Electronics for Embedded Systems

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For my loving wife, Yen Fen…

Preface

This book is written for young professionals, undergraduate and graduate students who have a background in basic circuit theory and want to learn about the circuits used in printed circuit boards and embedded systems. My teaching method in this textbook caters towards a lot of schematics, block diagrams and examples at the expense of text because I believe in engineers are "shape-oriented" people and learn from figures, charts and diagrams.

The book has nine chapters. Chapter 1 analyzes the first-order passive RC and RL circuits and the second-order passive RLC circuits encountered in all Printed Circuit Boards (PCB). The general understanding of passive circuits also establishes a vital background for more complex circuits that contain active elements such as diodes and transistors.

Chapter 2 reviews rectifier diodes, light emitting diodes, Zener diodes and explains simple circuits incorporating them. This chapter is also a review chapter for bipolar transistors, specifically NPN transistors, and discusses the circuit behavior and the conditions that lead to the NPN bipolar transistor in cut-off, active and saturation regions.

Chapter 3 explains the N-channel and the P-channel MOS transistors, their current-voltage characteristics and CMOS gates, and then discusses the proper circuit design techniques that lead to transistor sizing in CMOS to meet design requirements prior to simulation.

Chapter 4 starts with Transistor-Transistor-Logic (TTL), explains the circuit operation of a TTL inverter, its logic levels and fan-out limit. However, the emphasis of this chapter is more about the CMOS-TTL interface and the various circuits used at the interface for successful logic translation.

Sensors and preliminary sensor physics are given in Chapter 5. The most common sensors such as thermocouple, photo-diode and photo-detector, Hall-effect device and piezoelectric sensors are discussed in this chapter.

Chapter 6 examines the operational amplifiers and low-frequency operation amplifier circuits used for sensor output amplification. Voltage and trans-resistance amplifiers, analog comparators, Schmitt triggers, square waveform generators are included in this chapter.

Chapter 7 reviews the theory behind data converters such as analog-to-digital converters (ADC) and digital-to-analog converters (DAC). Many different types of ADC designs, such as flash, ramp and successive approximation are explained in this chapter with numerical examples. The weighted adder-type and ladder-type DAC designs are also shown in this chapter.

Chapter 8 combines most of the sensors studied in Chapter 6 and the operational amplifier circuits in Chapter 7 to explain the electromechanical control circuits. The usage of relay switch, opto-isolator, Hall-effect device, pulse-width-modulation (PWM) circuits to operate electromechanical devices, such as DC motors, are also discussed. In the last part of this chapter, several full-scale electronics projects are presented. In each project, the characteristics of sensors used in the project are discussed, and the signal conditioning stage is designed to prepare the unit for analog-to-digital conversion. In the last stage of the design, an ADC is selected to interface with the microcontroller, integrating the design with the rest of the system.

In order to provide a reference material for all the past eight chapters, a brief review of combinational and sequential logic design principles is presented in Chapter 9. A complete design does not only contain a sensor, a signal conditioning circuit and a data converter. Combinational and sequential logic blocks, in the form of "glue logic", support various parts of the analog data-path, and therefore they constitute the major part of a design. Some of the analog front-end projects presented at the end of Chapter 8 prove that both analog and digital components must be integrated in a design in order to achieve complete functionality. Therefore, a solid understanding in digital logic design becomes a requirement to be able to build the entire analog front-end electronics for a sensor array prior to interfacing with a microcontroller.

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About the Author

Ahmet Bindal received his M.S. and Ph.D. degrees in Electrical Engineering from the University of California, Los Angeles CA. His doctoral research was on the material characterization for HEMT GaAs transistors. During his graduate studies, he was a research associate and a technical consultant for Hughes Aircraft Co. In 1988, he joined the technical staff of IBM Research and Development Center in Fishkill, NY, where he worked as a device design and characterization engineer. He developed asymmetrical MOS transistors and ultra thin Silicon-On-Insulator (SOI) technologies for IBM. In 1993, he transferred to IBM at Rochester, MN, as a senior circuit design engineer to work on the floating-point unit for the AS-400 mainframe processor. He continued his circuit design career at Intel Corporation in Santa Clara, CA, where he designed 16-bit packed multipliers and adders for the MMX unit for Pentium II processors. In 1996, he joined Philips Semiconductors in Sunnyvale, CA, where he was involved in the designs of instruction/data caches and various SRAM modules for the Trimedia processor. His involvement with VLSI architecture also started in Philips Semiconductors and led to the design of the Video-Out unit for the same processor. In 1998, he joined Cadence Design Systems as a VLSI architect and directed a team of engineers to design self-timed asynchronous processors. After approximately 20 years of industry work, he joined the Computer Engineering faculty at San Jose State University in 2002. His current research interests range from nano-scale electron devices to robotics. Dr. Bindal has over 30 scientific journal and conference publications and 10 invention disclosures with IBM. He currently holds three U.S. patents with IBM and one with Intel Corporation.