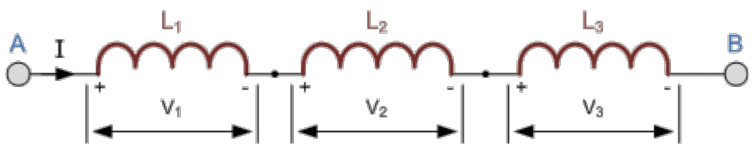


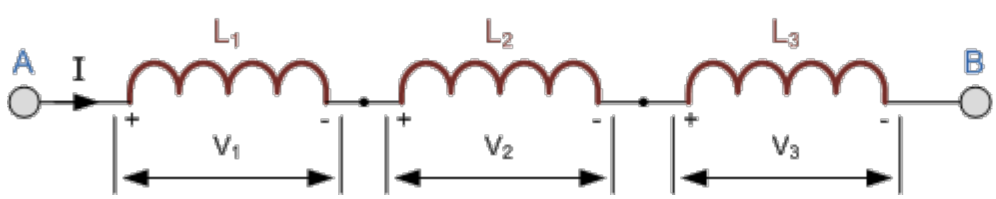
Inductors in Series

Inductors can be connected together in a series connection when the are daisy chained together sharing a common electrical current

These interconnections of inductors produce more complex networks whose overall inductance is a combination of the individual inductors. However, there are certain rules for connecting inductors in series or parallel and these are based on the fact that no mutual inductance or magnetic coupling exists between the individual inductors.

Inductors are said to be connected in “Series” when they are daisy chained together in a straight line, end to end. In the Resistors in Series tutorial we saw that the different values of the resistances connected together in series just “add” together and this is also true of inductance. Inductors in series are simply “added together” because the number of coil turns is effectively increased, with the total circuit inductance L_T being equal to the sum of all the individual inductances added together.

Inductor in Series Circuit



The current, (I) that flows through the first inductor, L_1 has no other way to go but pass through the second inductor and the third and so on. Then, series inductors have a **Common Current** flowing through them, for example:

$$I_{L1} = I_{L2} = I_{L3} = I_{AB} \text{ ...etc.}$$

In the example above, the inductors L_1, L_2 and L_3 are all connected together in series between points A and B. The sum of the individual voltage drops across each inductor can be found using Kirchoff's Voltage Law (KVL) where, $V_T = V_1 + V_2 + V_3$ and we know from the previous tutorials on inductance that the self-induced emf across an inductor is given as: $V = L\, di/dt$.

So by taking the values of the individual voltage drops across each inductor in our example above, the total inductance for the series combination is given as:

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

By dividing through the above equation by di/dt we can reduce it to give a final expression for calculating the total inductance of a circuit when connecting inductors together in series and this is given as:

Inductors in Series Equation

$$L_{total} = L_1 + L_2 + L_3 + \ldots.. + L_n \text{ etc.}$$

Then the total inductance of the series chain can be found by simply adding together the individual inductances of the inductors in series just like adding together resistors in series. However, the above equation only holds true when there is "NO" mutual inductance or magnetic coupling between two or more of the inductors, (they are magnetically isolated from each other).

One important point to remember about inductors in series circuits, the total inductance (L_T) of any two or more inductors connected together in series will always be **GREATER** than the value of the largest inductor in the series chain.

Inductors in Series Example No1

Three inductors of 10mH, 40mH and 50mH are connected together in a series combination with no mutual inductance between them. Calculate the total inductance of the series combination.

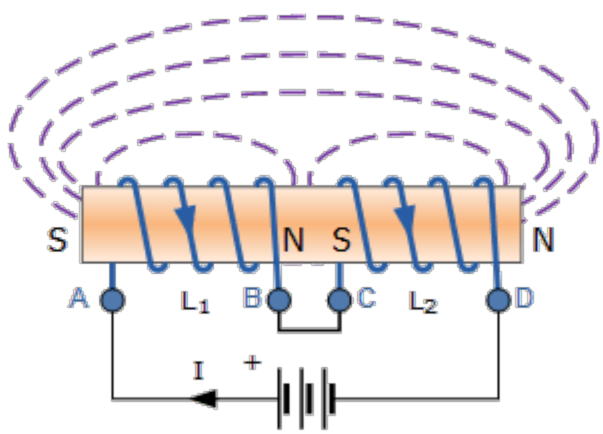
$$L_T = L_1 + L_2 + L_3 = 10mH + 40mH + 50mH = 100mH$$

Mutually Connected Inductors in Series

When inductors are connected together in series so that the magnetic field of one links with the other, the effect of mutual inductance either increases or decreases the total inductance depending upon the amount of magnetic coupling. The effect of this mutual inductance depends upon the distance apart of the coils and their orientation to each other.

Mutually connected series inductors can be classed as either “Aiding” or “Opposing” the total inductance. If the magnetic flux produced by the current flows through the coils in the same direction then the coils are said to be **Cumulatively Coupled**. If the current flows through the coils in opposite directions then the coils are said to be **Differentially Coupled** as shown below.

Cumulatively Coupled Series Inductors



While the current flowing between points A and D through the two cumulatively coupled coils is in the same direction, the equation above for the voltage drops across each of the coils needs to be modified to take into account the interaction between the two coils due to the effect of mutual inductance. The self inductance of each individual coil, L_1 and L_2 respectively will be the same as before but with the addition of M denoting the mutual inductance.

Then the total emf induced into the cumulatively coupled coils is given as:

$$L_T \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + 2\left(M \frac{di}{dt}\right)$$

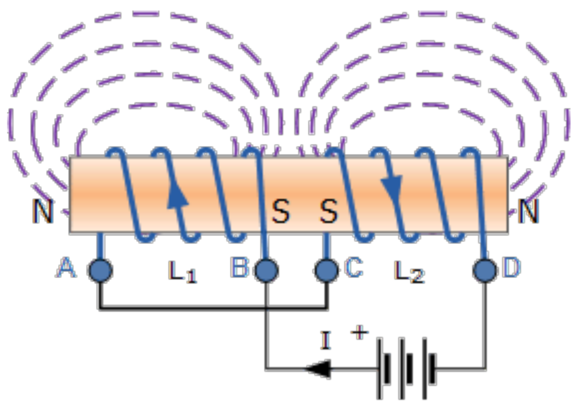
Where: 2M represents the influence of coil L_1 on L_2 and likewise coil L_2 on L_1.

By dividing through the above equation by di/dt we can reduce it to give a final expression for calculating the total inductance of a circuit when the inductors are cumulatively connected and this is given as:

$$L_{total} = L_1 + L_2 + 2M$$

If one of the coils is reversed so that the same current flows through each coil but in opposite directions, the mutual inductance, M that exists between the two coils will have a cancelling effect on each coil as shown below.

Differentially Coupled Series Inductors



The emf that is induced into coil 1 by the effect of the mutual inductance of coil two is in opposition to the self-induced emf in coil one as now the same current passes through each coil in opposite directions. To take account of this cancelling effect a minus sign is used with M when the magnetic field of the two coils are differentially connected giving us the final equation for calculating the total inductance of a circuit when the inductors are differentially connected as:

$$L_{total} = L_1 + L_2 - 2M$$

Then the final equation for inductively coupled inductors in series is given as:

$$\boxed{L_T = L_1 + L_2 \pm 2M}$$

Inductors in Series Example No2

Two inductors of 10mH respectively are connected together in a series combination so that their magnetic fields aid each other giving cumulative coupling. Their mutual inductance is given as 5mH. Calculate the total inductance of the series combination.

$$\begin{aligned} L_T &= L_1 + L_2 + 2M \\ L_T &= 10mH + 10mH + 2(5mH) \\ L_T &= 30mH \end{aligned}$$

Inductors in Series Example No3

Two coils connected in series have a self-inductance of 20mH and 60mH respectively. The total inductance of the combination was found to be 100mH. Determine the amount of mutual inductance that exists between the two coils assuming that they are aiding each other.

$$L_T = L_1 + L_2 \pm 2M$$

$$100 = 20 + 60 + 2M$$

$$2M = 100 - 20 - 60$$

$$\therefore M = \frac{20}{2} = 10mH$$

Inductors in Series Summary

We now know that we can connect together **inductors in series** to produce a total inductance value, L_T equal to the sum of the individual values, they add together, similar to connecting together resistors in series. However, when connecting together inductors in series they can be influenced by mutual inductance.

Mutually connected series inductors are classed as either “aiding” or “opposing” the total inductance depending whether the coils are cumulatively coupled (in the same direction) or differentially coupled (in opposite direction).

In the next tutorial about Inductors, we will see that the position of the coils when connecting together Inductors in Parallel also affects the total inductance, L_T of the circuit.

43 Comments

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Roselyn

Everything is perfect

Posted on December 18th 2020 | 3:22 am

Reply

Manfred

Two coils are connected in parallel, both have 40mH and 10 respectively. The total inductance of the circuit is found to be 60mH determine the mutual inductance of both.

Posted on December 14th 2020 | 1:49 pm

Reply

Wayne Storr

Please read the tutorial about Mutual Inductance

Posted on December 15th 2020 | 8:13 am

Reply

Melbert

How much inductance of a coil that induces 500-V when the current change at the rate of 5 mA in 12uS

Posted on November 10th 2020 | 7:07 am

Reply

Mark Branz

Drawings are "technically" incorrect, showing a DC source (battery). An AC source is a circle with a sine wave inside the circle.

Posted on March 10th 2020 | 1:03 pm

Reply

Wayne Storr

The images are "technically" correct as they are a DC supply. No AC source was used in the tutorial

Posted on March 10th 2020 | 1:48 pm

Reply

BENARD DAUD

I UNDERSTAND

Posted on November 28th 2019 | 5:32 am

Reply

Ranganatha M S

Good explanation.

Posted on September 13th 2019 | 3:06 pm

Reply

Farzana

I want to join here and want to learn more and more

Posted on September 01st 2019 | 2:00 am

Reply

Anoop

Inductor problem.

Posted on March 08th 2019 | 8:33 am

Reply

Mahendra

two 2h inductance coils are connected in series and are also magnetically coupled to each other, if coefficient of coupling is 0.1 then total inductance is?

Posted on January 12th 2019 | 9:40 am

Reply

Pranab Das

Sir plzz answer this question….
Q/.The combined inductance of two coils connected in series is 1.2 H or 0.2H ,depending on the relative directions of the currents in the coils .if one the coils,when isolated has a self inductance of 0.4 H, calculate
a/.The mutual inductance and
b/.The coupling coefficient

Posted on December 18th 2018 | 8:04 am

Reply

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subhadip dey

very helpful . for a learnr.

Posted on October 31st 2018 | 7:50 am

Reply

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moin

what is faraday's law

Posted on October 01st 2018 | 10:29 am

Reply

Jaydipsinh Parmar

Inductor current path.

Posted on September 27th 2018 | 3:28 pm

Reply

Aubs

Very helpful! Helped me figure out some things for my electronics class! Thanks!

Posted on September 21st 2018 | 11:47 pm | Reply

M Hassan

I really appreciate your efforts I'm excited

Posted on September 06th 2018 | 8:03 pm | Reply

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khilesh Rahangdale

good but i can't ac ckt calculation

Posted on August 07th 2018 | 12:52 pm | Reply

Rowland Williams

God bless you. Ride on.

Posted on July 13th 2018 | 1:29 pm | Reply

Dave

The source in the above diagram is DC ??
di/dt = 0. emf = 0.
Unless you are switching the circuit on and off.

Posted on July 08th 2018 | 9:08 pm

Reply

Aditya

Three magnetically coupled inductive coils having the following data are connected in series as shown in Figure.
L1 = 0.12 H; L2 = 0.14 H; L3 = 0.16 H
k12 = 0.3; k23 = 0.6; k31 = 0.9
Find the equivalent inductance of the circuit.
The series is of the form (dot L1 L2 dot L3 dot). (I wasnt able to put the diagram here so I had to type it out. Hope you could understand it. It is in the dot convention)
Please reply fast.

Posted on June 05th 2018 | 3:22 am

Reply

Adex

Two inductors 5H and 15H are connected in series with 5A.canculate the total energy stored?

Posted on March 10th 2018 | 12:20 pm

Reply

More

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