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BASICS OF CIRCUITRY OF ELECTRONIC SYSTEMS

TRANSLATION FROM UKRAINIAN by E. A. BATINA

*Approved by Ministry of Education and Science of Ukraine
as textbook for students of institutions of higher education*

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Basics of circuitry are stated, principles of operation are considered, it is given calculations of analog, digital and pulse devices of electronic systems, based on semiconductor devices, integrated operational amplifiers and integrated logic circuits of TTL, MOS, CMOS types, construction principles of systems of control by electronics devices based on microprocessors and microcontrollers.

For students of institutions of higher education. It can be useful for specialists on electronic engineering, specializing in the area of development, fabrication and maintenance of electronic systems and devices.

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PREFACE

Electronics is the area of current physics and electrical engineering. It studies and applies phenomena, devices and systems, based on passage of electrical current through vacuum, gas and solid body, investigates and develops electronic measures and systems and the principles of their application. The information interchange in electronic systems is realized with the help of signals, which carriers can be represented by various physical quantities – currents, voltages, magnetic states, light waves. The analog (continuous) and discrete signals can be recognized. There are two types of discrete signals: the first is got by the way of digitization of continuous signals by amplitude or time, the second one – as a set of code combinations of signs.

The advantages of digital devices and systems comparatively with analog ones are increased interference immunity, high reliability, ability to store information for a long time without losses, economic and energetic efficiency, compatibility with integrated technology, high manufacturability and reproducibility, and disadvantages – slow operating speed and low accuracy.

The base of development of electronics is progressive complication of functions. It is impossible as for now to solve the new tasks by old electronic measures with the help of available element base. The main factors are reliability increasing, decreasing of overall dimensions, mass, power consumption and depreciation.

The important assignment of high education – is right orientation of future specialist at the stage of study of fundamental and professionally-oriented special disciplines, where the depth of important physical processes statement and their optimal volume are joined. The most of published textbooks and educational manuals on analog and digital circuitry or devoted to statement of only some parts of this discipline, either give common knowledge of the main parts or insufficiently reflect tendency of present-day electronics development. In offered textbook the authors made attempt to liquidate referred above failings.

The textbook consists of five parts.

The part one – "Electronic devices with continuous signals" – contains 12 chapters on analog circuitry, which considers the questions:

main components of electron systems, subsystems and units, amplifiers;

RC-voltage amplifiers on bipolar and unipolar FET-transistors according to different connection circuits by common emitter, collector, drain, source;

frequency responses of audio RC-amplifiers, amplifier operation in the range of low, medium and high frequencies; logarithmic amplitude-frequency responses, computations examples; matching of signal source with load, single- and two-step power amplifiers and amplifiers without transformers;

through stage characteristics, temperature influence on bipolar transistor characteristics, origins and calculation methods of nonlinear distortions;

classification of analog microelectronic structures, integrated circuit operational amplifiers, their circuitry elements;

construction of solving structures on the operational amplifier base, linear and non-linear functional generators, adders, integrators, differentiators, frequency correction, taking the logarithm, multipliers, dividers, rectifiers, detectors;

generalities of the theory of different type selective amplifiers;

LC-generators of periodic oscillations at unipolar FET and bipolar transistors;

basics of theory of RC-generators with different type phase shifters and without them.

Part two – "Pulse devices" – contains 5 chapters, considering the questions:

pulses passage through circuits of integration, differentiation, dividing, clampers;

squarer, keys, limiters, models for large signal;

multivibrators and single-shot multivibrators; frequency regulation, thermostabilization (heatset) and improvement of circuits output voltage waveform; ramp generators;

coding devices analysis, ADC and DAC, sample-and-hold devices.

Part three – "Digital circuitry" – includes 6 chapters, viewing the questions:

mathematical fundamentals of digital circuitry, numerical systems, codes, binary arithmetic and forms of number presentation, logic algebra, method of Boolean functions minimization;

combinational circuits, multi- and demultiplexers, adders, coders, decoders, comparators, code converters;

trigger elements, FS-, D-, JR-triggers;

functional blocks of sequential logic devices: shift registers, counters, digital phase shifters;

microcircuits of memory devices: static, dynamic main, and microcircuits of read-only memory (ROM);

digital integrated circuits application, interferences and interference immunity, digital integrated circuits mounting.

Part four – "Microprocessors and microcontrollers" – consists of 4 chapters, which exposes such issues:

main ideas of microprocessor technology: common principles of microprocessor systems construction, buses organization, conception of microprocessors architecture;

architecture of microprocessors: single-chip 8 (octal) – and 16 (hexadecimal) -bit microprocessors, features of architecture of Pentium and 64-bit microprocessors;

fundamentals of Assembler programming;

microprocessor systems hardware construction: of ROM and RAM module, of In/Out interfaces;

present-day microprocessors and microcontrollers: single-chip microcontrollers with CISC- and RISC- architecture, signal microprocessors, neuron computers and their functions.

Part five – "Systems of power supply and control" – the next aspects are considered:

circuitry of the main blocks of switched power supplies (SMPS), power electronics element base;

control systems of power complex of beam processing station; control systems and their junctions computation, microprocessor control systems.

The problems for current monitoring and testing are given; exercises for independent and individual solving are listed.

All parts of bachelors training program for "Electronics", "Power engineering", "Radio engineering" and others, according to Ukrainian standard are stated in the textbook in a compact and available form, which should promote increasing efficiency of both auditorium lessons and independent work of students. Material was arranged with each next part being logic continuation of previous.

The result of course study is learning by students of principles of functioning, choice, practical realization of devices and electronic systems of different purpose, principles of development of electronic devices control systems. Students must know: principles of analog and digital circuitry devices construction and functioning; principles of microprocessor and microcontroller systems construction and functioning.

The textbook has been written based on experience of teaching of disciplines according to bachelor training program for "Electronics" at the National Technical University of Ukraine "KPI", Donetsk National Technical University and Dneprodzerzhinsk State Technical University.

Course is provided with main disciplines: mathematics, physics and basics of electrical engineering.

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INTRODUCTION

Industrial development of electronics possesses two directions:

1. Informational, embracing electronic instrumentation and systems of measurement, control and monitoring by different technological processes at fabrication, scientific research, in biology, medicine. Signals amplifiers, generators of voltages, currents and power of various waveforms and frequency, logic circuits, counters, indicating devices – all these are devices and systems of informational electronics, based on integrated circuits application.
2. Power direction, concerned with transformation of alternating and direct currents for electrical power engineering, metallurgy, chemistry, transport electric motive power and so on. The main types of electronic systems are rectifiers, inverters, frequency converters, controlled converters.

Electronic systems are divided into two classes by the way of electric signals formation and transmission – analog (continuous) and discrete (discontinuous), being divided in-turn into pulse, relay and digital.

Analog electronic devices and systems are destined for reception, conversion and transmission of electric signal, changing according to continuous (analog) function. Unique, completely defined value of chosen electrical parameter of direct or alternating current corresponds to each specific value of real physical quantity at the input of electronic system of analog type. It can be voltage or current at electrical subcircuit, frequency, phase and others. Both the physical quantity and its electric equivalent at that, being possessed of infinite number of values, can be determined at any moment and change on the same time scale. It should be noted, that electric equivalent contains full information about real process, though in a common case the moments of real quantity possessing specific value and its electric equivalent appearing, can mismatch, i.e. there can be some delay between these moments. The advantages are theoretically obtainable accuracy and operating speed, system simplicity, lacks – low interference immunity and parameters instability, caused by considerable device behavior dependence on external destabilizing factors, for example temperature, time (elements ageing), external fields action and

others, considerable distortions during transmission at a great distance, difficulties in a case of results' long-term storage, low energy efficiency.

Discrete electronic devices (systems) are destined for reception, conversion and transmission of electric signals, obtained in result of quantization (process of continuous signal's change by its values in some points) by time or (and) by amplitude of given analog function. Therefore, signals acting in them, are proportional to limited number of values, chosen by specific law, of real physical quantity, represented by various parameters of pulses or drops of voltages (currents) (amplitudes, pulses rise and fall time, pulse duration, period and frequency of pulses propagation, spacing interval and so on). Discrete electronic systems (DES) use only part of information about real physical quantity, i.e. information partial losses take place during its supply. Pulse and mean power are defined by means of pulse ratio, which also can be referred to advantages, therefore it's possible to get essential power redundancy in pulse, allowing mass and overall dimensions indices improvement; power dissipation is minimal in a switch mode, which increases device coefficient of utilization; the discrete devices behavior less depends on instability of utilized devices parameters; interference immunity is higher, since time interval, when interference can influence on signal decreases; monotypic element base is used, causing reliability rise, providing cheapness.

DES discrete signals are divided into pulse, relay and digital according to quantization type. Pulse electronic systems realize quantization of initial signal. Output sequence pulses waveform remains constant during pulse modulation. Pulse-amplitude, pulse-width, pulse-phase modulations are spread. Relay systems realize initial signal quantization by amplitude and transform it into step function, with each level height being proportional to some quantity given in advance.

In the near future digital electronics will occupy most likely the leading place in the market of electronic devices and systems. Now digital personal computers and controllers practically displace analog ones, created earlier. The same takes place with equipment of radio communication, broadcasting (TV-sets, radio sets, video recorders, devices of audio recording, photo-apparatus).

However, digital technique is not able to displace fully analog in principle, because physical processes, providing electronic system with information, is analogous by nature; in that case, analog-digital and digital-analog

devices are required at the input and output.

Industrial development of electronics for almost century of its existence numbers four generations, characterizing by following microminiaturization of electronic components, devices and systems based on application of large-scale-integration (LSI) and very-large-scale-integration (VLSI) circuits. Some functional blocks are fabricated in one integrated circuit, being finished electronic device or system of information reception, transformation and transmission. Such electronic devices allows entire providing required algorithm of initial information processing and essential increasing reliability of their functioning. Mounting compactness of electronic devices of the forth generation comes to nearly 1000 el/cm^3 and more (for comparison: the third generation electronic devices – 50 el/cm^3). Integrated circuits application in modern electronic systems essentially increases system reliability and lowers their cost, overall dimensions and power consumption.

CONTENTS

BASICS OF CIRCUITRY OF ELECTRONIC SYSTEMS

(textbook for students of technical institutions of higher education,
studying in English in Ukraine.: "Avers", 2005.-750 p.)

PREFACE	5
INTRODUCTION	9

PART I

Electronic devices with continuous signals

CHAPTER 1. AMPLIFYING DEVICES

1.1. Electronic systems, subsystems and units	12
1.2. The main components of electronic devices	13
1.3. Amplifying devices. The main definitions	14
1.4. The main technical attributes of amplifiers	17
RESUME	21
1.5. Tasks for current testing	22

CHAPTER 2. RC-VOLTAGE AMPLIFIERS ON BIPOLAR JUNCTION AND FIELD-EFFECT TRANSISTORS

2.1. Bipolar junction transistor amplifier, switched by the common base circuit	24
2.2. Bipolar junction transistor amplifier, switched by the common emitter circuit	28
2.3. Bipolar junction transistor amplifier, connected by the common collector circuit	35
2.4. Bipolar junction transistor amplifier, switched by the common base circuit	38
RESUME	42
2.5. Tasks for current testing	43

CHAPTER 3. FREQUENCY RESPONSES OF AUDIO RC-AMPLIFIERS

3.1. Audio frequencies. Typical ranges of audio frequencies ...	47
3.2. Voltage amplifiers responses in the range of medium audio frequencies	51
3.3. Low audio frequencies	52
3.4. Operation of the amplifier in the high audio frequencies range	54
RESUME	57
3.5. Tasks for current testing	58

CHAPTER 4. POWER AMPLIFIERS

4.1. The signal source matching with the load	60
4.2. Single-ended power amplifiers	63
4.3. Push-pull amplifiers	69
4.4. Transformerless power amplifiers	71
RESUME	73
4.5. Tasks for current testing	74

CHAPTER 5. ANALOG MICROELECTRONIC STRUCTURES

5.1. Classification of the analog integrated circuits and of their circuitry, reciprocal components, output stages	77
5.2. Shifts voltage, input currents and their temperature drifts	81
5.3. Operational amplifiers, equivalent circuit of the amplifier ...	85
RESUME	87
5.4. Tasks for current testing	88

CHAPTER 6. BUILDING OF DECISION STRUCTURES ON THE OPERATIONAL AMPLIFIERS BASE. LINEAR AND NONLINEAR FUNCTIONAL CONVERTERS

6.1. Inverting and non-inverting amplifiers	90
6.2. Summers, integrators and differentiators on the base of amplifiers	94
6.3. Circuits of zero adjustment and amplifiers frequency correction	97

RESUME	99
6.4. Tasks for current testing	100

CHAPTER 7. SELECTIVE AMPLIFIERS

7.1. The parallel and series oscillating loops' characteristics ...	103
7.2. Selective amplifiers of LC-type	109
7.3. General aspects of the selective RC-system theory	112
7.4. Dual T-bridge, the main characteristics and parameters ...	114
7.5. Circuit diagrams of selective RC-amplifiers	119
RESUME	121
7.6. Tasks for current testing	123

CHAPTER 8. PERIODIC OSCILLATIONS GENERATORS OF LC TYPE

8.1. Methods of analysis of generators excitation conditions ...	125
8.2. LC-generator on unipolar FET-transistor with a loop in the gate circuit	127
8.3. LC-generators on bipolar transistors	130
8.4. General issues of the RC-generator theory	133
8.5. RC-generators with 180° phase-shifted links	134
8.6. RC-generator with zero phase-shifter	138
RESUME	141
8.7. Tasks for current testing	144

PART II

Pulse devices

CHAPTER 9. RC-CIRCUITS AT PULSE INFLUENCE

9.1. Pulses, classification, description, parameters	146
9.2. Differential, dividing and integrating RC-circuits	149
9.3. Limiters on diodes of serial and parallel types	156
9.4. Transistor linear models in large signal mode	161
9.5. Calculations of transistor keys	165
RESUME	170
9.6. Tasks for current testing	171

CHAPTER 10. MULTIVIBRATORS AND UNIVIBRATORS (MONOSTABLE MULTIVIBRATORS)

10.1. Transistor multivibrator. Principle of operation, operation oscillograms	173
10.2. Computation of multivibrator oscillations period	176
10.3. Frequency regulation, heatset and improvement of multivibrator output voltage form	178
10.4. Transistor monostable (one-shot) multivibrator. Principle of operation, oscillograms, computations	183
10.5. General characteristic and construction principles of generators	187
10.6. Astable generators on transistors	191
10.7. Triggered generators on transistors and operational amplifiers	195
RESUME	199
10.8. Tasks for current testing	201

CHAPTER 11. POTENTIAL LOGICAL ELEMENTS

11.1. Potential logical elements. Types, characteristics, parameters	204
11.2. Diode and diode-transistor logic	213
11.3. Transistor-transistor logic	215
11.4. Logical elements on MDS transistors	218
11.5. Logical elements of integral injector logic	222
11.6. Multivibrators on potential logical elements	225
RESUME	228
11.7. Tasks for current testing	230

CHAPTER 12. CODING DEVICES. ANALOG-DIGITAL AND DIGITAL-ANALOG CONVERTERS

12.1. Time intervals' coding, voltage coding	233
12.2. Analog-digital converters. Main characteristics and parameters	235
12.3. Digital-analog converters. Structure, general characteristics and parameters	238
12.4. Sample-and-hold device	242
RESUME	244
12.5. Tasks for current testing	246

PART III**Digital circuitry****CHAPTER 13. MATHEMATICAL FUNDAMEN-
TALS OF DIGITAL DEVICES**

13.1. Number systems. Procedure of conversion. Binary arithmetic	250
13.2. Main laws of algebra of logic	260
13.3. Forms of logical functions and their application for synthesis of logic circuits	265
13.4. Logical elements and schemes. Duality principle	272
13.5. Classification of logical devices	274
13.6. Logic elements of digital device, their comparative characteristic	277
13.7. Methods of minimization of Boolean functions	280
13.8. Karnaugh method	282
RESUME	284
13.9. Tasks for current testing	285

CHAPTER 14. COMBINATIONAL CIRCUITS

14.1. Steps of logic circuit constructing	290
14.2. Synthesis of logic devices in a specified basis	291
14.3. Multiplexers and demultiplexers	292
14.4. Decoders, decoders-multiplexers and coders	296
14.5. Adders, comparators	306
RESUME	318
14.6. Tasks for current testing	319

CHAPTER 15. TRIGGER ELEMENTS

15.1. Basic concepts. Classification and overalls	321
15.2. Asynchronous RS-flip-flop and its varieties	328
15.3. Synchronous flip-flops	341
15.4. Examples of flip-flops usage	347
RESUME	352
15.5. Tasks for current testing	353

CHAPTER 16. FUNCTIONAL BLOCKS OF SEQUENTIAL LOGICAL DEVICES

16.1. Shift registers	354
16.2. Mod M counters	359
16.3. Counters on the shift registers	372
16.4. Reversible counters	378
RESUME	385
16.5. Tasks for current testing	387

CHAPTER 17. INTEGRATED CIRCUITS OF MEMORY DEVICES

17.1. Integrated circuits of static and dynamic RAM	389
17.2. Integrated circuits of masked ROM	420
17.3. PROM Integrated circuits	427
17.4. Reprogrammable ROM integrated circuits	432
RESUME	447
17.5. Tasks for current testing	448

CHAPTER 18. THE DIGITAL INTEGRATED CIRCUITS APPLICATION

18.1. Interference and interference immunity of digital devices	450
18.2. Recommendations on mounting of integrated circuits ...	457
RESUME	472
18.3. Tasks for current testing	473

PART IV

Microprocessors and controllers

CHAPTER 19. MAIN CONCEPTS OF MICRO-PROCESSOR TECHNOLOGY

19.1 Classification of microprocessors	475
19.2. Organization of buses	477
19.3. Principles of microprocessor system construction	478
19.4. Presentation of numbers in microprocessors	482
RESUME	485
19.5. Tasks for current testing	486

CHAPTER 20. ARCHITECTURE OF MICROPROCESSORS

20.1. Microprocessors with 8-bit data bus	488
20.2. Microprocessors with 16-bit data bus	493
20.3. Architecture of 32-bit microprocessors	508
20.4. Pentium microprocessors	517
20.5. Particular features of 64-bit microprocessor architecture ...	520
RESUME	521
20.6. Tasks for current testing	524

CHAPTER 21. BASICS OF PROGRAMMING IN ASSEMBLER

21.1. Format of commands	529
21.2. Example of commands of MP <i>i8086</i>	530
21.3. Examples of command execution	535
21.4. Types of operand addressing	550
21.5. Programming in Assembler language	556
RESUME	573
21.6. Tasks for current testing	574

CHAPTER 22. CONSTRUCTING OF MICROPROCESSOR SYSTEM HARDWARE

22.1. Constructing of central processor unit on basis of <i>i8086</i> ...	577
22.2 Constructing of ROM modules	583
22.3 RAM module constructing	585
22.4 The input/output interface constructing	587
RESUME	593
22.5. Tasks for current testing	595

CHAPTER 23. MODERN MICROCONTROLLERS AND PROCESSORS

23.1 Single-chip microcontrollers with CISC architecture	598
23.2. Single-chip microcontrollers with RISC architecture	607
23.3. Signaling microprocessors	610
23.4. The basic concepts and tasks of neural computers	612
RESUME	618
23.5. Tasks for current testing	620

PART V

Power supply and control systems

CHAPTER 24. SWITCHED POWER SUPPLIES. ELEMENT BASE OF POWER ELECTRONICS

24.1. Block diagrams and main problems of switched power supplies	622
24.2. Circuitry of switched power supplies' principal blocks	626
24.3. Power semiconductor elements and units	642
24.4. Tendencies of electronic components' development	652
RESUME	661

CHAPTER 25 CONTROL SYSTEMS OF ENERGY BEAM PROCESSING PLANTS' COMPLEX

25.1 General provisions on control systems	663
25.2 Standard block diagrams of the beam processing plants power complexes' control	669
25.3 Secondary power supplies schematic circuits	693
25.4 Generalized block diagrams of secondary power supplies control	698
RESUME	704

CHAPTER 26. CALCULATIONS OF CONTROL SYSTEMS AND THEIR COMPONENTS AT THE ELEMENTS WITH FIXED CONNECTIONS

26.1 Digital circuits of pulse-phase control	707
26.2 Digital pulse generators	715
RESUME	733

CHAPTER 27. MICROPROCESSOR CONTROL SYSTEMS

27.1 Construction principles of processing plants MP control systems	735
27.2. Control systems based on MP complex	739
27.3 Microcomputer in the control systems of beam processing plants	752
27.4 Multimicroprocessor system	753
27.5 Software support of power supply controllers	756
27.6. MP secondary power supply stability	761
RESUME	768

REFERENCES	770
CONTENTS	772