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Practical Embedded Controllers

Design and Troubleshooting with the Motorola 68HC11

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Practical Embedded Controllers: Design and Troubleshooting with the Motorola 68HC11

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Preface

From microwave ovens to alarm systems to industrial programmable logic controllers (PLCs) and distributed control systems (DCSs), embedded controllers are running our world.

Embedded controllers are used in most items of electronic equipment today. They can be thought of as intelligent electronic devices used to control and monitor devices connected to the real world. This can be a PLC, DCS or a smart sensor. These devices are used in almost every walk of life today. Most automobiles, factories and even kitchen appliances have embedded controllers in them.

The microcontrollers that are at the heart of these and many more devices are becoming easier and simpler to use. But when these devices fail, the solution to the problem needs to be found and repairs done quickly.

This book will help technicians, engineers and even the casual user understand the workings of microcontrollers, along with the most common problems and their solutions.

This book covers all aspects of embedded controllers but is biased towards troubleshooting and design. The book also covers design, specification, programming, installation, configuration and troubleshooting.

After reading this book we hope you will have learnt how to:

- Design, set up and program a complete embedded controller development system
- Apply the latest techniques in programming these versatile devices
- Apply troubleshooting tips and tricks for microcontrollers
- Apply the best techniques for installation of microcontrollers
- Fix problems due to electrical noise and interference
- Design correctly the first time to avoid grounding and EMC problems
- Choose and configure the correct software

Typical people who will find this book useful include:

- Electronic technicians and engineers
- Instrumentation and control engineers and technicians
- Process control engineers and technicians
- Electrical engineers
- Consulting engineers
- Process development engineers
- Design engineers
- Control systems sales engineers

A basic knowledge of electrical principles is useful in understanding the concepts outlined in the book, but the contents are of a fundamental nature and are easy to comprehend.

The structure of the book is as follows.

Chapter 1: Introduction. This chapter gives a brief overview of the main components of a microcontroller.

Chapter 2: Microcontroller basics. A review of the basics of this device with a discussion on number systems, Boolean logic, accumulators, registers, data communications, power systems, crystals and oscillators, is done in this chapter.

Chapter 3: Microcontroller programming. A review of the simple techniques involved in programming a microcontroller with a discussion on the various programming issues such as programming structures, addressing modes, operations and finally a short comparison of C++ and BASIC, is done in this chapter.

Chapter 4: Microcontroller memory. The main types and techniques in the effective use of memory such as user RAM, BUFFALO routines, interrupts, control registers, and EEPROM are assessed here.

Chapter 5: Microcontroller inputs and outputs. Analog and digital inputs, keypad and LCD interfacing are described here.

Chapter 6: Data communications. This important topic is broken down into a discussion on the fundamentals, the OSI model, modes of communication and RS-232 and RS-485.

Chapter 7: Noise reduction. This chapter gives an overview of noise reduction and a discussion on conductive, capacitive, and magnetically coupled noise.

Chapter 8: EMC grounding solutions. The most important features of grounding (and protection from lightning) to protect the microcontroller from the effects of EMC are discussed here.

Chapter 9: Installation and troubleshooting. This chapter is a short discussion on connections, cable runs and trays, wire management and troubleshooting techniques.

Chapter 10: End notes. A wrap discussion on the issues discussed in the earlier chapters with a few words on assembly language programming, memory, inputs and outputs, data communication, noise reduction and grounding solutions and finally installation techniques.

Contents

1

Introduction

Objectives

When you have completed this chapter, you will be able to:

- Describe the basic parts and functions of microcontrollers
- Explain what assembly language is and how it is used
- Describe memory mapping
- Describe the basics of inputs and outputs
- Describe what types of data communications controllers use
- Explain noise reduction and its relationship to good signals
- Describe potential grounding problems

1.1 Microcontroller introduction

Embedded controllers are used in most commercial and industrial electronic equipment. The sheer volume of embedded controllers used in the world drives us to understand how they work and then how to troubleshoot and repair them. The microcontrollers and support chips used in these controllers are becoming smarter and easier to use. This is bringing the design and use of embedded controllers to more and more engineers hence the need for a good understanding of what embedded controllers are and how to troubleshoot them.

Embedded controllers are intelligent electronic devices used to control and monitor devices connected to the real world. This can be a microwave oven, programmable logic controller (PLC), distributed control system (DCS) or a smart sensor. These devices are used in almost every walk of life today. Most automobiles, factories and even kitchen appliances have embedded controllers in them. As time goes on and electronic devices get smarter and smaller, the embedded controller will be in or associated with everything we touch throughout the day.

Early embedded controllers contained a CPU (central processing unit) and a multitude of support chips. As time went on, support chips were included in the CPU chip until it became a microcontroller. A microcontroller is defined as a CPU plus random access memory (RAM), electrically erasable programmable read only memory (EEPROM),

inputs/outputs (I/O) and communications (Comms). The embedded controller is a microcontroller with peripherals such as keypads; displays and relays connected to it and is often connected to other embedded controllers by way of some type of communication system.

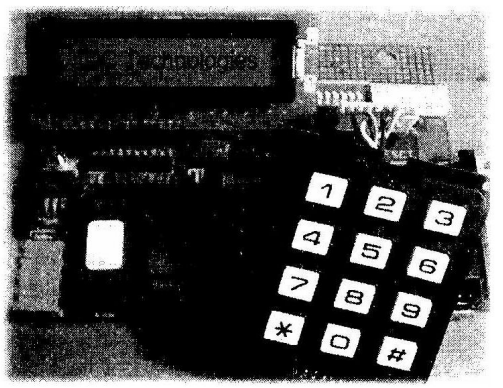

Figure 1.1
Embedded controller development board

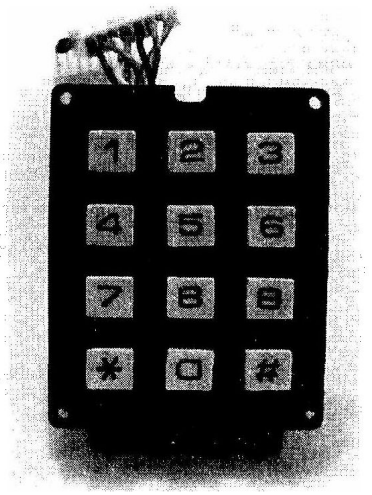

Figure 1.2
Keypad for embedded controller

Electronic equipment is becoming more and more susceptible to noise and other outside influences that can cause catastrophic problems. To be able to troubleshoot and ultimately repair the embedded controller it is not only necessary to understand the inter-workings of the embedded controller but also the external forces that can affect the normal operation of the controller. This may be noise, bad connections or incorrect installation of the system. Often simple things like bad grounds or incorrectly made connections can cost the user hundreds, if not thousands of dollars in down-time. Although the embedded controller ultimately can be a complicated device, when disassembled into its basic parts it becomes simple, clear and easy to understand.

1.2 Microcontroller design and functions

The microcontroller is a direct descendent of the CPU, in fact every microcontroller has a CPU as the heart of the device. It is therefore important to understand the CPU in order to ultimately understand the microcontroller and embedded controller.

The central processor unit (CPU) is the brain of the microcontroller. The CPU controls all functions and uses the program that resides in RAM, EEPROM or EPROM to function. The program may reside in one or more of these devices at the same time. Part of the program might be in RAM while another might be in EEPROM.

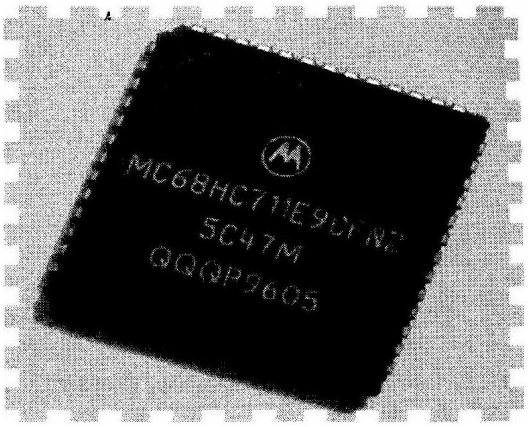

Figure 1.3
68HC11 CPU

A program is a sequence of instructions that tell the CPU what to do. These instructions could be compared to instructions a teacher may give to a student to get a desired result. The instructions sent to the CPU are very, very simple and it usually takes many instructions to get the CPU to do what is necessary to accomplish a task. Upper level programming languages like BASIC and C++ include multiple instructions in one command to speed up the process of programming the CPU. Just like the human brain the CPU is made up of regions that have specific functions. These components are controlled by the program instructions.

The main components of the microcontroller are as follows:

- CPU
- External address bus
- External data bus
- External control bus
- Internal RAM
- Internal ROM
- Internal ERPROM
- Internal EEPROM
- Internal registers
- Digital inputs
- Counter inputs
- Digital outputs
- Analog inputs
- Serial data communications
- Parallel ports

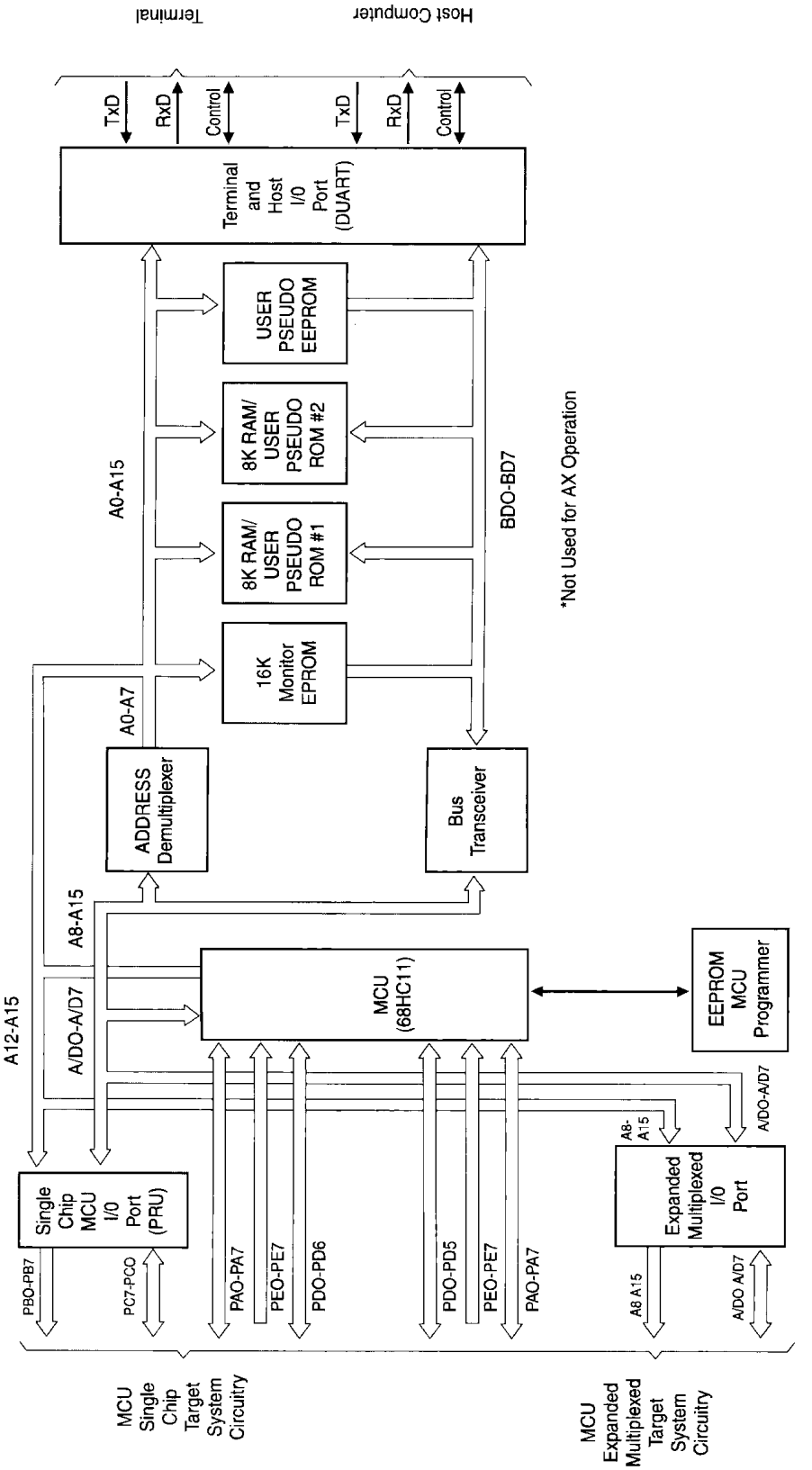

Figure 1.4
Block diagram of a microcontroller