Analog Electronics - Course Introduction and Materials

Introduction

Welcome to the ARRL's Continuing Education course on Analog Electronics! I hope you'll enjoy learning some of the basics of electronics. "Analog electronics" means circuits that use continuously varying voltages and currents. This is the way all circuits behave at their most basic level, so even your "digital" computer is really analog at the level of the individual transistors. Most radio circuits are analog, so you'll find a lot of what you learn in the course to be immediately useful around the shack and shop. Ready? Let's go!

Who is This Course For?

This course is designed for the electronics student that is comfortable with 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. You will need to know Ohm's Law and the relationship between power, voltage, current, and resistance. You'll need to be able to handle basic math equations--no more than simple algebra. I assume that you're comfortable with the notions of frequency and phase, as well as impedance and reactance--the resistance to the flow of ac current. (If you're a little shaky on these last few ideas, you might want to spend some time browsing the first few sections of Chapter 6 "AC Theory and Reactive Components" in the ARRL Handbook or pick up a copy of WR1B's "Understanding Basic Electronics.")

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 analog electronic circuits and design problems.

Lesson 1. Introduction to Analog Electronics
Lesson 2. Use of Instrumentation
Lesson 3. Basic Circuit Analysis
Lesson 4. Diodes
Lesson 5. Rectifier Circuits
Lesson 6. Bipolar and Field-Effect Transistors
Lesson 7. Common Emitter/Common Source Amplifier
Lesson 8. Common Collector/Common Drain Amplifier
Lesson 9. Miscellaneous Useful Amplifiers
Lesson 10. Driver Circuits
Lesson 11. Passive Filters and Frequency Response
Lesson 12. Op-Amps: Principles and Basic Circuits
Lesson 13. Op-Amps: Active Filters
Lesson 14. Timers
Lesson 15. Linear Voltage Regulators
Lesson 16. Understanding Data Sheets and Design Resources

Is There a Textbook?

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

ACTFILT.exe designs some active filters - this program may be useful when studying lesson 13.
The ARRL Handbook--this will be the most-used reference
Understanding Basic Electronics--by Larry Wolfgang WR1B
The Art of Electronics--by Horowitz and Hill
Op-Amp Cookbook - Walter Jung
Active Filter Cookbook - Don Lancaster and Walter Jung

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 present any interesting history and explain the circuit's relevance and the characteristics that make it useful. Once introduced, we'll cover the fundamental equations and relationships that determine the circuit's behavior. With these tools, you'll then be shown how to design the circuit based on some initial required characteristics, such as gain for an amplifier or frequency response for a filter. I'll present useful ways to apply the circuit to common needs.

Each lesson concludes with a five-question quiz and a set of exercises. The exercises take three forms. First, you will have a design problem to work out with pencil and paper. Next, I'll present the part of the exercise that requires the minimum amount of test equipment. Finally, if you have a fully equipped workbench, a more complex experiment can be performed. You are encouraged to do whichever set of exercises 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 electronics 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:

- 12 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. Your rig's power supply (most likely set to 13.8 V dc) will also work. You can also use batteries (a sealed lead-acid type or D-cells are recommended). Don't use a wall-transformer supply--they're

too poorly regulated. Whatever power supply you use, add a fuse to its output with an in-line fuse holder such as RadioShack 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.
- 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.
- Tools--you'll need a small pair of needle-nosed pliers, wire clippers, and wire strippers. Soldering will be optional--a small, 30 W iron with some 60/40 solder is sufficient.
- Electronic Parts--A master list of parts for the course is provided here. 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
- adjustable resistors or "pots" of 1 kΩ, 10 kΩ, and 100 kΩ
- several of each value and type of capacitor listed below
- 1, 10, and 100 mF electrolytic capacitors rated at 25 V dc or better
- 100, 470, 1000, 1500, 2200, 3300, 4700 pF, 0.01, 0.1 mF ceramic capacitors
- signal diodes such as 1N4148 and low-voltage rectifiers such as the 1N4001
- 2N3904 (NPN) and 2N3906 (PNP) transistors
- 741 Op-amps

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.

The more complex portions of the experiments will require equipment that can generate and measure ac signals. This equipment is optional. If you expect to be building and testing analog 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.
- Adjustable, Dual Power Supply, 0 ~ 20 V dc @ 0.5 A--a dual supply provides both positive and negative voltages. Adjustable supplies are useful as a source of variable dc voltage. Dual supplies will be needed for the op-amp experiments. A pair of power supplies will work if their outputs are not connected to ground internally. Two sets of batteries can also be used.

- Audio Oscillator or Function Generator--as with the 'scopes, used equipment or kits are available for under $50. The generator should be able to supply a sine wave output from 10 Hz to 100 kHz at voltages from 0.1 V p-p to 5 V p-p. A function generator that can also output square or triangle waves, add a dc voltage to its output (called "DC Offset"), or sweep the output frequency is not required, but is quite useful. If your generator has a coaxial cable output (usually BNC or phono plug) you'll need either an adapter (for connecting the clip leads) or a cable with test clips on one end.
- A second VOM and test probes--a second meter is very useful to allow comparisons in real-time or to allow monitoring of one parameter while adjusting another. An analog meter (one with a meter and needle, instead of a numeric display) can be useful during adjustments to see variations in voltage or current. The second meter can be less capable than the primary meter and should be able to measure voltage at a minimum.

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. If you have a soldering iron, keep the cord out of your working area. 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.

Enough preparation--let's get going and learn some analog electronics!