CHAPTER 4

Magnetic Amplifier Circuits

Nonpolarized Circuits

In the nonpolarized circuit, the actual performance of the magnetic amplifier is evident that the load current I_L is not zero when the control current is zero. Actually, with Ic = 0 the magnetizing current Im flows through the load resistance R_L and produces the corresponding load voltage ImR_L

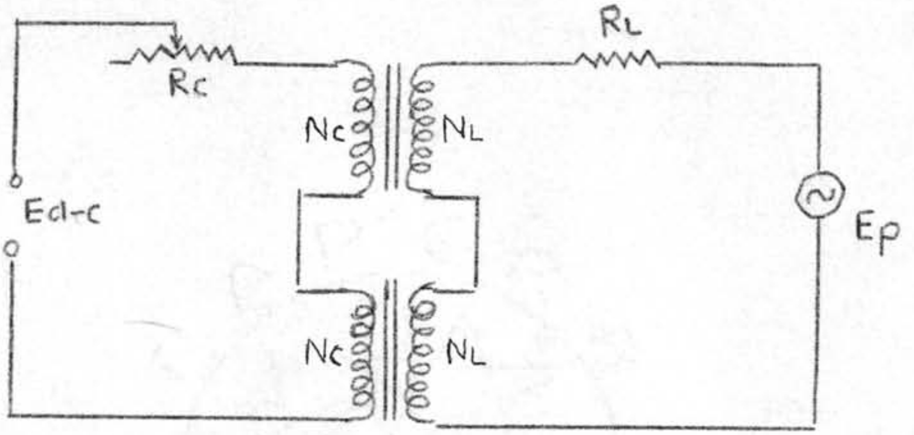

Fig. 12 Nonpolarized circuit of magnetic amplifier

Application of a control current Ic causes the load current to increase from I_{Lo} (load current when Ic = 0) to I_L. The increment

$$I_{Lc} = I_L - I_{Lo}$$

represents the "load component" flowing in response to c changes in control current Ic It is to be noted that, even when high-permeability core material is used, the actual value of the excitation current component I_{Lo} may be a substantial percentage of that of the load component I_{Lc}.

The output obtained with either positive or negative values of the control current does not change sign or amplitude. It is evident that exactly the same load current I_L would be obtained with the positive or negative control current. Thus the transfer characteristics is symmetrical, as shown in Fig. 13

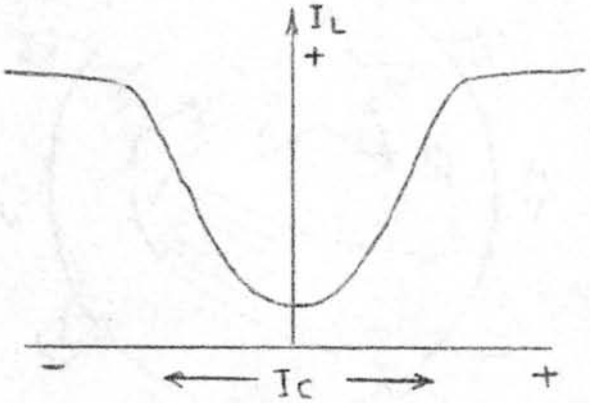

Fig. 13 Transfer characteristics of a nonpolarized circuit.

Polarized Circuits

It was indicated earlier in this chapter, with reference to the control characteristic of the magnetic amplifier shown in Fig. 13, that the circuit was not polarity sensitive. The output obtained does not change sign and amplitude, the magnetizing current Im still exists when Ic = 0, thus with regard to many practical applications of nonfeedback circuits, it is necessary to provide some special circuits to compensate for undesired effects of the magnetization current Im.

The bias circuit and push-pull circuit are usually introduced to compensate this undesired current.

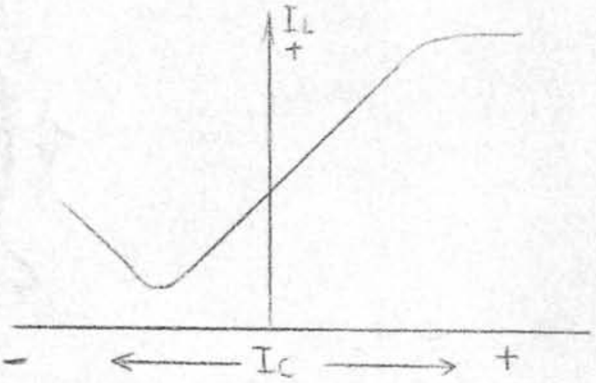

Fig.14 Characteristics of a polarized circuit using an additional bias magnetization.

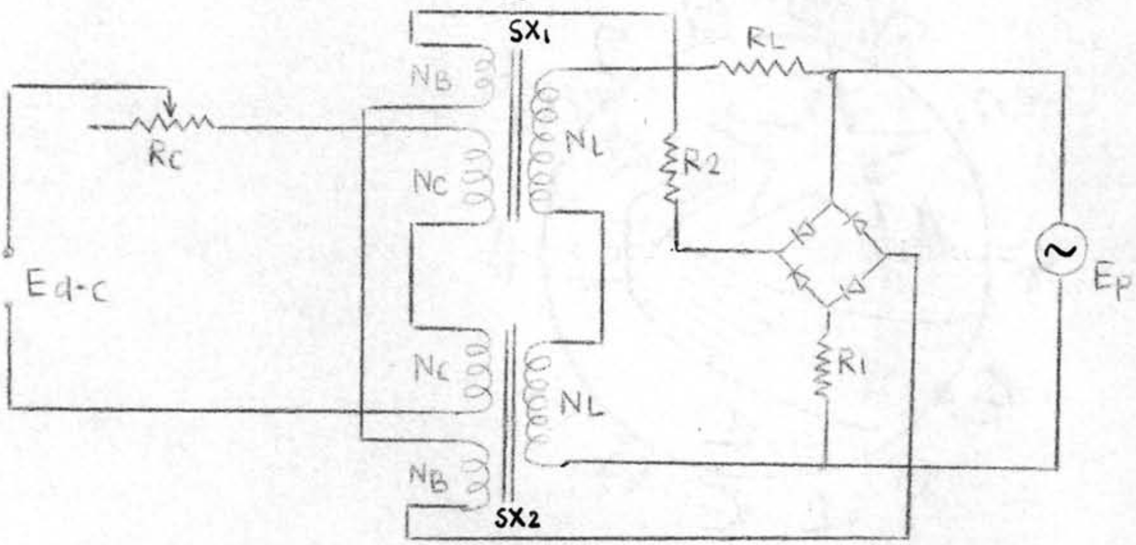

Fig. 15 Polarized magnetic amplifier circuit (bias type).

Refering to Fig.15 the bias current I_B is supplied t through a full-wave rectifier circuit with fixed resistors R_1 and R_2 from the power supply voltage E_p . Thus, I_B is proportional to E_p. The resultant magnetomotive force, applied to the core elements, will be proportional to the actual difference I_B and I_c. The resultant magnetomotive force will be proportional to the actual ampere-turns $(I_B N_B \pm I_c N_c)$.

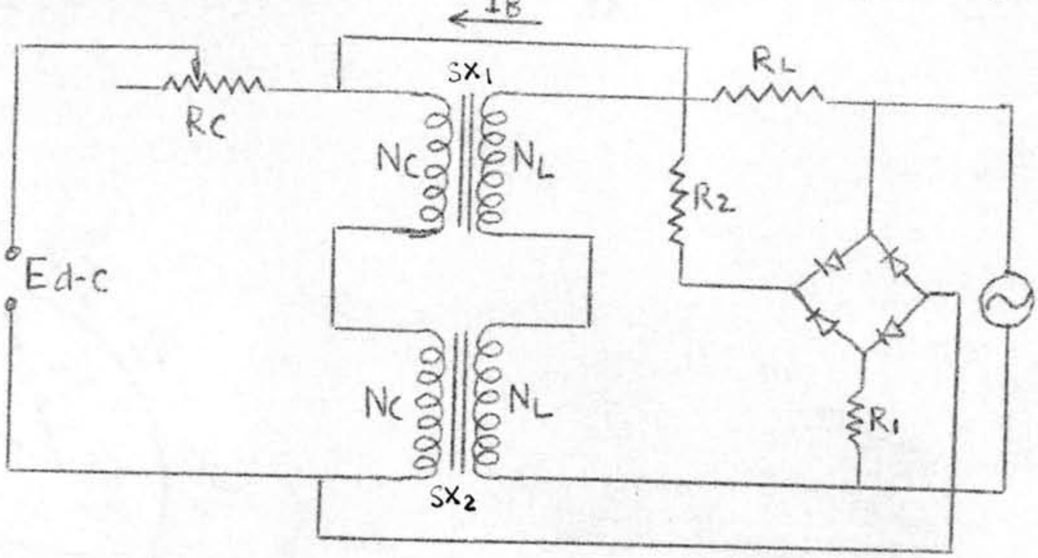

Fig.16 Polarity sensitive magnetic amplifier with control windings acting as bias windings.

In case of circuit shown in Fig. 16., the resultant magnetomotive force will be represented by the actual ampere-turns $(I_B \pm I_c)\, N_c$. For both cases, it can be seen that when the control current is applied to the circuit, the degree of core magnetization will change, decreasing if they oppose. It now becomes evident that the polarity of the control current, as well as its magnitude, will control the amount of load current in the magnetic amplifier. The transfer characteristics of a bias type polarized magnetic amplifier is shown in Fig.14.

rent in the magnetic amplifer. The transfer characteristics of a bias type polarized magnetic amplifier is shown in Fig. 14.

Duodirectional Circuits (Push-Pull Type)

In magnetic amplifiers of the balance-detector type, the load I_L must change its direction according to the reversible direction of the control current I_c as illustrated in Fig. 17.

A pair of magnetic amplifiers may be operated in such a manner that a balancing or push-pull effect is obtained. This is equivalent to two of the parallel magnetic amplifiers connected back to back, as shown in Fig.18. When the control

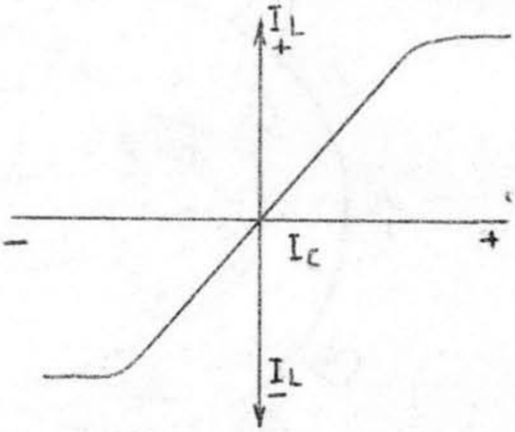

Fig.17 Transfer characteristics of a push-pull magnetic amplifier.

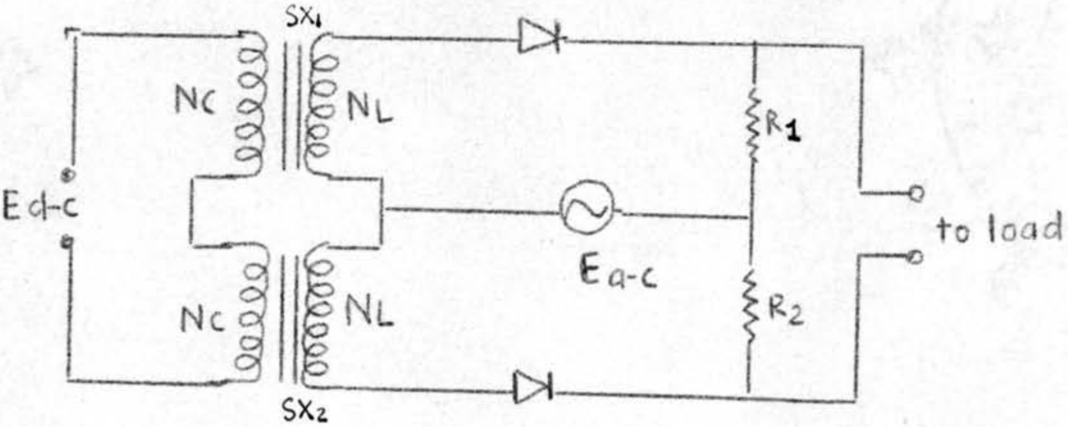

Fig. 18 Push-pull magnetic amplifier (half-wave circuit)

current of positive polarity flows, the voltage across R_1 will be greater than that across R_2; without control current the two voltages will be equal, and for negative control current the voltage across R_1 will be smaller than that across R_2. The polarity of the rectified current through the load resistance must, therefore, depend on the polarity of the control current. This type of the circuit, power must be wasted in the balancing resistances R_1 and R_2. This, of course, is of no consequence in low power applications.

Magnetic Amplifier Power Gain

In magnetic amplifiers, the power gain is dependent to a great degree upon the design, type, and physical size of the reactor device. For typical magnetic amplifiers the gain figures per stage varied from about 10 to 100. Power gain is, of course, the ratio between output power and input power, the output power is considered as that power developed in the load windings and delivered to the load; the input power is that developed in the control windings. Since power equivalent to I^2R, so the power gain can be shown as

$$\text{power gain (no feedback) } K_p = \frac{\text{power output}}{\text{power input}}$$

$$= \frac{I_L^2 R_L}{I_C^2 R_C} \quad \text{--------------- (4-1)}$$

where I_L = current in the load windings

I_C = current in the control windings

R_L = resistance of the load

R_C = resistance of the control windings.

Because of the current transformer characteristics of the reactor, the currents are inversely proportional to the turn ratio so that the Eq. (4-1) can be converted to

$$K_p = \frac{N_C^2 R_L}{N_L^2 R_C} \quad \text{------------- (4-2)}$$

where N_C = number of turns in the control winding

N_L = number of turns in the load winding.

With reference to Eq.(4-1) or (4-2), it is evident that an increase in the value of load resistance will produce an increased power gain. However, an increase of this type will continue within the limits without changing the current ratio I_L/I_C, within this limit the power gain is directly proportional to the load resistance expressed in terms of R_L/N_L^2, and that an attempted increase beyond these limits will, in effect, produce a reducedgain.

Magnetic Amplifier with External Feedback

Modern magnetic-amplifier practice requires that maximum gain be obtained in a single stage, where possible. This can be accomplished by " positive " or " regenerative feedback ". For preliminary considerations, the rectified load current I_L may be considered as an additional direct current, whose d-c control action is identical to that of the direct current I_c flowing through the control windings N_c, this additional d-c control action of feedback current I_F may be either aiding or opposing to the d-c control action of the input current I_c. If aiding control conditions are used, the feedback is "positive" ŏr "regenerative". However, if opposing control conditions are used, the feedback is "negative" or "degenerative"

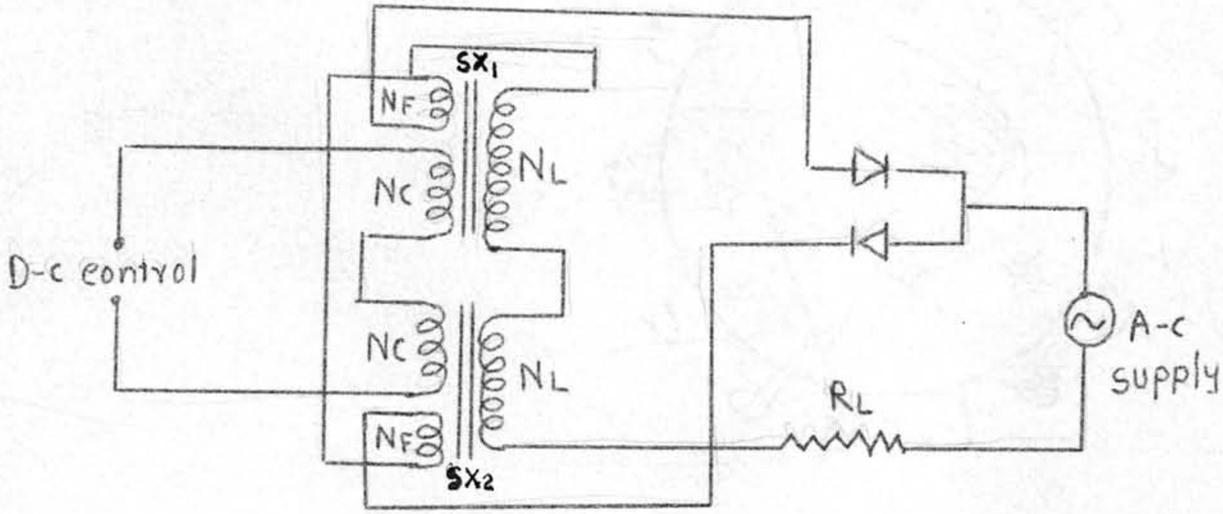

Fig. 19 Magnetic amplifier with external regenerative magnetic feedback, operating into a-c load.

Gains of Feedback Amplifiers

The current equivalency relationship for the magnetic amplifier without feedback is given as

$$N_c I_c = N_L I_L \qquad \text{---------} \quad (4\text{-}3)$$

When regenerative feedback is added, this relationship is modified to become

$$N_c I_c + N_F I_F = N_L I_L \qquad \text{--------} \quad (4\text{-}4)$$

where

N_F = number of turns in the feedback winding

I_F = current flowing in the feedback winding

solving Eq. (4-4) , we have

$$N_c I_c = N_L I_L (1 - N_F I_F / N_L I_L)$$

current gain $K_I = \dfrac{I_L}{I_c}$

$$= \frac{N_c}{N_L} \left(\frac{1}{1 - N_F I_F / N_L I_L} \right) \quad \text{------} \quad (4\text{-}5)$$

For the magnetic amplifier with series-connected load windings, it can be assumed that $I_F = I_L$ Eq.(4-5) resolves to

$$K_I = \frac{I_L}{I_c} = \frac{N_c}{N_L} \left(\frac{1}{1 - N_F/N_L} \right) \qquad \text{--------} \quad (4\text{-}6)$$

The denominator $(1 - N_F/N_L)$ in this equation is the feed-back factor. When $N_F = 0$, the case for a non-feedback amplifier, The power gain of positive feedback is given as

power gain (positive feedback) $K_p = \dfrac{N_c^2 R_L}{N_L^2 R_c} \left(\dfrac{1}{1 - N_F/N_L} \right)^2$ ----(4-7)

For negative or degenerative feedback amplifier,

power gain (negative feedback) $K_p = \frac{N_c^2 R_L}{N_L^2 R_c}\left(\frac{1}{1 + N_F/N_L}\right)^2$ ---(4-8)