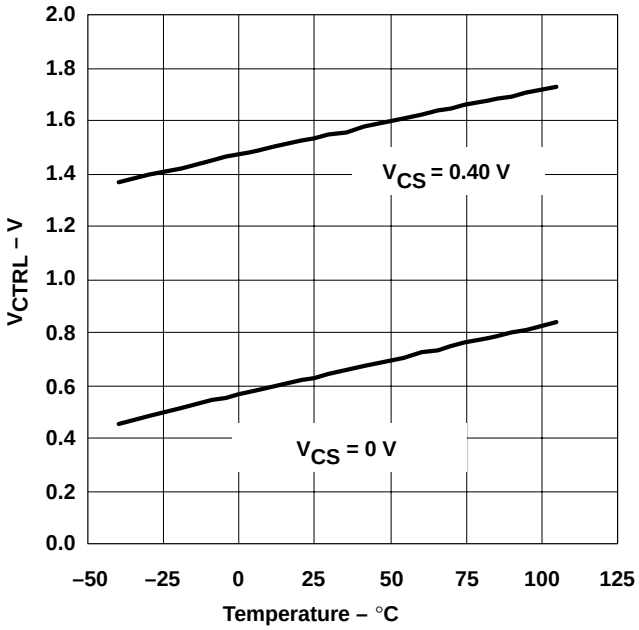


Figure 12

RAMP HEIGHT vs VDD

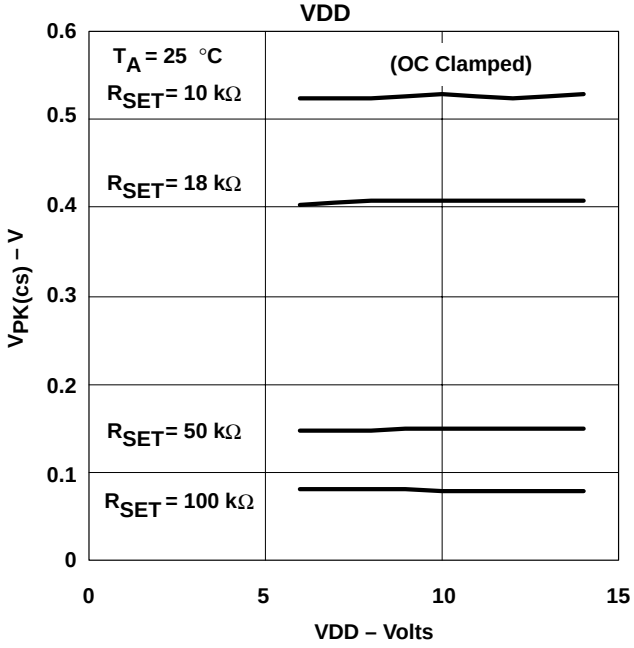


Figure 13

TYPICAL CHARACTERISTICS

RAMP HEIGHT
vs
RT

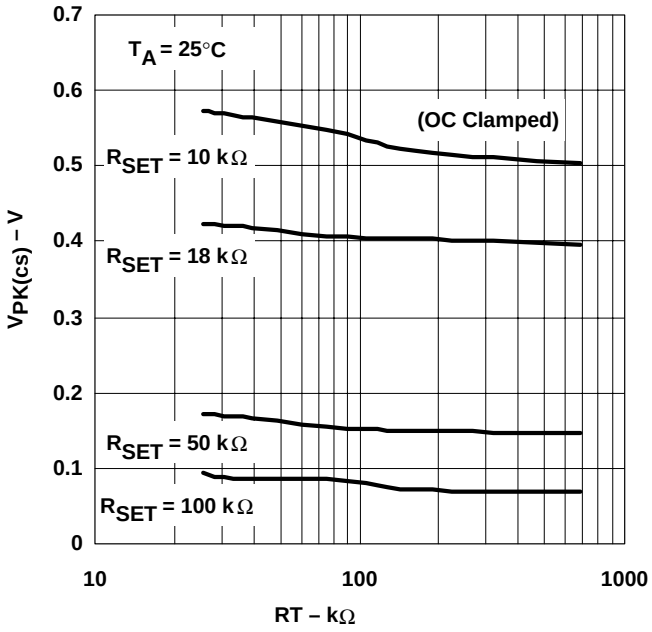


Figure 14

RAMP HEIGHT
vs
TEMPERATURE

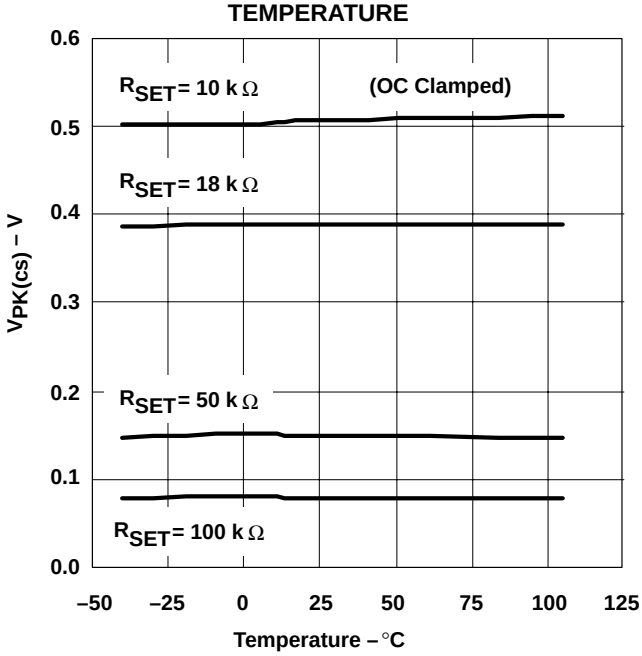


Figure 15

SOFT START
vs
TEMPERATURE, UCCx8083 AND UCCx8084

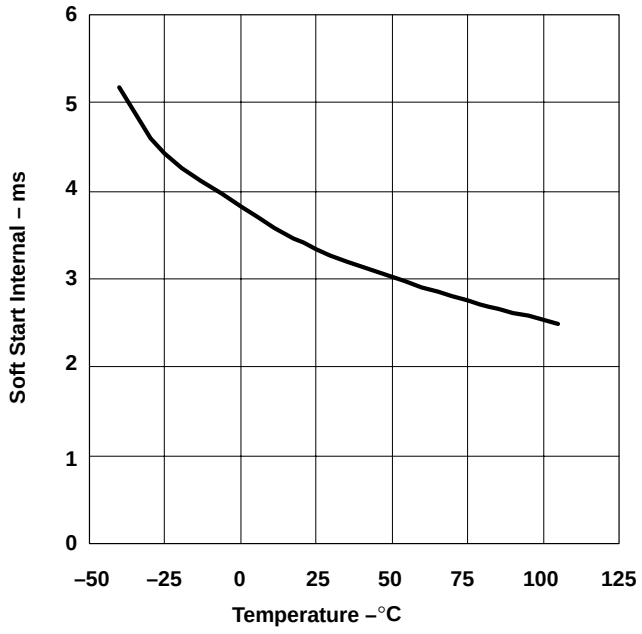


Figure 16

SOFT START
vs
TEMPERATURE, UCCx8085 AND UCCx8086

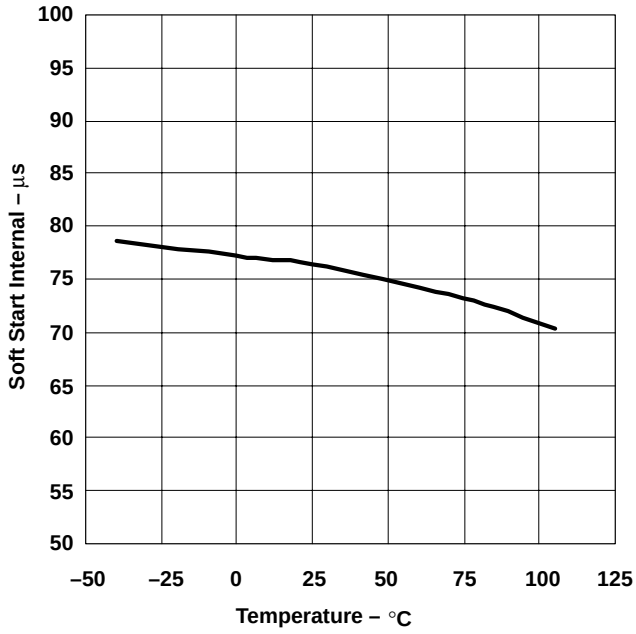


Figure 17

TYPICAL CHARACTERISTICS

CS TO OUTX DELAY

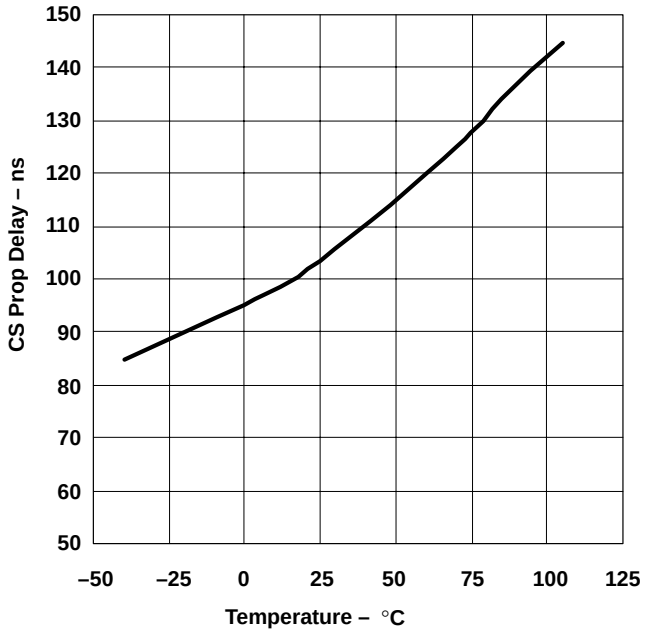


Figure 18

RELATED PRODUCTS

UCC3808, 8-Pin Low Power Current Mode Push-Pull PWM, TI Literature No. SLUS168

UCC3808A, 8-Pin Low-Power Current-Mode Push-Pull PWM, TI Literature No. SLUS456

UCC3806, Low Power, Dual Output, Current Mode PWM Controller, TI Literature No. SLUS272

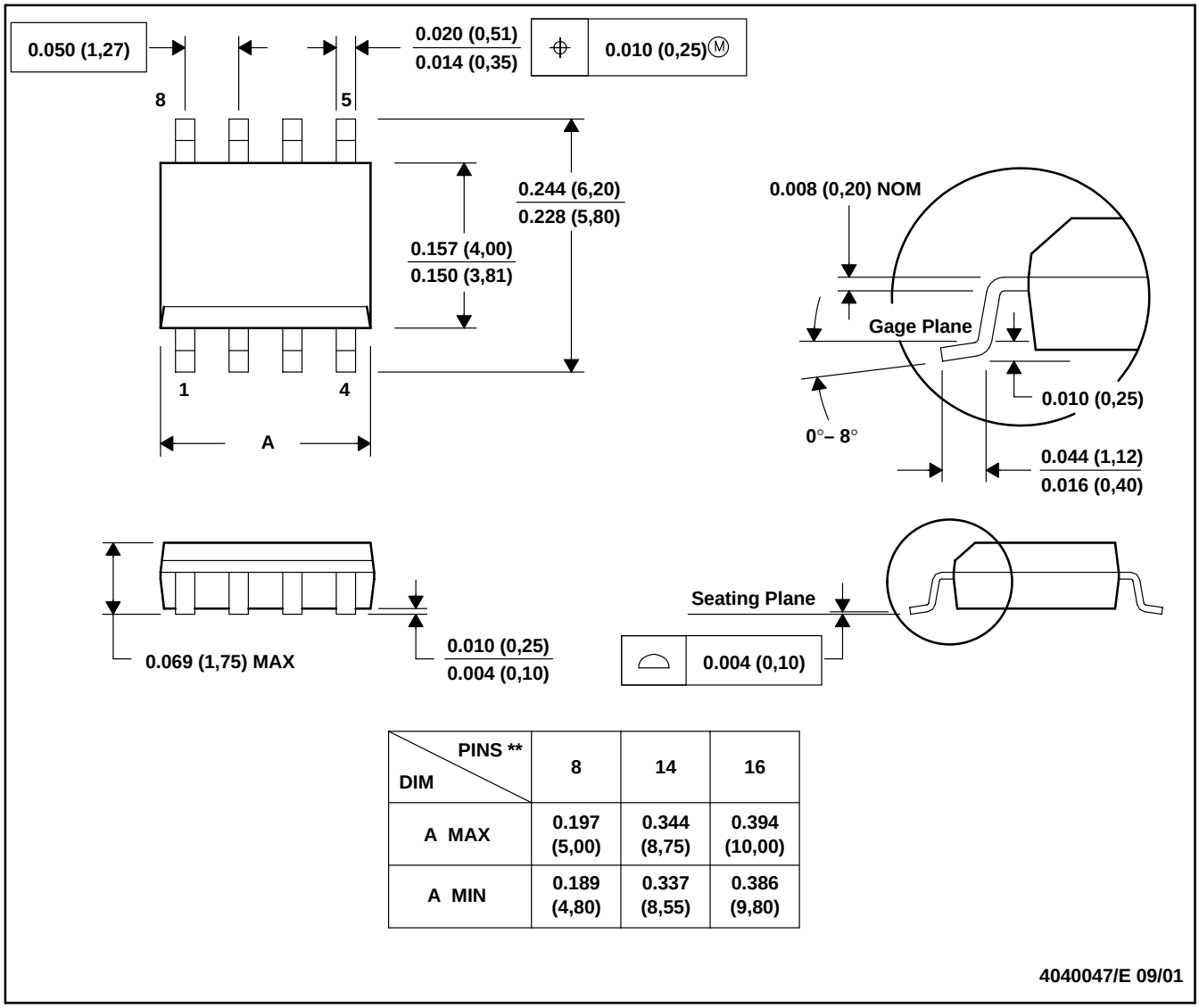
Table 1. 8-pin Push-Pull PWM Controller Family Feature Comparison

Part Number	UVLO On	UVLO Off	CS Discharge FET	Error Amplifier	Programmable Slope Compensation	Internal Softstart
UCC38083	12.5 V	8.3 V	Yes	No	Yes	Yes
UCC38084	4.3 V	4.1 V	Yes	No	Yes	Yes
UCC38085	12.5 V	8.3 V	Yes	No	Yes	No
UCC38086	4.3 V	4.1 V	Yes	No	Yes	No
UCC3808A–1	12.5 V	8.3 V	Yes	Yes	No	Yes
UCC3808A–2	4.3 V	4.1 V	Yes	Yes	No	Yes
UCC3808–1	12.5 V	8.3 V	No	Yes	No	Yes
UCC3808–2	4.3 V	4.1 V	No	Yes	No	Yes

MECHANICAL DATA

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



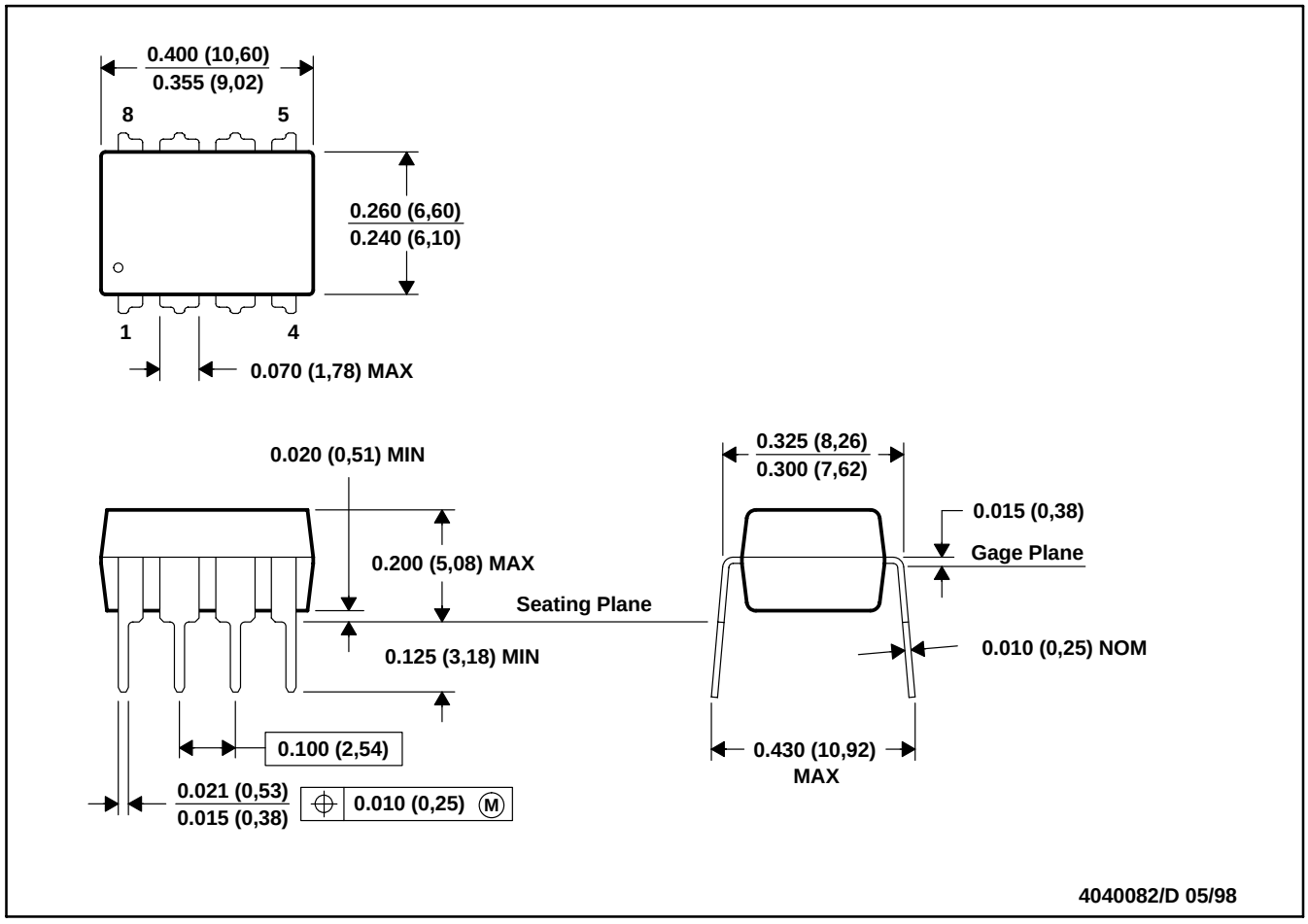
DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

MECHANICAL DATA

P (PDIP) **PLASTIC DUAL-IN-LINE**



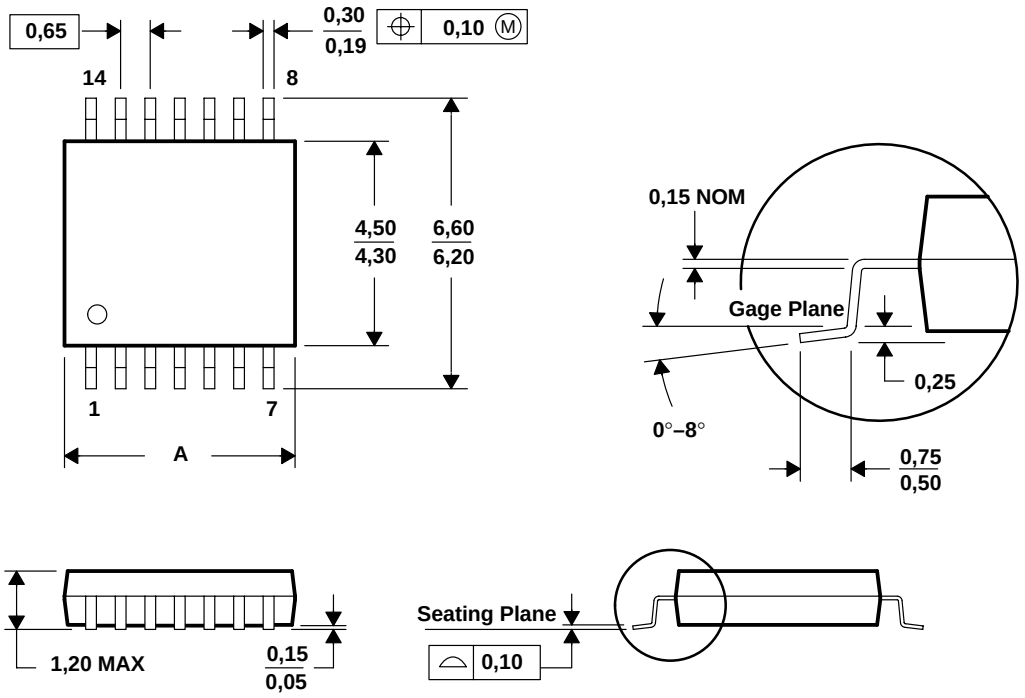
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

For the latest package information, go to http://www.ti.com/sc/docs/package/pkg_info.htm

MECHANICAL DATA

PW (R-PDSO-G) PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES:A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

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