Digital Electronics

Course Introduction and Materials

Introduction

Welcome to the ARRL's Certification/Continuing Education course on Digital Electronics! I hope you'll enjoy learning some of the basics of electronics. "Digital electronics" means circuits that operate only at certain levels of voltage and current. By doing so, they can perform functions that require acting on combinations of signals or stepping through certain sequences. We'll learn about the basic building blocks of digital electronics that are used to build the controllers and computers that make modern life hum. Ready? Let's go!

Who is this course for?

This course is designed for the electronics beginner that has an interest in electronics and has been introduced to the fundamental concepts of electricity and electronic components, such as resistors, capacitors, transistors, and so forth. You'll be reading some simple schematics, as well. If you have passed your Technician class license, then you are probably ready for this course. We will cover the elements of digital logic right away, so you needn't be a whiz at Boolean algebra. You'll be expected to be comfortable with the notions of frequency and phase, pulses and duty factor. We'll be using the binary number system (0 and 1) quite a lot and maybe even the hexadecimal system–which is just like the decimal system if you had sixteen fingers!

What will you learn? Here is the list of topics for each lesson. When you complete this course, you'll have been exposed to nearly all of the most common digital electronic circuits and design problems and will be experienced with the basic functions of digital math.

1. Introduction to Digital Electronics
2. Basic Boolean
3. Basic Gates
4. Flip-Flops–Part 1
5. Flip-Flops–Part 2
6. Counters and Shift Registers
7. Latches, Buffers and Drivers
8. Encoders and Decoders
9. Parallel Interfaces
10. Serial Interfaces
11. Input Devices
12. Displays
13. Logic Families
14. Microprocessor Basics
15. Connecting to Analog Electronics
16. Understanding Data Sheets and Design Resources

Is there a textbook?

No, but here are a couple of good reference books that you may either already have, can purchase, or borrow from a friend or library:

The ARRL Handbook–this reference covers the basics
The CMOS Cookbook–by Don Lancaster–this is an excellent desk and workbench reference

I will refer you to "extra reading" in these and other references that help explain the topic or provide supplemental information. Don't forget about the ARRL's Technical Information Service that lists many useful and interesting articles on the ARRL Web site at http://www.arrl.org/tis/.

How are the lessons organized?
Each lesson begins with some background on the topic for the lesson. I'll explain the circuit's relevance and the characteristics that make it useful. Once introduced, we'll cover the fundamental relationships that determine the circuit's behavior. With these tools, you'll then be shown how to apply the circuit to common needs.

Each lesson concludes with a five-question quiz and a student activity. The activity begins with a design problem to work out with pencil and paper. Next, I'll present a simple construction project. You are encouraged to do however much of the exercise for which you are equipped–doing so greatly increases your understanding (and confidence!).

What equipment do I need?
To perform the experimental portions of the exercises, you'll need to have some basic digital test equipment. These will also be very valuable around your shack beyond the class. If you don't have these now, you won't regret buying them for troubleshooting and testing your own gear.

Let's start with the minimum equipment that will enable you to perform the simpler portions of the experiments:

- 5 V dc Power Supply–these are widely available from all of the sources listed below. The supply should be capable of supplying current of at least 0.5 A. Don't use a wall-transformer supply–they're too poorly regulated. Three fresh 1.5 V batteries in series can be used in a pinch, but you should really have a power supply. If you use a large supply, add an in-line fuse such as Radio Shack 270-1281. None of our circuits will draw more than 1 A.
- Volt-ohm-meter (VOM) with test probes, digital or analog–use a name-brand meter, such as a Fluke, B&K, or those available from Radio Shack. Don't rely on a "mystery meter" from a hamfest–these are often inaccurate, have too great an effect on the circuit being tested, or have been damaged.
- Logic Probe–essentially an on/off indicator made for working with digital circuits. It's handier than a voltmeter for digital electronics and will be a valuable addition to your toolbox. The Tenma 72-190 or 72-500 from MCM Electronics are good examples. For the very simplest indicators, we'll just use an LED!

- A prototyping board or breadboard–because you will be making a lot of circuits and adjusting the values of the components frequently, a plug-in style base for construction is invaluable. You'll need one with at least 30 rows of contacts and dual power busses on each side. Radio Shack's 276-169 is a good example of what's needed.
- Clip leads–buy or make a dozen 10 ~ 18" leads of stranded hookup wire with small, insulated alligator clips on each end. These will be used for connecting the power supplies and meters. While you're at it, obtain a few feet of solid 20 AWG or 22 AWG wire for the prototype board. Used telephone twisted-pair cable is a good source.
- Tools–you'll need a small pair of needle-nosed pliers, wire clippers, and wire strippers. No soldering is required.
- Electronic Parts–each experiment will have a shopping list of components. A master list is also provided at the end of this lesson. Most parts are available from Radio Shack or at any of the recommended vendors. Generally speaking, if you have the following selection of components, you'll be ready to go!
  - ¼ W resistors from 10 Ω to 1 MΩ
  - several of each value and type of capacitor listed below
    - 1, 10, and 100 μF electrolytic capacitors rated at 25 V dc or better
    - 100 and 1000 pF, 0.01 and 0.1 μF ceramic capacitors
  - signal diodes such as 1N4148 and some red and green LEDs
  - CMOS logic IC's such as the CD4001, CD4011, CD4013, and others as noted for each experiment and in the master course parts list.

The Global Specialties "Protoboard Workstation" includes both a 5 V dc power supply and a function generator (see below). It's available from RadioShack as 910-4093.

Next is the more capable equipment that can generate and measure more complex digital signals. These equipment is optional. If you expect to be building and testing digital circuits on a regular basis, it would be a good idea to borrow or purchase this equipment. You can get by without it for most of the activities in this course.

- 20 MHz Oscilloscope with two probes–good deals abound for oscilloscopes with excellent specifications. Internet auction sites, hamfests, and ham swap web sites regularly show excellent scopes selling for less than $100. Be sure to get probes (they'll cost from $10 ~ 50 separately) and an operating manual. A good introduction to using the oscilloscope is on-line at http://website.lineone.net/~colin_mccord/Radio/oscilloscope.htm.

Function Generator–as with the 'scopes, used equipment or kits are available for under $50. The generator should be able to supply a 0 to 5 V (not ±5 V) square wave or pulse from 10 Hz to 100 kHz. It's not required, but very useful for the generator to be able to adjust the duty factor of the output to 10 % or less. Single pulse outputs aren't required, but are handy. If your generator has a coaxial cable output (usually BNC) you'll need either an adapter (for connecting the clip leads) or a cable with test clips on one end. As a simple substitute that can generate low frequency pulses, the Ramsey Kit UT-5 Universal Timer mini-kit only costs $10. I built one of the kits and mounted it on a small plastic sample box as shown in the photo. I added an on/off switch (next to the power cord), an

LED that lights when the output is HIGH, and a switch for adding capacitors in parallel with the main timing capacitor. The switch is seen on the left side of the box. By using the formula in the kit manual and experimenting with different values of capacitance, I have a handy pulse generator whose frequency is adjustable between 1.3 and 74 Hz in three ranges.

The Ramsey Kit UT-5 Universal Timer makes a handy pulse generator at low cost. It is easily modified to have multiple ranges and an output indicator.

Where can I get this stuff?

Here are a few of the distributors for components and equipment that I've found to be reliable vendors with good quality products:

- Radio Shack (**www.radioshack.com**)
- Digi-Key (**www.digikey.com**)
- Jameco (**www.jameco.com**)
- Marlin P. Jones (**www.mpja.com**)
- MCM Electronics (**www.mcmelectronics.com**)–a good source of consumer electronics repair supplies, as well
- Mouser Electronics (**www.mouser.com**)

There is a list of additional vendors and resources at my "Hands-On Radio" page on the ARRL Web site. Scroll down to the FAQ section for a discussion of purchasing used test equipment.

Safety

None of the circuits you'll encounter involve hazardous voltages or currents, but that's not an excuse to get sloppy at the workbench. If this is your first hands-on experience, now is the time to develop good working habits. Your working area should be clean and well-lit. Keep an eye on test leads and cords for tangles. Double check power connections before turning on the supply. When in doubt, use the voltmeter to check it out! If you're more experienced, use this course as an opportunity to break a bad habit or pick up a good one.