Voltage Regulators and the Handyboard

Carl Raffa
Feb 2, 2007
What is a voltage regulator?

A voltage regulator is an electronic circuit or device that takes a varying input voltage and produces a constant DC voltage output regardless of the output current.
Why are voltage regulators necessary?

Most electronic circuits require a constant voltage source, but most voltage sources cannot supply a constant voltage.

Also, many electronic circuits require multiple voltages. Using regulators is simpler than having multiple voltage sources.
Voltage Sources: AC Adapters

Consider an unregulated 12 VDC 500 mA AC adapter. How does the output voltage vary with load current?

Output voltage with no load (zero load current)

Output voltage with 24 Ω load (load current ≈ 500 mA)
Voltage Sources: Batteries

Battery voltage drops as the energy in the cell is used up. A typical NiCd cell may be 1.2 V when fully charged, but will drop to 1.0 V when nearly depleted.

Battery voltage also drops under high loads due to internal impedance. A new AA alkaline cell will be around 1.5 V but may only output 1.3 V with a 2 A load.
General Classes of Voltage Regulators

Linear – Uses a resistive element to dissipate excess power
- Easy to implement
- Low noise in output voltage
- Low efficiency
- Often requires large heatsinks
- Output voltage is always less than input voltage

Switching – Uses a switch to control the average power
- High efficiency
- Step-up and step-down configurations are possible
- Implementation is more difficult
- Higher noise in output voltage
Linear Voltage Regulator Block Diagram

Series linear regulator
Switching Voltage Regulator Block Diagram

Switching voltage regulator
Discrete Voltage Regulator Circuits

Voltage regulator circuits can be built from discrete components (resistors, capacitors, transistors, etc.), but this is no longer commonly done.

Discrete component linear voltage regulator
Integrated Circuit Voltage Regulators

IC regulators combine the necessary circuitry in a single package.

The most common IC linear voltage regulators are 3-terminal regulators. As the name suggests, these regulators have 3 terminals: an input, an output, and a common (or ground).

For most 3-terminal regulators, the only necessary external component is an input bypass capacitor, though an output bypass capacitor is also frequently used.

![Fixed Output Regulator](image)
3-Terminal Regulator Specifications

The two basic specifications for a 3-terminal regulator are:

- Output voltage
- Maximum output current

Additional specifications include:

- Maximum input voltage
- Minimum input voltage
- Output tolerance
- Line/load regulation
- Ripple rejection
- Maximum power dissipation
- Minimum output current
- Physical package

TO-92 (left) and TO-220 packages
What's Available?

There are hundreds of 3-terminal regulators available from dozens of manufacturers. Browsing the catalogs of one of the large electronics parts distributors such as Mouser, Digikey, or Jameco will give a good idea of what is available.

Common fixed output voltages include 3.3, 5, 12, and 15 with output currents up to a few amps. Variable output regulators are also available.

For circuits where the input voltage is less than a volt above the output voltage, special Low Dropout (LDO) regulators are available.
### General Purpose Linear Regulators

<table>
<thead>
<tr>
<th>Mouser Stock No.</th>
<th>On Semiconductor Part No.</th>
<th>Package</th>
<th>VO Typ. (V)</th>
<th>IO Typ. (A)</th>
<th>VDO Typ. (V)</th>
<th>VI Max. (V)</th>
<th>Price Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>863-NCV8502D25G</td>
<td>LM837BTG</td>
<td>TO-92</td>
<td>Adjustable</td>
<td>1.5</td>
<td>2.7</td>
<td>40</td>
<td>$0.30</td>
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<tr>
<td>863-NCV8501PDW25G</td>
<td>LM837BTG</td>
<td>TO-92</td>
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<td>2.7</td>
<td>40</td>
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<tr>
<td>863-NCP565D2T12G</td>
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<td>SOIC-8</td>
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<td>0.3</td>
<td>2</td>
<td>25</td>
<td>$0.18</td>
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<tr>
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<td>MC7805ACD2TG</td>
<td>D2PAK</td>
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<td>0.3</td>
<td>2</td>
<td>25</td>
<td>$0.18</td>
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<td>863-MC78M05CDTG</td>
<td>LM317D2TG</td>
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<td>1.5</td>
<td>2.25</td>
<td>40</td>
<td>$0.20</td>
<td>$0.23</td>
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<td>40</td>
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<td>$0.23</td>
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<td>2.25</td>
<td>40</td>
<td>$0.20</td>
<td>$0.23</td>
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<td>1.5</td>
<td>2.25</td>
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### Low Dropout Linear Regulators

<table>
<thead>
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<th>Package</th>
<th>VO Typ. (V)</th>
<th>IO Typ. (A)</th>
<th>VDO Typ. (V)</th>
<th>VI Max. (V)</th>
<th>Price Each</th>
</tr>
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<tr>
<td>863-NCV8501PDW25G</td>
<td>LM837BTG</td>
<td>TO-92</td>
<td>Adjustable</td>
<td>1.5</td>
<td>2.7</td>
<td>40</td>
<td>$0.25</td>
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<tr>
<td>863-NCP565D2T12G</td>
<td>MC7805ACD2TG</td>
<td>D2PAK</td>
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<td>2</td>
<td>25</td>
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<tr>
<td>863-NCP565D2T12G</td>
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<td>D2PAK</td>
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<td>Adjustable</td>
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</tr>
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<td>863-MC79L05ACPG</td>
<td>LM317D2TG</td>
<td>Adjustable</td>
<td>1.5</td>
<td>2.25</td>
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</tr>
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</table>

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(800) 346-6873
# ON SEMICONDUCTOR Power Management

## GENERAL PURPOSE LINEAR REGULATORS (CONT.)

For quantities of 1000 and up, call for quote.

<table>
<thead>
<tr>
<th>MOUSER STOCK NO.</th>
<th>On Semiconductor Part No.</th>
<th>Package</th>
<th>VO Typ. (V)</th>
<th>IO Typ. (A)</th>
<th>VDO Typ. (V)</th>
<th>VI Max. (V)</th>
<th>Price Each</th>
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### Positive Polarity, Single Output (cont.)

#### 863-NCV8508PD50G
- **NCV8508PD50G**
  - Package: SO-8 EP
  - VO Typ. (V): 5
  - IO Typ. (A): 0.25
  - Price Each: 4.32

#### 863-NCV8502PD80G
- **NCV8502PD80G**
  - Package: SO-8 EP
  - VO Typ. (V): 8
  - IO Typ. (A): 0.25
  - Price Each: 4.32

#### 863-NCV8502PD50G
- **NCV8502PD50G**
  - Package: TO-220
  - VO Typ. (V): 5
  - IO Typ. (A): 0.25
  - Price Each: 4.32

### Positive Polarity, Multiple Output

#### 863-NCV8509PD25G
- **NCV8509PD25G**
  - Package: DPAK
  - VO Typ. (V): 2.5
  - IO Typ. (A): 0.4
  - Price Each: 4.32

#### 863-NCV8502PDW25G
- **NCV8502PDW25G**
  - Package: DPAK
  - VO Typ. (V): 2.5
  - IO Typ. (A): 0.4
  - Price Each: 4.32

#### 863-NCV8501PDW25G
- **NCV8501PDW25G**
  - Package: DPAK
  - VO Typ. (V): 2.5
  - IO Typ. (A): 0.4
  - Price Each: 4.32

### Negative Polarity

#### 863-NCP1011AP100G
- **NCP1011AP100G**
  - Package: D2PAK
  - VO Typ. (V): 3.3
  - IO Typ. (A): 0.35
  - Price Each: 4.32

#### 863-NCP1012AP100G
- **NCP1012AP100G**
  - Package: D2PAK
  - VO Typ. (V): 3.3
  - IO Typ. (A): 0.35
  - Price Each: 4.32

#### 863-NCP1010AP100G
- **NCP1010AP100G**
  - Package: D2PAK
  - VO Typ. (V): 3.3
  - IO Typ. (A): 0.35
  - Price Each: 4.32

### OFF-LINE REGULATORS

For quantities of 1000 and up, call for quote.

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<th>MOUSER STOCK NO.</th>
<th>On Semiconductor Part No.</th>
<th>Package</th>
<th>VO Typ. (V)</th>
<th>IO Typ. (A)</th>
<th>VDO Typ. (V)</th>
<th>Price Each</th>
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#### Voltage Mode

#### 863-NCP1010AP065G
- **NCP1010AP065G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 0.7
  - Price Each: 4.32

#### 863-NCP1010AP130G
- **NCP1010AP130G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 1.3
  - Price Each: 4.32

#### 863-NCP1011AP100G
- **NCP1011AP100G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 1.3
  - Price Each: 4.32

#### 863-NCP1012AP100G
- **NCP1012AP100G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 1.3
  - Price Each: 4.32

#### 863-NCP1013AP100G
- **NCP1013AP100G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 1.3
  - Price Each: 4.32

#### 863-NCP1014AP100G
- **NCP1014AP100G**
  - Package: PDIP-7
  - VO Typ. (V): 10
  - IO Typ. (A): 1.3
  - Price Each: 4.32

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Example: The 7805 3-Terminal Regulator

The 7805 is a member of the 78xx series (xx is the output voltage.)
The specifications for the 7805 in a TO-220 package are:

- Output voltage – 5 V
- Maximum output current – 1 A
- Maximum input voltage – 35 V
- Minimum input voltage – 7.5 V
- Output tolerance – 4.8 V to 5.2 V
- Line/load regulation – < 50 mV
- Ripple rejection – > 68 dB
- Maximum power dissipation – 19 W (infinite heatsink @ 25°C)
- Minimum output current – 5 mA
LM340/LM78XX Series
3-Terminal Positive Regulators

General Description
The LM140/LM340A/LM340/LM78XXC monolithic
3-terminal positive voltage regulators employ internal
current-limiting, thermal shutdown and safe-area compensa-
tion, making them essentially indestructible. If adequate heat
sinking is provided, they can deliver over 1.0A output cur-
rent. They are intended as fixed voltage regulators in a wide
range of applications including local (on-card) regulation for
elimination of noise and distribution problems associated
with single-point regulation. In addition to use as fixed volt-
age regulators, these devices can be used with external
components to obtain adjustable output voltages and cur-
rents.

Considerable effort was expended to make the entire series
of regulators easy to use and minimize the number of exter-
nal components. It is not necessary to bypass the output,
although this does improve transient response. Input by-
passing is needed only if the regulator is located far from the
filter capacitor of the power supply.

Features
- Complete specifications at 1A load
- Output voltage tolerances of ±2% at Tj = 25˚C and ±4%
  over the temperature range (LM340A)
- Line regulation of 0.01% of VOUT/V of ∆VIN at 1A load
  (LM340A)
- Load regulation of 0.3% of VOUT/A (LM340A)
- Internal thermal overload protection
- Internal short-circuit current limit
- Output transistor safe area protection
- P* Product Enhancement tested

Typical Applications

Fixed Output Regulator

Adjustable Output Regulator

V_{OUT} = 5V + (5V/R1 + IQ) R2
5V/R1 > 3IQ,
load regulation (Lr) \approx \left(\frac{R1 + R2}{R1}\right) (Lr of LM340-5).

Current Regulator

\Delta IQ = 1.3 mA over line and load changes.

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<table>
<thead>
<tr>
<th>Package</th>
<th>Temperature Range</th>
<th>Part Number</th>
<th>Packaging Marking</th>
<th>Transport Media</th>
<th>NSC Drawing</th>
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<tbody>
<tr>
<td>3-Lead TO-3</td>
<td>0˚C to +125˚C</td>
<td>LM340K-5.0</td>
<td>LM340K-5.0 7805P+</td>
<td>50 Per Bag</td>
<td>K02A</td>
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<td>LM340K-12</td>
<td>LM340K 12 7812P+</td>
<td>50 Per Bag</td>
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<tr>
<td></td>
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<td>LM340K-15</td>
<td>LM340K 15 7815P+</td>
<td>50 Per Bag</td>
<td></td>
</tr>
<tr>
<td>3-lead TO-220</td>
<td>0˚C to +125˚C</td>
<td>LM340AT-5.0</td>
<td>LM340AT 5.0 P+</td>
<td>45 Units/Rail</td>
<td>T03B</td>
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<td>LM340T-5.0</td>
<td>LM340T5 7805 P+</td>
<td>45 Units/Rail</td>
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<td>3-Lead TO-263</td>
<td>0˚C to +125˚C</td>
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<td>LM340S-12 P+</td>
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<td>500 Units Tape and Reel</td>
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<td>2k Units Tape and Reel</td>
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<td>Unpackaged Die</td>
<td>-55˚C to 125˚C</td>
<td>LM140KG-5 MD8</td>
<td>221 Per Waffle Pack</td>
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<td>221 Per Waffle Pack</td>
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### Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 5)

<table>
<thead>
<tr>
<th>DC Input Voltage</th>
<th>All Devices except LM7824/LM7824C</th>
<th>35V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LM7824/LM7824C</td>
<td>40V</td>
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</tbody>
</table>

Internal Power Dissipation (Note 2) Internally Limited

Maximum Junction Temperature 150°C

Storage Temperature Range −65°C to +150°C

### Operating Conditions (Note 1)

Temperature Range (T_A) (Note 2)

LM140A, LM140 −55°C to +125°C

LM340A, LM340, LM7800 0°C to +125°C

### LM340A Electrical Characteristics

I_{OUT} = 1A, −55°C ≤ T_J ≤ +150°C (LM140A), or 0°C ≤ T_J ≤ +125°C (LM340A) unless otherwise specified (Note 4)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>5V</th>
<th>12V</th>
<th>15V</th>
<th>Units</th>
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<tbody>
<tr>
<td>VO</td>
<td>Output Voltage</td>
<td>T_J = 25°C</td>
<td>4.9</td>
<td>5</td>
<td>5.1</td>
<td>11.75</td>
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<tr>
<td></td>
<td></td>
<td>P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A</td>
<td>4.8</td>
<td>5.2</td>
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<td>11.5</td>
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<tr>
<td></td>
<td></td>
<td>V_MIN ≤ V_IN ≤ V_MAX</td>
<td>(7.5 ≤ V_IN ≤ 20)</td>
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<td></td>
<td>(14.8 ≤ V_IN ≤ 27)</td>
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<td>△VO</td>
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<td>I_O = 500 mA</td>
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<td>3</td>
<td>10</td>
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<td>4</td>
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<td></td>
<td></td>
<td>△V_IN</td>
<td>(7.5 ≤ V_IN ≤ 20)</td>
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<td>(14.8 ≤ V_IN ≤ 27)</td>
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<tr>
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<td>T_J = 25°C</td>
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<td>9</td>
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<td></td>
<td>Over Temperature</td>
<td>△V_IN</td>
<td>(8 ≤ V_IN ≤ 12)</td>
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<td></td>
<td>(16 ≤ V_IN ≤ 22)</td>
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<td>△VO</td>
<td>Load Regulation</td>
<td>T_J = 25°C</td>
<td>5 mA ≤ I_O ≤ 1.5A</td>
<td>10</td>
<td>25</td>
<td>12</td>
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<td>250 mA ≤ I_O ≤ 750 mA</td>
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<td>19</td>
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<td></td>
<td>Over Temperature</td>
<td>5 mA ≤ I_O ≤ 1A</td>
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<td>I_O</td>
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<td>Over Temperature</td>
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<td>△I_O</td>
<td>Quiescent Current Change</td>
<td>5 mA ≤ I_O ≤ 1A</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>T_J = 25°C, I_O = 1A</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V_MIN ≤ V_IN ≤ V_MAX</td>
<td>(7.5 ≤ V_IN ≤ 20)</td>
<td></td>
<td></td>
<td></td>
<td>(17.9 ≤ V_IN ≤ 30)</td>
</tr>
<tr>
<td></td>
<td>I_O = 500 mA</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V_MIN ≤ V_IN ≤ V_MAX</td>
<td>(8 ≤ V_IN ≤ 25)</td>
<td></td>
<td></td>
<td></td>
<td>(17.9 ≤ V_IN ≤ 30)</td>
</tr>
<tr>
<td>V_N</td>
<td>Output Noise Voltage</td>
<td>T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz</td>
<td>40</td>
<td>75</td>
<td>90</td>
<td>µV</td>
</tr>
<tr>
<td>△V_IN</td>
<td>Ripple Rejection</td>
<td>T_J = 25°C, f = 120 Hz, I_O = 1A</td>
<td>68</td>
<td>80</td>
<td>61</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>or f = 120 Hz, I_O = 500 mA,</td>
<td>68</td>
<td></td>
<td>61</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Over Temperature,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V_MIN ≤ V_IN ≤ V_MAX</td>
<td>(8 ≤ V_IN ≤ 18)</td>
<td></td>
<td></td>
<td></td>
<td>(18.5 ≤ V_IN ≤ 28.5)</td>
</tr>
<tr>
<td>R_O</td>
<td>Dropout Voltage</td>
<td>T_J = 25°C, I_O = 1A</td>
<td>2.0</td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>f = 1 kHz</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Output Resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### LM140 Electrical Characteristics (Note 4) (Continued)

\(-55^\circ\text{C} \leq T_J \leq +150^\circ\text{C}\) unless otherwise specified

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>(\Delta V_{IN}^{\Delta V_{OUT}}) Ripple Rejection</th>
<th>(\Delta V_{IN}) Line Regulation</th>
<th>(V_{IN}) Input Voltage Required to Maintain Line Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\Delta V_{IN}^{\Delta V_{OUT}}) Ripple Rejection</td>
<td>(I_O \leq 1\text{A}, T_J = 25^\circ\text{C}) or (-55^\circ\text{C} \leq T_J \leq +150^\circ\text{C})</td>
<td>(V_{MIN} \leq V_{IN} \leq V_{MAX})</td>
<td>(0^\circ\text{C} \leq T_J \leq +125^\circ\text{C})</td>
<td>(T_J = 25^\circ\text{C}, I_O \leq 1\text{A})</td>
</tr>
<tr>
<td></td>
<td>(f = 120\text{ Hz})</td>
<td>(I_O \leq 500\text{ mA})</td>
<td>(8 \leq V_{IN} \leq 18)</td>
<td>(15 \leq V_{IN} \leq 25)</td>
<td>(18.5 \leq V_{IN} \leq 28.5)</td>
</tr>
<tr>
<td></td>
<td>(R_{O}) Dropout Voltage</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(I_O = 1\text{A})</td>
<td>(f = 1 \text{ kHz})</td>
<td>(T_J = 25^\circ\text{C})</td>
</tr>
<tr>
<td></td>
<td>Output Resistance</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(2.0)</td>
<td>(8)</td>
<td>(2.1)</td>
</tr>
<tr>
<td></td>
<td>Short-Circuit Current</td>
<td>(f = 1 \text{ kHz})</td>
<td>(18)</td>
<td>(19)</td>
<td>(1.5)</td>
</tr>
<tr>
<td></td>
<td>Peak Output Current</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(120)</td>
<td>(190)</td>
<td>(1.2)</td>
</tr>
<tr>
<td></td>
<td>Average TC of (V_{OUT})</td>
<td>(0^\circ\text{C} \leq T_J \leq +150^\circ\text{C})</td>
<td>(-0.6)</td>
<td>(-1.5)</td>
<td>(-1.8)</td>
</tr>
</tbody>
</table>

### LM340/LM78XXC Electrical Characteristics (Note 4)

\(0^\circ\text{C} \leq T_J \leq +125^\circ\text{C}\) unless otherwise specified

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>(\Delta V_{IN}) Line Regulation</th>
<th>(\Delta V_{O}) Load Regulation</th>
<th>(I_{O}) Quiescent Current</th>
<th>(\Delta I_{O}) Quiescent Current Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(V_{O}) Output Voltage</td>
<td>(T_J = 25^\circ\text{C}), (5\text{ mA} \leq I_O \leq 1\text{A})</td>
<td>(4.8) (5) (5.2) (11.5) (12) (12.5)</td>
<td>(4.75) (5.25) (11.4) (12.6) (14.5 \leq V_{IN} \leq 27)</td>
<td>(4.8) (5) (5.2) (11.5) (12) (12.5)</td>
<td>(4.75) (5.25) (11.4) (12.6) (14.5 \leq V_{IN} \leq 27)</td>
</tr>
<tr>
<td></td>
<td>(P_{D}) ≤ 15W, (5\text{ mA} \leq I_O \leq 1\text{A})</td>
<td>(V_{MIN} \leq V_{IN} \leq V_{MAX})</td>
<td>(44.4) (45) (45.6) (14) (15) (16)</td>
<td>(4.75) (5.25) (11.4) (12.6) (14.5 \leq V_{IN} \leq 27)</td>
<td>(4.75) (5.25) (11.4) (12.6) (14.5 \leq V_{IN} \leq 27)</td>
<td>(4.75) (5.25) (11.4) (12.6) (14.5 \leq V_{IN} \leq 27)</td>
</tr>
<tr>
<td></td>
<td>(\Delta V_{O}) Line Regulation</td>
<td>(I_O = 500\text{ mA})</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(\Delta V_{IN})</td>
<td>(3) (5) (50)</td>
<td>(4) (120) (14.5 \leq V_{IN} \leq 30)</td>
</tr>
<tr>
<td></td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(0^\circ\text{C} \leq T_J \leq +125^\circ\text{C})</td>
<td>(\Delta V_{IN})</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
</tr>
<tr>
<td></td>
<td>(I_O \leq 1\text{A})</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(\Delta V_{IN})</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
</tr>
<tr>
<td></td>
<td>(0^\circ\text{C} \leq T_J \leq +125^\circ\text{C})</td>
<td>(\Delta V_{IN})</td>
<td>(50) (120) (14.5 \leq V_{IN} \leq 30)</td>
<td>(25) (60) (16 \leq V_{IN} \leq 22)</td>
<td>(75) (150) (20 \leq V_{IN} \leq 26)</td>
<td>(75) (150) (20 \leq V_{IN} \leq 26)</td>
</tr>
<tr>
<td></td>
<td>(\Delta V_O) Load Regulation</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(5\text{ mA} \leq I_O \leq 1.5\text{A})</td>
<td>(25\text{ mA} \leq I_O \leq 750\text{ mA})</td>
<td>(5\text{ mA} \leq I_O \leq 1\text{A}), (0^\circ\text{C} \leq T_J \leq +125^\circ\text{C})</td>
<td>(5\text{ mA} \leq I_O \leq 1\text{A}), (0^\circ\text{C} \leq T_J \leq +125^\circ\text{C})</td>
</tr>
<tr>
<td></td>
<td>(I_O \leq 1\text{A})</td>
<td>(T_J = 25^\circ\text{C})</td>
<td>(8) (8) (8)</td>
<td>(8.5) (8.5) (8.5)</td>
<td>(8) (8) (8)</td>
<td>(8.5) (8.5) (8.5)</td>
</tr>
<tr>
<td></td>
<td>(\Delta I_O) Quiescent Current Change</td>
<td>(T_J = 25^\circ\text{C}), (I_O \leq 1\text{A})</td>
<td>(0.5) (0.5) (0.5)</td>
<td>(1.0) (1.0) (1.0)</td>
<td>(0.5) (0.5) (0.5)</td>
<td>(1.0) (1.0) (1.0)</td>
</tr>
</tbody>
</table>
### LM340/LM78XXC Electrical Characteristics (Note 4) (Continued)

0°C ≤ TJ ≤ +125°C unless otherwise specified

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Output Voltage</th>
<th>Input Voltage (unless otherwise noted)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5V</td>
<td>10V</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>12V</td>
<td>19V</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>15V</td>
<td>23V</td>
<td>V</td>
</tr>
<tr>
<td>Parameter</td>
<td>Conditions</td>
<td>Min</td>
<td>Typ</td>
</tr>
<tr>
<td>V_MIN ≤ VIN ≤ V_MAX</td>
<td>(7.5 ≤ VIN ≤ 20)</td>
<td>(14.8 ≤ VIN ≤ 27)</td>
<td>(17.9 ≤ VIN ≤ 30)</td>
</tr>
<tr>
<td>I_O ≤ 500 mA, 0°C ≤ TJ ≤ +125°C</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>V_MIN ≤ VIN ≤ V_MAX</td>
<td>(7 ≤ VIN ≤ 25)</td>
<td>(14.5 ≤ VIN ≤ 30)</td>
<td>(17.5 ≤ VIN ≤ 30)</td>
</tr>
</tbody>
</table>

#### VN
- Output Noise Voltage
  - TA = 25°C, 10 Hz ≤ f ≤ 100 kHz
  - 40, 75, 90 µV

#### ΔV_IN / ΔV_OUT
- Ripple Rejection
  - f = 120 Hz
    - I_O ≤ 1A, TJ = 25°C
    - 62, 80, 55, 72, 54, 70 dB
  - or I_O ≤ 500 mA, 0°C ≤ TJ ≤ +125°C
    - 62, 55, 54 dB
  - V_MIN ≤ VIN ≤ V_MAX
    - (8 ≤ VIN ≤ 18) | (15 ≤ VIN ≤ 25) | (18.5 ≤ VIN ≤ 28.5) |

#### R_D
- Dropout Voltage
  - TJ = 25°C, I_O = 1A
  - 2.0, 2.0, 2.0 V
  - f = 1 kHz
  - 8, 18, 19 mA

#### R_O
- Short-Circuit Current
  - TJ = 25°C
  - 2.1, 1.5, 1.2 A

#### Average TC of V_OUT
- 0°C ≤ TJ ≤ +125°C, I_O = 5 mA
  - −0.6, −1.5, −1.8 mV/°C

#### V_IN
- Input Voltage Required to Maintain Line Regulation
  - TJ = 25°C, I_O = 1A
  - 7.5, 14.6, 17.7 V

---

**Notes:**

**Note 1:** Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Conditions are conditions under which the device functions but the specifications might not be guaranteed. For guaranteed specifications and test conditions see the Electrical Characteristics.

**Note 2:** The maximum allowable power dissipation at any ambient temperature is a function of the maximum junction temperature for operation (T MAX = 125°C or 150°C), the junction-to-ambient thermal resistance (θ JA), and the ambient temperature (TA). PDMAX = (T MAX − TA)/θ JA. If this dissipation is exceeded, the die temperature will rise above T MAX and the electrical specifications do not apply. If the die temperature rises above 150°C, the device will go into thermal shutdown. If the TO-263 package is used, the thermal resistance can be reduced by increasing the PC board copper area thermally connected to the package: Using 0.5 square inches of copper area, θ JA is 50°C/W; with 1 square inch of copper area, θ JA is 37°C/W; and with 1.6 or more inches of copper area, θ JA is 32°C/W.

**Note 3:** ESD rating is based on the human body model, 100 pF discharged through 1.5 kΩ.

**Note 4:** All characteristics are measured with a 0.22 µF capacitor from input to ground and a 0.1 µF capacitor from output to ground. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_p ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

**Note 5:** A military RETS specification is available on request. At the time of printing, the military RETS specifications for the LM140AK-5.0/883, LM140AK-12/883, and LM140AK-15/883 complied with the min and max limits for the respective versions of the LM140A. At the time of printing, the military RETS specifications for the LM140K-5.0/883, LM140K-12/883, and LM140K-15/883 complied with the min and max limits for the respective versions of the LM140. The LM140H/883, LM140K/883, and LM140AK/883 may also be procured as a Standard Military Drawing.
**Typical Performance Characteristics**

**Maximum Average Power Dissipation**

<table>
<thead>
<tr>
<th>AMBIENT TEMPERATURE (°C)</th>
<th>POWER DISSIPATION (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-75</td>
<td>25</td>
</tr>
<tr>
<td>-50</td>
<td>20</td>
</tr>
<tr>
<td>-25</td>
<td>15</td>
</tr>
<tr>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>75</td>
<td>1</td>
</tr>
<tr>
<td>100</td>
<td>0.5</td>
</tr>
<tr>
<td>125</td>
<td>0</td>
</tr>
</tbody>
</table>

- INFINITE HEAT SINK
- WITH 10°C/W HEAT SINK
- NO HEAT SINK

**Maximum Power Dissipation (TO-263)**

(See Note 2)

<table>
<thead>
<tr>
<th>AMBIENT TEMPERATURE (°C)</th>
<th>POWER DISSIPATION (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>3.5</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>1.5</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
</tr>
</tbody>
</table>

ΘJA = 52°C/W
ΘJA = 57°C/W
ΘJA = 50°C/W
ΘJA = 73°C/W

**Output Voltage (Normalized to 1V at TJ = 25°C)**

<table>
<thead>
<tr>
<th>JUNCTION TEMPERATURE (°C)</th>
<th>NORMALIZED OUTPUT VOLTAGE (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-75</td>
<td>1</td>
</tr>
<tr>
<td>-50</td>
<td>0.999</td>
</tr>
<tr>
<td>-25</td>
<td>0.995</td>
</tr>
<tr>
<td>0</td>
<td>0.990</td>
</tr>
<tr>
<td>25</td>
<td>0.985</td>
</tr>
<tr>
<td>50</td>
<td>0.980</td>
</tr>
<tr>
<td>75</td>
<td>0.975</td>
</tr>
<tr>
<td>100</td>
<td>0.970</td>
</tr>
<tr>
<td>125</td>
<td>0.965</td>
</tr>
<tr>
<td>150</td>
<td>0.960</td>
</tr>
</tbody>
</table>

**Ripple Rejection**

<table>
<thead>
<tr>
<th>FREQUENCY (Hz)</th>
<th>RIPPLE REJECTION (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>1k</td>
<td>60</td>
</tr>
<tr>
<td>10k</td>
<td>40</td>
</tr>
<tr>
<td>100k</td>
<td>20</td>
</tr>
</tbody>
</table>

VOUT = 5V
VOUT = 24V

**Note:** Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.
Typical Performance Characteristics (Continued)

Output Impedance

![Output Impedance Graph]

Quiescent Current

![Quiescent Current Graph]

Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

Dropout Characteristics

![Dropout Characteristics Graph]

Peak Output Current

![Peak Output Current Graph]

Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

 Dropout Voltage

![Dropout Voltage Graph]

Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.

Quiescent Current

![Quiescent Current Graph]

Note: Shaded area refers to LM340A/LM340, LM7805C, LM7812C and LM7815C.
Line Regulation
140AK-5.0, I_{OUT} = 1A, T_{A} = 25˚C

Line Regulation
140AK-5.0, V_{IN} = 10V, T_{A} = 25˚C

Equivalent Schematic
Application Hints

The LM340/LM78XX series is designed with thermal protection, output short-circuit protection and output transistor safe area protection. However, as with any IC regulator, it becomes necessary to take precautions to assure that the regulator is not inadvertently damaged. The following describes possible misapplications and methods to prevent damage to the regulator.

**SHORTING THE REGULATOR INPUT**

When using large capacitors at the output of these regulators, a protection diode connected input to output (Figure 1) may be required if the input is shorted to ground. Without the protection diode, an input short will cause the input to rapidly approach ground potential, while the output remains near the initial $V_{OUT}$ because of the stored charge in the large output capacitor. The capacitor will then discharge through a large internal input to output diode and parasitic transistors. If the energy released by the capacitor is large enough, this diode, low current metal and the regulator will be destroyed. The fast diode in Figure 1 will shunt most of the capacitors discharge current around the regulator. Generally no protection diode is required for values of output capacitance $\leq 10 \, \mu F$.

**RAISING THE OUTPUT VOLTAGE ABOVE THE INPUT VOLTAGE**

Since the output of the device does not sink current, forcing the output high can cause damage to internal low current paths in a manner similar to that just described in the “Shorting the Regulator Input” section.

**REGULATOR FLOATING GROUND (Figure 2)**

When the ground pin alone becomes disconnected, the output approaches the unregulated input, causing possible damage to other circuits connected to $V_{OUT}$. If ground is reconnected with power “ON”, damage may also occur to the regulator. This fault is most likely to occur when plugging in regulators or modules with on card regulators into powered up sockets. Power should be turned off first, thermal limit ceases operating, or ground should be connected first if power must be left on.

**TRANSIENT VOLTAGES**

If transients exceed the maximum rated input voltage of the device, or reach more than 0.8V below ground and have sufficient energy, they will damage the regulator. The solution is to use a large input capacitor, a series input breakdown diode, a choke, a transient suppressor or a combination of these.
Application Hints (Continued)

HEATSINKING TO-263 AND SOT-223 PACKAGE PARTS

Both the TO-263 ("S") and SOT-223 ("MP") packages use a copper plane on the PCB and the PCB itself as a heatsink. To optimize the heat sinking ability of the plane and PCB, solder the tab of the plane.

shows for the TO-263 the measured values of $\theta_{(J-A)}$ for different copper area sizes using a typical PCB with 1 ounce copper and no solder mask over the copper area used for heatsinking.

As shown in the figure, increasing the copper area beyond 1 square inch produces very little improvement. It should also be observed that the minimum value of $\theta_{(J-A)}$ for the TO-263 package mounted to a PCB is 32°C/W.

As a design aid, Figure 5 shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device (assuming $\theta_{(J-A)}$ is 35°C/W and the maximum junction temperature is 125°C).

Please see AN-1028 for power enhancement techniques to be used with the SOT-223 package.

Figures 6, 7 show the information for the SOT-223 package. Figure 6 assumes a $\theta_{(J-A)}$ of 74°C/W for 1 ounce copper and 51°C/W for 2 ounce copper and a maximum junction temperature of 125°C.
Typical Applications

Fixed Output Regulator

Note: Bypass capacitors are recommended for optimum stability and transient response, and should be located as close as possible to the regulator.

High Input Voltage Circuits

High Current Voltage Regulator

\[ \beta(Q1) \geq \frac{I_{Q1}}{I_{REG_{Max}}} \]

\[ R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1) V_{BE}(Q1)}{I_{REG_{Max}} (\beta + 1) - I_{Q1_{Max}}} \]
Connection Diagrams and Ordering Information

TO-3 Metal Can Package (K)

Bottom View
Steel Package Order Numbers:
LM140K-5.0  LM140K-12  LM140K-15
LM340K-12  LM340K-15
LM340K-5.0
See Package Number K02A
LM140K-5.0/883  LM140K-12/883  LM140K-15/883
See Package Number K02C

TO-220 Power Package (T)

Top View
Plastic Package Order Numbers:
LM340AT-5.0  LM340T-5.0
LM340T-12  LM340T-15
LM7805CT  LM7812CT
LM7815CT  LM7808CT
See Package Number T03B

TO-39 Metal Can Package (H)

Top View
Metal Can Order Numbers†:
LM140H-5.0/883  LM140H-6.0/883
LM140H-8.0/883  LM140H-12/883
LM140H-15/883  LM140H-24/883
See Package Number H03A

TO-263 Surface-Mount Package (S)

Top View
Surface-Mount Package Order Numbers:
LM340S-5.0  LM340S-12
See Package Number TS3B

3-Lead SOT-223
(Front View)
Order Number LM340MP-5.0
Package Marked NO0A
See Package Number MA04A

†The specifications for the LM140H/883 devices are not contained in this datasheet. If specifications for these devices are required, contact the National Semiconductor Sales Office/Distributors.
Physical Dimensions  inches (millimeters) unless otherwise noted (Continued)

TO-220 Power Package (T)
LM7805CT, LM7812CT, LM7815CT, LM7806CT, LM7808CT, LM7818CT or LM7824CT
NS Package Number T03B
Example Application

Assume an 8 cell NiCd battery pack and a circuit that requires 5 V at 100 mA. Can a 7805 be used?

At full charge, the battery pack voltage is

\[ 8 \times 1.2 \text{ V} = 9.6 \text{ V} \]

When nearly depleted, the battery pack voltage is

\[ 8 \times 1.0 \text{ V} = 8.0 \text{ V} \]

The battery pack voltage is above the 7.5 V necessary for guaranteed operation of the 7805 voltage regulator.
Power Dissipation

Power dissipation in the regulator is simply the voltage difference across the regulator multiplied by the current through the regulator.

For the previous example (with the battery pack at full charge), the power dissipation is

\[(9.6 \text{ V} - 5.0 \text{ V}) \times 100 \text{ mA} = 460 \text{ mW}\]

This is below the maximum power dissipation at any temperature.
Voltage Regulators on the Handyboard
Where are the input capacitors?

The Handyboard does not have input capacitors for either of the voltage regulators. Without input capacitors, the voltage regulator is prone to oscillation.
What about minimum output current?

The LM2931 is used to power the RAM when the Handyboard is turned off. The current draw of the RAM is on the order of microamps, but the regulator performance is not guaranteed below a few milliamps.
Handyboard Fix #1

Add a 0.1 µF capacitor between the input and ground terminals of the LM2931.
Handyboard Fix #2

Add a 4.7 kΩ resistor between MEM-PWR and ground pins of the 62256 RAM.
The End