

# Advanced Regulating Pulse Width Modulators

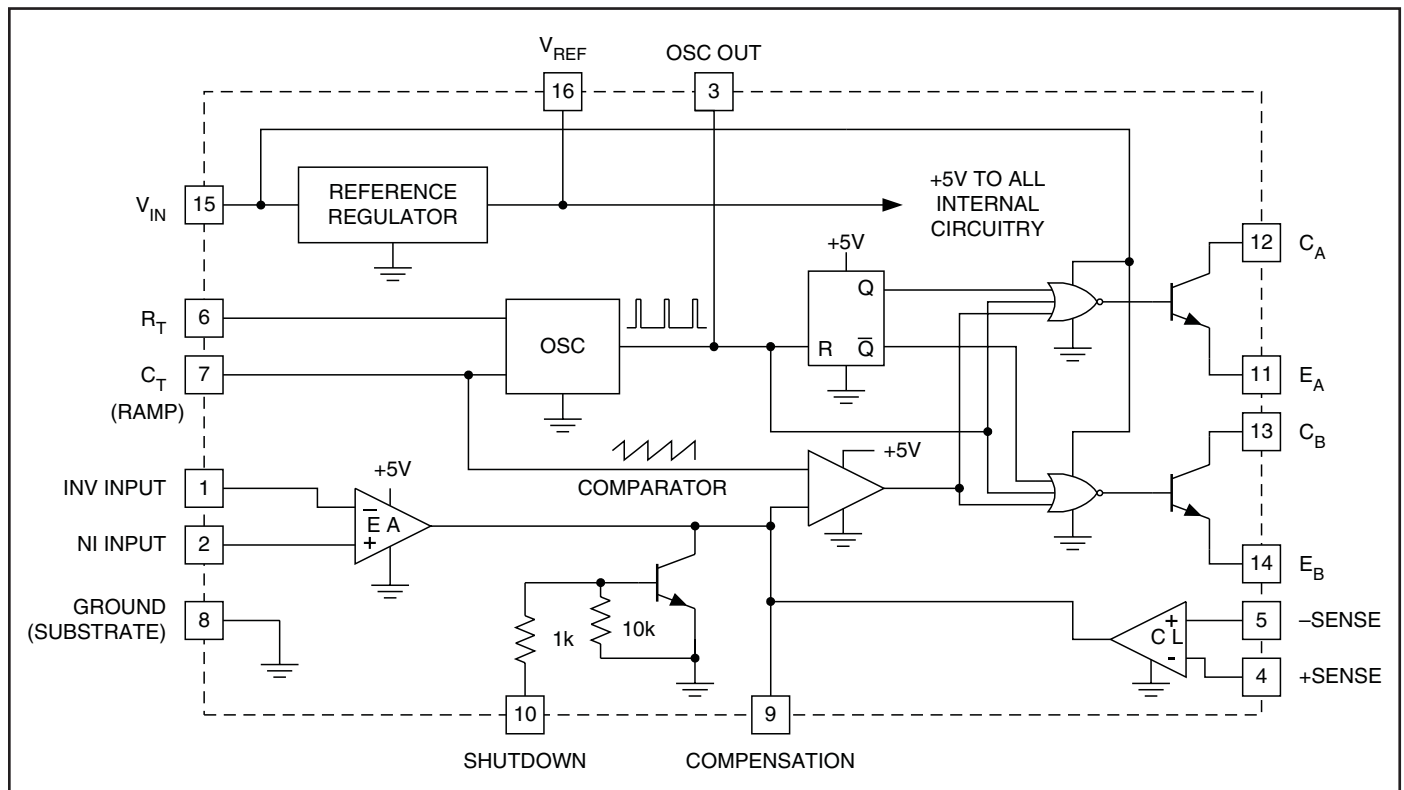
## FEATURES

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for Single-ended or Push-pull Applications
- Low Standby Current...8mA Typical
- Interchangeable with SG1524, SG2524 and SG3524, Respectively

## DESCRIPTION

The UC1524, UC2524 and UC3524 incorporate on a single monolithic chip all the functions required for the construction of regulating power supplies, inverters or switching regulators. They can also be used as the control element for high-power-output applications. The UC1524 family was designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers and polarity converter applications employing fixed-frequency, pulse-width modulation techniques. The dual alternating outputs allow either single-ended or push-pull applications. Each device includes an on-chip reference, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted output transistors, a high-gain comparator, and current-limiting and shut-down circuitry. The UC1524 is characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . The UC2524 and UC3524 are designed for operation from  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  and  $0^{\circ}$  to  $+70^{\circ}\text{C}$ , respectively.

## BLOCK DIAGRAM



### ABSOLUTE MAXIMUM RATINGS (Note 1)

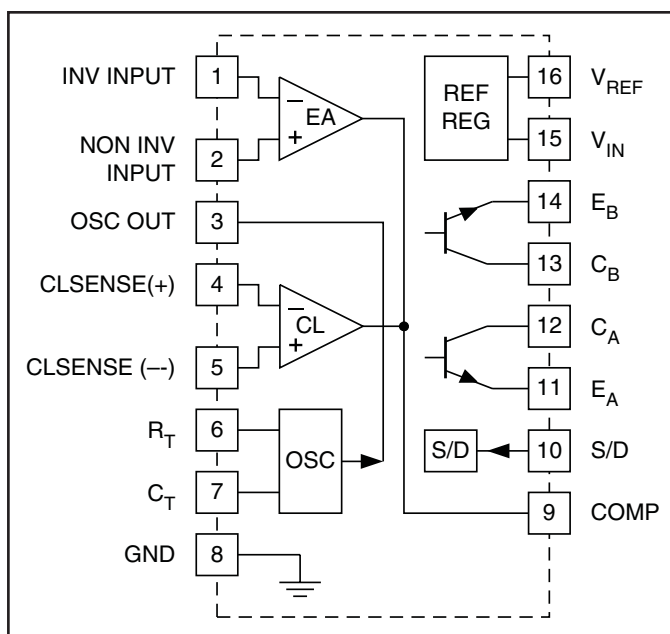
Supply Voltage, $V_{CC}$ (Notes 2 and 3)	40V
Collector Output Current	100mA
Reference Output Current	50mA
Current Through $C_T$ Terminal	-5mA
Power Dissipation at $T_A = +25^\circ\text{C}$ (Note 4)	1000mW
Power Dissipation at $T_C = +25^\circ\text{C}$ (Note 4)	2000mW
Operating Junction Temperature Range	$-55^\circ\text{C}$ to $+150^\circ\text{C}$
Storage Temperature Range	$-65^\circ\text{C}$ to $+150^\circ\text{C}$

- Note 1: Over operating free-air temperature range unless otherwise noted.
- Note 2: All voltage values are with respect to the ground terminal, pin 8.
- Note 3: The reference regulator may be bypassed for operation from a fixed 5V supply by connecting the  $V_{CC}$  and reference output pins both to the supply voltage. In this configuration the maximum supply voltage is 6V.
- Note 4: Consult packaging section of databook for thermal limitations and considerations of package.

### RECOMMENDED OPERATING CONDITIONS

Supply Voltage, $V_{CC}$	8V to 40V
Reference Output Current	0 to 20mA
Current through $C_T$ Terminal	-0.03mA to -2mA
Timing Resistor, $R_T$	1.8k $\Omega$ to 100k $\Omega$
Timing Capacitor, $C_T$	0.001 $\mu\text{F}$ to 0.1 $\mu\text{F}$
Operating Ambient Temperature Range	
UC1524	$-55^\circ\text{C}$ to $+125^\circ\text{C}$
UC2524	$-25^\circ\text{C}$ to $+85^\circ\text{C}$
UC3524	$0^\circ\text{C}$ to $+70^\circ\text{C}$

### CONNECTION DIAGRAM



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^\circ\text{C}$  to  $+125^\circ\text{C}$  for the UC1524,  $-25^\circ\text{C}$  to  $+85^\circ\text{C}$  for the UC2524, and  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  for the UC3524,  $V_{IN} = 20\text{V}$ , and  $f = 20\text{kHz}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	UC1524/UC2524			UC3524			UNITS
		MIN		MAX	MIN		MAX	
<b>Reference Section</b>								
Output Voltage		4.8	5.0	5.2	4.6	5.0	5.4	V
Line Regulation	$V_{IN} = 8$ to $40\text{V}$		10	20		10	30	mV
Load Regulation	$I_L = 0$ to $20\text{mA}$		20	50		20	50	mV
Ripple Rejection	$f = 120\text{Hz}$ , $T_J = 25^\circ\text{C}$		66			66		dB
Short Circuit Current Limit	$V_{REF} = 0$ , $T_J = 25^\circ\text{C}$		100			100		mA
Temperature Stability	Over Operating Temperature Range		0.3	1		0.3	1	%
Long Term Stability	$T_J = 125^\circ\text{C}$ , $t = 1000$ Hrs.		20			20		mV
<b>Oscillator Section</b>								
Maximum Frequency	$C_T = .001\text{mfd}$ , $R_T = 2\text{k}\Omega$		300			300		kHz
Initial Accuracy	$R_T$ and $C_T$ Constant		5			5		%
Voltage Stability	$V_{IN} = 8$ to $40\text{V}$ , $T_J = 25^\circ\text{C}$			1			1	%
Temperature Stability	Over Operating Temperature Range			5			5	%
Output Amplitude	Pin 3, $T_J = 25^\circ\text{C}$		3.5			3.5		V
Output Pulse Width	$C_T = .01\text{mfd}$ , $T_J = 25^\circ\text{C}$		0.5			0.5		$\mu\text{s}$
<b>Error Amplifier Section</b>								
Input Offset Voltage	$V_{CM} = 2.5\text{V}$		0.5	5		2	10	mV
Input Bias Current	$V_{CM} = 2.5\text{V}$		2	10		2	10	$\mu\text{A}$
Open Loop Voltage Gain		72	80		60	80		dB
Common Mode Voltage	$T_J = 25^\circ\text{C}$	1.8		3.4	1.8		3.4	V

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  for the UC1524,  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UC2524, and  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  for the UC3524,  $V_{IN} = 20\text{V}$ , and  $f = 20\text{kHz}$ ,  $T_A = T_J$ .

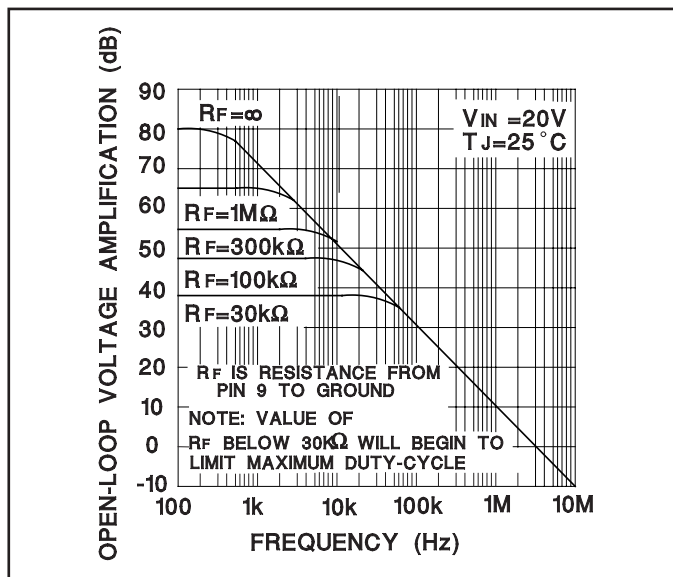
PARAMETER	TEST CONDITIONS	UC1524/UC2524			UC3524			UNITS
		MIN		MAX	MIN		MAX	
<b>Error Amplifier Section (cont.)</b>								
Common Mode Rejection Ratio	$T_J = 25^{\circ}\text{C}$		70			70		dB
Small Signal Bandwidth	$A_v = 0\text{dB}$ , $T_J = 25^{\circ}\text{C}$		3			3		MHz
Output Voltage	$T_J = 25^{\circ}\text{C}$	0.5		3.8	0.5		3.8	V
<b>Comparator Section</b>								
Duty-Cycle	% Each Output On	0		45	0		45	%
Input Threshold	Zero Duty-Cycle		1			1		V
	Maximum Duty-Cycle		3.5			3.5		V
Input Bias Current			1			1		$\mu\text{A}$
<b>Current Limiting Section</b>								
Sense Voltage	Pin 9 = 2V with Error Amplifier Set for Maximum Out, $T_J = 25^{\circ}\text{C}$	190	200	210	180	200	220	mV
Sense Voltage T.C.			0.2			0.2		$\text{mV}/^{\circ}\text{C}$
Common Mode Voltage	$T_J = -55^{\circ}\text{C}$ to $85^{\circ}\text{C}$ for the $-1\text{V}$ to $1\text{V}$ Limit	-1		+1	-1		+1	V
	$T_J = 125^{\circ}\text{C}$	-0.3		+1				V
<b>Output Section (Each Output)</b>								
Collector-Emitter Voltage		40			40			V
Collector Leakage Current	$V_{CE} = 40\text{V}$		0.1	50		0.1	50	$\mu\text{A}$
Saturation Voltage	$I_C = 50\text{mA}$		1	2		1	2	V
Emitter Output Voltage	$V_{IN} = 20\text{V}$	17	18		17	18		V
Rise Time	$R_C = 2\text{k}\Omega$ , $T_J = 25^{\circ}\text{C}$		0.2			0.2		$\mu\text{s}$
Fall Time	$R_C = 2\text{k}\Omega$ , $T_J = 25^{\circ}\text{C}$		0.1			0.1		$\mu\text{s}$
<b>Total Standby Current (Note)</b>	$V_{IN} = 40\text{V}$		8	10		8	10	mA

## PRINCIPLES OF OPERATION

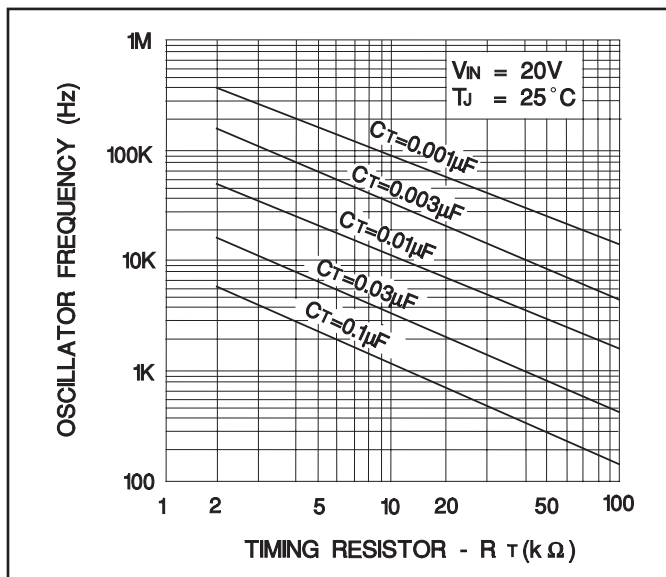
The UC1524 is a fixed-frequency pulse-width-modulation voltage regulator control circuit. The regulator operates at a frequency that is programmed by one timing resistor ( $R_T$ ), and one timing capacitor ( $C_T$ ),  $R_T$  establishes a constant charging current for  $C_T$ . This results in a linear voltage ramp at  $C_T$ , which is fed to the comparator providing linear control of the output pulse width by the error amplifier. The UC1524 contains an on-board 5V regulator that serves as a reference as well as powering the UC1524's internal control circuitry and is also useful in supplying external support functions. This reference voltage is lowered externally by a resistor divider to provide a reference within the common-mode range of the error amplifier or an external reference may be used. The power supply output is sensed by a second resistor divider network to generate a feedback signal to the error amplifier. The amplifier output voltage is then compared to the linear voltage ramp at  $C_T$ . The resulting modulated pulse out of the high-gain comparator is then steered to

the appropriate output pass transistor ( $Q_1$  or  $Q_2$ ) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to assure both outputs are never on simultaneously during the transition times. The width of the blanking pulse is controlled by the value of  $C_T$ . The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current limiting and shutdown circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, or to compensate, the error amplifier or to provide additional control to the regulator.

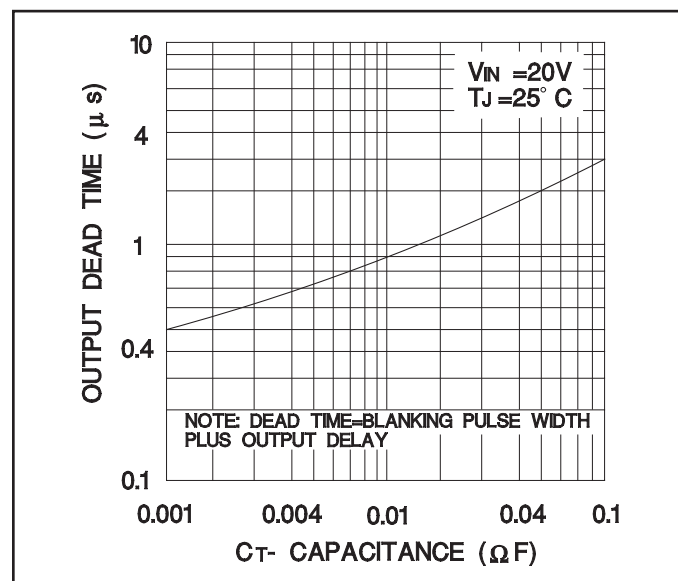
TYPICAL CHARACTERISTICS



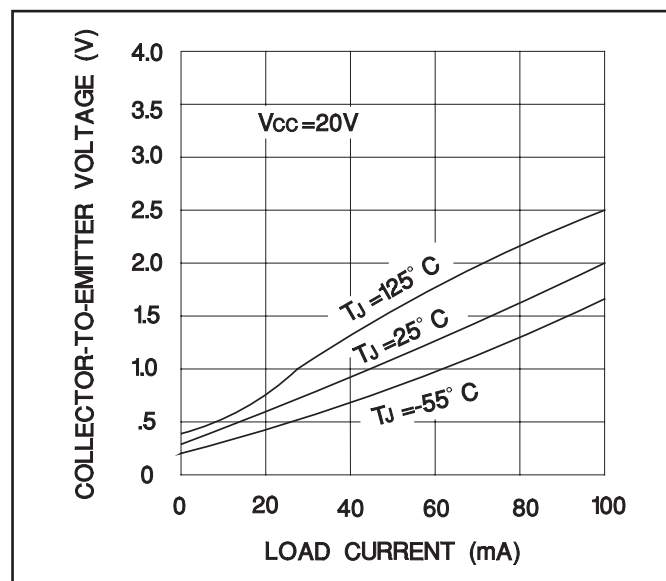
Open-loop voltage amplification of error amplifier vs frequency.



Oscillator frequency vs timing components.



Output dead time vs timing capacitance value.



Output saturation voltage vs load current.

## APPLICATION INFORMATION

### Oscillator

The oscillator controls the frequency of the UC1524 and is programmed by  $R_T$  and  $C_T$  according to the approximate formula:

$$f' = \frac{1.18}{R_T C_T}$$

where  $R_T$  is in  $k\Omega$   
 $C_T$  is in  $mF$   
 $f$  is in  $kHz$

Practical values of  $C_T$  fall between 0.001mF and 0.1mF. Practical values of  $R_T$  fall between 1.8k $\Omega$  and 100k $\Omega$ . This results in a frequency range typically from 120Hz to 500kHz.

### Blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse width is controlled by the value of  $C_T$ . If small values of  $C_T$  are required for frequency control, the oscillator output pulse width may still be increased by applying a shunt capacitance of up to 100pF from pin 3 to ground. If still greater dead-time is required, it should be accomplished by limiting the maximum duty cycle by clamping the output of the error

amplifier. This can easily be done with the circuit in Figure 1:

### Synchronous Operation

When an external clock is desired, a clock pulse of approximately 3V can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2k $\Omega$ . In this configuration  $R_T$   $C_T$  must be selected for a clock period slightly greater than that of the external clock.

If two or more UC1524 regulators are to operated synchronously, all oscillator output terminals should be tied together, all  $C_T$  terminals connected to single timing capacitor, and the timing resistor connected to a single  $R_T$  terminal.

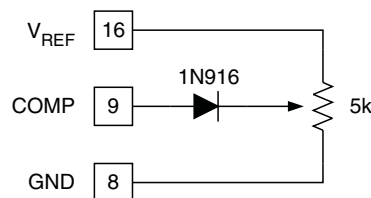


Figure 1. Error amplifier clamp.

The other  $R_T$  terminals can be left open or shorted to  $V_{REF}$ . Minimum lead lengths should be used between the  $C_T$  terminals.

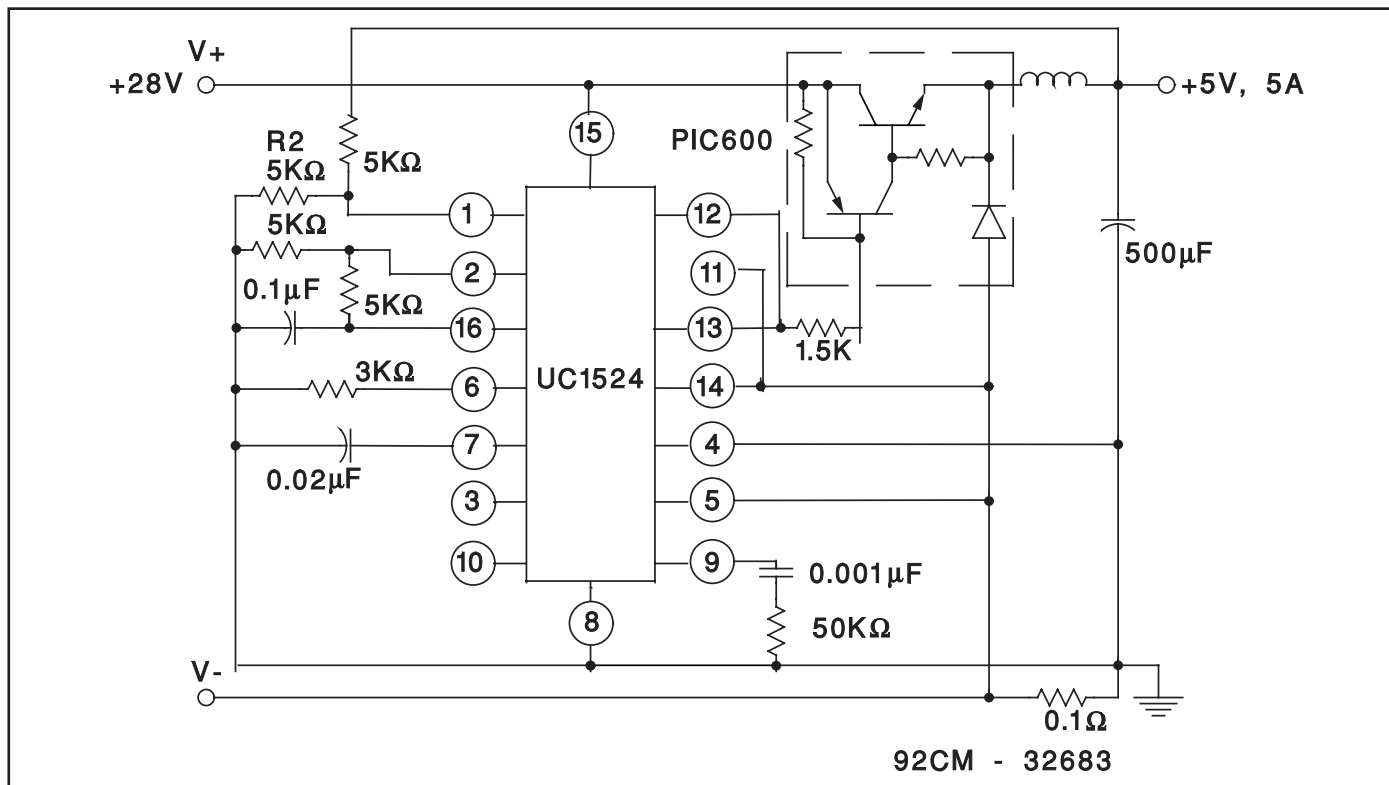


Figure 2. Single-ended LC switching regulator circuit.

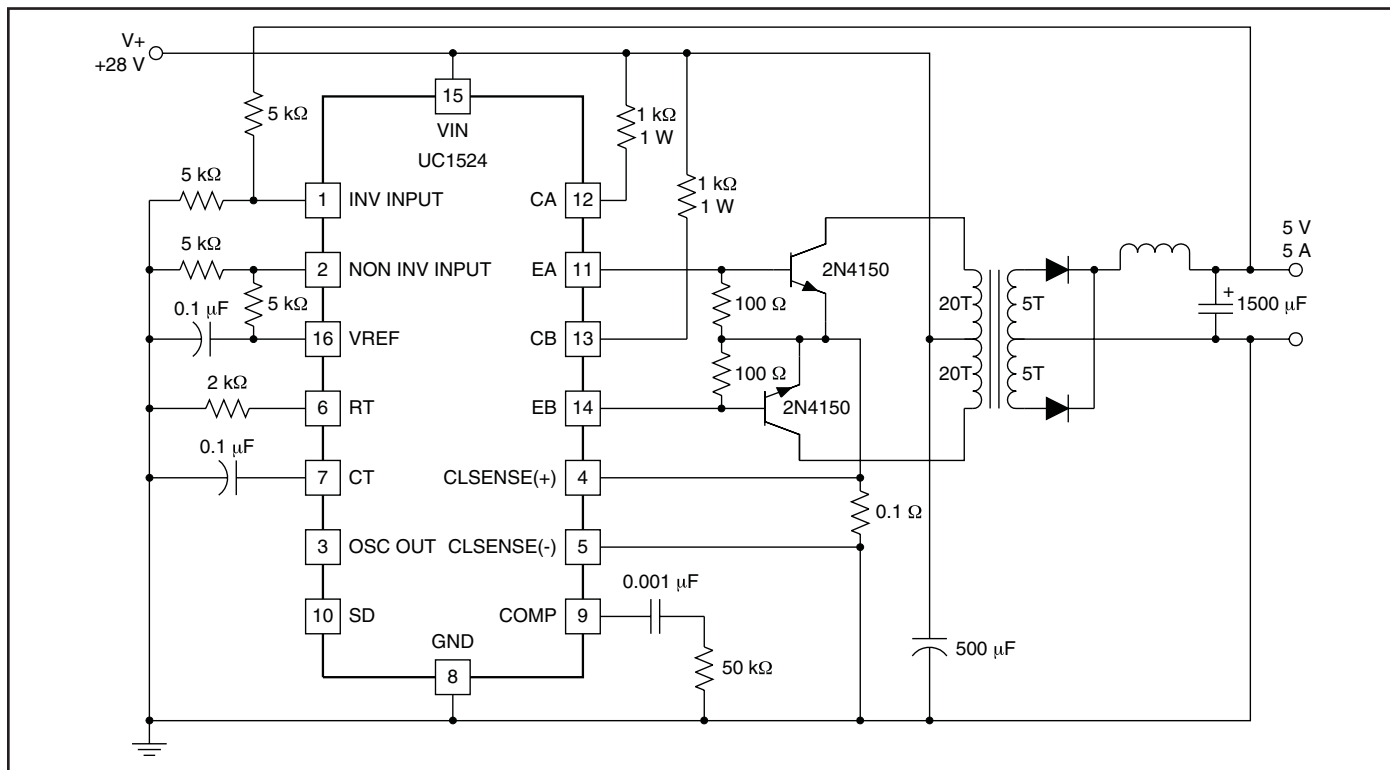


Figure 3. Push-pull transformer coupled circuit.

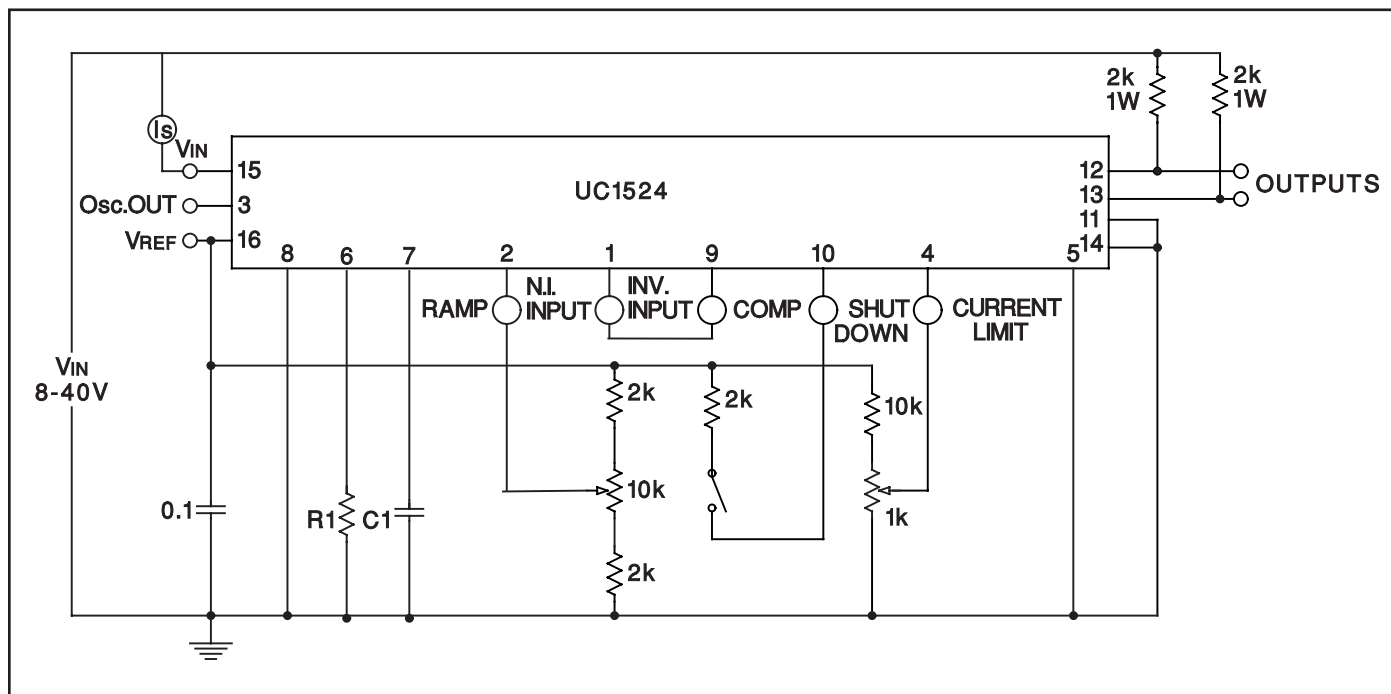


Figure 4. Open loop test circuit.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
UC1524J	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
UC1524J/80937	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
UC1524J883B	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
UC2524DW	ACTIVE	SOIC	DW	16	40	None	CU NIPDAU	Level-2-220C-1 YEAR
UC2524DWTR	ACTIVE	SOIC	DW	16	2000	None	CU NIPDAU	Level-2-220C-1 YEAR
UC2524J	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
UC2524N	ACTIVE	PDIP	N	16	25	None	CU SNPB	Level-NA-NA-NA
UC3524D	ACTIVE	SOIC	D	16	40	None	CU NIPDAU	Level-1-220C-UNLIM
UC3524DTR	ACTIVE	SOIC	D	16	2500	None	CU NIPDAU	Level-1-220C-UNLIM
UC3524DW	ACTIVE	SOIC	DW	16	40	None	CU NIPDAU	Level-2-220C-1 YEAR
UC3524DWTR	ACTIVE	SOIC	DW	16	2000	None	CU NIPDAU	Level-2-220C-1 YEAR
UC3524J	OBSOLETE	CDIP	J	16		None	Call TI	Call TI
UC3524N	ACTIVE	PDIP	N	16	25	None	CU SNPB	Level-NA-NA-NA

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**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.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

**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.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<b>Products</b>		<b>Applications</b>	
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>	Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>	Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>	Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>	Digital Control	<a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>	Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>	Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>	Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
		Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
		Video & Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
		Wireless	<a href="http://www.ti.com/wireless">www.ti.com/wireless</a>

Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265