INTEGRATED CIRCUITS
UNITRODE

UC1526A
UC2526A
UC3526A

Regulating Pulse Width Modulator

FEATURES

- Reduced Supply Current
- Oscillator Frequency to 600kHz
- Precision Band-Gap Reference
- 7 to 35V Operation
- Dual 200mA Source/Sink Outputs
- Minimum Output Cross-Conduction
- Double-Pulse Suppression Logic
- Under-Voltage Lockout
- Programmable Soft-Start
- Thermal Shutdown
- TTL/CMOS Compatible Logic Ports
- 5 Volt Operation (V_{IN} = V_C = V_{REF} = 5.0V)

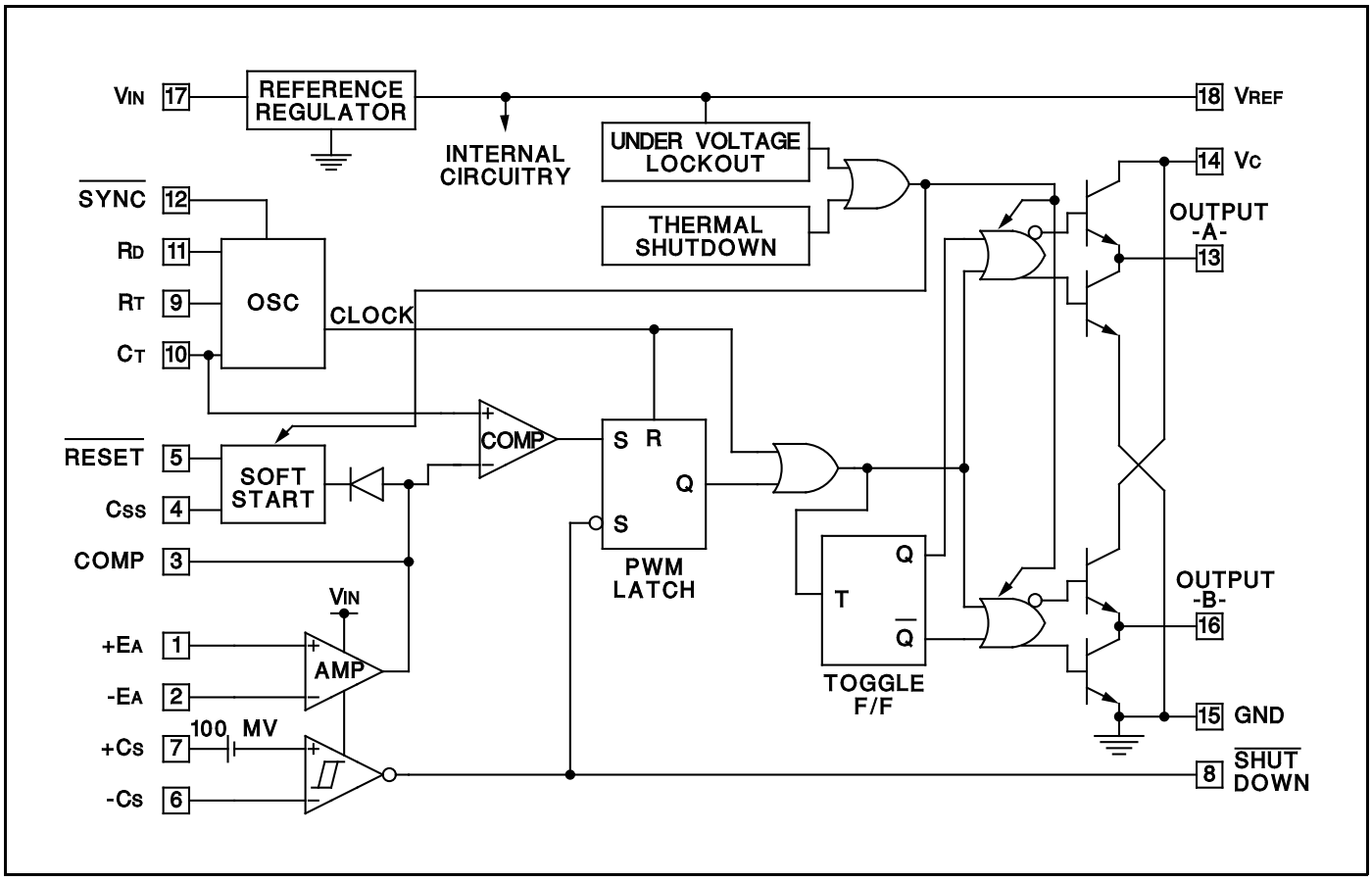
DESCRIPTION

The UC1526A Series are improved-performance pulse-width modulator circuits intended for direct replacement of equivalent non- “A” versions in all applications. Higher frequency operation has been enhanced by several significant improvements including: a more accurate oscillator with less minimum dead time, reduced circuit delays (particularly in current limiting), and an improved output stage with negligible cross-conduction current. Additional improvements include the incorporation of a precision, band-gap reference generator, reduced overall supply current, and the addition of thermal shutdown protection.

Along with these improvements, the UC1526A Series retains the protective features of under-voltage lockout, soft-start, digital current limiting, double pulse suppression logic, and adjustable deadtime. For ease of interfacing, all digital control ports are TTL compatible with active low logic.

Five volt (5V) operation is possible for “logic level” applications by connecting V_{IN}, V_C and V_{REF} to a precision 5V input supply. Consult factory for additional information.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS (Note 1, 2)

Input Voltage ($+V_{IN}$) . . . . . +40V
Collector Supply Voltage ($+V_C$) . . . . . +40V
Logic Inputs . . . . . -0.3V to +5.5V
Analog Inputs . . . . . -0.3V to $+V_{IN}$
Source/Sink Load Current (each output) 200mA
Reference Load Current 50mA
Logic Sink Current 15mA
Power Dissipation at T_A = +25°C (Note 2) 1000mW
Power Dissipation at T_C = +25°C (Note 2) 3000mW
Operating Junction Temperature . . . . . +150°C
Storage Temperature Range . . . . . -65°C to +150°C
Lead Temperature (soldering, 10 seconds) . . . . . +300°C

Note 1: Values beyond which damage may occur.
Note 2: Consult packaging Section of Databook for thermal limitations and considerations of package.

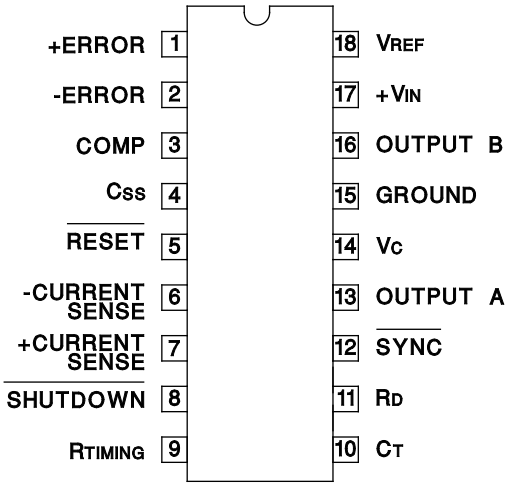
RECOMMENDED OPERATING CONDITIONS

(Note 3)
Input Voltage . . . . . +7V to +35V
Collector Supply Voltage . . . . . +4.5V to +35V
Sink/Source Load Current (each output) . . . . . 0 to 100mA
Reference Load Current . . . . . 0 to 20mA
Oscillator Frequency Range . . . . . 1Hz to 600kHz
Oscillator Timing Resistor . . . . . 2kΩ to 150kΩ
Oscillator Timing Capacitor . . . . . 400pF to 20µF
Available Deadtime Range at 40kHz . . . . . 1% to 50%
Operating Ambient Temperature Range
UC1526A . . . . . -55°C to +125°C
UC2526A . . . . . -25°C to +85°C
UC3526A . . . . . 0°C to +70°C

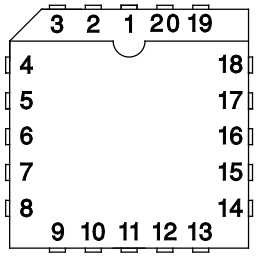
Note 3: Range over which the device is functional and parameter limits are guaranteed.

CONNECTION DIAGRAMS

DIL-18, SOIC-18 (TOP VIEW)
J or N Package, DW Package



PLCC-20, LCC-20
(TOP VIEW)
Q and L Packages



PACKAGE PIN FUNCTION	
FUNCTION	**PIN**
N/C	1
+ERROR	2
-ERROR	3
COMP.	4
C_{SS}	5
$\overline{\text{RESET}}$	6
- CURRENT SENSE	7
+ CURRENT SENSE	8
$\overline{\text{SHUTDOWN}}$	9
R_{TIMING}	10
C_T	11
R_D	12
$\overline{\text{SYNC}}$	13
OUTPUT A	14
V_C	15
N/C	16
GROUND	17
OUTPUT B	18
$+V_{IN}$	19
V_{REF}	20

ELECTRICAL CHARACTERISTICS: +V_{IN} = 15V, and over operating ambient temperature, unless otherwise specified T_A = T_J.

PARAMETER	TEST CONDITIONS	UC1526A / UC2526A			UC3526A			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Reference Section (Note 4)								
Output Voltage	T_J = +25°C	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	+V_{IN} = 7 to 35V		2	10		2	15	mV
Load Regulation	I_L = 0 to 20mA		5	20		5	20	mV
Temperature Stability	Over Operating T_J (Note 5)		15	50		15	50	mV
Total Output Voltage Range	Over Recommended Operating Conditions	4.90	5.00	5.10	4.85	5.00	5.15	V
Short Circuit Current	V_{REF} = 0V	25	50	100	25	50	100	mA
Under-Voltage Lockout								
$\overline{\text{RESET}}$ Output Voltage	V_{REF} = 3.8V		0.2	0.4		0.2	0.4	V
	V_{REF} = 4.7V	2.4	4.7		2.4	4.8		V
Oscillator Section (Note 6)								
Initial Accuracy	T_J = +25°C		±3	±8		±3	±8	%
Voltage Stability	+V_{IN} = 7 to 35V		0.5	1		0.5	1	%
Temperature Stability	Over Operating T_J (Note 5)		2	6		1	3	%
Minimum Frequency	R_T = 150kΩ, C_T = 20µF (Note 5)			1			1	Hz
Maximum Frequency	R_T = 2kΩ, C_T = 470pF	550			650			kHz
Sawtooth Peak Voltage	+V_{IN} = 35V		3.0	3.5		3.0	3.5	V
Sawtooth Valley Voltage	+V_{IN} =7V	0.5	1.0		0.5	1.0		V
$\overline{\text{SYNC}}$ Pulse Width	T_J = 25°C, R_L = 2.7kΩ to V_{REF}		1.1			1.1		µs
Error Amplifier Section (Note 7)								
Input Offset Voltage	R_S ≤ 2kΩ		2	5		2	10	mV
Input Bias Current			-350	-1000		-350	-2000	nA
Input Offset Current			35	100		35	200	nA
DC Open Loop Gain	R_L ≥ 10MΩ	64	72		60	72		dB
HIGH Output Voltage	$V_{PIN\ 1}$ - $V_{PIN\ 2}$ ≥ 150mV, I_{SOURCE} = 100µA	3.6	4.2		3.6	4.2		V
LOW Output Voltage	$V_{PIN\ 2}$ - $V_{PIN\ 1}$ ≥ 150mV, I_{SINK} = 100µA		0.2	0.4		0.2	0.4	V
Common Mode Rejection	R_S ≤ 2kΩ	70	94		70	94		dB
Supply Voltage Rejection	+V_{IN} = 12 to 18V	66	80		66	80		dB
PWM Comparator (Note 6)								
Minimum Duty Cycle	$V_{COMPENSATION}$ = +0.4V			0			0	%
Maximum Duty Cycle	$V_{COMPENSATION}$ = +3.6V	45	49		45	49		%
Digital Ports ($\overline{\text{SYNC}}$, $\overline{\text{SHUTDOWN}}$, and $\overline{\text{RESET}}$)								
HIGH Output Voltage	I_{SOURCE} = 40µA	2.4	4.0		2.4	4.0		V
LOW Output Voltage	I_{SINK} = 3.6mA		0.2	0.4		0.2	0.4	V
HIGH Input Current	V_{IH} = +2.4V		-125	-200		-125	-200	µA
LOW Input Current	V_{IL} = +0.4V		-225	-360		-225	-360	µA
Shutdown Delay	From Pin 8, T_J = 25°C		160			160		ns
Current Limit Comparator (Note 8)								
Sense Voltage	R_S ≤ 50Ω	90	100	110	80	100	120	mV
Input Bias Current			-3	-10		-3	-10	µA
Shutdown Delay	From pin 7, 100mV Overdrive, T_J = 25°C		260			260		ns

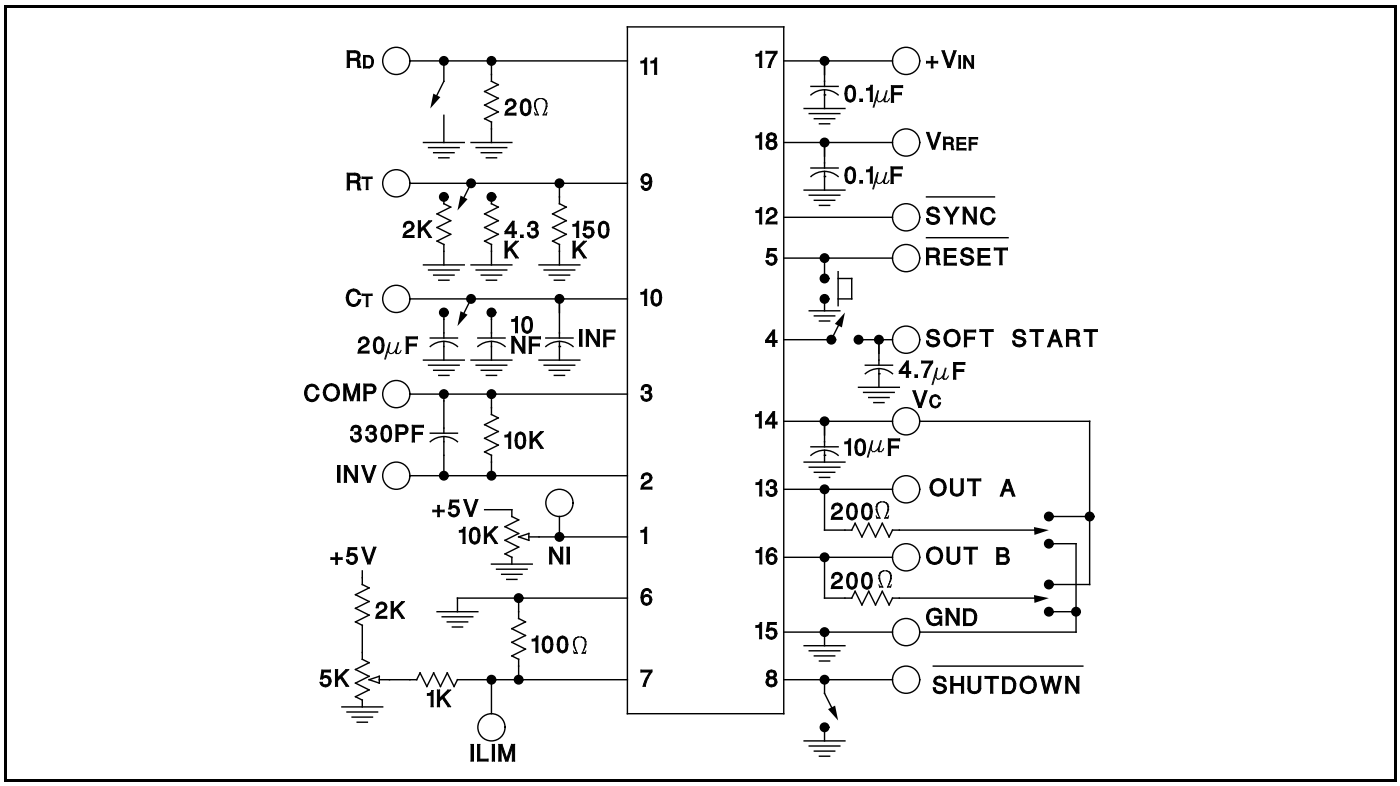
Note 4: I_L = 0mA.
Note 5: Guaranteed by design, not 100% tested in production.
Note 6: F_{OSC} = 40kHz, (R_T = 4.12kΩ ± 1%, C_T = 0.01µF± 1%, R_D = 0 Ω).
Note 7: V_{CM} = 0 to +5.2V
Note 8: V_{CM} = 0 to +12V.
Note 9: V_C = +15V.
Note 10:V_{IN} = +35V, R_T = 4.12kΩ.

ELECTRICAL CHARACTERISTICS: +V_{IN} = 15V, and over operating ambient temperature, unless otherwise specified $T_A = T_J$.

PARAMETER	TEST CONDITIONS	UC1526A UC2526A			UC3526A			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Soft-Start Section								
Error Clamp Voltage	$\overline{RESET}$ = +0.4V		0.1	0.4		0.1	0.4	V
C_S Charging Current	$\overline{RESET}$ = +2.4V	50	100	150	50	100	150	µA
Output Drivers (Each Output) (Note 9)								
HIGH Output Voltage	I_{SOURCE} = 20mA	12.5	13.5		12.5	13.5		V
	I_{SOURCE} = 100mA	12	13		12	13		V
LOW Output Voltage	I_{SINK} = 20mA		0.2	0.3		0.2	0.3	V
	I_{SINK} = 100mA		1.2	2.0		1.2	2.0	V
Collector Leakage	V_C = 40V		50	150		50	150	µA
Rise Time	C_L = 1000pF (Note 5)		0.3	0.6		0.3	0.6	µs
Fall Time	C_L = 1000pF (Note 5)		0.1	0.2		0.1	0.2	µs
Cross-Conduction Charge	Per cycle, T_J = 25°C		8			8		nC
Power Consumption (Note 10)								
Standby Current	$\overline{SHUTDOWN}$ = +0.4V		14	20		14	20	mA

Note 4: I_L = 0mA.
Note 5: Guaranteed by design, not 100% tested in production.
Note 6: F_{OSC} = 40kHz, (R_T = 4.12kΩ ± 1%, C_T = 0.01µF± 1%, R_D = 0 Ω).
Note 7: V_{CM} = 0 to +5.2V
Note 8: V_{CM} = 0 to +12V.
Note 9: V_C = +15V.
Note 10: V_{IN} = +35V, R_T = 4.12kΩ.

Open Loop Test Circuit UC1526A



APPLICATIONS INFORMATION

Voltage Reference

The reference regulator of the UC1526A is based on a precision band-gap reference, internally trimmed to ±1% accuracy. The circuitry is fully active at supply voltages above +7V, and provides up to 20mA of load current to external circuitry at +5.0V. In systems where additional current is required, an external PNP transistor can be used to boost the available current. A rugged low frequency audio-type transistor should be used, and lead lengths between the PWM and transistor should be as short as possible to minimize the risk of oscillations. Even so, some types of transistors may require collector-base capacitance for stability. Up to 1 amp of load current can be obtained with excellent regulation if the device selected maintains high current gain.

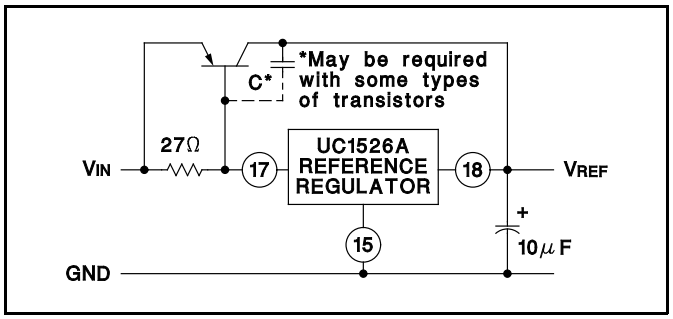


Figure 1. Extending Reference Output Current

Under-Voltage Lockout

The under-voltage lockout circuit protects the UC1526A and the power devices it controls from inadequate supply voltage, If +VIN is too low, the circuit disables the output drivers and holds the RESET pin LOW. This prevents spurious output pulses while the control circuitry is stabilizing, and holds the soft-start timing capacitor in a discharged state.

The circuit consists of a +1.2V bandgap reference and comparator circuit which is active when the reference voltage has risen to 3VBE or +1.8V at 25°C. When the reference voltage rises to approximately +4.4V, the circuit enables the output drivers and releases the RESET pin, allowing a normal soft-start. The comparator has 350mV of hysteresis to minimize oscillation at the trip point. When +VIN to the PWM is removed and the reference drops to +4.2V, the under-voltage circuit pulls RESET LOW again. The soft-start capacitor is immediately discharged, and the PWM is ready for another soft-start cycle.

The UC1526A can operate from a +5V supply by connecting the VREF pin to the +VIN pin and maintaining the supply between +4.8 and +5.2V.

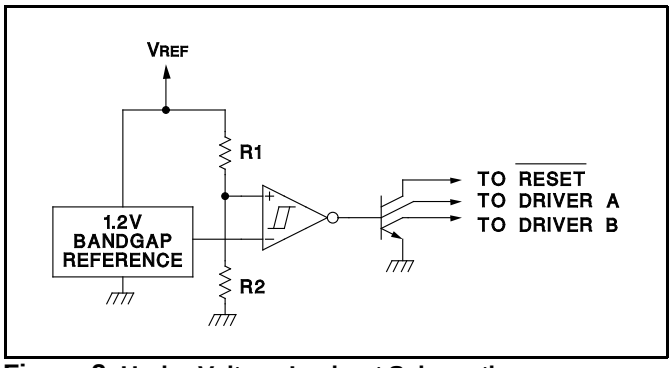


Figure 2. Under-Voltage Lockout Schematic

Soft-Start Circuit

The soft-start circuit protects the power transistors and rectifier diodes from high current surges during power supply turn-on. When supply voltage is first applied to the UC1526A, the under-voltage lockout circuit holds RESET LOW with Q3. Q1 is turned on, which holds the soft-start capacitor voltage at zero. The second collector of Q1 clamps the output of the error amplifier to ground, guaranteeing zero duty cycle at the driver outputs. When the supply voltage reaches normal operating range, RESET will go HIGH. Q1 turns off, allowing the internal 100μA current source to charge CS. Q2 clamps the error amplifier output to 1VBE above the voltage on CS. As the soft-start voltage ramps up to +5V, the duty cycle of the PWM linearly increases to whatever value the voltage regulation loop requires for an error null.

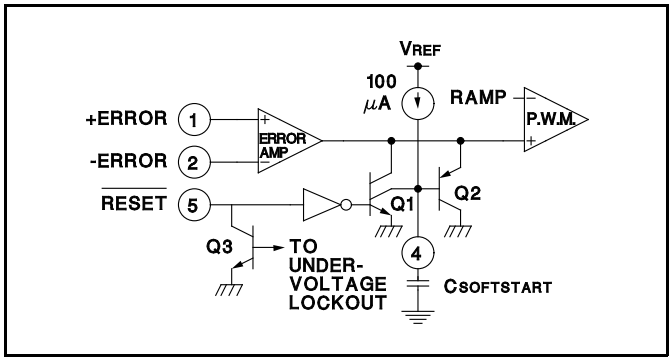


Figure 3. Soft-Start Circuit Schematic

Digital Control Ports

The three digital control ports of the UC1526A are bi-directional. Each pin can drive TTL and 5V CMOS logic directly, up to a fan-out of 10 low-power Schottky gates. Each pin can also be directly driven by open-collector TTL, open-drain CMOS, and open-collector voltage comparators; fan-in is equivalent to 1 low-power Schottky gate. Each port is normally HIGH; the pin is pulled LOW to activate the particular function. Driving SYNC LOW initiates a discharge cycle in the oscillator. Pulling SHUTDOWN LOW immediately inhibits all PWM output pulses. Holding RESET LOW discharges the soft-start

APPLICATIONS INFORMATION (cont.)

capacitor. The logic threshold is +1.1V at +25°C. Noise immunity can be gained at the expense of fan-out with an external 2k pull-up resistor to +5V.

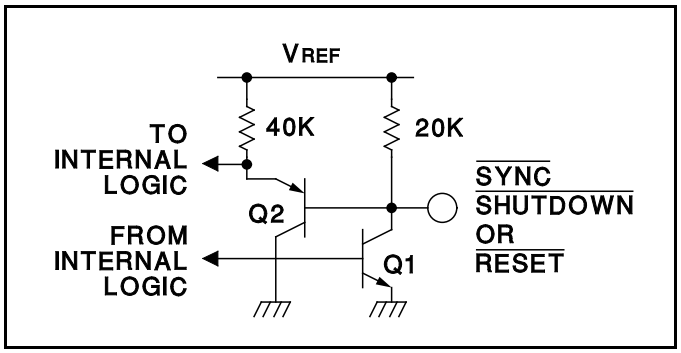


Figure 4. Digital Control Port Schematic

Oscillators

The oscillator is programmed for frequency and dead time with three components: RT, CT and RD. Two waveforms are generated: a sawtooth waveform at pin 10 for pulse width modulation, and a logic clock at pin 12. The following procedure is recommended for choosing timing values:

1. With RD= 0Ω (pin 11 shorted to ground) select values for RT and CT from the graph on page 4 to give the desired oscillator period. Remember that the frequency at each driver output is half the oscillator frequency, and the frequency at the +VC terminal is the same as the oscillator frequency.

2. If more dead time is required, select a larger value of RD. At 40kHz dead time increases by 400ns/Ω.

3. Increasing the dead time will cause the oscillator frequency to decrease slightly. Go back and decrease the value of RT slightly to bring the frequency back to the nominal design value.

The UC1526A can be synchronized to an external logic clock by programming the oscillator to free-run at a frequency 10% slower than the $\overline{\text{SYNC}}$ frequency.

A periodic LOW logic pulse approximately 0.5µs wide at the $\overline{\text{SYNC}}$ pin will then lock the oscillator to the external frequency.

Multiple devices can be synchronized together by programming one master unit for the desired frequency, and then sharing its sawtooth and clock waveforms with the slave units. All CT terminals are connected to the CT pin of the master and all $\overline{\text{SYNC}}$ terminals are likewise connected to the $\overline{\text{SYNC}}$ pin of the master. Slave RT terminals are left open or connected to VREF. Slave RD terminal may be either left open or grounded.

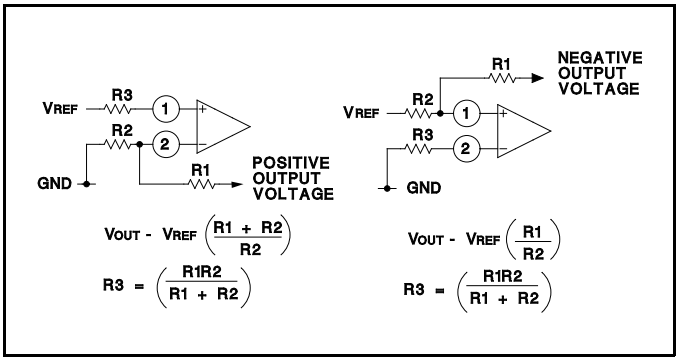


Figure 6. Error Amplifier Connections

Error Amplifier

The error amplifier is a transconductance design, with an output impedance of 2MΩ. Since all voltage gain takes place at the output pin, the open-loop gain/frequency characteristics can be controlled with shunt reactance to ground. When compensated for unity-gain stability with 100pF, the amplifier has an open-loop pole at 800Hz.

The input connections to the error amplifier are determined by the polarity of the switching supply output voltage. For positive supplies, the common-mode voltage is +5.0V and the feedback connections in Figure 6A are used. With negative supplies, the common-mode voltage is ground and the feedback divider is connected between the negative output and the +5.0V reference voltage, as shown in Figure 6B.

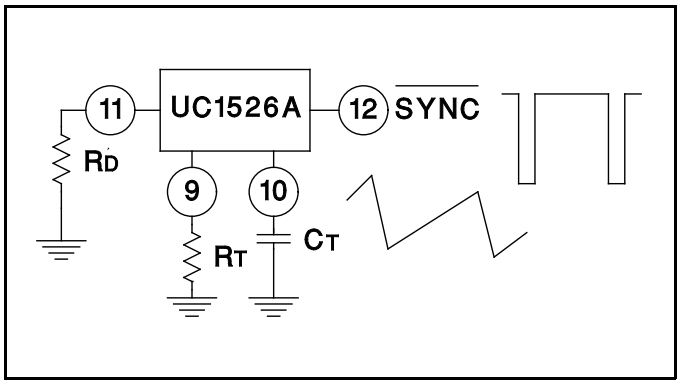


Figure 5. Oscillator Connections and Waveforms

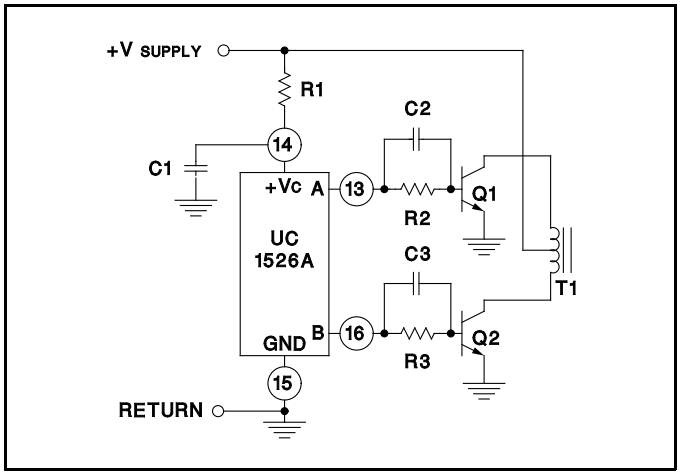


Figure 7. Push-Pull Configuration

APPLICATIONS INFORMATION (cont.)

Output Drivers

The totem pole output drivers of the UC1526A are designed to source and sink 100mA continuously and 200mA peak. Loads can be driven either from the output pins 13 and 16, or from the +Vc, as required.

Since the bottom transistor of the totem-pole is allowed to saturate, there is a momentary conduction path from the +Vc terminal to ground during switching; however, improved design has limited this cross-conduction period to less than 50ns. Capacitor decoupling at Vc is recommended and careful grounding of Pin 15 is needed to insure that high peak sink currents from a capacitive load do not cause ground transients.

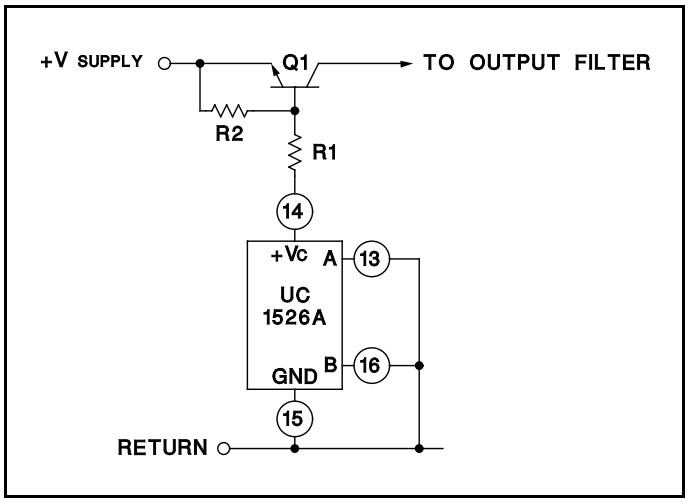


Figure 8. Single-Ended Configuration

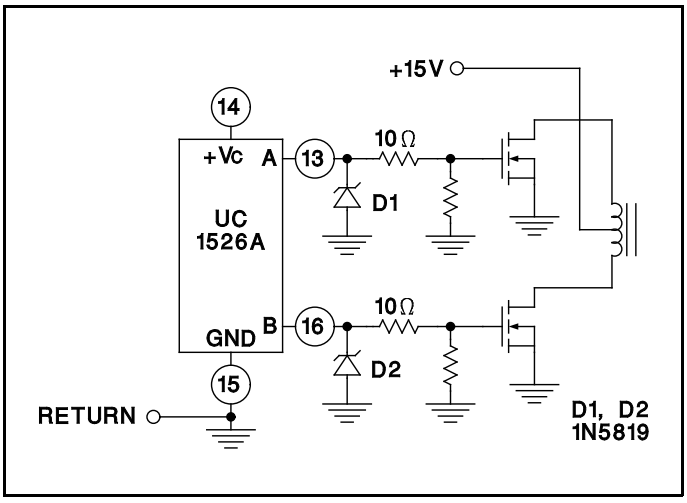
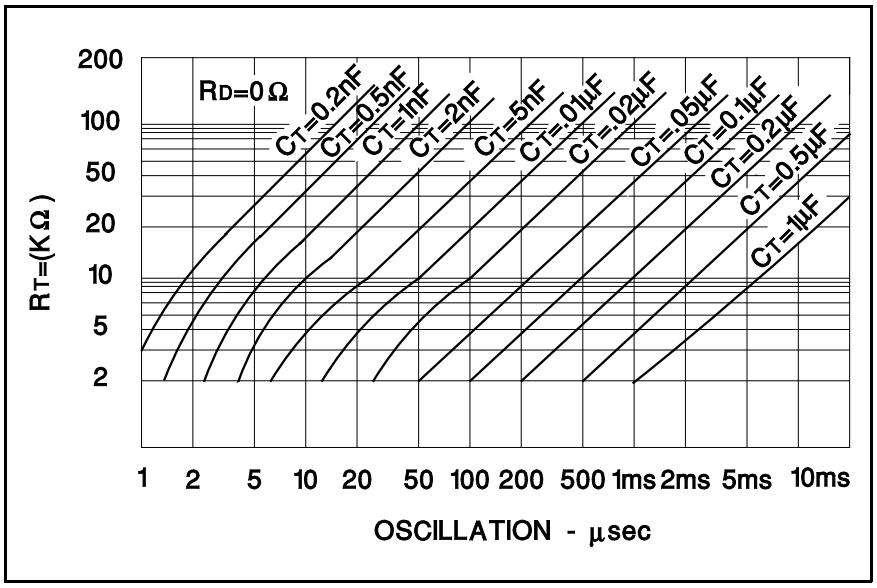


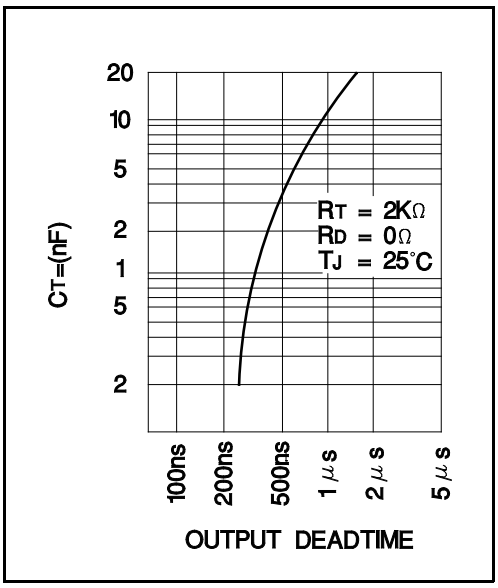
Figure 9. Driving N-Channel Power MOSFETs

TYPICAL CHARACTERISTICS

OSCILLATOR PERIOD vs RT and CT

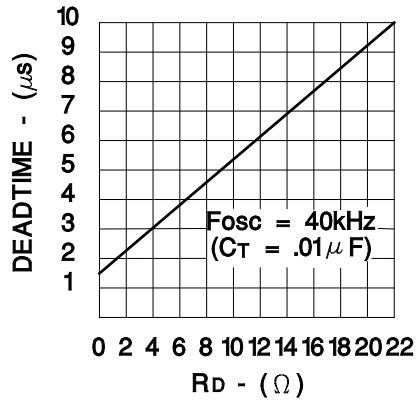


OUTPUT BLANKING

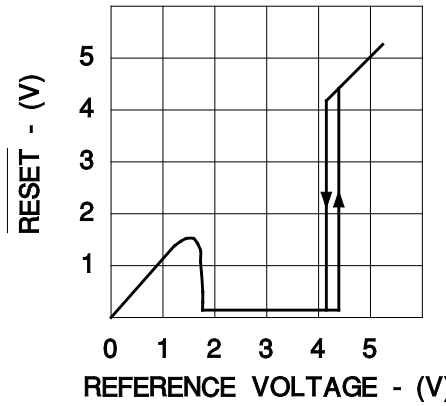


TYPICAL CHARACTERISTICS (Cont.)

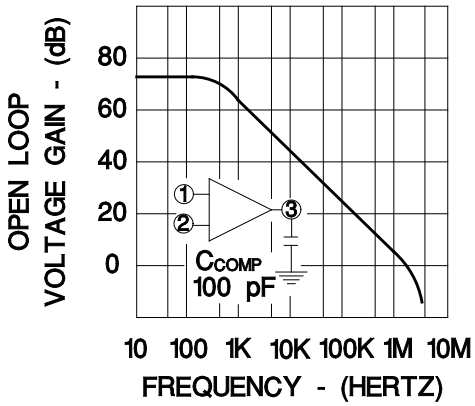
Output Driver Deadtime vs. R_D Value



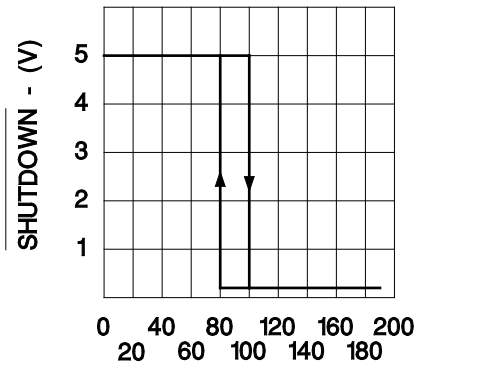
Under Voltage Lockout Characteristic



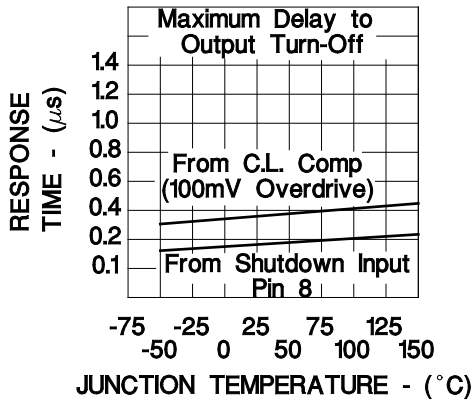
Error Amplifier Open Loop Gain vs. Frequency



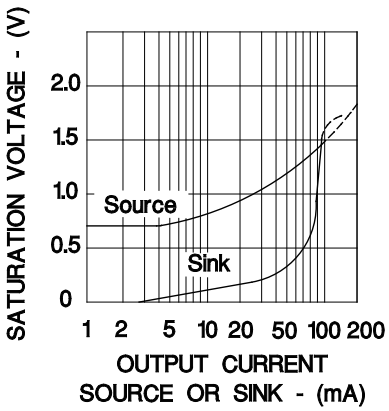
Current Limit Transfer Function



Shutdown Delay



Output Driver Saturation Voltage



UNITRODE INTEGRATED CIRCUITS
7 CONTINENTAL BLVD. • MERRIMACK, NH 03054
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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
85515022A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	85515022A UC1526AL/ 883B	Samples
8551502VA	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	8551502VA UC1526AJ/883B	Samples
UC1526AJ	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	UC1526AJ	Samples
UC1526AJ883B	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-55 to 125	8551502VA UC1526AJ/883B	Samples
UC1526AL	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	UC1526AL	Samples
UC1526AL883B	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	85515022A UC1526AL/ 883B	Samples
UC2526ADW	ACTIVE	SOIC	DW	18	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2526ADW	Samples
UC2526ADWG4	ACTIVE	SOIC	DW	18	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2526ADW	Samples
UC2526ADWTR	ACTIVE	SOIC	DW	18	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2526ADW	Samples
UC2526ADWTRG4	ACTIVE	SOIC	DW	18	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-25 to 85	UC2526ADW	Samples
UC2526AN	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	UC2526AN	Samples
UC2526ANG4	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-25 to 85	UC2526AN	Samples
UC2526AQ	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-25 to 85	UC2526AQ	Samples
UC2526AQG3	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-25 to 85	UC2526AQ	Samples
UC2526J	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	-25 to 85	UC2526J	Samples
UC3526ADW	ACTIVE	SOIC	DW	18	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3526ADW	Samples
UC3526ADWG4	ACTIVE	SOIC	DW	18	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3526ADW	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
UC3526ADWTR	ACTIVE	SOIC	DW	18	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3526ADW	Samples
UC3526ADWTRG4	ACTIVE	SOIC	DW	18	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	0 to 70	UC3526ADW	Samples
UC3526AN	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	UC3526AN	Samples
UC3526ANG4	ACTIVE	PDIP	N	18	20	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	0 to 70	UC3526AN	Samples
UC3526AQ	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 70	UC3526AQ	Samples
UC3526AQG3	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 70	UC3526AQ	Samples
UC3526J	ACTIVE	CDIP	J	18	1	TBD	A42	N / A for Pkg Type	0 to 70	UC3526J	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(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.

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OTHER QUALIFIED VERSIONS OF UC1526A, UC2526A, UC2526M, UC3526A, UC3526M :

- Catalog: UC3526A, UC2526, UC3526AM, UC3526
- Military: UC2526AM, UC1526A, UC1526

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

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