Zener Diode

Using notations as for a conventional diode

For a ZD, the interest is in the **breakdown region** (regulation region), that is a nondestructive region.
Zener Diode

To operate with positive values let’s introduce

\[ i_Z = -i_D \]

\[ v_Z = -v_D \]

The ZD is normally used in reverse bias!
Regulation region of the ZD

\[ I_{Z_{\text{max}}} = \frac{P_{d_{\text{max}}}}{V_{Z}} \]

Nominal operating point: \( V_Z @ I_Z \)
Excerpt from a datasheet

**1N4728A - 1N4758A**

**Zener Diodes**

**Tolerance = 5%**

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_Z (V)$ @ $I_Z$ (Note 1)</th>
<th>Test Current $I_Z$ (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
<td>Typ.</td>
</tr>
<tr>
<td>1N4728A</td>
<td>3.135</td>
<td>3.3</td>
</tr>
<tr>
<td>1N4729A</td>
<td>3.42</td>
<td>3.6</td>
</tr>
<tr>
<td>1N4730A</td>
<td>3.705</td>
<td>3.9</td>
</tr>
<tr>
<td>1N4731A</td>
<td>4.085</td>
<td>4.3</td>
</tr>
<tr>
<td>1N4732A</td>
<td>4.465</td>
<td>4.7</td>
</tr>
<tr>
<td>1N4733A</td>
<td>4.845</td>
<td>5.1</td>
</tr>
<tr>
<td>1N4734A</td>
<td>5.32</td>
<td>5.6</td>
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<tr>
<td>1N4735A</td>
<td>5.89</td>
<td>6.2</td>
</tr>
<tr>
<td>1N4736A</td>
<td>6.46</td>
<td>6.8</td>
</tr>
<tr>
<td>1N4737A</td>
<td>7.125</td>
<td>7.5</td>
</tr>
<tr>
<td>1N4738A</td>
<td>7.79</td>
<td>8.2</td>
</tr>
<tr>
<td>1N4739A</td>
<td>8.645</td>
<td>9.1</td>
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<tr>
<td>1N4740A</td>
<td>9.5</td>
<td>10</td>
</tr>
<tr>
<td>1N4741A</td>
<td>10.45</td>
<td>11</td>
</tr>
<tr>
<td>1N4742A</td>
<td>11.4</td>
<td>12</td>
</tr>
</tbody>
</table>

$P_{D\text{max}} = 1\text{W}$

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1N4728A - 1N4758A Rev. H3
Parametric voltage regulator

Maintains the output voltage constant against input voltage variation, output current variation, temperature variation, etc.

Let’s suppose $DZ$: 1N4740. What is $V_O$ if:

- $v_I = 15$ V
- $v_I = 17$ V
- $I_O = 5$ mA
- $I_O = 10$ mA
- $v_I = 7$ V
Parametric voltage regulator

Maintains output voltage constant

\[ i_Z = i_R - I_O \]
\[ i_R = \frac{v_I - V_Z}{R} \]
\[ i_Z = \frac{v_I - V_Z}{R} - I_O \]

**Exercise**

\[ v_I \approx 12\, \text{V}, \quad V_O = 7.5\, \text{V}, \quad I_O = 70\, \text{mA} \]

\[ R = ? \]
Light-Emitting Diode: LED

- A light-emitting diode (LED) is a two-lead semiconductor light source.
- A p–n junction diode that emits light when activated.

When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons.

This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.
Light-Emitting Diode: LED cont.

- behaves similarly to conventional diodes
- 1.5V to 3V forward voltage drop
  - forward current, type, color
- in forward bias the LED lights up: red, yellow, green, blue, white, infrared – (remote control)
- emits radiation in the visible, infrared, or laser range
- typically **5mA to 20mA @ 2-2.5V**
- **power LED:** 3.5V @ 500mA
High Efficiency LED in Ø 3 mm Tinted Diffused Package

APPLICATIONS
- Status lights
- Off/on indicator
- Background illumination
- Readout lights
- Maintenance lights
- Legend light

PRODUCT GROUP AND PACKAGE DATA
- Product group: LED
- Package: 3 mm
- Product series: standard
- Angle of half intensity: ± 30°

PARTS TABLE

<table>
<thead>
<tr>
<th>PART</th>
<th>COLOR</th>
<th>LUMINOUS INTENSITY (mcd)</th>
<th>at IF (mA)</th>
<th>WAVELENGTH (nm)</th>
<th>at IF (mA)</th>
<th>FORWARD VOLTAGE (V)</th>
<th>at IF (mA)</th>
<th>TECHNOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MIN.</td>
<td>TYP.</td>
<td>MAX.</td>
<td>MIN.</td>
<td>TYP.</td>
<td>MAX.</td>
<td>MIN.</td>
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<tr>
<td>TLHR4400</td>
<td>Red</td>
<td>1.6</td>
<td>13</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td>612</td>
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<tr>
<td>TLHO4400-MS12Z</td>
<td>Soft orange</td>
<td>1.6</td>
<td>13</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td>598</td>
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<tr>
<td>TLHY4400</td>
<td>Yellow</td>
<td>1.6</td>
<td>10</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td>581</td>
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<tr>
<td>TLHG4405</td>
<td>Green</td>
<td>6.3</td>
<td>15</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td>562</td>
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<tr>
<td>TLHP4401</td>
<td>Pure green</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>10</td>
<td></td>
<td></td>
<td>555</td>
</tr>
</tbody>
</table>

ABSOLUTE MAXIMUM RATINGS (Tamb = 25 °C, unless otherwise specified)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITION</th>
<th>SYMBOL</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse voltage</td>
<td></td>
<td>VR</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>DC forward current</td>
<td></td>
<td>IF</td>
<td>30</td>
<td>mA</td>
</tr>
<tr>
<td>Surge forward current</td>
<td>t_p ≤ 10 μs</td>
<td>IFSM</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>Tamb ≤ 60 °C</td>
<td>PV</td>
<td>100</td>
<td>mW</td>
</tr>
</tbody>
</table>
Problem

A voltage in a circuit can be +5V, 0V, or -5V.

How can one signalize what is the voltage value using two LEDs (green for +5V and red for -5V)?
The current through the conducting LED should be 10mA.
7-segment Display (LED)

HDSP-7801 Common Anode, Right Hand Decimal, Green
HDSP-7803 Common Cathode, Right Hand Decimal, Green

2.1V @ 20mA / segment (DP)

[7-segment Display, https://www.electronics-tutorials.ws/blog/7-segment-display-tutorial.html]

Allows to display each of the ten decimal digits 0 through to 9 on the same 7-segment display

What is the connection to display “7”? 
7-segment Display - utilization

[7-segment Display, https://www.electronics-tutorials.ws/blog/7-segment-display-tutorial.html]
4-digit 7-segment Display (LED)

Use time-multiplexing technique. Multiplexing technique is based on the idea of “persistence” of vision of the human eyes.

[http://www.hobbytronics.co.uk/4digit-7segment-red]
4-digit 7-segment Display (LCD)

EDC190 4 Digit 7 Segment LCD Display Digital Clock Tube Static Driving 3V TN Pin

LED strips

Single Color LED Strip

Diagram showing the connection of LED strips with different voltage inputs (3V, 6V, 12V, 24V) and diodes.
LED strips

Single Color LED Strip

RGB LED Strip
LED light bulbs

230-volt LED light bulb with E27 screw

Disassembled LED-light bulb with driver circuit board (dc power supply)
E27 base, 5W, 450lm, CRI >7

Dmitry G - Own work

https://en.wikipedia.org/wiki/LED_filament
Electromagnetic Spectrum \( \lambda = \frac{c}{f} ; \ c = 3 \times 10^8 \text{ m/s} \)
Wavelength vs. period (or frequency)

The **wavelength** of a sinusoidal wave is its **spatial period**:
- the distance over which the wave's shape repeats.

\[
\lambda = cT = \frac{c}{f};
\]

\[
c = 3 \cdot 10^8 \text{ m/s}
\]
Wavelength vs. period (or frequency) — cont.

\[ \lambda = cT = \frac{c}{f} ; \]
\[ c = 3 \cdot 10^8 \text{ m/s} \]

- **Red light**
  \[ \lambda = 650 \text{ nm}, \quad T = \frac{\lambda}{c} = \frac{650 \cdot 10^{-9}}{3 \cdot 10^8} = 216.7 \cdot 10^{-17} \text{ s} = 2.17 \text{ fs}, \quad f = 460.8 \text{ THz} \]

- **GSM frequency band 900MHz, 1800 MHz (mobile phones)**
  \[ f = 900 \text{ MHz}, \quad T = \frac{1}{900 \cdot 10^6} = 1.1 \text{ ns}, \quad \lambda = \frac{3 \cdot 10^8}{900 \cdot 10^6} = 0.33 \text{ m} = 33 \text{ cm} \]

- **FM: Radio Impuls Cluj-Napoca 101.5MHz**
  \[ f = 101.5 \text{ MHz}, \quad T = \frac{1}{101.5 \cdot 10^6} = 9.85 \text{ ns}, \quad \lambda = \frac{3 \cdot 10^8}{101.5 \cdot 10^6} = 2.95 \text{ m} \]