

**OPEN THIS PACKAGE FIRST!**

(47)



# HOW TO ASSEMBLE AND USE YOUR INDIVIDUAL LEARNING PROGRAM

**Model EE-3401**

**595-2039-02**

Before you begin to use this Individual Learning Program you will need to assemble and organize it. The printed material, looseleaf binder, electronic parts and cassette tapes have been packed to provide maximum protection during shipping. By assembling this material yourself you will check to see that nothing is missing. At the same time, it will give you an opportunity to look over the program and get familiar with it.

Follow the step-by-step instructions below to assemble your program. Check off each step as you complete it. Then begin the program as indicated in the last step.

1. Be sure that you have received all of the materials. This Individual Learning Program contains:
  - One package of printed material wrapped in plastic.
  - Two looseleaf binders.
  - One Final Examination Kit envelope.
  - One tape holder with two cassette tapes.
  - One audio-visual flip chart.
  - Package(s) of electronic parts. Exact content will be checked in a later step.
  - One set of tab dividers.

(over)

2. Put the printed material and the tab dividers into the looseleaf binder. The printed material has already been collated in the proper sequence, but you will have to separate it and place it after the appropriate tab dividers. Colored sheets have been placed between the different sections to help you separate them quickly. The material is divided into units, and there is a tab divider for each unit. Place all of the introductory material in front of the tab divider for unit one. Place units 1 through 6 and the cassette holder in one binder. Place units 7 through 10 and Appendixes A and B in the second binder.
3. Locate the Parts List which should follow this sheet in the introductory material. Check the parts you received against this list. If you are missing parts, use the enclosed Parts Order Form to order replacements.
4. You will not need the Final Examination Kit until you complete the program, but you can take a look at it now. Check the contents against the list on the front of the envelope.
5. Begin your program. Start by playing cassette tape 1 side A. Follow the instructions given there.

# INDIVIDUAL LEARNING PROGRAM IN MICROPROCESSORS



EE-3401

## COURSE OBJECTIVES AND OUTLINE

### COURSE OBJECTIVES

When you have completed this course, you will be able to do the following:

1. Program a representative microprocessor.
2. Interface a representative microprocessor with the "outside world."

### COURSE OUTLINE

- UNIT 1 NUMBER SYSTEMS AND CODES
  - I. Introduction
  - II. Unit Objectives
  - III. Unit Activity Guide
  - IV. Decimal Number System
  - V. Binary Number System
    - A. Positional Notation
    - B. Converting Between the Binary and Decimal Number Systems
  - VI. Octal Number System
    - A. Conversion from Decimal to Octal
    - B. Converting Between the Octal and Binary Number System
  - VII. Hexadecimal Number System
    - A. Converting from Decimal to Hexadecimal
    - B. Converting Between the Hexadecimal and Binary Number Systems
  - VIII. Binary Codes
    - A. Binary Coded Decimal
    - B. Special Binary Codes
    - C. Alpha Numeric Codes
  - IX. Experiment
  - X. Unit Examination
  - XI. Examination Answers

**UNIT 2      MICROCOMPUTER BASICS**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Terms and Conventions
  - A. Stored Program Concept
  - B. Computer Words
  - C. Word Length
- V. An Elementary Microcomputer
  - A. The Microprocessor Unit (MPU)
  - B. Memory
  - C. Fetch — Execute Sequence
  - D. A Sample Program
- VI. Executing a Program
  - A. The Fetch Phase
  - B. The Execute Phase
  - C. Fetching the Add Instruction
  - D. Executing the Add Instruction
  - E. Fetching and Executing the HLT Instruction
- VII. Addressing Modes
  - A. Inherent or Implied Addressing
  - B. Immediate Addressing
  - C. Direct Addressing
  - D. Sample Program Using Direct Addressing
  - E. Executing the Sample Program
  - F. Combining Addressing Modes
- VIII. Experiment
- IX. Unit Examination
- X. Examination Answers

**UNIT 3      COMPUTER ARITHMETIC**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Binary Arithmetic
  - A. Binary Addition
  - B. Binary Subtraction
  - C. Binary Multiplication
  - D. Binary Division
  - E. Representing Negative Numbers
- V. Two's Complement Arithmetic
  - A. Ten's Complement Arithmetic
  - B. Two's Complement Subtraction
  - C. Arithmetic With Signed Numbers
- VI. Boolean Operations
  - A. AND Operation
  - B. OR Operation
  - C. Exclusive OR Operation
  - D. Invert Operation
- VII. Experiment
- VIII. Unit Examination
- IX. Examination Answers

**UNIT 4 INTRODUCTION TO PROGRAMMING**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Branching
  - A. Relative Addressing
  - B. Executing a Branch Instruction
  - C. Branching Forward
  - D. Branching Backward
- V. Conditional Branching
  - A. Condition Codes
  - B. Conditional Branch Instructions
- VI. Algorithms
  - A. Multiplying by Repeated Addition
  - B. Dividing by Repeated Subtraction
  - C. Converting BCD to Binary
  - D. Converting Binary to BCD
- VII. Additional Instructions
  - A. Add With Carry (ADC) Instruction
  - B. Subtract With Carry (SBC) Instruction
  - C. Arithmetic Shift Accumulator Left (ASLA) Instruction
  - D. Decimal Adjust Accumulator (DAA) Instruction
- VIII. Experiment
- IX. Unit Examination
- X. Examination Answers

**UNIT 5 THE 6800 MICROPROCESSOR — PART 1**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Architecture of the 6800 MPU
  - A. Programming Model of the 6800 MPU
  - B. Block Diagram of the 6800 MPU
- V. Instruction Set of the 6800 MPU
  - A. Arithmetic Instructions
  - B. Data Handling Instructions
  - C. Logic Instructions
  - D. Data Test Instructions
  - E. Index Register and Stack Pointer Instructions
  - F. Branch Instructions
  - G. Condition Code Register Instructions
  - H. Summary of Instruction Set
- VI. New Addressing Modes
  - A. Extended Addressing
  - B. Indexed Addressing
  - C. Instruction Set Summary
- VII. Experiment
- VIII. Unit Examination
- IX. Examination Answers

**UNIT 6 THE 6800 MICROPROCESSOR — PART 2**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Stack Operations
  - A. Cascade Stack
  - B. Memory Stack
- V. Subroutines
  - A. Jump (JMP) Instruction
  - B. JSR and RTS Instructions
  - C. Nested Subroutines
  - D. Branch to Subroutine (BSR) Instruction
  - E. Summary of Subroutine Instructions
- VI. Input-Output (I/O) Operations
  - A. Output Operations
  - B. Input Operations
  - C. Input-Output Programming
  - D. Program Control of I/O Operations
  - E. Interrupt Control of I/O Operations
- VII. Interrupts
  - A. Reset
  - B. Non-Maskable Interrupts
  - C. Return From Interrupt (RTI) Instruction
  - D. Interrupt Request (IRQ)
  - E. Interrupt Mask Instructions
  - F. Software Interrupt (SWI) Instruction
  - G. Wait for Interrupt (WAI) Instruction
- VIII. Experiment
- IX. Unit Examination
- X. Examination Answers

**UNIT 7 INTERFACING — PART 1**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Interfacing Fundamentals
  - A. Buses
  - B. 3-State Logic
  - C. The 6800 MPU Interface Lines
  - D. Instruction Timing
  - E. Timing of Program Segment
  - F. The 6800 Data Sheet
- V. Interfacing With Random Access Memory
  - A. The Static RAM Storage Cell
  - B. A 128-Word by 8-Bit RAM
  - C. A 256-Word by 4-Bit RAM
  - D. Connecting RAM to the MPU
  - E. Address Decoding
- VI. Interfacing With Displays
  - A. The 7-Segment Display
  - B. Driving the 7-Segment Display
  - C. Using an Addressable Latch
  - D. Multiplexing Displays
- VII. Experiment
- VIII. Unit Examination
- IX. Examination Answers

**UNIT 8 INTERFACING — PART 2**

- I. Introduction
- II. Unit Objectives
- III. Unit Activity Guide
- IV. Interfacing With Switches
  - A. Interfacing Requirements
  - B. A Typical Keyboard Arrangement
- V. The Peripheral Interface Adapter (PIA)
  - A. I/O Diagram
  - B. PIA Registers
  - C. Addressing the Registers in the PIA
  - D. Initializing the PIA
  - E. Addressing the PIA
- VI. Using the PIA
  - A. Driving 7-Segment Displays
  - B. Decoding Keyboards
  - C. Decoding a Switch Matrix
- VII. Experiment
- VIII. Unit Examination
- IX. Examination Answers

**UNIT 9 PROGRAMMING EXPERIMENTS**

- I. Introduction
- II. Experiment 1. Binary/Decimal Training Program
- III. Experiment 2. Hexadecimal/Decimal Training Program
- IV. Experiment 3. Straight Line Programs
- V. Experiment 4. Arithmetic and Logic Instructions
- VI. Experiment 5. Program Branches
- VII. Experiment 6. Additional Instructions
- VIII. Experiment 7. New Addressing Modes
- IX. Experiment 8. Arithmetic Operations
- X. Experiment 9. Stack Operations
- XI. Experiment 10. Subroutines

**UNIT 10 INTERFACING EXPERIMENTS**

- I. Introduction
- II. Experiment 1. Memory Circuits
- III. Experiment 2. Clock
- IV. Experiment 3. Address decoding
- V. Experiment 4. Data Output
- VI. Experiment 5. Data Input
- VII. Experiment 6. Introduction to the Peripheral Interface Adapter (PIA)
- VIII. Experiment 7. Audio Output
- IX. Experiment 8. Key Matrix and Parallel-to-Serial Conversion
- X. Experiment 9. Digital-to-Analog and Analog-to-Digital Conversion

**APPENDIX A DEFINITION OF THE EXECUTABLE INSTRUCTIONS**

- I. Nomenclature
- II. Executable Instructions (definition of)
- III. Table A-1. Addressing Formats (1)
- IV. Table A-2. Addressing Formats (2)
- V. Table A-3. Addressing Formats (3)
- VI. Table A-4. Addressing Formats (4)
- VII. Table A-5. Addressing Formats (5)
- VIII. Table A-6. Addressing Formats (6)
- IX. Table A-7. Addressing Formats (7)
- X. Table A-8. Addressing Formats (8)

**APPENDIX B DATA SHEETS**

- I. MC6800 Data Sheet
- II. MC6820 Data Sheet
- III. MC6850 Data Sheet
- IV. MC6810 Data Sheet
- V. MC6830 Data Sheet
- VI. MC6832 Data Sheet
- VII. Positive Powers of Two
- VIII. Negative Powers of Two
- IX. Positive Powers of Eight
- X. Positive Powers of Sixteen
- XI. Negative Powers of Sixteen



## PARTS LIST

This parts list contains most of the parts used in the experiments which you will perform with this course. The key number in the parts list corresponds to the numbers in the parts pictorials. Some parts are packaged in envelopes. Except for this initial parts check, keep these parts in their envelopes until they are called for in an experiment. Some of the parts saved from assembly of the ET-3400 will also be used in the experiments.

KEY No.	HEATH Part No.	QTY.	DESCRIPTION
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CIRCUIT Comp. No.
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### RESISTORS

#### (1/4-Watt)

A1	6-471-12	8	470 $\Omega$ (yellow-violet-brown)
A1	6-102-12	5	1000 $\Omega$ (brown-black-red)

#### (1/2-Watt)

A2	6-101	2	100 $\Omega$ (brown-black-brown)
A2	6-202	1	2000 $\Omega$ (red-black-red)
A2	6-272	2	2700 $\Omega$ (red-violet-red)
A2	6-103	2	10 k $\Omega$ (brown-black-orange)
A2	6-105	1	1 M $\Omega$ (brown-black-green)

### CAPACITORS

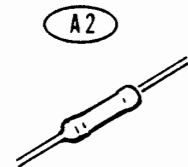
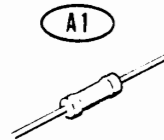
A3	21-147	1	47 pF ceramic
A3	21-172	3	100 pF ceramic
A4	25-117	1	100 $\mu$ F electrolytic

### PUSHBUTTON SWITCHES

A5	64-724	1	Switch #1
A5	64-725	1	Switch #2
A5	64-726	1	Switch #3
A5	64-727	1	Switch #4

### DIODES

A6	56-56	1	1N4149
A6	56-616	1	5.6 V Zener



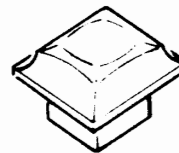
A3



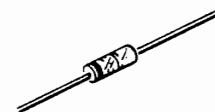
A4



A5



A6



**INTEGRATED CIRCUITS (IC'S)**

NOTE: Integrated Circuits are marked for identification in one of the following ways:

1. Part number.
2. Type number.
3. Part number and type number.
4. Part number with a type number other than the one listed.

Disregard any letters that precede or follow the numbers on an IC.

—	B1	442-22	1	741
—	B1	442-39	1	301
—	B2	443-1	1	7400
—	B2	443-13	2	7474
—	B2	443-717	1	74126
—	B2	443-719	1	74LS266
—	B2	443-732	2	74LS30
—	B2	443-800	1	74LS27
—	B2	443-842	1	1406
—	B3	443-694	1	9368
—	B3	443-804	1	74LS259
—	B3	443-807	1	74LS42

NOTE: Do not remove the next two IC's from their protective foam packing until you are instructed to. This anti-static foam packing protects the IC's from damage due to static electricity.

—	B3	443-721	2	2112
—	B4	443-843	1	6820

**MISCELLANEOUS**

C1	10-936	2	1000 $\Omega$ control
C2	73-92	1	Foam tape
	344-59	12'	White wire
C3	401-163	1	Speaker
C4	411-819	1	FND-500 7-segment display
C5	411-831	1	TIL-312 7-segment display
C6	432-875	1	Connector block
	266-945	1	Cassette holder
	266-962	1	Parts container (plastic box)
	448-251	1	Cassette tape #1
	448-252	1	Cassette tape #2
	597-1661	1	Instruction set summary card

