Experimenting with Raspberry Pi

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This book is dedicated to the memory of my father, Charles Wallace Gay, who passed away this year. He didn't remember it when we discussed it last, but he was responsible for sparking my interest in electronics at an early age. He had brought home from his used-car business two D cells, a piece of blue automotive wire, and a flashlight bulb. After showing me how to hold them together to complete the circuit and light the bulb, I was hooked for life.

I am also indebted to my family for their patience. Particularly my wife Jacqueline, who tries to understand why I need to do the things I do with wires, solder, and parts arriving in the mail. I am glad for even grudging acceptance because I'm not sure that I could give up the thrill of moving electrons in some new way. Sometimes hobby electronics projects have no real justification beyond "because we can!"

Contents at a Glance

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About the Author

Warren W. Gay started out in electronics at an early age, dragging discarded TVs and radios home from public school. In high school he developed a fascination for programming the IBM 1130 computer, which resulted in a career plan change to software development. After attending Ryerson Polytechnical Institute, he has enjoyed a software developer career for more than 30 years, programming mainly in C/C++. Warren has been programming Linux since 1994 as an open source contributor and professionally on various Unix platforms since 1987.

Before attending Ryerson, Warren built an Intel 8008 system from scratch before there were CP/M systems and before computers got personal. In later years, Warren earned an advanced amateur radio license (call sign VE3WWG) and worked the amateur radio satellites. A high point of his ham radio hobby was making digital contact with the Mir space station (U2MIR) in 1991.

Warren works at Datablocks.net, an enterprise-class ad-serving software services company. There he programs C++ server solutions on Linux back-end systems.

About the Technical Reviewer

Stewart Watkiss graduated from the University of Hull, United Kingdom, with a master's degree in electronic engineering. He has been a fan of Linux since first installing it on a home computer during the late 1990s. While working as a Linux system administrator, he was awarded Advanced Linux Certification (LPIC 2) in 2006 and created the Penguin Tutor web site to help others learning Linux and working toward Linux certification (www.penguintutor.com).

Stewart is a big fan of the Raspberry Pi. He owns several Raspberry Pi computers that he uses to help to protect his home (Internet filter), provide entertainment (XBMC), and teach programming to his two children. He also volunteers as a STEM ambassador, going into local schools to help support teachers and teach programming to teachers and children

Acknowledgments

In the making of a book, there are so many people involved. I first want to thank Michelle Lowman, acquisitions editor, for her enthusiasm for the initial manuscript and pulling this project together. Enthusiasm goes a long way in an undertaking like this.

I'd also like to thank Kevin Walter, coordinating editor, for handling all my e-mail questions and correspondence and coordinating things. I greatly appreciated the technical review performed by Stewart Watkiss, checking the facts presented, the formulas, the circuits, and the software. Independent review produces a much better end product.

Thanks also to Sharon Wilkey for patiently wading through the copy edit for me. Judging from the amount of editing, I left her plenty to do. Thanks to Douglas Pundick, development editor, for his oversight and believing in this book. Finally, my thanks to all the other unseen people at Apress who worked behind the scenes to bring this text to print.

I would be remiss if I didn't thank my friends for helping me with the initial manuscript. My guitar teacher, Mark Steiger, and my brother-in-law's brother, Erwin Bendiks, both volunteered their time to help me with the first manuscript. Mark has no programming or electronics background and probably deserves an award for reading through "all that stuff." I am indebted also to my daughter Laura and her husband Michael Burton, for taking the time to take my photograph while planning their wedding at that time.

There are so many others I could list who helped me along the way. To all of you, please accept my humble thanks, and may God bless.

Introduction

These are exciting times for the computing enthusiast. AVR and PIC microcontrollers make low-level digital computing readily accessible. At the high-level there exist System on a Chip (SoC) platforms, such as the Raspberry Pi. These are capable of supporting complex applications at affordable prices.

New challengers to the Raspberry Pi regularly appear now, yet the Pi remains popular. This is because of the Raspberry Pi Foundation's excellent support and the unit's continuing dominance in price. Both are critical to success. Foundation support provides continued Raspbian Linux development, making it easier for people to get started and use the platform. The foundation also continues to provide documentation and to develop Pi specific peripherals such as the camera. Finally, low cost allows more people to participate and at lower risk, should an experiment go bad.

Content of This Book

This book was formed from a category of chapters in the full volume *Mastering the Raspberry Pi*. The focus in this particular book is experiments in Raspberry Pi interfacing to the outside world. Every chapter involves some aspect of interfacing GPIO, PWM, I2C bus, or SPI bus to some external electronics.

More than the electronic interface design is covered, however, since every interface requires software to drive it. In some cases, applications will utilize Raspbian Linux drivers to control the peripheral (such as the I2C bus). In other experiments, the application software must control the GPIO pins directly. In every case, simplified C programming is used as a place to start. The reader is encouraged therefore to apply these programs as "idea generators." Jump in and modify the programs to adapt to your own ideas. Software is infinitely malleable.

Approach Used

The focus of this text is on learning. You would not be well served if you were presented some kind of "end product" to be plugged in and simply used. Instead, you are encouraged to learn to design interfaces to the Pi for yourself—to build from scratch or to modify existing designs. This book will give you some practical examples to work through. Experience is the best teacher.

While this is not an electronics engineering text, a light engineering approach is applied. For example, the difference between the signal levels of the Pi versus the levels required by an interfaced IC is scrutinized for some experiments. These parameters are taken from the IC's datasheet. This design work is to counter the glib "seems to work" approach often given in web blogs. It is better to *know* that it will work and that it will *always* work. Getting it right is not difficult when a little care and understanding goes into the process.

Assumptions About the Reader

Since the experiments in this book involve attaching things to the Raspberry Pi's GPIO pins, some digital electronics knowledge is assumed. The reader should have a good grasp of DC voltage, current, and resistance at a minimum. Students who know Ohm's law will fare best in these experiments. For students who have not yet committed Ohm's law to memory, Appendix C serves a quick reference.

The Raspberry Pi uses 3.3 V digital logic. This creates a special problem when interfacing to older TTL logic, which operates at the 5 V level. The experiment in Chapter 4 Real Time Clock, for example, demonstrates how to interface safely to a 5 V device, after making some modifications to a purchased pcb. These experiments require extra care to avoid damaging the Pi.

Experiments involving the I2C bus require the reader to be familiar with the concept of open collector drivers. Without this understanding, the student will not appreciate why a 3.3 V Pi can interface to a 5 V real-time clock chip, using the I2C bus. This concept is also critical to understanding why several peripherals can share that same bus.

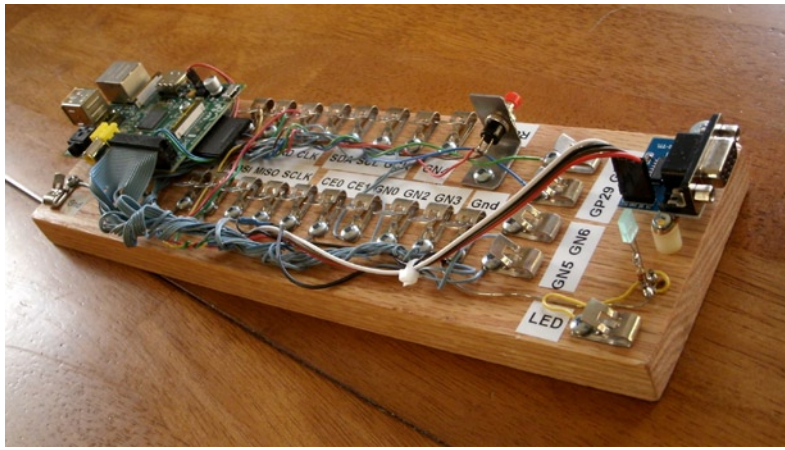
Hardware for the experiments assumes a student budget. The parts and assembled pcbs used in this book were purchased from eBay, usually as buy-it-now auctions (with free shipping). For this reason, the student need not have deep pockets to acquire the parts used in these experiments.

Since hardware needs software to direct it, C programs are used and provided. Consequently, it is best that you have at least a vague idea about the C programming language to get the most out of the experiments. The example programs are simplified as much as they could be without sacrificing function. This keeps the software accessible to the reader and eases the learning process.

Pi Hardware Assumed

All of the experiments in this book interface directly to the Raspberry Pi. No special Gertboard or other special product is used. For this "bare-metal approach," all you need is a Raspberry Pi and the involved experiment's hardware.

For my own experiments, I constructed a home-brewed setup where I placed the Pi on a block of wood and ran wires out to some retro Fahnestock clips. While this worked quite well, building this setup required considerable effort. I would recommend that students get something easier like the Adafruit Pi Cobbler.



A simple homemade Raspberry Pi workstation

For the reader, the advantage of this "bare-metal" approach is threefold:

- There is no dependence on product availability.
- There is no built-in buffering between the Pi and your peripheral.
- It costs less.

Products come and go, so why build on that foundation? Add-on products also often provide buffering between the Pi and the outside world. But this feature would eliminate the need to design this yourself.

Finally, in a large project like a robot, where several motor and sensor interfaces exist, the need to economize becomes essential. This is where learning to design your own interfaces pays off.

Test Equipment

The experiments in this book require access to a digital multimeter (DMM). This is critical for testing voltages for the Raspberry Pi's own safety. The Pi will not tolerate inputs above +3.3 V without possible damage. Consequently, voltage readings are recommended as part of several experiments to make sure that no damage to the Pi occurs whenever voltages exceeding 3.3 V are involved.

Many experiments can be laid out on breadboards without the need for soldering. A huge time saver is the use of ready-made breadboard jumper wires. These can be purchased from eBay for about $1.50 for about 50 to 65 wires. They come in different colors, fit the breadboard well, and don't require you strip the ends. Students have better things to do with their time.

Final Words

By now, you are probably itching to get started. There is no better time than the present!