Electrical Science: 2021-22
Lecture 9
Inductors

By Dr. Sanjay Vidhyadharan

Inductors

- An Inductor is a device which can store energy.

- Inductance is the property of a conductor to oppose a change in current.

Inductor symbols

Air core | Iron core | Ferrite core | Variable

Types of Inductors

Self Inductance of a Coil

- Self inductance of a circuit element (a coil, wire, resistor or whatever) as

  $L = F_B/I$

- From this we have $F_B = LI$ and so

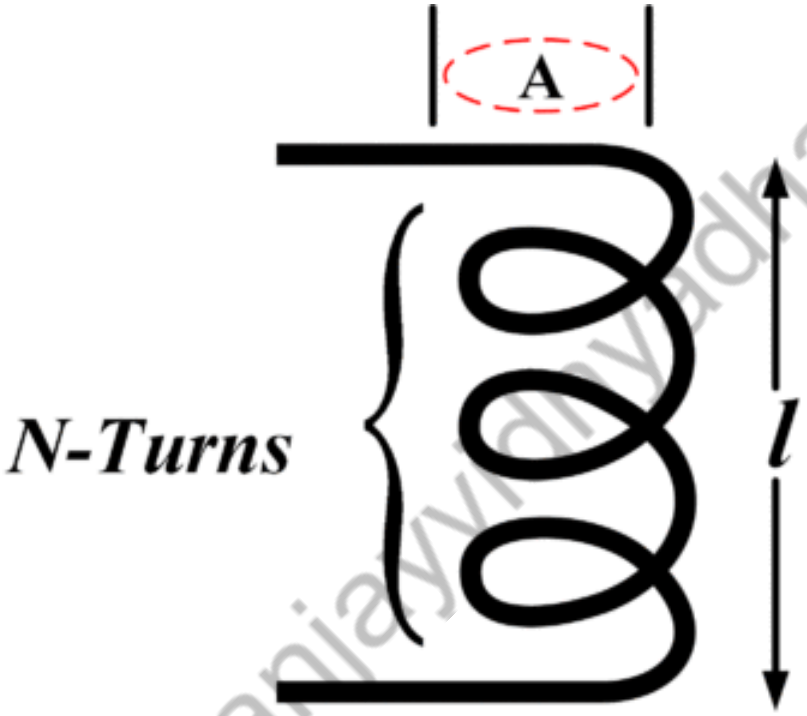
  $dF_B/dt = L\ dI/dt$

- and Faraday's law gives

  $E = - L\ dI/dt$

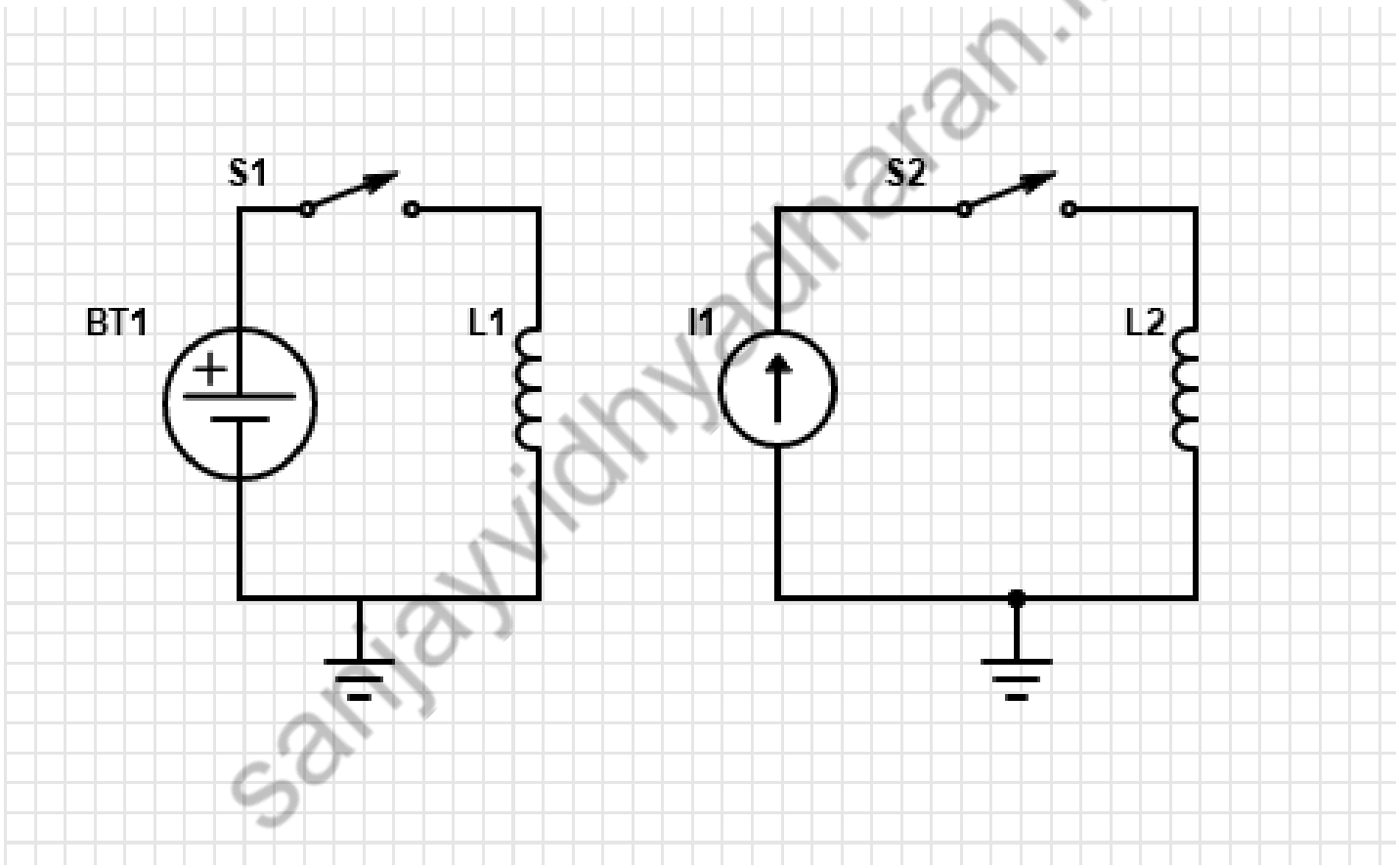
- Since this emf opposes changes in the current (in the component) it is often called the "back emf".
- From now own "inductance" means self-inductance.

Inductance Formula

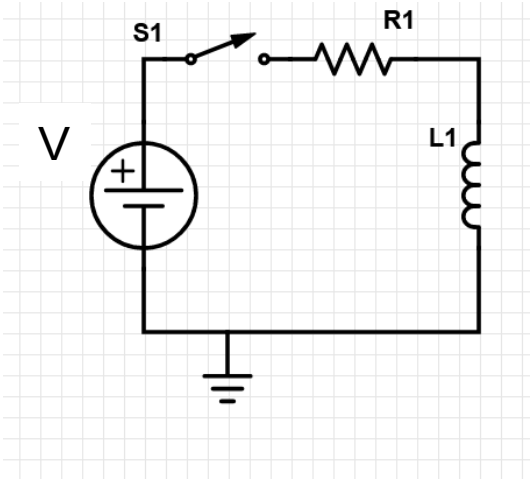


$$L = \mu_o \mu_r N^2 \frac{A}{l}$$

Steady State Current in an Inductor



Current in an Inductor

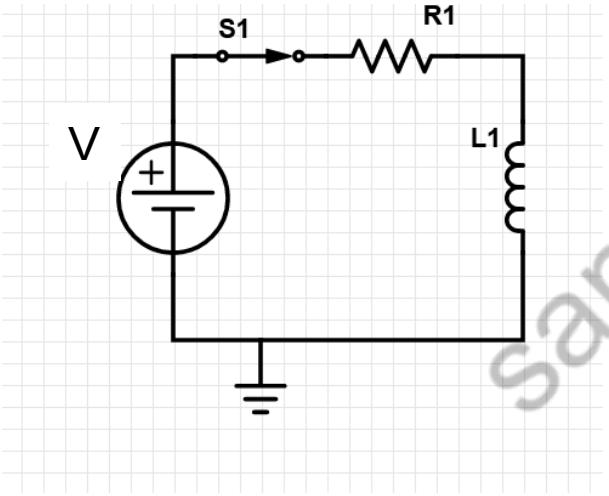


Switch Open : No Current

When Switch is closed

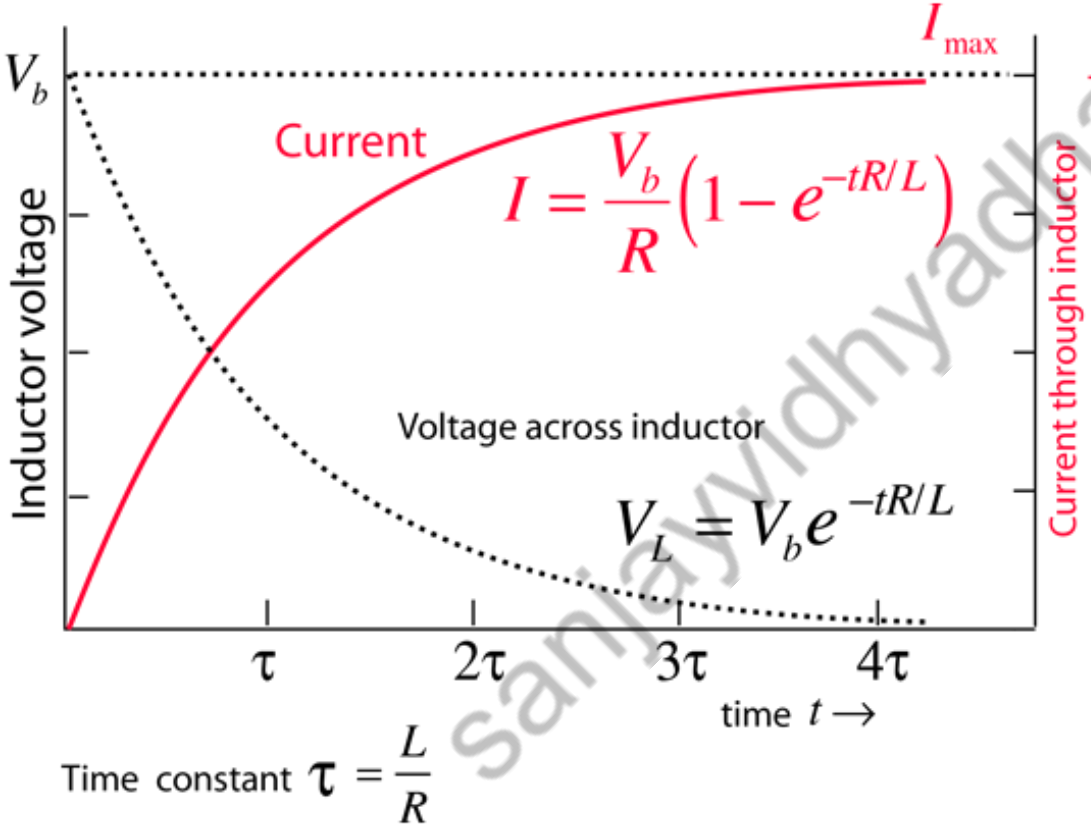
Current I flows, growing gradually, and a ‘back emf’ E_L is generated in inductor.
The emf E_L opposes the current I
$\Rightarrow E_L = - L\, dI/dt$

After a certain time the current (V/R) becomes steady. Then E_L is zero.



Current in an Inductor

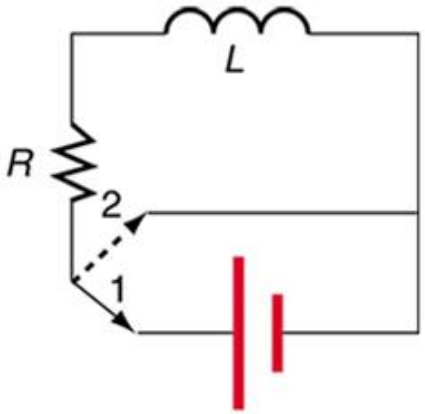
$$V_c = V\,(1 - e^{-t/RC})$$



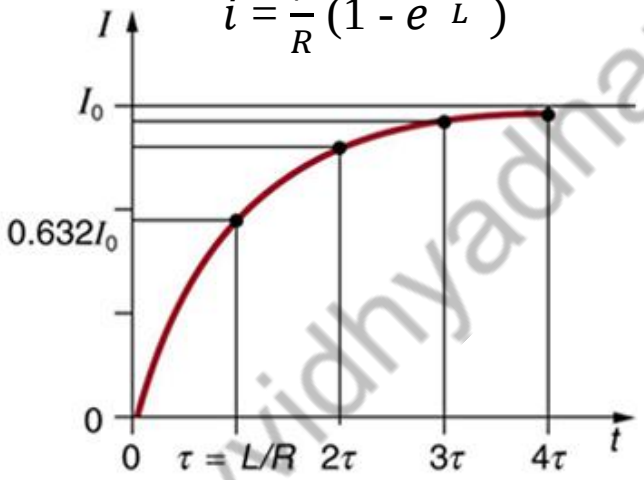
Time constant $\tau = \frac{L}{R}$

TIME CONSTANT (τ)	% ULTIMATE VALUE
0.1	10
0.5	40
0.7	50
0.9	60
1	63.2
2	86.5
3	95.1
4	98.2
5	99.3

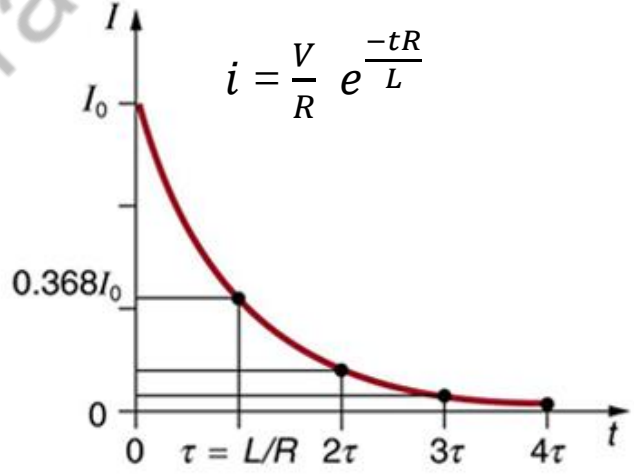
Current in an Inductor



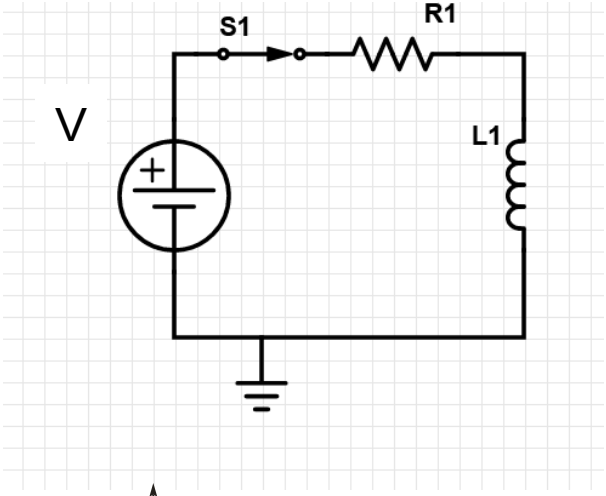
$$i = \frac{V}{R}(1 - e^{\frac{-tR}{L}})$$

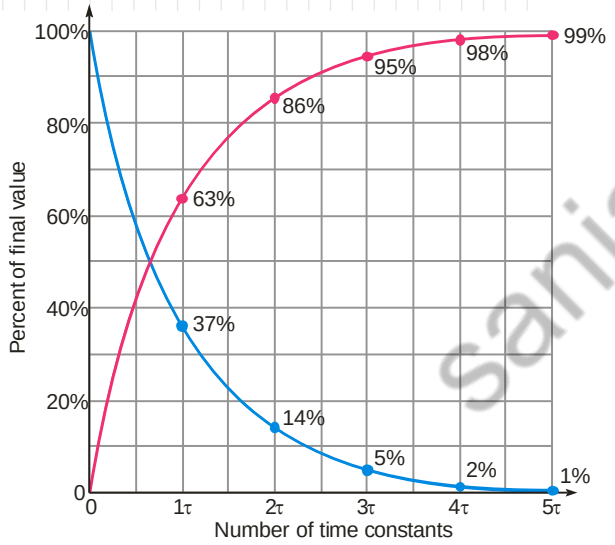


$$i = \frac{V}{R}\ e^{\frac{-tR}{L}}$$



Current in an Inductor





$$V - iR + E_L = 0$$

$$V - iR - L\,di/dt = 0$$

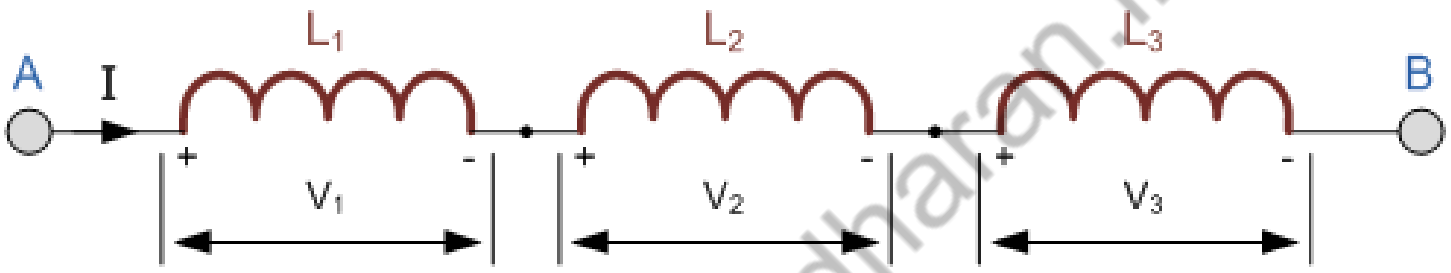
$$\frac{di}{V - iR} = \frac{dt}{L}$$

$$\int_0^i \frac{di}{V - iR} = \int_0^t \frac{dt}{L}$$

$$\frac{-1}{R}\left[\ln(V - iR)\right]_0^i = \frac{t}{L}\Big|_0^t$$

$$i = \frac{V}{R}\left(1 - e^{\frac{-tR}{L}}\right) \qquad V_c = V\left(1 - e^{-t/RC}\right)$$

Series Inductors



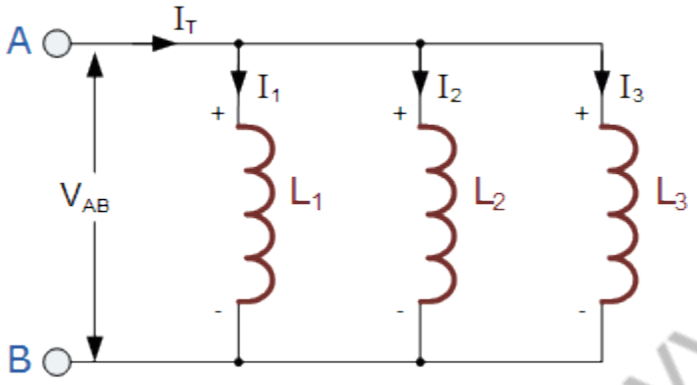
$$I_{L1} = I_{L2} = I_{L3} = I_{AB}$$

$$V_T = V_1 + V_2 + V_3$$

$$L_T \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt}$$

$$L_{total} = L_1 + L_2 + L_3$$

Parallel Inductors



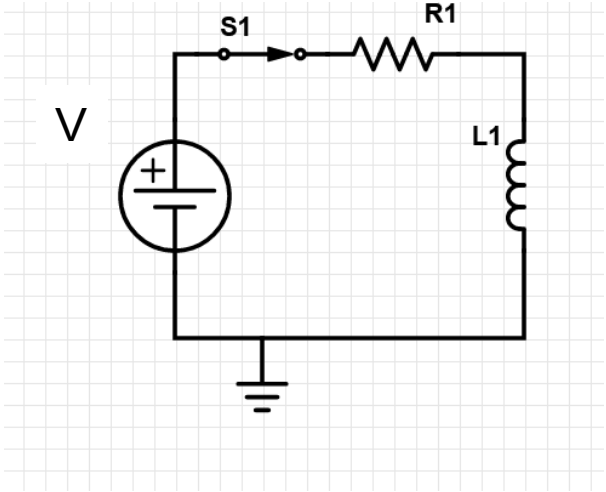
$$V_{L1} = V_{L2} = V_{L3} = V_{AB}$$

$$V_{AB} = L_T \frac{d}{dt}(i_1 + i_2 + i_3) = L_T\left(\frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt}\right)$$

$$V_{AB} = L_T\left(\frac{v}{L_1} + \frac{v}{L_2} + \frac{v}{L_3}\right)$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

Energy Stored in Inductor



Energy stored in Capacitor= $\int_0^V V_C \, C dV_c = \frac{1}{2} V^2 * C$

For Inductors

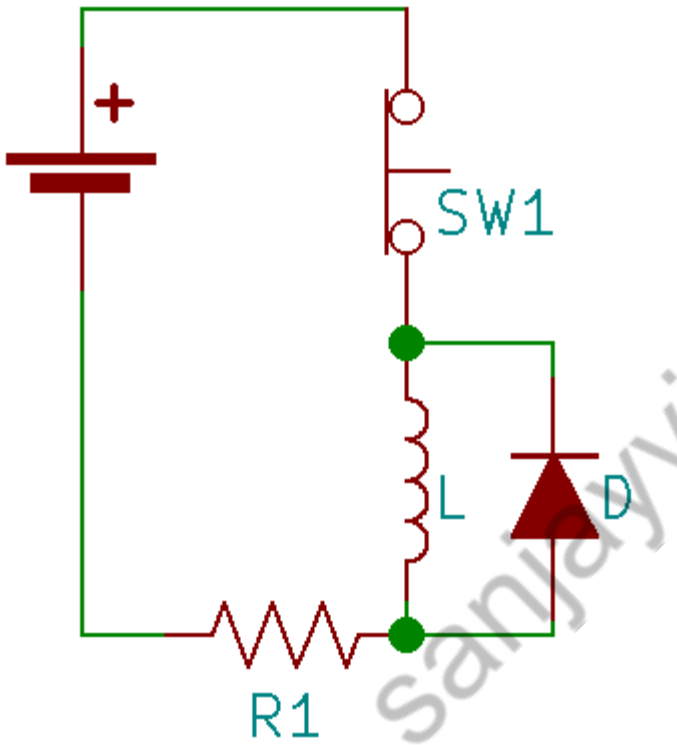
Power = $vi = iL\frac{di}{dt}$

Energy = $\int_0^t Pdt = \int_0^I Lidi = \frac{1}{2} I^2 * L \; where \; I = \frac{V}{R}$

Energy **consumed** from power supply = $V_{DD} \int_0^t i(t)dt = V_{DD} \int_0^t I(1 - e^{\frac{-tR}{L}})dt = I^2 * L$

Energy dissipated in Resistor = $\frac{1}{2} I^2 * L$

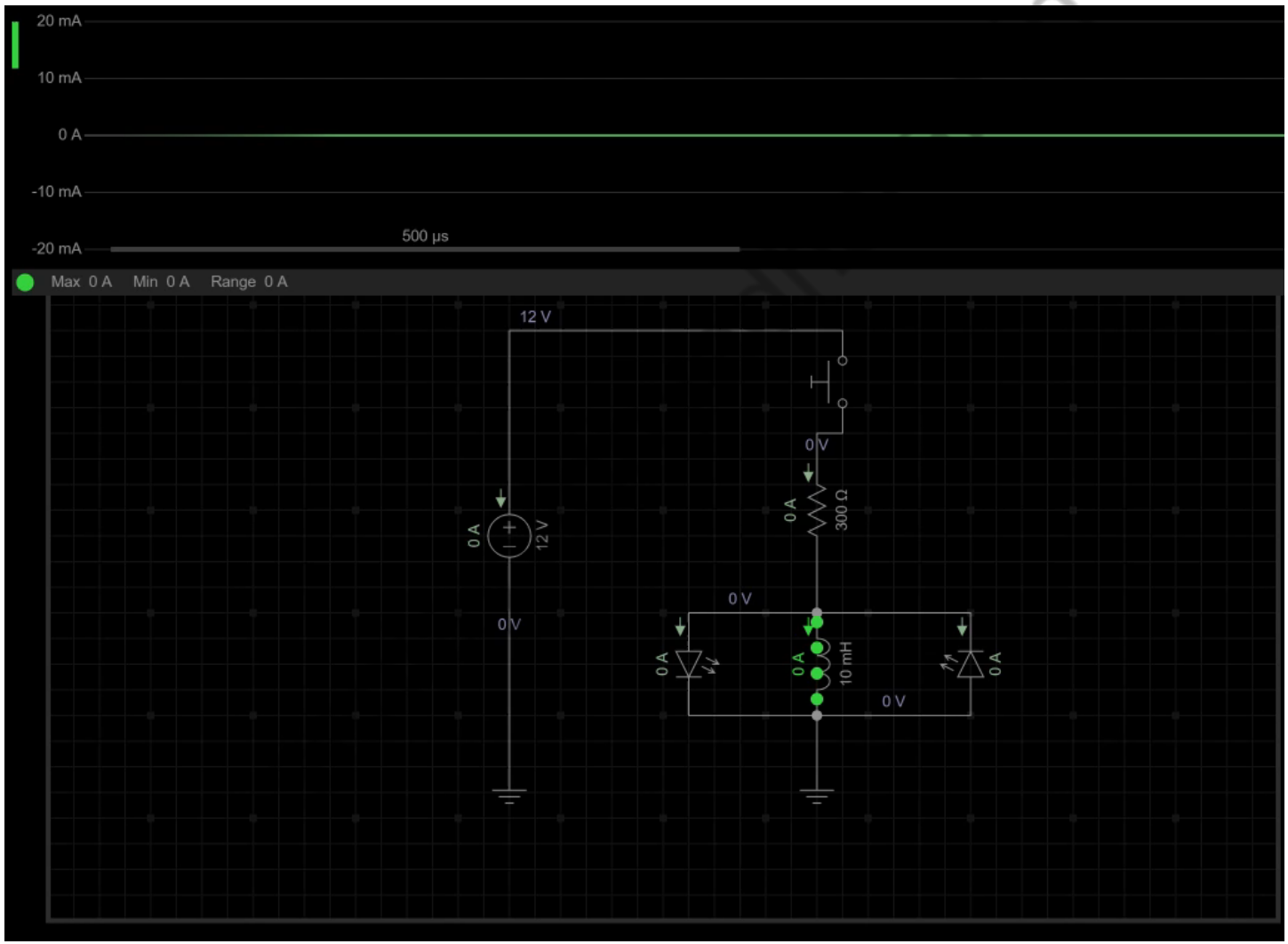
Energy Stored in Inductor



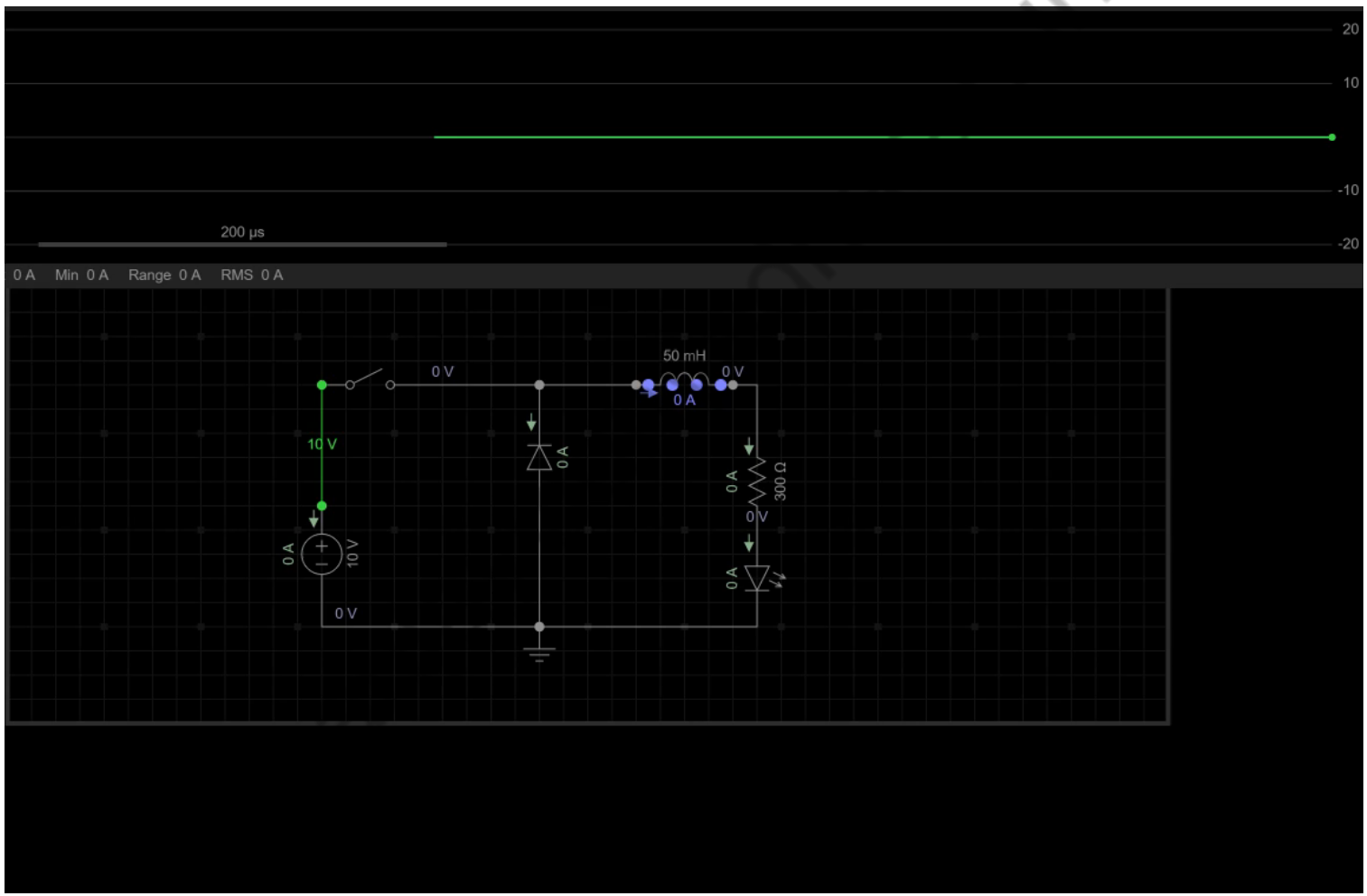
Applications of Inductors

1. Energy storage
2. Power conditioning
3. RF coupling and decoupling applications
4. LPF, HPF. BPF Filters
5. Oscillators
6. Noise Filters

Energy Stored in Inductors



Energy Stored in Inductors



Thank you