# Advanced Regulating Pulse Width Modulators
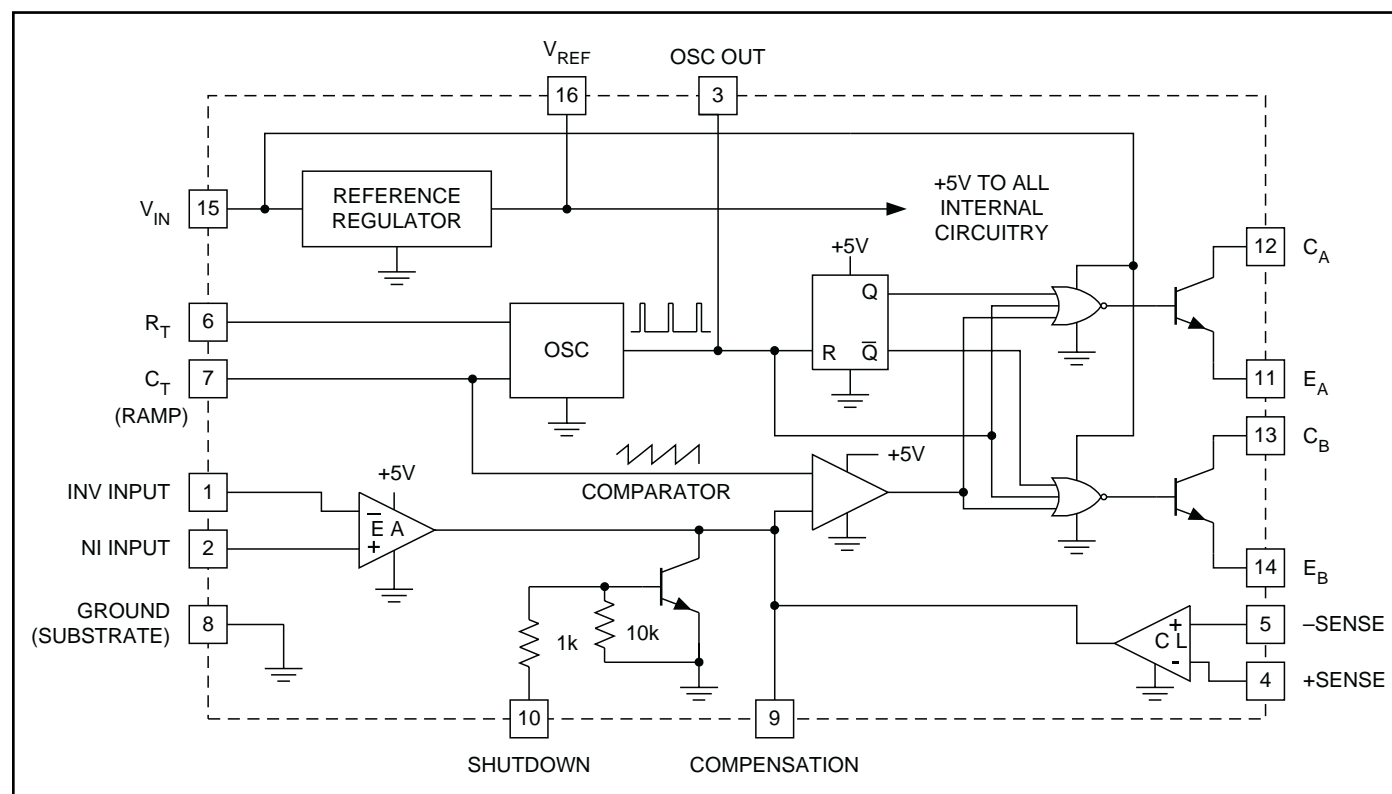
## FEATURES

- 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°C to +125°C. The UC2524 and UC3524 are designed for operation from -25°C to +85°C and 0° to +70°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°C (Note 4). . . . . . . . . . 1000mW
Power Dissipation at $T_C$ = +25°C (Note 4). . . . . . . . . . 2000mW
Operating Junction Temperature Range . . . . –55°C to +150°C
Storage Temperature Range . . . . . . . . . . . . . –65°C to +150°C

Note 1: *Over operating free-air temperature range unless oth-
erwise noted.*
Note 2: *All voltage values are with respect to the ground termi-
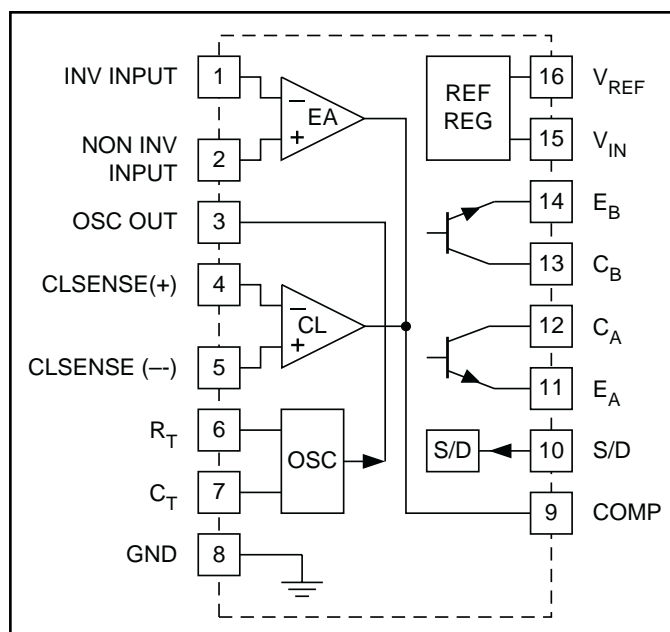nal, pin 8.*
Note 3: *The reference regulator may be bypassed for operation
from a fixed 5V supply by connecting the $V_{CC}$ and ref-
erence output pins both to the supply voltage. In this
configuration the maximum supply voltage is 6V.*
Note 4: *Consult packaging section of databook for thermal lim-
itations 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, $R_T$ . . . . . . . . . . . . . . . . . . . . . . 1.8kΩ to 100kΩ
Timing Capacitor, $C_T$ . . . . . . . . . . . . . . . . . . . . 0.001μF to 0.1μF
Operating Ambient Temperature Range
  UC1524 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . –55°C to +125°C
  UC2524 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . –25°C to +85°C
  UC3524 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0°C to +70°C

## CONNECTION DIAGRAM



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

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

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

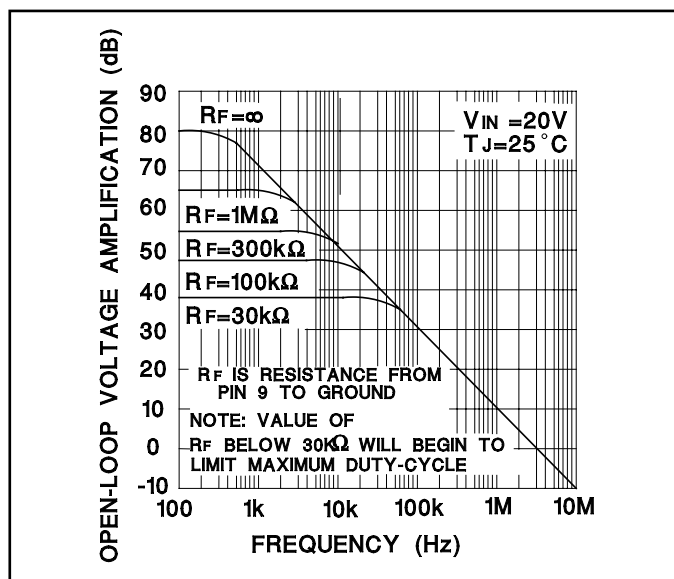| PARAMETER | TEST CONDITIONS | UC1524/UC2524 MIN | TYP | MAX | UC3524 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| **Error Amplifier Section (cont.)** | | | | | | | | |
| Common Mode Rejection Ratio | $T_J = 25°C$ | | 70 | | | 70 | | dB |
| Small Signal Bandwidth | $A_V = 0dB$, $T_J = 25°C$ | | 3 | | | 3 | | MHz |
| Output Voltage | $T_J = 25°C$ | 0.5 | | 3.8 | 0.5 | | 3.8 | V |
| **Comparator Section** | | | | | | | | |
| 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 | | μA |
| **Current Limiting Section** | | | | | | | | |
| Sense Voltage | Pin 9 = 2V with Error Amplifier Set for Maximum Out, $T_J = 25°C$ | 190 | 200 | 210 | 180 | 200 | 220 | mV |
| Sense Voltage T.C. | | | 0.2 | | | 0.2 | | mV/°C |
| Common Mode Voltage | | −1 | | +1 | −1 | | +1 | V |
| **Output Section (Each Output)** | | | | | | | | |
| Collector-Emitter Voltage | | 40 | | | 40 | | | V |
| Collector Leakage Current | $V_{CE} = 40V$ | | 0.1 | 50 | | 0.1 | 50 | μA |
| Saturation Voltage | $I_C = 50mA$ | | 1 | 2 | | 1 | 2 | V |
| Emitter Output Voltage | $V_{IN} = 20V$ | 17 | 18 | | 17 | 18 | | V |
| Rise Time | $R_C = 2k\Omega$, $T_J = 25°C$ | | 0.2 | | | 0.2 | | μs |
| Fall Time | $R_C = 2k\Omega$, $T_J = 25°C$ | | 0.1 | | | 0.1 | | μs |
| **Total Standby Current (Note)** | $V_{IN} = 40V$ | | 8 | 10 | | 8 | 10 | mA |

*Note: Excluding oscillator charging current, error and current limit dividers, and with outputs open.*
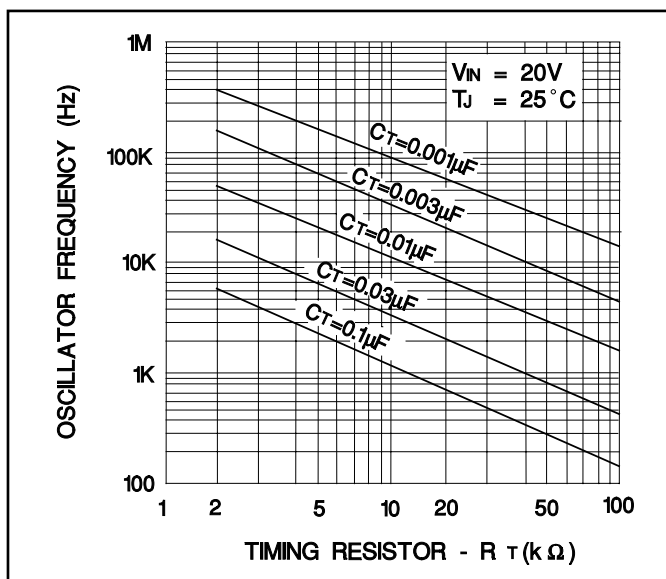
## PRINCIPLES OF OPERATION

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 valve 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.
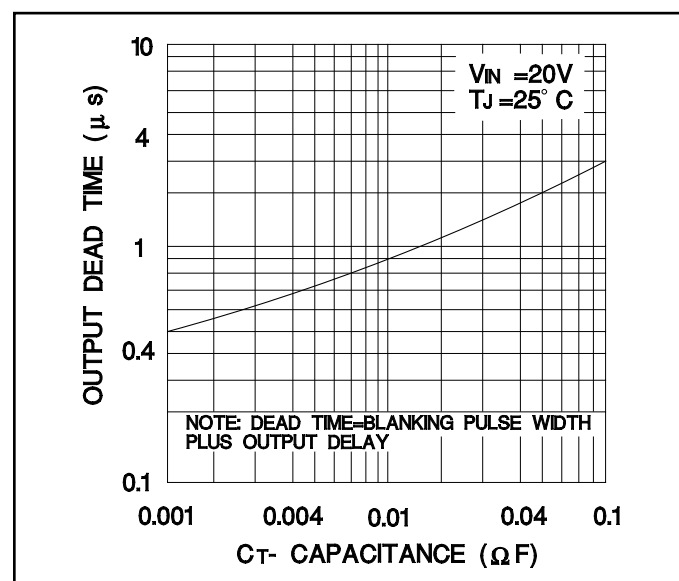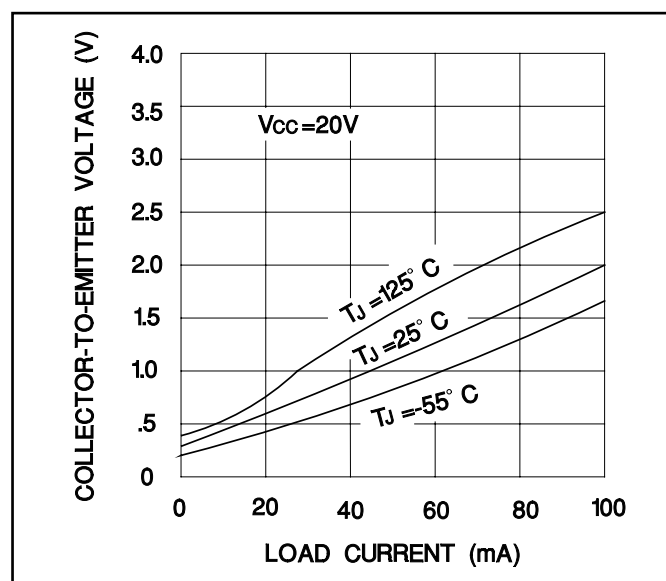
## TYPICAL CHARACTERISTICS



*Open-loop voltage amplification of error amplifier vs frequency.*



*Oscillator frequency vs timing components.*



*Output dead time vs timing capacitance value.*



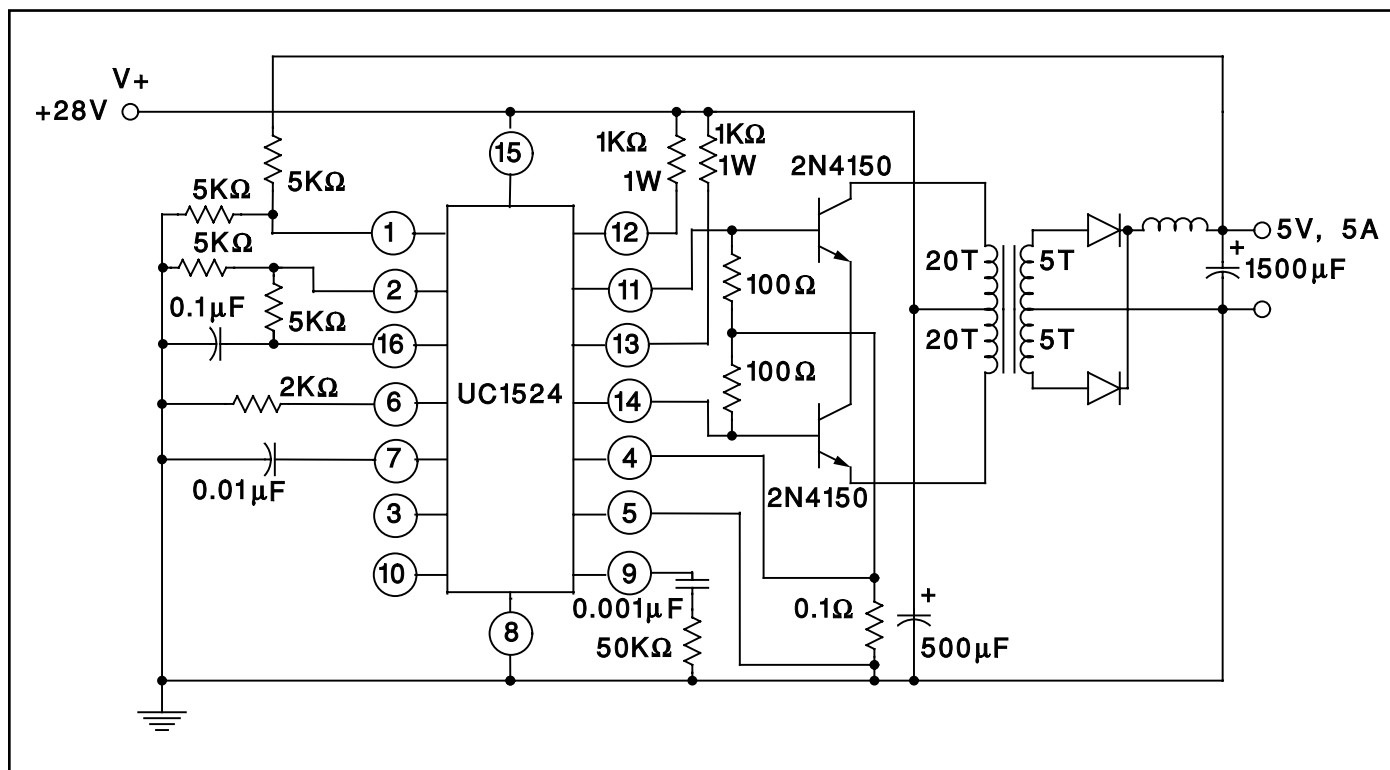*Output saturation voltage vs load current.*

## 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:

$$f \cong \frac{1.18}{R_T C_T}$$

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. 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 1. Error amplifier clamp.**

**Figure 2. Single-ended LC switching regulator circuit.**

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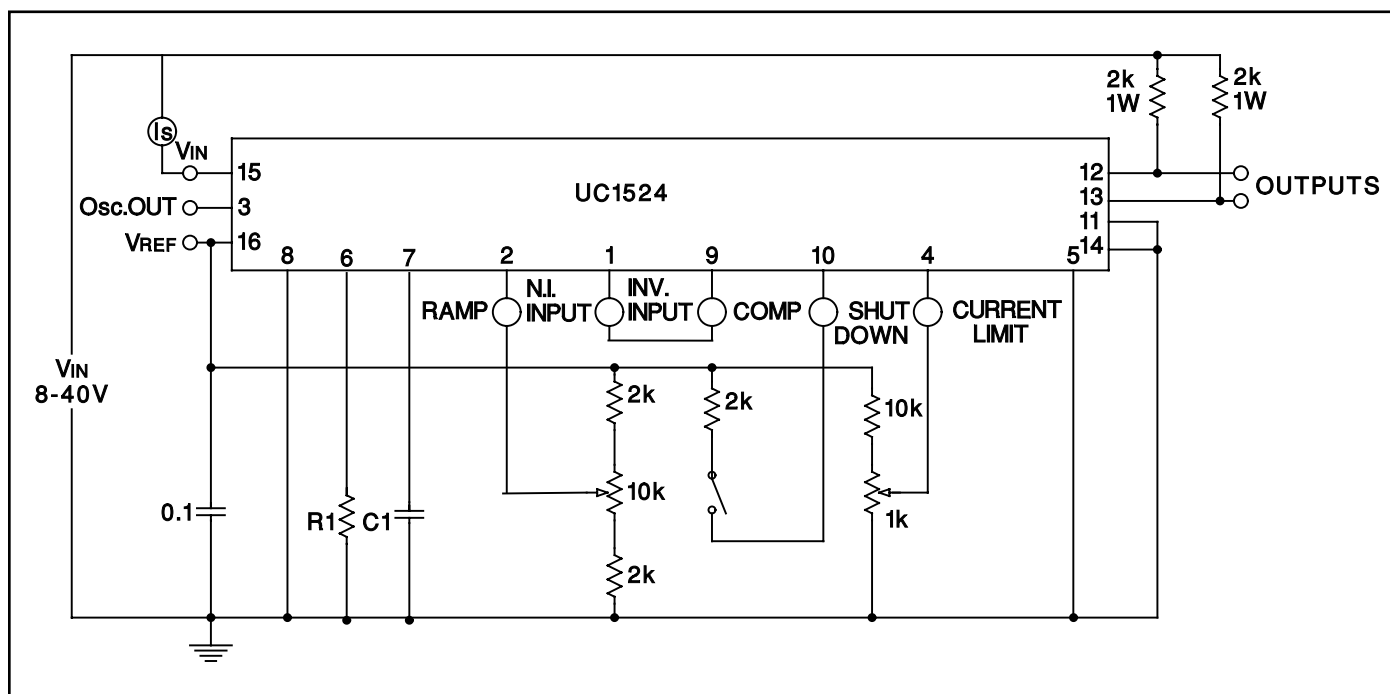**Figure 3. Push-pull transformer coupled circuit.**



**Figure 4. Open loop test circuit.**

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