National Semiconductor

June 1989

LM494
Pulse Width Modulated Control Circuit

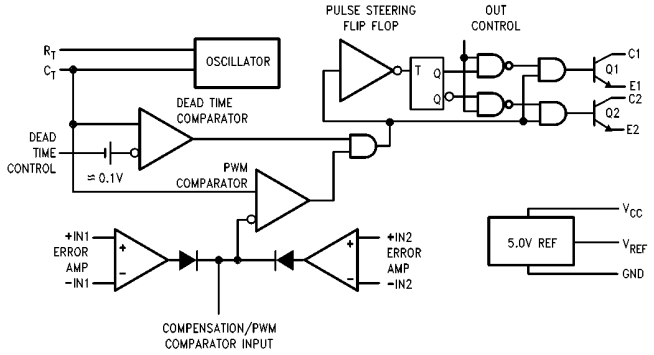
General Description

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

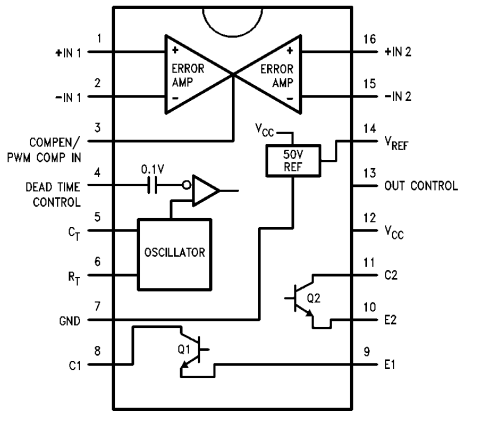
Block Diagram



TL/H/10056–2

Connection Diagram

16-Lead DIP



TL/H/10056–1

Top View

Ordering Information

Device Code	Package Code	Package Description
LM494IN	N16A	Molded DIP
LM494CJ	J16A	Ceramic DIP
LM494CN	N16A	Molded DIP

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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	
Ceramic DIP	−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 (except Lead 8 and Lead 11)	V_{CC} + 0.3V
Output Collector Voltage	42V
Peak Collector Current (I_{C1} and I_{C2})	250 mA
ESD Susceptibility	(to be determined)

Recommended Operating Conditions

Power Supply Voltage (V_{CC})	7.0V to 40V
Voltage on Any Lead except Leads 8 and 11 (Referenced to Ground) (V_I)	−0.3V to V_{CC} + 0.3V
Output Voltage Collector (V_{C1}, V_{C2})	−0.3V to 40V
Output Collector Current (I_{C1}, I_{C2})	200 mA
Timing Capacitor (C_T)	470 pF to 10 μF
Timing Resistor (R_T)	1.8 kΩ to 500 kΩ
Oscillator Frequency (f_{OSC})	1.0 kHz to 300 kHz

LM494

Electrical Characteristics

T_A = 0°C to +70°C for the LM494C, T_A = −40°C to +85°C for the LM494I, V_{CC} = 15V, f_{OSC} = 10 kHz, unless otherwise specified

Symbol	Parameter	Conditions		Min	Typ	Max	Units
REFERENCE SECTION							
V_{REF}	Reference Voltage (Note 3)	I_{REF} = 1.0 mA		4.75	5.0	5.25	V
Reg_{LINE}	Line Regulation of Reference Voltage	7.0V ≤ V_{CC} ≤ 40V			2.0	25	mV
TCV_{REF}	Temperature Coefficient of Reference Voltage	0°C ≤ T_A ≤ 70°C			0.01	0.03	%/°C
Reg_{LOAD}	Load Regulation of Reference Voltage	1.0 mA ≤ I_{REF} ≤ 10 mA			1.0	15	mV
I_{OS}	Output Short Circuit Current	V_{REF} = 0V	0°C ≤ T_A ≤ +70°C	10	35	50	mA
			−40°C ≤ T_A ≤ +85°C		35		
OSCILLATOR SECTION							
f_{OSC}	Oscillator Frequency *(Figure 10)*	C_T = 0.01 μF, R_T = 12 kΩ			10		kHz
Δf_{OSC}	Oscillator Frequency Change	C_T = 0.01 μF, R_T = 12 kΩ	0°C ≤ T_A ≤ +70°C			2.0	%
			−40°C ≤ T_A ≤ +85°C			2.0	
DEAD TIME CONTROL SECTION							
$I_{IB\ (DT)}$	Input Bias Current	V_{CC} = 15V, 0V ≤ V_4 ≤ 5.25V			−2.0	−10	μA
$DC_{(Max)}$	Maximum Duty Cycle, Each Output	V_{CC} = 15V, Lead 4 = 0V, Output Control = V_{REF}		45			%
$V_{TH(in)}$	Input Threshold Voltage	Zero Duty Cycle			3.0	3.3	V
		Maximum Duty Cycle		0			
ERROR AMPLIFIER SECTIONS							
V_{IO}	Input Offset Voltage	V_3 = 2.5V			2.0	10	mV
I_{IO}	Input Offset Current	V_3 = 2.5V			25	250	nA
I_{IB}	Input Bias Current	V_3 = 2.5V			0.2	1.0	μA
V_{ICR}	Input Common Mode Voltage Range	7.0V ≤ V_{CC} ≤ 40V		−0.3		V_{CC}	V
A_{VS}	Large Signal Voltage Gain	0.5V ≤ V_3 ≤ 3.5V		60	74		dB
BW	Bandwidth				650		kHz

LM494

Electrical Characteristics $T_A = 0°C$ to $+70°C$ for the LM494C, $T_A = -40°C$ to $+85°C$ for the LM494I, $V_{CC} = 15V$, $f_{OSC} = 10$ kHz, unless otherwise specified (Continued)

Symbol	Parameter	Conditions		Min	Typ	Max	Units
PWM COMPARATOR SECTION *(Figure 9)*							
V_{THI}	Inhibit Threshold Voltage	Zero Duty Cycle			4.0	4.5	V
I_O^-	Output Sink Current (Note 4)	$0.5V \le V_3 \le 3.5V$		−0.2	−0.6		mA
I_O^+	Output Source Current (Note 4)	$0.5V \le V_3 \le 3.5V$		2.0			mA
OUTPUT SECTION							
$V_{CE(sat)}$	Output Saturation Voltage Common Emitter Configuration *(Figure 3)*	$V_E = 0V$, $I_C = 200$ mA	$0°C \le T_A \le +70°C$ $-40°C \le T_A \le +85°C$		1.1	1.3	V
	Emitter Follower Configuration *(Figure 4)*	$V_C = 15V$, $I_E = 200$ mA			1.5	2.5	
$I_{C(off)}$	Collector Off-State Current	$V_{CC} = 40V$, $V_{CE} = 40V$			2.0	100	μA
$I_{E(off)}$	Emitter Off-State Current	$V_{CC} = V_C = 40V$, $V_E = 0$	$0°C \le T_A \le +70°C$, $-40°C \le T_A \le +85°C$			−100	μA
OUTPUT CONTROL *(Figure 6)*							
V_{OCL}	Output Control Voltage Required for Single Ended or Parallel Output Operation					0.4	V
V_{OCH}	Output Control Voltage Required for Push-Pull Operation			2.4			V
TOTAL DEVICE							
I_{CC}	Standby Power Supply Current				6.0	10	mA
OUTPUT AC CHARACTERISTICS Use Recommended Operating Conditions with $T_A = 25°C$							
t_r	Rise Time of Output Voltage Common Emitter Configuration *(Figure 3)*				100	200	ns
	Emitter Follower Configuration *(Figure 4)*				100	200	
t_f	Fall Time of Output Voltage Common Emitter Configuration *(Figure 3)*				25	100	ns
	Emitter Follower Configuration *(Figure 4)*				40	100	

Note 1: $T_{J\,Max} = 150°C$ 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 wave form 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.

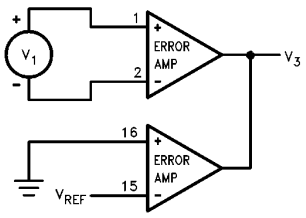
The output control logic selects either push-pull or single-ended operation of the output transistors (see *Figure 6*).

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.

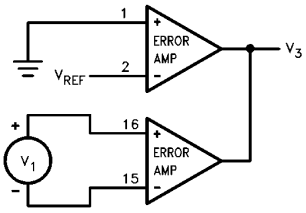
The switching frequency of two or more LM494 circuits can be synchronized. The timing capacitor, C_T, is connected as shown in *Figure 8*. Charging current is provided by the master circuit. Discharging is through all the circuits slaved to the master. R_T is required only for the master circuit.

Test Circuits



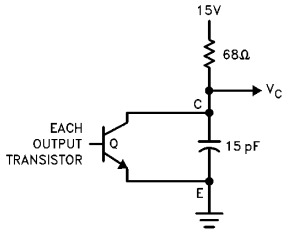
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FIGURE 1. Error Amplifier Test Circuit

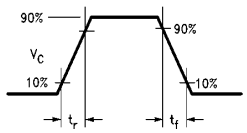


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FIGURE 2. Current Limit Sense Amplifier Test Circuit

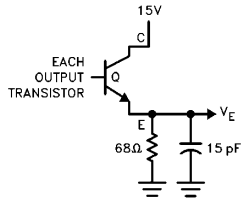


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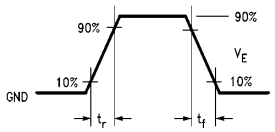


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FIGURE 3. Common Emitter Configuration Test Circuit and Waveform

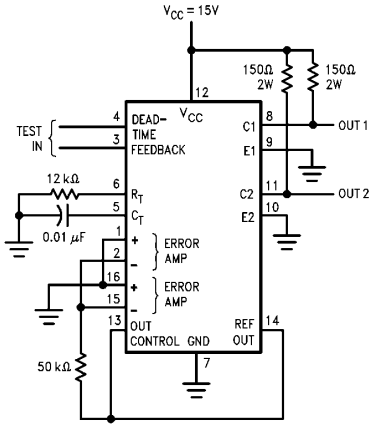


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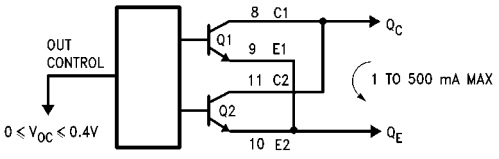
FIGURE 4. Emitter Follower Configuration Test Circuit and Waveform



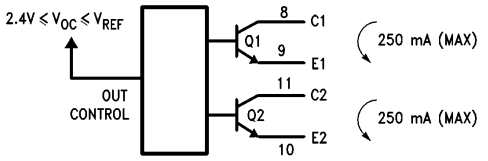
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FIGURE 5. Dead Time and Feedback Control Test Circuit

Typical Applications

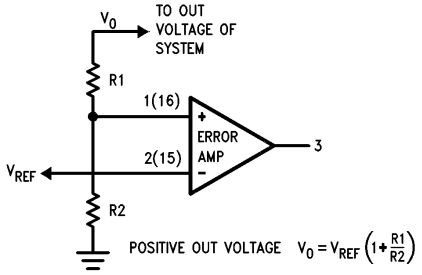


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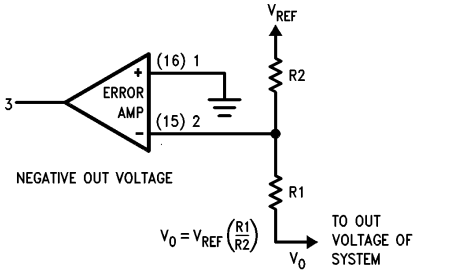


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FIGURE 6. Output Connections for Single Ended and Push-Pull Configurations

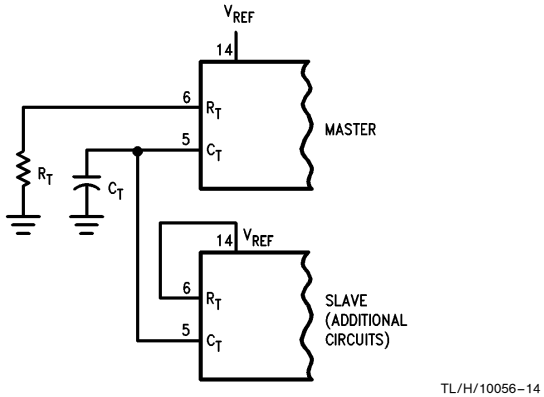


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TL/H/10056–13

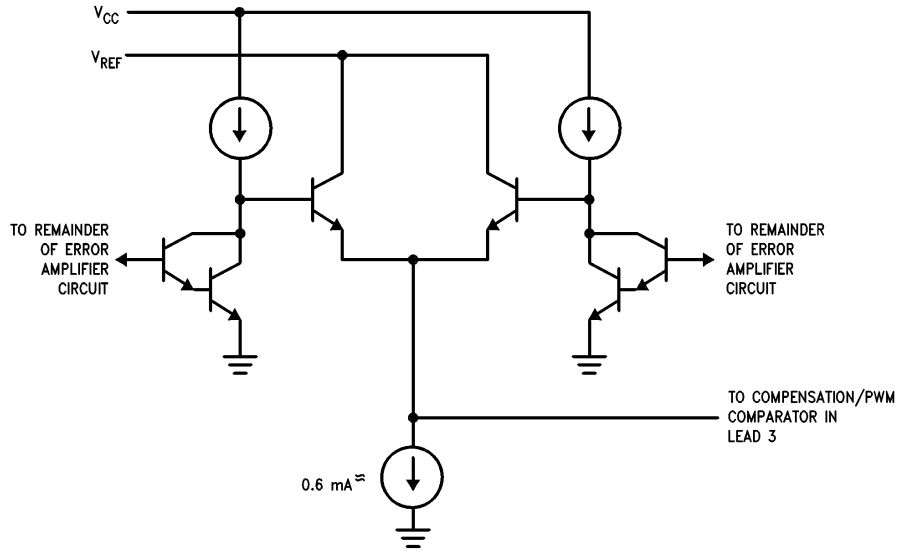
FIGURE 7. Error Amplifier Sensing Techniques



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FIGURE 8. Slaving Two or More Control Circuits

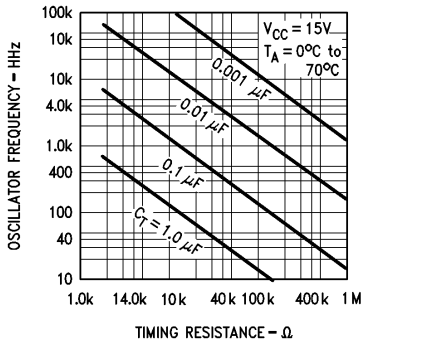
Typical Applications (Continued)



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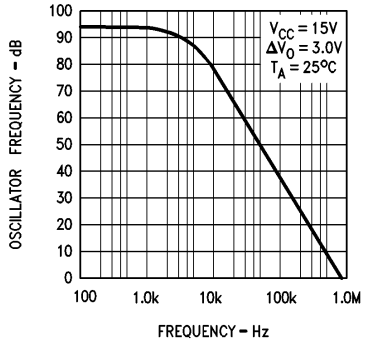
FIGURE 9. Error Amplifier and Current Limit Sense Amplifier Output Circuits

Typical Performance Characteristics



TL/H/10056–16

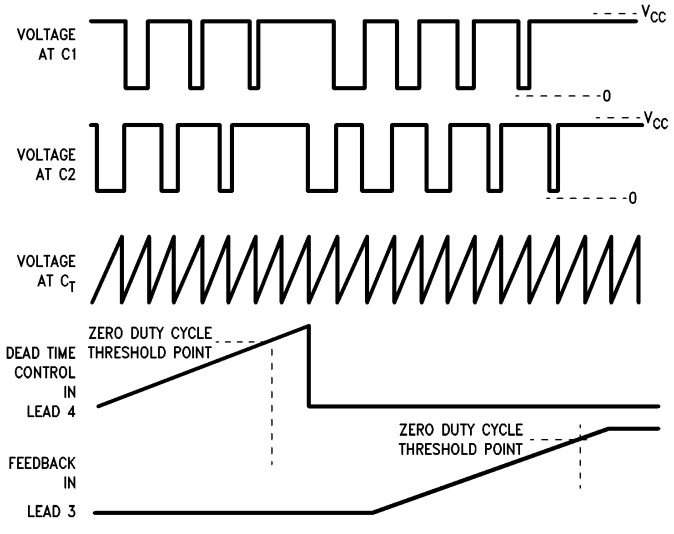
FIGURE 10. Oscillator Frequency vs Timing Resistance



TL/H/10056–17

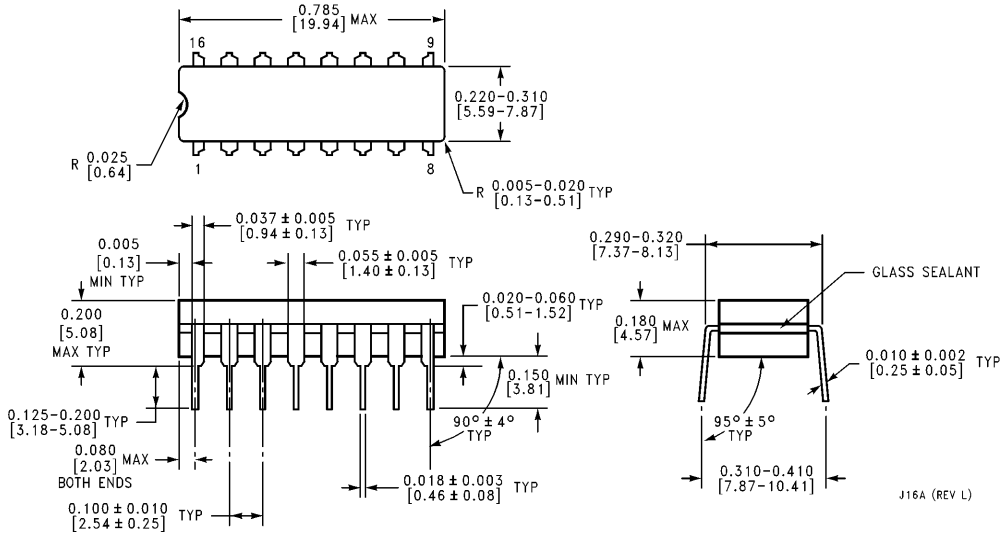
FIGURE 11. Amplifier Voltage Gain vs Frequency

Voltage Waveforms



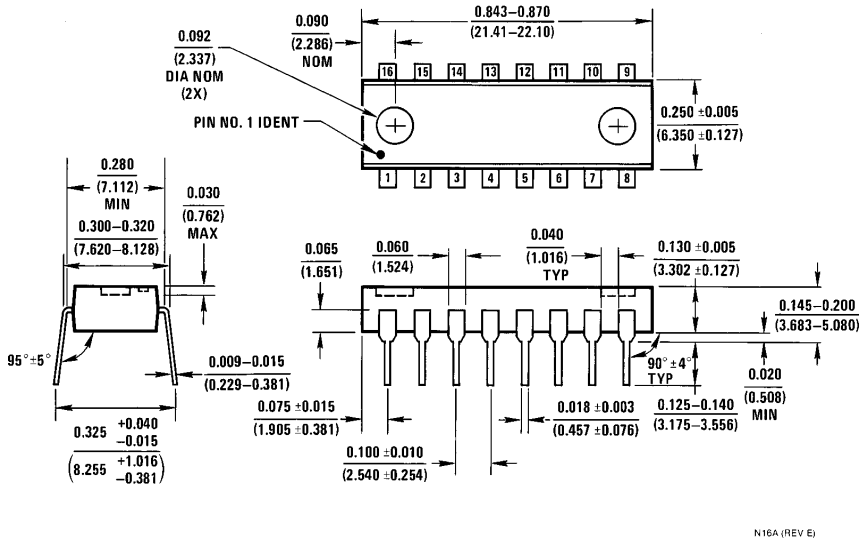
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Physical Dimensions inches (millimeters)



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

Physical Dimensions inches (millimeters) (Continued)



16-Lead Molded Dual-In-Line Package (N)
Order Number LM494CN or LM494IN
NS Package Number N16A

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