**LM494**

**Pulse Width Modulated Control Circuit**

**General Description**

The LM494 is a monolithic integrated circuit which includes all the necessary building blocks for the design of pulse width modulated (PWM) switching power supplies, including push-pull, bridge and series configurations. The device can operate at switching frequencies between 1.0 kHz and 300 kHz and output voltages up to 40V. The operating temperature range specified for the LM494C is 0°C to 70°C and for the LM494V is −40°C to +85°C.

**Features**

- Uncommitted output transistors capable of 200 mA source or sink
- On-chip error amplifiers
- On-chip 5.0V reference
- Internal protection from double pulsing of outputs with narrow pulse widths or with supply voltages below specified limits
- Dead time control comparator
- Output control selects single ended or push-pull operation
- Easily synchronized (slaved) to other circuits

**Connection Diagram**

![Connection Diagram](TL/H/10056-1)

**Ordering Information**

<table>
<thead>
<tr>
<th>Device Code</th>
<th>Package Code</th>
<th>Package Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM494IN</td>
<td>N16A</td>
<td>Molded DIP</td>
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<tr>
<td>LM494CJ</td>
<td>J16A</td>
<td>Ceramic DIP</td>
</tr>
<tr>
<td>LM494CN</td>
<td>N18A</td>
<td>Molded DIP</td>
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</table>
Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Storage Temperature Range
-65°C to +175°C

Molded DIP
-65°C to +150°C

Operating Temperature Range
Industrial (LM494I)
-40°C to +85°C

Commercial (LM494C)
0°C to +70°C

Lead Temperature
Ceramic DIP (Soldering, 60 sec.)
300°C

Molded DIP (Soldering, 10 sec.)
265°C

Internal Power Dissipation (Notes 1, 2)
16L-Ceramic DIP
1.50W

16L-Molded DIP
1.04W

Supply Voltage
42V

Voltage from Any Lead to Ground
(VCC) 0.3V

Output Collector Voltage
42V

Peak Collector Current
(Ic1 and Ic2) 250 mA

ESD Susceptibility
(to be determined)

Recommended Operating Conditions

Power Supply Voltage (VCC) 7.0V to 40V

Voltage on Any Lead except Leads 8 and 11
(Referenced to Ground) (Vj) −0.3V to VCC + 0.3V

Output Voltage Collector (Vc1, Vc2) −0.3V to 40V

Output Collector Current (Ic1, Ic2) 200 mA

Timing Capacitor (Ct) 470 pF to 10 μF

Timing Resistor (Rt) 1.8 kΩ to 500 kΩ

Oscillator Frequency (fosc) 1.0 kHz to 300 kHz

LM494 Electrical Characteristics

Symbol | Parameter | Conditions | Min | Typ | Max | Units
---|---|---|---|---|---|---

REFLINE | Reference Voltage (Note 3) | IREF = 1.0 mA | 4.75 | 5.0 | 5.25 | V

RegLINE | Line Regulation of Reference Voltage | 7.0V ≤ VCC ≤ 40V | 2.0 | 25 | mV

TCVREF | Temperature Coefficient of Reference Voltage | 0°C ≤ TA ≤ 70°C | 0.01 | 0.03 | %/°C

RegLOAD | Load Regulation of Reference Voltage | 1.0 mA ≤ IREF ≤ 10 mA | 1.0 | 15 | mV

Ios | Output Short Circuit Current | VREF = 0V | 0°C ≤ TA ≤ +70°C | 10 | 35 | 50 | mA

−40°C ≤ TA ≤ +85°C | 35 | mA

Ct | Oscillator Frequency Change | 0.01 μF, R̅T = 12 kHz | 10 | kHz

Δfosc | Oscillator Frequency Change | 0°C ≤ TA ≤ +70°C | 2.0 | %

−40°C ≤ TA ≤ +85°C | 2.0 | %

DEAD TIME CONTROL SECTION

Ib (DT) | Input Bias Current | VCC = 15V, 0V ≤ VA ≤ 5.25V | −2.0 | −2.0 | −10 | μA

DC(Max) | Maximum Duty Cycle, Each Output | VCC = 15V, Lead 4 = 0V, Output Control = VREF | 45 | %

Vth(in) | Input Threshold Voltage | Zero Duty Cycle | 3.0 | 3.3 | V

Maximum Duty Cycle | 0 | %

ERROR AMPLIFIER SECTIONS

Vio | Input Offset Voltage | V̅3 = −2.5V | 2.0 | 10 | mV

Iio | Input Offset Current | V̅3 = −2.5V | 25 | 250 | nA

Iib | Input Bias Current | V̅3 = −2.5V | 0.2 | 1.0 | μA

Vicr | Input Common Mode Voltage Range | 7.0V ≤ VCC ≤ 40V | −0.3 | VCC | V

AVS | Large Signal Voltage Gain | 0.5V ≤ V3 ≤ 3.5V | 60 | 74 | dB

BW | Bandwidth | 650 | kHz

REFERENCE SECTION

VREF | Reference Voltage (Note 3) | IREF = 1.0 mA

RegLINE | Line Regulation of Reference Voltage | 7.0V ≤ VCC ≤ 40V

TCVREF | Temperature Coefficient of Reference Voltage | 0°C ≤ TA ≤ 70°C

RegLOAD | Load Regulation of Reference Voltage | 1.0 mA ≤ IREF ≤ 10 mA

Ios | Output Short Circuit Current | VREF = 0V | 0°C ≤ TA ≤ +70°C

−40°C ≤ TA ≤ +85°C | 10 | 35 | 50 | mA

OSCILLATOR SECTION

fosc | Oscillator Frequency | Ct = 0.01 μF, R̅T = 12 kHz

Δfosc | Oscillator Frequency Change | Ct = 0.01 μF, R̅T = 12 kHz | 0°C ≤ TA ≤ +70°C | 2.0 | %

−40°C ≤ TA ≤ +85°C | 2.0 | %

DEAD TIME CONTROL SECTION

Ib (DT) | Input Bias Current | VCC = 15V, 0V ≤ VA ≤ 5.25V | −2.0 | −2.0 | −10 | μA

DC(Max) | Maximum Duty Cycle, Each Output | VCC = 15V, Lead 4 = 0V, Output Control = VREF | 45 | %

Vth(in) | Input Threshold Voltage | Zero Duty Cycle | 3.0 | 3.3 | V

Maximum Duty Cycle | 0 | %

ERROR AMPLIFIER SECTIONS

Vio | Input Offset Voltage | V̅3 = −2.5V | 2.0 | 10 | mV

Iio | Input Offset Current | V̅3 = −2.5V | 25 | 250 | nA

Iib | Input Bias Current | V̅3 = −2.5V | 0.2 | 1.0 | μA

Vicr | Input Common Mode Voltage Range | 7.0V ≤ VCC ≤ 40V | −0.3 | VCC | V

AVS | Large Signal Voltage Gain | 0.5V ≤ V3 ≤ 3.5V | 60 | 74 | dB

BW | Bandwidth | 650 | kHz
### LM494 Electrical Characteristics

**TA = 0°C to +70°C for the LM494C, TA = -40°C to +85°C for the LM494I, VCC = 15V, fOSC = 10 kHz, unless otherwise specified (Continued)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
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<tbody>
<tr>
<td>PWM COMPARATOR SECTION (Figure 9)</td>
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<td></td>
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<tr>
<td>VTHI</td>
<td>Inhibit Threshold Voltage</td>
<td>Zero Duty Cycle</td>
<td>4.0</td>
<td>4.5</td>
<td></td>
<td>V</td>
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<tr>
<td>I0↓</td>
<td>Output Sink Current</td>
<td>0.5V ≤ V3 ≤ 3.5V, (Note 4)</td>
<td>-0.2</td>
<td>-0.6</td>
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<td>mA</td>
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<td>I0↑</td>
<td>Output Source Current</td>
<td>0.5V ≤ V3 ≤ 3.5V, (Note 4)</td>
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<td>mA</td>
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<td>OUTPUT SECTION</td>
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<tr>
<td>VCE(sat)</td>
<td>Output Saturation Voltage</td>
<td>Common Emitter Configuration (Figure 3)</td>
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<td></td>
<td>1.1</td>
<td>V</td>
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<td>Emitter Follower Configuration (Figure 4)</td>
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<td>1.5</td>
<td>V</td>
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<tr>
<td>IC(off)</td>
<td>Collector Off-State Current</td>
<td>VCC = 40V, VCE = 40V</td>
<td>2.0</td>
<td>100</td>
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<td>µA</td>
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<tr>
<td>IE(off)</td>
<td>Emitter Off-State Current</td>
<td>VCC = VCE = 40V, VE = 0</td>
<td>-100</td>
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<td></td>
<td>µA</td>
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<td>OUTPUT CONTROL (Figure 6)</td>
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<tr>
<td>VOCL</td>
<td>Output Control Voltage</td>
<td>Required for Single Ended or Parallel Operation</td>
<td>0.4</td>
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<td>V</td>
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<td>VOCH</td>
<td>Output Control Voltage</td>
<td>Required for Push-Pull Operation</td>
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<td></td>
<td>V</td>
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<td>TOTAL DEVICE</td>
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<tr>
<td>ICC</td>
<td>Standby Power Supply Current</td>
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<td>6.0</td>
<td>10</td>
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<td>mA</td>
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<td>OUTPUT AC CHARACTERISTICS Use Recommended Operating Conditions with TA = 25°C</td>
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<td>Rise Time of Output Voltage</td>
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<td>ns</td>
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<td>Emitter Follower Configuration (Figure 4)</td>
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<td>200</td>
<td></td>
<td>ns</td>
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<td>tf</td>
<td>Fall Time of Output Voltage</td>
<td>Common Emitter Configuration (Figure 3)</td>
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<td>100</td>
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<td>Emitter Follower Configuration (Figure 4)</td>
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<td>100</td>
<td></td>
<td>ns</td>
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</tbody>
</table>

**Note 1:** TJ\(_{Max}\) = 150°C for the Molded DIP, and 175°C for the Ceramic DIP.

**Note 2:** Ratings apply to ambient temperature at 25°C. Above this temperature, derate the 16L-Ceramic DIP at 10 mW/°C, and the 16L-Molded DIP at 8.3 mW/°C.

**Note 3:** Selected devices with tightened tolerance reference voltage available.

**Note 4:** These limits apply when the voltage measured at Lead 3 is within the range specified.
Functional Description

The basic oscillator (switching) frequency is controlled by an external resistor (R_T) and capacitor (C_T). The relationship between the values of R_T, C_T and frequency is shown in Figure 10.

The level of the sawtooth waveform is compared with an error voltage by the pulse width modulated comparator. The output of the PWM Comparator directs the pulse steering flip-flop and the output control logic.

The error voltage is generated by the error amplifier. The error amplifier boosts the voltage difference between the output and the 5.0V internal reference. See Figure 7 for error amp sensing techniques. The second error amp is typically used to implement current-limiting.

The output control logic selects either push-pull or single-ended operation of the output transistors (see Figure 6).

The dead time control prevents on-state overlap of the output transistors as can be seen in Figure 5. The dead time is approximately 3.0% or 5.0% of the total period if the dead time control is grounded. This dead time can be increased by connecting the dead time control to a voltage up to 5.0V.

The frequency response of the error amps (Figure 11) can be modified by using external resistors and capacitors. These components are typically connected between the compensation terminal and the inverting input of the error amps.

The switching frequency of two or more LM494 circuits can be synchronized. The timing capacitor, C_T, is connected as shown in Figure 8. Charging current is provided by the master circuit. Discharging current is provided by the master circuit. R_T is required only for the master circuit.

Test Circuits

Test Circuits

Test Circuits

Test Circuits

Test Circuits

Test Circuits

Test Circuits
Typical Applications

**FIGURE 6. Output Connections for Single Ended and Push-Pull Configurations**

**FIGURE 7. Error Amplifier Sensing Techniques**

**FIGURE 8. Slaving Two or More Control Circuits**
Typical Applications (Continued)

FIGURE 9. Error Amplifier and Current Limit Sense Amplifier Output Circuits

Typical Performance Characteristics

FIGURE 10. Oscillator Frequency vs Timing Resistance

FIGURE 11. Amplifier Voltage Gain vs Frequency
Voltage Waveforms

Physical Dimensions inches (millimeters)

16-Lead Ceramic Dual-In-Line Package (J)
Order Number LM494CJ
NS Package Number J16A
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