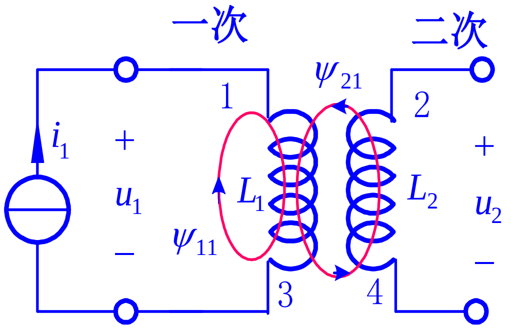
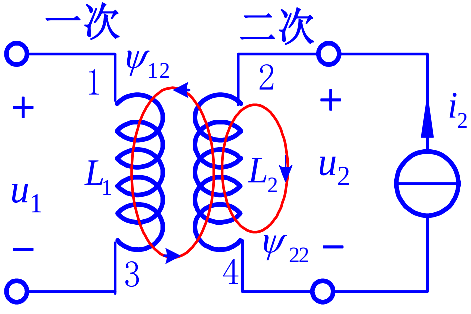
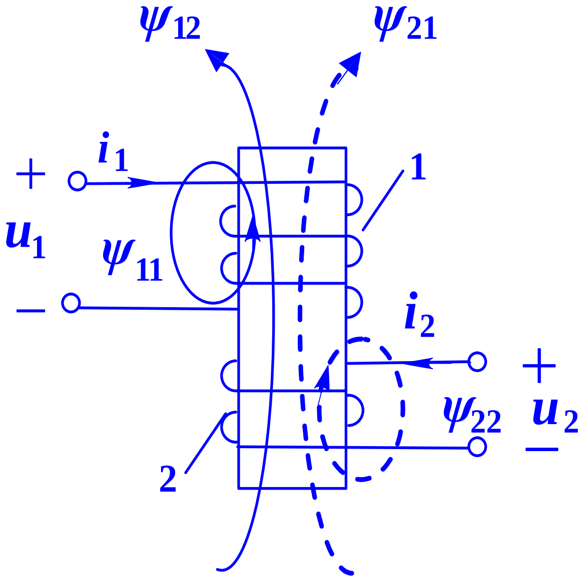
互感元件







	i_1	i_2
自感磁链	ψ_{11}	ψ_{22}
互感磁链	ψ_{21}	ψ_{12}

$$\psi_1 = \psi_{11} \pm \psi_{12} = L_1 i_1 \pm M_{12} i_2$$

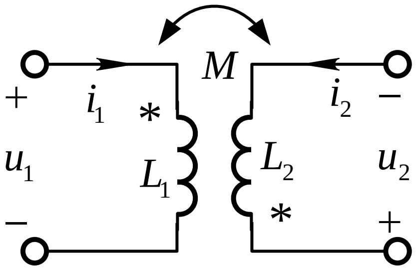
$$\psi_2 = \pm\psi_{21} + \psi_{22} = \pm M_{21} i_1 + L_2 i_2$$

$$u_1 = \frac{\mathrm{d}\psi_1}{\mathrm{d}t} = L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} \pm M \frac{\mathrm{d}i_2}{\mathrm{d}t} = u_{11} + u_{12}$$

$$u_2 = \frac{\mathrm{d}\psi_2}{\mathrm{d}t} = \pm M \frac{\mathrm{d}i_1}{\mathrm{d}t} + L_2 \frac{\mathrm{d}i_2}{\mathrm{d}t} = u_{21} + u_{22}$$

互感元件

同名端 使所激发的自感磁链和互感磁链方向一致的两个线圈电流同进端或同出端。



$$u_1 = L_1\frac{\mathrm{d}i_1}{\mathrm{d}t} - M\frac{\mathrm{d}i_2}{\mathrm{d}t}$$

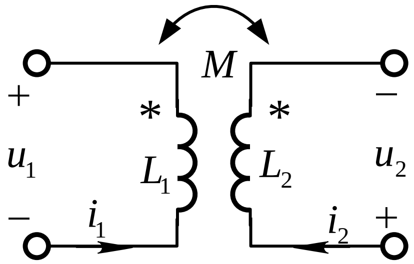
$$u_2 = M\frac{\mathrm{d}i_1}{\mathrm{d}t} - L_2\frac{\mathrm{d}i_2}{\mathrm{d}t}$$

分析

1）端口 1 的电压和电流为关联参考方向，自感电压u_{11}前为正；

2）引起互感电压u_{12}的电流 i_2 参考方向是从所在端口2的非 * 指向 * 端，与引起u_{11}的电流 i_1从自端口 * 端指向非 * 端方向相反，因此 u_{12}前取负；

互感元件



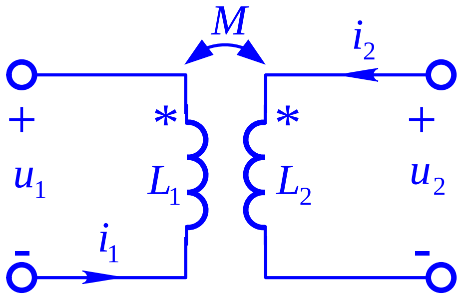
$$u_1 = -L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} - M\frac{\mathrm{d}i_2}{\mathrm{d}t}$$

$$u_2 = M\frac{\mathrm{d}i_1}{\mathrm{d}t} + L_2\frac{\mathrm{d}i_2}{\mathrm{d}t}$$

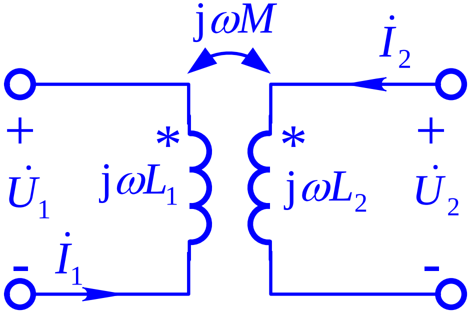
$$\dot{U}_1 = -\mathrm{j}\omega L_1 \dot{I}_1 - \mathrm{j}\omega M \dot{I}_2$$

$$\dot{U}_2 = \mathrm{j}\omega M \dot{I}_1 + \mathrm{j}\omega L_2 \dot{I}_2$$

含互感的相量电路模型



(a)

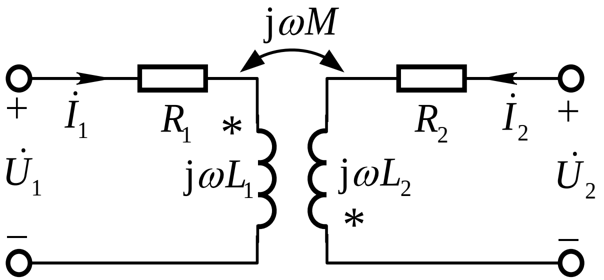


(b)

$$\dot{U}_1 = -\mathrm{j}\omega L_1 \dot{I}_1 + \mathrm{j}\omega M \dot{I}_2$$

$$\dot{U}_2 = \mathrm{j}\omega M \dot{I}_1 - \mathrm{j}\omega L_2 \dot{I}_2$$

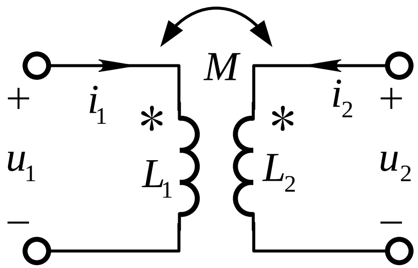
一个实际耦合电感，一般需要考虑绕组电阻，此时可用带有串联等效电阻的互感来表示其电路模型



端口特性方程

$$\begin{cases}\dot{U}_1 = R_1\dot{I}_1 + \mathrm{j}\omega L_1\dot{I}_1 - \mathrm{j}\omega M\dot{I}_2 \\ \dot{U}_2 = R_2\dot{I}_2 - \mathrm{j}\omega M\dot{I}_1 + \mathrm{j}\omega L_2\dot{I}_2\end{cases}$$

互感功率



$$P = u_1 i_1 + u_2 i_2$$

$$= [L_1(\mathrm{d}i_1/\mathrm{d}t) \pm M(\mathrm{d}i_2/\mathrm{d}t)]i_1 + [\pm M(\mathrm{d}i_1/\mathrm{d}t) + L_2(\mathrm{d}i_2/\mathrm{d}t)]i_2$$

$$= \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{1}{2}L_1 i_1^2 \pm M i_1 i_2 + \frac{1}{2}L_2 i_2^2\right) = \frac{\mathrm{d}w_\mathrm{m}}{\mathrm{d}t}$$

$$w_\mathrm{m} = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 \pm M\, i_1\, i_2 \qquad w_\mathrm{m} \geq 0$$

若没磁耦合，M=0，磁能就是两个自感元件分别储能之和