National Semiconductor

# LM78S40
# Universal Switching Regulator Subsystem

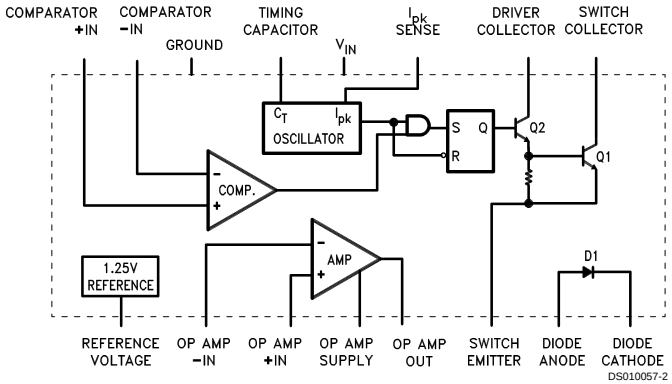
## General Description

The LM78S40 is a monolithic regulator subsystem consisting of all the active building blocks necessary for switching regulator systems. The device consists of a temperature compensated voltage reference, a duty-cycle controllable oscillator with an active current limit circuit, an error amplifier, high current, high voltage output switch, a power diode and an uncommitted operational amplifier. The device can drive external NPN or PNP transistors when currents in excess of 1.5A or voltages in excess of 40V are required. The device can be used for step-down, step-up or inverting switching regulators as well as for series pass regulators. It features wide supply voltage range, low standby power dissipation, high efficiency and low drift. It is useful for any stand-alone, low part count switching system and works extremely well in battery operated systems.

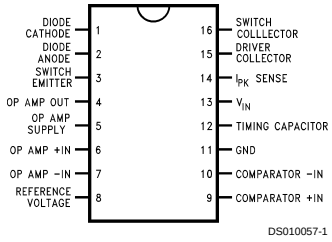
## Features

- Step-up, step-down or inverting switching regulators
- Output adjustable from 1.25V to 40V
- Peak currents to 1.5A without external transistors
- Operation from 2.5V to 40V input
- Low standby current drain
- 80 dB line and load regulation
- High gain, high current, independent op amp
- Pulse width modulation with no double pulsing

## Block and Connection Diagrams




**16-Lead DIP**




**Top View**

## Absolute Maximum Ratings (Note 1)

**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 | |
| Extended (LM78S40J) | −55˚C to +125˚C |
| Industrial (LM78S40N) | −40˚C to +125˚C |
| Commercial (LM78S40CN) | 0˚C to +70˚C |
| Lead Temperature | |
| Ceramic DIP (Soldering, 60 sec.) | 300˚C |
| Molded DIP (Soldering, 10 sec.) | 265˚C |
| Internal Power Dissipation (Note 2) (Note 3) | |
| 16L-Ceramic DIP | 1.50W |
| 16L-Molded DIP | 1.04W |
| Input Voltage from $V_{IN}$ to GND | 40V |
| Input Voltage from $V^+$ (Op Amp) to GND | 40V |
| Common Mode Input Range (Comparator and Op Amp) | −0.3 to V+ |
| Differential Input Voltage (Note 4) | ±30V |
| Output Short Circuit Duration (Op Amp) | Continuous |
| Current from $V_{REF}$ | 10 mA |
| Voltage from Switch Collectors to GND | 40V |
| Voltage from Switch Emitters to GND | 40V |
| Voltage from Switch Collectors to Emitter | 40V |
| Voltage from Power Diode to GND | 40V |
| Reverse Power Diode Voltage | 40V |
| Current through Power Switch | 1.5A |
| Current through Power Diode | 1.5A |
| ESD Susceptibility | (to be determined) |

## LM78S40
## Electrical Characteristics (Note 5)

$T_A$ = Operating temperature range, $V_{IN}$ = 5.0V, $V^+$(Op Amp) = 5.0V, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **GENERAL CHARACTERISTICS** | | | | | | |
| $I_{CC}$ | Supply Current (Op Amp Disconnected) | $V_{IN}$ = 5.0V | | 1.8 | 3.5 | mA |
| | | $V_{IN}$ = 40V | | 2.3 | 5.0 | mA |
| $I_{CC}$ | Supply Current (Op Amp Connected) | $V_{IN}$ = 5.0V | | | 4.0 | mA |
| | | $V_{IN}$ = 40V | | | 5.5 | mA |
| **REFERENCE SECTION** | | | | | | |
| $V_{REF}$ | Reference Voltage | $I_{REF}$ = 1.0 mA, Extend −55˚C < $T_A$ < +125˚C, Comm 0 < $T_A$ < +70˚C, Indus −40˚C < $T_A$ < +85˚C | 1.180 | 1.245 | 1.310 | V |
| $V_{R\ LINE}$ | Reference Voltage Line Regulation | $V_{IN}$ = 3.0V to $V_{IN}$ = 40V, $I_{REF}$ = 1.0 mA, $T_A$ = 25˚C | | 0.04 | 0.2 | mV/V |
| $V_{R\ LOAD}$ | Reference Voltage Load Regulation | $I_{REF}$ = 1.0 mA to $I_{REF}$ = 10 mA, $T_A$ = 25˚C | | 0.2 | 0.5 | mV/mA |
| **OSCILLATOR SECTION** | | | | | | |
| $I_{CHG}$ | Charging Current | $V_{IN}$ = 5.0V, $T_A$ = 25˚C | 20 | | 50 | µA |
| $I_{CHG}$ | Charging Current | $V_{IN}$ = 40V, $T_A$ = 25˚C | 20 | | 70 | µA |
| $I_{DISCHG}$ | Discharge Current | $V_{IN}$ = 5.0V, $T_A$ = 25˚C | 150 | | 250 | µA |
| $I_{DISCHG}$ | Discharge Current | $V_{IN}$ = 40V, $T_A$ = 25˚C | 150 | | 350 | µA |
| $V_{OSC}$ | Oscillator Voltage Swing | $V_{IN}$ = 5.0V, $T_A$ = 25˚C | | 0.5 | | V |
| $t_{on}/t_{off}$ | Ratio of Charge/ Discharge Time | | | 6.0 | | µs/µs |
| **CURRENT LIMIT SECTION** | | | | | | |
| $V_{CLS}$ | Current Limit Sense Voltage | $T_A$ = 25˚C | 250 | | 350 | mV |
| **OUTPUT SWITCH SECTION** | | | | | | |
| $V_{SAT\ 1}$ | Output Saturation Voltage 1 | $I_{SW}$ = 1.0A (*Figure 1*) | | 1.1 | 1.3 | V |
| $V_{SAT\ 2}$ | Output Saturation Voltage 2 | $I_{SW}$ = 1.0A (*Figure 2*) | | 0.45 | 0.7 | V |

## LM78S40
## Electrical Characteristics (Note 5) (Continued)

$T_A$ = Operating temperature range, $V_{IN}$ = 5.0V, $V^+$(Op Amp) = 5.0V, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **OUTPUT SWITCH SECTION** | | | | | | |
| $h_{FE}$ | Output Transistor Current Gain | $I_C$ = 1.0A, $V_{CE}$ = 5.0V, $T_A$ = 25˚C | | 70 | | |
| $I_L$ | Output Leakage Current | $V_O$ = 40V, $T_A$ = 25˚C | | 10 | | nA |
| **POWER DIODE** | | | | | | |
| $V_{FD}$ | Forward Voltage Drop | $I_D$ = 1.0A | | 1.25 | 1.5 | V |
| $I_{DR}$ | Diode Leakage Current | $V_D$ = 40V, $T_A$ = 25˚C | | 10 | | nA |
| **COMPARATOR** | | | | | | |
| $V_{IO}$ | Input Offset Voltage | $V_{CM}$ = $V_{REF}$ | | 1.5 | 15 | mV |
| $I_{IB}$ | Input Bias Current | $V_{CM}$ = $V_{REF}$ | | 35 | 200 | nA |
| $I_{IO}$ | Input Offset Current | $V_{CM}$ = $V_{REF}$ | | 5.0 | 75 | nA |
| $V_{CM}$ | Common Mode Voltage Range | $T_A$ = 25˚C | 0 | | $V_{IN}$–2 | V |
| PSRR | Power Supply Rejection Ratio | $V_{IN}$ = 3.0V to 40V, $T_A$ = 25˚C | 70 | 96 | | dB |
| **OPERATIONAL AMPLIFIER** | | | | | | |
| $V_{IO}$ | Input Offset Voltage | $V_{CM}$ = 2.5V | | 4.0 | 15 | mV |
| $I_{IB}$ | Input Bias Current | $V_{CM}$ = 2.5V | | 30 | 200 | nA |
| $I_{IO}$ | Input Offset Current | $V_{CM}$ = 2.5V | | 5.0 | 75 | nA |
| $A_{VS}^+$ | Voltage Gain$^+$ | $R_L$ = 2.0 kΩ to GND; $V_O$ = 1.0V to 2.5V, $T_A$ = 25˚C | 25 | 250 | | V/mV |
| $A_{VS}^-$ | Voltage Gain$^-$ | $R_L$ = 2.0 kΩ to $V^+$ (Op Amp) $V_O$ = 1.0V to 2.5V, $T_A$ = 25˚C | 25 | 250 | | V/mV |
| $V_{CM}$ | Common Mode Voltage Range | $T_A$ = 25˚C | 0 | | $V_{CC}$ − 2 | V |
| CMR | Common Mode Rejection | $V_{CM}$ = 0V to 3.0V, $T_A$ = 25˚C | 76 | 100 | | dB |
| PSRR | Power Supply Rejection Ratio | $V^+$ (Op Amp) = 3.0V to 40V, $T_A$ = 25˚C | 76 | 100 | | dB |
| $I_O^+$ | Output Source Current | $T_A$ = 25˚C | 75 | 150 | | mA |
| $I_O^-$ | Output Sink Current | $T_A$ = 25˚C | 10 | 35 | | mA |
| SR | Slew Rate | $T_A$ = 25˚C | | 0.6 | | V/µs |
| $V_{OL}$ | Output Voltage LOW | $I_L$ = −5.0 mA, $T_A$ = 25˚C | | | 1.0 | V |
| $V_{OH}$ | Output Voltage High | $I_L$ = 50 mA, $T_A$ = 25˚C | V + (Op Amp) − 3V | | | V |

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when ordering the device beyond its rated operating conditions.

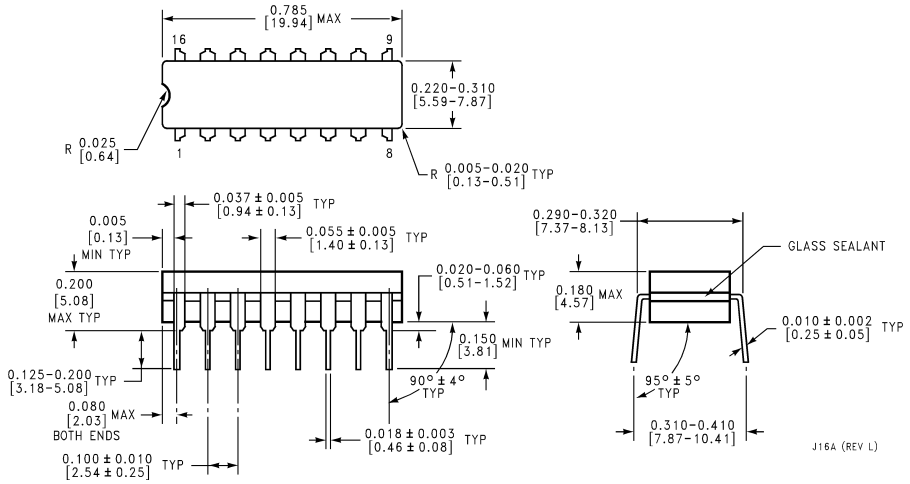
**Note 2:** $T_{J\ Max}$ = 150˚C for the Molded DIP, and 175˚C for the Ceramic DIP.

**Note 3:** 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.

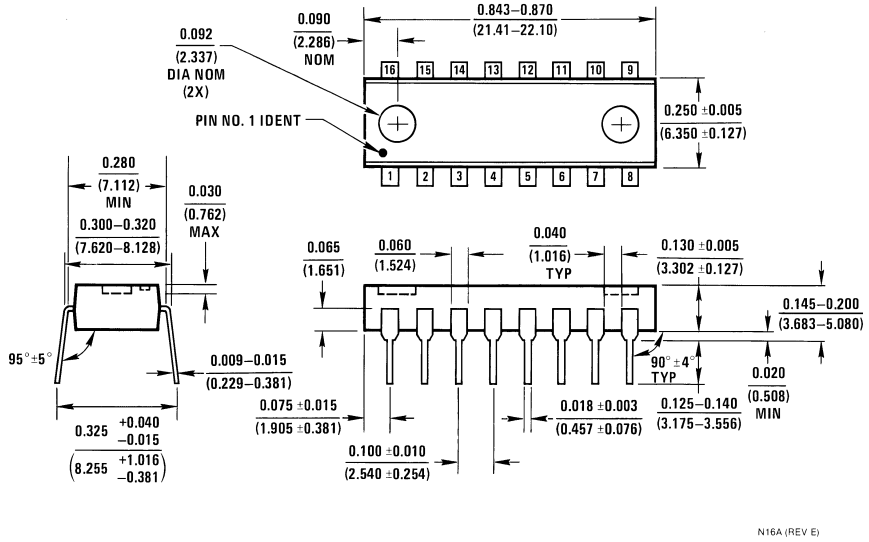
**Note 4:** For supply voltages less than 30V, the absolute maximum voltage is equal to the supply voltage.

**Note 5:** A military RETS specification is available on request. At the time of printing, the LM78S40 RETS specification complied with the Min and Max limits in this table. The LM78S40J may also be procured as a Standard Military Drawing.

## Physical Dimensions inches (millimeters) unless otherwise noted




**16-Lead Ceramic Dual-In-Line Package (J)**
**Order Number LM78S40J/883**
**NS Package Number J16A**




**16-Lead Molded Dual-In-Line Package (N)**
**Order Number LM78S40N or LM78S40CN**
**NS Package Number N16A**