# CHAPTER 5

## Laboratory Experiments

EXPERIMENT NO.1

The Study of Saturation-core Reactors

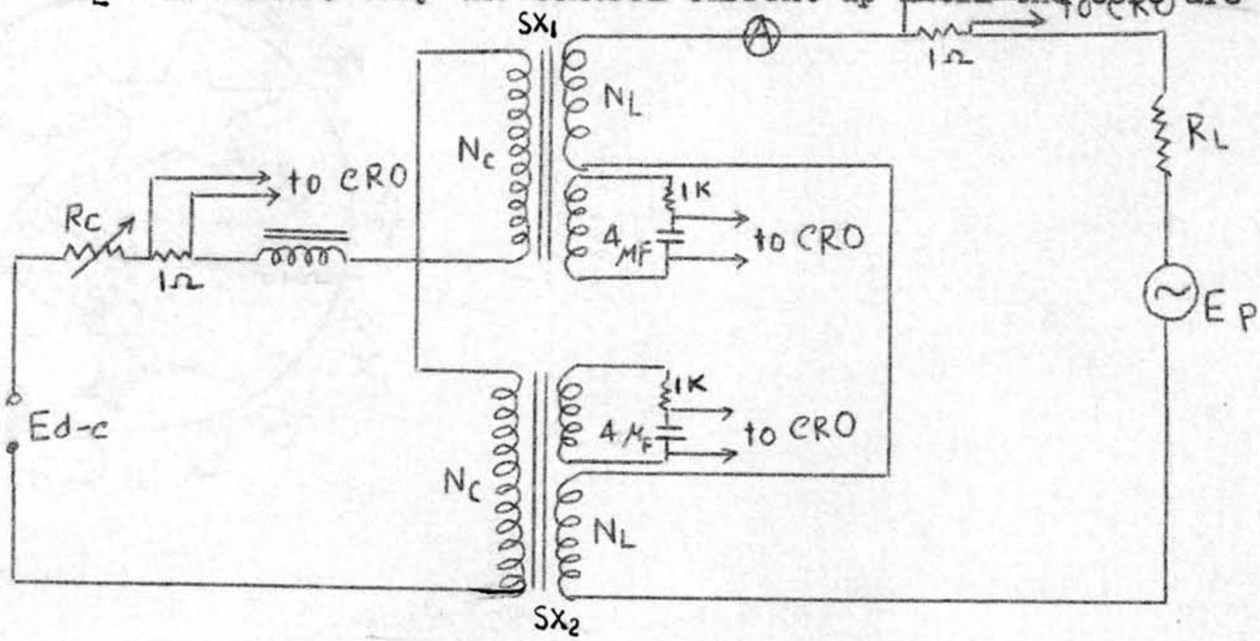
Purpose

The purpose of this experiment is to observe the waveshape of core flux, supply voltage, control current and load current under forced and natural magnetization.

Procedure

(1) Forced magnetization of the saturable reactor.

Connect the circuit as shown. Set Ep = 60 volts $R_L$ = 100 ohms. Vary the control current up until the core are



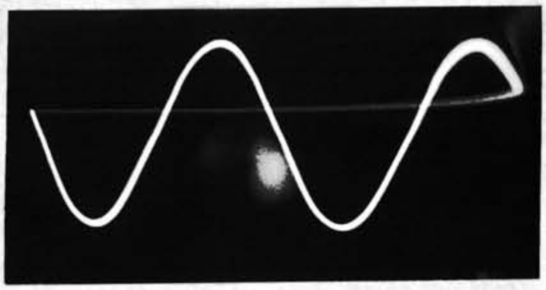

saturated (i.e., no change in load current) by means of the resistor Rc. Observe the waveforms of a-c supply voltage, control current, load current, magnetic flux in core(1)and(2). Copy down all the wavefroms.

(2) Natural magnetization of saturable reactor.

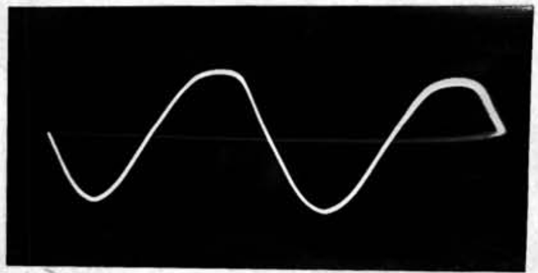
Repeat the procedure by using the same circuit as in (1) except that the choke is removed.

Report

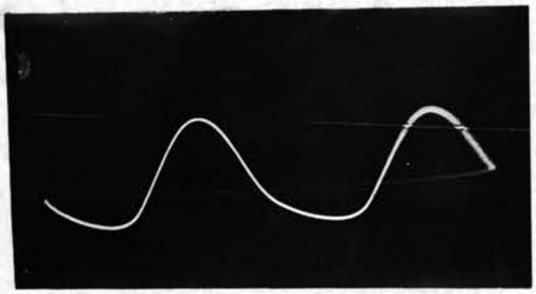
Discuss the waveforms obtained from the test.



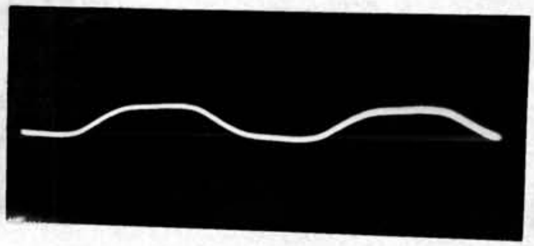
(a) Supply voltage



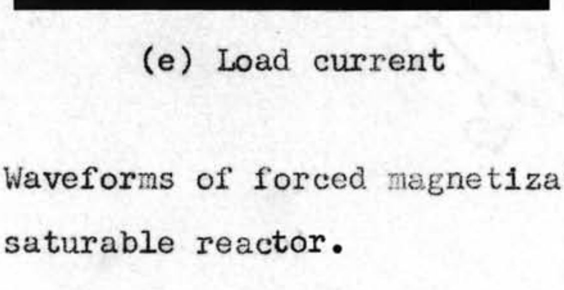
(b) Core flux (core 1)



(c) Core flux (core 2)



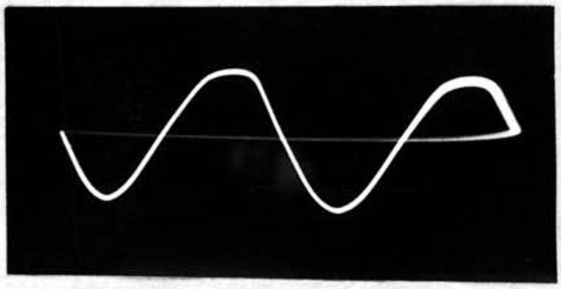
(d) Control current



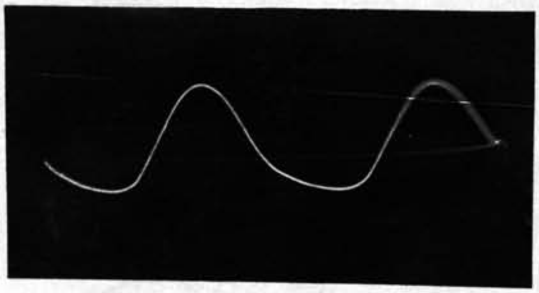
(e) Load current

Fig. 20 Waveforms of forced magnetization of the saturable reactor.

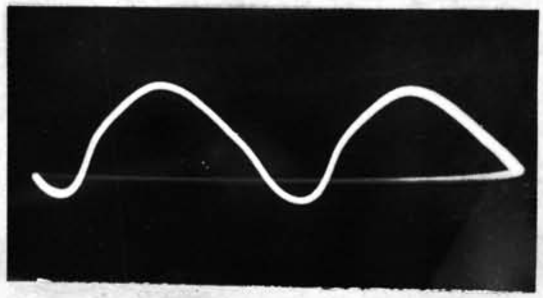
(a) Supply voltage



(b) core flux (core 1)



(c) Core flux (core 2)



(d) Control current

(e) Load current

Fig. 21 Waveforms of natural magnetization of the saturable reactor.

Discussion

Forced magnetization

For Fig. 20 (b), assume that the control current is sufficient to move both cores into positive saturation. During the half-cycle, the a-c current flowing in the load coil of core 1 can produce no change in magnetization, since the core is presently saturated. Because the flux cannot change, the flat-topped magnetization state, which is shown in Fig. 20 (b), and which indicates core saturation exists for core 1.

During this same half-cycle, the load current produces a field of direction opposite to that produced by the control current in core 2. The a-c field is such as to bring core 2 out of its positive saturated state, and move it over the linear section of the B-H curve toward negative saturation. Thus the core 2 magnetization state varies during this half-cycle as shown in Fig. 20 (c)

On the nex half-cycle, similar circuit conditions exist. However core 2 now is saturated while the stage of core 1 varies sinusoidally.

The even harmonics is suppressed by a high impedance of the series choke. The control current passed freely through the control circuit and the waveform is nearly smooth (which depends on the impedance of the choke coil, i.e., of the control circuit).

Natural magnetization

The d-c control circuit is now without the series choke, and the double-frequency component currents induced into the control winding by the changing flux in the core is not at saturation. These result in the pulsation of the d-c control current, as shown in Fig. 21 (d). In order for the load current to maintain the required sinusoidal change in flux, it must take on the sharp-pulsed appearance as shown in Fig. 21 (e).

EXPERIMENT NO.2

Static Characteristics of a Saturable Reactor

With Resistive Load and Free Even-harmonics Current.

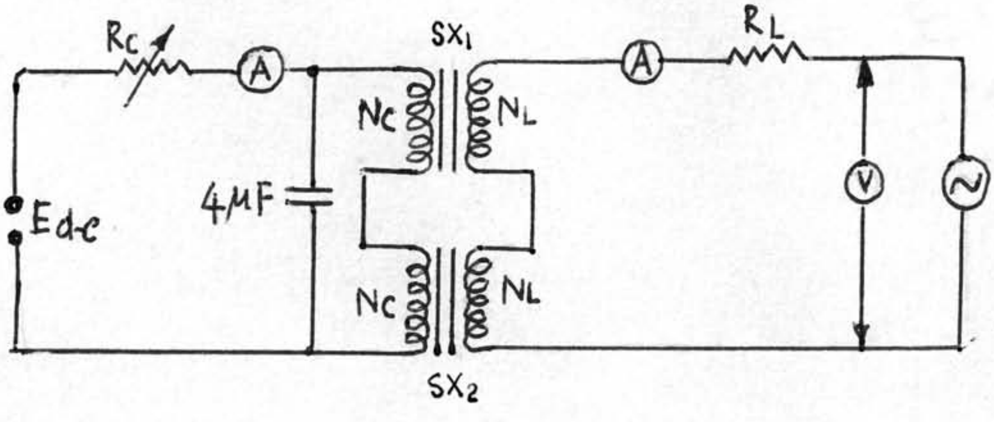
## Purpose.

The purpose of this experiment is to determine the relations of the supply voltage,loadcurrent,load resistance and the actual impedance of the saturable reactor when the control current is supplied to the control circuit.

## Procedure

(1) To determine the load current as a function of the power supply voltage with the control current as a parameter.

Connect the circuit as shown.Set $R_L$ = 600 ohms and $I_C$ = 0. Vary the supply voltage from 10 to 60 volts for about 8 readings




by means of a variable a-c transformer. Take readings of the corresponding load currents.

Repeat the procedure with the control current setting at 100 mA, 200 mA, 300 mA and 400 mA respectively.

Report

(1) Plot graphs of load current as a function of power supply voltages with the control current as a parameter.

(2) Calculate the value of an impedance of the load circuit when $I_C = 0$ and plot graphs for impedances and load currents against supply voltages.

(2) To determine the load current as a function of the control current with the load resistance as a parameter.

Using the same circuit as in (1). Set the supply voltage at 50 volts and $R_L$ = 100 ohms, then vary the control current from 0 to 500 milliamps by means of the resistor $R_C$ for about 9 steps. Take readings of the corresponding load currents.

Repeat the procedure with $R_L$ setting at 200, 500 and 800 ohms respectively.

Report

Plot graphs of control currents against load currents using the load resistance as a parameter.

Test Data The data is obtained from the measurements carried out on the ferrite core with

1) a-c load windings of 1000 turns each of № 25 wire (Standard Wire gauge)

2) d-c control windings of 1000 turns each of № 25 wire (Standard Wire gauge)

The magnetic circuit of each core has an effective area of 0.785 $cm^2$ and a means length of 15 cms.

(1)

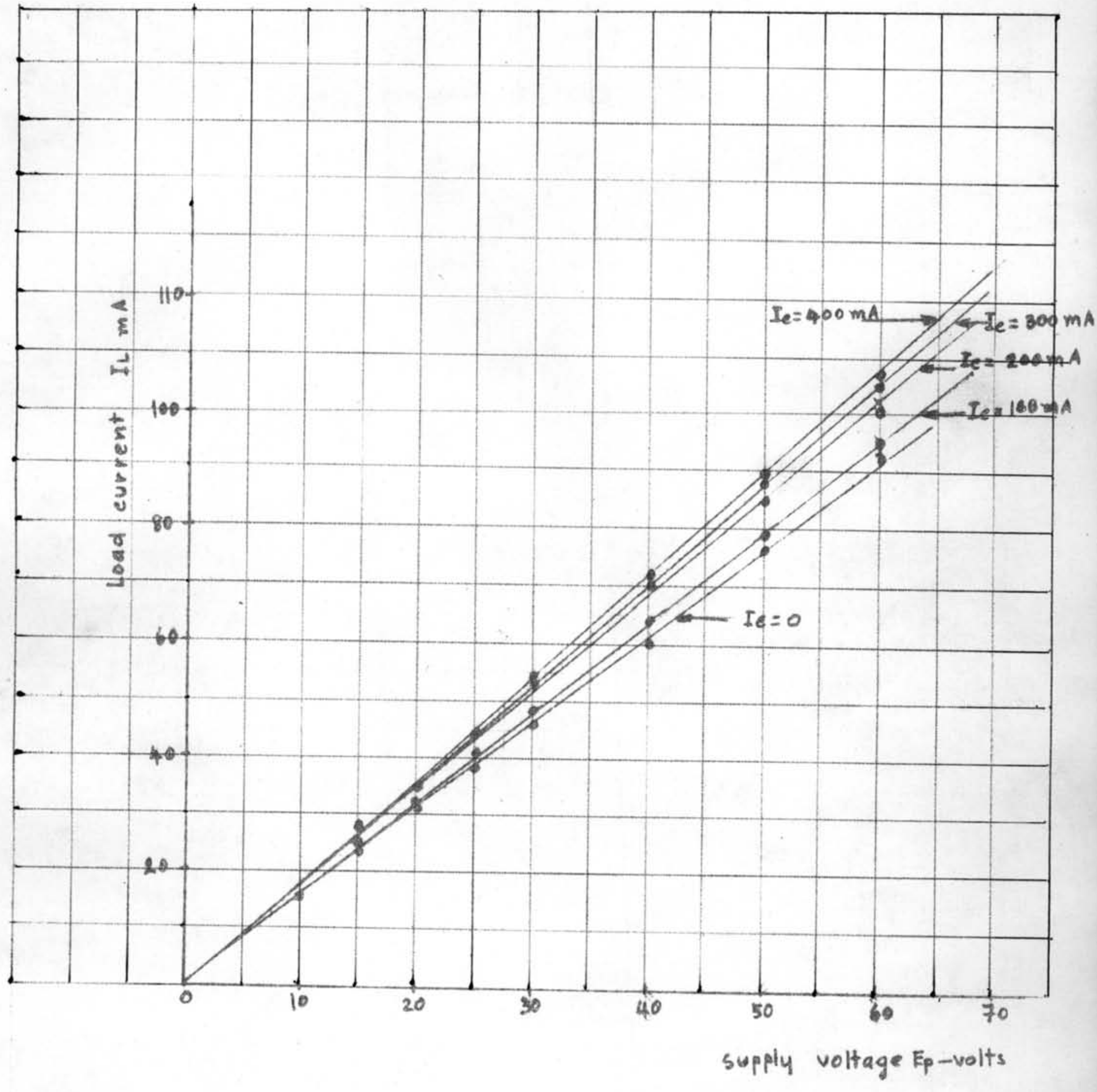
| Control current Ic, mA | Supply voltage Ep, Volts | Load current $I_L$, mA | Impedance $Z = E_p/I_L$ |
|---|---|---|---|
| 0 | 10 | 16.0 | 0.625 |
| | 15 | 24.0 | 0.625 |
| | 20 | 31.0 | 0.645 |
| | 25 | 38.5 | 0.649 |
| | 30 | 46.0 | 0.652 |
| | 40 | 60.0 | 0.666 |
| | 50 | 76.5 | 0.654 |
| | 60 | 92.5 | 0.65 |
| 100 | 10 | 16 | |
| | 15 | 25 | |
| | 20 | 32 | |
| | 25 | 41 | — |
| | 30 | 48 | |
| | 40 | 64 | |
| | 50 | 79 | |
| | 60 | 95 | |

| Control current Ic, mA | Supply voltage Ep, Volts | Load current $I_L$, mA | Impedance $Z = Ep/I_L$ |
|---|---|---|---|
| 200 | 10 | 16 | |
| | 15 | 28 | |
| | 20 | 35 | |
| | 25 | 44 | |
| | 30 | 53 | |
| | 40 | 70 | |
| | 50 | 85 | |
| | 60 | 101 | |
| 300 | 10 | 16 | |
| | 15 | 28 | |
| | 20 | 35 | |
| | 25 | 44 | |
| | 30 | 53 | |
| | 40 | 70.5 | |
| | 50 | 88 | |
| | 60 | 105 | |
| 400 | 10 | 16.0 | |
| | 15 | 28.0 | |
| | 20 | 35.0 | |
| | 25 | 45.0 | |
| | 30 | 54.5 | |
| | 40 | 71.5 | |
| | 50 | 88.5 | |
| | 60 | 105.5 | |

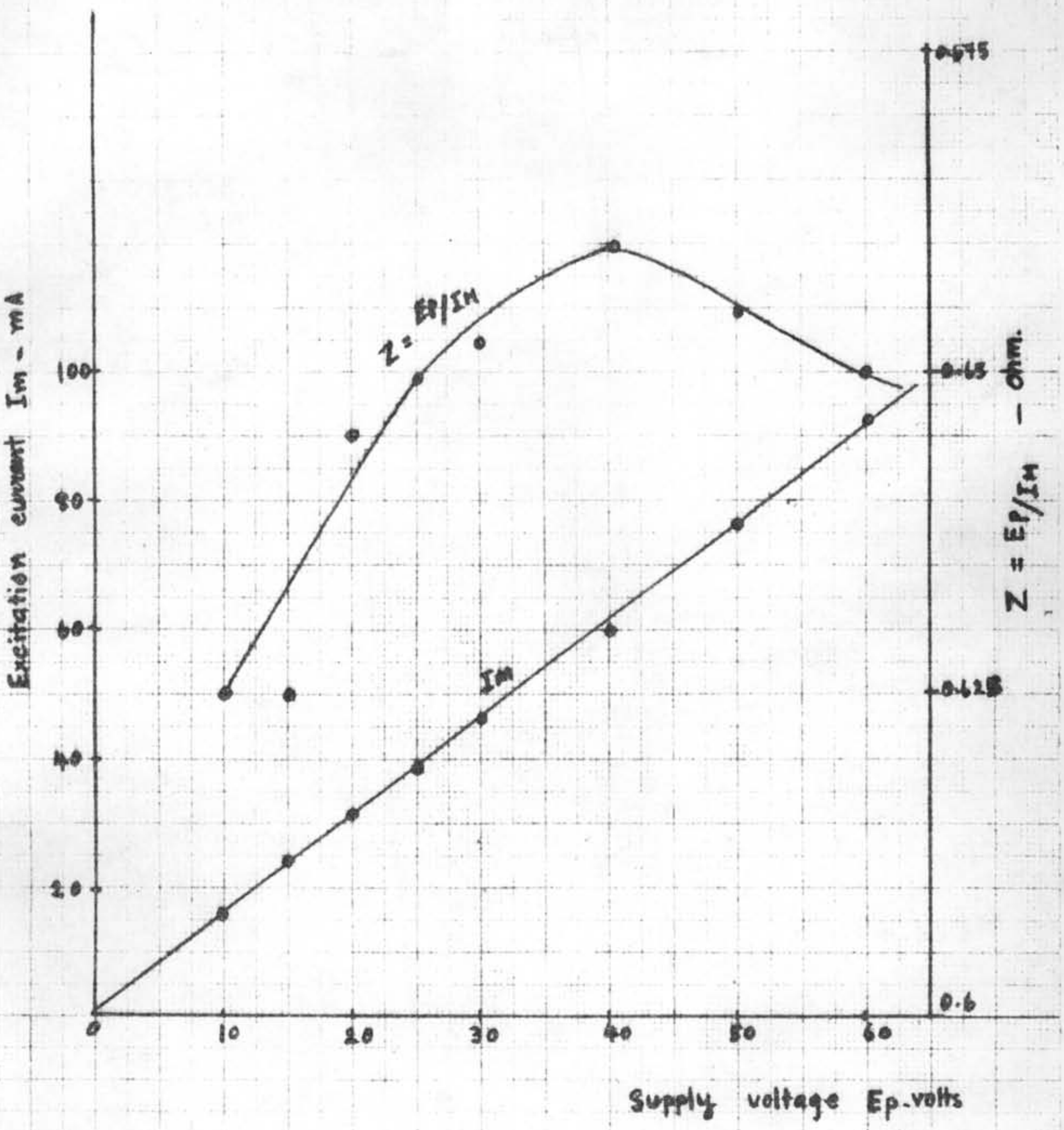
(2)

| Load resistance ohms | Control current mA | Load current mA |
|---|---|---|
| 100 | 0 | 204 |
| | 40 | 209 |
| | 80 | 210 |
| | 140 | 211 |
| | 180 | 212 |
| | 220 | 216 |
| | 260 | 220 |
| | 300 | 228 |
| | 400 | 251 |
| | 500 | 266 |
| 200 | 0 | 146.0 |
| | 40 | 147.0 |
| | 80 | 148.0 |
| | 140 | 150.5 |
| | 180 | 154.5 |
| | 220 | 161.0 |
| | 260 | 166.0 |
| | 300 | 172.0 |
| | 400 | 186.0 |
| | 500 | 186.0 |

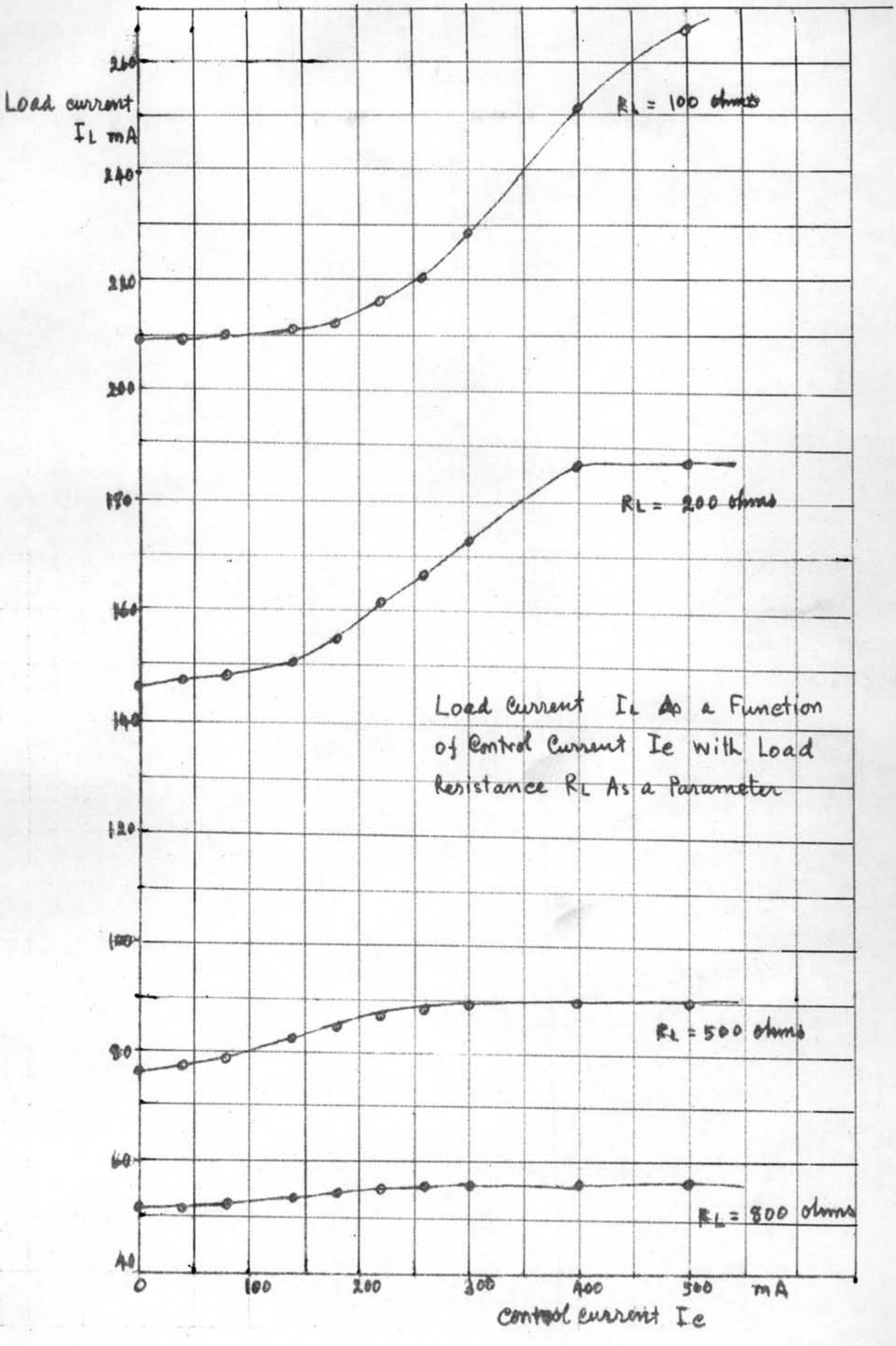
| Load resistance | Control current | Load current |
|---|---|---|
| 500 | 0 | 76.0 |
| | 40 | 77.0 |
| | 80 | 78.5 |
| | 140 | 82.0 |
| | 180 | 84.0 |
| | 220 | 86.0 |
| | 260 | 87.0 |
| | 300 | 88.0 |
| | 400 | 88.5 |
| | 500 | 88.5 |
| 800 | 0 | 51.5 |
| | 40 | 51.6 |
| | 80 | 52.0 |
| | 140 | 53.25 |
| | 180 | 54.0 |
| | 220 | 55.0 |
| | 260 | 55.5 |
| | 300 | 55.7 |
| | 400 | 55.9 |
| | 500 | 56.0 |




Load current $I_L$ as a function of supply voltage $E_p$ with control current $I_c$ as a parameter




Excitation current Im ( $I_L$ when $I_c = 0$ ) and actual impedance Z as a function of supply voltage Ep.



Load current
$I_L$ mA
260
240
220
200
180
160
140
120
100
80
60
40
$R_L$ = 100 ohms
$R_L$ = 200 ohms
$R_L$ = 500 ohms
$R_L$ = 800 ohms
Load Current $I_L$ As a Function of Control Current Ic with Load Resistance $R_L$ As a Parameter
0
100
200
300
400
500
mA
control current Ic

Discussion

From the graphs obtained from the test it can be seen that the actual impedance of the load circuit, when Ic = 0, is increasing as the supply voltage increases up to 40 volts. Beyond this point the actual impedance decreases because the load current changes rapidly in magnitude. For magnetizing current, the curve seems to be a straight line which means that there is no saturation effect of the core. In fact, this effect occurs beyond 40 volts of the supply voltage. This effect shows clearly on the actual impedance curve.

## EXPERIMENT NO.3

### Nonpolarized, Polarized Types of Nonfeedback Magnetic Amplifiers

---

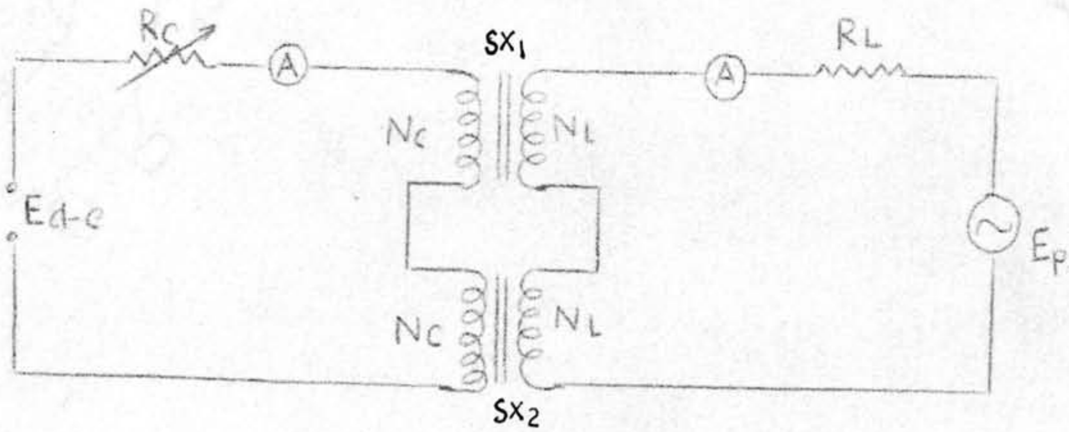
#### Purpose

The purpose of this experiment is to study the transfer characteristics of nonpolarized and polarized types of nonfeedback magnetic amplifier.

#### Procedure

(1) Nonpolarized magnetic amplifier

Arrange the circuit as shown. Set Ep = 10 volt and $R_L$ = 17 ohms. Vary the control current from 0 to 500 mA




by means of the resistor Rc. Take the readings of load currents. Reverse the polarity of the control current and repeat the procedure.

Repeat the procedure with Ep setting at 12 volts and 15 volts respectively by using $R_L$ of both cases at the same value.

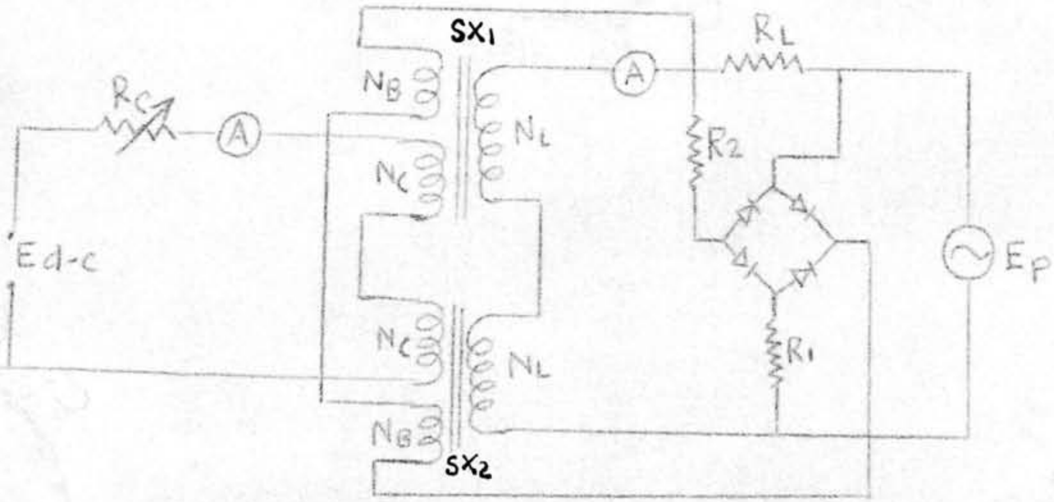
Report

Plot graphs of control current against load current.

(2) Polarized magnetic amplifier

(a) Separate bias windings

Connect the circuit as shown. Set Ep = 16.5 volts, $R_L$ = 60 ohms and the bias current = 300 mA. Vary the

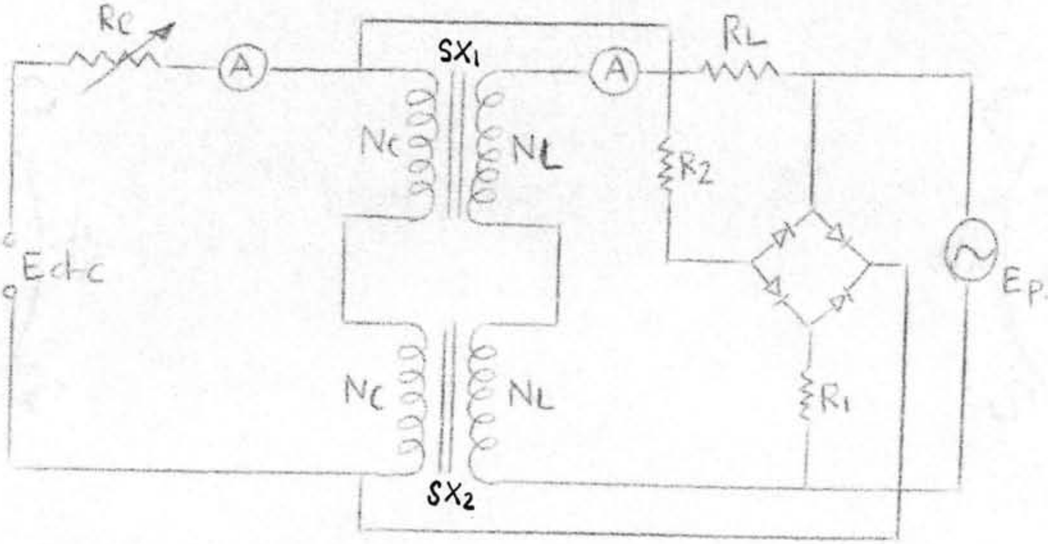



control current from 0 to 600 mA by means of the resistor $R_c$. Take the readings of load current for every step of current changing in the control circuit. Reverse the polarity of the d-c supply and then repeat the procedure.

Repeat this experiment with bias current = 300 mA.

(b) Control windings acting as bias windings.

Connect the circuit as shown. Set Ep = 16.5 volts, R = 60 ohms and bias current = 200 mA. Vary the control current from 0 to 600 mA by means of the resistor Rc. Take the




readings of load currents for every step of current changing in the control circuit. Reverse the polarity of the d-c supply and then repeat the procedure.

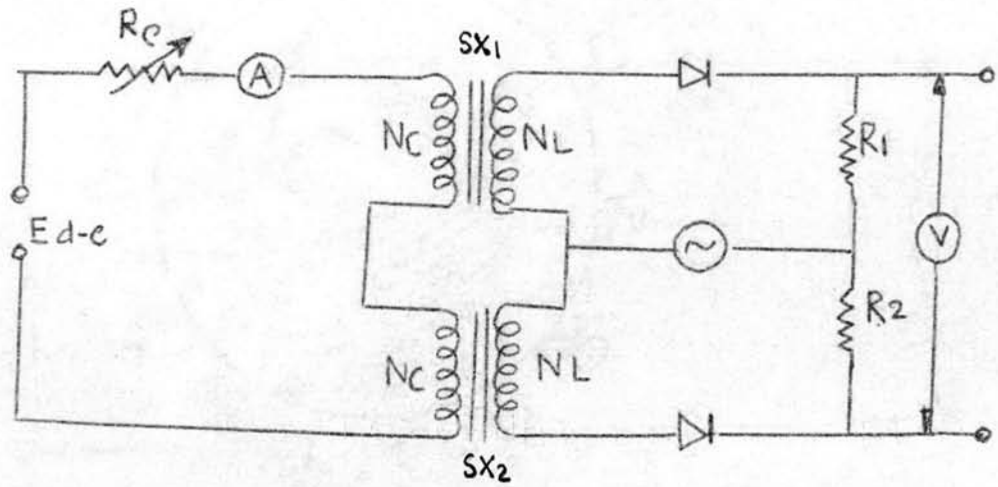
Repeat this experiment with bias current = 300 mA.

## Report

Plot graphs of control currents against load currents for both cases.

(3) Push-pull type magnetic amplifier

Connect the circuit as shown. Set Ep = 19 volts. With no current in the control circuit, adjust the resistor $R_1$




and $R_2$ until the zero output voltage is obtained, vary the control current from 0 to 100 mA. Take the readings of output voltage. Reverse the polarity of the d-c supply and then repeat the procedure.

## Report

Plot graph of output voltages against control currents.

<u>Test Data</u> The test data is obtained from the measurements carried out on the ferrite core with

1) a-c load windings of 1000 turns each of No 25 wire (Standard Wire gauge)

2) d-c control windings of 1000 turns each of No 25 wire (Standard Wire gauge).

The magnetic circuit of each core has an effective area of 0.785 $cm^2$ and a mean length of 15 cms.

(1) <u>Nonpolarized Magnetic Amplifier</u>

Supply voltage = 10 volts

Load resistance = 17 ohms

| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 108 | 0 | 108 |
| 40 | 109 | 40 | 109 |
| 80 | 114 | 80 | 114 |
| 120 | 122 | 120 | 122 |
| 160 | 130 | 160 | 130 |
| 200 | 134 | 200 | 134 |
| 240 | 140 | 240 | 140 |
| 280 | 144 | 280 | 144 |
| 320 | 147 | 320 | 147 |
| 360 | 150 | 360 | 150 |
| 400 | 152 | 400 | 152 |

Supply voltage = 12 volts
Load resistance = 17 ohms

| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 130 | 0 | 130 |
| 40 | 132 | 40 | 132 |
| 80 | 138 | 80 | 138 |
| 120 | 147 | 120 | 147 |
| 160 | 155 | 160 | 155 |
| 200 | 164 | 200 | 164 |
| 240 | 170 | 240 | 170 |
| 280 | 176 | 280 | 176 |
| 320 | 180 | 320 | 180 |
| 360 | 182 | 360 | 182 |
| 400 | 184 | 400 | 184 |

Supply voltage = 15 volts
Load resistance = 17 ohms

| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 161 | 0 | 161 |
| 40 | 163 | 40 | 163 |
| 80 | 171 | 80 | 171 |
| 120 | 182 | 120 | 182 |
| 160 | 194 | 160 | 194 |
| 200 | 203 | 200 | 203 |
| 240 | 210 | 240 | 210 |
| 280 | 216 | 280 | 216 |
| 320 | 221 | 320 | 221 |
| 360 | 224 | 360 | 224 |
| 400 | 228 | 400 | 228 |

(2) Polarized Magnetic Amplifier

(a) The test data is obtained from the measurements carried out on the ferrite core as in the nonpolarized circuit but with the additional bias windings of 300 turns each of No 25 wire (Standard Wire gauge).

Supply voltage = 16.5 volts

Load resistance = 60 ohms

Bias current = 300 mA

| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 104.5 | 0 | 104.5 |
| 40 | 106.5 | 40 | 102.5 |
| 80 | 108.5 | 80 | 101.5 |
| 120 | 110.5 | 120 | 100.0 |
| 160 | 113.0 | 160 | 100.5 |
| 200 | 115.0 | 200 | 101.5 |
| 300 | 118.0 | 300 | 105.0 |
| 400 | 120.0 | 400 | 110.5 |
| 500 | 121.5 | 500 | 114.0 |
| 600 | 123.0 | 600 | 117.0 |

Supply voltage = 16.5 volts.

Load resitance = 60.0 ohms.

Bias current = 500 mA.

| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 110.0 | 0 | 110.0 |
| 40 | 111.5 | 40 | 107.0 |
| 80 | 113.5 | 80 | 104.5 |
| 120 | 116.0 | 120 | 102.0 |
| 200 | 118.0 | 200 | 100.2 |
| 300 | 120.5 | 300 | 102.0 |
| 400 | 122.5 | 400 | 107.0 |
| 500 | 123.0 | 500 | 112.0 |
| 600 | 125.0 | 600 | 115.5 |

(b) Supply voltage = 16.5 volts.

Load resistance = 60.0 ohms.

Bias current = 200 mA

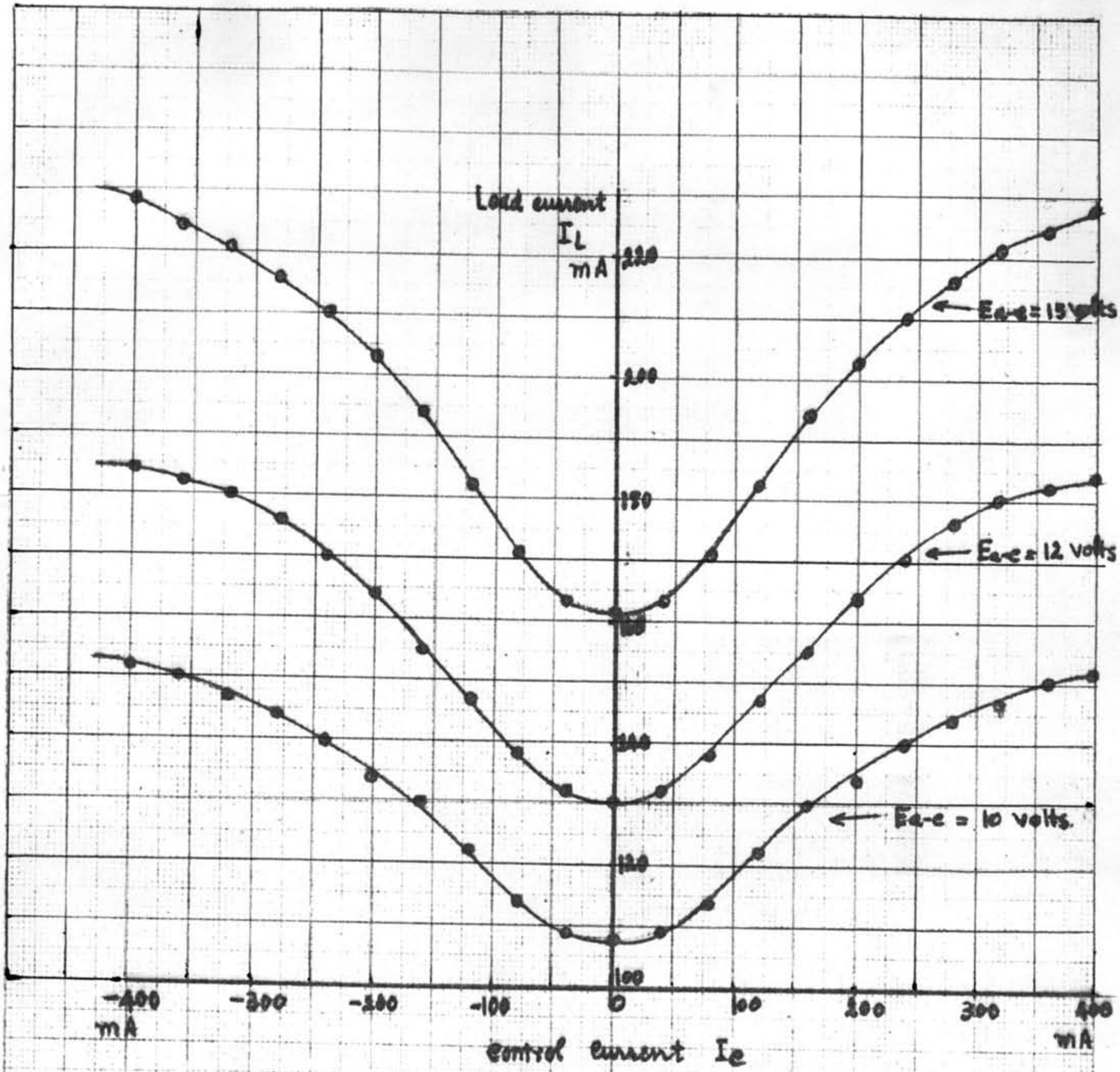
| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 105.0 | 0 | 105.0 |
| 40 | 107.0 | 40 | 104.0 |
| 80 | 109.5 | 80 | 102.0 |
| 120 | 111.0 | 120 | 100.0 |
| 160 | 112.0 | 160 | 99.0 |
| 200 | 113.5 | 200 | 98.0 |
| 240 | 115.0 | 240 | 98.5 |
| 300 | 115.5 | 300 | 99.0 |
| 400 | 117.5 | 400 | 104.0 |
| 500 | 119.0 | 500 | 108.5 |
| 600 | 119.5 | 600 | 112.5 |

Bias current = 300 mA.

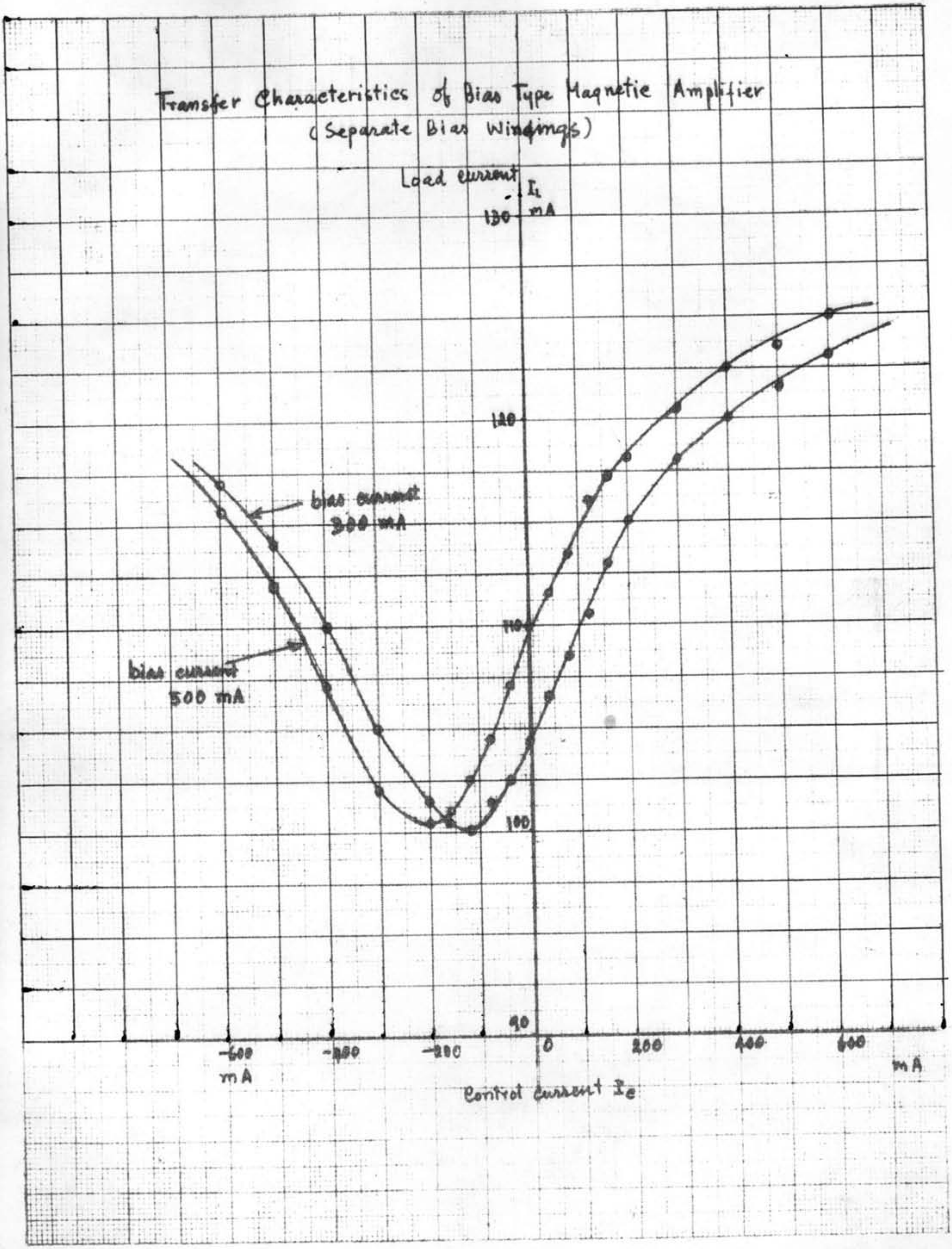
| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
|---|---|---|---|
| 0 | 111.0 | 0 | 111.0 |
| 40 | 113.5 | 40 | 110.5 |
| 80 | 114.5 | 80 | 110.0 |
| 120 | 116.0 | 120 | 108.0 |
| 160 | 117.0 | 160 | 106.0 |
| 200 | 118.0 | 200 | 103.0 |
| 240 | 118.5 | 240 | 101.5 |
| 300 | 119.5 | 300 | 100.5 |
| 400 | 120.5 | 400 | 101.0 |
| 500 | 121.5 | 500 | 105.5 |
| 600 | 122.0 | 600 | 110.0 |

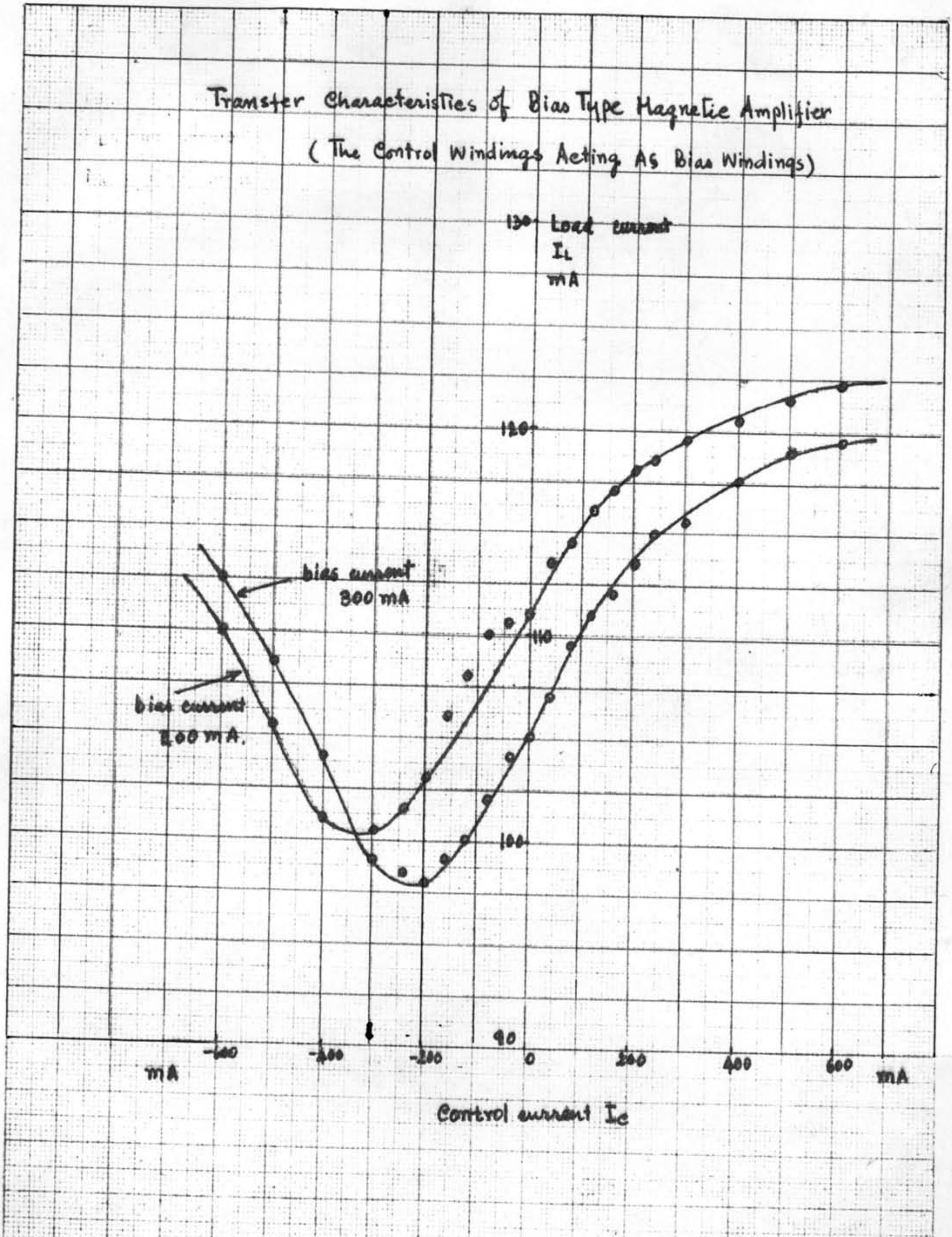
(3) Push-pull Type Magnetic Amplifier

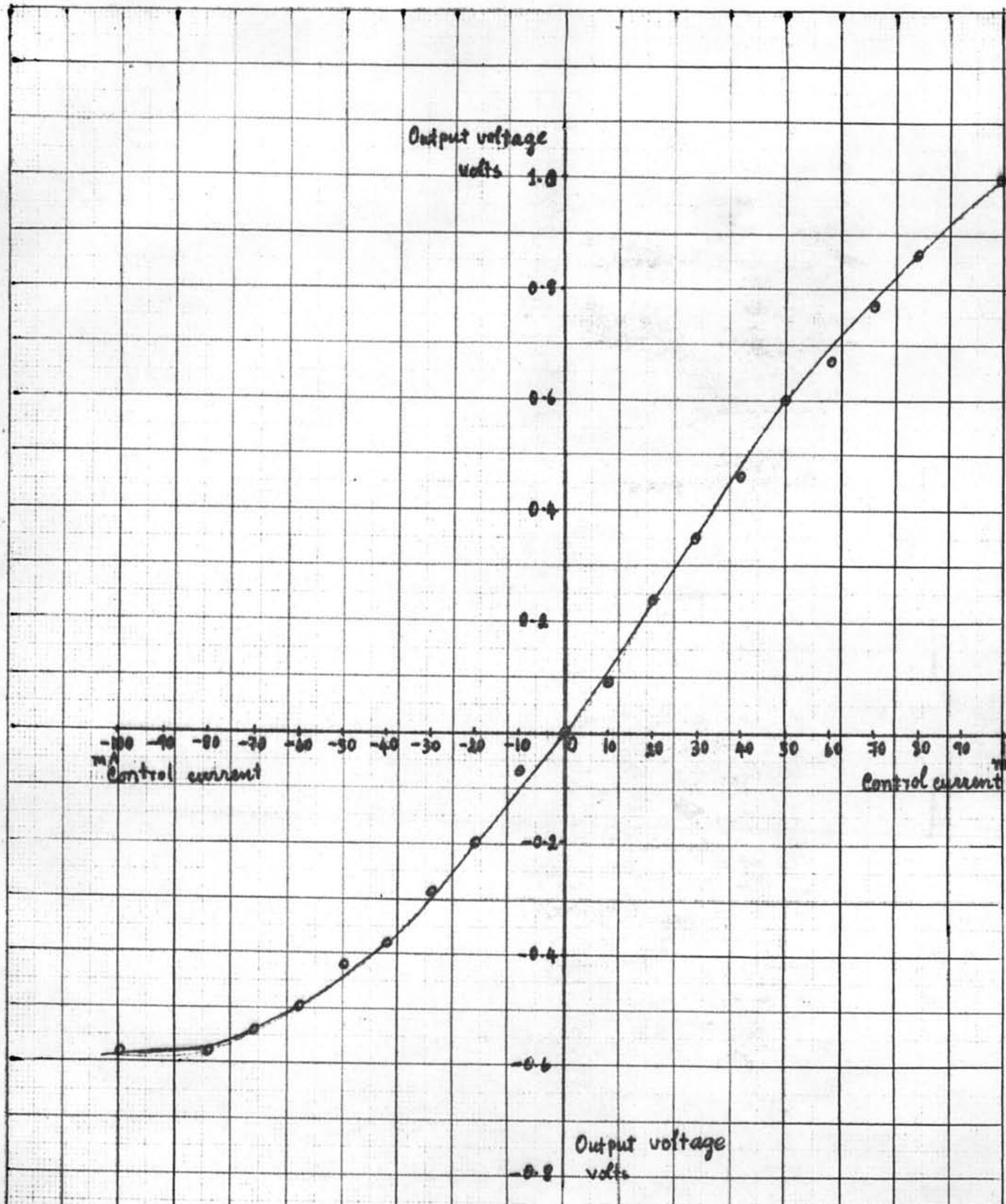
| Supply voltage = 19 volts | | | |
|---|---|---|---|
| Positive control current mA | Positive output voltage volts | Negative control current mA | Negative output voltage volts |
| 0 | 0.00 | 0 | 0.00 |
| 10 | 0.09 | 10 | 0.07 |
| 20 | 0.24 | 20 | 0.20 |
| 30 | 0.35 | 30 | 0.29 |
| 40 | 0.46 | 40 | 0.38 |
| 50 | 0.60 | 50 | 0.42 |
| 60 | 0.67 | 60 | 0.50 |
| 70 | 0.77 | 70 | 0.54 |
| 80 | 0.86 | 80 | 0.58 |
| 100 | 1.00 | 100 | 0.58 |




Transfer Characteristics of Saturable Reactor.


Transfer Characteristics of Bias Type Magnetic Amplifier
(Separate Bias Windings)
Load current $I_L$ mA
130
120
110
100
90
bias current 300 mA
bias current 500 mA
-600 mA
-400
-200
0
200
400
600
mA
Control current $I_c$


Transfer Characteristics of Bias Type Magnetic Amplifier
(The Control Windings Acting As Bias Windings)
130
Load current
$I_L$
mA
120
110
100
90
bias current
300 mA
bias current
200 mA.
-600
-400
-200
0
200
400
600
mA
mA
Control current $I_c$




Transfer Characteristics of Push-pull Magnetic Amplifier.

Discussion

The bias current produces the magnetomotive force in the reactor core and drives the flux in the positive directinn. The impedance of the load circuit decreases as the control current increases in positive directiom and causes increasing in the load current. Now, for applying the negative control current into the control circuit the flux produced by the control current is opposed to that of the bias current. For this fact, the impedance of the load circuit is increased and the output current decreases. It can be pointed out that a positive control signal causes an increased output while a negative control signal reduces the output.

For the graph page 68, the positive and negative portions of the composite characteristic are not symmetry. This is because of the two reactors have not identical characteristics.

# EXPERIMENT NO.4

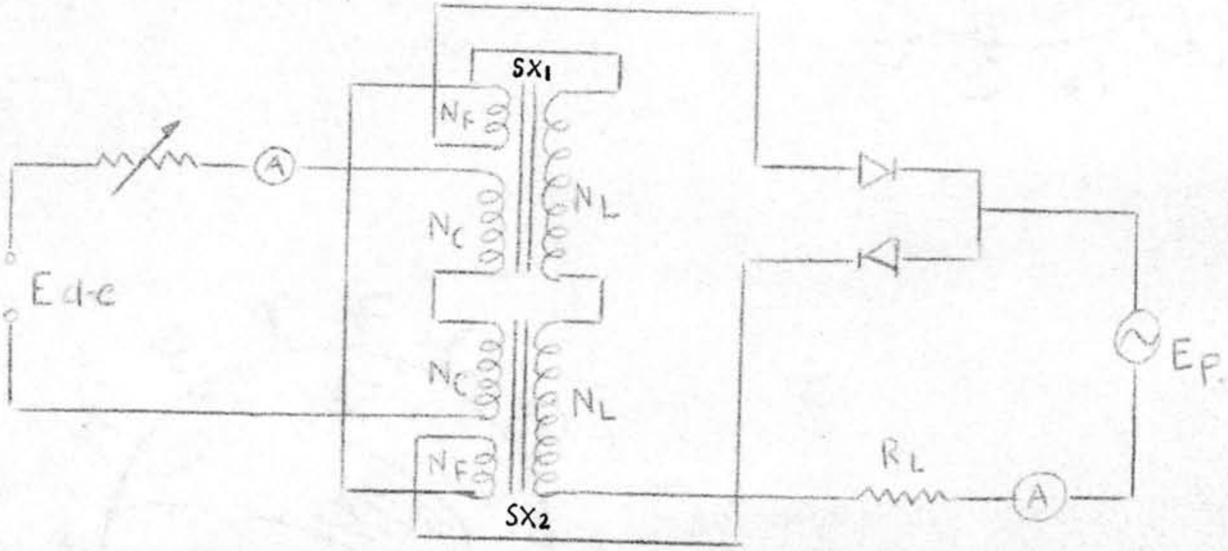
## External Feedback Magnetic Amplifier

### Purpose

The purpose of this experiment is to study the control characteristics of the feedback magnetic amplifier.

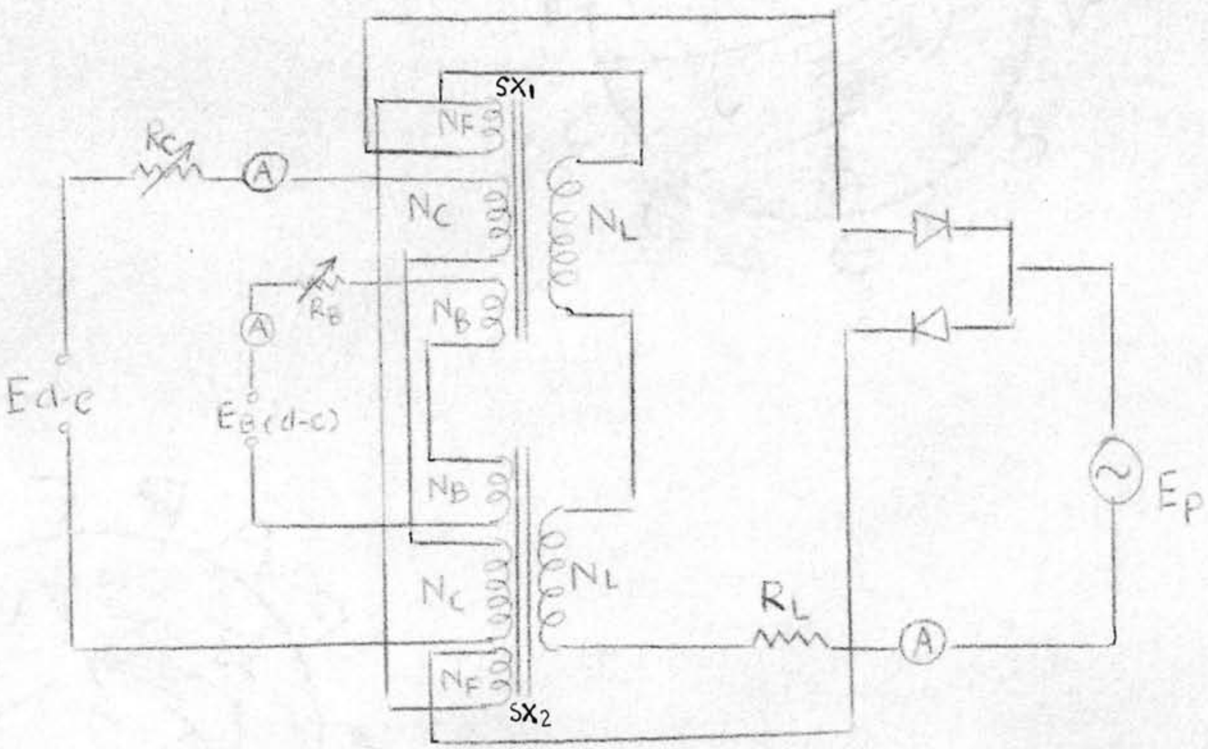
### Procedure

(a) Connect the circuit as shown. Set Ep = 20 volts, $R_L$ = 40 ohms. Vary the control current from 0 to 600 milliamps




by means of the resistor Rc about 8 steps. Take the readings of the load currents. Reverse the d-c power supply and then repeat the procedure.

(b) Connect the circuit as shown. Set Ep = 20 volts, R = 40 ohms and the bias current = 160 milliamps. Repeat the procedure as in (a)




Set the bias current = 300 milliamps and repeat the proce dure

Report

Plot graps of control currents against load currents for (a) and (b).

**Test Data** The test data is obtained from the measurements carried out on the ferrite core with

NL = 1000 turns

NC = 1000 turns

NF = 300 turns

NC = 300 turns

The magnetic circuit has an effective area of 0.785 $cm^2$ and a means length of 15 cms.

Without bias

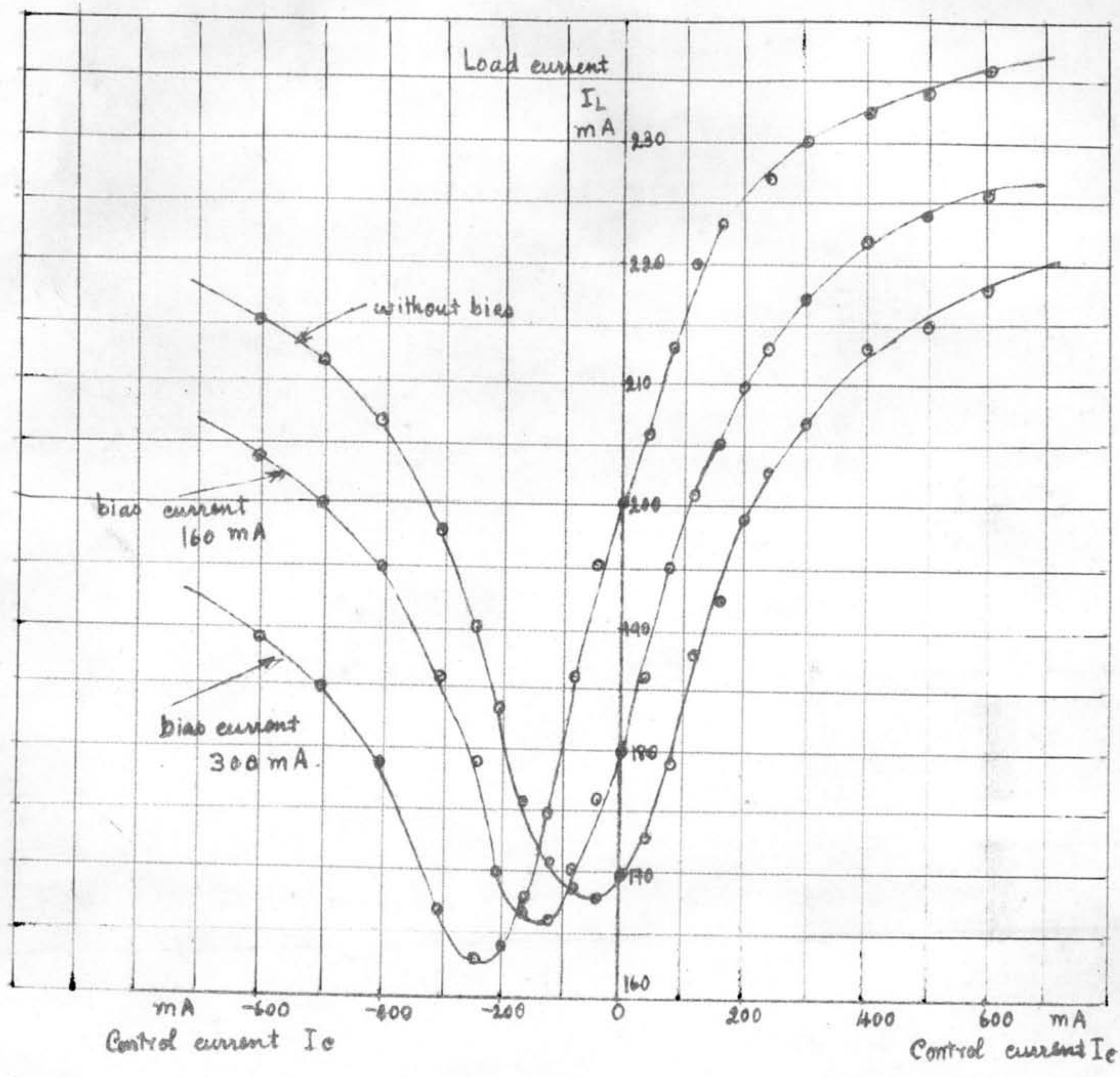
| Supply voltage = 20 volts. Load resistance = 40 ohms | | | |
|---|---|---|---|
| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
| 0 | 170 | 0 | 170 |
| 40 | 173 | 40 | 168 |
| 80 | 179 | 80 | 169 |
| 120 | 188 | 120 | 171 |
| 160 | 192 | 160 | 176 |
| 200 | 199 | 200 | 183 |
| 240 | 203 | 240 | 198 |
| 300 | 207 | 300 | 207 |
| 400 | 213 | 400 | 207 |
| 500 | 215 | 500 | 212 |
| 600 | 218 | 600 | 215 |

Bias current = 160 mA

| Supply voltage = 20 volts. Load resistance = 40 ohms. | | | |
|---|---|---|---|
| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
| 0 | 180 | 0 | 180 |
| 40 | 186 | 40 | 176 |
| 80 | 195 | 80 | 170 |
| 120 | 201 | 120 | 166 |
| 160 | 205 | 160 | 167 |
| 200 | 210 | 200 | 170 |
| 240 | 213 | 240 | 179 |
| 300 | 217 | 300 | 186 |
| 400 | 222 | 400 | 195 |
| 500 | 224 | 500 | 200 |
| 600 | 226 | 600 | 204 |

Bias current = 340 mA

| Supply voltage = 20 volts. Load resistance = 40 ohms. | | | |
|---|---|---|---|
| Positive control current mA | Load current mA | Negative control current mA | Load current mA |
| 0 | 200 | 0 | 200 |
| 40 | 206 | 40 | 195 |
| 80 | 213 | 80 | 186 |
| 120 | 220 | 120 | 175 |
| 160 | 223 | 160 | 168 |
| 200 | 226 | 200 | 164 |
| 240 | 227 | 240 | 163 |
| 300 | 230 | 300 | 167 |
| 400 | 232 | 400 | 179 |
| 500 | 234 | 500 | 185 |
| 600 | 236 | 600 | 189 |




Characteristics of External Feedback Magnetic Amplifier

Discussion

From the graphs obtained from the test it can be seen that the transfer characteristics of the external feedback circuit are similar to those of bias circuit. In the bias circuit the bias current produces the fixed magnetomotive force to the reactor core whereas in the feedback circuit the magnetomotive force produced by the feedback windings depends on the load current.

# EXPERIMENT NO.5

Single Stage and Multi Stage Magnetic Power Amplifiers

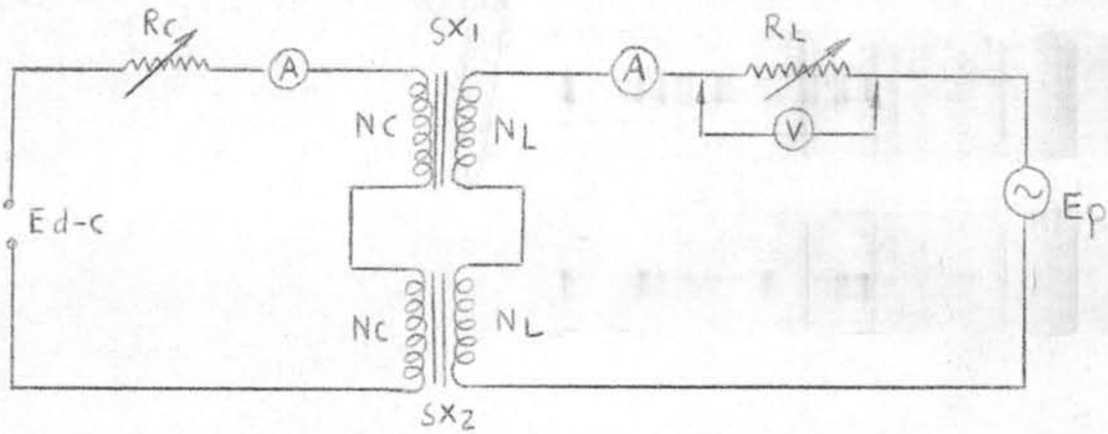
## Purpose

The purpose of this experiment is to study the power gain and load characteristics of magnetic amplifiers.

## Procedure

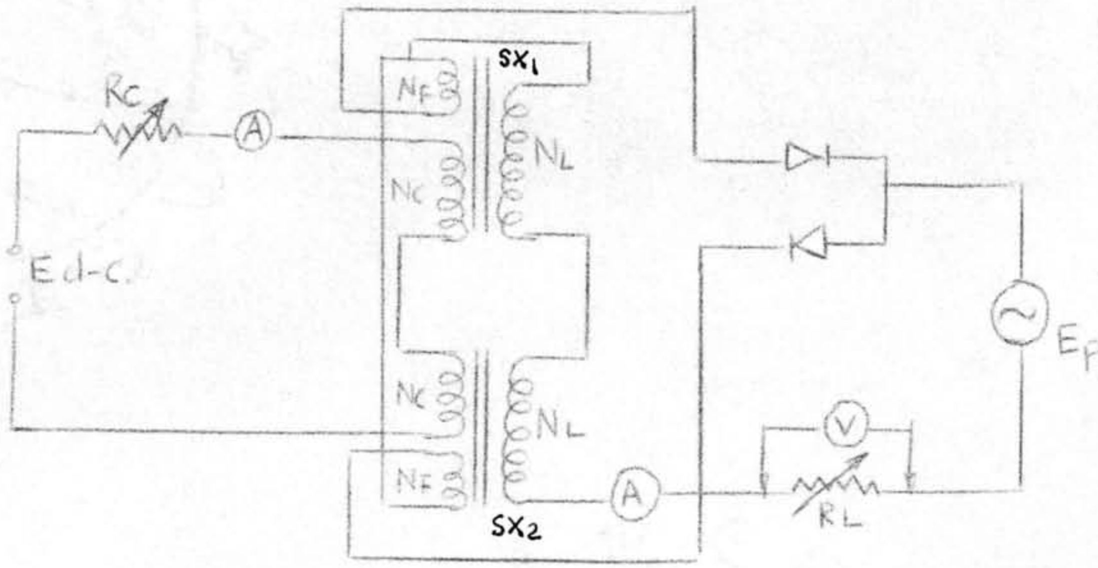
### Single stage magnetic amplifier

(a) Connect the circuit as shown. Set $E_p$ = 18 volts, $I_C$ = 200 milliamps. Vary the load resistance $R_L$ about 8 steps




from its minimum to its maximum value (80 ohms). Take the readings of load currents and load voltages, and also measure the d-c supply voltage.

(b) Connect the circuit as shown. Repeat the procedure




as in (a)

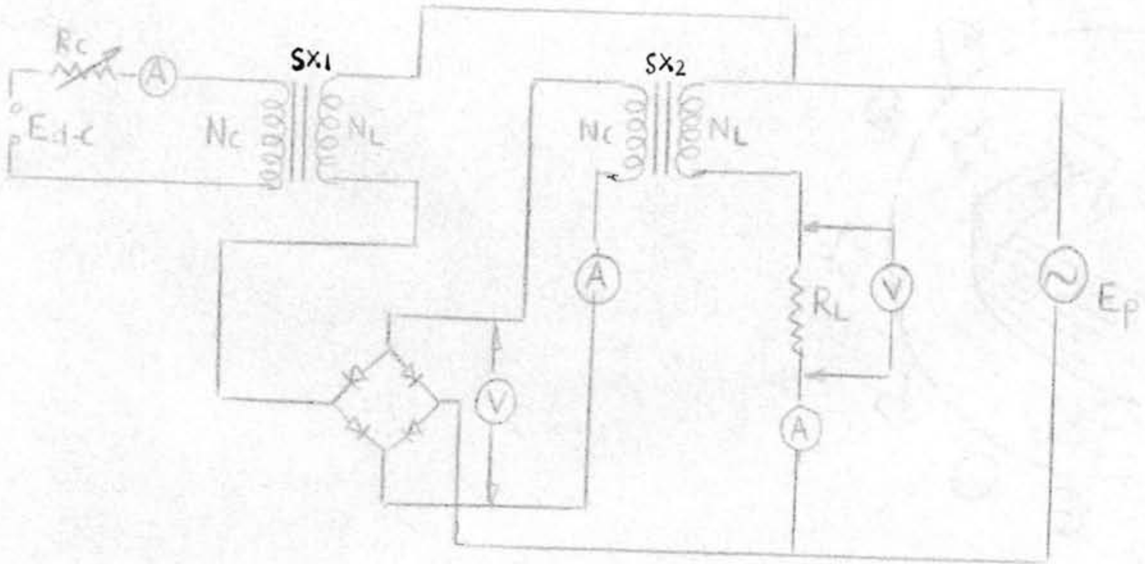
Report

(1) Calculate the power gain and the load resistance

(2) Plot graphs of the power gain against the load resistance

Multistage magnetic amplifiers

Connect the circuit as shown. Set Ep = 7.5 volts, $R_L$ = 40 ohms. Vary the control current from 20 to 200 milliamps-about 8 steps. Measure the voltages and the




currents in the control windings of the second stage and also measure the load currents and the load voltages.

Set the dc control voltage at 10 volts and then repeat the procedure

## Report

Compute the power gain of the first, the second stage and the overall power gain.

**Test Data** The test data is obtained from the measurements carried out on the ferrite core with

$N_L$ = 1000 turns, each of № 25 wire (Standard Wire gauge)

$N_C$ = 1000 turns, each of № 25 wire (Standard Wire gauge)

$N_F$ = 300 turns, each of № 25 wire (Standard Wire gauge)

The magnetic circuit has an effective cross-sectional area of 0.785 $cm^2$ and a means length of 15 cms.

Single stage magnetic amplifier

(1) No feedback

Control current = 0.2 amp. Control voltage = 1.12 volts.
Power input = 0.224 watt.

| Load current amp. | Load voltage volts | Load resistance ohms | Power output watts | Gain = Power output / Power input |
|---|---|---|---|---|
| 0.50 | 5.8 | 11.6 | 2.90 | 13.0 |
| 0.45 | 7.0 | 15.6 | 3.15 | 14.1 |
| 0.40 | 8.2 | 20.5 | 3.28 | 14.6 |
| 0.35 | 10.0 | 28.6 | 3.50 | 15.6 |
| 0.30 | 11.2 | 37.4 | 3.36 | 15.0 |
| 0.25 | 12.7 | 51.0 | 3.17 | 14.2 |
| 0.20 | 14.1 | 70.5 | 2.82 | 12.6 |

(2) With external regenerative feedback

Control current = 0.2 amp. Control voltage = 1.12 volts
Power input = 0.224 watts

| Load current amp. | Load voltage volts | Load resistance ohms | Power output watts | Gain = Power output / Power input |
|---|---|---|---|---|
| 0.50 | 8.5 | 17.0 | 4.25 | 19.0 |
| 0.45 | 9.5 | 21.2 | 4.28 | 19.2 |
| 0.40 | 10.4 | 26.0 | 4.16 | 18.6 |
| 0.35 | 11.3 | 32.3 | 3.96 | 17.7 |
| 0.30 | 12.2 | 40.7 | 3.66 | 16.4 |
| 0.25 | 13.1 | 52.5 | 3.27 | 14.6 |
| 0.20 | 14.1 | 70.5 | 2.82 | 12.6 |

Multistage magnetic amplifier

Supply voltage = 7.5 volts
Load resistance = 40.0 ohms

| Control current amp | Control voltage volt | Power input watt | First Stage | | | |
|---|---|---|---|---|---|---|
| | | | Load current amp | Load voltage volts | Power output watts | Power gain |
| 0.02 | 0.10 | 0.0020 | 0.175 | 1.000 | 0.175 | 87.5 |
| 0.04 | 0.16 | 0.0064 | 0.180 | 1.015 | 0.1825 | 28.5 |
| 0.06 | 0.33 | 0.0198 | 0.185 | 1.030 | 0.190 | 9.6 |
| 0.08 | 0.40 | 0.0320 | 0.190 | 1.090 | 0.27 | 8.18 |
| 0.12 | 0.64 | 0.0768 | 0.198 | 1.160 | 0.25 | 3.26 |
| 0.16 | 0.92 | 0.1470 | 0.215 | 1.240 | 0.266 | 1.81 |
| 0.20 | 1.12 | 0.3550 | 0.225 | 1.300 | 0.292 | 1.30 |

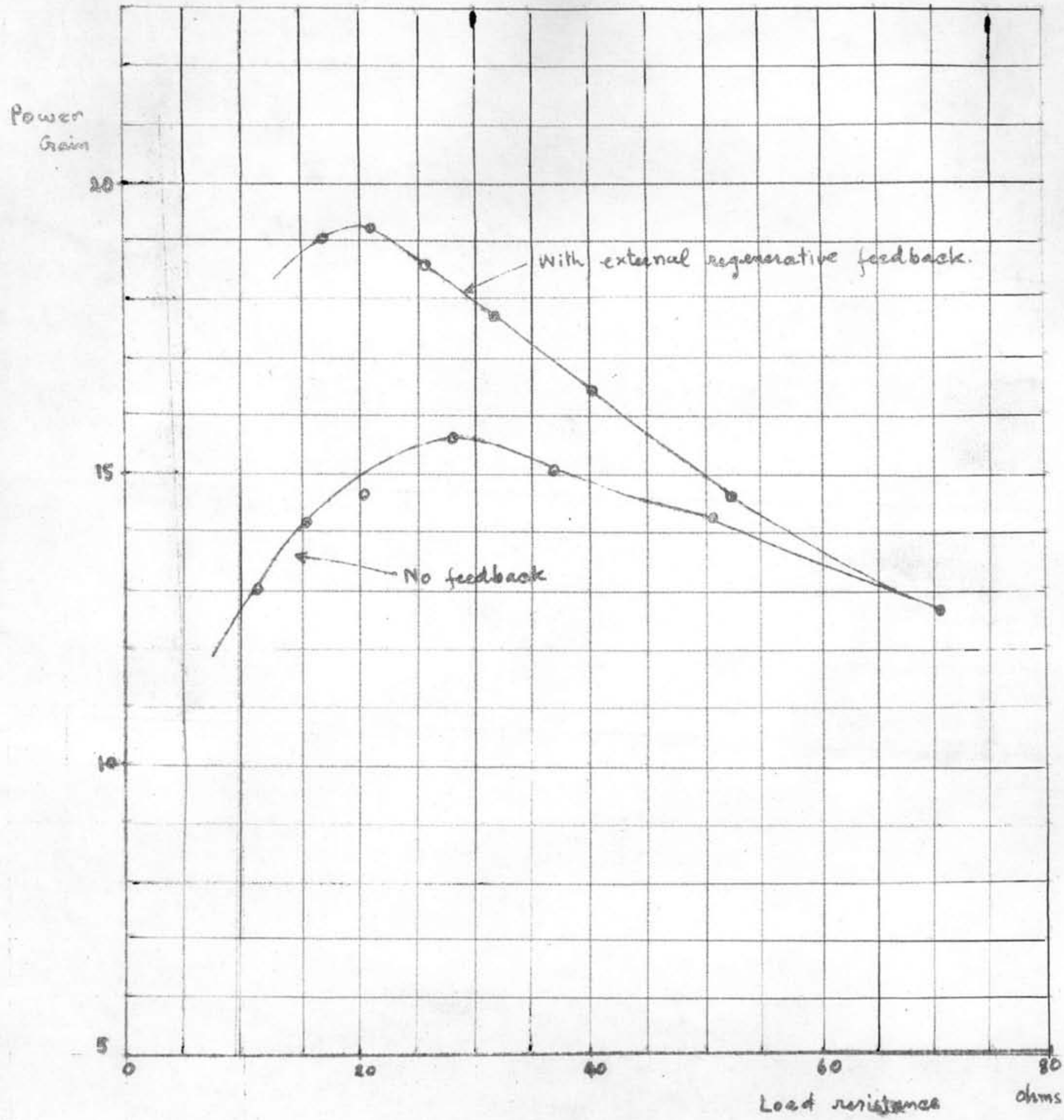
| Control current mA | Control voltage volt | Power input watt | Second Stage | | | | |
|---|---|---|---|---|---|---|---|
| | | | Load current amp | Load voltage volts | Power output watts | Power gain | Overall gain |
| 0.02 | 0.10 | 0.0020 | 0.0800 | 3.65 | 0.292 | 1.67 | 146.00 |
| 0.04 | 0.16 | 0.0064 | 0.0815 | 3.67 | 0.296 | 1.62 | 46.00 |
| 0.06 | 0.33 | 0.0198 | 0.0810 | 3.69 | 0.298 | 1.57 | 15.01 |
| 0.08 | 0.40 | 0.0320 | 0.0815 | 3.70 | 0.302 | 1.46 | 9.45 |
| 0.12 | 0.64 | 0.0768 | 0.0825 | 3.73 | 0.308 | 1.25 | 4.00 |
| 0.16 | 0.92 | 0.1470 | 0.0835 | 3.75 | 0.314 | 1.18 | 2.14 |
| 0.20 | 1.12 | 0.2240 | 0.0845 | 3.80 | 0.320 | 1.10 | 1.43 |

Supply voltage = 10 volts

Load resistance = 40 ohms

| Control current amp | Control voltage volt | Power input watt | First Stage | | | |
|---|---|---|---|---|---|---|
| | | | Load current amp | Load voltage volts | Power output watts | Power gain |
| 0.02 | 0.10 | 0.0020 | 0.239 | 1.38 | 0.330 | 165.00 |
| 0.04 | 0.21 | 0.0084 | 0.248 | 1.42 | 0.352 | 42.00 |
| 0.06 | 0.32 | 0.0192 | 0.255 | 1.48 | 0.377 | 19.60 |
| 0.08 | 0.42 | 0.0336 | 0.260 | 1.52 | 0.395 | 11.50 |
| 0.12 | 0.63 | 0.0756 | 0.275 | 1.60 | 0.440 | 5.82 |
| 0.16 | 0.92 | 0.1470 | 0.290 | 1.70 | 0.493 | 3.36 |
| 0.20 | 1.14 | 0.2280 | 0.300 | 1.78 | 0.535 | 2.34 |

| Control current mA | Control voltage volt | Power input Watt | Second Stage | | | | |
|---|---|---|---|---|---|---|---|
| | | | Load current amp | Load voltage volts | Power output watts | Power gain | Overall gain |
| 0.02 | 0.10 | 0.0020 | 0.1090 | 5.00 | 0.545 | 1.65 | 272.5 |
| 0.04 | 0.21 | 0.0084 | 0.1100 | 5.09 | 0.560 | 1.59 | 66.7 |
| 0.06 | 0.32 | 0.0192 | 0.1105 | 5.10 | 0.563 | 1.50 | 29.3 |
| 0.08 | 0.42 | 0.0336 | 0.1110 | 5.11 | 0.568 | 1.44 | 16.9 |
| 0.12 | 0.63 | 0.0756 | 0.1120 | 5.14 | 0.575 | 1.31 | 7.60 |
| 0.16 | 0.92 | 0.1470 | 0.1125 | 5.17 | 0.582 | 1.18 | 3.96 |
| 0.20 | 1.14 | 0.2280 | 0.1130 | 5.20 | 0.588 | 1.10 | 2.58 |




Load characteristics of magnetic amplifier.

## Discussion

The maximum power gain is obtained when the load resistance is 28.6 ohms. Beyond this point the power gain tends to decrease. Adding the feedback windings causes an increase in power gain but cause no change in load characteristics.

In the multistage circuit, from the data it can be seen that the power gain of the second stage is very low. This is because of the saturation of magnetic core.

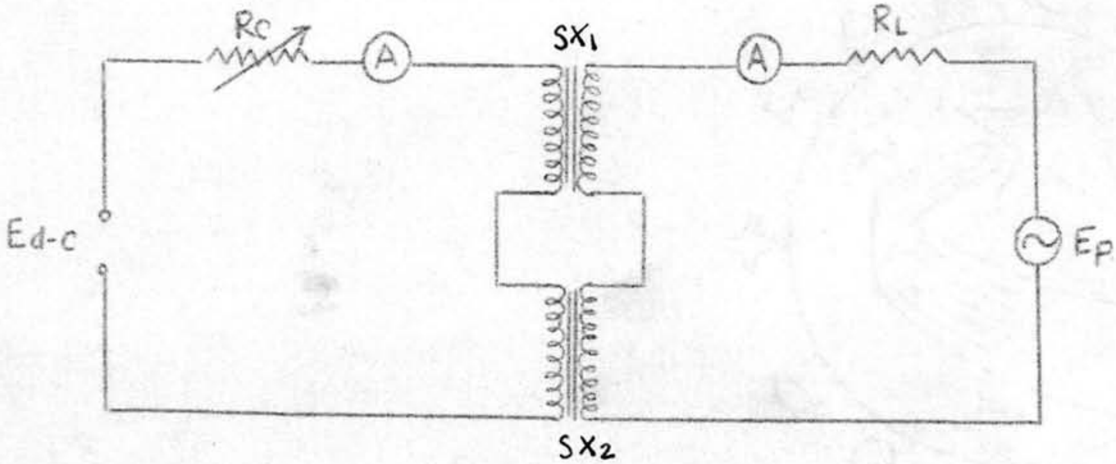
The Proposed Experiment on Magnetic Amplifier for Undergraduate Students in Electrical Engineering

## Purpose

The purpose of this experiment is to study the characteristics of the magnetic amplifier.

## Procedure

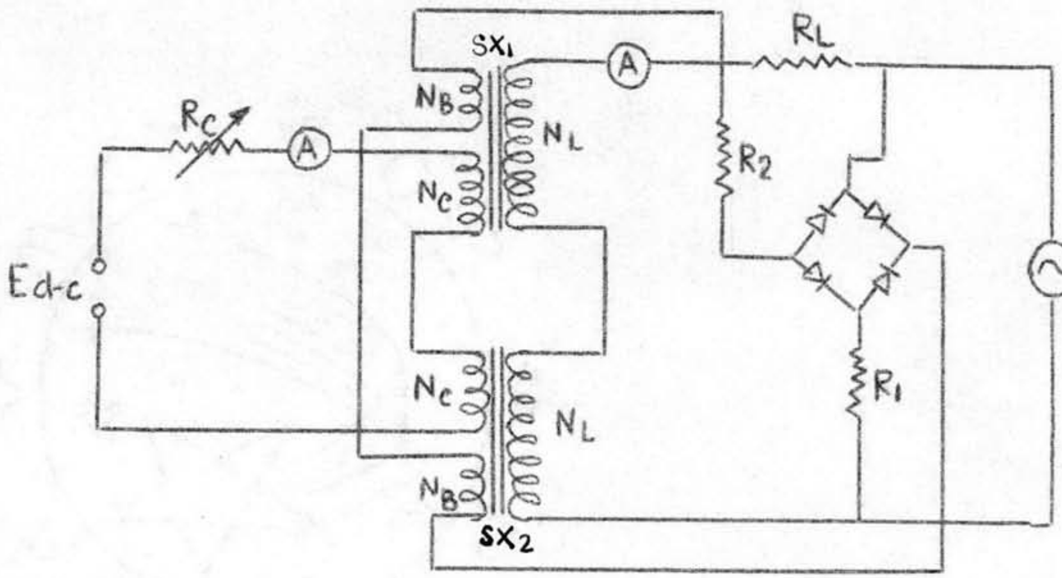
(1) Connect the circuit as shown. Set Ep = 10 volts and $R_L$ = 17 ohms. Vary the control current from 0 to 500 mA




by means of the resistor Rc. Take the readings of load current. Reverse the polarity of control current and repeat the procedure

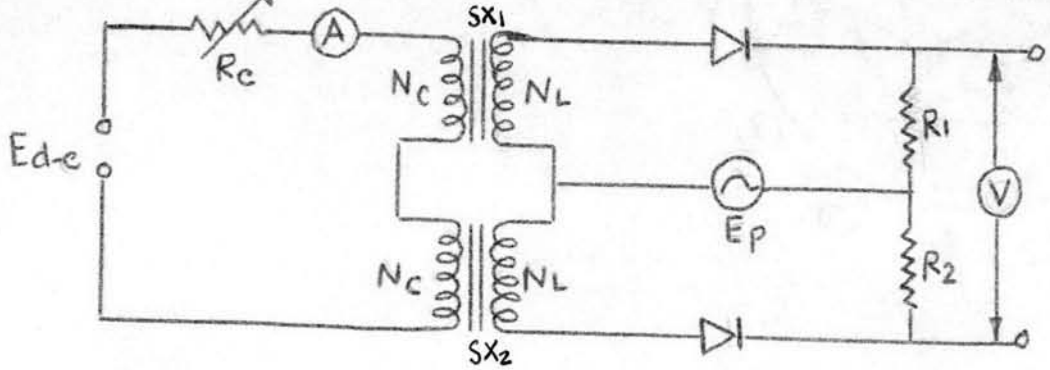
(2) Arrange the circuit as shown. Set Ep = 10 volts, $R_L$ = 17 ohms and the bias current = 300 mA. Vary the control

current from 0 to 600 mA by means of the resistor Rc. Take



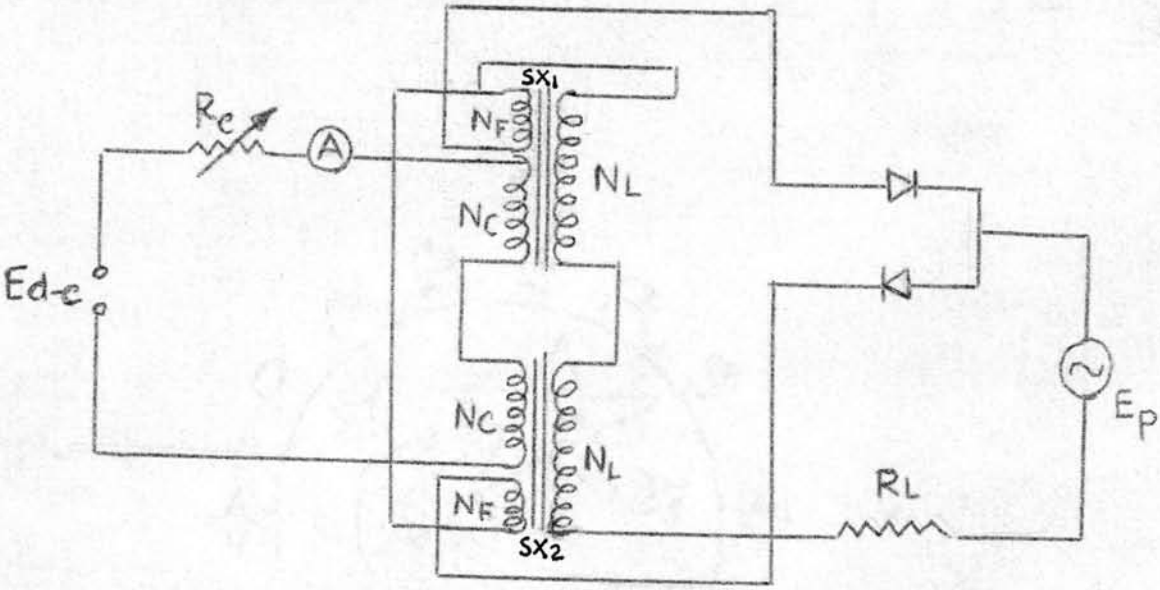

the readings of load current for every step of current changing in the control circuit. Reverse the polarity of the d-c supply and then repeat the procedure.

(3) Connect the circuit as shown. Set Ep = 19 volts. With no current in the control circuit, adjust the resistor $R_1$



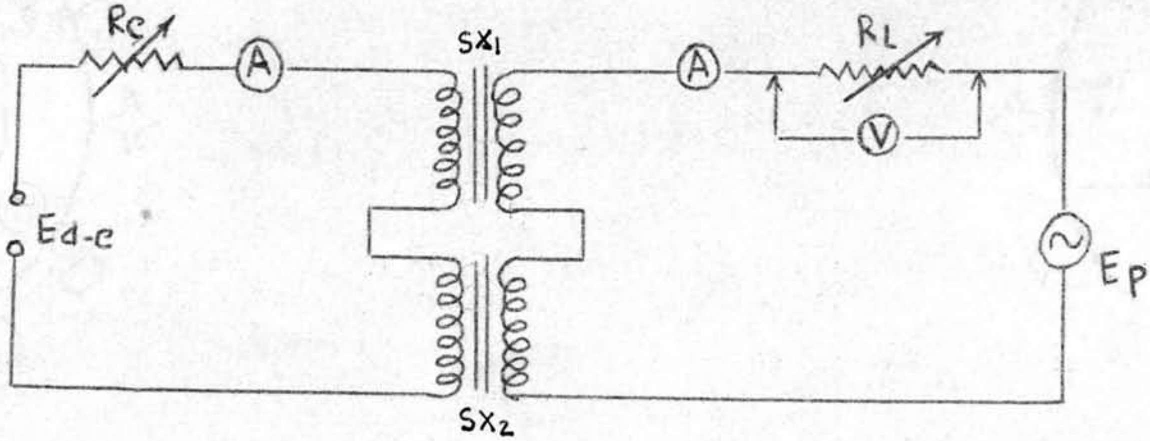
and $R_2$ until the zero output voltage is obtained. Vary the control current from 0 to 100 mA. Take the readings of output voltage. Reverse the polarity of the d-c supply and then repeat the procedure.

(4) Connect the circuit as shown. Set Ep = 20 volts, $R_L$ = 40 ohms. Vary the control current from 0 to 600




milliamps by means of the resistor Rc about 8 steps. Take the readings of the load currents. Reverse the d-c power supply and then repeat the procedure.

(5) Arrange the circuit as shown. Set Ep = 18 volts,




Ic = 200 milliamps. Vary the load resistance $R_L$ about 8 steps from its minimum to its maximum value (80 ohms). Take the readings of load currents and load voltages, also measure the d-c supply voltage.

## Report

(1) Plot graphs of control currents against load currents for test (1) and (2)

(2) Plot graph of output voltages against control currents for test (3)

(3) Plot graph of control currents against load currents for test (4)

(4) Calculate the power gain for test (5)

(5) Plot graph of the power gain against the load resistance.

# CONCLUSION

Most results of all experiments are closed to the theory. Only some of them differ from the typical characteristics of the magnetic amplifiers. This is due to the fact that the core material of the saturable reactor has considerably different characteristics from the standard material used in magnetic amplifier circuits. The core structure is not a solid unit. It consists of two separate parts. This causes an air gap to exist between them. This results in producing large leakage flux and lowering the power gain of the amplifier. Furthermore, the core material has a low saturation flux density which in turn causes a low inductance in the load circuit. This results in a narrow controlling range of the output. Besides, the measuring instruments used in performing the experiments have low quality and the measuring range is not low enough to carry out the lower portions of the characteristic curves. However, the author has tried his best to cover as many experiments as the equipments are available.

Whenever the magnetic amplifier laboratory is complete, it can be extended to cover the experiments on the magnetic measurement, the frequency response and the internal feedback circuits with some more equipment needed. If this could be done the course in magnetic amplifier is expected to be more complete than it used to be.