MOTOROLA

µA78S40

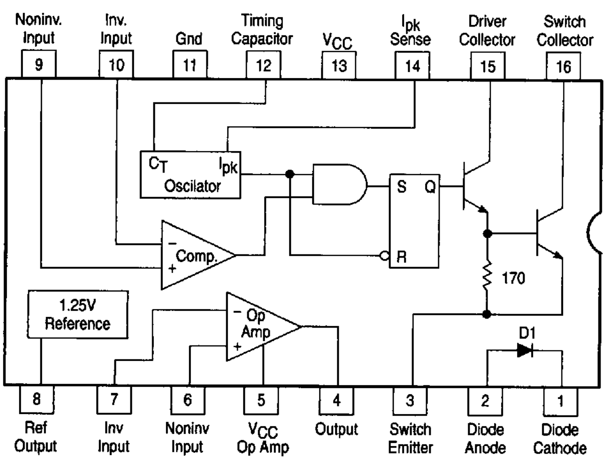
Universal Switching Regulator Subsystem

The µA78S40 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 µA78S40 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

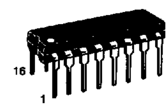
Simplified Block Diagram



(Bottom View)

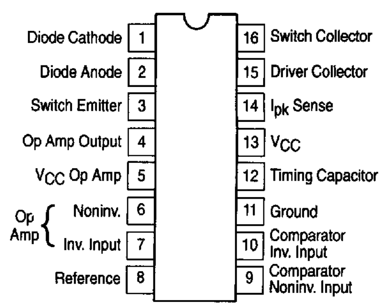
UNIVERSAL SWITCHING REGULATOR SUBSYSTEM

SEMICONDUCTOR TECHNICAL DATA



P SUFFIX
PLASTIC PACKAGE
CASE 648

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

Device	Temperature Range	Package
µA78S40PC	T_A = 0° to +70°C	Plastic
µA78S40PV	T_A = – 40° to +85°C	Plastic

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}	± 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°C) Derate above + 25°C (Note 1)	 P_D $1/R_{\theta JA}$	 1500 14	 mW mW/°C
Storage Temperature Range	T_{stg}	–65 to + 150	°C
Operating Temperature Range µA78S40V µA78S40C	T_A	 –40 to +85 0 to +70	°C

NOTES: 1. T_{low} = –40° for µA78S40PV; = 0° for µA78S40PC. T_{high} = +85° for µA78S40PV; = +70° for µA78S40PC
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
GENERAL					
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
REFERENCE					
Reference Voltage (I_{ref} = 1.0 mA)	V_{ref}	1.180	1.245	1.310	V
Reference Voltage Line Regulation (3.0 V ≤ V_{CC} ≤ 40 V, I_{ref} = 1.0 mA, T_A = 25°C)	Reg_{line}	–	0.04	0.2	mV/V
Reference Voltage Load Regulation (1.0 mA ≤ I_{ref} ≤ 10 mA, T_A = 25°C)	Reg_{load}	–	0.2	0.5	mV/mA

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

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

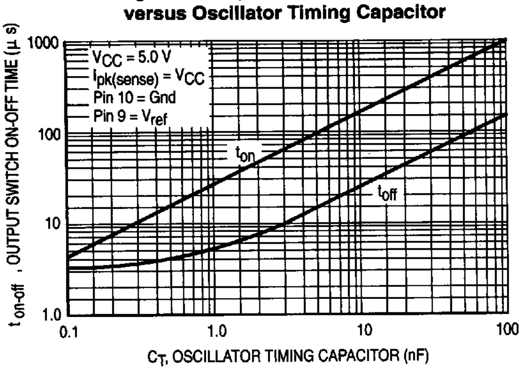


Figure 2. Standby Supply Current versus Supply Voltage

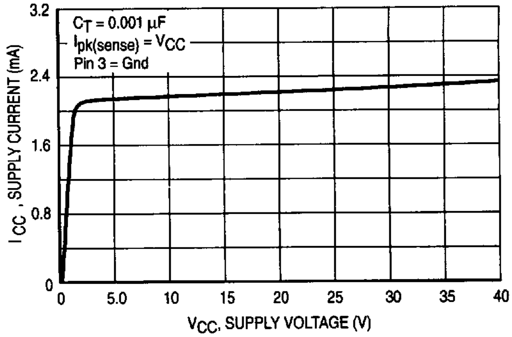


Figure 3. Emitter–Follower Configuration Output Switch Saturation Voltage versus Emitter Current

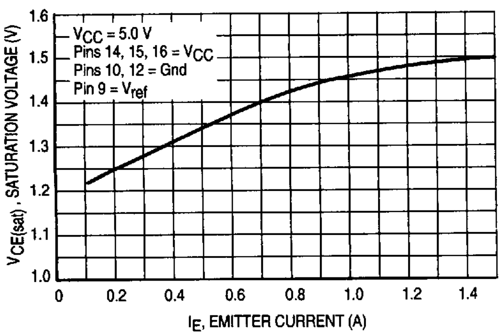


Figure 4. Common–Emitter Configuration Output Switch Saturation Voltage versus Collector Current

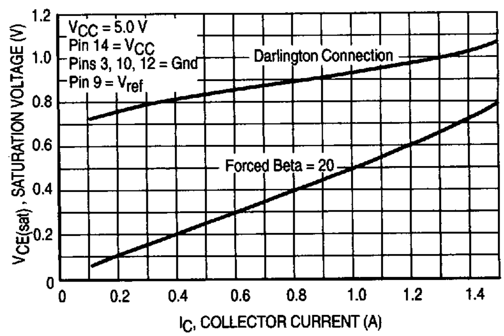
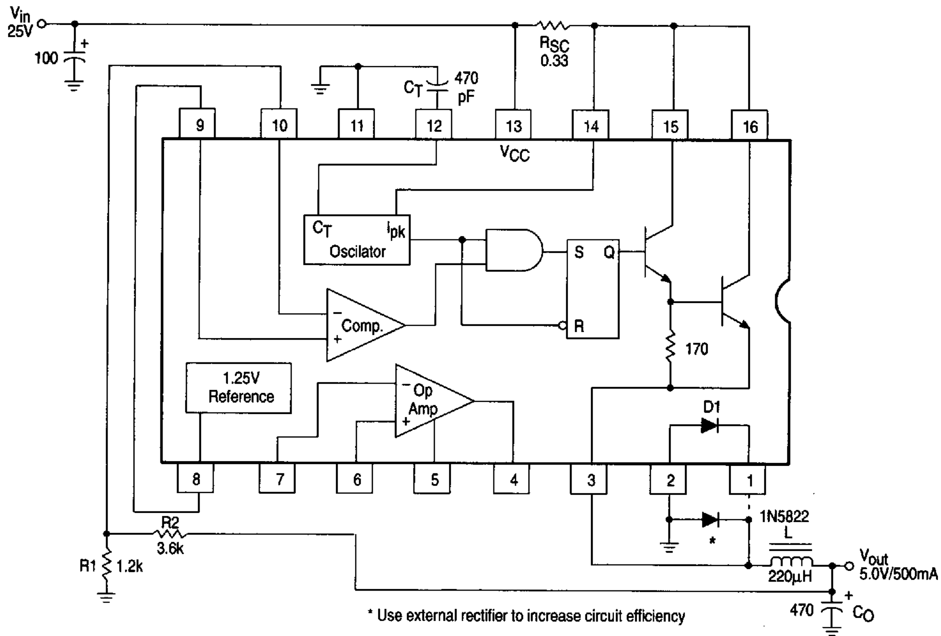
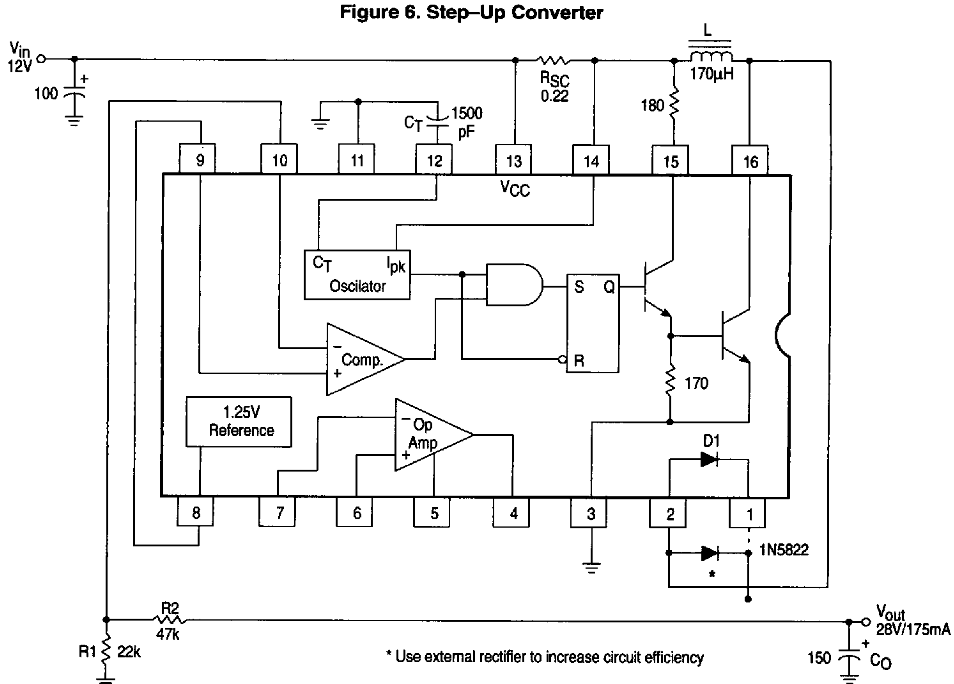


Figure 5. Step–Down Converter



* Use external rectifier to increase circuit efficiency

Figure 6. Step–Up Converter



* Use external rectifier to increase circuit efficiency

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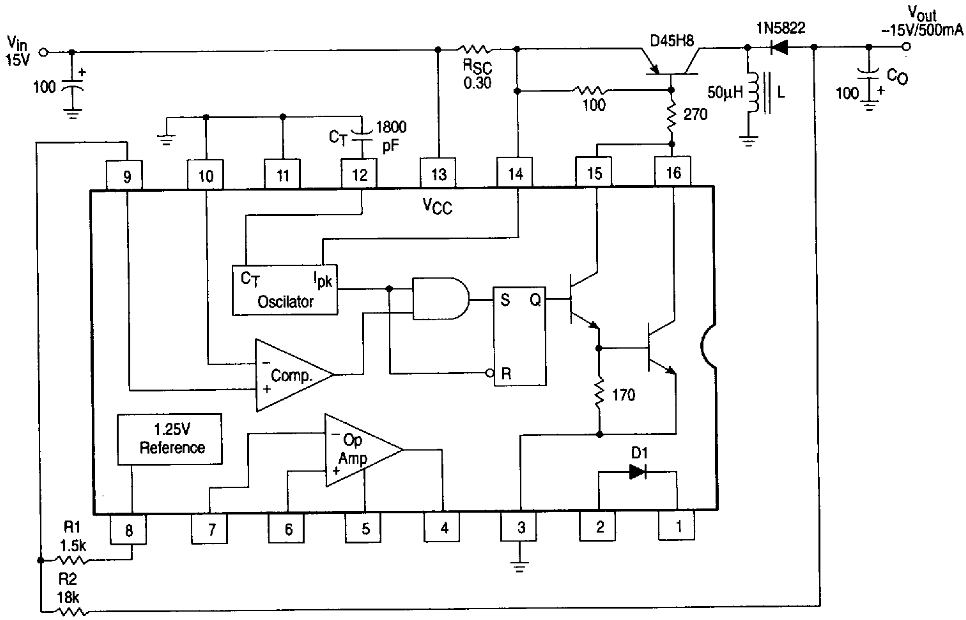
Figure 7. Inverting Converter



Design Formula Table

Calculation	Step–Down	Step–Up	Inverting
$\frac{t_{on}}{t_{off}}$	$\frac{V_{out} + V_F}{V_{in(min)} - V_{sat} - V_{out}}$	$\frac{V_{out} - V_F\ \ V_{in(min)}}{V_{in(min)}\ \ V_{sat}}$	$\frac{V_{out} + V_F}{V_{in(min)} - V_{sat}}$
$(t_{on} + t_{off})$ max	$\frac{I}{f_{min}}$	$\frac{I}{f_{min}}$	$\frac{I}{f_{min}}$
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 convertor.
- **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.
- **$V_{ripple(pp)}$** – 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