

## SWITCHING REGULATOR CONTROL CIRCUIT

### DESCRIPTION

The  $\mu$ PC494 is an inverter control unit which provides all the control circuitry for PWM type switching regulators. Included in this device is the voltage reference, dual error amplifiers, oscillator, pulse width modulator, pulse steering flip flop, dual alternating output switches and dead-time control.

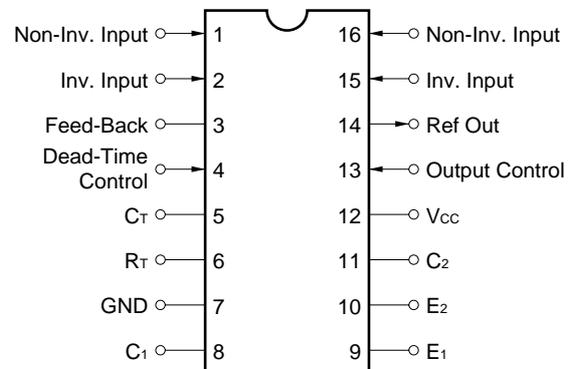
### FEATURES

- Complete PWM power control circuit.
- Adjustable dead-time (0 to 100%).
- No double pulsing of same output during load transient condition.
- Dual error amplifiers have wide common mode input voltage capability ( $-0.3$  V to  $V_{CC}-2$  V).
- Circuit architecture provides easy synchronization.
- Uncommitted outputs for 250-mA sink or source.
- With miss-operation prevention circuit for low level supply voltage.
- Full pin-compatible TL494C.

### ★ ORDERING INFORMATION

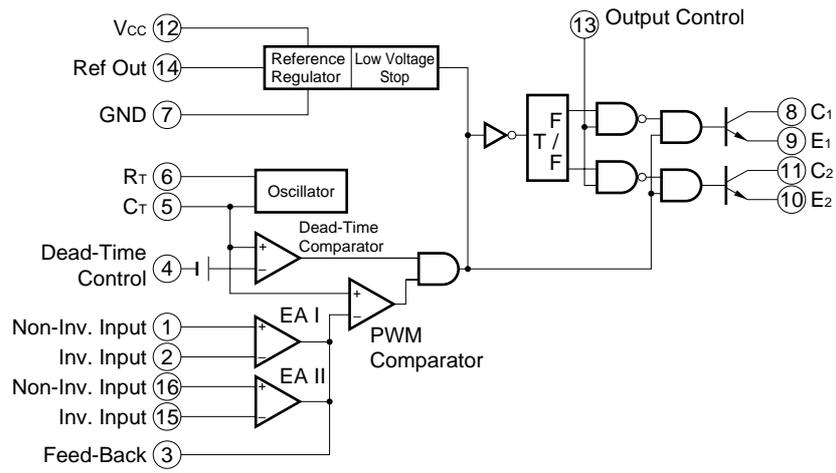
Part Number	Package
$\mu$ PC494C	16-pin plastic DIP (7.62 mm (300))
$\mu$ PC494G	16-pin plastic SOP (9.53 mm (375))
$\mu$ PC494GS	16-pin plastic SOP (7.62 mm (300))

### ★ PIN CONFIGURATION (Top View)



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BLOCK DIAGRAM



★ **ABSOLUTE MAXIMUM RATINGS (T<sub>A</sub> = 25°C, unless otherwise noted)**

Characteristics	Symbol	μPC494C	μPC494G	μPC494GS	Unit
Supply Voltage	V <sub>CC</sub>	-0.3 to +41	-0.3 to +41	-0.3 to +41	V
Error Amplifier Input Voltage	V <sub>ICM</sub>	-0.3 to V <sub>CC</sub> + 0.3	-0.3 to V <sub>CC</sub> + 0.3	-0.3 to V <sub>CC</sub> + 0.3	V
Output Voltage	V <sub>CER</sub>	-0.3 to +41	-0.3 to +41	-0.3 to +41	V
Output Current	I <sub>C</sub>	250	250	250	mA
Total Power Dissipation	P <sub>T</sub>	1000	780 <sup>Note</sup>	650 <sup>Note</sup>	mW
Operating Ambient Temperature	T <sub>A</sub>	-20 to +85	-20 to +85	-20 to +85	°C
Storage Temperature	T <sub>stg</sub>	-65 to +150	-65 to +150	-65 to +150	°C

**Note** With 25 cm<sup>2</sup> x 1.6 mm glass-epoxy substrate.

- ★ **Caution** Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

**RECOMMENDED OPERATING CONDITIONS**

Characteristics	Symbol	MIN.	TYP.	MAX.	Unit
Supply Voltage	V <sub>CC</sub>	7		40	V
Output Voltage	V <sub>CER</sub>	-0.3		40	V
Output Current	I <sub>C</sub>			200	mA
Error Amplifier Sink Current	I <sub>OAMP</sub>			-0.3	mA
Timing Capacitor	C <sub>T</sub>	0.47		10000	nF
Timing Resistance	R <sub>T</sub>	1.8		500	kΩ
Oscillation Frequency	f <sub>OSC</sub>	1		300	kHz
Operating Temperature	T <sub>opt</sub>	-20		+70	°C

- ★ **Caution** The recommended operating range may be exceeded without causing any problems provided that the absolute maximum ratings are not exceeded. However, if the device is operated in a way that exceeds the recommended operating conditions, the margin between the actual conditions of use and the absolute maximum ratings is small, and therefore thorough evaluation is necessary. The recommended operating conditions do not imply that the device can be used with all values at their maximum values.

★ ELECTRICAL SPECIFICATIONS (V<sub>CC</sub> = 15 V, f = 10 kHz, -20 ≤ T<sub>A</sub> ≤ +70°C, unless otherwise noted)

(1/2)

Block	Characteristics		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Reference Section	Output Voltage		V <sub>REF</sub>	I <sub>REF</sub> = 1 mA, T <sub>A</sub> = 25°C	4.75	5	5.25	V
	Line Regulation		REG <sub>IN</sub>	7 V ≤ V <sub>CC</sub> ≤ 40 V, I <sub>REF</sub> = 1 mA, T <sub>A</sub> = 25°C		8	25	mV
	Load Regulation		REG <sub>L</sub>	1 mA ≤ I <sub>REF</sub> ≤ 10 mA, T <sub>A</sub> = 25°C		1	15	mV
	Temperature Coefficient		ΔV <sub>REF</sub> / ΔT	-20°C ≤ T <sub>A</sub> ≤ +85°C, I <sub>REF</sub> = 1 mA		0.01	0.03	%/°C
	Short Circuit Output Current <sup>Note1</sup>		I <sub>SHORT</sub>	V <sub>REF</sub> = 0 V		50		mA
Oscillator Section	Frequency		f <sub>OSC</sub>	C <sub>T</sub> = 0.01 μF, R <sub>T</sub> = 12 kΩ, T <sub>A</sub> = 25°C		10		kHz
	Standard Deviation of Frequency <sup>Note2</sup>			7 V ≤ V <sub>CC</sub> ≤ 40 V, T <sub>A</sub> = 25°C, C <sub>T</sub> , R <sub>T</sub> , const.		10		%
	Frequency Change with Temperature			0°C ≤ T <sub>A</sub> ≤ 70°C, C <sub>T</sub> = 0.01 μF, R <sub>T</sub> = 12 kΩ		1	2	%
	Frequency Change with Voltage			7 V ≤ V <sub>CC</sub> ≤ 40 V, T <sub>A</sub> = 25°C, C <sub>T</sub> = 0.01 μF, R <sub>T</sub> = 12 kΩ		1		%
Dead-Time Control Section	Input Bias Current			0 V ≤ V <sub>I</sub> ≤ 5.25 V		-2	-10	μA
	Maximum Duty Cycle (Each Output)			V <sub>I</sub> = 0 V	45	49		%
	Input Threshold Voltage 1		V <sub>TH1</sub>	Output pulse 0% duty cycle		3	3.3	V
	Input Threshold Voltage 2		V <sub>TH2</sub>	Output pulse maximum duty cycle	0			V
Error Amplifier Section	Input Offset Voltage		V <sub>IO</sub>	V <sub>OAMP</sub> = 2.5 V		2	10	mV
	Input Offset Current		I <sub>IO</sub>	V <sub>OAMP</sub> = 2.5 V		25	250	nA
	Input Bias Current			V <sub>OAMP</sub> = 2.5 V		0.2	1	μA
	Common Mode Input Voltage	Low	V <sub>ICM</sub>	7 V ≤ V <sub>CC</sub> ≤ 40 V	-0.3			V
		High			V <sub>CC</sub> -2			
	Open Loop Voltage Amplification		A <sub>V</sub>	V <sub>OAMP</sub> = 0.5 to 3.5 V, T <sub>A</sub> = 25°C	60	80		dB
	Unity Gain Bandwidth			T <sub>A</sub> = 25°C	500	830		kHz
	Common Mode Rejection Ratio		CMR	V <sub>CC</sub> = 40 V, T <sub>A</sub> = 25°C	65	80		dB
	Output Sink Current			V <sub>OAMP</sub> = 0.7 V	0.3	0.7		mA
Output Source Current			V <sub>OAMP</sub> = 3.5 V	-2	-10		mA	
PWM Section	Input Threshold Voltage (3-pin)			Output pulse 0% duty cycle, see <b>Figure 1</b> .		4	4.5	V
	Input Sink Current			V <sub>(pin 3)</sub> = 0.7 V	0.3	0.7		mA

**Remark** The TYP. values are values at T<sub>A</sub> = 25°C, except for the characteristics of temperature.

Block	Characteristics		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output Section	Collector Cut-off Current		$I_{CER}$	$V_{CE} = 40\text{ V}, V_{CC} = 40\text{ V},$ Common Emitter			100	μA
	Emitter Cut-off Current			$V_{CC} = V_C = 40\text{ V}, V_E = 0\text{ V},$ Emitter Follower			-100	μA
	Collector Saturation Voltage	Common Emitter	$V_{CE(sat)}$	$I_C = 200\text{ mA}, V_E = 0\text{ V}$		0.95	1.3	V
		Emitter Follower	$V_{CE(ON)}$	$I_E = -200\text{ mA}, V_C = 15\text{ V}$		1.6	2.5	V
	Output Voltage Rise Time	Common Emitter	$t_{r1}$	$V_{CC} = 15\text{ V}, R_L = 150\ \Omega,$ $I_C \cong 100\text{ mA}, T_A = 25^\circ\text{C},$		100	200	ns
	Output Voltage Fall Time		$t_{f1}$	see <b>Figure 1.</b>		70	200	ns
	Output Voltage Rise Time	Emitter Follower	$t_{r2}$	$V_C = 15\text{ V}, R_L = 150\ \Omega,$ $I_E \cong 100\text{ mA}, T_A = 25^\circ\text{C},$		100	200	ns
	Output Voltage Fall Time		$t_{f2}$	see <b>Figure 1.</b>		70	200	ns
Total Device	Standby Current		$I_{CC(S.B)}$	$V_{CC} = 15\text{ V},$ all other pins open.		8	12.5	mA
	Bias Current		$I_{CC(BI)}$	$V_{(pin\ 4)} = 2\text{ V},$ see <b>Figure 1.</b>		10		mA

**Remark** The TYP. values are values at  $T_A = 25^\circ\text{C}$ , except for the characteristics of temperature.

**Notes 1.** The short circuit output current flows for no more than 1 second. Repeat operation is possible if the internal heat accumulation is not within a harmful range.

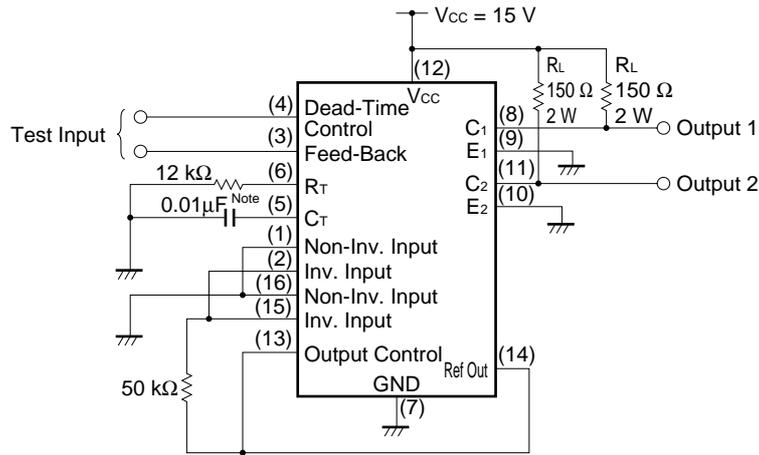
**2.** Standard deviation is a measure of the statistical distribution about the mean as derived from the formula ;

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (X_n - \bar{X})^2}{N - 1}}$$

Calculation expression of frequency  $f_{osc}$  is as follows ;

$$f_{osc} \cong \frac{1}{0.817 R_T \cdot C_T + 1.42 \cdot 10^{-6}} \text{ (Hz)} \quad [R_T] = \Omega, [C_T] = F$$

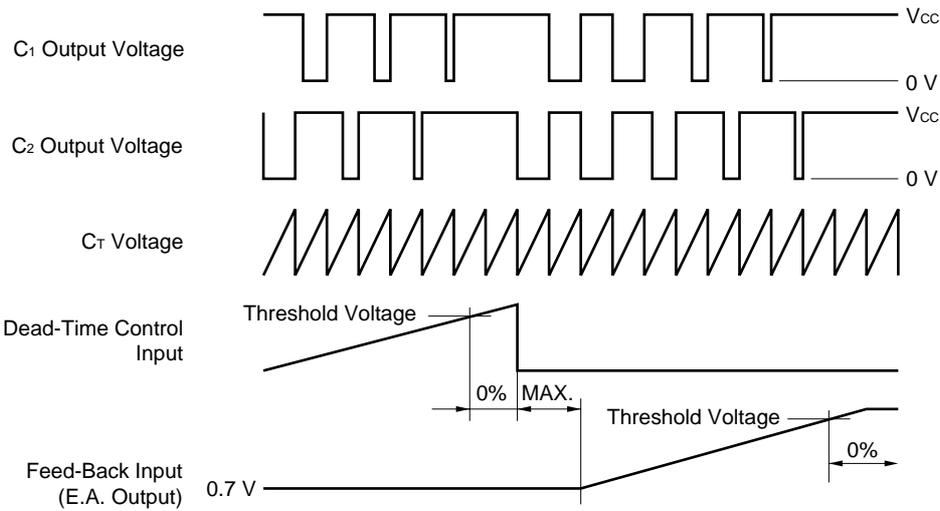
Figure1. Test Circuit



**Note** Recommend film capacitor.

★ **Caution** When the emitter follower is output, connect C<sub>1</sub> and C<sub>2</sub> to V<sub>cc</sub> and E<sub>1</sub> and E<sub>2</sub> to GND via R<sub>L</sub>.

Figure2. Voltage Waveform

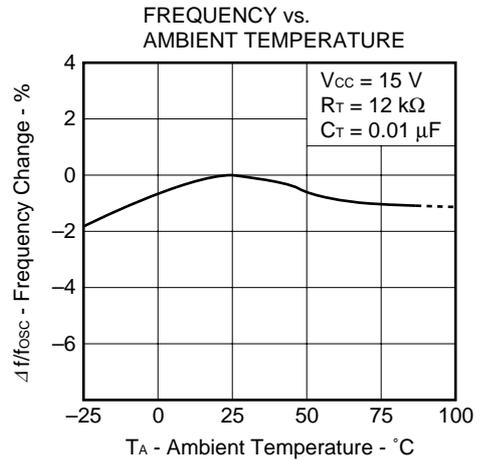
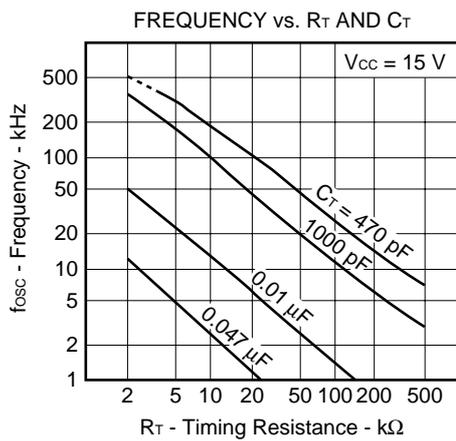
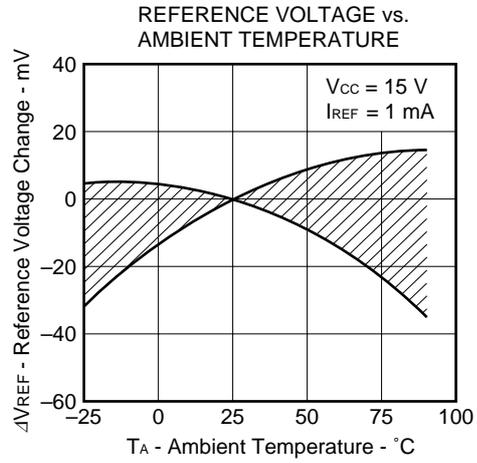
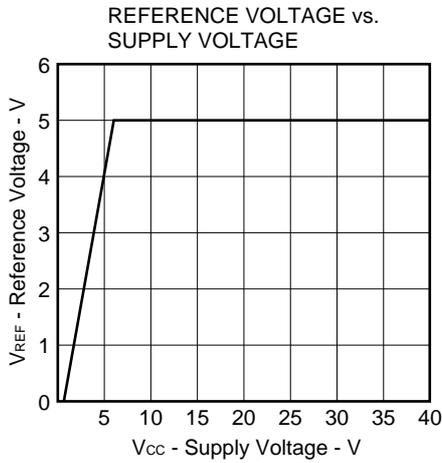
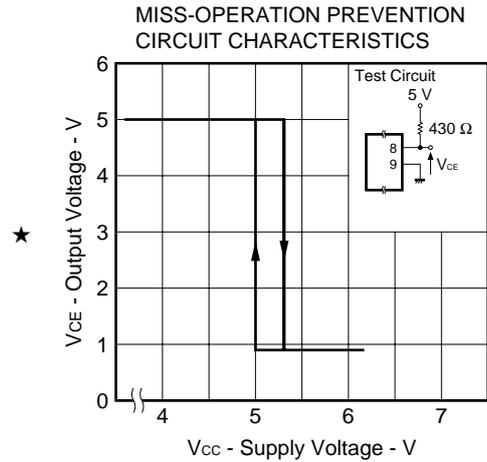
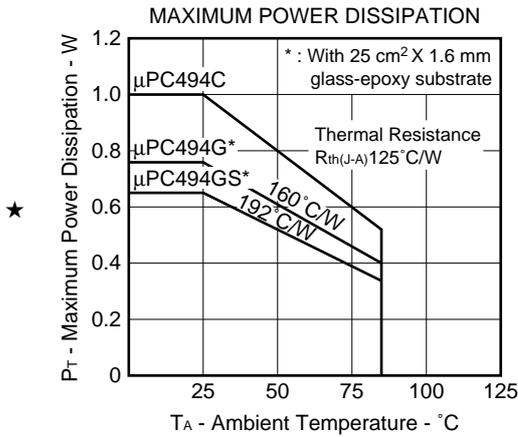


**Connection of Output Control Pin (Pin No.13)**

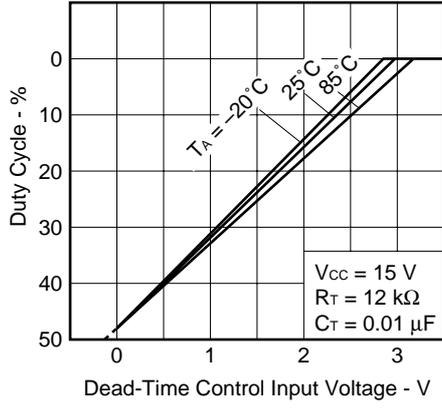
Output Control Input (Pin No.13)	Operation Mode
At Ref Out	Normal push-pull operation
Grounded	Single-ended or parallel output

TYPICAL PERFORMANCE CHARACTERISTICS

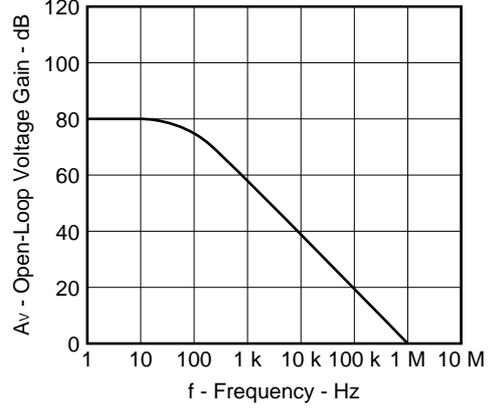
★ (Unless otherwise specified,  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 15\text{ V}$ , Reference)



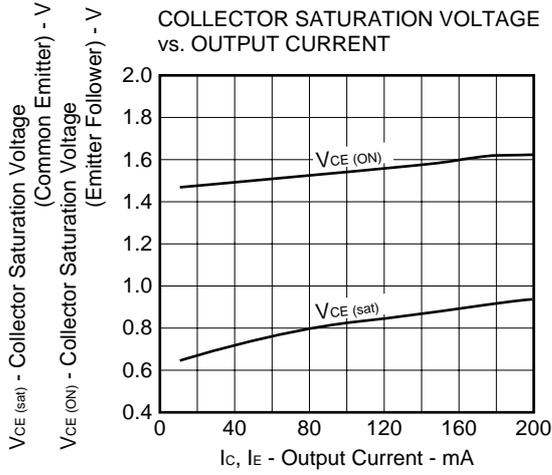
DUTY CYCLE vs. DEAD-TIME CONTROL INPUT VOLTAGE



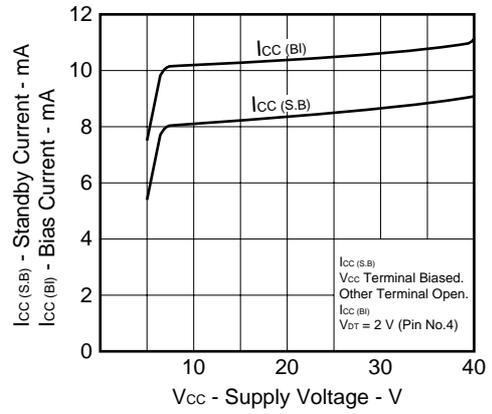
OPEN-LOOP VOLTAGE GAIN vs. FREQUENCY



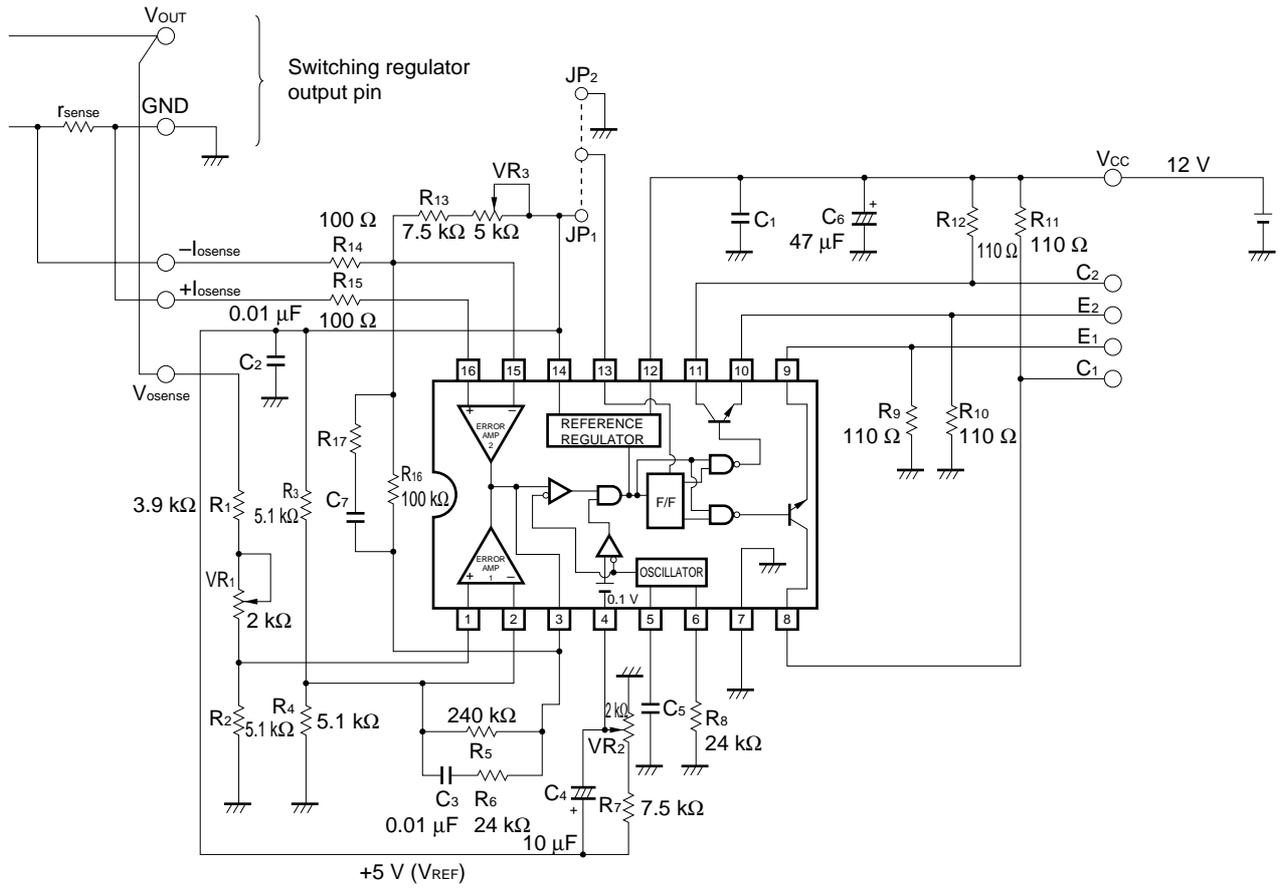
COLLECTOR SATURATION VOLTAGE vs. OUTPUT CURRENT



STANDBY AND BIAS CURRENT vs. SUPPLY VOLTAGE



BASIC APPLICATION CIRCUIT

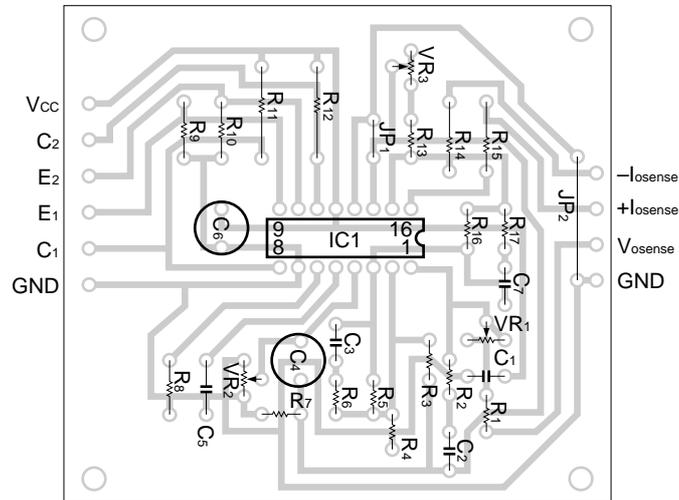


★ Remark  $f_{osc} \cong 40$  kHz, C<sub>5</sub> = 1000 pF (Recommend film capacitor)

CONNECTION DIAGRAM

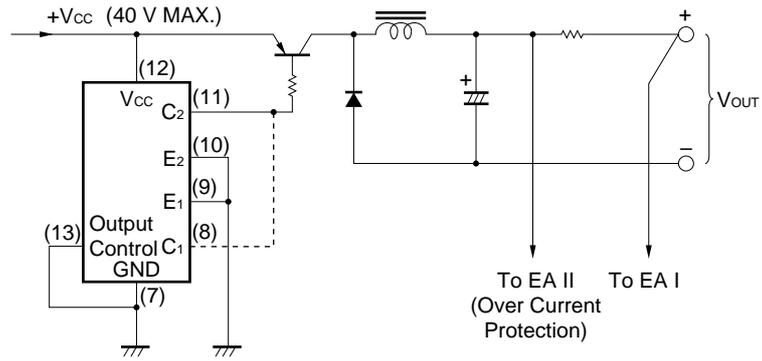
Operation Mode	Output Control Input (Pin No.13)	Output Mode	Output Voltage Waveform
Push-pull operation	At Ref-out (JP1 Wired)	Open collector ( $R_9, R_{10} 0\Omega$ )	C <sub>1</sub>  C <sub>2</sub> 
		Emitter follower ( $R_{11}, R_{12} 0\Omega$ )	E <sub>1</sub>  E <sub>2</sub> 
Single-ended or parallel output	Grounded (JP2 Wired)	Open collector ( $R_9, R_{10} 0\Omega$ )	C <sub>1</sub> , C <sub>2</sub> 
		Emitter follower ( $R_{11}, R_{12} 0\Omega$ )	E <sub>1</sub> , E <sub>2</sub> 

Printed Pattern (Example of μPC494C) (Pattern side, Actual size)





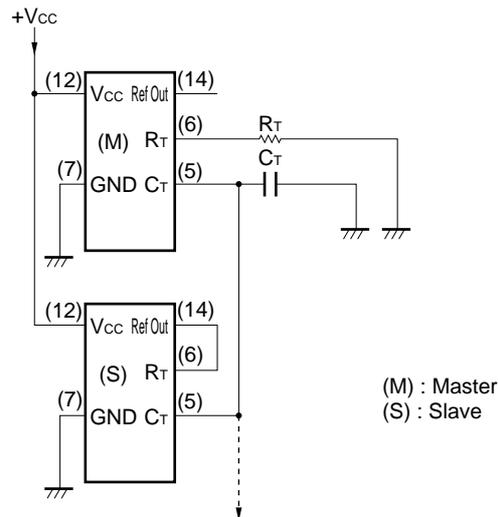
3) Step-down Chopper



**Remark** The dotted line indicates the connection in case of large current.

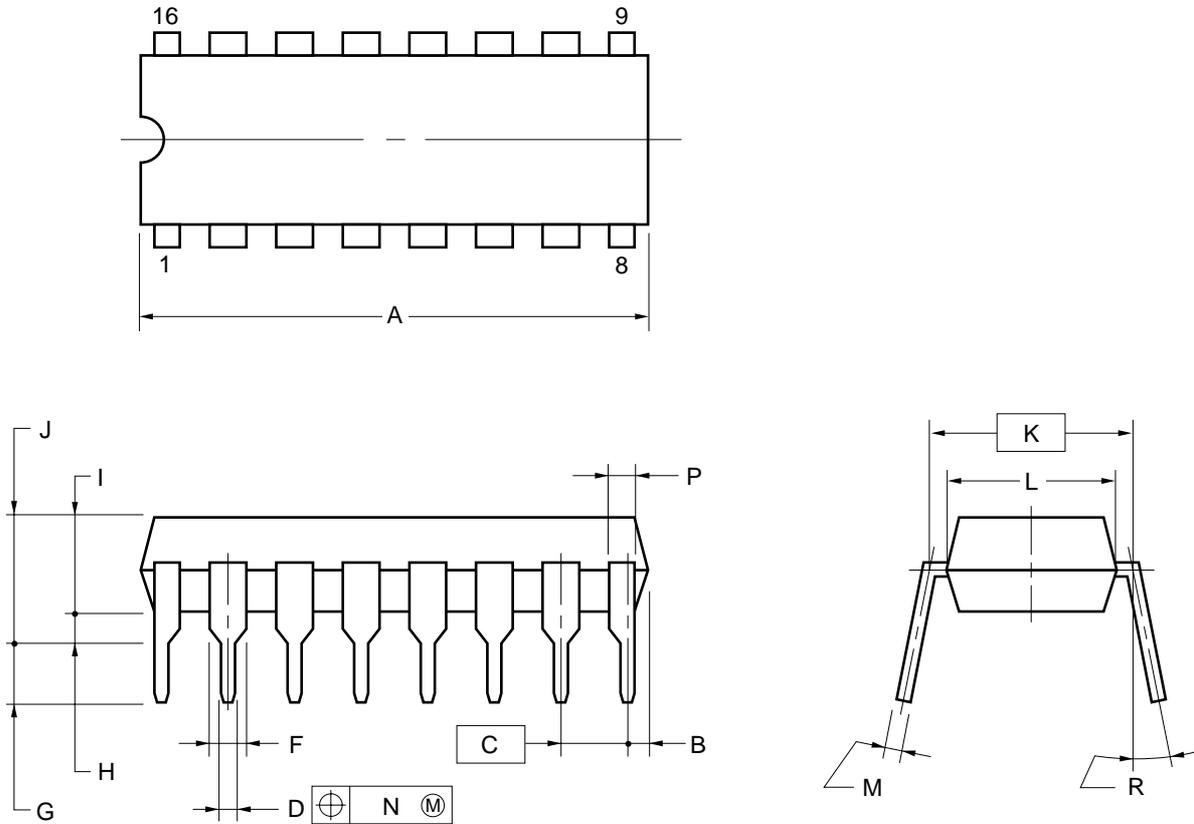
SYNCHRONIZED OPERATION

If synchronized operation is needed, master-slave circuit can be used. This circuit is shown below. Initially,  $R_T$  terminal of slave IC is connected to pin 14(Ref Out) and internal oscillator is stopped.



★ PACKAGE DRAWINGS (Unit : mm)

16-PIN PLASTIC DIP (7.62mm(300))



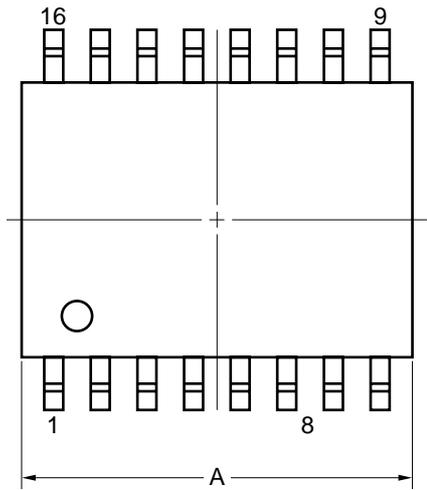
NOTES

1. Each lead centerline is located within 0.25 mm of its true position (T.P.) at maximum material condition.
2. Item "K" to center of leads when formed parallel.

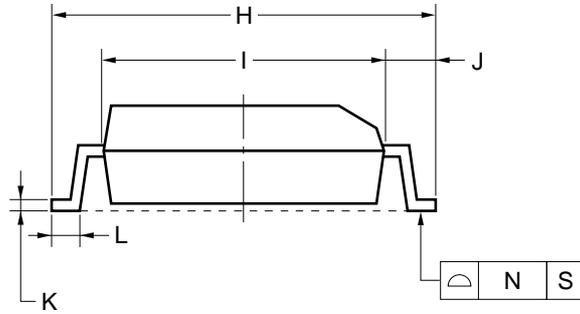
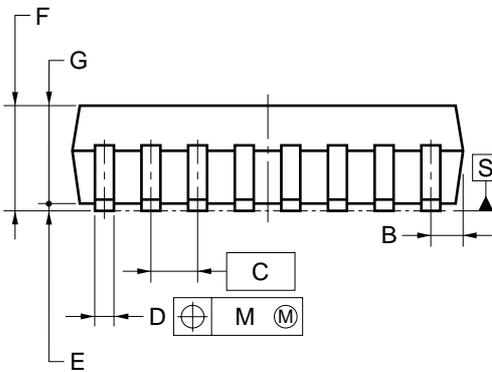
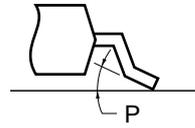
ITEM	MILLIMETERS
A	20.32 MAX.
B	1.27 MAX.
C	2.54 (T.P.)
D	0.50±0.10
F	1.1 MIN.
G	3.5±0.3
H	0.51 MIN.
I	4.31 MAX.
J	5.08 MAX.
K	7.62 (T.P.)
L	6.5
M	0.25 <sup>+0.10</sup> <sub>-0.05</sub>
N	0.25
P	1.1 MIN.
R	0~15°

P16C-100-300B-2

16-PIN PLASTIC SOP (9.53 mm (375))



detail of lead end



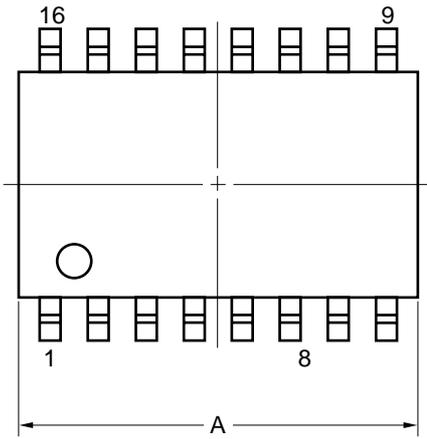
NOTE

Each lead centerline is located within 0.12 mm of its true position (T.P.) at maximum material condition.

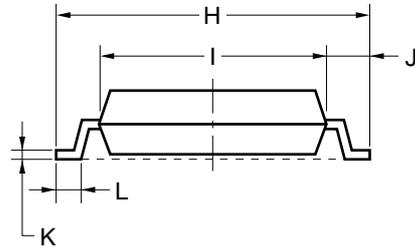
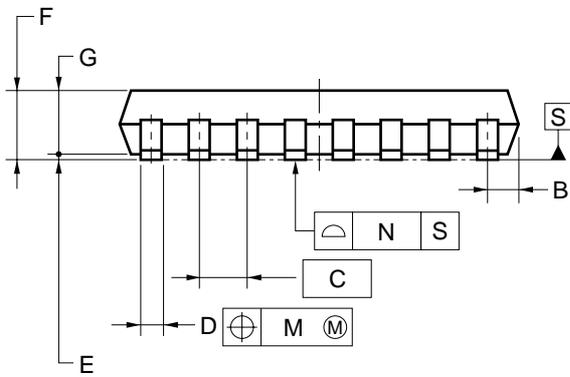
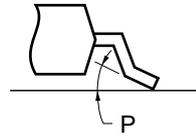
ITEM	MILLIMETERS
A	10.0±0.2
B	0.78 MAX.
C	1.27 (T.P.)
D	0.42 <sup>+0.08</sup> <sub>-0.07</sub>
E	0.125±0.075
F	2.77 MAX.
G	2.47±0.1
H	10.3±0.3
I	7.2
J	1.6
K	0.17 <sup>+0.08</sup> <sub>-0.07</sub>
L	0.8±0.2
M	0.12
N	0.15
P	3° <sup>+7°</sup> <sub>-3°</sub>

P16GM-50-375B-6

16-PIN PLASTIC SOP (7.62 mm (300))



detail of lead end



NOTE

Each lead centerline is located within 0.12 mm of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS
A	10.2±0.2
B	0.78 MAX.
C	1.27 (T.P.)
D	0.42 <sup>+0.08</sup> <sub>-0.07</sub>
E	0.1±0.1
F	1.65±0.15
G	1.55
H	7.7±0.3
I	5.6±0.2
J	1.1±0.2
K	0.22 <sup>+0.08</sup> <sub>-0.07</sub>
L	0.6±0.2
M	0.12
N	0.10
P	3° <sup>+7°</sup> <sub>-3°</sub>

P16GM-50-300B-6

★ RECOMMENDED SOLDERING CONDITIONS

When soldering this product, it is highly recommended to observe the conditions as shown below. If other soldering processes are used, or if the soldering is performed under different conditions, please make sure to consult with our sales offices.

For more details, refer to our document "SEMICONDUCTOR DEVICE MOUNTING TECHNOLOGY MANUAL"(C10535E).

Type of Through-hole Device

μPC494C: 16-pin plastic DIP (7.62 mm (300))

Process	Conditions
Wave Soldering (only to leads)	Solder temperature: 260°C or below, Flow time: 10 seconds or less.
Partial Heating Method	Pin temperature: 300°C or below, Heat time: 3 seconds or less (per each lead).

**Caution** For through-hole device, the wave soldering process must be applied only to leads, and make sure that the package body does not get jet soldered.

Type of Surface Mount Device

μPC494G: 16-pin plastic SOP (9.53 mm (375))

μPC494GS: 16-pin plastic SOP (7.62 mm (300))

Process	Conditions	Symbol
Infrared Ray Reflow	Peak temperature: 230°C or below (Package surface temperature), Reflow time: 30 seconds or less (at 210°C or higher), Maximum number of reflow processes: 1 time.	IR30-00-1
Vapor Phase Soldering	Peak temperature: 215°C or below (Package surface temperature), Reflow time: 40 seconds or less (at 200°C or higher), Maximum number of reflow processes: 1 time.	VP15-00-1
Wave Soldering	Solder temperature: 260°C or below, Flow time: 10 seconds or less, Maximum number of flow processes: 1 time, Pre-heating temperature: 120°C or below (Package surface temperature).	WS60-00-1
Partial Heating Method	Pin temperature: 300°C or below, Heat time: 3 seconds or less (Per each side of the device).	-

**Caution** Apply only one kind of soldering condition to a device, except for "partial heating method", or the device will be damaged by heat stress.

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