MAGNETIC & ELECTROMAGNETIC INDUCTION - LR Circuits

A sine wave is input to a series circuit consisting of a decade inductor and a decade resistor. The voltage across the resistor and the inductor is observed on an oscilloscope. The phase shift can be changed by adjusting the components. This demonstration can also be shown using the large Å 1 H solenoid.
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Ref: hb x77; w/ tape 4-04:09:03
H23

LR PHASE SHIFT

R = 270Ω
L = 90mH

$$\theta = \tan^{-1}\left(\frac{wL}{R}\right)$$

$f = 60 \text{ Hz}$

$w = 2\pi f = 377 \text{ rad/sec}$

$$\theta = \tan^{-1}\left(\frac{wL}{R}\right) = 7.16^°$$

Period = 16.7 mSec

$$\frac{1^°}{360^°} = \frac{16.7 \text{ mSec}}{360^°} = \frac{46.4 \mu\text{Sec}}{360^°}$$

$$\theta = 46.4 \mu\text{Sec} \times 7.16^° = 331 \mu\text{Sec}$$

$f = 600 \text{ Hz}$

$w = 2\pi f = 3770 \text{ rad/sec}$

$$\theta = \tan^{-1}\left(\frac{wL}{R}\right) = 51.5^°$$

Period = 1.66 mSec

$$\frac{1^°}{360^°} = \frac{1.66 \text{ mSec}}{360^°} = \frac{4.64 \mu\text{Sec}}{360^°}$$

$$\theta = 4.64 \mu\text{Sec} \times 51.5^° = 238 \mu\text{Sec}$$

$f = 2 \text{ kHz}$

$w = 2\pi f = 12566 \text{ rad/sec}$

$$\theta = \tan^{-1}\left(\frac{wL}{R}\right) = 76.6^°$$

Period = 500μSec

$$\frac{1^°}{360^°} = \frac{500\mu\text{Sec}}{360^°} = 1.38\mu\text{Sec}$$

$$\theta = 1.38\mu\text{Sec} \times 76.6^° = 106\mu\text{Sec}$$

GP 3'93
LR PHASE SHIFT

\[ R = 270 \Omega, \quad L = 90 \text{ mH}, \quad \theta = \tan^{-1}\left(\frac{\omega L}{R}\right) \]

a) \( f = 60 \text{ Hz} \) (Range: 10, frequency: 6)
\[ \omega = 2\pi f = 377 \text{ rad/sec} \]
\[ \theta = \tan^{-1}\left(\frac{\omega L}{R}\right) = 7.16^\circ \]

b) \( f = 600 \text{ Hz} \) (Range: 100, frequency: 6)
\[ \omega = 3770 \text{ rad/sec} \]
\[ \theta = 51.5^\circ \]

c) \( f = 2000 \text{ Hz} \) (Range: 100, frequency: 20)
\[ \omega = 12566 \text{ rad/sec} \]
\[ \theta = 76.6^\circ \]
\( L = 90 \text{ mH} \)
\( R = 270 \Omega \)
\( f = 2 \text{ kHz} \)
\( \phi = \tan^{-1}\left(\frac{\omega L}{R}\right) = 76.5^\circ \)
\( T = 500 \text{ msec} \Rightarrow 1^\circ = 0 \text{ msec} \)
\( \phi = 4.64 \text{ msec} \times 76.5^\circ = 106 \text{ psec} \)
L - R CIRCUIT PHASE SHIFT

THE PHASE SHIFT BETWEEN THE DRIVING VOLTAGE AND THE CURRENT (THE VOLTAGE ACROSS THE RESISTOR) IN AN L-R CIRCUIT IS DEMONSTRATED.

EQUIPMENT LIST:

1 DECADE RESISTOR - TYPE 102L SERIAL # 781, GENERAL RADIO, LABELED R3 IN YELLOW, LABELED R102 IN WHITE, WOODEN HOUSING.
1 STEP INDUCTOR - GR 10mH PER STEP, 500mAMP MAX.
1 HP 3310A FUNCTION GENERATOR
1 TEKTRONIC 465 OSCILLOSCOPE
ASSORTED BANANA AND BNC CABLES

SET UP:

FUNCTION GENERATOR, INDUCTOR AND RESISTOR ARE CONNECTED IN SERIES. HIGH SIDE OF FUNCTION GENERATOR IS AT INDUCTOR, GROUND OF FUNCTION GENERATOR IS LOW SIDE OF RESISTOR. SCOPE TRIGGER SOURCE IS SET TO EXTERNAL AND SYNC OUTPUT OF FUNCTION GENERATOR IS INPUT TO SCOPE EXTERNAL TRIGGER. SCOPE CHANNEL 1 MEASURES TOTAL OUTPUT OF FUNCTION GENERATOR, CHANNEL 2 MEASURES DROP ACROSS RESISTOR.

R AND L:

STARTING VALUES ARE R=270 OHMS, L=90 MILLI H

SET SCOPE AS FOLLOWS:
TIME/DIV TO 5 mSEC/DIV
VERT MODE SHOULD BE CHOP
CH1 AND CH2 TO 1 VOLT/DIV
SELECT DC (3-POSITION SWITCH) FOR CH1 AND CH2

FUNCTION GENERATOR:
USE SINE OUTPUT
SET FREQUENCY DIAL TO 6
SET FREQUENCY RANGE (REALLY A MULTIPLIER) TO 10
DC OFFSET IS 0
ADJUST OUTPUT LEVEL KNOB TO GIVE ABOUT 3 VOLTS ON CH 1, CH 2 WILL GIVE A SLIGHTLY LOWER VOLTAGE

THIS GIVES AN INITIAL FUNCTION GENERATOR FREQUENCY OF f = 6 x 10 = 60hz.
THE ANGULAR FREQUENCY IS W = 2 x PI x f = 377 radians/sec.

THE PHASE DIFFERENCE BETWEEN THE SOURCE AND THE CURRENT IS

\[
\tan(\text{Phase Angle}) = \frac{W L}{R}
\]

THE INITIAL PHASE DIFFERENCE (for R=270ohm, L=90mh, f=60hz) IS ABOUT 7 DEGREES.
NOW CHANGE THE FUNCTION GENERATOR FREQUENCY TO 600Hz BY SWITCHING THE 
MULTIPLIER KNOB TO 100. THE PHASE DIFFERENCE IS NOW ABOUT 50 DEGREES. 
CHANGE THE SCOPE TIME/DIV TO .5mSEC/DIV SO THAT IT IS EASY TO SEE THE 
INCREASED PHASE DIFFERENCE. THE AMPLITUDE OF CH2 WILL NOW BE DECREASED.

TO INCREASE THE PHASE ANGLE TO ABOUT 70 DEGREES TURN THE FUNCTION 
GENERATOR DIAL TO 20. THIS GIVES A FREQUENCY OF 20 X 100 = 2000Hz. 
IT WILL BE NECESSARY TO TURN THE SCOPE TIME/DIV KNOB TO .1mSEC TO SEE 
THE PHASE DIFFERENCE.
LR PHASE SHIFT

\[ R = 270 \, \Omega, \quad L = 90 \, \text{mH}, \quad \theta = \tan^{-1}\left(\frac{\omega L}{R}\right) \]

a) \( f = 60 \, \text{Hz} \) (Range: 10, frequency: 6)
\[ \omega = 2\pi f = 377 \, \text{rad/sec} \]
\[ \theta = \tan^{-1}\left(\frac{\omega L}{R}\right) \approx 7.16^\circ \]
\[ \Delta t_{\text{lag}} = \frac{1}{60} \cdot \frac{377}{360} = 331 \, \mu\text{s} \]

b) \( f = 600 \, \text{Hz} \) (Range: 100, frequency: 6)
\[ \omega = 3770 \, \text{rad/sec} \]
\[ \theta = 51.5^\circ \]
\[ \Delta t_{\text{lag}} = \frac{1}{60} \cdot \frac{51.5}{360} = 238 \, \mu\text{s} \]

c) \( f = 2000 \, \text{Hz} \) (Range: 100, frequency: 20)
\[ \omega = 12566 \, \text{rad/sec} \]
\[ \theta = 76.6^\circ \]
\[ \Delta t_{\text{lag}} = \frac{1}{2000} \cdot \frac{76.6}{360} = 106 \, \mu\text{s} \]