

# Programmable, Off-Line, PWM Controller

## FEATURES

- All Control, Driving, Monitoring, and Protection Functions Included
- Low-current, Off-line Start Circuit
- Voltage Feed Forward or Current Mode Control
- Guaranteed Duty Cycle Clamp
- PWM Latch for Single Pulse per Period
- Pulse-by-Pulse Current Limiting Plus Shutdown for Over-Current Fault
- No Start-up or Shutdown Transients
- Slow Turn-on Both Initially and After Fault Shutdown
- Shutdown Upon Over- or Under-Voltage Sensing
- Latch Off or Continuous Retry After Fault
- PWM Output Switch Usable to 1A Peak Current
- 1% Reference Accuracy
- 500kHz Operation
- 18 Pin DIL Package

## DESCRIPTION

The UC1841 family of PWM controllers has been designed to increase the level of versatility while retaining all of the performance features of the earlier UC1840 devices. While still optimized for highly-efficient bootstrapped primary-side operation in forward or flyback power converters, the UC1841 is equally adept in implementing both low and high voltage input DC to DC converters. Important performance features include a low-current starting circuit, linear feed-forward for constant volt-second operation, and compatibility with either voltage or current mode topologies.

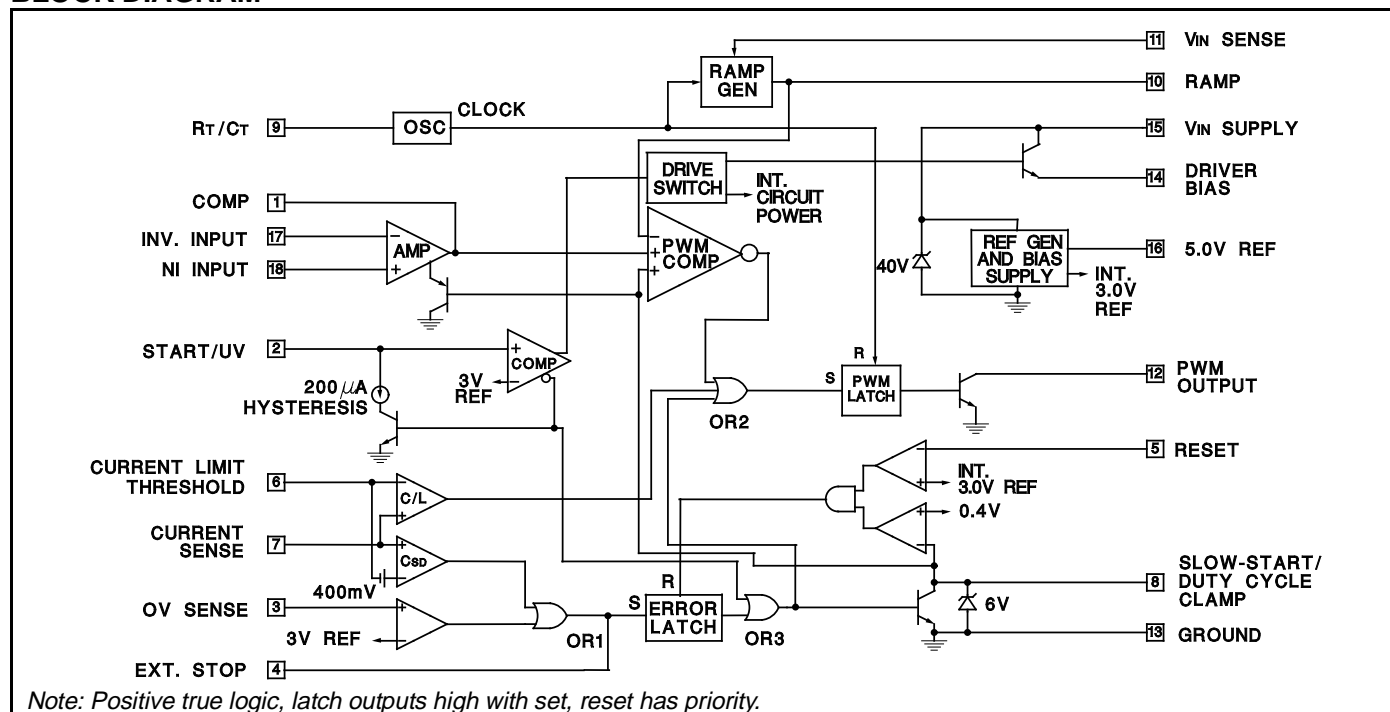
In addition to start-up and normal regulating PWM functions, these devices include built in protection from over-voltage, under-voltage, and over-current fault conditions with the option for either latch-off or automatic restart.

While pin compatible with the UC1840 in all respects except that the polarity of the External Stop has been reversed, the UC1841 offers the following improvements:

1. Fault latch reset is accomplished with slow start discharge rather than recycling the input voltage to the chip.
2. The External Stop input can be used for a fault delay to resist shutdown from short duration transients.
3. The duty-cycle clamping function has been characterized and specified.

The UC1841 is characterized for -55°C to +125°C operation while the UC2841 and UC3841 are designed for -25°C to +85°C and 0°C to +70°C, respectively.

## BLOCK DIAGRAM



UC1841

UC2841

UC3841

**ABSOLUTE MAXIMUM RATINGS**Supply Voltage, +V<sub>IN</sub> (Pin 15) (Note 2)

Voltage Driven . . . . . +32V

Current Driven, 100mA maximum . . . . . Self-limiting

PWM Output Voltage (Pin 12) . . . . . 40V

PWM Output Current, Steady-State (Pin 12) . . . . . 400mA

PWM Output Peak Energy Discharge . . . . . 20μJoules

Driver Bias Current (Pin 14) . . . . . -200mA

Reference Output Current (Pin 16) . . . . . -50mA

Slow-Start Sink Current (Pin 8) . . . . . 20mA

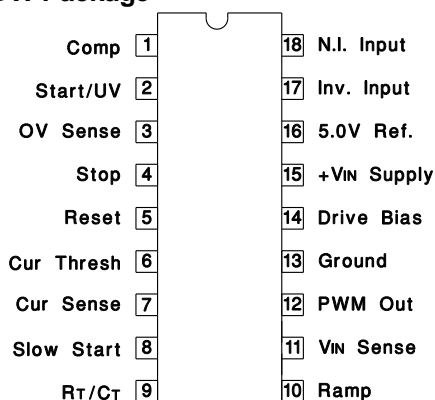
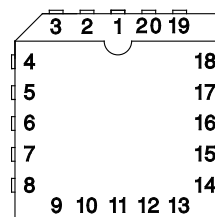
V<sub>IN</sub> Sense Current (Pin 11) . . . . . 10mA

Current Limit Inputs (Pins 6 &amp; 7) . . . . . -0.5 to +5.5V

Stop Input (Pin 4) . . . . . -0.3 to +5.5V

Comparator Inputs

(Pins 1, 7, 9-11, 16) . . . . . Internally clamped at 12V

Power Dissipation at T<sub>A</sub> = 25°C (Note 3) . . . . . 1000mWPower Dissipation at T<sub>C</sub> = 25°C (Note 3) . . . . . 2000mW**CONNECTION DIAGRAMS****DIL-18, SOIC-18 (TOP VIEW)****J or N, DW Package****PLCC-20, LCC-20  
(TOP VIEW)****Q or L Package****PACKAGE PIN FUNCTIONS**

FUNCTION	PIN
Comp	1
Start/UV	2
OV Sense	3
Stop	4
Reset	5
CUR Thresh	7
CUR Sense	8
Slow Start	9
RT/CT	10
Ramp	11
VIN Sense	12
PWM Out	13
Ground	14
Drive Bias	15
+VIN Supply	17
5.0V REF	18
Inv. Input	19
N.I. Input	20

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for T<sub>A</sub> = -55°C to +125°C for the UC1841, -25°C to +85°C for the UC2841, and 0°C to +70°C for the UC3841; V<sub>IN</sub> = 20V, R<sub>T</sub> = 20kΩ, C<sub>T</sub> = .001mfd, R<sub>R</sub> = 10kΩ, C<sub>R</sub> = .001mfd, Current Limit Threshold = 200mV, T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	UC1841 / UC2841			UC3841			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Power Inputs								
Start-Up Current	V <sub>IN</sub> = 30V, Pin 2 = 2.5V		4.5	6		4.5	6	mA
Operating Current	V <sub>IN</sub> = 30V, Pin 2 = 3.5V		10	14		10	14	mA
Supply OV Clamp	I <sub>IN</sub> = 20mA	33	40	45	33	40	45	V
Reference Section								
Reference Voltage	T <sub>J</sub> = 25°C	4.95	5.0	5.05	4.9	5.0	5.1	V
Line Regulation	V <sub>IN</sub> = 8 to 30V		10	15		10	20	mV
Load Regulation	I <sub>L</sub> = 0 to 10mA		10	20		10	30	mV
Temperature Stability	Over Operating Temperature Range	4.9		5.1	4.85		5.15	V
Short Circuit Current	V <sub>REF</sub> = 0, T <sub>J</sub> = 25°C		-80	-100		-80	-100	mA
Oscillator								
Nominal Frequency	T <sub>J</sub> = 25°C	47	50	53	45	50	55	kHz
Voltage Stability	V <sub>IN</sub> = 8 to 30V		0.5	1		0.5	1	%
Temperature Stability	Over Operating Temperature Range	45		55	43		57	kHz
Maximum Frequency	R <sub>T</sub> = 2kΩ, C <sub>T</sub> = 330pF	500			500			kHz

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  for the UC1841,  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UC2841, and  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  for the UC3841;  $V_{IN} = 20\text{V}$ ,  $R_T = 20\text{k}\Omega$ ,  $C_T = .001\text{mfd}$ ,  $R_R = 10\text{k}\Omega$ ,  $C_R = .001\text{mfd}$ , Current Limit Threshold =  $200\text{mV}$ ,  $T_A = T_J$ .

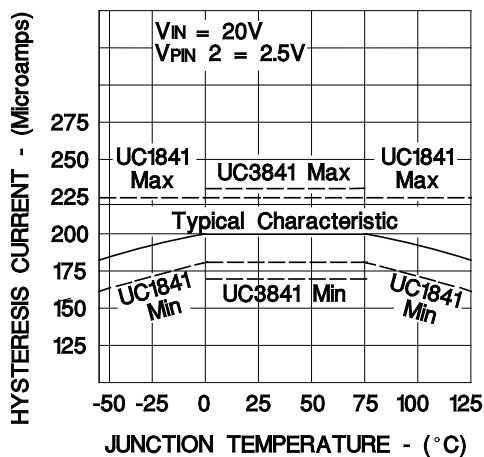
PARAMETER	TEST CONDITIONS	UC1841 / UC2841			UC3841			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Ramp Generator								
Ramp Current, Minimum	I <sub>SENSE</sub> = -10μA		-11	-14		-11	-14	μA
Ramp Current, Maximum	I <sub>SENSE</sub> = 1.0mA	-0.9	-.95		-0.9	-.95		mA
Ramp Valley		0.3	0.4	0.6	0.3	0.4	0.6	V
Ramp Peak	Clamping Level	3.9	4.2	4.5	3.9	4.2	4.5	V
Error Amplifier								
Input Offset Voltage	V <sub>CM</sub> = 5.0V		0.5	5		2	10	mV
Input Bias Current			0.5	2		1	5	μA
Input Offset Current				0.5			0.5	μA
Open Loop Gain	ΔV <sub>O</sub> = 1 to 3V	60	66		60	66		dB
Output Swing (Max. Output ≤ Ramp Peak - 100mV)	Minimum Total Range	0.3		3.5	0.3		3.5	V
CMRR	V <sub>CM</sub> = 1.5 to 5.5V	70	80		70	80		dB
PSRR	V <sub>IN</sub> = 8 to 30V	70	80		70	80		dB
Short Circuit Current	V <sub>COMP</sub> = 0V		-4	-10		-4	-10	mA
Gain Bandwidth*	T <sub>J</sub> = 25°C, A <sub>VOL</sub> = 0dB	1	2		1	2		MHz
Slew Rate*	T <sub>J</sub> = 25°C, A <sub>VCL</sub> = 0dB		0.8			0.8		V/μs
PWM Section								
Continuous Duty Cycle Range* (other than zero)	Minimum Total Continuous Range, Ramp Peak < 4.2V	4		95	4		95	%
50% Duty Cycle Clamp	R <sub>SENSE</sub> to V <sub>REF</sub> = 10k	42	47	52	42	47	52	%
Output Saturation	I <sub>OUT</sub> = 20mA		0.2	0.4		0.2	0.4	V
	I <sub>OUT</sub> = 200mA		1.7	2.2		1.7	2.2	V
Output Leakage	V <sub>OUT</sub> = 40V		0.1	10		0.1	10	μA
Comparator Delay*	Pin 8 to Pin 12, T <sub>J</sub> = 25°C, R <sub>L</sub> = 1kΩ		300	500		300	500	ns
Sequencing Functions								
Comparator Thresholds	Pins 2, 3, 5	2.8	3.0	3.2	2.8	3.0	3.2	V
Input Bias Current	Pins 3, 5 = 0V		-1.0	-4.0		-1.0	-4.0	μA
Input Leakage	Pins 3, 5 = 10V		0.1	2.0		0.1	2.0	μA
Start/UV Hysteresis Current	Pin 2 = 2.5V	170	200	220	170	200	230	μA
Ext. Stop Threshold	Pin 4	0.8	1.6	2.4	0.8	1.6	2.4	V
Error Latch Activate Current	Pin 4 = 0V, Pin 3 > 3V		-120	-200		-120	-200	μA
Driver Bias Saturation Voltage, V <sub>IN</sub> - V <sub>OH</sub>	I <sub>B</sub> = -50mA		2	3		2	3	V
Driver Bias Leakage	V <sub>B</sub> = 0V		-0.1	-10		-0.1	-10	μA
Slow-Start Saturation	I <sub>S</sub> = 10mA		0.2	0.5		0.2	0.5	V
Slow-Start Leakage	V <sub>S</sub> = 4.5V		0.1	2.0		0.1	2.0	μA
Current Control								
Current Limit Offset			0	5		0	10	mV
Current Shutdown Offset		370	400	430	360	400	440	mV
Input Bias Current	Pin 7 = 0V		-2	-5		-2	-5	μA
Common Mode Range*		-0.4		3.0	-0.4		3.0	V
Current Limit Delay*	T <sub>J</sub> = 25°C, Pin 7 to 12, R <sub>L</sub> = 1k		200	400		200	400	ns

\* These parameters are guaranteed by design but not 100% tested in production.

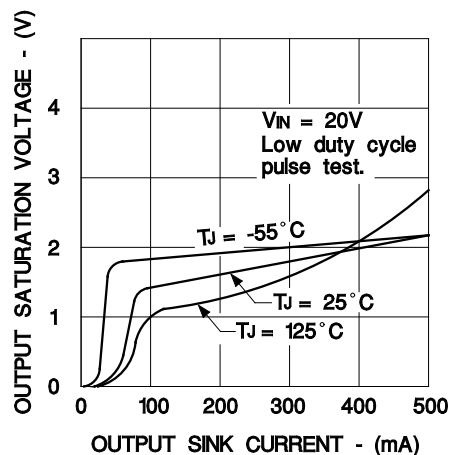
## FUNCTIONAL DESCRIPTION

PWM CONTROL	
1. Oscillator	Generates a fixed-frequency internal clock from an external $R_T$ and $C_T$ . Frequency = $\frac{K_C}{R_T C_T}$ where $K_C$ is a first order correction factor $\approx 0.3 \log(C_T \times 10^{12})$ .
2. Ramp Generator	Develops a linear ramp with a slope defined externally by $\frac{dv}{dt} = \frac{\text{sense voltage}}{R_R C_R}$ $C_R$ is normally selected $\leq C_T$ and its value will have some effect upon valley voltage. Limiting the minimum value for $I_{SENSE}$ will establish a maximum duty cycle clamp. $C_R$ terminal can be used as an input port for current mode control.
3. Error Amplifier	Conventional operational amplifier for closed-loop gain and phase compensation. Low output impedance; unity-gain stable. The output is held low by the slow start voltage at turn on in order to minimize overshoot.
4. Reference Generator	Precision 5.0V for internal and external usage to 50mA. Tracking 3.0V reference for internal usage only with nominal accuracy of $\pm 2\%$ . 40V clamp zener for chip OV protection, 100mA maximum current.
5. PWM Comparator	Generates output pulse which starts at termination of clock pulse and ends when the ramp input crosses the lowest of two positive inputs.
6. PWM Latch	Terminates the PWM output pulse when set by inputs from either the PWM comparator, the pulse-by-pulse current limit comparator, or the error latch. Resets with each internal clock pulse.
7. PWM Output Switch	Transistor capable of sinking current to ground which is off during the PWM on-time and turns on to terminate the power pulse. Current capacity is 400mA saturated with peak capacitance discharge in excess of one amp.
SEQUENCING FUNCTIONS	
1. Start/UV Sense	With an increasing voltage, it generates a turn-on signal and releases the slow-start clamp at a start threshold. With a decreasing voltage, it generates a turn-off command at a lower level separated by a 200 $\mu$ A hysteresis current.
2. Drive Switch	Disables most of the chip to hold internal current consumption low, and Driver Bias OFF, until input voltage reaches start threshold.
3. Driver Bias	Supplies drive current to external power switch to provide turn-on bias.
4. Slow Start	Clamps low to hold PWM OFF. Upon release, rises with rate controlled by $R_S C_S$ for slow increase of output pulse width. Can also be used as an alternate maximum duty cycle clamp with an external voltage divider.
PROTECTION FUNCTIONS	
1. Error Latch	When set by momentary input, this latch insures immediate PWM shutdown and hold off until reset. Inputs to Error Latch are: a. OV > 3.2V (typically 3V) b. Stop > 2.4V (typically 1.6V) c. Current Sense 400mV over threshold (typical). Error Latch resets when slow start voltage falls to 0.4V if Reset Pin 5 < 2.8V. With Pin 5 > 3.2V, Error Latch will remain set.
2. Current Limiting	Differential input comparator terminates individual output pulses each time sense voltage rises above threshold. When sense voltage rises to 400mV (typical) above threshold, a shutdown signal is sent to Error Latch.
3. External Stop	A voltage over 1.2V will set the Error Latch and hold the output off. A voltage less than 0.8V will defeat the error latch and prevent shutdown. A capacitor here will slow the action of the error latch for transient protection by providing a typical delay of 13ms/ $\mu$ F.

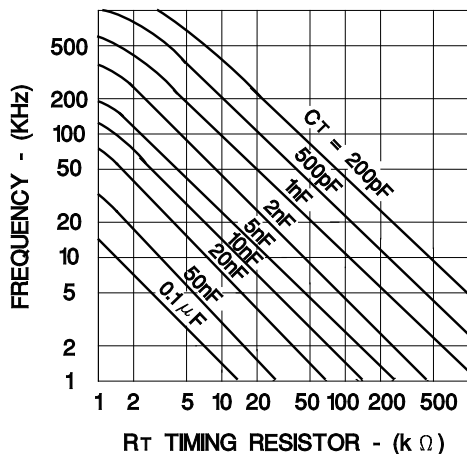
Start/UV Hysteresis



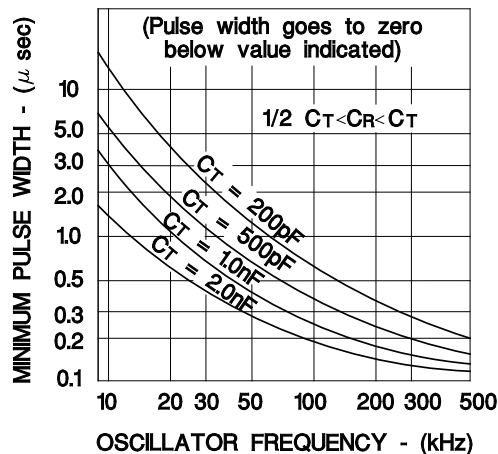
PWM Output-Saturation Voltage



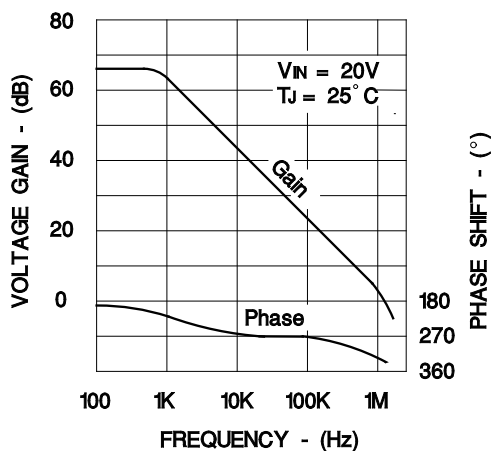
Oscillator Frequency



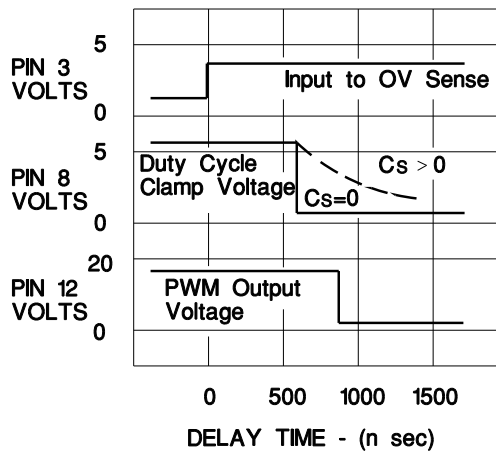
PWM Output Minimum Pulse Width



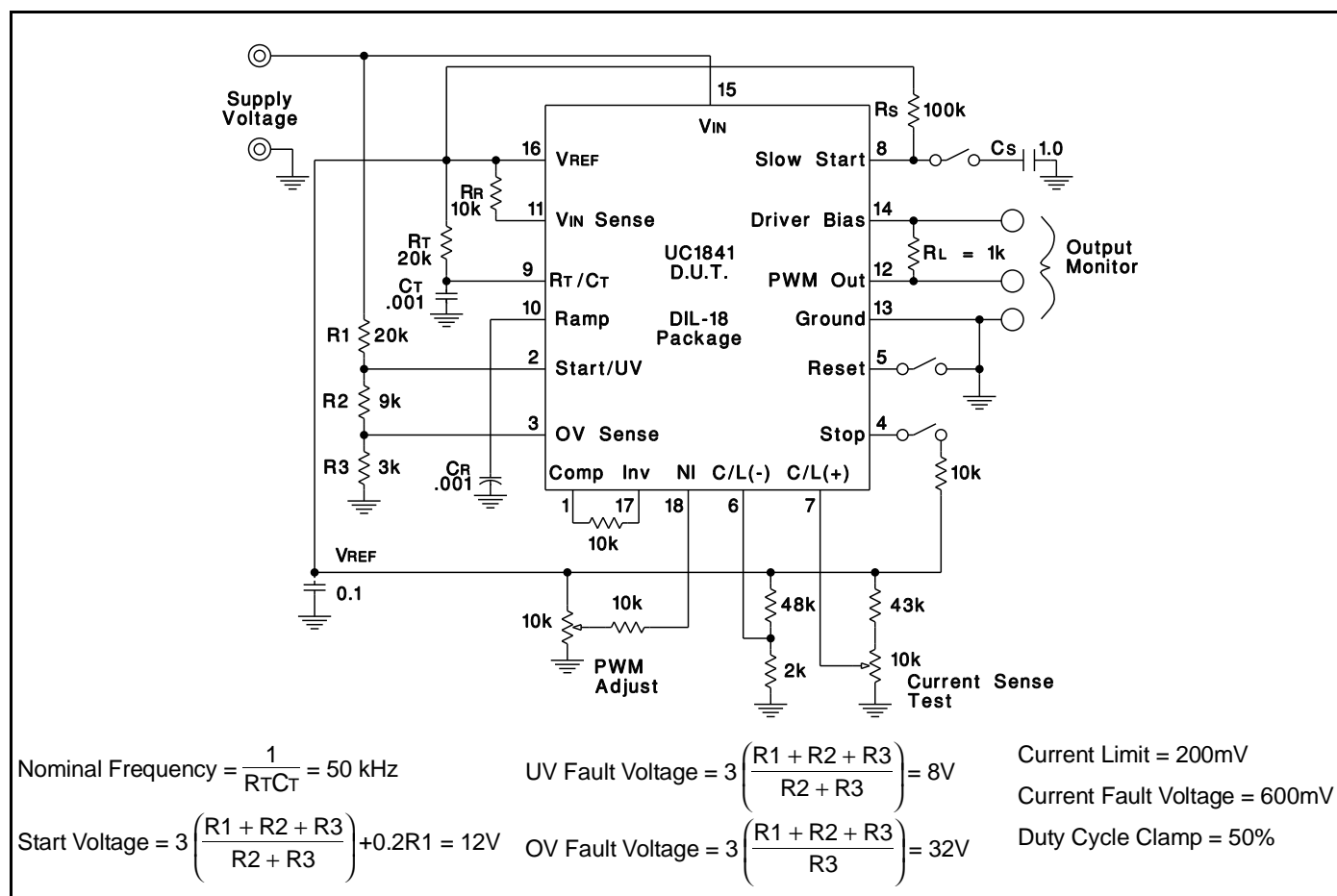
Error Amplifier Open Loop Gain and Phase



Shutdown Timing



## OPEN-LOOP TEST CIRCUIT



## FLYBACK APPLICATION (A)

In this application (see Figure A, next page), complete control is maintained on the primary side. Control power is provided by  $R_{IN}$  and  $C_{IN}$  during start-up, and by a primary-referenced low voltage winding, N2, for efficient operation after start. The error amplifier loop is closed to regulate the DC voltage from N2 with other outputs following through their magnetic coupling – a task made even easier with the UC1841's feed-forward line regulation.

An extension to this application for more precise regulation would be the use of the UC1901 Isolated Feedback Generator for direct closed-loop control to an output.

Not shown, are protective snubbers or additional interface circuitry which may be required by the choice of the high-voltage switch, Qs, or the application; however, one example of power transistor interfacing is provided on the following page.

## REGULATOR APPLICATION (B)

With the addition of a level shifting transistor, Q1, the UC1841 is an ideal control circuit for DC to DC converters such as the buck regulator shown in Figure B opposite. In addition to providing constant current drive pulses to the PIC661 power switch, this circuit has full fault protection and high speed dynamic line regulation due to its feed-forward capability. An additional feature is the ability to

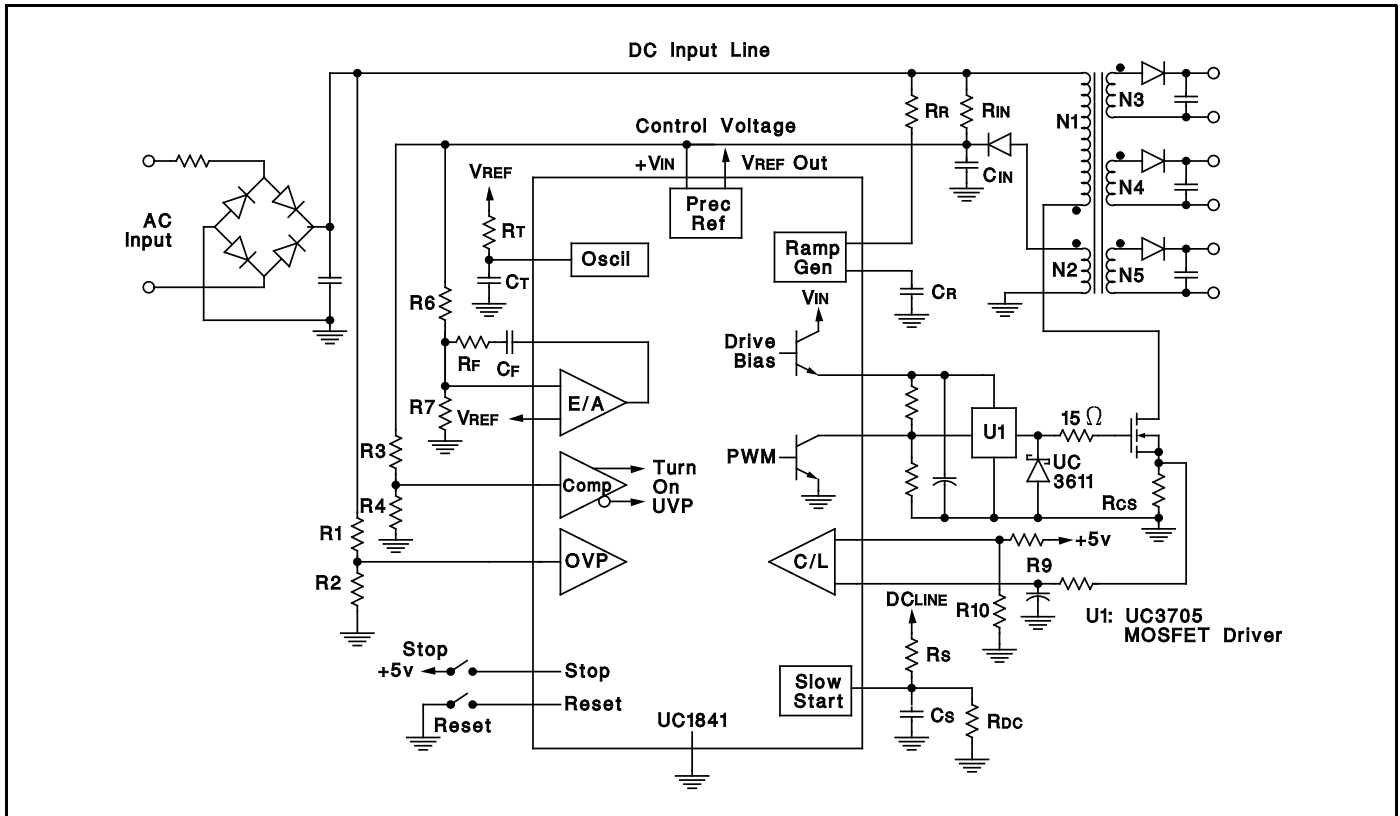


Figure A. UC1841 Programmable PWM Controller In A Simplified Flyback Regulator

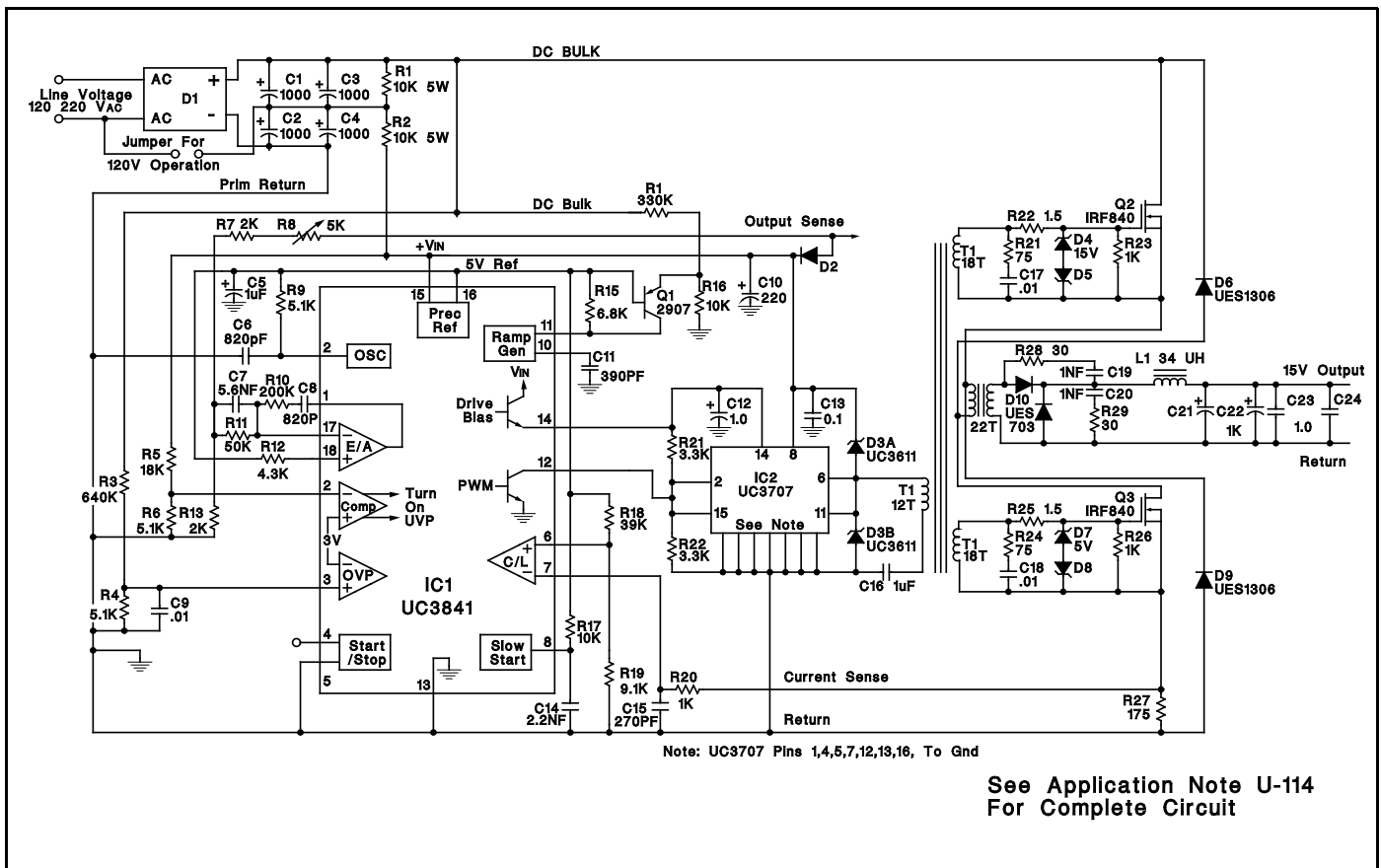
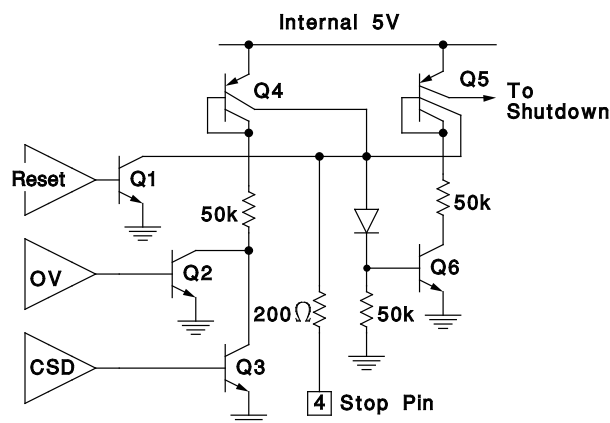


Figure B. Overall Schematic For A 300 Watt, Off-line Power Converter Using The UC3841 For Control

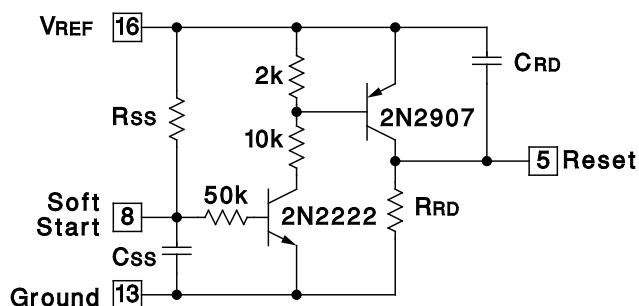


## ERROR LATCH INTERNAL CIRCUITRY



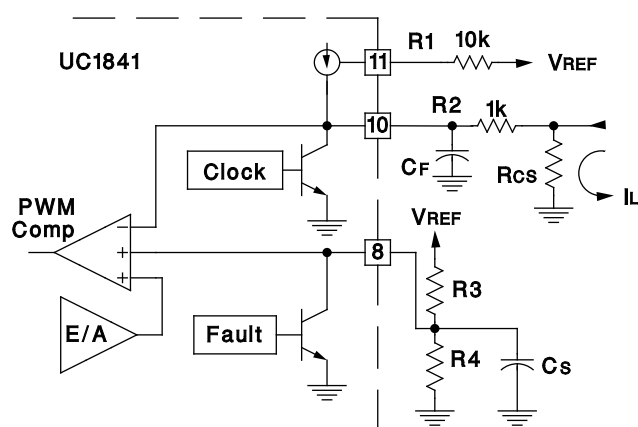
The Error Latch consists of Q5 and Q6 which, when both on, turns off the PWM Output and pulls the Slow-Start pin low. This latch is set by either the Over-Voltage or Current Shutdown comparators, or by a high signal on Pin 4. Reset is accomplished by either the Reset comparator or a low signal on Pin 4. An activation time delay can be provided with an external capacitor on Pin 4 in conjunction with the  $\approx 100\mu\text{A}$  collector current from Q4.

## PROGRAMMABLE SOFT START AND RESTART DELAY CIRCUIT



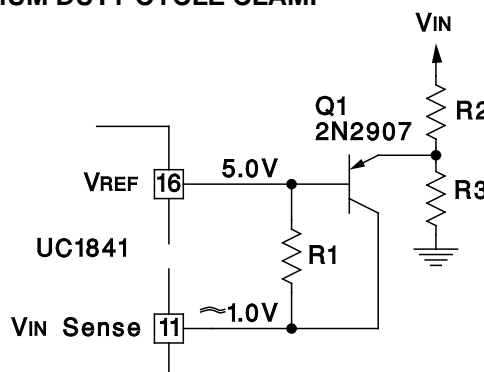
$$\text{Restart Delay} = (.51)(R_{RD})(C_{RD})$$

## CURRENT MODE CONTROL



Since Pin 10 is a direct input to the PWM comparator, this point can also serve as a current sense port for current mode control. In this application, current sensing is ground referenced through Rcs. Resistor R1 sets a 400mV offset across R2 (assuming  $R2 > R_{cs}$ ) so that both the Error Amplifier and Fault Shutdown can force the current completely to zero. R2 is also used along with Cf as a small filter to attenuate leading-edge spikes on the load current waveform. In this mode, current limiting can be accomplished by divider R3/R4 which forms a clamp overriding the output of the Error Amplifier.

## VOLTAGE FEED-FORWARD COMBINED WITH MAXIMUM DUTY-CYCLE CLAMP



In this circuit, R1 is used in conjunction with CR (not shown) to establish a minimum ramp charging current such that the ramp voltage reaches 4.2V at the required maximum output pulse width.

The purpose of Q1 is to provide an increasing ramp current above a threshold established by R2 and R3 such that the duty cycle is further reduced with increasing VIN.

The minimum ramp current is:

$$I_{R(MIN)} = \frac{V_{REF} - V_{IN\ SENSE}}{R_1} \approx \frac{4V}{R_1}$$

The threshold where VIN begins to add extra ramp current is:

$$V_{IN} \approx 5.6V \left( \frac{R_2 + R_3}{R_3} \right)$$

Above the threshold, the ramp current will be:

$$I_R (VARIABLE) \approx \frac{4}{R_1} + \frac{V_{IN} - 5.6}{R_2} - \frac{5.6}{R_3}$$



## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
UC2841DW	ACTIVE	SOIC	DW	18	40	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-20 to 85	UC2841DW	<a href="#">Samples</a>
UC2841N	ACTIVE	PDIP	N	18	20	RoHS & Green	NIPDAU	N / A for Pkg Type	-20 to 85	UC2841N	<a href="#">Samples</a>
UC3841N	ACTIVE	PDIP	N	18	20	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	UC3841N	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

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**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

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(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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## TUBE



\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
UC2841DW	DW	SOIC	18	40	507	12.83	5080	6.6
UC2841N	N	PDIP	18	20	506	13.97	11230	4.32
UC3841N	N	PDIP	18	20	506	13.97	11230	4.32

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