Voltage
Regulators
Voltage Regulator Applications

FUNCTION TABLE
(each gate)

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>L</td>
</tr>
</tbody>
</table>

logic diagram, each gate (positive logic)

recommended operating conditions (see Note 3)

<table>
<thead>
<tr>
<th></th>
<th>SN5400</th>
<th>SN7400</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>NOM</td>
</tr>
<tr>
<td>$V_{CC}$</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Voltage Regulators Classification

- Voltage Regulators
  - Pulse Regulators
  - Continuous Regulators
    - Parametric Regulators
    - Compensatory Regulators
Application Basic Parameters:

- Output Voltage - \( V_{\text{out}} \)
- Input Voltage Range - \( V_{\text{in}} \)
- Stabilization Ratio - \( I_{\text{R}} \)
- Max. Output Current - \( I_{\text{out \, max}} \)
- Short-Circuit Output Current - \( I_{\text{sc}} \)
- Efficiency,
- Temperature Range.

\[
I_{\text{R}} = \frac{\Delta U_{\text{wy}}}{\Delta U_{\text{we}}} \cdot 100\%
\]
DC Voltage Regulators

Output Characteristic

\[ U_0 \]

\[ \Delta U_0 \]

Working Area

\[ I_{omin} \]

\[ I_{omax} \]
DC Voltage Regulators

\[ U_o \]

\[ \Delta U_o \]

Working Area

\[ U_{imin} \]

\[ U_{imax} \]

Transfer Characteristic
The parametric regulator uses as operating principle the nonlinear current-voltage characteristic of the Zener diode.

\[ U_o \uparrow, I_o \uparrow, I_z \downarrow, U_z \downarrow, U_o \downarrow \]

\[
Rs_{\text{min}} = \frac{V_{\text{imax}} - V_z}{I_{z\text{max}} + I_{\text{omin}}} \\
Rs_{\text{max}} = \frac{V_{\text{imin}} - V_z}{I_{z\text{min}} + I_{\text{omax}}}
\]
Zener Diode- Parametric Regulator

Zener Diode Characteristic

\[ U_R \quad U_{Z_{\text{max}}} \quad U_{Z_{N}} \quad U_{Z_{\text{min}}} \]

\[ I_{Z_{\text{min}}} \quad I_{Z_{N}} \quad I_{Z_{\text{max}}} \]

\[ I_F \quad U_F \]
Zener Diode - Parametric Regulator

\[ U'_Z = U_Z + U_{BE} \]

High Power Zener Diode
Parametric Regulators

\[ U_O = U_Z - U_{BE} \]

Parametric Regulator Voltage With Follower Output
Parametric Regulators

Paralleled Parametric Regulator

\[ I_i = I_z + I_o \]
Parametric Regulators

Serial Parametric Regulator

\[ U_o \downarrow, I_o \downarrow, I_b \downarrow, I_z \uparrow, U_z \uparrow, U_o \uparrow \]
Compensatory Regulator

\[ U_0 = U_{ref}(1 + \frac{R_1}{R_2}) \]

Simply Compensatory Regulator
Compensatory Regulators

Simply Compensatory Regulator ver.1.

\[ U_0 = U_z \cdot \left(1 + \frac{R_1}{R_2}\right) \]
Compensatory Regulators

Simply Compensatory Regulator ver.2.

\[ U_o = U_{ref} \cdot (1 + \frac{R_2}{R_1}) \]
Protections in Voltage Regulators

Negative Voltage Protection
Reverse Voltage Protection
Current Limit
Overvoltage protection

U_i

T

U_r, Error Amplifier

U_o
Precision Integrated-Circuit
Voltage Regulator UA723

Precision Integrated-Circuit Voltage Regulator UA723

Temperature Compensated Zener

Current Source

Voltage Reference Amplifier

Voltage Reference Amplifier

Invert Input

Frequency Compensation

Current Limit

Error Amplifier

Non Invert Input

Schematic Diagram
**Precision Integrated-Circuit**
**Voltage Regulator UA723**

Application Basic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>U input</td>
<td>9.5V-40V</td>
</tr>
<tr>
<td>U output</td>
<td>2V-37V</td>
</tr>
<tr>
<td>I output max</td>
<td>150 mA</td>
</tr>
<tr>
<td>U reference</td>
<td>6.8V-7.5V</td>
</tr>
<tr>
<td>I standby</td>
<td>Max 4mA</td>
</tr>
</tbody>
</table>
Precision Integrated-Circuit
Voltage Regulator UA723

Schematic Diagram

[Source: www.elportal.pl]
Precision Integrated-Circuit
Voltage Regulator UA723

Error Amplifier

Current Limit
Precision Integrated-Circuit Voltage Regulator UA723

Basic Low-Voltage Regulator (VO = 2 V to 7 V)

R3 = \frac{R1 \cdot R2}{R1 + R2}
Precision Integrated-Circuit Voltage Regulator UA723

Basic High-Voltage Regulator (VO = 7 V to 37 V)

\[ R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2} \]
High Power Positive-Voltage Regulator (External npn Pass Transistor)
### 3-Terminal 1 A Positive Voltage Regulator

**78xx**

<table>
<thead>
<tr>
<th>Type</th>
<th>Uout [V]</th>
<th>Uin max [V]</th>
<th>Iout max [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7805</td>
<td>5</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7806</td>
<td>6</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7808</td>
<td>8</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7809</td>
<td>9</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7810</td>
<td>10</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7812</td>
<td>12</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7815</td>
<td>15</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7818</td>
<td>18</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>7824</td>
<td>24</td>
<td>40</td>
<td>1</td>
</tr>
</tbody>
</table>

Application Basic Parameters
3-Terminal 1 A Positive Voltage Regulator

78xx

1 IN

2 GND

3 OUT

Starting Circuit

Reference Voltage

Current Generator

SOA Protection

Error Amplifier

Thermal Protection

Series Pass Element

78xx Block Diagram
3-Terminal 1 A Positive Voltage Regulator

78xx

V in

330 nF

2 GND

100 nF

V out

78xx- Typical Application
3-Terminal 1 A Positive Voltage Regulator

78xx

Circuit for Increasing Output Voltage
3-Terminal 1 A Positive Voltage Regulator

78xx

High-CURRENT Voltage Regulator
3-Terminal 1 A Positive Voltage Regulator

78xx

High Output Current with Short-Circuit Protection
3-Terminal 1 A Positive Voltage Regulator

78xx

TO92
I_{omax}=500mA

TO220
I_{omax}=1A-3A

TO2
I_{omax}=1A-3A

LM78xx Packages
3-Terminal 1 A Positive Voltage Regulator
78xx

Heatsinks

[Source: http://tme.com/]
### 3-Terminal 1 A Negative Voltage Regulator

#### 79xx

<table>
<thead>
<tr>
<th>Type</th>
<th>Uout [V]</th>
<th>Uin max [V]</th>
<th>Iout max [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7905</td>
<td>-5</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7906</td>
<td>-6</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7908</td>
<td>-8</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7909</td>
<td>-9</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7910</td>
<td>-10</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7912</td>
<td>-12</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7915</td>
<td>-15</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7918</td>
<td>-18</td>
<td>-35</td>
<td>1</td>
</tr>
<tr>
<td>7924</td>
<td>-24</td>
<td>-40</td>
<td>1</td>
</tr>
</tbody>
</table>

Application Basic Parameters
3-Terminal 1 A Negative Voltage Regulator

79xx

Typical Application

79xx - Typical Application
3-Terminal 1 A Negative Voltage Regulator

79xx

Split Power Supply (±15 V - 1 A)
### Three-Terminal Adjustable Regulator - LM117, LM317

**Application Basic Parameters**

<table>
<thead>
<tr>
<th>Parametr</th>
<th>min</th>
<th>typical</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>V out [V]</td>
<td>1,2</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>I out [A]</td>
<td></td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>Vref [V]</td>
<td>1,2</td>
<td>1,25</td>
<td>1,3</td>
</tr>
</tbody>
</table>
Three-Terminal Adjustable Regulator- LM117, LM317

LM 117- Block Diagram
Three-Terminal Adjustable Regulator - LM117, LM317

Uo = Uref \left(1 + \frac{R2}{R1}\right), \quad Uref = 1.25V

LM117 - Typical Application
Three-Terminal Adjustable Regulator - LM117, LM317

The diagram shows a circuit with an LM117 three-terminal regulator. The input voltage (Vin) is connected to the input terminal of the regulator (3 Vin). The output voltage (Vout) is connected to the output terminal (2 Vout). The ground (GND) terminal is connected to the ground point (1 GND). Resistance R1 of 150 ohms is connected in series with the output terminal, and R2 of 5k ohms is connected in parallel with the output terminal via a diode. A capacitor of 100 nF is connected to the input voltage (Vin) and a capacitor of 1 uF is connected to the output voltage (Vout). A 680 ohm resistor is also connected in series with the input voltage (Vin). The LM113 diode is used to protect the regulator from reverse polarity. The circuit can be used as a 0V-30V Regulator.
Low Drop-Out Regulator: LDO

\[ \Delta U = U_i - U_o \]

Typical Regulator: \( \Delta U > 2V \)

LDO: \( \Delta U = 0.2V \div 0.5V \)
Low Drop-Out Regulator: LDO

Package

| Size (mm) | 6.5 x 3.5 x 1.65 |
| P_{tot} (mW) | 1700 |

<table>
<thead>
<tr>
<th>V_{max} (V)</th>
<th>I_{max} (A)</th>
<th>V_{out drop} (V) @ 800 mA</th>
<th>V_{out} (V)</th>
<th>V_{out} tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1</td>
<td>1.1</td>
<td>1%</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.25 adjustable</td>
<td>NX1117CADJZ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.2</td>
<td>NX1117C12Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td>NX1117C15Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.8</td>
<td>NX1117C18Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.9</td>
<td>NX1117C19Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>NX1117C20Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>NX1117C25Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.85</td>
<td>NX1117C285Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>NX1117C33Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.0</td>
<td>NX1117C50Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE12Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE15Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE18Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE19Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE20Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE25Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE285Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE33Z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NX1117CE50Z</td>
</tr>
</tbody>
</table>

Low-dropout adjustable and fixed linear voltage regulator NX1117

[Source: www.npm.com]
Functional Diagram

[Source: pl.mouser.com]
Low Drop-Out Regulator: LDO

Typical application for fixed output voltage versions

[Source: www.npx.com]
Key applications

- Post regulation for SMPS (Switched Mode Power Supply)
- Consumer and industrial equipment
- Battery charger
- Hard drive controllers
- Core voltage supply: FPGA, PLD, DSP, CPU
- LCD TV
- DVD player
Linear regulator efficiencies is about 40%.

The larger the difference between the input and output voltage, the more heat is produced.

Even the new LDO (low drop-out) regulators are still inefficient linear regulators.

A switching regulator works by taking small chunks of energy.

Practical switching regulator efficiencies typically range from 70%-95%.

The highest efficiency is desired when battery life is critical.

The lost power is dissipated as heat.
Switching Regulators

Block Diagram

Switch

PWM Controller

Low Pass Filter

Filter

Error Amplifier

Vi

Vo

Vref

Switching Regulators
Switching Regulators

Low Pass Filter

Switch PWM Control

Step-Down Switching Regulator
Switching Regulators

On State

Off State

Switching Regulators

\[ \frac{V_o}{V_{in}} = \frac{t_{on}}{T} \]

\[ V_o = \frac{t_{on}}{T} V_{in} \]
\[ \frac{V_o}{V_{in}} = \frac{T}{t_{off}} \]

\[ V_o = \frac{T}{t_{off}} V_{in} \]

Step-Up Switching Regulator
**LM2574 Switching Regulator**

**Block Diagram**

[Source: www.ti.com]
LM2574 Switching Regulator

Typical Application

R1 = 1k
3.3V, R2 = 1.7k
5V, R2 = 3.1k
12V, R2 = 8.84k
15V, R2 = 11.3k
For Adj. Version
R1 = Open, R2 = 0Ω

[Source: www.ti.com]
LM2574 Switching Regulator

Parameters

- 3.3V, 5V, 12V, 15V and Adjustable Output Version
- Adjustable Output Version Voltage Range: 1.23V - 37V
- Specified 0.5A Output Current
- Wide Input Range: 40V
- 52kHz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- High Efficiency
- Thermal Shutdown and Current Limit Protection
At low input voltages efficiency is degraded. Higher inputs make the fixed loss a smaller percentage, improving efficiency.
LT1109 Switching Regulator

Block Diagram

[Source: http://cds.linear.com/]
LT1109 Switching Regulator

Typical Application

[Source: http://cds.linear.com/]
Parameters:

Output Voltage: 5V, 12V, Adjustable Voltage

120kHz Oscillator

1.6V Minimum Start-Up Voltage

Logic Controlled Shutdown

Output Current 100mA (Output 5V), 60mA (output 12V)
MC34063 Switching Regulator

Step-Up/Down/Inverting Switching Regulator

Block Diagram

[Source: www.ti.com]
MC34063 Switching Regulator

Inverting Switching Regulator

[Source: www.ti.com]
MC34063 Switching Regulator

Parameters:

- Operation from 3V to 40V Input
- Low Standby Current
- Current Limiting
- Output Switch Current to 1.5A
- Output Voltage Adjustable
- Frequency Operation to 100kHz
- Precision Reference
2A Standard Buck PWM Regulator ISL 8500

Functional Block Diagram
2A Standard Buck PWM Regulator ISL 8500

Typical Application Schematic
Parameters:

Standard Buck Controller with Integrated Switching Power MOSFET

Integrated Boot Diode

Input Voltage Range: Fixed 5V ±10%, Variable 5.5V to 25V

PWM Output Voltage Adjustable from 0.6V to 19V with Continuous Output Current up to 2A

Fixed 500kHz Switching Frequency

Output Undervoltage Protection

Enable Inputs

Overcurrent Protection, Thermal Overload Protection

Internal 5V LDO regulator
LM 317- Switching Regulator

Low Cost 3A Switching Regulator

[Source: www.ti.com]
UA723 - Switching Regulator

[Source: www.ti.com]
78xx- Switching Regulator

Source: www.farichaldsemi.com