

# $\mu$ A78S40

## Universal Switching Regulator Subsystem

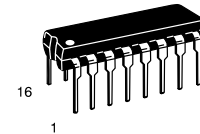
The  $\mu$ A78S40 is a switching regulator subsystem, consisting of a temperature compensated voltage reference, controlled-duty cycle oscillator with an active current limit circuit, comparator, high-current and high-voltage output switch, capable of 1.5 A and 40 V, pinned-out power diode and an uncommitted operational amplifier, which can be powered up or down independent of the IC supply. The switching output can drive external NPN or PNP transistors when voltages greater the 40 V, or currents in excess of 1.5 A, are required. Some of the features are wide-supply voltage range, low standby current, high efficiency and low drift. The  $\mu$ A78S40 is available in commercial (0° to + 70°C), and automotive (-40° to + 85°C) temperature ranges.

Some of the applications include use in step-up, step-down, and inverting regulators, with extremely good results obtained in battery-operated systems.

- Output Adjustable from 1.25 V to 40 V
- Peak Output Current of 1.5 A Without External Transistor
- 80 dB Line and Load Regulation
- Operation from 2.5 V to 40 V Supply
- Low Standby Current Drain
- High Gain, High Output Current, Uncommitted Op Amp

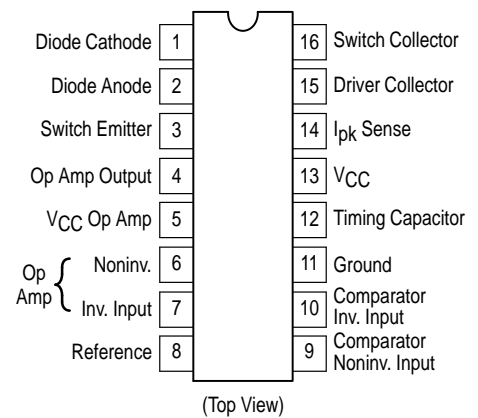
### UNIVERSAL SWITCHING REGULATOR SUBSYSTEM

#### SEMICONDUCTOR TECHNICAL DATA

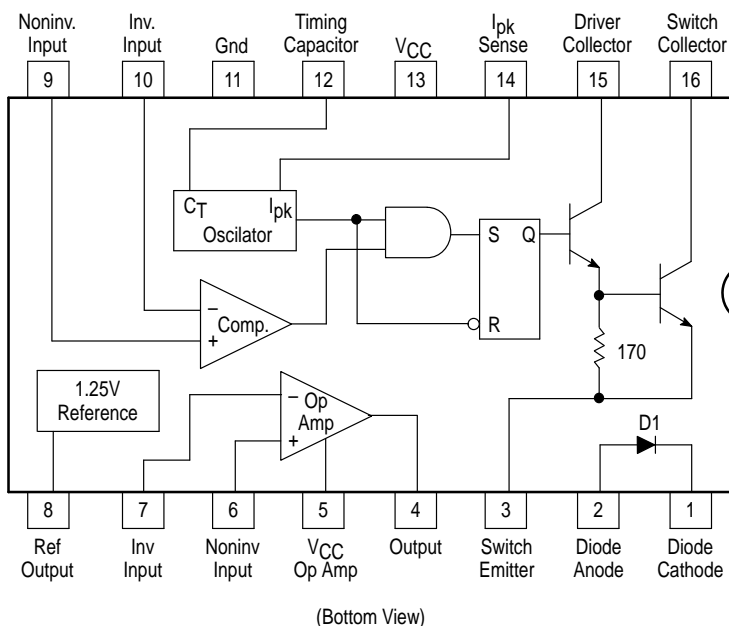


**P SUFFIX**  
PLASTIC PACKAGE  
CASE 648

### PIN CONNECTIONS



### Simplified Block Diagram



### ORDERING INFORMATION

Device	Temperature Range	Package
$\mu$ A78S40PC	$T_A = 0^\circ$ to $+70^\circ\text{C}$	Plastic
$\mu$ A78S40PV	$T_A = -40^\circ$ to $+85^\circ\text{C}$	Plastic

# μA78S40

## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Voltage	$V_{CC}$	40	V
Op Amp Power Supply Voltage	$V_{CC}$ (Op Amp)	40	V
Common Mode Input Range (Comparator and Op Amp)	$V_{ICR}$	-0.3 to $V_{CC}$	V
Differential Input Voltage (Note 2)	$V_{ID}$	$\pm 30$	V
Output Short Circuit Duration (Op Amp)		Continuous	-
Reference Output Current	$I_{ref}$	10	mA
Voltage from Switch Collectors to Gnd		40	V
Voltage from Switch Emitters to Gnd		40	V
Voltage from Switch Collectors to Emitter		40	V
Voltage from Power Diode to Gnd		40	V
Reverse-Power Diode Voltage	$V_{DR}$	40	V
Current through Power Switch	$I_{SW}$	1.5	A
Current through Power Diode	$I_D$	1.5	A
Power Dissipation and Thermal Characteristics: Plastic Package ( $T_A = +25^\circ\text{C}$ ) Derate above $+25^\circ\text{C}$ (Note 1)	$P_D$ $1/R_{\theta JA}$	1500 14	mW mW/ $^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	-65 to +150	$^\circ\text{C}$
Operating Temperature Range $\mu\text{A78S40V}$ $\mu\text{A78S40C}$	$T_A$	-40 to +85 0 to +70	$^\circ\text{C}$

- NOTES:** 1.  $T_{low} = -40^\circ$  for  $\mu\text{A78S40PV}$   $T_{high} = +85^\circ$  for  $\mu\text{A78S40PV}$   
 $= 0^\circ$  for  $\mu\text{A78S40PC}$   $= +70^\circ$  for  $\mu\text{A78S40PC}$   
 2. For supply voltages less than 30 V the maximum differential input voltage (Error Amp and Op Amp) is equal to the supply voltage.

## ELECTRICAL CHARACTERISTICS ( $V_{CC} = V_{CC}$ (Op Amp) 5.0 V, $T_A = T_{low}$ to $T_{high}$ , unless otherwise noted.)

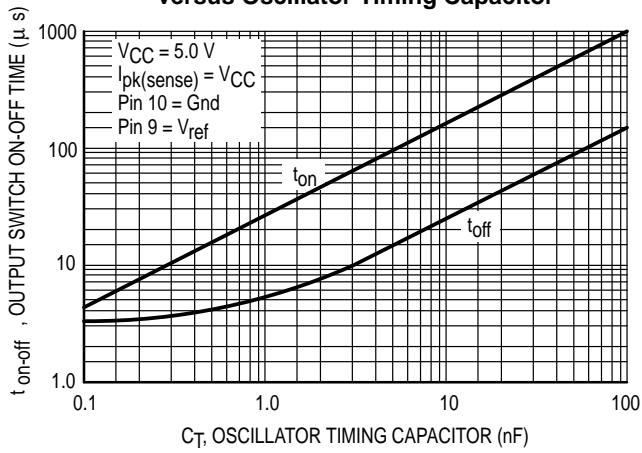
Characteristic	Symbol	Min	Typ	Max	Unit
<b>GENERAL</b>					
Supply Voltage	$V_{CC}$	2.5	-	40	V
Supply Current (Op Amp $V_{CC}$ , disconnected) ( $V_{CC} = 5.0$ V) ( $V_{CC} = 40$ V)	$I_{CC}$	- -	1.8 2.3	3.5 5.0	mA
Supply Current (Op Amp $V_{CC}$ , connected) ( $V_{CC} = 5.0$ V) ( $V_{CC} = 40$ V)	$I_{CC}$	- -	- -	4.0 5.5	mA
<b>REFERENCE</b>					
Reference Voltage ( $I_{ref} = 1.0$ mA)	$V_{ref}$	1.180	1.245	1.310	V
Reference Voltage Line Regulation ( $3.0$ V $\leq V_{CC} \leq 40$ V, $I_{ref} = 1.0$ mA, $T_A = 25^\circ\text{C}$ )	$Reg_{line}$	-	0.04	0.2	mV/V
Reference Voltage Load Regulation ( $1.0$ mA $\leq I_{ref} \leq 10$ mA, $T_A = 25^\circ\text{C}$ )	$Reg_{load}$	-	0.2	0.5	mV/mA

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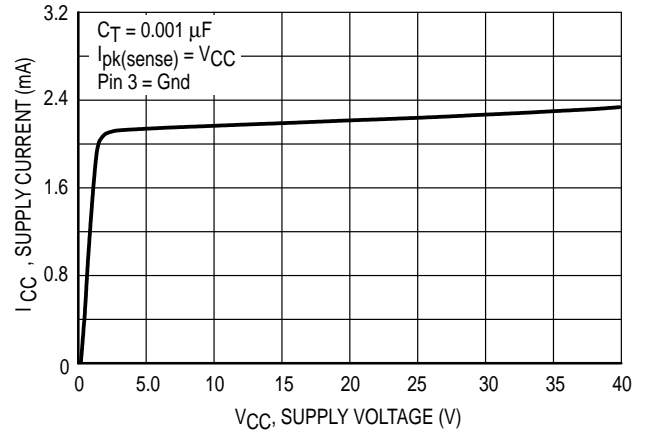
## ELECTRICAL CHARACTERISTICS ( $V_{CC} = V_{CC} \text{ (Op Amp)}$ 5.0 V, $T_A = T_{\text{low}}$ to $T_{\text{high}}$ , unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>OSCILLATOR</b>					
Charging Current ( $T_A = 25^\circ\text{C}$ ) ( $V_{CC} = 5.0 \text{ V}$ ) ( $V_{CC} = 40 \text{ V}$ )	$I_{\text{chg}}$	20 20	– –	50 70	μA
Discharging Current ( $T_A = 25^\circ\text{C}$ ) ( $V_{CC} = 5.0 \text{ V}$ ) ( $V_{CC} = 40 \text{ V}$ )	$I_{\text{dis}}$	150 150	– –	250 350	μA
Oscillator Voltage Swing ( $T_A = 25^\circ\text{C}$ ) ( $V_{CC} = 5.0 \text{ V}$ )	$V_{\text{osc}}$	–	0.5	–	V
Ratio of Charge/Discharge Time	$t_{\text{chg}}/t_{\text{dis}}$	–	6.0	–	–
<b>CURRENT LIMIT</b>					
Current-Limit Sense Voltage ( $T_A = 25^\circ\text{C}$ ) ( $V_{CC} - V_{\text{Ipk Sense}}$ )	$V_{\text{CLS}}$	250	–	350	mV
<b>OUTPUT SWITCH</b>					
Output Saturation Voltage 1 ( $I_{\text{SW}} = 1.0 \text{ A}$ , Pin 15 tied to Pin 16)	$V_{\text{sat1}}$	–	0.93	1.3	V
Output Saturation Voltage 2 ( $I_{\text{SW}} = 1.0 \text{ A}$ , $I_{15} = 50 \text{ mA}$ )	$V_{\text{sat2}}$	–	0.5	0.7	V
Output Transistor Current Gain ( $T_A = 25^\circ\text{C}$ ) ( $I_C = 1.0 \text{ A}$ , $V_{\text{CE}} = 5.0 \text{ V}$ )	$h_{\text{FE}}$	–	70	–	–
Output Leakage Current ( $T_A = 25^\circ\text{C}$ ) ( $V_{\text{CE}} = 40 \text{ V}$ )	$I_{\text{C(off)}}$	–	10	–	nA
<b>POWER DIODE</b>					
Forward Voltage Drop ( $I_D = 1.0 \text{ A}$ )	$V_D$	–	1.25	1.5	V
Diode Leakage Current ( $T_A = 25^\circ\text{C}$ ) ( $V_{\text{DR}} = 40 \text{ V}$ )	$I_{\text{DR}}$	–	10	–	nA
<b>COMPARATOR</b>					
Input Offset Voltage ( $V_{\text{CM}} = V_{\text{ref}}$ )	$V_{\text{IO}}$	–	1.5	15	mV
Input Bias Current ( $V_{\text{CM}} = V_{\text{ref}}$ )	$I_{\text{IB}}$	–	35	200	nA
Input Offset Current ( $V_{\text{CM}} = V_{\text{ref}}$ )	$I_{\text{IO}}$	–	5.0	75	nA
Common Mode Voltage Range ( $T_A = 25^\circ\text{C}$ )	$V_{\text{ICR}}$	0	–	$V_{\text{CC}} - 2.0$	V
Power-Supply Rejection Ratio ( $T_A = 25^\circ\text{C}$ ) ( $3.0 \leq V_{\text{CC}} \leq 40 \text{ V}$ )	PSRR	70	96	–	dB
<b>OUTPUT OPERATION AMPLIFIER</b>					
Input Offset Voltage ( $V_{\text{CM}} = 2.5 \text{ V}$ )	$V_{\text{IO}}$	–	4.0	15	mV
Input Bias Current ( $V_{\text{CM}} = 2.5 \text{ V}$ )	$I_{\text{IB}}$	–	30	200	nA
Input Offset Current ( $V_{\text{CM}} = 2.5 \text{ V}$ )	$I_{\text{IO}}$	–	5.0	75	nA
Voltage Gain + ( $T_A = 25^\circ\text{C}$ ) ( $R_L = 2.0 \text{ k}\Omega$ to Gnd, $1.0 \text{ V} \leq V_O \leq 2.5 \text{ V}$ )	$A_{\text{VOL+}}$	25	250	–	V/mV
Voltage Gain – ( $T_A = 25^\circ\text{C}$ ) ( $R_L = 2.0 \text{ k}\Omega$ to $V_{\text{CC}}$ (Op Amp), $1.0 \text{ V} \leq V_O \leq 2.5 \text{ V}$ )	$A_{\text{VOL-}}$	25	250	–	V/mV
Common Mode Voltage Range ( $T_A = 25^\circ\text{C}$ )	$V_{\text{ICR}}$	0	–	$V_{\text{CC}} - 2.0$	V
Common Mode Rejection Ratio ( $T_A = 25^\circ\text{C}$ ) ( $V_{\text{CM}} = 0 \text{ V}$ to $3.0 \text{ V}$ )	CMRR	76	100	–	dB
Power-Supply Rejection Ratio ( $T_A = 25^\circ\text{C}$ ) ( $3.0 \text{ V} \leq V_{\text{CC}}$ (Op Amp) $\leq 40 \text{ V}$ )	PSRR	76	100	–	dB
Output Source Current ( $T_A = 25^\circ\text{C}$ )	$I_{\text{Source}}$	75	150	–	mA
Output Sink Current ( $T_A = 25^\circ\text{C}$ )	$I_{\text{Sink}}$	10	35	–	mA
Slew Rate ( $T_A = 25^\circ\text{C}$ )	SR	–	0.6	–	V/μs
Output Low Voltage ( $T_A = 25^\circ\text{C}$ , $I_L = -5.0 \text{ mA}$ )	$V_{\text{OL}}$	–	–	1.0	V
Output High Voltage ( $T_A = 25^\circ\text{C}$ , $I_L = 50 \text{ mA}$ )	$V_{\text{OH}}$	$V_{\text{CC}}$ (Op Amp) – 3.0	–	–	V

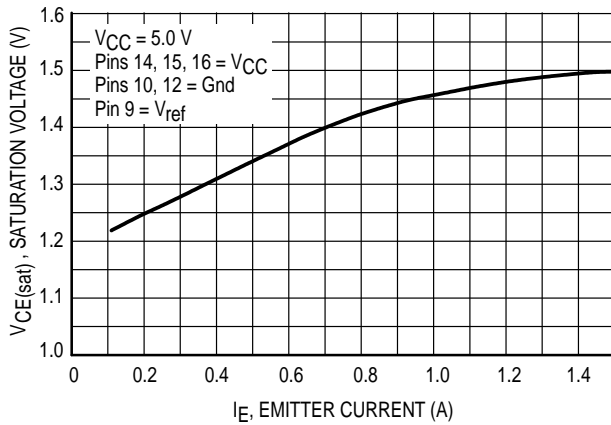
**Figure 1. Output Switch On/Off Time versus Oscillator Timing Capacitor**



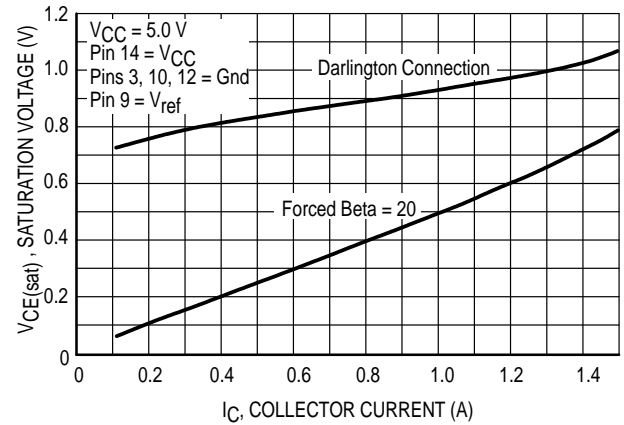
**Figure 2. Standby Supply Current versus Supply Voltage**



**Figure 3. Emitter-Follower Configuration Output Switch Saturation Voltage versus Emitter Current**

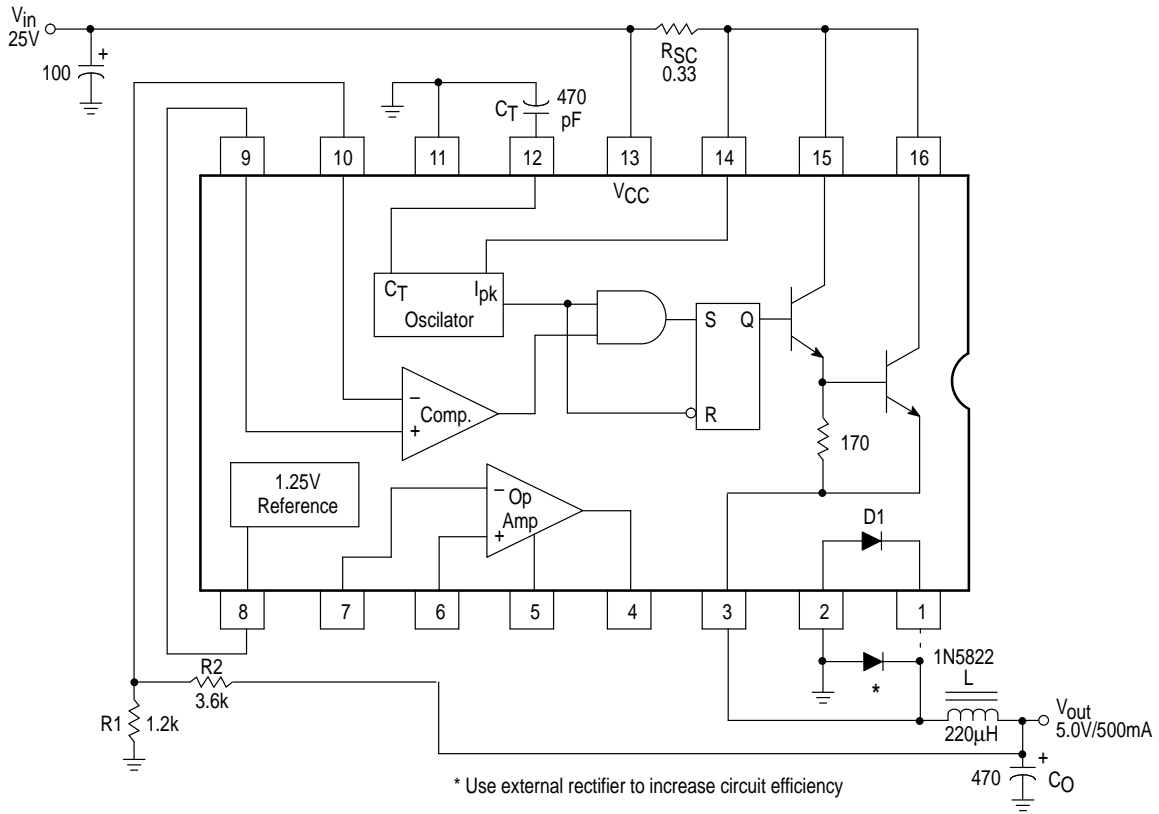


**Figure 4. Common-Emitter Configuration Output Switch Saturation Voltage versus Collector Current**

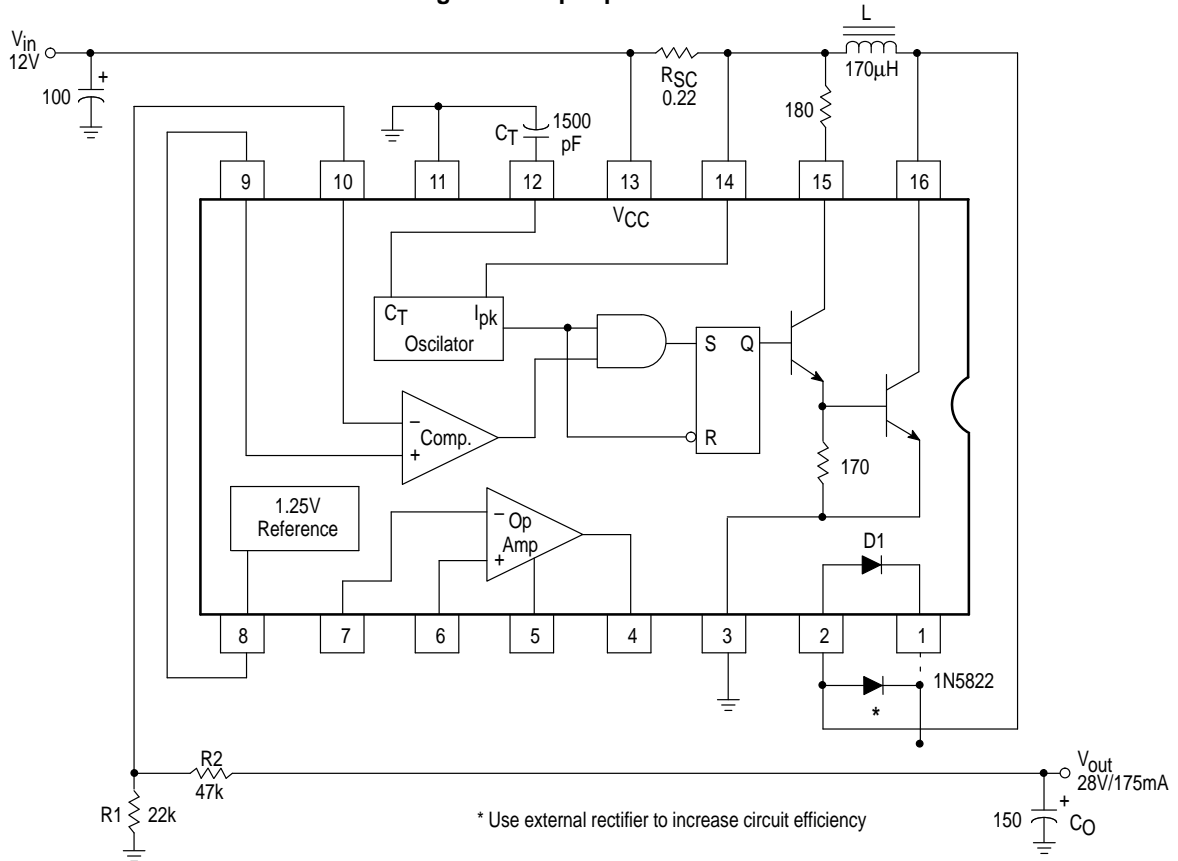


# $\mu$ A78S40

## Figure 5. Step-Down Converter

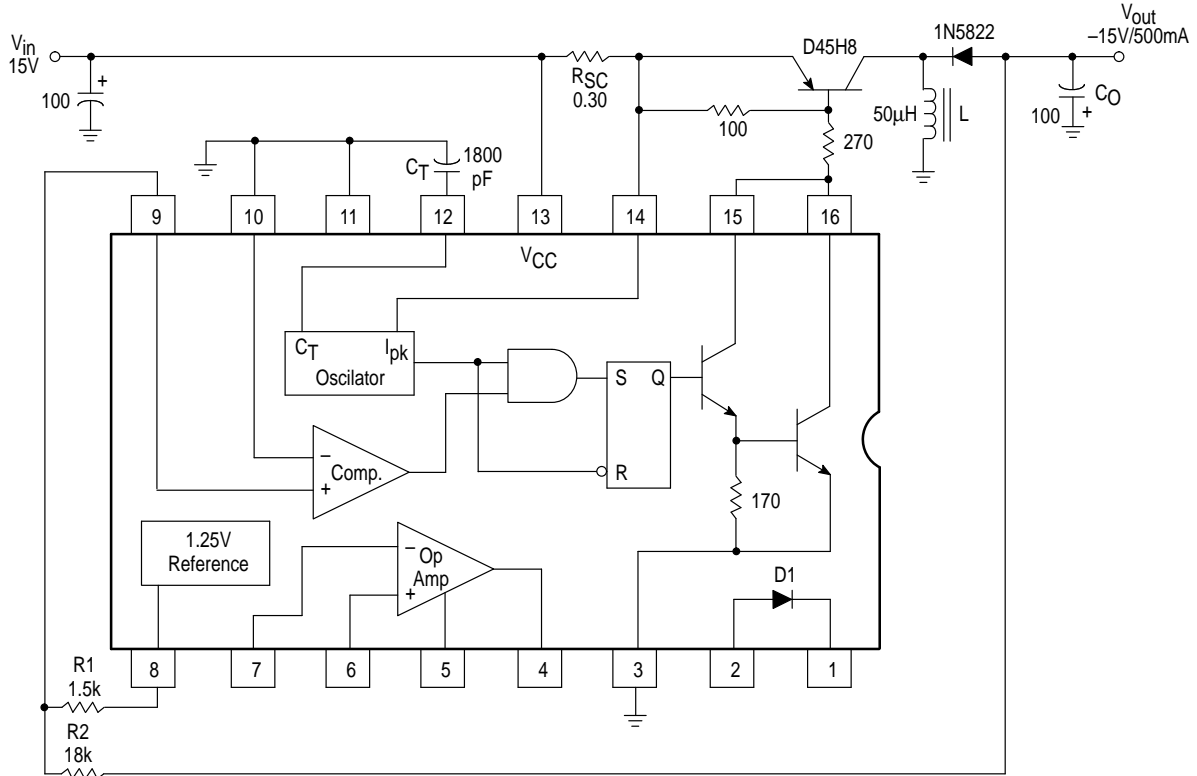


## Figure 6. Step-Up Converter



# μA78S40

Figure 7. Inverting Converter



Design Formula Table

Calculation	Step-Down	Step-Up	Inverting
$\frac{t_{on}}{t_{off}}$	$\frac{V_{out} + V_F}{V_{in(min)} - V_{sat} - V_{out}}$	$\frac{V_{out} - V_F}{V_{in(min)} - V_{sat}}$	$\frac{V_{out} + V_F}{V_{in(min)} - V_{sat}}$
$(t_{on} + t_{off})_{max}$	$\frac{1}{f_{min}}$	$\frac{1}{f_{min}}$	$\frac{1}{f_{min}}$
$C_T$	$4 \times 10^5 t_{on}$	$4 \times 10^5 t_{on}$	$4 \times 10^5 t_{on}$
$I_{pk(switch)}$	$2 I_{out(max)}$	$2 I_{out(max)} \left( \frac{t_{on} - t_{off}}{t_{off}} \right)$	$2 I_{out(max)} \left( \frac{t_{on} + t_{off}}{t_{off}} \right)$
$R_{SC}$	$\frac{0.33}{I_{pk(switch)}}$	$\frac{0.33}{I_{pk(switch)}}$	$\frac{0.33}{I_{pk(switch)}}$
$L_{(min)}$	$\left( \frac{V_{in(min)} - V_{sat} - V_{out}}{I_{pk(switch)}} \right) t_{on(max)}$	$\left( \frac{V_{in(min)} - V_{sat}}{I_{pk(switch)}} \right) t_{on(max)}$	$\left( \frac{V_{in(min)} - V_{sat}}{I_{pk(switch)}} \right) t_{on(max)}$
$C_O$	$\frac{I_{pk(switch)} (t_{on} + t_{off})}{8 V_{ripple(pp)}}$	$\approx \frac{I_{out} t_{on}}{V_{ripple}}$	$\approx \frac{I_{out} t_{on}}{V_{ripple}}$

$V_{sat}$  = Saturation voltage of the output switch.  $V_F$  = Forward voltage drop of the ringback rectifier.

**The following power supply characteristics must be chosen:**

$V_{in}$  – Nominal input voltage. If this voltage is not constant, then use  $V_{in(max)}$  for step-down and  $V_{in(min)}$  for step-up and inverting converter.

$V_{out}$  – Desired output voltage:  $V_{out} = 1.25 \left( 1 + \frac{R_2}{R_1} \right)$  for step-down and step-up:  $V_{out} = \frac{1.25 R_2}{R_1}$  for inverting.

$I_{out}$  – Desired output current.

$f_{min}$  – Minimum desired output switching frequency at the selected values for  $V_{in}$  and  $I_O$ .

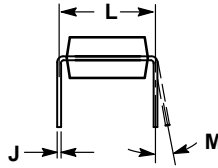
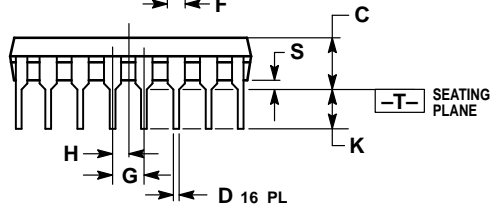
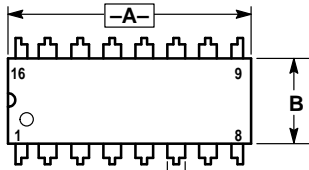
**Ripple(pp)** – Desired peak-to-peak output ripple voltage. In practice, the calculated value will need to be increased due to the capacitor's equivalent series resistance and board layout. The ripple voltage should be kept to a low value since it will directly effect the line and load regulation.

See Application Note AN920 for further information

# μA78S40

## OUTLINE DIMENSIONS

**P SUFFIX**  
**PLASTIC PACKAGE**  
**CASE 648-08**  
**ISSUE R**




⊕ 0.25 (0.010) Ⓜ T A Ⓜ

**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.740	0.770	18.80	19.55
B	0.250	0.270	6.35	6.85
C	0.145	0.175	3.69	4.44
D	0.015	0.021	0.39	0.53
F	0.040	0.70	1.02	1.77
G	0.100 BSC		2.54 BSC	
H	0.050 BSC		1.27 BSC	
J	0.008	0.015	0.21	0.38
K	0.110	0.130	2.80	3.30
L	0.295	0.305	7.50	7.74
M	0°	10°	0°	10°
S	0.020	0.040	0.51	1.01

# μA78S40

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**MFAX:** RMFAX0@email.sps.mot.com – TOUCHTONE 602-244-6609  
**INTERNET:** <http://Design-NET.com>

**JAPAN:** Nippon Motorola Ltd.; Tatsumi-SPD-JLDC, 6F Seibu-Butsuryu-Center,  
3-14-2 Tatsumi Koto-Ku, Tokyo 135, Japan. 03-81-3521-8315

**ASIA/PACIFIC:** Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park,  
51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852-26629298



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