Electronics You Might Not Have Learned In College: Lesson 2 - Resistors, Batteries, Ohm's Law, Fuses, and Multimeters

An Online Continuing Education Course for Engineers

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1 What is Covered in Lesson 2 - *Resistors and Basic DC Circuits*

The focus of this lesson is primarily BATTERIES, RESISTORS, terminology, and measurements used in low voltage DC (DIRECT CURRENT) circuits that are common in electronic equipment such as toys, video games, entertainment systems, measuring and monitoring equipment, and computers. AC (ALTERNATING CURRENT) and higher voltage DC (over 32 volts) are covered in later lessons.

- Basic concepts of VOLTAGE, RESISTANCE, AMPERAGE, and POWER will be introduced because knowledge of these is necessary when learning about electronic components and how they work.
- OHM'S LAW, which defines the relationship between VOLTS, RESISTANCE, and AMPS, is the foundation for all electronic knowledge. The specifications for even simple wire cannot be understood without knowing the basics of OHM'S LAW.
- The WATER ANALOGY for a simple series resistance circuit will be introduced to help understand the basics of electrical measurements and terminology.
- CONDUCTORS will be discussed in detail because they are the most essential item in the electrical world.
- BATTERIES are introduced because they are the most common low voltage DC power source. Without a source of energy, electronic circuitry, no matter how complex, is useless.
- RESISTORS are the simplest but also the most useful component used in electronic circuitry. Understanding of resistors is essential to understanding electronic circuits.
- VARIABLE RESISTORS are essential to adjusting and controlling electronic circuitry INPUTS and OUTPUTS.
- PROTECTIVE DEVICES, such as fuses and circuit breakers, are essential for the protection of all electronic circuitry.
- MULTIMETERS are the most useful measuring tool for anyone working with electrical circuits. They can be used to measure POTENTIAL (VOLTAGE), CURRENT (AMPERES), and RESISTANCE (OHMS). Among many other things, they are useful for checking batteries, testing fuses, measuring the amount of current being used by an electric device, and checking for voltage loss in long wires.

1.1 Details Covered in This Lesson

Lesson 2 introduces BATTERIES and RESISTORS and their relationship to voltage and power. It will explain the meanings of VOLTS, AMPERES, OHMS, and WATTS. Water analogies comparing water systems to electrical circuits are heavily used to explain the invisible and seemingly magical world of electron flow.

Much of Lesson 2 is preoccupied with RESISTORS and POTENTIOMETERS. These are simple devices but are easy to misapply. Their use in SERIES, PARALLEL, and VOLTAGE DIVIDER networks will be heavily discussed as well as resistor types, how to select the right resistor, how resistors are marked for their ratings, resistor error tolerances, resistor temperature effects, and wattage. Also, VARIABLE RESISTORS, such as POTENTIOMETERS and RHEOSTATS, are included in this lesson.

There is a lot of emphasis on WORST CASE ANALYSIS and TOLERANCE SPECIFICATIONS for components because these topics are especially important considerations in circuit design and repair. Unfortunately, as important as tolerance specifications are, they tend to be lost or ignored in the massive piles of information provided in electronics courses.

Pictures and illustrations are used to simplify explanations and increase the reader's understanding of complicated and often confusing concepts. **Readers gain more than the knowledge of what electrical components are. They learn about how they work and how they are used and selected to do their jobs.**

Details are presented concerning BATTERIES and RESISTORS, including how their specifications are derived and what should be considered when selecting them for use in a circuit design. It also introduces the basics of how to calculate how batteries and resistors are used in PARALLEL and SERIES networks. Other important elements, such as CONDUCTORS (WIRES) AND PROTECTIVE DEVICES (FUSES and CIRCUIT BREAKERS), are also discussed.

This lesson also introduces MULTIMETERS (combination volt-ohm-amp meters) and an introduction to how to use them to measure what is happening in the invisible world of electricity. The combination of knowing the basics of how electrical components work and how to measure their effect on electron flow can be extremely useful when troubleshooting, testing, designing, or simply using electronic equipment.

1.2 Reading an Electrical Engineer's Mind

The explanation and analysis of examples in this course may often appear more detailed and thorough than needed. Normally, an experienced electrical engineer will do a lot of the work in his head or just scratch it in a notebook. **The involved processes in the explanation of the examples herein are like overhearing an engineer "talking in his head"** as he goes through the thought processes and step-by-step procedures that are required for successful circuit design.

For a simple "one-off" electronic circuit, an experienced design engineer will usually sketch out a SCHEMATIC of a circuit that should work. Then, the engineer gathers some components and BREADBOARDS them into a circuit. Using knowledge and experience of how electronic components work and the flow of CURRENT and VOLTAGE, combined with tools such as MULTIMETERS, the circuit is TWEAKED by changing components until the circuit performs as desired.

However, when designing a product that will be mass-produced millions of times, the design gets far more involved. The design process must be far more organized and detailed because small errors and costs for needless components quickly add up as products are manufactured in large quantities.

1.3 Considerations for Analyzing and Designing Electronic Circuits

The actual design of electronic circuits will be covered in detail in later courses. However, as a foundation for the more advanced lessons, the examples in this course will be presented as they would to a learning electronics designer. One doesn't need to be a circuit designer to be an engineer, or vice-versa. However, knowing the basics of circuit design and how to select and work with electronic components in the real world is as helpful to engineers as knowing the basics of how cars work is helpful to automobile owners and drivers.

2 Introduction to the "*Electronics You Might Not Have Learned In College*" Course Series

This introduction is included in all lessons in the "*Electronics You Might Not Have Learned In College*" series. If you have completed any of the other lessons in this series, you can skip or just skim over Part 2, depending on how good your memory is.

2.1 Why This Series Was Created

The "**Electronics You Might Not Have Learned In College"** series is written for those who never needed to delve into electronics because their profession is very specialized, and they can usually call on other experts when they need them. Most **engineers, regardless of their specialty, often must communicate with other engineers that work in a totally different world**. Learning as much as possible about their world and language saves a lot of instruction time and, more importantly, can **save a lot of costly misunderstandings.**

Originally, I was designing a course for non-electrical engineers who might have only had a little exposure to electronics. Working in engineering without at least some familiarity with electricity is like cooking without knowing how to use a stove. It can be done, but you totally have to rely on others to do the work and know what is going on. Every engineering profession contains a complicated world filled with special tools and equipment. Unfortunately, many University Engineering Curriculums don't offer much instruction in the many other engineering professions. Therefore, engineering graduates must learn the basics of other specialties that apply to their work on the job.

When I went to work in railroad signaling, I compared having an engineering degree to being a grade school graduate instead of a kindergartener. I knew plenty about electronics and logic design, but nothing about how it applied to a signal system. My electrical engineering education was a great help, of course. But I wished there had been courses that would have prepared me more for my chosen career. In my 50-year career working with railroads and electromagnetic interference, I've constantly been learning things I was never taught in college.

It is wonderful to be able to select courses that fill holes in an engineer's education or help review forgotten knowledge that can easily be taken online. Even better, helpful courses will even provide the necessary learning credits for engineer license requirements. I have profited so much from online courses that I decided it is worth the time and effort to use this method to share my many years of experience with you.

This course is divided into several lessons that can stand as individual courses in themselves. Each lesson has material and tests that can qualify for CEUs. **The term lesson will be used to refer to each separate part of the course. The term course is used to refer to the entire group of lessons on specialized subjects that make up the course.** The lessons are designed to be taken in order, so each lesson provides the background and knowledge to understand the next. However, **there is no prerequisite for any of the courses. If you feel you have sufficient basic knowledge to skip to later lessons in the series, feel free to do so.**

As I proceeded with writing this course that attempts to pass my knowledge on to others, I found that even with 50 years of experience and training in electronics, there were some basic things I never really understood or simply forgot. While researching details on the internet, I found that even experienced electronic designers don't always understand how electronics works and may even give out incorrect information. I learned a lot while creating this course despite my education and life experience, always being in the electronics field. I am using these courses to pass on all I have learned to you in a concentrated form. I am trying to provide enough science and physics to help understand how things work, but not so complicated as classes designed for those who specialize in research and development of the many distinct areas of electronics.

2.2 What Might Not Have Been Learned In College

The college courses for electrical engineers delve into the science and physics behind the world of electronics, but sometimes the complex technical details inhibit understanding of the simple basics of how electronic devices work and interact. The phrase "can't see the forest for the trees" comes to mind.

During my college years, I had a really difficult time understanding a lot of what was being taught. Professors seemed to assume their students were just as brilliant as they were, which often was not the case. My best professors were those who had as much difficulty learning as I did. They could understand why their students might not "get it" and bring the complicated details down to their level.

This series of courses are meant to be a good place for engineers in disciplines that required very little electrical instruction. A basic understanding of the main components used in DC circuits and the way the power that drives them is measured is useful to anyone working in any engineering profession. Some knowledge of electronics is critical in instrumentation, measurement, and control for any design or construction project. All complex measuring equipment has instruction manuals, but they commonly assume some electronics knowledge by the user.

During this course, I will be sharing as much of my 50 years of Electrical Engineering experience as I can. Therefore, there will be many asides that I hope may be of interest to the student as background and general knowledge even though they may not be essential to the basic course and won't be in the course tests. Some of the information contained herein is purely to help students who have not been exposed to the electrical world to understand a little better how electricity works. After all, very little of our technology and industry would even exist if it wasn't for the many miracles electricity has brought to us in the short 150 years since Tesla, Edison, Westinghouse, and Faraday first took the novel magic of electricity and put it to work. It now does everything from power tiny computer microcircuits to major cities.

Basically, I hope the factoids picked up in this course will pique the curiosity of the student enough to search the myriad sources of information in libraries, on the internet, and in the media. There are many videos and lessons in various detail and complexity. This course will provide the student with sufficient knowledge to understand and learn from our amazing information networks that were not available only 30 years ago.

Some knowledge of molecular physics is important to nearly all engineering professions. Civil engineers need a little understanding of atomic structure to understand how concrete works, as well as the strength of materials. Mechanical engineers must understand the atomic structures of metals, alloys, lubricants, and the effects of friction. From the beginning, advances in the electrical world relied on experiments in physics and chemistry done by curious scientists who slowly gained an understanding of the atomic world. Eventually, they learned how it works enough to manipulate it to allow humans to do things they never did before.

2.3 Notes Concerning This Course

Engineers understand that there are no absolutes, which is why not many of them are in sales or politics where all information is pushed as "absolutely, positively true" even when it isn't. Every rule has an exception. Often/usually/commonly modifiers will be used often in this course because custom designs and advances in technology create exceptions. All that might be certain are things that are true by definition, such as 2 + 2 = 4, but there are even exceptions to them. This course is to pass on knowledge, not to sell or convince anyone of anything.

Every course is presented in a different way. Usually, the student is plunged headfirst into the material without an understanding of why the course was written the way it was. Trying to analyze the reasoning behind the layout of the course can sometimes distract from the course itself. As you proceed through this lesson, the reasoning behind its design will be as clear as possible.

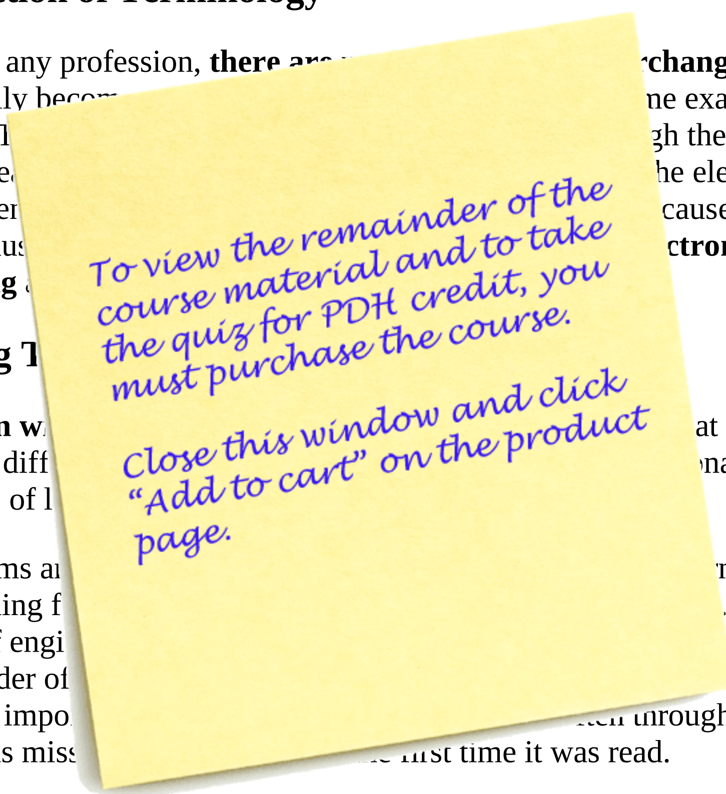
For those more experienced in electronics, there will be many subjects that are "over-explained." Feel free to simply skim over sections that you already know and understand, but don't skip them altogether. There might be nuggets that you misunderstood or didn't know. **Basically, I would rather supply too much information for those who don't need it than not enough for those who do.**

2.4 Introduction to Tools of the Trade

All engineering professions have a myriad of components and tools that are essential to their work. Through years of experience, items experts use every day become so familiar that it is easy for them to assume those outside the profession are familiar with the tools and terminology too. Some items have become so useful that hobbyists and handymen outside the profession are also familiar with them. I have learned, however, that thorough working knowledge of even commonly used components such as batteries and MULTIMETERS cannot be assumed.

2.5 Introduction of Terminology

In electronics, as in any profession, **there ar** ... **rchangeably** and some
jargon that eventually becom ... me examples include
VOLTAGE, ELECT ... gh these terms have
slightly different me ... he electronics profession.
This lesson will often ... cause that is what is
found out in the indus ... **ctromotive force would**
be like not knowing ...



2.6 Learning T...

Much of this lesson w ... at similar terms and
facts crop up under diff ... nal because we all
have different ways of l ...

Some important items a ... n by repetition and to
increase understanding f ... . Also, creative
minds, like those of engi ... when the mind is
distracted. A reminder of ... s the chance of
learning it, or more impo ... through the lesson to find
information that was miss ... first time it was read.