**NTE923 & NTE923D**
*Integrated Circuit*
**Precision Voltage Regulator**

**Description:**
The NTE923 and NTE923D are voltage regulators designed primarily for series regulator applications. By themselves, these devices will supply output currents up to 150mA; but, external transistors can be added to provide any desired load current. The circuits feature extremely low standby current drain, and provision is made for either linear or foldback current limiting.

These devices are also useful in a wide range of other applications such as shunt regulators, current regulators, and temperature controllers.

**Features:**
- 150mA Output Current without External Pass Transistor
- Output Currents in Excess of 10A Possible by Adding External Transistors
- Input Voltage: 40V Max
- Output Voltage Adjustable from 2V to 37V
- Can be Used as Either a Linear or a Switching Regulator

**Absolute Maximum Ratings:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NTE923</th>
<th>NTE923D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Voltage from V+ to V− (50ms)</td>
<td>50V</td>
<td></td>
</tr>
<tr>
<td>Continuous Voltage from V+ to V−</td>
<td>40V</td>
<td></td>
</tr>
<tr>
<td>Input−Output Voltage Differential</td>
<td>40V</td>
<td></td>
</tr>
<tr>
<td>Maximum Amplifier Input Voltage</td>
<td>8.5V</td>
<td>5.0V</td>
</tr>
<tr>
<td>Either Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current from VZ</td>
<td>25mA</td>
<td></td>
</tr>
<tr>
<td>Current from VREF</td>
<td>15mA</td>
<td></td>
</tr>
<tr>
<td>Internal Power Dissipation</td>
<td>800mW</td>
<td>660mW</td>
</tr>
<tr>
<td>NTE923</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTE923D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>0° to +70°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−65° to +150°C</td>
<td></td>
</tr>
<tr>
<td>NTE923</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTE923D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead Temperature (During Soldering, 4sec max)</td>
<td>+300°C</td>
<td>+260°C</td>
</tr>
</tbody>
</table>
### Electrical Characteristics:  (Note 1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Regulation</td>
<td>$V_{IN} = 12V$ to $15V$</td>
<td>−</td>
<td>0.01</td>
<td>0.1</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$0^\circ \leq T_A \leq +70^\circ C$</td>
<td>−</td>
<td>−</td>
<td>0.3</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$V_{IN} = 12V$ to $40V$</td>
<td>−</td>
<td>0.1</td>
<td>0.5</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>$I_L = 1mA$ to $50mA$</td>
<td>−</td>
<td>0.03</td>
<td>0.2</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td></td>
<td>$0^\circ \leq T_A \leq +70^\circ C$</td>
<td>−</td>
<td>−</td>
<td>0.6</td>
<td>% $V_{OUT}$</td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>$f = 50Hz$ to $10kHz$</td>
<td>$C_{REF} = 0$</td>
<td>−</td>
<td>74</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>$C_{REF} = 5\mu F$</td>
<td>−</td>
<td>86</td>
<td>−</td>
<td>dB</td>
</tr>
<tr>
<td>Average Temperature Coefficient of Output Voltage</td>
<td>$0^\circ \leq T_A \leq +70^\circ C$, Note 2</td>
<td>−</td>
<td>0.003</td>
<td>0.015</td>
<td>%/°C</td>
</tr>
<tr>
<td>Short Circuit Current Limit</td>
<td>$R_{SC} = 10\Omega$, $V_{OUT} = 0$</td>
<td>−</td>
<td>65</td>
<td>−</td>
<td>mA</td>
</tr>
<tr>
<td>Reference Voltage</td>
<td></td>
<td>6.80</td>
<td>7.15</td>
<td>7.50</td>
<td>V</td>
</tr>
<tr>
<td>Output Noise Voltage</td>
<td>$BW = 100Hz$ to $10kHz$</td>
<td>$C_{REF} = 0$</td>
<td>−</td>
<td>86</td>
<td>$\mu V_{rms}$</td>
</tr>
<tr>
<td></td>
<td>$C_{REF} = 5\mu F$</td>
<td>−</td>
<td>2.5</td>
<td>−</td>
<td>$\mu V_{rms}$</td>
</tr>
<tr>
<td>Long Term Stability</td>
<td></td>
<td>−</td>
<td>0.05</td>
<td>−</td>
<td>%/1000Hrs</td>
</tr>
<tr>
<td>Standby Current Drain</td>
<td>$I_L = 0$, $V_{IN} = 30V$</td>
<td>−</td>
<td>1.7</td>
<td>4.0</td>
<td>mA</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td></td>
<td>9.5</td>
<td>−</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td></td>
<td>2.0</td>
<td>−</td>
<td>37</td>
<td>V</td>
</tr>
<tr>
<td>Input–Output Voltage Differential</td>
<td></td>
<td>3.0</td>
<td>−</td>
<td>38</td>
<td>V</td>
</tr>
<tr>
<td>Thermal Resistance, Junction to Ambient NTE923D</td>
<td></td>
<td>−</td>
<td>105</td>
<td>−</td>
<td>°C/W</td>
</tr>
<tr>
<td>NTE923</td>
<td>Board mount in still air</td>
<td>−</td>
<td>225</td>
<td>−</td>
<td>°C/W</td>
</tr>
<tr>
<td></td>
<td>Board mount in 400LF/Min Air flow</td>
<td>−</td>
<td>90</td>
<td>−</td>
<td>°C/W</td>
</tr>
<tr>
<td>Thermal Resistance, Junction to Case</td>
<td></td>
<td>−</td>
<td>25</td>
<td>−</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

Note 1. Unless otherwise otherwise specified, $T_A = +25^\circ C$, $V_{IN} = V_+ = V_C = 12V$, $V_- = 0$, $V_{OUT} = 5V$, $I_L = 1mA$, $R_{SC} = 0$, $C_I = 100pF$, $C_{REF} = 0$ and divider impedance as seen by error amplifier $\leq 10k\Omega$. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

Note 2. Guaranteed by correlation to other tests.

Note 3. For metal can applications where $V_Z$ is required, an external 6.2V zener diode should be connected in series with $V_{OUT}$.

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### Pin Connection Diagram

**NTE923**  
(2W Top View)  

- V (+)  
- Freq Comp  
- Current Limit  
- Invert Input  
- Non–Invert Input  
- V (−)/Case  
- V (−)  
- Vref  
- 7  
- 6  
- 5  
- 4  
- 3  
- 2  
- 1  

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**NTE923D**  

N.C.  
- 14  
- 13  
- 12  
- 11  
- N.C.  
- 10  
- 9  
- 8  
- 7  
- 6  
- 5  
- 4  
- 3  
- 2  
- 1  

- Current Limit  
- Freq Comp  
- V (+)  
- V (−)  
- Vout  
- Vref  
- VZ  
- N.C.
TABLE 1. Resistor Values (kΩ) for Standard Output Voltage:

<table>
<thead>
<tr>
<th>Output Voltage</th>
<th>Applicable Figures</th>
<th>Fixed Output ±5%</th>
<th>Output Adjustable ±10% (Note 5)</th>
<th>Output Voltage</th>
<th>Applicable Figures</th>
<th>Fixed Output ±5%</th>
<th>Output Adjustable ±10% (Note 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>4.12</td>
<td>1.8 0.5 1.2</td>
<td>+100</td>
<td>7</td>
<td>3.57</td>
<td>102 2.2 10 91</td>
</tr>
<tr>
<td>+3.6</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>3.57</td>
<td>1.5 0.5 1.5</td>
<td>+250</td>
<td>7</td>
<td>3.57</td>
<td>255 2.2 10 240</td>
</tr>
<tr>
<td>+5.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>2.15</td>
<td>0.75 0.5 2.2</td>
<td>−6 (Note 6)</td>
<td>3 (10)</td>
<td>3.57</td>
<td>243 1.2 0.5 0.75</td>
</tr>
<tr>
<td>+6.0</td>
<td>1, 5, 6, 9, 12 (4)</td>
<td>1.15</td>
<td>0.5 0.5 2.7</td>
<td>−9</td>
<td>3, 10</td>
<td>3.48</td>
<td>5.36 1.2 0.5 2.0</td>
</tr>
<tr>
<td>+9.0</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>1.87</td>
<td>0.75 1.0 2.7</td>
<td>−12</td>
<td>3, 10</td>
<td>3.57</td>
<td>8.45 1.2 0.5 3.3</td>
</tr>
<tr>
<td>+12</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>4.87</td>
<td>2.0 1.0 3.0</td>
<td>−15</td>
<td>3, 10</td>
<td>3.65</td>
<td>11.5 1.2 0.5 4.3</td>
</tr>
<tr>
<td>+15</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>7.87</td>
<td>3.3 1.0 3.0</td>
<td>−28</td>
<td>8</td>
<td>3.57</td>
<td>24.3 1.2 0.5 10</td>
</tr>
<tr>
<td>+28</td>
<td>2, 4, (5, 6, 9, 12)</td>
<td>21.0</td>
<td>5.6 1.0 2.0</td>
<td>−45</td>
<td>8</td>
<td>3.57</td>
<td>41.2 2.2 10 33</td>
</tr>
<tr>
<td>+45</td>
<td>7</td>
<td>3.57</td>
<td>2.2 10 39</td>
<td>−100</td>
<td>8</td>
<td>3.57</td>
<td>97.6 2.2 10 91</td>
</tr>
<tr>
<td>+75</td>
<td>7</td>
<td>3.57</td>
<td>2.2 10 68</td>
<td>−250</td>
<td>8</td>
<td>3.57</td>
<td>249 2.2 10 240</td>
</tr>
</tbody>
</table>

Note 4. Figures in parentheses may be used if R1/R2 divider is placed on opposite input of error amp.
Note 5. Replace R1/R2 in figures with divider shown in Figure.
Note 6. V+ and VCC must be connected to a +3V or greater supply.

TABLE 2. Formulae for Intermediate Output Voltages:

Outputs from +2 to +7 Volts
(Figures 1, 4, 5, 6, 9, 12)

\[ V_{OUT} = \left( \frac{V_{REF} \times R_2}{R_1 + R_2} \right) \]

Outputs from +4 to +250 Volts
(Figure 7)

\[ V_{OUT} = \left( \frac{V_{REF}}{2} \times \frac{R_2 - R_1}{R_1} \right) \]

Current Limiting

\[ I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}} \]

Outputs from +7 to +37 Volts
(Figures 2, 4, 5, 6, 9, 12)

\[ V_{OUT} = \left( \frac{V_{REF} \times R_1 + R_2}{R_2} \right) \]

Outputs from −6 to −250 Volts
(Figures 3, 8, 10)

\[ V_{OUT} = \left( \frac{V_{REF}}{2} \times \frac{R_1 + R_2}{R_1} \right) \]

Foldback Current Limiting

\[ I_{KNEE} = \left( \frac{V_{OUT} R_3}{R_{SC} R_4} + \frac{V_{SENSE} (R_3 + R_4)}{R_{SC} R_4} \right) \]

\[ I_{SHORT \ C K T} = \left( \frac{V_{SENSE}}{R_{SC}} \right) \times \left( \frac{R_3 + R_4}{R_4} \right) \]

Typical Applications:

(Pin numbers relative to the plastic package)

Figure 1. Basic Low Voltage Regulator
(VOUT = 2 to 7 Volts)

Figure 2. Basic High Voltage Regulator
(VOUT = 27 to 37 Volts)

For minimum temperature drift.

Typical Performance

Regulated Output Voltage 5V
Line Regulation (ΔVIN = 3V) 0.5mV
Load Regulation (ΔIL = 50mA) 1.5mV

Note: R3 = R1 x R2

Note: R3 may be eliminated for minimum component count.

Typical Performance

Regulated Output Voltage 15V
Line Regulation (ΔVIN = 3V) 1.5mV
Load Regulation (ΔIL = 50mA) 4.5mV

Note: R3 = R1 x R2

for minimum temperature drift.
Figure 3. Negative Voltage Regulator

Figure 4. Positive Voltage Regulator
(External NPN Pass Transistor)

Figure 5. Positive Voltage Regulator
(External PNP Pass Transistor)

Figure 6. Foldback Current Limiting

Figure 7. Positive Floating Regulator

Figure 8. Negative Floating Regulator

Typical Performance
- Regulated Output Voltage: 15V
- Line Regulation ($\Delta V_{IN} = 3V$): 1mV
- Load Regulation ($\Delta I_L = 100mA$): 2mV

Typical Performance
- Regulated Output Voltage: +15V
- Line Regulation ($\Delta V_{IN} = 3V$): 1.5mV
- Load Regulation ($\Delta I_L = 1A$): 15mV

Typical Performance
- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 3V$): 0.5mV
- Load Regulation ($\Delta I_L = 1A$): 5mV

Typical Performance
- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 3V$): 0.5mV
- Load Regulation ($\Delta I_L = 10mA$): 1mV
- Short Circuit Current: 20mA

Typical Performance
- Regulated Output Voltage: +100V
- Line Regulation ($\Delta V_{IN} = 20V$): 30mV
- Load Regulation ($\Delta I_L = 100mA$): 20mV

Typical Performance
- Regulated Output Voltage: -100V
- Line Regulation ($\Delta V_{IN} = 20V$): 30mV
- Load Regulation ($\Delta I_L = 100mA$): 20mV
Figure 9. Positive Switching Regulator

Typical Performance
- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 30V$): 10mV
- Load Regulation ($\Delta I_L = 2A$): 80mV

Figure 10. Negative Switching Regulator

Typical Performance
- Regulated Output Voltage: −15V
- Line Regulation ($\Delta V_{IN} = 20V$): 8mV
- Load Regulation ($\Delta I_L = 2A$): 6mV

Figure 11. Remote Shutdown Regulator with Current Limiting

Typical Performance
- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 3V$): 0.5mV
- Load Regulation ($\Delta I_L = 50mA$): 1.5mV

Figure 12. Shunt Regulator

Typical Performance
- Regulated Output Voltage: +5V
- Line Regulation ($\Delta V_{IN} = 10V$): 0.5mV
- Load Regulation ($\Delta I_L = 100mA$): 1.5mV

Figure 13. Output Voltage Adjust (Note 6)