

Contents

CONTENTS	1
1 INTRODUCTION	4
1.1 COURSE CATEGORIZATION WITHIN THE FRAMEWORK OF STUDY PROGRAMME.....	4
1.2 COURSE OBJECTIVE.....	4
2 ELECTRONIC CIRCUITS	4
2.1 BASIC CONCEPTS AND CIRCUITS CLASSIFICATION	4
2.2 LINEAR AND NONLINEAR CIRCUITS	5
2.3 CIRCUITS CLASSIFICATION.....	5
2.4 CIRCUIT AND ITS MODEL.....	6
2.5 CIRCUIT ANALYSIS AND SYNTHESIS	6
2.6 CIRCUIT DESIGN.....	7
2.7 NETWORK FUNCTIONS	7
2.8 FREQUENCY CHARACTERISTICS	8
3 ELECTRONIC CIRCUIT COMPONENTS	10
3.1 COMPONENTS CLASSIFICATION.....	10
3.2 COMPONENT DESCRIPTION.....	11
3.3 TWO-POLE COMPONENTS	12
3.3.1 <i>Elementary two-poles</i>	12
3.3.2 <i>Diode</i>	12
3.4 MULTIPORT COMPONENTS AND FUNCTIONAL BLOCKS	13
3.4.1 <i>Nonlinear two-ports</i>	13
3.4.2 <i>Controlled sources</i>	14
3.4.3 <i>Functional blocks</i>	14
3.4.4 <i>Operational amplifier</i>	16
3.4.5 <i>Real voltage operational amplifier</i>	17
3.4.6 <i>Operational amplifier models</i>	19
4 FEEDBACK IN ELECTRONIC CIRCUITS	21
4.1 FEEDBACK PRINCIPLE	21
4.2 FEEDBACK CONNECTION CLASSIFICATION	23
4.3 FEEDBACK EFFECT ON CIRCUIT PARAMETERS	23
4.4 FEEDBACK IN AMPLIFIERS.....	25
5 CIRCUITS WITH OPERATIONAL AMPLIFIERS	25
5.1 VOLTAGE AMPLIFIERS.....	25
5.2 CURRENT AMPLIFIERS.....	27
5.3 VOLTAGE AND CURRENT TRANSDUCERS	28
5.4 MEMORY CIRCUITS	29
5.5 FUNCTIONAL BLOCKS	30
5.6 NONLINEAR CIRCUITS	31
6 ELECTRICAL FILTERS	32
6.1 SCOPE AND CLASSIFICATION OF FILTERS	32
6.2 FILTERS PRINCIPLE, FIRST-ORDER PASSIVE FILTERS	33
6.3 SECOND-ORDER PASSIVE FILTERS	34

6.4	ACTIVE FILTERS	37
6.5	HIGHER-ORDER RLC PASSIVE FILTERS.....	39
6.6	HIGHER-ORDER ACTIVE FILTERS	40
7	BASIC TRANSISTOR STAGES	41
7.1	COMMON-EMITTER CONNECTION	42
7.2	COMMON-COLLECTOR CONNECTION	47
7.3	COMMON-BASE CONNECTION.....	48
7.4	OVERALL COMPARISON OF BASIC STAGES	49
7.5	FREQUENCY DEPENDENCE OF BASIC STAGES	50
	7.5.1 <i>Common-emitter stage on HF</i>	50
	7.5.2 <i>Common-collector stage on HF</i>	50
	7.5.3 <i>Common-base stage on HF</i>	51
7.6	FEEDBACK IN BASIC STAGES.....	51
	7.6.1 <i>CE connection with current feedback</i>	51
	7.6.2 <i>CE connection with voltage feedback</i>	52
8	TRANSISTOR CIRCUITS.....	53
8.1	BJT CURRENT SOURCES.....	53
8.2	CURRENT MIRRORS	54
8.3	DARLINGTON CONNECTION	55
8.4	CASCADE CONNECTION OF CE-CB STAGES.....	56
8.5	ANOTHER CASCADE CONNECTIONS OF STAGES.....	57
8.6	DIFFERENTIAL AMPLIFIER	57
9	AMPLIFIERS	59
9.1	AMPLIFIERS PRINCIPLE AND CLASSIFICATION.....	59
9.2	AMPLIFIERS WITH CAPACITIVE COUPLING	61
9.3	WIDEBAND AMPLIFIERS	63
9.4	NARROW-BAND TUNED AMPLIFIERS	64
	9.4.1 <i>Amplifiers with single tuned circuit</i>	64
	9.4.2 <i>Tuned power amplifiers</i>	66
	9.4.3 <i>Amplifiers with multi tuned circuits</i>	67
	9.4.4 <i>Amplifiers with coupled tuned circuits</i>	68
9.5	POWER LOW-FREQUENCY AMPLIFIERS.....	69
	9.5.1 <i>Class-A power amplifiers</i>	69
	9.5.2 <i>Class-B power amplifiers with transformers</i>	71
	9.5.3 <i>Class-B power amplifiers without transformers</i>	72
	9.5.4 <i>Switched power amplifiers</i>	74
10	SUPPLY UNITS.....	74
10.1	CURRENT REGULATORS.....	74
10.2	VOLTAGE REGULATORS.....	76
10.3	DC VOLTAGE RECTIFIERS AND CONVERTERS.....	78
	10.3.1 <i>Rectifiers with resistive load</i>	78
	10.3.2 <i>Rectifiers with capacitive load</i>	79
	10.3.3 <i>DC voltage multipliers</i>	80
	10.3.4 <i>DC/DC voltage converters</i>	81
11	SIGNAL CONVERTERS	82
11.1	SHAPING NETWORKS	82

11.2 RECTIFIERS AS SIGNAL CONVERTERS 84

11.3 ANALOG MULTIPLIERS 86

11.4 AM MODULATORS 88

11.5 MIXERS 89

12 SIGNAL GENERATORS..... 91

12.1 CLASSIFICATION OF SIGNAL GENERATORS 91

12.2 TWO-NODE LC OSCILLATORS 91

12.3 FEEDBACK OSCILLATORS 94

12.4 THREE-NODE OSCILLATORS 95

12.5 COMPLETE CIRCUIT DIAGRAMS OF THE LC OSCILLATORS 97

12.6 CRYSTAL OSCILLATORS 98

12.7 RC OSCILLATORS 100

12.8 ELECTRONICALLY TUNABLE OSCILLATORS 102

13 REFERENCES 103

1.3. Course objective

After the completion of this course, the student should be able to:

- Analyze and design rectifier circuits.
- Analyze and design multiplier circuits.
- Analyze and design AM modulators and mixers.
- Analyze and design LC, RC and crystal oscillators.
- Analyze and design electronically tunable oscillators.

2 Electronic circuits

Chapter objective: To show a mutual connection and inseparability between circuits and signals. Basic concepts and circuits classification. To make students familiar with principles of circuits modeling and solving with basic circuit functions (transfer and impedance), with their symbols for frequency characteristics, poles and zeros.

Basic concepts and circuits classification: Depending on whether they contain any controlled components the circuits are classified as controlled and uncontrolled. Depending on whether they are continuous-time (operating continuously both in time and in value), the circuits are classified as continuous-time and discrete-time. Depending on whether they are capable of performing operations with an analog signal:

- amplifiers
- AM signal detectors
- frequency multipliers
- frequency dividers
- mixers
- modulators
- oscillators
- tunable oscillators

An arbitrary circuit is generally described by a differential equation:

$$a_n \frac{d^n y(t)}{dt^n} + a_{n-1} \frac{d^{n-1} y(t)}{dt^{n-1}} + \dots + a_1 \frac{dy(t)}{dt} + a_0 y(t) = b_m \frac{d^m x(t)}{dt^m} + b_{m-1} \frac{d^{m-1} x(t)}{dt^{m-1}} + \dots + b_1 \frac{dx(t)}{dt} + b_0 x(t) \quad (1.2)$$

where $x(t)$ and $y(t)$ are the input and output signals, respectively. The transfer function of the circuit is defined as the ratio of the output signal to the input signal in the frequency domain:

$$H(s) = \frac{Y(s)}{X(s)} = \frac{b_m s^m + b_{m-1} s^{m-1} + \dots + b_1 s + b_0}{a_n s^n + a_{n-1} s^{n-1} + \dots + a_1 s + a_0}$$

The circuit contains n independent circuit components and m dependent circuit components. The circuit is a well-arranged picture representing a given system by means of an analog electronic circuit (graphic symbols) of individual circuit components.