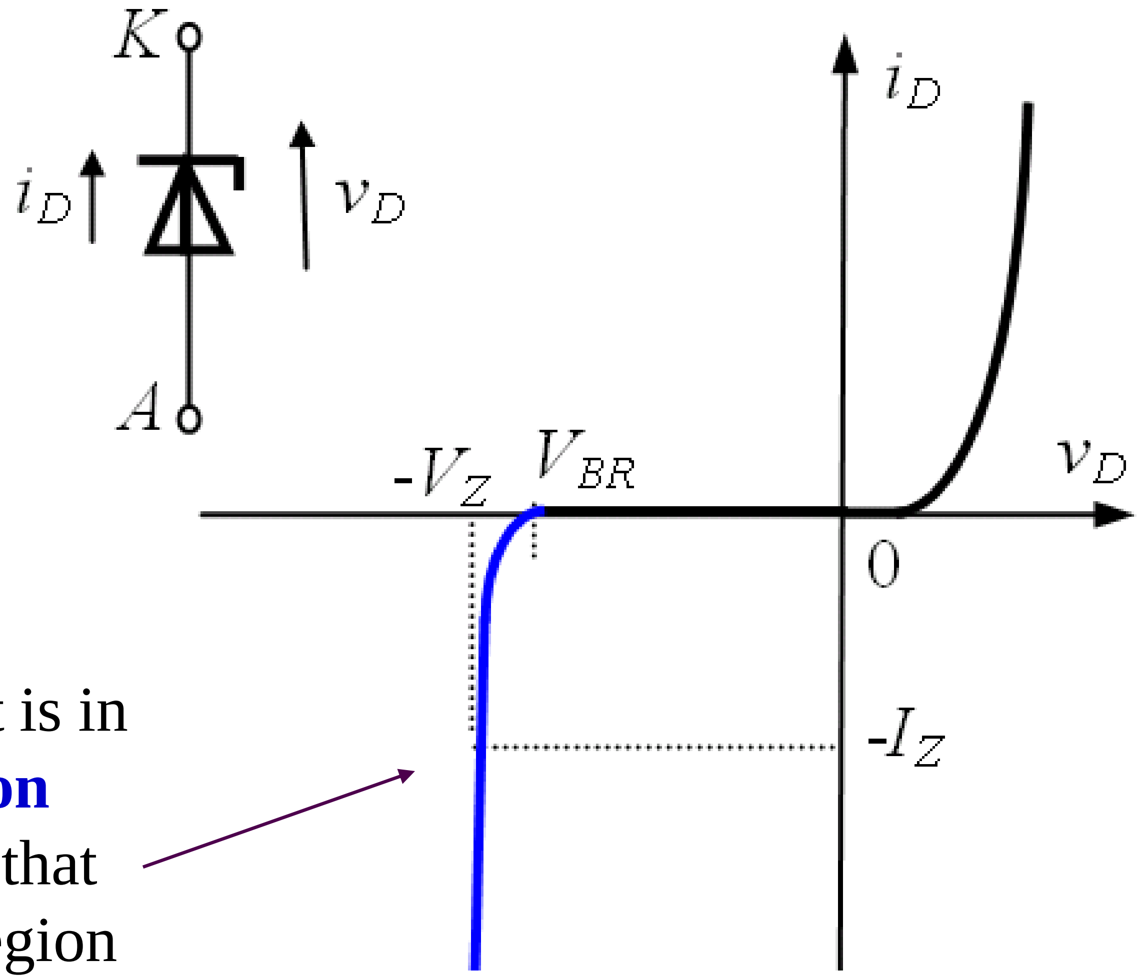
Zener Diode

Using notations as for a conventional diode



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

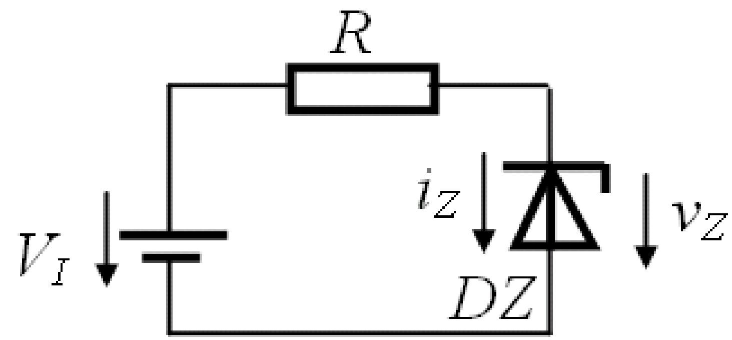
Zener Diode

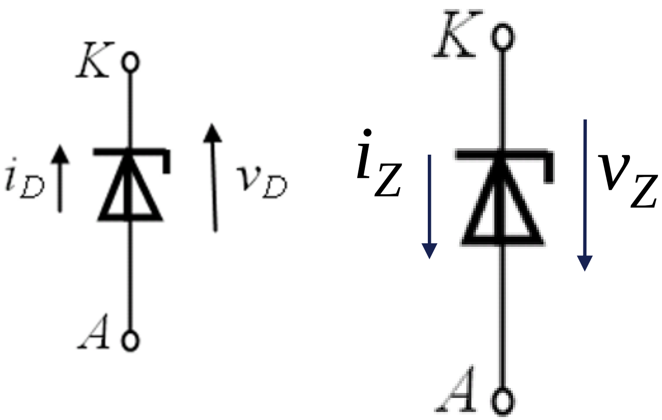
To operate with positive values let's introduce

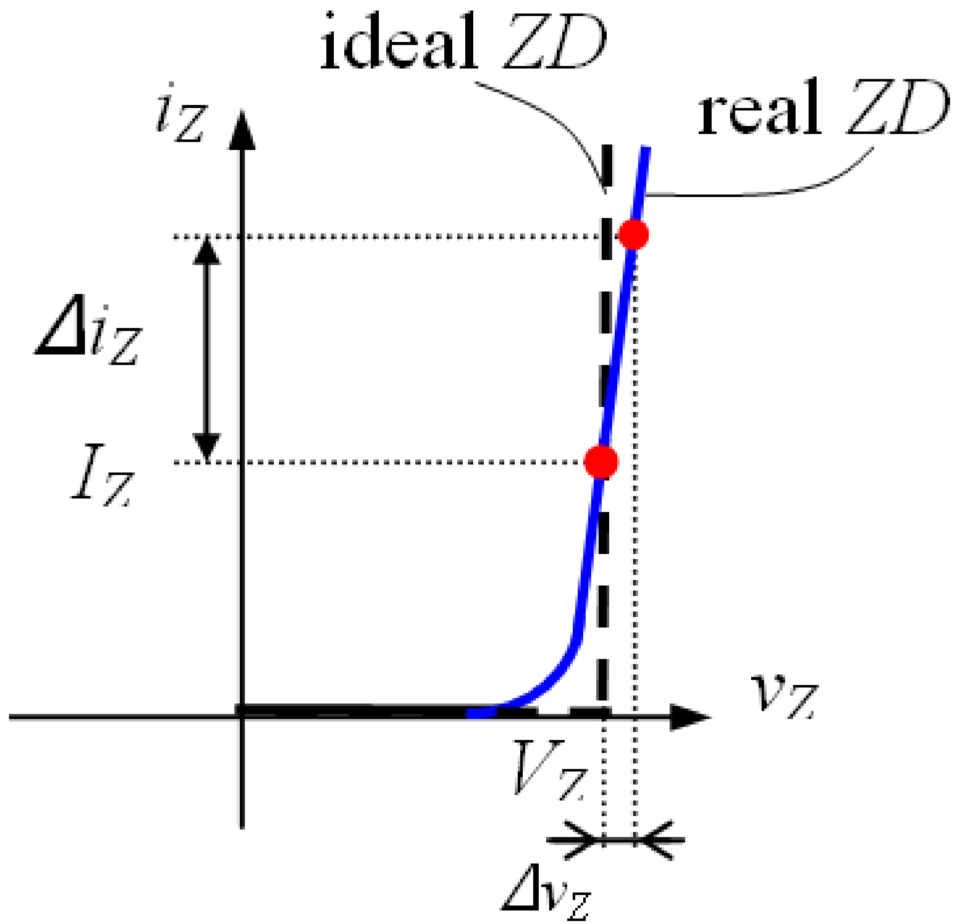
$$i_Z = -i_D$$

$$v_Z = -v_D$$

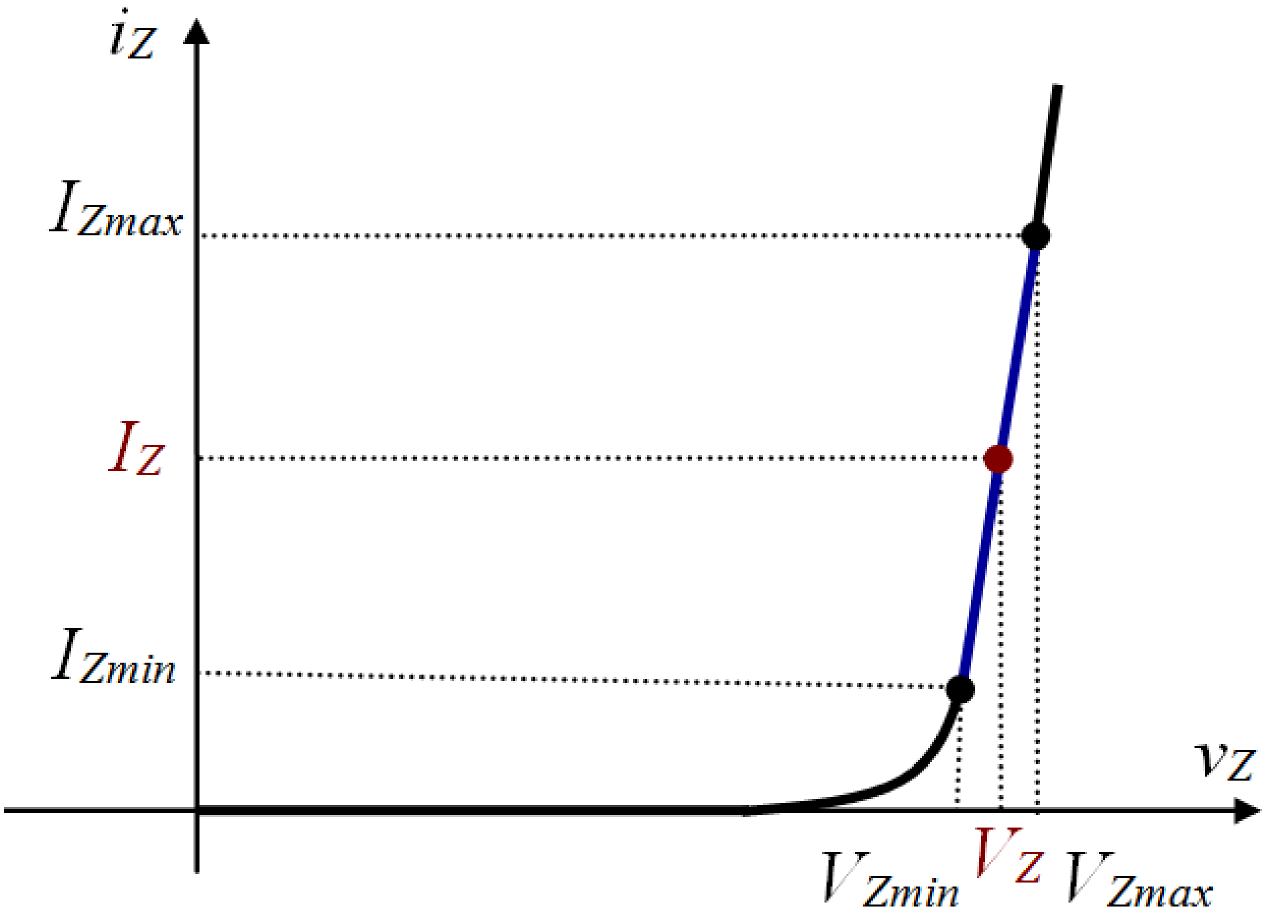
The *ZD* is normally used in **reverse bias**!







Regulation region of the ZD



Nominal operating point

$$\boxed{V_Z \,@\, I_Z}$$

$$I_{Z\max} = \frac{P_{d\max}}{V_Z}$$

Excerpt from a datasheet

FAIRCHILD SEMICONDUCTOR®

1N4728A - 1N4758A Zener Diodes

Tolerance = 5%

DO-41 Glass case

COLOR BAND DENOTES CATHODE

$$P_{Dmax} = 1\text{W}$$

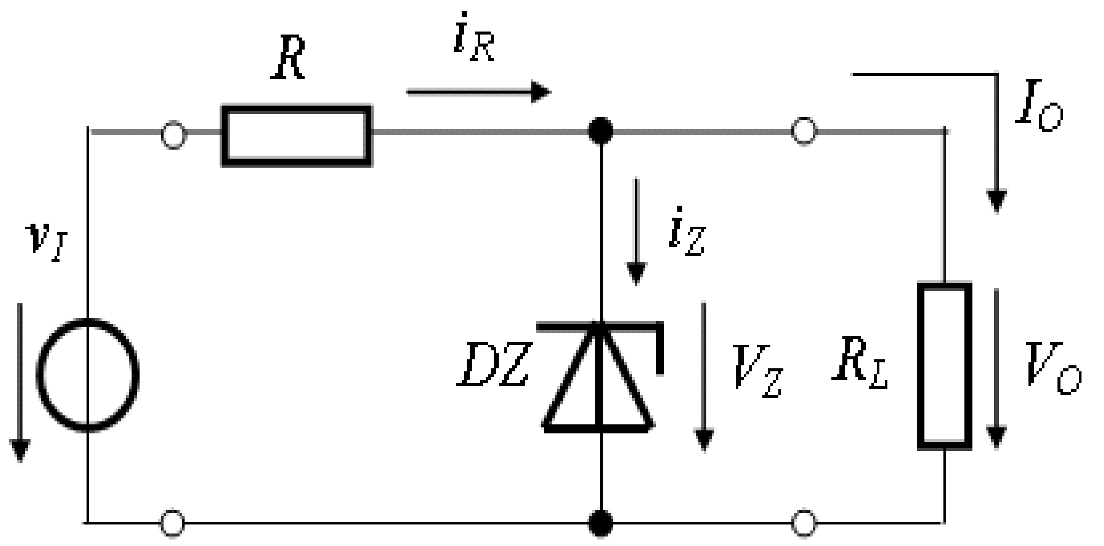
Electrical Characteristics T_a = 25°C unless other

Device	V_Z (V) @ I_Z (Note 1)			Test Current I_Z (mA)
	Min.	Typ.	Max.	
1N4728A	3.135	3.3	3.465	76
1N4729A	3.42	3.6	3.78	69
1N4730A	3.705	3.9	4.095	64
1N4731A	4.085	4.3	4.515	58
1N4732A	4.465	4.7	4.935	53
1N4733A	4.845	5.1	5.355	49
1N4734A	5.32	5.6	5.88	45
1N4735A	5.89	6.2	6.51	41
1N4736A	6.46	6.8	7.14	37
1N4737A	7.125	7.5	7.875	34
1N4738A	7.79	8.2	8.61	31
1N4739A	8.645	9.1	9.555	28
1N4740A	9.5	10	10.5	25
1N4741A	10.45	11	11.55	23
1N4742A	11.4	12	12.6	21

Parametric voltage regulator

Maintains the output voltage constant against

- input voltage variation,
- output current variation,
- temperature variation,
- etc

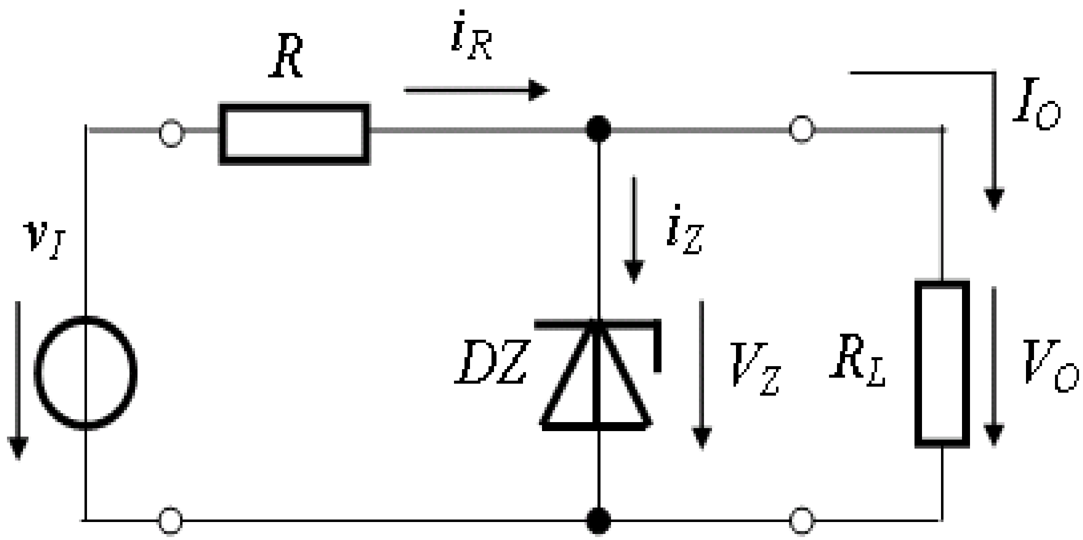


Let's suppose *DZ*: 1N4740. What is V_O if:

- $v_I = 15$ V
- $v_I = 17$ V
- $v_I = 7$ V

Parametric voltage regulator

Maintains the output voltage constant



$$i_Z = i_R - I_O$$

$$i_R = \frac{v_I - V_Z}{R}$$

$$i_Z = \frac{v_I - V_Z}{R} - I_O$$

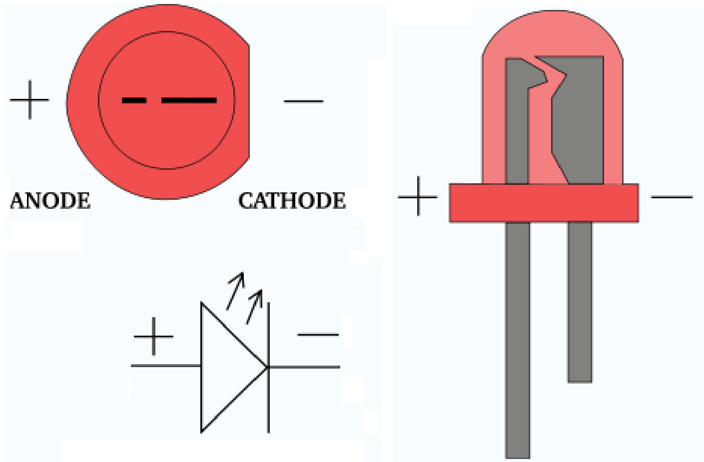
$$R = \frac{v_I - V_Z}{I_{Znom} + I_O}$$

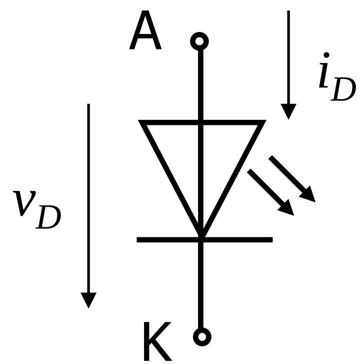
Exercise

$v_I \approx 12\text{V},\ V_O = 7.5\text{V},\ I_O = 70\text{mA}$

$R = ?$

Light-Emitting Diode: LED

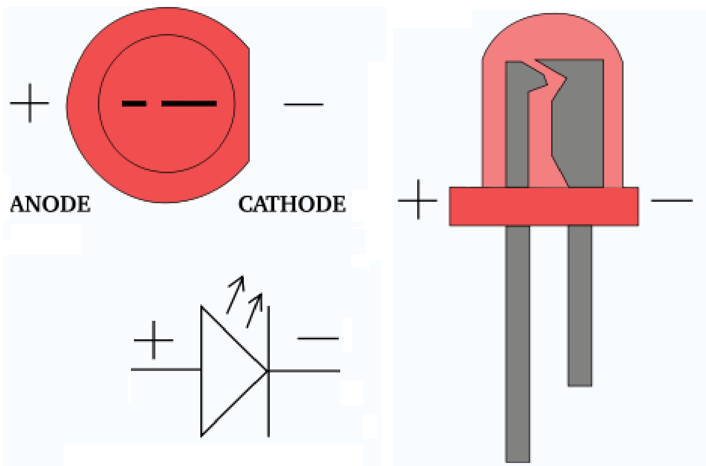


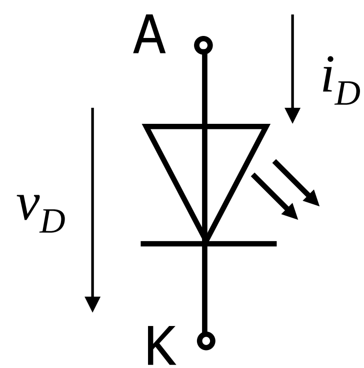


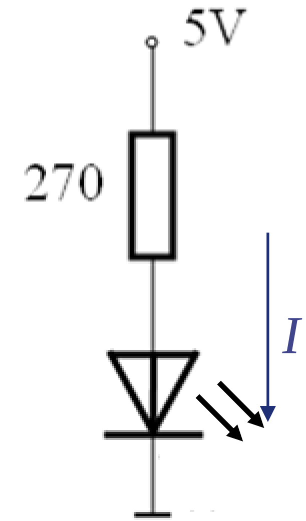
- A light-emitting diode (LED) is a two-lead semiconductor light source.
- A *p–n* junction diode that emits light when activated.

- When a suitable voltage is applied to the leads, electrons are able to recombine with 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.







- 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

Current through the LED?

Excerpt from the datasheet

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°

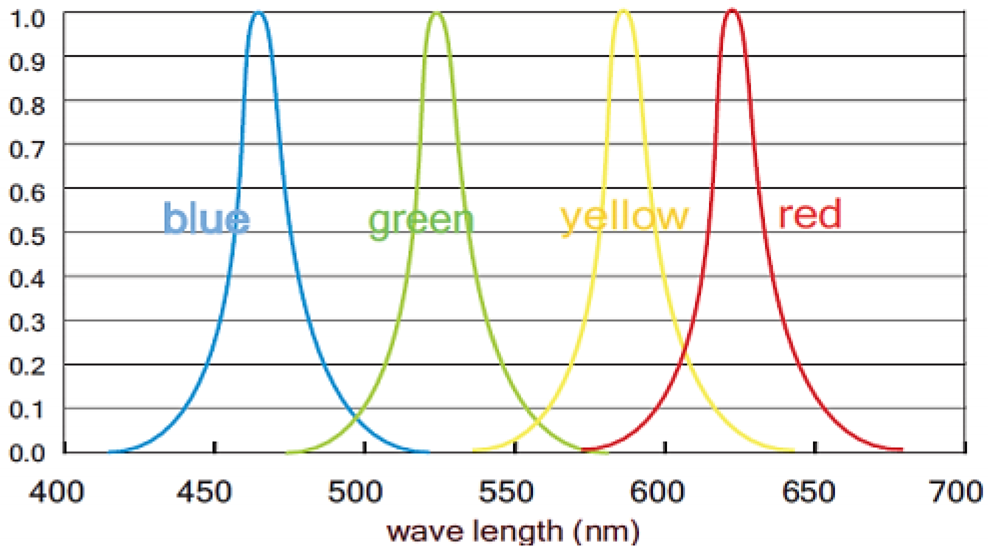
PARTS TABLE

PART	COLOR	LUMINOUS INTENSITY (mcd)			at I_F (mA)	WAVELENGTH (nm)			at I_F (mA)	FORWARD VOLTAGE (V)			at I_F (mA)	TECHNOLOGY
		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		
TLHR4400	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHO4400-MS12Z	Soft orange	1.6	13	-	10	598	-	611	10	-	2.4	3	20	GaAsP on GaP
TLHY4400	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHG4405	Green	6.3	15		10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHP4401	Pure green	1	4	-	10	555	-	565	10	-	2.4	3	20	GaP on GaP

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified) TLHR440., TLHO440., TLHY440., TLHG440., TLHP440.

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	6	V
DC forward current		I_F	30	mA
Surge forward current	$t_p \leq 10$ µs	I_{FSM}	1	A
Power dissipation	$T_{amb} \leq 60$ °C	P_V	100	mW

LED Color Spectrum for Red, Green, Blue, Yellow:



5050 SMD 60 LED/m
Indoor Strip LED

Problem

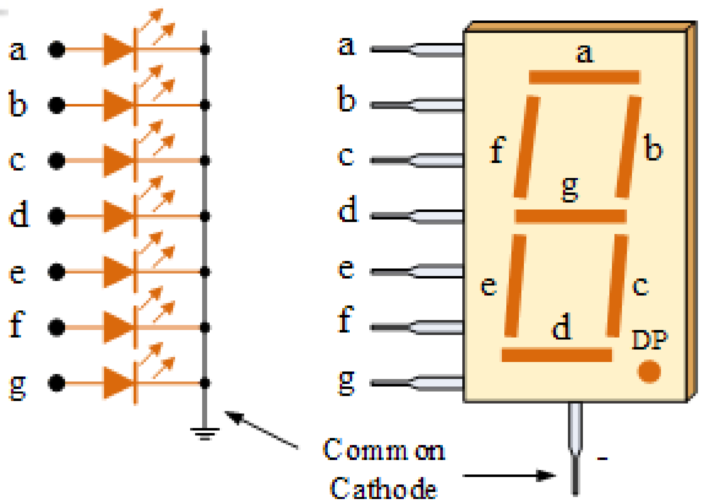
A voltage in a circuit can be +5V, 0V, or -5V.

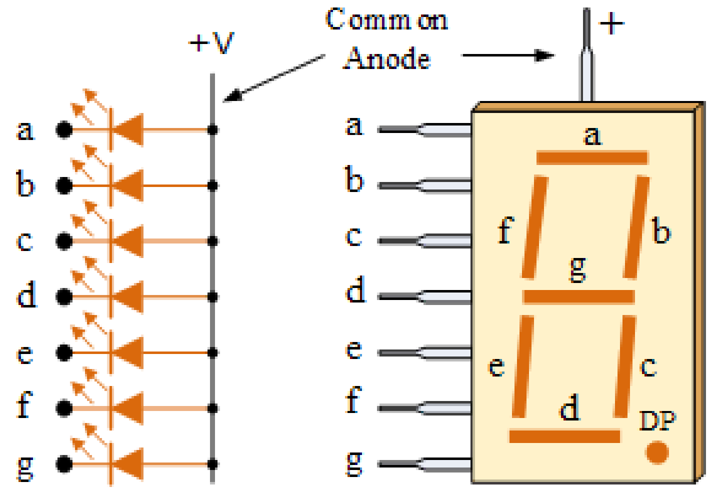
How can one signalize the voltage value using two LEDs (green for +5V and red for -5V)?
The current through the conducting LED should be 10mA.

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)



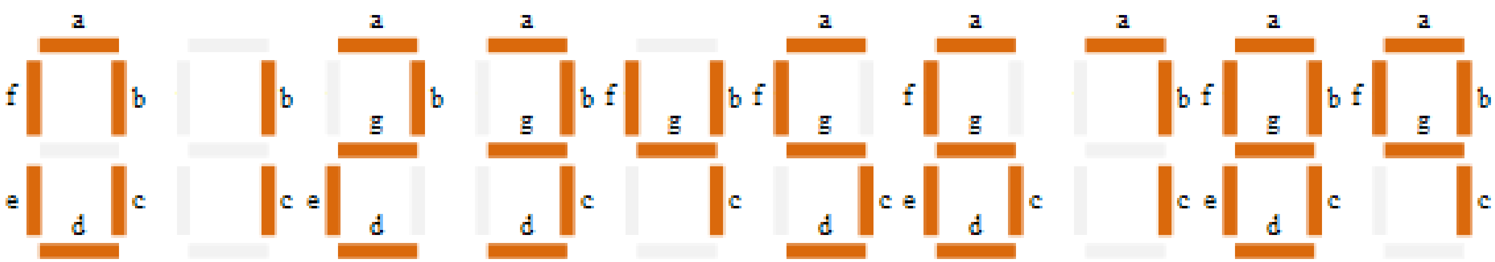


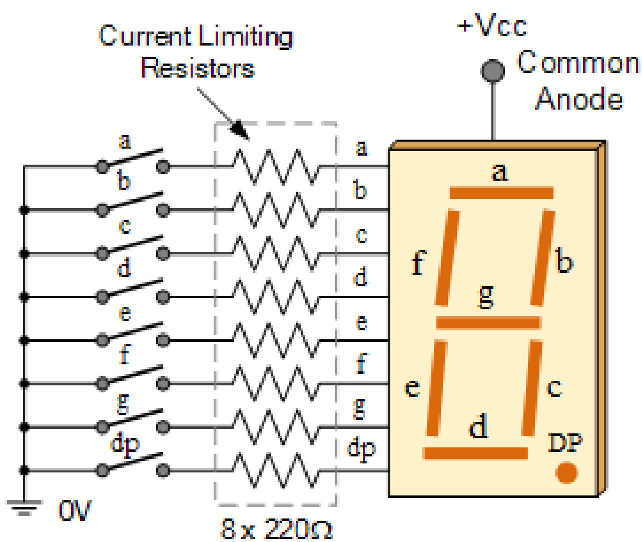
[7-segment Display, https://www.electronics-tutorials.ws/blog/7-segment-display-tutorial.html]

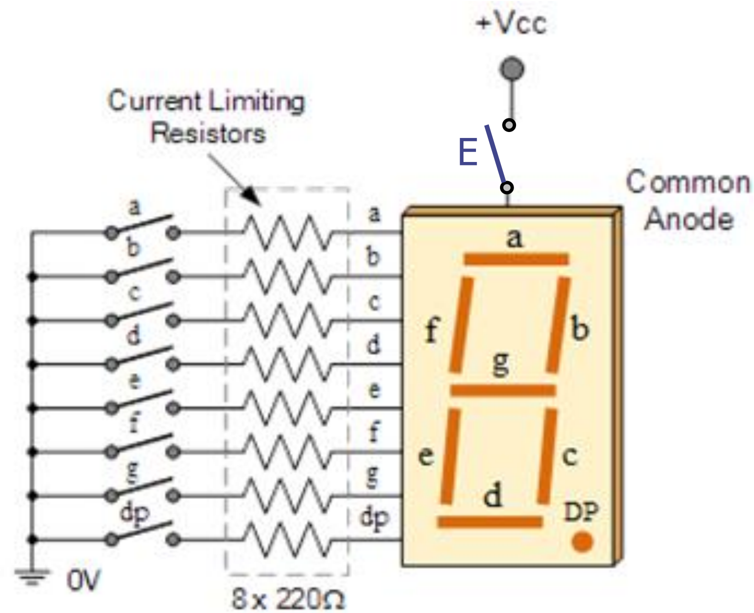
Allows to display each of the ten decimal digits 0 through 9 on the same 7-segment display

What is the connection to display “7” ?

7-segment Display - utilization

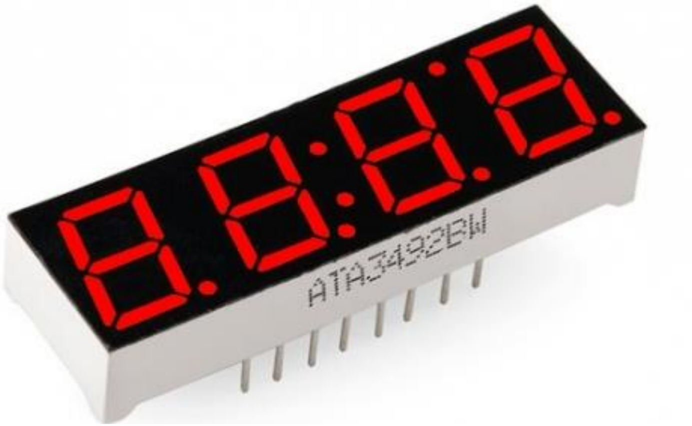


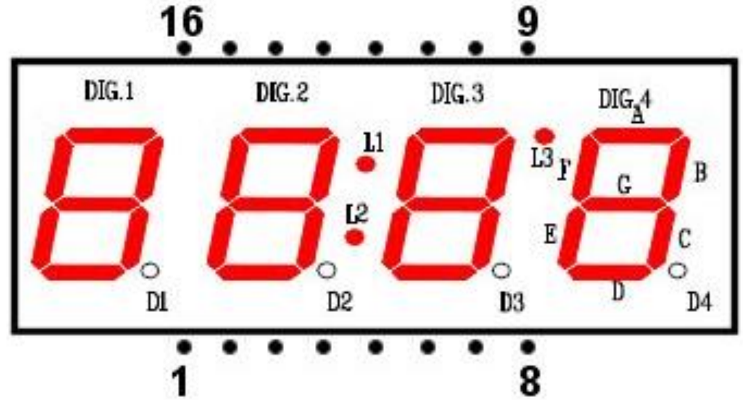


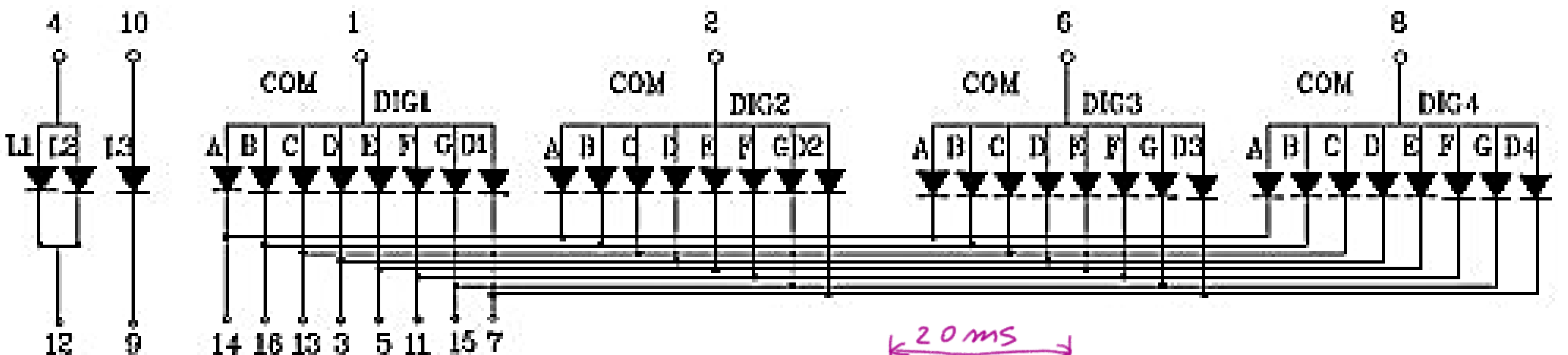


[7-segment Display, https://www.electronics-tutorials.ws/blog/7-segment-display-tutorial.html]

4-digit 7-segment Display (LED)

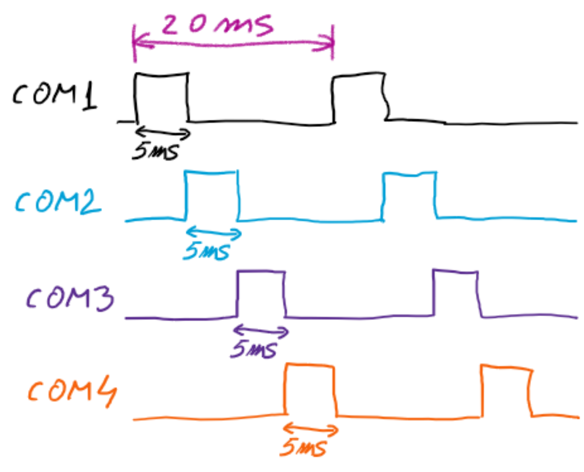






Use time-multiplexing technique.

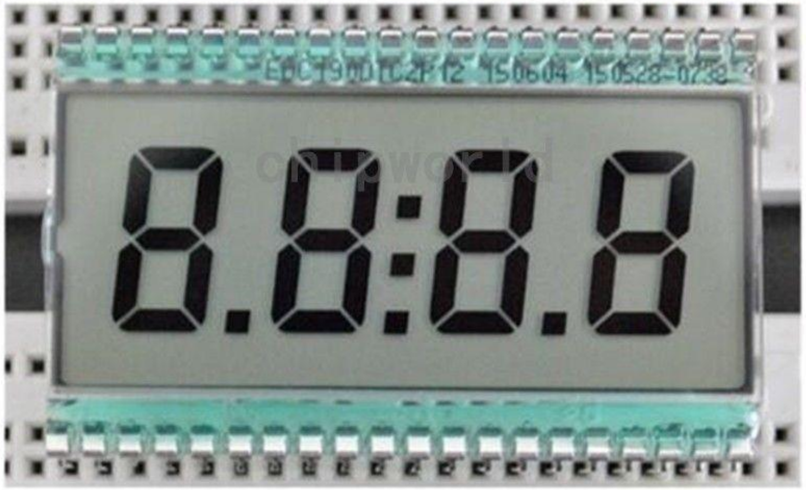
Multiplexing technique is based on the idea of "persistence" of vision of the human eyes.



[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

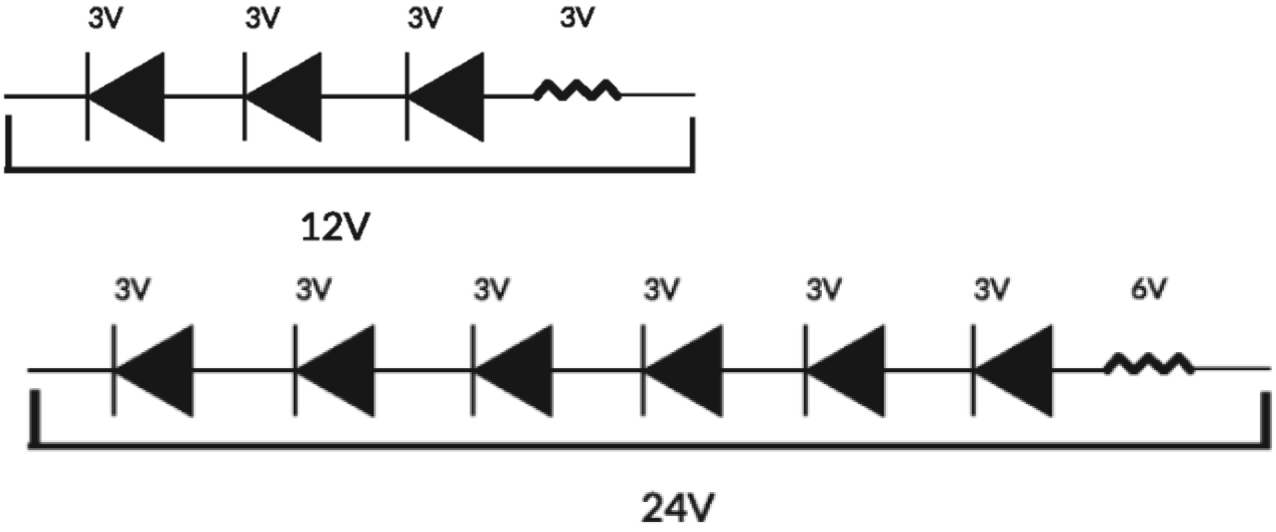


PIN NO.	1	2	3	4	5	6	7	8	9	10
SEGMENT	COM	/	/	/	1E	1D	1C	DP1	2E	2D
PIN NO.	11	12	13	14	15	16	17	18	19	20
SEGMENT	2C	DP2	3E	3D	3C	DP3	4E	4D	4C	4B
PIN NO.	21	22	23	24	25	26	27	28	29	30
SEGMENT	4A	4F	4G	3B	3A	3F	3G	COL	2B	2A
PIN NO.	31	32	33	34	35	36	37	38	39	40
SEGMENT	2F	2G	/	1B	1A	1F	1G	/	/	COM

[https://ro.mouser.com/datasheet/2/244/715201534828-LCD-A401C71TR-765680.pdf]

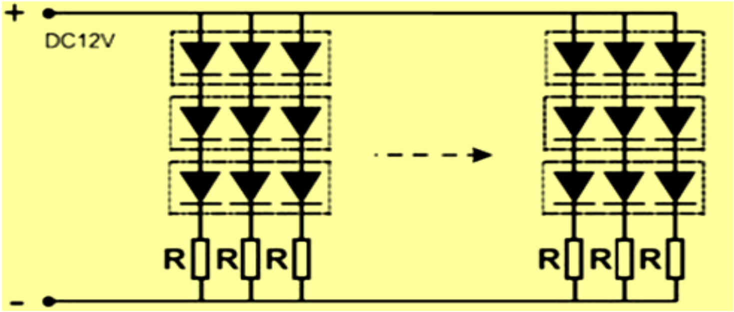
LED strips

Single Color LED Strip

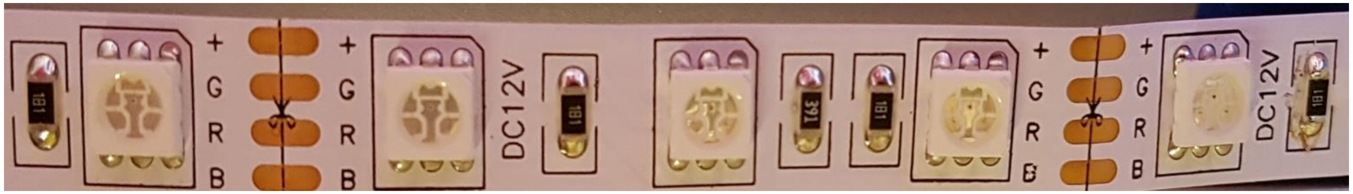


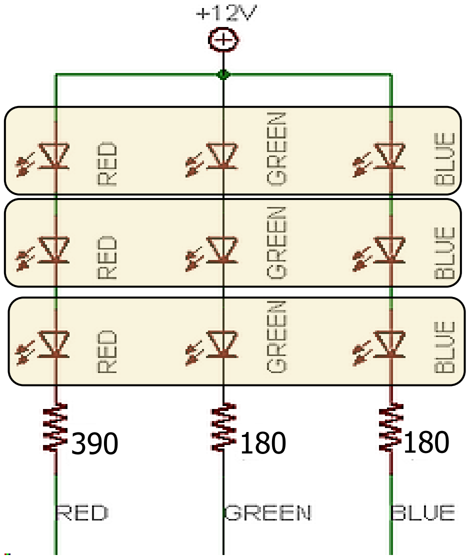
LED strips

Single Color LED Strip



RGB LED Strip

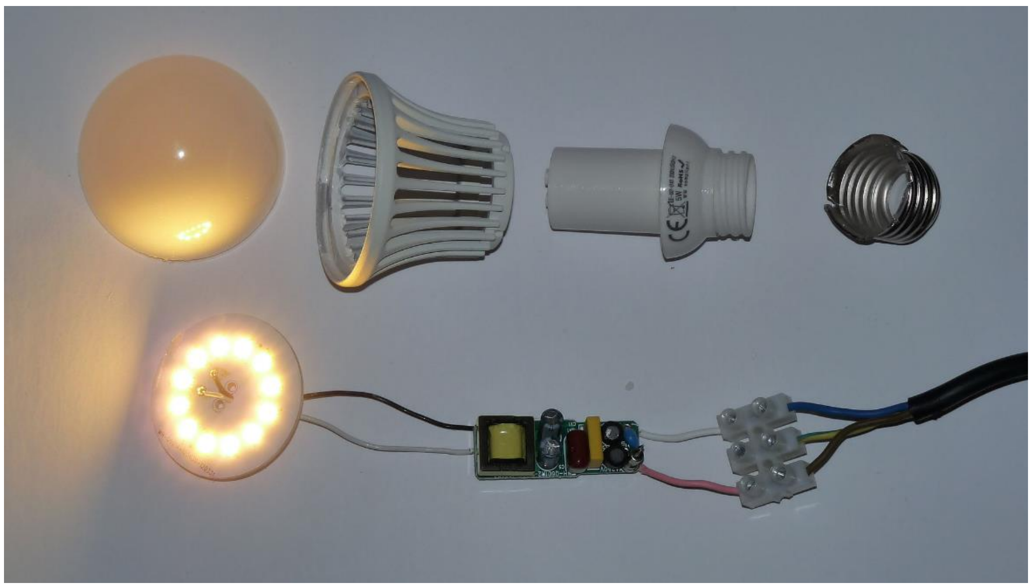




LED light bulbs

BONUS

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

A 230-volt LED filament light bulb, with a B22 base. The filaments are visible as the four yellow vertical lines.

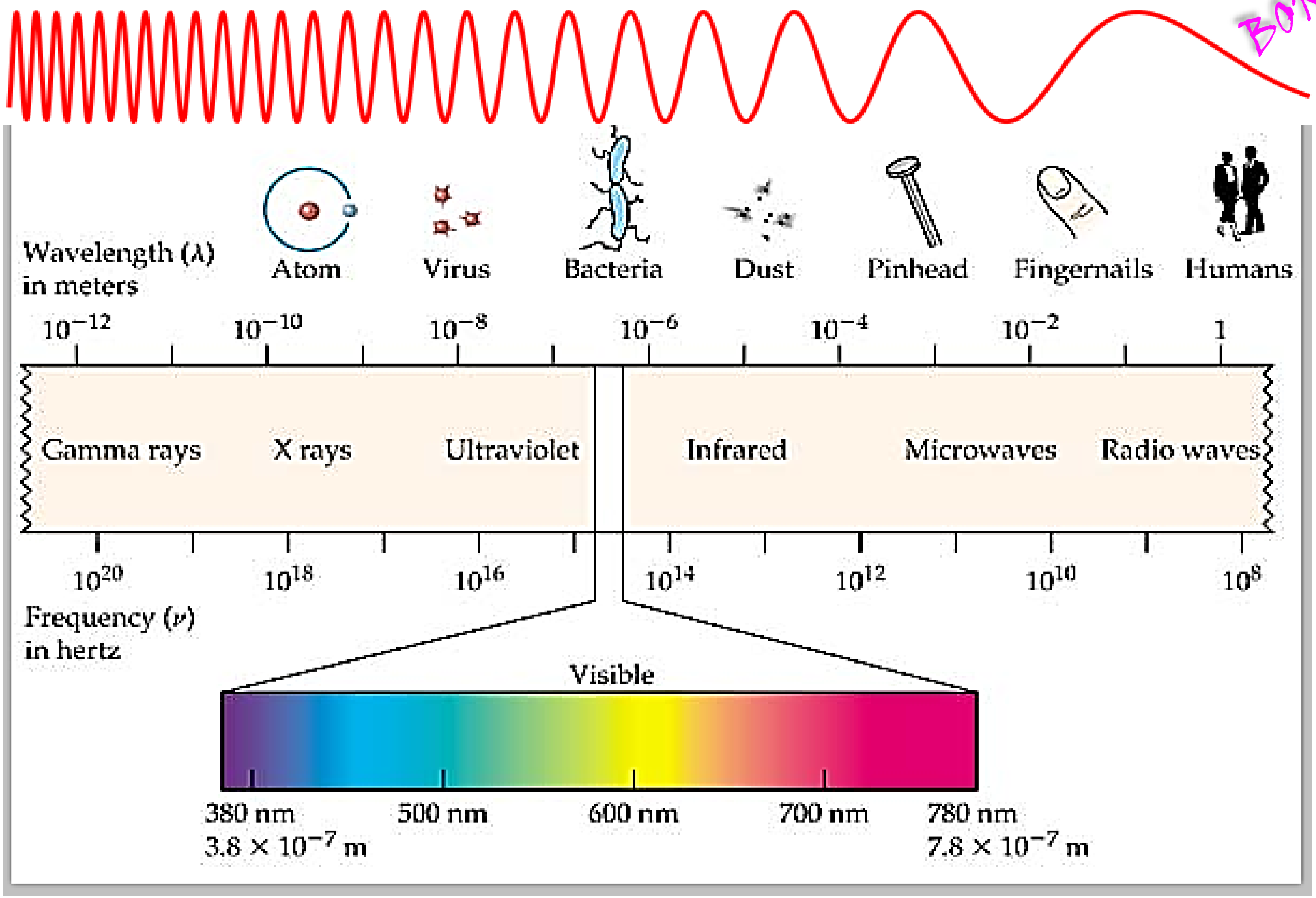
Closeup of a filament at 5% power;

https://en.wikipedia.org/wiki/LED_filament

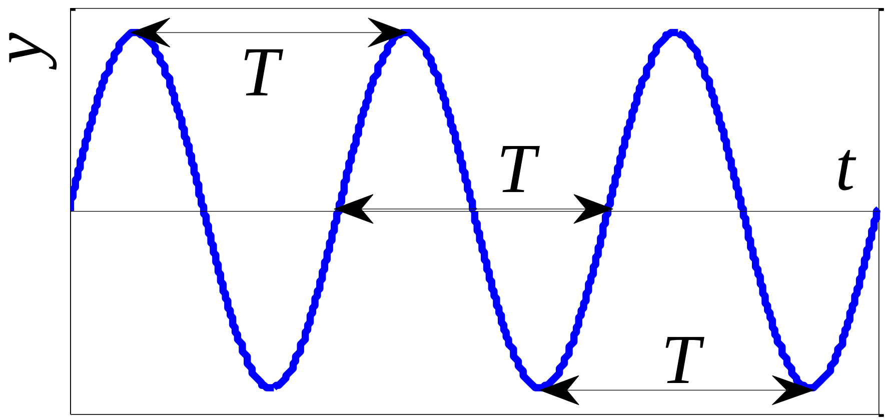
Electromagnetic Spectrum

$$\lambda = \frac{c}{f}; \quad c = 3 \cdot 10^8 \, \text{m/s}$$

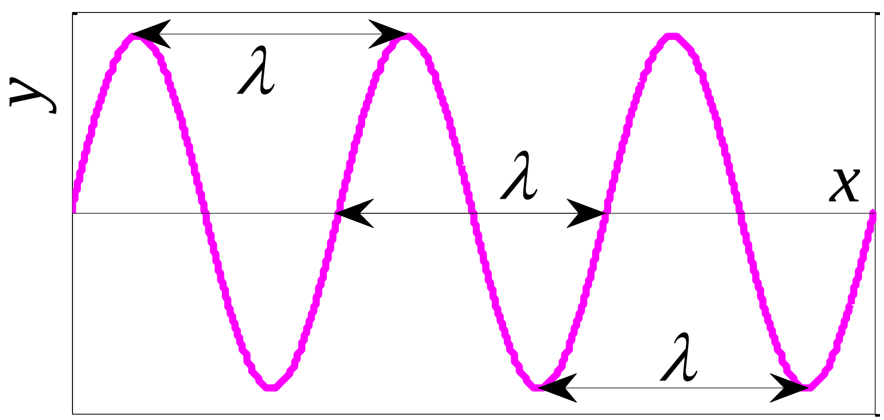
BONUS



Wavelength vs. period (or frequency)



BONUS



$$\lambda = cT = \frac{c}{f};$$

$$c = 3 \cdot 10^8 \, \mathrm{m/s}$$

The **wavelength** of a sinusoidal wave is its **spatial period**

- the distance over which the wave's shape repeats

Wavelength vs. period (or frequency) – *cont.*

BONUS

$$\lambda = cT = \frac{c}{f};$$

$$c = 3\cdot 10^{8}\,\text{m/s}$$

- Red light

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

- GSM frequency band 900MHz, 1800 MHz (mobile phones)

$$f = \boxed{900\text{MHz},}\quad T = \frac{1}{900\cdot 10^{6}} = 1.1\text{ns},\quad \lambda = \frac{3\cdot 10^{8}}{900\cdot 10^{6}} = 0.33\text{m} = \boxed{33\text{cm}}$$

- FM: Radio Impuls Cluj-Napoca 101.5MHz

$$f = \boxed{101.5\text{MHz},}\quad T = \frac{1}{101.5\cdot 10^{6}} = 9.85\text{ns},\quad \lambda = \frac{3\cdot 10^{8}}{101.5\cdot 10^{6}} = \boxed{2.95\text{m}}$$