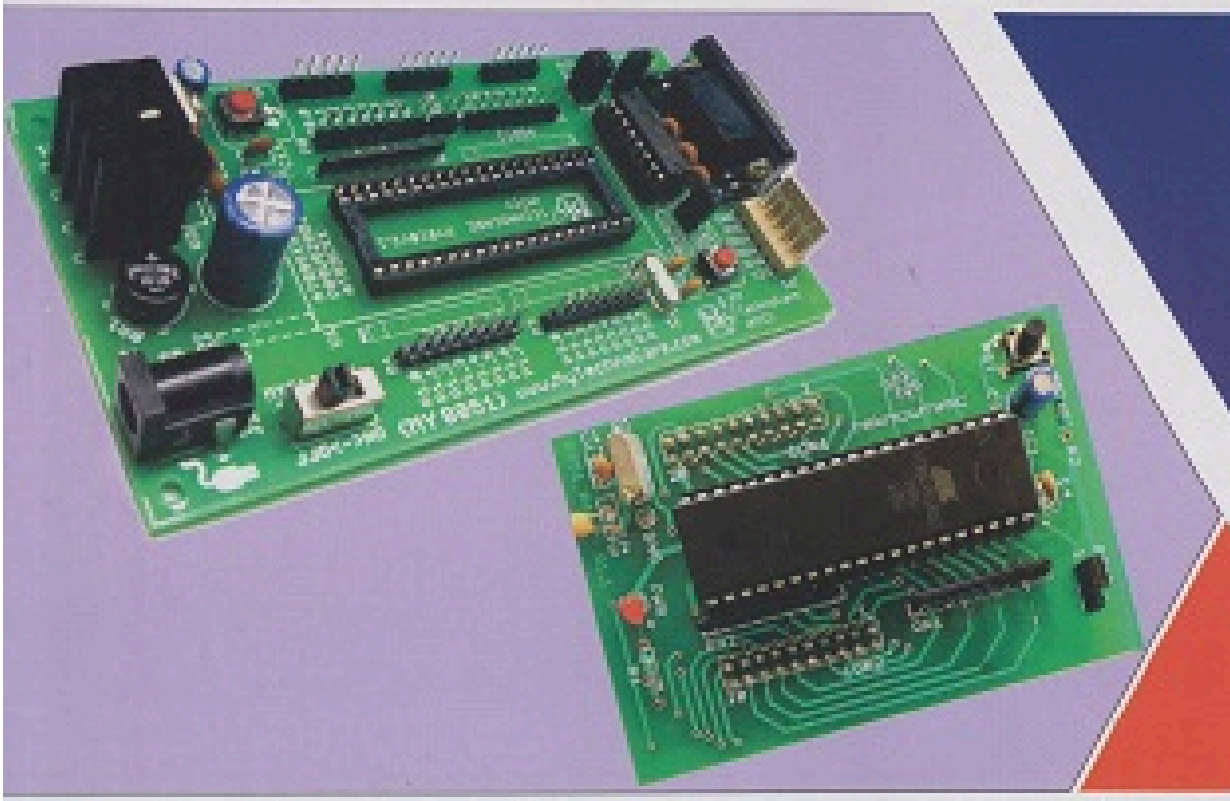
SECOND YEAR DIPLOMA
Engineering and Technology

ELECTRONICS/AUTOMATION AND ROBOTICS/DIGITAL ELECTRONICS/
ELECTRONICS AND TELECOMMUNICATION/ELECTRONICS AND COMMUNICATION/
INSTRUMENTATION AND CONTROL/INDUSTRIAL ELECTRONICS/INSTRUMENTATION/
ELECTRONICS AND COMPUTER ENGINEERING GROUPS

MSBTE's K SCHEME

SEMESTER-IV



MICROCONTROLLER AND APPLICATIONS

KISHOR P. AKOLE

DEEPAK A. KULKARNI

NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A Text Book Of

MICROCONTROLLER AND APPLICATIONS

(314328)

Semester - IV

Second Year Diploma in Electronics Engineering / Automation and Robotics / Digital Electronics / Electronics and Telecommunication Engineering / Electronics and Communication Engineering / Instrumentation and Control / Industrial Electronics / Instrumentation / Electronics and Computer Engineering

(EX / AO / DE / EJ / ET / IC / IE / IS / TE)

As Per MSBTE's 'K' Scheme Curriculum

KISHOR P. AKOLE

B.E. (E & TC), M.E. (Comp.), M.I.E.T.E., M.I.E.
Lecturer in Electronics Department,
Government Polytechnic,
Jalgaon.

DEEPAK A. KULKARNI

B.E. (Electronics), M.E. (E & TC),
Head of Department (EJ),
Kala Vidya Mandir Institute of Technology,
Malad West, Mumbai

NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

N8194

Microcontroller and Applications (Electronics Engg. Gr.) (Sem. - IV) **ISBN 978-93-6109-986-1**

First Edition : January 2025

© : Authors

The text of this publication, or any part thereof, should not be reproduced or transmitted in any form or stored in any computer storage system or device for distribution including photocopy, recording, taping or information retrieval system or reproduced on any disc, tape, perforated media or other information storage device etc., without the written permission of Authors with whom the rights are reserved. Breach of this condition is liable for legal action.

Every effort has been made to avoid errors or omissions in this publication. In spite of this, errors may have crept in. Any mistake, error or discrepancy so noted and shall be brought to our notice shall be taken care of in the next edition. It is notified that neither the publisher nor the authors or seller shall be responsible for any damage or loss of action to any one, of any kind, in any manner, therefrom. The reader must cross check all the facts and contents with original Government notification or publications.

Published By :
NIRALI PRAKASHAN
Abhyudaya Pragati, 1312, Shivaji Nagar,
Off J.M. Road, Pune – 411005
Tel - (020) 25512336/37/39
Email : niralipune@pragationline.com

Polyplate

Printed By :
YOGIRAJ PRINTERS AND BINDERS
Survey No. 10/1A, Ghule Industrial Estate
Nanded Gaon Road
Nanded, Pune - 411041

DISTRIBUTION CENTRES

PUNE

Nirali Prakashan
(For orders outside Pune)
S. No. 28/27, Dhayari Narhe Road, Near Asian College
Pune 411041, Maharashtra
Tel : (020) 24690204; Mobile : 9657703143
Email : bookorder@pragationline.com

Nirali Prakashan
(For orders within Pune)
119, Budhwar Peth, Jogeshwari Mandir Lane
Pune 411002, Maharashtra
Mobile : 9657703145, 9890997937
Email : niralilocal@pragationline.com

MUMBAI

Nirali Prakashan
Rasdhara Co-op. Hsg. Society Ltd., 'D' Wing Ground Floor, 385 S.V.P. Road
Girgaum, Mumbai 400004, Maharashtra
Mobile : 7045821020, Tel : (022) 2385 6339 / 2386 9976
Email : niralimumbai@pragationline.com

DISTRIBUTION BRANCHES

DELHI

Nirali Prakashan
Room No. 2 Ground Floor
4575/15 Omkar Tower, Agarwal Road Darya Ganj, New Delhi 110002
Mobile : 9555778814/9818561840
Email : delhi@niralibooks.com

BENGALURU

Nirali Prakashan
Maitri Ground Floor, Jaya Apartments, No. 99, 6th Cross, 6th Main, Malleswaram, Bengaluru 560003 Karnataka; Mob : 9686821074
Email : bengaluru@niralibooks.com

NAGPUR

Nirali Prakashan
Above Maratha Mandir, Shop No. 3, First Floor, Rani Jhanshi Square, Sitabuldi Nagpur 440012 (MAH)
Tel : (0712) 254 7129
Email : nagpur@niralibooks.com

KOLHAPUR

Nirali Prakashan
438/2, Bhosale Plaza, Ground Floor
Khasbag, Opp. Balgopal Talim
Kolhapur 416 012, Maharashtra
Mob : 9850046155
Email : kolhapur@niralibooks.com

JALGAON

Nirali Prakashan
34, V. V. Golani Market, Navi Peth, Jalgaon 425001, Maharashtra
Tel : (0257) 222 0395
Mob : 94234 91860
Email : jalgaon@niralibooks.com

SOLAPUR

Nirali Prakashan
R-158/2, Avanti Nagar, Near Golden Gate, Pune Naka Chowk
Solapur 413001, Maharashtra
Mobile 9890918687
Email : solapur@niralibooks.com

marketing@pragationline.com | www.niralibooks.com
Also find us on www.facebook.com/niralibooks

Preface ...

With the grace of god, it gives us immense pleasure to bring the first edition of this book to you. It has been written according to new 'K' scheme, curriculum designed by the Board of Technical Education, Mumbai.

This text provides all the basics of Microcontroller and Applications, which will help the diploma engineers to understand all the concepts of Microcontroller Overview and 8051 Architecture; 8051 Programming; 8051 Timers; Interrupts, Serial and Parallel Communication; 8051 Interfacing and 8051 Applications. This knowledge of Microcontroller and Applications will be helpful to the students, since it will be easier for them to understand the basic programming of examples.

We hope the students and teachers will highly appreciate and accept the book.

Our special appreciation goes to Shri. Dineshbhai Furia, Shri. Jigneshbhai Furia, Shri. Kiran Kamble, Mr. Ilyas Shaikh and Miss Shraddha Shedge of Nirali Prakashan, Pune for publishing this book in a good and presentable manner, within very short time.

We are also thankful to our family members for their constant support and motivation.

Teachers, students and practicing engineers are requested to suggest for further improvement of this book.

Authors



Syllabus ...

1. Microcontroller Overview and 8051 Architecture (Hours 11, Marks 14)

1.1 Features and selection factors for Microcontroller.

1.2 Block diagram of 8051 Microcontroller: CPU, input device, output device, memory and buses.

1.3 Comparison of Microcontroller and Microprocessor on the basis of Memory, Complexity, Type of Architecture, Cost, Applications, Typical examples of Microcontrollers and Microprocessors.

1.4 Architectures of Microcontroller: Harvard, Von Neumann. Concept of pipelining.

1.5 8051 Microcontroller: Architecture, Pin Configuration, Memory Organization, Power saving options.

1.6 Derivatives of 8051 (8951, 8031, 8751). Comparison between derivatives.

2. 8051 Programming (Hours 08, Marks 12)

2.1 Software Development cycle: Editor, Assembler, Compiler, Cross-Compiler, Linker, Locator.

2.2 Addressing Modes: Immediate, Register, Direct, Indirect, Indexed.

2.3 Instruction Sets: Data Transfer, Arithematic, Logical, Branching, Machine control and Boolean.

2.4 Assembler Directives: ORG, DB, EQU, END, CODE, DATA.

2.5 Assembly Language Programmimg (ALP): Data Manipulation, Masking, Stack Operation, Branch related programming.

3. 8051 Timers, Interrupts, Serial and Parallel Communication (Hours 10, Marks 14)

3.1 Configuration and Programming of Timer/Counter using Special Function Registers [SFRs]: TMOD, TCON, THx, TLx, Simple programs to generate the time delays.

3.2 Configuration and Programming of Interrupts using SFRs: IE, IP.

3.3 Serial Communication SFRs: SCON, SBUF, PCON, Modes of serial communication, Simple Programs on serial communication. Serial Communication using MAX 232.

3.4 Configuration and Programming of I/O Port : P0, P1, P2, P3.

4. 8051 Interfacing (Hours 10, Marks 18)

4.1 I/O Interfacing: Keyboard, Relays, LED, LCD, Seven Segment display.

4.2 Interfacing ADC 0808/09 with 8051. Simple programs for ADC interfacing.

4.3 Interfacing DAC 0808/09 with 8051. Simple programs for DAC interfacing.

4.4 Memory Interfacing: Program and Data Memory.

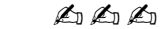
5. 8051 Applications (Hours 06, Marks 12)

5.1 Square and Triangular waveform generation using DAC.

5.2 Temperature Sensor (LM35) Interfacing using DAC to 8051.

5.3 Water Level Controller design using 8051.

5.4 Stepper Motor Interfacing to 8051 to rotate in clockwise and anticlockwise direction.



Contents ...

1. Microcontroller Overview and 8051 Architecture 1.1 – 1.26

Introduction 1.1

1.1 Features and Selection Factors for Microcontroller 1.1

1.1.1 Features 1.1

1.1.2 Microcontroller Selection Factors 1.2

1.2 Block Diagram of 8051 Microcontroller 1.2

1.2.1 Elements of Microcomputer 1.3

1.2.2 Buses 1.4

1.3 Comparison of Microcontroller and Microprocessor 1.4

1.4 Architectures of Microcontroller : Harvard, Von-Neumann 1.6

1.4.1 Von-Neumann Architecture 1.6

1.4.2 Harvard Architecture 1.6

1.4.3 Concept of Pipelining 1.9

1.5 8051 Microcontroller 1.10

1.5.1 Architecture 1.10

1.5.2 Pin Configuration 1.19

1.5.3 Memory Organization 1.22

1.5.4 Power Control Register 1.23

1.6 Derivatives of 8051 (8951, 8031, 8751) 1.24

1.6.1 Comparison Between Derivatives 1.25

- Practice Questions 1.25

2. 8051 Programming 2.1 – 2.14

2.1 Assembly Language Programming Tools 2.1

2.1.1 Embedded Software Development Cycle 2.2

2.2 Addressing Modes of 8051 2.2

2.2.1 Immediate Addressing Mode 2.3

2.2.2 Direct Addressing Mode 2.3

2.2.3 Register Addressing Mode 2.3

2.2.4 Register Indirect Addressing Mode 2.3

2.2.5 Indexed Addressing Mode 2.3

2.2.6 Implied Addressing Mode 2.3

2.3 Instruction Sets of 8051 2.4

2.3.1 Data Transfer Instructions 2.4

2.3.2 Arithmetic Instructions 2.5

2.3.3 Logical Instructions 2.6

2.3.4 Rotate and Swap Instructions 2.6
2.3.5 Branching Instructions 2.7
2.3.6 Machine Control Instructions 2.8
2.3.7 Boolean (Bit-Level) Instructions 2.9
2.4 Assembler Directives 2.9
2.5 Assembly Language Programming 2.10
• Practice Questions 2.14
3. 8051 Timers, Interrupts, Serial and Parallel Communication 3.1 – 3.19
Introduction 3.1
3.1 Timer/Counter 3.2
3.2 8051 Interrupts 3.8
3.2.1 Interrupts in (MCS 51) 8051 3.8
3.2.2 Interrupt Enable Register (IE) 3.8
3.2.3 Interrupt Priority Register (IP) 3.9
3.2.4 Comparison between Polling and Interrupt Method 3.10
3.3 Serial Communication 3.11
3.3.1 SCON Register 3.11
3.3.2 PCON Register (SFR) 3.12
3.3.3 Modes of Serial Communication 3.13
3.3.4 Multiprocessor Communication 3.13
3.4 Input/Output Port Structure 3.15
• Important Points 3.18
• Practice Questions 3.18
4. 8051 Interfacing 4.1 – 4.24
Introduction 4.1
4.1 Interfacing I/O Devices 4.2
4.1.1 Interfacing Switches and LEDs to 8051 4.2
4.1.2 Keyboard Interfacing to 8051 4.2
4.1.3 Interfacing of Relay to 8051 4.6
4.1.4 Seven Segment Display Interfacing to 8051 4.8
4.1.5 Liquid Crystal Display (LCD) Display 4.11
4.2 Interfacing ADC 0808/0809 with 8051 4.16
4.2.1 ADC IC 0808/09 4.16
4.2.2 ADC Interfacing with 8051 4.18
4.3 Interfacing DAC 0808/0809 with 8051 4.18
4.3.1 DAC Interfacing 0808/09 4.19
4.3.2 DAC Interfacing with 8051 4.19

4.4 Memory Interfacing: Program and Data Memory 4.20
4.4.1 Accessing Internal Memory 4.21
4.4.2 Accessing External Memory 4.21
4.4.3 Linear and Absolute Decoding 4.21
• Practice Questions 4.24
5. 8051 Applications 5.1 – 5.14
Introduction 5.1
5.1 Square and Triangular Waveform Generation using DAC 5.1
5.2 DAC Interfacing to 8051 5.7
5.3 Water Level Indicator 5.9
5.4 Stepper Motor Interfacing 5.11
5.5 Troubleshooting 5.12
• Practice Questions 5.14
Appendices A.1 – A.2
Sample Summative and Formative Assessment Papers P.1 – P.4

✍ ✍ ✍

Chapter 1...

Microcontroller Overview and 8051 Architecture

Weightage of Marks = 14, Teaching Hours = 11

Curriculum Theory Contents

1.1 Features and selection factors for Microcontroller.
1.2 Block diagram of 8051 Microcontroller: CPU, input device, output device, memory and buses.
1.3 Comparison of Microcontroller and Microprocessor on the basis of Memory, Complexity, Type of Architecture, Cost, Applications, Typical examples of Microcontrollers and Microprocessors.
1.4 Architectures of Microcontroller: Harvard, Von Neumann. Concept of pipelining.
1.5 8051 Microcontroller: Architecture, Pin Configuration, Memory Organization, Power saving options.
1.6 Derivatives of 8051 (8951, 8031, 8751). Comparison between derivatives.

Unit Outcomes

After completion of this chapter, students will be able to

- List the features of 8051 Microcontroller.
- Explain the significance of selection factors while selecting Microcontroller for application.
- Describe the 8051 block diagram.
- Differentiate Microcontroller and Microprocessor for the given parameters.
- Compare Harvard architecture and Von-Neumann architecture.
- Explain functions of each block of 8051 Microcontroller.
- Compare the given derivatives of 8051 Microcontroller.

INTRODUCTION

Microcontrollers plays a very important role in the design, development of embedded systems. Automation is used in every field of engineering and microcontroller is inbuilt component of these systems. Now-a-days many industrial and domestic products like remote controllers, automatic and semi-automatic washing machines, automobile engines, and other applications involve automation. Automation is necessary to facilitate the process and control. Data storage and data processing is an integral part of automation. A microcontroller is a device which controls the timing and sequencing of these processes. A microcontroller performs simple arithmetic and logical operations. Microcontrollers are single-chip microcomputers, suitable for control and automation of machines and processes.

1.1 FEATURES AND SELECTION FACTORS FOR MICROCONTROLLER

Microcontrollers are available and designed with various features and suitable for all types of applications. Features available with a particular microcontroller make it applicable as selection factors for a particular application . So it is essential to know significance of general features and selection factors.

1.1.1 Features

Microcontroller is a digital IC with program execution capability. It has two main types of features: (A) Hardware features, (B) Software features.

Hardware features include:

1. Simultaneously data processing capacity in bits.
2. Maximum memory size externally can be interfaced (Number of address lines).

3. Internal memory type and size.
4. Number of I/O ports.
5. Number of hardware interrupts.
6. Number of internal timers with their size in bits.
7. Operating speed (Maximum clock rate).
8. Chip package type and number of pins.
9. Serial communication features.
10. Power control features.
11. Number of flag bits.
12. Number of bit operating locations.
13. Internal ADC.
14. Power consumptions and operating voltages.
15. Number of clock cycles per machine cycle.

Software features include:

1. Number of instructions.
2. Addressing modes.
3. Special instructions.
4. Number of bytes per instruction.
5. Types of software interrupts.
6. Machine cycles required for instruction execution.

1.1.2 Microcontroller Selection Factors

[W-18, 16, 15, 14; S-19]

(1) Architecture : For most embedded systems, there is a choice between 8-bit, 16-bit and 32-bit cores. When the application involves computations, 32-bit cores are preferable over 8-bit and 16-bit. The architecture of a microcontroller includes details like, the number of registers used, whether the code can be executed out of the data memory, whether the peripherals are treated like memory or registers, whether there is stack and so on. A RISC processor can handle simple mathematical functions faster, but a CISC processor may handle complicated functions faster because it can do them at once instead of the several processing commands that a RISC processor would require.

Architecture and memory technology also need to be considered as these affect the real calculation speed rather than MHz and memory size requirements.

Another issue may be whether to use a DSP or a general purpose microcontroller. Microcontrollers are designed for simple math and control functions. DSPs are processors which are optimised for processing the streaming signal. These have special instructions which speed-up common tasks such as multiply-accumulate in a single instruction.

(2) Programming Language : The most popular programming languages for MCUs are Assembly (ASM) and Embedded C. Working with ASM is much more time consuming, but gives you an insight to the architecture and actual working of MCU. However, when the code size efficiency does not matter as much as the time to develop, Embedded C is the way. We can write efficient codes in 'C'.

(3) Input/Output Pins : Try to keep external chip interfacing minimum. This will simplify the design. Make sure that MCU has sufficient Input/Output pins. Try to use alternate modes for peripherals like 4-bit LCD mode - to save some input/output pins.

(4) Availability : Select an MCU that will be available for a long time.

(5) Packaging : DIP package is suitable and easy to work with. SMD package is a bit difficult to work with.

(6) Memory : While choosing the memory size, consider the scalability, such that if the program has to be updated, additional memory would be required, the MCU should have the margin already built in. The memory technology used inside the MCU also affects its calculation speed. Some MCUs use MON 05 flash technology, which can run upto 100 MHz with zero wait states. This differs from other MCUs that use normal flash technology and need to insert wait states, dropping the CPU performance.

(7) Word Length : The word length of the microcontroller may be either 8 bit, 16 bit, or 32 bit. 8 bit microcontroller is used in applications like temperature controller, motor speed control systems, etc. The cost of the microcontroller, power dissipation and speed increase with increase in the word length. 16 bit microcontroller is used in applications like communication systems and 32 bit microcontrollers are used in satellites etc.

(8) Clock Frequency : The speed of a microcontroller depends on the clock frequency and the clock frequency depends on the system application.

(9) Instruction Set : The microcontrollers can be classified as (i) CISC controller and (ii) RISC controller. CISC controller provides software flexibility, hence used in general purpose system. (iii) RISC controller improves the speed of response, hence used in high speed applications.

(10) Power Dissipation : Power dissipation of a microcontroller is dependent on factors like clock frequency, speed, supply voltage, VLSI technology, etc.

1.2 BLOCK DIAGRAM OF 8051 MICROCONTROLLER [W-19]

Fig. 1.1 shows the fundamental block diagram of general purpose microcontroller. Microcontroller mainly consists of CPU, input device, output device, memory and buses. CPU has three main units ALU, Control unit and Memory unit.